

Report for the year 2018 and future activities

SOLAS ‘Belgium’ **compiled by: ‘Nathalie Gypens’**

This report has two parts:

- **Part 1:** reporting of activities in the period of January 2018 – Jan-Feb 2019
- **Part 2:** reporting on planned activities for 2019/2020 and 2021.

The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity or specify an overlap between Themes or Cross-Cutting Themes.

- 1 Greenhouse gases and the oceans;
 - 2 Air-sea interfaces and fluxes of mass and energy;
 - 3 Atmospheric deposition and ocean biogeochemistry;
 - 4 Interconnections between aerosols, clouds, and marine ecosystems;
 - 5 Ocean biogeochemical control on atmospheric chemistry;
- Integrated studies;
Environmental impacts of geoengineering;
Science and society.

IMPORTANT: *This report should reflect the efforts of the SOLAS community in the entire country you are representing (all universities, institutes, lab, units, groups, cities).*

PART 1 - Activities from January 2018 to Jan/Feb 2019

1. Scientific highlight

Highlight 1 : Continental shelves as a variable but increasing global sink for atmospheric carbon dioxide

As more carbon dioxide enters the atmosphere, the global ocean soaks up much of the excess, storing roughly 30 percent of the carbon dioxide emissions coming from human activities. In this sense, the ocean has acted as a buffer to slow down the greenhouse gas accumulation in the atmosphere and, thus, global warming. However, this process also increases the acidity of seawater and can affect the health of marine organisms and the ocean ecosystem.

It has been speculated that the partial pressure of carbon dioxide ($p\text{CO}_2$) in shelf waters may lag the rise in atmospheric CO_2 . An international study led by researchers from the ULB and published in Nature Communication, shows that this is the case across many shelf regions, implying a tendency for enhanced shelf uptake of atmospheric CO_2 . This result is based on analysis of long-term trends in the air–sea $p\text{CO}_2$ gradient ($\Delta p\text{CO}_2$) using a global surface ocean $p\text{CO}_2$ database spanning a period of up to 35 years. Using wintertime data only, we find that $\Delta p\text{CO}_2$ increased in 653 of the 825 0.5° cells for which a trend could be calculated, with 325 of these cells showing a significant increase in excess of $+0.5 \mu\text{atm yr}^{-1}$ ($p < 0.05$). Although noisier, the deseasonalized annual data suggest similar results. If this were a global trend, it would support the idea that shelves might have switched from a source to a sink of CO_2 during the last century.

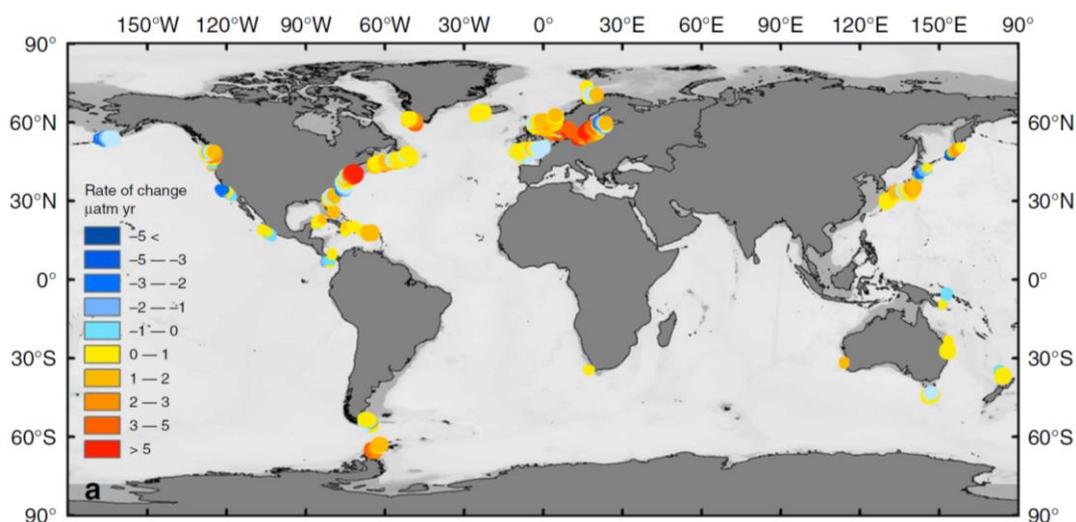


Figure 1: Location of 0.5° cells for which the decadal trend in winter $\Delta p\text{CO}_2$ is calculated. Large dots correspond to cells shallower than 200 m and small dots correspond to cells located within 100 km from the coast or depth less than 500 m.

