7. BIOGEOCHEMISTRY (BGC)

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A comprehensive summary of the bio-geochemical measurements during all 5 cruise legs will be published in the *Special Feature: The Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC)* of the scientific journal *Elementa: Science of the Anthropocene* (https://online.ucpress.edu/elementa/collection/269/Special-Feature-The-Multidisciplinary-Drifting)

Background and objectives

In a changing Arctic scenario, the study of climate relevant trace gas (CRTG) fluxes is essential for the improvement of future climate models. Coupling of ice and snow dynamics and the biogeochemical processes that occur during sea-ice freezing and melt cycles trigger transformations of organic matter and elements that control the cycling of CRTG (such as methane (CH_4), Nitrous oxide (N_2O), and dimethyl sulfide (DMS)) across the ocean-ice-atmosphere interface. This results in CRTG exchange with both the overlying atmospheric boundary layer and the underlying ocean down to the deep layers. Therefore, the aim for the Leg 5 BGC team was to study the spatial and temporal variability of CRTG concentration and fluxes in the melt pond, lead, sea ice, and seawater during the transition from melting and freezing phase in the Central Arctic Ocean (CAO) and ice edge region during the way to the North pole and Bremerhaven.

Work at Polarstern for CTD Rosette, contentious underway water and atmospheric measurement

We have collected seawater and air samples for investigating the following parameters (Table 7.1):

- CH_4/N_2O/CO concentrations (Y. Li) + $^{13}CH_4$ isotopic ratios
- DMS, DMSP and DMSO
- Pigments – HPLC
- Neodymium
- $\delta^{18}O$
- Dallosto's chamber experiment
- Underway water N_2O/CO contentious measurement (air also)
- Air $^{13}CH_4$ contentious measurement

Tab. 7.1: Seawater sampling events from Polarstern CTD Rosette, with sampled parameters (DIC/TA, nutrients, Chl. a etc with ECO team).

Date	DSHIP. no	$\delta^{18}O$	$CH_4/N_2O/CO$	DMS/DMSP	HPLC	$^{13}CH_4$	Nd	Aerosol chamber
17/08/2020	PS122/5_59-62	X	X	X	X			
18/08/2020	PS122/5_59-72	X	X	X	X	X		
19/08/2020	PS122/5_59-149	X	X	X	X			
26/08/2020	PS122_5_59-274		X	X	X			
27/08/2020	PS122_5_59-306		X					
29/08/2020	PS122_5_59-357		X			X		
01/09/2020	PSS122/5_60-280			X	X			
03/09/2020	PS122_5_60-69		X	X	X			
07/09/2020	PS122/5_61-271			X	X			
11/09/2020	PS122_5_61-161		X	X	X			
12/09/2020	PS122_5_61-189	X	X					X
13/09/2020	PS122_5_61-211		X					
15/09/2020	PS122_5_62-38	X	X			X	X	
17/09/2020	PS122_5_62-88		X					
24/09/2020	PS122/5_63-35	X	X			X		X
25/09/2020	PS122/5_63-53	X	X	X	X	X		X
26/09/2020	PS122/5_63-85							
27/09/2020	PS122/5_63-100	X	X			X		X
28/09/2020	PS122/5_63-111	X	X			X		X

Work on sea ice for ice sampling

Figure 7 indicates the map of our sampling station.

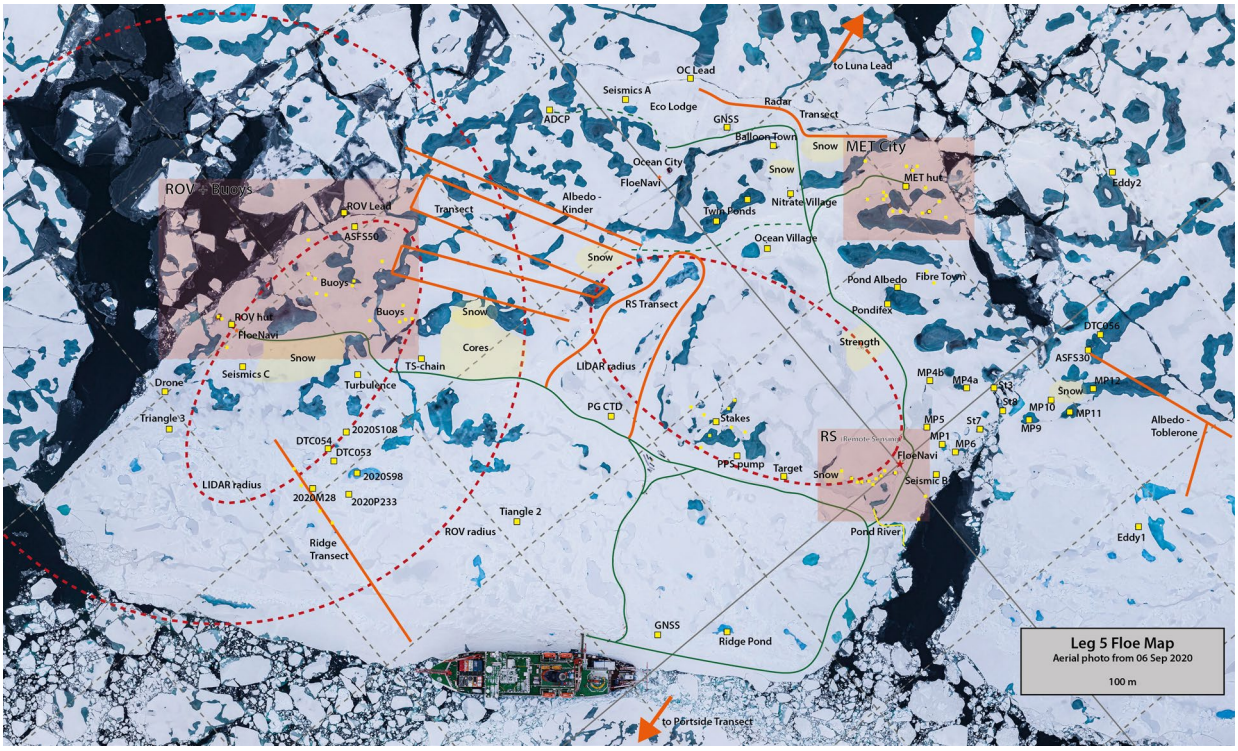

Figure 7. Map of our sampling station (this map was made by M. Nicolaus). See mainly right side of this figure near remote sensing site. MP means melt pond. Sts. 3 and 8 were originally crack site. However, crack become lead at 24 August.

