7. BIOGEOCHEMISTRY

Jacqueline Stefels[1], Jeff Bowman[2], Ellen Damm[3], Chris Marsay[4], Annette Rinke[3], Torsten Sachs[5], Patric Simoes Pereira[6], Liyang Zhan[7]

[1]NL.UGroningen
[2]CH.SIO
[3]DE.AWI
[4]US.SKIO
[5]DE.GFZ
[6]SE.UGOT
[7]CH.TIO

Grant-No. AWI_PS122_00

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)

Objectives

The main objective of the BGC team is to obtain a year-round process-level understanding of fluxes of climate relevant trace gases (CRTG) during the MOSAiC drift. This implies an understanding of the physical boundary conditions on the one hand and of ecosystem processes on the other. Shifts in physical and biological processes over the course of the seasons result in numerous biogeochemical reactions during freezing and melting cycles of sea ice and results in CRTG exchange with both the overlying atmospheric boundary layer and the underlying ocean down to the halocline. Quantifying seasonally varying fluxes is essential for future improvements of climate models. It is therefore paramount to acquire detailed knowledge of these physical and biological boundary conditions through interdisciplinary collaborations. The collected data link to measurements taken in the atmosphere, snow, sea ice, ocean, and ecosystem domains.

Work at sea

The main compounds sampled from ice during Leg 3 were: halocarbons (~10 different compounds were found), methane (CH_4 and $\delta^{13}C$-CH_4), dimethylsulfide (DMS) and related sulfur compounds, N_2O, stable water isotopes ($\delta^{18}O/\delta D$) and ^7Be. All these compounds were also sampled from water, but in addition samples for nutrients, DNA, Net Community Production and HPLC were taken; the latter four in collaboration with team ECO. Occasionally, samples were collected for Neodynium isotopes and Iodine in ice and water (Table 7.1-4). Large quantities of snow were sampled for ^7Be and when in conjunction with coring activities also for halocarbons. CH_4, $\delta^{13}C$-CH_4, CO_2, CO, N_2O and halocarbons were measured continuously in the surface water and halocarbons also in the atmosphere.

Main sites for coring events were adopted from Legs 1 and 2: BGC1 (FYI), BGC2 (SYI with a refrozen freshwater upper layer), BGC3 (SYI), and a FYI and SYI site in the dark sector sampled during the cross-cutting Monday coring. In addition, two of the L-sites (L1 and L2) were revisited to compare with samples taken during Leg 1 and 2. Core lengths at these sites varied between 150 to 250cm. A lead that had formed at the end of Leg 1 near the Dark Site and had been followed during Leg 2 was sampled two more times during Leg 3. By that time, ice thickness had grown until almost a meter and the lead ice could be regarded FYI. The sites that were visited are indicated in Figure 1.6 of Chapter 1.

From the start of Leg 3, the ice appeared highly dynamic which resulted in the formation of leads on multiple sites. The extremely cold conditions until mid of April guaranteed fast refreezing and the formation of frost flowers and very salty slush on the new ice. In order to monitor these quick freezing events and their impact on CRTG fluxes, various matrices of multiple leads were sampled as long as the leads were not destroyed due to ridging (table 7.2). Ice-air fluxes of CO_2, CH_4, CO and N_2O from several leads were monitored in two different flux chambers.

In total, the BGC team took 115 ice cores (Table 7.1) and 51 snow samples (Table 7.2), sampled 22 leads (Table 7.3), deployed 34 CTD's (Table 7.4) and deployed flux-chambers during 10 events (Table 7.5). Due to inaccessibility of a CTD hole near the Polarstern, all CTD's after the 15th of March were taken from Ocean City. The measurements of halocarbons, CH_4 and $\delta^{13}C$-CH_4 and sulfur compounds were performed on board. Discrete samples for the analysis of N_2O and $\delta^{18}O/\delta D$ from ice and water, as well as the ECO-related samples and all ^{7}Be samples, will be brought back to the various home labs.

The atmospheric concentrations of BrO and IO were measured with a MAX DOAS. This instrument had been running from Leg 1 onwards, but shut-off during darkness. When the light returned it was switched on again.

The total sampling listed here also covered sampling for several projects not on board: flux chambers for Nomura et al., Neodymium samples from ice and water for Laukert et al., samples for stable isotopes of water for Bauch et al. and Iodide samples from ice and water for Jacobi et al..

Tab.7.1: *Ice-coring events with sampled parameters*

Action log ID	Date	Site	VHOC	CH_4	$\delta^{13}C$-CH_4	DMS (O/P)	N_2O	^{18}O	I^-	Nd	^{7}Be
PS122/3_29-27	26/02/2020	DS Lead	x	x	x		x	x			
PS122/3_30-87	02/03/2020	BGC1	x								
PS122/3_30-75	07/03/2020	DS Lead	x	x	x	x	x	x			x
PS122/3_31-5	09/03/2020	BGC1	x	x		x	x	x			
PS122/3_31-33	11/03/2020	BGC3	x	x		x	x	x			
PS122/3_32-6	16/03/2020	BGC2	x	x	x	x	x	x			
PS122/3_32-58	20/03/2020	BGC1	x	x		x	x	x			
PS122/3_32-63	21/03/2020	DS FYI	x	x		x	x	x			
PS122/3_33-21	23/03/2020	BGC1									x
PS122/3_33-18	24/03/2020	DS SYI	x	x	x	x	x	x			
PS122/3_34-107	01/04/2020	BGC1	x								
PS122/3_35-11	06/04/2020	DS FYI	x	x		x	x	x	x		x
PS122/3_35-80	08/04/2020	DS FYI								x	
PS122/3_35-152	10/04/2020	BGC3	x	x	x	x	x	x			
PS122/3_36-4	13/04/2020	DS SYI	x	x	x	x	x	x			
PS122/3_36-21	14/04/2020	DS FYI	x	x	x		x	x			x
PS122/3_37-32	22/04/2020	BGC2	x	x	x	x	x	x			
PS122/3_37-95	24/04/2020	BGC1									x
PS122/3_37-97	25/04/2020	DN L1 (FYI, SYI)	x	x	x	x	x	x			
PS122/3_38-24	27/04/2020	DS FYI	x			x	x	x			
PS122/3_38-16	27/04/2020	DS SYI	x	x	x		x	x			
PS122/3_38-57	30/04/2020	DN L2 (FYI, SYI)	x	x	x		x	x			

PS122/3_39-7	04/05/2020	DS FYI								x
PS122/3_39-18	04/05/2020	DS SYI	x	x	x	x	x	x		
PS122/3_39-83	09/05/2020	BGC1	x						x	

Tab. 7.2: *Snow sampling events with sampled parameters*

Action log ID	Date	Site	VHOC	^{7}Be
PS122/3_29-26	26/02/2020	DS Lead		x
PS122/3_29-27	26/02/2020	DS Lead	x	
PS122/3_29-31	26/02/2020	BGC2		x
PS122/3_30-14	02/03/2020	BGC1		x
PS122/3_30-87	02/03/2020	BGC1	x	
PS122/3_30-56	06/03/2020	"closed" lead near runway	x	
PS122/3_30-70	07/03/2020	DS Lead		x
PS122/3_30-75	07/03/2020	DS Lead	x	
PS122/3_31-33	11/03/2020	BGC3	x	
PS122/3_31-65	13/03/2020	Lead near gangway	x	
PS122/3_31-61	14/03/2020	Lead near gangway	x	
PS122/3_31-91	15/03/2020	BGC2		x
PS122/3_32-5	16/03/2020	BGC2		x
PS122/3_32-6	16/03/2020	BGC2	x	
PS122/3_32-57	20/03/2020	BGC1		x
PS122/3_32-58	20/03/2020	BGC1	x	
PS122/3_32-63	21/03/2020	DS FYI	x	
PS122/3_33-20	23/03/2020	BGC1		x
PS122/3_33-106	25/03/2020	Snow2		x
PS122/3_33-68	27/03/2020	BGC2		x
PS122/3_34-36	02/04/2020	BGC1		x
PS122/3_34-37	02/04/2020	BGC1		x
PS122/3_34-95	03/04/2020	Snow2		x
PS122/3_34-96	05/04/2020	BGC2		x
PS122/3_35-135	10/04/2020	BGC3		x
PS122/3-35-136	11/04/2020	Snow2		x
PS122/3-35-137	11/04/2020	BGC1		x
PS122/3-35-138	11/04/2020	BGC1		x
PS122/3_36-185	13/04/2020	BGC3	x	
PS122/3_36-21	14/04/2020	DS FYI	x	
PS122/3_36-139	14/04/2020	DS FYI		x
PS122/3_36-140	17/04/2020	BGC1		x
PS122/3_36-141	17/04/2020	BGC2		x
PS122/3_37-32	22/04/2020	BGC2	x	
PS122/3_37-92	23/04/2020	Snow2		x
PS122/3_37-93	23/04/2020	David's Ridge		x