Citation: Laruelle, G. G., Cai, W. J., Hu, X., Gruber, N., Mackenzie, F. T., and Regnier, P.: Continental shelves as a variable but increasing global sink for atmospheric carbon dioxide. Nature communications 9 (1), 454, 2018.

Highlight 2 : Uncertainty in the global oceanic CO_2 uptake induced by wind forcing

The calculation of the air–water CO_2 exchange ($F\text{CO}_2$) in the ocean not only depends on the gradient in CO_2 partial pressure at the air–water interface but also on the parameterization of the gas exchange transfer velocity (k) and the choice of wind product. Here, we present regional and global-scale quantifications of the uncertainty in $F\text{CO}_2$ induced by several widely used k formulations and four wind speed data products (CCMP, ERA, NCEP1 and NCEP2). Our results show that the range of global $F\text{CO}_2$, calculated with these k relationships, diverge by 12% when using CCMP, ERA or NCEP1. Due to differences in the regional wind patterns, regional discrepancies in $F\text{CO}_2$ are more pronounced than global. To minimize uncertainties associated with the choice of wind product, it is possible to recalculate the coefficient c globally (hereafter called c^*) for a given wind product and its spatio-temporal resolution, in order to match the last evaluation of the global k value. We thus performed these recalculations for each wind product at the resolution and time period of our study

but the resulting global FCO_2 estimates still diverge by 10%. These results also reveal that the Equatorial Pacific, the North Atlantic and the Southern Ocean are the regions in which the choice of wind product will most strongly affect the estimation of the FCO_2 , even when using c^* .

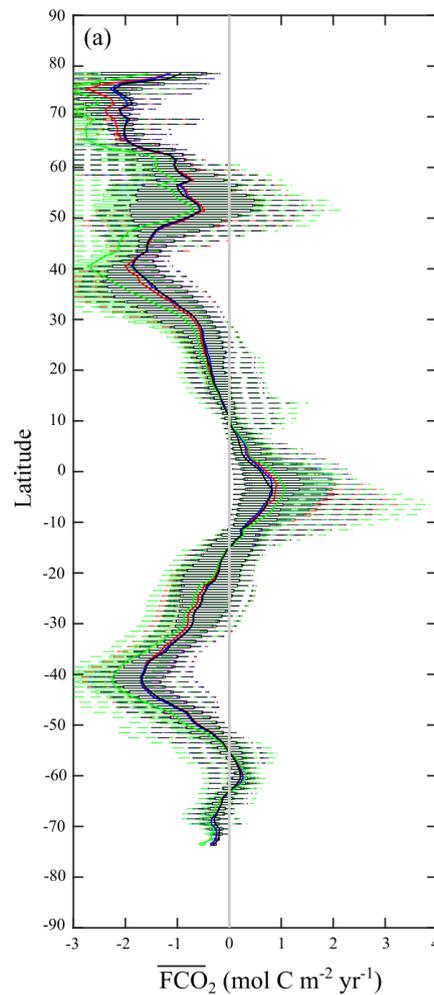


Figure 2: Latitudinal distribution of FCO_2 (mol C m⁻² yr⁻¹) using the CCMP, ERA, NCEP1 and NCEP2 wind products. FCO_2 is calculated using the quadratic K_{U10} relationship from Wanninkhof (2014). Results refer to the 1991–2011 period. The median value for each latitude is represented by a line, while the box plots delineate the 5th and 95th percentile of the variation within each 1° latitudinal band, respectively.

Citation: Roobaert, A., Laruelle, G. G., Landschützer, P., and Regnier, P.: Uncertainty in the global oceanic CO₂ uptake induced by wind forcing: quantification and spatial analysis, *Biogeosciences*, 15, 1701-1720, <https://doi.org/10.5194/bg-15-1701-2018>, 2018.

