Project information

Project title

The role of Sea Ice processes on CO_2 exchange and Calcium Carbonate saturation levels - SICCA

Year

2013/2014

Project leader

Agneta Fransson, NPI

Participants

Project leaders:

- Agneta Fransson (NPI) and Melissa Chierici (IMR)

Participants:

- Mats Granskog (NPI),
- Evgeniy Yakushev (NIVA)
- Daiki Nomura (NPI and Hokkaido University, Japan)

Flagship

Ocean acidification, Theme: Understanding the physical and chemical mechanisms controlling ocean acidification in Arctic waters - past, present and future.

Funding Source

Fram Centre, MFCA

Summary of Results

Two years of sea-ice and water carbonate system study along a gradient from glacier front to the sea-ice edge in a Svalbard fjord (Tempelfjorden, TempICE). The influence of oceanic water and glacier ice melt was investigated. Preliminary results show variability in all parameters between the two years in winter, in both sea ice and underlying water as an effect of biological processes, glacier melt water and Atlantic water during the contrasting years and sea-ice conditions. Influence of glacier water was observed in the underlying water at stations near the glacier, affecting pH and aragonite saturation. In 2012 sea-ice formation was late and relatively thin ice, in contrast to in 2013 when sea ice arrived early and developed to a thick layer with large extent.

Seasonal changes near the glacier edge in Tempelfjorden are shown in the water column hydrochemistry and carbonate system in winter period (under the ice cover in February) and in summer (early September, intensive melting and organic matter, phytoplankton bloom). Typical ranges of concentrations were estimated in the coastal area in the vicinity of the glacier edge in winter and summer for dissolved oxygen, pH, phosphate, nitrate, silicate, total alkalinity and dissolved inorganic carbon (DIC) (Figure 1).

• In the vicinity of the glacier the water was slightly oversaturated in regard to aragonite saturation in winter under the ice cover (1.2-1.3), and in a larger degree oversaturated in summer (1.4-2.0). In winter, pH was distributed in the water column (average about 8.04) with increased values in the surface (8.25) compared to near the bottom (8.16).

• Significant seasonal changes of DIC (from 2240 μM in winter to 1600-2000 μM in summer) and total alkalinity (from 2340 μM in winter to 1800-1900 μM in summer) can be connected to an intensive costal discharge and biological production in summer or interannual changes. Calculated pCO_2 of 190-280 μatm in summer and 400-407 μatm in winter suggest potential evasion of CO_2 from water to atmosphere in winter/spring.

• First $CaCO_3$ crystals (ikaite) found in Arctic sea ice (Figure 2; Nomura et al., 2013a)

Ikaite formation may have implications for CO_2 flux and ocean

acidification during ice melt due to excess alkalinity left in the ice at

$CaCO_3$ formation

• Kongsfjorden study: influence of glacier water on the carbonate system and $CaCO_3$ in frost-flowered snow

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

For the Management

• Two years of winter data of carbonate system in Svalbard fjord shows variability in the parameters in sea ice and underlying water due to contrasting sea-ice conditions. Influence of glacier water was observed in the carbonate system and ocean acidification state. This directs to large interannual variability which motivates further field sampling

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acidification during ice melt due to excess alkalinity left in the ice at

$CaCO_3$ formation and needs to be investigated further.

• OA studies in Svalbard fjords in collaboration with Monitoring of Svalbard and Jan Mayen- MOSJ 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.

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

Published Results/Planned Publications

Peer-viewed publications

- Nomura D, Assmy P, Nehrke G, Granskog MA, Fischer M, Dieckmann GS, Fransson A, Hu Y, Schnetger B, 2013a. Characterization of ikaite (CaCO32 •6H2O) crystals in first- year Arctic sea ice north of Svalbard. Annals of Glaciology, 54(63)doi:10.3189/2013AoJ62A034
- Nomura, D. Mats A. Granskog, P. Assmy, D. Simizu, G. Hashida. 2013. Arctic and Antarctic sea ice acts as a sink for atmospheric CO2 during periods of snow melt and surface flooding. *Journal of Geophysical Research*, doi: 10.1002/2013JC009048
- Yakushev E., Sørensen K. 2013. On seasonal changes of the carbonate system in the Barents Sea: observations and modeling. Marine Biology Research. 9(9): 822-830.
- Assmy P., J. K. Ehn, M. Fernández-Méndez, H. Hop, C. Katlein, A. Sundfjord, K. Bluhm, M. Daase, A. Engel, A. Fransson, M. A. Granskog, S. R.Hudson, S. Kristiansen, M. Nicolaus, I. Peeken, A. H. H. Renner, G. Spreen, A. Tatarek, J. Wiktor. 2013. Floating Ice-Algal Aggregates below Melting Arctic Sea Ice. *Plos One*, Vol 8, e76599.

