PROPOSITION DE SUJET DE THESE

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

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Identification du projet

Acronyme du projet (8 caractères maximum) : MIXED
Intitulé du projet en langue française : Modélisation des Impacts des flux hydrothermaux de Fe sur la biogéochimie du Pacifique tropical sud
Intitulé du projet en langue anglaise : Hydrothermal iron fluxes impacts on the south tropical Pacific biogeochemistry

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

Établissement porteur du projet : Université de Bretagne Occidentale (UBO)
École Doctorale : EDSML ☒ SPI ou MATHSTIC pour les projets ISblue ☐

Identification du responsable du projet (futur directeur de thèse)

Nom du laboratoire d’accueil : Laboratoire d’Océanographie Physique et Spatiale (LOPS)
Code du laboratoire (U/UMR/USR/EA/JE/…) : UMR 6523
Directeur du Laboratoire : Jérome Paillet
Nom de l’équipe de recherche : Océan & Climat

Nombre HDR dans le laboratoire : 13 Nombre de thèses en cours : 29 Nombre de post-docs en cours : 23

Nom et prénom du directeur* de thèse (HDR), porteur du projet : Gorgues Thomas
- e-mail : thomas.gorgues@ird.fr
- Téléphone : + 33 2 90 91 55 27
- Publications récentes du directeur de thèse (nb total et 5 références max au cours des 5 dernières années) :
  28 publications (Web Of Science : 23)

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

Thèses en cours :
• Aïda Beye (co-tutelle entre UBO et UCAD (Dakar)) : « Distribution et variabilité à petite échelle de la biomasse de phytoplancton et de sa diversité à partir de différents types d’observations sur le plateau large sud-sénégalais », funding ANR-SOLAB/ARED-IRD, PhD to be defended June 2023
Supervisors : E. Machu, T. Gorgues (porteurr HDR jusqu’à la soutenance HDR de E. Machu),

1 Ce formulaire est rédigé en style épiciène
Joana Roussillon : « Approche par apprentissages profonds pour reconstruire de longues séries chronologiques de la biomasse phytoplanctonique et évaluer les mécanismes dynamiques sous-jacents en lien avec les cycles climatiques », funding ARED-ISBlue/UBO, Phd to be defended in 2022.
**Supervisors** : E. Martinez, T. Gorgues, R. Fablet, L. Dremetz.

**Thèses soutenues** :

- **Houda Beghoura** (Phd defended in 2020) : « Modélisation de l'impact du Fer particulaire d'origine sédimentaire sur les cycles biogéochimiques marins », funding ARED-labexMER/UBO.
  **Supervisors** : T. Gorgues (HDR), H. Planquette, O. Aumont, A. Tagliabue.
  **Current position** : Postdoctorante sur le projet LHYFE (PIs : T. Gorgues, L. Memery)

- **Sarah Asdar**, co-tutelle between UBO and UCT (Afrique du Sud), (Phd defended in 2018) : “climate change impact on ecosystems of prince edward islands: role of oceanic mesoscale processes”, funding IRD.
  **Supervisors** : P. Penven (HDR), J. Deshayes, T. Gorgues, I. Ansorge.
  **Current position** : Postdoctorante à la « Nelson Mandela University » en Afrique du Sud.

- **Mathilde Cadier** (Phd defended in 2016) : « Diversité des communautés phytoplanctoniques en relation avec les facteurs environnementaux en mer d'Iroise : approche par la modélisation 3D », funding ARED-labexMER/UBO.
  **Supervisors** : Laurent Memery (HDR), H. Memery, M. Sourisseau, T. Gorgues, S. L'Hélguen.
  **Current position** : Chercheure IFREMER (DYNECO)

**Co-directeur de thèse (HDR ou équivalent étranger) éventuel** : Tagliabue Alessandro

**Laboratoire de recherche** : (nom + code U/UMR/USR/EA/JE/… ) University of Liverpool
- **e-mail** : a.tagliabue@liverpool.ac.uk
- **Téléphone** : +44 (0) 151 794 4096
- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**

