Summary BEPSII & ECVice Meeting April 3-5th 2017, La Jolla, California

- Scripps institute of Oceanography -

Participants:
Ana Aguilar-Isalis, Jeff Bowman, Melissa Chierici, Florian Deman, Jens Ehn, Brent Else, James France,Agneta Fransson, Francois Fripiat, Daniela Koenig, Marie Kotovitch, Delphine Lannuzel (Skype), Marion Lebrun, Oliver Legge, Klaus Meiners, Lisa Miller, Eric Mortenson, CJ Mundy, Daiki Nomura, Bonnie Raffel, Janne-MarkusRintala, Lynn Russel, Jacqueline Stefels, Nadja Steiner, Letizia Tedesco, Max Thomas,

Brief summary:
The ***BEPSII research community*** is a global community of sea-ice biogeochemists which had been initiated as SCOR WG 140 which addressed fundamental issues in communication and methods. BEPSII was then approved by SOLAS (Surface Ocean Lower Atmosphere Study) and CliC (Climate and Cryosphere) as a longer-lived activity with additional endorsement from SCAR (Scientific Committee of Antarctic Science) . With additional support from IASSC a Workshop was being held in La Jolla, April 2017, discussing updates of activities including science talks and poster presentations. Focus of the 2nd phase is to develop the tools to tackle big-picture questions of global relevance and feedbacks. A set of objectives has been compiled with specific task groups which comprises the base for a draft 5 year -science plan. As a BEPSII subgroup the new SCOR Working Group 152 was established: Measuring Essential Climate Variables in Sea Ice (ECV-Ice) which had its first meeting within the BEPSII workshop. Upcoming tasks include several method intercalibration projects, support for the MOSAiC field program, 1-D and 3-D model intercomparisons, a student field school and various experimental and modelling approaches enhancing our understanding of biogeochemical exchange processes at sea -ice interfaces (BEPSII).

Meeting goals:
- Update of activities
- Fringing activities
- First annual meeting of the new SCOR WG ECV-ice
- Science talks & Poster presentations
- Planning BEPSII's future: Drafting of a 5-year science plan

Update on Activities:
TG1 - Lisa/Klaus:
- Intercalibration & intercomparison campaign: now ECV-ice
- In-situ platforms / sensor development & validation: presentation on developments at AWI by Klaus (see below), Klaus' & Lisa's posters.
- Remote-sensing tools and algorithms: nobody has stepped in, so for now this topic will not be pursued.
- Designing time series process studies and inform MOSAiC: part of ECVice; Jacq & Jeff are primary links with MOSAiC.
- Guide of best Practice as life document: a page on the BEPSII website will be established with what we have right now (Lisa, Max, Bruno, Klaus)
- Historical data collation and analysis; emphasis on Arctic: Francois' & Delphine's papers on nutrient- and iron distributions have been published in *Elementa*. Several collations and papers are under construction:
    - Ice-algal biodiversity and productivity parameters (Maria et al.).
    - Antarctic POC & DOC (Francois & Florian)
    - Antarctic land-fast ice Chl-a (Martin & Klaus)
    - TA/DIC compilation is done (Bruno will lead the paper)
    - There is a gap in Arctic data collation!!: Christine & Ilka are sitting on important Arctic chlorophyll data, but publication is uncertain. They need help!
- Arctic Data Center call for proposals (deadline: 26 April): not applicable to BEPSII data.
- Tools and protocols for genetic community assessments: Changed to more informal format to make room for drafting recommendations to MOSAIC (Jeff Bowman, Katja Metfies?)

New ideas:
- Sampling thin/MIZ ice? Does not need to be a separate task.
- Gas transfer velocity parameterizations? Will be part of ECV-Ice review papers.
- Pressure effects on biogeochemistry? Max thinks it's premature to establish a task now – maybe next year

- Implications of rain on sea ice? Put into 'Atmospheric deposition' task.