Highlight 3 : Dimethylsulfoniopropionate and dimethylsulfoxide in seagrass meadows_(result of a collaboration between Belgian, French and Portuguese institutions)

Posidonia oceanica is the only reported seagrass to produce dimethylsulfoniopropionate (DMSP) and the biggest producer among marine and inter-tidal autotrophs. We studied the temporal and depth variability of DMSP and its derivative dimethylsulfoxide (DMSO) in *P. oceanica* leaves of a non-disturbed meadow in Corsica and the potential role of light, temperature, photosynthetic activity and leaf size on DMSP and DMSO contents. The annual average concentrations of organosulfured compounds in *P. oceanica* leaves were $129 \pm 39 \mu\text{mol.g}_{fw}^{-1}$ for DMSP and $5.0 \pm 2.1 \mu\text{mol.g}_{fw}^{-1}$ for DMSO. Concentrations of both DMSP and DMSO decreased from a maximum in the fall to a minimum in the summer and were inversely correlated to the leaf size, *i.e.*, the leaf age. Concentrations of the two molecules were weakly to modestly correlated with light and temperature along the year, but not with effective quantum yield of photosystem II. To explain this seasonal pattern we hypothesized two potential protection functions for young leaves: antioxidant against

reactive oxygen species and predator-deterrent. The similar variation of the two molecule concentrations over time and with depth suggested that DMSO content in *P. oceanica* leaves results from oxidation of DMSP. More research is now needed to confirm the functions of DMSP and DMSO in seagrasses.

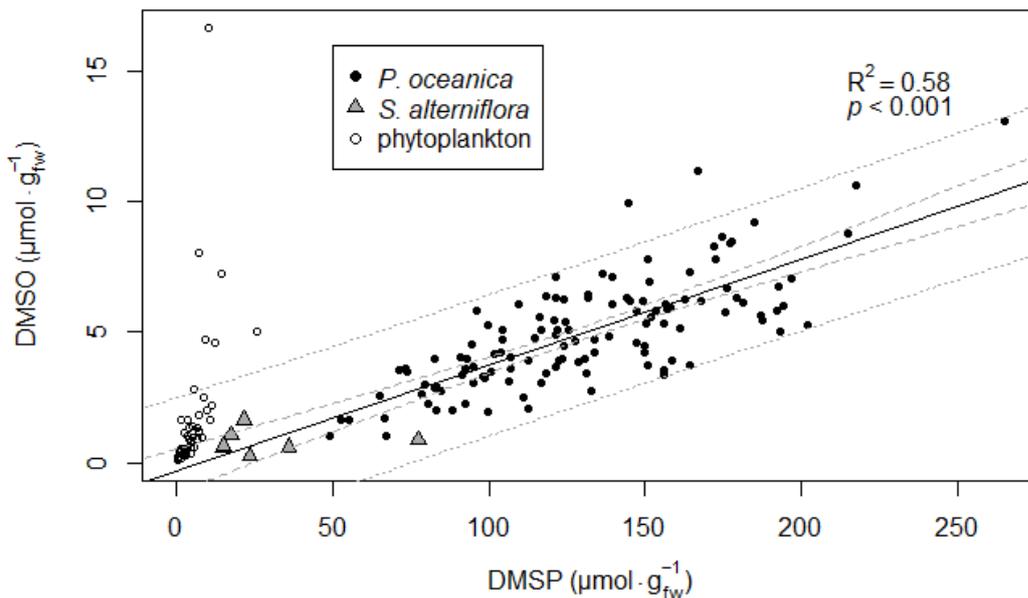


Figure 3: Scatterplot of DMSP and DMSO concentrations ($\mu\text{mol} \cdot \text{g}_{\text{fw}}^{-1}$) in *Posidonia oceanica* leaves (black dots), *Spartina alterniflora* leaves (grey triangles) and marine phytoplankton communities (empty dots). *S. alterniflora* and phytoplankton data are from literature (Husband and Kiene (2007), Husband et al. (2012) and McFarlin and Alber (2013) Simó and Vila-Costa (2006)). The full black line is the linear regression modelling the relationship between *P. oceanica* DMSP and DMSO concentrations. Model R^2 and p -value are shown on the graph. 95% confidence (dashed grey lines) and prediction (dotted grey lines) intervals are plotted.

