Project information

Keywords

Carbon flux, Biological carbon pump, sea ice cover

Project title

Carbon flux dynamics in ice-free versus ice-covered Svalbard fjords-Exploring the effects of sea ice variability on the downward flux of biogenic particles

Year

2016

Project leader

Gérald Darnis

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

Kongsfjorden mooring: 78°57.76’N 11°47.93’E; Rijpfjorden mooring: 80o17.223’N 22o15.455’E

Participants

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Janne E. Søreide (University Centre in Svalbard)

Philipp Assmy (Norwegian Polar Institute)

Catherine Lalande (Université Laval)

Finlo Cottier (Scottish Association of Marine Sciences and UiT The Arctic University of Norway)

Flagship

Fjord and Coast

Funding Source

Fram Centre

Summary of Results

In 2016, sediment trap samples were prepared for various types of analysis and measurement of total particulate mass, particulate organic carbon (POC) and nitrogen (PON) were carried out. The samples originated from the annual cycle 2012-2013 in Kongsfjorden and Rijpfjorden and from a trap deployment from January to early April 2014 in Kongsfjorden. Some ensuing results are used in different studies for which we provide the relevant description here:

1) Role of zooplankton diel vertical migration (DVM) in the functioning of the biological pump

The flagship project contributed to this research by enabling quantification of POC and PON flux in Kongsfjorden for comparison with the active transport of dissolved carbon and nitrogen by DVM of various zooplankton groups.

Key results:

- Due to their strong DVM patterns and high migrant biomass, euphausiids (mainly *Thysanoessa* spp.) contribute largely to the active transport of carbon to depth in Kongsfjorden (Fig. 1).

- Large copepods (mainly *Calanus* spp.) dominate the active transport of nitrogen to depth, due to their high excretion rate compared to other groups.

- DVM-mediated vertical transport of carbon represents around 40% of the integrated winter carbon sinking flux of POC measured in sediment traps from 21 January to 3 April (Fig. 1), a ratio in the range of what has been reported in lower latitude regions of the World Ocean (13-70%).

- DVM-mediated vertical transport of nitrogen represents respectively 12 and 49% of the PON sinking flux at 40 and 100 m integrated over the winter period, which is again in the range of ratios found in oligotrophic and more seasonally stable sub-Arctic to equatorial systems (7-108% of daily PON flux). Thus, our study reveals that the importance of active transport of C and N in the Kongsfjorden ecosystem compares well with other oceanic systems despite the complex DVM regime and particular environmental settings of the high-Arctic Fjord.

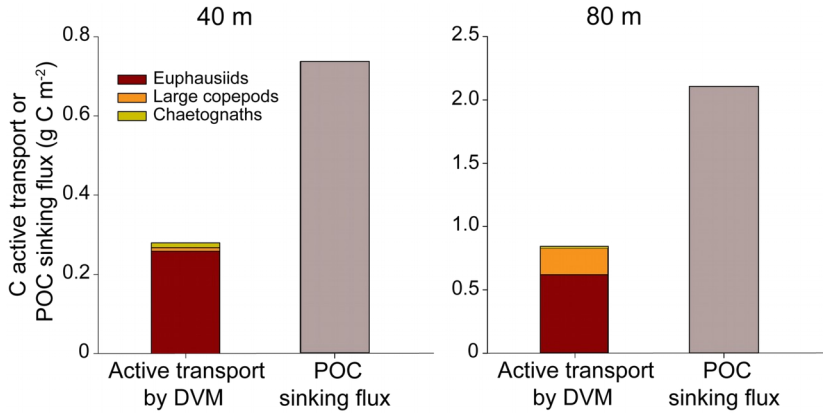

Fig. 1. DVM-mediated active transport of carbon released by zooplankton respiration below 40 m and below 80 m depth versus sinking flux of POC at these depths.

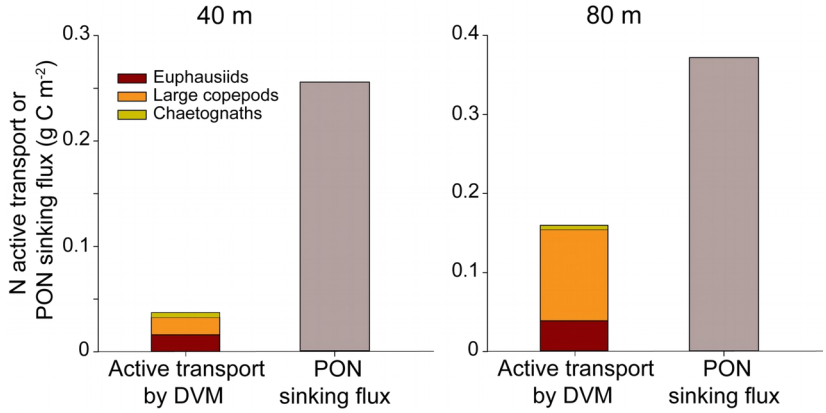

Fig. 2. DVM-mediated active transport of nitrogen released by zooplankton ammonium excretion below 40 m and below 80 m depth versus sinking flux of PON at these depths.