TG2 on Modelling and Observational process studies – Nadja:
- Ridges-associated processes – some progress on an individual project based level
- Impact of micro plastics on sea-ice ecosystems will be removed from the task list for now
- Time variability of algal wax and wane: this component still requires some detailed attention and clarification. Ideally we would like to focus on particular processes that have been identified and where we have either little understanding or controversial ideas. Examples include potential seasonal switches in community structure and impacts on efficiency of light uptake, nutrient conversion, uptake and preferences, causes for mortality and parameterized form.
- Interactions of snow and sea ice is covered via our link to the new CATCH initiative
- Impact of biochemistry on physical ice properties is a component frequently asked for by physical sea ice-ocean modellers and which should be addressed, but at this point we have not made a clear plan about it. Examples are impacts on radiative fluxes , melting and porosity (ice strength). Some efforts are on their way on an individual project based level.
- Upscaling- Efforts are underway with respect to scaling up from localized measurements to larger scales, e.g. via ROVs, as well as downscaling from larger scale models to community relevant scales and impacts
- Intercomparison of 1D models, now active again: sharing via drop box folder has been initiated. Letizia will continue to lead and perform initial testing and send out final details and requests for output.
- Intercomparison of 3D models – link to FAMOS, an effort is underway to compare sea ice algae models to be finalized in 2018.
- Analysis of regional and global climate models. Work on this is active and publications in preparation (e.g. impacts of changes in sea ice/snow melt onset on algal growth onset)

TG3 on synthesis - Delphine/Martin:
Not much has been going on. The different topics need to be discussed and leaders assigned: done at the Future planning agenda item (see below).

TG4 on Outreach - Letizia:
- Letizia will continue taking care of the Twitter page (bepsii_seaice): please subscribe and send her information if you want to advertise!
- Marie Kotovisch is maintaining the Facebook page
- Max Thomas will help Bruno maintaining the website.
- Stakeholders (Nadja): The need to identify stakeholders has been highlighted, since this becomes more and more relevant also for project proposals:
    - With respect to climate change impacts on Arctic Marine ecosystems links via ice algae associated key species (e.g. Arctic/Polar cod) to higher trophic levels and humans have been identified and are being worked on a project base linked to AMAP.
    - Collaborative project with Inuvialuit Game Council to model Arctic cod development with changing climate. Very positive response from the community.
    - Also the impact on carbon uptake and export is still a relevant question with policy implications. (Two publications in Elementa address this issue)
    - With respect to method development small businesses were identified as potential stakeholders.
- Logo: both Bruno and Lisa drafted a potential logo. Letizia asks Bruno to combine some of Lisa's ideas in his and correct the title (the word "exchange" was missing from the BEPSII acronym).
- It is decided not to produce a news bulletin, but add news items to bulletins of our sponsors; e.g. SOLAS asks a few young scientists to write on their work (4 names have been submitted).
- Summer school: the options to organize a BEPSII training school in conjunction with an ECVice intercalibration campaign and potentially in collaboration with MOSAiC will be investigated. The current idea is to organize the summer school in Cambridge Bay 1 week after the intercalibration experiment in April 2019.

Fringing activities:
CATCH and RvG ASIC (James France):
The aim of this presentation was to outline details of experiments from the Roland von Glasow Air-Sea-Ice-Chamber (RvG ASIC) and to introduce CATCH, a new IGAC emerging activity, focusing on Atmospheric Chemistry in the Cryosphere. Feasibility of running experiments at the UEA Sea-Ice Chamber were discussed within the framework of ECV-ice. The Sea-ice Chamber is currently funded under the EUROCHAMP infrastructure banner.

Over the last year there has been a flurry of proof of concept work going on, trying to find the limits of the RvG ASIC. The sea-ice tank is 2.4m in length by 1.4m wide by 1m deep with optional additional up to 1m high PTFE-FEP atmosphere, housed in an environmental chamber, capable of temperatures -55 to +35°C with stability of ~ ±0.3°C. There is no biology in the tank, yet.
The three experiments presented at BEPSII focussed on gas fluxes (methane fluxes from ocean to atmosphere during sea-ice growth and melt), ice physics (vertical pressure profile which forms during sea-ice growth; Max Thomas) and sea-ice optical properties (in situ profile measurements of light attenuation in growing and melting sea-ice).