Citation: J. Richir et al. A 15-month survey of dimethylsulfoniopropionate and dimethylsulfoxide contents in *Posidonia oceanica*. Submitted in Frontiers in Ecology and Evolution.

Highlight 4 : Nutrient controls of marine nitrogen fixation

Biological nitrogen (N_2) fixation represents the major source of new nitrogen input to the ocean. Diazotrophic activity has thus great implications in the biogeochemical cycling of nitrogen and plays an important role in marine primary productivity. Iron (Fe) and phosphorus (P) are considered to be co-limiting factors in most regions and the deposition of mineral dust is believed to promote N_2 fixation through increasing availability of both Fe and P. Laboratory bioassays (+Fe, +P, +Dust) via incubation experiments performed on *Trichodesmium* IMS101, show that the addition of Fe, P or desert particles could stimulate the growth and N_2 fixation of this cyanobacteria. In addition, during a field study using natural phytoplankton assemblages from the temperate Northeast Atlantic Ocean the key role of dissolved Fe (DFe) has been furthermore highlighted by the remarkably enhanced N_2 fixation rate observed after the addition of DFe under low temperature and P-depleted conditions. Figure 4 shows as an example of the results obtained for the dust addition incubation experiments.

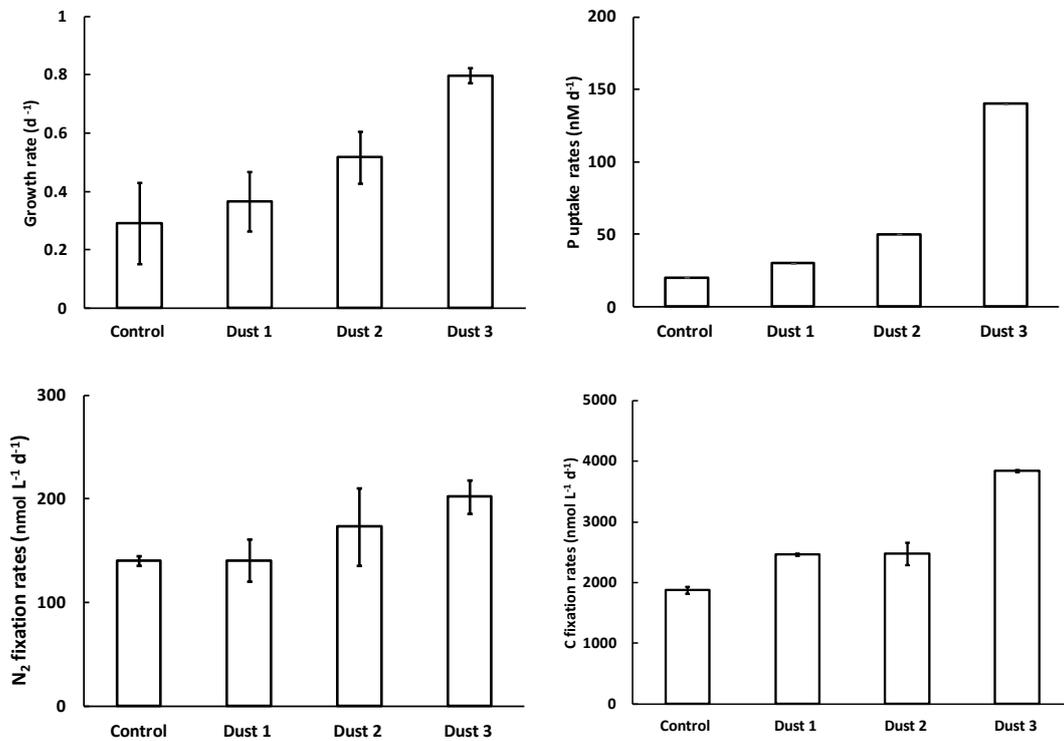


Figure 4. (a) Chl-a concentrations, (b) PO₄ uptake rates, (c) N₂ fixation rates and (d) C fixation rates of *Trichodesmium* IMS-101 for Control (without dust addition), and three +Dust addition treatments (25, 50 and 100 mg L⁻¹) during 24h incubations at 24°C (incident irradiance at 150 μmol photons m⁻² s⁻¹, 