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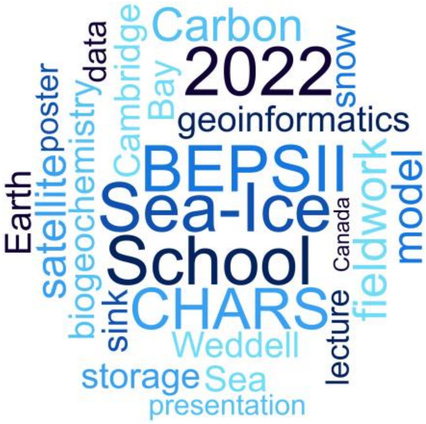
Report 31 I August 2023

Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) Sea-Ice School 2022

14 – 23 May 2022
Cambridge Bay, Canada



About the school. One of the goals of the Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) working group is to educate and support Early Career Scientists (ECS). With the first BEPSII Sea-Ice School, we aimed to teach the students different aspects of sea-ice biogeochemistry, from theory to lab work to fieldwork. The school took place in Cambridge Bay, Nunavut, Canada, from 14 to 23 May 2022 (Figure 1). Organised by BEPSII Scientific Steering Committee members Letizia Tedesco of the Finnish Environment Institute, Finland, Bruno Delille and Odile Crabeck of the University of Liège, Belgium, and with the support of the Climate and Cryosphere (CliC) project, the International Arctic Science Committee (IASC), the National Science Foundation (NSF), Polar Knowledge Canada, the Scientific Committee on Antarctic Research (SCAR), the Scientific Committee on Oceanic Research (SCOR), and SOLAS, it was the first initiative of its kind within the BEPSII network. 29 participants from Canada, the United States, South Africa, Japan, Finland, Germany and the United Kingdom, just to mention a few of the represented countries, gathered at the Canadian High Arctic Research Station (CHARS) for a full immersion into sea ice. CHARS served as the headquarters of the school, providing accommodation for students and lecturers alike, as well as spaces for frontal lectures and presentations, poster sessions, and lab work – all in a unique setting decorated with local ornaments, paintings, and cultural artefacts.

In this report

Attendees research profiles

Figure 1: Group photo of Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) Sea-Ice School 2022.

Meet the students. At the beginning of the school, students presented some introductory slides about themselves, their studies and the focus of their research (Figure 2). The introductory session was an excellent way for each student to learn more about others, the focus of their studies and also about their personal interests. Hiking, jogging, kayaking and crocheting but also collecting worms, naming a trout, winter camping and playing underwater hockey, just to mention a few… plenty of unique hobbies and passions under the CHARS roof. To unpack students' study and research work further, they were given the chance to participate in evening poster sessions. Be it a digital or a printed one, each poster was not only a snapshot of what each BEPSII School attendee was up to, but it also became an opportunity for enriching conversations, feedback exchanges and the exploration of potential future collaborations (Figure 3). Everything is in a unique setting: the CHARS round meeting room, decorated with paintings and ornaments representative of the local community and culture.

Figure 2: Photos of students' introductory talks.

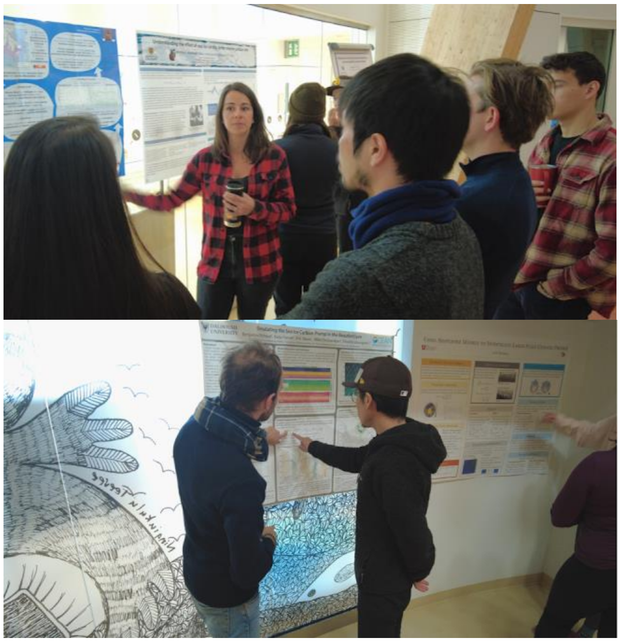


Figure 3: Photos of students' poster presentations.