CATCH is having its first meeting on 19-20 April in Paris and focuses on current and future science relevant to atmospheric chemistry in the cold regions. The main aim of the workshop is to develop wider trans-disciplinary research questions and establish linkages to neighbouring disciplines including ocean, ice, snow, biology, clouds, dynamics, and fundamental chemistry. The links to the BEPSII community are quite clear, and James will act as the go-between to facilitate collaborations which would benefit from members of each community.

MOSAiC: Introductions by Jacqueline Stefels and Jeff Bowman

- Both BEPSII & ECV-Ice terms of reference include helping define core MOSAIC sea-ice sampling program
- BEPSII has potentially useful role as neutral party in development of science program

A preliminary minimum wish list of parameters to be taken during MOSAiC was drafted.
We will write to MOSAiC to ask to provide us with a sampling protocol onto which we will give expert advice.

COST-Action: Introduction by Jacqueline Stefels
JS will ask COST whether we can finance a summer school in Canada.

Automated Observatories and sensors (Klaus Meiners)
A brief overview on automated observatories and emerging sensors was presented. Key to improved understanding of sea-ice processes will be to increase sampling effort both spatially and temporally. There is a number of groups working on this, but currently there seems to be little international co-ordination or efforts to learn from each other. BEPSII could help in this space. We could try to organise a "mini-workshop" or out-break discussion at Polar2018. Klaus will discuss this with German and Australian colleagues.

First annual meeting of the new SCOR WG ECV-ice

Co-chairs of ECV-ice are: Francois Fripiat, Daiki Nomura and Brent Else. The aim of this first meeting was to start the working group, to attribute tasks and leadership, and to elaborate an agenda. Discussions were held in two break-out groups and two plenary sessions. An elaborate report has been prepared and sent to SCOR. A summery of the Task Group activities is provided here.

Design and coordinate intercalibration experiments: Three different intercalibrations were discussed:
1. Primary production and ancillary biogeochemical parameters:
The preferred location is Cambridge Bay, Canada. The location is characterised by relatively low salinity (~28PSU) and only a bottom-ice community. The purpose is to compare various techniques to measure primary production: isotope incubations (^{13}C, ^{14}C), O_2:Ar ratios, P vs I incubations versus in-situ bottles, biomass accumulation, PAM/absorption, under-ice eddy covariance, under-ice microelectrodes. Also ice-treatment methods will be compared: direct melt versus crushed ice versus buffered melt.
2. Gas concentration:
Ice-tank experiments at the RvG-ASIC, Norwich, UK. The purpose is to compare all the techniques available to date to measure gas concentration in sea ice (sampling, processing, storage, analysis): peepers, sackholes, ice crushing, equilibrating method, melting-refreezing method, bulk melt for DIC/TA. The following gases will be tested (N_2O, CH_4, CO_2) but with a special emphasis on pCO_2. Comparisons will be done at two different ice temperatures.
3. Trace metals:
To test the existing methods and devices to sample, process, store, and analyze trace metal concentrations in sea ice. An initial experiment will most likely take place in the Ross Sea during a voyage in austral fall 2017. Duplicate cores will be collected using 3 different coring devices.

Synthetic reviews on methodological discrepancies
1. Discrepancies between eddy covariance and chamber measurements of sea ice-air CO_2 fluxes: Brent & Daiki + Bruno, Lisa, Kristina Brown (data from Michael Fisher?)
2. Air-ocean fluxes with sea ice floating around (Brice)

3. Primary production method discrepancies: CJ for Arctic data; Florian & Francois for Antarctic data + Maria, Mar, Martin. Potentially include model results?
4. At a later stage: review on light transmission through sea ice. (Ehn?)

Outreach:

- Website to be merged with the BEPSII website (Max Thomas).
- To contact Marcello Vichi as the South African representative.
- We discussed also the possibility to collaborate with the Arctic communities to perform simple intercalibration experiments at different time of the year (mainly Cambridge Bay).

