Project 10 (WP1, collaboration with LABEX MER): Role of daily vertical migrations of zooplankton on carbon cycle

Project lead: Olivier Aumont / Laurent Bopp
Post-doctoral researcher: Stelly Lefort
Project Start/End: September 2014 – April 2015

Position offer:

Context: The diurnal vertical migration (DVM) of zooplankton is a widespread phenomenon in the marine environment. Conventionally, zooplankton is at the surface during the night and goes down to several hundred meters at dawn before rising to the surface at dusk. Many observations (essentially acoustic) have demonstrated the existence of this type of migration in numerous biogeochemical provinces. Various explanations have been advanced to explain these DVMs. One of the most explored explanation is related to predator avoidance: preys leave the illuminated layers during the day to reduce the predation pressure. Because of the strong vertical gradients of temperature and of food, DVMs could have a significant impact on the growth and reproduction of many marine organisms, and hence could inlfuence the ecology of the ocean. In addition, these migrations will also have an impact on the biogeochemical fluxes of nutrients, carbon and oxygen . Migrant organisms will generally feed on the surface, but they excrete, respire, produce fecal pellets and die at depth, inducing a vertical transport of nutrients and carbon from the surface to the subsurface. This could increase the efficiency of the carbon pump. Numerous studies have shown the importance of this active transport. They suggest a contribution of up to 10-30% to carbon export.
In the 90s, pioneering modelling work has focused on the representation of the distribution of migrant organisms in response to stimuli such as light, predation and food [Andersen and Nival , 1991; Richards et al, 1996]. However , these studies were more focused on the characteristics of migration in idealized configurations, rather than on the potential feedbacks on biogeochemistry in time and space. To study the effects of DVM on the biogeochemical cycles of carbon and nutrients, it is necessary to integrate a model of migration in a biogeochemical model. To our knowledge, there is to date only one study in which the impact of diurnal vertical migrations on marine biogeochemistry was explicitly analyzed at three contrasting stations in the Pacific [Bianchi et al. , 2013] .

Description of work: During the ANR - CEPS project MACROES (2010-2013), the ocean biogeochemical model NEMO-PISCES was coupled to an ecosystem model, APECOSM, in global-scale configurations to study the impact of climate change on marine upper trophic levels. This coupling is complete and represents the trophic and biogeochemical interactions in both directions (low to high trophic levels trophic levels and vice versa). In APECOSM, the marine ecosystem is represented by three generic communities, one of which corresponding to the organisms performing daily vertical migrations. This modeling system is therefore a perfect tool to study the impact of DVM on the marine biogeochemistry at the global level.

In this project, the succesfull candidate will use this modeling platform to meet the following two objectives:

1 . analysis and evaluation of spatial and seasonal patterns of migrations predicted by the NEMO-PISCES – APECOSM platform
2 . determination of the impact of DVM on the biogeochemical cycles of carbon , nutrients and oxygen .
3 . determination of the role of DVM in the context of a changing climate (potential retro-actions on the marine carbon sink)

This study will be conducted on the global scale in a low-resolution model forced by climate conditions (average seasonal cycle without interannual and decadal variability) for the current period, but also for a future state, representing the end of the 21st century.

In a first step, the successful candidate will use simulations carried out in the frame of the MACROES project. The distribution of migrant organisms will be analyzed and compared with available observations. The vertical distribution produced by the model will be assessed by acoustic observations. Once this step evaluation / validation will be completed, the impact of DVM will be analyzed. Additional sensitivity simulations may be performed to estimate the impact induced by vertical migrations on biogeochemical fluxes. Finally, the impact of DVM changes under a climate change scenario (RCP8.5) will be analysed using climate change simulations performed with the IPSL-CM5 model.

Supervision Team: This project is a joint project bewteen the 2 LABEX : Labex -Mer and Labex - IPSL. It is part of the objectives of both Labex and is based on a close collaboration between researchers from the LPO and LSCE / LOCEAN. For the Labex-Mer, this issue has been identified in the roadmap drafted during the implementation of the first phase (Action 3 Objective 2). Regarding Labex - IPSL , this action falls within the objectives of WP1 (Composition of the atmosphere - Coupling Cycles / Climate). It also addresses some of the objectives of WP4 on the development of indicators of climate change.

