3 Post-doctoral positions FLUMINANCE group

Study of ocean stochastic models for ensemble forecasting and data assimilation from high-resolution data

General description

Several three-years post-doctoral positions are opened in the Fluminance Inria team, (INRIA Rennes, France) to work within the ERC project "Stochastic Transport in Upper Ocean Dynamics" (STUOD) in collaboration with Ifremer and Imperial College London.

The proposed research positions are at the crossing between Applied Mathematics, Computer Science and Physical Oceanography. The objective is to investigate specific stochastic parametrization for large-scale ocean models to model the effect of the unresolved components of the flow. The relevance of these stochastic dynamics will be explored in terms of oceanic modeling capacities as well as for data assimilation and ensemble forecasting purposes (see section « Detailed subject » for more information).

Environment

The candidate will be hosted in the Fluminance Inria team located in Rennes (Britany) and will work in close collaboration with Ifremer Brest, Imperial College London and the Air-Sea Inria team in Grenoble. Fluminance and Air-Sea are part of INRIA (www.inria.fr), which is one of the leading research institute in Computer Sciences in France. Fluminance is also affiliated to the mathematics research institute of the Rennes University (IRMAR). These position are funded by the ERC project STUOD.

Skills and profile

The candidate should have a solid background in applied mathematics and/or in fluid mechanics and/or in geophysical dynamics. She/he must have a good knowledge of Fortran/C/C++. He/She must have a PhD related to computational physics (Computational Fluid Dynamics, Numerical geophysical modeling and simulation, Data assimilation) or in applied mathematics.

Salary

The gross salary ranges from 2936€ to 4150€ depending on the years of research experiences after the PhD.

Contact

Applicants must send their candidature (resume and letter of motivation) to
Etienne Mémin
Fluminance team
INRIA Rennes-Bretagne Atlantique
email : etienne.memin@inria.fr

Detailed subject

For several years there is a growing interest in geophysical sciences and climate studies to set up flow models that incorporate uncertainties or errors [1, 2, 3, 4, 5,6]. This interest is strongly motivated by the necessity of devising large scale evolution models that take into account the actions of processes we do not wish to accurately model -- to keep for instance an affordable computational time. This includes complex physical forcing (internal gravity waves, submesoscale eddies, boundary layer turbulence, etc.) or uncertainties coming either from scale coarsening or from the numerical schemes used. In large-scale flow modeling the interaction between the resolved and unresolved components lies essentially in the constitution of a so called subgrid stress tensor, which is usually not related to uncertainty concept. We believe it is important to extend this notion to take into consideration in a more appropriate way the action on the resolved component of all the uncertainties we have to cope with.

The modeling and the handling along time of these uncertainties related to the flow dynamics are crucial for instance for ensemble forecasting issues. An ensemble of runs can be generated through randomization of the dynamical parameters or by considering a set of perturbed initial conditions possibly accompanied with stochastic forcing mimicking the effect of unresolved processes. The underestimation of the ensemble spread and the lack of representativity of errors by the subgrid models constitute problematic limitations of the ensemble techniques forecasting skill. In such a situation we have thus to deal with a flow evolution model that should incorporate stochastic forcing terms and a subgrid tensor term directly related to these uncertainties. The derivation of such models is a difficult problem that can hardly be achieved on heuristic grounds.

In this set of studies, we propose to stick to a recent derivation [1, 2, 4, 6] that naturally emerges from a decomposition of the flow velocity field into a smooth component and a time uncorrelated uncertainty random term. Such decomposition is reminiscent, in spirit, of the classical Reynolds decomposition. The dynamics associated to the resolved flow components can be then derived from a stochastic version of the Reynolds transport theorem. It includes in its general form an uncertainty dependent 'subgrid' expression that incorporates meaningful terms for turbulence modeling. It involves in a natural way a modified advection term akin to the Stokes drift [1], a large-scale diffusion term and a random backscattering term. Several promising results have been obtained on simplified oceanic models. The principal objective will be to explore and study numerically the behavior and the properties of such large-scale random modeling in the context of realistic ocean models such as Nemo or Croco (Coastal and Regional Ocean COmmunity model -- https://www.croco-ocean.org). To that end we will explore several strategies to define the noise component and its dynamics from high-resolution data or observations. We aim in particular at exploring modal representations proposed recently in fluid mechanics and their coupling with methodological tool proposed in the machine learning community. We intend to investigate several forms for the uncertainty component going from simple specifications to more complex data driven strategies.

The final objective will be to go toward, the development of a Bayesian ensemble data assimilation technique built on top of this stochastic parameterization. A focus will be given on the definition of hierarchical particle filters, in order to benefit from both the nesting properties of the stochastic modelling and from the high theoretical potentials of such nonGaussian Monte-Carlo techniques. The idea will be to work with a nesting of models of increasing complexity together with an ensemble of realizations of gradually reduced size to comply with operational constraints.

As a rapid summary, the different post-doctoral positions we are offering aim to explore the following issues:

- Modelling/simulation of stochastic ocean models for ensemble forecasting and uncertainty quantification
- Data driven dynamics specification and learning from high-resolution data
- Hierarchical Data assimilation ensemble strategies to couple stochastic ocean model and high resolution satellite data
- Use of stochastic transport for satellite image motion analysis and interpolation

The precise definition of the different positions' objectives will be defined with respect to the candidates' profile and willing. These positions will be coupled to several PhD positions and will provide the opportunity to participate to the supervision of several PhD students.

Bibliography

1. Bauer, W., Chandramouli, P., Chapron, B., Li, L., Mémin, E, (2020), Deciphering the role of small-scale inhomogeneity on geophysical flow structuration: a stochastic approach, J. Phys. Oceanogr., in press.
2. Chapron, B., Dérian, P., Mémin, E., Resseguier, V., (2018), Large scale flows under location uncertainty: a consistent stochastic framework, Quarterly Journal of the Royal Meteorological Society, 144 (710), pp.251-260.
3. Franzke, C., O'Kane, T., Berner, J., Williams, P. and Lucarini, V., (2015), Stochastic climate theory and modeling. WIREs Clim Change, 6: 63–78.
4. Mémin, E. (2014). Fluid flow dynamics under location uncertainty. Geophysical & Astrophysical Fluid Dynamics , 108(2): 119-146.
5. Palmer, T., and Williams, P., (2008). Theme issue 'stochastic physics and climate modelling'. Phil. Trans. R. Soc.,366(1875).
6. Resseguier, V., Mémin, E., Chapron, B., (2017), Geophysical flows under location uncertainty, Part I, II & III, Geophysical and Astrophysical Fluid Dynamics, 111 (3), pp.149-176.

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