Project information

Keywords

Carbon flux, Pelagic processes, Protists, Biological carbon pump, Sea ice cover, Svalbard

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

2017

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: 78o57.76'N 11o47.93'E; Rijpfjorden mooring: 80o17.223'N 22o15.455'E

Participants

Gérald Darnis (Akvaplan-niva)

Jørgen Berge (UiT The Arctic University of Norway and University Centre in Svalbard)

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

1) Role of zooplankton diel vertical migration (DVM) in the transport of carbon and nitrogen to depth

A contribution to the F&C flagship was published in *Limnology and Oceanography*.

Key results of the paper:

- 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.

- 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, 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.

2) The role of zooplankton processes in the export of biogenic matter to depth during the transition from polar night to spring in a high-Arctic fjord

Another paper looking into the role of zooplankton in the functioning of the biological carbon pump in a high-Arctic fjord (Kongsfjorden) is in preparation and should be submitted in early 2018 to *Biogeosciences*.

Key results of the manuscript:

- Total mass and POC sinking flux at 40 m depth start to increase substantially as early as early March (Fig. 1a 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 no significant 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. 1c).

- Zooplankton fecal pellet carbon (FPC) made a minor contribution to the low total POC sinking flux from January to mid-March (Fig. 1d). This contribution increased steeply afterward (>50%) to make most of the POC export below 40 m depth.

- The lack of increase in euphausiid and large copepod biomass in the surface layer above the depth of the trap during the sampling period (Fig. 2) suggests that the observed increase in zooplankton fecal flux is due to a rise in zooplankton activity most likely fuelled by a moderate pelagic primary production starting in March.

- The dissolved carbon actively transported through DVM and respiration below 40 m depth in winter was lower than the zooplankton fecal pellet carbon flux at that same depth (Fig. 2). Thus, 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 and over an extensive part of the Barents Sea in winter.

- Krill dominate the DVM-mediated active transport whereas copepods contribute most to the sinking flux of fecal pellet carbon (Fig. 3).

