

Project information

Keywords

ocean acidification, biogeochemical processes, sea ice, glacial water, freshwater, Arctic, Svalbard fjords

Project title

Biogeochemical drivers and climate change on OA – OA DRIVER (ECOAN WP1)

Year

2017

Project leader

Agneta Fransson (NPI) and Melissa Chierici (IMR)

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

70°N-90°N; 20°W to 35°E, Arctic Ocean/Nansen Basin, Svalbard fjords, Fram Strait, East Greenland Current, Barents Sea.

Participants

Participants:

Mats Granskog (NPI),

Collaborators:

Eva Falck (UNIS)

Daiki Nomura (Hokkaido University, Japan)

Ellen Damm (AWI, Germany)

Gernot Nehrke (AWI), Gerhard Dieckman (AWI)

Flagship

Ocean Acidification

Funding Source

Fram Centre Ocean Acidification Flagship

Collaboration with the flagships “Sea-Ice and technology in the Arctic Ocean, and agreements” for the MOSJ/KF and NPI Fram Strait expeditions, and Fjord and Coast for the new project KongCarbon in 2017.

Summary of Results

Results from previously collected samples on sea ice and water column from Kongsfjorden, Tempelfjorden and Fram Strait in 2012-2017 have been published in manuscripts and conference abstracts/posters/oral presentations. Data from Van Mijenfjorden (April/May 2017) was interpreted and added to the Svalbard data set. New samples for chemistry in sea ice and water column were collected in Kongsfjorden, VanMijenfjorden and Fram Strait in 2017. Sea ice samples collected for the determination of methane was analysed and added to the data set. Most data have been quality checked, data interpreted and included in manuscripts and conference abstracts. Large emphasis in 2017 has been several field expeditions such as the Kongsfjorden glacial front and effect of freshwater, VanMijenfjorden sea ice and water and Fram Strait studies. Continuation of the publications of N-ICE 2015 data covering winter to spring data of sea ice and water column.

All the water samples were analysed for dissolved inorganic carbon (DIC), total alkalinity (A_T), phosphate, silicate, nitrate, and stable isotopic ratio of oxygen ($\delta^{18}O$).

In 2017, we published the findings from N-ICE seasonal study. We found that fCO_2 was undersaturated in the surface water under the sea ice from winter to spring and that processes in sea ice such as calcium carbonate (ikaite) precipitation/dissolution was the main reason for undersaturation in winter. In spring, primary production was the main reason.

New data on fjord hydrographical conditions and studies of the effect of glacial runoff water and Atlantic water. Influence of glacial water runoff was mainly observed at the stations near the glacier, decreasing pH and aragonite saturation state.

Thorough analysis of data confirmed previous findings and publications have been published or sent for peer-review focusing on:

Influence of freshwater such as glacial meltwater and sea ice melt on the carbonate chemistry and ocean acidification (OA) in Svalbard fjords

Effect of sea ice processes on CO_2 -driving processes and OA state

Development of sea ice carbonate chemistry and sea-ice-air CO_2 fluxes (N-ICE)

Seasonal study in Kongsfjorden using automated CO_2 sensor on mooring

Seasonal studies of the surface water $f\text{CO}_2$ in the Arctic and around Svalbard using automated $f\text{CO}_2$ instrumentation

Winter-to-spring study of sea ice and water in VanMijenfjorden, Svalbard

Highlights

- Influence of glacial meltwater in Svalbard fjords decreased pH and calcium carbonate saturation state, particularly near the glacier front
- Kongsfjorden had critical aragonite saturation levels for pteropod *Limacina helicina* in winter
- Large ocean CO_2 uptake in winter due to strong winds and open leads in winter ice cover (N-ICE)
- Ocean $f\text{CO}_2$ largely decreased in spring due to large under-ice bloom (N-ICE)
- Successful measurements of the surface water $f\text{CO}_2$ in the Arctic and around Svalbard using automated $f\text{CO}_2$ instrumentation on RV Lance

The results obtained are used for the (i) future field studies planning, (ii) database work and (iii) the models validation.

Master and PhD-students involved in the project

Several master students (UiT, UGOT, UNIS) and PhD students are involved in the project, mainly during field activity. The PhD student Y. Ericsson (UNIS) is indirectly involved in the project (M. Chierici co-advisor).

M. Chierici and A. Fransson involved in UNIS master/PhD course "Chemical oceanography" where field work and lab experiments are engaging the students.

