Bolin Centre for Climate Research

CRUISE REPORT SWERUS-C3 LEG 1

Meddelanden från Stockholms universitets
Bolin Centre for Climate Research No 1

Stockholm University

SMHI

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Melt ponds
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MEDDELANDEN från STOCKHOLMS UNIVERSITETS
BOLIN CENTRE FOR CLIMATE RESEARCH No 1

The Swedish-Russian-US Arctic Ocean Investigation of Climate-Cryosphere-Carbon Interactions

The SWERUS-C3 2014 Expedition

SWERUS-C3

CRUISE REPORT – LEG 1 (of 2)
The SWERUS Scientific Party

Science and Ship crew (Leg 1) on the i/b Oden in icy and sunny waters north of Bennett Island on 28 July 2014.
Photo by Jorien Vonk

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Leg 1 had excellent support from the Oden ship crew (captain Matttias Pettersson) with additional logistics/technical at-sea support by the Swedish Polar Research Secretariat lead by the expedition coordinator Ulf Hedman.

Context, Scientific Objectives and Summary

Introduction and context

The SWERUS-C3 2014 expedition was one component, a central component, of the multi-disciplinary international SWERUS-C3 program. The expedition charter of the i/b Oden was financed both by a grant from the Swedish Knut and Alice Wallenberg Foundation (KAW) to ten co-PIs based on Swedish universities and by operational base funds of the Swedish Polar Research Secretariat (SPRS). The multi-year preparations, execution (and forthcoming multi-year scientific analyses, interpretations and publishing phases) are financed by institutional base funding and grants of the participating SWERUS-C3 PIs from several funding agencies in Sweden, Russia, USA and elsewhere. The 45-day Leg 1 of the SWERUS-C3 2014 expedition builds on several long-term lines of international collaboration, including the International Siberian Shelf Study program (ISSS) and the Arctic Clouds in Summer Experiment (ACSE, a development of ASCOS). The unifying aims of the SWERUS-C3 are to investigate the present and historical functioning of the multi-process Climate-Cryosphere-Carbon (C3) system of the East Siberian Arctic Ocean (ESAO) (Figure 1). A large part of the Leg 1 study area was within the Russian EEZ. A scientific permit for scientific investigations of several requested study polygons was granted for the SWERUS-C3 expedition by the Russian Ministry of Education and Science (permit nr 51). This permit was issued, per our application/Zayavka, to the Pacific Oceanological Institute (POI, Febras, Vladivostok) as the lead organization of the Russian-international collaboration. Consequently, for the work performed in the Rus EEZ this was a Russian-lead international expedition, with chief scientist Igor Semiletov in charge of execution and fulfillment. The objective of this Leg 1 cruise report is to provide a cohesive overview of the execution of the first leg; the expedition organizational structure, cruise track and stations, names and contact information of all participating scientists, and, organized by work packages, detailed information on the employed at-sea methods and a preliminary account of results (obtained samples, direct observations and generated at-sea analysis data). This cruise report was written onboard i/b Oden toward the end of Leg 1 with contributions from many participants. Additional information of the SWERUS-C3 program may be found at (http://swerus-c3.geo.su.se/), some of the additional common documents include a Scope of Work for the expedition (Leg 1 At-Sea Work Package descriptions) and a pre-departure cruise plan. Corresponding documents also exist for Leg 2 of the SWERUS-C3 2014 expedition.

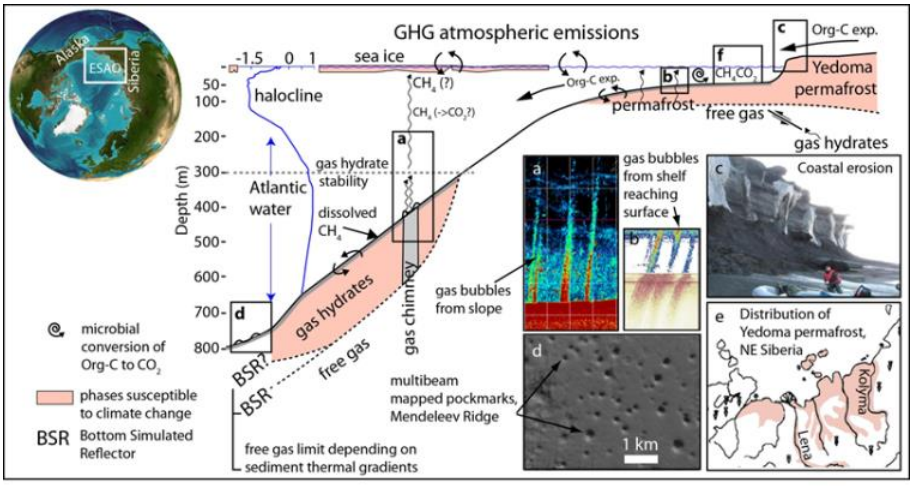


Figure. 1. *Schematics of key components of the Arctic climate-cryosphere-carbon (C3) system that are addressed by the SWERUS-C3 program. The insets* ***a-f*** *illustrates the Arctic C3-system in focus for the SWERUS-C3 two-leg expedition.* ***a,b)*** *Sonar images of gas plumes in the water column caused by sea floor venting of methane (****a****: slope west of Svalbard (Westbrook et al., 2009);* ***b****: ESAO (Shakhova et al., 2010).* ***c)*** *Coastal erosion of organic-rich Yedoma permafrost, Muostoh Island, SE Laptev Sea. d) Multibeam image showing pockmarks from gas venting off the East Siberian shelf. e) Distribution of Yedoma permafrost in NE Siberia. f) Multiple transport, conversion, and venting processes of released permafrost organic matter,* CH_4 *and* CO_2*.*

SWERUS-C3 Leg 1 Scientific Objectives

To address the SWERUS-C3 general scientific objectives, Leg 1 and 2 of the 2014 Oden expedition were designed to focus on specific scientific objectives. Leg 1 is specifically designed to investigate:

1. **CH4 release from subsea permafrost and shelf+slope hydrates**

What are the sources, mechanisms and magnitudes of the CH4 releases? What are the permafrost and gas hydrate stability fields of Arctic subsea CH4 pools and how will they respond to increased ocean warming?

2. **The fate of carbon in the shelf sea released from thawing coastal permafrost**

Are there differential fate of different permafrost carbon pools released to the ESAO? Lateral transport across the shelf? Microbial degradation and CO2 fluxes to the atmosphere? Or re-sequestration through sediment burial and off-shelf export? Ocean acidification?

3. **The sediment record of historical permafrost carbon releases**

Is the present carbon release from thawing permafrost unprecedented since the last glacial period?

4. **Air-sea heat exchange and the effects on clouds in different sea ice conditions**

What are the fluxes across the air-ocean interface of momentum, heat, water and CO2? What governs cloud formation, cloud properties and boundary layer dynamics in the summer Arctic?

Summary of the execution of SWERUS-C3 Leg 1

The overall objectives of the expedition were met. All major activities of all Work Packages were achieved. All regions/systems of the ambitious pre-departure cruise plan were investigated as part of the achieved cruise track and its 67 oceanographic stations (see Fig 2, above). At sea, we focused on one segment/section at a time, defined as work between each of waypoints A-G (see description of this approach in WP A – Coordination, below). The obtained data and samples should provide good opportunities for all participating scientists to contribute new understanding toward the collection of specific scientific aims of each Work Package, and naturally in collaboration between Work Packages onboard the SWERUS-C3 2014 Oden Leg 1 expedition, as well with Leg 2.

Cruise Track and Stations

Leg 1 cruise map

The expedition was executed by-and-large according to the ambitious pre-departure cruise plan A2. The weather and ice conditions were overall favorable.

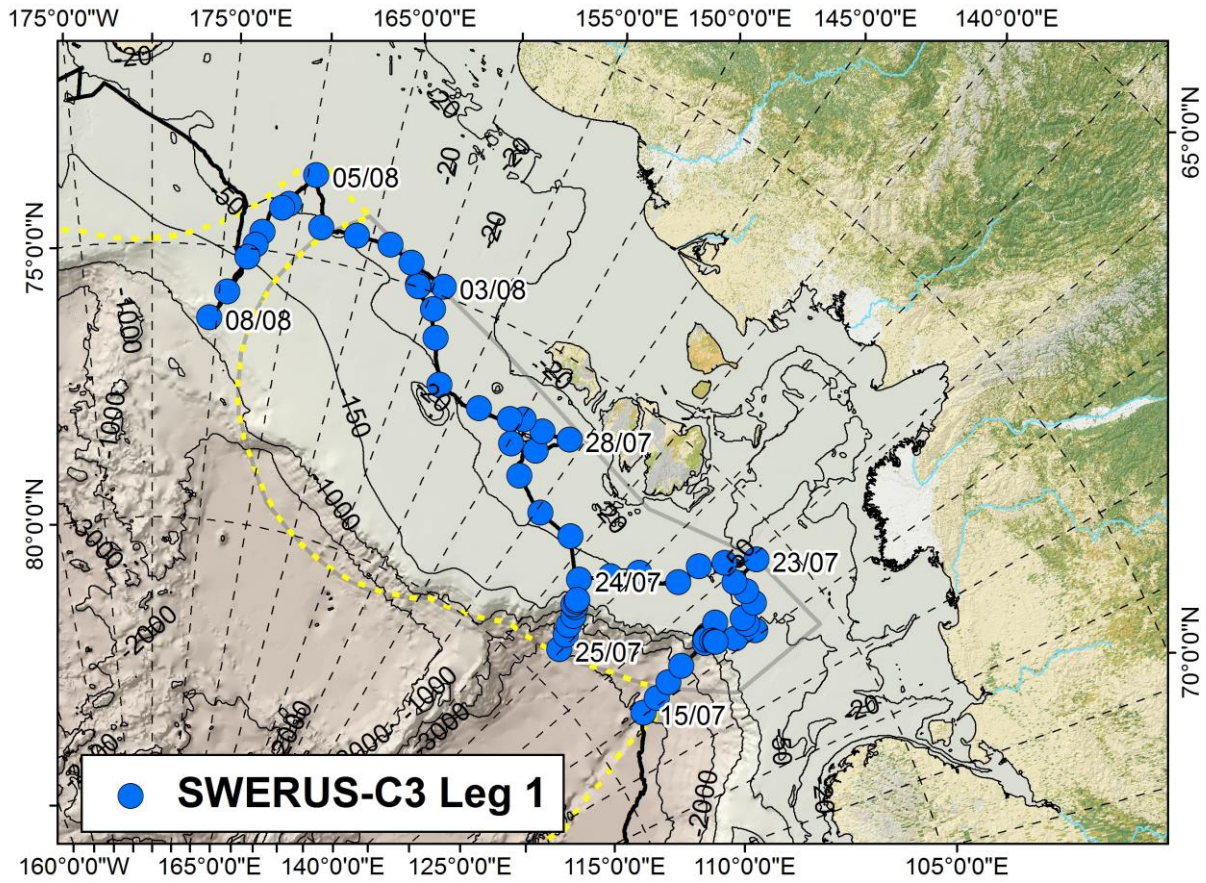


Figure. 2. *Cruise track and station locations of the Leg 1 part of the SWERUS-C3 2014 Oden expedition. The expedition Leg 1 started in Tromsö on 5 July and ended in Barow on 20 Aug. In addition to the focus area shown in this map, many continuous measurements and sample collections were performed in transit to the focus area from Tromsö and from the focus area in transit to Barrow. The latter included surveying of several lines in Herald Canyon, where large swell prevented us from taking stations.*

On positions of stations, observations and sampling

A wide breadth of observations and samples were collected both during transit and at each of the 67 stations. Two stations were taken at anchor. Since the other stations were drift stations, the exact location of observations/sampling varied slightly because of both drift and repositioning. Each work package maintain an exact record of UTC of observation/sampling and in many cases of the LAT/LON position. Useful references are the ship and navigation files provided by the Oden/SPRS to all participants. These detail not only UTC and LAT/LON but also ship-meteorological data, including wind speed and true+relative wind directions as well as parameters from the ship-fast on-line sensors of the seawater intake system (e.g., S and T).

Cruise segments and waypoints

The expedition was executed segment by segment, defined as stations between major waypoints, labelled A through G. See further details below under WP A – Coordination. The Waypoints were defined as follows from the list below, with each segment and its associated station locations and ice coverage indicated on the segment maps that follows thereafter.

Segment A- B: stations 1-12

Segment B-C: stations 13-24

Segment C-D: stations 25-30

Segment D-D (a slope-rise segment – same line back/forth): stations 31-38

Segment D-E-F: stations 39-47

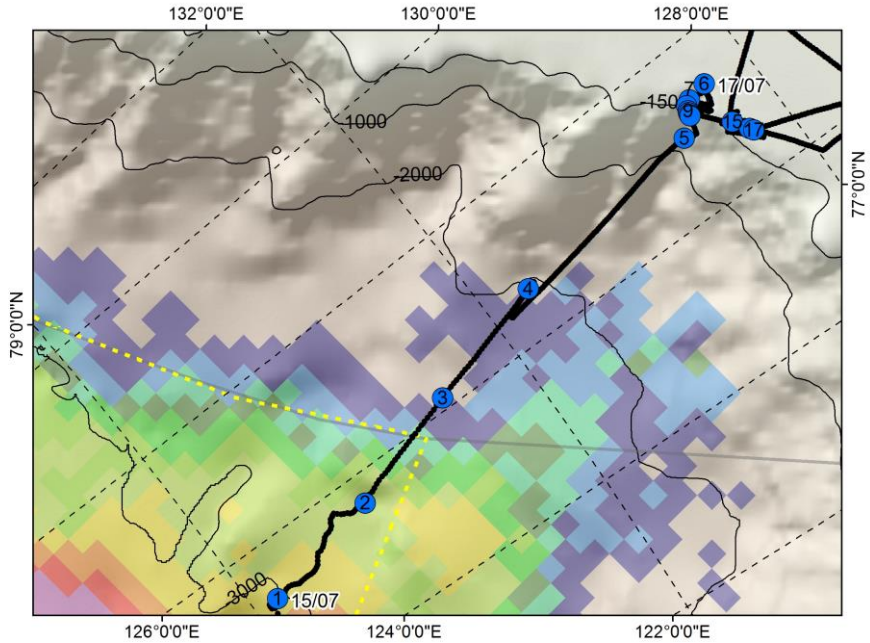
Segment F-G: stations 48-63

Segment G – Barrow: stations 64-67

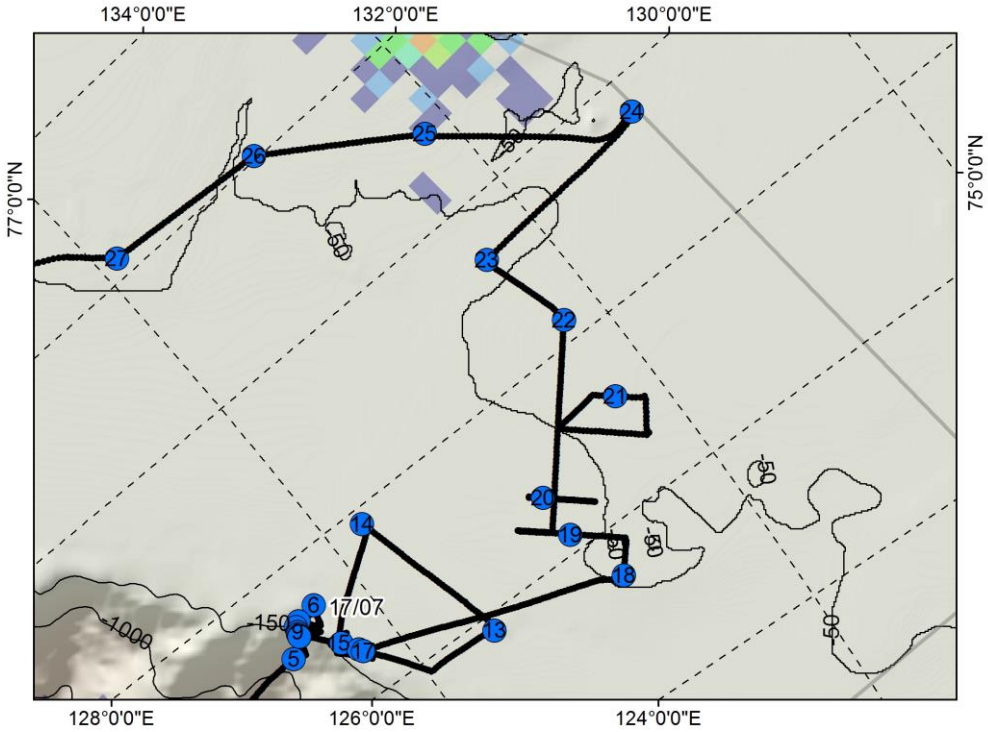
There was additional sample collection and air, seawater observations along the route from Tromsö to station 1, as well as from station 67 to Barrow. Additionally, acoustics surveying was performed in international waters and in the polygon 2 area of the permit for scientific investigations of the Russian EEZ; two lines were detailed in Herald Canyon region of the Chuckchi Sea.

Cruise segment maps with track, stations and ice coverage

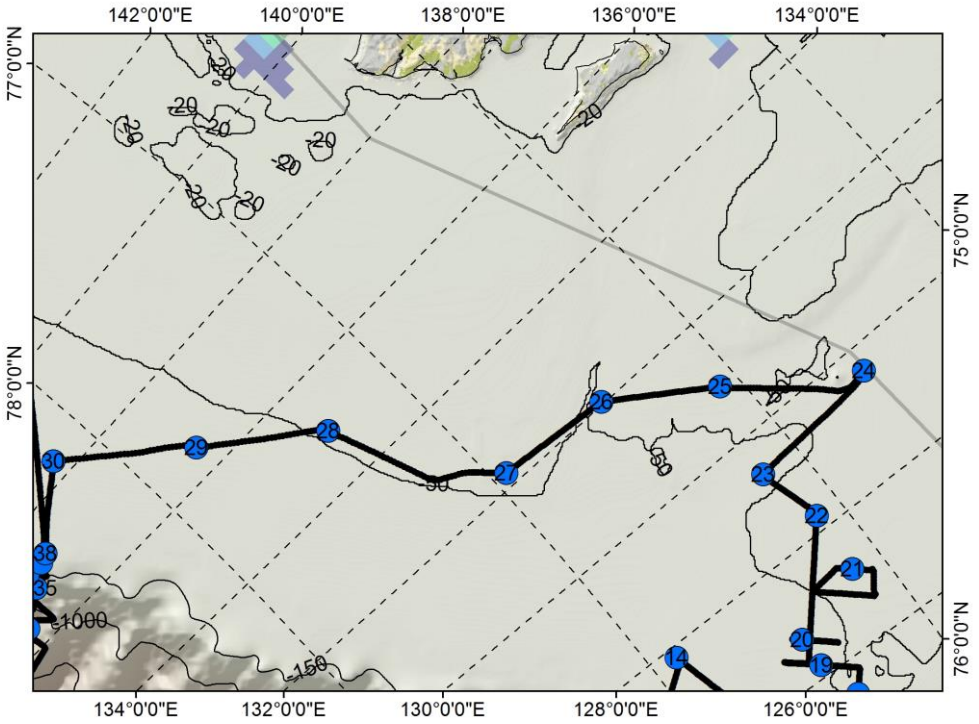
Segment A-B: stations 1-12



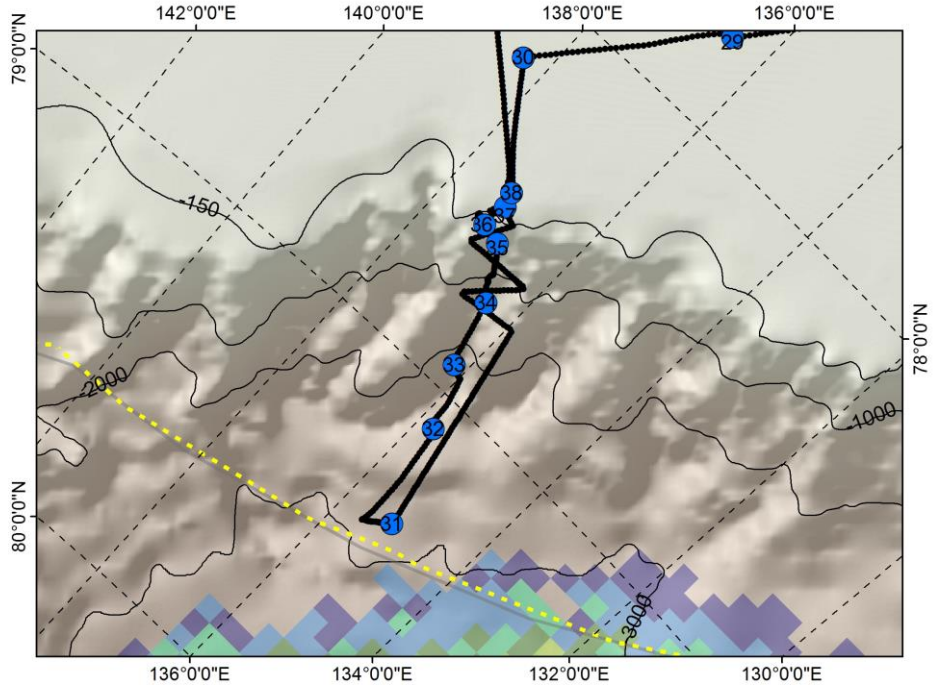
Segment B-C: stations 13-24



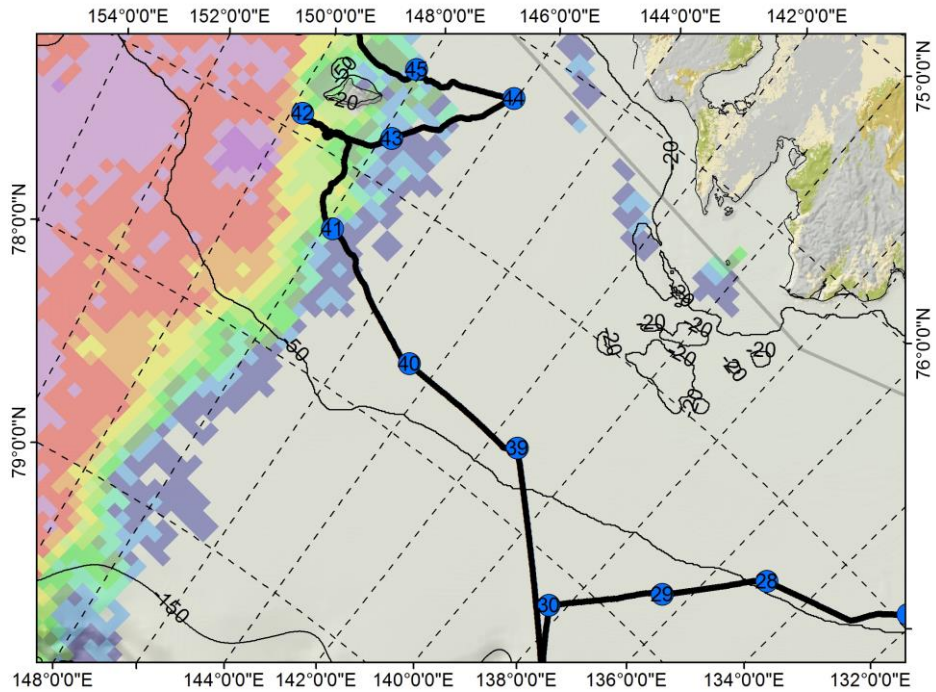
Segment C-D: stations 25-30



Segment D-D (a slope-rise segment – same line back/forth): stations 31-38

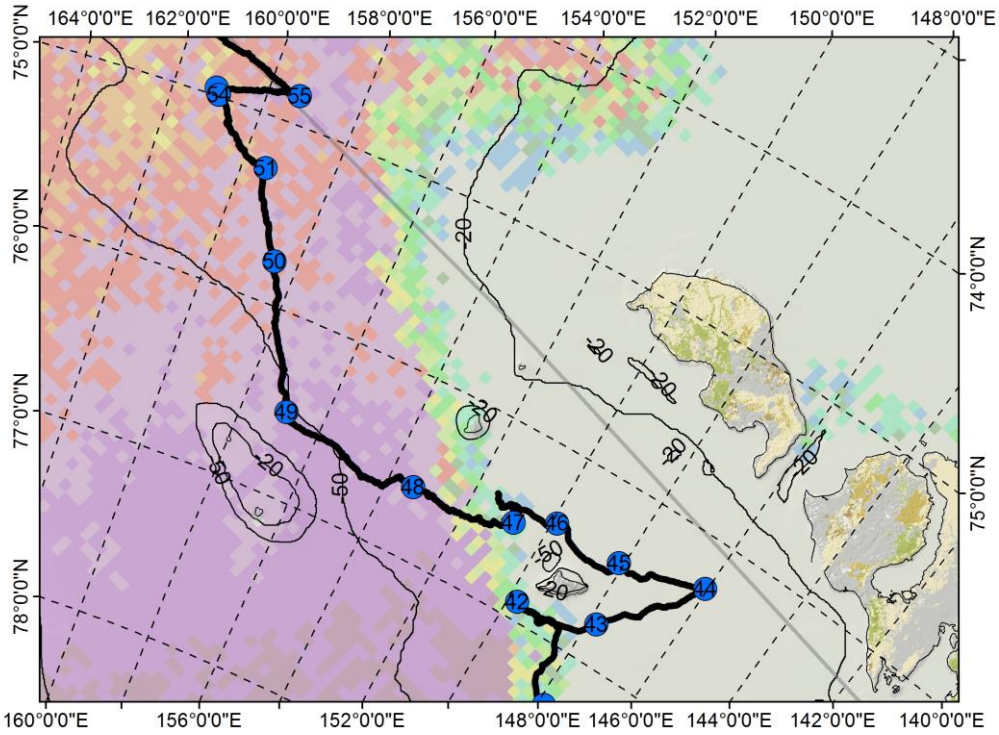


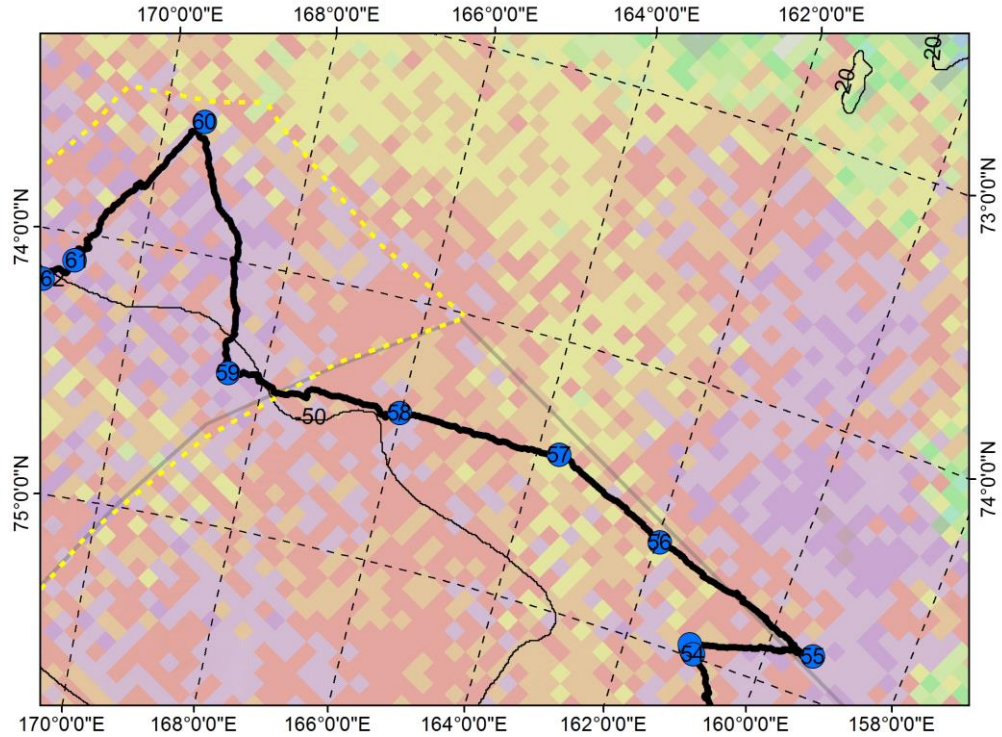
Segment D-E-F: stations 39-47



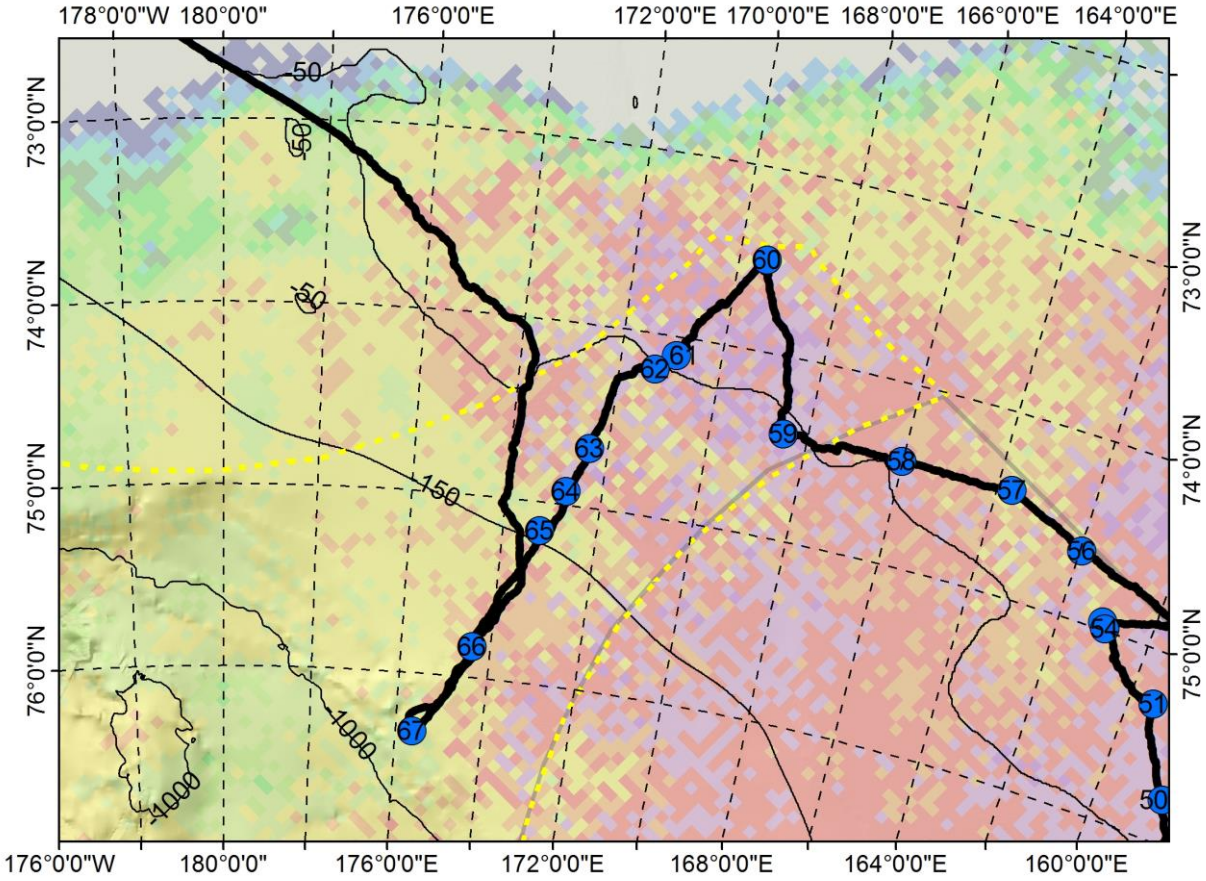
Segment F-G: stations 48-63

This segment (work) was so extensive that it was broken up in two parts both for the detailed planning in the WP lead meetings and for execution. Two maps shown below.





Segment G – Barrow: stations 64-67 (and surveying/on-line sampling/observations beyond)



Methods – Sampling, Observations and At-Sea Analyses

WP A Coordination and Organization

The at-sea organization of the scientific party and management of research activities were elaborated during more than a year before cruise departure among the SWERUS co-PIs. The at-sea cruise leadership and coordination was also established well ahead of departure amongst both SWERUS-C3 co-PIs and within a common steering group consisting of the SWERUS-C3 lead-PIs, the leadership of i/b Oden land the Swedish Polar Research Secretariat (SPRS). Below, first the work package structure is detailed and then the at-sea cruise management and information methods are described.

Work Packages

The work packages (WPs) were composed so that there would be sufficient and qualified manning to accomplish the sampling and observational tasks and to have good representation of all key scientific organizations in the different work tasks. Each WP had assigned one to two WP leads and/or a deputy lead (see fist overview table below). Each WP had as required by the permit for work in the Russian EEZ at least one lead/engaged person representative from the permit-holding Pacific Oceanological Institute (POI). By enlarge this structure and manning plan worked out well. Most WPs found a working two-shift system (often using the 8+8+4+4 watch system). In periods of particularly high workloads in one WP, we moved over manpower from some WPs that were less active during those periods.

Overview list of work packages

Work Package	**WP Lead**	**WP Lead**	**Deputy**
WP A. Coordination	Gustafsson	Semiletov	Dudarev
WP B. Water Biogeochem	Humborg	Charkin	Anderson
WP C. Methane/gases in water	Semiletov	Holmstrand	Steinbach
WP D. Methane/gases in air	Crill	Semiletov	
WP E. Sediments	Dudarev	Tesi	Vonk
WP F. Microbial Biogeochem	Brüchert	Samarkin	Sawicki

WP G. CTD / Physical Oceanography	Björk	Salyuk	Assmann
WP H. Acoustics	Noormets	Kosmach	Kirchner
WP I. Boundary Layer Meteorology	Tjernström	Salyuk	Brooks

Manning of the individual Work Packages

WP A. Coordination	**Institution**	**Main Role**	**2 pers**
Örjan Gustafsson	SU	Chief Scientist	
Igor Semiletov	POI	Chief Scientist, Rus EEZ	
Oleg Dudarev*	POI	2nd Deputy Chief Sci	

WP B. Water column biogeochemistry	**Institution**	**Main Role**	**WP Responsibility 8 pers**
Christoph Humborg	SU	Scientist	**WP Leader,** data mgmt., wet deck sheets
Martin Kruså*	SU	Technician	Assist w hi-vol POM filtr, SPE
Emma Karlsson	SU	PhD student	Hi-vol filtr (GFF+lignin); SPE (14C-DOM etc)
Marcus Sundbom	SU	Technician	Onboard DOC analyses, Niskin POC filtr

Jörgen Ek	SU	Technician	Nutrient analyses
Barbara Deutsch*	SU	Scientist	SPE-DOM extractions
Leif Anderson	UG	Scientist	IC system, O2, wet deck sheets, deputy WP lead
Frank Zemlyak	UG	Technician	IC system, O2,
Marc Geibel	SU	Post-doc	Picarro sys for aq. CO2, CH4
Alexander Charkin	POI	Scientist	Ra isotope program, co-WP Lead
Note: *This WP will assist WP G with CTD deployment and recovery*			

WP C. Methane and other trace gases in water			**6 pers**
Igor Semiletov*	POI	Co-Chief Scientist	**WP co-lead;** sampling strategy
Henry Holmstrand	SU	Scientist	**WP co-lead**; 3D-iso-CH4; CH4+gases conc
Julia Steinbach	SU	Post-doc	3D-iso-CH4; CH4+gases conc
Denis Kosmach	POI	PhD student	CH4+gases, conc onboard, 3D-isotopes
Ksenia Shcherbakova	POI	PhD student	CH4+gases conc onboard, 3D-isotopes
Celia Sapart	Utrecht Uni	Scientist	CH4+gases; 3D-iso-CH4,
Anatoly Salyuk	POI	Scientist	Sampling He+Ne isotopes, CH4 program

WP D. Carbon gases AIR fluxes, conc, isotopes			**2 pers**

Patrick Crill	SU	Scientist	**WP Leader;** CH4 conc/2H/13C instr, A/W instr
Igor Semiletov	POI	Scientist	**WP co-coordinator**
Brett Thornton	SU	Post-doc	CH4 conc/2H/13C instr
Celia Sapart*	Utrecht Uni	Scientist	Atm discrete samples: gas conc/isotope composition

WP E. Sediment Collection and Processing			**7 pers**
Tommaso Tesi	SU	Post-doc	**WP lead**; cruise lead support; coring, sectioning, temp logging, cameras, subsampling CH4 prog
Oleg Dudarev	POI	Scientist	**WP lead**, coring, section, scanning
Volker Brüchert*	SU	Scientist	Coring
Pete Hill	UNIS	PhD stud/Techn.	Coring, sectioning, lead for piston coring, core probes
Martin Kruså	SU	Technician	Core logger, assist coring/sectioning
Anton Salvado	SU	Post-doc	Coring, sectioning, temp loggers
Alexander Gukov	ULNR	Scientist	Coring, macrobenthos
Jorien Vonk	Univ Utrecht	Scientist	Coring, sectioning

WP F. Microbial Biogeochemistry			**4 pers**
Volker Brüchert	SU	Scientist	**WP Leader,** incubations, pw profiling, assist w coring

Vladimir Samarkin	POI and Uni Georgia	Scientist	**WP co-lead,** Sed + water incubations (3H-spiked methane oxidation)
Joanna Sawicka	SU	Post-doc	Incubations
Lisa Bröder	SU	PhD student	O2 microelectr; penetration depth, Assist w coring
Note: *This WP will assist WP E with coring deployment and recovery*			

WP G. PO/CTD/Niskin			**3 pers**
Göran Björk	GU	Scientists	**WP Leader**
Anatoly Salyuk	POI	Scientist	**WP co-coordinator**
Karen Assman	GU	Post-doc	**Deputy lead**, CTD
Barbara Deutsch	SU	Scientist	Main task: CTD team
Christoph Humborg*	SU	Scientist	Assist w CTD runs

WP H. Geophysical bubble and sedim echosounding			**4 pers**
Riko Noormets	UNIS	Scientist	**WP Leader** MB/chirp +Skidbladner
Alexey Khortov	Shirshov IO, RAS	Scientist	MB/Chirp
Nina Kirschner	SU	Scientist	WP deputy lead MB/Chirp
Denis Chernikh	POI, RAS	PhD student	WP co-lead, MB/mid-water sonar – focus on bubbles in water column

WP I. Boundary Layer Meteorology			**5 pers**
Michael Tjernström	SU	Scientist	**WP Leader,** Sounding program
Ian Brooks	Leeds Univ	Scientist	Surface flux obs
Dominic Salisbury	Leeds Univ	Post-doc	Surface flux obs
Matthew Shupe	CIRES/NOAA	Scientist	Remote sensing
Paul Johnston	NOAA	Engineer	Remote sensing

Expedition management

Mattias Pettersson served as Master of i/b Oden for Leg 1. Örjan Gustafsson and Igor Semiletov served as co-chief scientists (CS) for Leg 1. Igor Semiletov was chief scientist, with Oleg Dudarev and Örjan Gustafsson serving as deputy chief scientists for the work in the Russian EEZ. Ulf Hedman of the Swedish Polar Research Secretariat served as expedition coordinator for Leg 1.