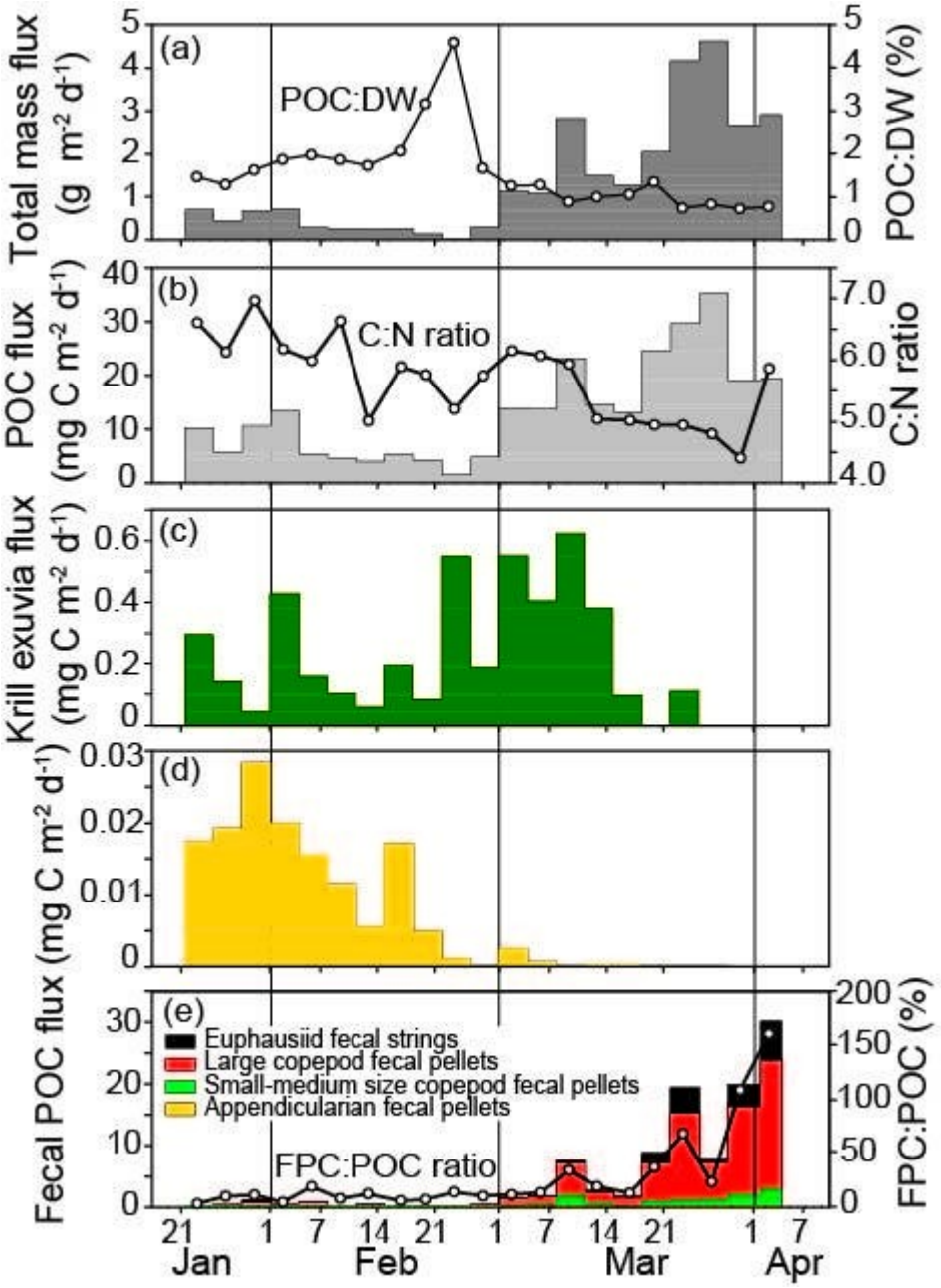

Fig. 1. Sinking fluxes at 40 m depth of (a) total mass, (b) POC, (c) krill exuviae, (d) Fecal pellet carbon due to appendicularians, and (e) to various zooplankton groups in Kongsfjorden in winter 2014.

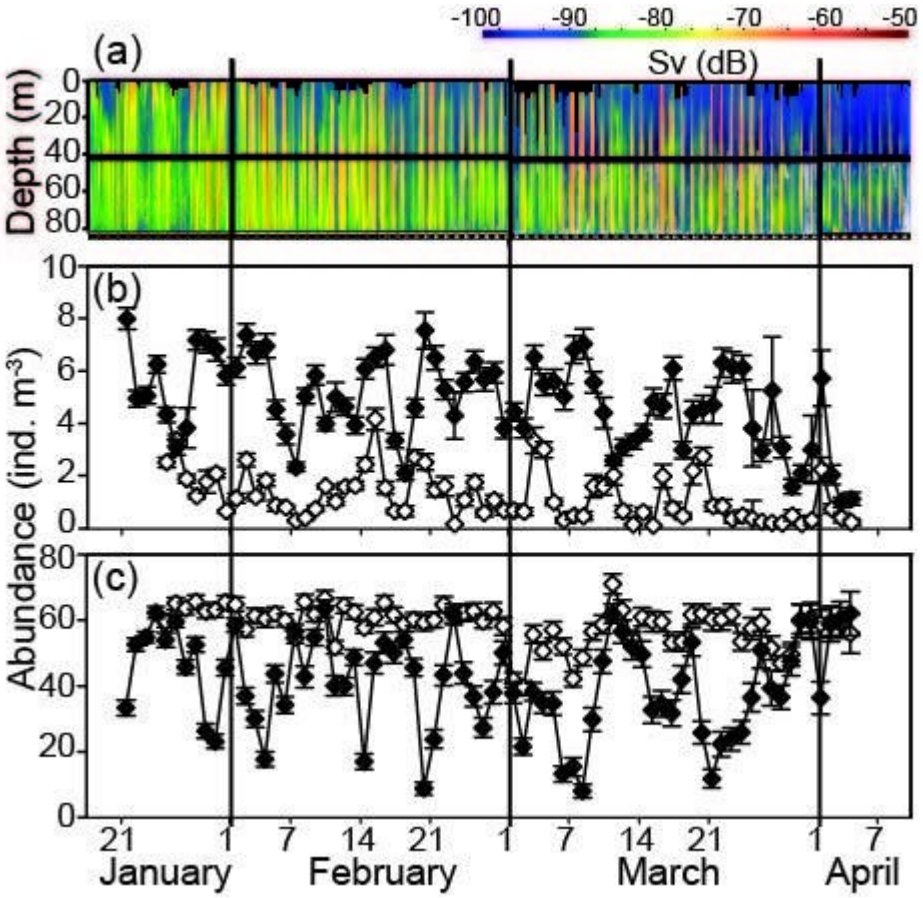

Fig. 2. Time series of (a) backscatter for the 125 kHz frequency of the AZFP in the top 80 m layer, (b) Euphausiid and (c) large copepod abundance (± 1 SE) at day and at night above 40 m depth. Thick black horizontal line at 42 m indicates depth of sediment trap.