14h/10h light/dark cycle). The initial dissolved Fe and PO₄ concentrations were 5 nM and 90 nM in the medium respectively. The dust particles (< 63 μm) were taken from the Kubuqi desert (Inner Mongolia, Autonomous Region, China), which contained 2.58% Fe and 0.19% P.

Citation: Li X, Fonseca-Batista D, Røevros N, Dehairs F and Chou L (2018) Environmental and nutrient controls of marine nitrogen fixation. *Progress in Oceanography*, 167, 125-137. <https://doi.org/10.1016/j.pocean.2018.08.001>.

Highlight 5 : Impact of climate change on N₂ fixation

Recently, the effects of ongoing climate change (ocean warming and acidification) on N₂ fixation has been intensively studied but controversial conclusions have been reached. Semi-continuous dilution growth experiments were conducted on *Trichodesmium* IMS101 under two pCO₂ (400 μatm and 800 μatm) and temperature (24°C and 28°C) conditions. The results indicate that higher pCO₂ and therefore ocean acidification may be beneficial for *Trichodesmium* growth and N₂ fixation. However, Fe or P limitation in oligotrophic seawaters may offset the stimulation induced on *Trichodesmium* IMS101 resulting from ocean acidification. In contrast, ocean warming may not play a crucial role in *Trichodesmium* growth and N₂ fixation with a 4°C increase from 24°C to 28°C. Nevertheless, ocean warming is predicted to cause a shift in the geographical distribution of *Trichodesmium* species towards higher latitudes, extending its niche to subtropical ocean regions and potentially reducing its coverage in tropical ocean basins. Figure 5 shows the results of the influence of pCO₂ and temperature on *Trichodesmium* growth and N₂ fixation.