- Glacial drainage water (freshening) in Svalbard fjords decreases calcium carbonate saturation and pH and increases ocean acidification.
- Aragonite saturation close to critical limit for the pteropod *Limacina helicina* in Kongsfjorden due to freshening
- Sea ice contributes to alkalinity during melting in spring, hence partly mitigates OA and increases the potential for more ocean uptake of atmospheric CO₂
- Large sea-air CO₂ fluxes in Arctic winter due to storm events and open water as leads in the ice cover
- Large fCO₂ undersaturation under the Arctic sea ice due to large under-ice bloom in spring
- OA studies in Svalbard fjords in collaboration with Monitoring of Svalbard and Jan Mayen- MOSJ/KF project (NPI), shows large variability of pH and OA state in the fjord-water column. Necessary to continue to fill in data gaps to increase knowledge on biological and chemical coupling for calcifiers in the fjord.
- Competence and expertise for sea ice chemistry studies has advanced rapidly at Fram centre. Contribute with knowledge transfer to other science fields.

All projects produce data necessary for data bases, models and validations.

Published Results/Planned Publications

Peer-viewed publications in 2017

Fransson A., M. Chierici, I. Skjelvan, A. Olsen, P. Assmy, A. Peterson, G. Spreen and B. Ward (2017) Effect of sea-ice and biogeochemical processes and storms on under-ice water $f\text{CO}_2$ during the winter-spring transition in the high Arctic Ocean: implications for sea-air CO_2 fluxes. JGR- Oceans, N-ICE special issue, doi: 10.1002/2016JC012478.

Assmy P. M. Fernandez-Mendez, P. Duarte, A. Meyer, M. Chierici, A. Fransson, M. Granskog et al. (2017). Leads in Arctic pack ice enable early phytoplankton blooms below snow covered sea ice. Scientific Report, 7:40850, DOI: 10.1038/srep40850.

Manno C. (M. Chierici, A. Fransson) et al., Shelled pteropods in peril: assessing vulnerability in a high CO_2 ocean (2017). Earth Science Review, doi: 10.1016/j.earscirev.2017.04.005.

Thor P., A. Bailey, C. Halsband, E. Guscelli, E. Gorokhov, A. Fransson (2016) Seawater pH predicted for the year 2100 affects the metabolic response to feeding in copepodites of the Arctic copepod *Calanus Glacialis*. PLoS ONE 11(12): e0168735. doi:10.1371/journal.pone.0168735.

Fransson A. M. Chierici, D. Nomura, M. A. Granskog, S. Kristiansen, T. Martma, G. Nehrke. Winter-time sea ice carbonate chemistry and effect of glacial melt water in a Spitsbergen fjord during two contrasting years. Submitted to Journal of Geophysical Research: Oceans, 2017.

Fransson A, M Chierici, P Dodd, M Granskog, C Stedmon, E Hansen. Feedbacks of freshwater and primary production on the carbonate system, air-sea CO₂ fluxes and ocean acidification state in the Djimphna Sound, NE Greenland. To be submitted, 2017.

Opstad, I., P. Dalpadado., A. Mangor Jensen, E. Speerfeldt., A. Fransson., M. Chierici Effects of elevated pCO₂ on northern krill species *Thysanoessa inermis*: survival, moulting, growth, grazing and respiration. In review, Journal of Plankton Research, 2017

Yasunaka S. (M. Chierici, A. Fransson) et al Arctic Ocean CO₂ uptake: an improved multi-year estimate of the air–sea CO₂ flux incorporating chlorophyll-a concentrations, submitted to Biogeosciences, 2017

Nomura D, M. A. Granskog, A. Fransson, M. Chierici, A. Silyakova, B. Delille, ,L. Cohen, S.R. Hudson, K.I. Ohshima and G.S. Dieckmann. CO₂ dynamics over young and snow-covered Arctic sea ice in winter and spring. Submitted to JGR, 2017.

Publications (reports)

Chierici, M., I. Skjelvan., R. Bellerby., M. Norli., L. Lunde Fønnes., H. Lødemel Hodal., K.Y. Børsheim., K. S. Lauvset., T. Johannessen., K. Sørensen., E. Yakushev. 2017. Overvåking av havforsuring i norske farvann, Rapport, Miljødirektoratet

Public report

Pteropod research presented in Forskning.no Havforsuring påvirker skallet til vingesneglen, (Fransson NPI/Chierici IMR)

Related papers

Fripiat F et al. including A. Fransson (2017). Macro-nutrient concentrations in Antarctic pack ice: overall patterns and overlooked processes, Elementa, doi.org/10.1525/elementa.217.

