EXPEDITION REPORT

SWEDARCTIC
Arctic Ocean 2018

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Arctic Ocean 2018: MOCCHA – ACAS – ICE

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Arctic Ocean 2018: MOCCHA – ACAS – ICE

1 Introduction

1.1 Background to the US-Swedish collaboration on Arctic Ocean 2018 (Dr. Gårdfeldt)

An US-Swedish workshop on joint Arctic Ocean research was held in Sigtuna, Sweden in late March 2015. Building on earlier successful cooperation in polar research between Sweden and the US, the aim of the workshop was to increase scientific collaborations using the icebreaker I/B *Oden* as a platform for Arctic Science[1].

The workshop was funded by the Swedish Polar Research Secretariat (SPRS) and the US National Science Foundation (NSF) Polar Programs (PLR) and jointly organized with the Swedish Research Council VR (VR) and the Swedish Research Council Formas (Formas).

Approximately 15 scientists from each nation (selected through an open process), funders, and logistics personnel from the US and Sweden participated. Three objectives were addressed: (1) Prioritization of scientific themes, geographical regions, sampling seasons, international collaborations and future demands on technology in this harsh environment; (2) Scientific priorities, collaboration and synergies for a first expedition focusing on the "Linkages and feedbacks among surface energy, cloud formation, biological processes and climate in the High Arctic"; and (3) A process for joint, international decision-making, funding and logistics.

It was stated that ship-time onboard I/B *Oden* would be continued to be driven by merit-reviewed funded proposals through regular proposals in the US and Sweden. The workshop provided an opportunity to explore the scientific and interagency context that would enable these collaborations to develop.

A bi-lateral agency meeting between NSF, VR, Formas, and SPRS was held and followed up by a discussion with the workshop participants. It was stated from the Swedish side that Sweden had decided to start the logistic planning for the "High Arctic clouds" proposal which belongs to the Swedish National Programmes for polar research selected in a peer review process through VR and Formas[2]. Data management was also discussed, and it was stated that that the Arctic US-Sweden collaboration will involve data sharing agreement that address both sharing of data among PIs and for long term public archival and access.

Outcomes from the workshop were presented at a meeting at the House of Sweden in Washington, DC, US and a Research Agreement between Sweden and the United States was signed on May 25th 2015. The agreement resulted in a joint research expedition to the Arctic 2018 and positive synergies for future Swedish polar and climate research.

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[1] Matrai, P., C. Leck, P. Minnett, L. Anderson. 2015. U.S-Swedish Planning Workshop on Joint Arctic Research using the I/B Oden. Sigtuna, Sweden. 27pp. https://polar.se/dok/oden-arctic-report-final.pdf

[2] SWEDARCTIC och SWEDARP Svenska nationella polarforskningsprogram. 2014 och framåt. ISBN 978-91-7307-238-0

1.2 Background to the Expedition Arctic Ocean 2018 (Drs. Leck & Matrai)

The expedition Arctic Ocean 2018 with the icebreaker I/B *Oden* was conducted by the SPRS in collaboration with NSF. The main theme for the research was the “Life cycle of clouds in the high Arctic summer with linkages to the microbial life in ocean and ice”.

To obtain the best circumstances to achieve the stated scientific goals discussed in Section 2, I/B *Oden* sailed into the High Arctic where the ship, logistics and scientific staff scouted for a suitable ice floe to sample from. I/B *Oden* was moored to this floe for approx. 5 weeks in mid-August 2018 such that the scientific work could cover the minimum ice extent period and, most importantly, the refreezing processes.

Arctic Ocean 2018 used 5 work packages (WP) to achieve the stated aims of understanding the controlling factors of the proposed negative feedback involving micro-organism and clouds over the Arctic pack ice area. This 5 WP grouping reflects the outcome of the 2 science workshops held prior to the expedition and agreed upon by the participating scientists at the time (section 6).

WP1: Meteorology and vertical profiling

WP2: In-situ characterization of ambient gases, aerosols and clouds

WP3: Air-sea interaction

WP4: Sea surface microlayer composition

WP5: Physics, microbiology and biogeochemistry of ocean water and ice

Table 1 shows how different projects in the field and their responsible PIs in the field combined into the WP. All projects, including land-based PIs, and collaboration between projects in field and in subsequent lab work are presented in section 4.

Table 1. The work packages onboard I/B *Oden* during the expedition Arctic Ocean 2018

WP	Research project	PI in the field
1a	Arctic climate across scales (ACAS) [3]	Dr. Michael Tjernström
1b	Cloud & boundary layer measurements (MOCCHA) [4]	Dr. Ian Brooks
1c	Vertical profiling of turbulence, aerosol and cloud water with tethered balloons (MOCCHA)	Dr. Ian Brooks
2a	Aerosol-cloud interactions in the High Arctic (MOCCHA)	Dr. Paul Zieger
2b	Identifying the origins of summertime Arctic cloud condensation nuclei usingo online fine aerosol composition measurements (MOCCHA)	Dr. Michael ‘Mike’ Lawler
2c	The sources, concentrations and impact of ice-nucleating particles in the high Arctic (MOCCHA)	Grace Porter
2d	The life cycle of clouds in the High Arctic summer with linkages to the microbiological life in ocean and ice (MOCCHA)	Dr. Caroline Leck
2e 3a	Marine aerosols in the Arctic: linking surface water chemistry and biology with primary particle production (MOCCHA)	Dr. Patricia ‘Paty’ Matrai

[3] ACAS: Arctic Climate Across Scales
[4] MOCCHA: Microbiology-Ocean-Cloud-Coupling in the High Arctic

3b	Quantifying the source of aerosols from open leads in the High Arctic (MOCCHA)	Dr. Matt Salter
3c	Bubbles near sea ice & their contribution to aerosol production (MOCCHA)	Dr. Helen Czerski
4a	Sea surface microlayer sampling and the role of transparent exopolymer particles (MOCCHA)	Tiera-'Brandy' Robinson
5a	Spatial and temporal variability of (bio-) physical properties of the atmosphere, sea ice and upper ocean (ICE)[5]	Dr. Mario Hoppmann
5b	Microbial oceanography links to new aerosols in the ice-covered regions in the High Arctic (MOCCHA)	Dr. Giacomo 'Jack' Di Tullio
5c	The impact of seasonal sea ice on the contribution of ozone depleting halogens in the Arctic (ICE)	Dr. Katarina Abrahamsson
5d	The effect of carbonate chemistry on the sea ice community in the High Arctic (MOCCHA)	Dr. Walker Smith

[5] International Cooperative Effort

2 The Scientific Layout of the Expedition Arctic Ocean 2018 (Drs. Leck & Matrai)

2.1 Scientific motivation

An adequate understanding of the past and the present Arctic climate, and of the processes that shape it, is key to projecting the future of this unique region, and the climate impact on society, including health, social issues and commerce. Over the last several decades, climate change has been larger in the Arctic than elsewhere on Earth, with the most obvious consequence being a rapidly diminishing sea ice extent and mass. There is not yet a clear understanding of the strong feedback mechanisms, local and distant, between climate and sea ice, nor any consensus on their relative importance.

The surface energy budget is an essential component of the changing Arctic, both through direct means and through various feedback processes, which might be well described, at least conceptually, but currently lack quantification and understanding of details.

Clouds are critical in modulating the radiative components of the surface energy budget in all seasons, both directly and through cloud-related feedbacks. Knowledge of cloud occurrence and formation, microphysical properties, phase partitioning and many cloud processes is inadequate, and consequently these processes are not correctly represented in models. A major problem in characterizing the surface energy budget results from surface heterogeneities, especially in transition regions and periods where open water and sea ice occur on a wide range of spatial scales. Most of these are not resolved in current coupled ocean-ice-atmosphere models. An adequate understanding is lacking of the relative importance of local and remote sources of moisture, heat, and aerosol particles and how these impact cloud formations. Two-way interactions in open leads of the pack ice are important in the exchanges between atmosphere and ocean, and for the energy budgets in the ocean mixed layer, atmospheric boundary layer, and sea ice surface. The vertical mixing processes communicate information across an otherwise stratified atmospheric environment.

Measurements are required in all seasons; winter conditions are especially understudied, particularly the impact of leads on energy exchanges. Data from the transition seasons are needed because of the influence of energy fluxes on forcing the transitions and the changes in energy exchange processes. In the summer, large radiative fluxes have importance for ice melt processes.

The significant temporal variability of Arctic climate on not only inter-annual but also on inter-decadal time scales necessitates long-term data collection across different years. A major impediment to such long-term measurements is the hostility of the Arctic environment and the sheer complexity of accessing the region routinely. There are very few weather observations from the central Arctic Ocean and almost no information at all on the vertical structure of the atmosphere from regular *in situ* observations since continuously drifting sea-ice hinders measurements at any fixed point. Further, although there is a wealth of information from polar orbiting satellites, these have poor coverage in the central Arctic and it remains difficult to retrieve quantitative information, in particular near the ocean surface.

To ensure the continuity of our sparse archives of Arctic *in situ* data, unique measurements were conducted during a research cruise to the high Arctic in summer and autumn 2018 aboard the Swedish icebreaker (I/B *Oden*). The main activities took place while I/B *Oden* was moored to an ice floe in the inner pack ice area and drifted passively, transitioning the biologically most active period into autumn freeze-up conditions, roughly mid-August through mid-September. Instruments were deployed on board I/B *Oden* and on the ice. Additional sampling was performed during the transit into and out of the ice, before and after the ice camp was established.

The frame setting scientific motivation behind the Arctic Ocean 2018 expedition should be viewed in the context of a series of unique Swedish-led international atmospheric studies on icebreakers to the high Arctic (north of 80°) in the years of 1980, 1991, 1996, 2001, and 2008 to remediate the largest deficiency in previous cruises: **understanding in what way the**

life cycle of clouds over the central Arctic Ocean is linked to the microbiological life in the ocean and ice.

The Arctic Ocean expedition received scientific support from three complimentary programs: MOCCHA (Microbiology-Ocean-Cloud-Coupling in the High Arctic), ACAS (Arctic Climate Across Scales), and ICE (International Cooperative Effort, on ice work). The expedition was part of both the Swedish road-map for Polar Research "2014 and beyond" and of the US-Swedish Arctic scientific cooperation[2].

A negative feedback involving microorganism and clouds

The shrinking area of summer sea ice is one of the most visible manifestations of Arctic climate change. Sea ice reflects incoming solar radiation, while the open ocean absorbs and stores solar radiation during the summer. Later, during the autumn, this heat is released and further warms the atmosphere. As more ocean is exposed, a positive feedback loop develops accelerating summer sea ice melt.

But low-altitude clouds (usually called low-level clouds), while modulating the radiative components of the Arctic surface energy budget, could potentially counter the warming. For most of the year, such clouds tend to warm the Arctic surface. However, during the peak-melt season at the end of the summer, low-level clouds may cool the surface and thereby influence the timing of the autumn freeze-up. Earlier freeze-up will cause thicker ice that might melt less during the following summer, surviving into the subsequent winter. If such a process were to recur over several years, it could delay or even prevent sea ice from melting completely during the Arctic summer. In other words, *it would constitute a negative feedback*.

The most common type of low-level clouds in the Arctic is a mixed-phase cloud where the cloud top contains a relatively thin layer of liquid water that semi-constantly precipitates ice particles. Neither the processes that control the balance between formation of either liquid or ice water in the clouds, nor those that control the resilience of the clouds and their impact on the vertical structure of the Arctic atmospheric boundary layer are well understood. However, the clouds form first in the liquid phase and are dependent on tiny airborne aerosol particles, known as cloud condensation nuclei (CCN), while the transition to ice is critically dependent on the part of the aerosol population that could form ice crystals, known as ice nuclei (IN). Presently, the exact properties of a good IN are neither well identified nor quantified.

The optical properties of the summer Arctic low-level clouds relate to clean air (limited man-made influence) with its low concentration of cloud droplets. Therefore, the Arctic low-level clouds are often optically thin, that is, have fewer but larger droplets compared to other regions. This makes them reflect less shortwave radiation than clouds with numerous but smaller droplets, everything else being the same. Combined with the semi-permanent ice cover, small changes in either are very important to the heat transfer to the ice and the subsequent summertime ice-melt. An increase in CCN in summer could increase the albedo of the clouds (more reflecting), as the condensed water is distributed over many small droplets rather than over a few large ones, and therefore lead to decreased ice-melt.

A link between CCN and microorganisms has been demonstrated over the pack ice, more specifically via marine biogenic polymer gels that are also present in aerosol particles, cloud and fog water. Sea ice microalgae and phytoplankton are likely to be strongly affected by changing sea ice conditions. But whereas both groups generate dissolved organic matter (DOM) and are hence a potential source of airborne gels, their relative importance in the central Arctic Ocean is still not fully understood.

Recent observations of extensive sub-ice phytoplankton blooms suggest increased biological activity as the Arctic warms. If the blooms are found to be a strong contributor of aerosol precursors, phytoplankton might facilitate an increased reflectivity of the low-level clouds, which helps counteract enhanced ice melt. On the other hand, the melting of sea ice might reduce or even eliminate the habitat of ice algae and reduce their role as a source of biogenic aerosols.

The presence of sea ice significantly controls wind-driven mixing of the surface layer of the central Arctic Ocean. Combined with light availability, this has kept phytoplankton mostly at the surface. Thinner ice or more open ocean areas would allow the wind to mix the surface ocean more effectively, deepening the mixed layer, thereby potentially reducing algal growth.

As ice algal DOM has, during the most recent expedition in 2008, been confirmed to be a major source of airborne gels, future warming might imply a reduced supply of CCN and thus very optically thin clouds with enhanced surface warming. On the other hand, ice formation during freeze-up excludes salt brine and other substances, including DOM likely assembled as primary particles that could end up in both the surrounding water and the atmosphere with implications for new particle formation and cloud droplet activation during this crucial period. How microorganisms in seawater and/or sea ice respond to the melting sea ice will thus influence formation of Arctic low-level clouds and their optical properties, and perhaps the rate of future melting.

Clearly, there are too many unknowns at this stage to fully assess the likelihood of a negative feedback involving microorganisms and clouds. But given how sensitive the Arctic is to climate change and how important it is for the regional and global radiation balance, there is a strong rationale for continued research to test this hypothesis. Further, the processes that control potential links between cloud radiative properties and marine primary production are not only in their infancy, many of the controlling processes remain obscure or poorly constrained.

Examples of questions that still remain, that also formed the scientific rationale behind the Arctic Ocean expedition 2018:

- How large is the control for DOM release on radiation/photochemical processes, temperature and nutrients availability in water and ice?
- How can primary marine biogenic particles be transferred from the ocean surface microlayer into the atmosphere, and how does this depend on oceanic and atmospheric properties?
- How large is the contribution of high Arctic marine biogenic sources (over the pack ice and/or from the marginal ice edge) of CCN or IN, compared to transport of aerosol particles and precursors from outside the central Arctic, and how efficient are they as CCN and/or IN?
- How are aerosol particles formed and transformed in the atmospheric boundary layer and inside the clouds?
- How efficient is the exchange between the surface and the free troposphere where other aerosols or aerosol precursors may exist, and what are the effects on the clouds by this exchange?
- What meteorological conditions favor the formation of optically thin clouds?
- How do the clouds affect the surface energy balance?

2.2 Sampling considerations and limitations

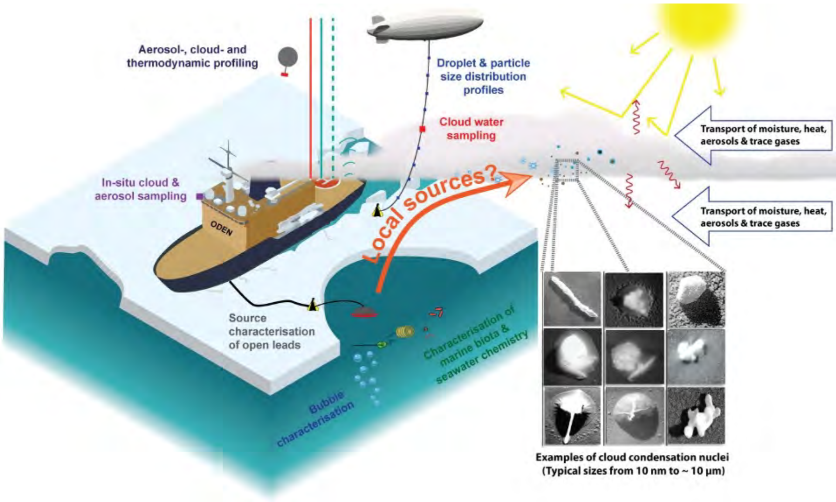


Figure 1**.** The figure outlines the identified basic needs of characterisation of marine biota (ocean and ice), gas/aerosol chemistry/aerosol/cloud physics, meteorology, as well as physical and chemical oceanography that will advance our understanding of the key questions listed above.

To fully assess the likelihood of a negative feedback involving microorganisms and clouds not only requires an interdisciplinary approach but also necessitates an integrated approach of data collection. Arctic Ocean 2018 (AO2018) was therefore designed with contributions from experts from across many fields in the natural sciences: synoptic-scale and boundary-layer meteorology, atmospheric gaseous and particulate phase chemistry and physics, marine chemistry and biology, and physical oceanography. The integrated approach of the data collection was accomplished by deploying multiple observation systems that track various aspects of the system from the upper 1000 m of the ocean, through the air–sea interface and the lowest atmosphere including the clouds, up through the free troposphere, with a focus on the lower parts of the atmosphere. Sampling rates were different for different variables, ranging from 10 Hz for the turbulence observations, over seconds and minutes – for clouds and gaseous compounds, some aerosol physics and surface heat fluxes – to a few samples per day or every fourth day for marine chemistry and biology, and aerosol chemical composition. The sampling strategy in each case was determined by a combination of the scientific requirements and practical considerations and utilized a number of innovative techniques and novel measurement approaches.

Vertical profiling of several parameters is part of the questions listed above, especially considering the multi-layered structure of Arctic low-level clouds. In particular for linking aerosol particles and gases measured on the ship to properties and processes in the clouds, profile observations are indispensable. *In situ* observations of cloud microphysics were utilized through an extensive suite of surface-based remote-sensing instruments deployed on board the ship. This provided continuous and simultaneous high temporal- and vertical-resolution information on cloud micro - and macrophysics characteristics typically not available with *in situ* techniques.

For observation of turbulent fluxes through the clouds, we deployed a tethered lifting system, which allowed sampling of turbulence at different heights. Slow ascents/descents provided turbulence profile information using the highest frequency observations and turbulence similarity relationships. An additionally tethered system was deployed for the first time to actually collect cloud water for later laboratory analyses and to continuously record vertical profiles of aerosol, IN and hydrometeor size-distributions.

Shipboard observations are a challenge. Observations of exchange processes near the surface are sensitive to flow distortion around the superstructure of the ship. Some instruments are sensitive to the environment on board (heat transfer, hydraulic noise, vibrations, etc.). This necessitated deployment of such instrumentation away from the ship, on the ice. The size and scope of many of these instruments preclude short-term deployments, necessitating an Ice-Drift strategy with the ship moored to a drifting ice floe. This in turn requires a sufficiently thick and stable ice floe.

In the pristine Arctic environment, gases and aerosol particles must be sampled with minimum interference from the ship and from human activity on the surface immediately surrounding the ship. Measurements of aerosols challenge the detection limits of even the most sophisticated instruments. It is particularly difficult to determine the organic properties of the ambient aerosol due to the very low masses present, ranging between ca. 10^{-15} to 10^{-18} grams. Quantitative chemical characterisation of the organic constituents in airborne aerosol particles is therefore still notably fragmentary and has required advances in an array of analytical techniques not previously applied. Sufficient mass therefore had to be collected for a proper analysis, and in pristine Arctic conditions this takes time such that even brief contamination during a long sampling period can destroy the whole sample. Therefore, a procedure to detect and avoid contamination by the ship or activity on the ice had to be established together with methods to automatically interrupt sampling when necessary, due to unfavorable conditions. Because of the sampling sector restrictions, we also required the ship to be approximately facing into the wind. During the Ice-Drift. this necessitated finding, or making, a “harbor” in the ice where the ship could be moored in several main orientations, and turned as the wind direction changed. Turning of the ship unfortunately had consequences for the power supply to instruments on the ice; as such instruments on the ice need to be battery-powered, they were continuously charged through battery chargers fed by a power cable from the ship. Power was thus temporarily interrupted without affecting the measurements on the ice.

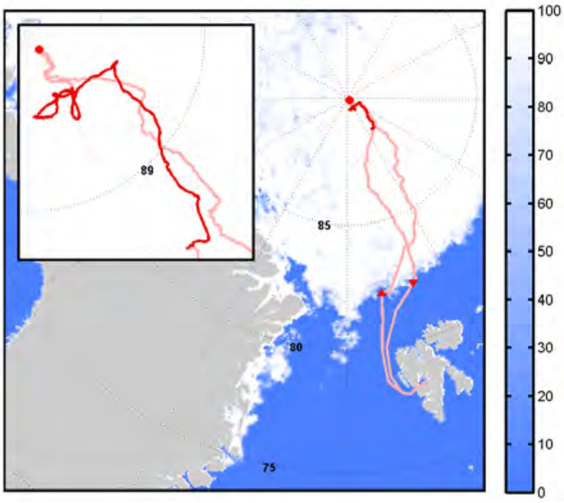
Similar contamination constraints apply for the marine chemical and biological observations. Although I/B *Oden* has an advanced system for waste management and minimizes environmental impacts, the presence of a ship in the water always means a risk of contaminated water samples. Turning of the ship also disturbs the water column in its immediate vicinity. Therefore, marine sampling had to be performed from the ice away from the ship, with a safe access to the ice edge. This also implied transporting equipment and staff across the ice on a daily basis. Instruments and computers at that site had to rely entirely on battery power, since the distance precluded powering by cable from the ship. Close coordination with the I/B *Oden* engineers also to occur daily and in advance for any sampling of seawater that required ship-based equipment, especially down to 1000m depth.

Finally, the harsh Arctic environment, with sometimes low temperatures, at times strong winds and always high relative humidity, affects both instruments and people. Because of these conditions, there was a need for instrument redundancy. Many instrument systems therefore had to be doubled and some even tripled. Risks involved in operating with people on the ice, also the natural habitat for polar bears, would affect the use of instrument systems that needed continuous manual intervention. Some systems, for example for the marine biological, oceanographic, atmospheric tethered measurements and the determination of bulk chemical mass, are labor-intensive, and manpower on an Arctic expedition is limited by the number of berths on board the ship, which also has limiting effects on some observations.

It is worth noting that, although the above discussed concerns were carefully considered in the logistical planning of the expedition, it was not until it was launched on site in the central Arctic Ocean that specific conditions could be determined. It thus fell upon the chief scientists, the scientific coordinator and the captain of I/B *Oden*, and the whole science team to be flexible and adapt, even on very short notice.

3 Sampling Design (Drs. Leck & Matrai)

3.1 Cruise Track



I/B *Oden* departed Longyearbyen, Svalbard on August 1, 2018 and returned to the same port on September 20, 2018. The cruise track is shown in pink in the figure above. The insert shows the track of the Ice-Drift Station in red. Also shown are two stations at the marginal ice zone (▲) and one at the North Pole (●).

3.2 Sampling stations

Northbound MIZ (N82º 9.28', E9º 58.17', 20180802)

This 24h station initiated atmospheric sampling in the 4th and 7th decks, though with a limited suite of instruments. Seawater samples were collected with the CTD/rosette system for the Abrahamsson (WP 5c), DiTullio (WP 5b), and Matrai (WP 3a) groups. Ice core samples were also collected.

North Pole (N89º 53.59', E38º 2.54', 20180812)

This short station (8 hours) maintained atmospheric sampling in the 4th and 7th decks. Seawater samples were collected with the CTD/rosette system for the Abrahamsson (WP 5c), DiTullio (WP 5b), Matrai (WP 3a) and Smith groups (WP 5d). Ice core samples were also collected. Much helicopter reconnaissance was done to find a suitable ice floe to establish the drift ice station.

Southbound MIZ (N82º 17', E19º 50', 20180919-20)

This 24h station maintained atmospheric sampling in the 4th and 7th decks, though with a limited suite of instruments, with all activities ending at midnight. Weather balloons were launched in the morning and evening. Seawater samples were collected with the CTD/rosette system at dawn on the 20th, prior to departure at 0600. Daily details listed in Appendix A. Many expedition participants were busily packing or had finished packing.

Ice-Drift Station (N89º 0’, E39º 11.51’ until N88º 29.56’, E39º 10.05’, 20180814-20180914)

Mobilization and demobilization of the drift ice station were only possible due to extensive SPRS logistical leadership, with on ice collaboration by the I/B *Oden* crew and multiple research groups. SPRS and I/B *Oden* bear guard assistance was invaluable. Daily details listed in Appendix A.

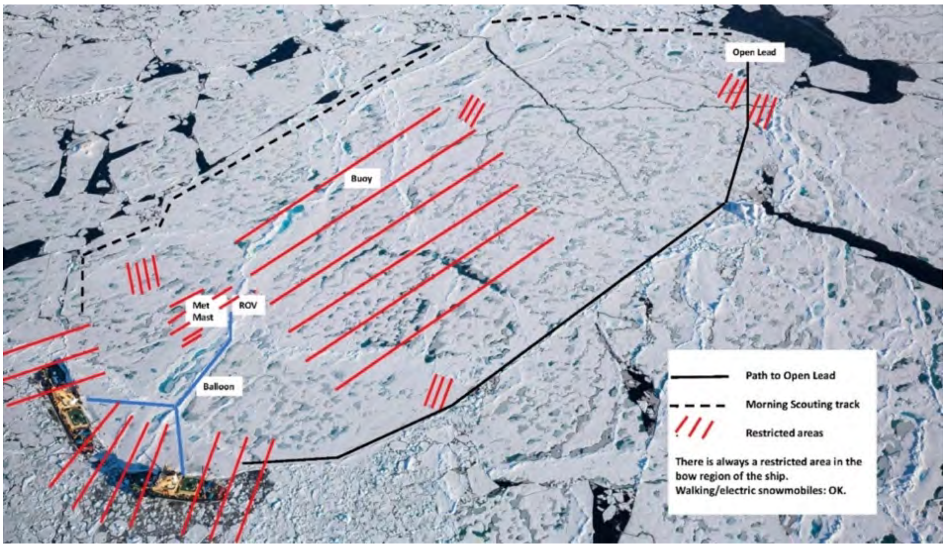


Figure 2. View of the Arctic Ocean 2018: MOCCHA-ACAS-ICE ice floe from above (Photo: P. Zieger, top) with I/B *Oden* in the bottom left corner and the open lead in the top right corner. Also shown is an aerial view of the various working sites on the ice floe (Photo: SPRS, bottom).

Helicopter-based

Helicopter-based research stations occurred at each of the four discrete stations described above, during the northbound and southbound transit legs (20180804 –0813; 20180915 – 0918, and during the Ice-Drift period (details listed in Appendix C). Ice cores and ice samples were collected for the Abrahamsson (WP 5c) and Smith (WP 5d) groups. Buoys, buoy-related sampling and expendable CTDs were deployed by the Hoppmann (WP 5a) group.

3.3 Sampling sites during the Ice Drift Station

Met Alley

This ice site was led and maintained by the Brooks team (WP 2) primarily for micrometeorological observations, radiative fluxes and some aerosol physical properties. Details can be seen in section 4.1.

Figure 3. Micrometeorology mast. (Photo: I. Brooks)

Balloon site

This ice site was led and maintained by the Brooks team (WP 1b,c), in collaboration primarily with students M. Gotschalk, J. Zinke, and G. Porter as well as others. Details can be seen in section 4.1.

Figure 4. Balloon site. (Photo: G. Porter)

ROV site

This ice site was led and maintained by the Hoppmann team (WP 5a). Details can be seen in section 4.5.

Figure 5. ROV site. (Photo: M. Hoppmann)

Buoy site

This ice site was led and maintained by the Hoppmann team. Details can be seen in section 4.5.