The scientific coordination was executed in several ways. The group of WP leaders/co-leaders agreed to perform detailed at-sea planning and execution segment per segment, as defined as the stations between the different Waypoints (A-G) listed above. Ahead of approaching each segment, we met amongst all WP leads (and Ulf Hedman) in the conference room for a segment planning meeting. The CS started out with a presentation of the original (cruise plan A2) plan, some key scientific motivations for the segment, a recent ice map, weather information, any information on our progress in time/bunker and other external factors. A suggested detailed route and station plan was presented. Based on the subsequent discussion and input as well as requests for stations and sampling activities, the CS put together a "Segment Activity Plan" (see example in Appendix 1). All such were distributed by email to all scientific program participants. These contained a front page with summary/overview information; a second page showed a map with route and sampling stations, overlaid on bathymetry and ice information; a third page had a detailed Activity Table (one station per row); often a fourth page was included with some "science" figures of either something we found in the earlier segment or something from the literature of relevance for the upcoming segment work.

The daily execution/management started with a morning meeting before breakfast on the bridge with the two CSs, SPRS coordinator, the Master and the First Officer (Mats Wirsén). These meetings started with a weather report/maps presented by Michael Tjernström and a look at ice maps. We then quickly moved to "Day of the Plan", which almost always was based on the Segment Activity Plan and the stations that were coming up for the day, as well as a discussion of any specific support required from the crew for the execution of the station work or servicing of the infrastructure. The Plan-of-the-Day info screen was updated right before breakfast for all participants to get fresh information. At times, the CS also informed at breakfast using the mic.

The actual stations were executed efficiently. All major sampling deployment teams (CTD, Aft deck sediment coring and red winch Go-Flo/submersible pump) occupied a unique VHF channel. A detailed individual Station Record sheet was used by the Bridge mates and the two CSs to coordinate the multiple station activities (one example shown in App. 2). The complete "Station Records" files of what activities actually were accomplished at each stations, in what sequence and at what times, roughly at what positions and additional observations/records were shared on the common server to all participants.

A substantial emphasis was placed at spreading up-to-date information to all participants. Regular all-science-hands information meetings were held in the mess, all activity plans and much other information was sent to the email list leg1@swerus.polar.se. The “Plan-of-the-Day” page on the info screens were updated frequently during the days. All WP leads briefed each WP shift team frequently. We also carried out many additional ad hoc meetings between co-PIs and in various other constellations. The First Officer (Mats W.) carried out detailed “Toolbox” meetings both in the mess and on deck for each sampling activity to ensure proper safety methods. The CS was also using the opportunity to grab the mic at meals to inform about updates. The info screens also had an ice map with all upcoming stations and the ship position (fugawi) that helped all to see approx. distance to next station. We also employed am “approaching station” wake-up scheme (executed by CSs and the Acoustics team) to maximize sleep of all participants. A seminar series was also run during the first phase of the expedition – open to both crew and scientists. Finally, the common server “vdata” was used to share information and data between participants.

WP B Water Column Biogeochemistry

This project aims at increasing our understanding of the feedbacks among components of the Arctic Ocean carbon system, which include the assessment of biogeochemical carbon transformation in the water column and air-sea exchange of CO_2 and CH_4 on the large shelf areas and the exchange with the deep central basins, when the sea ice coverage is absent during the productive summer season. A decrease in summer sea ice coverage likely affects the magnitude of primary production and resulting export of marine produced organic matter to the underlying waters. A summer sea ice-free Arctic Ocean will also result in more brine formation through an enhanced sea ice production during the winter season that might contribute to a larger subsurface water formation. Both changes in export production and ventilation of the deep waters impact the sequestration of anthropogenic CO_2. Moreover, a warmer climate may increase river and groundwater discharge and may lead to a redistribution of terrestrial carbon from land to sea, which huge implication for C degradation patterns along the Siberian Shelf and air-sea exchange. Finally we also aim at assessing the natural ocean acidification, i.e. that caused by biogeochemical processes, in relation to that originating from uptake of anthropogenic CO_2.

In this working package we addressed the dynamics and fate of marine and terrestrial carbon in the water column along the Siberian Shelf by means of i) bulk inorganic carbon biogeochemistry (TC, Alk, O2, pH), bulk organic biogeochemistry (POC, DOC, TOC) and nutrient biogeochemistry (N, P, Si). Continuous and vertical profile measurements of ii) gaseous carbon species CO_2 and CH_4 will allow an estimate of air-sea exchange of these significant GHG. We applied a multiple stable isotope approach to the inorganic (δ^{13}C-DIC, δ^{13}C-CO_2, δ^{13}C-CH_4) and iii) organic carbon variables (dissolved organic carbon; ^{14}C-DOC, δ ^{13}C-DOC, δ^2H-DOM, δ ^{15}C-DON; particulate organic carbon, ^{14}C-POC, δ ^{13}C-POC, δ^2H-POM, δ ^{15}N-PON) enabling us to constrain the contribution of terrestrial and marine carbon sources, i.e., autochthonous primary production, and their degradation products along the estuarine gradient of the entire Lapted Sea (LS) and East Siberian Sea (ESS). The studies on organic carbon variables were complemented with biomarker studies (CuO reaction products, solvent extractable lipid, black carbon, bulk characterization via FT-ICR-MS etc. Finally v) tracers for groundwater inputs (Ra) have been determined.

Seawater samples for most of the analyses that have been or will be performed within this WP were collected both from Niskin bottles on a rosette attached to a Seabird® CTD and from a continuously flushed seawater intake (SWI) system during transit. Water was pumped from 8 m depth at about 60L/min through stainless steel and plastic tubes and further distributed within the main lab for the on board analyses of the greenhouse gases CO_2 and CH_4 and for the high volume filtration of particulate organic matter; the latter have ben also sampled with an in-situ pump. In total some 67 distinct stations over the entire transect have been sampled for biogeochemical variables in the water column.

Inorganic carbon, organic carbon and nutrients (TC, Alk, O2, pH, POC, DOC, TOC, N, P, Si)

Technical description of sampling/ Oxygen, total alkalinity and pH/ POC, DOC and TOC/ N, P, Si

Water samples were collected using a rosette system equipped with 24 bottles of Niskin type each having a volume of 7 L. The bottles were closed at predefined depth during the return of the CTD-rosette package from the bottom to the surface.

Methods for sampling/data collection for using sampling/ Oxygen, total alkalinity and pH

Water samples for all constituents were drawn soon after the rosette was secured in the CTD container. The order of sampling was determined by the risk of contamination and therefore the oxygen samples were drawn first in flasks of approximately 150 ml equipped with glass stoppers. The oxygen was directly fixated by the addition of 1 mL each of concentrated manganese sulphate and basic iodide solutions to form $MnO(OH)_2(s)$. Samples for the determination of pH and total alkalinity were collected as soon as possible as atmospheric CO_2 can impact the former. 250 mL Pyrex© bottles having tight plastic stoppers were filled to the rim in order to minimize contamination. Samples were stored at temperatures between 10 and 15 ^{o}C before analysis within hours of collection.

Analytical methods

Oxygen was measured using an automatic Winkler titration with UV detection. Before each titration session the system blanks were determined by addition of reagents to MilliQ water. The titrations were performed in the same flasks as the used for the collection of the samples from the rosette after the $MnO(OH)_2$ was dissolved by sulphuric acid. A sodium thiosulphate solution was used for the titration and its concentration was calibrated each day using pre-weighted KIO_3 standard. Precision was determined using replicates from the same depth and was better than 0.5 µmol/kg.

The determination of **pH** was done on the total scale applying a spectrophotometric method using the indicator m-Creosol Purple (mCP). Pure mCP was purchased from the laboratory of Bob Byrne, Univ. South Florida, USA. A 0.2 mM indicator solution was prepared by dissolving pre-weighted mCP indicator in 0.5 L filtered seawater of about 34 salinity. The indicator was adjusted to a pH in the same range as the samples, approximately ± 0.2 pH units, by adding a small volume of concentrated HCl or NaOH. Before running a set of samples, the pH of the indicator was measured using a 0.02 cm cuvette. The measurements were performed on board within hours of sampling. An automatic system was used where the sample and indicator was mixed in a syringe (Klohnen) before injected to a 1 cm cuvette of a diode array spectrophotometer (Agilent 8453), where the absorbance was measured at wavelengths 434 and 578 nm. Indicator corrections were made according to the recommendations from Chierici et al. 1999. The pH values are corrected to 15°C on the total scale.

The accuracy is determined by the pureness of the indicator and was also checked by the determination of reference water certified for total alkalinity and total dissolved inorganic carbon. The latter measurements indicate that it should be well below 0.01 pH unit. The precision as determined by replicates from the same sample bottle was in the range of ±0.001 pH unit.

Total Alkalinity (TA) was measured after pH from the same Pyrex© bottle. It was determined using an open cell potentiometric titration method using a GRAN point determination (Haraldsson et al., 1997). The system measures alkalinity in µmol/L using the nominal acid concentration of 0.05 mol/L. Certified reference material (CRM) as supplied by A. Dickson, Scripps Institution of Oceanography was used to determined accuracy. For all samples and CRM analysis the alkalinity in µmol/kg was calculated using the salinity (from the CTD bottle file and the certified salinity, respectively) and the temperature measured at the beginning of the titration. Sample results were then multiplied with the factor determined from the CRM measurements at each individual station, and the correction was always below 0.5%.

The given precisions were computed as standard deviations of duplicate analyses preformed continually during the cruise. Duplicates were run from the same sample bottle since alkalinity is not sensitive to atmospheric contamination with the results typically deviating less than 2 µmol/kg.

Methodological approach to sampling/data collection using sampling/ POC, DOC, TOC

Water for total organic carbon (TOC) was sampled directly from the Niskin bottles into 40 mL glass vials (EPA vials) belonging to the autosampler unit of the TOC analyzer. The TOC samples were acidified shortly after sampling with 2 drops 37% hydrochloric acid and thereafter analysed directly or, when many samples were waiting for to be analysed, stored cool and dark until analysis. The EPA vials were rotated throughout the cruise and rinsed 3 times with hot water and 3 times with MQ water after each completed analysis. At some stations, during periods of very frequent station stops, the water for TOC was withdrawn from the nutrient sample bottle (after the small volume nutrient sample had been collected) because all available EPA vials being in circulation.

Seawater for POC and DOC analyses was sampled from the Niskin bottles into 1.4 L PET bottles. The bulk organic carbon was separated into POC (> 0.7 µm GF/F filters pre-combusted at 460°C for at least 4 hours) and DOC (GF/F filtrate) components using an on-board vacuum filtration system with five parallel, independently manoeuvrable filter holders (Fig X). The PET sample bottles were wiped clean and seated directly in the filter funnels by quickly turning the bottle upside down and thus minimizing contact with other surfaces than the filter and filter holder. The filtrate was collected directly into 40 ml glass vials (EPA), immediately acidified with 2 drops 37% HCl and then analysed on board for DOC as soon as possible.

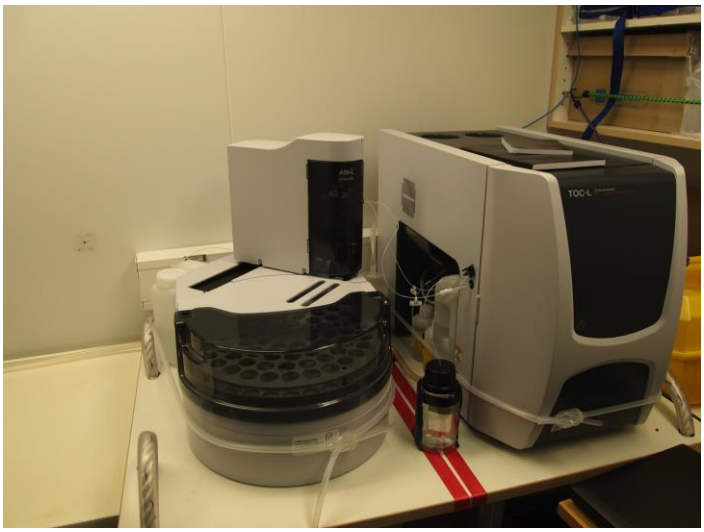
The GF/F filters for POC and PON analyses were folded once and packed into brown Eppendorf vials and stored at -80°C for elemental and isotopic analyses later in Stockholm.

Vacuum filter system used for small-volume GF/F filtration. Five parallel filter devices are hooked up to the same vacuum source.

Analytical methods

The DOC and TOC analyses were performed continually on board by high-temperature catalytic oxidation (Shimadzu TOC-L). Inorganic carbon was removed by acidifying the samples to pH 2 with 37% HCl and sparging for 8 min with carbon-free synthetic air prior to analysis of the total carbon content (NPOC method). Typically, total carbon 3-5 sample injections with a volume of 100 µL was determined for each sample. A five-point calibration curve (0-330 µM) was made by diluting a 1000 µg/L stock solution of potassium hydrogenphthalate in MQ water. The stock solution was stored at 4°C and prepared weekly whereas the diluted standard used for the calibration curve were freshly prepared on a daily basis. The stability of the response factor was monitored by including standards of two different concentrations in each analysis batch. Moreover, MQ-blanks as well as Consensus Reference Materials (CRM, from University of Miami) of low carbon content (1-2 µM C) and deep-sea reference water (41-44 µM C) were run prior to and after every 10-15 samples within every analysis batch.

Catalytic combustion of seawater quickly leads to the accumulation of solids in the combustion tube that affects the analytic performance. When control samples indicate severe drift or poor reproducibility the analysis was stopped the batch of samples was reanalysed on board after satisfactory performance had been restored. Moderate drift in response factor or system blanks did not lead to on-board reanalysis but can be accounted for by analytical methods. All TOC and DOC results in this cruise report are preliminary. Final assessment will be carried out in Stockholm.

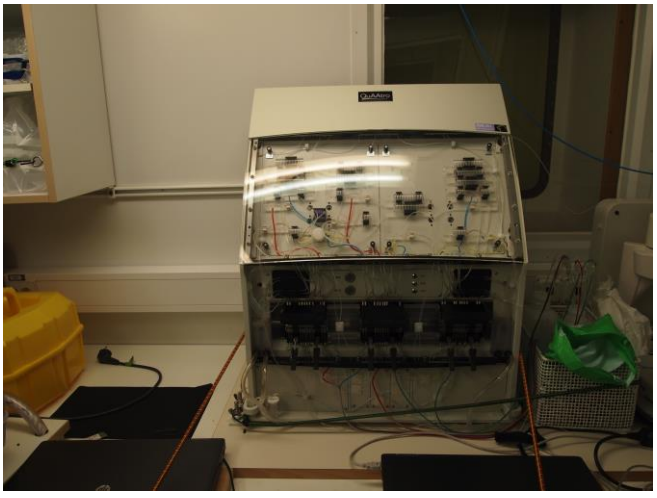


Shimadzu TOC-L total organic carbon analyser with autosampler (left) in the clean lab on board ODEN.

Methodological approach to sampling/data collection using sampling/ N, P, Si

Nutrient samples were retrieved directly from the Niskin bottles into 100 ml HDPE-bottles (Kautex). The bottles were rinsed with sample water 2-3 times before completely filled and closed with a plastic cap. Samples were kept cold (4°C) and dark until analysis, typically taking place the same day or the day after samples were taken. The bottles and caps were machine washed (70°C) and rinsed with deionized water prior to the cruise.

Nutrients (NH4, NO2/3, PO4 and SiO4) were determined colorimetrically onboard using a four-channel continuous flow analyzer (QuAAtro system from SEAL Analytical). Each analysis run were preceded by running standard samples of prepared from stock solutions of NH4Cl, KNO3, K2HPO4, and a commercial stable silica-compound solution. Drift controls and certified reference material (QC RW1, Batch VKI-9-3-0702). If analytical problems, manifested as abnormal peaks, occurred, the sample batch was reanalyzed immediately after the problem was located and fixed.



Continuous flow analyser QuAAtro from SEAL Analytical in the clean lab on ODEN. The instrument was used for continual onboard measurements of nutrients in water throughout Leg 1.

Gaseous and dissolved inorganic carbon species and their stable isotope composition

Technical description of sampling/CO2, δ^{13}C-CO2 and CH4 in surface water

Continuous measurements of surface water have been performed using the SWI. Water was pumped through spray nozzles into the open headspace equilibrator at ˙~4.5 l min-1. By creating a fine spray of droplets, the exchange surface between headspace and water is maximized and an optimal equilibration is achieved. The gas of the headspace was analyzed using two different CRDS (cavity ringdown) analyzers. Only the GHG analyzer (flow ~250ml/min, see methodological approach) is modified for closed cycle operation. The second analyzer was operated in parallel and its flow (~25ml/min) was not fed back into the closed cycle. Thus, it created a defined vent flow. This vent flow is compensated by a flow of ambient air (AA) taken from the top inlet of the Met mast. To be able to correct the data for the vent flow, the concentration of CH4 and CO2 and the δ13C of CO2 in AA is monitored by frequent switching.

Technical description of sampling/ CO2, δ^{13}C-CO2, CH4 and δ^{13}C –CH4 in the water column

Discrete samples for vertical profiling of the CO2, δ^{13}C-CO2, CH4 and δ^{13}C –CH4 composition were taken from the CTD's Niskin bottles each having a volume of 7 L. The bottles were closed at predefined depth during the return of the CTD-rosette package from the bottom to the surface.

Preparation:

Two liter sample containers were evacuated, re-filled and flushed with carbon free air (ZeroAir) and evacuated to a sampling pressure of 500mbar. For each sampled station five containers were prepared.

Sampling:

The prepared sample containers were attached to the CTD's Niskin bottle with a silicon tubing.

The tubing was attached to the closed sample valve and the valve was opened. After removing the air in the tubing it was attached to the inlet port of the sample container. A pressure gauge (PG) was attached to the outlet port. Then, both inlet and outlet valve were opened and the container was filled with water. When the PG showed ambient pressure, both valves were closed and tubing and PG were removed. Each sample was subsequently shaken by hand for 30s the initiate equilibration and to clean the inlet port from excess water.

Technical description of sampling/ δ^{13}C-DIC in the water column

Water samples were collected using a rosette system equipped with 24 bottles of Niskin type each having a volume of 7 L. The bottles were closed at predefined depth during the return of the CTD-rosette package from the bottom to the surface.

Methods for sampling/data collection / CO2, δ^{13}C-CO2 and CH4 in surface waters

CRD spectrometer measurements were used to continuously monitor CH_4 and CO_2 concentrations and δ^{13}C-CO2 composition of gas stripped via headspace equilibration from the water column using the Water Equilibration Gas Analyser System (WEGAS). It consists of three major components:

- Water handling system including:
    - showerhead equilibrator (head space volume 1l) fed by the SWI
    - continuous pH measurements by E&H electrode probe
    - T and salinity measurements by Seabird TSG 45

- Cavity ring-down spectroscopy (CRDS) gas analyzers for CO2 stable carbon isotopes (model G2131-i, Picarro Inc., Sunnyvale, CA) and CO2 and CH4 concentrations (GHG analyzer, model G2301, Picarro Inc., Sunnyvale, CA)
- Gas handling system with circulation pumps for headspace and ambient air from Met mast
- Data logging and control system
- Notebook with GUI for WEGAS

WEGAS equilibrator, WEGAS and WEGAS GUI

Methodological approach to sampling/data collection using sampling/ CO2, δ^{13}C-CO2, CH4 and δ^{13}C – CH4 in the water column water

CRD (cavity ringdown) spectrometer measurements were used to determine the CH_4 and CO_2 concentrations and δ^{13}C-CO2 and δ^{13}C-CH4 composition in the water column (vertical profiling). Therefor, distinct water samples (~1000ml) were taken from CTD Niskin bottles and analyzed with Stable Carbon Isotope Analyzer for Small Samples (SCIGASS) via headspace equilibration.

It consists of following components:

- Gas handling system with closed cycle circulation pump for headspace, dilution modules and cryo cooler
- Cavity ring-down spectroscopy (CRDS) gas analyzers for CO2 and CH4 stable carbon isotopes (model G2201-i, Picarro Inc., Sunnyvale, CA)
- 2l sample containers with quick connectors
- NKF 920 vacuum pump for evacuation of sample containers
- Notebook

Analysis (for a single sample):

Step 1:

SCIGASS was flushed in open mode with ZeroAir until the analyzer's readings were 0 ppm for CH4 and below 1ppm for CO2. Then, the closed cycle mode was activated for a few minutes. After this, the system was flushed again with ZeroAir. The drain pump of the cryo cooler was stopped.

Step 2:

The sample container was attached to SCIGASS. The valves of the container were opened and the system switched to closed cycle mode. As a final step, the sample stream was connected to the closed cycle.

Step 3:

After 15min of continuous closed cycle measurement, the readings for 12CH4, 13C-CH4, 12CO2 and d13C-CO2 were noted to the sample sheet. The cycle was opened; the sample detached and the drain pump of the cryo cooler started. The data of the 15min sample run was stored in a dedicated folder on the server. After this, the sample container was opened and the water volume measured.

SCIGASS and evacuated sample container

Methodological approach to sampling/data collection using sampling/ δ^{13}C-DIC in the water column

The samples were directly injected with a syringe into 12 ml septum-seal glass vials (Labco Limited), which had been flushed with argon gas (75 mL min^{-1}) for 5 min. To each vial, 100 µl of 85.5% H_3PO_4 was added to act as a preservative and to transform all the HCO_3^- and CO_3^{2-} ions to $CO_2(g)$. Transfer by needle injection through the septa avoided both air entering the vial and CO_2 leaving it. The

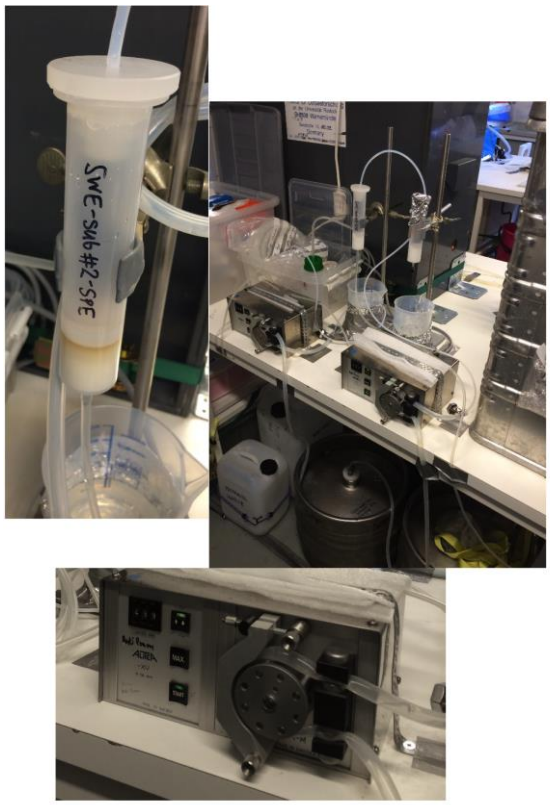
samples were stored under cold (+4°C) and dark conditions until analysis. The $\delta^{13}C$-*DIC* samples will be measured back in Stockholm using a Gasbench II extraction line coupled to a Finnigan MAT 252 mass spectrometer.

Stable isotope composition and biomarkers of dissolved & particulate organic carbon species

Technical description of sampling/^{14}C-DOC, δ ^{13}C-DOC, CuO reaction products, solvent extractable lipids

Samples were collected in 30L beer kegs (prewashed aluminum kegs with headpiece of Teflon and steel tubing reaching down to bottom). The water was taken pre-filtered directly from the high volume GFF system, with a cutoff of 0.7µm. Samples were acidified with concentrated Hydrochloric acid down to ~pH2; 1.3 ml/L of water of 37% HCl (39 ml/30L sample). HCl AnalaR NORMAPUR grade in glass bottles. Sample volumes varied between 26 and 30 L each.

A peristaltic pump was then used at a flow rate of 100ml/min to extract sample onto a C18 Bond Elut column to gain the High volume Solid Phase Extraction (SPE). Columns were preconditioned with 5 resin volumes of methanol that were sucked through with syringe, and a subsequent 5 resin volumes of MilliQ water at pH2 (1.3 ml HCl 37% for ~pH2 in milliQ). MilliQ water was taken from onboard system in the main lab. Exact volume of sample extracted was recorded through measuring waste volume. After extraction samples were desalted through addition of 5 resin volumes of pH2 MilliQ water. Sample cartridges were packed in aluminum foil and stored in 4°C cooling container.

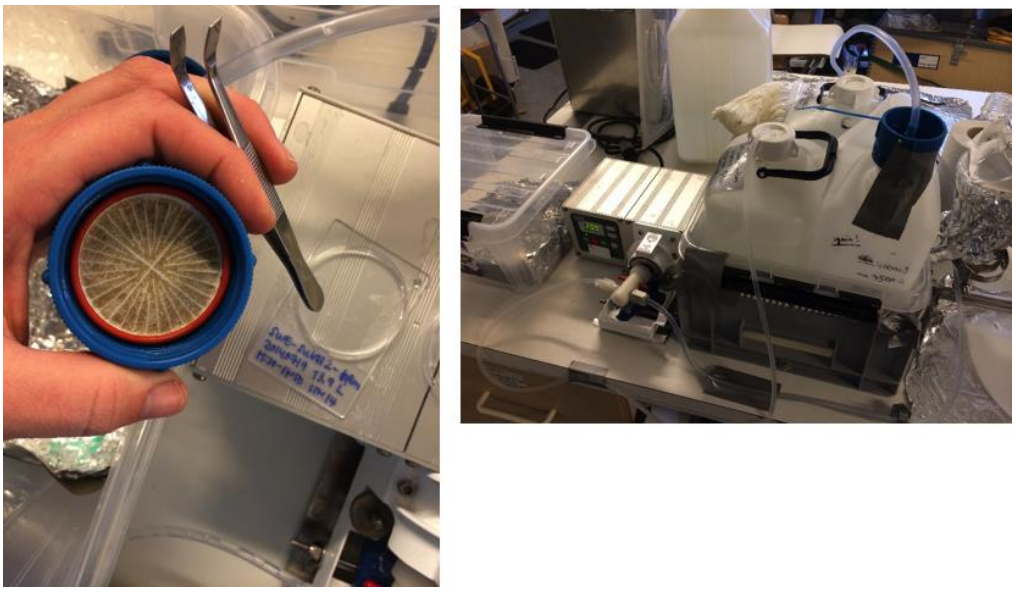


Filtration unit for High volume solid phase extraction

Technical description of sampling/CuO oxidation for POC

Samples were collected either directly from the stainless steel SWI in main lab container, or from 1000L tanks at the submersible pump stations and at stations in ice. SWI samples were collected in 1000L tanks and filtered from these (SWI got frequently clogged with ice and was not giving even flow, why we filled up the tanks and pumped water via tanks instead).

47 mm Teflon filters were placed in a filtration unit. Positive pressure flow was applied with a peristaltic pump at a flow rate of 25 ml/min to run sample. Filtered volume was recorded through measuring filtrate volume. Filtered volume varies from 4 to 15 liters. Sample filters were folded in two, placed in petri dishes and stored in -20°C freezer.



Filtration unit for Teflon filters

Technical description of sampling/ ^{14}C-POC, δ ^{13}C -POC, molecular analysis of black carbon and other biomarkers

Sea water was filtered on 293mm GFF filters with a 0.7µm cut-off in stainless steel filter holders. The whole system consisted of the following parts described below.

Submersible pump

Submersible pump (Model AN-19, 380V, Flow rate 30l/min; Debe pumpar AB, Sundbyberg, Sweden)
Wetted parts of nylon plastic, brass and stainless steel.
Tubing: Rigid “fire hose” type tubing. 1 in Inner diameter, wetted parts silicone.
The pump was deployed from the red-winch at the starboard side. During the SWERUS-C3 the pump was always deployed near bottom (-5m) at selected shelf stations.

Seawater distribution network incl. 1000L tanks

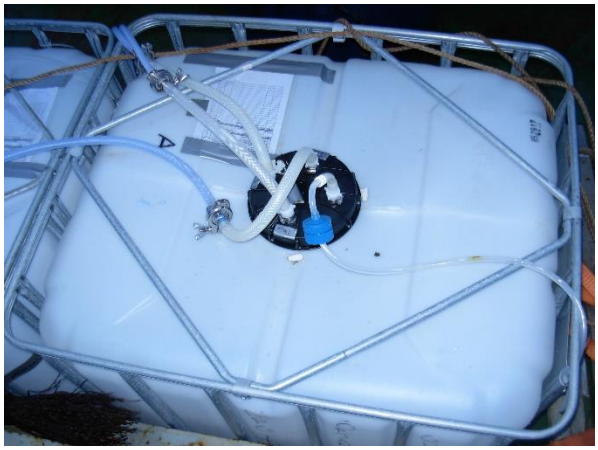
1000L tanks

Tanks were made of HDPE. Tanks had drainage valves near bottom. On top of each tank there was a lid of ca 30cm in diameter which could be screwed on and off. To each lid 4 holes were drilled to enable the following.

1) Filling of the tank with submersible pump
2) Filling of tanks from SWI
3) Re–circulation of excess water not used for GFF-filtrations back to the tank.
4) Pumping water out of the tank with impeller pump to GFF-systems.
5) Air out and inlet. This hole was equipped with a 47mm diameter filter holder and a GFF-filter to not contaminate the water. At the inlet of the filter holder there was a tube of 1m facing down to protect the filter from water.

To each hole there was a piece of armored silicone tubing inserted into the container which was squeezed out with a plastic nipple to perfectly tighten hole in the lid, (see picture below). The hole for pumping water out of the tank had a silicone hose reaching the bottom of the tank, the other three holes had just a just a small piece of silicone tubing immersed into the tank.

To avoid contamination the tank when it was not in use the holes where closed with plastic stoppers, (see picture 2.9.2.3). The stoppers were attached to the nipples with a string not to get lost.



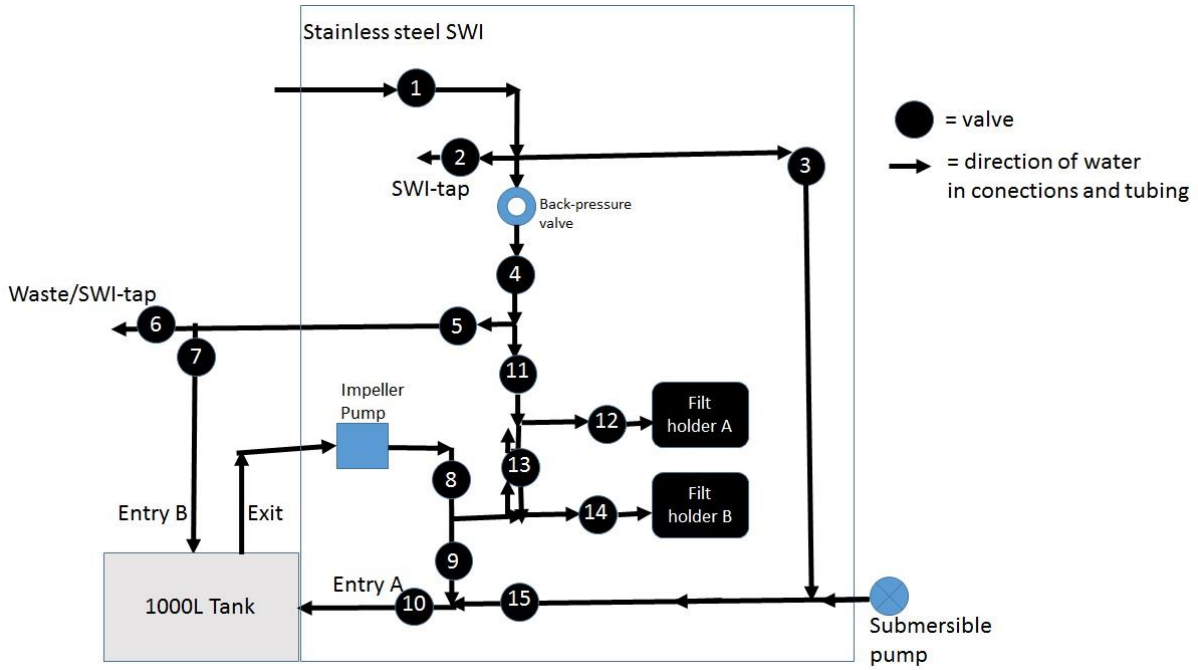
1000 l Tanks

Hoses: Hoses leading from the SWI to the 293mm filter holders were of re-inforced silicone (Sveflow, Sweden) in the sea water distribution network were of armored PVC (Ahlsell, Sweden) except for the last 2 meters of the hoses leading to the 1000L tanks, and the hose leading down into each 1000L tank. Those pieces of hose were of armored silicone (SweFlow). The reason for that is that armored silicone in contrast to armored pvc remains soft and smooth at most temperatures and could therefore easily be attached and detached from the nipples on the 1000L tanks.

Valves, T-pieces, hose barb fittings, seals: Valves, t-pieces, hose barb fittings and seals used to join the different parts in the water distribution network were all of stainless steel and silicone (Sveflow, Sweden).

Nipples: Plastic nipples on the lids of the tank were from Noax Lab, Sweden.

Pump for 1000 L tanks: A 380V impeller pump (25L/min), purchased from Telfa, Sweden.



Sea water and submersible pump distribution network. Objects inside square where inside main lab, objects outside square were out on deck.

