Post-doctoral position FLUMINANCE group:

Study of oceanic stochastic subgrid scale parameterization for ensemble forecasting and data assimilation

General description

We seek a candidate for a 18 month post-doctoral position within the Fluminance team, (INRIA Rennes, France). This study at the cross section between Applied Mathematics, Computer Science and Physical Oceanography, we will investigate the use of ocean dynamics models with an uncertainty random component aiming at modeling the action of the unresolved small-scale component of the flow. The relevance of such stochastic dynamics will be explored in terms of oceanic modeling capacities (see section « Detailed subject » for more information).

Environment

The candidate will be hosted in the Fluminance team located in Rennes and will work in close collaboration with the Air-Sea team in Grenoble. Both teams are part of INRIA (www.inria.fr), which is one of the leading research center in Computer Sciences in France. The main research activities of Fluminance focus on the study of turbulent flows from image data sequences, which encompasses many applications in industrial and academic projects. We refer the candidates to the team's website for more information: http://www.irisa.fr/fluminance/indexFluminance.html. Airsea focuses on the study and simulation of oceanic and atmospheric flows. The team studies in particular the design of efficient numerical schemes for high-performance oceanic simulation, data assimilation, atmosphere and ocean coupling, model reduction, as well as uncertainty quantification. For a detailed description of the Airsea team's activity:

https://team.inria.fr/airsea/en/

This work will take place in the new collaborative Inria project SURF.

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**.

Contact

Applicants must send their candidature (resume and letter of motivation) to

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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]. 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 processes such as complex physical forcing (cloud convection, boundary layer turbulence, etc.) or uncertainties coming either from scale coarsening or from the discrete 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 state variable dynamics are crucial for instance for ensemble forecasting issues in meteorology or oceanography. 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 study, we propose to stick to a recent derivation [1, 3, 5] 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 random velocity fluctuations considered here are not differentiable with respect to time, and must be handled through stochastic calculus. The dynamics associated to the differentiable drift component can be then derived from a stochastic version of the Reynolds transport theorem. It includes in its general form an uncertainty dependent 'subgrid' term that incorporates meaningful for turbulence modeling. It involves in a natural way a modified advection term, 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 the Coastal and Regional Ocean COmmunity model Croco (https://www.croco-ocean.org). This study will involve first the development of multiple case studies. For several of those modified models we will explore the relevance of the uncertainty modeling in term of forecasting skill. We will in particular compare the performances of these stochastic systems with classical deterministic parameterization and assess their capacities to improve the solutions and to represent the errors. 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 an ensemble data assimilation technique built on top of this stochastic parameterization.

Bibliography:

1. B. Chapron, P. Dérian, E. Mémin, V. Resseguier (2018), Large scale flows under location uncertainty: a consistent stochastic framework, Quarterly Journal of the Royal Meteorological Society, 144 (710), pp.251-260.
2. Majda A (2012) Challenges in climate science and contemporary applied mathematics. Commun Pure Appl Math 65(7):920–948.
3. Mémin, E. (2014). Fluid flow dynamics under location uncertainty. Geophysical & Astrophysical Fluid Dynamics , 108(2): 119-146.

4. T. Palmer and P. Williams (2008). Theme issue ’stochastic physics and climate modelling’. Phil. Trans. R. Soc.,366(1875).
5. V. Resseguier, E. Mémin, B. Chapron (2017), Geophysical flows under location uncertainty, Part I, II & III, Geophysical and Astrophysical Fluid Dynamics, 111 (3), pp.149-176.