PhD POSITION

Organization	Laboratory for Ocean Physics and Satellite remote sensing
Location	Laboratoire d'Océanographie Physique et Spatiale - UMR6523 CNRS/IFREMER/IRD/UBO Ifremer - Centre de Bretagne ZI de la Pointe du Diable, CS10070, F-29280 Plouzané
Research field	Biogeochemical oceanography
Type of contract	3-year PhD position
Website to apply	https://theses.doctorat-bretagneloire.fr/sml/campagne-2023 (SDU/UMR 6523 LOPS)
Application deadline	**15/5/2023**
Position start date	01/09/2023

PRESENTATION

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 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[3]. River runoff[4], upwelling or eddy-driven advection of nutrients[5] were also reported to sustain blooms. On the other hand, in ice-covered regions, a thinner sea ice (allowing more light penetration to stimulate phytoplankton 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[6,7]. Overall, a full understanding of the relative role of the physical processes driving the phytoplankton 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 phytoplankton 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 phytoplankton under a warming climate.

In this context, the objective of this PhD is 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.

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 phytoplankton biomass). Different DL schemes from purely data-driven schemes (Y= f(X); e.g., ConvNets, recurrent architectures)[8] to physics-informed approaches (e.g., ∂tY=f(Yt, Xt))[9] will be applied to identify evolution laws and assess the relative contribution of physical processes on phytoplankton dynamics. The specific objectives are:

1) **To investigate the temporal variability and trends of phytoplankton 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[10] very recently developed specifically for the AO, where the standard methods perform poorly. **To consider the impact of physical predictors on phytoplankton 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 phytoplankton 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[11]. Building emulators will be implemented considering:

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

2.b) simultaneously all platforms, to try emulating phytoplankton 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 phytoplankton dynamics and PP**.

References

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 Song et al., Limnology and Oceanography, 66(6), 2498-2508 (2021).
4 Dunse et al., Biogeosciences Discussions, 2021, 1-30 (2021).
5 Oziel et al., Global Biogeochemical Cycles, 36, e2021GB007268. (2022).
6 Horvat et al., Science advances, 3(3), e1601191 (2017).
7 Ardyna et al., Frontiers in Marine Science, 7, 608032 (2020).
8 Martinez et al., Frontiers in Marine Science 7, 464 (2020).
9 Fablet et al., Journal of Advances in Modeling Earth Systems, 13(10), e2021MS002572 (2021).
10 Lewis & Arrigo, Journal of Geophysical Research: Oceans, 125(6), e2019JC015706 (2020)
11 Rabe et al., Elementa: Science of the Anthropocene 10 (1): 00062(2022)

Scientific Environment

The originality of this thesis 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. https://climarctic.cnrs.fr

The student 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).

The student will be based at LOPS, as a member of the 'Ocean and Climate' team, benefiting from the strong expertise regarding this work. 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.

Scientific collaborations

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 this PhD work 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) and Ronan Fablet (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.

Qualifications

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.

Application

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