PS122/3_37-94	24/04/2020	BGC1		x
PS122/3_37-97	25/04/2020	DN L1 (FYI, SYI)	x	
PS122/3_37-139	26/04/2020	BGC2		x
PS122/3_38-24	27/04/2020	DS FYI	x	
PS122/3_38-27	27/04/2020	DS FYI		x
PS122/3_38-57	30/04/2020	DN L2 (FYI, SYI)	x	
PS122/3_38-115	30/04/2020	L2 site		x
PS122/3_38-116	02/05/2020	BGC1		x
PS122/3_38-117	02/05/2020	"Logistics lead"		x
PS122/3_38-118	03/05/2020	ROV City		x
PS122/3_39-7	04/05/2020	DS FYI	x	
PS122/3_39-40	06/05/2020	Fort Ridge Lead	x	
PS122/3_39-99	06/05/2020	BGC2		x
PS122/3_39-83	09/05/2020	BGC1	x	
PS122/3_39-100	09/05/2020	BGC1		x
PS122/3_39-101	09/05/2020	BGC1		x
PS122/3_39-102	09/05/2020	BGC1		x

Tab. 7.3: *Lead-ice sampling events with sampled parameters*

Action log ID	Date	Site	matrix	VHOC	CH_4	DMS(O/P)	^{18}O	N_2O
PS122/3_29-87	01/03/2020	Dranistyn Track	FF		x			
PS122/3_30-29	04/03/2020	Dranistyn Track	FF	x			x	x
PS122/3_30-56	06/03/2020	Lead east of runway	new ice, brinacles	x	x	x	x	
PS122/3_31-43	11/03/2020	Lead near gangway	FF, slush, new ice	x	x	x	x	
PS122/3_31-44	12/03/2020	Lead near gangway	new ice	x	x		x	
PS122/3_31-66	13/03/2020	Lead near gangway	10cm core	x	x		x	
PS122/3_31-61	14/03/2020	Lead near gangway	15cm core	x	x	x	x	
PS122/3_31-80	15/03/2020	Met City Lead	new ice		x			
PS122/3_31-97	16/03/2020	Met City Lead	new ice		x		x	
PS122/3_32-24	18/03/2020	PS front Lead	FF, slush, new ice		x	x	x	x
PS122/3_32-74	21/03/2020	Droveville Lead	FF, slush	x		x	x	
PS122/3_33-1	23/03/2020	Droveville Lead	FF, slush, new ice	x	x	x	x	x
PS122/3_33-53	26/03/2020	Lead in front of bow	FF, slush, new ice	x	x	x	x	x
PS122/3_34-62	04/04/2020	Lead in front of bow	FF, slush, new ice	x	x	x	x	x
PS122/3_35-5	06/04/2020	Crack near Balloon Town	FF, slush, new ice	x	x		x	
PS122/3_35-8	06/04/2020	Crack to Droneville	new ice		x	x		
PS122/3_35-9	06/04/2020	Lead at stern	slush, new ice		x	x		
PS122/3_35-96	11/04/2020	Stern lead	slush, 50cm core		x	x (slush)		
PS122/3_37-49	23/04/2020	Fort Ridge	brine	x	x			
PS122/3_37-70	24/04/2020	Bow+Stern lead	new ice, 40cm core	x	x	x		
PS122/3_37-155	26/04/2020	Fort Ridge Lead	55cm core		x	x	x	x
PS122/3_37-159	26/04/2020	Fort Ridge	brine	x	x	x	x	x

PS122/3_39-39	06/05/2020	Fort Ridge Lead	55cm core	x	x	x	x	x
PS122/3_39-134	06/05/2020	Fort Ridge	brine	x	x	x	x	x

Tab.7.4: *Water sampling events with sampled parameters*

Action log ID	Date	Site	VHOC	CH_4	$\delta^{13}C$-CH_4	N_2O	^{18}O	nutr	Chin. sample	DMS (O/P)	MetOx	NCP	DNA	I^-	Nd
PS122/3_29-8	25/02/2020	Ocean City	x	x	x	x	x	x	x					x	
PS122/3_29-74	29/02/2020	Ocean City		x	x	x	x								
PS122/3_30-9	02/03/2020	Ocean City	x	x	x		x		x						
PS122/3_30-38	05/03/2020	Ocean City	x	x	x		x			x					
PS122/3_30-53	06/03/2020	Polarstern	x								x		x		
PS122/3_31-18	10/03/2020	Ocean City	x	x	x	x	x	x		x					
PS122/3_31-19	10/03/2020	Ocean City		x	x					x		x	x		
PS122/3_31-59	14/03/2020	Polarstern	x			x					x		x		
PS122/3_31-63	14/03/2020	Polarstern									x		x		x
PS122/3_31-81	15/03/2020	Ocean City		x	x		x	x	x	x					
PS122/3_32-12	17/03/2020	Ocean City	x	x	x	x	x	x		x		x	x		
PS122/3_32-38	19/03/2020	Ocean City								x			x		
PS122/3_32-77	22/03/2020	Ocean City	x	x	x	x	x	x		x		x	x		
PS122/3_33-82	28/03/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_33-80	28/03/2020	Ocean City						x				x	x		
PS122/3_34-17	31/03/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_34-64	04/04/2020	Ocean City								x			x		
PS122/3_34-77	05/04/2020	Ocean City	x	x	x	x	x	x		x		x	x		
PS122/3_35-25	07/04/2020	Ocean City	x	x	x	x	x	x	x	x	x	x	x		
PS122/3_35-92	11/04/2020	Ocean City	x	x	x	x	x	x	x	x	x	x	x		
PS122/3_36-18	14/04/2020	Ocean City								x			x		
PS122/3_36-19	14/04/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_36-115	18/04/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_37-14	21/04/2020	Ocean City													x
PS122/3_37-15	21/04/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_37-116	26/04/2020	Ocean City	x	x	x	x	x	x		x		x	x		
PS122/3_38-5	27/04/2020	Ocean City								x			x		
PS122/3_38-31	28/04/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_38-100	02/05/2020	Ocean City	x	x	x	x	x	x	x	x		x	x		
PS122/3_39-16	05/05/2020	Ocean City	x			x	x	x	x	x		x	x		
PS122/3_39-69	08/05/2020	Ocean City													x
PS122/3_39-70	08/05/2020	Ocean City								x			x		x
PS122/3_39-82	09/05/2020	Ocean City	x			x	x	x		x		x	x		
PS122/3_40-36	16/05/2020	Polarstern	x			x				x					

Tab. 7.5: *Flux-chamber events with sampled parameters. N_2O, CO and DMS were sampled in Tedlar air bags from a Teflon-coated metal chamber; CO_2 and CH_4 were sampled with an automatic LI-COR 8100-104 chamber*

