Sorbonne Université/ China Scholarship Council program 2020

Thesis proposal

Title of the research project:

Spatial and temporal variability of the microbial carbon and iron metabolism in the Southern Ocean

Keywords:

heterotrophic microbes, carbon metabolism, iron, trace metals, metabolic strategy, Southern Ocean

Joint supervision: yes (name/surname) /~~no~~

Joint PhD (cotutelle): yes (name/surname) /~~no~~

Thesis supervisor: **Ingrid Obernosterer**

Email address of the thesis supervisor: Ingrid.obernosterer@obs-banyuls.fr

Institution: Sorbonne University

Doctoral school (N°+name): ED 129 “Sciences de l’Environnement”

Research laboratory: Microbial Oceanography Laboratory (LOMIC)

Address of the laboratory: Observatoire Océanologique de Banyuls

1 ave Pierre Fabre

66650 Banyuls sur mer, France

Name of the laboratory director: Fabien Joux

Email address of the laboratory director: fabien.joux@obs-banyuls.fr

SORBONNE UNIVERSITÉ

Subject description (2 pages max):

1) Study context

The Southern Ocean is the largest High Nutrient Low Chlorophyll (HNLC) area where major nutrients are perennially present at high concentrations yet phytoplankton biomass remains low. Surface depletion in iron (Fe) was demonstrated to be the cause of an inefficient biological pump of carbon in the Southern Ocean (Blain et al., 2007). While the effect of Fe on phytoplankton has been investigated in detail, it is not well understood how this and potentially other trace metals affect heterotrophic microbial metabolism. Fe and carbon are tightly coupled in a suite of metabolic processes crucial for growth. Fe plays a pivotal role in the carbon metabolism, in particular because processes related to respiration rely on multiple Fe-containing enzymes. A deficiency in Fe ultimately results in a reduction in the metabolic activity and the transformation of organic carbon (Fourquez et al., 2014; Obernosterer *et al.*, 2015).

These observations raise the question of the mechanisms used by microbial taxa to acquire and metabolize Fe and organic carbon in cellular processes. Several recent studies have provided novel insight to the gene inventories and expression patterns of related pathways in a diverse range of microbial taxa (Hopkins and Barbeau 2012, Toulza et al. 2012, Debeljak et al. 2019). Fe-limitation has been shown to induce the glyoxylate shunt in heterotrophic bacterial model organisms (Smith *et al.*, 2010; Fourquez *et al.*, 2014; Koedooder *et al.*, 2018), a pattern that was also observed for SAR11 in the HNLC Southern Ocean (Beier *et al.*, 2015). The glyoxylate shunt bypasses two decarboxylation steps and the coupled release of CO_2 and reducing equivalents ($NADH_2$) of the TCA cycle, with important consequences on ATP production and processing of organic carbon (Koedooder *et al.*, 2018).

The objectif of the doctoral thesis is to study the temporal and spatial variability of physiological strategies of heterotrophic microbes to process organic carbon under trace element limiting conditions. The doctoral student will mainly utilize « Meta-omics » methodologies providing insight to the metabolic potential of taxonomically diverse marine microbes, and thereby address the fundamental question of which microbial taxa participate to biogeochemical fluxes and what are their environmental drivers in a changing state of the Southern Ocean.

2) Details of the proposal

The temporal aspect will be adressed using already existing samples from a recent successful deployement of an innovative *in situ* sampling platform (the Remote Access Sampler, RAS) in a naturally iron-fertilized region of the Southern Ocean (Kerguelen plateau, project SOCLIM). The RAS was deployed from November 2016 to April 2017, covering the entire productive season. A total of 12 metagenomes are already available for the PhD thesis work. The parallel recording of key biogeochemical parameters using sensors mounted on the RAS mooring, and chemical and biological analyses provide contextual data on the seasonal changes in environmental factors.