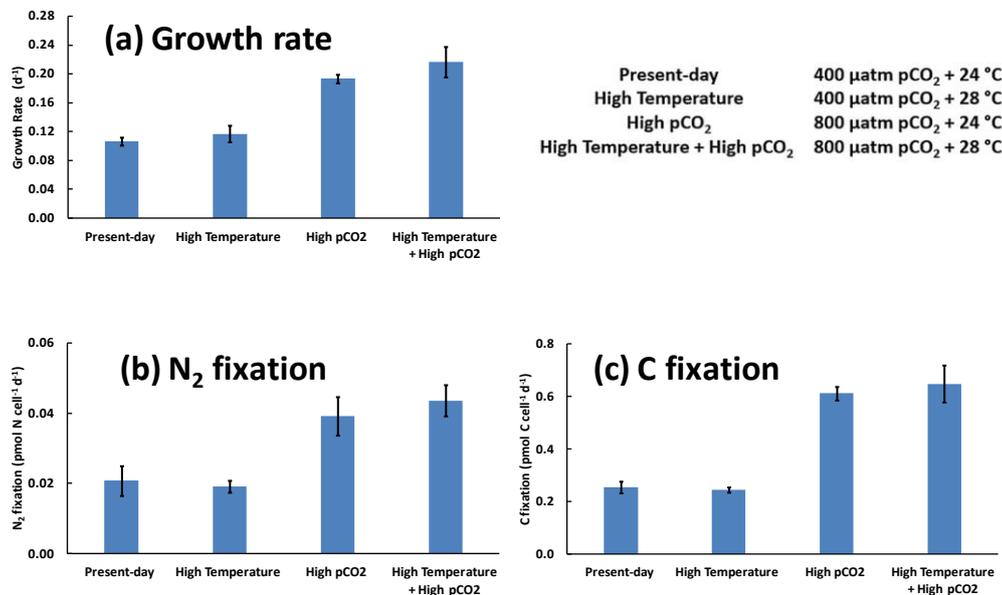


Figure 5. (a) Growth rates, and cell-number normalised (b) N₂ and (c) C fixation rates of *Trichodesmium* IMS 101 acclimated to different pCO₂ and temperature conditions during 24h incubations (incident irradiance at 150 μmol photons m⁻² s⁻¹, 14h/10h light/dark cycle). The various treatments correspond to Present-day (400 μatm pCO₂ and 24°C), High Temperature (400 μatm pCO₂ and 28°C), High pCO₂ (800 μatm pCO₂ and 24°C), and High Temperature+High pCO₂ (800 μatm pCO₂ and 28°C) conditions.

Citation: Li X, Fonseca-Batista D, Roevros N, Dehairs F and Chou L (2018) Environmental and nutrient controls of marine nitrogen fixation. *Progress in Oceanography*, 167, 125-137. <https://doi.org/10.1016/j.pocean.2018.08.001>.

2. Activities/main accomplishments in 2018 (projects, field campaigns, events, model and data intercomparisons, capacity building, international collaborations, contributions to int. assessments such as IPCC, interactions with policy makers or socio-economics circles, social sciences, and media).

Field campaign and project

- The University of Liège (A.V. Borges) was involved in the international intercomparison of CH₄ and N₂O measurement techniques under SCOR 143. The results were published in: Wilson ST, HW Bange, DL Arévalo-Martínez, J Barnes, AV Borges, I Brown, JL Bullister, M Burgos, DW Capelle, M Casso, M de la Paz, L Farías, L Fenwick, S Ferrón, G García, M Glockzin, DM. Karl, A Kock, S Laperriere, CS. Law, CC Manning, A Marriner, J-P Myllykangas, JW. Pohlman, A P. Rees, AE. Santoro, M Torres, PD. Tortell, RC Upstill-Goddard, DP. Wisegarver, GL Zhang, G Rehder (2018) An intercomparison of oceanic methane and nitrous oxide measurements, *Biogeosciences*, 15, 5891-5907.
- In order to understand the role played by environmental parameters, i.e., light availability on the production dynamics of DMSP and DMSO in *P. oceanica*, 9 m² seagrass bed quadrats were shaded. Light reduction was 15, 30 and 60 %. The experience was conducted in situ from April to August 2018, and sampling and measurements were performed monthly. DMSP and DMSO analysis will be done during year 2019. Available results already showed a net effect on the plant photosynthetic activity. This research work is done in collaboration with French and German partners.
- Intercalibration experiment for sea ice primary production in Saroma-ko Lagoon, Hokkaido, Japan. Collaboration with D. Nomura in the frame of ECV-ice SCOR working group. March 2018.
- Optimist 2018 sea ice survey in Storefjord in April 2018. This survey was carried out in the frame of the project OPTIMIST-bio (Observing Processes impacting The sea Ice Mass balance from In Situ Measurements: from physics to its impacts on biology) funded by the CNRS (France) and led by F. Viviers. We will measure greenhouse gases (CO₂, CH₄, N₂O) concentration and air-ice fluxes. We will also collect sea ice for measurement of related

physical and biogeochemical parameters. Belgian Partner Bruno Delille (Université de Liège)