Action log ID	Date	Site	N_2O	CO	DMS	CO_2	CH_4
PS122/3_31-15	10/03/2020	BGC1				x	x
PS122/3_32-101	16/03/2020	BGC2				x	x
PS122/3_32-103	21/03/2020	Stern Lead				x	x
PS122/3_33-116	24/03/2020	Dronevill Lead			x	x	x
PS122/3_35-142	06/04/2020	stern lead			x	x	x
PS122/3_35-145	07/04/2020	Stern Lead	x	x	x		
PS122/3_35-146	10/04/2020	Stern Lead	x	x			
PS122/3_35-144	11/04/2020	stern lead				x	x
PS122/3_35-147	11/04/2020	Stern Lead	x	x	x		
PS122/3_36-182	13/04/2020	Stern Lead	x	x			
PS122/3_36-180	14/04/2020	stern lead				x	x
PS122/3_36-183	14/04/2020	Stern Lead	x	x			
PS122/3_36-181	17/04/2020	stern lead				x	x
PS122/3_36-184	18/04/2020	Stern Lead	x	x			
PS122/3_37-150	22/04/2020	BGC1	x	x			
PS122/3_37-151	23/04/2020	BGC1	x	x			
PS122/3_37-152	24/04/2020	BGC1	x	x			
PS122/3_37-153	25/04/2020	Stern Lead	x	x	x		
PS122/3_38-147	29/04/2020	Stern Lead	x	x			
PS122/3_38-146	01/05/2020	stern lead				x	x
PS122/3_38-149	01/05/2020	Stern Lead	x	x			
PS122/3_38-150	02/05/2020	Stern Lead	x	x			
PS122/3_38-151	03/05/2020	Stern Lead	x	x			
PS122/3_39-113	04/05/2020	Stern Lead	x	x			
PS122/3_39-114	05/05/2020	Stern Lead	x	x			
PS122/3_39-112	06/05/2020	BGC1				x	x
PS122/3_39-115	06/05/2020	BGC1	x	x			
PS122/3_39-116	07/05/2020	BGC1	x	x	x		
PS122/3_39-117	09/05/2020	Stern Lead	x	x			

Preliminary (expected) results

See the individual projects for preliminary results

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). See the individual projects for specific data management issues.

7.1 Fate and Pathways of Methane in Sea Ice and Surface Water

Ellen Damm[1], Annette Rinke[1], Torsten Sachs[2] [1]DE.AWI
[2]DE.GFZ

Objectives

The coupling of ice and snow physics on one side with the ecosystem on the other side induces numerous biogeochemical reactions during freezing and melt cycles of sea ice, which finally results in methane exchange with both the overlaying Arctic atmospheric boundary layer and the underlying, sea-ice influenced ocean down to the halocline. By combining year-round observations, we will be able to evaluate how seasonal variability in physical and biogeochemical regimes affect the methane distribution, isotopic fractionation and sea/ice air fluxes. We consider direct interactions, i.e. from ice and snow to surface water and indirect interactions, where methane circulates through more than one environment before leaving to the atmosphere. During the freeze period, we focus on potential alterations in the isotopic composition of methane along these pathways, mainly induced by kinetic isotopic fractionation. Fractionation initiates modifications in the isotopic signature of sea-ice related methane, which when unconsidered, encourages a misleading source identification of Arctic emissions. The collected data links to most of the measurements in the atmosphere, snow, sea ice, ocean, and ecosystem domains. The enhanced process understanding contributes to future improvements of climate models.

Work at sea

Seawater sampling occurred up to 250 m water depth from the Ocean City rosette two times per week. Selected sampling depths varied over time related to gradients in temperature, salinity and former measured methane profiles.

Ice cores from all three BGC sites and both locations at the Dark Site, i.e. FYI and SYI were taken and analyzed (Table 7.1). In addition lead ice sampling occurred (Table 7.3).

After coring with a standard Kovacs 9 cm ice corer, ice cores were divided into 10 cm sections and thawed in gas-tight Tedlar™ bags. The melted ice was filled in 160 ml and 500 ml glass bottles for the analysis of methane concentration and stable carbon isotopic signature of methane, respectively.

The concentration and stable carbon isotopic signature of methane were analysed directly on board. Methane concentration was measured with the headspace method, i.e. 1.5 mL gas sample was taken from the headspace of a 160 mL water bottle and injected into a gas chromatograph (Agilent GC 7890B) with a flame ionization detector (FID). For gas chromatographic separation a packed column (Porapac Q 80/100 mesh) was used. The GC operated isothermally (60°C) with a detector temperature of 200°C.

For the analysis of the stable carbon isotopic signature a 25 ml headspace with methane free air was created. After shaking, a 20 ml gas sample was taken and injected into the SSIM mounted on a PICARRO 2132.

Preliminary results

Seawater - Winter mixed layer

The deepening of the well-mixed surface water observed during leg 2 continued also in March and April. The depths of the winter mixed layer (WML) increased from 50 m in mid-February to 65 m in early March and to more than 100 m at the end of the freeze period, i.e. in early May. Within this well mixed layer, methane was super-saturated while under-saturated underneath the WML. In continuation of leg 2, the stable carbon isotopic signature of dissolved methane further shifted to values more enriched in ^{13}C within the WML. Ongoing over the course of the drift up the beginning of April, this pronounced isotopic shift disappeared after

crossing the Gakkel ridge, i.e. when the floe drifted from the Amundsen basin into the Nansen basin.

Sea ice

Both, the spatial and temporal variability of sea ice was considered. The former was taken into account by coring of different types of sea ice, i.e. first- and second-year ice: (FYI, SYI) but also rafted ice and freshly formed ice on leads. The latter by repeated coring/analysis of ice of the chosen coring sites, BGC1, BGC 2, BGC 3, FYI and SYI at the dark site and leads over the duration of leg 3 (Table 7.1). Methane concentration in FYI and lead ice corresponded to the range of magnitude as the seawater underneath sea ice, i.e. the WML. While in comparison, SYI and rafted ice showed slightly enhanced values. In all types of sea ice, the stable isotopic signature of methane shifted towards values depleted in ^{13}C compared to those in seawater.

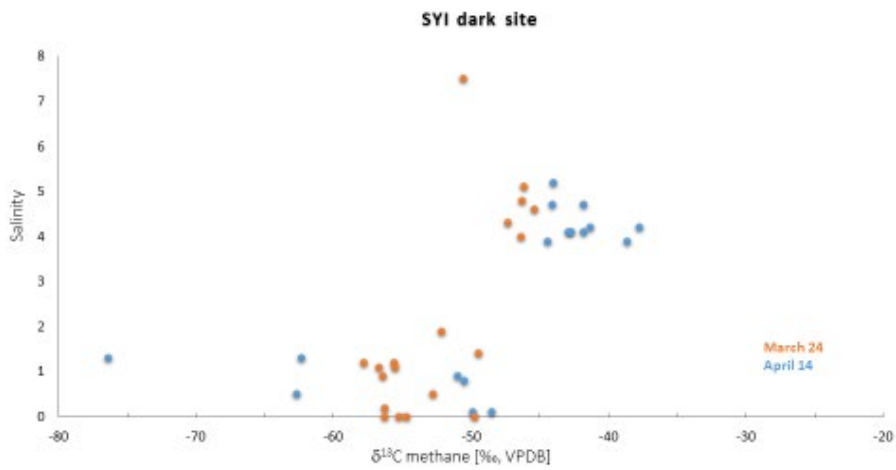

Fig 1.: *Stable carbon isotopic signature ($\delta^{13}C$) of methane vs. salinity in second year ice (SYI)*

Data management

The raw data are available according to the data policy of the MOSAiC expedition.

7.2 Quantifying microbial Controls on the annual Cycle of Methane and Oxygen within the ultraoligotrophic Central Arctic during MOSAiC (METHOX).