We have collected sea ice (core and block) for the following parameters (Table 7.2):

- CH_4/N_2O concentrations (B. Delille) + $^{13}CH_4$ isotopic ratios (2 cores in freezer)
- DMS, DMSP and DMSO
- Pigments – HPLC
- Neodymium (10 cores in freezer)
- $\delta^{18}O$
- Dallosto's chamber experiment
-

Tab. 7.2: Ice cores and ice block samples at ice coring site, melt pond, and lead sites with sampled parameters (DIC/TA, nutrients, Chl.a etc with ECO team) (Ice density, thick and thin section, and CT with ICE team)

Date	Location	DSHIP n.	$\delta^{18}O$	CH_4/N_2O	DMS/DMSP/DMSO	DNA Sequencing	$^{13}CH_4$	Aerosol chamber	Comment
22/08/2020	St. MP1	PS122/5_59-433	X	X	X	X			ice block
22/08/2020	St. MP2	PS122/5_59-434	X	X	X	X			ice block

22/08/2020	St. 3	PS122/5_59-435	X	X	X	X			ice block
22/08/2020	St. MP4a	PS122/5_59-436	X	X	X	X		X	ice block
22/08/2020	St. MP5	PS122/5_59-437	X	X	X	X			ice block
22/08/2020	St. MP6	PS122/5_59-438	X	X	X	X			ice block
22/08/2020	St. MP7	PS122/5_59-439	X	X	X	X			ice block
22/08/2020	St. MP9	PS122/5_59-440	X	X	X	X			ice block
22/08/2020	St. MP10	PS122/5_59-441	X	X	X	X			ice block
22/08/2020	St. MP11	PS122/5_59-442	X	X	X	X			ice block
22/08/2020	St. MP12	PS122/5_59-443	X	X	X	X			ice block
28/08/2020	St. MP1	PS122/5_59-445	X	X	X	X			ice block
28/08/2020	St. MP4a	PS122/5_59-444	X	X	X	X			ice block
29/08/2020	St. 3	PS122/5_59-446	X	X	X	X			ice block
29/08/2020	St. OC lead	PS122/5_59-447	X	X	X	X			ice block
31/08/2020	St. Ice coring site	PS122/5_60-16	X	X	X		X		ice core
06/09/2020	St. Luna lead	PS122/5_60-205			X	X			ice block
07/09/2020	St. Ice coring site	PS122/5_61-6	X	X	X		X		ice core
12/09/2020	St. OC lead	PS122/5-61-262			X	X			ice block
12/09/2020	St. MP4b	PS122/5_61-206	X	X	X	X			Ice core
14/09/2029	St. MP4a	PS122/5_62-35	X	X					Ice core
15/09/2029	St. 8	PS122/5_62-42	X	X	X	X			ice block
18/09/2020	St. MP1	PS122/5_62-120	X	X					Ice core
18/09/2029	St. OC lead	PS122/5_62-138			X	X			ice block
26/09/2029	Puffy Lead, MIZ Station 2	PS122/5_63-83			X				ice block

Work on sea ice for melt pond and lead water sampling

We have collected freshwater and seawater samples in the melt pond and lead for the following parameters (Table 7.3):

- CH_4/N_2O/CO concentration (Y. Li)
- DMS(P)
- Pigments – HPLC
- $\delta^{18}O$
- Dallosto's chamber experiment

Tab. 7.3: Freshwater and seawater sampling events from melt pond and lead with sampled parameters (DIC/TA, nutrients, Chl.a etc with ECO team)

Date	Location	DSHIP n.	$\delta^{18}O$	CH_4/N_2O/CO	DMS/DMSP	HPLC	Aerosol chamber

22/08/2020	St. MP1	PS122/5_59-200	X	X	X	X	
22/08/2020	St. MP2	PS122/5_59-202	X	X	X	X	
22/08/2020	St. 3	PS122/5_59-203	X	X	X	X	
22/08/2020	St. MP4a	PS122/5_59-207	X	X	X	X	
22/08/2020	St. MP5	PS122/5_59-208	X	X	X	X	
22/08/2020	St. MP6	PS122/5_59-209	X	X	X	X	
22/08/2020	St. MP7	PS122/5_59-210	X	X	X	X	
22/08/2020	St. MP8	PS122/5_59-211	X	X	X	X	
22/08/2020	St. MP9	PS122/5_59-212	X	X	X	X	
22/08/2020	St. MP10	PS122/5_59-213	X	X	X	X	
22/08/2020	St. MP11	PS122/5_59-214	X	X	X	X	
22/08/2020	St. MP12	PS122/5_59-215	X	X	X	X	
25/08/2020	St. 8	PS122/5_59-290	X	X	X	X	X
28/08/2020	St. MP1	PS122/5_59-343	X	X	X	X	X
28/08/2020	St. MP4a	PS122/5_59-344	X	X	X	X	X
29/08/2020	St. OC lead	PS122/5_59-389	X	X	X	X	
29/08/2020	St. 3	PS122/5_59-392	X	X	X	X	
31/08/2020	St. MP near coring site	PS122/5_60-16	X	X			
01/09/2020	St. MP4a	PS122/5_60-23			X	X	X
01/09/2020	St. 3	PS122/5_60-22			X	X	
02/09/2020	St. ROV lead	PS122/5_60-133	X	X	X	X	
02/09/2020	St. MP4a	PS122/5_60-61	X	X	X	X	X
04/09/2020	St. ROV lead	PS122/5_60-130	X	X	X	X	
05/09/2020	St. ROV lead	PS122/5_60-146	X	X			
06/09/2020	St. Luna lead	PS122/5_60-202			X	X	
07/09/2020	St. OC lead	PS122/5_61-273			X	X	

08/09/2020	St. OC lead	PS122/5_61-272			X	X	
09/09/2020	St. Pond river 1-12	PS122/5_61-126	X	X			
12/09/2020	St. MP4b	PS122/5_61-205	X	X	X	X	
14/09/2020	St. near PS lead	PS122/5_62-92			X	X	
14/09/2020	St. MP4a	PS122/5_62-33	X	X	X	X	X
15/09/2020	St. 8	PS122/5_62-40	X	X	X	X	X
17/09/2020	St. MP1	PS122/5_62-117	X	X	X	X	X
18/09/2020	St. OC lead	PS122/5_62-137			X	X	

Work on sea ice for gas flux chambers between sea ice and atmosphere

The automatic CO_2/CH_4 gas flux chamber and metal chamber were deployed at multiple sites including the inside of the melt pond and lead by using float (Table 7.4).

Tab. 7.4: The automatic CO_2/CH_4 gas flux chamber and metal chamber activities (inter-comparison and multiple measurements with ATOM team).

Date Collected	Location	Chamber/comment	DSHIP n. related
31/08/2020	Ice coring site and near melt pond	Automatic chamber	PS122/5_60-17
01/09/2020	Near St. MP4a	Metal chamber	PS122/5_60-260
02/09/2020	St. MP4a	Metal chamber	PS122/5_60-61
05/09/2020	St. ROV lead	Metal chamber	PS122/5_60-146
07/09/2020	Ice coring site and near melt pond	Automatic chamber	PS122/5_61-6
09/09/2020	Met city site	Automatic chamber	PS122/5_61-131
24/09/2020	Near PS	Automatic chamber	PS122/5_63-324

7.1 MELT POND AND LEAD OBSERVATION

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7.1.1 Objectives

To understand variations in biogeochemical properties such as DMS, N_2O, CH_4, DIC/TA (CO_2) and nutrients in melt ponds and lead water during the open water and freezing period, and to study the interactions with the atmosphere and ecological parameters. To this end, we have examined the melt pond and lead surveys performed during Leg 5. This work was collaboration with Team ECO, ATMO, ICE and OCEAN (details were shown in the cross cutting section).

7.1.2 Ice and water sampling at melt pond and lead

On initial arrival at the Leg 5 floe, a survey was undertaken of 12 melt ponds, selected for different size and optical parameters (see Figure 7). Following breakup of the floe immediately following the survey, several of the melt ponds were now inaccessible, and 2 of the melt ponds had been destroyed by the crack opening (24 August 2020) directly through them. The decision was made to focus specifically on 2 melt ponds: Sts. MP1 and 4. Sts. 3 and 8 were continually sampled as part of the lead sampling project (Figure 7.1.2).