- We have been involved in a RV Xuelong cruise in Pridz Bay and Ross sea (Nov 2017- Feb 2018) Polynyas (Dec 2017) supported by the State Oceanic Administration in collaboration with Liyang Zhan. We will focus on Nitrogen cycle (including N₂O) in sea ice and the water column. Belgian Partner Bruno Delille (Université de Liège), Frank Dehairs (Vrije Universiteit Brussel) and Jean-Louis Tison (Université Libre de Bruxelles).
- A (bio)geochemical investigation was conducted from 20 June to 4 July 2018 on board the RV Belgica in the Gotland basin of the Baltic Sea where low dissolved oxygen concentrations had been recurrently observed in deep waters. The objectives were to understand benthic nutrient and trace metal cycling, benthic-pelagic coupling and diagenetic pathways (oxic, anoxic) and the impact of hypoxia on these processes. Microprofiling of geochemical gradients of dissolved O₂, pH and H₂S were taken on board the ship. Sediment cores were taken and porewaters were extracted using the Rhizon technique under nitrogen atmosphere for nutrient and trace metal determinations. The analyses of samples collected are underway. This work was conducted in the framework of the BENTHOX project funded by the Fund for Scientific Research - FNRS (Belgium).
- Also for the BENTHOX project, work is ongoing for a biogeochemical cruise conducted on board the RV Mare Nigrum during August-September 2017 in the Black Sea on the Ukrainian shelf and in the deep basin. During this cruise, bottom hypoxia on the shelf was observed. This investigation was carried out in collaboration with the EMBLAS-II project funded by UNDP and EU. The objective was to obtain a better understanding of the impact of benthic hypoxia on the diagenetic pathways. Microprofiling of geochemical gradients of dissolved O₂, pH, H₂S and N₂O were taken on board the ship. Porewaters were extracted on board the ship using the Rhizon technique under N₂ atmosphere for laboratory dissolved nutrients and major ions.

Conferences

- Plante A., N. Roevros, A. Capet, M. Grégoire, N. Fagel and L. Chou (2018) Black Sea north-western shelf hypoxia: a study based on diagenetic processes and sedimentary proxies. EGU General Assembly, Vienna, Austria, 8-13 April 2018. Poster presentation
- Plante A., N. Ahmed Butt, N. Roevros, A. Capet, M. Grégoire, N. Fagel and L. Chou (2018) Coastal hypoxia in the Black Sea: Effects on diagenetic pathways and benthic fluxes. Ocean Deoxygenation Conference 2018, Kiel, Germany, 02-08 September 2018. Poster presentation.
- Li X., D. Fonseca-Batista, N. Roevros, F. Dehairs and L. Chou (2019) Marine nitrogen fixation: Environmental and nutrient controls. Forth Xiamen Symposium on Marine Environmental Sciences. Xiamen, China, 6-10 January 2019. Oral presentation.

3. Top 5 publications in 2018 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

- Borges AV, G Abril, S Bouillon (2018) Carbon dynamics and CO₂ and CH₄ outgassing in the Mekong delta, Biogeosciences, 15, 1093-1114
- Carnat, G., W. Said-Ahmad, F. Fripiat, B. Wittek, J-L. Tison, C. Uhlig and A. Amrani (2018). Variability in sulfur isotope composition suggests unique dimethylsulfoniopropionate cycling and microalgae metabolism in Antarctic sea ice. Communication Biology. 1 (212). Doi: 10.1038/s42003-018-0228-y
- Nomura D, Granskog M A, Fransson A, Chierici M, Silyakova A, Ohshima K I, Cohen L, Delille B, Hudson S R and Dieckmann G S (2018) CO₂ flux over young and snow-covered Arctic pack ice in winter and spring, Biogeosciences 15, doi:10.5194/bg-15-3331-2018, 2018.
- Li X, Fonseca-Batista D, Roevros N, Dehairs F and Chou L (2018) Environmental and nutrient controls of marine nitrogen fixation. Progress in Oceanography, 167, 125-137.

<https://doi.org/10.1016/j.pocean.2018.08.001>.

- Speeckaert G, AV Borges, W Champenois, C Royer and N Gypens (2018) Annual cycle of dimethylsulfoniopropionate (DMSP) and dimethylsulfoxide (DMSO) related to phytoplankton succession in the Southern North Sea, *Science of the Total Environment*, 622–623, 362-372

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2018? If yes, who? How did you engage?

PART 2 - Planned activities for 2019/2020 and 2021

1. Planned major field studies and collaborative laboratory and modelling studies, national and international (incl. all information possible, dates, locations, teams, work, etc.).