Torstensson A. A. Fransson, A. Wulff, M. Chierici (2017). Pack ice algal PSII performance is controlled by light, salinity and dissolved inorganic in the Amundsen and Ross Sea. Submitted to Scientific Report.

Expertise/advice:

Advice “Biological effect indicators for OA ”, 2017, Miljødirektoratet (A. Fransson presentation)

Marine Protected Areas (MPA) advice in OA, Helsinki, 2017 (A. Fransson)

Arctic Ocean Assessment-AMAP vs 2

BEPSII (Biogeochemical processes in sea ice) expert meeting in San Diego/La Jolla, USA, 2017 (Chierici and Fransson poster presentations)

BEPSII (Biogeochemical processes in sea ice) expert meeting in Amsterdam, 2017 (A. Fransson)

Planned publications/in preparation

Fransson A. et al., Seasonal impact of sea-ice processes and freshwater on calcium carbonate saturation in the Svalbard fjords. In prep.

Chierici et al., Drivers of OA state and net community production in Arctic waters.

Kotowich M., B. Delille, A. Fransson, M. Chierici, M. Granskog et al. Nitrous oxide in Arctic sea ice and water from winter to spring, N-ICE. To submit to JGR 2017.

Siljakova A., M. Granskog, A. Fransson, M. Chierici et al., Seasonal variability in methane in Arctic sea ice and water, N-ICE. To submit to JGR 2017.

Hendry K.R, (A. Fransson, M. Chierici, P.A. Dodd) et al., Spatiotemporal variability of barium in Arctic sea-ice and seawater. To submit JGR 2017.

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Conferences/workshops abstracts 2017

Fransson Agneta, Melissa Chierici, Ingunn Skjelvan, Are Olsen, Philipp Assmy, Algot K. Peterson, Gunnar Spreen, Brian Ward. Effects of sea-ice and biogeochemical processes and storms on under-ice water $f\text{CO}_2$ from winter to spring in the high Arctic Ocean: Implications for sea-air CO_2 fluxes.

Abstract submitted to the Ocean Science Meeting, Portland, USA, 2018.

Fransson A. M. Chierici, D. Nomura, M. A. Granskog, S. Kristiansen, T. Martma, G.

Nehrke. Wintertime sea-ice carbonate system and influence of sea-ice processes and glacial freshwater discharge during two contrasting years in a West-Spitsbergen fjord. Abstract submitted to the Polar2018 conference, Davvos, Switzerland, 2018.

Chierici M., A. Fransson, M. Granskog, P. Dodd et al. Ocean acidification in Arctic outflow water. Abstract submitted to the Polar2018 conference, Davvos, Switzerland, 2018.

Fransson Agneta, Melissa Chierici, Ingunn Skjelvan, Are Olsen, Philipp Assmy, Algot K. Peterson, Gunnar Spreen, Brian Ward. Effects of sea-ice and biogeochemical processes and storms on under-ice water $f\text{CO}_2$ from winter to spring in the high Arctic Ocean: Implications for sea-air CO_2 fluxes. Abstract submitted to the Polar2018 conference, Davvos, Switzerland, 2018.

Fransson Agneta, Melissa Chierici, Ingunn Skjelvan, Are Olsen, Philipp Assmy, Algot K. Peterson, Gunnar Spreen, Brian Ward. Effects of sea-ice and biogeochemical processes and storms on under-ice water $f\text{CO}_2$ from winter to spring in the high Arctic Ocean: Implications for sea-air CO_2 fluxes. Abstract submitted to the Arctic Frontier Conference, Tromsø, Norway 2018.

Fransson A. M. Chierici, H. Hop, S. Kristiansen, A. Wold. Seasonal variability of the carbonate chemistry and ocean acidification state in Kongsfjorden: Implications for calcifying organisms. Abstract accepted for the Svalbard Science Forum, Oslo, Norway 2018

Assmy P, et al. (A. Fransson) Emerging physical and biological properties in a new Arctic ice regime. Abstract submitted to the Ocean Science Meeting, Portland, USA, 2018.

