

PROPOSITION DE SUJET DE THESE

Formulaire demande de financement : ARED - ISblue - ETABLISSEMENTS - ...

pour dépôt sur le serveur <https://theses.u-bretagne-ouest.fr/sml> au format PDF

Identification du projet

Acronyme du projet (8 caractères *maximum*) : DDAI

Intitulé du projet en langue française : Approche basée données et apprentissage pour le design de systèmes d'observation multi-plateformes adaptatifs de processus océaniques

Intitulé du projet en langue anglaise : Data-driven and AI-guided multi-platform observing systems for poorly-resolved ocean processes

Domaine d'innovation stratégique (DIS) du projet

Cocher le DIS prioritaire au sein duquel le projet de thèse s'intègre.

- DIS 1 : Innovations sociales et citoyennes pour une société ouverte et créative
- DIS 2 : Chaîne alimentaire durable pour des aliments de qualité
- DIS 3 : Activités maritimes pour une croissance bleue
- DIS 4 : Technologies pour la société numérique
- DIS 5 : Santé et bien-être pour une meilleure qualité de vie
- DIS 6 : Technologies de pointe pour les applications industrielles
- DIS 7 : Observation et ingénieries écologique et énergétique au service de l'environnement

Si aucun DIS ne correspond, cocher « Projet Blanc ».

« Projet Blanc »

Préciser le sous-domaine correspondant : liste en dernière page de ce document

DIS secondaire si nécessaire :

Présentation de l'établissement porteur (bénéficiaire de l'aide régionale)

Établissement porteur du projet : IMT Atlantique

Ecole Doctorale : ED MathSTICC

Identification du/de la responsable du projet (futur-e directeur-trice de thèse)

Nom du laboratoire d'accueil : Lab-STICC

Code du laboratoire (U/UMR/USR/EA/JE/...) : UMR 6285

Directeur du Laboratoire : G. Coppin

Nom de l'équipe de recherche : TOMS

Nombre HDR dans le laboratoire : > 50

Nombre de thèses en cours : > 100

Nombre de post-docs en cours : > 100

Nom et prénom du directeur de thèse (HDR), porteur du projet :

- e-mail : ronan.fablet@imt-atlantique.fr

- Téléphone : 0229001287

- Publications récentes du directeur-trice de thèse (nb total et 5 références max au cours des 5 dernières années) : 25 articles de revue internationale, >25 actes de conférence avec comité de lecture

A. Sánchez-Román, L. Gómez-Navarro, R. Fablet, D. Oro, E. Mason, J. M. Arcos, S. Ruiz & A. Pascual. Rafting behaviour of seabirds as a proxy to describe surface ocean currents in the Balearic Sea. *Scientific Reports*, 9(17775), 2019

R. Fablet, P. Viet, R. Lguensat, P.H. Horrein, B. Chapron. Spatio-Temporal Interpolation of Cloudy SST Fields Using Conditional Analog Data Assimilation. *Remote Sensing*, 2018.

R. Fablet, P. Viet, R. Lguensat. Data-driven Methods for Spatio-Temporal Interpolation of Sea Surface Temperature Images. *IEEE Trans. on Computational Imaging*, 2017.

R. Lguensat, P. Tandeo, P. Aillot, R. Fablet. The Analog Data Assimilation. *Monthly Weather Review*, 2017.

A. Bertrand, D. Grados, F. Colas, S. Bertrand, X. Capet, A. Chaigneau, G. Vargas, A. Mousseigne, R. Fablet. Broad impacts of fine-scale dynamics on seascape structure from zooplankton to seabirds *Nature Communications*, 5: 5239, 2014.

Liste complète accessible sur <http://scholar.google.fr/citations?user=odonG7gAAAAJ&hl=en>

- Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)

(nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

Direction de thèses soutenues :

Manuel Lopez Radcenco, thèse soutenue en 2018, postdoc LOPS, France

Redouane Lguensat, thèse soutenue en 2017, postdoc IGE, France

Brahim Boussidi, thèse soutenue en 2016, postdoc URI, USA

Marza Marzuki, thèse soutenue en 2017, Fonctionnaire, Indonésie

Budhi Gunadharma, thèse soutenue en 2017, Fonctionnaire, Indonésie

Daniel Grados, thèse soutenue en 2014, chercheur IMARPE, Pérou

Kien Nguyen, thèse soutenue en 2017, ingénieur, Vietnam

Direction de thèses en cours :