Meet the lecturers. The 2022 BEPSII School brought together lecturers with different expertise from a variety of institutions around the world. Besides organising the school, Letizia, Bruno, and Odile were also lecturers at the school. Letizia gave the students an introduction to the world of marine biogeochemical modelling with a focus on sea ice biogeochemistry. She also provided the students with tools that enabled them to develop a model of their choice in a group exercise. Bruno and Odile taught the basics of sea ice physics and thermodynamics in the class, in the field and in the lab. University of Manitoba's CJ Mundy also worked with students in the classroom and on the ice, with lectures on sea ice optics and ecology and fieldwork sessions on sea ice coring, sample collection and under-ice light measurements. Sian Henley from the University of Edinburgh took students into the world of sea ice nutrients, as well as marine policy and accompanied them on the field and in the lab for sampling and analysis work. Additionally, she supervised students in their work on a nutrients-related data set. Daiki Nomura from Hokkaido University and Naoya Kanna from the University of Tokyo lectured about gas exchange and land–sea ice–ocean interaction, respectively. In the lab, they both assisted the students in making thick and thin sea-ice sections among the other things. Brent Else of the University of Calgary taught the students about sea-ice carbonate chemistry, while Karley Campbell from the University of Tromsoe gave a class on sea ice algae with some practical sessions in microscopy. Finally, Podcasting Consultant and Communication Expert Yann Ilunga, who was in charge of all BEPSII School content and social media-related matters, brought his experience to CHARS in a lecture dedicated to advice and strategies ECSs can follow and leverage to better communicate and present themselves online.

Figure 4: Photos of Canadian High Arctic Research Station.

Figure 5: Photos of fieldwork.

Getting hands dirty. While students were not busy with lectures, presentations and conversations, they had the opportunity to experience plenty of fieldwork (Figure 5). For most days, different groups headed out on the ice near CHARS to participate in fieldwork sessions coordinated by some of the lecturers: CJ Mundy, Bruno Delille, Sian Henley, and Odile Crabeck. Students worked with and tested different gear sets and tools used for a wide range of measurements. From ice coring and measuring snow thickness to measuring environmental variables and collecting sea ice samples, students were able to take part in a diverse range of field activities. While few participants had been out in the field before, for most of the others, this represented the first opportunity to carry out actual fieldwork, and it was even the first time on sea ice for a few students (Figure 5).

Once the samples had been collected, it was time to work on them – and that is where lab work at the CHARS facilities came into the picture (Figure 6-1 & 6-2). Over several days, while some of the students were busy out in the field, others took turns carrying out measurements and analyses of some of the samples collected while out on the ice. From measuring salinity to chlorophyll filtration, there were different lab techniques and tools participants of the BEPSII School got to experiment with.

Figure 6-1: Photos of lab work.

Figure 6-2: Photos of lab work.

During the last day of the school, students had the chance to present the topic that took mostly their attention and wanted to develop further in small groups. They all did an excellent job, showing the school was successful despite all the challenges due to Corona Virus Disease (COVID) at the school, and showcased their incredible learning skills (Figure 7).

Figure 7: Photos of final student presentations.

Time to go home. All participants of the school experienced science work in a unique location like Cambridge Bay while also having a glimpse of the local culture and its traditions. Theory through lectures, conversations and poster sessions, fieldwork and lab sessions, group presentations, and a unique setting…there was so much the school offered attendees, becoming an experience they are likely to remember for a very long time – and that, we hope, has played a role in the development of their careers in science.