Assmy P, et al. (A. Fransson) Emerging physical and biological properties in a new Arctic ice regime. Abstract submitted to the Arctic Frontier Conference, Tromsø, Norway 2018.

Chierici Melissa., Agneta Fransson, Ylva Ericsson, Eva Falck, Svein Kristiansen. Influence of glacial water on carbonate chemistry and biogeochemical processes in Svalbard fjords with different characteristics. Abstract submitted to the Arctic Frontier Conference, Tromsø, Norway 2018.

Chierici Melissa., Agneta Fransson, Ylva Ericsson, Eva Falck, Svein Kristiansen. Influence of glacial water on carbonate chemistry and biogeochemical processes in Svalbard fjords with different characteristics. Abstract submitted to the Ocean Science Meeting, Portland, USA, 2018.

Ericson Ylva, Falck Eva, Chierici Melissa, Fransson Agneta. Temporal variability in surface water $p\text{CO}_2$ in Adventfjorden (West Spitsbergen): physical and biogeochemical drivers. Abstract submitted to the Arctic Frontier Conference, Tromsø, Norway 2018.

Ericson Ylva, Falck Eva, Chierici Melissa, Fransson Agneta. Temporal variability in surface water $p\text{CO}_2$ in Adventfjorden (West Spitsbergen): physical and biogeochemical drivers. Abstract submitted to the Ocean Science Meeting, Portland, USA, 2018.

Itkin (Fransson, Chierici, Granskog) et al. Impact of winter storms in a thinner Arctic sea-ice regime, Abstract submitted to Ocean Science meeting, 2018.

Itkin (Fransson, Chierici, Granskog) et al. Impact of winter storms in a thinner Arctic sea-ice regime, Abstract submitted to Arctic Frontier, 2018. Oral presentation.

Nomura D. et al. (A. Fransson). ECV-Ice: Measuring Essential Climate Variables in Sea Ice–SCOR

Working Group 152. Abstract submitted to ASAR conference, Tokyo, Japan, 2018.

Nomura D. et al. (A. Fransson). ECV-Ice: Measuring Essential Climate Variables in Sea Ice–SCOR Working Group 152. Abstract submitted to Ocean Science meeting, 2018.

Silyakova A., M. Kotovitch, B. Delille, D. Nomura, A. Fransson, M. Chierici, M. Granskog. Methane chemistry in the ice covered Arctic Ocean from winter to summer time. Abstract submitted to the Ocean Science Meeting, Portland, USA, 2018.

Fransson A. Sea-ice carbonate chemistry and influence of biogeochemical processes and glacial water in Spitsbergen fjords. ESSAS conference, Tromsø, Norway, 2017, oral, invited

Fransson A., M. Chierici, M. P. Assmy, P. Dodd, M. Fernandez-Mendez, M. Granskog, A. Meyer, D. Nomura, A. Rösel, A. Silyakova, H. Steen. Winter-to-spring evolution of Arctic Ocean acidification state in under-ice water and effect of sea-ice processes during N-ICE2015 ice drift project. Abstract to ESSAS, Tromsø, Norway, 2017.

Fransson A. M. Chierici, H. Hop, S. Kristiansen, A. Wold. Seasonal variability of the carbonate chemistry and ocean acidification state in Kongsfjorden: Implications for calcifying organisms. Abstract to ESSAS, Tromsø, Norway 2017.

Fransson A., M. Chierici, M. P. Assmy, P. Dodd, M. Fernandez-Mendez, M. Granskog, A. Meyer, D. Nomura, A. Rösel, A. Silyakova, H. Steen. Winter-to-spring evolution of Arctic Ocean acidification state in under-ice water and effect of sea-ice processes during N-ICE2015 ice drift project. Abstract to the Gordon Ocean Research Conference, Ventura, USA, May, 2017.

Chierici M. Fransson A., H. Hop, S. Kristiansen, A. Wold. Late-winter to summer change of the carbonate chemistry and ocean acidification state in Kongsfjorden: Implications for calcifying organisms. Abstract to the Gordon Ocean Research Conference, Ventura, USA, May, 2017.

Fransson A., M. Chierici, M. P. Assmy, P. Dodd, M. Fernandez-Mendez, M. Granskog, A. Meyer, D. Nomura, A. Rösel, A. Silyakova, H. Steen. Winter-to-spring evolution of Arctic Ocean acidification state in under-ice water and effect of sea-ice processes during N-ICE2015 ice drift project. Abstract to Arctic Frontier 2017.