Guillaume Beaumont, co-direction A. Drémeau (Lab-STICC), soutenance prévue en 2019

Huimin Li, encadrement B. Chapron, A. Mouche (LOPS), soutenance prévue en 2019

Said Ouala, co-direction A. Pascual (CSIC/IMEDEA), soutenance prévue en 2020

Co-directeur-trice de thèse et co-encadrant scientifique : (précisé si HDR) Steven Brunton

- **Laboratoire de recherche co-encadrant** (nom + code U/UMR/USR/EA/JE/...) Univ. of Washington

- **e-mail : sbrunton@uw.edu**

- **Téléphone :**

- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**

Prof. S. Brunton led a research group at Univ. of Washington (currently, 10 Phd Students and 3 postdoc/research staff).

H-index : 26 (Google scholar), >3000 of citations overall, > 1000 for 2018

This PhD will also involve Dr. B. Chapron (LOPS), who has a proven supervision experience:
<https://annuaire.ifremer.fr/cv/15870/>

Présentation du projet (en langue française ou anglaise, 2 à 3 pages)

Résumé du projet (4000 caractères maxi espaces compris) :

Artificial Intelligence (AI) technologies, models and strategies open new paradigms to address poorly-resolved or poorly-observed processes **in ocean-atmosphere science** from the in-depth exploration of available observation and simulation big data. **This proposal aims to investigate such data-driven and AI-guided strategies for future ocean observing systems with a focus on context-aware and adaptive multi-platform systems.** From a methodological point of view, bridging the physical model-driven paradigm underlying ocean science and AI paradigms will be at the core of this PhD with a view to developing geophysically-sound learning-based and data-driven representations of geophysical flows accounting for their key features (e.g., chaos, extremes, high-dimensionality). Such representations will then be exploited for design and optimization of adaptive multi-platform observing systems. Using OSSE (Observing System Simulation Experiments), case-studies representative of multi-platform systems (e.g., synergies between different satellite sensors as well as satellite systems and in situ networks (e.g., ARGO floats)) will be considered to implement and evaluate the proposed methods and strategies.

The PhD candidate will benefit from the multidisciplinary expertise of the supervision team with proven expertise in Ocean Science, Ocean Remote Sensing, Fluid Dynamics, Artificial Intelligence and Control.

Keywords: Observing systems, space oceanography, in situ systems, data-driven methods, machine learning, dynamical systems, Adaptive observation.

Présentation détaillée du projet :

1 - **Scientific context and objectives.** Hypothèse et questions posées, identification des points de blocages scientifiques

Understanding, modeling, forecasting and reconstructing fine-scale and large-scale processes and their interactions are among the key scientific challenges in ocean-atmosphere science. State-of-the-art approaches strongly rely on joint research effort in observing systems (e.g., in situ monitoring, satellite observations) and numerical simulations, especially ensemble simulation schemes [e.g., 6-7]. The ability to relate models and observation data, though significant advances in data assimilation, remain open questions for numerous processes (e.g., small-scale parameterization, ocean-atmosphere interactions, biogeochemical ocean dynamics, climate-scale dynamics) [e.g., 1-4]. Artificial Intelligence (AI) technologies, models and strategies open new paradigms to address these questions from the in-depth exploration of the existing observation and simulation big data [4,7-11].

The general goal of this project is to explore and develop these AI paradigms and their interactions with model-based approaches [5] for the design of future multi-platform adaptive ocean observing systems. It is widely acknowledged that no single-platform system may provide direct observations of all ocean processes and scales of interest. Sea surface winds, currents and waves are typical examples, for which for instance no in situ or space observing system can alone provide the direct observation of their dynamics at a synoptic scale even for the mesoscale range (i.e., up to horizontal scales of ~ten kilometers).