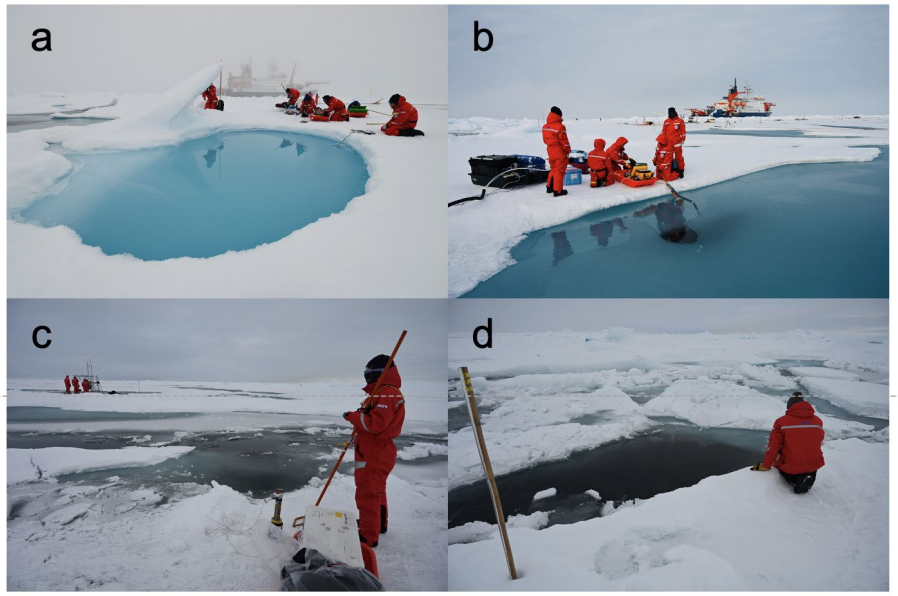

Figure 7.1.2. Pictures of Sts. MP1 (a) (22 Aug.2020), MP4 (b) (2 Sep. 2020), 3 (c) (4 Sep.2020), and 8 (d) (4 Sep.2020).

We collected surface ice blocks/cores from the melt ponds and leads by the saw/ice corer on multiple occasions across the duration of Leg 5 (Table 7.2). Ice samples were melted in gas-tight bags at +4°C in the dark for gas parameters such as DMS, N_2O, CH_4, DIC/TA etc. Simultaneous to ice collection, water from melt ponds and leads was collected using the peristatic pump (Master flex E/S portable sampler) from the surface 0.1 m down to 2 m (generally, 3‑4 layers) and subsampled into gas-tight bottles for each parameter (Table 7.3). By using the portable CTD (ASTD103, JFE Rinko profiler), temperature, salinity, and dissolved oxygen (DO) concentration were measured within the melt ponds and leads. In addition, CO_2 equilibrated air-in-water was measured in-situ with the CO_2 analyzer (LI8100A, LI-COR).

7.1.3 Gas flux measurements within the melt pond and lead

Air–ice CO_2/CH_4 fluxes were measured with the automatic open-closed chamber system (Table 7.4 and Figure 7.5). This system consists in one CO_2 analyzer (LI-8100A, LI-COR, USA), one CO_2/CH_4 analyzer (915-0011, Los Gatos Research, USA), one long-term chamber (LI8100-104, LI-COR, USA), one battery, air tubes and cables etc. We also determined N_2O/CO/DMS fluxes from the sea-ice surface to the atmosphere by using an airtight, Teflon-coated metal chamber (0.50 m in diameter and 0.30 m high with a serrated bottom edge) (Nomura et al., 2012). Every 5 or 10 minutes during an experiment, about 500 mL of air in the chamber was collected using a 50 mL glass syringe with a three-way valve and then transferred to a 3000 mL Tedlar bag. Then, gases (CO_2/CH_4/N_2O/CO/DMS) concentrations were measured by the analyser used for the underway/atmospheric continuous measurement on board. Gases fluxes were calculated by the variation of gases concentration within chamber.

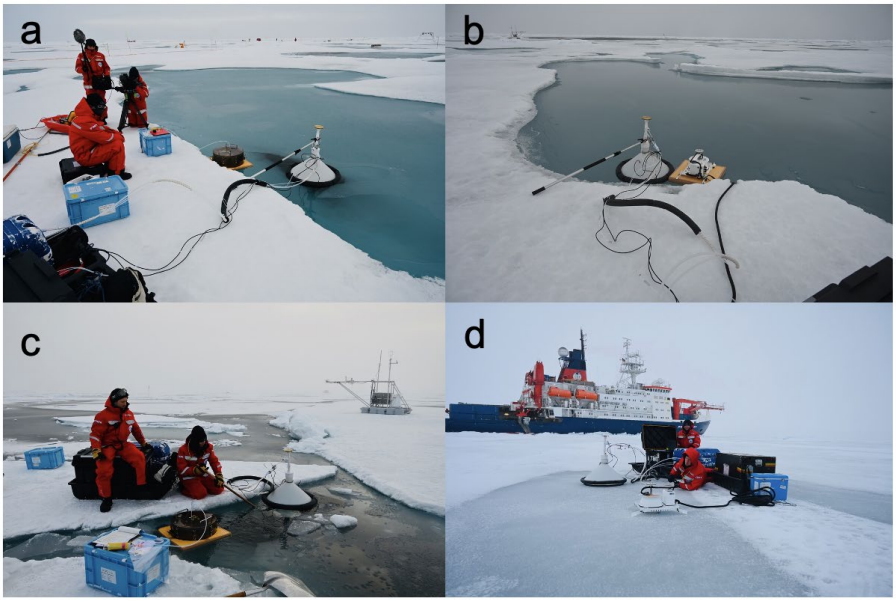

Figure 7.5. Pictures of gas flux chamber measurements in MP4a (a) (2 Sep.2020), near ice coring site (b) (31 Aug. 2020), St. ROV lead (c) (5 Sep. 2020), and near PS (d) (24 Sep. 2020).

7.2. SIMBRICS: Sea Ice Microbiology and the Role in Cycling of Sulphur

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Objectives

Dimethylsulphoniopropionate (DMSP) is an organic osmolyte, cryoprotectant and anti-oxidant (Stefels et al 2000) produced by globally by many groups of marine phytoplankton and particular groups of marine bacteria as a significant source of biogenic sulphur in surface ocean waters. In the polar regions, DMSP is of particular relevance to protect cells from freezing, particularly during the polar winters, and is produced within cells during the freeze-up period and released into the water column during melt. DMSP is an important part of the marine organic sulphur cycle, which also includes the smaller compounds dimethylsulphide (DMS), methanethiol (MT) and the oxidation product DMSO, the concentrations of which are governed by processes within individual cells and within the overall microbial community. In addition, DMS is the primary route for the transport of Sulphur from the ocean to the atmosphere, and previous studies in the Antarctic marginal ice zone have found fluxes of DMS over 900 µmol m^{-2} d^{-1}, associated with release during sea ice melt (Webb et al 2019). Particular emphasis has always been placed on the concentrations of these compounds during the melting period, but less information is available for the freeze-up period.