**Thèses en cours** :

- **Daniela Koenig** (University of Liverpool, UK): Oct 2018 – ongoing
- **Lewis Wrightson** (University of Liverpool, UK): Oct 2017 – ongoing
- **Shaun Rigby** (University of Liverpool, UK): Oct 2016 - Dec 2019 (viva pending)

**Thèses soutenues** :

- **Arthur Gourain** (University of Liverpool, UK): Completed 2020
- **Valérie Le Guennec** (University of Liverpool, UK): Completed 2020
- **Jorge Martinez-Rey** (University of Versailles, France):
  Co-supervision with Laurent Bopp and Marion Gehlen (LSCE) – Graduated February 2015
- **Marco van Hulten** (University of Groningen, the Netherlands):
  Co-supervision with Hein de Baar (NIOZ) and Andreas Sterl (KNMI) – Graduated November 2014
- **Nicholas Rogan** (University of Liverpool, UK):
  Co-supervision with Ric Williams (UoL) – Graduated August 2014

**Et/ou co-encadrant-e scientifique** : Jonathan Gula

**Laboratoire de recherche co-encadrant (nom + code U/UMR/USR/EA/JE/…)**
- **e-mail** : gula@univ-brest.fr
- **Téléphone** : +33 (0)2.90.91.55.39
- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**

**Thèses en cours** :

- **L. Wang** : “Impact of the meso and submesoscale dynamics on the fate of exported particles in the deep ocean”. Funding ISblue, PhD to be defended June 2022
  **Supervisors** : 30% co-direction with L. Memery

- **A. Chouksey** : “Submesoscale coherent vortices in the Atlantic and their impact on the large scale circulation”. Funding CNRS / Région Bretagne, PhD to be defended Dec. 2022
  **Supervisors** : 90% co-direction with X. Carton

- **A. Vic** : “The dynamics of oceanic VOrtices Coupled with the Atmosphere at the Mesoscale and submesoscale. Funding ENS”, Phd to be defended in 2023
  **Supervisors** : 30%, co-direction with X. Carton
- **C. Lemaréchal**: «Deep Hydrodynamic Processes near Hydrothermal vents.», Funding H2020 / UBO, PhD to be defended in 2023
  
  **Supervisors**: 30% co-direction with G. Roullet

- **P. Tedesco**: “Mesoscale eddy energy dissipation”, Funding Labex Mer / Ifremer, PhD to be defended in Feb. 2021
  
  **Supervisors**: 40% co-direction with P. Penven and C. Menesguen

**Thèses soutenues**:

- **M. Le Corre** (PhD defended in June 2020): “Impact of the topography and mesoscale turbulence activity on the dynamics of the North-Atlantic subpolar gyre”, Funding Labex Mer / UBO.
  
  **Supervisors**: 90% co-direction with A.-M. Tréguier

  **Current position**: CDD Ingénieur de recherche LEGOS

Le cas échéant, autres collaborations (co-encadrant et laboratoire concerné): Hélène Planquette (LEMAR), Anne Petrenko (MIO), Christophe Maes (LOPS), Cécile Guieu (LOV), Sophie Bonnet (M.I.O, Marseille)

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**Financement du projet de thèse**

En cas de financement à 50 %, le cofinancement est-il déjà identifié *(oui/non)*: Non

Si oui, préciser la nature du cofinancement *(ANR, partenaire privé, Ademe, etc.)*:

Si le cofinancement n’est pas encore confirmé, date prévue de réponse du cofinanceur:

En cas de non-obtention du cofinancement demandé, une autre source de cofinancement est-elle identifiée *(oui/non)*: Oui

Si oui, laquelle: UBO, ARED, ARED-IRD

Sollicitez-vous un co-financement Is-Blue *(y compris ARED Is-Blue)* *(oui/non)*? Oui

**Important**: Veillez à bien compléter les différents cofinancements sollicités sur le serveur Thèses en Bretagne Loire lors du dépôt de votre dossier.