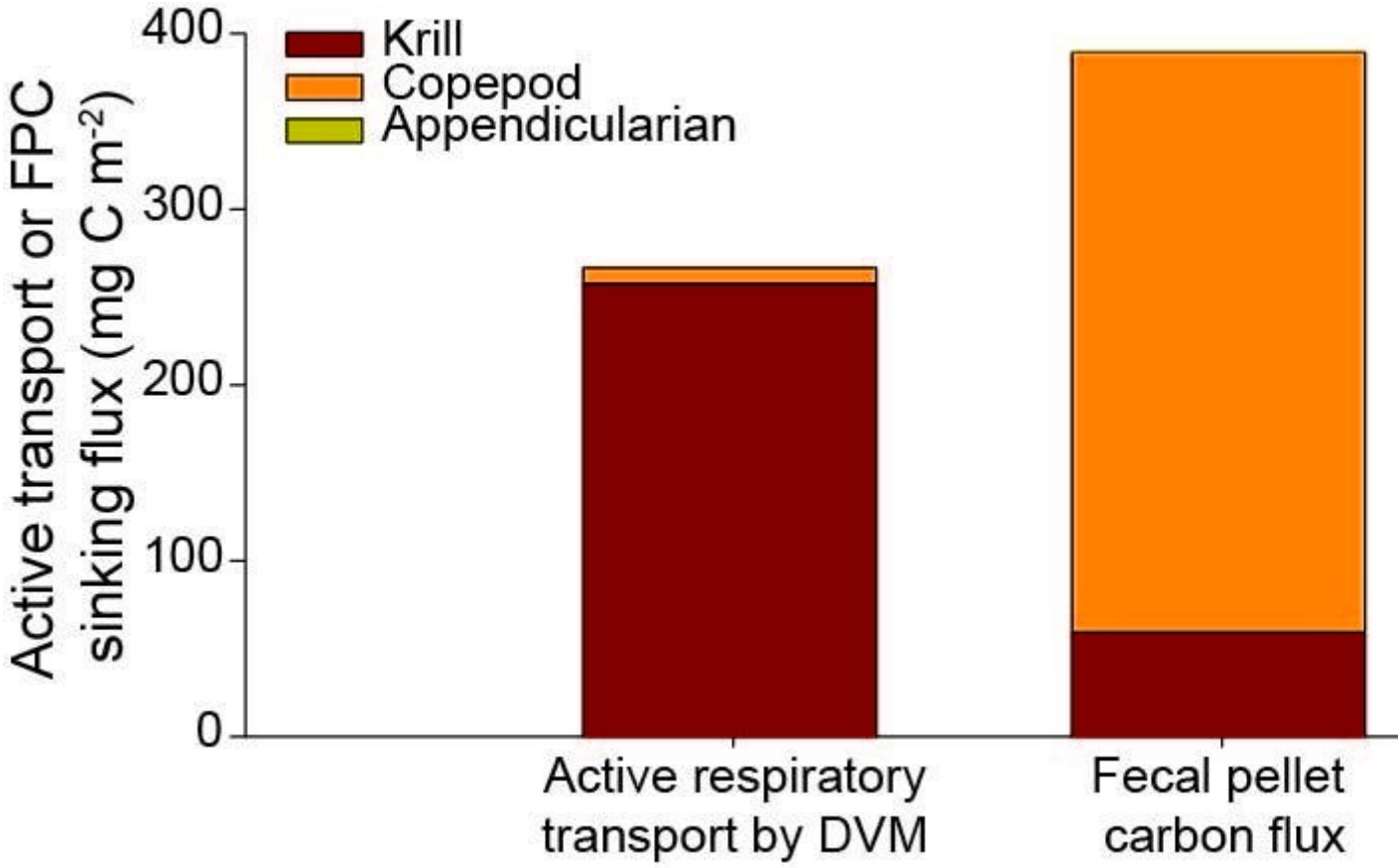

Fig. 3. DVM-mediated active transport of carbon below 40 m depth and sinking flux of fecal pellet carbon at 40 m depth integrated over the period 21 January-3 April 2014 in Kongsfjorden.