This study aims to investigate the concentrations of DMS, DMSP and DMSO during the freeze period in different environments in the Arctic sea ice zone. These areas include the sea ice itself, meltpond and lead water, meltpond and lead new ice formation, immediate under ice water, platelet ice and in the deeper water column underlying the ice. To study the turnover of these different compounds, samples of ice and water will be incubated with stable isotope addition to determine carbon uptake, production and loss of the different sulphur compounds. Concentrations and turnover will be studied alongside biological parameters of algal activity, including algal community composition using photosynthetically active pigment concentrations (HPLC) and photophysiology using PhytoPAM, and melt-water will be sent for filtration and subsequent metagenomics sequencing for the bacterial and algal populations to directly relate the availability of sulphur cycling genes with concentrations of these compounds.

DMSP-related parameters will always be collected in partnership with additional BGC parameters of CO_2, CH_4, N_2O and DO (see Section 7.0) and ECO parameters of Chlorophyll-a, nutrients, flow cytometry and DNA (See Section XX). Water and ice DMS concentrations will be related to DMS fluxes and atmospheric DMS concentrations collected by ATMO (See Section XX)

Work at Sea

MOSAIC Leg 5 was different from the other legs of MOSAIC in the original MOSAIC floe has broken up at the end of leg 4, necessitating the identification of further ice sites. To this end, Polarstern headed north once more, crossing the North Pole and identifying a floe at 88N and 140E. This new floe consisted of a strong ridge of FYI several metres thick, with a large area of flat ice covered with extensive meltponds. Due to the arrival of Polarstern at the 22nd August 2020, the floe was in a transition from summer to autumn, with meltponds still liquid but showing signs of freezing. A strong freshwater lens was present on all exposed water surfaces, meltponds and leads, which changed throughout the duration of leg 5, until a strong wind mixing event was able to break up the stratification. The floe was significantly smaller than the original MOSAIC floes, and therefore ‘real estate’ for sampling was limited.

On the return journey to Bremerhaven, a number of ice and water stations were located in the marginal ice zone, where some ice and water were collected to compare to that further north.

DMS/P/O core samples were collected from the Polarstern CTD on a weekly basis, focused on profiling the surface water down to 100m. In addition, samples were taken from gas-tight melt of 2 ice cores during the weekly ice coring activity.

Due to the change in floe, less emphasis was placed on following the MOSAIC core program, and therefore much more flexibility was available for cross cutting activities and emphasis on experimental work. These projects have been collated in separate sections, and the relevant DMS work has been highlighted here. This included:

1. Meltpond survey (depth profiles, BGC and ECO discrete sampling) and extended duration study of two different meltponds during the freeze up period (Section)
2. Lead survey of available open water surrounding the floe to study the freshwater lens and the production immediately beneath this stratified layer (depth profiles, ECO, BGC and ATMO discrete sampling) (Section)
3. 14 ice melt experiments using stable isotopes as tracers for the turnover of DMSP and uptake of C^{13} HCO_3 during the repeated freeze/ melting cycles observed at the floe during this season
4. 2 water incubation experiments to study the effect of light on the phytoplankton community.

Sampling consisted of gas tight water samples analysed for DMS, DMSP (total and dissolved) and DMSO by PTRMS, large volume water samples collected for filtering for algal pigment composition (HPLC) and small volume water samples collected for analysis of algal community photophysiology (PhytoPAM). DMS samples from meltponds and leads were analysed by PTRMS within 12 hours of collection, with further samples treated with NaOH for DMSP (total and dissolved), and DMSO (total), which were analysed after 2-3 days for conversion to DMS. DMSP samples were analysed until the 11th September, after which samples were frozen for analysis back at home due to time constraints. DMSO samples were all analysed on board.

Meltpond Sampling (See section 7.1)

Team BGC started with a survey of 12 meltponds in the area of the new CO, sampling the sea ice and surface water from each pond for trace gases and ECO parameters. Due to a breakup of the floe early in the leg, over half the meltponds were subsequently inaccessible, so the decision was made to focus on Meltponds 1 and 4. Meltpond 1 was shallow, solid bottomed and isolated from surrounding ponds, with a maximum depth of 30cm. Meltpond 4 was deeper, connected to other meltponds and the surrounding seawater, as evidenced by presence of a jellyfish in the pond during one sampling event. This meltpond had a false bottom at around 40cm, with a maximum depth of 100cm, to a bottom which had obvious biological activity due to the dark colour within the ice.

Profile sampling took place over several weeks, including a simulated mixing event to attempt to break up the stratification and measure the release of gases trapped beneath the surface lens. Gas samples were collected for CO_2, N_2O and CH_4, along with measurements of DIC and ECO parameters (Chlorophyll a, nutrients, flow cytometry and DNA sequencing as a minimum, see SECTION). Eventually the meltponds were sampled destructively, with both surface and bottom ice sampled using Kovacs ice corers through to the underlying water column. Ice from beneath and alongside the meltponds was also studied by the ice physics team to give an overview of the structure.

Gas tight DMSP samples were collected at the same time as other BGC and ECO parameters for direct comparison, using the peristaltic pump from three water depths in Meltpond 4: surface, mid-layer (dependent on salinity profiles, immediately below the

halocline), and bottom; and from 2 depths in Meltpond 1: surface and bottom. Due to concerns over removal of excess water from a limited source, HPLC samples of multiple litres were taken from mid-depth only using the hand pump. Where ECO team were not present, water samples were collected for them for minimal ECO parameter analysis.

Table 1. Summary of activities for the meltpond survey

Sampling Date	**ActionLog ID**	**Site**	**Activity**	**Cross cutting activities (See section)**
22/8/20	multiple	Meltponds 1-12	Meltpond survey	
23/8/20	multiple	Meltponds 1-12	Meltpond Survey (CTD only)	
28/8/20	PS122/5_59-343	Meltpond 4	water, ice and gas sampling	
28/8/20	PS122/5_59-344	Meltpond 1	water, ice and gas sampling. Installation of T thermistor	
1/9/20	PS122/5_60-23	Meltpond 4	DMSP time-series measurement	
2/9/20	PS122/5_60-60	Meltpond 4a	Simulated mixing event before/ after	
12/9/20	PS122/5_61-205	Meltpond 4b	Destructive sampling, water surface and bottom ice sampling	
17/9/20	PS122/5_62-117	Meltpond 1	Destructive sampling, water sampling	

Lead Sampling (See Section XXX)

Team ECO, assisted by team BGC, undertook to survey the leads opening around the floe and to investigate the relationship between the freshwater lens and the underlying high salinity waters which showed evidence of high secondary production. This was of particular interest for the SIMBRICS DMS project, due to the potential bacterial driven turnover of the various Sulphur compounds alongside extremely low primary productivity. As this was an ECO driven activity, samples were taken at the same time for DNA sequencing by Emelia Chamberlain at the Bowman lab; community analysis will be used to identify specific S-compound processing species. In addition, all ECO parameters (e.g. Chlorophyll-a, nutrients, flow cytometry, microscopy, bacterial-and-primary productivity) were taken at the same time for direct comparison with S-compounds.

Table 2. Summary of Lead sampling activities during leg 5.

