

STAGE DE RECHERCHE de MASTER 2^{ème} ANNEE

Master SOAC / WAPE

Année Universitaire 2025-2026

LABORATOIRE : Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN)

SUJET DU STAGE : How reversible are physical and biogeochemical ocean changes for different global warming levels?

COORDONNEES DU RESPONSABLE :

Nom – Prénom : Köhn, Eike

Adresse: Tour 55-56 - 4^è étage - Bureau 413, 4, place Jussieu 75252 PARIS

Téléphone : +33 7 53 67 02 70

E-mail : eike.koehn@locean.ipsl.fr

NATURE DU SUJET :

Théorie	Pas du tout	Un peu	Beaucoup
Modélisation num.	Pas du tout	Un peu	Beaucoup
Expérimentation	Pas du tout	Un peu	Beaucoup
Analyse de données	Pas du tout	Un peu	Beaucoup
Instrumentation	Pas du tout	Un peu	Beaucoup

SUJET :

To stay within the global temperature targets set in the Paris Agreement in 2015, periods of net-negative emissions of carbon dioxide (CO₂) are becoming increasingly necessary. Most of these negative emission scenarios include a period where global mean temperatures transiently overshoot the targets, increasing the risk for drastic and potentially irreversible changes (on human time scales) of climate system components, often referred to as the crossing of tipping points (Lenton et al., 2008; Armstrong McKay et al., 2022). To better understand how susceptible the climate system is to such tipping points, an ensemble of Earth System Model simulations have been performed (in the context of the European TipESM and OptimESM projects), in which CO₂ emissions first drive a rise in global mean temperatures, before net-zero emissions stabilise temperatures and subsequent negative emissions drive a global cooling. These simulations provide a unique opportunity to investigate how the climate system behaves under net-negative emissions, as well as how the likelihood of crossing tipping thresholds changes in a 1.5-4°C warmer climate.

In this M2 stage, the Master student would make use of the TipESM/OptimESM model simulations, foremost using the in-house IPSL model, to conduct a global assessment of the reversibility of changes in physical and biogeochemical oceanographic variables (e.g., sea surface temperature, stratification, sea ice cover, winds, nutrients, primary productivity, ...) as a function of the global warming level and the duration of the stabilisation at these high temperatures. This analysis will reveal hysteresis hotspots (Kim et al., 2022) which will then be the subject of further investigation, targeting a mechanistic understanding of the biogeochemical hysteresis (John et al., 2015). One of

these hotspots is expected to be the North Atlantic, where a (transient) weakening of the Atlantic Meridional Overturning Circulation (AMOC) or the subpolar gyre (SPG, Sgubin et al., 2017) will heavily alter physical and biogeochemical ocean processes.

Proposed research questions:

- Does a certain warming level/duration lead to (local or regional) changes that net-negative emissions cannot directly reverse? How does the degree of such hysteresis scale with warming levels?
- What are the cascading effects of an AMOC/SPG weakening on nutrient dynamics and primary productivity in the North Atlantic?

REFERENCES :

Armstrong McKay et al. (2022) : <https://doi.org/10.1126/science.abn7950>

John et al. (2015) : <https://doi.org/10.1002/2015GL066160>

Kim et al. (2022) : <https://doi.org/10.1038/s41558-022-01452-z>

Lenton et al. (2008) : <https://doi.org/10.1073/pnas.0705414105>

Sgubin et al. (2017) : <https://doi.org/10.1038/ncomms14375>

POURSUITE :

Ce stage peut-il donner lieu à un sujet de thèse ?

No. Depending on the results of the internship, a scientific publication may be considered.