3) Export fluxes of biogenic particles in the sea ice-free Kongsfjorden and the seasonally ice-covered Rijpfjorden (Svalbard)

In 2017, we achieved the analysis of the protist fraction of the total sinking flux in the two study fjords for the annual cycles 2012-2013, 2013-2014 (only Rijpfjorden samples available), and 2015-2016. The latter is recognised as a year with a reduced ice cover in Rijpfjorden. The soon-starting analysis of a heavy ice-cover annual cycle (2016-2017) will allow to contrast with patterns during the light ice-cover year already analysed. Work on the zooplankton fecal fraction on the sinking flux in Kongsfjorden and Rijpfjorden was initiated by Steffen Swoboda, master student at UNIS.

Key preliminary results:

- Integrated over the annual cycle, total mass flux was higher in Kongsfjorden (459-1462 g m^{-2}) than in Rijpfjorden (88-468 g m^{-2}).

- The very low sinking flux from late May to July in the 2 fjords (Fig. 4) was completely unexpected. This seasonal pattern contrasts with what has been observed in other less coastal seasonally ice-covered arctic regions where the total mass flux generally increases in summer.

- There was a typical strong single peak of protist flux dominated by diatoms in May that can be linked with the spring bloom in the two fjords (Fig. 5). Maximum flux of protists was not necessarily earlier in in Kongsfjorden than in Rijpfjorden despite the absence of ice in the former but protist flux was much larger in Kongsfjorden than Rijpfjorden.

- The annual cycle 2013-2014 in Rijpfjorden was different, as it did not show a pulsed single peak and the magnitude of the protist flux was an order of magnitude lower than for other annual cycles.

- Over the three annual cycles available for comparison, lag between timing of the ice alga *Nitzschia frigida* peak export and timing of phytoplankton export was variable (Fig. 6). Duration of this lag is thought to be important for trophic transfer of energy via the key copepods *Calanus* spp. Protist flux data appear as useful tools to identify potential match/mismatch years between pelagic primary producers and their algal food source.

- Identification, count and size measurement of fecal pellets are undertaken at UNIS as part of the master project of Steffen Swoboda under the direction of Janne Søreide. The annual cycle 2015-2016 in Kongsfjorden has been completed and the analysis for Rijpfjorden is underway. The annual cycle 2016-2017 will be added to this dataset.