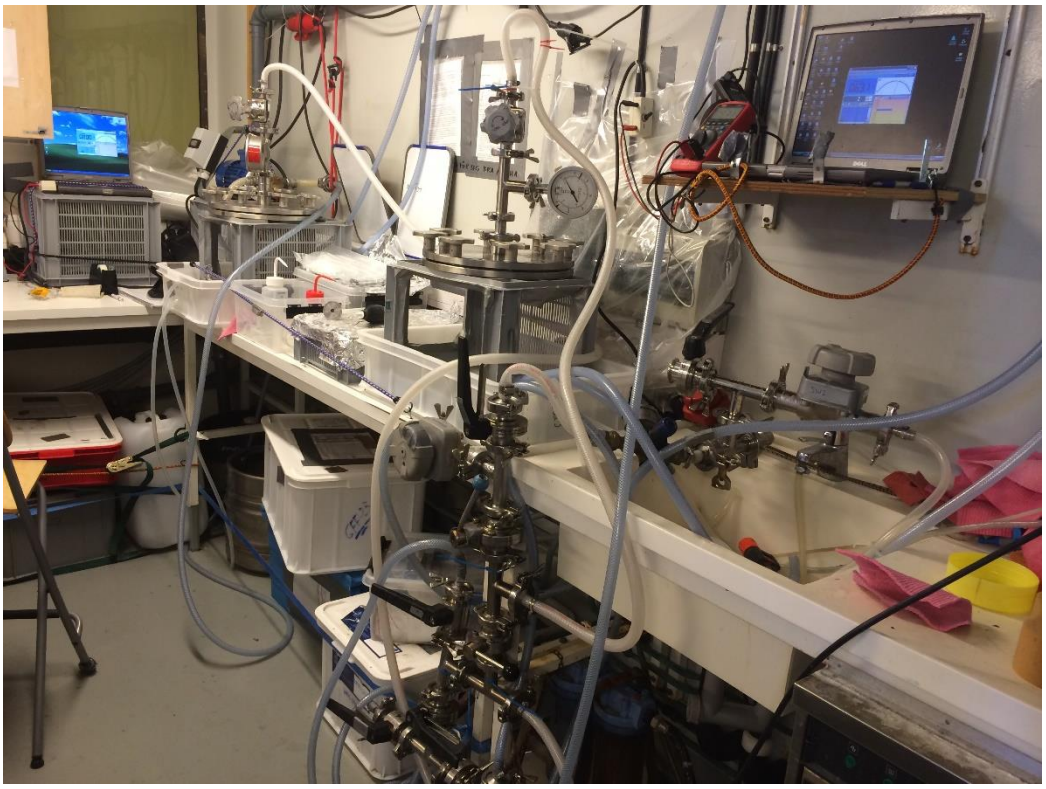
Some common system operations of sea water and submersible pump distribution network used during SWERUS-C3

1) Filling of 1000L tank with in-situ pump. To do this valves 15 and 10 had to be opened. All other valves closed.
2) Filtration directly from SWI. Valves 1, 4, 5, 6, 11, 13 and the valves to the filter holders, 12 and 14, had to be opened. All other valves closed.
3) Filling of 1000L tank from SWI. Valves 1, 4, 5 and 7 opened. All other valves closed.
4) Filtration from 1000L tank. Valves 8, 9, 10 and 13 opened and the valves to the filter holders, 12 and 14, opened. Impeller pump used.
5) Filtration directly from SWI on filter holder A and filtering from 1000L tank on filter holder B. Valves 1, 4, 5, 6, 8, 9, 10, 11 and the valves to the filter holders, 12 and 14, opened.
6) Flushing the tubing with SWI-water between stations to avoid freezing in tubing. To do this the fire hose connected to the submersible pump had to be disconnected and lead over board and valves 1 and 3 opened. All other valves closed.

Before filling a tank with water from submersible pump or SWI the tubing and tank was flushed out for a few minutes to clean away old water and particles. This was done by opening the valve at the lower part of the tank and pumping in water.

Filtration on 293mm stainless steel filter holders

During SWERUS-C3 two 293 mm glass fibre filter (GFF; Whatman Inc.) filtration systems were connected to the seawater distribution system and samples were filtered either directly from SWI or by pumping water from 1000L tanks previously filled from SWI or submersible pump. When the ship was in ice the seawater intake of the ship often got clogged with ice which caused sudden pressure changes that caused breakage of the filters. Therefore when in ice filtering was not done directly from SWI but 1000L tanks were filled first and filtering was done by pumping water from the tanks.



Hi-vol 293mm filtration system

The large-diameter GFF filtration system was constructed of stainless steel with silicon seals between all connections. The tubing used was re-inforced silicone tubing. Pre-combusted GFF filters kept in pre-combusted aluminium foil envelops were used.

The systems were connected to an electronic flow meter, in the flow path below the filter, and a pressure meter situated directly above the GFF filter holder (see figure). The electronic flow meters were connected to multimeters, which were connected to a computer to log the flow during the runs in order to calculate the total flow through the filter. The multimeters log the flow in Hz and these can be converted into L/min.

During the runs a flow was maintained with a maximum of about 130 Hz, equal to about 8.5 L/min. Filtering was stopped when the backpressure reached 1 bar to avoid cell lyzing. In case there 1000L tanks were emptied but the backpressure had not reached 1 bar the filtering was stopped anyway.

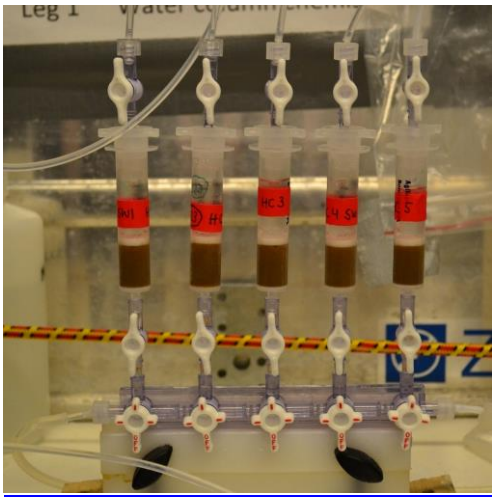
After the filters had clogged and the water flow was stopped as much water as possible was sucked off the filter using a hand pump. This to make sure the filters were stored with minimal amount of seawater, which reduces the freeze-drying time later as well as reduces the possibility of corrosion of the aluminium envelopes during storage. The filters were folded, put in a pre-combusted aluminium foil envelop and put in a zip-lock bag and stored cold (-20°). All samples were double-labelled with a label both on the aluminium foil bag and the zip-lock bag.

Technical description of sampling plankton from sea water intake

The same setup as used for Hi-vol POC filtrations was used. Water was always taken directly from the sea water intake. An acetone pre-washed 6µm cut-off 293mm in diameter Nytex filter was placed in a 293mm Millipore stainless steel filter holder. A pre-filter of Nytex with a 200µm cut-off was used to avoid *copepods*. After filtering (1000- 10,000 L) plankton was scraped off the Nytex filter and put in a petri-dish in the freezer.

Technical description of sampling/SPE for bulk DOM via stable isotope analysis δ ^{13}C, δ ^{15}N, δ ^{2}H and FT-ICR-MS

Directly after sampling from the Niskin bottles the samples were pre-filtered through pre-combusted GFF-Filters (poresize 0.7 µm) and the bulk DOM from 4 L pre-filtered sea water was collected via Solid Phase Extraction on Bond Elut columns (Agilent, resin type PPL, see photo) and stored at 4°C until the end of the cruise.



Solid Phase Extraction on Bond Elut columns

Methodological approach to sampling/^{14}C-DOC , δ ^{13}C -DOC, CuO reaction products, solvent extractable lipids

Samples will be taken back to Stockholm University for elution with Methanol and molecular and isotopic analysis. Subsamples will be acidified for reduction of DIC and sent off for carbon isotope analysis on AMS for 14C at NOSAMS (Woods Hole National Oceanographic Accelerated Mass Spectrometer facility) and to stable isotope laboratory (SIL), at Stockholm University for 13C on HR-irMS. Biomarker analysis will be carried out at the Department of Applied environmental Analysis. Intended biomarker analysis are CuO oxidation and solvent extraction for free lipids.

CuO oxidation is a microwave assisted extraction in alkaline solution with CuO to retrieve reaction products to trace (mainly) lignin phenols, cutin acids, fatty acids, dicarboxylic and benzoic acids. Compounds are extracted and derivatized for detection on GC-MS.

Free lipid solvent extraction is carried out through a variant of Bligh and Dyer extraction to retrieve straight chain hydrocarbons (*n*-alkanes, *n*-alkanoic acids, *n*-alkanols, sterols, stanols and similar fraction compounds). Extraction is followed by clean-up process, derivatization, separation and detection on GC-MS.

Methodological approach to sampling/ ^{14}C-POC, δ ^{13}C -POC, molecular analysis of black carbon and other biomarkers

Samples are intended for molecular analysis on POC. Samples will be taken back to Stockholm University for molecular and isotopic analysis. Black carbon will be analyzed according to the CTO-375 method in Stockholm. Subsamples of black carbon and isolated molecules will be sent off for carbon isotope analysis on AMS for 14C at NOSAMS (Woods Hole National Oceanographic Accelerated Mass Spectrometer facility) and to stable isotope laboratory (SIL), at Stockholm University for 13C on HR-irMS.

Methodological approach to sampling /SPE for bulk DOM via stable isotope analysis δ ^{13}C, δ ^{15}N, δ ^{2}H and FT-ICR-MS

Stable isotope analysis of δ ^{13}C, δ ^{15}N, δ ^{2}H in dissolved organic matter will be performed using Isotope Ratio Mass Spectrometry at Stockholm University and characterization of functional groups in dissolved organic matter using Fourier-Transform Ion Cyclotron Resonance Mass Spectrometry.

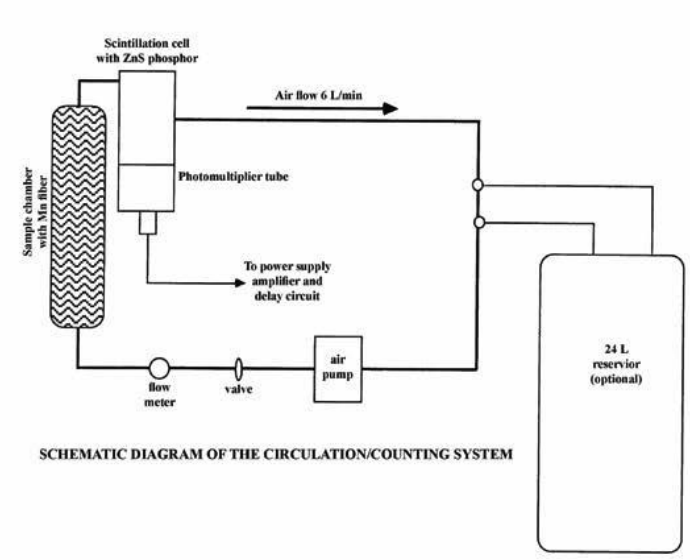
Tracers for groundwater

Technical description of sampling/ Ra

Seawater samples for the ^{223}Ra, ^{224}Ra, ^{228}Ra and ^{226}Ra activity determination were collected from Niskin bottles (for bottom and intervening horizons) on a rosette attached to a Seabird® CTD, from a continuously flushed seawater intake (SWI) system (8 meters horizon) and by pumping for bottom horizon on the shallow stations. Samples are collected in 60 liter tanks (60-120 liters for each horizon). In turbid waters samples are filtered (e.g., 0.7 µm GFF or 0.45 Millipore filters). The filtrate is then passed through a column of MnO2-coated acrylic fiber ("Mn-fiber") at <1 l/min to quantitatively remove radium. Each Mn-fiber sample containing adsorbed Ra is washed with fresh water and partially dried.

Methodological approach to sampling/data collection using sampling/ Ra

For determination of ^{223}Ra (half life = 11.4 days) and ^{224}Ra (half life = 3.66 days) the damp fiber is fluffed and placed in a tube connected to the closed loop circulation system described by Moore and Arnold (1996) and counted immediately via a Radium Delayed Coincidence Counter (RaDeCC). Helium is circulated over the Mn fiber to sweep the ^{219}Rn and ^{220}Rn generated by ^{223}Ra and ^{223}Ra decay through a 1 L Lucas cell where alpha particles from the decay of Rn and daughters are recorded by a photomultiplier tube (PMT) attached to the scintillation cell. Signals from the PMT are routed to a delayed coincidence system pioneered by Giffin et al. (1963) and adapted for Ra measurements by Moore and Arnold (1996). The delayed coincidence system utilizes the difference in decay constants of the short-lived Po daughters of ^{219}Rn and ^{220}Rn to identify alpha particles derived from ^{219}Rn or ^{220}Rn decay and hence to determine activities of ^{223}Ra and ^{224}Ra on the Mn fiber.



SCHEMATIC DIAGRAM OF THE CIRCULATION/COUNTING SYSTEM

RaDeCC system

After the ^{223}Ra and ^{224}Ra measurements are complete, the Mn fiber samples will be aged for 2-6 weeks to allow initial excess ^{223}Ra to equilibrate with ^{223}Th adsorbed to the Mn fiber. The samples will be measured again (one part in the end of crusie another part in the shore lab) to determine ^{228}Th and thus to correct for supported ^{224}Ra. After the short-lived measurements are complete, the Mn fibers will be used for long-lived ^{226}Ra (^{226}Ra–t1/2 = 1600 years) and ^{228}Ra (^{228}Ra–t1/2 = 5.75 years) isotope measurements in the shore lab.

WP C Methane and other trace gases in the water column

WP C tasks

The tasks of WP C were to:

- Collect samples for analysis of helium, tritium, methane, carbon dioxide and ethane in the water column
- Analyse samples for concentrations of methane, carbon dioxide and ethane using gas chromatography onboard I/B Oden
- Preparation of vertical profiles of water column methane samples for stable C and H isotope analysis
- Preparation of methane samples from seawater for carbon-14 analysis through sample pre-concentration using helium stripping and subsequent trapping of the methane on molecular sieve at liquid nitrogen temperature
- Analyze hydrocarbons (C1-C5), CO and H2 in the top sediments

Sampling strategy

A set of samples for concentrations and stable isotopes of methane (50 mL + 2x120 mL serumbottles) was taken for every CTD cast where the Niskin bottles were used. Hotspot areas were usually sampled in duplicate. Additionally, samples were taken for on-the-fly concentrations measurements at these points (using 60 mL plastic syringes). Samples for concentration and isotopes of N2O, and for helium and tritium isotopes, were taken at many stations according to the sample records.

Quick on-the-fly concentration measurements were performed for methane (also using 60 mL plastic syringes) on samples from selected depths at all stations where Niskin bottles were used during the CTD cast. These results were used to decide whether one or several GO-FLO casts for sampling for carbon-14 in methane should be performed.

Some stations with large methane seeps (“megaflares”) were investigated using “drag CTD”, i.e. closing Niskin bottles at constant depth at different times when drifting over the target area.

Sediment samples for concentration analysis were taken at most stations, whereas samples for carbon-14 of methane were taken at a few stations where concentrations in the bottom water indicated that the limit of quantification would be reached.

Sampling system: CTD rosette with Niskin bottles

Technical description of sampling system: CTD/Niskin bottles

The CTD rosette with 24 Niskin bottles, 7 L each, was the primary sampling infrastructure for all samples except those for carbon-14 of CH4. The bottles were closed at selected depths using an electrical triggering system. Subsampling was performed using silicon tubing. The sample containers for different sample types were:

- 500 mL PET bottles

Used for samples for tritium in seawater. These were Coca-Cola bottles, rinsed with tap water and dried.

- 3/8” copper tubing

Used for samples for helium isotope measurements. The tubes were temporarily sealed with a 5 cm length of silicon tubing over each end, into which the plunger from a 5 mL plastic syringe was inserted as a stopper. The permanent sealing was done using custom crimp clamps, which were screwed down tightly over the copper tube.

- Plastic syringes

60 mL luer-lock plastic syringes (centric hole), with rubber-gasket plungers, were used for sampling and extraction for on-the-fly concentration measurements of CH4, CO2, and C2H6. A three-way valve was fitted on the luer-lock fitting for efficient sampling and manipulation of headspace.

- 50 mL serum bottles

Clear bottles, used for samples for storage and subsequent concentration analysis of dissolved gases. Sealed with red butyl stoppers, approximately 1 cm thick, and aluminum crimp caps.

- 120 mL serum bottles

Amber bottles, used for stable-isotope samples. Same sealing as for the 50 mL serum bottles.

Methodological approach to sampling using CTD/Niskin bottles

Sampling for gases were performed directly after the CTD rosette had been brought in to the CTD container after a cast. The sampling procedures were, in the order of execution for each Niskin bottle (i.e. tritium was not subsampled from all Niskin bottles before e.g. the helium subsampling commenced):

- Tritium

The thin tubing from the Niskin bottle was positioned at the bottom of the PET flask, which was filled and then allowed to overflow before closing.

- Helium

A thin tube was inserted to the bottom end of the copper tube (prepared by filling with degassed water) to fill it from the bottom up. The tube was allowed to overflow before being temporarily closed using the syringe plunger. Permanent closing was performed within 30 min of the Niskin subsampling.

- CH4, CO2 and C2H6 for on-the-fly concentration analysis

The 60 mL plastic syringes were connected to the Niskin bottle using the silicon tubing. 5 mL of sample was aspirated and ejected three times to remove any bubbles from the syringe. 45-50 mL of sample was the aspirated for further analysis. Two samples were normally taken also for Quick Analysis, typically from Niskin bottles containing water from the bottom and from just below the pycnocline. These samples were taken immediately, without any hold-up time for subsampling of intermediate Niskin bottles.

- CH4, CO2 and C2H6 for storage in serum bottles

The serum bottles were rinsed with seawater and then filled from the bottom by insertion of the tubing, overflowing for 3 seconds. 0.5 mL of ZnCl2 preservative solution (2000 g ZnCl2/L) was added to the bottle at mid height using a plastic syringe with long hypodermic needle. Pressing down a rubber stopper sealed the bottle immediately, using a hypodermic needle through it to displace sample water. The bottle was then crimp capped for further storage in the +4 C cooler container.

Sampling system: Red winch/ISSS-08 winch for GO-FLO bottles

Technical description of sampling system: Red winch/ISSS-08 winch for GO-FLO bottles

The red winch on the starboard side next to the mainlab, with Kevlar line routed via the davit aft of the garbage van, was the primary sampling platform for retrieval of the samples for carbon-14 of CH4 using 60L GO-FLO bottles down to depths of 250 m. The aft-deck ISSS-08 with 8.15 mm conductor wire was used as the secondary sampling platform for this purpose, either because ice conditions would not allow the use of the red winch or because the sampling depth at the station exceeded 250 m. Both systems had metering wheels installed to gauge the length of line/wire that was fed out to reach a specific depth. The davit for the red winch was equipped with a small block (Rutgerson tripple sheaves; 400 kg rating, as used on small sailing boats), which had a tendency to wear out quickly. For future reference, replacement blocks are needed.

Two 60 L GO-FLO bottles were used from either the red winch or the ISSS-08 winch. The bottles were triggered using the GO-DEVIL messenger weight, with a falling speed of approximately 5 m/s through water. Subsampling was performed using silicon tubing with stainless steel Swagelok quick connectors for attachment to kegs and also to thinner tubing for sampling to serum bottles and syringes.

The sample containers used for GO-FLO subsampling were:

- Plastic syringes

60 mL luer-lock plastic syringes (centric hole), with rubber-gasket plungers, were used for sampling and extraction for on-the-fly concentration measurements of CH4, CO2, and C2H6. A three-way valve was fitted on the luer-lock fitting for efficient sampling and manipulation of headspace.

- 50 mL serum bottles

Clear bottles, used for samples for storage and subsequent concentration analysis of dissolved gases. Sealed with red butyl stoppers, approximately 1 cm thick, and aluminum crimp caps.

- 120 mL serum bottles

Amber bottles, used for stable-isotope samples. Same sealing as for the 50 mL serum bottles.

- 30 L kegs

Beverage kegs of stainless steel or aluminum, with threaded mouths, used for carbon-14 samples of methane in seawater. Kegs had been cleaned using RBS solution before the expedition.

Methodological approach to sampling using Red winch/ISSS-08 winch for GO-FLO bottles

Subsamples were taken for on-the-fly concentration analysis and storage for analysis of concentrations and stable isotopes of CH4, CO2, and C2H6 in the same way as for Niskin subsampling. Briefly, one 60 mL plastic syringe was filled for Quick Analysis, and 1x50 mL + 2x120 mL serumbottles were filled and preserved with ZnCl2 for storage and subsequent analysis.

- CH4 for carbon-14 analysis

30 L kegs were prepared in advance by screwing on a headpiece, evacuation and leak checking for 1 h, filling with helium to ambient pressure (this state allows for storage until needed for sampling), and evacuation to 300 mbar (done maximum one day in advance). The keg was connected to the GO-FLO bottle using the silicon tubing with quick connects, and filled until the internal under pressure was 0 bar (i.e. equal to ambient pressure). This procedure was used for the keg samples that were processed onboard Oden using the stripping boards.

20 kegs were prepared/used to take additional samples for processing with stripping boards back in the laboratories of ITM. These kegs were primed with 150 mL of ZnCl2 preservative and closed with a headpiece, awaiting further sampling. At the sampling event, the keg was filled almost to the rim with seawater and then re-sealed using the headpiece.

Sampling system: the Oden seawater intake (SWI)

Technical description of sampling system: the Oden seawater intake (SWI)

The all-stainless-steel section of the SWI to the mainlab was used for sampling inbetween and at stations, for all types of CH4 sampling (see explanatory text for Niskin and GO-FLO sampling for details). The SWI draws water from the bottom of Odens hull at approximately 8 m depth. The outlet at the sink in the starboard side of the mainlab was used.

Methodological approach to sampling using the Oden seawater intake (SWI)

A T-piece for soft tubing was used to divert some of the water flow to the sink, and thus to regulate the flow and pressure to the keg. This was useful to avoid bubbles in the sampling stream, and also to avoid too high pressure spikes. Other than this, the sampling methods were the same for the SWI as for Niskin and GO-FLO subsampling. Please refer to those sections for details.

Sampling system: the multicorer (MUC)

Technical description of sampling system: the multicorer (MUC)

Sediment samples were obtained for analysis of gas concentrations (H2, CO, C1-C5 hydrocarbons) and for carbon-14 analysis of methane. Please refer to the WP E report for details about the multicorer deployment.

- Sediment-gas concentration analysis

5 mL plastic syringes were cut at the front end to take 5 ml sediment samples horizontally from a pre-drilled multicorer PVC liner. Clean 20 mL serum bottles were used for sediment sample analysis of dissolved gases (CH4, CO2, H2, CO, C1-C5 hydrocarbons) in sediment pore water. The bottles were sealed with grey butyl stoppers and aluminum crimp caps. An ultrasonic bath (SAPPHIRE USB-12, САПФИР УЗВ-12) was used for ultrasonic extraction of dissolved gases (CH4, CO2, H2, CO, C1-C5 hydrocarbons) in sediment pore water.

- Sediment sampling for carbon-14 in CH4

Sampling for carbon-14 analysis of methane in sediments was performed by horizontal sub-coring of the MUC cores using 60 mL plastic syringes (with the ends cut off) and pre-drilled core liners. The samples were transferred to 1 L glass jars with stainless steel tubing going through the plastic lids, ending 1 cm below the lids. The stainless steel tubing was equipped with Swagelok quick connects of the same type as used for the headpieces on the kegs for seawater sampling.

Methodological approach to sampling using the multicorer (MUC)

- Sediment-gas concentration analysis

The 5 mL plastic syringes with fronts cut off were used to take 5 mL samples at each 4 cm depth. Out of the 5 mL samples, 3 mL were ejected into the 20 ml serum bottles with air headspace. After that the serum bottles were sealed.

- Sediment sampling for carbon-14 in CH4

For methane samples for carbon-14 analysis, three 60-mL portions were taken from each core and transferred to the sediment-sampling jar, which was half-filled with saturated NaCl solution. The headspace was quickly displaced with helium gas after the sample transfer. Two jars were filled for each cast up until station 40. After station 40, entire top sections of the MUC cores were taken and transferred to sediment sampling jars (up to four jars were used for each MUC cast). This was to gather more sediment to meet detection limits for carbon-14 analysis. The samples were shaken vigorously before being processed using stripping boards in the same manner as for seawater samples in kegs. An empty sediment jar was used as a "dirt-trap" between the filled jars and the stripping board.

Sample preparation system: stripping of CH4 from seawater

Technical description of CH4 pre-concentration system: stripping boards

Four stripping boards were used to harvest CH4 from seawater samples in 30 L kegs. Briefly, the stripping boards were built from Swagelok fittings and ¼" tubing which were held in position by a plexiglass backbone. The units were screwed down to the bench in the mainlab. The stripping of seawater to pre-concentrate dissolved methane on the molecular sieve of the U-traps was at all times performed using liquid nitrogen as cryogen, and usually directly after the sampling. Two to four kegs were connected in series to collect enough methane for the carbon-14 analysis. The following cut-off values were used to determine the number of kegs:

Water CH4 conc. (nM)	No. required 60L GO-FLOs	No. required kegs, 20 filled in each
25	2	4
50	1	2
100	0.5	1

A metal bellows pump was used to circulate the helium carrier gas for two hours at a flow of approximately 2 L/min through the seawater and subsequent traps for moisture, CO2, and CH4. Please see Kessler et al. (2005) for more information.

Four samples of CO2 were also obtained, using U-traps filled with glass beads instead of molecular sieve.

Methodological approach to the operation of the stripping boards

The operation of the stripping boards followed the laboratory checklist, which is presented here:

	CH4 STRIPPING ROUTINES
	preparing beerkegs
1	remove old water (if any left)
2	connect headpiece to beerkeg (screw in with help of wrench)
3	connect evacuation/filling adapter to beerkeg (blue), Helium line (yellow) and vacuum line (white)
4	connect pressure sensor to tube on red outlet valve on beerkeg
5	open beerkeg valves
6	turn 3way valve with handle to vacuum, start vacuum pump
7	keg should be evacuated (bottom of p-scale) in about 10min
8	close valves and wait for 10min to assure there is no leak (do next keg in the meantime)
9	turn 3way valve with handle to Helium, open He line and fill keg to ambient pressure
10	evacuate keg again
11	fill again with Helium, but only to 300mbar! (-0.7, black line on sensor)
12	close valves on beerkeg, remove adapter and pressure sensor
	CH4 stripping
1	connect beerkegs to each other, outleg of keg1 to inlet of keg 2
2	connect beerkegs to stripping board: inlet of keg1 (green) to "to sample" (darkblue) and outlet of keg 2 (red) to "from sample" (red)
4	connect Helium (yellow-green QC) and vacuum line (white QC) to stripping board
5	connect clean trap to flexible ss tubing using ss nuts and teflon ferrules (note in- and outlet of trap), and attach trap in dewar lid
6	open trap needle valves and toggle valves to trap and trap bypass
7	check that both sample bypass valve and valves to and from sample are open (valves on kegs closed!)
8	open circulation pump bypass !
9	evacuate system: open needle valve to vacuum, wait until pressure is at bottom of sensor and flow at zero
10	leak check: close vacuum needle valve and wait for a few minutes to see if pressure is stable
11	fill system with He (by opening needle valve at He in) to ambient pressure (=0)
12	repeat evacuation and filling twice, end with system at ambient pressure
13	flow check: first open bypasses for trap and samples, close valves to/from trap and sample, start circulation pump and check that flow is between 2.5 and 3 l/min. stop pump, open valves to/from trap, close bypass and start pump again - the flow should only be a little lower. stop pump.
14	fill dewar with liquid nitrogen and place trap in dewar
14	open valves to/from and close sample bypass
15	open in/outlet valves on both beerkegs
16	check if pressure is still at ambient, refill He if needed
17	start circulation pump (if necesssary, stop after short while and adjust pressure again)
18	monitor if flow stays 2-3 liters, if it goes down, check if trap outlet is frozen (warm)
19	continue stripping for 2 hours or more (flow can drop down 1l/min towards the end)
20	switch off circulation pump

21	close to/from trap/sample valves and open trap/sample bypass
22	close trap needle valves, disconnect tubing to/from trap and close trap with attached plugs
23	remove trap from LN2 and place on holder
24	disconnect beerkegs from stripping board and empty/clean them

Analytical system: headspace extraction and analysis of gases in water

Headspace extraction of gases in water

Two different methods were used for the headspace equilibration of gases in water; the Quick_Analysis (for guiding of subsequent sampling at the stations), and the Accurate_Analysis (higher quality data, used to obtain full depth profiles of gases after the sampling events at the stations).

Our so named "Accurate_Analysis" was perfomed at each station for the full set of samples to obtain concentration depth profiles. Headspace extraction of gases for concentration analysis was performed directly in the 60 mL plastic syringes. The volume was adjusted to 40 mL and 15 mL of helium was aspirated. The syringes were shaken in a horizontal position for 30 min, and left still for an additional 30 min (shaker was installed on the floor next to the GC to prevent vibrations; a thermometer was mounted on the shaker fundament to monitor the temperature of the headspace equilibration). Prior to the injection of 10 mL headspace to the GC directly from the syringe, the 3-way valve on the syringe was dried by compressing the headspace slightly and very quickly open and close the valve to eject any water from the interior of the valve. After this, the valve aperture was carefully dried using a cotton applicator ("cue tip"; wooden stick with a head of spun cotton).

A further step of water separation was added for the analyses performed on the SRI-GC (see the following text section). A 5-10 mL plastic syringe with a 2-way valve was connected to the 60 mL syringe. 3 portions of 1 mL headspace were used to rinse the smaller syringe, and then the remaining headspace was aspirated into the smaller syringe for injection to the GC. It is recommended to use this method also for the Agilent GC-FID.

This method of headspace extraction in syringes gives very reproducible results (RSD <4%) and a cross-check between the methods of Marc Geibel (laser spectroscopy), Denis Kosmach (SRI-GC), Joanna Sawicka (second SRI-GC) and our method gave the same results for samples taken from the SWI (5 nM at that point of the transit to transect A-B). Labtests prior to the expedition show that the results do not differ from headspace extraction in serum bottles. Tests onboard Oden also showed that syringe headspace extraction of samples from serum bottles gives results that are consistent with direct to syringe and subsequent headspace extraction.

Our second extraction method was named "Quick_Analysis" and was used to generate results with a lead time of <15 min total. The method is the same as for "Accurate_Analysis" with the exception of the shaking time (2 min instead of 30 min) and the subsequent resting time (3 min instead of 30 min). The Quick_Analysis typically gives results within 10% of that of the Accurate_Analysis.

Concentration analysis of gases in water using gas chromatography

Two instruments were used for gas chromatography and flame ionization detection (GC-FID) during the onboard concentration measurements of gases in the water column. The first instrument was an Agilent GC-FID with capillary column. This was the main instrument, belonging to the group of Örjan Gustafsson. However, the Agilent GC-FID broke down and analysis had to be migrated to the SRI GC-

FID brought by the group of Volker Brüchert. Methods for both instruments are outlined in the following text.

- The Agilent GC-FID instrument

A 7890N series gas chromatograph with flame ionization detection was used for the quantification of CH4, CO2 and C2H6 up to station 37, where the instrument broke down and an analytical gap exists for stations 37-39. The analytical activity was at this point transferred to the SRI-GC of Volker Brücherts group. Analysis using the Agilent GC-FID was again attempted at couple of stations (48-49), using injection by Hamilton syringe (2 mL injected volume) directly to the split/splitless injector. However, results were not satisfactory and analysis on the SRI-GC was resumed.

For the Agilent GC-FID, 2 mL of sample was injected to the instrument using a sample loop held at 150 C (total injected volume was 10 mL). The split ratio in the split/splitless injector was R=2 (temperature 150 C). Separation was performed on a 50 m PoraBOND column (0.53 mm i.d., PLOT type) using helium as carrier gas at 8 mL/min. The temperature program was [60 C isothermal, duration 5.5 min] for Quick_Analysis (peformed directly after a CTD cast to guide further activities with GO-FLO sampling for carbon-14 methane samples). The full water column concentration profile was obtained using Accurate_Analysis with a temperature program according to [35 C for 3.9 min, ramp 60 C/min to 70 C and hold 1.5 min, ramp 40 C/min to 35 C and hold 0.5 min]. The methanator catalyst was in all cases heated to 375 C, and the detector to 300 C (45 mL/min hydrogen from the hydrogen generator, 400 mL/min technical air, 25 mL/min helium makeup). The detection limit for methane was <1 nM in seawater. Ethane had a lower detection limit due to its twice as large response, compared to methane, but was never observed in the water column.

The cause for the instrument breakdown is not known, but the source of the problem is upstream of the split/splitless injector and could have been caused either by exposure to moisture, seawater or vibrations (instrument has been on Oden since April 1, 2014; transit Helsingborg-Tromsö was rough at times). We speculate that the rotor in the six-port valve needs replacement.

- The SRI GC-FID instrument

From station 40 and onwards, the analyses were carried out on the SRI gas chromatograph of Volker Brücherts group. Samples were injected using a 750 uL sample loop held at 60 C. Separation was performed on a HaysepD packed column (1/8” diameter, 1+2 m precolumn and analytical column) using nitrogen as the carrier gas. The instrument was equipped with flame ionization detection, fueled by a hydrogen generator and laboratory air. Only CH4 and CO2 were analyzed on this instrument.

Analytical system: headspace extraction and analysis for gases in sediment

Headspace extraction of gases in water

Headspace extraction of gases for concentration analysis was performed directly in the 20 (22.5) mL glass serum bottles. The volume was adjusted to 5 mL for sediment sample and 18.5 mL for air. The bottles with samples were degassed (headspace extracted) in the ultrasonic bath for 1 min, and were left for additional 30 min for headspace equilibration (temperature was 22 C). 5 ml of headspace was taken by 5 ml syringe from the serum bottle and then injected directly to the GC.

Concentration analysis of gases in water using gas chromatography

A SRI – 8610C series gas chromatograph equipped with flame ionization detector (FID) and methanator was used for the analysis of CH4, CO, CO2 and C2-C5 hydrocarbons. The instrument also

had a helium ionization detector (HID; for H2, O2, N2, CH4) and a thermal conductivity detector (TCD; for O2, N2, CH4). This instrument (brought by the POI group) is not the same SRI-GC as the one used for the analysis of concentrations in seawater.

For the SRI GC, 1+1 mL of sample was injected to the instrument using a 2 sample-loop system held at 130 C (total injected volume was 5 mL). Separation prior to FID was performed on a HaysepD packed column (1/8" diameter, 2 m) using helium as the carrier gas at 25 mL/min. Separation to TCD - HID was performed on a Mol Sieve 13x packed column (1/8" diameter, 2 m) using helium as the carrier gas at 25 mL/min. The sediment concentration profile was obtained with a temperature program according to [40 C for 5 min, ramp 7 C/min to 210 C and hold 7.7 min]. The FID was in all cases heated to 300 C, HID to 300 C and the TCD to 150 C (25 mL/min hydrogen from the hydrogen generator, 250 mL/min air, 25/40+10/25 mL/min helium). The detection limit for methane was 1 ppm.

- Calibration of GC instruments

The instruments were always calibrated before each station using a three-point linear calibration line consisting of blank (non-detects for methane; forced regression through zero was used), Standard 1 (n=3; low span), and Standard 2 (n=1; high span). Standard 3 was used only for the sediment-gas analysis. Additional standards, blanks and lab air were injected as needed to verify the instrument performance.

Component	Standard 1 concentration	Standard 2 concentration	Standard 3 concentration
CH4	15.08 ppm	147.2 ppm	-
CO2	205.5 ppm	2032 ppm	-
C2H6	15.06 ppm	153.4 ppm	-
N2O	300 ppb	-	-
H2	100 ppm	-	-
CO	14.35 ppm	-	-
C3H8	-	-	154 ppm
nC4H10	-	-	153.7 ppm
iC4H10	-	-	157.3 ppm
nC5H12	-	-	148.7 ppm
iC5H12	-	-	149.6 ppm

IMPORTANT NOTE: The Standard 1 contains CO, which was not sufficiently resolved from CH4 on the packed column. Thus, the calibration curve may be influenced by the sum of CO and CH4 concentrations in the standard. This effect is greatly reduced by the dominance of Standard 2 on the regression line used for the calibration, and a linearity check (or r2 values) reveals the actual effect on the obtained measurement results. Indeed, no such effect was noticed; for a sample with a concentration of 15 ppm, the difference with Standard 1 calibration included or excluded, respectively, is 0.01 ppm. This corresponds to a difference of 0.1 nM for a seawater sample, and therefore has no practical significance.

Data and sample storage

Labeling and storage of samples

The corrected sample records, containing lists of collected samples and the GC measurement results, are gathered in the folder “Final sample records”. Observe that the samples for helium and tritium (by Anatoly Saluyk) are listed in the decksheets produced by WP B. The physical samples are packed in plastic boxes, with IDs on the format WPC_XXX (where XXX are numericals). The labeling of the samples followed the following system:

- CH4, CO2 and C2H6 for storage in serum bottles

Each serum bottles was labeled using a machine-printed sticker, on the format “SWERUS14-CH4_STNXX_Y_ZZ”, where XX is the station number, Y is the cast number in roman numericals, and ZZ is the sampling device (Ni=Niskin; GO=GO-FLO; SWI=seawater intake). The storage box ID can be found in the sample record file (on the form WPC_XXX).

- CH4 for carbon-14 analysis in molsieve U-traps

The U-traps containing the pre-concentrated methane samples for carbon-14 analysis are labeled with key-ring shields holding a three digit ID number. The ID number and corresponding sample is listed in a special file, prepared by Julia Steinbach. The U-traps are stored in flat plastic boxes in the cooler container.

- 30 L kegs

Twenty kegs were prepared for storage of samples taken on Leg 2. These kegs are identifyed by blue tape on the handle with the text ZnCl2. They are also numbered, and a log must be kept for these to identify the sample contents.

Samples for tritium and helium isotopes are kept by Anatoly Salyuk, POI.

Data storage

- Which computers/servers were used?

The GC data and sample records were stored on the instrument laptops, on the Remus server (ref. Marc Geibel), on the new Dell laptop used for the label printer etc, and on the Polar server as backup. The corrected sample records, containing lists of collected samples and the GC measurement results, are gathered in the folder “Final sample records”. Observe that the samples for helium and tritium (by Anatoly Saluyk) are listed in the decksheets produced by WP B. Data for sediment-gas concentrations is managed by Denis Kosmach, POI.