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**Projet de thèse en cotutelle internationale**

S’agit-il d’un projet de thèse en cotutelle internationale dans le cadre d’une convention *(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)*: non

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

Préciser quel est le stade du projet international *(joindre une lettre d’engagement du partenaire)*
Nitrogen fixation is a major source of new nitrogen in the ocean and the Western Tropical South Pacific (WTSP) has recently been identified as a hot spot for such atmospheric nitrogen fixation with some of the highest rates measured in the world ocean. Nitrogen-fixing organisms (diazotrophs) have high cell quotas of iron (Fe) relative to non-diazotrophic plankton, making them prone to growth limitation by this scarce micro-nutrient. Their relatively high concentration in this specific region has then been attributed to high Fe inputs. Indeed, during oceanographic cruises (i.e. OUTPACE and TONGA), a shallow source (<500 m) of Fe of hydrothermal origin has been identified in the Tonga Volcanic Arc region. However, our knowledge of the sources/distribution of Fe in the WTSP remains limited. Dispersion of the volcanic plumes and the rates at which Fe reaches the euphotic zone and therefore fuels the surface organisms (including diazotrophs) has still to be understand and quantified.

This PhD project then aims to characterize and quantify the potential impacts of such hydrothermal inputs on regional Fe budgets (dissolved and particulate), on nitrogen fixation and therefore on biogeochemical cycles.

A coupled dynamical-biogeochemical model, able to explicitly simulate the regional nitrogen fixation (and that will include Fe hydrothermal inputs, ligands, and colloidal Fe) will be used as an integrative framework to test and quantify processes observed during the TONGA cruise. Indeed, this thesis topic is part of the TONGA project (shallow hydroThermal sOurses of trace elemeNts: potential impacts on biological productivity and the bioloGicAI carbon pump, http://tonga-project.org/web/, 2018-2022) and is notably based on the oceanographic cruise carried out at the end of 2019 in the Southwest Pacific (N/W L’Atalante). On a broader perspective, this PhD project will also bring new knowledge to constrain more efficiently the controls of ocean nitrogen fixation that is increasingly recognized as a major uncertainty in climate biogeochemical future projections.

The UMR LOPS, with the combination of expertise in ocean dynamics, biogeochemistry, and modelisation will host the PhD. In addition, the PhD project will benefit from the support of a group of expert with complementary skills gathered from IUEM (LEMAR), French (MIO, LOCEAN) and international laboratories (Univ. of Liverpool). In addition, the TONGA community of observers will make their expertise and the cruise data available to the PhD student.

Présentation détaillée du projet :

1 - Hypothèse et questions posées, état de l’art, identification des points de blocages scientifiques

The ocean plays a key role in climate regulation through its capacity to absorb atmospheric CO₂. This absorption depends in particularly on maintaining a vertical gradient of inorganic carbon concentrations with lower concentrations at the surface than at depth. The activity of phytoplanktonic organisms (photosynthetic microalgae) which use light and nutrients to fix inorganic carbon by photosynthesis in the surface layer makes it possible to maintain this gradient. Some of the organic carbon produced is remineralised and some is exported (by gravity, active transport or ocean dynamics) to the inner ocean [Falkowski et al. 1998], constituting the biological carbon pump. Biological production linked to phytoplankton activity therefore directly influences the absorption of CO₂ by the ocean and generates a coupling between the carbon cycle and many other elements such as nitrogen, phosphorus, silica and iron which can limit the growth of organisms [Broecker and Peng, 1982].

In particular, iron is considered to directly limit biological production in about 40% of the ocean [Boyd & Ellwood 2010; Moore et al. 2013]. However, in addition to this direct limitation of phytoplankton growth, iron is also involved in controlling the supply of nitrogen to the ocean, which is a limiting element in about 60% of the global ocean (mainly oligotrophic areas, Falkowski et al., [1997]). Indeed, in these areas, the main source of nitrogen is linked to atmospheric nitrogen fixation by diazotrophs (nitrogen-fixing organisms) that support 50-90% of new primary production in these regions [Karl et al. 2012; Caffin et al., 2018]. Nitrogen fixation relies on the iron-rich nitrogenase enzyme, which requires 5 to 100-fold more iron than non-diazotrophs [Kustka et al., 2003]. By influencing nitrogen fixation [Morel & Price 2003], iron thus indirectly controls primary production in these nitrogen-limited areas. Moreover, nitrogen fixation is growingly acknowledge as a significant source of uncertainty in the 21st century projections of oceanic biogeochemistry [Wrightson et al. 2020].