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Mansi Joshi finished her master's in geoinformatics from India. She joined PhD in 2020, and her research focuses on analysing sea ice formation, growth and deformation in the Weddell Sea, Antarctica using Ice, Cloud and land Elevation Satellite (ICESat-2).

Variations in sea ice thickness over Weddell Sea for 2019-2022 using ICESat-2

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Changes in salinity in the Antarctic Bottom Water (AABW) influence the strength of the thermohaline circulation (Orsi *et al.*, 2002). Sea ice formation in the Weddell Sea accounts for 5% – 10% of annual ice production around Antarctica and is the largest source of AABW (Gill, 1973; Tamura *et al.*, 2008; Shi *et al.*, 2020). Sea ice in the Weddell Sea exhibited an increasing trend from the beginning of the satellite period in 1978 until 2016 but has since been decreasing (Parkinson, 2019; Wang *et al.*, 2020). However, water mass transformation is driven by ice growth and changes in thickness over the continental shelf rather than changes in extent. Thus, it becomes important to measure variability in sea ice thickness over the Weddell Sea along with sea ice extent to understand the role each one plays in the thermohaline circulation. In this study, we have estimated sea ice thickness using ICESat-2 data over the Weddell Sea for the years 2019-2022. The freeboard product ATL10 provides estimates of sea ice freeboard with a variable along-track resolution of 20 – 200 meters, with each segment consisting of 150 returned signal photons. Sea ice thickness is calculated from ATL10 using the Improved Buoyancy Equation (BOC, eq. 1). In eq. 1, here I is the sea ice thickness, S is the snow depth which is derived from the empirical parameters in eq. 2. The c and d values are used from Ozsoy-Cicek *et al.*, 2013 for snow depth estimations. F is the total freeboard from ICESat-2, ATL10 product. ρ_w, ρ_i and ρ_s are densities of water, ice, and snow respectively. The densities used in this study are 1023.9, 915.1, and 300 kg/m^3 for water, ice, and snow, respectively (Kern *et al.*, 2016; Li *et al.*, 2018; Zwally *et al.*, 2008).

$$\mathrm{I} = \frac{\rho_w F - (\rho_w - \rho_s) S}{\rho_w - \rho_i} \ldots\ldots\ldots \quad (1)$$

$$\mathrm{S} = c + d * F \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

We find that the mean sea-ice thickness decreases in the summer with minimum thickness observed during Jan–Mar and increases towards the winter (July–November) in the Weddell Sea. Future studies will include comparing the satellite results with coinciding field measurements. Analysing seasonal and interannual sea ice variability over the Weddell Sea will help us understand its role in global climate on longer temporal scales.

References

Gill, A.E. (1973). Circulation and bottom water production in the Weddell Sea. *Deep Sea Research and Oceanographic Abstracts*, 20(2), 111–140. https://doi.org/10.1016/0011-7471(73)90048-X

Kern, S., Ozsoy-Çiçek, B. & Worby, A.P. (2016). Antarctic sea-ice thickness retrieval from ICESat: inter-comparison of different approaches. *Remote Sens.*, 8(7), 538. https://doi.org/10.3390/rs8070538

Li, H., Xie, H., Kern, S., *et al.* (2018). Spatio-temporal variability of Antarctic sea-ice thickness and volume obtained from ICESat data using an innovative algorithm. *Remote Sens. Environ.*, 219, 44–61. https://doi.org/10.1016/j.rse.2018.09.031

Orsi, A.H., Johnson, G.C. & Bullister, J.L. (1999). Circulation, mixing, and production of Antarctic Bottom Water. *Prog. Oceanogr.*, 43(1), 55–109. https://doi.org/10.1016/S0079-6611(99)00004-X

Ozsoy-Cicek, B., Ackley, S., Xie, H., *et al.* (2013). Sea ice thickness retrieval algorithms based on in situ surface elevation and thickness values for application to altimetry. *J. Geophys. Res.-Oceans*, 118(8), 3807–3822. https://doi.org/10.1002/jgrc.20252

