Doctoral position FLUMINANCE group:

«Mathematical analysis of stochastic oceanic dynamics models»

General description

We are offering a PhD position in the Fluminance team, (INRIA/IRMAR Rennes, France). This study, at the cross section between Mathematics and Physical Oceanography, 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. This modeling strategy leads to the emergence of stochastic partial differential equations with strong conservation properties. They have been successfully simulated for different flow configurations, however their mathematical properties are poorly known and needs to be studied in depth.

This PhD will take place within an European project between Ifremer (Brest), Imperial college (London) and Inria (Rennes). The PhD will be performed in strong collaboration with Dan Crisan (Imperial College), Arnaud Debussche (ENS Rennes) and Roger Lewandowski (Fluminance). It will be mainly supervised by Etienne Mémin (Fluminance).

Environment

The candidate will work in the Fluminance team located in Rennes . The team is part of INRIA (www.inria.fr), and the Mathematics research institute of the Rennes I University (IRMAR). The european project in which the PhD will take place is focused on the study of stochastic models for the ocean upper dynamics. It aims at proposing efficient data-driven models enabling to forecast the ocean state variables together with their associated uncertainty.

Skills and profile: The candidate should have a solid background in mathematics (analysis and stochastic processes).

Contact

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

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Detailed subject

The precise characterization of geophysical flows is becoming a crucial need in many aspects of our everyday life for it strongly impacts many environmental and economical fields. We may think, among others, to applications related to climate studies, oceanographic analysis or weather forecasting which are of paramount importance for the study of global warming, the tracking of polluting sheets or the prediction of catastrophic events. Unfortunately, the laws ruling such geophysical processes depend on state variables evolving in huge dimensional spaces with a strong scale coupling in space and time. The range of these interactions is so large that only large-scale representations of the system of interest can be simulated.
In order to incorporate inherent uncertainties or errors and to better represent the effect of the neglected scales, there is a growing interest to set up random representations for those flows [1,2,3]. The modelling and the handling along time of uncertainties are crucial for instance for ensemble forecasting and data assimilation issues. In this study, we propose to stick to a recent derivation [3,4,5,6] that naturally emerges from a decomposition of the flow velocity field into a differentiable drift component and a time uncorrelated uncertainty random term. This framework has shown to enable the derivation of meaningful dynamical

random oceanic models with results greatly improved when compared to deterministic simulations. Reliable analyses in terms of likely scenarios, dynamics bifurcations, or extreme events detection are as well easier to achieve.

The resulting models open very exciting mathematical questions we wish to study within this PhD. These models in their full complexity consists in a system of stochastic partial differential equation that has nearly the same shape as the deterministic corresponding system. As in the deterministic case they exhibits strong conservation properties. However, their fine mathematical properties are unknown. The overall objective of the thesis will be to explore to what extent the known properties of deterministic flow dynamics are conserved in the stochastic framework. This concerns for instance local well-posedness of the Navier-Stokes equation or of its oceanic representatives. As for the ocean models, a known hierarchy of approximate stochastic models can be built from the Navier-Stokes equations almost exactly in the same way as in the deterministic setting. In this latter case, some convergence results are well known and their stochastic counterparts need to be investigated. Another issue concerns the physical analysis of such system. Do the stochastic systems still admits some waves solutions (Rossby wave, Gravity waves, internal waves, etc.) ? The characterization of the statistical moments associated to those wave solutions would be very interesting from a physical point of view but also to define from a physical analysis a proper shape for the random terms involved.

Depending on the applicant's background and interest those questions will be oriented toward a particular focus of interest.

Bibliography:

1. D. Holm, (2015), Variational principles for stochastic fluid dynamics., *Proc Math Phys Eng Sci*, Vol: 471, ISSN: 1364-5021.
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. V. Resseguier, E. Mémin, B. Chapron, Geophysical flows under location uncertainty, Part I Random transport and general models, Geophysical & Astrophysical Fluid Dynamics, accepted for publication, 2017
5. V. Resseguier, E. Mémin, B. Chapron, Geophysical flows under location uncertainty, Part II: Quasigeostrophic models and efficient ensemble spreading, Geophysical & Astrophysical Fluid Dynamics, accepted for publication, 2017
6. V. Resseguier, E. Mémin, B. Chapron, Geophysical flows under location uncertainty, Part III: SQG and frontal dynamics under strong turbulence, Geophysical & Astrophysical Fluid Dynamics, accepted for publication, 2017