Related papers:

- Granfors A., M. Andersson, M. Chierici, A. Fransson, K. Gårdfeldt, A. Torstensson, A. Wulff, and K. Abrahamsson (2013), Biogenic halocarbons in young Arctic sea ice and frost flowers. Marine Chemistry, 155, 124–134.
- Mattsdotter-Bjørk M., A. Fransson and M. Chierici, 2013. Ocean acidification state in western Antarctic surface waters: drivers and interannual variability. Accepted for Discussion, resubmitted to Biogeosciences, "Ocean in a high CO2 world".
- Tortell, P.D., M. M. Mills., C.D. Payne., M.T. Maldonado., M. Chierici., A. Fransson., A-C Alderkamp., and K. R., Arrigo, 2013. Inorganic C utilization by phytoplankton and sea ice algal assemblages in Antarctic polynyas, Marine Ecology Progress Series, 483, doi: 10.3354/meps10279

Planned publications/in preparation:

- Fransson, Chierici, Nomura, Granskog, Kristiansen, Hedblom, Torstensson, Wulff, Tonu. Winter-time sea-ice-water biogeochemistry and ocean acidification in a Svalbard fjord during two contrasting years. In preparation.
- Fransson et al., Seasonal impact of sea-ice processes on calcium carbonate saturation in the East Greenland Current.
- Fransson et al., Export of sea-ice inorganic carbon from Arctic Ocean: implication for ocean acidification
- Yakushev E.V, Staalstrøm A., Isachsen P.E. Modeling of the pollutant propagating in the Barents sea. (to be submitted to J. of Mar. Sys.)

Conference abstracts 2013:

Conference/workshop proceedings: International conferences

- CO2 conference Beijing (1 abstract), AOA i Bergen (2) , Arctic Futures symposium (1), Authors/presenter: Norli M., Yakushev E., Sørensen K. Title: Studying the surface Arctic ocean acidification state using ships of opportunity. Poster at Arctic Ocean Acidification, Bergen, Norway, 6-8 May, 2013. Abstract Volume. 28-29. Authors/presenter: Agneta Fransson, Melissa Chierici, Daiki Nomura, Mats Granskog
- Oral presentation at the AOA in Bergen, May 2013 Title: Sea-ice processes and glacier runoff as drivers of inorganic carbon and ocean acidification state in the Arctic Ocean Observations from field campaigns in Svalbard, Fram Strait and Canadian Arctic showed large regional and temporal variability in surface-water (under-ice water) carbonate system and calcium

carbonate saturation (Ω). We investigated the carbonate system in sea ice, snow, brine and in the under-ice water. Part of the variability of the carbonate system and Ω in the under-ice water was explained by the impact of sea-ice processes, such as calcium carbonate ($CaCO_3$) formation, brine transport, ice melt and freezing, and glacier runoff. During sea-ice formation, carbon and other chemical substances are rejected from the ice, forming concentrated brine. In this study, brine and melt water were released to the surface water under the ice, reflected by the changes of total alkalinity in the water under the ice. In addition, $CaCO_3$ crystals were formed within the ice, changing the carbonate system and Ω in the ice and in the under-ice water. With changing seasonal ice cover, increased summer ice melt (from sea ice and glacier ice) and river runoff in the Arctic Ocean, CO_2 fluxes, vertical carbon transport and carbonate system will be affected; increased freshwater may change the brine-carbon pump as well as dilute the carbonate system, changing the uptake of atmospheric CO_2. In this presentation we discuss the effect of sea-ice processes and glacier runoff on the surface water during the seasons in the context of decreased ice cover. Author/presenter: Agneta Fransson