Jeff Bowman[1], Brice Loose (not on board)[2], Alessandra D'Angelo[2] (not on board), Emelia Chamberlain (not on board)[1], Jessie Creamean (not on board)[3]

[1]CH.SIO
[2]US.URI
[3]US.CSU

Grant-No. NSF-OPP-1821911

Objectives

Methane is consumed in the water column by methanotrophic bacteria. We seek to quantify the contribution of methanotrophy to the methane budget of the central Arctic. We will also quantify the contributions of specific groups of bacteria, archaea, and eukaryotes to the oxygen and carbon budgets of the central Arctic inferred from net community production. Specific objectives to support these aims include 1) measurements of ambient methane concentration and isotopic ratio, 2) incubations with labeled methane to derive specific estimates of methane oxidation, 3) continuous measurements of O_2 and Ar from the ship's flow through seawater system to support an estimate of net community production, 4) discrete measurements of O_2 and Ar from CTD casts, 5) daily DNA samples from the flow through seawater system, 6) DNA samples paired with all discrete measure of O_2/Ar, 7) RNA samples paired with the labeled methane incubations.

Work at sea

DNA and RNA

A total of 416 samples were collected for DNA and RNA. For each sample between 500 ml and 1000 ml of seawater was vacuum filtered through a 25 mm, 0.2 µm Durapor filter (PALL). The filters were immediately transferred to Fisher Microbiome Ultra extraction kit bead beating tubes and stored at −80 °C. Filters for RNA samples were first treated by drawing 1 ml of Zymo DNA/RNA shield through the filter.

Labeled Methane Incubations

57 incubations were initiated with labeled methane. 12 ml of methane was added to between 500 ml and 1000 ml of sample in gas-tight mylar bags with 100 ml of headspace. Incubations were carried out in a water bath at 1 °C. A T_0 reading was made within 48 hours on a Picarro cavity ringdown spectrometer, and each incubation was measured approximately weekly after T_0. All samples were left at 1 °C for a final measurement by the Leg 4 team.

Measurements of Ambient Methane Concentration

To minimize overlap with project 7.1, measurements of ambient methane were de-emphasized on Leg 3. A total of 17 measurements were made. 50 ml of headspace was created in mylar bags containing approximately 1500 ml of seawater. The samples were allowed to equilibrate in a water bath at room temperature for 24 hours before measurement on a Picarro cavity ringdown spectrometer.

Preliminary results

No preliminary results are available. Preliminary results for the incubations will be generated following the final measurement of Leg 4. DNA and RNA sequence data will be available after sample return to Scripps Institution of Oceanography, following extraction and shipment to the sequencing facility.

Data management

Data associated with the Picarro cavity ringdown spectrometer are available according to the data policy of the MOSAiC expedition.

7.3 *In situ* Measurements (CH_4, N_2O, CO and CO_2) in Sea Water and Air

Liyang Zhan[1], Bruno Delille[2] (not on board), Daiki Namura[3] (not on board), Lei Wang[4] (not on board)

[1]CH.TIO
[2]BE.ULiège
[3]JP.UHokkaido
[4]CH.BUT

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 the effect and may have their feedback on this change. However, compare to tropical area, less summer data available, whereas winter data is absent. To understand the above process, underway observation system for CO_2 and CH_4, N_2O and CO were deployed onboard the Polarstern and conducted on the ice during leg 3.

Work at sea

Underway observation

Two sets of underway systems were deployed onboard the Polarstern.

The CO_2 and CH_4 underway system is launched since leg 1. The system located outside of fish lab. Surface sea water flow through shower type equilibrators, headspace gas phase were measured continuously using a Picarro CH_4/CO_2 analyzer.

The automatic N_2O and CO underway system was deployed in the wet lab and launched since Leg 3.Surface water flow through a bubble type equilibrator, sample gas bubbles the water sample in the equilibrator and sent to the Los gatos for measurement, system calibrated every 10 days, meanwhile, the atmosphere N_2O and CO will be measured, however, due to the wind directly, most of the N_2O and CO may be contaminated by the ship exhaust.

Chamber measurement

To measure the ice-atmosphere flux of CO_2 and CH_4, N_2O and CO, two different methods were used.

An automatic chamber was used for CO_2 and CH_4 ice atmosphere flux measurement. The instrument consisted of a Licor CO2 analyzer, a LGR CH_4 analyzer and an automatic chamber. During Leg 3, 10 chambers deployment were conducted, study sides including BGC 1, BGC2, Stern Lead and Droneville Lead.

N2O and CO chamber sampling is a method developed during Leg 3. A metal chamber was deployed on the snow or ice of BGC 1, Stern Lead and Droneville Leads, samples were taken from the chamber into Tedlar Bags, and optimum sample interval is 4 min. The N_2O and CO samples were then taken back to Polarstern and analyzed using Los gatos N_2O/CO. 19 sets of data were obtained between 7th April and 9th May.

Preliminary results

N_2O and CO underway observations

Surface water N_2O concentrations ranged between 16.2 -17.4nM, with a maximum between 87.5-88.0°N, and then decreasing southward (Fig. 7.4.1). The CO concentrations showed several maxima along the cruise track, with two maxima with concentrations higher than 2nM observed at about 86°N.

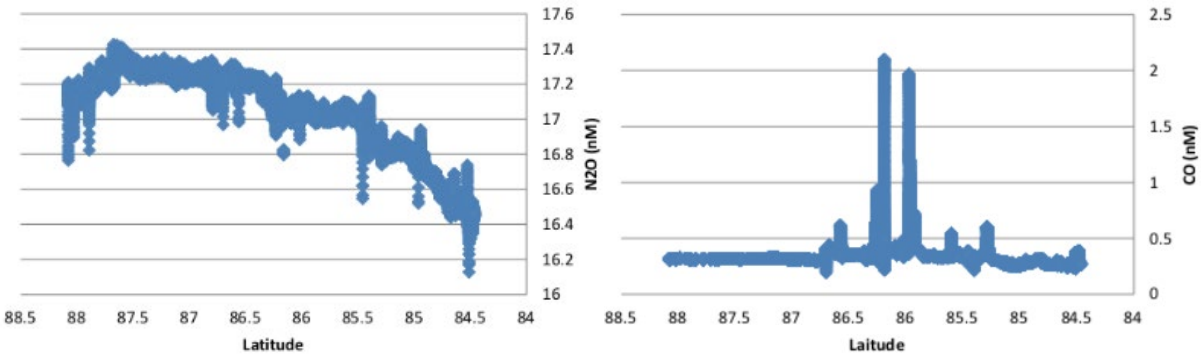

Fig. 7.4.1: *Surface water N_2O and CO concentration along the cruise track*

CO Chamber measurements

CO fluxes were measured on different thickness of sea ice including first year sea ice (BGC1 160cm) and Lead Ice (20cm, 30cm, 40cm, 90cm) (Fig 7.4.2). However, no relationship between CO emission rate and thickness of the ice could be identified so far. Further evaluation of the data will be done post-cruise.

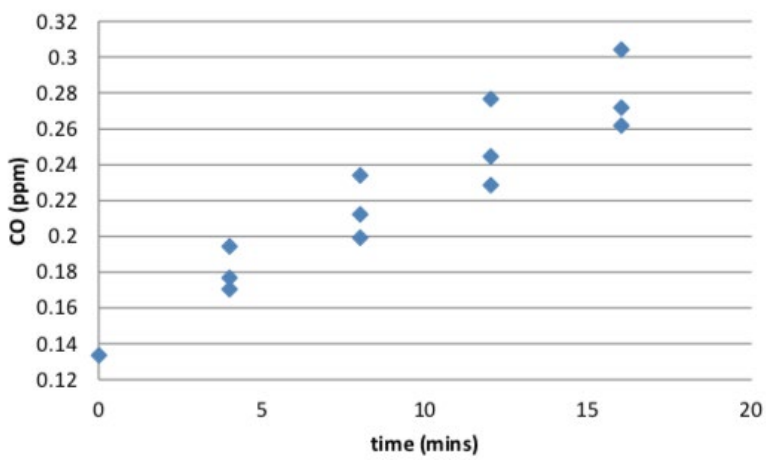

Fig. 7.4.2: *chamber measurement of CO on lead ice (thickness: 93cm)*

Data management

The underway observation and chamber data are available according to the data policy of the MOSAiC expedition.

