PROPOSITION DE SUJET DE THESE

Formulaire demande de financement : ARED - ISblue – Etablissement(s) - …

pour dépôt sur le serveur SML — TEBL (doctorat-bretagneloire.fr) *au format* ***PDF***

NB : ce dossier ne vous dispense pas de déposer en parallèle votre dossier sur l'extranet de la Région

Acronyme : PhytAO

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

Établissement porteur du projet : UBO X UBS ☐ Institut Agro Rennes ☐

IMTA ☐ ENSTA ☐ ENIB ☐

Ecole Doctorale : EDSML X

SPI BZH ☐ SPIN ☐ MATHSTIC Bretagne Océane ☐ pour les projets ISblue ☐

Identification du projet

Intitulé du projet	**PHYT**oplankton dynamics and underlying processes in the **A**rctic **O**cean based on observations and deep learning
Nom	MARTINEZ
Prénom	Elodie

Demande d'ARED

Se reporter à la notice ARED Région Bretagne et préciser :

Priorité régionale	PR 1- "contribuer à l'atténuation et/ou à l'adaptation au changement climatique "
DIS	DIS 1 "économie maritime pour une croissance bleue"
Levier thématique	Environnement, santé des océans et gestion du littoral
DIS secondaire	
Levier thématique secondaire	
Axe transversal	

Organisme de tutelle : encadrement et unité de recherche

Porteur du projet HDR

Date obtention de l'HDR	21 mai 2021
Nom	Martinez

Prénom	Elodie
Adresse électronique	elodie.martinez@ird.fr
Tel	02 90 91 55 86
Expérience d'encadrement	Hirohiti. Raapoto (2015-2018, University of French Polynesia, funding Delegation of French Polynesian Research), Joana Roussillon (2020-soutenance expected in April 2023, UBO, funding Isblue-EDSML), Thomas Hermilly (2022-2025, IRD, funding IRD-ARED IRD)

Unité de recherche

Nom de l'unité	Laboratoire d'Océanographie Physique et Spatiale
Acronyme de l'Unité (umr xx, .)	LOPS (UMR 6523)
Nom et prénom du responsable	Jérôme Paillet
Le cas échéant, nom de l'équipe de recherche	Océan et Climat
Le cas échéant, nom du responsable de l'équipe de recherche	Camille Lique et Florian Sevellec

Co-directeur de thèse – si nécessaire

Nom	Lique
Prénom	Camille
Adresse électronique	camille.lique@ifremer.fr
Unité de recherche	LOPS
Établissement de tutelle	Ifremer
Expérience d'encadrement	Peter Davis (2012-2015, University of Oxford), Benjamin Barton (2016-2019, UBO, funding DGA-Dstl), Angelina Cassianides (2020-2022, soutenance planned in March 2023, Ifremer, funding: ANR - Ifremer). Alice Richards (2019-2022, University of Oxford), Ophelie Meuriot (2019-2023, Imperial College London), Emma Bent *(2021-2023, Ifremer, funding: ERC WAAXT - ISblue)*

Co-encadrant (s) de thèse – si nécessaire

Nom	Drumetz
Prénom	Lucas
Unité de recherche	LabStiCC
Etablissement de tutelle	IMT Atlantique
Expérience d'encadrement	Paul Aimé (2020-2023, IMT Atlantique, ongoing, funding Isblue/Carnot TSN institute), Anthony Frion (2021-2023, IMT Atlantique, ongoing, funding ANR JCJC), Raphaël Baena (2020-2023, IMT Atlantique, ongoing, funding IMT Atlantique), Aymane Abdali (2022-2023, IMT Atlantique/Schneider Electric, ongoing, funding Schneider Electric), Zakaria Jarraya (2022-2023, ongoing, Funding IMT Atlantique)

Nom	Oziel
Prénom	Laurent
Unité de recherche	Marine Biogeochemistry Department - MarESys
Établissement de tutelle	Institut Alfred Wegener pour la recherche polaire et marine (Bremerhaven, Allemagne)
Expérience d'encadrement	Gerrit Eisele (2022, MSc. U. Bremen)

Description du projet : complément

Lieu principal de déroulement du projet en Bretagne : LOPS, équipe Océan et Climat

Lieu principal de déroulement du projet si hors Bretagne :

Libellé (attention veiller à respecter le nombre de caractères imposés par le serveur de la Région)