Fransson A. M. Chierici, H. Hop, S. Kristiansen, A. Wold. Seasonal variability of the carbonate chemistry and ocean acidification state in Kongsfjorden: Implications for calcifying organisms. Abstract to the Arctic Frontier, Tromsø, Norway 2017.

OA flagship meetings, 2017, NPI, IMR, NIVA, Akvaplan-Niva, UiT, NINA, NORUT.

N-ICE mini works shops at NPI every week, Sept to Dec 2017.

N-ICE workshop, November 2017, Tromsø, Norway.

BEPSII (Biogeochemical processes in sea ice) expert meeting in San Diego/La Jolla, USA 2017 (A. Fransson/M. Chierici poster presentations)

MOSAIC sea ice planning meetings, 2017

BEPSII (Biogeochemical processes in sea ice) expert meeting in Amsterdam, 2017(A. Fransson presentation)

ICOS (Integrated carbon observing system) meetings in Bergen, and skype meetings 2017 (A. Fransson presentations)

Communicated Results

[Conferences/workshops 2017 \(see publications and abstracts above\)](#)

Gordon Research Conference in Ventura, USA, May 2017 (poster presentations A. Fransson, M. Chierici)

N-ICE workshop, November 2017, Tromsø, Norway

Open section meeting presentation on fjord work, carbonate chemistry and pteropods (A. Fransson), NPI, Tromsø, 2017

Miljødirektoratet presentation of OA flagship work and pteropods, 2017 (A. Fransson)

Marine Protected Areas (MPA) workshop in Helsinki, September, 2017 (A. Fransson, OA advice)

Pteropod research presented in Forskning.no, 2017 (NPI/IMR)

Arctic Frontier (poster presentations), January 2017

BEPSII (Biogeochemical processes in sea ice) expert meeting in San Diego/La Jolla in 2017 (A. Fransson/M. Chierici poster presentations)

BEPSII (Biogeochemical processes in sea ice) expert meeting in Amsterdam, 2017 (A. Fransson presentation)

ICOS (Integrated carbon observing system) meetings in Bergen, 2017 and several skype meetings 2017

Interdisciplinary Cooperation

The project has had great benefit of the large collaboration between the natural science disciplines. In particular, inter-disciplinary cooperation between chemical and physical oceanographers and biologists in the Svalbard fjord studies, MOSJ/KF and the N-ICE 2015 expedition offers a wide range of knowledge and contribution to the project. Only positive aspects.

For all studies (including Fram Strait expedition and N-ICE), we collaborated with biologists regarding nutrient availability. For the fjord studies of the sea ice, we also collaborated with biologists from E. Leu (Faabulous project in VanMijenfjorden), UNIS (Svalbard). Only positive aspects.

Storm paper/interdisciplinary studies N-ICE and poster, Itkin (Fransson, Chierici, Granskog) et al

Collaborations on the sea-ice carbonate chemistry study with Japanese scientists at Hokkaido University and JAMSTEC (aragonite shell analyses). Extended collaboration with AWI for methane studies in sea ice and crystal content in sea ice. Very rewarding.

Budget in accordance to results

The project funding has been fundamental to implement this project. It partly supports the hiring of A. Fransson (project PI), and supports the high costs associated with Arctic field work and extensive sample analysis required in the work.

For the Svalbard fjord study, funding was used to support field activity in April/May, which could not have been performed without the funding. It also supported sampling and analysis of several chemical and physical parameters which are used as tracers for water mass composition.

Field work, travel costs for personal and instrumentation

Reagents and devices

Certified Reference Material, chemicals, sampling bottles, and transportation of equipment.

Could not have been performed without the funding.

Could results from the project be subject for any commercial utilization

No

Conclusions

a) Indicate future research and/or perspectives which the project results have led to

b) List and describe new methods or techniques that have been developed during the project or that the project has revealed a need for

a) increased knowledge about biogeochemical processes in ocean and sea ice and their effect on ocean acidification state

a) and b) Add and extend the use of chemical and biological sensors (e.g. pCO₂, pH, O₂, chl, CDOM) to

moorings in Fram Strait and Svalbard fjords to investigate diurnal and seasonal variability in sea-ice carbonate dynamics and biogeochemical drivers of carbon fluxes. Seasonal data from pCO₂ sensor deployed in Kongsfjorden in 2016 and recovered in 2017 for autonomous measurements.