During an oceanographic cruise conducted in one of the ocean oligotrophic regions (OUTPACE in 2015), the "Western Tropical South Pacific" zone (WTSP), the hypothesis of iron fertilisation by hydrothermalism from shallow submarine volcanoes located on the volcanic arc of Tonga-Kermadec was put forward [Guieu et al., 2018] to explain the observed
high rates of nitrogen fixation (among the most intense measured in the global ocean) [Bonnet et al. 2017, 2018]. The TONGA cruise, conducted in 2019, therefore specifically focused on studying the impacts of these shallow submerged volcanoes and the associated iron inputs on carbon production, export and ecosystem structure in the WTSP. Through process studies carried out above two underwater volcanoes (200-500 m), a series of measurements including hydrothermal tracers and all physical/hydrological/biogeochemical/biological parameters were measured simultaneously with atmospheric inputs.

Taking advantage of the TONGA project (Fig. 1), the main goal of this thesis is thus to decipher, integrate and quantify, using a coupled physical-biogeochemical model as an integrator, the processes impacting the WTSP ecosystem (in particular nitrogen fixation) identified during the cruise.

By parameterizing the hydrothermal source according to the observations, the thesis proposes to:
1/ study the fate of shallow hydrothermal plumes in the water column on a local and regional scale, and in particular how the ocean dynamic influence the delivery of iron within the euphotic zone,
2/ study the potential impact of these hydrothermal inputs on planktonic communities (e.g. relative importance of diazotrophs) and biogeochemical cycles in the WTSP.

![Figure 1: Schematic of the TONGA project organization](image)

2 - Approche méthodologique et techniques envisagées :

The use of a coupled dynamical-biogeochemical model is considered. The dynamical model will be chosen among the NEMO or the CROCO models following a review of the most important skills to adequately reproduce the physical plume dispersion in the WTSP region. Physical parameterization might be developed if needed with the help of LOPS experts in regards to the analysis of fixed and drifting moorings, turbulence profilers and ARGO floats that were deployed to determine how physical parameters affect plume dilution and transport.

The biogeochemical model used during the PhD will be the PISCES model, which has been widely used in a variety of studies focusing on the iron cycle [e.g. Tagliabue et al., 2010; Gorgues et al., 2010; Raapoto et al., 2019]. The chosen PISCES version will include an explicit representation of a compartment of nitrogen fixers: the cyanobacteria *Trichodesmium* [see Dutheil et al. 2018]. Then, the variables sampled during TONGA (e.g. including dissolved iron, particulate iron, and iron ligands data) will present a unique opportunity to realistically parameterize the hydrothermal source of iron and the effect of the iron biogeochemistry on the dispersion of the iron plume under the euphotic layer, which will probably require complexifying the iron cycle as currently considered in biogeochemical models.
Following those parameterizations, hydrothermal sources will then be added to the dynamical-biogeochemical coupled model simulating the biogeochemistry of the WTSP. By comparison with standard simulations (without hydrothermal iron sources), the specific impact of iron transported in the euphotic layer on production and ecosystem structure can thus be quantified on a regional scale, which cannot be done from observations alone. Observations of stocks, fluxes and ecosystem structure along the hydrothermal gradients encountered will allow the validation of the simulations. In particular, the simulated nitrogen fixation, Trichodesmium biomasses (nitrogen fixers) and iron uptake can be compared with local values measured during the cruise.

**Bibliography:**

- Bonnet et al., *PNAS*, 114, 2017
- Bonnet et al., *Biogeosciences*, 15, 2018
- Caffin et al., *Biogeosciences*, 15, 2018
- Dutheil et al., *Biogeosciences*, 15, 2018
- Gorgues et al., *Deep-Sea Research Part I*, 57, 2010
- Guieu et al., *Scientific Reports*, 8, 2018
- Moore et al., *Nat. Geosci.*, 6, 2013
- Raapoto et al., *JGR: Oceans*, 11, 2019
- Tagliabue et al., *Nat. Geosci.*, 3, 2010
- Wrightson et al., *Frontiers in Marine Science*, 7, 2020