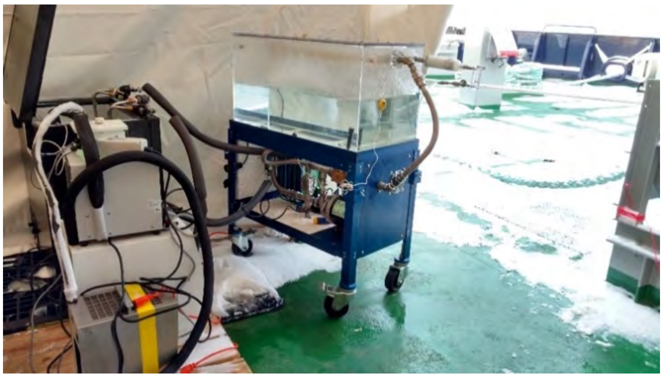
Figure 6. Buoy site. (Photo: M. Hoppmann)

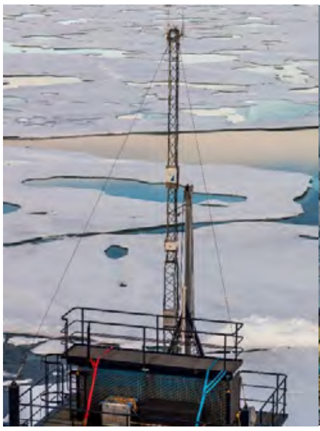
Open Lead site

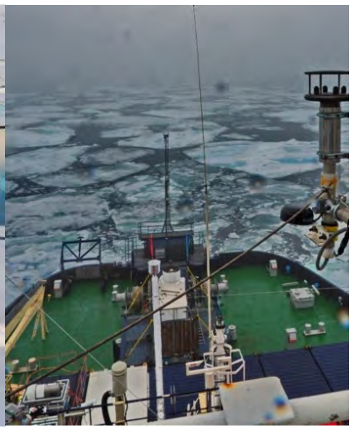
This site was led and maintained by M. Salter (WP 3b), H. Czerski (WP 3c) and J. Prytherch (WP 1a). The site hosted 4 primary projects: floating aerosol chamber (WP 3b), bubble quantification and lead physical characterization (WP 3c), micromet and CO2 flux measurements (WP 1a) and surface microlayer sampling plus CO2 fluxes (WP 4a). Several other projects also sampled in the vicinity of this lead site (Abrahamsson (WP 5c), DiTullio (WP 5b), Lawler (WP 2b), Leck (WP 2d), Matrai (WP 3a) and Smith (WP 5d)). (Photo courtesy of SPRS).

I/B *Oden* site

Several projects were primarily stationed on board the I/B *Oden*. On the main deck, the ACAS main mast (WP 1a; photo courtesy of M. Tjernström) and the Marine Aerosol Research Tank (MART) plus associated aerosol instrumentation (WP 3a; photo courtesy of P. Matrai) were located on the bow and the re-purposed CTD van, respectively. Remote sensing instrumentation was deployed on top of the CTD van (Photo courtesy of M. Tjernström) and operated by the Brooks team (WP 1b).







The main lab hosted the halogen gas sampling by the Abrahamsson group (WP 5c) on the port side as well as the CO2 analyses done by the Smith-team (WP 5d) and the seawater filtrations of the Di Tullio (WP 5b), Robinson (WP 4) and Matrai (WP 3a) groups on the starboard side.

Above the main lab, several groups operated from dedicated lab vans. These included the Brooks (WP 1b) and Tjernström (WP 1a) groups for remote sensing and meteorological operations; the Smith (WP 5d) and DiTullio (WP 5b) groups for cold biological incubations of seawater and ice samples in a dedicated temperature-controlled van as well as individual vans dedicated to filtrations of ice and seawater for ice algae (Smith, WP 5d) and phytoplankton (DiTullio, WP 5b) experiments, respectively.

The fantail hosted all CTD, Niskin bottle and seawater pump operations (Abrahamsson (WP 5c), DiTullio (WP 5b), Matrai (WP 3a), and Smith (WP 5d) groups; photo courtesy of P. Matrai), preparation and refurbishment of the large surface microlayer sampler plus CO2 flux system (Robinson, WP 4) and maintenance of the bubble system (Czerski, WP 3c).

Figure 7: I/B *Oden*, 4th and 7th deck. (Photo: M. Tjernström)

The 4th and 7th deck hosted the sampling of gas, aerosol and fog/cloud (M. Lawler, WP 2b; C. Leck, WP 2d; P. Matrai, WP 2e; G. Porter, WP 2c; P. Zieger, WP 2a; Figure 7). The sampling was divided into two main interlinked themes: (a) gases, chemical composition and fog/cloud water sampling and (b) sampling of fog/cloud droplets and aerosol by number.

The 7th deck also hosted an advanced weather station which, in addition to basic meteorological variables, sampled surface temperature, incoming broad-band solar and thermal radiation, cloud geometry and back-scatter profiles, and precipitation intensity and visibility (M. Tjernström, WP 1a).

3.4 Sampling during Transit periods

Northbound

Helicopter-based ice stations were occupied by the Abrahamsson (WP 5c) and Smith (WP 5d) groups. Expendable CTDs were deployed by the Hoppmann (WP 5a) group.

Atmospheric sampling continued in the 4th and 7th decks, though with a limited suite of instruments.

Southbound

Helicopter-based ice stations were occupied by the Abrahamsson (WP 5c) and Smith (WP 5d) groups. Expendable CTDs were deployed by the Hoppmann (WP 5a) group.

Atmospheric sampling continued in the 4th and 7th decks, though with a limited suite of instruments.

3.5 Sampling logs

Appendix A presents the daily science plan of the ice drift station, Appendix B shows the seawater sampling log and Appendix C includes the helicopter flight log.

4 Projects

4.1 WP 1: Meteorology and vertical profiling

a. Arctic climate across scales (ACAS)

Participants in the field

Dr. Michael Tjernström (PI), Dr. John Prytherch

Other project participants

Dr. Rodrigo Caballero, Dr. Annica Ekman, Dr. Hans-Christen Hansson, Dr. Radovan Krejci, Dr. Johan Nilsson, Dr. Ilona Riipinen, Dr. Gunilla Svensson and Dr. Paul Zieger.

Summary and background

Climate is the average of the weather and weather is made up of processes in the atmosphere on scales from meters to hundreds of kilometers and understanding these processes improves understanding both of Arctic climate and its weather. Ultimately, how the air moves and transforms over the Arctic determines the formation of clouds, modifying the surface energy budgets that determine how the ice moves, melts or freezes.

Arctic climate is changing faster than elsewhere on Earth but there are very few observations of climate related processes from the Arctic and this contributes to the uncertainty on climate assessment and projections for the Arctic. The Arctic is a remote and harsh environment making long-term observations difficult or impossible, hence, much of our understanding of this system is based on data from a few field campaigns.

One aim of the *Arctic Climate Across Scales* (ACAS) project is increased capacity to observe the Arctic atmosphere and processes through developing observing platforms for semi-unattended use on I/B *Oden*. During Arctic Ocean 2018, we deployed and tested an embryo to such a system. The main targets of ACAS were to observe the lower troposphere's vertical structure, the part of the atmosphere closest to the earth and what happens there. The project has emphasis on clouds, and the exchange of heat, gases and momentum at the surface, using in situ and remote sensing instruments. ACAS is also endorsed by the Polar Prediction Project's "Year of Polar Prediction" (PPP/YOPP) and collaborated with *Environment and Climate Canada*, the *UK Met Office* and *National Centre for Atmospheric Science*, and the *European Centre for Medium-range Weather Forecasts*, internationally sharing observations in near-real time to improve weather forecasting.

Methods

ACAS installed an advanced weather station on I/B *Oden's* 7th deck that, in addition to basic meteorological variables, sampled surface temperature from downward-looking infrared thermometers, incoming broad-band solar and thermal radiation, cloud geometry and back-scatter profiles from a lidar ceilometer, and precipitation intensity and visibility from a so-called present-weather sensor.

We also deployed an eddy-covariance system in I/B *Oden's* foredeck mast for measurements of turbulent surface fluxes of momentum heat and water vapor. In collaboration with Stockholm University scientists Patrick Crill and Brett Thornton, we also sampled their LGR system for profiles and eddy-covariance fluxes of methane and carbon dioxide. As a collaboration within the Year of Polar Prediction project, we launched 6-hourly radiosoundings from I/B *Oden's* helipad; the data from these were distributed in near-real time across the WMO Global Telecommunication System and were assimilated in weather-forecast models across the world.

Finally, as a separate effort, we also deployed a flux station at the open lead station, across the ice floe from I/B *Oden*. This battery-powered station measured covariance fluxes of momentum, heat, water vapor and carbon dioxide and (in collaboration with Matt Salter, WP 3b) aerosols. It was deployed close to the ice edge by an open water lead that remained open for most of the expedition and ran for about four weeks; it was eventually lost to sea-ice convergence on the last night of the expedition.

Research activities and preliminary results

We monitored the vertical structure of the atmosphere from the ice surface and through the troposphere. Figure 8 shows a well-mixed shallow boundary layer up to about 200 to 300 m capped by a broad interval that is moderately stable reaching ~1.5-2 km. The latter is the result of a very variable layer with multiple cloud layers and several shallow inversions at multiple heights. Like the boundary layer proper, this layer is also very moist. Above ~2 km is the free troposphere.

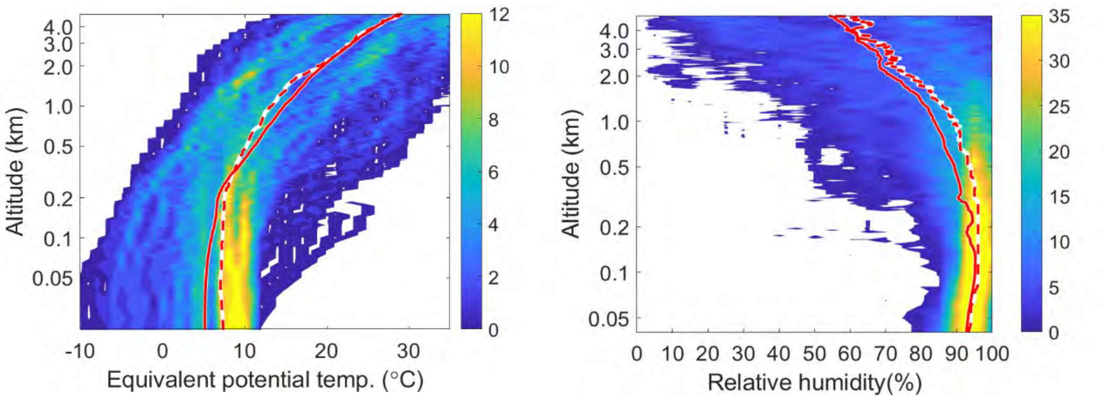


Figure 8. Statistic summary of (left) equivalent potential temperature and (right) relative humidity showing probability as a function of height. Solid red line represents the average and the dashed red line the median profile from the entire expedition.

Figure 9 summarizes some other statistics, indicating the very moist nature of the Arctic boundary layer. The left panel shows the probability of the lowest and second lowest cloud base heights. The lowest cloud layer on average covered 79% of the sky, although in reality this average is made up of a majority of overcast conditions and a few clear or partly clear cases. When a second layer could be detected, as the lowest layer was either broken or optically thin, on average 29% of the remaining 21% was also covered for a cloud-cover average of 85%; in very few cases were there more than two layers. The most common lowest cloud base was below 100 m and for the second layer 0.5 – 1 km.

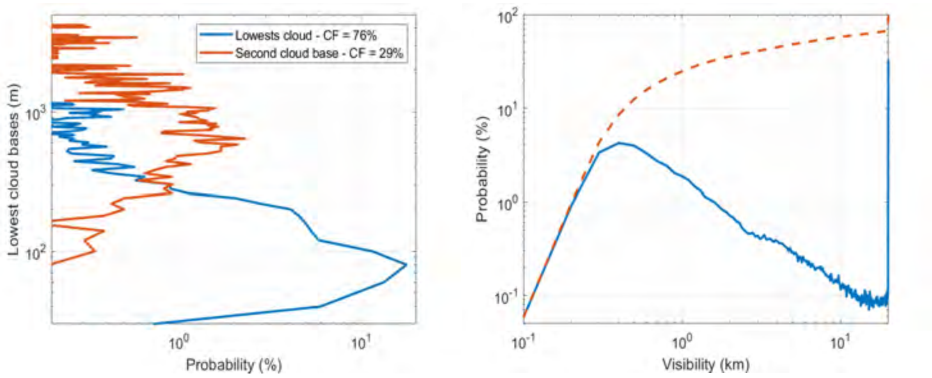


Figure 9. Statistics of (left) clouds, showing the height to the lowest cloud base (blue) and, when two layers were indicated, also the height to the next layer up (red), and (right) visibility showing the actual (blue) and cumulative (red dashed) probability.

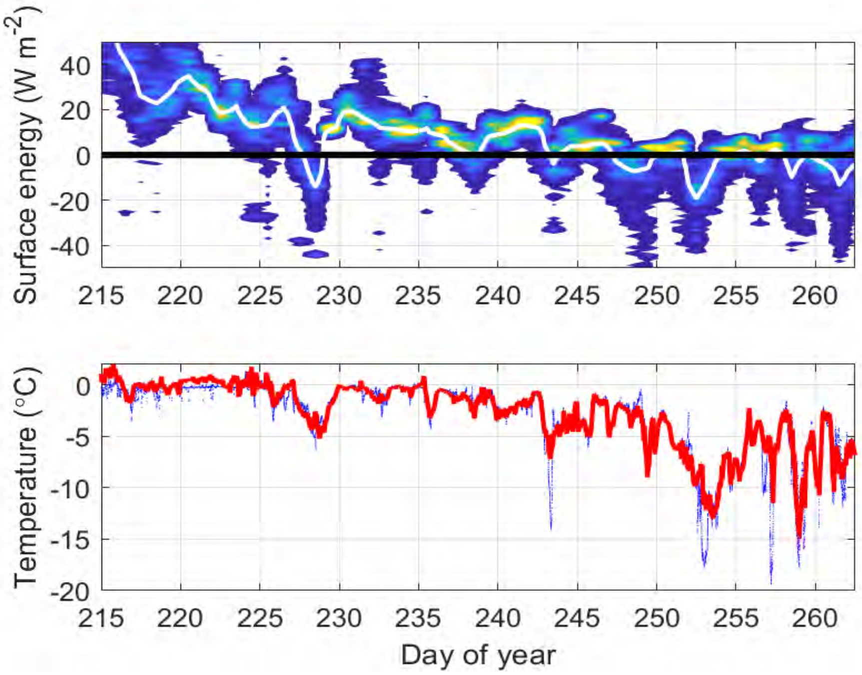


Figure 10. Time trace of (top) probability of daily surface energy budget with median value (white line) and (bottom) near-surface air temperature (red) and surface skin temperature (blue).

We also followed the development of the surface energy budget from the seasonal melt into the freeze-up that we determined started at the beginning of September (Sept 1st is day 244, Figure 10). This preliminary result consists of turbulent fluxes from a bulk formula using weather station data, incoming radiation also from the weather station, outgoing longwave radiation using surface temperature as a black-body temperature and a shortwave albedo based on assessment of photos. These results show– perhaps counterintuitively – that the surface loses energy and the temperature drops as clouds dissipate and solar radiation increases, due to the effects of the clouds on the thermal radiation. The autumn freeze starts gradually, but dominates around the beginning of September. One puzzling fact is that the surface temperature (blue line) drops much more than the near-surface air temperature for a similar change in surface energy.

b. Cloud & boundary layer measurements (MOCCHA)

Participants in the field

Dr. Ian Brooks (PI), Dr. Peggy Achtert

Other project participants

Dr. Ryan Neely III, Dr. Jutta Vüllers, Dr. Gillian Young

Summary and background

What Controls Arctic Cloud Properties?

Clouds are the most important factor controlling the amount of energy reaching the surface as sunlight and emitted from it as radiated heat. They are also the single largest source of uncertainty in climate models. Clouds present a particular problem in the Arctic because the conditions differ so much from those at lower latitudes while also being where there are fewest measurements with which to study them. Low-level clouds are a ubiquitous feature of the summer Arctic boundary layer; their properties and structure both depend upon, and influence, the thermodynamic and turbulent structure of the boundary layer.

The properties of clouds and the boundary layer processes controlling them are sub-grid scale in both climate and weather forecast models, and must thus be parameterized. Models currently do a poor job of representing these processes within the Arctic environment, leading to biases in the surface energy budget, and large uncertainties in projections of future climate.

In order to better understand the processes controlling Arctic clouds, we made detailed measurements of the clouds, and the meteorological conditions that determine where they form.

Methods

We utilize a suite of remote sensing instruments with which to make measurements of clouds and atmospheric structure, installed on I/B *Oden*:

- A Doppler cloud radar provides information about the location and properties of cloud, and air motions within it.
- A laser ceilometer and Doppler lidar give additional information about the cloud, the concentration of aerosol below cloud, and air motions throughout the lower atmosphere. The lidar provides profiles of wind speed up into the cloud layer.
- A scanning microwave radiometer provides estimates of the total amount of liquid water in the cloud and the vertical variations of air temperature and water vapour concentration.
- Radiosondes (weather balloons) are launched every 6 hours to provide direct, in situ measurements of temperature, humidity and wind speed from the surface up to an altitude of about 25 km.

All these measurements are brought together through a sophisticated processing algorithm, *Cloudnet* (Illingworth et al. 2007), to calculate vertical profiles of cloud properties over time. These include liquid and ice concentrations, precipitation, and under some conditions information on the strength of turbulence within the boundary layer and cloud. These can then be used directly to study the relationships between cloud properties and other aspects of the atmosphere such as its dynamics and aerosol properties, and also to test how well weather forecast models represent the clouds.

In addition to the remote sensing measurements made on board I/B *Oden*, we made measurements of the different contributions to the surface energy balance over sea ice from a mast erected on the floe. The energy budget is made up of solar and infrared radiation, and turbulent fluxes: energy transported towards or away from the surface by the motion of warmer/cooler and more/less humid parcels of air, all measured over undisturbed ice away from the ship.

Figure 11. The micrometeorology mast and radiometers installed on the sea ice.

Figure 12. Ian Brooks working on the cloud radar. (Photo: Matthias Gottschalk)

Figure 13. Bear guards by the micrometeorology mast.

Research activities and preliminary results

Preliminary results were presented at the 2019 spring Artic Ocean 2018 workshop.

c. Vertical profiling of turbulence, aerosol and cloud water with tethered balloons (MOCCHA)

Participants in the field

Dr. Ian Brooks (PI), Grace Porter (deputy PI), Dr. Paul Zieger (PI), Matthias Gottschalk, Michael Adams, Dr. Peggy Tesche-Achtert, Julika Zinke, Linn Karlsson

Other project participants

Dr. Manfred Wendisch, Dr. Ulrike Egerer, Dr. Holger Siebert, Dr. Ben Murray, Dr. Caroline Leck

Summary and background

Measurements made on board I/B *Oden* or from the masts on the ice are representative only of the near-surface well-mixed layer. The summertime atmospheric boundary layer in the central Arctic has been observed to often be decoupled – there are turbulently well mixed layers at both the surface and extending from within to some distance below the stratocumulus clouds capping the boundary layer, but these layers are separated by a shallow stable layer at an altitude of between about 100 and 400m (Brooks et al. 2017). This stable layer prevents moisture or aerosols from the surface mixing up into cloud. In order to fully understand the processes controlling Arctic clouds, it is thus necessary to obtain measurements from above the surface mixed layer.

Methods

Two different tethered balloons were operated throughout the Arctic Ocean 2018 ice drift: a 25 m^3 Helikite with a static lift of 13 kg, and a 9 m^3 blimp with a static lift of about 6 kg.

The blimp was used to make continuous profiling measurements from the surface up to an altitude of order 1 km, carrying a combination of different instrument payloads: mean meteorology (air temperature, humidity, pressure, wind speed), radiation (up- and down-welling solar and infrared radiative flux densities), and turbulence (hot-wire probe). On occasions it also carried an aerosol optical particle counter.

The Helikite was used to carry heavier instruments for sampling of aerosols and cloud water. Both instruments required long sampling periods of several hours at a fixed level in order to sample a sufficient volume of air. For the aerosol instrument package, the Helikite ascended to a fixed altitude above the decoupling layer – initially identified from an earlier radiosonde profile, and then from a live data-feed from a temperature and humidity sensor on the instrument package – and allowed to sample for up to 6 hours. The cloud-water sampler was lifted into cloud and sampled for as long as altitude could be maintained against the slow accumulation of ice on the balloon tether and instrument package.

Analysis of the cloud water samples will be coordinated with C. Leck (WP 2d) and P. Matrai (WP 3a) and will involve analysis on polysaccharides, proteins, and fatty acids with mass spectrometry with methods common to discrete aerosol and fog water samples described in section 4.2, as well as analysis on bacteria and viruses. DNA analysis will allow to link the presence of gels in cloud water to the oceanic biota. These samples are currently stored pending availability of funds for their analysis.

Research activities and preliminary results

Preliminary results were presented at the 2019 spring Artic Ocean 2018 workshop.

References

Brooks, I. M., M. Tjernström, P. O. G. Persson, M. D. Shupe, R. A. Atkinson, G. Canut , C. E. Birch, T. Mauritsen, J. Sedlar, B. J. Brooks, 2017: The vertical turbulent structure of the Arctic summer boundary layer during ASCOS. *J. Geophys. Res.* 122, doi:10.1002/2017JD027234

4.2 WP 2: In-situ characterization of ambient gases, aerosols and clouds

Gases and aerosol particles were sampled with a minimum interference from the ship and from the sea/ice surface surrounding the ship. Aerosol particles and cloud residuals were sampled by specially designed inlets, which were installed on top of the triplet (# 18+19+20 in Figure 14) and Swiss (#21 in Figure 14) containers located on the 4th Deck. The inlets were faced into the forward direction to maximize both the distance from the sea and from the ship's superstructure.

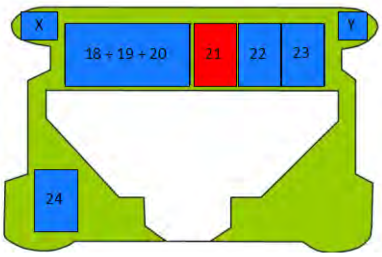


Figure 14. Top view of the location of the laboratory containers on the 4th Deck: #18-20 "Triplet container", #21 "Swiss container", # 22 "Chemistry container" and X "Pump container".

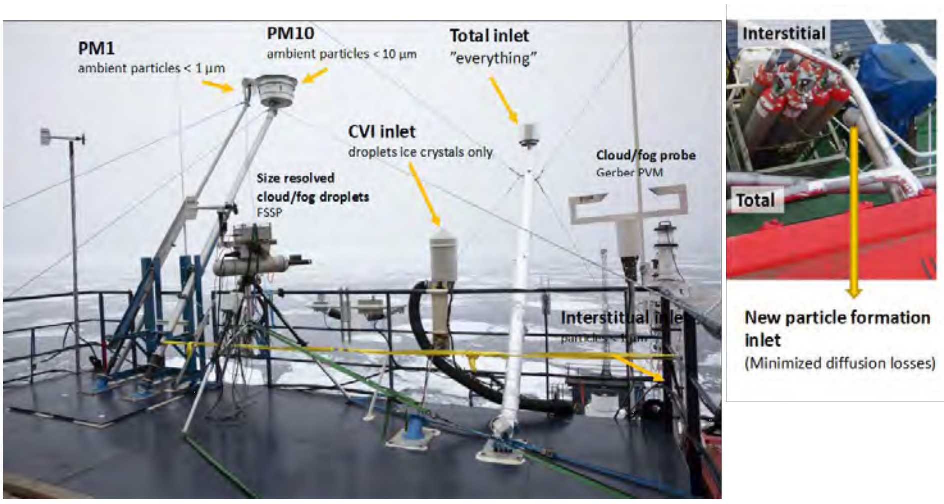


Figure 15. Container set-up with existing and newly deployed inlets (further described below). Depicted are also the cloud/fog probes installed on the roof of the container (#18-20). The Gerber PVM probe was used to measure the effective radius and liquid water content of present clouds or fog, whereas the FSSP probe recorded droplet number size distribution. (Photo: C. Leck)

Six independent inlet systems (Figure 15) were installed to continuously sample ambient aerosol particles and cloud droplets:

1. **PM_1 inlet**: This inlet sampled particles with an aerodynamic diameter smaller than 1 µm. Lines for sampling of gas phase dimethyl sulfide (DMS) and sulfur dioxide (SO2) were running from this inlet to the chemistry container (#22 in Figure 14) on the starboard side.
2. **PM_{10} inlet**: This inlet sampled particles and cloud/fog droplets with an aerodynamic diameter smaller than 10 µm.
3. **CVI (Counterflow Virtual Impactor) inlet:** This inlet sampled cloud/fogdroplets (residuals) only.
4. **Whole air inlet**: This inlet sampled all particles and cloud/fog droplets/ice crystals smaller than ~45 µm diameter.
5. **Interstitial inlet:** This inlet sampled the non-activated aerosol
6. **New particle formation inlet:** This inlet was designed to capture the smallest particles minimizing losses.

Inlets 1 and 2 have been installed during all previous atmospheric expeditions, while inlets 3-6 were newly installed for the Arctic Ocean 2018 campaign.

Extreme care must be exercised to prevent contamination of the air samples. Direct contamination from the ship's exhaust and vents can, to a large extent, be excluded in the samplers connected to the PM10 inlet by a pollution sensor. Experiments were carried out already in the expedition of 1991 to determine wind sectors safe from shipboard pollution by measuring condensation nucleus concentrations while releasing massive amounts of smoke from various parts of the ship, which was successively oriented in different directions relative to the wind. The set up showed that sampling of air was uncontaminated by ship borne emissions provided that the wind was within the sector ± 70° of the bow and larger than 2 ms^{-1}. The waste flow of all intakes and instruments was conducted to the pump container (Figure 16), located at the port side (shown in Figure 15), through dry air gas meters and pumps to a plenum. A particle filter connected to this plenum filtered all exhaust air. For further description of the used instrument see WP 2a-d.

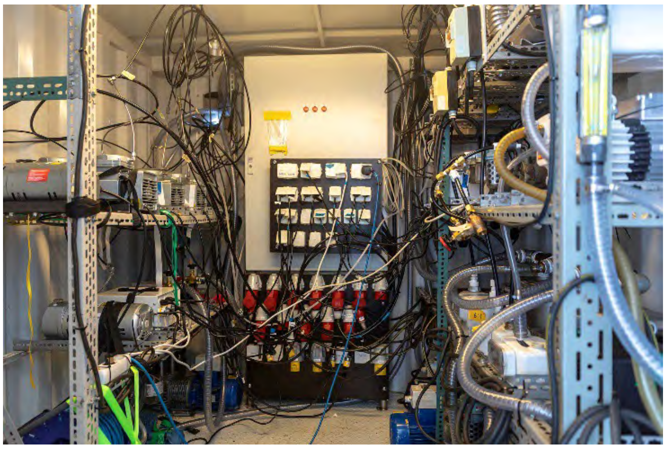


Figure 16. View of the "Pump container" located at the port side of the 4th Deck (Figure 14). (Photo: K. Alfredsson)

a. Aerosol-cloud interactions in the High Arctic (MOCCHA)

Participants in the field

Dr. Paul Zieger (PI), Dr. Julia Schmale, Linn Karlsson, Patrick Duplessis, Andrea Baccarini

Other project participants

Dr. Michael Wheeler, Dr. Richard Leaitch, Dr. Rachel Chang

Summary and background

The Arctic is experiencing a dramatic transformation as a result of anthropogenic climate change. The processes driving the accelerated change are not fully understood, yet they propagate through the entire global climate system with impacts on weather, ecosystems and geopolitics. Clouds play a major role in the Arctic system and are among the main contributors to the overall uncertainties of future predictions. In accordance with the science goals of MOCCHA (section 2) to better understand cloud processes in clean atmospheric conditions, we chose to do measurements in the North Pole area where data are particularly scarce and in the strategic time around the re-freezing period to investigate the change in the atmospheric particles as the season changes.

Within our project, we installed various inlet systems (cf. inlets 3, 4 5, and 6 in Figure 15 and the shown close up in Figure 17) to experimentally determine the microphysical and chemical properties of aerosols and cloud droplet residuals using a large suite of novel experimental techniques. For example, we determined the size distribution and composition of particles with various sizing instruments and mass spectrometers. An additional focus was the characterization of newly formed nano-particles. Gigabytes of data were recorded and the analysis will keep us busy for the next years.