Sampling Date	ActionLog ID	Site	Activity	Cross cutting activities (See Secion)
25/8/20	PS122/5_59-290	Seismic Lead, Station 8 (was meltpond 8)	New lead opening, was only a crack the previous day	
29/8/20	PS122/5_59-392	Seismic Lead St 3	BGC sampling	
29/8/20	PS122/5_59-389	Ocean City Lead		ECO sampling
1/9/20	PS122/5_60-22	Seismic Lead St 3	Sampled at the same time as Meltpond 4	
2/9/20	PS122/5_60-133	ROV Lead		ECO sampling
4/9/20	PS122/5_60-130	ROV Lead	Sampled prior to Lead mixing experiment (not undertaken for DMS)	
6/9/20	PS122/5_60-202	Luna Lead	New sea ice formation at Luna Lead	ECO sampling
7/9/20	PS122/5_61-273	Ocean City Lead	Well mixed due to wind event	ECO sampling
8/9/20	PS122/5_61-272	Ocean City Lead	Sampling interrupted due to a bear arrival	
12/9/20	PS122/5-61-278	Ocean City Lead		ECO sampling
14/9/20	PS122/5_62-92	Big Lead		Sampled by ATMOS to tie in with chamber measurements
15/9/20	PS122/5_62-40	Seismic Lead St 8		
18/9/20	PS122/5_62-137	Ocean City Lead		ECO sampling

Ice Incubation Experiments

During the period at the floe, meltponds and leads showed ongoing changes between melting and refreezing, with the freezing periods gradually increasing. Initially, prior to the wind driven mixing event, surface freezing was of the freshwater lens, with salinity of the surface ice gradually increasing throughout the period. To try and determine the changes which were taking place during the melting periods, ice samples were collected from multiple lead and meltpond sources and melted in NaCl water of salinity equivalent to the underlying water column salinity, and the addition of stable isotopes. Melt took place in the light in triplicate, and where additional ice was available, triplicate ice samples were melted in the dark, at a constant temperature of 0.7 – 1 °C. Bags were mixed daily and moved around within the culture cabinet.

On completion of melt of all replicate samples, a 70ml sample of water is removed for immediate analysis: from this sample, 10ml is removed for total DMSP + DMS, and 2 samples removed for immediate analysis for DMS by PTRMS. Following analysis, one sample was fixed for DMSPd and the other for DMSO, which were analysed later in the leg. The remaining water was filtered for particulate DMSP, POC and DNA sequencing (in

collaboration with Emelia Chamberlain and Jeff Bowman). All community analysis by DNA sequence data will be compared to in situ concentrations of standing stocks of DMS, DMSP and DMSO, and additional PCR will be carried out to specifically target S-related genes present within the community and associate S-compound turnover rates.

Table 3. Ice incubation experiments performed during Leg 5.

Experiment Number	Ice Sampling Date	ActionLog ID	Site	Activity
1	26/8/20	PS122/5_59-(433-441)	MP 1-10	Meltpond survey surface Ice
2	28/8/20	PS122/5_59-(444 and 445)	Meltpond 1 Meltpond 4	Time series ice melt for the studied meltponds
3	28/8/20	PS122/5_59-(446 and 447)	Seismic Lead St.3 Ocean City Lead	Newly formed surface ice from Leads
4	6/9/20	PS122/5_60-205	Luna Lead	Newly formed Sea ice
6	8/9/20	PS122/5_61-6	Ice Coring Site	Bottom ice sections from 160cm FYI cores
7	12/9/20	PS122/5-61-262	Ocean City Lead	New ice formation following wind-driven mixing event.
8	12/9/20	PS122/5_61-206	Meltpond 4b	Surface ice sampling during destructive meltpond sampling.
9	12/9/20	PS122/5_61-206	Meltpond 4b bottom ice	Bottom ice from the meltpond during destructive sampling
10	15/9/20	PS122/5_62-42	Seismic Lead St.8	Ice sampling from lead surface during freeze up
11	18/9/20	PS122/5_62-138	Ocean City Lead	Ice sampling from OC lead during freeze up period
12	26/9/20	PS122/5_63-83	Puffy Lead, Ice Station 2	Slush ice on surface of Marginal Ice zone lead at 82N, 70E
14	26/9/20	PS122/5_63-83	Puffy Lead, Ice Station 2	Sheet ice on surface of Marginal Ice zone lead at 82N, 70E

Under Ice incubation Experiments

Two opportunities arose to collect under ice algae. One sample (Experiment 5; PS122/5_61-271) was collected in the slush of an ice hole during the weekly coring event, and the other (Experiment 13; PS122/5_63-85) was removed using an ice saw from the edge of a lead at the second marginal ice zone station (82.07°N, 70.42°E). Due to the extreme homogeneous distribution of these algae, no other samples were collected during the leg. Both samples were incubated in NaCl solution equivalent to the under ice water salinity, and spiked with stable isotopes. Due to the extreme activity of these samples, as well as the usual DMS, DMSP and DMSO samples, sufficient volume was available to take particulate DMSP, POC and HPLC filters for analysis back home, as well as to filter for DNA sequencing by Emelia Chamberlain. In addition, these samples were the only samples (aside from the meltpond bottom ice) taken during the entire leg which gave a strong significant signal on the PhytoPAM, indicating healthy photosynthetic activity.

Water Incubation Experiments

Water was collected only once during this leg for incubation; plans for a second water collection were halted by a polar bear visit during the last days at the floe. Water was collected in bulk using the hand pump from Seismic lead Station 3 at 2m depth (below the level of the sea ice), and split into two sub-samples. Water from the first was incubated with D_3-DMSP and $NaH^{13}CO_3$ for 24 hours at six different light intensities, before being sampled for DMS/P and POC and analysed using the PAM. The second water sample was inoculated with vitamin B12 and nutrients, and were incubated at low light intensity for 7-9 days, before being further inoculated with D_3-DMSP and $NaH^{13}CO_3$ and incubated a further 24 hours at a single light intensity. This experiment was then processed as per the first 24hr incubation, with water sampled gas-tight for DMS/P, followed by filtration for DNA sequencing by Emelia Chamberlain.

DMS Flux (See Section)

The team ATMOS flux chamber was regularly deployed on new surface ice and on water surfaces to measure the flux of DMS from the water surface. Sampling for water column DMS in the surface 10cm was performed alongside this deployment wherever possible, or samples collected by the ATMOS team and returned to the lab for water DMS analysis.

Initial results

Sub samples were taken from the HPLC bulk water collection for analysis on PhytoPAM to analyse photosynthetic health of the phytoplankton community. On every occasion, the gains on the PhytoPAM were over 14 for both in and out gain, and therefore indicative that the signal was no different to the background from filtered seawater. The only significant PAM signals occurred during the two under ice algal incubation experiments, where the gains were below 7. At all other times, the signal was indistinguishable from background.

No preliminary data is available for HPLC analysis, however it was clear from the lack of colour following the filtration of large volumes of seawater that phytoplankton abundance was low.

Initial results showed low but detectable concentrations of DMS in the surface water column down to 50m, whereby the concentrations were below the detection limit of the instrument. CTD results, backed up by DMS and DMSP concentrations, showed the surface 15m mixed by ship movement and therefore uniform in concentration.

Meltponds

Initial results of DMSP and DMS show lower concentrations at the 10cm samples, increasing significantly below the freshwater lens layer, the same as seen in the leads. DMSO shows the opposite trend, with concentrations higher closest to the surface. All data need fully integrating and further processing.

Leads

Initial results of DMSP and DMS show lower concentrations at the 10cm samples, increasing significantly below the freshwater lens layer, the same as seen in the meltponds. DMSO shows

the opposite trend, with concentrations higher closest to the surface. All data need fully integrating and further processing.