Future Planning:

Steering committee changes: none, but ECV-ice representative will rotate.
Elementa special feature: BEPSII is currently finalizing a special feature in the journal Elementa, with 16 excellent papers, some of them already with high citations. A 2nd special issue initialized by the end of 2017
Next meeting: 15-17 June 2018, before POLAR2018.
A 5-year science plan was drafted based on updated goals and task groups and will be finalized and distributed for community input.

Science talks & discussions & Poster presentations

Janne-Markus Rintala - *The phases of wintertime succession in the northern Baltic Sea with emphasis on microalgae in sea ice and water column (Enberg, Majaneva, Autio, Blomster and Rintala)*
This study describes the micro-algal succession during the cold-water season in the Baltic. Samples were obtained weekly from the water column between October 2012 and May 2013 and from the sea ice during the ice-covered season. Our results showed that the biomass in the water column remained low until the end of the ice-covered season and was dominated by small flagellates and dinoflagellates. The biomass increased in the ice and water column during the spring and the community changed from flagellate-dominated to diatom- and dinoflagellate-dominated community. The chlorophyll-a concentration in the ice was higher than in the spring bloom, but microscopic species identification, cell enumerations and conversions to POC revealed that highest biomasses occurred in the spring bloom. Therefore conclusions on biomass that rely solely on chlorophyll-a concentrations may cause overestimations of sea-ice algal biomass. In addition to microscopic observations, 18S rRNA gene was used in the identification of the smaller taxa <20µm. These results showed that the sea-ice algae formed a separate community than the spring community and suggest that sea-ice algae are of limited importance to the spring bloom community.

Daniela König - *Carbon dynamics during the formation of sea ice at different growth rates*
Ice-tank experiments were conducted in a small (1 m^3) tank, where sea ice was grown up to a thickness of 20 cm. Experiments were conducted at -40 °C, -25 °C, and -15 °C, which resulted in average growth rates of ca. 10 cm/d, 3.5 cm/d, and 0.8 cm/d. After each experiment, under ice water and ice was sampled, and its total inorganic carbon (TIC) content determined. This TIC content was then compared to the TIC content of water samples taken before any ice was formed, whereby the difference was ascribed to exchange with air. This meant that if the TIC content of the initial water was higher than the combined TIC content of ice and under ice water, CO_2 must have been released to the air, whereas if the initial content was lower, CO_2 must have been taken up from the air during the ice formation.
This TIC budget approach showed that for faster growth rates, more TIC remains in the ice (ca. 10 % for ice grown at -40 °C), and relatively less gets rejected to the underlying water (ca. 89 %), while for slow growth, the TIC content remaining in ice is smaller (ca. 5 % at -15 °C), and more TIC ends up in the water beneath the ice (ca. 94 %). All experiments showed a release of a small amount of TIC (ca. 1 %) to the air, but as this flux was not measured directly, the associated uncertainty was relatively large, and the numbers for the air fraction were not significant.

CJ Mundy - *Sea ice nutrient measurements: the role of ice algal intracellular nutrients (Mundy, C.J., Tremblay, J.-E., Gosselin, M.)*
Nutrient availability is a main factor influencing maximum production, taxonomic composition, and termination of the spring ice algae bloom in ice-covered seas. However, measuring nutrients available to ice algae is not a straightforward task and a lack of a standard method for sea ice researchers has plagued the field. In particular, the common assumption that as ice core samples melt, nutrients remain conservative, and therefore, their concentrations in ice melt would be a function of salinity. However, positive relationships between nutrient concentrations and algal biomass in ice melt samples led studies dating back to the early 90s to hypothesize that algae maintain an intracellular nutrient pool that is released upon melting an ice core due to osmotic stress. As part of a process-based landfast ice study near Resolute Bay, Nunavut called the Arctic - Ice Covered Ecosystem