Methods

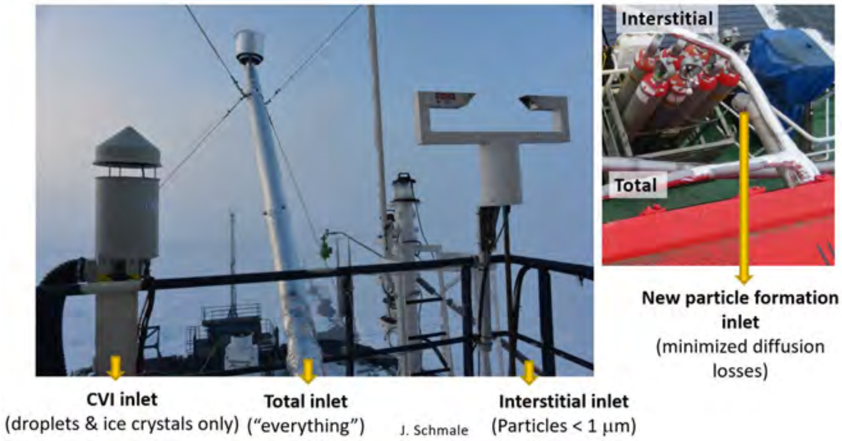


Figure 17: Photo of the inlets used to sample aerosol particles and cloud droplets installed on top of the triplet container. Particles were analyzed in the lab below (triplet lab and Swiss container). The PVM probe to the left was used to measure the effective radius and liquid water content of present clouds or fog. The right photo shows the inlet for the new particle formation study.

Behind the inlets depicted in Figure 17, several instruments were attached to determine the chemical composition (using various mass spectrometers), the particle size distribution, the black carbon content, the fluorescence of particles (biogenic contribution), the water vapor mixing ratio, the ability to act as cloud condensation nuclei and the chemical composition of particles and gases using aerosol mass spectrometers. In addition, trace gases were monitored to provide a general characterization of the air mass sampled or whether polluted conditions were present or not. An overview of the instruments installed in the Swiss container (#21) can be seen in Figure 18b, while the installation in the triplet container are depicted in Figure 18a. These measurements were accompanied by ambient cloud measurements on the roof of the triplet container (Fig 19, container # 18-20). A list with all instrumentation installed and operated within this project can be read below.

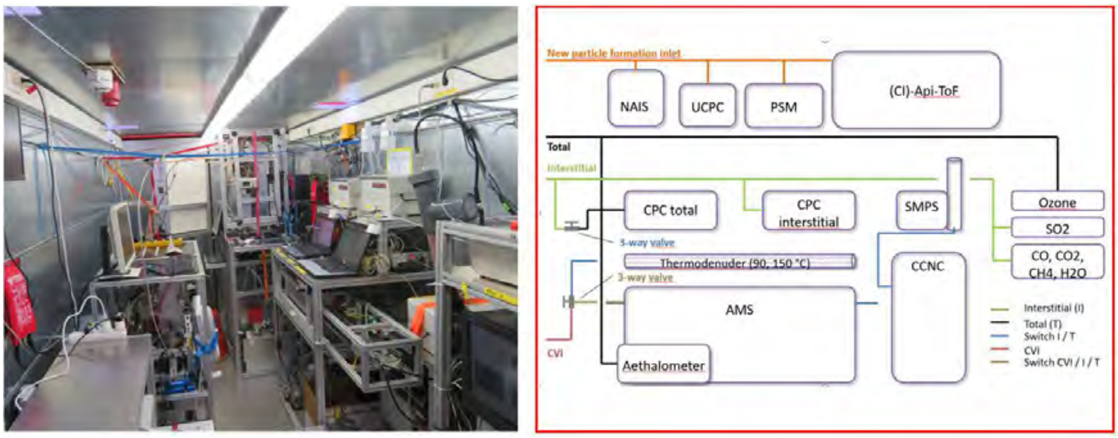


Figure 18. Image (a) and schematic set-up (b) of the instruments installed in the Swiss container.

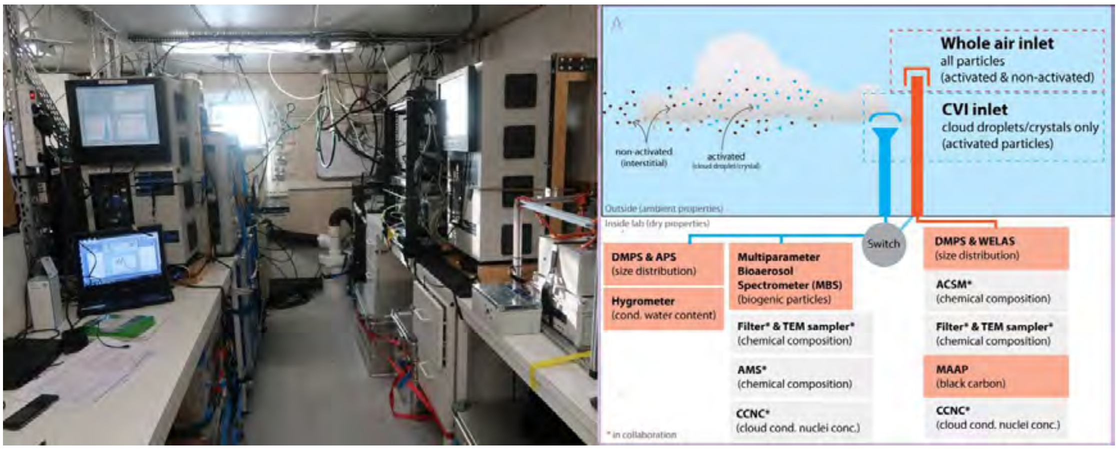


Figure 19. Image and schematic set-up of the instruments installed in the triplet container.

List with all instrumentation installed and operated within this project

Triplet container:

- 2 Differential Mobility Particle Sizers (DMPS): Measured aerosol number size distribution between 10 and 1000 nm
- 2 Condensation Particle Counters (CPC): Measured total number concentration
- 1 Ultra-fine CPC (UCPC, provided by Lund University)
- 1 Optical Particle Size Spectrometer (OPSS): Measured particle number size distribution (> 0.6 µm)
- 2 Cloud Condensation Nucleus Counter (CCNC): Measured the ability of particles to form cloud droplets (instruments were provided by Lund University, and Environmental Canada).
- 1 Multiparameter Bioaerosol Spectrometer (MBS): Measured the shape, size and fluorescence of particles
- 1 Hygrometer: Measured the water vapour mixing ration
- 1 Whole-air-inlet: Main sampling line which was attached to the roof of the container and was heated
- 1 CVI inlet: Special inlet to sample cloud droplets (provided by Environmental Canada). The CVI inlet also recorded ambient visibility and RH/T.
- 1 Particle Volume Meter (PVM): Measured ambient cloud droplet size and liquid water content
- 1 Multi-Angle Absorption Photometers: Measured black carbon content
- 1 Aerosol Chemical Specification Monitor (provided by Environmental Canada): Aerosol mass spectrometer which measured aerosol chemical composition

Swiss container:

- 3 Condensation Particle Counters (CPCs) behind all inlets for comparability
- 1 Aerodynamic Particle Sizer (APS): provided information on large particle size distribution, e.g., the contribution of sea spray particles
- 1 Aerosol Mass Spectrometer (AMS): provided information on the chemical constituents of submicron aerosol, this information provides hints on the sources of particles
- 1 Scanning Particle Size Spectrometer (SMPS): provided the size distribution of particles that are characteristic for certain sources
- 1 Cloud Condensation Nuclei Counter (CCNC): provided the particle number that activates as cloud drop-let under a given supersaturation (provided by TROPOS, Germany)
- Trace gas monitors: provided a general characterization of the air mass, e.g., whether polluted conditions are present or not. Gases measured were: CO, CO_2, CH_4 and O_3.

- 1 Thermodenuder (TD): The SMPS and CCNC were operated alternatingly behind the thermodenuder. The TD removes (highly) volatile chemical components. The thermograms give information about the chemical composition of particles.
- 1 Nitrate Chemical Ionization Mass Spectrometer (CIMS): provided the chemical information of the molecules and ions that form new particles
- 1 Neutral Cluster and Air Ion spectrometer (NAIS); provided information on the size distribution of the smallest particles and ions,
- 1 Particle Size Magnifier (PSM): provides particle number concentration information down to particles with a diameter of 1 nm.

Samples of cloud residuals (using the CVI inlet) were taken for the projects of C. Leck (WP 2d) and P. Matrai & R. Kirpes (WP 2e) (both for electron microscopy analysis). In addition, sporadic filter samples were taken for chemical offline analysis using a chemical ionization mass spectrometer (C. Mohr, SU-ACES). The whole-air inlet was also used for filter sampling for later INP (ice nucleating particles) analysis (G. Porter & B. Murray (WP 2c), Leeds).

Research activities and preliminary results

More than 30 instruments were operated within this project, gathering several hundreds of gigabytes of data. The data have been initially screened and analyzed but it will take more time to fully analyze them. We show two example results below.

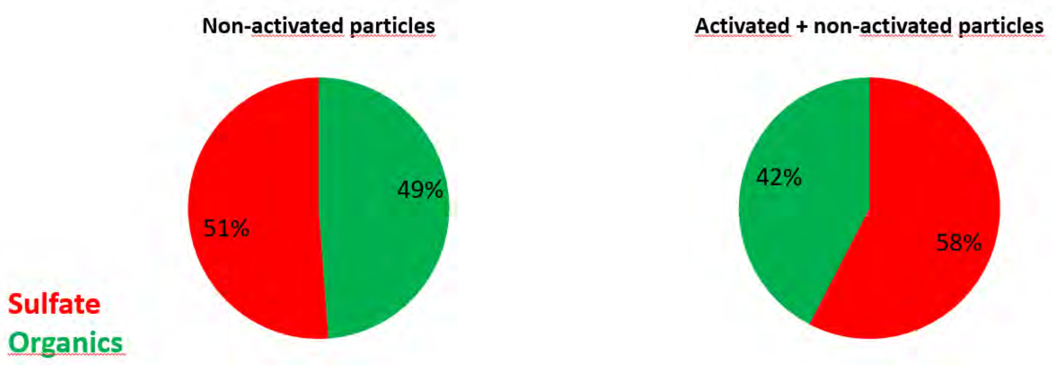


Figure 20: Left panel: contribution of sulfate and organic compounds to non-activated (interstitial) measured by the aerosol mass spectrometer. Right panel: same but for all (activated and interstitial) particles (whole air inlet).

Figure 20 shows the mean chemical composition during one fog-event of non-activated (interstitial) and total aerosol (interstitial and activated) aerosol. The contribution of particulate sulfate and organics is roughly the same for non-activated particles, i.e. those that cannot form cloud droplet. The mix of non-activated and activated particles exhibits a different chemical composition. Here, the contribution of particulate sulfate is larger. This means that particulate sulfate contributes more to aerosol particles that form cloud droplets. This result makes sense, because particulate sulfate is hygroscopic (water attracting). Further analysis will reveal the different organic constituents that contribute to activating and non-activating particles.

As an example for cloud residual measurements, Figure 21 shows the particle number size distribution measured between 10 and approx. 900 nm of ambient aerosol collected using the whole-air inlet as an example for the 18th of August 2018. The distribution on that day shows in terms of variability and shape only a little variation. Clearly two modes at approx. 40 and 180 nm are visible. In the evening of the 18th, I/B *Oden* was surrounded by fog (or a low-level cloud), interrupted by short precipitation intervals (indicated in blue). The particle size distribution of the cloud droplet residuals were then successfully sampled using CVI inlet system and a second DMPS system. As seen in Figure 21 (right panel), the cloud residual size distribution showed the same shape as the ambient particle size distribution, however, at a much lower concentration (note the two different axis in the right panel). Even very particles below 100 nm acted as cloud condensation nuclei. It is not fully clear, why the concentration of sampled CCN (blue curve) is significantly lower than the total concentration (green curve; which includes both activated and non-activated aerosol). Several steps have to be tested to further investigate this observation. For example: (a) what was the actual collection efficiency of the CVI system? (b) How important was entrainment for this specific period and was the cloud period influenced by snow or ice crystals? For this, it will be important to include auxiliary data to the analysis such as ambient cloud droplet distribution measurements and cloud radar observations.

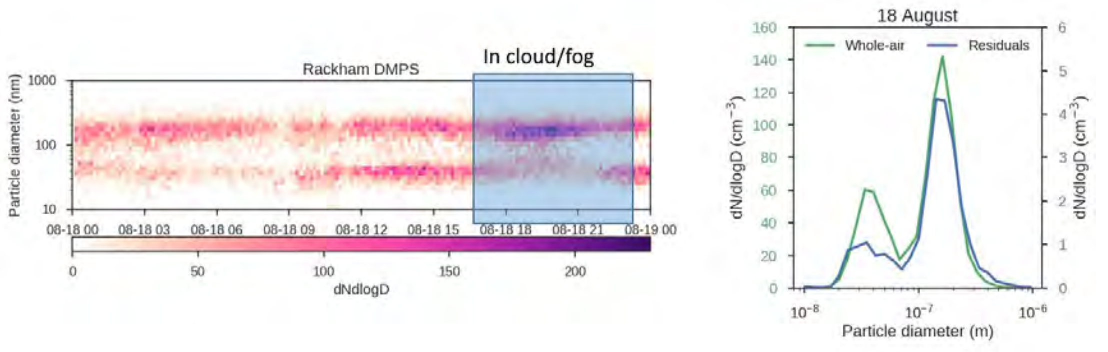


Figure 21: Left panel: Particle size distribution measured on August 18 using a differential mobility particle sizer (DMPS). Right panel: Mean particle number size distribution measured on the whole air inlet (all particles including cloud droplets; green curve) and on the CVI inlet (cloud residuals, blue curve).

In addition, as a small side project, regular Sun photometer measurements were performed for the NASA's AERO-NET Maritime Aerosol project (PI Alexander Smirnov, NASA). This data is valuable use for various remote sensing application such as the improvement and validation of satellite retrievals. The data can already be downloaded here: https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Oden_18_0.html.

b. Identifying the Origins of Summertime Arctic Cloud Condensation Nuclei Using Online Fine Aerosol Composition Measurements (MOCCHA)

Participants in the field

Dr. Michael 'Mike' Lawler (PI)

Other project participants

Dr. Eric Saltzman (PI)

Summary and background

The goal of this project is to characterize the sources and composition of the cloud-forming aerosol in the summertime high Arctic. Specifically, we aim to clarify the roles and importance of primary aerosol emission of (e.g.) sea salt and biogenic polysaccharides and the secondary formation of (e.g.) sulfate and sulfonate salts from gas phase precursors. Understanding the aerosol sources is important for understanding and predicting the future relationships among clouds, sea ice, and climate in the Arctic.

Methods

We used an *in situ* mass spectrometer which can collect and analyze size-resolved aerosol for both inorganic and organic components with high chemical specificity (TDCIMS: thermal desorption chemical ionization mass spectrometer). This sampled essentially continuously from transit through ice station and back, from the PM-10 inlet (2, cf Figure 15) on the 4th deck lab (Figure 14, container # 18-20). We also used this technique to analyze some cloud water retrieved from the cloud water sampler.

We sampled bulk sub-micron aerosol into liquid vials, from the one-micron inlet (1, cf Figure. 15) on the 4th deck lab. These samples have not yet been analyzed. They have a roughly 40-minute time resolution.

Several sea surface microlayer samples were collected and frozen, but not yet analyzed. Several surface snow /ice samples were collected, but not yet analyzed.

Research activities and preliminary results

From TDCIMS we have composition information primarily for Aitken mode particles, with some excursions to measure accumulation mode aerosol. These data have 1-8 hr time resolution. The initial results indicate the presence of polysaccharide material and salts of sulfur and iodine in both aerosol modes. The initial cloud water sample analysis shows some similarity to the aerosol composition.

C. The sources, concentrations and impact of ice-nucleating particles in the high Arctic (MOCCHA)

Participants in the field

Grace Porter (deputy PI), Michael 'Mike' Adams

Other project participants

Dr. Ben Murray (PI)

Summary and background

Low-level Arctic stratus clouds are a critical part of the high Arctic climate system (Morrison et al., 2012). However, these moderately supercooled low-level clouds are poorly understood and therefore poorly represented in models. Observations clearly show that ice forms in Arctic clouds leading to precipitation and removal of water, but despite these Arctic clouds can have very long lifetimes. A major unknown is the source of aerosol particles which can serve as ice nucleating particles (INP). INP trigger ice formation in supercooled clouds, strongly influencing cloud properties, precipitation and cloud lifetime. The formation of ice in clouds is needed to not only improve current models but to predict how cloud will change in the future as the Arctic changes. Both local sources, associated with ocean biology, and long range transported aerosol have been proposed as being important. Without knowledge of the sources and concentration of INP in the high Arctic we will not be able to build a predictive understanding of how changes in these clouds will feedback onto the Arctic climate as the Arctic climate changes.

This project will try to determine the concentration of ice nucleating particles (INPs) at a range of altitudes from ship level through to above clouds. We will bring our suite of instruments for the offline analysis of INP concentrations (the NIPI suite). These will be housed in the IcePod, our mobile laboratory together with the necessary equipment for clean working. We will sample aerosol from the community inlet on I/B *Oden* and will also deploy our newly developed balloon borne aerosol sampler (SHARK) using a Helikite lifting platform which will be launched from the ice. We anticipate having the first height and size resolved INP concentration spectra dataset for the high Arctic. After the campaign we will actively use this dataset to: i) test our model of global INP concentrations, ii) use back trajectory analysis tools to establish the likely sources of INP at different altitudes, iii) inform cloud modelling activities.

Methods

Ship based measurements were made using the whole-air inlet on the 4th deck lab (inlet 4, cf Figure 15; Figure 14, container # 18-20) of I/B *Oden* and two aerosol samplers on the 7th deck. The aerosol samplers collected aerosol at PM10 and PM2.5 to allow some data about the size of the INP to be inferred. The filters from these samplers were analyzed in Container # 24 (Figure 14) and according to the method described in (Wilson et al., 2015) in which the aerosol on the filters is immersed in a volume of water, before being pipetted onto a temperature controlled plate. The plate temperature is then lowered until the droplets of sample freeze and the freezing events are recorded. Another instrument which works in a similar way but uses infrared imagery to capture the freezing events and uses larger volume droplets was also used to analyze these liquid samples (Harrison et al., 2018). This data was then combined with the volume of air sampled to produce an INP concentration per volume of air at the sampling location. The dataset comprising whole air, PM10 and PM2.5 filters was taken throughout the cruise on average every two days. These samples also underwent heat treatment to probe the temperature stability of the INP collected.

Airborne aerosol collection was achieved with a newly developed suite of radio-controlled cascade impactors (publication pending). The impactors collected aerosol at 9 L/min and 100 L/min and size segregated the aerosol into bins between 0 - >10 um. The suite was lifted via a Helikite balloon to a selected altitude, whether that was close to ground or above the boundary layer, and real time atmospheric data was fed back to the ship to allow the impactors to be remotely turned on/off from the ground when favorable conditions were reached. The impaction substrates of the impactors were then analyzed using the same method as for the filters from the ship.

A Scanning Mobility Particle Sizer (SMPS) and Aerodynamic Particle Sizer (APS) system were also brought aboard to provide constant particle size data throughout the cruise on the PM10 inlet (2, cf Figure 15) on Deck 4.

Research activities and preliminary results

There were preliminary results presented at the spring Arctic Ocean 2018 workshop - but we noted interesting variability in the concentration of ice nucleating particles throughout the cruise!

d. The life cycle of clouds in the High Arctic summer with linkages to the microbiological life in ocean and ice (MOCCHA)

Participants in the field

Dr. Caroline Leck (PI, Co-Chief Scientist), Alister ‘James’ Cumming, Dr. Luisa Ickes, Karolina Seigel, Julika Zinke

Other project participants

Dr. Birgitta Svenningsson, Dr. Erik Swietlicki, Dr. Leopold Ilaq, Emmy Nilsson, Joachim Dillner and Nils Walberg

Summary and background

Understanding how current climate change is affecting the Arctic system is vital to making projections about the future of the climate system. Clouds play a key role in the Arctic climate by regulating surface energy fluxes affecting the freezing and melting of the sea ice. The radiative properties of these often optically thin fogs and low-level clouds, their reflectivity and long wave emissivity, are strongly dependent on the number and properties of airborne particles known as cloud condensation and ice nuclei. Changes in the life cycle of these particles due to climate change have the potential to alter the surface energy balance, as well as the structure of the atmospheric boundary layer and therefore the local mixing of air. This in turn can affect the melting and freezing of the sea ice and also feedback on surface albedo through changes in melt pond formation. Sources, properties and effects of aerosol particles on regional fogs and cloud in the summer Arctic are not sufficiently understood and quantified to parameterize them in climate models. Arctic 2018 MOCCHA was set in a strategic time around the re-freezing period to investigate the change in the life cycle of the atmospheric particles as the season changes (cf. science goals in section 2).

Within our project, we experimentally determined aerosol precursor gases, the microphysical and chemical properties of aerosols, cloud/fog droplet residuals and fog/cloud physical and bulk chemical inorganic/organic properties, using a large suite of novel experimental techniques. For example, we determined the size distribution and composition of particles with various sizing instruments and mass spectrometers. An additional focus was the characterization of morphology and state of mixture of individual particles and newly formed nano-particles.

Methods

Discrete measurements for aerosol chemical characterization

Behind the inlets 1 and 2 (depicted in Figure 15), several samplers for discrete sampling of size resolved aerosol were attached. Downstream from the PM10 inlet located in the Triplet container (Figure 14), eight aerosol high performance cascade and low pressure impactors (ranging from 30nm to 10µm diameter) were connected through isokinetic take offs in conjunction with the Matrai & Kirpes project (WP 2e). Also connected to the PM10 inlet were stacked filter units for sampling of total suspended matter and collection of individual particles for subsequent electron microscopy analysis. A second filter group for bulk chemical and optical analyses sampled off the PM1 inlet. This group used one duplicate filter pack cassette, and a special filter stack unit for collecting (black carbon) BC.

An overview of the right-hand side of the Triplet container hosting the PM10 and PM1 samplers is shown in Figure 22.

Figure 22. Image of the filter samplers installed in the right-hand section of the triplet container. (Photo: K. Alfredsson).

To collect sufficient material for above detection limit analyses, the cascade impactor samples for aerosol inorganic characterization and the PM1 filter cassette samples for organic analyses had the highest time resolution of all size resolved chemical samples (in total 25) performed during the expedition. The more detailed size segregated low pressure impactor, cascade impactors for organics and the rest of the filter samplers, required significantly longer sampling times, 24-96 hours, so that 9 to 13 sampling periods were obtained. Ambient samples and blanks were carefully handled in a glove box both prior to and after sampling (Figure 23).

Figure 23. View of inside the glove box installed in the Chemistry container. (Photo: K. Alfredsson).

To obtain quantitative information on aerosol chemistry, we will use size-segregated bulk mass detection for a wide spectrum of inorganic/organic water-soluble and–insoluble components. Quantitative chemical characterization of the e.g. biogenic polysaccharides will be performed with state-of-the-art liquid chromatography coupled with highly selective/sensitive electrospray (ESI) Triple quadrupole and/or ion mobility tandem Mass Spectrometry (LC-MS/MS). The ESI-LC-MS/MS is a highly selective technique for the successful quantitative determination of polysaccharides in the size-segregated aerosol samples with complex matrix including interfering substances from air sampling, the biological matrix (i.e. peptides and lipids) and sea salt. A novel approach that is recently developed in terms of detection of amino acids is derivatisation with alkylated 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate AAQC and sub-sequent ESI LC-MS/MS analysis. The AAQC-tag makes the amino acids more hydrophobic and carry a permanent charge for superior detection. Fast ion mobility mass spectrometry strategy will be used for quantifying fatty acids. The Ion Chromatography (IC) technique will provide a full suite of inorganic constituents. The main fraction of aerosol inorganic analyses was performed on board ship in the Chemical lab (Figure 23), whereas the suit of organic analyses will be performed during stable conditions in the laboratory at Stockholm University, post-cruise.

Moreover, post cruise determination of chemical properties, morphology and state of mixture of individual particles down to particles of the order of 10nm will be allowed by Scanning – and Transition Electron Microscopicity (SEM/TEM), with associated chemical tests (e.g. dialysis, X-ray analysis, reaction with organic vapours, reactions with solutions of various compounds.

Measurements of gas phase DMS and SO_2

Sulfur dioxide. SO_2 was monitored continuously at every 10 to 20 minutes with a modified auto- mated real-time technique involving High Performing Liquid Chromatography with Fluorescence Detection (HPLC/FD). The instrument samples off the PM1 inlet (#1, Figure 15) and was located in the Chemistry lab (container #22) on the 4th deck of I/B *Oden*.

Dimethyl sulfide. DMS was automatically collected with in general 15 minutes time resolution and pre-concentrated in two steps, 1) a gold trap 2) a (TENAX) medium to achieve a sharp injection of the analyte into the Gas Chromatograph Flame Photometric Detection system (GC-FPD). The instrument sampling off the PM1 inlet was located in the Chemistry lab (container #22, Figure 14) on the 4th deck of I/B *Oden*.

Measurements of fog water chemical properties

Three fog water samplers were placed on the 7th deck to allow for the determination of chemical properties in fog droplets and cloud water collected. One of the liquid fog-water samplers was a cascade impactor, which uses two jet impaction stages, with cut diameters at 6 µm and 40µm. Fog water samples were collected in two brown 250 ml plastic bottles connected to the collector. The sampler was connected to four blowers with total volumetric flow rate to about 530 $m^3 h^{-1}$. The two other samplers were duplicate active strand fog water collectors attached to the 7th Deck, front railing. The collectors will sample droplets with less than 23µm diameter. Fog droplets are aspirated by a fan and impact on heated Teflon-coated wires from which they run into a sample flask. Fog water samples are collected in brown 125 ml plastic bottles connected to the collector.

The fog droplets will be captured on TEM grids for further post cruise identification by means of microspectrometry and chemically characterized for inorganic/organic using bulk mass detection (also common to the discrete aerosol samples discussed above).

Research activities and preliminary results

Discrete measurements for aerosol chemical and measurements of gas phase DMS and SO2 were done as well as measurements of fog water chemical properties

Samples are being analyzed and preliminary results were presented at the 2019 spring Arctic Ocean 2018 workshop.

e. Marine aerosols in the Arctic (ambient): linking surface water chemistry and biology with primary particle production (MOCCHA)

Please see below at 4.3.a.

4.3 WP 3: Air-sea interaction

a. Marine aerosols in the Arctic (experimental): linking surface water chemistry and biology with primary particle production (MOCCHA)

Participants in the field

Dr. Patricia 'Paty' Matrai (PI, Co-Chief Scientist), Carlton Rauschenberg, Rachel Kirpes, Allison Remenapp

Other project participants

Dr. Kerri Pratt (PI), Dr. Amanda Grannas (PI), Dr. Vanessa Boschi, Dr. Andrew Ault (PI), Liam Reeves, Savannah Haas

Summary and background

The Marine Aerosols in the Arctic project, joint between the University of Michigan, Bigelow Laboratory for Ocean Sciences, and Villanova University, is investigating the interactions between the surface of the Arctic Ocean and the atmosphere above. The Arctic is disproportionately affected by global climate change, as shown by profound sea ice loss and increasing surface temperatures. These surface changes are affecting air-sea exchange processes, not solely due to ever larger areas of open water but likely also in areas of increasingly broken sea ice. These changes impact ocean microbiology which in turn influences atmospheric composition and processes. Changes in the atmospheric composition then impact cloud formation, properties, and precipitation, which subsequently affect climate. Experiments were conducted to better understand the physical properties and chemical makeup of marine aerosols produced from seawater and how aerosols change in different sea ice conditions. Controlled atmospheric aerosol generation experiments were conducted aboard I/B *Oden* using seawater collected under several combinations of sea ice and open water conditions. The biology and chemistry of the experimental seawater were also sampled and will be compared to the composition of the atmospheric and generated aerosols. Offline measurements focus on individual aerosol particle morphology and composition, organic compound molecular composition, and microbiology. Specific links between seawater microbiology and aerosol composition and morphology will be described. The nature of marine aerosol sources will be defined and quantified for use in climate models to improve understanding of Arctic ocean-atmosphere connections and impacts.

The Marine Aerosols in the Arctic project will result in an unprecedented level of understanding of Arctic marine aerosol production and links to seawater microbiology. This will lead to improved predictions of Arctic aerosol composition and clouds for the rapidly changing Arctic system. Integrated educational and outreach project activities will increase awareness of Arctic change and build upon the investigators' longstanding commitment to education and public outreach. In addition to the co-PIs and the technical staff, our project will involve 2 Ph.D. students, 2 M.S. students, 5+ undergraduate students (including participation of a Research in an Undergraduate Institution and through a summer Research Experience for Undergraduates). A short documentary film on the changing Arctic Ocean and this research project will be made by Villanova communications majors, on expedition material collected by A. Remenapp. Outreach was conducted through social media during the cruise and is being conducted at each institution through public and school events.