- Data structure
    - GC data files

All measurement data, i.e. GC peak areas, were entered in an Excel file to perform calculations for calibration and headspace vs. water gas concentrations. Calculations were performed using Henrys law and give in every practical sense the same results as the Bunsen-Ostwald approach. There is one such file for each transect, with one tab for each station.

    - Station sample and data records

All the samples taken, and the corresponding gas concentrations, were entered in a separate Excel document called “Sample record”. There is one such file for every station.

    - Final data files

Files have been prepared by Julia Steinbach, and also by Christoph Humborg separately, with sample types taken at each CTD station and corresponding CTD and concentration data.

Tips for future expeditions

- Fast switching between GO-FLO bottles on the red winch was facilitated by assigning each GO-FLO bottle a separate weight, which was attached by a wire clamped to the two lower GO-FLO mounting brackets. The Kevlar line was attached to the wire eyelet using a shackle, and was led through the top GO-FLO mounting bracket. Thus, no weights or wires had to be shifted inbetween the casts, and the Kevlar wire could be shifted between bottles using only light hand force. Shifting of bottles on the ISSS-08 winch was helped by the custom made tools for the GO-FLO wing nuts.
- Subsampling from the CTD rosette was made feasible through the use of "kit boxes" with holders for 10 mL vials (N_2O concentration), 50 & 120 mL serum bottles, 100 mL plastic bottles (N_2O isotopes), compartments for rubber stoppers already prepared with needles for water displacement, and room for 60 mL syringes. Syringes, and box compartments, were labelled with the Niskin bottle numbers and identifiers to make the subsampling efficient and accurate (preventing mix-up of bottles).
- Helium was a very important gas for headspace extraction and GC blanks. We devised the so called "bladder system" to be able to draw helium at ambient pressure. A Tedlar gas sampling bag (0.5 L) was connected to the helium gas line via a toggle valve. A T-piece and a toggle valve was connected to the intermediate line. The Tedlar bag could then be filled with helium which could be be aspirated to a syringe at ambient pressure.
- A pulley (3:1 gearing) was arranged to hoist kegs from the main deck to the mainlab deck. This was a vast improvement compared to using the HIAB crane, which requires a crew member from Oden
- Headpieces for the beer kegs held up well, but the next generation can be improved by letting the stainless steel tubes go parallel to the axis of the keg. This would reduce the risk of leakage caused by torque on, and subsequent rotation of the stainless steel tube fittings.
- GC onboard Oden: It is important to secure the capillary column in the GC oven, so that it does not swing together with the mounting frame. This was done successfully during SWERUS-14 and the column held up well to the vibrations during ice breaking. It is also important to secure the press-tight column fittings with polyimide resin. One column started leaking at the transit to the first stations, but it was old and had experienced several transports on trucks and ships.
- Cryogens for stripping of CH_4 from seawater – lessons learned:
    - The LN_2 problem; do not trust the AGA pressurized tanks unless they respond well to our criticism and prepare better in terms of carefully checking the tanks for delivery. SWERUS-14 suffered from excessive evaporative losses from two out of three AGA pallet tanks (see special report to AGA)
    - Consider non-pressurized large vessels; consider electrical cryocoolers
    - Ethanol was not a good cooling medium for the electrical cooler at -130 C in a marine environment. Air moisture dissolves in the ethanol and freezes out on the cold head. Pentane works very well.

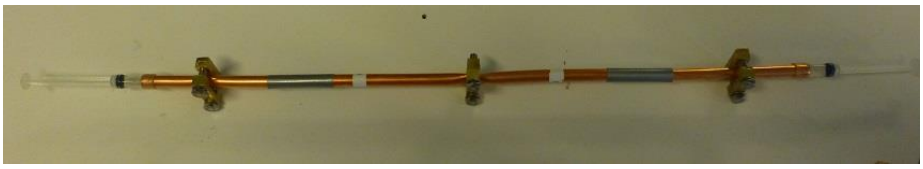
Illustrative photographs and figures

A 60 L GO-FLO bottle used to obtain large sample volumes for carbon-14 analysis of seawater methane. Two such bottles were used in parallel during the expedition.

The GO-FLO bottle hanging in the black Kevlar line from the red winch, and a red rope used to manually fix the bottle in a hanging position while swinging the davit out or in over the railing.

A GO-FLO bottle with mounted wire for quick switch between GO-FLO bottles on the Red Winch Kevlar line. A weight of 15-20 kg was attached to the wire during operation. Also note the tool used to quickly open/fasten the weldment wing nuts (a pipe with a matching slot in it).

The CTD rosette with 24 Niskin bottles, here ready to be deployed from the forward A-frame.

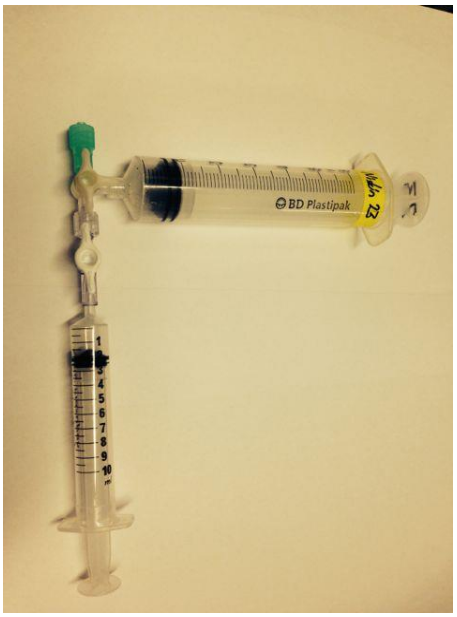


A copper tupe of the type used for sampling for helium isotopes in seawater.

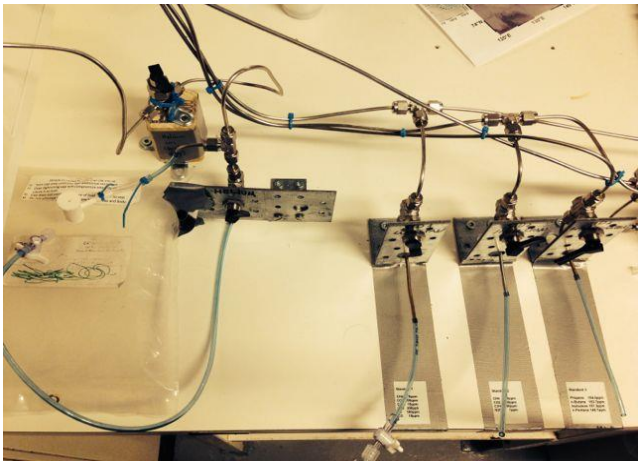
Examples of the 60 mL plastic syringe, 120 mL serum bottle, stoppers, crimp caps and crimp tool used during sampling from all sampling platforms.

Two “kit boxes” like this were used to prepare and organize sampling vials, stoppers with needles through them, sub-sampling tube, our own decksheet, and 60 mL plastic syringes. This was a great help, considering that five to six sample types were taken from every Niskin bottle.

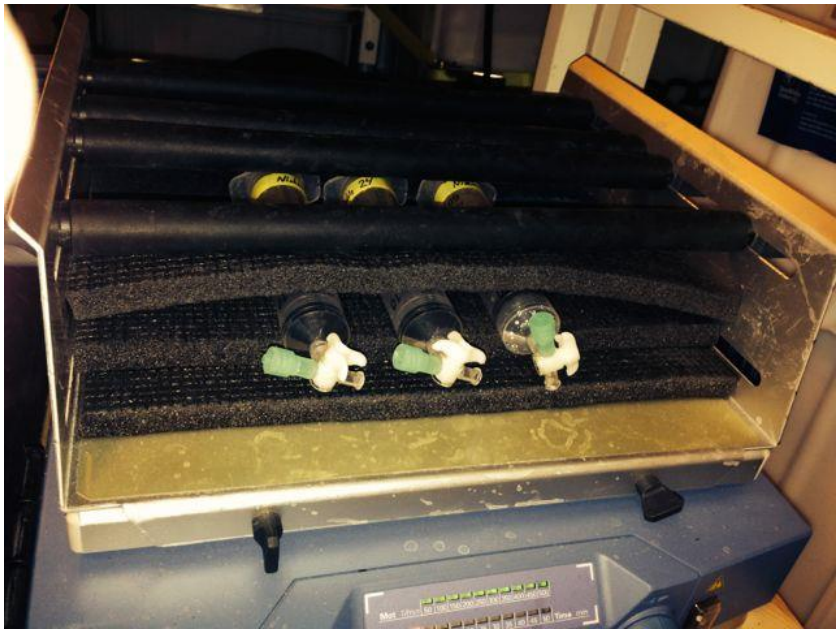
Subsampling from a Niskin bottle to 60 mL syringe using a silicon tube and a 3-way valve.



The two types of syringes used for the headspace extraction and the injection to GC. Not how the two valves are attached with Luer-Lock fittings to each other for flushing with, and transfer of, headspace.



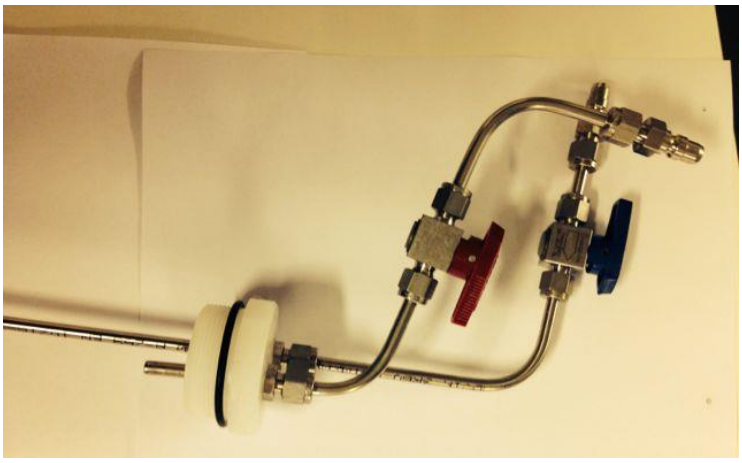
The helium bladder system and valves for standard gases were screwed down on the table next to the starboard entry to the mainlab.



The shaker table that was positioned on the floor. The syringes are fixed between two stationary pieces of sleeping pad on the bottom of the shaker table, and one loose piece on top of the syringes.

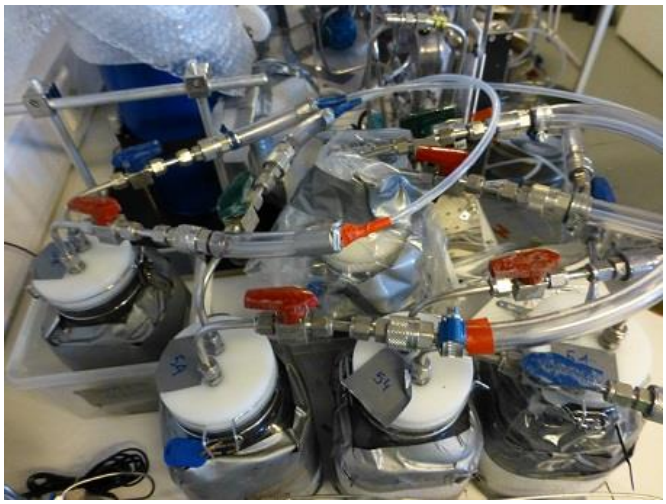
Kegs prepared for subsampling of GO-FLO bottles. They have been leak checked and filled with helium, then evacuated to 300 mbar total pressure. This is indicated by the blue tape on the kegs top. Valves have been fixed using black isolation PVC tape, and headpieces are protected from fog and seaspray with grey plastic garbage bags.

Kegs ready for sampling of seawater for storage and stripping back at ITM. Some kegs have stubs instead of the normal tubing of the headpieces. Others have white plastic screwtop lids. They are all marked with blue tape at the handle, with the text “ZnCl2”.

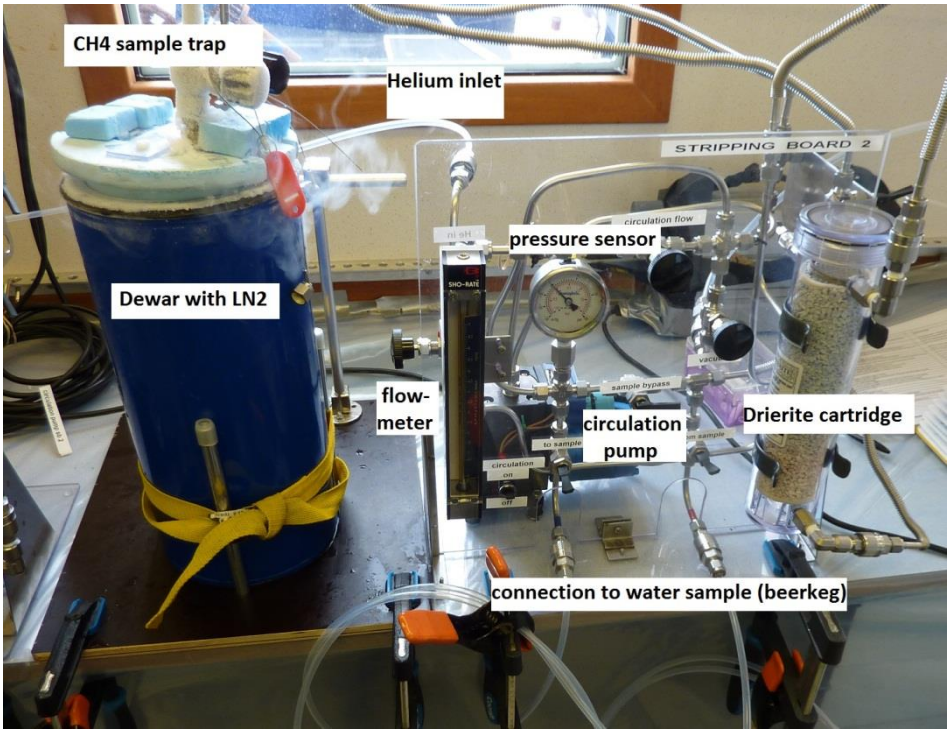


A headpiece, as used for kegs when sampling for stripping onboard Oden. The short tube,S-shaped with red handle, is for manipulation and pressure monitoring of the headspace. The long tube goes down to the bottom of the keg.

The “red lift” block and tackle used to hoist kegs from the main deck to the mainlab.



Four sediment jars connected in series with an empty jar (serving as “dirt trap”) for stripping of CH4 in sediment.



One of the four stripping boards used during the expedition, here installed during the test cruise on Fyrbyggaren.

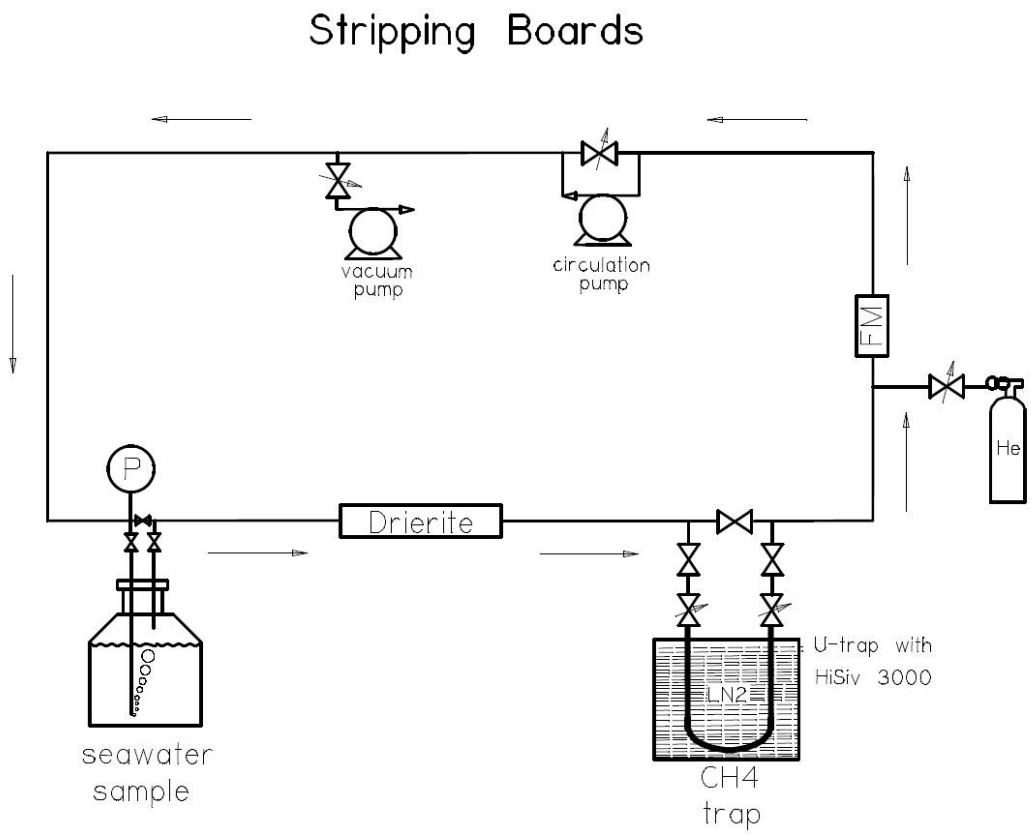


Diagram over the stripping board principles. See the main text for details.

U-traps of the type used to capture CH4 from seawater during the stripping process. The traps are made from stainless steel and are closed using needle valves and Swagelok threaded caps. Furthermore, they are packed with pellets of molecular sieve (5 Å) of the brand HiSieve 3000.

The setup of four stripping boards, with kegs for stripping standing below on the floor. Note the plastic tubing hanging on the table sides; one for helium, one for stripping board evacuation, and one (on the left side) for evacuation of kegs. Kegs always cause some moisture in the pump system, whereas stripping boards should be kept as dry as possible. Hence the two different evacuation systems.

The type of pressurized LN2 tank delivered by AGA, that did not meet the specifications for loss by evaporation.

The metering wheel for the red winch, sitting on the wire handle (used to feed the line properly onto the drum).

WP D CH_4 and other trace gases in the atmosphere

Brief description of the WP scientific and technical scope

The overall objective of the work package D was to characterize ambient trace gases in the near surface atmospheric boundary layer along the cruise track during the SWERUS Leg 1 expedition. This includes a mix of discrete sampling followed by later post-analysis of samples at the home institution for all the isotopologues of N_2O, CO_2 and CH_4 and high precision continuous sampling and analysis of CO_2, CH_4 and the stable isotopologues of CH_4. Fluxes of CH_4 and CO_2 will be determined by high frequency *in situ* measurements of mixing ratios and isotopes at four heights in order to resolve near-surface gradients using laser spectroscopy will be made at the same time as direct air/water fluxes will be made using eddy correlation methods in collaboration with WP I ASCE/Boundary Layer Meteorology.

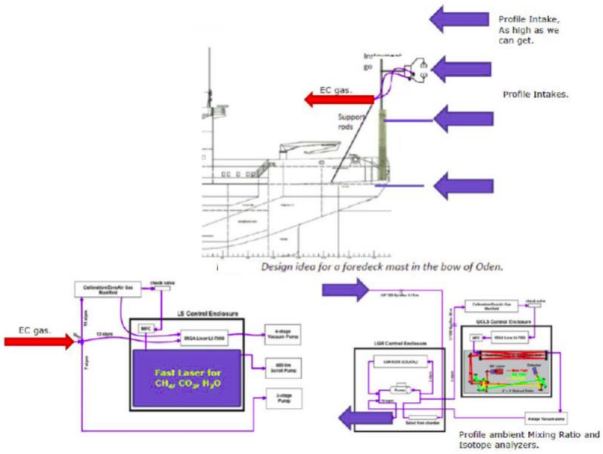
The work package is coordinated by Prof Patrick Crill, Stockholm University (SU) and includes Dr. Celia Sapart, Utrecht University (UU), Dr Brett Thornton, Stockholm University (SU) and Prof Igor Semiletov, Pacific Oceanological Institute, Far Eastern Branch of the Russian Academy of Sciences (POI).

The work plan within the WP is focused on a number of specific tasks

1.1 Continuous automated measurements of ambient mixing ratios of CO_2 and CH_4 at four heights, one minute averaging times using fast CRDS laser (Los Gatos Research Inc., model FGGA 24r-EP) (SU).

1.2 Continuous automated measurements of $\delta^{13}C$-CH_4 and δD-CH_4 of ambient air at four heights one minute averaging times using QCL laser (Aerodyne Corporation, Billerica, MA Custom Built) (SU).

1.3 Continuous eddy correlation measurements of CO_2 and CH_4 flux using fast CRD laser (Los Gatos Research Inc., model FGGA 24r-EP) (SU).



1.4 Greenhouse gases. Discrete air samples to be taken for subsequent analysis of concentrations and stable carbon and deuterium isotopic signatures of CO_2 and CH_4 (UU, SU)

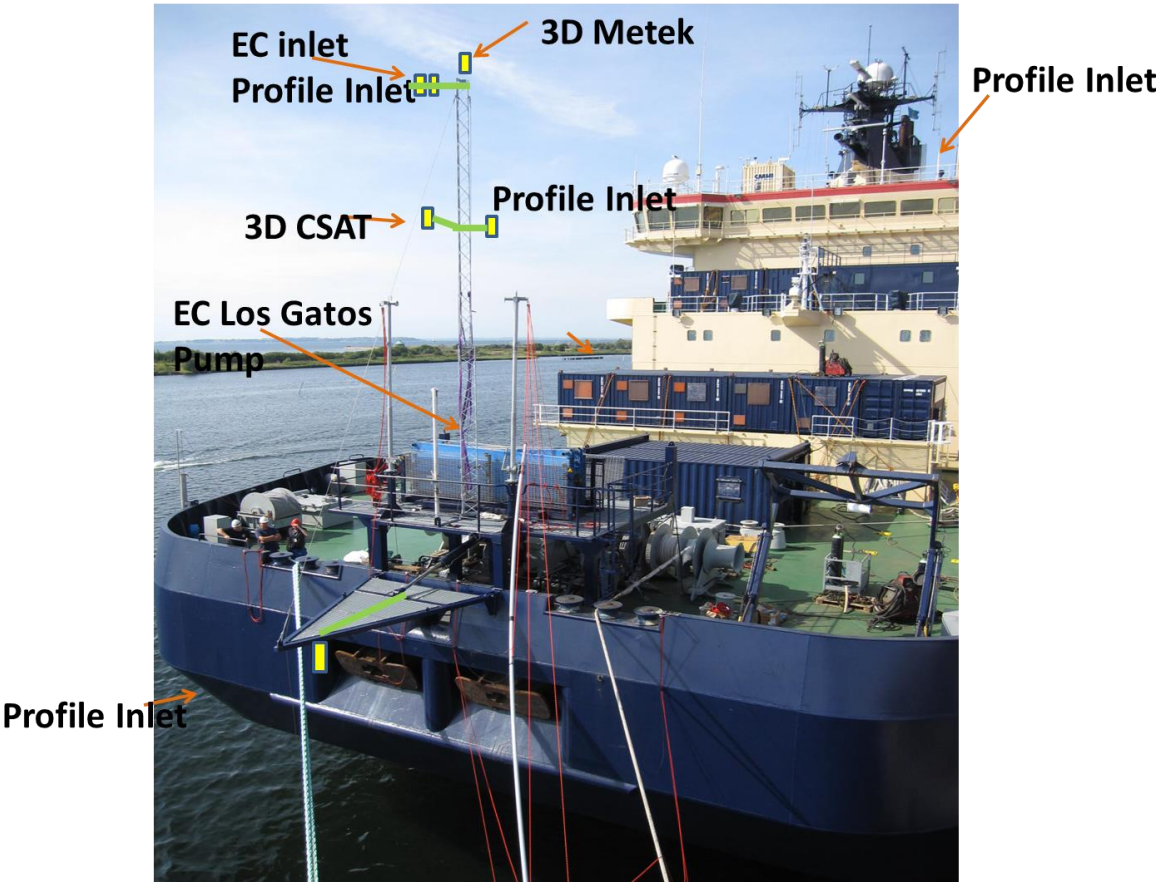
1.5 Atmospheric composition. Discrete air samples to be taken for subsequent analysis of concentrations and stable isotopologue signatures of H_2, CO, CH_4, CO_2 and N_2O (including isomers of N_2O) (UU).

1.6 Radiocarbon analysis of ambient CO_2 and CH_4.

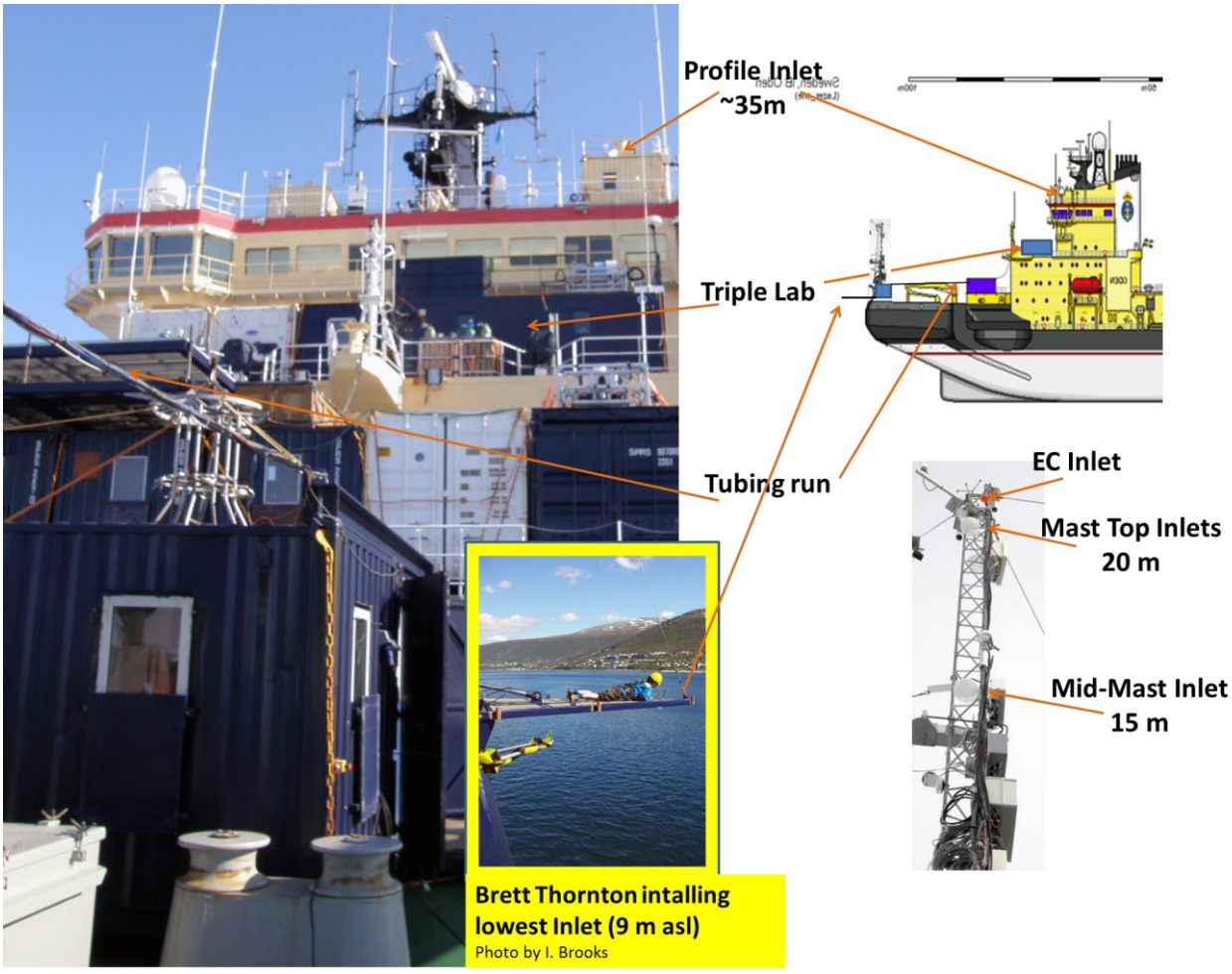
Air sampling observational system: LGR laser spectrometer

A 10m meteorological tower is located near the bow of Oden. The mast is supported by guy cables behind the mast, and one attached to a triangular prow on Oden's bow. Access to the mast is provided a scissorlift (saxlift) stored just aft of the mast.

Air was sampled from a common set of four profile inlets mounted on the ship at approximately 9, 15, 20 and 35m. Each profile inlet was an inverted 20 cm funnel with a set of three baffles to exclude spray and rainwater. The large diameter was to reduce air velocities of the sampled air and to provide about a 1 liter mixing volume at the head of the system. There were two inlets near the top of the forward met tower (ca. 20 m a.s.l.), one for the UU systems and the other for the SU system. Both systems used Synflex 1600 composite plastic lined and jacketed aluminum pipe. The UU system was ca. 55 m of 3/8" o.d. tubing that ran from the top of the tower to the triple lab on the 4the deck of the Oden. A second 3/8" tube was teed from this and run to the WEGAS system in the wet laboratory. Air was pulled through the system to the sampling laboratory on the fourth deck of the ship with a metal bellows pump at 4-5 lpm.



The profile inlets were mounted at four heights. The lowest was 8-9 m asl on the forward stabilizing/sampling platform (picture above shows B.Thornton installing the inlet in Tromsö). Two of the others were located on the forward meteo mast at 15 m asl (mid-mast) and at 20 m asl (top of mast). An additional inlet was located on top of the instrument shack on the 7th deck of the Oden (ca. 35 m asl). Synflex 1600 10 mm o.d. tubing connected the inlets to the 4th deck triple laboratory. The tubing was cut into equal 55 m lengths for each height. Air was continually drawn through all the tubing at ca. 4 lpm continuously with a knf 920 diaphragm pump (see following figures and descriptions). The lengths of all Synflex tubes from the inlets to the spectrometers in the Triple Lab are the same. Negligible additional time, approximately 1 second, is added between the LGR and the Aerodyne spectrometer in the Triple Lab.



At a limited number of stations when Oden was anchored, we relocated the midmast inlet from 15 m height to a position below the triangle prow, 4 m above the sea surface. This position was not possible during heavy seas, deep water or when Oden was underway. The transfer time from the inlets to the LGR #1 spectrometer in the Triple Lab is 55 seconds.

An additional inlet was installed near the Leeds University Metek sonic anemometer at 20 m asl to draw air for eddy correlation measurements. It is connected directly to LGR#2, located just aft of the base of the meteorological mast saxlift. Air was drawn through the analyzer at the base of the

meteorology tower with an Edwards xds 35i scroll pump. Transfer time was less than 1 second. The inlet/water shield was smaller and simpler to facilitate very rapid sampling and to minimize high frequency flux loss.

The air sampling system was used for both tasks 1.1 and 1.2. The same air packet was routed through a Los Gatos (model 911-0010) FGGA-24r-EP off-axis integrated cavity output spectrometer to measure ambient CH4, CO2 and H2O in the air stream. The manufacturers specifications:

Measurement Range: CH_4: 0.01-100 ppm, CO_2: 200-20000 ppm, H_2O: 7000-70000 ppm

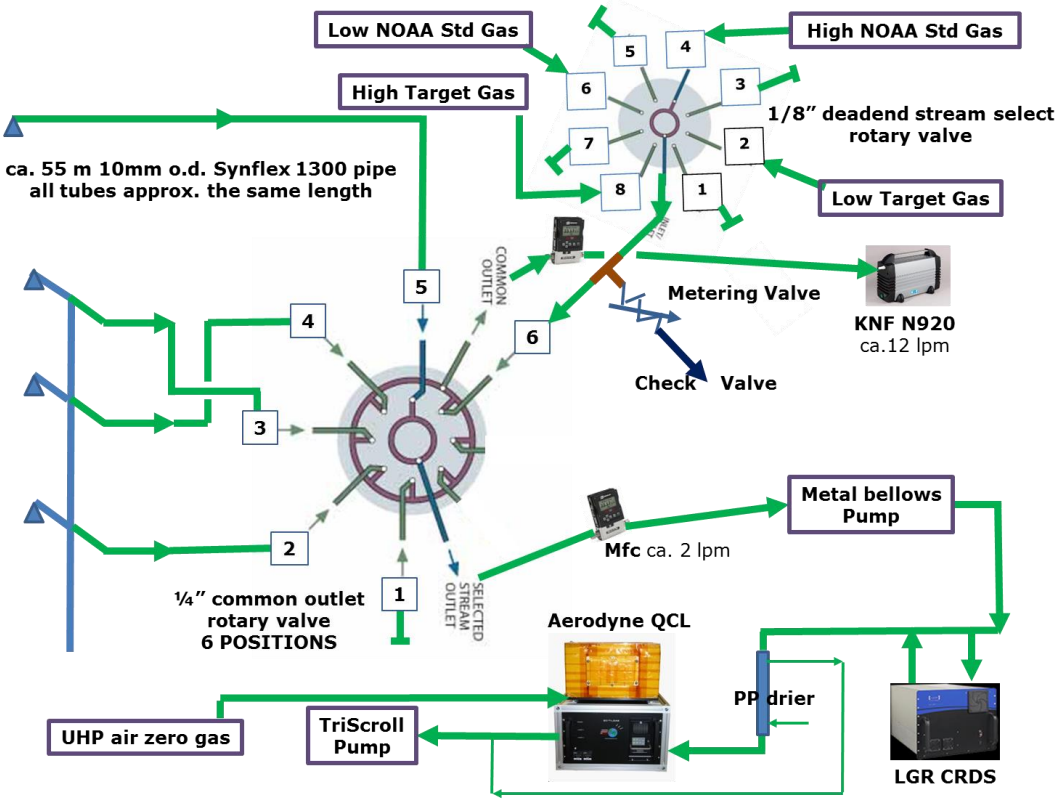
Precision (1σ, 5 sec / 100 sec): CH_4: 1 ppb / 0.25 ppb, CO_2: 150 ppb / 35 ppb, H_2O: 100 ppm / 35 ppm.

Air was then routed for determination of natural abundance stable carbon and hydrogen isotope composition of CH_4 in air through an Aerodyne Research Quantum Cascade Laser spectrometer (QC-TILDAS-CS) for $\delta^{13}C$-CH_4 and δD-CH_4 of ambient air. The custom built Dual Quantum Cascade Laser Trace Gas Monitor specifications are listed as:

Precision: 0.2 ppb CH_4 at 1 sec

Precision (100 sec) $\delta^{13}C$-CH_4: 0.3 per mil, δD-CH_4: 10 per mil

All the lasers are owned by Stockholm University.



The above figure sketches the flow, sampling and analysis of ambient gas. Air is continuously drawn from the inlets through approximately 55 m of 10 mm o.d. at 12 lpm total flow (3-4 lpm each) through a ¼" common outlet 6 position rotary valve (EMT2VLSC6MWE2, Valco Instruments Co.Inc) with a KNF 920 pump. A one micron sintered high flow filter is placed in line of every sample level before the valve. The valve is rotated to select a level every two minutes. The usual order was Low, Top of Mast, Mid-Mast, High inlet. A metal bellows pump (MBE-16) pulled the air from the selected level through the valve. The flow was controlled at 2 lpm with a mass flow controller. That air was

pulled through the LGR using its internal pumps then returned to the sample stream. The cell of the LGR was kept at 140.2 torr.

Sample air continued through a perma-pure drier where a reduced pressure counter flow pulled out most of the ambient water in the sample stream. The metered counter flow also served as a bypass flow to help balance the pressures of the laser cells in the system. A Varian triscroll dry vacuum pump downstream of the instrument pulled sample through the QCL and allowed the pressure of the cell to be maintained at 30 torr. Excess air was vented.

To quantify the performance variation of the instruments, target gases were run every two hours. Target gases were commercial standards purchased from Air Liquide of approximately 1800 ppb CH4 and 345 CO2 for the low targets and 4000 ppb CH4 and 445 ppm CO2 for the high targets. The target gases were calibrated against NOAA ESRL certified standards. These are our laboratory's basic standards and are secondary standards derived from the WMO CO_2 standard and the CH_4 standard held at NOAA Earth Systems Research Laboratory.