This paper is in press in *Limnology and Oceanography*.

2) Downward export of biogenic matter during the transition from polar night to spring in Kongsfjorden and the key role of zooplankton processes

The flagship project supports this study by providing total mass and POC data to describe the seasonal dynamics in the flux of biogenic matter from January to April in Kongsfjorden.

Key results:

- Total mass and POC sinking flux at 40 m depth start to increase substantially as early as early March (Fig. 3a and b), several months before the onset of the phytoplankton bloom (late May in 2014). This pattern is different from what is seen in seasonally ice-covered regions where there is usually little increase in fluxes before the ice breaks up in May-July.

- Carbon sinking flux in the form of krill exuviae was rather low and showed a slight increase in the first half of March, after which this flux ceased (Fig. 3c).

- Zooplankton fecal pellet carbon (FPC) made a minor contribution to total POC sinking flux from January to mid-March (Fig. 3d). This contribution increased steeply afterward (>50%).

- The dissolved carbon actively transported through DVM and respiration below 40 m depth in winter was of the same magnitude as the zooplankton fecal pellet carbon flux at that same depth (Fig. 4). However, the sinking flux should be considered more important for the biological pump than the active transport of elements released in the dissolved form in the context of the homogeneous winter water column in Kongsfjorden.

- Krill dominate the DVM-mediated active transport whereas copepods contribute most to the sinking flux of fecal pellet carbon (Fig. 4).

Fig. 3. Sinking fluxes at 40 m depth of (a) total mass, (b) particulate organic carbon (POC), (c) krill exuviae, (d) fecal particulate carbon due to various zooplankton groups in Kongsfjorden in winter 2014.

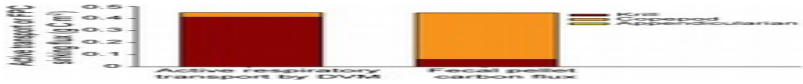

Fig. 4. DVM-mediated active transport of carbon below 40 m depth and sinking flux of fecal pellet carbon at 40 m depth integrated over the period 21 January-3 April 2014 in Kongsfjorden.

This paper is in preparation for publication in Biogeosciences.

3) Annual cycle of particle flux in Kongsfjorden and Rijpfjorden

An important first step in the characterization of the annual cycle of biogenic matter is the measurement of total mass flux. This was done using sediment trap samples from the annual cycle 2012-2013 in the ice-free Kongsfjorden heavily influenced by Atlantic Water, and in the ice-covered Rijpfjorden further north.

Key results:

- Integrated over the annual cycle, total mass flux was higher in Kongsfjorden (348 g m^{-2}) than in Rijpfjorden (67 g m^{-2}).

- The very low sinking flux from late May to July in the 2 fjords (Fig. 5) was completely unexpected. Visual examination of the time-series of samples from the annual cycles 2013-2014 and 2015-2016 indicates that this is a recurrent pattern. This seasonal pattern contrasts with what has been observed in other less coastal Arctic regions where the total mass flux generally increases in summer.

- Pictures were taken for the image analysis of zooplankton fecal pellets in subsamples of known size. Identification, count and size measurement of fecal pellets will be done in 2017 and will make it possible to quantify the fraction of the biogenic carbon flux contributed by fecal pellets throughout 2012-2013 in the 2 studied fjords.

- Identification of protists that sank into the traps in 2012-2013 is currently being carried out and will allow for the determination of the protist flux.

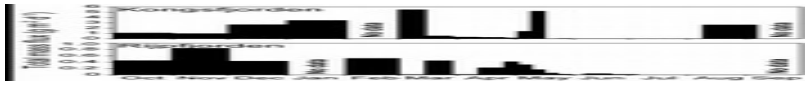

Fig. 5. Sinking flux at 100 m depth of total particulate mass expressed as dry weight, in Kongsfjorden and in Rijpfjorden throughout the annual cycle 2012-2013.