Parkinson, C.L. (2019). A 40-y record reveals gradual Antarctic sea ice increases followed by decreases at rates far exceeding the rates seen in the Arctic. *Proc. Natl. Acad. Sci. U. S. A.*, 116(29), 14414–14423. https://doi.org/10.1073/pnas.1906556116

Shi, Q., Yang, Q., Mu, L., *et al.* (2021). Evaluation of sea-ice thickness from four reanalyses in the Antarctic Weddell Sea. *Cryosphere*, 15(1), 31–47. https://doi.org/10.5194/tc-15-31-2021

Tamura, T., Ohshima, K.I. & Nihashi, S. (2008). Mapping of sea ice production for Antarctic coastal polynyas. *Geophys. Res. Lett.*, 35(7), L07606. http://dx.doi.org/10.1029/2007GL032903

Wang, X., Jiang, W., Xie, H., *et al.* (2020). Decadal variations of sea ice thickness in the Amundsen-Bellingshausen and Weddell seas retrieved from ICESat and IceBridge laser altimetry, 2003-2017. *J. Geophys. Res.-Oceans*, 125(7), e2020JC0160 77. https://doi.org/10.1029/2020JC016077

Xu, Y., Li, H., Liu, B., *et al.* (2021). Deriving Antarctic sea-ice thickness from satellite altimetry and estimating consistency for NASA's ICESat/ ICESat-2 missions. *Geophys. Res. Lett.*, 48(20), e2021GL093425. https://doi.org/10.1029/2021GL093425

Zwally, H.J., Yi, D., Kwok, R., & Zhao, Y. (2008). ICESat measurements of sea ice freeboard and estimates of sea ice thickness in the Weddell Sea. *J. Geophys. Res.-Oceans*, 113(C2), C02S15. https://doi.org/10.1029/2007JC004284

Benjamin Richaud studied physical oceanography and naval engineering in France. After a year of assessing resources for a tidal turbine company in Ireland, he moved to Canada in 2018 to start a PhD at Dalhousie University, Canada. He focuses on modelling ice-ocean interactions in the Arctic Ocean under a changing climate.

Underestimation of oceanic carbon uptake in the Arctic Ocean: Ice melt as predictor of the sea ice carbon pump

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The Arctic Ocean is generally undersaturated in carbon dioxide (CO_2) and acts as a net sink of atmospheric CO_2. This oceanic uptake is strongly modulated by sea ice, which can prevent air-sea gas exchange and has major impacts on stratification and primary production. Moreover, sea ice is a dynamic biogeochemical system where ice-air gas exchange, sympagic productivity and calcium carbonate precipitation can impact the carbonate properties stored in sea ice (e.g. Delille *et al.*, 2014). This leads to a ratio of alkalinity to dissolved inorganic carbon that is larger than in seawater. It has been suggested that a higher ratio within sea ice amplifies the seasonal cycle of seawater pCO_2 and leads to an increase in oceanic carbon uptake in seasonally ice-covered regions compared to those that are ice-free (Rysgaard *et al.*, 2007). The regional and global impact of this process is not clearly established yet (Grimm *et al.*, 2016; Moreau *et al.*, 2016; Mortenson *et al.*, 2020). The Arctic Ocean is undergoing a rapid change with amplified warming due to positive feedback mechanisms leading to a replacement of perennial sea ice by seasonal sea ice. A better understanding of the link between the seasonal cycle of sea ice and oceanic uptake of CO_2 is needed. In this study, we investigate how the storage of carbon in sea ice affects the air-sea CO_2 flux. We quantify its dependence on the ratio of alkalinity to inorganic carbon in ice and identify the main drivers of the induced air-sea CO_2 flux. To this end, we present a simple parameterisation of carbon storage in sea ice implemented in a one-dimensional physical-biogeochemical ocean model. Sensitivity simulations show a linear relation between ice melt and the amplification of seasonal carbon uptake (Figure 8, Richaud *et al.*, 2023). The slope of this linear relation depends on the temporally-integrated ice cover. A 30% increase in carbon uptake in the Arctic Ocean is estimated compared to ice melt without amplification. Applying this relationship to different future scenarios from an Earth System Model (ESM) that do not account for the effect of carbon storage in sea ice suggests that Arctic Ocean carbon uptake is underestimated by 5 to 15% in these simulations.

