Proposition de sujet de thèse 2026

(A remplir par les équipes d'accueil et à retourner à Isabelle HAMMAD : hammad@cerege.fr
**à renseigner obligatoirement pour la validation du sujet, (1) : A remplir lors de la campagne d'attribution des allocations, à l'issue de la session de juin des Masters*

Sujet de doctorat proposé *: Ocean dynamics and the potential for anoxia across the Phanerozoic in the Earth System Model IPSL-CM5A2

Encadrant(s), *nom, prénom, adresse mail *: Donnadieu, Yannick, donnadieu@cerege.fr*
Laboratoire *: CEREGE

Tableau récapitulatif du sujet

Candidat(e)(1)	
Nom - Prénom :	
Date de naissance :	
Licence (origine, années, mention) :	
Mention et classement au Master 1 année (Xème sur Y)	
Mention et classement au S3 du Master 2 (Xème sur Y)	
Mention et classement au S4 du Master 2 (Xème sur Y)	
Mention et classement au M2 (année) (Xème sur Y)	
MASTER (nom, université)	
Sujet de doctorat proposé*	**Ocean dynamics and the potential for anoxia across the Phanerozoic in the Earth System Model IPSL-CM5A2**
Encadrants (2 max, indiquer si HDR ou pas)*	Yannick Donnadieu (HDR)
Laboratoire*	CEREGE
Programme finançant la recherche (indiqué si obtenu ou envisagé) (1)	Appel d'offre pour les heures de calcul, moyen nationaux, TGCC Irène, Projet GEN2212 - 30 Millions d'heures par an + financement conférence et workshop (ANR JCJC PROCOPE – JB Ladant + Fonds Propres – Y. Donnadieu)

Sujet de doctorat proposé*

Intitulé* :

Ocean dynamics and the potential for anoxia across the Phanerozoic in the Earth System Model IPSL-CM5A2

Descriptif *:

Among the dramatic consequences of human activities on the Earth system, changes in the oxygenation state of the ocean have attracted the attention of the scientific community over the last decade (Kwiatkowski et al., 2020; Breitburg et al., 2018). All Earth System Models (ESMs) project a consistent decrease in oceanic oxygen content for the coming decades due to ocean warming, reduced ventilation, and increased stratification, although large uncertainties remain—owing, for instance, to how nitrogen fixation is resolved (Bopp et al.,

2022). This change in oceanic oxygen content may result in the destabilization of sediments and fundamental shifts in the availability of key nutrients, with the potential to alter the abundance and distribution of marine species.

The rock record shows large fluctuations in oceanic oxygen content, including iconic periods of global anoxia (e.g., OAEs), which can serve as a surrogate to better ground-truth the predictability of Earth System Models. Periods of OAEs were characterized by organic-matter-enriched sediments and have been studied for several decades using various geochemical proxies (metal enrichment, stable isotopes as $\delta 13C$, etc.; see Reershemius and Planavsky, 2021, for a complete review). These events are also commonly associated with major extinctions or biotic turnover events (Bambach, 2006). Improving our knowledge of these intervals is therefore central to understanding the interdependence between geochemical cycling and biotic events throughout the Phanerozoic.

Two main processes have been widely suggested to explain OAEs: on the one hand, they are intrinsically related to specific large-scale ocean circulation patterns favoring dysoxia in isolated oceanic basins (Laugié et al., 2021); on the other hand, they stem from the need for large nutrient inputs to boost primary productivity (PP) (Monteiro et al., 2012), either through subaerial/marine Large Igneous Provinces (LIPs) or through internal feedbacks that increase phosphorus recycling. Up to now, OAEs have primarily been studied using relatively simple models (e.g., box models or EMICs) that rely on parameterized relationships linking disturbances in the marine biosphere to biogeochemical cycles. Such approaches overlook important feedbacks—for example, the influence of ecosystem structure on ocean chemistry—as well as spatial variability, thereby limiting our understanding of the processes that lead to OAEs.

The French deep-time modeling group has developed a series of tools facilitating the application of the IPSL-CM, enabling a global investigation of ocean dynamics through the Phanerozoic and their consequences on oxygen distribution using PISCES-Offline. The high complexity of the biological ecosystem representation in PISCES opens the door to investigating the role of various biological innovations over the Phanerozoic. Furthermore, the IPSL-CM allows for the prediction of dust transport and distribution in the atmosphere, as well as fallout patterns into the ocean. The role of dust as a nutrient input to boost marine productivity is intriguing and remains almost unstudied. This component may have been of paramount importance during the early Phanerozoic, when land plants were largely absent, as well as during eruptive volcanic episodes, which are suggested as the priming factor for OAEs.

The overall objective of this project is to explore ocean dynamics and the potential for anoxia across the Phanerozoic using both the IPSL-CM5A2 Earth System Model and the complex oceanic biogeochemical model PISCES. Several goals will be pursued:

1. Determine to what extent changes in ocean dynamics driven by paleogeographic evolution can explain the likelihood of OAEs.
2. Define the role of dust inputs on primary productivity for contrasting time periods (e.g., Early and Late Cambrian, Late Ordovician, Devonian, P-T, Toarcian, Aptian).
3. Establish the link between Oxygen Minimum Zone (OMZ) extent and the potential for anoxia over continental slopes and epeiric seas.
4. Investigating the influence of extreme events—by considering time-series outputs rather than mean states—on the representation of biological ecosystems in the PISCES model.