- Intercalibration experiment for measurement of carbonate system parameter in sea ice, University of East Anglia, Norwich, UK in the frame of ECV-ice SCOR working group. Spring 2019.
- MOASIC, International Arctic Drift Expedition on the RV Polarstern led by AWI.
- Two field studies are planned for 2019 by the The University of Liège (J. Richir and A.V. Borges). First, we will test the effect of heat waves on DMSP and DMSO production dynamics in *P. oceanica*. This will be done in collaboration with colleagues of the Stazione Zoologica Anton Dohrn (SZN), Napoli, Italy. Second, we will test the potential role as predator deterrent played by DMS(P) on seagrass grazers (urchins).
- In addition, we will finish analysing DMSP and DMSO contents in *P. oceanica* leaves in order to propose a mass balance analysis at the scale of a meadow (above-ground tissues). We will also perform analyses in leaves of *Zostera* sp. in collaboration with colleagues from the Netherlands. Indeed, *Zostera* is the most widely distributed seagrass genus, so its role in the coastal dynamic of DMSP(O) require to be investigated next.
- The results obtained in the framework of the BENTHOX project continues to be worked out and will be disseminated via publications.
- Within the framework of the C-Cascades project (<https://c-cascades.ulb.ac.be/>) funded by the EU (Horizon 2020), efforts are undertaken to make a breakthrough in the understanding of the transfer of carbon along the land and ocean continuum (via rivers, lakes and coastal waters) at the global scale. This will allow a better quantification of the fluxes of greenhouse gases (primarily CO₂ and CH₄) exchanged with the atmosphere and their impacts on the climate system.

2. Events like conferences, workshops, meetings, schools, capacity building etc. (incl. all information possible).

Conferences

- Capet A., A. Plante, L. Chou, N. Fagel, A. Teaca and M. Grégoire (2019) Upscaling the impact of varying macro-benthic activity from local diagenesis to biogeochemical cycles in the frame of Black Sea northwestern shelf hypoxia dynamics. EGU General Assembly, Vienna, Austria, 7-12 April 2019.
- Grégoire M., A. Capet, L. Chou, N. Fagel, A. Plante and A. Teaca (2019) Upscaling the impact of coastal hypoxia from species to ecosystem function. The case of bioturbation in the Black Sea. EGU General Assembly, Vienna, Austria, 7-12 April 2019.
- The University of Liège (J. Richir and A.V. Borges) will participate at the 42nd CIESM Congress in Cascais, Portugal, in October 2019. The Mediterranean Science Commission CIESM involves researchers from all shores of the Basin in its activities. The Commission integrates a broad spectrum of marine disciplines, encompassing geo-physical, chemical and biological processes.

3. Funded national and international projects / activities underway.

- ISOtopic Investigation of Greenhouse GAses in Polar regions: An Ocean Ice-Atmosphere Continuum (ISOGGAP) funded by the FRS-FNRS (2016-2019, 432 kEur). This project covers the theme 8 "High Sensitivity Systems- HS2" but will focus on arctic systems. ISOGGAP will address: 1) Gas exchange monitoring and process studies; 2) Regional dynamics of stressors and their effect in sea ice systems; 3) Improvement of the

representation of biogeochemistry in regional models of sea ice 4) Identification of the elements of HS² that are key parameters to global change and incorporate them into Earth System Models. Partners: Jean-Louis Tison (Univesité Libre de Bruxelles) Bruno Delille (Université de Liège)

- OCeANIC (nitrous Oxide and nitrogen Cycling in ANtarctic sea Ice Covered zone, BL/12/C63, 2016-2019, 250 kEur) funded by the Belgian Science Policy. Partners: Bruno Delille (Université de Liège), Frank Dehairs (Vrije Universiteit Brussel), Jean-Louis Tison (Université Libre de Bruxelles)

4. Plans / ideas for future projects, programmes, proposals national or international etc. (please indicate the funding agencies and potential submission dates).

The University of Liège (J. Richir and A.V. Borges) aim at describing factors that drive DMSP and DMSO production in seagrasses, at quantifying their role as provider of the dissolved DMS(P)(O) pool in the above water column and their sea-air transfer and at studying the ecological functions these molecules play in seagrass beds. This will be done in collaboration with European academic partners.

5. Engagements with other international projects, organisations, programmes etc.

- BEPSII (Biogeochemical Exchange processes at the Sea ice Interfaces) joint SOLAS-CLIC-IASC working group
- ECVice (Essential Climate Variable for sea ice) SCOR working group
- SOOS task group on Air-Sea Fluxes

Comments