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

The Laboratory of Physical and Spatial Oceanography (UMR LOPS) provide a unique environment to host the PhD with a combination of expertise in ocean dynamics, biogeochemistry and modelisation. Within IUEM, the PhD project will benefit from the support of expert in trace metal cycling from the LEMAR. This regional team will also benefit from collaborations at the national level with the teams that took part in the TONGA cruise in order to benefit from the observations made that are necessary for the modelling exercise, with in particular an involvement from the MIO (Marseille) and the LOV (Villefranche sur mer). Finally, the Univ. of Liverpool and the national but abroad UMR ENTROPIE (New Caledonia) will participate to this PhD project.

4 - Contexte scientifique et partenarial : éléments généraux (ERC, CPER, FEDER, Breizhcop ...)

This thesis topic is part of the TONGA project (shallow hydroThermal sOuRces of trace elemeNts: potential impacts on biological productivity and the biololoGicAl carbon pump, 2018-2022). TONGA is a multidisciplinary project dedicated to the study of the control of oceanic productivity and carbon sequestration by micronutrients of hydrothermal origin (http://tonga-project.org/web/). It involves 90 scientists from 19 international institutions and is based both on a 37-day oceanographic campaign in the southwest Pacific (N/W L’Atalante, campaign carried out at the end of 2019) and on modelling work. TONGA has received co-funding from ANR, INSU, the A-Midex foundation and IRD, and has been labelled by the international programmes GEOTRACES and IMBER. This project will finance the side costs of the thesis until 2022, by taking charge in particular of the set-up of the thesis student (purchase of informatique equipment, missions at the beginning of the thesis to meet abroad advisors, etc ...). A LEFE project will then be submitted to finance the side costs of the remaining part of the thesis.
Vous sollicitez un financement ISblue, ou une ARED ISblue : Oui

Précisez le lien du sujet avec les thèmes ISblue

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Expliquez/précisez en quelques lignes dans quelle mesure votre demande correspond à l’un ou plusieurs des critères ISblue ci-dessous :

1- Originalité, impact potentiel du projet
This interdisciplinary project involves ocean dynamic and biogeochemistry. It will also take advantages of in-situ measurements and model in order to achieve an integrated view of the processes at play in sustaining the ecosystem structure and production of the WTSP. It also tackles the understanding of processes controlling the nitrogen fixation, which is of great importance to the regional primary production (and its impacts on regional halieutic ressources) and is also a major source of uncertainty in climate models.

2- Positionnement international du sujet, cotutelle ou co-encadrement international
This project focuses notably on identifying processes and quantifying fluxes that control the distribution of iron, which fall within the main interests of the GEOTRACES international program. Close international collaborations with the University of Liverpool as well as with our colleagues from the south Pacific (UMR ENTROPIE) will provide the PhD students with abroad opportunities.

3- Effet intégrateur entre unités de recherche et / ou interdisciplinarités
The interdisciplinary nature of the PhD project is expected to foster established collaborations between the LOPS (e.g. ocean dynamic, biogeochemistry) and the LEMAR (e.g. trace metal cycle) at the local scale. At the national scale, collaborations with the MIO and the LOV through the TONGA project are envisioned. As previously mentioned, collaboration will also take place at international levels.

4- Potentiel d'insertion à un haut niveau dans la communauté académique ou non académique du docteur
This project involves a broad community of oceanographers at the national level as well as potential collaborations with international colleagues from the GEOTRACES program, which should provide good chances of postdoctoral opportunities to the PhD.

Le candidat

Profil souhaité du candidat (spécialité/discipline principale, compétences scientifiques et techniques requises) :

This subject is intended for a motivated candidate with a Master's degree in oceanography (e.g. marine biogeochemistry, physics or chemistry of the marine environment). Strong programming skills are required. In particular, a knowledge of programming languages (Fortran, Python, Matlab) and the UNIX/Linux environment is essential. Good communication skills in English will be appreciated.

ATTENTION :
Tout dossier non déposé sur le serveur dans les délais indiqués, ne pourra être pris en compte notamment par les instances ISblue, conseil de l’EDSML.