The upcoming oceanographic cruise SWINGS (January-February 2021) will provide samples to cover the spatial aspect. Samples will be collected in different water masses of the Sub Tropical,

Sub Antarctic and the Antarctic waters, with particular focus on the Antarctic Circumpolar Current and its associated frontal areas in the Indian Sector of the Southern Ocean. The concurrent detailed description of trace elemental distributions across ocean provinces and depth layers will provide the contextual data for the observations of the microbial functional and taxonomic diversity.

This PhD thesis is part of the multidisciplinary projects SOCLIM – Southern Ocean and Climate (www.soclim.com) and SWINGS - (South West Indian Geotraces Section). The LOMIC (Laboratoire d'Océanographie Microbienne) has an international leadership in Southern Ocean research through its steering of the projects KEOPS (http://keops.obs-vlfr.fr), SOCLIM, and MOBYDICK – Marine Ecosystem Biodiversity and Dynamics of Carbon around Kerguelen : an integrated view (https://www.mio.univ-amu.fr/mobydick/)(2017-2022). The PhD candidate will receive training in different molecular and bioinformatics techniques, will interact with a diverse team of researchers with expertise in marine biogeochemistry, microbial ecology and diversity, and physiology of key microbial model organisms.

3) References

Beier, S., Gálvez, M.J., Molina, V., Sarthou, G., Quéroué, F., Blain, S., and **I. Obernosterer** (2015) The transcriptional regulation of the glyoxylate cycle in SAR11 in response to iron fertilization in the Southern Ocean. *Environmental Microbiology Reports* 7: 427–434.

Blain, S., Queguiner, B., Armand, L.K., Belviso, S., et al. (2007) Effect of natural iron fertilization on carbon sequestration in the Southern Ocean. *Nature* 446: 1070–1074.

Debeljak P., E. Toulza, S. Beier, S. Blain, **I. Obernosterer** (2019) Microbial iron metabolism as revealed by gene expression profiles in contrasted Southern Ocean regimes Environ. Microbiol. 21: 2360-2374. doi:10.1111/1462-2920.14621

Fourquez, M., Devez, A., Schaumann, A., Guéneuguès, A., Jouenne, T., **Obernosterer, I.,** and Blain, S. (2014) Effects of iron limitation on growth and carbon metabolism in oceanic and coastal heterotrophic bacteria. *Limnology and Oceanography* 59: 349–360.

Hopkinson, B.M. and Barbeau, K.A. (2012) Iron transporters in marine prokaryotic genomes and metagenomes. *Environmental Microbiology* 14: 114–128.

Koedooder C., A. Guéneuguès, R. Van Geersdaële, V. Vergé, F.-Y. Bouget, Y. Labreuche, **I. Obernosterer**, S. Blain (2018) The role of the glyoxylate shunt in the acclimation to iron limitation in marine heterotrophic bacteria. Front.Mar. Sci. 5:435. doi: 10.3389/fmars.2018.00435

Obernosterer, I., Fourquez, M., and Blain, S. (2015) Fe and C co-limitation of heterotrophic bacteria in the naturally fertilized region off the Kerguelen Islands. *Biogeosciences* 12: 1983–1992.

Smith, D.P., Kitner, J.B., Norbeck, A.D., Clauss, T.R., Lipton, M.S., Schwalbach, M.S., et al. (2010) Transcriptional and Translational Regulatory Responses to Iron Limitation in the Globally Distributed Marine Bacterium Candidatus Pelagibacter ubique. *PLOS ONE* 5: e10487.

Toulza, E., Tagliabue, A., Blain, S., and Piganeau, G. (2012) Analysis of the global ocean sampling (GOS) project for trends in iron uptake by surface ocean microbes. *PLoS ONE* 7: e30931

SORBONNE UNIVERSITÉ

4°) Profile of the Applicant (skills/diploma…)

Applicants should hold a Masters degree in microbial oceanography and have good knowledge in aquatic microbial ecology. Candidates with experience in the treatment and analysis of high-throughput sequencing data and in statistical tools are particularly welcome.

Contacts:

Thesis supervisor

Ingrid Obernosterer

Email address of the thesis supervisor: Ingrid.obernosterer@obs-banyuls.fr