Résumé synthétique du projet

The Arctic Ocean (AO) is commonly referred to as a bellwether of global climate change, as no region on the planet is experiencing more dramatic climate change than the Arctic. These changes in environmental conditions are altering phytoplankton dynamics and consequently marine ecosystems. In the AO, phytoplankton dynamics is controlled by a complex interplay of light and nutrients which differs from the global ocean. Most of the previous studies have been conducted regionally and illustrate the complexity of the Arctic biogeography. Several issues remain: i) a lack of synoptic view of the phytoplankton spatio-temporal variations at the AO scale associated with ii) large uncertainties on the environmental conditions driving changes in the phytoplankton dynamics in ice free areas but especially under sea-ice, inducing iii) large uncertainties on how phytoplankton will evolve in a warming future.

The PhytAO project aims to fully comprehend the impacts of environmental drivers and their change on phytoplankton dynamics 1) at the surface of the Arctic Basin, 2) in the water column both in the ice free and ice covered regions, and 3) to reconcile the different estimates made at the surface from 1- and regionally from 2- to obtain an pan-Arctic estimate of the phytoplankton dynamics and primary production. The project will take advantage of a large range of *in situ* and satellite observations combining both biogeochemical and physical datasets, using advanced statistical methods based on artificial intelligence. Deep Learning schemes will be new means to automatically identify latent patterns and hidden trends from observations, to produce new knowledge on phytoplankton dynamics in a way that has not been achieved so far.

Hypothèses, questions posées, points de blocage, approche méthodologique, technique (4 000 caractères maximum)

The Arctic Ocean (AO) is undergoing one of the fastest transformations on the planet in response to climate change. The changes impact all the AO system's components (ocean, atmosphere, cryosphere), which in turn alter primary production (PP) and the marine ecosystems.

In the AO, phytoplankton (phyto) dynamics is controlled by a complex interplay of light and nutrients (and so of the processes supplying them toward the upper sunlit layer) which differs from the global ocean. **Previous studies, most often focusing on a given region, have revealed that the main environmental drivers may strongly differ spatially**. For instance in the ice-free regions, earlier sea-ice retreat has been considered a key driver for earlier and stronger blooms in large portions of the AO[1,2], while blooms have weakened in other places[5]. River

runoff[7], upwelling or eddy-driven advection of nutrients[6] were also reported to sustain blooms. On the other hand, in ice-covered regions, a thinner sea ice (allowing more light penetration to stimulate phyto growth) results in massive under-ice blooms which have been reported in recent years as having much more significance in terms of PP than previously thought[3,4]. Overall, a full understanding of the relative role of the physical processes driving the phyto dynamics is still lacking. **Due to the complexity of the AO biogeography, we are facing the following issues**: i) **a lack of synoptic view of the phyto dynamics at the AO scale**; ii) **large uncertainties on the environmental conditions driving their changes, especially under sea-ice**; iii) **large uncertainties on the future evolution of phyto under a warming climate.**

In this context, the objective of this PhD is to fully comprehend the interplay of environmental drivers and their changes on phyto dynamics at the pan-Arctic scale, in both ice-free and ice-covered regions.

This work will take advantage of **a large range of *in situ* and satellite datasets of both biogeochemical and physical observations, combined with advanced statistical methods based on deep learning (DL)** The proposed emulation-based methodology can be summarized as learning a function (f) that maps input variables (X, the predictors) to output variables (Y, such as chlorophyll concentration-Chl, a proxy of phyto biomass). **Different DL schemes** from purely data-driven schemes (Y= f(X); e.g., ConvNets, recurrent architectures)[9] to physics-informed approaches (e.g., ∂tY=f(Yt, Xt))[10] **will be applied to identify evolution laws and assess the relative contribution of physical processes on phyto dynamics.** The specific objectives are:

1) **To investigate the temporal variability and trends of phyto dynamics at the surface of ice-free regions over the past 25 years.** We will make use of ocean color satellite-based observations, and an algorithm[11] very recently developed specifically for the AO, where the standard methods perform poorly. **To consider the impact of physical predictors on phyto dynamics,** several emulators will be applied to ocean color vs. physical oceanic and atmospheric observations (e.g., light, sea ice, winds).

2) **To characterize the phyto dynamics and underlying processes in parts of the basin not monitored by satellite (i.e the subsurface and ice covered regions).** The DL schemes will be applied to Chl and physics time-series from both satellite and *in situ* observations such as Ice-Tethered Profilers under sea ice, moorings, BGC argo floats and the MOSAiC expedition[12]. Building emulators will be implemented considering:

2.a) each *in situ* platform independently **to contrast the phyto dynamics and forcing at play in the different regions (**and remove inter-plateforme calibration bias).