The successful candidate will work in between experts at IPSL (LSCE, Saclay and LOCEAN, Paris), as well as with experts at LPO (Brest). Main supervisors will be O. Aumont (LPO) and L. Bopp (LSCE).
In addition, this project will depend on several external collaborations, with UMR EME (O. Maury) in which the APECOSM model was developed, and with McGill University (E. Galbraith, D. Bianchi) in Canada for the use of acoustic data bases and expertise on diurnal vertical migration.

Experience: The applicant will have experience with numerical modeling of the Earth system based on global or regional model, if possible already with the NEMO-PISCES tool. He/she also have experience with handling large datasets. The applicant publication record should show a majority of papers published in English in top ranking journals.

Duration and salary: The post-doctorate will be recruited for 8 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a CV, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers.
Applications should be submitted by e-mail to Laurent Bopp (laurent.bopp@lsce.ipsl.fr) before 15 March 2014.

Preliminary results: The diurnal vertical migration (DVM) of zooplankton is a widespread phenomenon in the marine environment. Conventionally, zooplankton is at the surface during the night and goes down to several hundred meters at dawn. These migrations may have an impact on the biogeochemical fluxes of nutrients, carbon and oxygen. Migrant organisms will generally feed on the surface, but they excrete, respire, produce fecal pellets and die at depth, inducing a vertical transport of nutrients and carbon from the surface to the subsurface. This could increase the efficiency of the carbon pump. Numerous studies have shown the importance of this active transport, that could contribute up to 10-30% of the global carbon export.

The opportunity to co-design a ocean-focused project with the Labex Mer “A changing Ocean” (at the Université de Bretagne Occidentale) has led to propose to work on the incorporation of zooplankton diurnal migration in the PISCES model (marine biogeochemical component of the IPSL earth System

Model). This has been achieved by the coupling of PISCES with APECOSM (Maury, 2010), a model of marine upper trophic levels, which includes an explicit representation of migratory communities.

The first simulations using the coupled PISCES-APECOSM model have enabled to explicitly model the role of diurnal migration on marine biogeochemistry. Export of carbon induced by diel migrations is estimated to be about 13% of total Export (Figure 1). The concentrations of sub-surface oxygen appear to be very sensitive to the active export of organic matter through diurnal migration (Aumont et al. in prep)

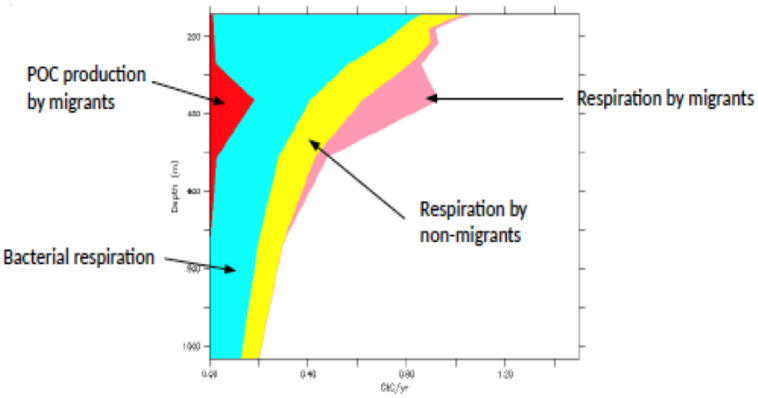

Figure 1 : Contribution of active and passive export to the export of carbon from the surface to the deep ocean (annual-mean, averaged over the global ocean).

In a second step, the coupled PISCES-APECOSM model has been forced by the output of the IPSL earth system model over the 21st century (RCP8.5 scenario) to explore the role of that active transport of carbon through diurnal vertical migration in a changing climate. Early results show that these processes have little impact on air-sea carbon fluxes and oceanic carbon storage in response to anthropogenic climate change (Lefort et al. in prep).

Aumont O., Lefort S., Maury O., Bopp L., Memery L., and Stegert S. (2014), Role of the diurnal vertical migrations of zooplankton and micronekton in the global carbon cycle, AMEMR 2014, Plymouth, UK, July 2014.

Aumont O., Lefort S., Maury O., Bopp L., Memery L., and Stegert S., Role of the diurnal vertical migrations of zooplankton and micronekton in the global carbon cycle, in preparation
Lefort S., et al., High trophic level feedbacks on ocean biogeochemistry under global climate change, in preparation.