Methods

a) CTD Niskin sampling (SPRS) in ice-free water from the fantail, surface pumping (DiTullio & Lee collaboration, WP 5b) in ice-covered water from the aft port side, and manual collection from the main lead and a melt pond (both supported by SPRS staff), followed by filtration (main lab starboard side), of surface seawater.
b) Ambient aerosol sampling on 4th deck from Stockholm Univ. sampling manifold: Atmospheric particle collection by two five-stage cascade impactors and a rotating micro-orifice uniform deposition impactor (MOUDI), from same sampling manifold; coordinated with C. Leck (WP 2d).
c) Atmospheric particle sampling on the 5th deck using a high-volume air sampler.
d) Counterflow virtual impactor fog residual particle and whole air atmospheric particle sampling, as possible, using a three-stage microanalysis particle sampler (MPS), coordinated with P. Zieger (WP 2a).
e) Aerosol generation experiments using a marine aerosol reference tank (MART) filled with local surface seawater (from I/B *Oden's* aft, from the lead, from melt pond), with particle collection using a cascade impactor and MOUDI and online aerosol size distribution analysis using a SMPS and APS; located outside (MART) and inside (instrumentation) the bow CTD container.

Research activities and preliminary results

We ran 9 MART experiments (MIZ, North Pole, and 7 during the ice drift component, each lasting approx. 4.5 days from sample collection to end of cleanup (except for the MIZ where it was shorter; none done while I/B *Oden* was in motion).

Pratt and Ault: From our MART experiments: Preliminary SMPS and APS data analysis conducted to determine size-resolved particle number concentrations. From MART experiments and ambient particle samples: Select samples have been analyzed by Computer-controlled scanning electron microscopy with energy dispersive X-ray spectroscopy (CCSEM-EDX), and preliminary analysis is being conducted to determine individual particle morphology and elemental composition. Raman microspectroscopy will be performed on select samples to investigate functional groups present in individual particles. Fluorescence microscopy will be used to identify individual particles containing primary biology material. Atomic force microscopy will be used to further examine individual particle morphology and phase. Preliminary results for targeted samples will be available by the spring Artic Ocean 2018 workshop.

Grannas: From our MART experiments and from ambient samples: all organic chemistry samples (carbohydrates, amino acids, organic functional groups (NMR studies), organic molecular composition (high resolution MS studies)) are being, or are scheduled to be analyzed. Sample analysis will continue well into the spring, and preliminary results on select samples will be available by the spring science Artic Ocean 2018 workshop.

Matrai: From our MART experiments: Chlorophyll a (Chl-a) samples were run while temperature and salinity were recorded on board. Other marine samples have been run (particulate organic carbon and nitrogen), are being run (dissolved organic carbon, DOC), or are scheduled to be run (flow cytometry counts of nano and picoplankton, bacteria, virus; DNA-derived microbial identity). From ambient samples: DOC was sampled from the lead (daily; to benefit all interested expedition participants) and flow cytometry was sub-sampled from the larger Wurl-Robinson microlayer sampler or from glass plates (occasionally; to benefit all interested expedition participants). Results were presented at the spring Artic Ocean 2018 workshop.

Surface microlayer samples were collected at the lead with a small, battery operated autonomous sampler, coordinated with C. Leck (WP 2d). These samples are currently stored for subsequent analysis on polysaccharides, amino acids, proteins and fatty acids with methods common to the aerosol and fog/cloud water discussed above. DNA samples are currently stored pending availability of funds for their analysis.

b. Quantifying the source of aerosols from open leads in the High Arctic (MOCCHA)

Participants in the field

Dr. Matt Salter (PI), Karin Alfredsson

Summary and background

In this project, we aimed to achieve a process understanding of the role that aerosol particles, generated at the ocean surface, play in governing the state of clouds in the high Arctic during summer. Since the formation of clouds is the most uncertain aspect of the energy balance in the Arctic, controlling the freezing and melting of sea ice, such understanding is critical if we are to determine the response of the Arctic to future changes in air pollution and climate. Arctic clouds are often a mixture of supercooled water and ice crystals, so-called mixed-phase clouds, further complicates our understanding of the process of cloud-formation. Cloud droplets and ice crystals require aerosol particles to form, but our understanding of the source of the particles that drive the cloud-forming process in the high Arctic during summer remains insufficient. One process, thought to generate particles within open leads that are present in the high Arctic during summer, is bubble-bursting at the water surface. However, this source has only ever been inferred and the direct mechanisms behind it have yet to be determined or quantified. Resolving this issue was the focus of this project. To do so, we deployed a novel floating aerosol flux chamber on the open leads. This enabled us to directly quantify the source of cloud droplets and ice crystals from open leads as a function of important environmental variables, such as the physicochemical and biological state of the seawater.

Methods

Since the aim of this project was to determine the source of aerosol particles being emitted from open leads in the high Arctic we deployed a custom-built floating aerosol chamber in an open lead in the pack ice. The chamber is very similar in design to the flux chambers that are commonly deployed to determine gas fluxes in lakes and other low turbulence environments. The simple design allowed easy deployment into the open lead and the chamber had a well-defined footprint. The chamber consisted of an enclosure that created a headspace over the surface of the open lead from which the particle fluxes were measured. The enclosure was constructed from stainless steel to minimize particles wall-losses and the sides penetrated the surface of the open lead so that the headspace contained within was isolated from the atmosphere. A constant flow of particle-free "sweep-air" entered the headspace after passing through ultrafilters and activated carbon filters to remove all particles and organic vapours. Thus, the only source of particles within the floating aerosol chamber was from the surface of the open leads. Aerosol-laden air was sampled through a port in the lid of the chamber and transferred under laminar flow conditions to the connected aerosol instrumentation. To prevent contamination by Arctic boundary layer air, the chamber was operated under slight positive pressure by maintaining the sweep-air flow several litres per minute higher than the sampling rate. Excess air was vented through a one-way flutter valve on the lid of the chamber. In order to generate clean dry air for the floating chamber we operated a 24VDC dry-air generator that was powered by a 24V lead-acid battery bank.

In order to enumerate the number of particles in the floating chamber that are larger than 7 nm we used a condensation particle counter (CPC). In order to size particles in the size range between 10 nm and 350 nm we used a TSI Nanoscan scanning mobility particle sizing (SMPS) instrument. In order to enumerate and size particles larger than ~200 nm we used an optical particle size spectrometer (OPSS). We also collected filters and transmission electron microscopy (TEM) grids for post-cruise determination of the chemical composition of the particles (in collaboration with C. Leck, WP 2d) present in the floating chamber as well as the ice-nucleating efficiency of the particles (in collaboration with B. Murray WP 2c). The CPC, SMPS, OPSS, temperature and relative humidity sensors and data-logging equipment were powered by a single Li- battery that was located on top of the floating chamber.

Research activities and preliminary results

Since the PI and only active member of the research team is on 100% parental leave between October 2018 and August 2019, preliminary results will not be available until late 2019.

c. Bubbles near sea ice & their contribution to aerosol production (MOCCHA)

Participants in the field

Dr. Helen Czerski (PI), Dr. Matt Salter, Karin Alfredsson

Other project participants

Dr. Steve Gunn

Summary and background

Studies of Arctic clouds have found that they contain tiny particles of organic material that look as though they originate in the ocean, but it is not clear how this material travels from the ocean into the air. This study was designed to investigate one potential mechanism for transfer: the bursting of bubbles in the patches of open water between ice floes. Bubbles spit tiny droplets upwards when they burst, and previous studies have seen bubbles in the water near ice floes. In collaboration with Matt Salter's project (WP 3b) to measure the aerosol particles produced at the water surface, this study was designed to test whether this mechanism was operating in open leads during the summer and freeze-up period.

Methods

The main focus of the project was to measure bubble number and size distribution in the lead, using a specialized bubble camera which floated at the water surface and measured bubbles at a depth of 30cm. These measurements were coordinated with measurements of particle production at the water surface (made using a floating aerosol chamber). We monitored the same patch of open water for four weeks, watching what happened as the ice moved, the weather changed, and as the water surface started to freeze at the end of the summer.

In addition to the main bubble measurements, we used commercial instrument packages to monitor water currents, relative ice movement, temperature, salinity and dissolved gases in the lead, in order to investigate how bubbles might form. Water bottle samples were also taken so that laboratory analysis of a wider range of dissolved gases could be carried out in the lab.

Research activities and preliminary results

No final results are available yet. Preliminary data, shown at the spring workshop, suggested that bubbles in the lead were not contributing significant quantities of aerosol to the atmosphere.

References

Norris, SJ, Brooks, IM, de Leeuw, G et al. (5 more authors) (2011) *Measurements of bubble size spectra within leads in the Arctic summer pack ice.* Ocean Science, 7 (1). 129 - 139. ISSN 1812-0784

4.4 WP 4: Sea surface microlayer composition

a. Sea surface microlayer sampling and the role of transparent exopolymer particles (MOCCHA)

Participants in the field

Tiera-'Brandy' Robinson (Deputy PI), Michaela Haack

Other project participants

Dr. Oliver Wurl (PI)

Summary and background

The proposal is that the ocean's surface biofilm-characteristics have a potentially significant impact on biogeochemical fluxes and air-sea gas exchange (Wurl et al. 2016). Cycling and recycling of particulate organic matter in the sea surface film and underlying water may influence global carbon distribution. Extracellular polymeric substances (EPS) also play a crucial role in the Carbon cycle via their formation of large particulate aggregates (marine snow) which act as a major source of Carbon sequestration and movement within the water column (Azetsu-Scott and Passow 2004). Through this, the abundance of EPS also influences the biogeochemical fluxes and air-sea CO_2 gas exchange. Additionally, EPS are the binding agent in forming biofilm like structures at the sea surface and their movement and abundance will directly influence the structure and characteristics of the sea surface microlayer (SML) (Wurl and Holmes 2008). To understand the role of EPS, we look at the abundance and movement of one of its most prominent components, transparent exopolymer particles (TEP). However, little is understood about the role that melting ice, with its enriched concentrations of TEP, has on the SML and therefore on the air-sea exchange processes.

The objective of this project was to investigate the chemical, physical and biological properties of the SML within an open lead in the high arctic. In particular, we wanted to characterize and understand the abundance and enrichment of TEP in the SML compared to underlaying water (ULW) as well as other chemical and biological properties. We were interested in seeing what effects the constant changing environment within an open lead, with its freezing and thawing patterns, would have on the formation and production of TEP and how TEP in turn might affect such changes.

Methods

A Catamaran (Ribas-Ribas et al. 2017) was used to collect large volumes of SML and ULW water samples from near the ice edge at the open lead. Samples were collected whenever possible with 14 days of samples collected. The Catamaran is attached with 6 rotating glass disks which use the glass plate technique to sample the SML with a rotation speed of 7 rpm which collects the SML with a rate of 20 L h^{-1} and a thickness of about 50–80 mm (Shinki et al. 2012). Samples were collected once each day in 20 L containers and brought back to the ship for distribution inside the main lab.

60 ml of water was stored at 4°C for transportation and later tested for surfactants back in our lab in Germany. 100ml of water was stored at room temperature in brown PPE bottles with 1ml of lugol for future analysis back in Germany.

Water samples for both SML and ULW were filtered for TEP, coomasie stainable particles (CSP), particulate organic carbon (POC), particulate organic nitrogen (PON) and Chl-a.

Additionally, multiparameter probes were submerged in the open lead for two separate time series, each lasting 7 days. There were 5 probes placed at 5 depths below the surface of the water. These probes collected in situ measurements of temperature, salinity, conductivity and density.

A CO_2 buoy was deployed to measure the transfer rate of CO_2 within the open lead. However due to accidental flooding of the system upon its first deployment, no data was obtained during this cruise

Research activities and preliminary results

All samples were transferred back to our lab in Germany for analysis, and will be analyzed in the near future.

References

Azetsu-Scott, K., and U. Passow. 2004. Ascending marine particles: Significance of transparent exopolymer particles (TEP) in the upper ocean. Limnology and Oceanography 49**:** 7.

Ribas-Ribas, M., N. I. Hamizah Mustaffa, J. Rahlff, C. Stolle, and O. Wurl. 2017. Sea Surface Scanner (S3): A Catamaran for High-Resolution Measurements of Biogeochemical Properties of the Sea Surface Microlayer. Journal of Atmospheric and Oceanic Technology 34**:** 1433-1448.

Shinki, M., M. Wendeberg, S. Vagle, J. T. Cullen, and D. K. Hore. 2012. Characterization of adsorbed microlayer thickness on an oceanic glass plate sampler. Limnology and Oceanography: Methods 10**:** 728-735.

Wurl, O., and M. Holmes. 2008. The gelatinous nature of the sea-surface microlayer. Marine Chemistry 110**:** 89-97.

Wurl, O., C. Stolle, C. Van Thuoc, P. The Thu, and X. Mari. 2016. Biofilm-like properties of the sea surface and predicted effects on air–sea CO2 exchange. Progress in Oceanography 144**:** 15-24. WP 12: Spatial and temporal variability of (bio-) physical properties of the atmosphere, sea ice and upper ocean (ICE).

4.5 WP 5: Physics and biogeochemistry of ocean and ice

a. Spatial and temporal variability (bio-) physical properties of the atmosphere, sea ice and upper ocean (ICE)

Participants in the field

Dr. Mario Hoppmann (PI), Philipp Anhaus, Dr. Christian Katlein, Matthieu Labaste

Other project participants

Dr. Marcel Nicolaus, Dr. Benjamin Rabe, Dr. Christine Provost, Dr. Paul Poli

Summary and background

Seasonal variability of atmospheric, sea-ice and ocean properties

The Arctic Ocean is a key area of global climate change, which has been undergoing drastic changes in the recent decade. As a moderator between the atmosphere and the ocean in the polar regions, sea ice is one of the most important components in the global climate system. But the Arctic sea ice cover is diminishing rapidly, and because the climate system is so complex, we cannot easily figure out why that is and what it means. An important tool to fill the observational gaps has been continuously developed in recent years, namely autonomous, ice-tethered observation platforms. These drifting systems are now able to carry a diverse, multidisciplinary scientific payload capable of obtaining data on basin scales and throughout the winter periods. In the past, individual realms, such as the atmosphere, sea ice or the upper ocean in the polar regions have been subject to targeted observations, yet to date significant knowledge gaps exist in their complex interactions, and how they impact the evolution of the polar marine ecosystems. In order to investigate the relative importance of different processes in the “new Arctic”, we deployed a network of autonomous platforms during the Arctic Ocean 2018 expedition that monitor the most essential climate and ecosystem parameters (as illustrated in Figure 24).

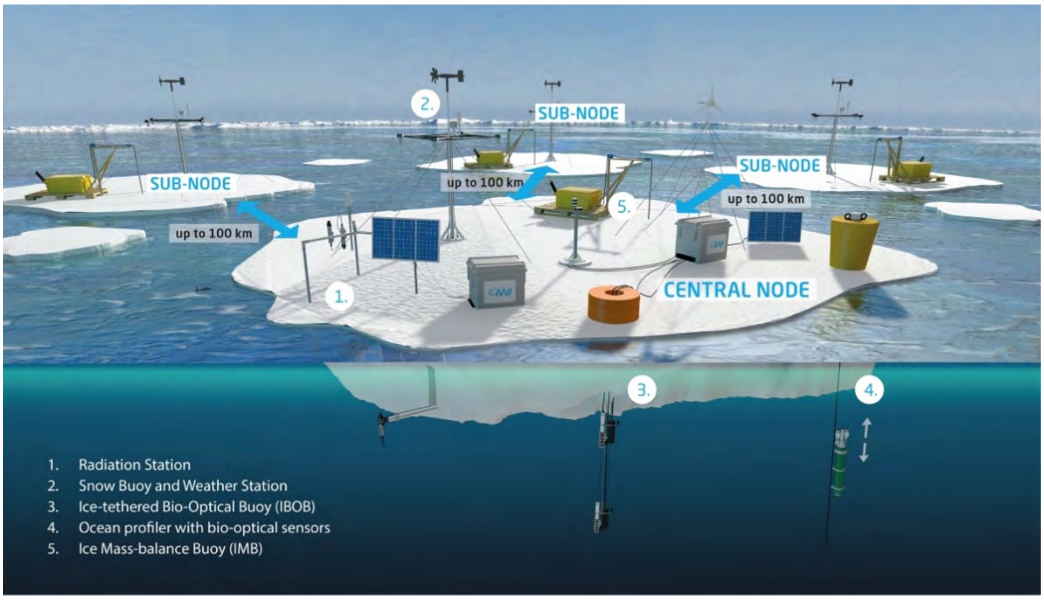


Figure 24. Schematic of multidisciplinary buoy array (Graphic: AWI/Sabine Lüdeling)

Bio-physical properties of the ice-ocean interface

Research at the ice-water interface below drifting sea ice is crucial for the investigation of the fluxes of energy, momentum, and matter across the atmosphere-ice-ocean boundary. Transmission of solar energy through the ice and snow layers causes warming of the upper ocean and melting of the ice itself. It is also a key factor for in- and under-ice primary production, supplying the ice associated food-chain, and causing carbon export to deeper water layers and the sea floor. Observations at the ice underside are however still sparse, as diving operations are risky and logistically challenging. In the last decade, robotic underwater technologies have evolved significantly and enabled the first targeted large-scale observations by remotely operated and autonomous underwater vehicles (ROVs and AUVs). During the Arctic Ocean 2018 expedition, we operated a new ROV system with a diverse scientific sensor payload (see also

Figure 25) to record the spatial variability of key parameters close to the ice-ocean interface, and record their temporal evolution during summer-autumn transition. The spectral radiation measurements from aboard the ROV (together with their meta data and complementary data sets) will help to fill the observational gap and will allow insights into the vertical and horizontal distribution of energy fluxes though summer sea ice in direct relation to habitat properties and ecosystem functions.

Turbulent heat exchange in the upper water column

The Arctic Ocean is a strongly stratified low-energy environment, where tides are weak and the upper ocean is protected by an ice cover during much of the year. Interior mixing processes are dominated by double diffusion. The upper Arctic Ocean features a cold surface mixed layer, which, separated by a sharp halocline, protects the sea ice from the warmer underlying Atlantic- and Pacific-derived water masses. These water masses carry nutrients that are important for the Arctic ecosystem. Hence vertical fluxes of heat, salt, and nutrients are crucial components in understanding the Arctic ecosystem. Yet, direct flux measurements are difficult to obtain and hence sparse. During the Arctic Ocean 2018 expedition, we obtained a time series of under-ice turbulence microstructure measurements on the central ice floe in order to determine dissipation rates of turbulent kinetic energy and fluxes of heat (and nutrients).

Research activities

Our research activities during the Arctic Ocean 2018 expedition can be separated into three aspects: the main activities included (a) the deployment of a major buoy cluster with one central and 4 remote nodes, (b) the regular operation of the ROV during the freeze-up, along with associated measurements such as scanning of the surface roughness and ice thickness transects, and (c) the determination of turbulent exchange processes within the ocean using the Microstructure profiler. Figure 25 shows a map of the main ice floe, where a majority of this work was conducted. The other aspect is the contribution of valuable data to a number of international programs. These include regular sea-ice observations from the bridge, the launch of expendable CTDs during ship transit, and the deployment of buoys along the way to enhance the network of barometric pressure measurements in an area where these are lacking most. All these activities are briefly described below.

Figure 25. Ortho-rectified aerial image of main ice floe, with relevant sites.

Buoy deployments as part of the MIDO observatory

In order to record many essential parameters in the atmosphere, sea ice and ocean of the "new Arctic" during and beyond the Arctic Ocean 2018 expedition, we deployed a number of autonomous platforms on the main ice floe, complemented by 4 remote nodes in some kilometers distance.

We deployed five different types of main platforms during the expedition (see also Figure 24): 5 Snow Buoys (SB), 5 Ice Mass-Balance Buoys (IMB), an Ice Tethered Bio-optical Buoy (ITBOB), a radiation buoy with a light chain prototype (RB) and a combined Ice – Atmosphere - Arctic Ocean Observing System (IAOOS). The central node of the observatory was located at the buoy site on the main ice floe (see Figure 25) and consisted of a full suite of sensors of all five types (Table 2, Figure 26). In addition, for the duration of the ice camp, we deployed a prototype of a new temperature & salinity chain with sensor pods at 5 m, 20 m and 40 m.

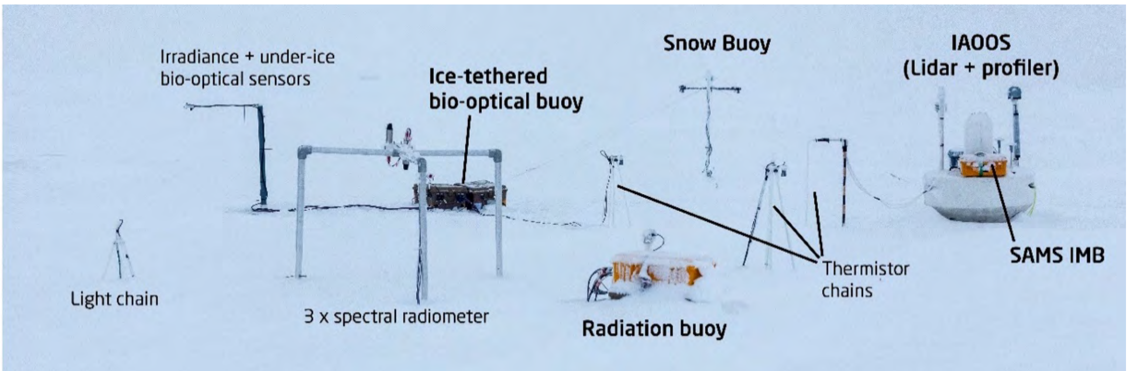


Figure 26. Buoy setup at central node.

In order to capture the spatial variability on different scales in the atmosphere, sea-ice, and ocean, the central node was complemented by 3 sub nodes each consisting of a Snow Buoy and an IMB, deployed via helicopter within 20km distance (Nodes 1 - 3), and a more remote site (Node 4) during the transit back (Table 2).

Table The data is expected to extend measurements taken by the scientific staff during the expedition into autumn and winter, long after the ship has left the study area.

Table 2. Buoy deployment overview

Buoy name	IMEI	Type	WMO#	Depl. Time	Latitude	Longitude	Node
2018M19	300025060608650	Bio	-	201809149:30	88.4774°N	038.4446°E	Buoy site
2018R4	300025060010720	Light	-	20180820 13:00	89.6192°N	033.0882°E	Buoy site
2018S69	300234066340550	Snow	6301598	20180827 10:15	89.6364°N	024.8954°E	Buoy site
		IMB	-	20180820 13:00	89.6192°N	033.0882°E	Buoy site
		IAOOS	-	20180820 13:00	89.6192°N	033.0882°E	Buoy site
2018S68	300234065722000	Snow	6301596	20180823 13:50	89.7188°N	033.0162°E	Node 1
2018T51	300234064816070	IMB	-	20180823 13:50	89.7188°N	033.0162°E	Node 1
2018M18	300025060607470	IMB	-	20180902 11:00	89.0867°N	079.9102°E	Node 2
2018S66	300234065628980	Snow	6301592	20180902 11:00	89.0867°N	079.9102°E	Node 2
2018S70	300234066341810	Snow	6301600	20180906 21:30	89.1873°N	034.8224°E	Node 3
2018T7	300234064819910	IMB	-	20180906 21:30	89.1873°N	034.8224°E	Node 3
2018M17	300025060605430	IMB	-	20180917 14:30	85.1829°N	020.4114°E	Node 4
2018S85	300234065629490	Snow	6301594	20180917 14:30	85.1829°N	020.4114°E	Node 4

The deployments are part of a network established by the Multidisciplinary Ice-based Distributed Observatory (MIDO) and Frontiers in Arctic Marine Monitoring (FRAM) infrastructure programs hosted at the Alfred-Wegener-Institute (AWI) in Germany, and the French Ice Atmosphere Arctic Ocean Observing System (IAOOS) project. The deployments complement various other international efforts in the Arctic, such as the International Arctic Buoy Programme (IABP) and the Year of Polar Prediction (YOPP), and are a part complemented by similar deployments from other ships during the same time period.

Remotely Operated Vehicle (ROV)

During the expedition, we used a new under-ice ROV system with a diverse scientific sensor payload (Figure 27) to record the spatial variability of key parameters close to the ice-ocean interface, and to record their temporal evolution during the transition from a pond-covered sea ice regime in summer to a snow-covered white desert in autumn (also referred to as "freeze-up").

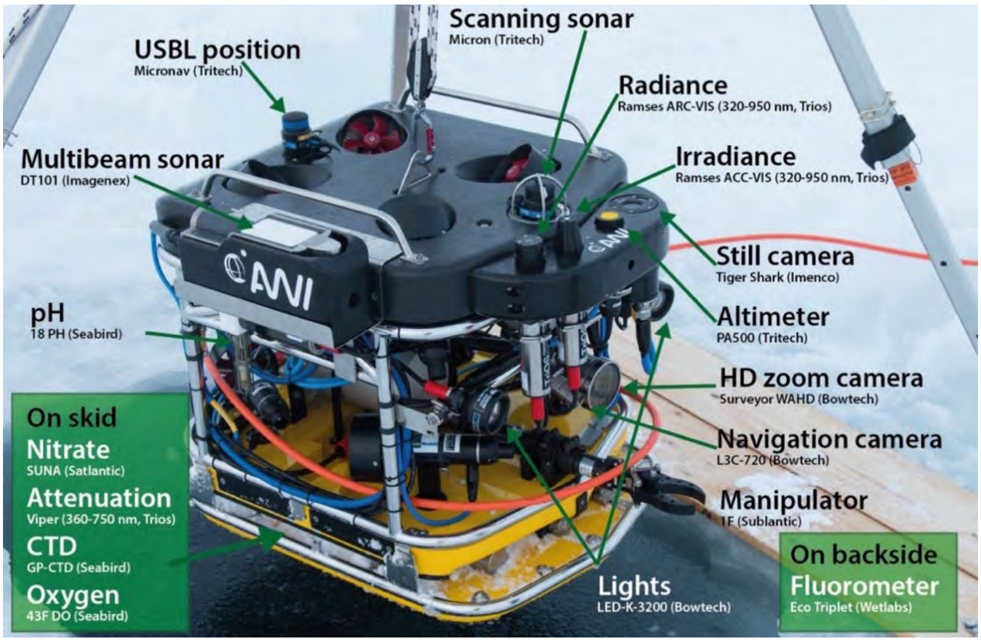


Figure 27. The remotely operated vehicle (ROV) and its multitude of scientific sensors.

The main sensor suite of the ROV is designed to obtain spectral light transmission through snow and sea ice, to acquire sea ice geometry using a multi-beam sonar, and measure physical, biological and biogeochemical properties of the underlying water column. The ROV was operated on a 300m long tether through an access hole in the ice at the ROV site. Our investigation focused on repeated transects within a predefined area (ROV grid, see Figure 28). An overview of all dives during the Arctic Ocean 2018 expedition is shown in ROV site and main sampling area (Table 3).

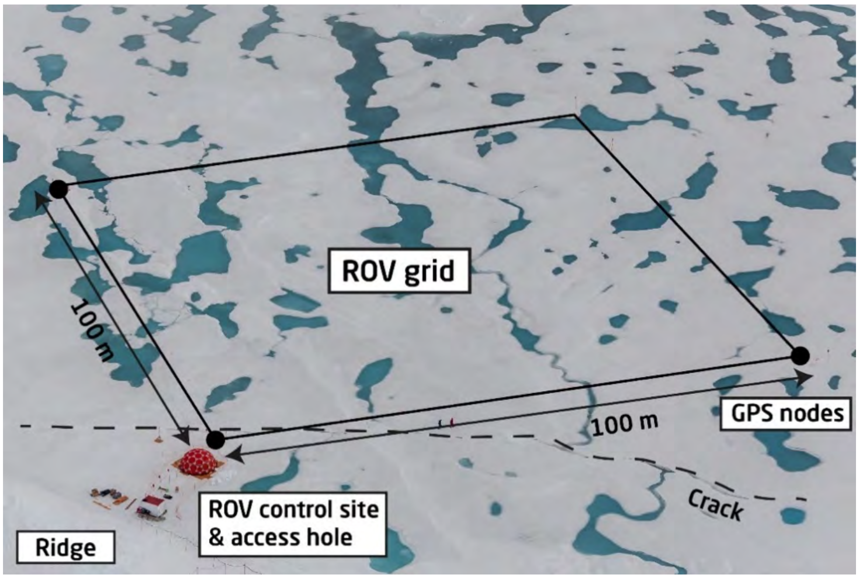


Figure 28. Aerial image of ROV site and main sampling area

Table 3. ROV dives overview.

