2019-01985 - PhD Position F/M Volume penalization methods for the representation of flows along topography in 3D ocean models

**Type de contrat :** CDD de la fonction publique  
**Niveau de diplôme exigé :** Bac + 5 ou équivalent  
**Fonction :** Doctorant

### A propos du centre ou de la direction fonctionnelle

Grenoble Rhône-Alpes Research Center groups together a few less than 800 people in 39 research teams and 8 research support departments. Staff is localized on 5 campuses in Grenoble and Lyon, in close collaboration with labs, research and higher education institutions in Grenoble and Lyon, but also with the economic players in these areas. Present in the fields of software, high-performance computing, Internet of things, image and data, but also simulation in oceanography and biology, it participates at the best level of international scientific achievements and collaborations in both Europe and the rest of the world.

### Contexte et atouts du poste

**Team Presentation:** the general scope of the AIRSEA project-team (http://team.inria.fr/airsea/) is to develop mathematical and computational methods for the modeling of oceanic and atmospheric flows. The used mathematical tools involve both deterministic and statistical approaches. The domains of applications range from climate modeling to the prediction of extreme events. The proposed work is at the bridge between applied mathematics and physical oceanography.

The PhD will be supervised by Laurent Debreu (Inria, LJ, AIRSEA team, Grenoble), Gurvan Madec (CNRS, LOCEAN, Paris and AIRSEA team) and Casimir de Lavergne (CNRS, LOCEAN, Paris).

**Context:**  
Waters colder than 4°C make up three fourths of the global ocean volume and hold the majority of carbon in the climate system. These dense waters circulate along a network of currents, called the thermohaline circulation, which connects the surface to abyssal depths and the poles to the tropics on timescales of decades to millennia. This circulation largely controls the carbon and heat storage capacity of the deep ocean, and therefore regulates slow variations in Earth’s climate. Yet state-of-the-art ocean models struggle to simulate this circulation accurately, in large part due to their poor representation of flows along topography. Formed at the surface around Antarctica and Greenland, cold dense waters sink along steep continental slopes and navigate along the complex bathymetry of the abyssal ocean. They must negotiate sills, straits and corrugations that have a prominent influence on their pathways and their mixing with surrounding waters. In ocean models, small-scale corrugations are absent due to limited resolution, and larger-scale bathymetric slopes often appear as steps that disallow a faithful simulation of currents following the ocean bottom. These limitations lead to large biases in the simulated properties and pathways of dense waters. This PhD proposal aims to alleviate such model deficiencies by representing topography effects through innovative penalization methods.

### Mission confiée

#### Penalization methods:

Penalization is a well-established way to implicitly enforce boundary conditions for complicated or moving geometries [Peskin, 1972, Angot et al., 1999]. When geometry is complex, explicitly imposing boundary conditions is computationally expensive, inaccurate or requires making assumptions about geometrical properties of the boundary (e.g. smoothness, normal direction). In contrast, penalization methods are simple to implement since they typically only require adding additional source terms to the dynamical equations. The accuracy of the boundary conditions is controlled easily by modifying the values of one or more control parameters.

In [Debreu and Kevlahan, 2019], the Brinkman volume penalization method has been extended to three-dimensional primitive equations (hydrostatic, Boussinesq) ocean models in order to avoid some of the drawbacks of the usual vertical coordinate systems. In particular, we eliminate the “stair-case” effect associated with following $\sigma$- or $\zeta$- generalized coordinates associated with steep bathymetry features.


### Informations générales

- **Thème/Domaine :** Sciences de la planète, de l’environnement et de l’énergie  
- **Ville :** Saint-Martin-d’Hères  
- **Centre Inria :** CRI Grenoble - Rhône-Alpes

**Date de prise de fonction souhaitée :** 2019-11-01  
**Durée de contrat :** 3 ans  
**Date limite pour postuler :** 2019-10-13

### Contacts

- **Equipe Inria :** AIRSEA  
- **Directeur de thèse :** Debreu Laurent / laurent.debreu@inria.fr

### A propos d'Inria

Inria, l’institut national de recherche dédié aux sciences du numérique, promeut l’excellence scientifique et le transfert pour avoir le plus grand impact. Il emploie 3400 personnes. Ses 200 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3000 scientifiques pour relever les défis des sciences informatiques et mathématiques, souvent à l’interface d’autres disciplines. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 160 start-up. L’institut s’efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l’économie.

### L'essentiel pour réussir

- **Strong interest in interdisciplinary research (applied mathematics/physical oceanography)**

### Consignes pour postuler

**Sécurité défense :**  
Ce poste est susceptible d’être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L’autorisation d’accès à une zone est délivrée par le chef d’établissement, après avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l’annulation du recrutement.

**Politique de recrutement :**  
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.

**Attention :** Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d’autres canaux n’est pas garanti.
Principales activités
The main objective of this PhD is to apply, develop and improve the Brinkman volume penalization method in the context of realistic oceanic simulations. A particular focus will be put on global scale simulations and the representation of currents carrying cold dense waters along topography. The target ocean modelling system is NEMO (Nucleus for European Modelling of the Ocean) and its ORCA configurations. The proposed work is at the bridge between physical oceanography and applied mathematics. As it would be the first application of the Brinkman penalization method in a realistic context, the subject of research is quite open and the potential for improvements is large. After a first evaluation of the method, several aspects will be studied. We detail some of them below noting that the penalization method opens many other possibilities. The work will begin with the implementation of the volume penalization method within the NEMO model. Global simulations at different resolutions will then be run both in geopotential (z), terrain following (σ) and with the penalization method. A series of physical diagnostics (thermohaline circulation, abyssal stratification, western boundary currents, bottom boundary layer, diapycnal mixing, . . . ) will be performed in order to evaluate the improvements. A sensitivity of the results against the parameters of the Brinkman penalization (porosity, permeability) will also be done. In the traditional volume penalization method, a no-slip boundary condition is applied at the bottom. This translates into a very rapid variation of the permeability coefficients at the water/land interface. A theoretical study on how the penalization method, via an appropriated water/land transition, can allow to impose other kinds of boundary conditions or more generally a bottom boundary layer parametrization will be conducted. One of the major advantages of the penalization method is to be able to represent subgrid-scale details of bathymetry. In the case of relatively low-resolution simulations, a potentially large error is done when considering a grid cell either completely dry or completely wet. This is typically the case for narrow straits or ridge crests. We may expect a much better representation by adjusting the value of the porosity coefficient within these regions. This will be evaluated in test cases and realistic global simulations.

Compétences
- Numerical Analysis
- Ocean modelling

Avantages
- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Rémunération
Gross salary: 1982€ the first and 2nd year; 2085€ the third year