(Arctic-ICE) project, we collected a bottom-ice dataset during the 2012 spring ice algal bloom to test this hypothesis. Using chlorophyll *a* concentration (chl) to standardize data, our analysis compares the bulk ice melt method to intracellular measurements from an ice-scrape sample (i.e., little osmotic stress) of nitrate+nitrite, silicic acid and phosphate concentrations. Significant positive relationships of each nutrient (bulk ice) versus chl highlighted non-conservative mixing during core processing. With a focus on nitrogen as the main limiting factor, intracellular concentrations of nitrate+nitrite ranged between 5.5 and 38.1 μmol mg chl^{-1} and varied as a function of snow depth (light access) and bloom period (bloom versus post bloom). Surprisingly, when standardized to bottom-ice chlorophyll *a* concentration, intracellular measurements fell along a 1:1 line with that of bulk ice melt measurements. These results demonstrate that ice algae likely exhibit some form of luxury uptake of nutrients when available in their environment and that intracellular nutrient measurements should be made when possible during ice algal studies. The ability of ice algae to store up a nutrient reserve during the early bloom also highlights a critical biological process that stands to shift our understanding of nutrient dynamics in sea ice.

Ambiguities in CJ's and Francois' measurements led to an extra discussion session the next day on the **Nutrient-chlorophyll paradox**: Active release of nutrients during stress (CJ's hypothesis) or uptake of nutrients in a biofilm (Francois' hypothesis).

Marie Kotovitch - *" Year Round Ocean Sea Ice Atmosphere Exchanges"* ***(YROSIAE)****, Highly productive, yet heterotrophic, and still pumping CO_2 from the atmosphere: a land fast ice paradigm?*
The YROSIAE field campaign took place in Mc Murdo Sound (land fast ice), in Nov 2011 and Dec 2012. Objectives: to look at the exchanges of energy and matter between the atmosphere, the ice and the underlying layer. The emphasis was on gases, but also on main biogeochemical parameters, including micronutrients like iron. The ice in Mc Murdo Sound was quite rich in chlorophyll-a. In particular, we observed a lot of algal filaments underneath the ice. As expected the ice is pretty productive, with Chl-a concentrations 10 to 100 times the water column concentration. What is surprising is that the increase in Chl-a corresponds to a significant increase in nutrients, especially of ammonium but also nitrate. This is **paradoxical**! This suggests that a strong remineralisation occur together with intense nitrification. And this remineralization outweighs the impact of nutrient uptake through primary production. **This raises the question: is the ice autotroph or heterotroph?**
From DIC, pCO2 and air-ice CO2 fluxes with automatic chambers we concluded that:
- The bottom of the ice is highly productive. It shows an intense remineralisation with nitrate, phosphate, ammonium accumulation – the land fast ice paradigm. On the whole, the bottom of the ice appears to be **autotrophic** (decrease of DICnorm).
- In the upper part of the ice, respiration is the main process, and the ice appears to be mainly **heterotrophic**. However, this does not prevent the decrease of pCO_2 and a shift from a source to a sink for atmospheric CO_2."

Eric Mortenson - Modeling carbon exchange in the seasonally ice-covered marine Arctic
Neglecting ice algae in the model results in higher ocean-uptake of pCO2 due to the fact that more nutrients are left for the pelagic bloom.