Name	Station#	Date	Start time	End time	Dive time [h]	Comment
BEAST_041	ODEN2018_817_1	17.08.2018	16:38	17:16	00:38	Engineering test
BEAST_042	ODEN2018_818_1	18.08.2018	16:41	16:58	00:17	Test
BEAST_043	ODEN2018_819_1	19.08.2018	14:45	20:15	05:30	
BEAST_044	ODEN2018_821_1	21.08.2018	10:00	12:08	02:08	
BEAST_045	ODEN2018_822_1	22.08.2018	14:32	16:18	01:46	
BEAST_046	ODEN2018_824_1	24.08.2018	10:10	16:28	06:17	
BEAST_047	ODEN2018_828_1	28.08.2018	09:39	15:27	05:48	
BEAST_048	ODEN2018_830_1	30.08.2018	09:57	13:11	03:14	
BEAST_049	ODEN2018_901_1	01.09.2018	13:30	16:11	02:40	
BEAST_050	ODEN2018_904_1	04.09.2018	13:32	19:22	05:50	
BEAST_051	ODEN2018_906_1	06.09.2018	13:01	16:40	03:39	
BEAST_052	ODEN2018_908_1	08.09.2018	09:54	13:30	03:35	
BEAST_053	ODEN2018_909_1	09.09.2018	18:10	20:40	02:30	ROV “party”
BEAST_054	ODEN2018_910_1	10.09.2018	10:07	16:25	06:18	
BEAST_055	ODEN2018_913_1	13.09.2018	10:08	13:51	03:43	

Ice thickness and snow depth surveys

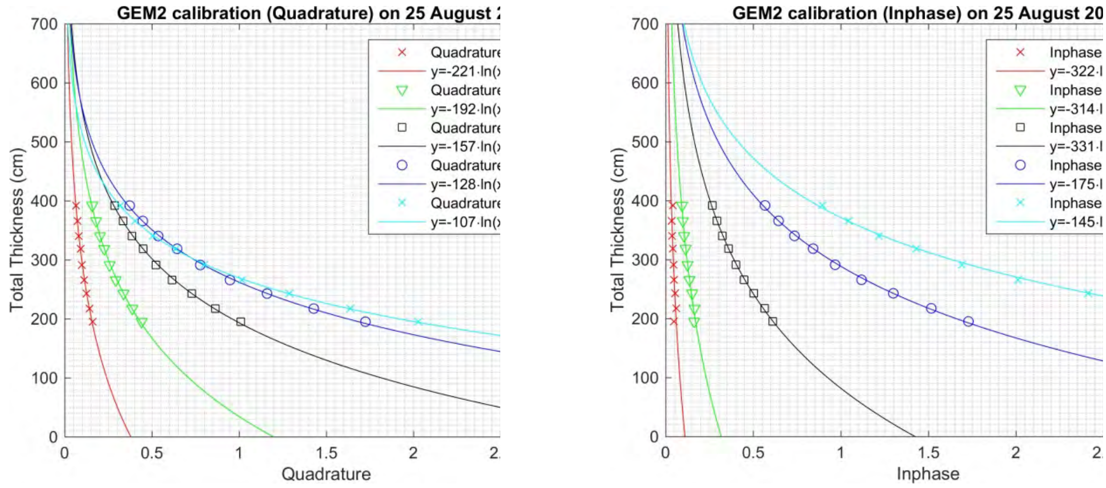


Figure 29: Preliminary calibration of GEM2 electromagnetic induction sounding data: quadrature (left) and inphase (right) of different signal frequencies. For the calculation of total (ice plus snow) thickness shown below, we used a frequency of 5310 Hz.

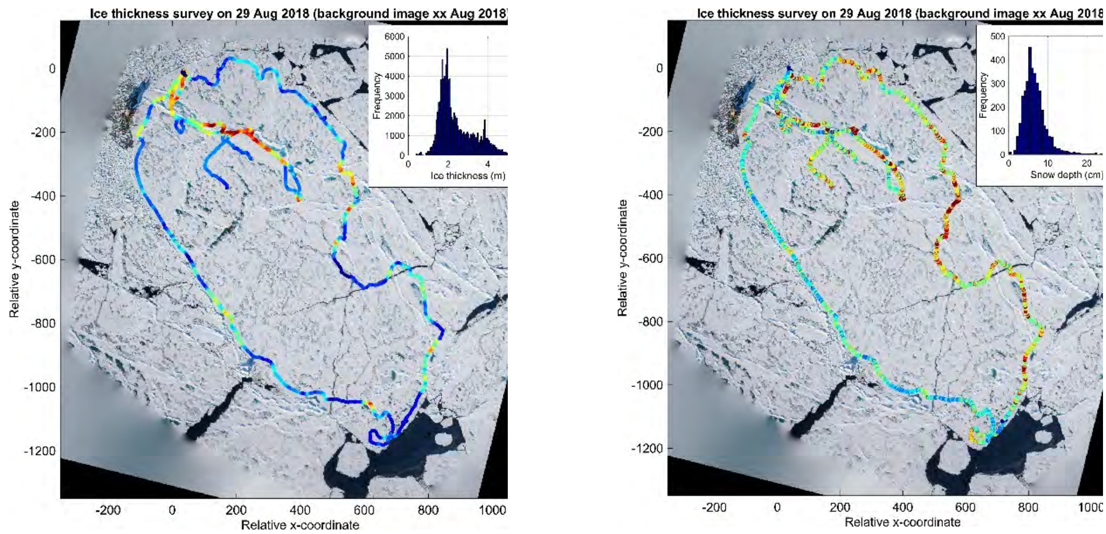


Figure 30: Results from GEM2 and Magnaprobe ice and snow surveys on the main ice floe performed on 29 August 2018. Ice thickness (left) was calculated from GEM2 calibrated total thickness minus Magnaprobe snow depth (shown on right panel).

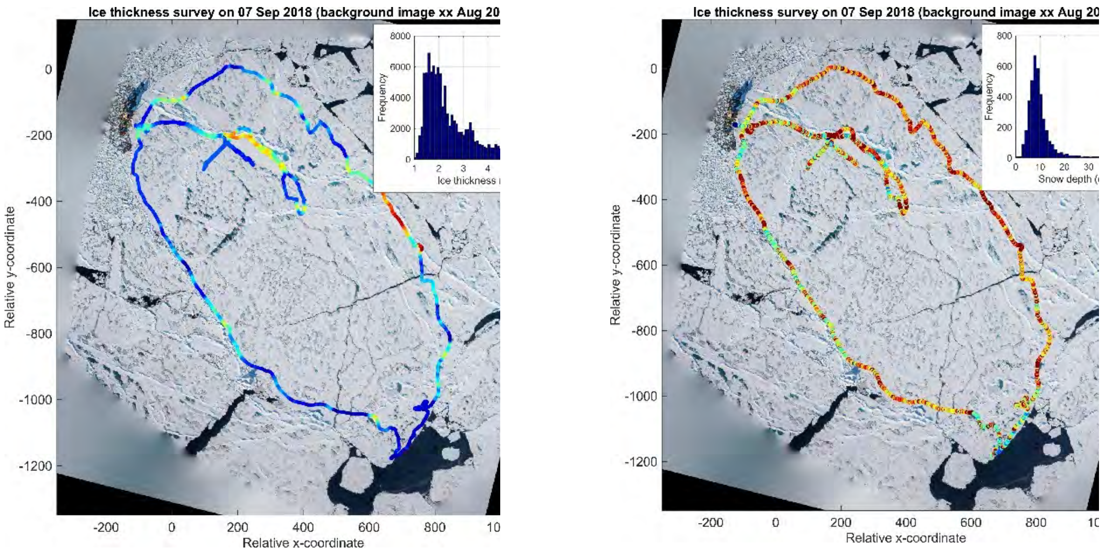


Figure 31: Results from GEM2 and Magnaprobe ice and snow surveys on the main ice floe performed on 07 September 2018. Ice thickness (left) was calculated from GEM2 calibrated total thickness minus Magnaprobe snow depth (shown on right panel).

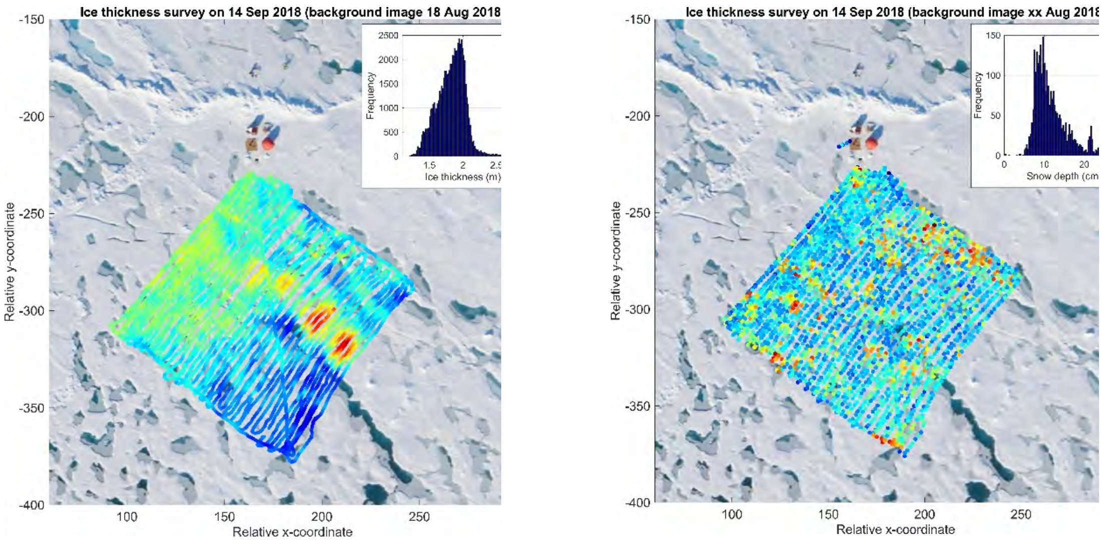


Figure 32: Results from GEM2 and Magnaprobe ice and snow surveys within the ROV grid performed on 14 September 2018. Ice thickness (left) was calculated from GEM2 calibrated total thickness minus Magnaprobe snow depth (shown on right panel).

Microstructure Sonde (MSS) & Acoustic Doppler Current Profiler (ADCP)

A turbulence profiler (MSS90L, Sea & Sun Technology) was regularly used from the access hole at the ROV site to obtain as many profiles as possible of temperature, salinity, Chl-a fluorescence and shear (Figure 33). The profiler was operated in free-falling mode to a depth of 600 m (the depth rating of the fluorometer), using an electrical winch. Additionally, a RDI Workhorse Longranger ADCP was operated within the access hole between August 21st and September 14th, 2018, to simultaneously record the current velocities in the upper 600 m. An overview of all MSS casts is presented in Table 4.

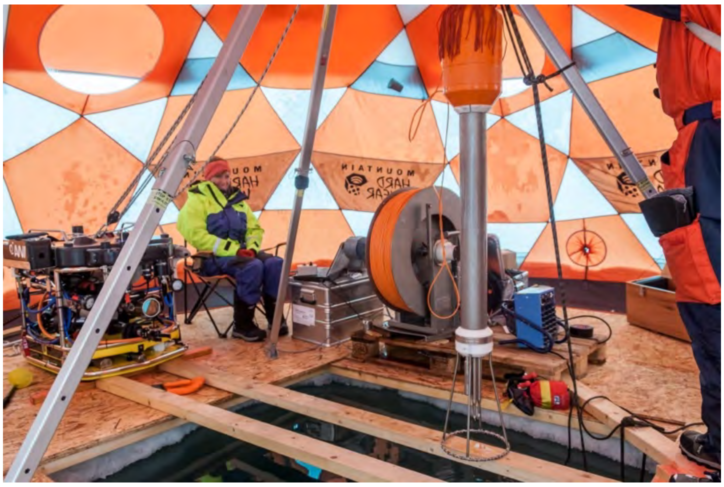


Figure 33. ROV tent with access hole, Microstructure profiler setup and ROV.

Table 4. MSS casts overview.

Date	Time Start	Time End	Profiles	Date	Time Start	Time End	Profiles
20180819	14:20	14:50	1	20180902	13:27	17:05	7
20180820	14:16	17:25	5	20180903	13:10	21:10	14
20180821	14:25	21:20	14	20180904	19:55	21:30	4
20180822	13:29	14:30	2	20180905	10:33	16:30	16
20180823	15:06	17:20	5	20180906	17:01	17:30	1
20180824	16:48	17:18	1	20180907	09:42	19:20	19
20180825	10:35	17:10	16	20180908	15:49	18:45	6
20180827	13:40	17:30	10	20180909	11:34	18:30	15
20180828	16:01	16:30	1	20180910	16:51	17:20	1
20180829	14:38	17:30	7	20180911	10:03	15:25	13
20180830	15:36	17:35	5	20180913	14:36	22:30	19
20180831	11:02	13:45	5	20180914	10:30	11:30	3
20180901	16:36	17:25	2				

Bio-profiler test trial

We performed a test trial of an improved resolution biogeochemical profiling float with updated firmware through a testing hole site. The profiler was deployed on a 250 m long cable for a 10-day period, and a number of configuration settings were tested during that time. After the successful test, the profiler was manually recovered using a special procedure as a preparation for a helicopter recovery operation of equipment later on (see below).

Ice thickness, snow depth and albedo transits

We measured sea-ice thickness, snow depth and surface albedo during two extensive transects around and across the main ice floe on August 29th and on September 7th, 2018. We used a

GEM-2 electromagnetic sounder (Geophex, USA) for total thickness, a semi-automatic GPS snow depth probe (Snow-Hydro, USA) for snow depth, and a custom-built Albedo stick with two Apogee SP-230 pyranometers for albedo. Additionally, we recorded a spatially very dense measurement transect covering the entire ROV grid on 14 September, shortly before leaving the main ice floe. The data will be used to calculate ice/snow thickness and albedo distributions, and together with the continuous GPS reference data (see below) yield maps of those parameters as well.

Laser scanning of the surface conditions

In order to complement the ROV-based measurements of under-ice roughness and light, we performed a number of high-resolution laser scans of the ROV grid and the ridge between the ROV site and Met Alley (see Figure 25) on several occasions using a Riegl VZ-400i Laserscanner (see Table 5). Since the data processing is not straightforward, the dataset will be available at a later stage.

Table 5. Laserscans overview.

Date	Scan positions	ROV grid	Ridge
20180818	19	x	
20180823	**27**	**x**	**x**
20180831	21	x	
20180905	**27**	**x**	**x**
20180909	27	x	x
20180913	**28**	**x**	**x**

GPS reference frame

In order to establish a constant reference frame on a drifting and rotating ice floe, we set up three reference GPS stations (see Figure 24, Figure 28) to correct all GPS-dependent data (such as for example ice thickness & snow depth transects, as well as the ADCP).

pH sensor test

Originally, we planned to test a new hybrid pH sensor on a continuous subsurface seawater intake, but the device was damaged upon installation and no data was collected.

Expendable CTDs (XCTDs)

During the transits to and from the main ice floe, we obtained a total of 26 CTD profiles from the ocean surface to a maximum depth of 1100 m using XCTD probes launched from the aft deck (see Table 6). These data complement hydrographic data collected in the previous years, as well as the regular CTD work during the Arctic Ocean 2018 expedition.

Table 6. XCTD casts overview.

ID	Serial no	Filename	DateTime	Latitude (°N)	Longitude (°E)	Depth (m)
XCTD_01	16103024	XCTD-00000802 2018.RAW	2018-08-02T21:28:00	82.18581	9.88034	713
XCTD_02	16103023	XCTD-00010804 2018.RAW	2018-08-04T03:10:00	82.38629	13.60221	1085
XCTD_03	16103022	XCTD-00020804 2018.RAW	2018-08-04T10:00:00	83.00000	16.90000	62
XCTD_04	16103023	XCTD-00030804 2018.RAW	2018-08-04T10:05:00	83.00100	16.90200	1085
XCTD_05	16103020	XCTD-00040804 2018.RAW	2018-08-04T15:10:00	83.34700	19.03200	1085
XCTD_06	16103021	XCTD-00050805 2018.RAW	2018-08-05T06:03:00	84.01634	26.40464	1085
XCTD_07	16103016	XCTD-00060805 2018.RAW	2018-08-05T11:58:00	84.46099	28.64822	339
XCTD_08	16103017	XCTD-00070805 2018.RAW	2018-08-05T21:01:00	85.02761	31.17409	885
XCTD_09	16103018	XCTD-00080806 2018.RAW	2018-08-06T08:09:00	85.53977	31.30297	1085
XCTD_10	16103015	XCTD-00090806 2018.RAW	2018-08-06T18:31:00	85.96039	31.79166	1085
XCTD_11	16103014	XCTD-00100807 2018.RAW	2018-08-07T11:43:00	86.49822	33.58531	788
XCTD_12	16103013	XCTD-00110808 2018.RAW	2018-08-08T09:04:00	87.01904	39.44135	411
XCTD_13	16103097	XCTD-00120808 2018.RAW	2018-08-08T21:45:00	87.49823	45.00386	1085
XCTD_14	16103010	XCTD-00130809 2018.RAW	2018-08-09T09:59:00	88.02960	46.94180	957
XCTD_15	16103007	XCTD-00140810 2018.RAW	2018-08-10T00:13:00	88.56828	45.86873	922
XCTD_16	16103004	XCTD-00150811 2018.RAW	2018-08-11T03:02:00	88.97156	51.20527	1085
XCTD_17	16103001	XCTD-00160811 2018.RAW	2018-08-11T16:38:00	89.54131	58.25168	217
XCTD_18	16103002	XCTD-00170916 2018.RAW	2018-09-16T17:27:00	86.33440	13.25975	409
XCTD_19	16103095	XCTD-00180917 2018.RAW	2018-09-17T02:05:00	85.80725	17.82720	235
XCTD_20	16103096	XCTD-00190917 2018.RAW	2018-09-17T11:27:00	85.37055	19.98950	1085
XCTD_21	16103011	XCTD-00200917 2018.RAW	2018-09-17T18:14:00	84.92801	20.76443	1085
XCTD_22	16103012	XCTD-00210918 2018.RAW	2018-09-18T04:17:00	84.21832	22.50298	1085
XCTD_23	16103005	XCTD-00220918 2018.RAW	2018-09-18T11:57:00	83.53279	21.94431	1038
XCTD_24	16103003	XCTD-00230918 2018.RAW	2018-09-18T21:02:00	82.65921	21.20364	1085
XCTD_25	16103008	XCTD-00240920 2018.RAW	2018-09-20T08:48:00	81.93000	16.88000	1081
XCTD_26	16103006	XCTD-00250920 2018.RAW	2018-09-20T12:32:00	81.39000	13.15300	1085

SVP-B buoy deployments during transit

We deployed 7 Surface Velocity Profilers with barometric pressure sensors (SVP-Bs) during the transit to and from the main site (see Table 7). Five of those buoys (without drogue) were placed on ice floes using the helicopter, while another 2 (with drogue) were dropped into open water close to the ice edge from the working deck. The buoys were provided by the EUMETNET program and contribute to the Year of Polar Prediction (YOPP).

Table 7. SVP-B deployments for EUMETNET/YOPP.

Buoy ID	IMEI	Type	WMO#	Depl. Time	Latitude	Longitude
2018P58	300234065745780	SVP	6301561	20180802 18:11	81.8924°N	009.8816°E
2018P64	300234065747810	SVP	6301564	20180805 13:14	84.7496°N	030.9053°E
2018P62	300234065745810	SVP	6301562	20180806 17:00	86.1100°N	032.9476°E
2018P63	300234065746750	SVP	6301563	20180809 22:00	88.5561°N	046.6622°E
2018P60	300234065741760	SVP	6301558	20180915 07:00	88.0728°N	020.7292°E
2018P61	300234065742820	SVP	6301560	20180918 19:00	82.8116°N	021.3326°E
2018P59	300234065741790	SVP	6301559	20180920 08:05	82.0058°N	017.6918°E

Sea ice bridge observations for ASSIST

An additional source of information regarding the state of the Arctic sea ice and its snow cover is visual classification of key sea ice variables. Though quite subjective, visual observations have the promise of creating large datasets due to the numbers of vessels in the summer Arctic. Such datasets are of high value to record the ice conditions during various observations during the cruise and for validation of remote sensing products. We carried out around 100 of such visual sea ice observations from the bridge of I/B *Oden* during the transits according to the ASSIST protocol (Arctic Shipborne Sea Ice Standardization Tool).

Satellite Radar imagery support

In order to facilitate navigation through the ice, we provided a number of Sentinel-1 (AWI/Drift&Noise) and TerraSAR-X (DLR, proposal with M. Tjernström) radar images along I/B *Oden*'s cruise track, using the position of a buoy on deck as the reference position. In addition, we provided sea ice drift forecast and sea ice concentration data (Drift&Noise) in near-real time.

"Barneo" buoy recovery

A number of autonomous instruments, including a bio-IAOOS platform, a SAMS IMB, a Snow Buoy, a Bruncin bio-optical buoy (ITBOB) and a PAMA (Seabird SBE37 Microcat + SAMI pCO2 sensor) were deployed at the "Barneo" North Pole field camp in April 2018. Since most of the instruments ceased operation during August 2018, we performed a recovery operation using the helicopter at the time when we were at closest distance to the camps location. The operation took place on 15 September 2018, a few hours after starting our transit back home. Upon reaching the site, it became apparent that all platforms suffered severe polar bear damage. We were able to recover most of the instruments within 4-5 hours. The snow buoy could be repaired and was left at the site. Additionally, SVP 2018P60 was deployed at that site (see Table 7). Examining the webcam images from one of the buoys, we could identify at least 9 instances where significant alterations of the site took place, (suggesting a substantial number of repeated polar bears visits).

Preliminary results

Ice floe backtracking

We calculated a backtracking of the main ice floe using weather and ice drift data from different sources (Figure 4). The results suggest that the ice floe where our camp was located was around three years old, and originated from the western Laptev Sea close to Sewernaya Semlja. These findings were also supported by measurements of ice core salinities, and by the presence of a large number of small icebergs in our study region, which must have originated from Siberian ice shelves.

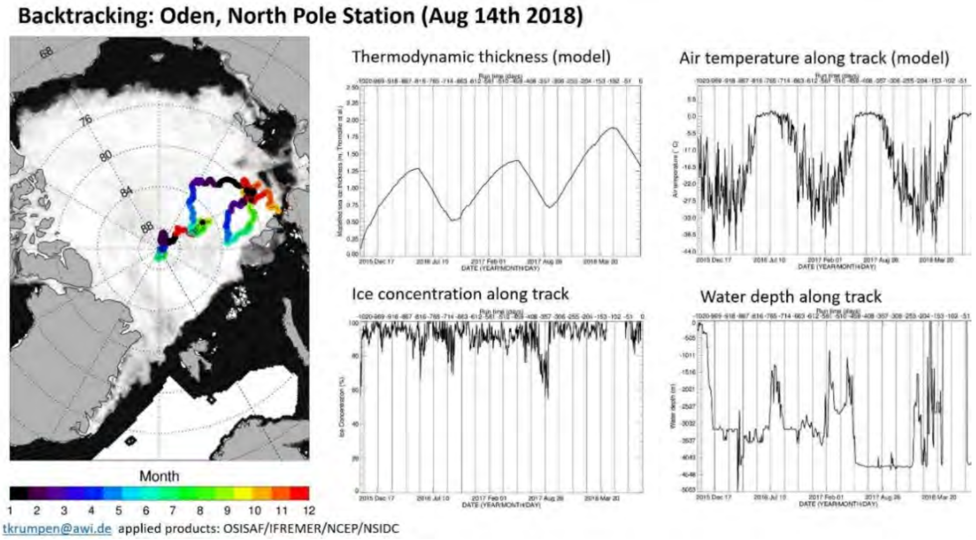


Figure 34. Results from a backtracking algorithm (courtesy of T. Krumpen) applied to the location of the main ice floe, suggesting that the ice was roughly 3 years old, and originated from the western Laptev Sea.

Buoy network

Between August 2018 and January 2019, most buoys deployed during Arctic Ocean 2018 have already drifted a long distance towards and beyond Fram Strait, with the southernmost 5 having left the Arctic Ocean as of 9 Jan 2019 (Figure 35). Unexpectedly, SVP 2018P58 deployed in open water on 2 August 2018 travelled a significant distance eastwards, without being crushed by newly formed ice. Unfortunately, quite a number of instruments, and especially those deployed at the central node, have already ceased operation in late 2018.

Since some co-located ones are still transmitting, we attribute this to polar bear damage. In this context, it has to be mentioned that the main ice camp was visited 3 times by polar bears. The first visit caused significant damage to the instruments, which could however be repaired. We don't show any buoy data here at this point, because most buoy data including plots is available at http://data.meereisportal.de/gallery/index_new.php?lang=en_US&survey=&active-tab1=method&active-tab2=buoy. Buoys not shown there require significant processing. Their data will be available later.

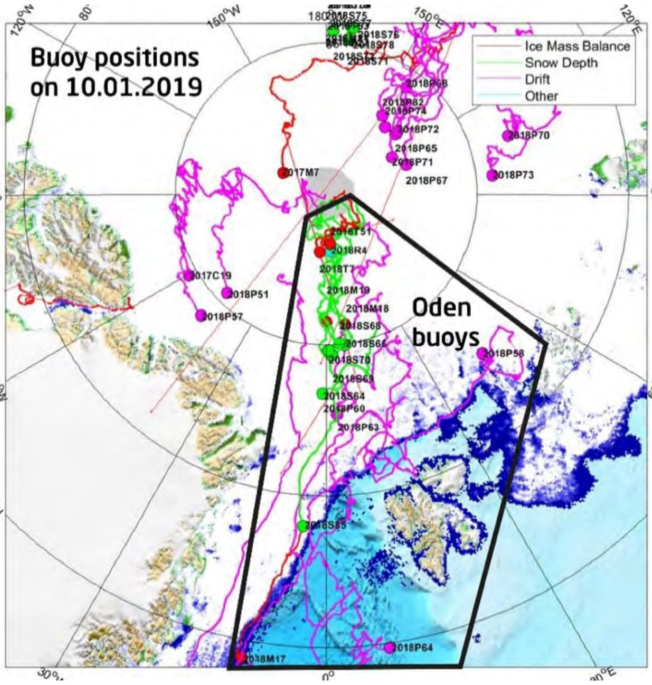


Figure 35. Drift tracks of AWI buoys deployed in 2018 (www.meereisportal.de). All tracks within the black boundary originate from buoys deployed during the Arctic Ocean 2018 expedition.

Remotely operated vehicle

The amount of data collected by the ROV is both extensive (>400GB) and very diverse, so we can only show some sample data below:

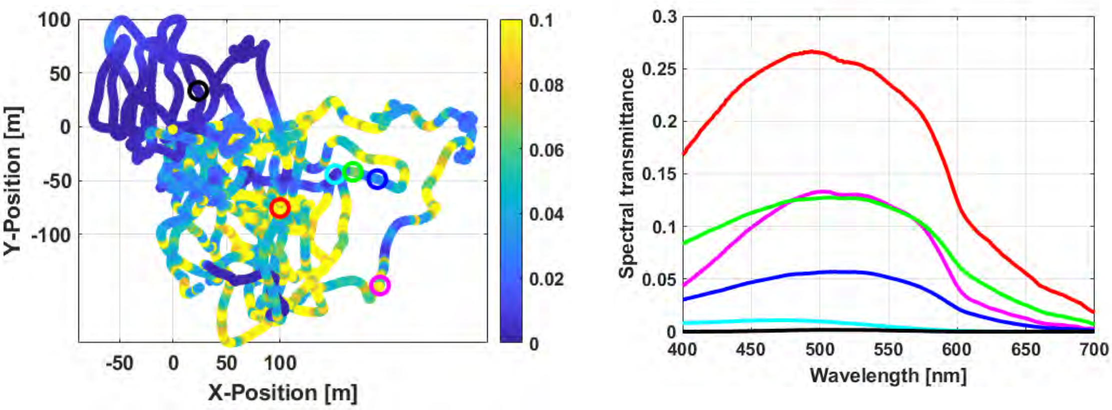


Figure 36. Sample map of light transmission through the ice within and beyond the ROV grid sampling area on 19 August 2018 (left), and selected transmittance spectra at five different sites (right). Their location in the map is indicated by colored circles. The origin of the map (0/0) is representing the access hole (ROV site). The ROV grid extends from 0 to 100 m (x) and 0 to -100 m (y), showing comparably high transmittance. The low transmittance area in the top left corner represents the ridge area between the ROV site and the Met alley. The measurements on the far right in the map represent the buoy site.