Continuous High Precision CH_4 and CO_2 Mixing Ratio Measurements (Tasks 1.1, 1.2, 1.3)

Ambient Trace Gas Analysis System (ATGAS) Summary

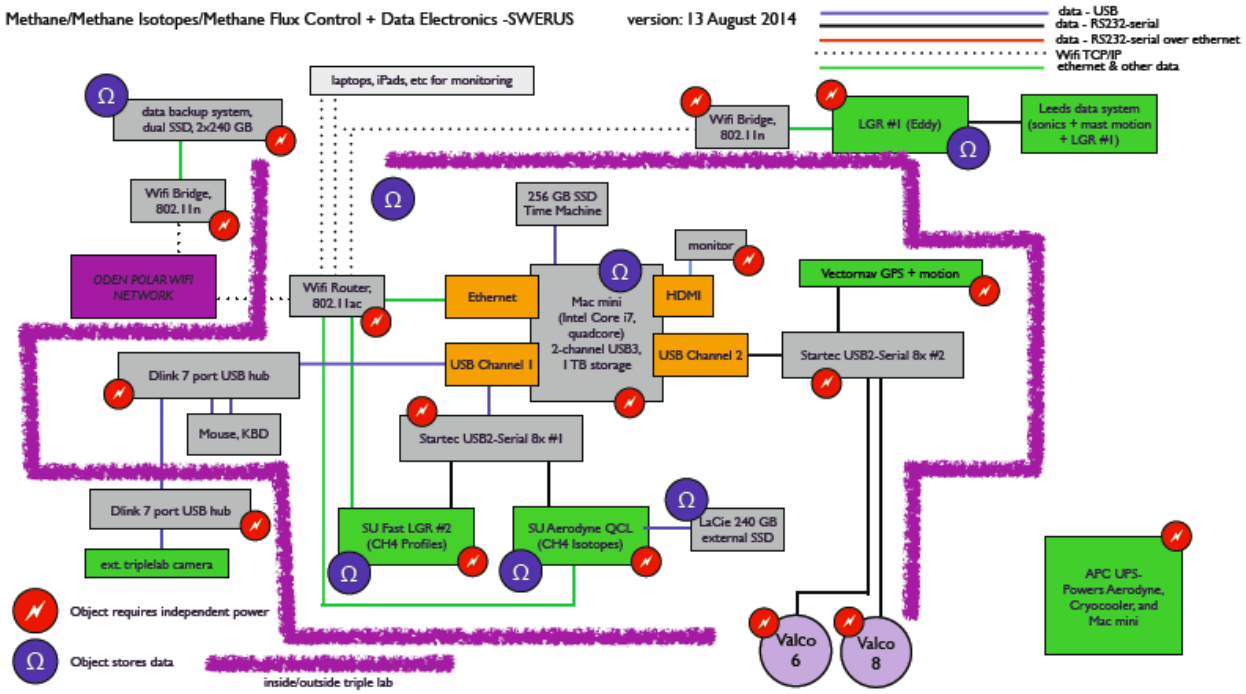
The ATGAS on Oden for SWERUS consists of three laser spectrometers. The spectrometers run mostly independently (two LGR cavity ringdown spectrometers and one Aerodyne Research tunable diode laser spectrometer). They send data to a central control computer. The control computer monitors a serial data stream from two of the three spectrometers. The control computer stamps the datastream from the these two spectrometers with the control computer's clock time, GPS navigation data, ship's meterorlogical data, and ship course, heading, and speed. Finally, a system of tubing collects air from various inlets on Oden, and routes it to valves controlled by the control computer. Each inlet is, in general, monitored for 2 minutes at a time, the system then switches to the next inlet in sequence. Once an hour zero air is flowed into the Aerodyne spectrometer for 50 seconds. Once every two hours, a low $[CH_4]+[CO_2]$ target gas and high $[CH_4]+[CO_2]$ target gas mixtures are flowed through both spectrometers for 4 minutes (two minutes per gas).

Laser room and data acquisition and control station in the triple lab of the Oden

Except for the eddy covariance laser and pump, the ATGAS is located in the Triple Lab, on the 4th deck of Oden in an insulated 2x2.5m room (the laser room) built for sound reduction and temperature control.

Control and Timing System

The data from the LGR-116 and Aerodyne instruments, as well as Oden ship data streams are combined by the Control and Timing System. The purpose of this system is to control the valves for inlet selection, as well as place all the data from various sources on the same time base.



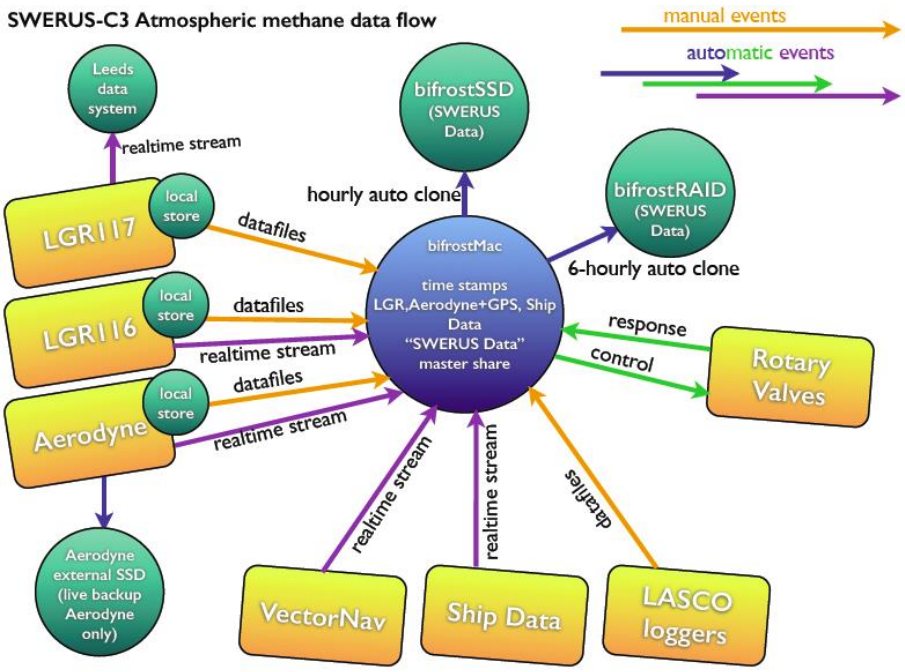
The control computer is an Apple, Inc. Mac mini, with a 2.3 GHz quad-core Intel Core i7 processor. The operating system is Mac OS X 10.9.3. RS-232 serial connections are provided using a StarTech USB-8 serial port adapter.

Custom software was developed to control the VALCO rotary valves, and use the GPS data as the time-basis for the LGR-116 and Aerodyne instruments. In addition, the software adds ship's data (speed, heading, course, seawater T, air T, true and relative wind speed and wind direction) to the Aerodyne and LGR data streams in realtime. Data streams are saved immediately to a text file.

The VALCO rotary valves are controlled for inlet selection and standard gas injection into the LGR-116 and Aerodyne instruments.

Every hour, an incremental backup takes place of all data stored on the Mac mini.

The Mac mini also creates two VNC connections to LGR-116 and LGR-117, for remote viewing (e.g. on the bridge of the Oden) and control of these two instruments. The link to LGR-116 is ethernet, to LGR-117,the link is over 802.11n wifi using a Netgear Ethernet-Wifi adapter.



Power for the Control and Timing System, as well as the Aerodyne Instrument and the Oasis Cryocooler, is provided through an APC UPS system.

LGR #1 (serial number 13-0116)

LGR #1 is located in the laser room in the Triple Lab on Oden. It is a Los Gatos Research Fast Greenhouse Gas Analyzer (FGGA); a cavity ringdown laser system. It measures [CH_4], [CO_2], and [H_2O]. Corrections for water vapor are made on-the-fly and it provides 1 Hz measurement of $[CH_4]_{dry}$ and $[CO_2]_{dry}$.

Communications with LGR #1 are via RS-232 link to the control computer, plus an ethernet connection.

LGR #2 (serial number 13-0117)

LGR #2 is located on the platform with the meteorological mast, aft of the scissor lift (see below). It is dedicated to collecting 10Hz [CH4] and [CO2] measurements for eddy covariance studies. It is otherwise an identical system as LGR #1. For weather protection, it is stored in a Hardigg "BlackBox" rackmount case. The rackmount case is further protected inside an outdoor plastic storage chest.

Communications between LGR#2 and the Triple Lab systems is provided via a NetGear Wireless-to-Ethernet adapter. The RS-232 serial output of LGR#2 is collected and time-stamped with GPS time by the meteorological group from University of Leeds. They will use their sonic anemometer data in combination with LGR#2 output for eddy covariance calculations.

Air sampling observational system: Aerodyne TDL Spectrometer for CH_4 Isotopes + Navigation System + Control and Timing System

Technical description: Aerodyne CH_4 Isotopes TDL

The Aerodyne Research CH_4 isotopes TDL laser spectrometer (henceforth "Aerodyne") is located in the Triple Lab's "laser room" on Oden. It is an Aerodyne tunable diode laser system. Temperature control for the Aerodyne instrument is assisted by an Solid State Systems Oasis 3 cryocooler.

The Aerodyne system and cryocooler are provided with power through an APC UPS. (Other systems do not have a UPS.)

The Aerodyne TDL Spectrometer (henceforth "Aerodyne") is an absorption laser spectrometer instrument produced by Aerodyne Research, Inc. in Billerica, Massachusetts, USA. The instrument provides real-time in-situ measurements of the concentrations of the CH_4 isotopologues $^{12}CH_4$, $^{13}CH_4$, and CH_3D at 1 Hz. (Delta values as often used in isotope work are not automatically provided; these are literally the concentrations of the individual isotopologues.) In the SWERUS-C3 configuration, the Aerodyne instrument is arranged in serial with the LGR-116 instrument. Thus both instruments are sampling the same air from four inlets (9m, 15m, 20m, and 35m asl).

The instrument consists of two lasers with wavelengths of -- and --. These mid-IR lasers allow probing of much stronger absorption lines than the near-IR lasers used in the LGR instruments; hence, higher precisions can be obtained. The measurement volume is an astigmatic multipass absorption cell with a volume of about 2 liters; the total absorption pathlength is 210 m.

Internal temperature control is provided by an Oasis 3 thermoelectric cryocooler/chiller (Solid State Cooling Systems, Wappingers Falls, NY, USA).

The lasers themselves are individually temperature controlled to +/- 1 mK. By rapidly sweeping the laser current, the laser output frequency is scanned over about 1 cm^{-1}. About 5000 spectra are averaged to produce 1 Hz data. Instrument control is via the Aerodyne TDLWintel Software, running in Windows 7.

1 Hz data was collected during SWERUS-C3 beginning ----. Data is stored internally, and on an external clone drive. Additionally, data is sent via RS-232 link to the Control and Timing system computer.

Communications between the Aerodyne instrument and the Control and Timing system computer are via an RS-232 link and an ethernet connection.

Spectroscopic Corrections

Spectroscopic corrections using the HITRAN2012 database (Rothman et al, 2013) are applied to the data by the Control and Timing system; raw data from the Aerodyne instrument does not include spectroscopic corrections.

Calibrations

Every hour a "zero air" gas is introduced into the Aerodyne instrument via a solenoid valve. This allows the instrument to reset a zero level for air containing no CH_4.

The data further relies on calibrations using a low and high target gas every two hours.

Additional calibrations were undertaken thrice during leg 1, using standard gases from NOAA. These standards are cross-calibrated with the target gases.

In the present data provided, the calibration corrections have not been applied to the data. Although the concentration data is more precise than the LGR data, without applying the calibrations, it is less accurate. Thus the data in its present form should not be used for any comparative work with other datasets.

Calibration data will be applied in the future to the raw data, after further cross-calibration work to be conducted onshore.

It is expected that the calibrated CH_4 isotopologue concentrations will be available soon after data clearance is obtained.

Navigation System

GPS Navigation data is provided by a VectorNAV VN-200 Rugged inertial navigation system (VectorNAV, Dallas, TX, USA). It is operated in GPS-priority mode. Via an RS-232 serial link, it sends 5 Hz position and motion vector data to the control computer. GPS time is also provided. GPS lock is determined by satellite count; below 4 satellites, and the control computer will favor location data from the ~0.2 Hz Oden data stream. Generally, GPS time is available even if GPS lock cannot be obtained.

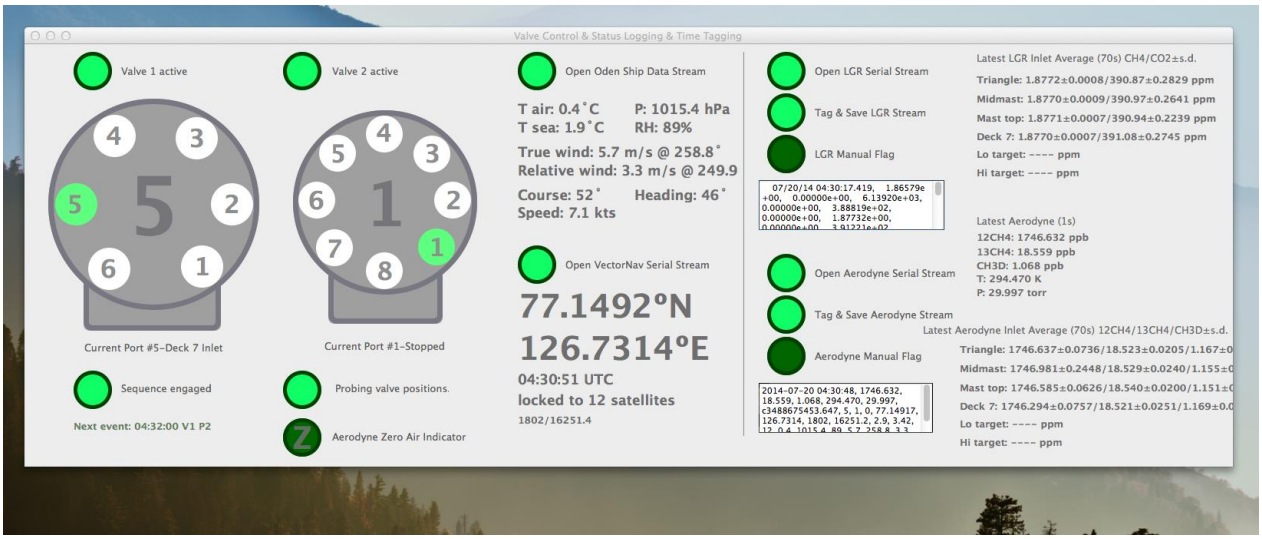
GPS time is treated as UTC time and is the master time base for the data files. Efforts are made to keep the control computer clock and instrument clocks synced with GPS time. Instrument time on LGR-117 (eddy covariance system) is allowed to drift.

Control and Timing System

The data from the LGR-116 and Aerodyne instruments, as well as Oden ship data streams are combined by the Control and Timing System. The purpose of this system is to control the valves for inlet selection, as well as place all the data from various sources on the same time base.

The control computer is an Apple, Inc. Mac mini, with a 2.3 GHz quad-core Intel Core i7 processor. The operating system is Mac OS X 10.9.3. RS-232 serial connections are provided using a StarTech USB-8 serial port adapter.

Custom software was developed to control the VALCO rotary valves, and use the GPS data as the time-basis for the LGR-116 and Aerodyne instruments. In addition, the software adds ship's data (speed, heading, course, seawater T, air T, true and relative wind speed and wind direction) to the Aerodyne and LGR data streams in realtime. Data streams are saved immediately to a text file.



The VALCO rotary valves are controlled for inlet selection and standard gas injection into the LGR-116 and Aerodyne instruments.

Every hour, an incremental backup takes place of all data stored on the Mac mini.

The Mac mini also creates two VNC connections to LGR-116 and LGR-117, for remote viewing and control of these two instruments. The link to LGR-116 is ethernet, to LGR-117, the link is over 802.11n wifi using a Netgear Ethernet-Wifi adapter.

Power for the Control and Timing System, as well as the Aerodyne Instrument and the Oasis Cryocooler, is provided through an APC UPS system.

Air sampling system: Discrete Sampling Program

This effort (Tasks 1.4, 1.5, 1.6) was the responsibility of Dr Célia Sapart, from Utrecht University with some assistance from Dr Brett Thornton, SU.

Research questions

I. What are the main sources of CH_4 and CO_2 to the atmosphere in the ESAS and what are their isotopic signatures?
II. Is there old CH_4 from the deep ESAS sea floor reaching the atmosphere?
III. Is the Arctic Ocean a source and/or a sink of nitrous oxide and how does sea ice affects the nitrous oxide cycle?
IV. How does the Arctic Ocean contribute to the molecular hydrogen cycle?

Methods for discrete air sampling

General

Discrete sampling from the second highest air inlet (~15m above water) of the forward mast was performed several times per day. For clean sampling conditions, the ship had to be moving at least at 4 knots and the relative wind direction had to be between 280° and 80° (Fig. 1).

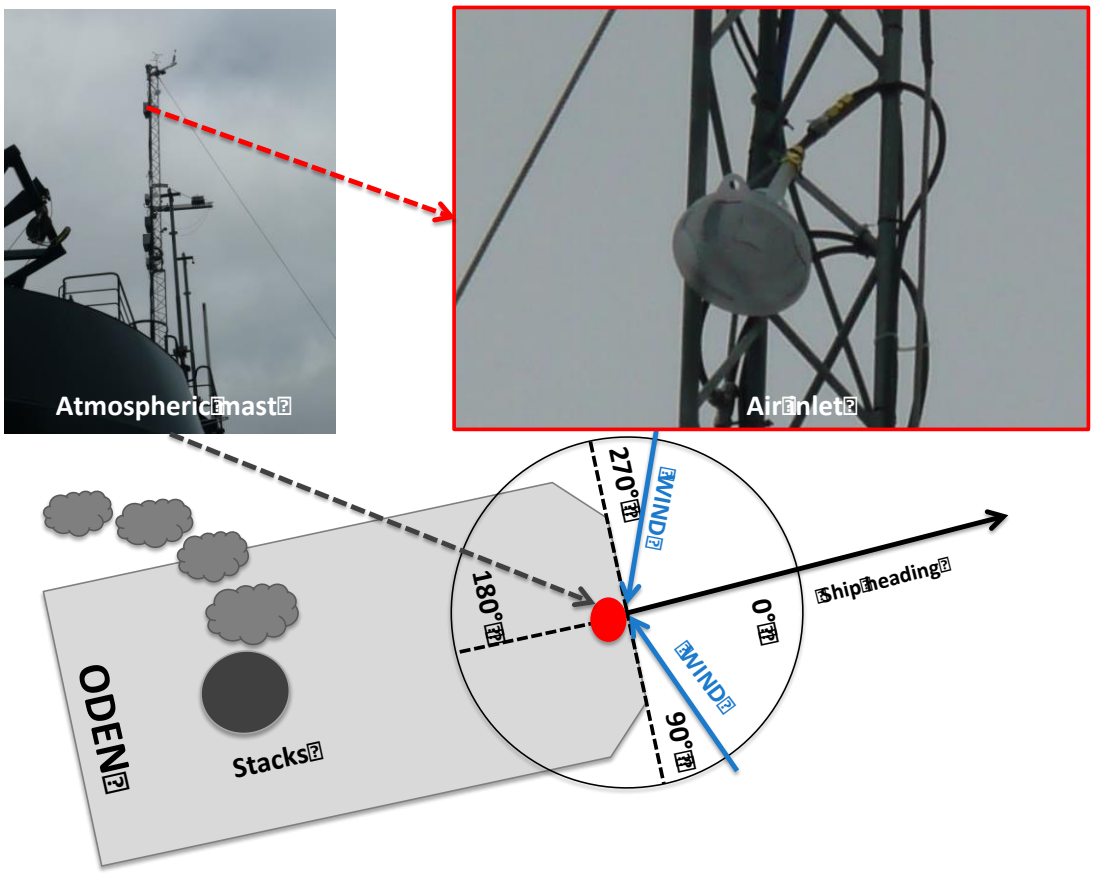


Fig. 1: General scheme of the atmospheric mast and of the wind direction relative to the bow.

A sampling procedure comprises the filling of two types of flasks, 2L Stainless Steel (SS) flasks (Fig. 2) and 1L glass flasks (Fig. 3). At certain sites a large volume sampling to extract CH_4 and CO_2 from the air was also performed.

Fig. 2: 2L SS flasks

Fig. 3: 1L glass flasks

System description

The discrete sampling system includes two parts as depicted in Fig. 4. The first part is used for atmospheric discrete sampling in SS or glass flasks and the second part allows the preconcentration of CH_4 and from large volume of air. The principle of our method is to absorb CH_4 and carbon dioxide at low temperature on a molecular absorbent while the rest of the air is vented to a pump. Then the trap is immerged in a warm bath to release CH_4 and carbon dioxide from the absorbent. Simultaneously, the sample bottle was cooled with liquid nitrogen to absorb the totality of the gases in a small volume. The advantage of this method is to preconcentrate large quantities of CH_4 and carbon dioxide in a small volume sample in order to allow the measurements of $^{14}CO_2$ and $^{14}CH_4$ at a later stage.

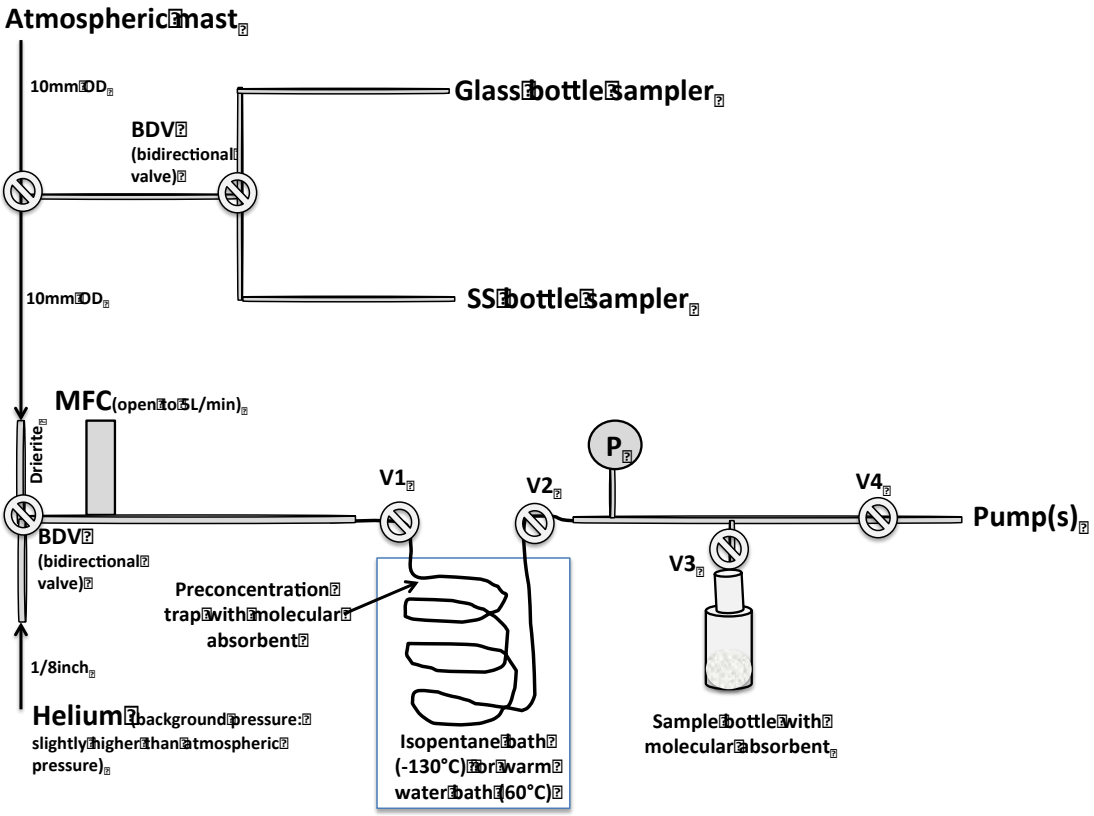


Fig. 4: General scheme of the discrete sampling system

The entire sampling sequence lasted 2 hours and was performed as followed:

1) Filling of 2L Stainless Steel (SS) canisters (Fig. 2) at 3,5b
2) Filling of 1L glass flasks (Fig. 3) at 1,7b
3) Large volume extraction (final pressure in sample bottle between 1-2b)
4) Filling of 2L SS canisters at 3,5b
5) Filling of 1L glass flasks at 1,7b

WP E Sediment - collection and handling

During the first leg, WPE collected sediment cores for all the scientists actively involved in the sediment sampling. In addition, this WP was responsible for providing samples for other workpackages (WPC and WPF). Samples were taken for the following programs:

- Organic geochemistry

- Methane concentration and ^{14}C signature (WPC)

- Sedimentology

- Microbial biochemistry/early diagenesis (WPF)

- Macrobenthos study

Previous expeditions and organic geochemistry programs (e.g.ISSS-08, TB-08, etc) covered primarily the inner-shelf and mid-shelf of the Laptev Sea and East Siberian Sea. The major goal of the organic geochemistry program during SWERUS-C3 leg 1 was to extend the distribution of sediment samples to include the extensive outer-shelf as well as slope and rise sediments in order to better understand the fate of permafrost carbon in different regions of the Arctic Ocean for modern and longer timescales. Similarly, the main objective of the sedimentology program was to increase the spatial coverage of the grain-size data building on the extensive number of samples previously collected by Russian scientists in the region. The main goal of the macrobenthos program was to investigate the effect of the ocean acidification in the Arctic benthic populations as well as the effect of CH4 hotspot areas on the benthic biodiversity. For detailed information about microbial biogeochemistry and methane programs see specific details in the WPF and WPC sections, respectively.

Sample labelling and coordinates

Sediment samples were logged and labeled according to station number, coring device used and cast number. For long cores (gravity and piston cores) the label includes the section of the core too. Two letters were used to identify the coring device: MC (multicorer), RU (Rumohr), PC (piston corer) and GC (gravity corer).

Example: 05-MC/II (station number 05, multicorer, second deployment)

Coordinates and deployment time were put down when the coring device touched the seabed.

Description of the sampling equipment

Multicorer (MUC)

This is a 8-tube multicorer made by Oktopus GmbH (Germany) which was developed to collect samples of the seabed with an undisturbed sediment-water interface. The liners are made of polycarbonate and are 60 cm long with a 10 cm diameter. The MUC was deployed with full weight (head weight about 500 kg) at a speed of 0.5 m/s near the seabed. To increase the recoveries, the MUC was left for 1 minute on the seafloor.

Figure E.1. Multicorer during deployment

Rumohr

This is a light gravity corer (about 100 kg) made by Oktopus GmbH (Germany) which was primarily used to collected samples for the microbial geochemistry WP (WPF). The Rumohr has a 1.8 m long polycarbonate tube (6 cm diameter) attached into the head weight via a clamping mechanism. To prevent the Rumohr from tipping over, a shorter liner (1.2 m long) was used when the penetration into the sediment was low.

Figure E.2. Rumohr corer after deployment

Piston corer

The Stockholm University Piston Corer was designed to recover up to 12 meter cores from the aft deck of Icebreaker Oden with a maximum head weight of 1485kg. The core barrel comes in 3 meter

sections and uses a standard plastic liner with internal diameter 100 mm, collecting approximately 29.5 dm^3 per meter length. The piston core can also be used as a conventional gravity corer with the trigger weight and piston removed.

Figure E.3. Piston corer during deployment

Core handling

Multicorer

Cores were measured and capped after arrival back on the aft deck platform. They were then taken out of the multicorer and divided between different people and workpackages (see Table E.2):

- Ecology (Aleksandr Gukov): Sediment was transferred into a bucket, and labeled with station number, and then wet-sieved (sieve size 1mm) for macrobenthos.
- Sedimentology and SPM (Oleg Dudarev): Sediment cores were subsampled with a stainless spoon (top 10 cm), transferred into pre-labeled LDPE roll-down bags and stored frozen (-20°C). At every station overlying (bottom) water was siphoned from the core liners (2-5L) into polycarbonate bottles. Within a few hours, this water was filtered on 47mm Whatman membranes (0.45um) for suspended particulate matter analyses.
- ^{14}C-CH_4 (Julia Steinbach/Henry Holmstrand): Sediment was extracted with 60mL syringes (total ca. 150mL) from pre-drilled core liners and transferred into sealed glass jars with swagelock valves. From station 49 onwards we transferred four complete sediment cores into four jars. The jars were filled up with salt solution (ca. 300 g kitchen salt into 1000mL MQ water), and headspace air was replaced with helium. The valves were taped to avoid re-opening and transported to the main lab for methane stripping.
- CH_4 (Denis Kosmach): see WPC section in the cruise report.
- Microbial studies (Volker Brüchert): see WPF section in cruise report
- Organic Geochemistry:
  1. *Cores for storage/core logging*: Overlying water was siphoned off, two pre-cut foam cylinders were pushed on top of the sediment, and the core liner was cut just above the

foam. The core liner was capped on both sides with HDPE yellow caps and sealed with broad black electrical tape, and labeled. One core was stored in the freezer (-20°C) and one in the fridge (+4°C). The 'fridge' core was run on the Multisensor Core Logger. A number of selected cores were split on a core splitter (GeoTek, UK) (see table E.2). After splitting the sediment surfaces were smoothened, the two half-liners wrapped in clean film, tightened with rubber bands, wrapped in thick plastic bags, labeled and then transferred into two white long core tubes and stored in fridge (+4°C). These split cores will be used for ^{210}Pb dating and XRF analysis.

2. *Cores for slicing* (see Table E.2): Overlying water was siphoned off, and the core was transferred to an extruder (Oktopus GmbH, Germany). The core was sectioned on low resolution (1cm intervals; shelf stations >200m water depth) or on high resolution (0.5cm intervals from 0-10cm, 1cm intervals >10cm depth; slope and rise stations >200m water depth). Sediment was transferred into pre-labeled LDPE roll-top bags, then combined into a large plastic bag and stored in the freezer (-20°C). For most stations, subsamples were taken with a spatula from every interval and transferred into pre-labeled epi-tubes and stored in the freezer (-20°C).

Rumohr coring

Rumohr cores were capped, labeled and stored cooled (further handling details see WPF section).

Piston coring

Cores were cut into 1.5 m sections (section I being the top of the core) with a pipe cutter, excess water was drained. A foam cylinder was added on the core surface before being capped.

Cores were then split by making an initial, shallow, cut with the core splitter (GeoTek, UK) and a final cut with a knife (to avoid plastic contamination of the core liner into the core). One half was kept in the fridge and the other in the freezer. The longest core (PC23) was subsampled at every 5 cm and the removed intervals were replaced with foam. Sediment was transferred into pre-labeled LDPE roll-down bags and frozen at -20°C.

Description of the performed measurements

The Multi-Sensor Core Logger (MSCL) and sediment properties

The MSCL is a core measurement system sold by Geotek (UK) which allows a series of non-destructive analyses of whole and split sediment cores. In our samples we focused essentially on bulk density and magnetic susceptibility (the degree of magnetization of a material in response to an applied magnetic field).

Bulk density. A gamma ray source and detector are mounted across the core on a sensor stand that aligns them with the center of the core. A narrow beam of collimated gamma rays is emitted from a Cesium-137 source with energies at 0.662 MeV. These photons pass through the core and are detected on the other side. At this energy level the primary mechanism for the attenuation of gamma rays is by scattering. The incident photons are scattered by the electrons in the core with a partial energy loss. The attenuation, therefore, is directly related to the number of electrons in the gamma ray beam (core thickness and electron density). By measuring the number of transmitted gamma photons that pass through the core unattenuated the density of the core material can be determined.

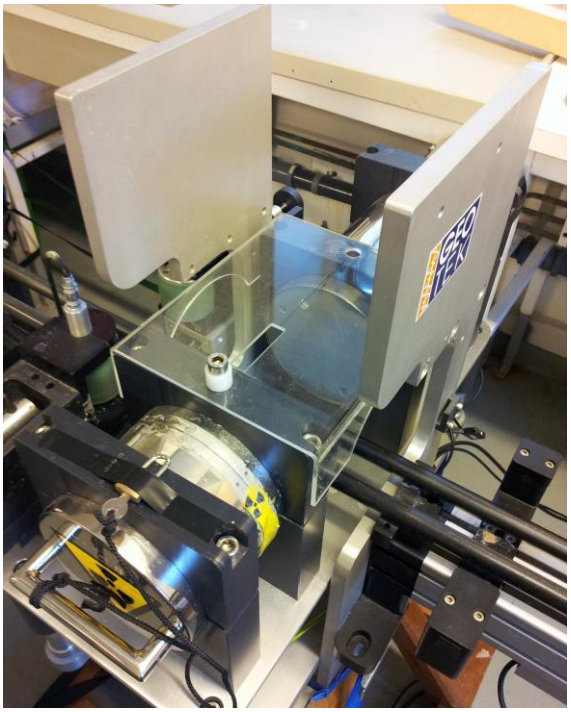


Figure E. 4. Photo of the gamma ray source and detector

Magnetic susceptibility. The Bartington loop sensor is used for magnetic susceptibility measurements on whole cores. An oscillator circuit in the sensor produces a low intensity and alternating magnetic field. Any material in the near vicinity of the sensor, that has a magnetic susceptibility, will cause a change in the oscillator frequency. The electronics convert this pulsed frequency information into magnetic susceptibility values.

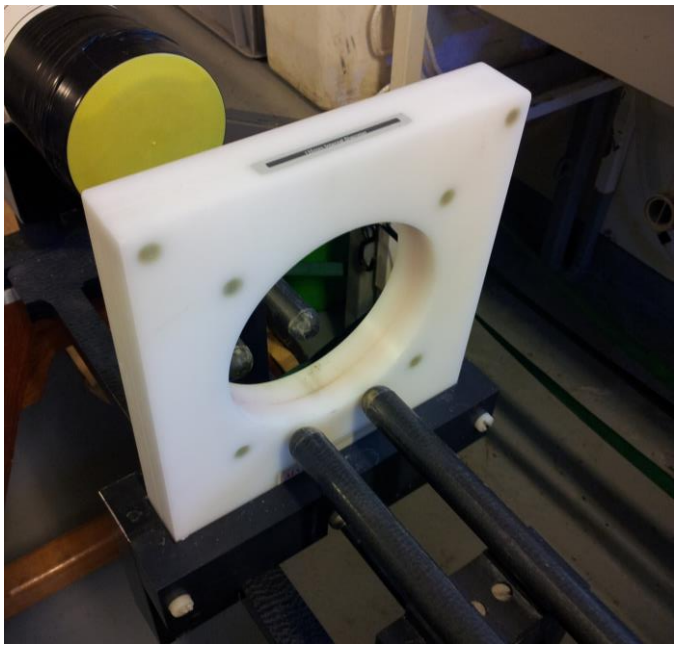


Figure E. 5. Photo of the Bartington loop sensor

Antares temp sensors

These temperature sensors (ANTARES) are autonomous miniaturized data loggers developed for use in marine settings. The main features of these loggers are their mechanical robustness, their pressure-safe housing and a high temperature resolution. The loggers are delivered together with a communication unit and the software to configure and download the loggers as well as to store the data in different formats. During the coring activity, one logger was mounted on the MUC frame to measure the bottom temperature 50 cm above the seafloor. Another logger was attached to the head weight via a bar to measure the temperature of the surface sediment. The penetration depth of the sediment logger was essentially a function of the sediment recoveries, and probably varied between 5 and 30 cm. A typical data series (Station 33) is shown below. The blue dots are the data from the logger attached to the frame (bottom water temperature) while red dots show the data from the logger that penetrates the sediment. The two profiles are similar until the MUC reaches the seabed. Here, the temperature measured by the logger attached to the frame remains stable while the friction with the sediment result in increasing the temperature of the other logger. After about 20 seconds the heat is dissipated and the logger gives the proper reading of the temperature in the sediment.

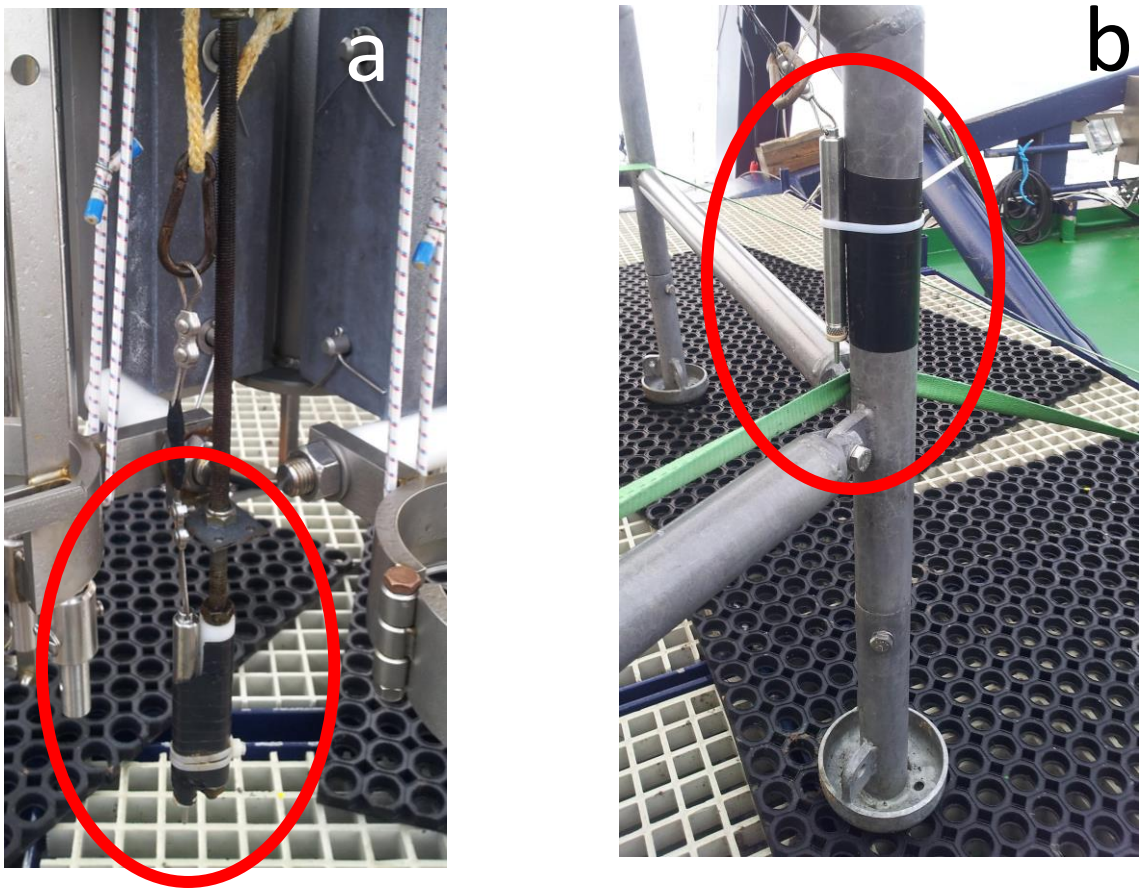


Figure E.6. Antares loggers attached to the (a) head weight and (b) frame.