7.4 Organic Sulfur Cycling in Arctic Sea Ice and Seawater

Jacqueline Stefels[1], Maria van Leeuwe[1] (not on board), Deborah Bozzato[1] (not on board), Alison Webb[2] (not on board), Hendrik Schäfer[2] (not on board)

[1]NL.RUG
[2]UK.UWarwick

Grant-No.: NWO 866.18.002

Objectives

Sea ice is an extreme habitat for organisms, which requires physiological adaptation of its inhabitants and results in a unique habitat with characteristic species diversity. A crucial compound for organisms to survive the cold and saline environment is dimethyl-sulfoniopropionate (DMSP) that is synthesized by algae. Between 1 and 10% of total primary production is invested in DMSP, thereby making it a key compound in the lower - and potentially also higher - trophic levels. DMSP is also the precursor of the climate active gas dimethyl sulfide (DMS). Upon sea-ice melt, DMS is released from the (potentially) huge pool of DMSP, present in sea-ice organisms. After emission to the atmosphere, the oxidation of DMS affects atmospheric chemistry, promoting the formation of new aerosol particles and cloud condensation nuclei (CCN) in remote marine regions, thereby contributing to regional climate feedbacks in the Arctic climate system.

The aim of the project is to carry out a detailed analysis of the organosulfur cycle over the course of the MOSAiC campaign, thereby addressing how seasonality, sea ice and water characteristics in the Arctic Ocean affect the cycling of organic sulfur compounds. The work combines measurements of concentrations of DMSP, DMS and dimethylsulfoxide (DMSO), transformation rates of these compounds using stable isotope additions and identification of the microorganisms (microalgae, bacteria, archaea) driving these processes using molecular biological approaches (collaboration Webb/Schäfer).

During Leg 3, the main objectives were:

1. To make a thorough inventory of the DMS(O/P) distribution and concentrations in various ice types over winter.
2. To investigate the coupling of DMS(O/P) between ice and water through the impact of brine release and new-ice formation on the S-budget.
3. To investigate rates of microbial processes that drive the biosynthesis and degradation of DMSP and conversions into and loss of DMS and DMSO during the winter-to-spring transition.

The dynamics of the microalgal community throughout the seasonal changes will be explored through the use of HPLC and microscopic analysis.

Work at sea

Ice-core sampling

Ice cores were taken from both the FYI and SYI site at the Dark Site in conjunction with the all-teams, time-series sampling event, from all three BGC sites and from multiple leads that

formed during Leg 3 (Table 7.1 and 7.3). After coring with a standard Kovacs 9 cm ice corer, ice cores were brought on board and stored frozen until sample preparation typically within a few days. Using the on-board band saw, cores were divided into 10 cm sections and thawed at room temperature and in the dark in gas-tight Tedlar bags, as prepared by Damm et al. (project 7.1). Ice and slush from leads were sampled immediately. Subsamples of the melted ice were transferred to 70 ml amber glass bottles and immediately analysed for its DMS, DMSPt and DMSOt content, using a Proton-Transfer Reaction Time-of-Flight Mass Spectrometer (PTR-TOF8000; IONICON Analytik, Innsbruck, Austria).

Ice-core experiments

In addition to the above time-series sampling, a selection of ice cores was used for rate measurements using stable-isotope additions (Table 7.4.1). Ice cores were cut in 10 cm sections and stored in gas-tight Tedlar bags to which hyper-saline water and stable isotopes of DMS and DMSP were added and head space was removed. The bags were stored in a water bath in the dark for slow and homogenous melting and sampled typically after 40-50 hours.

The Fort-Ridge core received, in addition to the DMS and DMSP isotopes, ^{13}C-DIC and the sections were incubated at dim light in a culturing cabinet at 2.5°C. This considerably slowed down the melting and sampling of the melted ice took place after ~110 hours.

Tab. 7.4.1: *Ice cores used for rate experiments with samples analysed*

Action log ID	Date	Site	DMS	DMSPd	DMSPt	DMSO	PAM	HPLC	DNA
PS122/3_32-63	21/03/2020	DS FYI	x	x	x	x			x
PS122/3_33-18	24/03/2020	DS SYI	x	x	x	x	x		x
PS122/3_35-11	06/04/2020	DS FYI	x	x	x	x	x		x
PS122/3_36-4	13/04/2020	DS SYI	x	x	x	x	x		x
PS122/3_38-24	27/04/2020	DS FYI	x	x	x	x	x		x
PS122/3_39-18	04/05/2020	DS SYI	x	x	x	x	x		x
PS122/3_39-39	06/05/2020	Fort Ridge Lead	x	x	x	x	x	x	x

Seawater sampling

Since the Polarstern CTD was not accessible after the 2nd week of Leg 3, seawater sampling was always done during a BGC-team effort using the Ocean City rosette two times per week (Table 7.4). Sampling depths increased over time from 75 to ~200m and were related to the mixed-layer depth (MLD), whereby the deepest sampling depth was below the MLD. 6 depths were sampled and immediately analysed for its DMS, DMSPt and DMSOt content.

Seawater experiments

In addition, regular incubation experiments were performed with surface seawater to investigate whether production and conversion rates within the S-cycle are impacted by different light levels and by the addition of nutrients or vitamin B12 (Table 7.4.2).

For the light-curve experiments (P vs I), water was sampled from 5m depth using the Ocean City rosette, stored in two 10L carboys, transported back to the ship and left overnight at 2°C in the dark. At the start of the experiment, HPLC samples were taken for phytoplankton-community identification. Then, DMS and DMSP isotopes and ^{13}C-DIC was added to the carboys and the content of each carboy was subdivided into 6x 1L Tedlar bags. T0 samples for total DMS+DMSPt were taken from each bag to establish exact isotope additions. Bags were incubated in a culture cabinet at 2.5°C and the following constant light intensities: 0, 4,

15, 30, 85 and 100 µE PAR. After ca. 2 days of incubations, all bags were harvested for DMS, DMSPd, DMSPp, DMSOt, DNA and POC (except the first 2). All S-compounds were immediately analysed, from which the mass distributions of the isotopes can be determined. DNA samples were taken by Bowman; POC filters will be analysed at the home institute.

For the B12-limitation experiments, the same water was used as for the P vs I experiments. Triplicate 1L Tedlar bags were prepared for each of the following conditions: with nutrients added, with nutrients + B12 added and controls without anything added. All 9 bags were incubated at 25 µE constant PAR and 2.5 °C for 9-11 days. After this incubation time, each bag received stable isotopes comparable to the PvsI experiment. Bags were incubated for another day and harvested for DMS, DMSPd, DMSPp, DMSOt and DNA.

In order to investigate whether the conversion rates in the above experiments are impacted by the administered concentrations of DMS and DMSP isotopes, a control experiment was performed with a concentration range of these added compounds.

Tab. 7.4.2: *Water-incubation experiments with sampled parameters*

Action log ID	Date	Experiment	DMS	$DMSP_d$	$DMSP_p$	$DMSO_t$	POC	HPLC	PAM	DNA	DIC
PS122/3_31-19	10/03/2020	Light curve	x	x	x			x		x	x
		B12 limitation	x	x	x	x				x	
PS122/3_32-38	19/03/2020	Light curve	x	x	x	x		x		x	x
		B12 limitation	x	x	x	x				x	
PS122/3_34-64	04/04/2020	Light curve	x	x	x	x	x	x	x	x	x
		B12 limitation	x	x	x	x			x	x	
PS122/3_36-18	14/04/2020	Substrate range (2x)	x	x	x	x				x	
PS122/3_38-5	27/04/2020	Light curve	x	x	x	x	x	x	x	x	x
PS122/3_39-70	08/05/2020	Light curve	x	x	x	x	x	x	x	x	x

Finally, a set of zooplankton samples were analysed for their DMSP content in order to investigate a potential shunt for DMSP away from the microbial conversion processes.