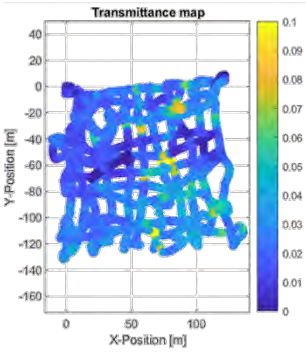


Figure 37. Detailed view of light transmittance within the ROV grid on 30 August 2018. In comparison to the above figure, there is much less light available in the ocean, which is mostly due to new snow accumulating on the ice surface.

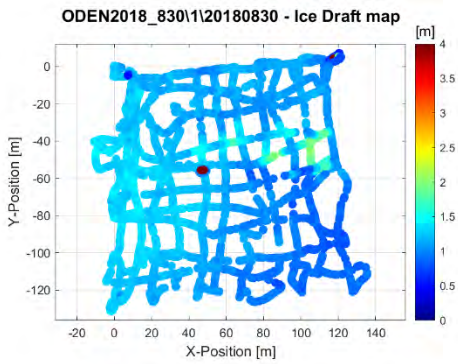


Figure 38. Corresponding sea ice draft map in the ROV grid from 30 August 2018. The thicker the ice is, the lesser light is transmitted through it.

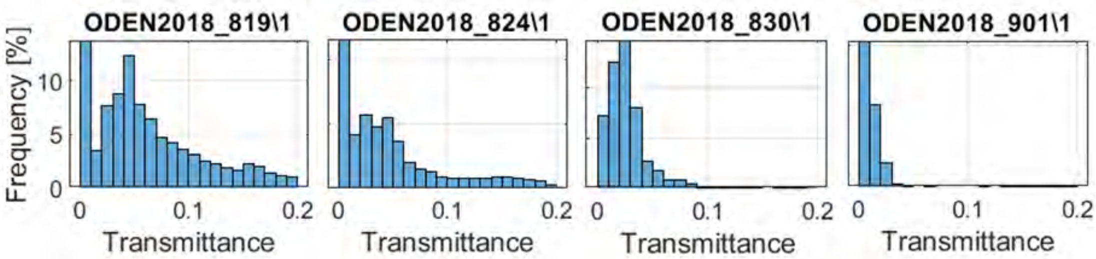


Figure 39. Evolution of light transmittance frequency distributions in the second half of August 2018 as another indicator of the impact of melt pond refreezing and snow cover on light availability in the upper ocean.

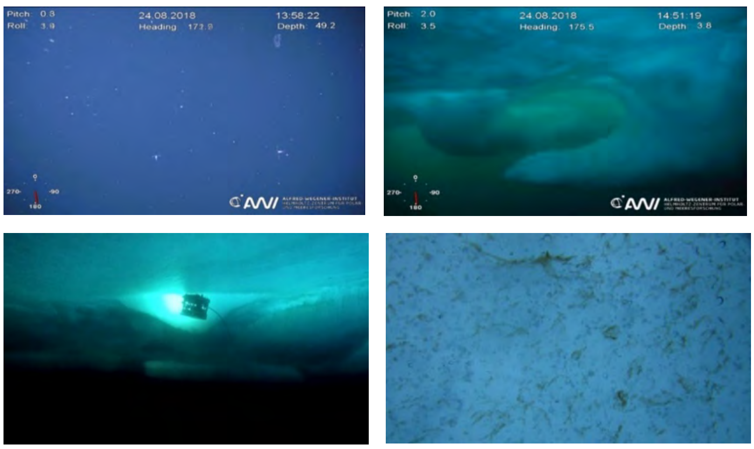


Figure 40. Selection of images to highlight the abundance of zooplankton (mostly copepods) in the water column (top left), the funny structures of ridges (top right), the ROV at work investigating a ridge (bottom left) and ice algae thriving on the ice underside (bottom right).

In summary our observations revealed that, although the light intensity decreased significantly as more snow accumulated on the sea ice, the ice-associated algae attached to the ice underside were still thriving, a quite unexpected and puzzling finding.

Microstructure profiler & ADCP

The processing of MSS data needs great care, so we can only show some basic results at this point. Figure 41 and Figure 42 show first plots of temperature, salinity and Chl-a data from all 192 MSS profiles recorded within the study period. The processing of the more complicated shear data is currently in progress.

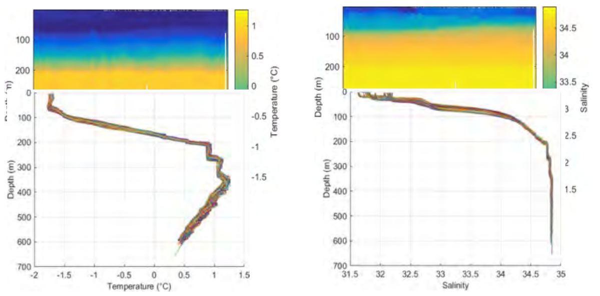


Figure 41. MSS temperature (left) and salinity plots (right) taken through the access hole at the ROV site between 19 August and 14 September 2018.

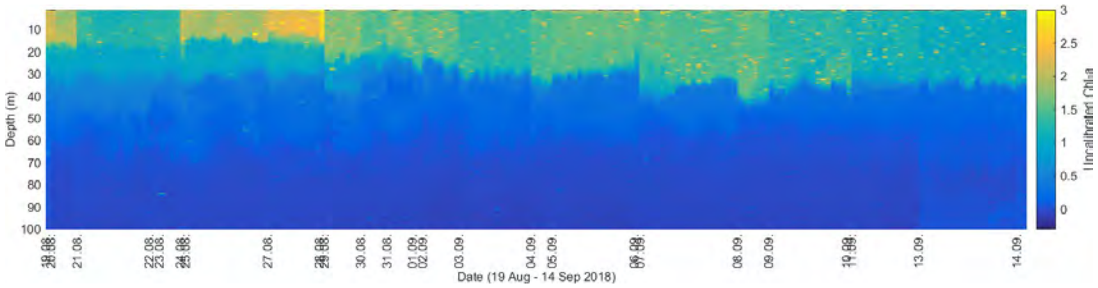


Figure 42. Contour plot of all MSS Chl-a profiles taken at the ROV site between 19 August and 14 September 2018.

With respect to ADCP data, the close proximity of the ice camp to the magnetic North Pole caused significant issues with the ADCP's internal compass. Combined with the ice floe rotation, the processing of the data is challenging and needs to include the rotation data from the GPS reference stations. The processed and quality controlled ADCP data will therefore be available at a later stage. However, Figure 43 shows the ADCP raw velocity magnitude (upper panel) and raw velocity direction (lower panel) between August 20th and September 14th, not taking into account the rotation.

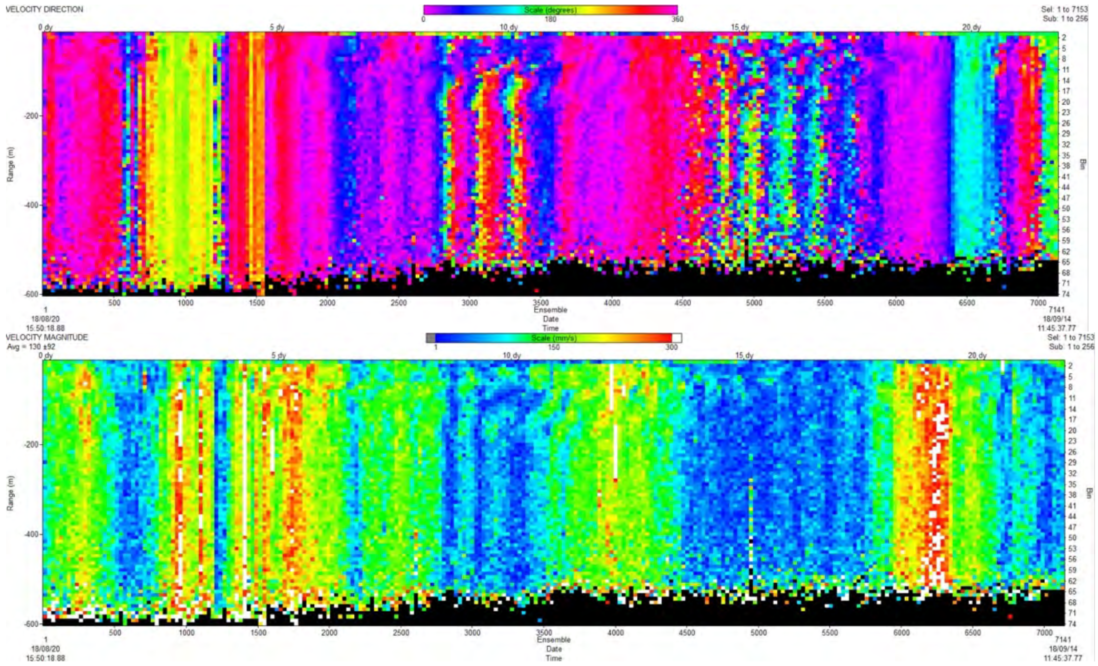


Figure 43. ADCP raw velocity magnitude (upper panel) and raw velocity direction (lower panel) between 20 August and 14 September 2018.

Expendable CTDs

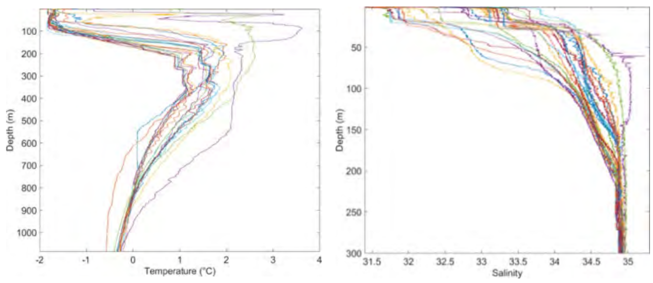


Figure 44**.** All XCTD temperature profiles in the upper 1100m (left) and salinity profiles in the upper 300m.

Data Management

Most data can be shared with any cruise participant on request. Please note that the amount of data can be very large, for example the ROV data exceed 400GB.

All data from the radiation measurements and the ROV require post-processing after the cruise and are fed into the AWI data-portal via the Raw-Data-Ingest framework. The data from AWI sensors will be made publically available in the PANGAEA database within one year.

Snow buoys and SVPs report their data into the Global Telecommunications System (GTS) in near real time, as well as into the database of the International Arctic Buoy Programme (IABP). Most buoy data is uploaded and made publicly available on www.meereisportal.de within a few days after deployment. The data is updated on a daily basis. The quality-controlled data are archived in PANGAEA after a buoy ceases operation.

Arctic Ocean 2018 visual sea ice observation data are already available from the standardized database at the International Arctic Research Center, University of Alaska, Fairbanks, under http://icewatch.gina.alaska.edu/cruises/78.

All processed ice & snow thickness measurements will be published in the online data repository PANGAEA after processing.

XCTD raw data is available under https://doi.org/10.1594/PANGAEA.895997. Processed and quality-controlled data will be made available within the next months.

MSS raw CTD data will be uploaded to PANGAEA in the coming weeks. The processed and quality controlled full dataset will be provided at a later stage. Same holds true for the associated ADCP data.

Our work is part of the Helmholtz strategic investment Frontiers in Arctic Marine Monitoring (FRAM), as well as the Multidisciplinary Ice based Distributed Observatory (MIDO) infrastructure program, and contributes to several projects on an international level (International Arctic Buoy Program, IABP; Forum for Arctic Modeling and Observational Synthesis, FAMOS; French equipex IAOOS, http://www.iaoos-equipex.upmc.fr and http://iaoos.ipev.fr; EU FP7 Ice Arc project, http://www.ice-arc.eu).

b. Microbial Oceanography Links to new aerosols in the ice-covered regions in the High Arctic (MOCCHA)

Participants in the field

Dr. Giacomo 'Jack' Di Tullio (PI), Allister 'James' Cumming, Francesco Bolinesi, Nicole Schanke

Other project participants

Dr. Peter Lee (PI)

Summary and background

Our primary objective was to determine the microbial composition and production of various gases within the upper water column at a station in the high Arctic Ocean during late summer and to determine the limiting factors that impacted microbial production and biomass in this region. In general, we observed that phytoplankton production and biomass were co-limited by light and concentrations of ambient nitrate, and trace metals. Previous reports have noted significant light limitation in the Arctic Ocean and have suggested that primary production rates could significantly increase in the future Arctic as sea ice melts and light levels increase. However, co-limitation by nutrients and trace metals could significantly decrease productivity rates in the future high Arctic Ocean unless changes in ocean circulation advect higher concentrations of nutrients and trace metals from Arctic continental shelves. Changes in the microbial community composition in the upper ocean could also impact the production and flux of various volatile organic carbon compounds into the atmosphere thereby impacting the radiation balance of the future Arctic Ocean.

Methods

Our research activities involved sampling of seawater samples collected using either (1) the ship's CTD system, (2) shipboard in-situ pumping using a Teflon diaphragm pump, (3) sea ice samples and (4) samples collected from either the open lead or from the ROV site. Gas samples were analyzed onboard using our membrane inlet mass spectrometer (MIMS) system for various gases including (but not limited to) nitrogen, oxygen, argon, dimethyl sulfide (DMS) and methane. The O_2/Ar ratio will be utilized to estimate net community production (NCP) in the water column. Various calibrations for these gases were performed periodically while at sea. Some of these data will be presented at the Arctic Ocean 2018 workshop in March, 2019. Large volume sampling was also performed to collect samples for both proteomics and genomic analyses. Those samples are currently still frozen awaiting analyses and will not be ready for the upcoming workshop. In addition, a number of shipboard incubation experiments were performed to investigate the bottom up controls (light, salinity and nutrients) on phytoplankton production and species composition. Samples were collected from the incubation experiments and CTD casts to determine nutrient concentrations (colorometrically), microbial community composition (via flow cytometry), phytoplankton community composition (via HPLC pigments), phytoplankton biomass (via Chl-a concentrations), various photosynthetic parameters including photosynthetic efficiency of PS

II (via pulse amplitude modulated fluorometry), NCP (via MIMS), diatom biomass (via biogenic silica concentrations), and concentrations of biogenic sulfur compounds including DMS and dissolved and particulate dimethylsulfoniopropionate (DMSP).

Research activities and preliminary results

Experiment 1: Methane/DMS Production Experiment

Goal: To investigate whether additions of DMSP and/or methyl phosphonate (MPn) can lead to microbial production of DMS or methane.

Experimental Setup: Water collected from CTD 4 (88° 53.48' N, 52° 2.53' E) at 10m. Water filtered with 63um mesh due to presence of copepods. Sampled in triplicate at three time points, using four treatments: Control (green), +DMSP (red), +MPn (yellow) and +DMSP+MPn (blue). 100 uM of DMSP and 100uM of MPn were added to each 1L sample bottle. 2.7 L bottles were used to sample pigments and transcripts at the final time point. Temperature was maintained at 0^{o} C with a light level of $10 uE/m^2/s$.

Sampling: T0 was sampled on 8/10/18 at 15:30 UTC. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling at T6, T8 and T12. Samples were taken for Chl-a, Fv/Fm, DMSP, gases and flow cytometry.

Results: Low initial Chl-a biomass led to very little phytoplankton growth and no significant differences were observed in DMS or methane concentrations relative to the control in any of the treatments.

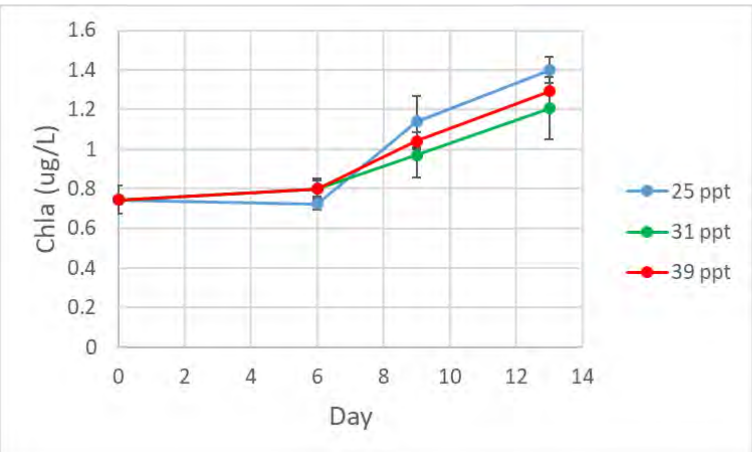
Experiment 2: Salinity

Goal: To investigate the impact of higher and lower salinity levels on various microbial processes and production of volatile organic compounds.

Experimental Setup: Water was collected using a Teflon pump instead of the CTD (89° 30.75' N, 31° 19.71' E). Water was pre-filtered with a 63 um mesh. The experiment was set up and sampled in triplicate at three time points with three treatments: (1) Control (31 ppt, green), (2) High salinity (39 ppt, red) and (3) Low salinity (25 ppt, blue). For the high salinity treatment, 50 ml of sample water was removed and replaced with 50 ml of 0.145 g/ml NaCl, giving a salinity of 38.95 ppt. For the low salinity treatment: 200 ml of sample water was removed and replaced with 200 ml of Milli-Q water. Additional incubation bottles (2.7 L polycarbonate) were used and samples were taken at the T-final timepoint for pigment and transcript samples. Temperature was maintained at 0^{o} C with a light level of $10 uE/m^2/s$.

Sampling: T0 was sampled on 8/17/18 at 19:00 UTC. Samples were taken for proteomics, biogenic silica (BSi), Chl-a, pigments, photosynthetic efficiency of PS II (Fv/Fm), gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling was performed at the T6, T9 and T13 timepoints.

Results: No major differences in Chl-a biomass were observed between salinity treatments. The low Chl-a biomass observed following the 13 day incubation period suggested the possibility of nutrient limitation (see Figure below).



Experiment 3: Nutrient-Light Interaction Experiment

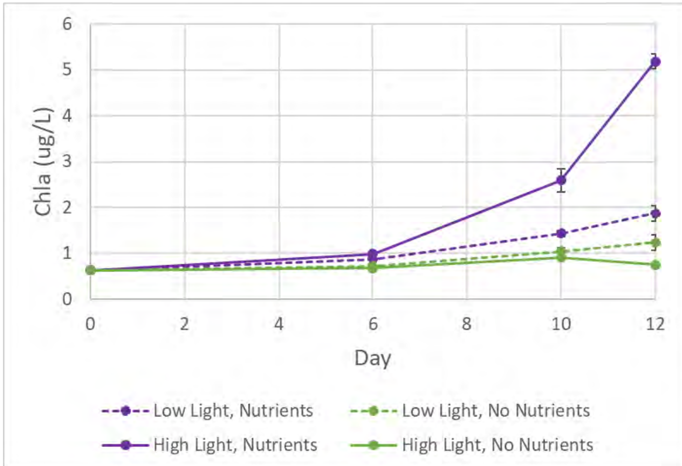
Goal: To investigate the interactive effects of light and nutrients on microbial processes.

Experimental Setup: Water was collected using the Teflon pump (89° 35.60' N, 20° 56.71' E). Seawater was pre-filtered through a 63 um Nitex mesh. Samples were collected in triplicate at three time points with four treatments: (1) High Control (20 uE, no nutrients added), (2) High Nutrients and light (20uE, nutrient replete), (3) Low light-Control (10uE, no nutrients added), and (4) Low-light, high nutrients (10uE, nutrient replete). Temperature was maintained at 0^o C with relatively high and low light levels of approximately 20 and 10 $uE/m^2/s$, respectively.

Nutrient Amendment: Per 1L bottle, nutrient additions consisted of 250 ul of a 50mM nitrate stock (12.5 uM final concentration), 500 ul of 2.5 mM phosphate stock (1.25 uM final concentration), 50 ul of L1 vitamin stock mix (includes vitamin B_1, B_6, and B_{12}), 100 ul of L1 trace metal stock solution, and 100 ul of L1 silicate stock. These nutrient additions are considered to provide a nutrient-replete condition.

Sampling: T0 was sampled on 8/21/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling was conducted at the T6, T10 and T12 timepoints. Samples were taken for Chl-a, Fv/Fm, DMSP, gases and flow cytometry.

Results: A significant effect was observed of both nutrients and light on phytoplankton biomass accumulation following a 12 day incubation period. A significant interactive effect was also observed. Without nutrient additions, the relatively low light treatment had a Chl-a biomass at the end of the incubation period that was significantly higher than observed in the higher light treatment.



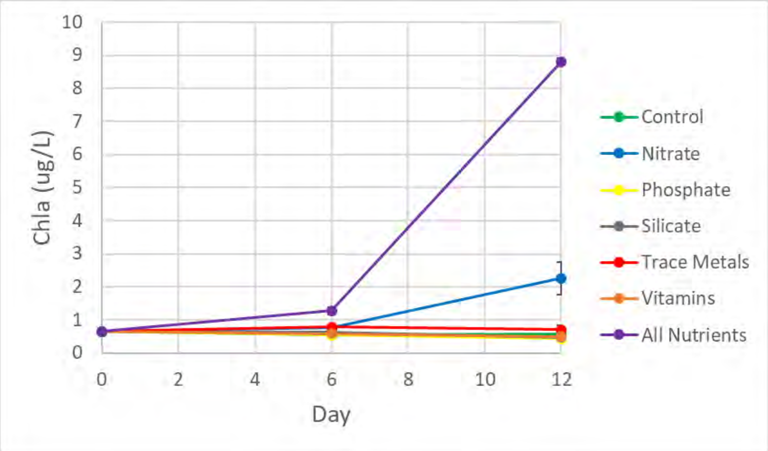
Experiment 4: Nutrient Bioassay

Goal: A nutrient bioassay experiment was set up to determine which major macro or micronutrient was limiting.

Experimental Setup: Water was collected from CTD 18 at 10m on 8/29/18, with an ambient water temp of -1.0^o C and a salinity of 31.58. Destructive sampling in triplicate was performed at two time points. Seven separate treatments were set up each with the addition of a single nutrient including: Control (no addition, green), All (all nutrients added, using the recipe from expt 3), Nitrate (250 ul of 50mM stock, 12.5 uM final conc, blue), Phosphate (500 ul of 2.5 mM stock, 1.25 uM final concentration, yellow), Silicate (100 ul of L1 stock, white), Trace Metals (100 ul of L1 stock, red) and Vitamins (50 ul of L1 stock, orange). Polycarbonate 2.7 L bottles were sampled at T-final timepoints for pigments and transcripts. Temperature was maintained at 0^o C with a light level of 20$uE/m^2/s$.

Sampling: T0 was sampled on 8/29/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling was performed at T6 and T12. Samples were taken for Chl-a, Fv/Fm, DMSP, gases, flow cytometry and halocarbons.

Results: Clear differences were observed indicating significant limitation of nitrate relative to the control treatment with a significant interactive effect observed between nitrate and other nutrients relative to the control treatment (See Figure below). Results indicated that that the nutrient interactive effect was not strictly additive.



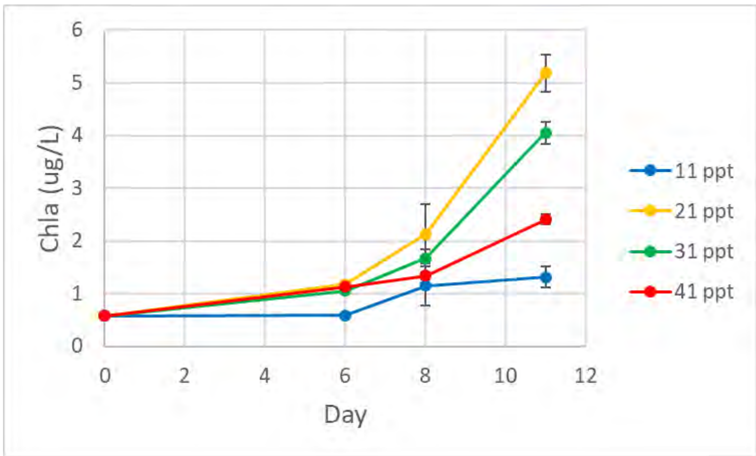
Experiment 5: Salinity-Nutrient Experiment

Goal: To determine the effects of salinity on various phytoplankton physiological parameters under nutrient replete conditions.

Experimental Setup: Water was collected on 9/1/18 using the Teflon pump at 10 m. Sampling in triplicate at three time points using four treatments: Control (31 ppt, green), 11.5 ppt (blue), 21.5 ppt (yellow) and 41.5 ppt (red). Due to a limited number of 1 L bottles, some 2.7 L bottles were using during the samplings. For the 41 ppt treatment, 47 ml of sample was removed from each 1 L bottle (130 ml from 2.7 L bottles) and replaced with 0.145 g/ml NaCl solution. For the 21 ppt treatment, 340 ml of sample was removed and replaced with Milli-Q water for each 1 L bottle (865 ml for 2.7 L bottles). For the 11 ppt treatment, 675 ml of sample was removed and replaced with Milli-Q water in 1 L bottles. For the 2.7 L bottles, 980 ml of sample was added and then the bottle was filled with Milli-Q water. All bottles were given complete set of nutrients as described above to provide nutrient-replete growing conditions. Temperature was maintained at 0^{o} C with a light level of 10 uE/m^2/s.

Sampling: T0 was sampled on 09/01/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling at T6, T8, and T11. Samples were also taken for Chl-a, Fv/Fm, DMSP, gases, flow cytometry and halocarbons.

Results: A significant difference was observed in phytoplankton biomass as a function of salinity following an 11 day incubation period. The highest biomass treatments were observed at salinities of 21 and 31 (see Figure below).



Experiment 6: Light-Trace Metal interactions

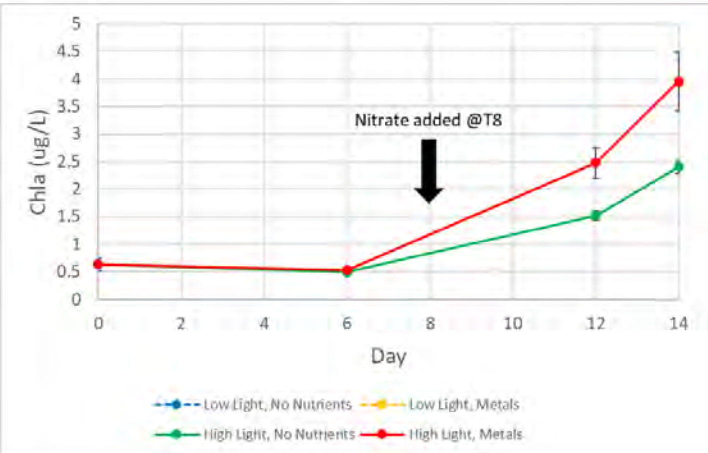
Goal: To determine the interactive effects of trace metal additions and light levels under nitrate sufficient conditions.

Experimental Setup: Water was collected on 9/5/18 using the Teflon pump at 10 m. Samples were run in triplicate at three time points, using four treatments: (1) Low light-Control (5uE, no metals added), (2) Low light-Metals (5uE, metals added), (3) High light-Control (20 uE, no metals added), and (4) High light- Metals (20 uE, metals added). A solution of trace metals (L1 stock) was diluted to ~11.8 uM, and 400 ul of this solution was added to the 'Metals' treatments. Polycarbonate 2.7 L bottles were incubated and filtered at the T-final timepoint for measurement of pigments and transcripts. Note, that nitrate was added to all bottles on 9/13/18 (T8) to prevent nitrate limitation.

Sampling: T0 was sampled on 9/5/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling was performed at T6, T12, and T14. Samples were taken for Chl-a, Fv/Fm, DMSP, gases, flow cytometry and halocarbons.

Note: At T6, all of the low light bottles froze and consequently had to be discarded.

Results: Significant impact of trace metal additions were observed under high light with respect to the control treatment (i.e. no trace metal addition).