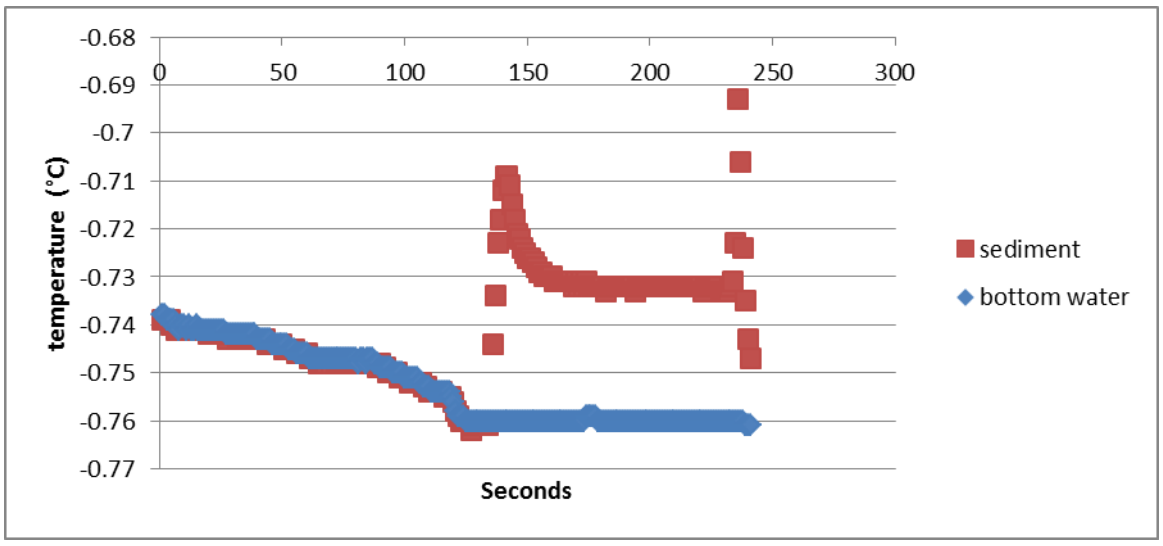


Figure E.7. Station 33 where the MUC stayed on the seabed for about 100 second. The two colors show the temperature measured by the two loggers mounted on the MUC.

Underwater Camera

Underwater video was recorded at many Multicore stations during the cruise. A GoPro Hero 3+ camera was used inside a Scout Pro H3 housing rated to a depth of 2750 meters. Video was captured

at 1440p resolution and 48 frames per second and a LED light in an underwater housing provided illumination. The camera and light were attached to the Multicore frame in several different configurations to observe seabed conditions, ebullition, gas bubbles in the water column and aspects of the coring process.

Figure E.8. Underwater camera being mounted

WP F Microbial Biogeochemistry

F.1. Introduction

1.1. Goals

The goals of the work package F 'Microbial biogeochemistry' were:

i. to obtain and prepare samples for the quantification of stable and radiotracer-based microbial transformation rates involved in methane cycling in Eastern Siberian shelf and slope sediments and water column,
ii. to obtain and prepare samples for the shore-based RNA/DNA-, phospholipid-, and ^{13}C tracer-based analysis of the active microbial communities in Eastern Siberian shelf and slope sediments,
iii. to determine aerobic and anaerobic carbon mineralization and nutrient regeneration rates in Eastern Siberian shelf and slope sediments,
iv. to analyze the porewater chemistry of Eastern Siberian shelf and slope surface sediments for quantification of organic matter mineralization processes by diagenetic modelling,
v. to quantify the exchange rates of oxygen, nutrients, methane, nitrous oxide, and carbon dioxide between sediment and bottom water at selected stations,
vi. to obtain water samples for the analysis of nitrous oxide as an intermediate in bacterial nitrification/denitrification in sediment or water column,

The general approach for conducting these studies builds on three complementary sets of data: (i) quantification of vertical concentration gradients in the water column and sediment for the purpose of establishing transport rates and directions, (ii) quantification of microbial process rates and exchange fluxes with intact core material and sectioned core material, (iii) microbial diversity, metagenomic, ^{13}C-stable isotope probing, and quantitative functional gene analysis of sediment and water samples.

1.2. Background

The concentrations of climate-active trace gases carbon dioxide, methane, and nitrous oxide in the ocean are tightly controlled by the biogeochemical cycling of carbon and nitrogen by microbial communities in sediment and the water column. Anaerobic microbial communities produce methane during methanogenesis in anoxic zones of sediments from where it can diffuse or is transported as bubbles to the surface of sediments. Here, methane can be oxidized microbially under both aerobic and anaerobic conditions by methanotrophic microorganisms. Aerobic microbial oxidation of

methane also takes place in the water column. The activity of different groups of microorganisms in the sediment and water column therefore affects the ambient concentration of methane and, consequently, the size of the flux of methane to the atmosphere. In our studies, high-resolution sediment methane concentration profiles were acquired from all major working areas during the SWERUS-C3 expedition. In addition, in-depth sampling of multiple sediment cores was conducted to acquire large sediment volumes for shore-based ^{3}H-, ^{14}C-, and ^{13}C-incubation studies in the Laptev and the Eastern Siberian Sea from two areas with demonstrated elevated concentrations of methane in the water column. The same investigations were also conducted at nearby reference stations that showed minor or no water column methane anomalies. At these stations we also acquired water samples for ^{3}H- and ^{13}C-tracer methane oxidation experiments.

Quantification of the degradation and oxidation rates of sedimentary organic matter in Siberian shelf and slope sediments to carbon dioxide is another key aspect of the SWERUS program. The oxidation of the organic matter by different electron acceptors follows a thermodynamic energy gradient that favors oxygen respiration over the anaerobic respiration processes denitrification, manganese reduction, iron reduction, and sulfate reduction. The presence and depth location of these processes was obtained to a first order from high-resolution concentration profiles of dissolved oxygen and will later be complemented by analysis of dissolved iron, manganese, sulfide, sulfate, and ^{35}S-sulfate reduction rates on land. Specific information on microbial reaction rates for the oxidation of organic matter was obtained from µm-scale high-resolution concentration profiles and tracer studies. For the latter, a radioactive tracer equivalent of a target compound was added in trace quantities to the sample and incubated under controlled conditions for a defined time period, after which the microbial activity in the sample was stopped by poisoning and preservation of the sample for quantification of the converted tracer after chemical separation, which will be done in the laboratory on land. Intact, stirred core incubations at in-situ temperatures were conducted with preserved bottom water and sediment-water interfaces to quantify the benthic exchange rates. The above investigations were complemented by an extensive sampling program to collect RNA and DNA on filters in the water column and from the sediment for in-depth microbial community analysis of active microorganisms.

F.2. Methods for water column studies on microbial methane and nitrous oxide dynamics

2.1 Introduction

We have used a multidisciplinary approach that combines gas chemical analysis, radio- and stable isotope labeling, and molecular biology to study water column CH_4 and N_2O cycling. Samples were collected to determine concentration gradients of N_2O and CH_4. and microbial community

composition responsible for cycling of the two gases. To gain information on the microbial community composition and the methanotrophic microorganisms contributing to CH_4 oxidation in the Siberian Arctic Sea we have acquired samples on which we will perform stable isotope probing studies, next-generation sequencing of environmental DNA and RNA, and functional gene expression analyses of the methane monooxygenase gene (*pmoA*).

2.2.Sampling and analytic methods for dissolved trace gas analysis

Water samples for CH_4 and N_2O determination were collected at 40 stations (Figure F.2.2 and Table F.2.2). Triplicate samples were collected in 12 ml Exetainer vials (Labco Scientific, UK) prefilled with 50 µl of a 7M $ZnCl_2$ and three glass beads to mix the samples with the preservative and stop the bacterial activity. 3 mL headspace was set by withdrawing 3 mL water sample and replacing it with helium gas. Samples were shaken for 30 minutes on the shaking table and left for another 30 minutes for equilibration. The CH_4 and N_2O measurements were carried out on a gas chromatograph (GC) with a flame ionization detector (FID) (SRI 8610C) and electron capture detector (ECD). The 2.5 mL sample was loaded on a 1000 µl injection loop and CH_4 was separated on a 1.5 m 10'x1/8" stainless steel column packed with a HayeSep D 100/120 mesh at 60°C. N_2 was used as carrier gas at 4 bars and 20 ml min^{-1} flow rate. Both methanizer and detection temperature were set to 330°C. CH_4 standards 15 ppm, 100 ppm, 150 ppm and 1000 ppm (Air Liquide) were used to construct a calibration curve. FID was calibrated with the standards twice a day. The columns were baked every night for 5 hours at 10°C. N_2O standards 300 ppb and 1000 ppb (AGA) were used to construct calibration curves. The ECD channel was calibrated after every 20th sample.

2.3. Methods for microbial community studies in the water column

Sampling and fixation of water samples for DNA/RNA extraction

Water samples were collected from the CTD Rosette sampler at 12 chosen stations (Table 1) at four different depths, one in the top 10 m, one at the bottom, and two in the mid-waters. Water was collected into the 1L Schott Duran bottles. 1 L of sample was filtered through 0.2 µm Millipore filter using Millipore filtration unit. Millipore filtration unit was sterilized with ethanol and RNAse free solution before sample filtration. Filtration was done within 5 hours after samples collection and filteres were frozen at -80°C within 20 minutes after filtration to avoid RNA degradation.

Fixation for DNA/RNA for stable isotope probing

Water samples from selected sites and depths were taken into 1L glass bottles, closed without head space with butyl rubber stopper and screw caps, and injected with $^{13}C\text{-}CH_4$ to the final concentration of $^{13}C\text{-}CH_4$ of 1000 nM. Samples were incubated for 1 week at low (0.5-1.5C) ambient temperature in a dark temperature-insulated container. After that 5ml subsample of water was transferred to 20 ml pre-evacuated vial and acidified as it is described in previous section. Enrichment of DIC in these samples with ^{13}C will be measured in the UGA laboratory. 1L of water was filtered through 0.2 micrometer Sterivex filter with peristaltic pump and stored frozen at -80^{o} C.

2.4. Methods for studying aerobic methane oxidation

Methane oxidation by aerobic methanotrophic bacteria is an important part of the biogeochemical methane cycling in marine systems. It is a major sink of CH_4 that control its emission to the atmosphere. Carbon dioxide and water soluble organic exometabolites produced by this process contribute to the sea water carbonate system and DOC. In order to evaluate the rates of methane oxidation, methane labeled with radioactive tracers ($^{3}H\text{–}CH_4$ and $^{14}C\text{-}CH_4$) are widely used. We tested the applicability of using methane labeled with stable carbon isotope ^{13}C ($^{13}C\text{-}CH_4$, 99,99%) for measuring potential methane oxidation rates in on board incubation experiments.

^{13}C-aerobic methane oxidation

In Oden onboard laboratory water samples were incubated with $^{13}C\text{-}CH_4$ in 27 ml glass vials for estimating potential methane oxidation. $^{13}C\text{-}CH_4$, 99.999 % (Cambridge Industries, USA) was diluted with pure N_2 to give 1000nM of dissolved ^{13}C-methane when 100 microliters of gas was injected into 27ml vial. Vials were incubated in dark at near “in situ” temperatures in insulated box for 2 weeks. After the incubation 5ml subsamples of water were taken from vials with syringes and transferred to 20ml pre-evacuated vials. Samples were acidified by injecting 100 microliters of 37% pure hydrochloric acid per vial and pressure was equilibrated to atmospheric with air

^{3}H-methane oxidation

For the same depths, water samples were collected for shore-based 3H-methane oxidation analysis in the laboratory at University of Georgia Athens.

2.5. Methods for sediment studies

2.5.1 Introduction and overview with sampling map

Table 2.6.1 lists the stations, at which samples were taken for specific research topics in WP F. Due to time constraints, the full program could not be performed at every station. 5 stations were selected for intensive investigations. The first three stations (Stns. 13, 14, 23) are located on the Laptev Sea. Station 13 and 14 were located in an area of elevated methane concentrations and acoustic indications of rising bubbles suggesting seep sites. Station 23 was selected as a reference and control station, because no strong methane anomaly was detected in the water column at this station and there was no evidence for rising gas bubbles. The other two intensive stations, 50 and 53, were selected to investigate the same processes in the Eastern Siberian Sea. Station 50 was again selected as a reference station and Station 53 as station within an areas of elevated surface methane concentrations. Stations for the other investigations were selected to optimize areal coverage across Laptev, Eastern Siberian Sea, and Chukchi shelf and slope.

Table 2.6.1. Summary of activities on sediment in work package F

Station	Latitude	Longitude	O_2 micro-electrode profiling	Porewater chemical profiles	^{35}S-sulfate reduction rates	Benthic flux experiments	Sediment methane cycle experiments	RNA/DNA studies
1	78.942	11 25.243	X	x	x			X
2	78.581	11 25.607	X		x			X
3	78.238	11 26.150	X					
4	77.855	11 26.664	X	x	x			
6	77.142	11 27.378	X	x	x			X
13	76.778	11 25.830	x*	x	x	X	x	X
14	76.894	11 27.799	x*	xx*	x	X	x	X
16	77.110	11 26.539	x					
19	76.456	11 26.211	x					
23	76.171	11 29.333		x	x	X	x	X
24	75.599	11 29.558	x	x	x			
27	76.943	11 32.229	x	x	x			X
30	78.181	11 38.354	x	x	x			X

31	7 9.396	1 35.497	x						
35	7 8.600	1 37.061	x						
37	7 8.521	1 37.170	x						
40	7 7.670	1 44.668	x	x	x				
43	7 6.780	1 47.791	x						
45	7 6.416	1 48.115	x	x	x				
48	7 6.615	1 53.345	x	x	x				
50	7 5.764	1 58.529	x	x	x	X	x	X	
53	7 4.957	1 61.090	x	x	x	X	x	X	
58	7 4.440	1 66.050	x	x	x				
63	7 4.685	1 72.361	x	x	x	X		X	

*** performed on two different casts with the Multicorer within several meters distance while vessel was anchored**

2.5.2. Methods for porewater chemical analysis

Dissolved ions

Porewaters were extracted from specially prepared Multicorer and Rumohr tubes into which 4 mm holes were drilled from the side of the tubes in two rows at 90° angle in 1-cm intervals. The holes were taped with black electric tape and the cores were mounted on the Multicorer. After retrieval of the cores from the multicorer, porewater extraction was done at air temperature (<4°C) within 24 hours of core retrieval. A rhizone (0.2 µm pore diameter) was attached to a 10 ml drawn syringe that was held under tension with a small wooden bar and was inserted from the side of the core to the level exactly above the sediment-water interface to extract bottom water (10 ml). Subsequently, the remaining overlying water was drained to the surface of the sediment. Rhizones were inserted in 1–cm intervals in the top 5 cm and in 2-cm intervals until the bottom of the core. For Rumohr cores, the depth resolution was 5 cm. A single sample was collected for porewater analysis from the bottom of the gravity core at Station 53 at 40 cm depth. Collected porewater (5-10 ml) was distributed to different vials for later chemical analysis. For metal analysis, 1 ml of porewater was preserved with 50 µl 1% nitric acid, 2 ml were frozen untreated for the analysis of nutrients ammonium, nitrate, nitrite, inorganic phosphate, and dissolved silica. 1.8 ml were stored cold in brown glass vials for analysis of dissolved inorganic carbon. 1 ml of porewater was saved for ion chromatographic and dissolved sulfide analysis preserved in 100 µl 5% zinc acetate and frozen.

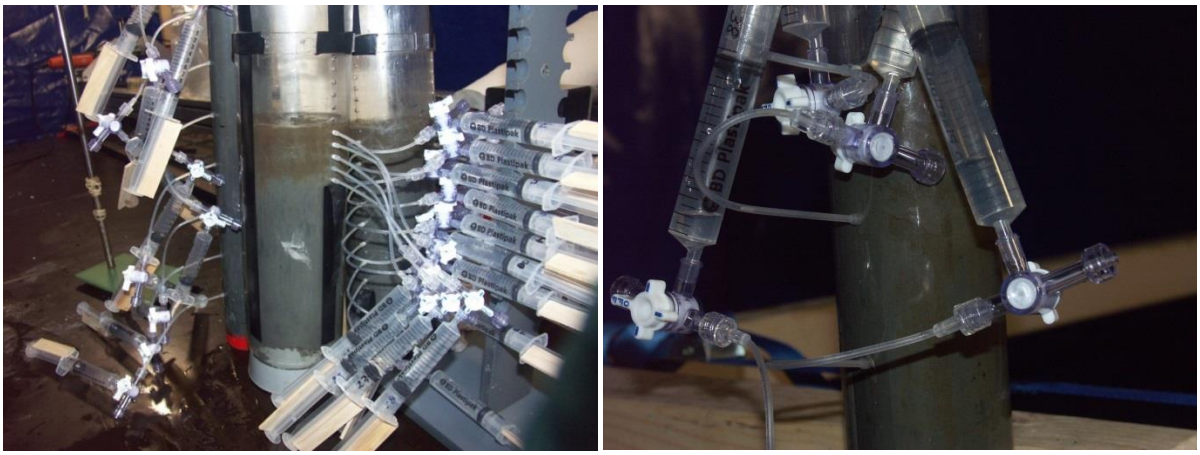


Fig. F. 2.6.1. Porewater extraction with rhizone samplers

Dissolved methane

For sampling, a Multicore and Rumohr core was drilled with holes with a diameter of 0.9 cm in 2-cm intervals and taped with black electric tape. After retrieval of the sediment corer, the core was sampled within 20 minutes by cutting through into taped holed with a carpet knife and inserting a 3

ml cutoff syringe; exactly 2.5 ml samples were withdrawn including two samples from the overlying bottom water and added to a 20 ml serum vial containing 5 mL 5 M NaCl and quickly closed with thick butyl rubber stoppers. For analysis, 3 ml of salt solution were added to the stopper and 3 ml of the headspace gas removed and injected on a SRI GC with FID detector. Operating conditions for the gas chromatograph are described in section 2 water column studies.

Figure F. 2.6.2 Sediment methane sampling through core liner

2.5.3.Methods for high-resolution O_2 profiling

High-resolution O_2-profiles across the water-sediment interface were obtained to determine oxygen penetration depths and the diffusive oxygen uptake across the diffusive boundary layer (Rasmussen and Jørgensen, 1992). The diffusive oxygen uptake reflects the combined aerobic and anaerobic carbon mineralization in sediments with low macrofauna, where bioturbation and bioirrigation are insignificant and where bottom waters are oxygenated (Glud, 2008). Oxygen penetration depths may also serve as qualitative indicators for the reactivity of the degrading organic carbon fraction (Hedges et al., 1999).

Sediment and overlaying water were subsampled with 5.6cm inner diameter tubes within 12h after the Multicorer casts. The tubes were then placed in an aquarium filled with bottom water from the same station, overflowing the sediment core. The water temperature was kept at ~2°C by circulation of cooling fluid through a Julabo cooling unit. A stable diffusive boundary layer above the sediment was generated by passing air from an aquarium pump over the surface through a Pasteur pipette. Bottom water oxygen saturation in the study area was never below 60% indicating well-oxygenated

bottom waters. To permit direct comparison of oxygen respiration activity between different stations, similar starting concentrations of bottom water oxygen were chosen.

At each station six to eight O_2 microprofiles were measured using Clark-type oxygen microelectrodes (OX-50, Unisense) mounted on a manual micromanipulator (MM33, Unisense). O_2 sensors were calibrated with fully oxygenated bottom water from the same station at ~2°C for saturation and Na_2SO_3 dissolved in the same water to obtain zero oxygen concentration. The first profile in each core was measured with a resolution of 1000µm as a quick scan to locate the sediment surface and adjust the depth measuring range. Then the vertical resolution was increased to 100-500µm and additional five to seven profiles were measured at different points on the surface, approximately 1cm apart from each other.

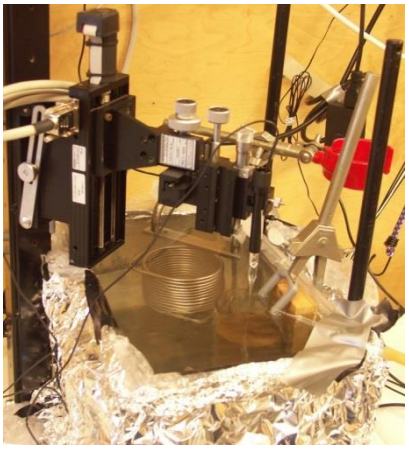


Figure F.2.6.3. Microelectrode setup and close-up of needle sensor

2.5.4. Methods for anaerobic carbon transformation experiments

The only anaerobic carbon transformation rate experiments conducted on board were rate measurements of bacterial sulfate reduction rates with ^{35}S-sulfate tracer using the whole-core incubation method of Jørgensen (1978). Due to time constraints, no other experiments were started on board. Instead, material was collected from 5 stations for detailed analysis on-shore. The planned analysis include measurements described in section 3.4.2.

Intact-core ^{35}S-sulfate reduction rates

Bacterial sulfate reduction is globally the most important anaerobic carbon mineralization process in shelf sediments and reflects the long-term degradation of buried sedimentary organic matter. Sediments for sulfate reduction rate (SRR) determination were subsampled from the Multicorer tubes with acrylic tubes (ID 26 mm diameter) at 18 stations (Table 3.1). SRRs were determined in two parallel cores using a whole-core incubation method (Jørgensen, 1978). $^{35}SO_4^{2-}$ tracer solution diluted in 0.5 mM SO_4^{2-} (<200 kBq per 3 cm^{-3}) was injected into the subcores through injection ports filled with silicone, at intervals of 1 cm down to the bottom of the core (Fig. F.3.4.2). The incubations were carried out for 8 up to 24 hours at 0°C The incubations were stopped by transferring the sediment into 50 ml plastic centrifuge tubes containing 20 ml zinc acetate (20%, v/v).

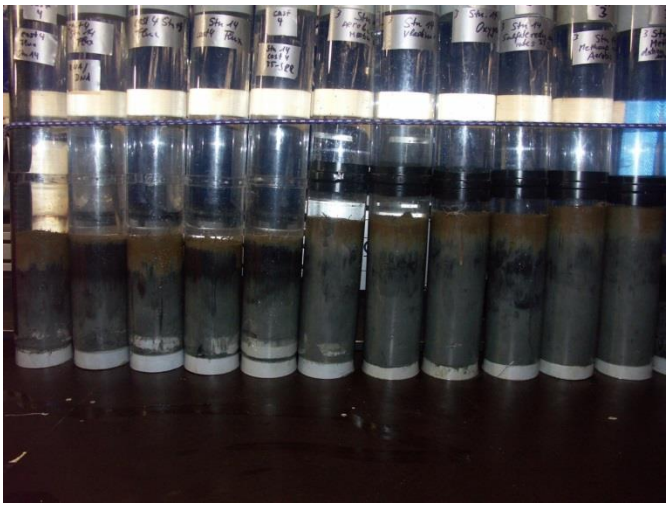


Figure F.3.4. Core photograph of multicore cores from two casts at Station 14. The shorter cores came from cast 3, the longer cores from cast 2.

2.5.5 Intact core incubations: Benthic exchange measurements

Benthic flux experiments were conducted to determine the net exchange rates of oxygen, nutrients, carbon dioxide, and the trace gases methane and nitrous oxide across the sediment-water interface. This was accomplished by incubating intact cores with enclosed overlying bottom waters for periods up to 48 hours at in-situ temperatures after 12 hours of equilibration of opened cores immersed in 25 l bottom water collected from the CTD or the submersible pump near the sediment surface. The water overlying the sediment was continuously stirred with magnetic stirrer bars at a rotation rate of

about $1s^{-1}$. Samples were withdrawn at the beginning and the end of the incubation. Incubations were performed on quadruplicates. A Firesting O_2 fiberoptic planar optode sensor spot was fixed to the inside of the cores for continuous measurements of O_2 concentrations inside the closed cores. The sensor spots were calibrated in fully oxygenated and anoxic water prior to each experiment. Data were continuously acquired every second for a period of 48 hours. Total oxygen uptake of the sediment was calculated from the gradient of the oxygen concentration taking into account water height in the core and the surface area of the cores.

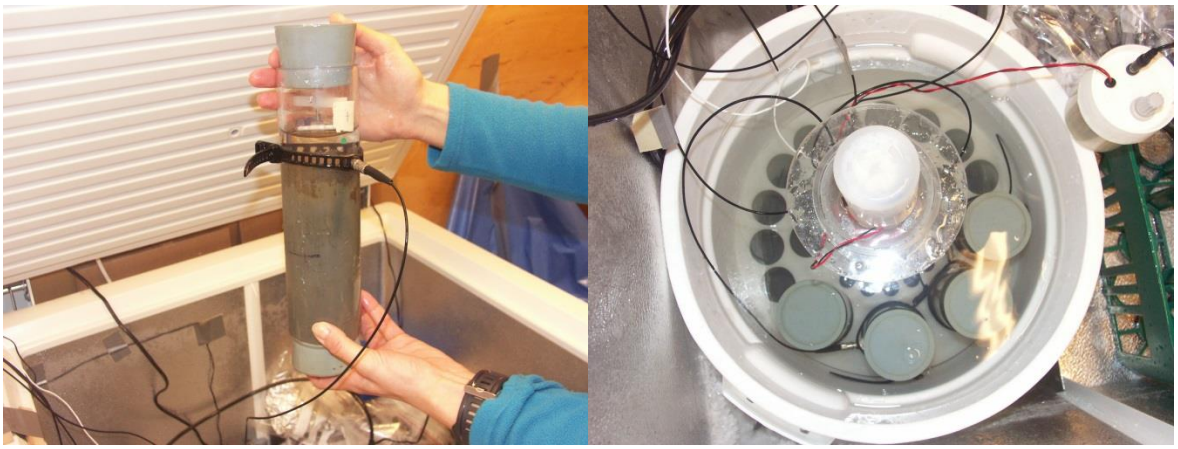


Figure F.2.6.5 Setup of benthic flux experiments. Left panel shows with planar optde spot sensor (green). Right panel shows incubation vessel with central stirring magnet.

2.5.6. Methods for sediment RNA/DNA studies

We will compare microbial community composition and functional gene distributions with our biogeochemical rate measurements. We will identify genes which may be indicators of respiration and methane metabolisms - methanogenesis - methyl co-enzyme M reductase (mcrA) and methane monooxygenase for aerobic methane oxidation. For sulfate reduction, we will target the genes dissimilatory sulfite reductase (dsrA) and adenylyl phosphosulfate reductase (APSR).

Fixation for RNA/DNA extraction

Sediment samples for molecular analysis of microbial community composition were collected at 11 stations (Tab. F3.6.1). 2.5 mL of sediment samples were collected with a sterile 5ml cut-off syringe. Samples were taken from the first 5 cm at the 1 cm depth interval and deeper in the core every 5 cm. Samples were frozen right away at -80°C.

Stable isotope probing

Oxic surface sediments (0-1cm) from 3 stations (Station 13, 50, 53) were collected into $5cm^3$ cutoff syringes in triplicates closed with butyl rubber stoppers, then injected with 25 microliters of $^{13}C\text{-}CH_4$

that was diluted with nitrogen to give final 1 micromolar concentration of dissolved CH_4 in pore water. The samples were incubated for one week at ambient temperature (0-1.5^o C). After that time samples were frozen at -80^o C. Further processing of samples will be conducted at UGA laboratory.

Figure F.2.6.6 Subsampling of sediment for ^{13}C-stable isotope probing experiments of methane oxidation.

WP G CTD-Niskin/Physical Oceanography

The physical oceanography program involved general CTD Niskin water bottle sampling at 63 stations with 77 casts over the continental slope and shelf. Specific objectives were to characterize water masses in terms of salinity and temperature, vertical stratification, surface mixed layer, near bottom temperatures and bottom boundary layers. A special subprogram was to identify submarine canyons at the slope and explore special dynamical features associated with the canyon such as dense bottom currents or up/down welling of ambient water masses. Upward and downward looking ADCPs were mounted on the rosette for measuring the ocean currents during each cast. Salinity samples were drawn from the same bottles as for the chemical water sampling program and were analyzed on a lab salinometer.

CTD/ADCP sampling system

The rosette included 24 Niskin bottles (7 liters) and was equipped with the following sensor packages:

- SeaBird 911 CTD
- Dual SeaBird temperature (SBE 3), conductivity (SBE 04C) and oxygen sensors (SBE 43)
- Turbidity sensor: Wetlabs ECO NTU S/N NTURTD-126
- Altimeter: BENTHOS ALTIMETER PSA-916D
- One upward and one downward looking Teledyne RD instruments WH 300kHz Monitor LADCP

Figure G1 gives an overview of the rosette setup.

Salinity samples were analyzed using a Guildline Autosal instrument which was kept in a well isolated lab container with relatively constant temperature. The salinometer was calibrated using one standard sea water ampule (IAPSO standard sea water from OSIL Environmental Instruments and Systems) before and after each batch of 24 samples.

Figure G1. The rosette setup with the upward and downward looking ADCPs (yellow casing) .

CTD Sampling method

At deep stations the rosette was typically lowered with 0.5 ms^{-1} at the upper 200 meters and then with 1 ms^{-1} from 200 m down to bottom. At the shallow shelf stations (~ 50 meter water depth) the rosette was lowered with about 0.4 ms^{-1}. The rosette was typically lowered to about 2 m above the bottom during flat bottom conditions while it was held at a larger distance above bottom (3-5 m) at deep stations with sloping bottom. The bottles were normally tripped after a 1 minute equilibration at constant depth.

Seven of the CTD casts were so-called drift casts when the ship drifted for a relatively long time and the bottles were all closed near the bottom, at positions based on features seen at the mid-water sonar. In order to ensure ventilation, the rosette was held at a parking depth of about 7 m above bottom between the bottle closures and was lowered to 2 m above the bottom before closing.

WP H Acoustics

The WP H aim was the geophysical seabed mapping using various echosounding techniques. 5 different echosoundes (3 on IB Oden and 2 on Skidbladner, described below) were operated, which provided detailed subsurface sediment structure, high-resolution seafloor morphology and sediment character as well as full water column backscatter structure. These data provide a complex picture of the seafloor, shallow sub-seafloor and water column acoustic structure. These data will provide basis for studying the geology and sedimentary environments of the investigated areas, and help to improve our understanding on the geological implications for the submarine gas and fluid flow processes on the vast Arctic East Siberian Shelf System.

Acoustic Instruments

General comments

Onboard Oden, three acoustic instruments were used to acquire data on the structure of the uppermost sediment pack, the seafloor morphology and the water column above: a Kongsberg SBP120 Chirp Subbottom Profiler, a Kongsberg EM122 Multibeam Echo Sounder and a Kongsberg EK60 Split-Beam Echo Sounder that commonly referred to as "fish finder" because it is mainly used for fish stock assessment. During SWERUS, its primary application was to detect gas bubbles in the water column. The acoustic instruments were operated continuously during the expedition by four operators according to the following watch scheme:

Time (UTC)	Name	
04-12 and 16-20	Riko Noormets*, University Centre in Svalbard	Alexej Khortov, Shirshov Institute of Oceanography
12-16 and 20-04	Nina Kirchner, Stockholm University	Denis Chernykh, Pacific Oceanological Institute, Russian Academy of Sciences

* WP lead

In addition, the small survey launch *Skidbladner* is equipped with a Kongsberg EM2040 multibeam echosounder and a Kongsberg EA600 15 kHz echosounder. *Skidbladner* was deployed on one occasion on 22. July 2014 at the Station 23, and operated by Noormets and Kirchner.

Log sheets were kept and continuously updated for each system, recording general settings and background information such as e.g. ice conditions, but also special missions, incidents, changes in parameters, sound velocity profiles used etc. They are archived together with the raw data.

Multibeam Bathymetric Echo Sounding

Icebreaker *Oden* is equipped with a hull-mounted Kongsberg EM122 12 kHz (1°x1° beam configuration) multibeam echo sounder, which is capable of sounding in the water depths from 20 m to 12 km. EM122 has a maximum swath width up to 75° to either side of the centerline. The current configuration on *Oden* (with existing ice protection) limits the effective coverage to ca. 2x65°. Good data quality for a swath angle of 2x60° is only obtained under favorable conditions such as collecting data in open waters in fair seas or when drifting with the ice. The generally high background noise level of the ship and the effects of ice and air bubbles swept underneath the ship's hull limit the

lateral coverage even more during heavy ice breaking and fast open water transits. During SWERUS-C3 Leg 1 the typical opening angle varied from 45° to 67° to either side of the centerline.

The EM122 also has a number of different sounding modes. With the "Equi-Angle" and "In-Between" modes there is a maximum of 288 bottom detections per swath, however there is a higher density mode ("HD Equi-Distant") that is capable of increasing the sounding sampling per beam, and which makes up to 432 bottom detections possible per swath. The HD equidistant mode was used throughout SWERUS-C3 LEG1. The EM122 also collects water column backscatter data for all beams.

Real-time heading, attitude, position and velocity are provided to the EM122 by the Kongsberg Seapath 320 integrated positioning and motion reference system. This system has been installed on *Oden* in June/July 2013, and replaces the previously used Kongsberg Seapath 200 system**.**

Kongsberg's Seafloor Information System (SIS) software controls the multibeam echosounder and integrates sounding data with the positioning and motion data. Version 4.1.3 (Build 14, DB version 24.0, CD generated Dec. 13, 2013, 10:06:08) was installed by Torgrim Eldevik (Kongsberg) March 28-30 2014 while in port in Luleå and was used for logging the data during the expedition. Installation parameters can be viewed in SIS->Installation Parametres. The software performance was good and stable for most of the time. Occasional exceptions are detailed in the log sheet. No major bugs in the SIS software were observed during SWERUS-C3 LEG1.

Skidbladner is equipped with a bow-mounted Kongsberg EM2040, which is designed for water depths up to 500 m. EM2040 has three frequency bands (200, 300, 400 kHz) and in addition to the bathymetric data it also records water column backscatter data. During SWERUS-C3 survey the system was operated in 300 kHz mode. The data acquired with *EM2040* was processed using Fledermaus software onboard *Oden*.

Subbottom Profiler ("chirp")

Icebreaker *Oden* is equipped with a Kongsberg SBP120 3°x 3° subbottom profiler primarily used for the acoustic imaging of the topmost sediment layers beneath the sea floor. The SBP120 subbottom profiler is an add-on to the EM122 multibeam echosounder, and operates in a frequency range of 2.5-7 kHz. It is integrated with the EM122 and has its own transmit array, whereas a common broadband receiver array is used for the EM 122 and the SBP120 systems. A frequency splitter directly after the receiver staves separates the 12 kHz multibeam signal from the lower-frequency chirp sonar signal.

The normal transmit waveform is a frequency modulated ('chirped' FM) pulse, either swept linearly or hyperbolically. Beyond these standard FM pulse forms, the SBP120 provides a number of additional pulse forms (non-chirp signals) to choose from (for a description of those, cf. Kongsberg's SBP120 operator manual). Chirp signals have a vertical resolution roughly given by the inverse of the sweep range (difference between sweep high frequency f_H and sweep low frequency f_L). With f_H= 7 kHz and f_L = 2.5 kHz, the system provides a maximal vertical resolution of approximately 1/ 4.5 milliseconds (ms) = 0.3 ms. The SBP120 has a beam width of 3°, and it is capable to form up to 11 beams in a transect across the ship's keel direction with a spacing of 3°. During SWERUS-C3 LEG 1, a hyperbolic FM pulse was used throughout, and all 11 beams were logged. As the EM122, the SBP120 receives position and attitude information from the Seapath 320.

KM SBP OPU is the software that controls the chirp sonar. Version 1.5.3 is used, and was installed during March 28-30, 2014, by Torgrim Eldevik (Kongsberg) while in port in Luleå. The settings used during SWERUS are saved to the configuration file C:\Users\dpos\AppData\Roaming\KM SBP OPU\config files\SBP_config_SWERUS_LEG1.