Synergies between different satellite sensors (e.g., scatterometers, SAR sensors, multi-spectral sensors), in situ networks (e.g., ARGO floats, buoys,...), airborne sensors (e.g., lidar sensors embedded on drones),... are clearly of interest. The rapid development of new embedded communication and processing capacities of such sensors further push for the design of **context-aware systems for the adaptive and optimized deployment of multi-platform observing systems** (e.g., acquisition or streaming of high-resolution satellite data conditionally to pre-analysis steps based on other observation/simulation data, adaptive routing of drone-based acquisitions based on synoptic observation and simulation data). **This PhD will investigate the data-driven and AI-guided methods and strategies that we envision to be the processing core of these new systems.**

2 - **Proposed approach** Approche méthodologique et techniques envisagées :

To address the general objective of the PhD, two specific methodological objectives will be considered:

- **The learning of geophysically-sound neural network representations of geophysical flows:** we aim to bridge model-driven formulations and learning-based representations [5,12-15]. Among the variety of machine learning frameworks, the focus will be given to neural networks, and more specifically to ResNet architectures. These computationally-efficient and highly-flexible models can be regarded as neural-network-based implementation of numerical schemes of ODE/PDE (Ordinary and Partial Differential Equations). From a methodological point of view, the focus will be given to (i) learning and reconstruction issues when dealing with partial and noisy observations [e.g., 14,16], (ii) accounting for specific geophysical features of interest (e.g., chaotic patterns, occurrence of extremes,..).
- **The exploitation of neural network representations for the design and optimization of adaptive multi-platform strategies:** Based on the previously mentioned neural network representations, new learning-based strategies will be developed for the deployment of context-aware multi-platform observing systems. Reinforcement learning strategies are expected to be of interest in this context.

For evaluation and demonstration purposes, case-studies representative of multi-platform systems (e.g., synergies between different satellite sensors as well as satellite systems and in situ networks (e.g., ARGO floats)) will be implemented. We first target a case-study on upper ocean currents combining ARGO floats and satellite sensors (SKIM, SWOT, nadir altimeter data). A second case-study on extreme winds will also be explored. These case-studies will be implemented as Observing System Simulation Experiments (OSSE), which will make possible the simulation of adaptive observation strategies. Depending on work progress, real case-studies might be considered in collaboration with operational oceanography centers. In this context, the ongoing international collaboration with IMEDEA/SOCIB (OSTST project MANATEE) might be of key interest to explore synergies between satellite sensors and gliders within the fast-sampling phase of SWOT mission.

3 - Positionnement et environnement scientifique dans le contexte régional, national et international :

This PhD proposal is a joint proposal between Lab-STICC/TOMS (R. Fablet, Prof. IMT Atlantique) and LOPS/SIAM (B. Chapron, Senior Scientist Ifremer), who have a proven collaboration experience. It will also benefit from the co-supervision, through mutual short-term visits, of Prof. S. Brunton, Univ. of Washington, who co-authored a pioneering work on the data-driven identification of governing equations of geophysical flows [12].

At the regional and national level, this PhD will be part of newly-launched LEFE initiative on artificial intelligence for Ocean, Atmosphere and Climate coordinated by R. Fablet. This initiative currently involves 9 research teams (LOPS, Lab-STICC, INRIA Rennes, LOCEAN, LATMOS, LIP6, IGE, INRIA Grenoble, CERFACS). It will provide a relevant platform for the scientific exchange and dissemination of the contributions expected from the PhD.

Besides the co-supervision of the PhD by Prof. S. Brunton, the PhD could benefit from the fruitful collaboration with IMEDEA/SOCIB (A. Pascual, J. Tintore) as mentioned above, especially regarding potential application to operational oceanography.

4 - Pour la région Bretagne: adéquation du projet au regard du DIS de rattachement (et/ou du DIS secondaire).

S.O. pas d'ARED demandé via ED SML ou ISBLUE

5 - Si « projet blanc » (hors DIS), préciser les raisons de ce choix :

S.O. pas d'ARED demandé via ED SML ou ISBLUE

6 - Si lien avec projet ERC, préciser lequel :

S.O

7 - Autres informations utiles (CPER, FEDER, concernant la politique régionale) :

S.O

8 - Le cas échéant, précisez le lien du sujet avec les thèmes ISblue

- la régulation du climat par l'océan
- les interactions entre la Terre et l'océan
- la durabilité des systèmes côtiers
- l'océan vivant et les services écosystémiques
- les systèmes d'observation à long terme

Contribution to ISBlue themes

This project contributes to Isblue theme "Observing Systems" through the development of novel data-driven and AI-guided strategies for the design and optimization of multi-platform ocean observing systems for poorly-resolved processes.

The considered case-studies on upper ocean dynamics are also of interest for Isblue theme "Ocean and Climate regulation".