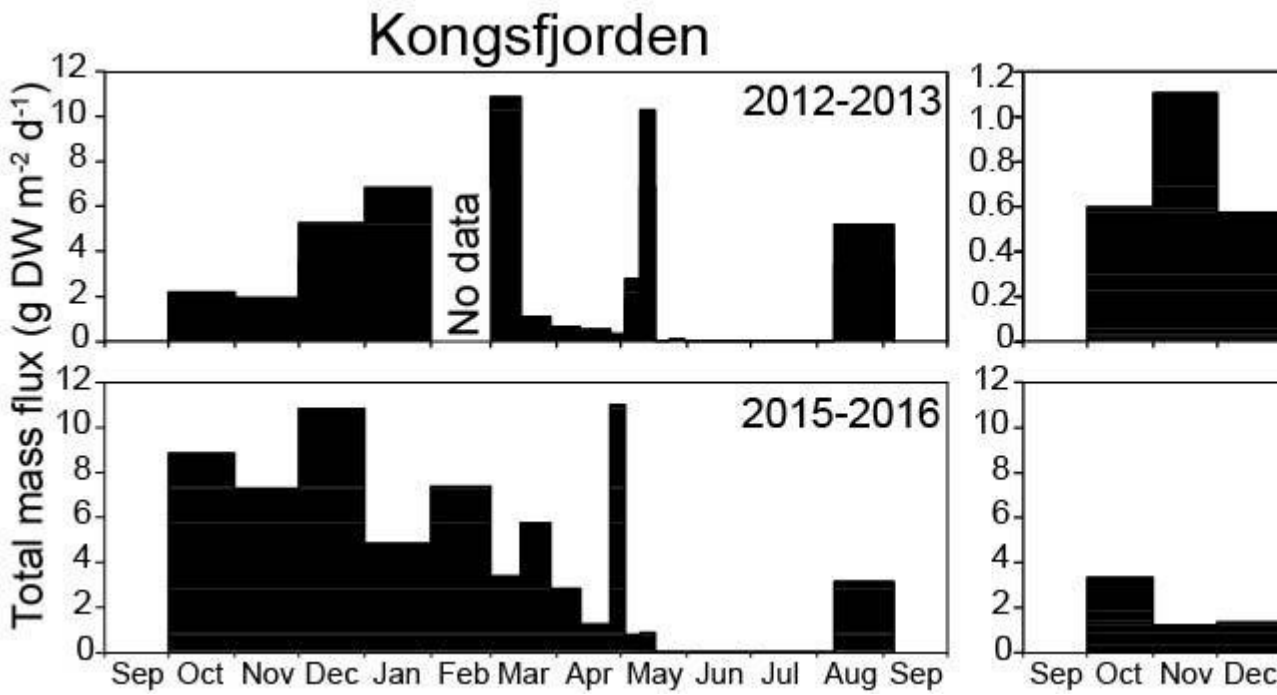

Fig. 4. Sinking flux at 100 m depth of total particulate mass expressed as dry weight in Kongsfjorden and in Rijpfjorden throughout the annual cycles 2012-2013 and 2015-2016.