Because marine ecosystems have evolved significantly over the Phanerozoic, we will leverage the complex biological descriptions in PISCES to investigate how this evolution influenced carbon export and oxygen distribution. This will be achieved by "turning off" specific phytoplankton functional types (e.g., diatoms), removing the grazing effects of mesozooplankton, or modifying the sinking rates of biogenic particles (accounting for the likelihood of an ocean dominated by picoplankton).

Ref:
Bambach, R., 2006. Phanerozoic biodiversity mass extinctions. Annu. Rev. Earth Planet. Sci. 34, 127–155.
Bopp et al., Diazotrophy as a key driver of the response of marine net primary productivity to climate change, Biogeosciences, 19, 4267–4285, https://doi.org/10.5194/bg-19-4267-2022, 2022.

Breitburg et al., Declining oxygen in the global ocean and coastal waters. Science359, eaam7240(2018). DOI:10.1126/science.aam7240
Kwiatkowski et al., Twenty-first century ocean warming, acidification, deoxygenation, and upper-ocean nutrient and primary production decline from CMIP6 model projections, Biogeosciences, 17, 3439–3470, https://doi.org/10.5194/bg-17-3439-2020, 2020.
Laugié et al., 2021, Exploring the Impact of Cenomanian Paleogeography and Marine Gateways on Oceanic Oxygen, doi:10.1029/2020PA004202, Paleoceanography and Paleoclimatology
Monteiro et al., Nutrients as the dominant control on the extent of anoxia and euxinia across the Cenomanian-Turonian oceanic anoxic event (OAE2): Model-data comparison, Paleoceanography, 27, PA4209, doi:10.1029/2012PA002351, 2012.
Pohl et al., 2022. Continental configuration controls ocean oxygenation during the Phanerozoic. Nature 608(7923), 523-527. doi:10.1038/s41586-022-05018-z
Reershemius and Planavski, What controls the duration and intensity of ocean anoxic events in the Paleozoic and the Mesozoic? ESR, 221, doi.org/10.1016/j.earscirev.2021.103787, 2021

Détail du Programme finançant la recherche* : Appel d'offre pour les heures de calcul, moyen nationaux, TGCC Irène, Projet GEN2212 - 30 Millions d'heures par an + financement conférence et workshop (ANR JCJC PROCOPE – JB Ladant + Fonds Propres – Y. Donnadieu)

Directeur(s) de thèse proposé(s)*

(limiter au plus à deux personnes principales, dont au moins une titulaire de l'HDR)

Directeur HDR proposé*

Nom - Prénom : Donnadieu - Yannick
Corps : DR1 CNRS
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Choix de cinq publications récentes (souligner éventuellement les étudiants dirigés co-signataires) :

1. Merdith A., Gernon TM, Maffre P., Donnadieu Y., et al., 2025, Phanerozoic icehouse climates as the result of multiple solid-Earth cooling mechanisms, Science Advances 11 (7), eadm9798. DOI: 10.1126/sciadv.adm9798

2. Pineau E., Donnadieu Y., Maffre P., Lique C., Huck T., Gramoullé A. and J-B. Ladant, 2025, A model based study of the emergence of North Atlantic deep water during the Cenozoic: A tale of geological and climatic forcings, Paleoceanography and Paleoclimatology, 40(5), e2024PA005020. https://doi.org/10.1029/2024PA005020

3. Pillot Q., Donnadieu Y., Sarr AC, Ladant JB and Sucheras-Marx B., 2022, Evolution of Ocean Circulation in the North Atlantic Ocean During the Miocene: Impact of the Greenland Ice Sheet and the Eastern Tethys Seaway, Paleoceanography and Paleoclimatology, 37, e2022PA004415, https://doi.org/10.1029/2022PA004415

4. Sarr, A-C., Donnadieu, Y., Bolton, C., Ladant, J-B., Licht, A., Fluteau, F., Laugié, M., Tardif, D., Dupont-Nivet, G., 2022, Neogene South Asian Monsoon Rainfall and Wind Histories diverged due to topographic effects, Nature Geosciences. DOI : 10.1038/s41561-022-00919-0

5. Laugié M., Donnadieu Y., Ladant J.-B., Bopp L., Ethe C. and F. Raisson, 2021, Exploring the Impact of Cenomanian Paleogeography and Marine Gateways on Oceanic Oxygen, doi:10.1029/2020PA004202, Paleoceanography and Paleoclimatology

Thèses encadrées ou co-encadrées au cours des quatre dernières années*

Nom : Pineau Erwan

Intitulé : Stability / instability of the Atlantic Meridional Oceanic Circulation: What the past can tell us and what were consequences on the oceanic carbon sink?
Type d'allocation : Co-Financement Institut Océan - Protisvalor
Date de début de l'allocation de doctorat : Octobre 2023
Date de soutenance (si la thèse est soutenue) : En cours, prévu pour Octobre 2026
Programme finançant la recherche : GENCI, heures de calcul + projet Camille Lique
Situation actuelle du docteur (si la thèse est soutenue) :
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : .....70...%
(codir = Camille Lique UBO)

Nom : Pillot Quentin
Intitulé : Évolution de l'écologie et du climat au cours du Miocène Supérieur, un regard croisé entre données marines et modélisation numérique du Système Terre
Type d'allocation : Thèse sur contrat ANR
Date de début de l'allocation de doctorat : Novembre 2020
Date de soutenance (si la thèse est soutenue) : Décembre 2023
Programme finançant la recherche : ANR MIOCARB
Situation actuelle du docteur (si la thèse est soutenue) : Boite de production de jeux de société en relation avec les changements environnementaux.
Pourcentage de participation du directeur à l'encadrement en cas de co-direction : .....50.....%
(codir = Baptiste Suchéras-Marx)