In collaboration with Zhan (project 7.3), air bags from chamber deployments on several ice types were analyzed (Table 7.5).

Preliminary (expected) results

Only some qualitative results on the S-cycle from visual data evaluation can be provided here, since all data still need to be integrated and calculated:

- Overall the DMS concentrations were extremely low if not undetectable in water and air throughout Leg 3.
- Distinct maxima of all S-compounds could be detected in internal layers of ice cores from all sites. At the end of the leg, bottom-layer communities started to develop with increased concentrations of S-compounds.
- Zooplankton seemed to contain substantial amounts of DMSP.
- Air bags from flux chambers did not contain measurable amounts of DMS.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX).

7.5 Seasonal Sea Ice – a new Source of Bromine during Polar Night

P. Simões Pereira[1], K. Abrahamsson[1] (not on board), A. Dumitrascu[1] (not on board), and A. Saiz Lopez[2] (not on board)

[1]SE.UGOT
[2]ES.CSIC?

Objectives

The main objective of our research project during Leg 3 is to study emissions of naturally occurring halogenated trace gases (i.e. volatile halogenated organic compounds – vHOC –, or halocarbons) during the transition from polar winter to springtime. Halocarbons exert an important control on atmospheric chemistry, as they are photochemically degraded to reactive halogens in the atmosphere which initiate the depletion of ozone and other climate active compounds such as dimethyl sulfide. Despite a wealth in research over the last decades to generate global budgets of halogenated compounds, observational data for the Central Arctic is still scarce, hindering accurate prediction of future atmospheric ozone concentrations in the years to come. In Antarctica, recent studies have shown that sea ice and snow surfaces provide major controls on halogen budgets during polar winter, with estimates of ozone-depleting halogen fluxes from seasonal ice to the atmosphere being 100 to 1000 times higher than during the summer. The exact biogeochemical processes involved in the formation and fluxes of these compounds remain, however, poorly understood or quantified, especially for the polar winter and springtime.

The main focus of the Leg 3 phase of our project is to continue with the time-series of halocarbon measurements in ocean, sea ice and air that was initiated during Leg 1 and carried on throughout Leg 2. These time-series will allow investigating the evolution of halocarbon fluxes and budgets in the Central Arctic during the crucial transition from polar winter to springtime, which is characterized by the return of sunlight to the floe, persistent cold temperatures but slower to no ice growth. This data will allow studying the different biogeochemical processes that occur within the various interfaces. Furthermore, our results will permit for the first time to evaluate the role of sunlight on the overall halocarbon flux in the Central Arctic during this period. Overall, I will measure halocarbon concentration in a variety of samples ranging from ocean water, sea ice, snow, frost flowers, brine and atmosphere. We will estimate the contribution of seasonal sea ice to the load of halogens in the atmosphere, with the overarching goal to amend existing uncertainties in global flux models of halocarbons and therefore improve current climate models.

Work at sea

Time-series of brominated, iodinated and chlorinated halocarbon compounds were conducted in ocean water, sea ice and atmosphere. For the sea ice study, research was carried out at the same study sites as during Legs 1 and 2, i.e. BGC1-3, the dark sites FYI, SYI and Lead, as well as the L-sites 1 and 2. Because of the gradual break-up of the MOSAiC floe since March 11, sampling campaigns to individual fields became increasingly irregular and opportunistic given the sporadic access possibilities to the sites. Due to the increased workload throughout Leg 3, we ceased with the continuation of the DS Lead time-series (for all of the BGC parameters). Two ice cores were taken for the halocarbon project during each BGC and DS and L-sites field campaign and taken back to the ship for further processing. Sea ice cores were consistently longer than 1.5m and on several occasions longer than 2m on SYI and rafted FYI. Ice cores were then cut in 5 to 10 cm sections with an electric saw and thawed at room temperature away from the light in gas-tight Tedlar™ bags. Samples were filtered before analysis if they presented significant amounts of particular algaes and sediments. Throughout

most of the Leg 3, first-year ice cores from each campaign were processed separately for halocarbon analysis, except towards the end of the leg when corresponding sections of each cores were merged and thawed together. Most of the second-year samples for the halocarbon project were taken from the leftovers of the processed cores for the methane isotope and concentration project (processed similarly as for the halocarbon project). Depending on sea ice type and snow thickness, two snow separate depth-profiles were taken at the same location of the coring event, with an emphasis on snow deposited on first-year ice. In the framework of the snow-salinity experiment that we started on Leg 2, high-resolution sampling (1-2cm depth profiles) and computer tomography (CT) profiling of the snow-ice interface were periodically performed at BGC 1 in collaboration with the ICE team. The aim of this project is to identify the process to which brine moves between the ice and snow, and influences the transport or flux of halocarbons between these two layers. To this end, we removed the saline snow cover from a small area at BGC 1 and let drifting fresh and non-saline snow accumulate in the newly made pit. Subsequent sampling of this snowpit will hopefully provide clues on brine transport and halocarbon flux from ice to snow.

In addition to sea ice sampling, a large number of frost flowers, slush and newly formed ice were collected at various locations within and around the MOSAiC floe. Shorter time-series of sea ice formation and growth will help assessing the importance of new ice and lead in the overall halocarbon budget during this time of the year. Slush and frost flowers contain high concentrations of bromoform (a halocarbon) and are therefore of scientific interest for this project. Brine samples from interstitial pores and channels of the sea ice were collected from various sackholes at different depths at BGC 1 and on a lead at Fort Ridge.

Ocean water samples were primarily taken from the CTD rosette sampler of Ocean City. The break-up of the floe and repeated grinding of the ice near the Polarstern led to the demolition of the hole near Polarstern that was used for the ship's deep CTD cast. Only one deep CTD cast was taken prior to the break-up and one final deep cast taken at the end of Leg 3 when the ship departed from the floe.

Measurements of discrete samples from the field were complemented by continuous measurements of halocarbon concentrations in surface seawater (from the ships underway inlet system) and air samples (extracted from ca. 25m altitude through a ~100m long 4mmTeflon tube with an air pump downstream of the tubing).

All discrete and continuous samples were measured for a set of halocarbon compounds, mainly $CHBr_3$, CH_2Br_2, $CHCl_2Br$, $CHClBr_2$, CH_3I, CH_2ClI and CH_2I_2. Two independent sets of instruments were used for the discrete and continuous samples, respectively. The discrete samples were measured on a purge-and-trap system with autosampler connected to a gas chromatograph with an electron counter detector, while the continuous samples were fed directly into a customized purge-and-trap system, also attached to a (separate) gas chromatograph with an electron counter detector.

The return of the sunlight beginning of March also allow to resume with the measurements BrO and IO in the atmosphere with the MAXDoas that is installed on the P-Deck of the ship.

Preliminary results

Sea ice and snow

Similar to Leg 1 and 2, first-year ice sites (i.e. DS, BGC1, BGC3) present significantly higher concentrations in bromoform ($CHBr_3$) than other types of ice (second-year ice, lead ice, ridges). Overall, we observe a sharp decline in bromoform concentrations in FYI over time (Fig. 7.6.1). Bromoform concentrations in the upper 5 cm of the core decrease from ~2000 to ~400 pM between January 31 and May 9 at BGC 1, and from ~1600 to ~400 pM between March 21 and May 10 at DS FYI. These findings contrast with observations from Legs 1 and 2, when bromoform concentrations in the surface core increased steadily over the course of the polar winter. High-resolution sampling shows that salinity plays an important role in the spatial distribution of these halocarbons within the same field. The significant decline in bromoform

over time relates, however, most likely to other biogeochemical processes. Such processes could be related to the atmosphere through possible interaction with ozone or other reactive gas compounds, or with the overlying snow which also present high concentrations of the same compound. This hypothesis will be more carefully investigated during the postcruise phase.