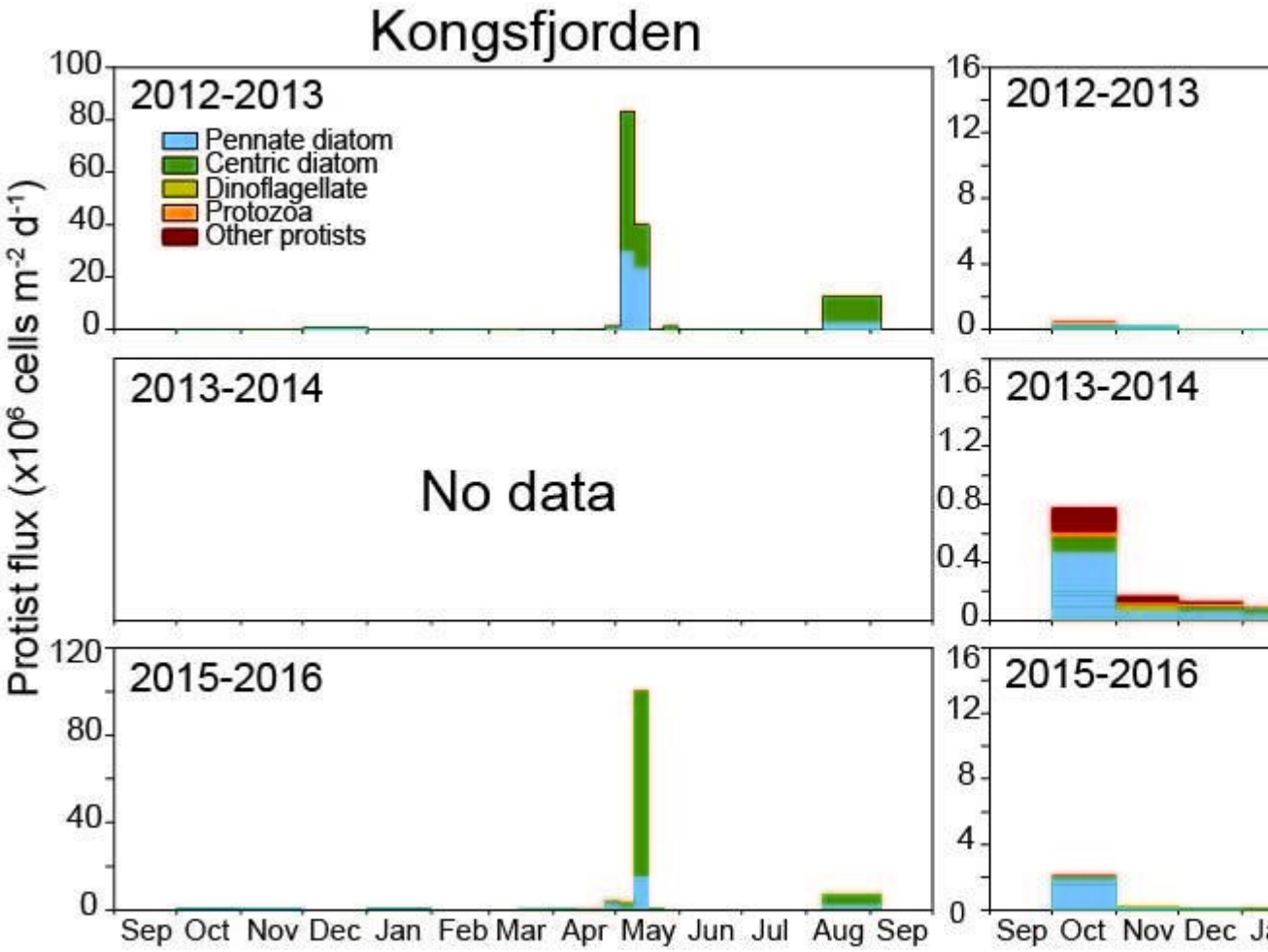

Fig. 5. Sinking flux at 100 m depth of protists in Kongsfjorden and Rijpfjorden throughout the annual cycles 2012-2013, 2013-2014 and 2015-2016.

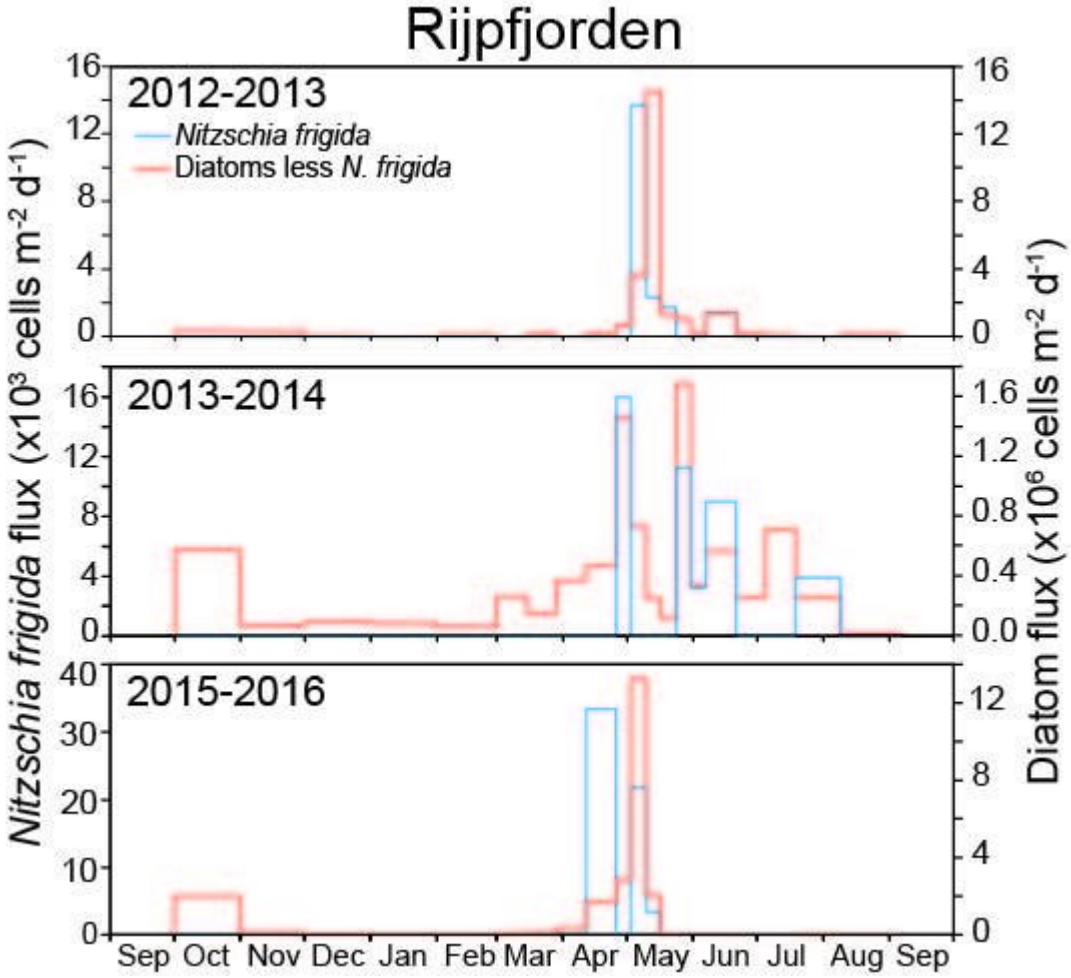

Fig. 6. Sinking flux at 100 m depth of the ice-obligate *Nitzschia frigida* and other diatoms in Kongsfjorden and Rijpfjorden throughout the annual cycles 2012-2013, 2013-2014 and 2015-2016.