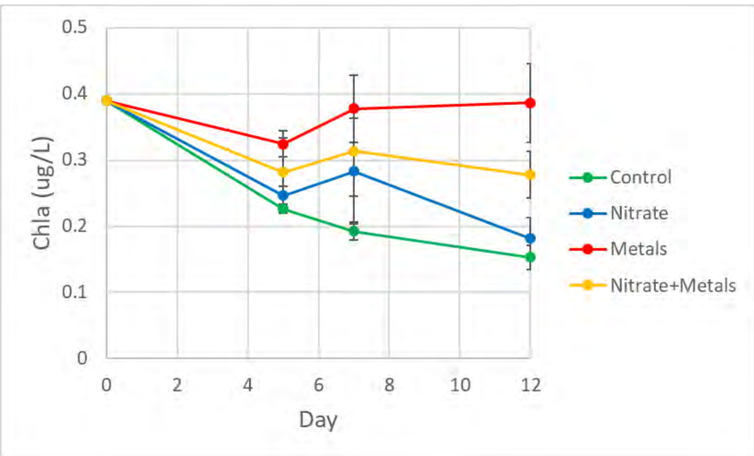
Experiment 7: Trace Metal-Nitrate Interaction Experiment

Goal: To investigate the co-limitation of trace metals and nitrate on phytoplankton biomass and species composition.

Experimental Setup: Water was collected on 09/11/18 from CTD 26 at 10 m. Samples were run in triplicate and sampled at three time points, using four treatments: Trace Metals (400 ul of 11.8uM TM solution, red), Nitrate (250 ul of 50mM stock, 12.5 uM final conc, blue), Metals and Nitrate (both additions, yellow) and Control (no additions, green). Polycarbonate 2.7 L bottles were used at Tfinal for pigments and transcripts. Temperature was maintained at 0º C with a light level of 20uE/m^2/s.

Sampling: T0 was sampled on 9/11/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling at T5, T7 and T12. Samples were taken for Chl-a, Fv/Fm, DMSP, gases, flow cytometry and halocarbons.

Results: Significant effects were observed relative to the control treatment. All but the trace metal treatment showed declines in phytoplankton biomass relative to the initial Chl-a biomass concentration.



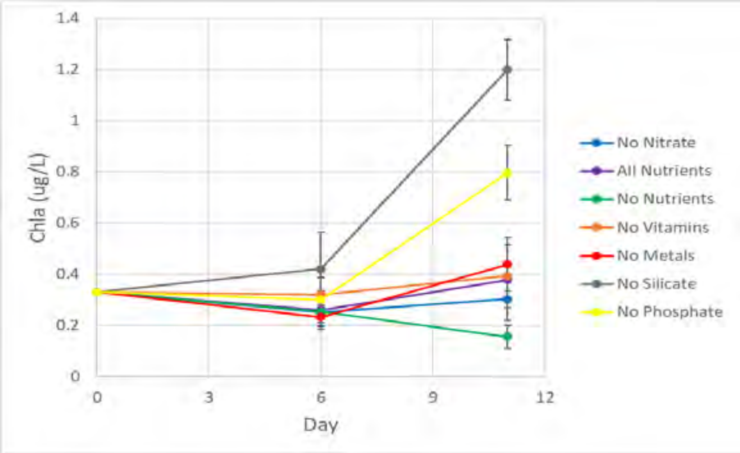
Experiment 8: Nutrient Bioassay II

Goal: To determine the major limiting nutrient(s) under relatively high light conditions. Treatments were given all nutrients except one.

Experimental Setup: Water was collected on 9/13/18 using the Teflon pump at 10 m. Samples were run in triplicate for two time points, using seven treatments: Control (no addition), All (all nutrients), Nitrate (All minus nitrate), Phosphate (All minus phosphate), Silicate (All minus silicate), Vitamins (All minus vitamins), Metals (All minus metals). Nutrient solutions followed nutrient replete recipe from experiment 3, but 350 ul of the 11.8 uM metals solution was used instead of 100 ul of the L1 stock metals, and 100 ul of a 1:5 L1 silicate stock solution was used. For each treatment, four 1 L bottles and two 2.7 L polycarbonate bottles were used. Temperature was maintained at 0º C with a light level of 20 uE/m^2/s.

Sampling: T0 was sampled on 9/13/18. Samples were taken for proteomics, BSi, Chl-a, pigments, Fv/Fm, gases, DMSP, transcriptomics, nutrients and flow cytometry. Subsequent sampling was done at T6 and T11. Samples were taken for Chl-a, Fv/Fm, DMSP, gases, flow cytometry and halocarbons.

Results: Silicate and phosphate were clearly non-limiting. Treatments without metals, vitamins or nitrate all grouped together; relatively low in biomass but significantly higher than the control indicating an interactive effect on phytoplankton biomass (see Figure below).



C. The impact of seasonal sea ice on the contribution of ozone depleting halogens in the Arctic (ICE)

Participants in the field

Dr. Katarina Abrahamsson (PI), Alexandra Walsh, Adela Dimitrascu

Summary and background

The changes in sea ice distribution, especially in the Arctic, where the extent of multiyear ice is declining in favour of seasonal ice, will affect the atmospheric composition of halogens, as well as their biogeochemical cycles. Halogen constituents, especially the brominated ones are directly or indirectly involved in the degradation of tropospheric and stratospheric ozone. The iodinated compounds are however only of importance in the lower troposphere. The organo-halogens have two formation pathways, either as a by-product of photosynthesis, or through a chemical reaction between ozone and bromide during darkness.

The major objectives were

- Estimates of the contribution of sea ice to the fluxes of halocarbons to the troposphere.
- Minimize the uncertainties in global flux models of halocarbons through air-sea-ice measurements.

Measurements of sea ice and sea water concentrations of halocarbons was performed to elucidate the poorly known relationship between sea ice, seawater and emissions of halogenated compounds to the atmosphere

Methods

Samples of ice, snow, and brine, were collected at in total 29 different positions, where 10 stations were accessed during transit with helicopter, 11 positions on the ice flow, and additional 8 stations on surrounding ice flows. Triplicate ice cores samples were collected at most of the stations. A Mark II coring system from Kovacs Enterprise with a diameter of 0.09 m made out of a light weight filament wound composite tube with plastic fitting was used. Ice cores were divided into 10 cm or 5 cm sections and individually packed in gas-tight TedlarTM bags. The air surrounding the sample was removed from the bags using a manual pump according to Granfors et al. (2013). The ice samples were thawed in darkness at room temperature for approximately 24 h. Snow samples were collected as close as possible to the ice coring site (maximum distance ca 10 m) individually packed in gas-tight Tedlar© bags. The snow samples were thawed in darkness at room temperature for approximately 12 h.

Water samples were collected from the ship´s rosette sampler at 20 occasions in order to study the variability with time.

The halocarbon compounds $CHBr_3$, CH_2Br_2, $CHCl_2Br$, $CHClBr_2$, CH_3I, CH_2ClI, CH_2BrI and CH_2I_2 were quantified. They were pre-concentrated using three purge-and-trap systems:

Velocity XPT (Teledyne Tekmar) connected to an autosampler (AQUATek70, Teledyne Tekmar), and two custom-made purge-and-trap system, which were coupled to gas chromatographs with electron capture detection (Varian 3800, Thermo), according to the methods described by Mattsson et al. (2012). One of the custom-made purge-and-trap instruments was equipped for air sample analysis in addition to water sample analysis. Air was continuously drawn through a 25 m, 4mm inner diameter, Teflon tube by an air pump located down-stream from the sampling loop. This instrument was also fed with a continuous stream of water from the ship´s surface water inlet. The system was set up to automatically alternate between water and air sampling. The systems were calibrated with external standards diluted from stock solutions in methanol (Sigma-Aldrich, suitable for purge and trap analysis) in seawater to give final concentrations in the picomolar range in the purge chamber. The same standard solutions were used for calibration of air measurements. The three instruments were inter-calibrated using standards as well as samples with high and low concentrations of the compounds.

Research activities and preliminary results

Sea water

There are only a few investigations of the distribution of halocarbons in the high Arctic. Earlier studies have mainly been focused on depth distribution of brominated and iodinated compounds as well as the biogenic formation in sea ice brine (Karlsson et al., 2013). In comparison to earlier studies since 1991 the surface sea water concentrations have been on average 10 pmol L^{-1}, which agrees with the preliminary results from this year (Figure 45). Figure 45 also shows the variability in time from the 13 August to the 15 September. The highest concentrations coincided with an increase in Chl-a , which indicates a biogenic origin.

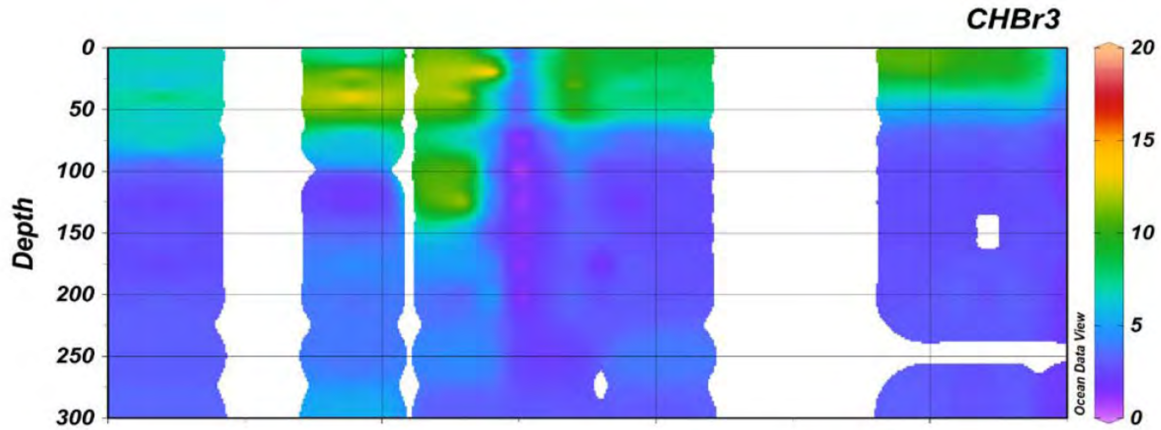


Figure 45. Depth distribution of the brominated compound CHBr3 with time. The x-axis stretches from 13 August to 15 September.

Sea ice

Multiple ice cores where collected from sea ice of different thickness. The distribution of halocarbons varied both with location and with time (Figure 46). As we went from a season of melting sea ice with sea ice of low salinity, to the start of freezing, the halocarbon concentrations increased with a decreasing brine volume. The core data will be evaluated together with Chlorophyll a data to discern if there was an active biogenic production of the organo-halogens. If possible the concentrations in sea ice will be used together with the collected air concentrations in order to estimate if the melting sea ice also contributes to the load of halogens in the atmosphere.

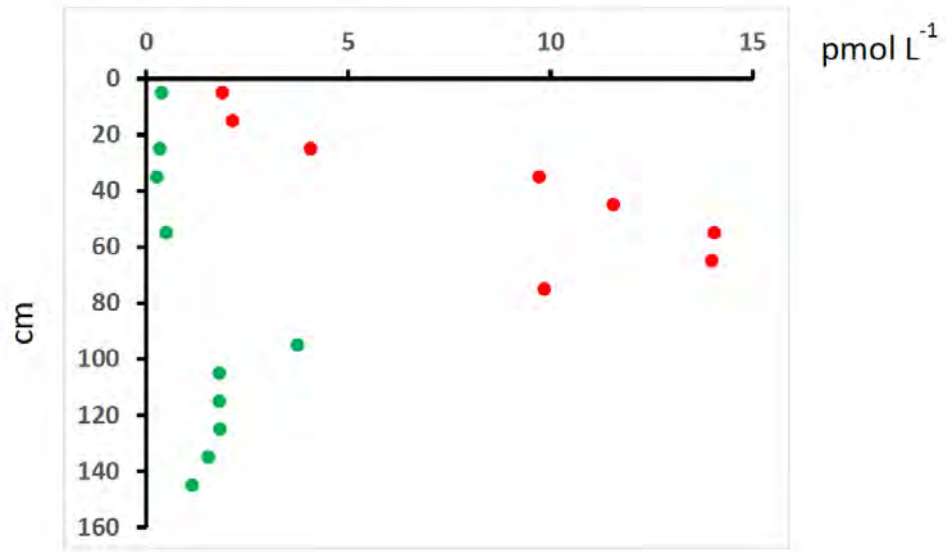


Figure 46. Depth distribution of the organo-halogen CHBr3 in sea ice. The core indicated in green was collected 12 August and the core indicated with red 19 September. The concentrations are given as bulk measurements and are not brine volume corrected.

Additional measurements

Halocarbons was measured in the experiments performed by Jack di Tullio (see WP 5b) and has not yet been evaluated. Also, acidification experiments were made on sea ice communities in collaboration with WP5d which are presently being evaluated.

References

Granfors, A. et al. (2013) Biogenic halocarbons in young Arctic sea ice and frost flowers. *Mar. Chem*. 155, 124–134.

Karlsson, A., Theorin, M. and Abrahamsson, K. (2013). Distribution, transport, and production of volatile halocarbons in the upper waters of the ice-covered high Arctic Ocean. *Global Biogeochemical Cycles*, *27*(4), pp.1246-1261.

Mattson, E., Karlsson, A., Smith, J. W. O. & Abrahamsson, K. (2012) The relationship between biophysical variables and halocarbon distributions in the waters of the Amundsen and Ross Seas, Antarctica. *Mar. Chem*. 140–141, 1–9.

d. The effect of carbonate chemistry on the sea ice community in the High Arctic (MOCCHA)

Participants in the field

Dr. Walker Smith (PI), Dr. Anders Torstensson, Dr. Andrew Margolin, Gordon 'Max' Showalter

Other project participants

Dr. Elizabeth Shadwick (PI), Dr. Jody Deming (PI), Olivia De Meo, Shelly Carpenter

Summary and background

The ocean absorbs approximately one third of the CO_2 released into the atmosphere each year, and this uptake of CO_2 is decreasing the pH of the seawater – a processed called ocean acidification. Ocean acidification is occurring throughout the ocean, but its effects will be greatest in polar regions due to the weaker buffering capacity of the waters in these regions.

Sea ice is a critical habitat for microorganisms (mainly microscopic algae and bacteria), which are the base of the Arctic food chain and producers of compounds and particles that can interact in cloud formation. Given the importance of sea ice and its associated biota to the Arctic system and the rapidly changing environmental conditions, the effects of these changes on the sea-ice microbial community need to be understood and included in predictions of anticipated anthropogenic climate change.

Although ocean acidification research on sea ice is a relatively new field, a few Antarctic studies have considered the effects of ocean acidification on sea-ice microorganisms and communities (e.g., Torstensson et al., 2013; 2015; McMinn et al., 2014). However, no such studies have yet been published on Arctic sea ice to our knowledge (reviewed in McMinn, 2017). We aim to fill one of the gaps in the understanding of ocean acidification in the Arctic by providing knowledge of how the development of microbial communities in sea ice may change in the future as CO_2 levels increase.

Methods

During the Arctic Ocean 2018, we performed four shipboard experiments and field observations on 19 ice stations to study how ocean acidification is affecting sea-ice microbial communities in the Central Arctic Ocean. We also sampled seawater by rosette, both at stations when moored to the ice floe and during the transit, to evaluate the carbonate system (pH, alkalinity, DIC) in the water column. Sea-ice cores were collected from multiple stations between August 6th to September 18th and were exposed to a range of CO_2 levels to better understand how the community composition and production of sea-ice microbial assemblages may change in the future. During the experiments, the carbonate system was monitored by measurements of pH, total alkalinity and dissolved inorganic carbon. After 10 days of incubation with four CO_2 concentrations, we sampled for Chl-a, particulate organic carbon and nitrogen, bacterial abundance, DNA (amplicon 16S/18S rRNA genes and metagenome), exopolymeric substances (EPS), dissolved organic carbon, inorganic nutrients, extracellular enzyme activity and photosynthetic activity (using PAM fluorometry).

Research activities and preliminary results

Research activities since the cruise have focused on sample analyses. Preliminary results will be available by the spring workshop Artic Ocean 2018.

References

McMinn A (2017) Reviews and syntheses: Ice acidification, the effects of ocean acidification on sea ice microbial communities. Biogeosciences 14:3927-3935

McMinn A, Müller MN, Martin A, Ryan KG (2014) The response of Antarctic sea ice algae to changes in pH and CO2. PLOS ONE 9:e86984 doi:10.1371/journal.pone.0086984

Torstensson A, Hedblom M, Andersson J, Andersson MX, Wulff A (2013) Synergism between elevated pCO2 and temperature on the Antarctic sea ice diatom *Nitzschia lecointei*. Biogeosciences 10:6391-6401

Torstensson A, Hedblom M, Mattsdotter Björk M, Chierici M, Wulff A (2015) Long-term acclimation to elevated pCO2 alters carbon metabolism and reduces growth in the Antarctic diatom *Nitzschia lecointei*. Proc R Soc Biol Sci Ser B 282

5 Concluding remarks (C. Leck & P. Matrai)

The Arctic 2018 MOCCHA-ACAS-ICE expedition resulted in a remarkable and unique collection of atmospheric, sea ice and ocean data sets, including biological, chemical and physical parameters. Sampling in the central Arctic Ocean is difficult; cold and constantly changing meteorological conditions constitute a continuous challenge. This challenge is compounded when cutting-edge technology is applied to atmospheric, ocean and sea ice organic compounds often found at very low concentrations. Indeed, we observed extremely low concentrations of particles in air and in water for extended periods; this often required longer sampling periods for a single sample to be quantitatively analyzed (later on) or required longer experimental incubations for treatment effects to be observed and quantified, if at all. These conditions also required a high level of cleanliness that, at times, was at odds with the sampling needs among different research groups.

The Arctic 2018: MOCCHA-ACAS-ICE expedition deployed a forward-looking combination of research expertise and instrumentation transitioning the summer-fall freeze up period, a season rarely sampled at these high latitudes. We sampled for atmospheric chemical organic composition, for minimally or unattended atmospheric fluxes, for in- and under-ice biological, chemical and physical observations, for *in situ* and experimental aerosol formation, and for marine production of climate-relevant gases, among others.

After 2 multi-day transit legs and 3 discrete short stations centered around an intense multi-week Ice Drift Station, a diverse group of scientists, logistical support staff and I/B *Oden* crew combined to create a set of observations that will quantify the current conditions in the high Arctic, will be compared with existing data for some parameters, and will be assimilated into Earth and regional system models.

These results were made possible by the excellent logistical organization and assistance by the SPRS staff and the I/B *Oden* crew, whose collective field expertise was invaluable to the science of this expedition.

We offer this summary to the 74 regular people who were on board I/B *Oden* during 7 weeks, to the broader scientific community with whom these data will be ultimately shared with, and to our fellow citizens on this Earth.

6 Participation List

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Appendix A

Logs for the Arctic 2018 MOCCHA-ICE-ACAS Daily Science Plan updated with the changes that occurred during the day for both the Drift Ice Station period, including mobilization and demobilization, and the southward transit period, ending with a marginal ice zone station

Drift Day	3
DATE	16-Aug
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING	
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.
6:00	Safety reconnaissance, Snowmobile (electrical)
6:00	Weather balloon launch heli-deck: Michael
8:30	LEAD: Stand by, function of winddirection, option to walk : bear watch, in or lunch (Matt, Helen, Karin, John & Paul), GUARD
8:30	ROV: Combination of tent and wood floor. Christian, Philippe, Matthieu & Adela.
8:30	ICE/ROV: Pull sledge for ice thinkness survey. Mario, Walker, Anders & Katarina
9:00	Met Allley: 1) mast (drilling) and securing, 2) Power, GUARD Matthias, Peggy, Grace, Ian
10:00	
11:00	
12:00	Weather balloon launch heli-deck: Michael
12:30	ROV: Snowmobile (electrical?) after lunch, Mario…
12:30	ROV: Combination of tent and wood floor. Christian, Philippe, Matthieu & Adela.
13:00	**TURNING OF SHIP**
13:00	LEAD: Brandy, stand by, Helicopter and Catamaran
14:00	
14:30	Met Allley: 1) mast (drilling) and securing, 2) Power, GUARD, power, winches, 2nd balloon; mast pending; Matthias, Peggy, Grace, Ian
14:30	LEAD: On ice moilasation (hut, mast, platform, iec achors)Stand by, function of winddirection, option to walk : need lunch and bear watch (Matt, Helen, Karin, John, Brandy & Paul), GUARD
15:00	
16:00	
17:00	
18:00	Weather balloon launch heli-deck: Michael
19:00	Site coordinating meeting, Paty&Caroline
20:00	
21:00	END OF ON ICE OPERATIONS!
22.00	
23.00	
TIME	17-Aug
0:00	Weather balloon launch heli-deck: NN
1:00	
2:00	
3:00	
4:00	
5:00	

Drift Day	4	
DATE	17-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
~~6:00~~	~~CTD: 2xshallow; 1 at 0-200m, SPRS and CREW, Paty and company~~	~~9:00~~
8:30	LEAD: By Foot, Intsrumentation by snowmobile (electrical), ramp (ice harbor) and winch: lunch boxes, SPRS ice edge safety & GUARD (Matt and company)	17:30
8:30	ROV:Cont. Set up, Mark transect with flags and holes, GUARD for transect only, volenteers: Mario and company	11:30
9:00	Met Alley: 1) Mast setting up, large electric drill, Balloon sampling, GUARD: Ian and company	11:30
~~10:00~~	~~Alternative CTD: 2x shallow; 1 at 0-200m, SPRS and CREW, Paty and company~~	~~13:30~~
11:00		
12:00	Weather balloon launch heli-deck: Michael	
13:00	Met Allley: 1) Mast setting up, Balloon sampling (cloud water), GUARD: Ian and company	17:30
13:00	ROV:Cont. Set up, Mark transect with flags and holes, GUARD for transect only, volenteers: Mario and company	17:30
13:00	ICE: Scout of not yet explored side of ice floe (5 cores), if not possible core lead site (electrical or manual need volenteers): tranport and GUARD	17:30
~~13:00~~	LEAD: Brandy, stand by, function of VISIBILITY, wind direction and speed, Catamaran & Buoy: Helicopter, SPRS assistance (needs ramp and winch)	~~16:00~~
15:00		
16:00	CTD: 2xshallow, ~~1x0-1000m~~ (manual Niskin, submersible pump?), SPRS and CREW, Paty and group	19:00
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
19:30	LEAD, ROV, Met Alley: pending, GUARD (SPRS, scientist)	
21:00	END OF ON ICE OPERATIONS!	
21:30		
23.00		
TIME	18-Aug	TIME
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

	Standby activities
	Cancelled activitie

Drift Day	5	
DATE	18-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind., New fog samplers.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	ICE: Our ice floe coring at a different sites (electrical) on this flow: minimum 3 people: transport and GUARD, (Walker and company)	11:30
9:30	LEAD: By Foot, Instrumentation by snowmobile (electrical), catamaran and CO2 buoy arrived, CAT sampled, CO2 flooded returned to ship, bubble camera working, lunch boxes: GUARD, (Matt and company)	17:30
9:30	ROV: Cont. Set up and sampling: GUARD for 2-4 hours for laser scanning, profiling, first ROV dive, 2 snowmobile shuttles from ship, (Mario and company)	11:30
9:30	Met Alley: Mast setting up begin sampling, Balloon sampling: GUARD, (Ian and company)	11:30
10:00	LEAD: Brandy, stand by, function of VISIBILITY, wind direction and speed, lead open water condition, Catamaran & Buoy: Helicopter, CAT left at LEAD with cover	17:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ROV: Cont. Sampling, (Mario and company)	17:30
13:00	Met Alley: Mast setting up begin sampling, Balloon sampling: GUARD, (Ian and company)	17:30
9:00	ICE: Niskin sampling of water at the ROV site, ice from lead, (Walker and company) = ask SPRS if Guard is needed	17:30
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	19-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	6	
DATE	19-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:30	~~LEAD: By Foot: Instrumentation (small SML boat possibility) by snowmobile (electrical) (two-way), lunch boxes, GUARD, (Matt and company) - SPRS suggestion of 2 new bridges~~	17:30
9:30	~~ROV: Cont. Sampling: lunch boxes, GUARD if possible (Mario and company)/return to ship fog~~	10:00
~~10:00~~	~~Met Alley: Mast automated sampling, Balloon sampling: GUARD for balloon site (Ian and company)~~	~~11:30~~
~~10:00~~	LEAD: Brandy, stand by, function of VISIBILITY, wind direction and speed, lead open water condition, Catamaran [recovery? TBD]: Helicopter	~~17:30~~
9:30	09:30 fog, 10:00 start ship turn, all on ice activities cancelled until 12:30.	
9:53	Moving snow mobile	9:55
10:30	**TURNING SHIP** (decided at the morning meeting)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ICE: Our ice floe walk-about and coring at a different sites (electrical): minimum 3 people: ice floe map and GUARD, (Walker and company)	17:30
13:00	ROV: Cont. Sampling, profiling, ROV dive: through dinner, GUARD if possible (Mario and company)	21:30
13:00	Met Alley: Mast automated sampling, Balloon sampling, radiation, LOAC, cloud water sampling: GUARD for balloon site (Ian and company)	17:30
13:00	LEAD: By Foot: Seawatere sampling, Instrumentation (small SML boat possibility) by snowmobile (electrical) (two-way), lunch boxes, GUARD, (Matt and company) - SPRS suggestion of 2 new bridges	17:30
~~13:00~~	LEAD: Brandy, stand by, walk to lead, CAT was not used: GUARD	~~17:30~~
14:00	CDT (0-1000m); (0-200m)	16:00
15:00		
16:00		
17:00	ROV: diesel drilling, check time for logging of possible pollutions.	18:00:00?
18:00	Weather balloon launch heli-deck: NN	
18:30	ICE: Coring at distant ice flow, Helicopter (Katarina and company)	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	20-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

ALL ICE ACTIVITIES WILL REQUIRE BEAR WATCHES (Polar, Ship, MOCCHA, ICAS, ICE)