Ice and water incubation experiments

No initial results are available for the ice or water incubation experiments, and need integrating and analysing. Samples for DNA analysis need extracting and sequencing for community composition.

7.5.4 Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All device operations were logged in the AWI sensorweb portal and all sensor raw data files are stored in platform section of MCS. Data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de.

7.3 UNDERWAY CONTINUOUS OUTSIDE AIR METHANE ANALYSIS

Daiki Nomura[1], Falk Pätzold[2](not on board), Ellen Damm[3] (not on board), A. Lampert[1] (not on board)

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7.3.1 Objectives

A Picarro G2132-i methane concentration and $\delta^{13}CH_4$ isotopy analyzer – used for samples obtained from water and ice samples during leg 1 to 3 – was connected to an outside air intake to acquire these data along the ship track from leg 4. This measurement was continued to leg 5.

7.3.2 Work at sea

The methane concentration and δC^{13} methane isotopy analyzer Picarro G2132-i (sensorweb: Pic2132ed) was running throughout leg 4. As this device was also used to analyze air samples obtained with (airborne) air extracting systems, the time series is irregularly interrupted. A calibration using two secondary standards was done.

The air intake on P-deck at 21 m above sea surface was shared with the halocarbon analyzer (see chapter …), which dominates the air flow rate through the tube. When the halocarbon analyzer was not operating anymore since 26 July 2020 a Boxer 3KQ diaphragm pump was installed instead.

7.3.3 Preliminary (expected) results

The data were observed but not analyzed onboard. A small increase in methane concentration and shift in δC^{13} methane isotopy was observed while moving closer to the marginal ice zone. The influence of ship exhaust must be taken into account when analyzing the data.

7.3.4 Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All device operations were logged in the AWI sensorweb portal and all sensor raw data files are stored in platform section of MCS. Data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de.

7.5 UNDERWAY CONTINUOUS SEA WATER ANALYZER

Yuhong Li[1], Liyang Zhan[1] (not on board), Lei Wang[2] (not onboard)

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7.5.1 Objectives

The Arctic Ocean is subjected to the amplification effect of global climate change on different aspects. The interface exchanges of greenhouse gases among ocean-ice-atmosphere are processes, which will reflect this amplification effect and may have their feedback on climate change. However, in comparison with tropical areas, less summer data available, and winter data is absent. To understand the above processes, an underway observation system for CO_2, CH_4, N_2O and CO were deployed onboard the *Polarstern* and conducted on the ice during Leg 5.

N_2O and CO analyzer (sensorweb: OA-ICOS_N2O; D-ship: PS122-5_0_Underway-24; PI: Y Li)

CH_4 concentration and $d^{13}CH_4$ isotope, CO_2 concentration and $d^{13}CO_2$ isotope (sensorweb: BNU-CRDS; D-ship: PS122-5_0_Underway-44; PI: L. Wang)

7.5.2 Work at sea

Two sets of underway systems were deployed onboard the *Polarstern*.

The CO_2 and CH_4 underway system is launched since Leg 1, with the system located outside the fish lab. Surface sea water flowed through shower type equilibrators, and the headspace of the gas phase were measured continuously using a Picarro CH_4/CO_2 analyzer. The system was calibrated with standard gases once each month.

The automatic N_2O and CO underway system was deployed in the wet lab and launched since Leg 3. Surface water flows through a bubble type equilibrator, and then, sample gas was then sent to the Los Gatos for analysis. The system was calibrated every 10 days. Meanwhile, the atmosphere N_2O and CO were also measured using the same instrument, however, due to the wind direction for the majority of the time at the floe, most of the N_2O and CO may be contaminated by the ship exhaust.

7.5.3 Preliminary (expected) results

During the drift with the floe, surface water headspace concentration for N_2O ranged between 368-391 ppb, with a maximum concentration on 24/8/2020 (Figure 7.5.1). After this date, concentrations then decreased and showed less variability, where atmospheric N_2O concentration was around at 332 ppb. This indicates that the surface water is releasing N_2O to the atmosphere.

During the drift with the floe, surface water headspace concentration for CO ranged between 196-447 ppb, with a maximum at the beginning of the drift, then decreases until the end of August (Figure 7.5.2). Concentrations increased again mid-September, where atmospheric CO concentration were around at 121 ppb, indicating that the surface water is releasing CO to the atmosphere.

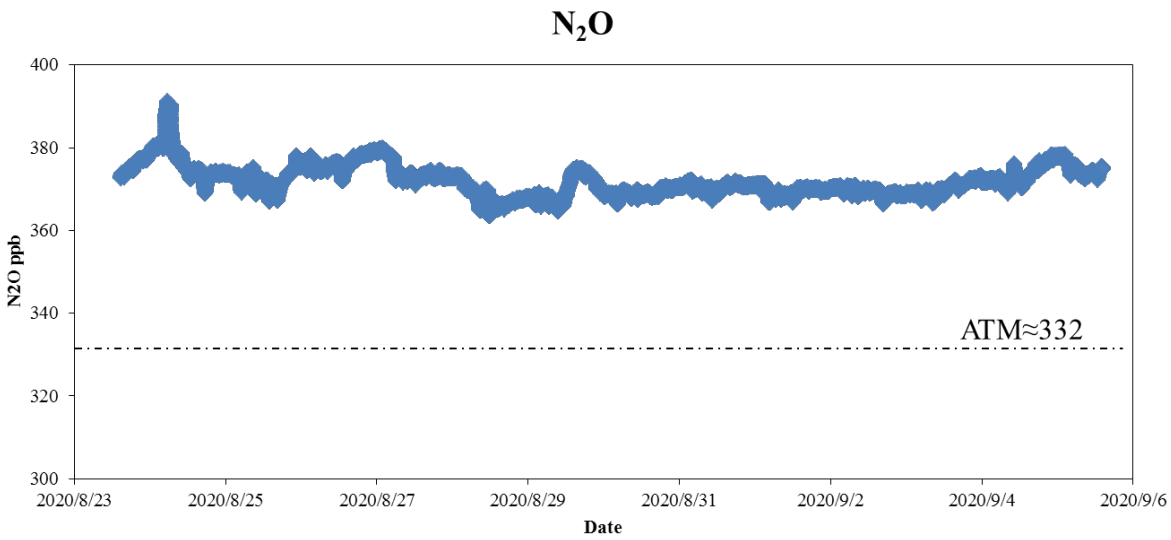

Fig 7.5.1. Surface water headspace concentration for N_2O during the drift with the floe.