Master and PhD-students involved in the project

Steffen Swoboda started a Master project in September 2017 under the supervision of Janne Søreide at UNIS. Steffen is studying the zooplankton fecal fraction of the sinking carbon flux in the two Svalbard fjords targeted by the project. He will also run some fecal pellet production experiments in late autumn and before the spring bloom to improve the fecal pellet volume-carbon conversion factors currently used and that are highly likely biased due to the fact that they were mostly produced during the higher biological production season.

Delphine Le Brun, a student in mechanical engineering at Institut Catholique d'Arts et Métiers (Icam) in France, did a 2-month internship in 2016 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.

For the Management

This project brings new expertise to the Fram Centre on sinking fluxes of organic matter in high-latitude ecosystems and provides results to: (1) further the understanding of fundamental Arctic marine ecosystem services such as biological productivity and carbon sequestration in the deep ocean and (2) study the responses of these ecosystems 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., Kristiansen, S., Daase, M., E. Søreide, J., Wold, A., Morata, N., Gabrielsen, T., 2017. From polar night to midnight sun: Diel vertical migration, metabolism and biogeochemical role of zooplankton in a high Arctic fjord (Kongsfjorden, Svalbard). Limnol. Oceanogr. 62, 1586-1605.

Darnis, G., Geoffroy, M., Daase, J., Renaud, P.E., Søreide, J., Cottier, F., M., Berge (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.

Darnis, G., Lalande, C., Swoboda, S., Søreide, J., Cottier, F., Assmy, P., Berge, J., (in preparation). Effects of sea ice on the biogenic carbon export in high-Arctic Svalbard fjords. For Glob. Biogeochem Cycles.

Communicated Results

Darnis, G., Lalande, C., Swoboda, S., Søreide, J., Cottier, F., Assmy, P., Berge, J., 2018. Effects of sea ice on the biogenic carbon export in high-Arctic Svalbard fjords, POLAR 2018, Davos, Switzerland, 15-26 June 2018.

Darnis, G., Lalande, C., Søreide, J., Berge, J., Assmy, P., Swoboda, S., Halsband, C., Cottier, F., 2018. Export fluxes in Svalbard fjords: an insight into the influence of sea ice on the sinking flux of biogenic matter Arctic Frontiers 2018, Tromsø, Norway, 21-26 January 2018.

Darnis, G., Lalande, C., Søreide, J., Berge, J., Assmy, P., Swoboda, S., Halsband, C., Cottier, F., 2017. Export fluxes of biogenic particles in the sea ice-free Kongsfjorden and the seasonally ice-covered Rijpfjorden (Svalbard), Arctic Frontiers 2017, Quebec City, 11-15 December.

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.

Could results from the project be subject for any commercial utilization

No

Conclusions

All participants in the project agreed that the addition of a new annual cycle (2016-2017) to the multiyear time-series is valuable. The samples are being processed at UNIS toward that goal. Already, the analysis of sinking protists in 2012-2016 have highlighted important patterns in the successive timings of ice algae and phytoplankton sinking that are of great importance for the functioning of the marine ecosystems of the seasonally ice-covered fjords.

Soon, data on the zooplankton fecal carbon component of the POC flux will be available for interannual and inter-fjord comparison.

Preliminary results on total mass flux and protist flux indicate that the seasonal patterns of particle flux are similar in Kongsfjorden and Rijpfjorden although the magnitude can be different, being much higher in Kongsfjorden than in Rijpfjorden in 2012-2013 and 2015-2016. The pattern characterized by extremely low sinking flux in summer has not been described in other Arctic regions where seasonal sea ice forms. Some technical issues with the elemental CHN analyser at UNIS have delayed the analysis of samples for POC/PON but these problems have been fixed. The addition of a new annual cycle with data on POC/PON, protist and zooplankton fecal flux from 2012-2017 should allow us to understand better this particularity of the 2 fjords regarding the sinking flux of particles and biogenic matter.