- Oral presentation at the Polar Foundation Arctic Futures Symposium, Brussels, Belgium, October 2013 Title: Arctic Ocean acidification and its impacts on marine ecosystems. The increased carbon dioxide (CO_2) concentration in the ocean, so-called ocean acidification (OA), has raised a number of questions regarding the effects on organisms and the marine ecosystem. What are the consequences of the decreased pH and carbonate ion concentration? Especially the colder and fresher Arctic waters are sensitive to changes, since they already have low carbonate ion concentrations and high CO_2 levels. This is the reason for the fact that Arctic Ocean is the first to experience a significant drop in pH, with consequence particularly for calcifying organisms. Coincidently, with increased atmospheric CO_2, the Arctic climate system is rapidly changing. Most evidently observed is the thinning of the Arctic sea ice, warming, and increased river runoff and terrestrial carbon inputs. Glacier and sea-ice melt results in naturally low calcium carbonate saturation in some areas, and an increase in fresher water could result in enhanced OA. When more CO_2 is taken up in the surface water, the calcium carbonate saturation state decreases as well as pH, resulting in less carbonate ions available for the marine organisms to build their calcareous shells and skeletons. Effect studies on marine organisms in high-CO_2 scenarios (low pH) have shown various results, such as changes in physical processes within the cell and changes in behaviour responses. However, some marine organisms will respond positively to new conditions associated with ocean acidification, and others will be disadvantaged, possibly to the point of local extinction. In particular, pH changes in combination with fresher and warmer environment have shown to have the largest effect on marine organisms. These changes will in turn also affect the high-latitude marine ecosystems. However, the complexity of the marine biogeochemical processes and the lack of complete knowledge on the cumulative effects of ocean acidification and climate change on key organisms, have led to difficulties in predicting the consequences for the whole marine ecosystem.
- Related science presented at CO_2 conference in Beijing, June 2013. Authors/presenter: Agneta Fransson, Melissa Chierici, Patricia L. Yager, and Walker O. Smith Jr. Poster presentation. Title: Antarctic sea ice CO_2 system and controls. In austral summer, from December 2008 to January 2009, we investigated the sea-ice carbon dioxide (CO_2) system and CO_2 controls in the Amundsen and Ross Seas, Antarctica. We sampled seawater, brine and sea ice for the measurements of total alkalinity (AT), total inorganic carbon (DIC), pH, inorganic nutrients, particulate organic carbon (POC) and nitrogen (PON), chlorophyll a, pigments, salinity and temperature. Large variability in all measured parameters was observed in time and space due to the complex sea-ice dynamics. We discuss the controls of the sea-ice CO_2 system, such as brine rejection, biological processes, calcium carbonate ($CaCO_3$) precipitation/dissolution and CO_2 exchange. Most (80 to 90%) of the DIC loss was due to brine rejection, which suggests that the sea ice acted as an efficient DIC sink from 0.8 and 2.6 mol m^{-2} yr^{-1} (9.6–31 g C m^{-2} yr^{-1}). The remaining change in DIC was to a large extent explained by net biological production. The AT:DIC ratio in the sea ice was higher than in the under-ice water (UIW), with ratios reaching 1.7, which indicated $CaCO_3$ precipitation and concomitant DIC loss in the sea ice. Elevated AT:DIC ratios and carbonate concentrations were also observed in the UIW, which reflect the solid $CaCO_3$ rejected from the ice during melt. The potential for uptake of atmospheric CO_2 in the mixed layer increased by approximately 56 μatm due to the combined effect of $CaCO_3$ precipitation during ice formation, and ice melt in summer.

Communicated Results

Conferences/workshops 2013

- 1st OA flagship data workshop on scientific results from OA Flagship, effects on organisms and socioeconomic impact at Fram Centre, Tromsø, 21-22 October 2013
- Project "Ocean Acidification in the Arctic: effects of ice (CARSIC)" kick-off meeting, Shirshov Institute of Oceanology RAS, Moscow, September 21-24 2013.
- OA Flagship meetings
- Status reports and presentations at OA Flagship meetings

Public presentations

- Børsheim, Y and M. Chierici, 2013. Skjellene dør på USAs vestkyst, kronikk, Bergens Tidende, 5th January 2013.

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 offers a wide range of knowledge and contribution to the project. Only positive aspects.

For all studies (including Fram Strait expedition), we collaborated with biologists regarding nutrient availability. For the fjord studies of the sea ice, we also collaborated with biologists from University of Gothenburg regarding bacterial biomass, chlorophyll and fatty acids in the sea ice, brine, snow, and underlying water. Only positive aspects.

Collaborations on the sea-ice CO2 system study with Japanese scientists at Hokkaido University. Visit to Sapporo, Japan by A. Fransson, M. Chierici and M. Granskog for collaboration, work on data and publications. Tempelfjorden studies were performed in collaboration with marine physics specialists (Prof. A.Marchenko). Only positive aspects.

Collaboration and participation of the Russian colleagues form the Shirshov Institute of Oceanology RAS (Moscow) in the 2013/14 expedition to Svalbard. Coordination with the group from UNIS (Prof. A.Marchenko) and the SICCA participants is planned.

Budget in accordance to results

The project funding has been fundamental to implement this project. It supports the hiring of A. Fransson (project post doc and 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 two major field activities in two different fjords in winter, which could not have been performed without the funding. It also supported sampling and analysis of several chemical and biological parameters which are used as tracers for water mass composition.

Field work, travel costs for personal and instrumentation

Field equipment (partly)

Reagents and devices (electrodes, pipettes etc.)

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

Could results from the project be subject for any commercial utilization

No

Conclusions

Future research:

a) Include more biological parameters such as zooplankton and ice algae for sea-ice system studies. Planned for the Lance N-ICE expedition 2014/2015.

NFR project CARSIC (http://www.niva.no/en/carsic)

b) Add chemical and biological sensors to moorings for use under the sea ice to investigate diurnal and seasonal variability in sea-ice dynamics and biogeochemical drivers of carbon flux. Planned for the Lance Young-ICE expedition 2014/2015.

Perform 2014 winter expeditional studies in the Svalbard fjord in collaboration with Russian colleagues (supported by project CARSIC) aiming at covering wider list of parameters (including DOC and pigments) and intercalibration of carbonate system techniques applied in Norway and Russia.