Le cas échéant (si financement ISblue demandé): en regard de la formation par la recherche du futur docteur, perspectives d'insertion professionnelle dans le milieu académique et non académique

The complementary expertise in data science/artificial intelligence and ocean science will clearly opens a number of professional opportunities both in academic institutions and in the industry.

9 - Contexte scientifique et partenarial : éléments généraux

As mentioned on item 3, this PhD proposal relates to regional and national collaborative initiatives at the regional and national level on Artificial Intelligence for Ocean Science: (i) collaboration between INRIA, IMT Atlantique and Ifremer on AI for ocean science initiated within an inter-labex (Mer-Lebesgue-Cominlabs) project (SEACS, 2016-2019, co-PI : R. Fablet, B. Chapron), (ii) LEFE/MANU project AI for Ocean, Atmosphere & Climate Science (2019-2021) involving 8 research groups (inc. Lab-STICC, LOPS, IGE, LOCEAN, LSCE, IGE, INRIA Rennes & Grenoble, CERFACS), (ii) animation and training initiatives at a national level (one-day workshop on AI for Ocean, Atmosphere & Climate, Rennes, Feb 2019, one-week doctoral course on data science for geosciences) (iii) OSTST Manatee project (co-PI, R. Fablet) in collaboration with IMEDEA (Spain) which includes AI-related themes, (iv) starting collaboration with S. Brunton, Prof ; Univ. Washington (first visit to Brest within the organisation of a workshop on AI for Geophysical dynamics, <https://seacs.cominlabs.u-bretagne-iloire.fr/ai4oceandyn>).

10 - Si projet de co-tutelle, internationale, précisez le pays et l'établissement

The possibility for a Phd « co-tutelle » may considered with Univ. of Washington through the co-supervision by Prof. S. Brunton. However, we might keep the administrative aspect as simple as possible and consider an IMT Atlantique/MathSTICC PhD with a co-supervision by Prof. S. Brunton.

11 - Financements Région Bretagne acquis par le porteur au cours des 3 dernières années (titre, montant)

ARED S. Ouala, 2017-2020

12 - Si projet cofinancé, nom du cofinancier (sollicité et ou acquis)

Demande de co-financement adressé au GIS Bretel

13 - Si cofinancement refusé, autres sources de cofinancement identifiées

Financement sur fonds propres

Le – la candidat.e

Profil souhaité du candidat (compétences scientifiques et techniques requises) :

Projet de thèse en cotutelle internationale

S'agit-il d'un projet de thèse en cotutelle internationale (oui/non) : non

Si oui, préciser l'établissement pressenti (et le pays de rattachement) :

Ce projet de thèse fera-t-il l'objet d'un cofinancement international (oui/non) :

(Rémunération du doctorant par l'établissement implanté sur le territoire régional (18 mois sur 36 mois), et l'établissement étranger, qui s'engage également à rémunérer le doctorant dans le cadre de son séjour à l'étranger, soit durant 18 mois -a minima-)

En cas de cofinancement international, préciser -si vous en avez connaissance- l'organisation du calendrier des périodes de séjour :

References :

- [1] Gross et al. *Mon. Weath. Rev.*, 2018
- [2] Klingbeil et al. *Ocean Mod.*, 125, 2018.
- [3] Pelletier et al. *QJRMS*, 2018.
- [4] Sévellec et al. *Nat. Comm.*, 9(3024), 2018
- [5] Karpatne et al., *IEEE TKDE*, 29(10), 2017.
- [6] Lorenz. *J. Atm. Sc.*, 20(2), 1963.
- [7] Carrassi et al. *WIREs: Clim. Ch.*, 9(5), 2018.
- [8] Fablet et al. *IEEE TCI*, 3(4), 647-657, 2017.
- [9] Lguensat et al. *MWR*, 145(10), 2017.
- [10] Yiou et al. *Adv. SCMO: 17-31*, 2017.
- [11] Zhao et al.. *Nonlinearity*, 29(9), 2016.
- [12] Brunton et al. *PNAS*, 113(15), 2016.
- [13] de Bezenac et al. *ICLR*, 2018
- [14] Fablet et al. *EUSIPCO*, 2018.
- [15] Lu et al. *ICML*, 3282–3291, 2018.
- [16] Ouala et al. *Remote Sensing*, 2018.