The software performance was good and stable for most of the time with few exceptions detailed in the logsheet. Two potential bugs of the software were observed during SWERUS-C3 LEG 1:

1. After having run the software in "convert" mode, and changing back to "survey" mode, the software did on several occasions neither get the correct time, nor incremented time correctly. Time at starting the "survey" mode appeared to be a random time, and from this, time was incremented in 15-20 s steps. Obviously, this led to wrong time stamps in the raw-files. Position input was unaffected. The time stamp was usually fixed after restarting the software.
2. The "Calculate delay from depth" option did not work. This did not affect data acquisition, because acquisition delay was set manually by the operators during the entire expedition.

EK60 echosounder

In June/July 2013, IB *Oden* was equipped with a Simrad EK60 echo sounder. The Simrad EK60 is a split-beam Windows operated echo sounder with built-in calibration that has become an international standard for fish stock assessment (e.g., cod of length 60 cm can be observed down to a depth of 1100 m). The Simrad EK60 operates at 18 kHz, and its maximum bottom detection range is 7000 m. During SWERUS-C3, the EK60 is used to detect the free gas in the water column and to map the distribution of seafloor gas seeps. Typical pulse length used during SWERUS-C3 LEG 1 ranged from 0.512 ms to 2.048 ms, operated at either 'maximum' or 'interval' ping rate. Kongsberg's ER60 v2.4.3 is the software that controls the EK60 and logs the raw data. The software performance was good and stable throughout the entire expedition.

Skidbladner is equipped with a Simrad EA600 echo sounder, operating at 15 kHz. This is a low-frequenct echosounder used to obtain information about the subsurface sediment thickness and structures. For details, see the echosounders technical specifications and operators manual.

Data acquired by the acoustic systems

General comments

Ca 500 GB of bathymetric- and water column data (EM122), chirp data (SBP120), and data from the water column and uppermost seafloor sediment layer (EK60), respectively, was acquired onboard *Oden* during SWERUS-C3 LEG 1. Onboard *Skidbladner*, 7 GB of bathymetric- and water column data (EM2040) and 300 MB of data from the water column and uppermost sediment layer (EA600) was acquired during a site survey in the Laptev Sea on July 22, 2014.

When SVP's from CTD's (WP G) were not available, the sound velocity through the water column was measured using Expendable Bathymetric Thermographs (XBT's). On *Skidbladner*, sound velocity in the water column was measured using Valeport's Mini SVP.

Data acquisition, storage and backup

EM 122data

The raw data recorded and stored by the SIS are organized by UTC day. A new survey was started every 24 hours at UTC 00.00. Both, *.all files and *.wcd (water column data) were logged. File naming convention is specified in the template chosen when setting up a new survey, and is as follows: LineNumber_yyyymmdd_hhmmss_Oden.all , LineNumber_yyyymmdd_hhmmss_Oden.wcd where *LineNumber* – the number of the line (line numbers start with 0000 whenever a new survey is initiated). System was set up to start a new line/file and increment line numbers every 30 minutes; in

certain situations (surveys, special maneuvers) manual line breaks are were made to facilitate post-processing of the data.

On the multibeam workstation, the raw files are stored in D:\sisdata\raw\YYYYMMDD, and two extra backups are made. One backup is in \\vdata3.polar\Raw Data\EM122\SWERUS-LEG1, and, after running out of space, in \\ vdata.polar\RawDataBackup\EM122\SWERUS-LEG1\). Another backup is kept in the H drive of Stockholm University's portable multibeam computer, H:\SWERUS-BACKUP-RAWDATA-LEG1\EM122\.

SBP120 (Chirp)

The raw files (*.raw format) collected and stored by the SBP are organized by UTC day, with a new survey started every day at UTC 00.00. Files are stored to the local hard drive, D:\RawData\SBP_Data\SWERUS\YYYYMMDD, with file naming convention of the raw files being YYYYMMDDHHMMSS.raw

Two backups are made: one in \\vdata3.polar\Raw Data\SBP120\SWERUS-LEG1\), and, after running out of space, to \\vdata.polar\RawDataBackup\SBP120\SWERUS-LEG1\). A second backup is made on the H drive of Stockholm University's portable multibeam computer, H:\SWERUS-BACKUP-RAWDATA-LEG1\SBP_120\.

Raw SBP data files have also been converted to SEG-Y format, and stored on the H: drive of Stockholm University's portable multibeam computer, H:\SWERUS-BACKUP-RAWDATA-LEG1\SBP120\SEG-Y CONVERTED.

EK60

The data collected by the EK60 is organized by UTC day, with a new survey started every day at UTC 00.00. Data is stored locally on D:\SWERUS-LEG1\YYYYMMDD\, and three types of files are logged: *.raw, *.idx and *.bot files. File naming convention is automatic as follows: Dyyyymmdd-Thhmmss.* for all three file types. Here, *D* indicates that the following characters indicate a datum (*yyyymmdd)*, *T* – indicates that the following characters indicate a time (*hhmmss)*.

Two backups are made: one backup is on \\vdata3.polar\Raw Data\EK60\SWERUS-LEG1\), and, after running out of space, to \\vdata.polar\RawDataBackup\EK60\SWERUS-LEG1\). Second backup copy was saved on H:\SWERUS-BACKUP-RAWDATA-LEG1\EK60\ of the Stockholm University's portable multibeam computer.

Skidbladner

EM2040 and EA600

Data acquired with the EM2040 and EA600 onboard *Skidbladner* (*.all, *.wcd and *.raw files) were stored on the local hard drives, and later backed up to the H: drive of Stockholm University's portable multibeam computer, together with the corresponding sound velocity profiles, H:\SWERUS-BACKUP-RAWDATA-LEG1\Skidbladner\.

Real time, snapshot documentation of data acquired

For all acoustic instruments, screenshots were taken when data observed in real time were especially interesting, and of potential use for subsequent assessment for e.g. coring sites, or areas where detailed surveys were to be undertaken. The screenshots are archived on \\vdata.polar\ScreenDumps_Swerus_LEG1_sorted, where they are sorted according to instrument and day.

Sound velocity profiles

The Multibeam Echo Sounders require sound velocity profiles in order to yield correct soundings.

For the EM122, sound velocity profiles (SVP's) during SWERUS-C3 LEG1 were obtained either from *Oden*'s Seabird 9/11 CTD (operated by WP G) or from XBT casts. Raw SVP's from the CTD were provided by WP G as *.asc files (with corresponding *.hdr files) via \\vdata3.polar\RawData\SVP\SWERUS\CONTAINER2BRIDGE , and further processed in SIS, using its SVP editor tool. Sound velocity profiles were always extended, and thinned whenever appropriate. SVP's from all stations were available to WP H, however, not all of them were used (e.g., multiple SVPs from the same station were typically not used in SIS). A dedicated log sheet for the SVP acquisition was kept along with the acoustic instrument log sheets, and the EM122 log sheet details which SVP was used and when. In addition, XBT casts were made between CTD casts whenever appropriate. Also these casts were recorded in the SVP acquisition log sheet. The raw files (*.edf and *.rdf) are archived on \\vdata3.polar\RawData\SVP\SWERUS, and subsequently processed using the SVP-editor tool in SIS. The EM122 log sheet specifies when SVPs from XBT casts were used.

General Mapping and Site Surveys

Seafloor bathymetric, subsurface sediment and water column data were recorded continuously along the survey tracks, and observations of features of special interest (e.g. seafloor seeps, bubbles in the water column and potentially gas-related features in the sediments) were logged, their position marked on the map (using GlobalMapper software) and screenshots made.

In designated work areas ("hot spot" regions, areas of high methane concentration, canyon mapping for subsequent deployment of oceanographic instruments, continental slope seep studies etc.), systematic site surveys were carried out. Realization of the site surveys depended on ice conditions and time constraints, and therefore some surveys appear less systematic than they were originally planned (Fig. H1).

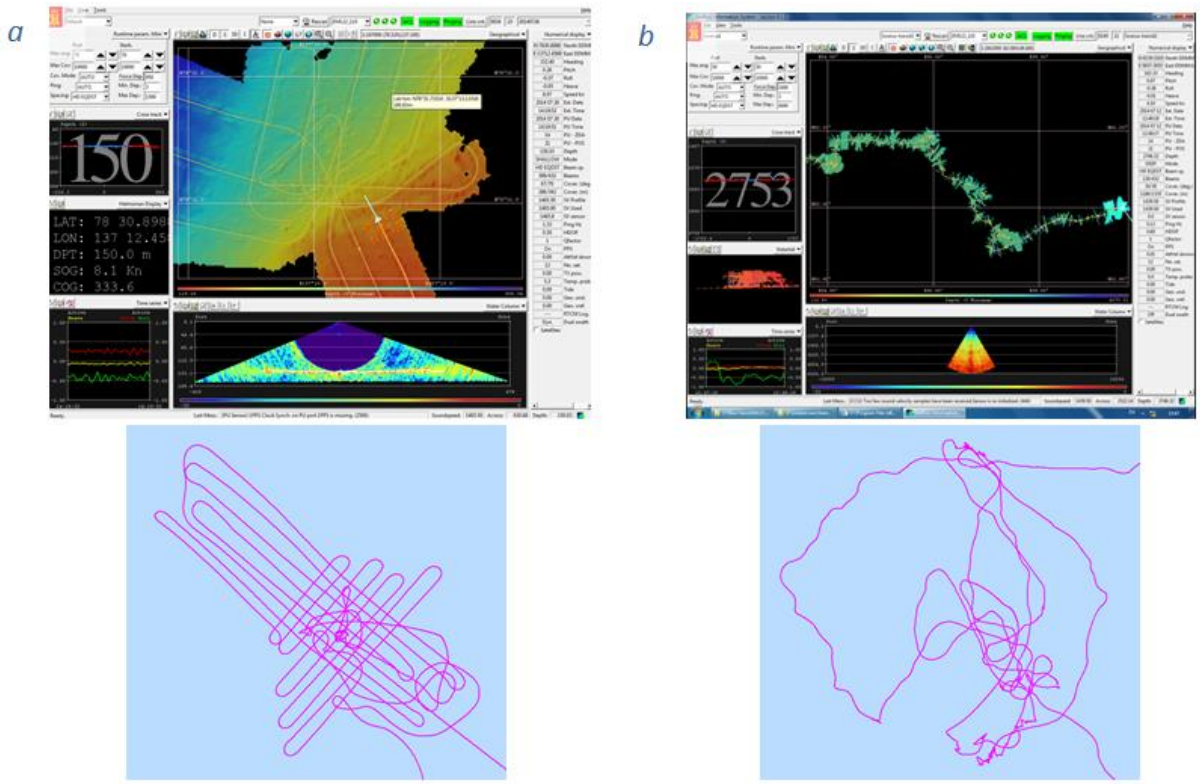


Fig. H1. Example of multibeam coverage and ship's tracks in the open water (a) vs. during ice breaking conditions (b). Effect of the heavy sea ice on the survey execution is noticeable.

During site surveys in selected key areas, the officer on watch steered *Oden* along tracks specified by the multibeam operators. Appropriate overlap of the bathymetric data collected along the survey lines was usually achieved, although, rapidly changing depth sometimes caused significant variations in the overlap. The acquired chirp and water column data were carefully examined for possible appearance of bubbles in the water column, seafloor gas seeps, or acoustic anomalies implying gas in the sediments.

Ship-board data processing

Shipboard data processing was performed for all soundings (*.all files) from EM122 and EM2040, and selected water column data (*.wcd files) from the EM122. Data from SBP120, EK60 and EA600 were not processed onboard. The soundings were processed by loading them into a DMagic project (with editing where necessary), and subsequent export to *.xyz files . These were imported into GlobalMapper for visualization and integration with other survey data.

WP I ACSE – Boundary Layer Meteorology

The overriding goal of the Arctic Clouds in Summer experiment (ACSE), also SWERUS WP I, is to better understand Arctic clouds and their role in regulating the surface energy balance. Clouds are known to have a profound influence on climate, reflecting solar radiation back to space and trapping infrared radiation near the surface. In the Arctic the surface energy balance is dominated by processes relating to low clouds and hence these have an important impact on the freezing and melting of the sea ice.

Low clouds and fog is abundant in the Arctic, climatologically cover the surface 60-100% of the time, more in summer than in winter. In the summer Arctic where the sun is low but above the horizon the whole diurnal cycle and in particular over sea ice, with a high reflectivity (albedo), the effects of low clouds is different from similar clouds over the world oceans. In short, while low clouds reflect solar radiation and hence limit the available energy at the surface, they absorb longwave radiation from the surface but also emit longwave radiation back to the surface, thus increasing the available energy at the surface. With a high surface albedo, the longwave ("greenhouse") effect often dominates and the surface is heated by low clouds and the surface temperature often falls when it becomes clear. This is also depends on and interact with the dynamics of the system, both the local cloud dynamics and the larger-scale motions of the atmosphere, which brings air of different origin to a given location.

Low clouds that has a layer of liquid water are efficient at emitting longwave radiation, thus heating the surface but also cooling the cloud top. The latter destabilizes the vertical column of air and drives buoyant vertical motions – turbulence – that tends to mix the lowest layers of the atmosphere; the boundary layer. If the cloud top temperature is below zero precipitation may in the form of ice crystals may form in the super cooled liquid layer; so called mixed-phase clouds. Such clouds are common in the Arctic but the interplay between radiation, turbulence, cloud microphysics and precipitation is poorly understood and hence weather and climate models struggle to get this right.

The large-scale atmospheric flow may bring warm and moist from south or cold, dry and clean air from north. As new air masses are gradually brought into balance with the local surface, especially over melting sea ice where the surface temperature is locked to near freezing, this also affects the properties of the clouds and hence the surface energy balance.

The goal of ACSE is to understand these processes better, and to do so necessitates simultaneous measurements of the vertical structure of the atmosphere in general and cloud properties in particular and also the energy fluxes at the surface, and to do so on a moving ship is a challenge. We accomplish this by continuous observations through the whole expedition, regardless of station or transit between stations, starting off Tromsö, Norway, and ending off Barrow, Alaska, using three main types of instrumentation systems; these are described below as are the involved technology and methods.

General meteorology observations

The general meteorology observations provide context to the more specialized observations described below. This program has two main components (total amount of data is 4GB for the weather station and 5GB for the soundings):

1) Weather station: This consists of a combination of instruments located on and in front of the railing in the forward center of the 7th deck of Oden, logged on a common logger all sampled at 1Hz:

a. Wind speed and direction with a Gill 2D Ultrasonic anemometer
b. Position and horizontal motions with a Garmin GPS
c. Temperature and relative humidity with a platinum resistor thermometer and a capacitive hygrometer, respectively
d. Local atmospheric pressure with an electronic barometer.
e. Incoming short and longwave radiation are measured with Eppley pyrano- and pyrgeometers, respectively, mounted on a gimbaled platform.
f. Additional to this, but logged separately at one minute intervals and sampled as one minute averages, are a visibility sensor and a cloud base lidar (so called ceilometer). Both are based on lidar technology and are.

All these instruments, with the exception of the GPS system and the ultrasonic anemometer, are from Vaisalla Oy.

2) Radiosoundings: Soundings through the entire troposphere and into the stratosphere are performed with free-flying helium-filled balloons carrying Vaisalla RS92 sondes; soundings are released every 6 hours from the helideck of Oden. The receiving station for the system is located on the 7th deck, in the port side container. Each sonde carries a barometer, thermometer and a hygrometer providing profiles of the state of the atmosphere; the techniques used are similar to instruments on the weather station but less expensive since they are only used once. Additionally, a GPS sensor on the sonde measures the track of the sonde; this is the same as the wind, so the sonde also provide profiles of wind speed and direction.

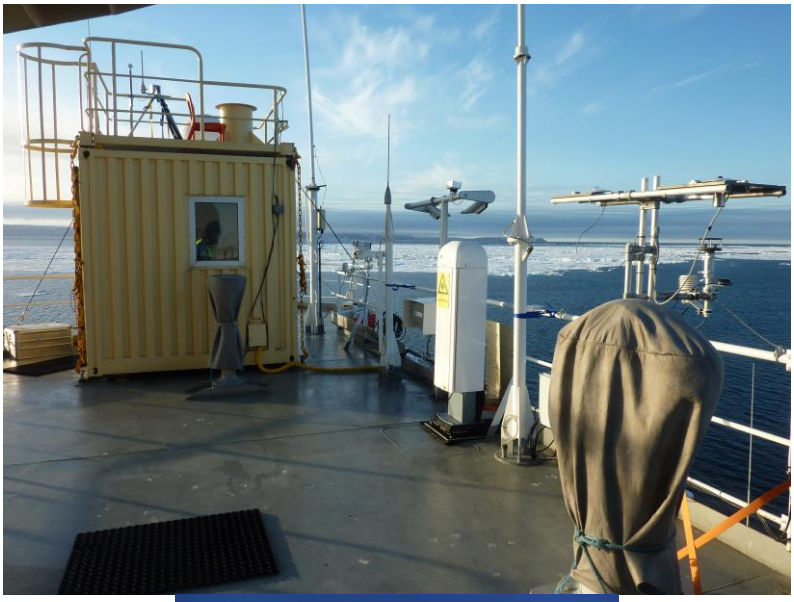


Figure MT1. Photos of (left) the 7th deck weather station with the radiosounding station in the small yellow container, and (right) a sounding lounge from the helipad. The left photo shows (from left to right) the sounding station and the weather station's instruments: the visibility sensor, the ceilometer and the stand for wind temperature/humidity and radiation observations.

Surface flux observations

Near surface atmospheric turbulence and the associated turbulent exchange of momentum, heat, water vapor and aerosol particles were made through the cruise, using so-called eddy-covariance technique. The system consists of several instruments installed at the top of the foremast.

1) At the top of the mast (total amount of data for leg 1 is 70GB):
    a. One Metek sonic anemometer measures the 3-dimensional turbulent velocity of the air flow at 20Hz. Along with this an XSens MTi-G-700 inertial motion unit that provides 3D accelerations, rotation rates, and GPS position at 40Hz. The frame of reference is aligned with that of the sonic anemometer. The measurements are combined with those from the ship's navigation system (heading, speed and course over ground) to correct the turbulent wind measurements for ship motion.

b. One Licor LI-7500 open path gas analyzer – water vapor concentration also at 20Hz; when combined with the vertical velocities from the Metek it provides turbulence fluxes of water vapor.
c. One CLASP aerosol spectrometer sampled at 10Hz. This provides particle size spectra for the size range 0.25 < R < 18.5µm, with 16 logarithmically spaced size bins.
d. Temperature and relative humidity sampled at 1Hz from instruments mounted in a fan-aspirated and radiation protected shield.

2) One third down in the mast:
a. One CSAT-3 sonic anemometer mounted on a 1.5 m boom directed forward measures the 3-dimensional turbulent velocity of the air flow at 20Hz. On the boom along with the CSAT an XSens MTi-G-700 inertial motion unit provides 3D accelerations, rotation rates, and GPS position at 40Hz. This will be treated the same way as the Sonic
b. Temperature and relative humidity sampled at 1Hz from instruments mounted in a fan-aspirated and radiation protected shield.

Figure MT2. Photos of the turbulence/surface flux instruments with (left) the top Metek/Licor/CLASP instrumentation with its motion sensor, and (right) the CSAT sonic on its retractable boom with the motion sensor mounted.

In addition to this flux system we sampled the high-rate data from Patrick Crill's LGR mass spectrometer system on the mast platform, drawing its sample from the top of the mast. This will enable turbulent fluxes of methane and carbon dioxide to be estimated.

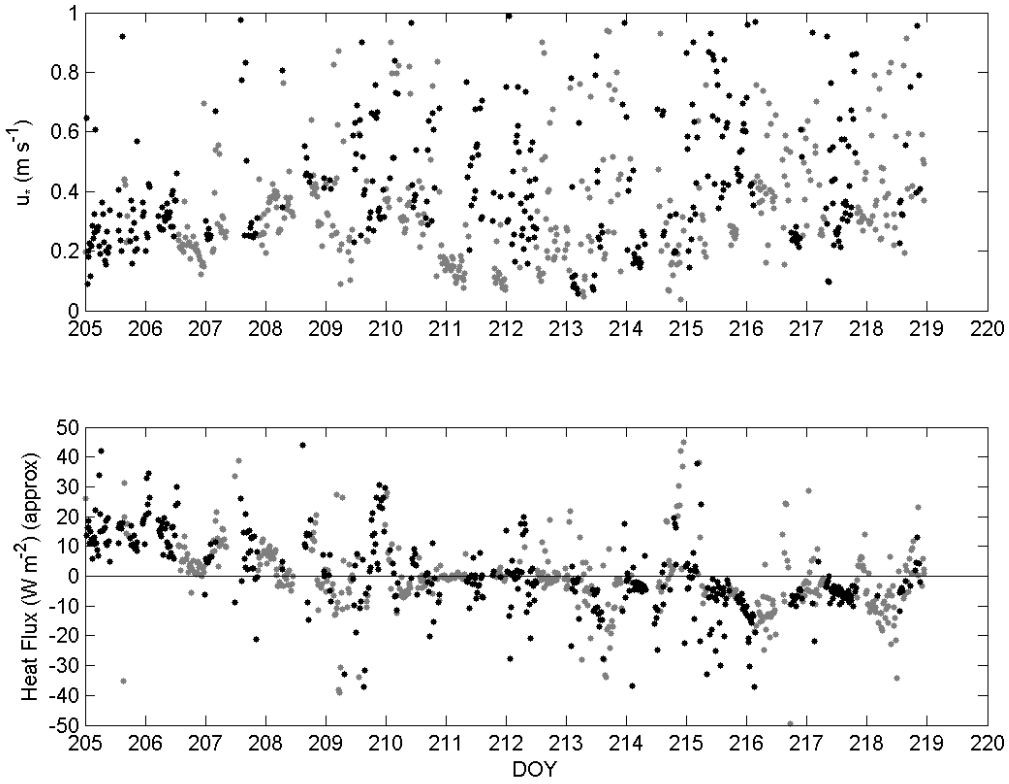


Figure MT3. Plots of very preliminary (top) momentum flux and (bottom) the latent heat flux as a function of day of the year (DoY). These are computed from the eddy covariance instrument (Metek) on top of the mast and has been corrected for ships motion but not quality controlled.

Surface based remote sensing

Surface based remote sensing relies on either active instruments (radar or lidar) or passive instruments (microwave radiometers). The former transmit energy and senses both the strength of the returned signal and its Doppler shift, while the former senses naturally emitted radiation from the atmosphere at different wavelength, emitted by different atmospheric constituents according to their temperature. We have deployed several such instruments.

1) W-band Cloud Radar**:** This is a NOAA-built cloud radar that was operated from the sea container in position 11 on the roof of Oden's foredeck lab. The system operates at 94-GHz and nominally points vertically. It is operated on a motion stabilizing platform designed to maintain the radar level in spite of ship's pitch and roll motions. Measurements include profiles of the full Doppler spectrum that results from backscatter of transmitted signals from hydrometeors in the vertical column. From the spectrum, standard radar moments are derived, including the reflectivity, mean Doppler velocity, and Doppler spectrum width. The system has operated near-continuously for the duration of Leg #1. Many files are produced each day including hourly raw Doppler spectra, Doppler moments, instrument health messages, and output from the positioning system

for the motion stabilized platform. Total data volume for Leg #1 is: 60 GB (moments); 900 GB (spectra); 9 GB (logs).

2) 449-MHz Wind Profiler**.** The wind profiler was also built at NOAA and is a phased-array Doppler radar operating with 5 fixed beams. The antenna is mounted above the containers mounted above Oden's main lab. It has two operational modes with vertical resolutions of 62 m and 400 m. Transmitted pulses reflect off of radial gradients in the atmospheric refractive index. Using Fourier transform techniques, the system converts raw reflected signals into averaged Doppler spectra that are then analyzed to produce information about the radial velocities and backscatter magnitude. These data are used to estimate hourly profiles of wind speed and direction. The 449 MHz radar operates continuously, and has been very reliable during the cruise but continues to have issues with so-called ground clutter; effects on the so-called side lobes of the instrument by the ocean surface especially as it passes by when the ship is moving. The system produces two daily raw files and two daily, first-estimate wind profile files. Total data volume for Leg #1: 46 GB.
3) LIDAR: A Halo Photonics scanning Doppler lidar was installed on the roof of the CTD winch container. The lidar measures the intensity of backscatter laser light, providing a measure of atmospheric particle loading and along-beam Doppler wind speed. Cross-polarization provides additional information on particle shape along cloud droplets and ice crystals to be distinguished. The lidar operated in multiple scan modes. Most of its time is spent staring vertically upwards to measure boundary layer structure and cloud. Every 10 minutes a 5-point wind profile is measured (vertical + 4 off-vertical (70° elevation) beams at azimuths of 0,90,180,270 allow a single wind profile to be estimated), every hour 0-90° elevation scans were undertaken forward over the bow and 30° either side, along with a single horizontal scan at an elevation of 0°. To keep the lidar pointing in the correct attitude it was mounted within a motion stabilized platform that keeps it within about 0.1° of the horizontal most of the time. The residual linear velocity of the platform (heave and ship horizontal motion) is monitored and can be used to correct the lidar Doppler velocity for ship motion. Data volume approximately 1GB per day (processed output) + 19GB per day (raw binary data files). The lidar data will be used to provide boundary layer wind profiles, information on vertical structure and mixing, turbulence intensity throughout the depth of the boundary layer, and information on cloud phase.
4) Scanning Microwave Radiometer: The HATPRO scanning radiometer mounted on the roof of the 4th deck triple-container lab makes a scan from 0-90° elevation over the bow, measuring the microwave brightness temperature at multiple wavelengths. Given an initial best guess of the vertical profile of temperature and humidity, high temporal resolution (5 minute) profiles of temperature and humidity, along with integrated precipitable water vapor and liquid water path can be retrieved. During the cruise the initial best guess profile is provided by a climatological profile for the Arctic. In post processing the radiosonde profiles will be used. Cruise retrievals are available immediately while reprocessed data will be available in approximately 6 months. Approximate data volume: 123MB per day, 5.7GB total.
5) Microwave Radiometer (MWR)**:** A Radiometrics MP-3058 multi-channel microwave radiometer was installed on the corner block of the CTD winch container in position 10 on Oden. It measures downwelling sky brightness temperatures in the range of 20-30 GHz, to derive the integrated liquid water and water vapor in the atmosphere (see Figure 1), and in the range of 50-60GHz, to derive profiles of atmospheric temperature and moisture. First-estimate geophysical parameters are derived operationally with a default retrieval algorithm that has been applied during the cruise. Best-estimate geophysical parameters will be derived post facto using input from radiosonde measurements of temperature and moisture structure during the cruise itself. Operations during leg #1 of the cruise have been fairly clean with minimal interruption. Data are provided in a suite of 5 ASCII files (lv0, lv1, lv2, tip, ser), all containing header information that

describes the fields, measurement units, operational modes, etc. "ser" files are instrument logs, "tip" files contain calibration information, "lv0" files contain raw voltage measurements, "lv1" files contain brightness temperature measurements, and "lv2" files contain the first-estimated retrievals of geophysical parameters. Total data volume for leg #1: 750 MB.

6) Ceilometer**:** A Vaisalla CT-31 ceilometer was installed to the rear of the sea container in position 11. It uses a near-infrared laser to derive the atmospheric backscatter and specifically to derive information on the cloud base height (see Figure X) and vertical visibility height. Cloud base height estimates for up to 3 layers, as well as the depth of penetration into low-level fogs, are derived operationally by the Vaisala software. Operations during leg #1 of the cruise have been continuous except for about 1 day when a computer failure occurred. Other than correcting the height measurements for the height of the ceilometer relative to the sea surface the raw measured data set will likely be the final data set. A single daily ASCII file is typically produced in standard Viasalla formats with naming convention CYMMDDhh.DAT, where Y is the last digit of the current year, MM is the month, DD is the day, hh is the hour. Total data volume for leg #1: 1 GB.

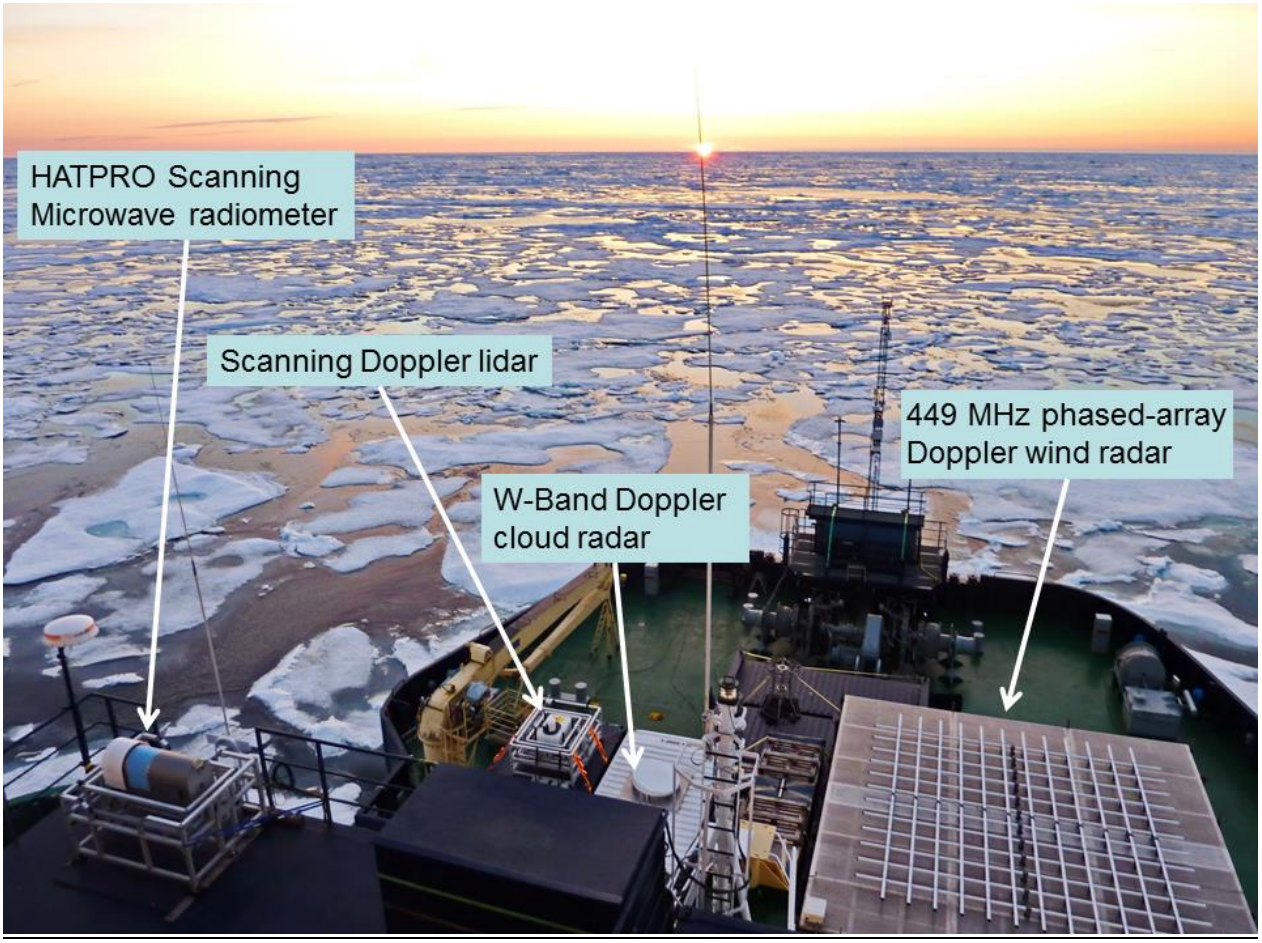


Figure MT4. Photo of remote sensing instruments on Oden's foredeck. Hidden from view are the MWR radiometer, on same container as the lidar, and the lidar ceilometer behind the radar container.

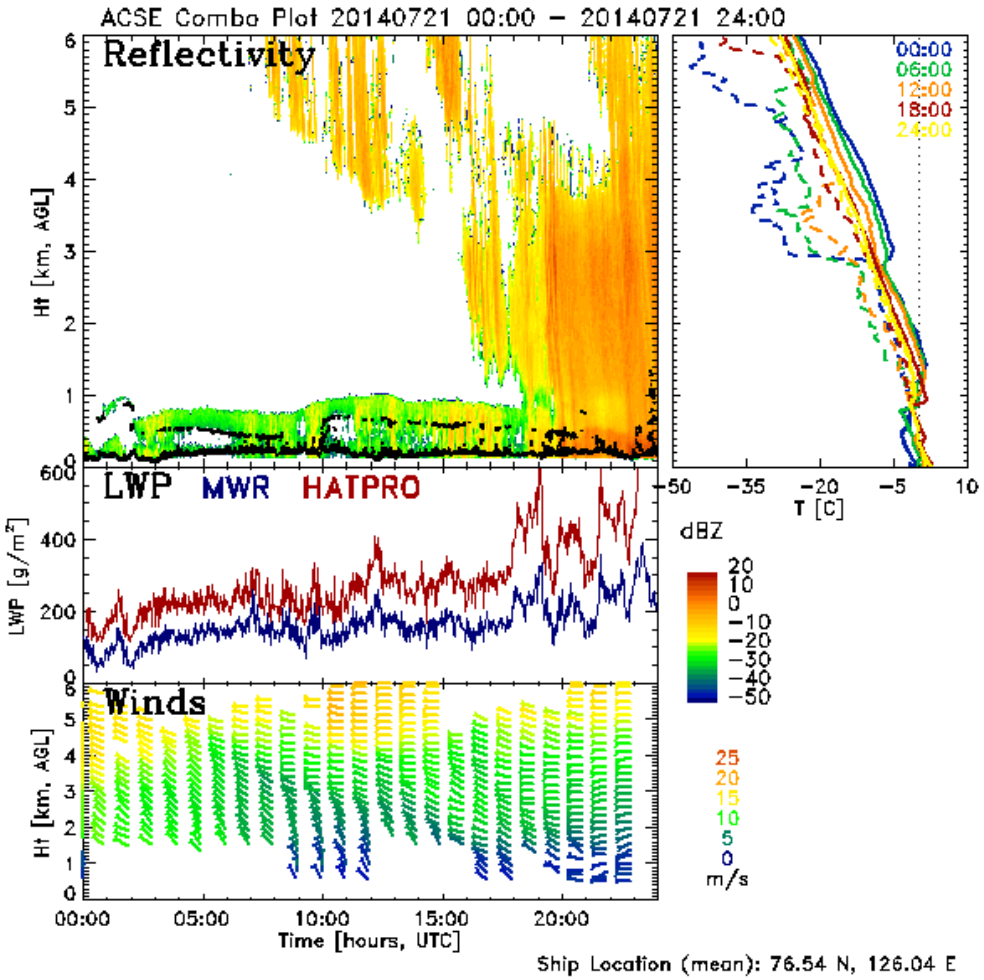


Figure MT5. Example of results showing measurements on 21 July 2014, including time-height contour of W-band radar reflectivity including ceilometer cloud base height (black dots) in top panel, derived cloud liquid water path from microwave radiometer and HATPRO in middle panel, derived profiles of wind speed and direction from the 449-MHz wind profiler in the bottom panel, and radiosonde temperature profiles in the panel to the right for context.

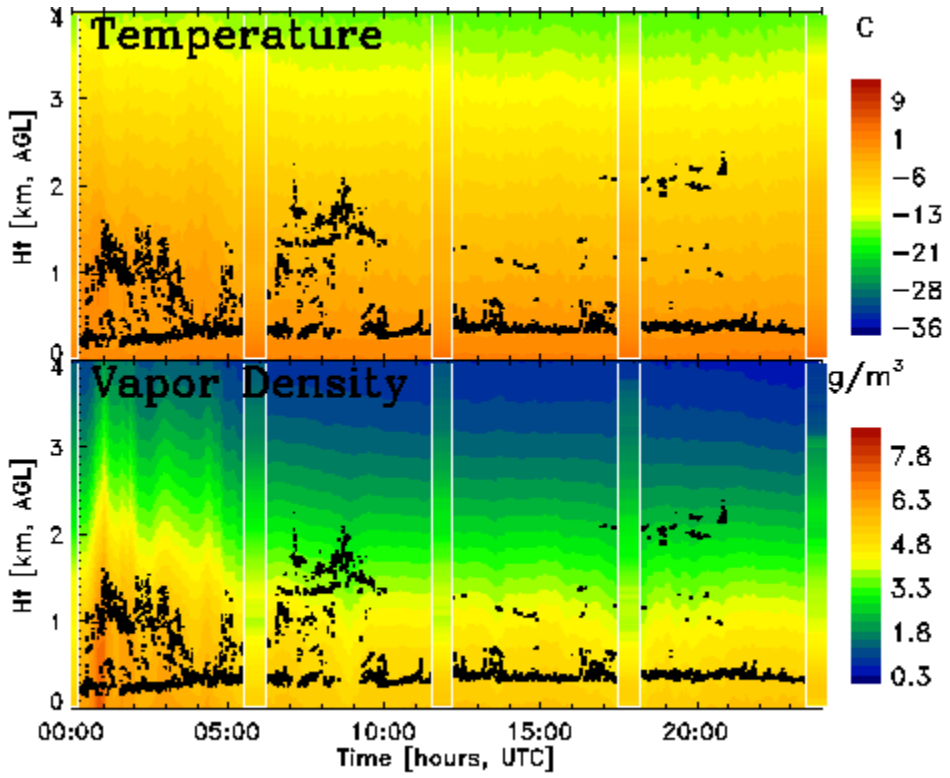


Figure MT6. Example of HATPRO temperature and water vapor profiles as a function of time, with corresponding radiosonde profiles overlaid within white lines.