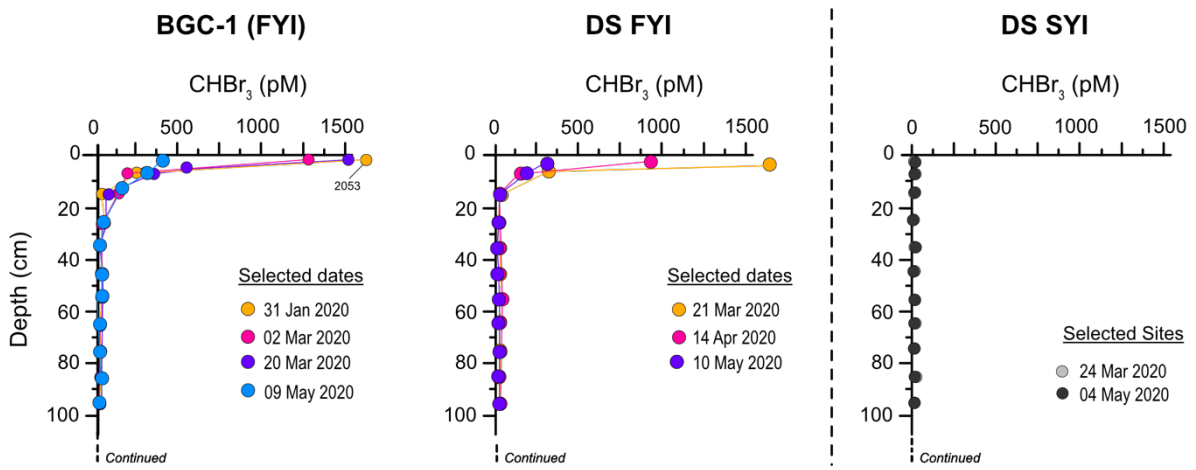

Fig 7.6.1. *Bromoform ($CHBr_3$) concentrations in first-year (BGC-1 and DS FYI) and second-year (DS SYI) profiles. Note the striking difference between FYI and SYI (right panel: grey circle is behind the black circle), as well as a pronounced decrease in bromoform concentrations over time at the surface of the ice core.*

In addition to bromoform, other halocarbons also show significant changes over time. Iodinate compounds, such as CHI_3 (iodoform) and CH_2ClI, manifest a marked increase in concentration since about end-February (Fig. 7.6.2). In contrast to bromoform, however, the observed increase occurs prominently in shallower depths of the ice core, around 10-30 cm. This finding suggests a different type of biogeochemical process for iodoform. Iodinate compounds are generally influenced by biological activity. The observed increase in those compounds also correlates with layers of significant particular algae contents (which are visible with the naked eye after melting of the core section). The role of biological activity will be further investigated upon return on land with other team members of BGC and ECO.

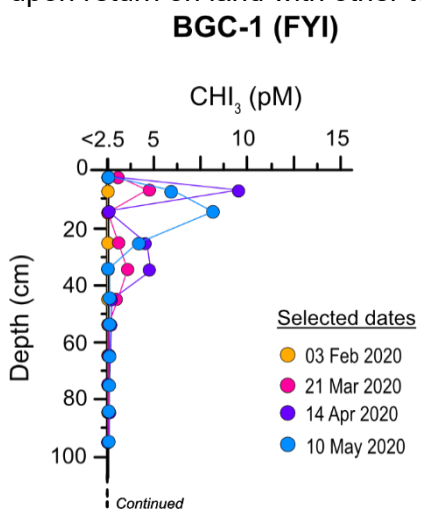

Fig 7.6.2. *Iodoform (CHI_3) concentrations in first-year (BGC-1) profiles. Since beginning of February, iodoform has increased above detection limit (~2.5 pM). The role of biology in iodoform production will be further investigated.*

Frost flowers, slush, leads, ridges and brine

Numerous samples of frost flowers, slush and new ice were taken from the field and analyzed for halocarbon concentrations. Similar to Leg 2, we observe high bromoform concentrations in all high-saline samples, especially in frost flowers and slush. The different environmental and

climate setting between Leg 2 and Leg 3 resulted in lower brine inclusions in most of the frost flowers, a phenomenon that will be further investigated postcruise. As a consequence, bromoform (and other brominated compounds) concentrations in frost flowers were less pronounced compared to Leg 2. Increasing ice dynamics during Leg 3 resulted in several lead (or crack) openings and closings, impeding time-series of ice growth on leads. Overall, halocarbon concentrations were low in new ice. An initial study on ridges aimed to collect shallow cores from several sides of an extruded block of ice (most likely FYI type) on a ridge near Met City. We observe different trends that are distinct from FYI profiles, which will be explored after the cruise. Brine was regularly collected from sackholes from BGC 1 and Fort Ridge. While BGC 1 produces brine with high bromoform concentrations, brine collected from the Fort Ridge lead (~50cm thick) record markedly lower concentrations of bromoform. Because of the relatively thin and permeable ice at Fort Ridge, seawater is likely to penetrate the ice through brine channels, resulting in overall low concentrations of halocarbons in brine from this site. This finding is important to examine the biogeochemical role of brine in the production of halocarbons in sea ice.

Ocean water

Similar to Leg 2, preliminary results of halocarbon measurements in ocean water (mainly from Ocean City) show a persistent well mixed surface layer, with relatively similar halocarbon concentrations through this layer up to the halocline, especially for chlorinated and brominated compounds. We also observed a thickening of this “winter mixed layer” over the course of Leg 3, as evidenced by the deepening of the halocline. Time-series of iodinated compounds since the start of Leg 2 reveal the marked deepening of the halocline (Fig. 7.6.3). We further observe a steady decrease in their concentrations over time. Whether this observation is a result of a biotic or abiotic process will be investigated postcruise. Beneath the halocline, concentrations of all brominated and iodinated compounds decrease sharply to lower values. Chlorinated compounds indicate the presence of different water masses beneath the halocline, but time-series for the lower depths has been severely hampered by the break-up of the hole meant for the deep CTD casts during Leg 3.

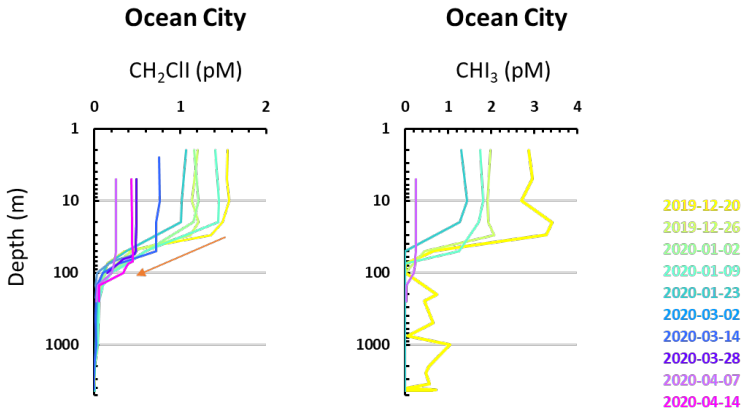

Fig 7.6.3. *Concentration profiles of iodinated compounds (CH2ClI and CHI3) in ocean water. Note a marked thickening of the well-mixed “winter mixed layer” which is concurrent with a deepening of the halocline (orange arrow). General decrease of iodinate compounds could be related to biotic or abiotic processes.*

Data management

All data from Leg 3 will be processed during the postcruise phase of the expedition. Quality control of the data will be based on standard calibrations and reproducibility of the instruments, as well as on an inter-calibration between the two independent instruments as soon as the participants are back on land. The data will be made available according to the data policy of the MOSAiC expedition.