(green)	Standby activities
(pink)	Cancelled activities

Drift Day	7	
DATE	20-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:30	LEADa: By Foot: Instrumentation by snowmobile (electrical) (two-way), drilling (electrical) 5 holes in collaboration with ICE, Catamaran sampling, lunch boxes, GUARD, (Matt and company)	17:30
9:30	ROV: Cont. Sampling (buoy, ADCP, MSS profiling, test holes: lunch boxes, GUARD if possible, 1-2 snowmobile runs in morning if possible (Mario and company)	17:30
9:30	Met Alley: Mast automated sampling, Balloon sampling (SHARC): GUARD for Mast (1h) and GUARD for balloon site, all day (Ian and company)	11:30
10:00	LEADb: Lillte boat on sledge (snowmobile)	
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ICE: Coring at a our ice flow and at the lead (electrical), either and/or ICE site: 2 people, snowmobil if possible GUARD, (Walker and company)	17:30
13:00	Met Alley: Balloon sampling only: chair and desk for balloon site if available, GUARD, (Ian and company)	17:30
13:00	LEEDc: Carlton, try the little boat	17:30
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	21-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	8	
DATE	21-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
9:30	LEAD: By Foot: Instrumentation by snowmobile (electrical) (two-way), both SML sampled were operated, CTD profiling, Niskin sampling for gases, lunch boxes, 2xGUARD, (Matt and company)	17:30
9:30	ROV: Cont. Sampling: lunch boxes, GUARD if possible, *1-2 snowmobile runs in morning if possible,* areal image of the bouy site (Mario and company)	17:30
9:30	Met Alley: Mast automated sampling, Balloon sampling (radiation): GUARD for Mast (1h) and GUARD for balloon site, all day (Ian and company)	11:30
9:30	CTD: Pumping for incubation sea water surface, 120L (Jack and company)	10:30
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ICE: Coring at a our ice flow (electrical): 2 people, snowmobile pick up only, GUARD if possible, (Walker and company)	17:30
13:00	Met Alley: Balloon sampling only: GUARD, (Ian and company)	17:30
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	22-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	9	
DATE	22-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		10:00
9:00		
10:00	CTD: 2 Pumping at 10m (Jack and co.)	13:00
10:00	ICE: Weather-dependent helicopter flight (2.5h) to other floe (Katarina	15:00
10:00	LEAD: By Foot: Instrumentation by snowmobile (electrical) (two-way), small boat and glass plates, lunch boxes, request of Lars for catamaran repair, self-GUARD possible, (Matt and company)	17:30
10:00	ROV: Cont. Sampling: lunch boxes, gas-drill, deployed a fish ecosounder, self-GUARD possible, (Mario and company)	17:30
10:30	MET ALLEY: Mast automated sampling, Balloon sampling (cloud water sampling): (Ian and company)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ROV: Weather-dependent helicopter flight (2h) to other floe (Mario and company)	15:00
13:00	Met Alley: Balloon sampling only: (Ian and company)	17:30
14:00	ICE: Coring at a our ice flow (electrical): 2 people, snowmobile pick up only, GUARD if possible, (Katarina? Walker and company)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00	Science seminar by Helen	20:30
21:00		
22.00		
23.00		
TIME	22-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	10	
DATE	23-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	SHIP TURN	
9:00		
9:30	LEAD: By Foot: Small boat, CAT, Instrumentation by snowmobile (electrical) (two-way), lunch boxes, self-GUARD possible, (Matt and company)	17:30
9:30	ROV: Cont. Sampling: lunch boxes, self-GUARD possible, (Mario and company)	17:30
9:30	MET ALLEY: Mast automated sampling, Balloon sampling: (Ian and company)	11:30
9:58	ROV:drilling, fossil fuel	10:07
10:00	ICE: Weather-dependent helicopter flight (2.5h) to other floe (Katarina	
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	Met Alley: Balloon sampling only: (Ian and company)	17:30
13:00	ROV: Weather-dependent helicopter flight (2h) to other floe (Mario and company)	
14:00	CTD: 2 casts, 0-1000m, then 0-200m (Katarina and co., Jack and co., Walker and co.)	15:00
15:00	ICE: Collection of new ice at our floe, water at ROV, (Katarina only)	15:30
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
21:00		
22.00		
22.00		
23.00		
TIME	24-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	11	
DATE	24-Aug	End Time
	PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING	
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind. Request Lars technical assistance with sampler (prioritized as #3 out of 3).	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
9:30	LEAD: By Foot: Small boat, Nitskin, Mart experiment, Marker buoys, Instrumentation by snowmobile (electrical) (two-way), including CO2 buoy, lunch boxes, self-GUARD possible, request Lars technical assistance with catamaran engine (prioritized as #1 out of 3) and perhaps with small boat rudder (prioritized as #2 out of 3) (Matt and company)	17:30
9:30	ROV: Cont. Sampling, 1) extensiv ROV dive, 2) profiles MSS, 3) Grid, 4) under Oden: lunch boxes, self-GUARD possible, can help w/ power line, (Mario and co.)	17:30
9:30	MET ALLEY: Mast automated sampling, Balloon sampling (aerosol, SHARC, cloud, turbulence: (Ian and co.)	17:30
9:30	ICE: ~~large ice coring~~, fresh ice frost flowers, sea water, snowmobile (electrical) two-way or at least return, lunch boxes (Walker and co.)	17:30
10:00		
11:00	Weather balloon launch heli-deck: NN	
12:00		
13:00	Met Alley: Balloon sampling only: (Ian and company)	17:30
14:00		
15:00		
15:30	CTD: 1 cast, 0-200m, if ice permits, pumping at 10m (Katarina and co., Jack and co.)	17:30
16:00		
17:00	Weather balloon launch heli-deck: NN	
17:00	Site coordinating meeting by phone, please be available, Paty&Caroline	17:30
18:00		
19:00		
20:00		
21:00		
22.00		
23.00	25-Aug	
TIME	Weather balloon launch heli-deck: NN	End Time
0:00		
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	12	
DATE	25-Aug	End Time
	PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING	
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind. Request Lars technical assistance with sampler (prioritized as #1).	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	ICE: large ice coring all day, snowmobile (electrical) two-way or at least return, lunch boxes (Walker and co.)	
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	LEAD: By Foot: Small boat, Instrumentation by snowmobile (electrical) (two-way), including CO2 buoy, dinner boxes, move winch for Cat., self-GUARD possible, (Matt and company)	21:30
13:00	MET ALLEY: Mast automated sampling, Balloon sampling: (Ian and co.)	17:30
14:00		
15:00		
15:30	CTD: 1 cast, 0-200m, if ice permits, (Katarina, Jack and co.)	16:30
16:00	ICE: new ice coring, snowmobile (electrical) two-way, or helicopter weather permitting, pending (Katarina and co.)	
18:00	Weather balloon launch heli-deck: NN	
18:30	MET ALLEY: Mast automated sampling, Balloon sampling: (Ian and co.)	21:30
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00	26-Aug	
TIME	Weather balloon launch heli-deck: NN	End Time
0:00		
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	13	
DATE	26-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind. Request Lars technical assistance with sampler (prioritized as #1).	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	Met Alley: Balloon sampling only: (Ian and company)	17:30
13:00	LEAD/CTD: Collection of 100L bulk surface water (Paty and company)	17:30
13:00	LEAD: By Foot: Instrumentation by snowmobile (electrical) (two-way), including CO2 buoy and small boat, lunch boxes, self-GUARD possible, (Matt and company)	17:30
13:00	MET ALLEY: Mast automated sampling, Balloon sampling: (Ian and co.)	17:30
15:00		
16:00	CTD: 1 cast, 0-1000m, if ice permits, (Katarina and co., Jack and co.)	
17:00	ICE: ice coring this floe, snowmobile (electrical) two-way, (Katarina, Walker and co.)	
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	27-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	14	
DATE	27-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind. Request Lars technical assistance with sampler (prioritized as #1).	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	HELI: Polar Bear	
9:00	MET ALLEY: Mast automated sampling, Balloon sampling (aerosol and cloud water): (Ian and co.)	11:30
9:30	ROV: Cont. Sampling, intrumental repairs after polar bear visit: lunch boxes, self-GUARD possible, (Mario and co.)	17:30
9:30	LEAD: By Foot: Instrumentation by snowmobile (electrical) (two-way), lunch boxes, self-GUARD possible, (Matt and company) - Indoor space requested on board to fix bubble camera, perhaps with SPRS assistance.	17:30
10:00		
10:30	CTD: 1 cast, 0-200m, if ice permits, (Katarina and co., Jack and co.)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	Met Alley: Balloon sampling only: (Ian and company)	21:30
14:00		
15:00	Science seminar for Oden crew and SPRS in Swedish, by Caroline. All invited.	16:00
16:00	CTD: surface pump, (Jack and co.)	17:00
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	28-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	15	
DATE	28-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	MET ALLEY: Sampling cancelled as of too strong winds: (Ian and co. Stay onboards ship all day)	
9:30	ROV: Cont. Sampling; in the morning lazer scanning along the ROV path, self-GUARD possible, after lunch by foot mapping of the ice flow (thickness, snow deposition and surface albedo): lunch boxes, (Mario and co.) - request using generator on ice for max 1 h	17:30
9:30	LEAD: By Foot: Small boat, CAT. Instrumentation by 2x snowmobile (electrical) (two-way), lunch boxes, self-GUARD possible, (Matt and company)	17:30
10:00	CTD: 1 cast, 0-200m,1 cast 0-10m all bottles, if ice permits, (Katarina and co., Jack and co.)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	29-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	16	
DATE	29-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
9:30	MET ALLEY: Mast automated sampling, red balloon destroyed, winch repair: (Ian and co.)	11:30
9:30	ROV: Cont. Sampling (Ice and snow depth, albedo near lead): lunch boxes, GUARD, (Mario and co.)	17:30
9:30	ICE: Ice coring this floe, water and aggregates from ROV-hole, snowmobile (electrical) two-way, (Walker and co.)	11:30
10:00		
10:30	CTD: 1 cast, 0-200m, if ice permits, (Katarina and co., Jack and co.)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Glass plates, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00	Science seminar, by Andrew and Anders. All invited	20:30
21:00		
22.00		
23.00		
TIME	30-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	17	
DATE	30-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	CTD: Melt pond near Oden, ice breaking assistance, sledge and crane- 200 L of water (Paty and co.)	11:30
9:00		11:00
10:00		
11:00	ICE: Weather-dependent helicopter flight to other floe (Katarina and Walker)	13:00
11:00	MET ALLEY: Balloon sampling: (Ian and company)	12:30
11:00	ROV: Cont. Sampling: lunch boxes, gas-drill, GUARD, (Mario and company)	17:30
12:00	Weather balloon launch heli-deck: NN	
13:00	Met Alley: Balloon sampling only: (Ian and company)	20:00
13:00	LEAD: By Foot: Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:30	LEAD: Weather-dependent helicopter flight for CATAMARAN rescue (Brandy)	14:30
14:00		
15:00		
16:00	CTD: 1 cast 0-200m (Katarina and co., Jack and co.)	17:30
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	31-Aug	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	18	
DATE	31-Aug	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	**SHIP TURN, heli , generator**	11:55
9:30	ROV: Cont. Sampling: lunch boxes, GUARD, (Mario and co.)	17:30
9:30	ICE: Ice coring this floe-brief, snowmobile (electrical) two-way, GUARD (Katarina and co.)	11:30
10:00		
10:30	CTD: Pump, 8m, (Jack and co.)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:00	ICE: Ice station : Helicopter (Katarina and co.)	
12:30	LEAD: By Foot: Lead frozen, euq. Moved to edge with open water, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
19:00	Sling CAT. Helicopter	
20:00		
21:00		
22.00		
23.00		
TIME	1-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	19	
DATE	1-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	Met Alley: Mast? Balloon teared	
9:30	ROV: Cont. Sampling: lunch boxes, GUARD, (Mario and co.)	17:30
9:30	ROV: Weather and wind -dependent helicopter flight for buoy deployment, 2-4 hours, 2 flights strictly down wind, (Mario)	
10:00		
10:30	CTD: pumping at 10m , (Jack and co.)	11:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead very open, Glass plates, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00	ICE: Ice coring this floe-brief, snowmobile (electrical) two-way, GUARD (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	2-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	20	
DATE	2-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	Met Alley: no balloon too windy - confirm	
9:00		
9:30	ROV: Cont. Sampling: lunch boxes, GUARD, (Mario and co.)	17:30
9:30	ROV: Weather and wind -dependent helicopter flight for buoy deployment, 2-4 hours, 2 flights strictly down wind, (Mario)	
10:00		
10:30	CTD: Pumping at 10m , (Jack, Katarina and co.)	11:30
11:00	ICE: Weather-dependent helicopter flight to other floe (Katarina and Walker)	
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Super open lead, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00		
15:00		
16:00		
17:00	Drilling in Ice, ROV Tri pode	
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	3-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	21	
DATE	3-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	ICE: Weather and wind - dependent helicopter flight for ice coring, flights strictly down wind, (Walker and Katarina)	
9:00	Met Alley: No balloon sampling	
9:30	ROV: Cont. Sampling (deployed a bio profiler): lunch boxes, GUARD, (Mario and co.)	17:30
10:00	CTD: Pump and Niskins , (Paty, Jack, Walker and co.)	12:30
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead veery open, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	4-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	22	
DATE	4-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00	Helicopter: Polar bear	
8:00	ICE: Weather and wind - dependent helicopter flight for ice coring, flights strictly down wind, (Katarina)	
9:00	Met Alley: No balloon sampling	
9:30	ROV: Cont. Sampling: lunch boxes, GUARD, (Mario and co.)	17:30
10:00		
10:30	CTD: Pump 10m, (Jack and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead very openSmall boat, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00	Science seminar, by Matt	20:30
21:00		
22.00		
23.00		
TIME	5-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	23	
DATE	5-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	ROV: Weather permitting Buoy deployment, (Mario and co.)	
9:30	ROV: Cont. Sampling (MSS profiles): lunch boxes, GUARD, (Mario and co.)	17:30
9:30	MET ALLEY: Balloon sampling: (Ian and company)	21:30
10:00		
10:30	~~CTD: Pump, (Jack and co.)~~	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Small boat, thin layer of ice over the entire ice, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and	17:30
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	6-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	24	
DATE	6-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	ROV: Weather and wind - dependent helicopter flight for buoy deployment, (Mario)	
9:00		
9:30	ROV: Cont. Sampling (MSS profiles, optical transects: lunch boxes, GUARD, (Mario and co.)	17:30
9:30	MET ALLEY: Balloon sampling (morning profiles): (Ian and company)	21:30
10:00		
10:30	CTD: Pumping 10m, (Jack and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Small boat, slushy surface layer over 70% lead, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00	ICE: Transect for (Chl) by Walker	
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00	Science seminar: Jack and Katarina	20:30
20:00	ROV: Weather and wind - dependent helicopter flight for buoy deployment, (Mario)	22:00
21:00		
22.00		
23.00		
TIME	7-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	25	
DATE	7-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Safety reconnaissance, Snowmobile (electrical)	7:00
6:00	Weather balloon launch heli-deck: Michael	
6:00	CTD: Niskin and pump at 8m, (Paty and co.)	7:30
7:00		
8:00	ICE: Weather and wind - dependent helicopter flight for large ice coring (Walker; hopefully also Katarina)	16:00
9:00	Met Alley: No balloon sampling	
9:30	ROV: Cont. Sampling: lunch boxes, GUARD, (Mario and co.)	17:30
10:00		
10:30	CTD: Pump at 10m, (Jack and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead surface slushy icy; greeze ice with with some open water, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00	ICE: Ice coring this floe, 45, sea water sampling to 200m at ROV for halogen gases (alternative to heli flight) (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	8-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	26	
DATE	8-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind. CPC fixed.	
6:00	We consider Saturday and Sunday as the most likely freeze up period, thus helicopter flights suspended. Only if winds go below 1 m/s flying could be condsidered.	
6:00		
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	ICE: Weather and wind - dependent helicopter flight for large ice coring (Katarina and co.)	
9:30	ROV: Cont. Sampling (ROV dive, MSS profile): lunch boxes, GUARD, (Mario and co.)	17:30
9:30	LEAD: Water sampling pending morning reconaissance: lunch box, GUARD, (Helen)	17:30
9:30	MET ALLEY: Balloon sampling (SHARK): (Ian and company)	21:30
10:00		
10:30	CTD: Pump, (Jack and co.)	12:00
11:00	CTD: 0-200m, 0-1000m, (Jack and co.)	
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Edge of lead covered with snow and dangerous:open water on rigth side towards Oden, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00	ICE: Ice coring this floe (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	9-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	27	
DATE	9-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	We consider Saturday and Sunday as the most likely freeze up period, thus helicopter flights suspended. Only if winds go below 1 m/s flying could be considered.	
6:00	Weather balloon launch heli-deck: Michael	
6:30	MET ALLEY: Balloon sampling: (Ian and company)	21:30
7:00		
8:00		
9:00		
9:30	ROV: Cont. Sampling (MSS profiles): lunch boxes, GUARD, (Mario and co.)	17:30
10:00		
10:30	CTD: CTD 0-200m, (Jack and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead surface frozen over, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00	SHIP TURN, generator	14:04
14:00	ICE: Ice coring this floe (frost flowers and new ice sampling (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	10-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	28	
DATE	10-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	During the freeze up period now ongoing, if wind is stable at > 2 m/s, we consider this to be our prioritized period for atmospheric sampling, and helicopter flights will be suspended. Otherwise, heli flights will be considered.	
6:00	Weather balloon launch heli-deck: Michael	
6:30	MET ALLEY: Balloon sampling: Guard (Ian and company)	21:30
7:00		
8:00		
9:00		
9:30	ROV: Cont. Sampling (MSS profiles): lunch boxes, GUARD, (Mario and co.)	17:30
10:00		
10:30	CTD: CTD 0-200m, 8m MART exp., (Paty, Jack, Katarina and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Lead surface covered with ice; frost flowers, chamber one last calibration, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00	ICE: Ice coring and or frost flower sampling this floe (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	11-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	29	
DATE	11-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Freeze up period ongoing - no helicopter	
6:00	Weather balloon launch heli-deck: Michael	
6:30	MET ALLEY: Balloon sampling: Guard (Ian and company)	21:30
7:00		
8:00		
9:00		
9:30	ROV: Cont. Sampling (MSS profiles, begin demob): lunch boxes, GUARD, (Mario and co.)	17:30
10:00		
10:30	CTD: CTD 0-200m, 10m, (Jack, Katarina and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot:Lead surface frozen and closed, Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	17:30
13:00		
14:00	~~ICE: Ice coring and or frost flower sampling this floe (Walker, Katarina and co.)~~	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00	Science seminar: Christian and Mario	20:30
21:00		
22.00		
23.00		
TIME	12-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Drift Day	30	
DATE	12-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Freeze up period ongoing, will make window for ICE coring using helicopter, weather and wind - dependent (Katarina and co.)	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	LEAD: By Foot: Batteries by snowmobile (electrical) (two-way), self-GUARD possible, (Matt and company)	
9:30	ROV: Cont. Sampling (MSS profiles): lunch boxes, GUARD, snowmobile (Mario and co.)	17:30
10:00	MET ALLEY: Balloon sampling (SHARK): Guard (Ian and company)	
10:30	CTD: CTD (0-1000m), (Jack, Katarina and co.)'	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
12:30	LEAD: By Foot: Batteries by snowmobile (electrical) (two-way), GUARD and demob, tentatively slinging chamber - Friday 00Z-06Z, weather permitting (Matt and company)	17:30
13:00		
14:00	ICE: Ice coring and or frost flower sampling this floe (Walker, Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	13-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00	**Instruments at OPEN LEAD gone into deep sea!!**	

Drift Day	31	
DATE	13-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
	Window for demobilisation and ice coring, Friday 00Z-06Z	
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	ICE: Weather and wind - dependent helicopter flight for large ice coring (Katarina and co.)	
9:30	ROV: Cont. Sampling and demob: lunch boxes, GUARD, snowmobile (Mario and GAURD)	17:30
9:30	MET ALLEY: Balloon sampling, weather permitting in the afternoon: (Ian and company)	11:30
10:00		
10:30	CTD: CTD (10m, 0-200m), (Jack, Katarina and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00		
22.00		
23.00		
TIME	14-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00	ICE: Weather and wind - dependent helicopter flight deploying buoys (Mario and co.)	
2:00		
3:00		
4:30	Snowmobile	4:50
5:00		

This marks the end of the ice drift station on sept 14, 2018

Drift Day	32	
DATE	14-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
	Window for demobilisation and ice coring, Friday 00Z-06Z	
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
9:30	ROV: Cont. Sampling and demob: lunch boxes, GUARD, snowmobile (Mario and GAURD)	17:30
10:00		
10:30	CTD: CTD 0-1000m, (Jack, Katarina and co.)	12:00
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	Final Ship and Ice demobilisation	17:00
14:00		
15:00		
16:00		
17:00		
18:00	END OF ATMOSPHERIC SAMPLING	
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	20:00
20:00		
21:00	DEPARTURE ICE-DRIFT FLOE!!!!!	
22.00		
23.00		
TIME	15-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Transit Da	1	
DATE	15-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00	ROV: Barneo visit, weather permitting, helicopter: (Mario and co.)	
8:00		
9:00		
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Drift farewell dinner (science coordinating meetings will resume on Sunday)	
20:00	Weather permitting window for ICE coring using helicopter (Katarina and co.)	
21:00		
22.00		
23.00		
TIME	16-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		
	Standby activities	
	Cancelled activities	

Transit Da	2	
DATE	16-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00	Weather permitting window for ICE coring using helicopter (Katarina and co.)	14:00
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00	ROV: Weather permitting buoy deployment, helicopter: (Mario and co.)	
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00		
20:00		
21:00		
22.00		
23.00		
TIME	17-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		
	Standby activities	
	Cancelled activities	

Transit Da	3	
DATE	17-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES BUT DURING SHIP TURNING		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	ROV: Buoy deployment, helicopter: (Mario and co.)	
9:00		
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00	Weather permitting window for ICE coring using helicopter (Katarina and co.)	
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00		
20:00	Site coordinating meeting, Paty&Caroline	
21:00		
22.00		
23.00		
TIME	18-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
1:00		
2:00		
3:00		
4:00		
5:00		

Transit Day	4	
DATE	18-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES		
6:00	4th and 7th Deck, continuous sampling throughout all hours when ship is into the wind.	
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00	Weather permitting window for ICE coring using helicopter; please, not in front of inlets (Katarina and co.)	
9:00		
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00		
15:00		
16:00		
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00	Site coordinating meeting, Paty&Caroline	
20:00	Science seminar: Mike & Andrea	20:30
21:00		
22.00		
23.00		
TIME	19-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
0:30	4th and 7th Deck, continuous clean sampling through midnight.	
1:00		
2:00		
3:00		
4:00		
5:00		

Transit Day	5	
DATE	19-Sep	End Time
PLEASE KEEP BOW OF SHIP INTO THE WIND AT ALL TIMES		
0:30	4th and 7th Deck, continuous online and filter sampling throughout all hours when ship is into the wind (no heli flights).	23:59:00 PM
6:00	Weather balloon launch heli-deck: Michael	
7:00		
8:00		
9:00		
10:00		
11:00		
12:00	Weather balloon launch heli-deck: NN	
13:00		
14:00		
15:00		
16:00	Science & crew meeting for cruise update	
17:00		
18:00	Weather balloon launch heli-deck: NN	
19:00		
20:00		
21:00		
22.00		
23.00		
TIME	20-Sep	End Time
0:00	Weather balloon launch heli-deck: NN	
0:00	**End of atmospheric station**	0:30
0:00	Weather permitting window for ICE coring using helicopter; please, not in front of inlets (Katarina and co.)	6:00
1:00		
2:00		
3:00		
4:00	CTD: 0-200m (Jack and co.)	
5:00		
6:00	ETD to LYR	

Appendix B

ARCTIC 2018 MOCCHA-ICE seawater sampling log

Date	Device	Depth [m]
20180802	CTD/rosette	900
20180802	CTD/rosette	3
20180802	CTD/rosette	0-200
20180810	CTD/rosette	10
20180812	CTD/rosette	5
20180812	CTD/rosette	0-200
20180812	CTD/rosette	250-1000
20180817	Niskins	5
20180817	pump	10
20180818 or 19?	CTD/rosette	250-1000
20180818 or 19?	CTD/rosette	0-40
20180821	pump	10
20180822	Niskins	5
20180822	pump	10
20180823	CTD/rosette	250-1000
20180823	CTD/rosette	0-200
20180824	CTD/rosette	0-200
20180825	CTD/rosette	0-200
20180826	CTD/rosette	0-1000
20180827	CTD/rosette	0-200
20180828	CTD/rosette	0-200
20180829	CTD/rosette	0-200
20180829	CTD/rosette	10
20180830	CTD/rosette	0-1000
20180831	pump	10
20180901	pump	10
20180902	pump	10
20180903	pump	10
20180903	Niskins	8
20180904	pump	10
20180906	pump	10
20180907	Niskins	8
20180907	pump	10
20180908	CTD/rosette	10-1000
20180908	CTD/rosette	0-200
20180909	CTD/rosette	0-1000
20180910	CTD/rosette	8
20180910	CTD/rosette	0-1000
20180911	CTD/rosette	0-1000
20180911	CTD/rosette	10
20180912	CTD/rosette	0-1000
20180913	CTD/rosette	0-200
20180913	CTD/rosette	10
20180914	CTD/rosette	0-1000
20180920	CTD/rosette	0-200

Appendix C

Summary log for helicopter flights during Arctic 2018 MOCCHA-ACAS-ICE

In addition to these successful flights, there were many others that had to be aborted due to quickly changing weather conditions, either while still on the heli deck or already on station. This highlights the additional effort of people that unfortunately did not result in or precluded the collection of new samples.

Flight Log summary								
Expedition Phase	**Date**	**Start Time**	**End Time**	**Minutes**	**Purpose**			
Transit	20180804	23:06	23:52	46	Reconnaissance			
Transit	20180805	12:50	13:33	43	Reconnaissance			
Transit	20180805	14:07	14:29	22	Ice station	Walker, Anders & Katarina		
Transit	20180805	15:44	18:39	175	Ice station	Walker, Anders & Katarina		
Transit	20180805	18:38	19:03	25	Reconnaissance			
Transit	20180806	10:42	11:46	64	Reconnaissance			
Transit	20180806	11:53	14:45	172	Ice station	Max, Mario & Christian		
Transit	20180806	15:58	16:53	55	Reconnaissance			
Transit	20180806	20:39	21:20	41	Reconnaissance			
Transit	20180806	18:35	18:57	22	Reconnaissance			
Transit	20180807	23:13	23:56	43	Reconnaissance			
Transit	20180808	8:33	9:36	63	Reconnaissance			
Transit	20180808	9:53	12:38	165	Ice station	Anders, Katarina & Jack		
Transit	20180808	13:29	14:09	40	Reconnaissance			
Transit	20180809	2:49	3:22	33	Reconnaissance			
Transit	20180809	18:49	19:38	49	Reconnaissance			
Transit	20180809	19:42	22:27	165	Ice station	Max, Mario & Christian		
Transit	20180810	0:06	0:36	30	Reconnaissance			
Transit	20180811	0:25	1:19	54	Reconnaissance			
Transit	20180811	7:58	8:49	51	Reconnaissance			
Transit	20180811	9:04	11:39	155	Ice station	Francesco, Katarina & Anders		
Transit	20180811	16:04	16:39	35	Reconnaissance			
Transit	20180811	18:37	19:26	49	Reconnaissance			
Transit	20180811	22:10	23:02	52	Reconnaissance			
Transit	20180812	10:50	11:29	39	Reconnaissance			
Transit	20180812	14:14	15:35	81	Reconnaissance			
Transit	20180813	8:14	8:49	35	Reconnaissance			
Transit	20180813	13:45	14:13	28	Reconnaissance			
Transit	20180813	15:17	16:29	72	Reconnaissance			
Mobilisation to ice	20180814	8:51	9:19	28	Mobilisation			
Mobilisation to ice	20180814	11:58	12:16	18	Mobilisation			
Mobilisation to ice	20180814	12:47	13:20	33	Mobilisation			
Mobilisation to ice	20180814	13:25	13:36	11	Mobilisation			
Mobilisation to ice	20180814	14:39	15:13	34	Mobilisation			
Mobilisation to ice	20180814	21:57	22:49	52	Mobilisation			
Mobilisation to ice	20180815	8:58	9:34	36	Mobilisation			
Mobilisation to ice	20180816	11:00	11:21	21	Mobilisation			
Mobilisation to ice	20180818	10:19	10:41	22	Catamaran			

Drift Ice Station	20180819	10:06	10:20	14	Ship turn	
Drift Ice Station	20180819	18:40	20:30	110	Ice station	Katarina, Adela & Max
Drift Ice Station	20180823	10:44	12:24	100	Ice station	Christian, Mario, Katarina
Drift Ice Station	20180823	12:47	14:14	87	AWI	
Drift Ice Station	20180826	21:43	22:07	24	Polar Bear Action	
Drift Ice Station	20180827	8:21	8:53	32	Polar Bear Action	
Drift Ice Station	20180831	9:36	9:47	11	Ship turn	
Drift Ice Station	20180831	12:15	16:29	120	Ice station	Walker, Anders & Katarina
Delayed due to non-optimal flight window: fog & icing conditions. Ice work approx 120 min, waiting 134 min: total 254 min						
Drift Ice Station	20180831	19:00	19:36	36	Catamaran	
Drift Ice Station	20180902	9:33	11:31	118	AWI	
Drift Ice Station	20180902	11:44	13:43	119	Ice station	Walker, Adela, Max
Drift Ice Station	20180903	9:09	11:05	116	Ice station	Max, Katarina & Anders
Drift Ice Station	20180904	6:53	7:18	25	Polar Bear Action	
Drift Ice Station	20180904	8:28	11:14	166	Ice station	Katarina, Adela & Philipp
Drift Ice Station	20180905	9:40	10:10	30	AWI	
Drift Ice Station	20180906	20:30	22:17	107	AWI	
Drift Ice Station	20180907	9:46	15:26	340	Ice station	Anders, Max & Andrew
Drift Ice Station	20180908	8:22	10:32	140	Ice station	Adela, Alexandra & Walker
Drift Ice Station	20180913	8:13	11:17	184	Ice station	Katarina, Max & Andrew
Demobilisation from ice	20180914	0:38	1:19	41	Demobilisation	
Demobilisation from ice	20180914	3:57	4:31	34	Demobilisation	
Drift Ice Station	20180914	12:35	13:07	32	Polar Bear Action	

Transit	20180914	19:29	20:20	51	Reconnaissance	
Transit	20180915	6:27	12:03	336	AWI	
Transit	20180915	13:00	15:16	136	Ice station	Walker, Katarina & Max
Transit	20180916	8:57	14:52	130	Ice station	Anders, Adela & Max
Delayed due to non-optimal flight window: fog & icing conditions. Ice work approx 130 min, waiting 225 min: total 355 min						
Transit	20180917	10:47	11:07	20	AWI	
Transit	20180917	13:02	14:38	96	AWI	
Transit	20180917	14:43	16:43	120	Ice station	Walker, Katarina & Max
Transit	20180918	17:57	19:26	89	Ice station	Katarina, Anders & Max

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