Delphine Lannuzel - *High and temperature-dependant iron uptake by Antarctic sea-ice algae: results from in situ and temperature controlled short-term radiotracer incubations.*
Despite the recognition that iron (Fe) released from melting sea ice may regulate marine productivity in ice-covered polar waters, the direct links between sea-ice Fe concentrations and Fe uptake by sea-ice algae are currently unknown. Radioactive Fe (^{55}Fe) and carbon (^{14}C) short-term uptake measurements were performed in parallel on natural samples of sea ice, under-ice seawater and slush collected during a spring-summer time series in Antarctic pack ice. Pennate diatoms dominated in bottom sea ice and *Phaeocystis* were the most abundant in seawater. Both intracellular (Fe_{intra}) and total Fe (Fe_{tot}) contents were measured. The Fe_{intra} uptake represented between 1 and 7% of the uptake of Fe_{tot} in sea ice, 8% in seawater and 1% in slush. Most of the Fe was therefore adsorbed on the outside of the sea-ice algal cells. The Fe_{intra} uptake rate reached 68 pmol Fe L^{-1} d^{-1} in under-ice seawater and was between 6 and 194 pmol Fe L^{-1} d^{-1} in bottom sea ice. Large algae (> 10 μm) were the main contributor to ^{55}Fe uptake in bottom sea ice (73 ± 24%, n = 4). Results clearly indicate that although the *in situ* dissolved Fe (DFe) concentrations decreased, the intracellular uptake of ^{55}Fe in bottom sea ice increased exponentially during the time series. We found a positive and significant correlation between sea-ice temperature and Fe_{intra} uptake rate by sea-ice algae; however, the decrease in DFe concentration in sea ice cannot be fully explained by the biology and is more likely the result of DFe drainage due to warming sea ice. *In situ* carbon assimilation in bottom sea ice was low, ranging between 0.03 and 3.2 μmol C L^{-1} d^{-1}. Apart from one outlier, the cellular Fe_{intra}:C ratios in bottom sea ice also increased with time, from 5.8 to 230 μmol Fe mol C^{-1} over a 26 days period, and were above the ranges reported for other Fe-fertilized areas of the Southern Ocean, potentially illustrating luxury Fe uptake in this ephemerally Fe-rich environment.

Poster presentations:
Ana M. Aguilar-Islas: Distribution of trace metals in the Arctic sea ice environment during summer 2015
Melissa Chierici: Winter-to-spring evolution of Arctic Ocean acidification state in under-ice water and effect of sea-ice processes during N-ICE 2015 ice drift project
Florian Deman: Nitrate isotopic composition in landfast sea ice: a time series study
Jens Ehn: Spectral light transmission through landfast sea ice during the melt season in southern Baffin Bay
Brent Else: Oxygen, salt, and heat exchange measured at the ice-ocean interface during the ice algae bloom period
Agneta Fransson: Late winter-to-summer change in ocean acidification state in Kongsfjorden, with implications for calcifying organisms
Hakase Hayashida (presented by N Steiner) Simulated impacts of ice algae on marine ecosystems and sulfur cycling in the Arctic.
Marion Lebrun: Future Arctic sea ice seasonality: drivers and impacts on light supply
Ollie Legge: The seasonal cycle of carbonate system processes in Ryder Bay, West Antarctic Peninsula
Klaus Meiners: Antarctic pack-ice algae mapped with a Remotely Operated Vehicle: identification of physical drivers at the floe scale
Lisa Miller: "That's Not What It Was Designed For": Breaking CO2 System Sensors in Polar Waters
Daiki Nomura: CO2 release over younger and thinner Arctic sea ice -
Bonnie Raffel: Quantifying the extinction coefficient of thin sea ice through in-situ measurements
Max Thomas: Two modes of pressure build up in young sea ice
Letizia Tedesco: Anticipated sea-ice phenology in a warmer Arctic
Maria van Leeuwe (presented by J. Stefels): Micro-algal biodiversity and primary production in sea ice: A synthesis.

A ***5 year science plan*** is currently being finalized and focuses on tasks around the **revised objectives**

- Develop dedicated consistent methodologies for sea ice biogeochemical research
- Establish effective sea-ice biogeochemical data archiving approaches and databases
- Foster process studies to determine impact on ecology and biogeochemical cycles.
- Foster technological developments and international knowledge transfer towards large-scale, autonomous and high-frequency sampling of sea ice biogeochemical parameters.
- Improve the representation and evaluation of sea ice biogeochemistry in regional and Earth System numerical models.
- Synthesize and integrate observational and modeling efforts.
- Continually revise and renew scientific foci, teams, and objectives.
- Develop conceptual models describing sea-ice interactions in or with the Earth System.

BEPSII website: https://sites.google.com/site/bepsiiwg140/home
BEPSII Twitter profile: @BEPSII_seaice
BEPSII Facebook page: https://www.facebook.com/SCOR.BEPSII/
BEPSII Elementa special feature website: https://home.elementascience.org/special- features/biogeochemical-exchange-processes-at-sea-ice-interfaces-bepsii/