7.6 Cosmogenic ^{7}Be as a Tracer of Atmospheric Fluxes of Trace Elements.

Chris Marsay[1], David Kadko[2] (not on board), William Landing[3] (not on board), Clifton Buck[1] (not on board), Mark Stephens[2] (not on board)

[1]US.SkIO
[2]FI.FiU
[3]US.FSU

Objectives

The radionuclide ^{7}Be (half-life 53 days) is produced in the atmosphere by cosmic radiation and deposited onto the ocean and ice surface via precipitation. Its known half-life and source enable us to quantitatively determine the fluxes of airborne particles that deliver trace elements to the Arctic Ocean ecosystem. However, no winter data from the Arctic are available so far. Our objective is to combine measurements of ^{7}Be in snow, ice and seawater with trace metal data from a time-series of aerosol collection, establishing the first winter time-series of atmospheric trace metal fluxes in the Arctic.

Work at sea

By measuring the inventory of ^{7}Be in snow, ice and seawater, we can determine the flux of ^{7}Be at the MOSAIC study area. The ^{7}Be fluxes will then be used with concentrations of trace elements and ^{7}Be in aerosol particles to calculate trace element fluxes.

Snow Sampling

24 bulk snow samples were collected during Leg 3. An area of at least 25x25cm was marked off and the entire snow column within that square was scooped into a clean bucket. Sites sampled included BGC1, BGC2, BGC3, Snow 2, Dark Site FYI coring site, L2 Site, and also leads at the Dark Site and the logistics area. Snow depths varied from 1.5cm to 25.5cm.

Snow profiles, in which two to four different depth intervals of the column are sampled separately, were collected at BGC1, BGC2, David's Ridge, Snow 2, and ROV City and a lead at the Dark Site. Sites were chosen to represent different depositional environments (e.g. flat area, drifting snow accumulation near ridges, etc.). Thirteen profiles were sampled during Leg 3, with total snow depths ranging from 7.5 to 56.8cm. Bulk snow and snow profile samples for ^{7}Be analysis are included in Table 7.2.

Fresh, falling snow or blowing snow was sampled by deploying a bucket attached to a rail on the p-deck of Polarstern during four events with winds ranging from light to moderate.

Ice Sampling

Ice cores were collected using a Kovacs 9cm corer at three sites (BGC1, Dark Site FYI, and the Dark Site lead). Three or four cores were collected each time and combined for one sample. Except for the Dark Site lead cores (92cm long), core lengths ranged from 153cm to 184cm. Ice core samples collected for ^{7}Be analysis are included in Table 7.1.

Sample Preparation

Snow and ice samples were prepared for gamma counting according to the following steps:

1. Samples were melted and acidified with 10ml of 6N HCl.
2. Iron chloride solution and stable beryllium spike were added to the sample.
3. After an equilibration period, the sample was precipitated using sodium carbonate.

4. The precipitate was centrifuged, washed, collected, dried and placed in a gamma counting vial.

Seawater Sampling

Mixed layer ^{7}Be concentrations will be determined from samples obtained in the Polarstern fish lab. Two 700 liter plastic tanks were filled from the seawater intake. The water was then pumped through an iron impregnated acrylic fiber filter, which absorbs beryllium. This procedure was carried out eleven times during Leg 3 (once per week).

It was not possible to collect any seawater samples from ten meters below the mixed layer, due to it deepening to more than 60m in early March (only 60m of hose was available). However, samples from deeper within the mixed layer were collected from the Polarstern CTD hole on 13th March (from 35-40m depth), and from the ROV City hole on 8th April and 29th April (both from around 60m depth). For each of these samples, approximately 2000 liters of water were pumped through fibers using a centrifugal pump and a PVC hose with an attached Seabird SBE19 CTD. Water column samples for ^{7}Be analysis are tabulated in Table 7.6.1.

Tab. 7.6.1: *Water column sampling for ^{7}Be with depth of sample collection (no depth shown for samples collected in the fish lab through the ship seawater intake)*

Action log ID	Date	Site	Depth
PS122/3_30-24	04/03/2020	Polarstern seawater intake	--
PS122/3_31-49	11/03/2020	Polarstern seawater intake	--
PS122/3_31-93	13/03/2020	Polarstern CTD hole	37m
PS122/3_32-19	17/03/2020	Polarstern seawater intake	--
PS122/3_33-22	24/03/2020	Polarstern seawater intake	--
PS122/3_34-25	31/03/2020	Polarstern seawater intake	--
PS122/3_35-55	07/04/2020	Polarstern seawater intake	--
PS122/3_35-54	08/04/2020	ROV City	60m
PS122/3_36-142	15/04/2020	Polarstern seawater intake	--
PS122/3_37-91	20/04/2020	Polarstern seawater intake	--
PS122/3_38-28	28/04/2020	Polarstern seawater intake	--
PS122/3_38-114	29/04/2020	ROV City	60m
PS122/3_39-15	05/05/2020	Polarstern seawater intake	--
PS122/3_40-2	11/05/2020	Polarstern seawater intake	--

Aerosol Sampling

Our bulk aerosol equipment consists of a Tisch high volume sampler fitted with twelve replicate Whatman W41 filters, a heated sonic anemometer, and a rain and snow sensor. The device is programmed to sample only when there is no precipitation and the wind direction is within 60 degrees of the bow (clean air, free of stack exhaust), though it can also be operated with no sector control settings. An additional sampler can be fitted with a five-stage impactor to collect size-fractionated samples.

The prevailing wind conditions during much of Leg 3, with wind coming from behind the ship made it very difficult to collect samples suitable for trace metal analysis, although samples were collected without sector control to get aerosol samples for ^{7}Be determination. Over the duration of the leg, a total 18 bulk and 6 size-fractionated samples were collected, with deployment periods of 1-5 days duration (Table 7.6.2).

Tab. 7.6.2: *Aerosol samples collected for ^{7}Be and trace metal analyses*

Action log ID	Deployment date	Recovery date	Bulk/size-fractionated
PS122/3_31-92	14/03/2020	18/03/2020	bulk
PS122/3_32-100	22/03/2020	24/03/2020	bulk
PS122/3_33-114	24/03/2020	25/03/2020	bulk
PS122/3_34-105	03/04/2020	04/04/2020	bulk
PS122/3_34-106	04/04/2020	07/04/2020	bulk
PS122/3_35-141	09/04/2020	11/04/2020	bulk
PS122/3_36-175	13/04/2020	16/04/2020	bulk
PS122/3_36-177	15/04/2020	20/04/2020	size-fraction
PS122/3_36-176	16/04/2020	18/04/2020	bulk
PS122/3_37-144	23/04/2020	25/04/2020	bulk
PS122/3_37-147	23/04/2020	26/04/2020	size-fraction
PS122/3_37-145	25/04/2020	26/04/2020	bulk
PS122/3_37-146	26/04/2020	30/04/2020	bulk
PS122/3_38-136	30/04/2020	03/05/2020	bulk
PS122/3_38-138	30/04/2020	03/05/2020	size-fraction
PS122/3_38-137	03/05/2020	07/05/2020	bulk
PS122/3_38-139	03/05/2020	08/05/2020	size-fraction
PS122/3_39-128	07/05/2020	09/05/2020	bulk
PS122/3_40-38	14/05/2020	20/05/2020	bulk
PS122/3_40-37	14/05/2020	20/05/2020	size-fraction
PS122/3_41-18	20/05/2020	26/05/2020	bulk
PS122/3_41-19	20/05/2020	26/05/2020	size-fraction
PS122/3_42-44	28/05/2020	31/05/2020	bulk
PS122/3_42-45	31/05/2020	02/06/2020	Bulk

Preliminary results

Unfortunately no gamma spectra for the snow and ice core samples could be obtained during Leg 3 due to an unresolved problem with the Canberra germanium gamma detector brought on Polarstern for the project, and so there are no preliminary results to report. Determination of chemical yield and ^{7}Be activity will be performed following Leg 3 at Florida International University.

All trace elements analysis of aerosol samples will be performed after Leg 3 at Skidaway Institute of Oceanography.

Data management

The CTD data and the wind and precipitation data associated with the aerosol sampler are available according to the data policy of the MOSAiC expedition.