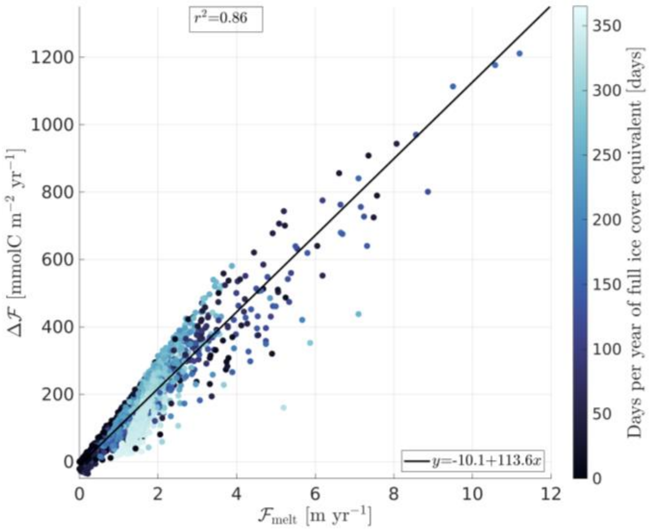

Figure 8: Sensitivity simulations from a one-dimensional numerical model. The supplementary carbon uptake $\Delta\mathcal{F}$ induced by the storage of carbon in sea ice is plotted as a function of the gross annual ice melt $\mathcal{F}$melt. The colour of the dots shows the temporal integral of ice melt over the year, in days. The squared correlation coefficient r^2 between both variables is given in the top left corner.

References

Delille, B., Vancoppenolle, M., Geilfus, N.-X., (2014) Southern Ocean CO_2 sink: The contribution of the sea ice. *J. Geophys. Res.-Oceans*, 119(9), 6340–6355. https://doi.org/10.1002/2014JC009941

Grimm, R., Notz, D., Glud, R.N., *et al.* (2016). Assessment of the sea-ice carbon pump: Insights from a three-dimensional ocean-sea-ice-biogeochemical model (MPIOM/HAMOCC). *Elementa-Sci. Anthrop.*, 4, 000136. https://doi.org/10.12952/journal.elementa.000136

Moreau, S., Vancoppenolle, M., Bopp, L., *et al.* (2016). Assessment of the sea-ice carbon pump: Insights from a three-dimensional ocean-sea-ice biogeochemical model (NEMO-LIM-PISCES), *Elementa-Sci. Anthrop.*, 4, 000122. https://doi.org/10.12952/journal.elementa.000122

Mortenson, E., Steiner, N., Monahan, A.H., *et al.* (2020). Modeled Impacts of Sea Ice Exchange Processes on Arctic Ocean Carbon Uptake and Acidification (1980–2015), *J. Geophys. Res.-Oceans*, 125(7), e2019JC015782. https://doi.org/10.1029/2019JC015782

Richaud, B., Fennel, K., Oliver, E.C.J., *et al.* (2023). Underestimation of oceanic carbon uptake in the Arctic Ocean: Ice melt as predictor of the sea ice carbon pump. *The Cryosphere*, 17(7), 2665–2680. https://doi.org/10.5194/tc-17-2665-2023

Rysgaard, S., Bendtsen, J., Delille, B., *et al.* (2011). Sea ice contribution to the air–sea CO_2 exchange in the Arctic and Southern Oceans. Tellus Ser. B-Chem. *Phys. Meteorol.*, 63, 823–830. https://doi.org/10.1111/j.1600-0889.2011.00571.x

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