2.b) simultaneously all platforms, to try emulating phyto time-series at AO scale and **reconcile the different results obtained for the different parts of the AO to get a pan-Arctic estimate of the phyto dynamics and PP**.

Publications in which the **supervisors have participated are in bold**

1 Kahru et al., Global Change Biology, 17(4), 1733-1739 (2011).

2 Ji et al., Global change biology, 19(3), 734-741 (2013).

3 Horvat et al., Science advances, 3(3), e1601191 (2017).

4 **Ardyna et al**., Frontiers in Marine Science, 7, 608032 (2020).

5 Song et al., Limnology and Oceanography, 66(6), 2498-2508 (2021).

6 **Oziel et al.,** Global Biogeochemical Cycles, 36, e2021GB007268. (2022).

7 Dunse et al., Biogeosciences Discussions, 2021, 1-30 (2021).

8 Lewis et al., Science 369, 198–202 (2020).

9 **Martinez et al.**, Frontiers in Marine Science *7*, 464 (2020).

10 **Fablet et al**., *Journal of Advances in Modeling Earth Systems*, *13*(10), e2021MS002572 (2021).

11 Lewis & Arrigo, Journal of Geophysical Research: Oceans, 125(6), e2019JC015706 (2020)
12 Rabe et al., Elementa: Science of the Anthropocene 10 (1): 00062(2022)

Environnement scientifique, positionnement dans contexte régional/national/international

The **originality of** PhytAO lies in its **inter- and trans-disciplinary** overview using physical oceanography, biogeochemistry and artificial intelligence in a hot spot regarding the impacts of climate changes.

The student will actively contribute to the CLIMArcTIC project (**PPR Ocean & Climat funded by France2030, PI. C. Lique)**, which is funding 50% of the studentship, and will attend the yearly meetings of the project. He/she will closely collaborate with the members of the broad consortium, in particular with the scientists involved in WP1 which aims at characterizing the past and future physical and biogeochemical changes in the AO using DL.

PhytAO will also benefit from 1) the multidisciplinary environment developed within the **ANR AI-Chair OceaniX (PI R. Fablet**) at the crossroads of physics-informed AI and ocean science on Brest campus as well as 2) previous and current work led by E. Martinez in collaboration with L. Drumetz/R. Fablet to provide DL schemes dedicated to satellite and *in situ* observations to investigate phytoplankton dynamics in the [50°N-50°S] region (e.g., Martinez et al., 2020; Roussillon et al., accep).

The student will be based at LOPS, as a member of the 'Ocean and Climate' team, benefiting from the strong expertise regarding PhytAO. He/she will be involved in the LOPS current initiative to develop a new synergy amongst researchers involved in different polar research activities, through the implementation of "axe transverse – recherches polaires".

He/she will also benefit from the international collaboration with L. Oziel (co-supervisor) and from the stimulating scientific environment at AWI (Germany), which is one of the world leading institutes in Arctic research. Short stays of the student at AWI are planned.

These collaborations, combined with attendance at international conferences and meetings, are expected to provide the student with the necessary national and international networks and exposure needed to start a successful scientific career.

Collaborations scientifiques (nature/partenariat/pays) et partenariat socio-économique envisagé

A direction team has been created to include the diverse scientific backgrounds necessary to make this thesis a success. The advisors' areas of expertise, most relevant to PhytAO and as presented above, are as follows:

- Elodie Martinez (Director, LOPS) : Remote-sensing and in situ studies of phytoplankton dynamics and its underlying processes, notably with machine learning approaches.
- Camille Lique (co-director, LOPS): Large-scale observational, modeling and remote sensing studies of Arctic ice-ocean dynamics.
- Lucas Drumetz (co-supervisor, LabStiCC): Machine Learning and AI, applied mathematics, remote sensing.
- Laurent Oziel (co-supervisor, AWI Allemagne): Large-scale remote sensing and modeling studies of Arctic phytoplankton dynamics.

Pour les demandes Région Bretagne

Adéquation du projet avec le DIS de Rattachement
Pour les demandes Région Bretagne

The project presented here clearly meets the expectations of **DIS 1** ("maritime economy for a blue development") since it aims to strengthen the scientific excellence of the region on the knowledge of the world's ocean. Today this knowledge is crucial to enable us to adapt to the effects of climate change. PhytAO is part of the **thematic leverage 5** "Environment, ocean health and coastal management".