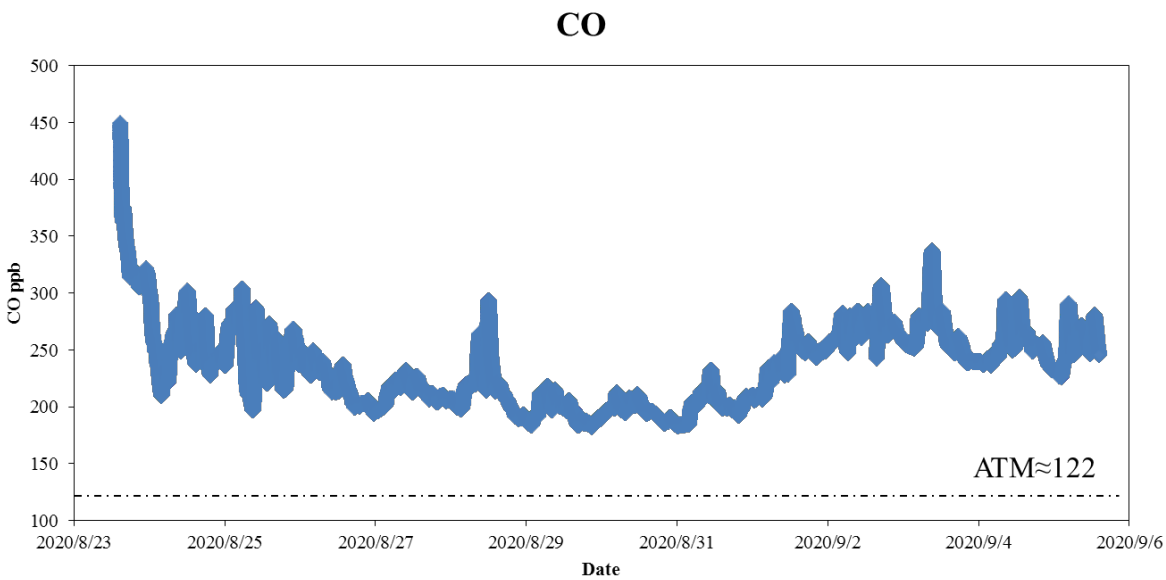

Figure 7.5.2. Surface water headspace concentration for CO during the drift with the floe.

7.5.4 Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All device operations were logged in the AWI sensorweb portal and all sensor raw data files are stored in platform section of MCS.

7.5 AEROSOL CHAMBER (OLLA)

Manuel Dall´Osto[1]

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7.5.1 Objectives

Spain contribution to Mosaic: Primary aerosol transport in the Arctic Atmosphere (SIMPATICO) aims - by using experimental and field approaches - to link aerosol emission processes with biological activities in surface polar waters, and disseminate results.

The SIMPATICO uses a novel state-of-the-art primary aerosol (PA) chamber developed at the ICM-CSIC in Spain, able to study the role of air-water-sea ice interactions in the formation of primary aerosols. We aim to collect polar open ocean water, melt pond water and melted ice water - then bubbled these water samples in the PA chamber so the physical, chemical and biological properties of primary aerosol emitted can be elucidated. In a nutshell, characterization of artificially generated primary polar aerosols with ad-hoc particulate matter PM1 sampling system, and characterization of (a) water, (b) primary aerosol generated within the chamber and (c) ambient aerosols. The results will be compared with the microbial communities, including micro-, nano- and pico-plankton photosynthetic organisms and bacteria, and viruses, with the MOSAiC collaborators.

At the same time, we will provide essential support in the continuity of other projects involved in MOSAIC, including helping Dr. Manuela van Pinxteren (TROPOS, Germany), Dr. Markus Frey (BAS, UK) and Dr. Julia Yvonne Schmale (PSI, Switzerland). SIMPATICO aims to integrate the expertise of several research groups - this integration is required to afford all the instrumentations, infrastructures and knowledge needed to address the multidisciplinary proposed objectives.

The results will commit to serve resulting datasets and collaborate with the modellers, to better integrate his research activity, for example, provision of data and diagnosis of model uncertainty. The multidisciplinary application of polar atmospheric science, marine biogeochemistry and microbial ecology techniques advocated in this project has not been used for examining the potential of changing environments on polar aerosol emissions strongly regulating our changing climate.

7.5.2 Work at sea

A number of aerosol chamber experiments were run, aiming to characterize the biogeochemical properties of the Mosaic different water including melt pond, leads, melted ice and CTD samples. In figure 1, the aerosol chamber olla mosaic can be seen, temperature of chamber was regulated via water continuous system from the RV Polartern.

Instruments connected to the aerosol chamber were:

- Scanning Mobility Particle Sizer (SMPS) in collaboration with BAS (Dr Anna Jones) and the SEANA project (Shipping Emissions in the Arctic and North Atlantic Atmosphere).
- PM1 aerosol (Tecora 38.3 l min-1) for 24h collection of Aerosol (collaboration with ISAC-CNR, Dr. Matteo Rinaldi) and Total suspended Particulate matter above 1um that was collected on the impactor (PM>1).

- PM1 aerosol (Tecora 38.3 l min-1) for 24h collection of Aerosol (collaboration with Dr. Y. Park, KOPRI) and Total suspended Particulate matter above 1um that was collected on the impactor (PM>1).
- TEM aerosol sampler (5 l min-1) for collection of single particles sampling in collaboration with Dr. Y Park (KOPRI).
- Ice Nuclei sampler (5 l min -1) in collaboration with Dr. Manuela van Pinxteren and Dr. Sebastian Zeppenfeld (TROPOS, Germany), Dr Markus Frey (BAS, UK) and Dr. Jessie Criemen (CU, USA). Filter measurements policarbonate 0.7um.

At the same time, the water that was used in the chamber was treated for different analysis including:

- Ice Nuclei IN measurements, 3 water samples (IN from normal unfiltered water, IN from filtered water by 0.2um siring and IN filtered by quartz filter 0.2 um). (TROPOS; BAS). this was 125ml
- IN measurements - Filter measurements policarbonate 0.7um. (TROPOS)
- Sugar samples, 3 measurements water samples (normal unfiltered water, IN from filtered water by 0.2um siring and IN filtered by quartz filter 0.2 um) (TROPOS), this was 3 bottles 125ml
- Lipid samples. 3 measurements water samples (normal unfiltered water, IN from filtered water by 0.2um siring and IN filtered by quartz filter 0.2 um) (TROPOS). this was 3 bottles 125ml
- H-NMR analysis. POC and DOC samples for ISAC-CNR. DOC sample was filtered by quartz 0.2 um (water sample). 3 filters were obtained (1) policarbonate 10nm filtration (2) Quartz total POC and (3) Quartz POC 0.2-10nm (ISAC-CNR)
- POC total 0.2 um quartz filter (KOPRI)

Figure 1. Chamber OLLA mosaic

Water measurements carried out:

				TROPOS				KOPRI	ISAC	
Day of collection (leg 5, year 2020)	Measurement (M) or experiment (E)	COMMENT	Name of the samples (manuel)	Sugar Water (3)	Lipid Water (3)	IN Water (3)	IN 0.7 Filter (1)	POC total (1)	POC total (1)	POC 0.2-10 and PC 10
22-08	M	PS122/5_59-200, 202, 203, 207-215	MP1	V	V	V	V	V	V	V
22-08	M	PS122/5_59-200, 202, 203, 207-215	MP2	V	V	V	V	V	V	V
25-08	M	B bottom, St. 8 PS122/5_59-200	LE1_B	V	V	V	V	V	V	V
25-08	M	M middle, St. 8 PS122/5_59-200	LE1_M	V	V	V	V	V	V	V
25-08	M	T top, St. 8 PS122/5_59-200	LE1_T	V	V	V	V	V	V	V
28-08	M	St. MP1 and 4 PS122/5_59-343 PS122/5_59-344	MP4	V	V	V	V	V	V	V
31-08	M	SI sea ice WATER taken from sea ice station, 2m below surface	SI_1	V	V	V	V	V	V	V
01-09	E	Addition of melosara algae to get the marker of this	SI_1M	V	V	V	V	V	V	V
01-09	E	This is the experiment to see if grazer of bob changed the properties of SI_1	SI_1MCB	V	V	V	V	V	V	V
01-09	E	This again is my first copepod experiment (24h) and see if signal is different from S1_1	SI_1C	V	V	V	V	V	V	V
01-09	E	This is melt water of the SI experiment (4 cores) 50cm bottom ice	SI_1A	V	V	V	V	V	V	V
02-09	M	St. MP4a PS122/5_60-61	LE_2B	V	V	V	V	V	V	V
02-09	M	St. MP4a PS122/5_60-61	LE_2T	V	V	V	V	V	V	V
02-09	M	St. MP4a PS122/5_60-61	LE_2M	V	V	V	V	V	V	V
04-09		Top St. ROV lead PS122/5_60-130	LE_3T	V	V	V	V	V	V	V
04-09	M	Bottom, St. ROV lead PS122/5_60-130	LE_3B	V	V	V	V	V	V	V
04-09	M	Mixed St. ROV lead PS122/5_60-130	LE_3M	V	V	V	V	V	V	V
04-09	E	LE_3 after bubbling final water	LE_3MF	V	V	V	V	V	V	V
09-09	M	This it a lead taken with Dr Webb on 09-09	LE_4	V	V	V	V	V	V	V
09-09	E	This is the lead LE4 After bubbling	LE_4A	V	V	V	V	V	V	V
11-09	E	This is a solo experiments, no other measurements. Same of LE_4 same location	LE_5	V	V	V	V	V	V	V
11-09	E	This is a solo experiments, no other measurements. Same of LE_4 same location	LE_5A	V	V	V	V	V	V	V
12-09	M	CTD water, CHL max.	C_1	V	V	V	V	V	V	V

12-09	E	CTD water from SURFARE of CTD 12 Sep. 2020 PS122_5_61-189	C_1S	V	V	V	V	V	V	V
12-09	E	12 Sep. 2020 PS122_5_61-189 C1 with copepod experiment (24h incubation)	C_1C	V	V	V	V	V	V	V
12-09	E	12 Sep. 2020 PS122_5_61-189 this is T for tre after 62 hours incubation	C_1T	V	V	V	V	V	V	V
12-09	E	Copepod bob	B_201	V	V	V	V	V	V	V
12-09	E	Copepod bob	B_204	V	V	V	V	V	V	V
12-09	E	Copepod bob	B_207	V	V	V	V	V	V	V
14-09	M	14 Sep. 2020 St. MP4a pond ice (core) PS122/5_62-35	MP_5	V	V	V	V	V	V	V
14-09	M	14 Sep. 2020 St. MP4a pond ice (core) PS122/5_62-35	MP_5T	V	V	V	V	V	V	V
14-09	M	14 Sep. 2020 St. MP4a pond ice (core) PS122/5_62-35	MP_5B	V	V	V	V	V	V	V
17-09	M	Solo (this is the MP1 blue MP we sample at beginning). (this is a clean good sample, it is the old MP1)	MP_6	V	V	V	V	V	V	V
18-09	M	Solo, this is the water	PM_7	V	V	V	V	V	V	V
18-09	M	Solo, this is the ice melted	PM_7I	V	V	V	V	V	V	V
18-09	M	Solo, this is remote sensing pond water	MP_RS	V	V	V	V	V	V	V
18-09	M	Solo, this is the ice of melt pond RS	MP_RSI	V	V	V	V	V	V	V
18-09	M	18 Sep. 2020 St. MP1 pond ice (core) PS122/5_62-120	PM8	V	V	V	V	V	V	V
18-09	M	18 Sep. 2020 St. MP1 pond ice (core) PS122/5_62-120	MP8I	V	V	V	V	V	V	V
24-09	M	Transect water t1 CTD 24 Sep. 2020 PS122/5_63-35	T1	V	V	V	V	V	V	V
25-09	M	Transect water t2 CTD 25 Sep. 2020 PS122/5_63-53	T2	V	V	V	V	V	V	V
25-09	E	We leave for 1 day This is water T2 with copepod CTD CTD 25 Sep. 2020 PS122/5_63-53	T2C	V	V	V	V	V	V	V
25-09	E	We leave it for 3 days This is water T2 with copepod CTD 25 Sep. 2020 PS122/5_63-53	T2C3	V	V	V	V	V	V	V
27-09	M	Transect water t3 CTD 27 Sep. 2020 PS122/5_63-100	T3	V	V	V	V	V	V	V
28-09	M	Transect water t4 CTD 28 Sep. 2020 PS122/5_63-111	T4	V	V	V	V	V	V	V

These were the aerosol sample chamber experiments, a total number of 22 aerosol chamber experiments was carried out.

	IN bubble 0.7(Tropos IN bubble chamber)	PM1 KOPRI quartz filter	PM1 ISAC Quartz filter	TEM Kopri single particle
MP_2 BUBBLE (This is the water of MP2)	V	39283 L	38560 L	SM-032
LE_2 BUBBLE (This is the lead we sampled St. 8 PS122/5_59-200)	V	83931 L	84292 L	SM-033
MP4 BUBBLE (This is the MP4 taken on 28-08)	v	50314 L	35925 L	Sm-034
SI_1 this is water taken from 2m below surface on first day of coring activities 31-08	V	44813 L	31807 L	SM-035
LE2_M (this is the LE2 experiment with mixed water of the LE top and bottom) potential contamination of PM1	v	36218 L	33800 L	Sm037
LE_3 B(potential contamination of PM)	v	X	46066 L	X
LE_3 M (good sample) from mixture of top and bottom	v	X	55963 L	Sm038
LE_4 this is the LE4 bubble, we also have after bubble water LE4A	V	X	57906 L	Sm039
LE_5 experiment, this is a solo experiment same location of LE4 but taken 2 days after	V	X	62444 L	SM 040
C1 this is the CTD MAX water taken on 12-09	v	x	54019 L	Sm041
C1C experiment run with copepod water and this is C1 water	V	X	41668 L	Sm042
C1T we also run bubble with copepod after 60h (tre trio three T)	V	X	55936 L	Sm043
MP6 (this is a clean good sample, it is the old MP1) run 17-09	V	X	53718	Sm044
MP7 (same ofMP6 and MP1) run on 18-08	V	86123 L	85438 L	Sm045
RS Remote sensing bond bubble	V	64293 L	63942 L	SM046
MP8	V	56534 L	57272 L	SM047
MP8I this is MP8 with some ice from PM8 melted	V	X	61148 L	Sm048
T1 bubble	V	X	62662 L	Sm049
T3 bubble	V	X	56000 l	Sm050
T4 bubble	V	X	52098 l	Sm 024
T2 C copepod T2 water bubble	V	X	38782 l	Sm025
T2 bubble	V	X	38308 L	Sm 026

The Aerosol chamber experiments of the waters mentioned above were run. Additionally experiments were run with copepod treatment described in the later sections.

7.5.3 Preliminary results

A number of results are expected to come including the role of different ecosystem and different biogeochemical processes affecting (1) primary aerosol emissions and (2) Ice nuclei concentrations. Very sticking differences were found for different waters across leg 5 mosaic. The grazing zooplankton experiments also look promising.

7.5.4 Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All device operations were logged in the AWI sensorweb portal and all sensor raw data files are stored in platform section of MCS. Data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de.