Master and PhD-students involved in the project

In this first year of the project, the main focus was on acquisition of technical expertise related to the work on long-term sediment trap samples.

Delphine Le Brun, a student in mechanical engineering at Institut Catholique d'Arts et Métiers (Icam) in France, did a 2-month internship within the project. She helped with the preparation of samples for TPM and POC/PON analysis. She also started to develop the technique for image analysis of fecal pellets.

Now that a good deal of the expertise for the various analyses is secured, the project plans to recruit 2 Master students early next year: 1) one Master project at UNIS with a main focus on determination of zooplankton carcass and molt fluxes throughout the annual cycle; and 2) one Master project, at UiT this time, to assess the fecal fraction of the POC annual flux in the two fjords.

Short projects of undergraduate students will also be integrated in the flagship work.

For the Management

This project initiates a time series dataset of annual sinking fluxes of organic matter in Svalbard fjords serving as long-term observatories to study the effects of climate change on the Norwegian Arctic marine ecosystem. This vertical transfer of organic matter links biological primary production in the sunlit surface layer with production in deeper layers of the ocean and at the seafloor. Results from the project contribute to: (1) furthering the understanding of fundamental Arctic marine ecosystem services such as marine biological productivity and carbon sequestration in the deep ocean and, (2) studying the responses of these ecosystem services to consequences of climate change such as sea ice decline and warmer inflow of Atlantic water.

Published Results/Planned Publications

Darnis, G., Hobbs, L., Geoffroy, M., Grenvald, J.C., Renaud, P.E., Berge, J., Cottier, F., Daase, M., Søreide, J., Kristiansen, S., Wold, A., Morata, N., Gabrielsen, T., (in press). From polar night to midnight sun: diel vertical migration, metabolism and biogeochemical role of zooplankton in a high Arctic fjord (Kongsfjorden, Svalbard). Limnology and Oceanography.

Darnis, G., Geoffroy, M., Daase, M., Berge, J., Renaud, P.E., Søreide, J., Cottier, F., (in preparation) Downward export of biogenic matter during the transition from polar night to spring in a high-Arctic Svalbard fjord-the key role of zooplankton processes. For Biogeosciences.

Communicated Results

Darnis, G., Berge, J., Søreide, J., Assmy, P., Lalande, C., Cottier, F., 2016. Carbon flux dynamics in ice-free versus ice-covered Svalbard fjords during the last decade-Exploring the effects of sea ice variability on the downward flux of biogenic particles, Fjord and Coast flagship annual meeting, 4-5 October. Sommarøy, Norway.

Darnis, G., Daase, M., Geoffroy, M., Renaud, P.E., Berge, J., 2016. Zooplankton fecal pellet export during the transition from polar night to spring in a high-Arctic Svalbard fjord, Kongsfjorden 6th Zooplankton Production Symposium, Bergen, Norway.

Interdisciplinary Cooperation

The project includes marine biologists specialised in phyto- and zooplankton biology, a physical oceanographer and a specialist in marine sinking particle flux.

Budget in accordance to results

Yes. The funds for the F&C flagship financed research time and costs for running analysis at Akvaplan-niva, UNIS and Université Laval. Due to the late start of the project, it was decided to cancel participation and presentation of results at the ArcticNet meeting in December 2016 in Winnipeg, Canada. The funding budgeted for this item was redirected toward the analysis of extra samples.

Could results from the project be subject for any commercial utilization

No

Conclusions

Analysis of the time series of sediment trap samples is well underway. Already, results on POC flux have been included in papers that will be published soon. One manuscript submitted after revision to *Limnology and Oceanography* would be a first contribution to this flagship project.

Analysis of fecal pellet carbon flux, an important aspect of the flux of biogenic carbon, has proven to be a challenge due to the unforeseen large amount of time that had to be dedicated to this task. We will try to tackle this issue by developing an imaging method based on the use of the Zooscan system in cooperation with Claudia Halsband at Akvaplan-niva.

Preliminary results on total mass flux seem to indicate that the seasonal patterns of particle flux are similar in Kongsfjorden and Rijpfjorden although the magnitude is different, being 5 times higher in Kongsfjorden in 2012-2013. This pattern characterized by extremely low sinking flux in summer has not been described in other Arctic regions where seasonal sea ice forms. Addition in 2017 of new annual cycles and data on POC/PON, protist and zooplankton fecal flux for 2012-2013 should help understand better this particularity of the 2 fjords regarding the sinking flux of particles and biogenic matter.