Phytoplankton is a key component of the carbon cycle and governs the evolution of primary production, which in turn affects marine ecosystems. Although the Arctic Ocean is undergoing one of the fastest transformations on the planet in response to climate change, large uncertainties remain about the phytoplankton dynamics in this remote and undersampled region. PhytAO aims to improve the understanding of the phytoplankton dynamics and the underlying mechanisms in the Arctic Ocean, to better understand past and present events and to help human societies anticipate future social and environmental challenges.

It will rely on the synergy of in situ data sets, in particular those provided by the Argo research infrastructure, through projects such as the CPER ObsOcean (2021-2026); the PIA3 project "Argo2030" (2021-2028); and the Ifremer PIE PIANO exceptional investment project (2021-2027). PhytAO will thus contribute to the scientific valorisation of Argo data in a structuring and very promising context.

Si priorité régionale, préciser

Demande de (co)financement ISblue

Vous sollicitez un financement ISblue,

Précisez le lien du sujet avec les thèmes ISblue

Thème ISblue	**Thème principal**	**Thème secondaire** (si nécessaire)	**Autre** (si nécessaire)
la régulation du climat par l'océan	**X**		
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		**X**	

The inter-disciplinary topic developed in this thesis has been clearly identified in the IsBlue Theme 1 and 5 topics through its component "Coupling between the dynamics, minor and major chemical elements, biogeochemistry, and ecology of plankton in the open ocean, from the scale of energy dissipation to the large-scale thermohaline circulation, and their modifications related to climate change" for **Theme 1** and the component "Extract, reconstruct, predict, and emulate physical, chemical, biological, geological, and ecological essential ocean variables (EOVs) from multisource ocean data streams to uncover local and remote short-term and climate-scale interactions, with an

emphasis on data-driven and model-data-coupled strategies, for operational oceanography applications and research purposes" for **Theme 5.**

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

1- Originalité, impact potentiel du projet

The **originality** of PhytAO lies in its **inter- and trans-disciplinary** overview using physical oceanography, biogeochemistry and artificial intelligence in a hot spot (the AO) regarding the impacts of climate changes. It will i**mprove the knowledge in the AO**, to better understand past and present events and to help human societies **to anticipate future social and environmental challenges**

2- Positionnement international du sujet, cotutelle ou co-encadrement international

We will apply to two specific IsBlue calls to support 1) "the international mobility of the PhD student" to visit and collaborate with one of his co-supervisor, Dr. Oziel, to the Alfred Wegener Institute in Germany; 2) "the hosting of internationally renowned researchers and professors" for periods of 1 to 6 months, namely Dr Oziel.

3- Effet intégrateur entre unités de recherche et / ou interdisciplinarités

The ambitious interdisciplinary approach proposed here is based on the strong expertise of the different collaborators and their complementary research fields: ocean dynamics and biogeochemistry of the ocean via satellite and in situ observations (LOPS and the Alfred Wegener Institute) combined with statistical and artificial intelligence approaches (LabSTICC).

4- Potentiel d'insertion à un haut niveau dans la communauté académique ou non académique du docteur (4 lignes maxi)

The interdisciplinary aspect of this thesis opens both professional insertion perspectives in the i) academic world by its inherent component linked to its research activity itself towards themes in physics/ biogeochemistry/ Artificial Intelligence (AI), but also ii) non-academic by its component linked to the AI approach (engineering jobs related to information technologies, signal processing and telecommunication)

Financement du projet de thèse

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

Si oui, préciser la nature du cofinancement (*ANR, partenaire privé, Ademe, etc.*) : PPR CLIMArcTIC (PI C. Lique, financement ANR France2030)

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 : ARED-UBO

Sollicitez-vous un co-financement Is-Blue *(oui/non)* **? oui**

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)

Vous sollicitez un financement UBO EDSML qui sera porté à la décision du Conseil de l'ED

Indiquez le ici, oui X non ☐

Le candidat

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

This subject is addressed to a motivated candidate with a master degree in oceanography (e.g. marine biogeochemistry, physical oceanography). Strong numerical programming skills are required. In particular, knowledge of programming languages (e.g., Python) and the UNIX/Linux environment is essential. Writing and communication skills in English will be appreciated.