Miscellaneous observations

Some complementary observations were also made, in support of the main observations:

1. Surface skin temperature: Infrared surface temperature estimates were made with two Heitronics KT15.85 IR temperature sensors. Both are mounted on the starboard rail of the 7th deck, one pointing about 45° forward and one 45° aft. Both are angled out to measure outside the ship wake in open water. Data is available immediately, however, a refined and quality controlled data set will be available within about 6 months. Data volume: 11MB per day.
2. Sea surface temperature: A simple measurement of the sea surface temperature was made using a thermistor in a long hose; the "Sea Snake". This was deployed off the port side of Oden when in open water; the sensor was generally not deployed while in ice to avoid damage to the system. Total data volume for leg #1: 3.3 MB
3. Surface imagery: Three webcams were installed on the rail on 7th deck, pointing forward, port and starboard. Each camera has a 90° field of view and records one image per minute. Imagery will be used to provide a visual record of the surface conditions through the cruise, and potentially estimates of local ice fraction. Data volume: approximately 250GB.
4. Surface waves: Datawell DWR-4-G Waverider buoy was deployed, tethered to the ship on a 200-m line. The waverider measures the 3-dimensional velocity of the buoy, integrating to obtain the displacements, from which directional wave spectra and basic wave statistics can be derived: significant wave height, wave periods (zero crossing, period of spectral peak, 'energy' period, etc.) The very short periods on station in open water, and the high ice concentration for the majority of the cruise meant that there were few opportunities to deploy the buoy; in the end it was deployed just 4 times: July 18, 19, and August 14 & 15, for a period of just 1-2 hours each.

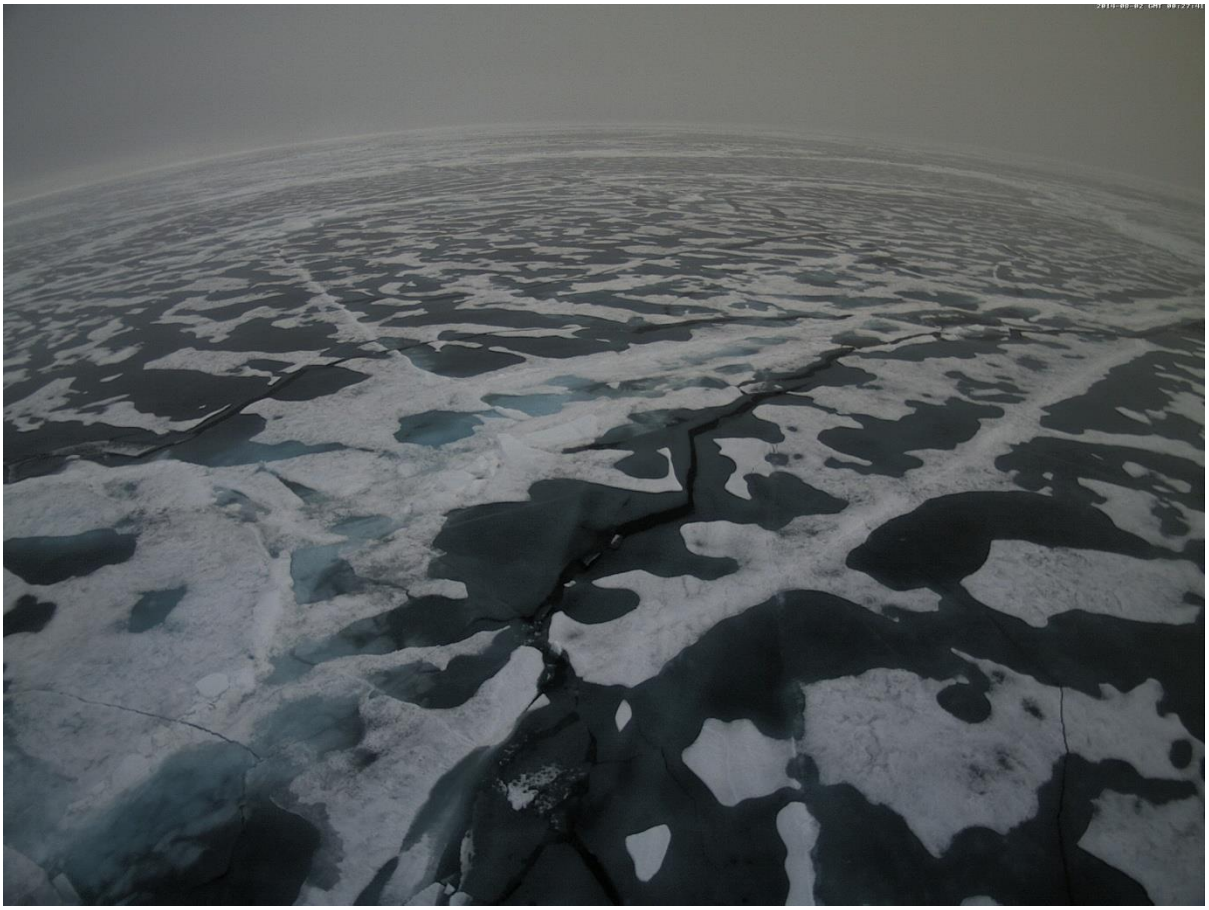


Figure MT7. Sample image from web-cam at the 7th deck.

Results – Metadata, data, samples collected

WP B Water Column Biogeochemistry

Inorganic carbon, organic carbon and nutrients (TC, Alk, O2, pH, POC, DOC, TOC, N, P, Si)

Metadata description of observational dataset

The total number of samples that were determined on board for TC, Alk, O2, pH, POC, DOC, TOC, N, P, Si collected at 67 stations are shown in the following table:

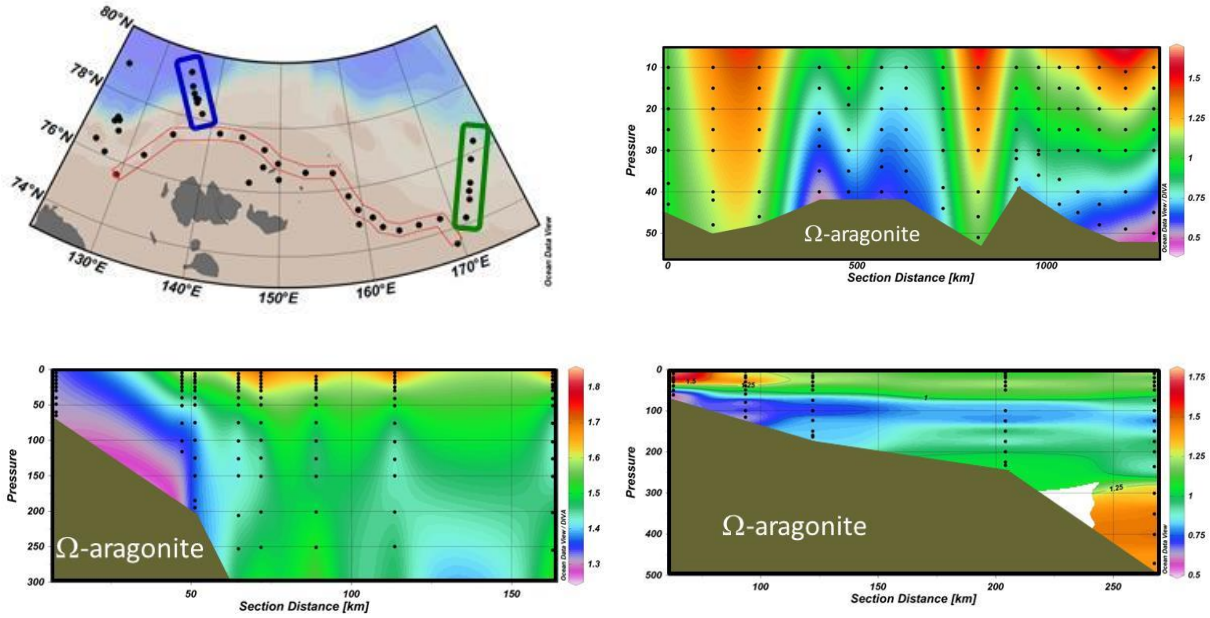
Station Nr	Lat °N	Lon °E	Maximum Depth m	DOC	TOC	Nutrients	Oxygen	Total Alkalinity	DIC	pH
1	78.93	125.22	3126	9	22	22	21	22	22	22
4	77.87	126.64	2098	11	21	21	21	21	21	21
5	77.28	126.99	830	13	18	18		19	19	19
6	77.14	127.38	87							
7	77.20	127.34	323	4	15	15		14	14	14
8	77.22	127.30	511	10	14	16	17	17	17	17
10	77.22	127.21	752		3	3		3	3	3
13	76.78	125.82	69	6	11	11	10	11	11	11
14	76.90	127.80	62	9	13	11	11	11	11	11
15	77.14	126.79	385	8	12	12	12	12	12	12
16	77.11	126.59	271	5	11	11				
17	77.11	126.53	198							
18	76.40	125.45	50	6	9	9	9	9	9	9
19	76.45	126.20	49	6	9	9	9	9	9	9
20	76.45	126.74	50			9				
21	76.13	127.18	43			9	9	9	9	9
22	76.11	128.24	46			9				
23	76.17	129.34	51	2		9	9	9	9	9
24	75.60	129.57	44	7	8	8	7	8	8	8
25	76.08	130.92	46	3	8	8				
26	76.47	132.04	48	7	9	9	9	9	9	9
27	76.94	132.23	44	2	8	8				
28	77.34	134.98	46	2	9	9		9	9	9
29	77.76	136.51	53	7	10	10				
30	78.18	138.35	65	7	10	10	10	10	10	10
31	79.36	135.22	3084	9	23	24	22	23	23	23
33	78.94	135.98	2366	8	22	22	22	22	22	22
34	78.74	136.46	1886	3		21	22	22	21	21
35	78.61	136.91	679	9		20	20	20	20	20
36	78.59	137.22	397	6	17	17	17	17	17	17
37	78.52	137.17	198	7	14	14	14	14	14	14
38	78.48	137.24	116	7	11	11	10	11	11	11
39	77.68	141.37	40	7		8	8	8	8	8
40	77.67	144.61	42	8	8	8	8	8	8	8

Station Nr	Lat °N	Lon °E	Maximum Depth m	DOC	TOC	Nutrients	Oxygen	Total Alkalinity	DIC	pH
41	77.32	147.83	40	7	8	8	8	8	8	8
42	76.90	149.76	40	7	8	8	8	8	8	8
43	76.78	147.79	38	7	8	8	8	8	8	8
44	76.27	146.05	38	6	8	8	8	8	8	8
45	76.42	148.12	36	3	8	8				
46	76.40	149.88	36	7	8	8	8	8	8	8
47	76.52	150.80	40	1	8	8				
48	76.61	153.36	44	7	8	8	8	8	8	8
49	76.53	156.92	51	8	9	9	9	9	9	9
50	75.76	158.53	37	5	8	8	8	8	8	8
51	75.29	159.47	36	7	8	8	8	8	8	8
52	74.98	161.02	43	6	8	8	8	8	8	8
53	74.96	161.08	43	7	8	8				
54	74.99	160.98	43	8	8	8				
55	74.84	159.33	42	5	6	8	8	8	8	8
56	74.63	161.96	45	10	8	8	8	8	8	8
57	74.42	163.69	48	1	8	8	8	8	8	8
58	74.43	166.02	49	8	8	8	8	8	8	8
59	74.42	168.50	50	3	8	11	8	8	8	8
60	73.51	169.48	38	10	8	9	8	8	8	8
62	74.19	171.30	50	10	9	9	9	9	9	9
63	74.68	172.39	62	6	8	8	8	8	8	8
64	74.93	172.75	116	6	10	10	10	10	10	10
65	75.16	173.21	164	10	12	12	12	12	12	12
66	75.83	174.41	233	10	14	14	14	14	14	14
67	76.32	175.61	471	12	17	17	17	17	17	17
Total				365	544	636	496	546	545	545

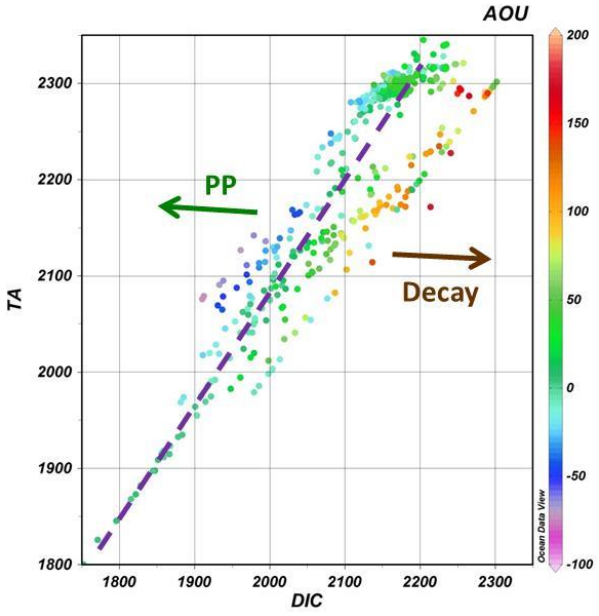
Data and sample set

All samples for oxygen, TA and pH were determined on board and some specific feature can be seen at a first glance of the data. The natural ocean acidification by decay of organic matter is visible as under-saturation of aragonite in the bottom water of large parts of the East Siberian Sea but not in the Laptev Sea. This under-saturated water also spreads out along the halocline of the deep basin north of the East Siberian Sea.

Another feature is that the effect of primary production and decay of organic matter can be evaluated from the TA to Dissolved Inorganic Carbon (DIC) relationship. The deviation from a strait mixing line correlation illustrate the uptake or release of DIC from these processes as clearly seen in the oxygen concentration relative to saturation with the atmosphere. Very close to a 1:1 relationship of DIC to AOU is seen. A more thorough evaluation of these data has to be done in order to evaluate the quantitative magnitudes.



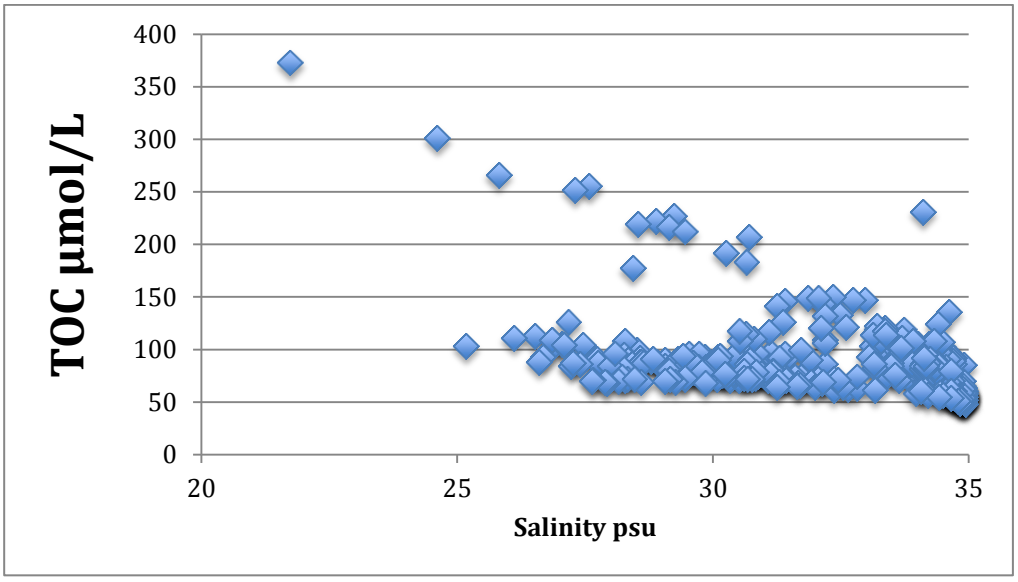
Saturation state of aragonite as computed from Total Alkalinity, pH, salinity and temperature along three sections: Upper right, along the shelf (noted red in map), lover left, across the Laptev Sea shelf break (blue in map), and lower right, across the East Siberian Sea shelf break (green in map).



Total Alkalinity versus Dissolved Inorganic Carbon (DIC) of all samples analysed during Leg 1 of SWERUS C3. The data points are colour coded by its Apparent Oxygen Utilization (AOU). The effects of primary production (PP) and decay of organic matter are illustrated by the green and brown arrows respectively. A mixing line between the surface water and that of Atlantic Ocean origin is indicated by the interrupted line. All units are in µmol/kg.

Preliminary results from on board analyses of total organic and dissolved organic carbon are available whereas the analyses of the stable isotope composition of dissolved and particulate organic carbon (δ ^{13}C-DOC, δD-DOM, δ ^{15}C-DON; δ ^{13}C-POC, δD-POM, δ ^{15}N-PON) will be performed in Stockholm. A property salinity plot shows the dissolved organic carbon concentrations a function of salinity. A first analyses may indicate two different end members, whereas the higher TOC concentrations may be an indication of Lena river water and the lower TOC concentrations forming a straight in the

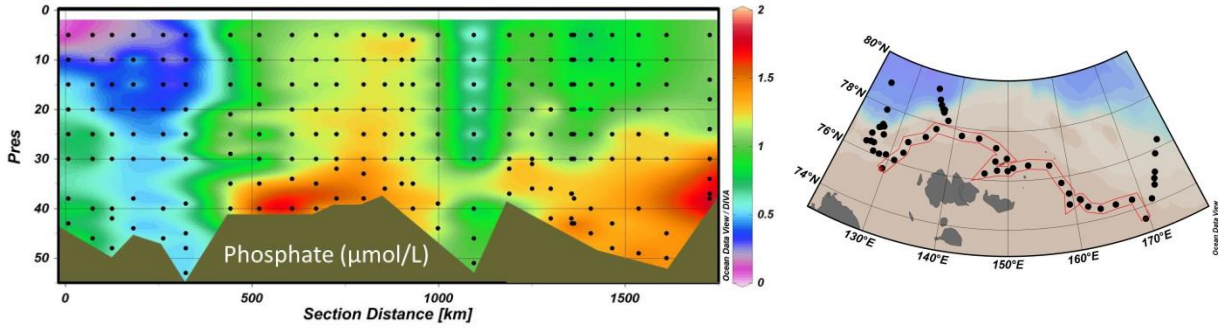
property-salinity plot may be either an other river water end-member (for example Kolyma river) or a result from sea water melting.

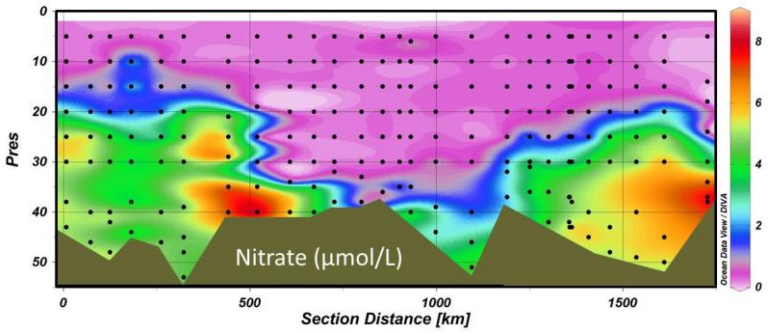


Mixing diagram of TOC vs. salinity along the Siberian Shelf

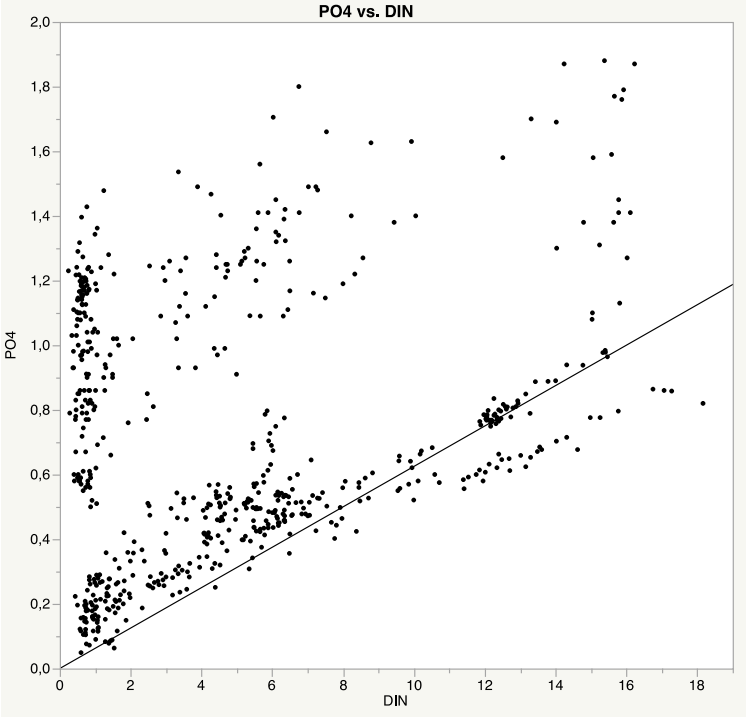
The nutrient distribution clearly shows several regimes within the outer shelves of the Laptev and East Siberian Seas. The nitrate concentrations are close to zero throughout the top 20 to 30 meters while phosphate only has very low concentrations in the Laptev Sea. This agrees with earlier studies that has reported influence of Atlantic water characteristics in the Laptev Sea but of Pacific water in the East Siberian Sea. The latter has a deficit in nitrate compared to the classic Redfield ratio as a result of degradation of organic matter in low oxygen environment. The very low concentration of nitrate all along the section is due to primary production, which also can be seen in elevated oxygen concentrations at many stations.

The bottom waters are high in nutrients caused by degradation of organic matter, most likely mainly at the sediment surface. This is less pronounced in the Laptev Sea where we had open water that promoted wind mixing more or less throughout the water column.





Concentration of phosphate and nitrate along the outer shelf of the Laptev and East Siberian Seas. Positions of the stations are indicated by red in the map.



N/P ratio of dissolved inorganic nitrogen (NO2/3 + NH4) and phosphate

We anticipate that the final analyses of the inorganic carbon, organic carbon and nutrients (TC, Alk, O2, pH, POC, DOC, TOC, N, P, Si) data will continue over the next 4-12 month.

Gaseous and dissolved inorganic carbon species and their stable isotope composition

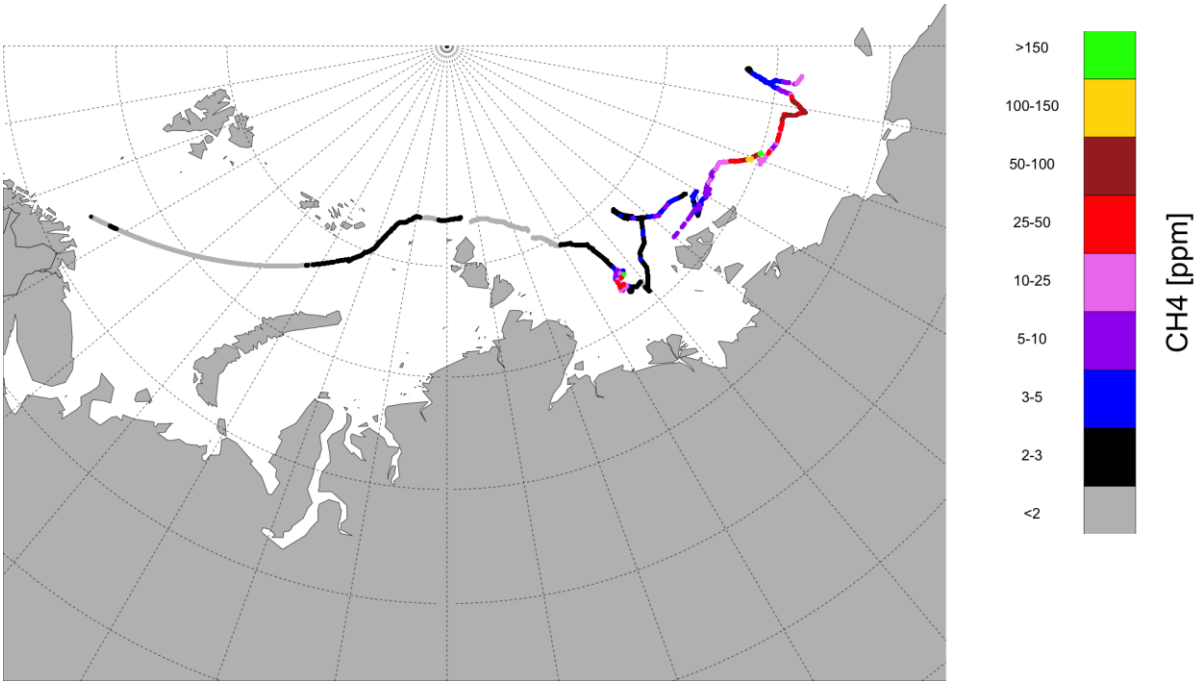
Metadata description of observational dataset

A continuous data set of CH4 and CO2 and the δ^{13}C-CO2 in surface water (containing over 250.000 data points) was generated by the WEGAS system during the first leg of the SWERUS-C3 expedition. In addition 195 SCIGASS samples and δ^{13}C-DIC (vertical profiles) were taken at 39 stations with 5 vertical water column samples per station on average.

Stations sampled for SCIGASS and δ^{13}C-DIC analyses: 1, 4, 5, 7, 8, 13, 14, 15, 16, 18, 19, 21, 23, 24, 26, 29, 30, 31, 33, 36, 37, 38, 39, 40, 42, 43, 46, 48, 49, 51, 53, 54, 56, 58, 60, 62, 64, 66, 67

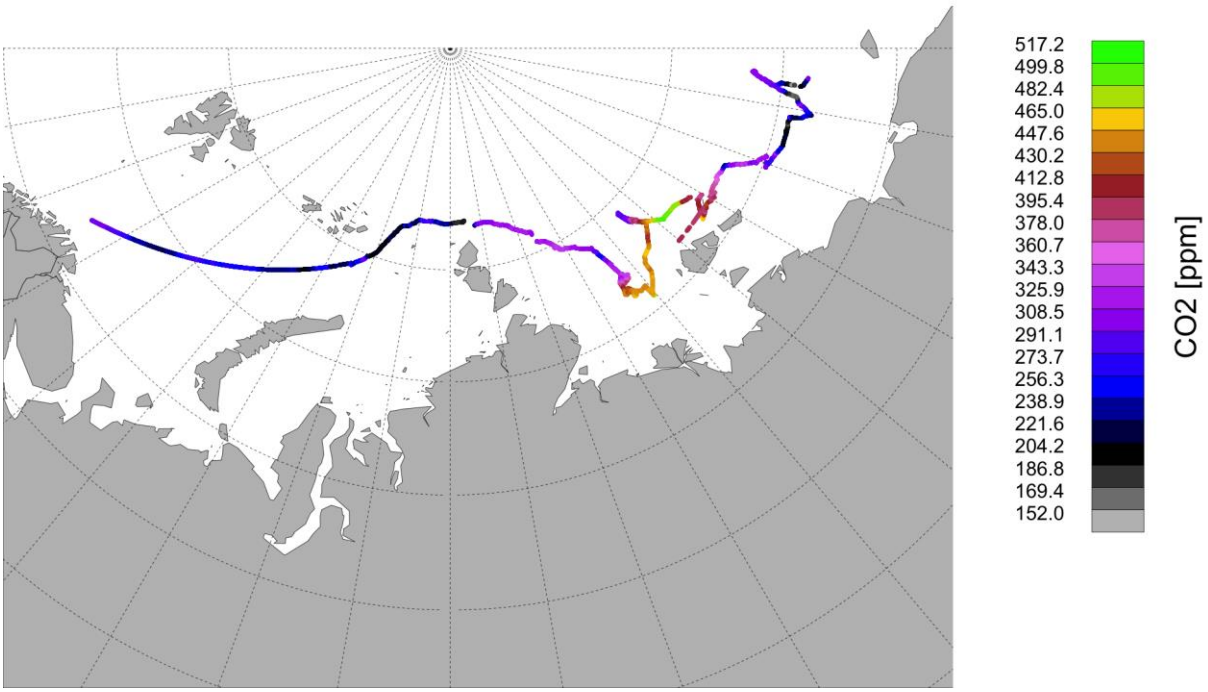
Dataset

The unvalidated raw data indicate elevated CH4 concentrations (> 150 ppm) in the hot spot areas in both the Laptev Sea and the East Siberian Sea. In between these hot spots the CH4 concentrations the concentrations were one order of magnitude lower.



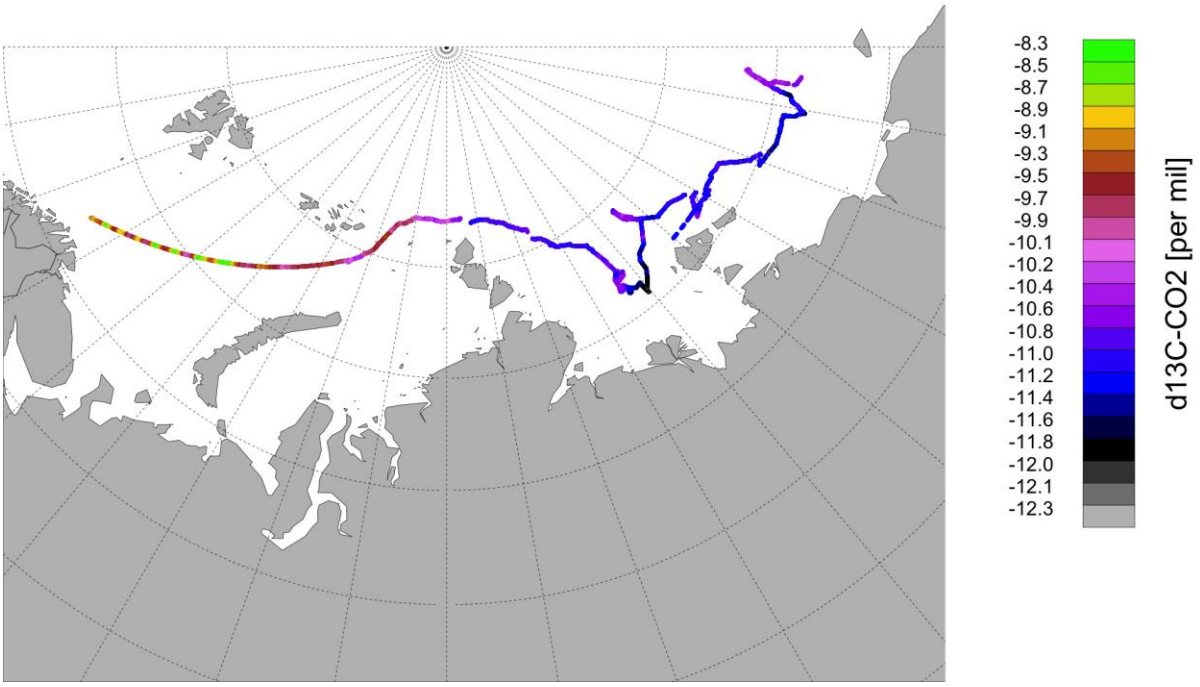
Preliminary data on CH4 concentrations in surface water measured by WEGAS

The unvalidated raw data indicate both under and oversaturation of CO2 along the transect. The East Siberian Sea showed a significant undersaturation in CO2 due to the ongoing growth period, whereas in the Laptev Sea oversaturations has been observed. Highest concentrations of CO2 were found near the river mouth of the Lena. Thus, the WEGAS data set corroborates the first conclusion drawn from the spatial distributions of TA and DIC measurements and inferred CO2 saturation state of the various water masses in the Laptev Sea and East Siberian Sea.



Preliminary data on CO2 concentrations in surface water measured by WEGAS

The unvalidated raw data on δ^{13}C-CO2 in surface water along the transect indicate more depleted values in the Laptev and East Siberian Sea compared to the Barents Sea and Kara Sea. The most depleted values are probably caused by degradation products of terrestrial derived organic matter that is more depleted in δ^{13}C-CO2 than marine organic matter. Thus, the areas with highest CO2 oversatuation correspond with areas showing the most depleted δ^{13}C-CO2 values corroborating patterns of intensive degradation of terrestrial derived organic matter.



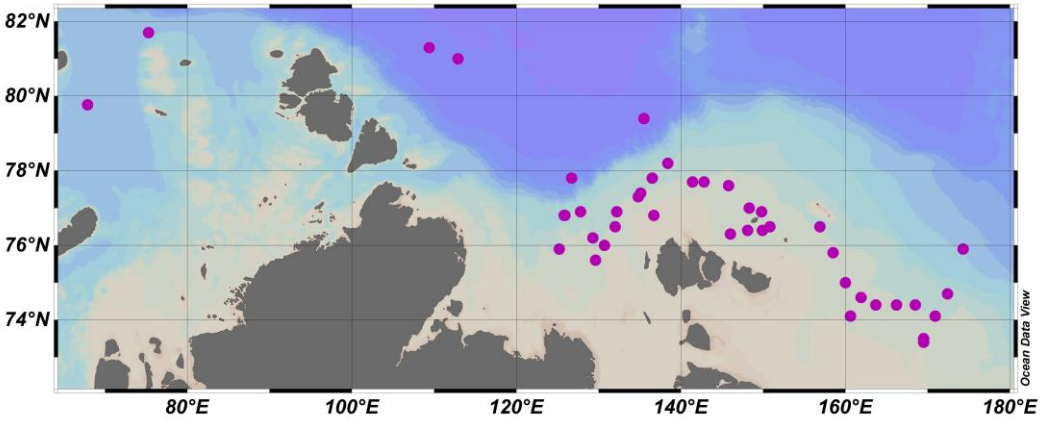
Preliminary data on δ ^{13}C-CO2 signatures in surface water measured by WEGAS

The continuous data set of CH4 and CO2 concentrations and the δ^{13}C-CO2 signatures in the surface waters along the SWERUS transect will serve as a baseline study to determine how isotopic fingerprints of different carbon pools in the water column correspond to CO2 and CH4 net exchange patterns and how the respiration of terrestrial organic carbon will change the isotopic fingerprints in 13C-CO2. The specific aims of the forthcoming analyses are: 1. To develop a general model to quantitatively link CO2 and CH4 fluxes the Laptev Sea and East Siberian Sea to primary productivity, degradation and outgassing. 2. To quantitatively integrate the surface emissions of CH4 and CO2 with the seasonal water column C dynamics. 3. To provide an integrated update of GHG emissions from the ESAO. We anticipate that the analyses of these data and model development will continue over the next 12 month.

Stable isotope composition and biomarkers of dissolved and particulate organic carbon species

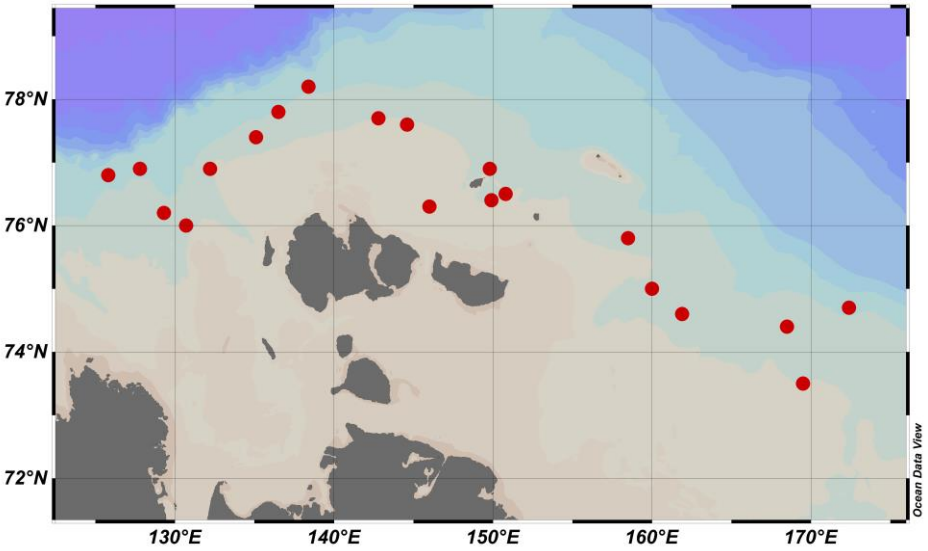
Metadata description of observational dataset and collected sample set

Surface water via stainless steel line of SWI was sampled at 38 locations and filtered on high volume 293 mm GF/F filters. Out of these 35 stations were filtered on Teflon filters and ran for high volume SPE for extraction of DOC.



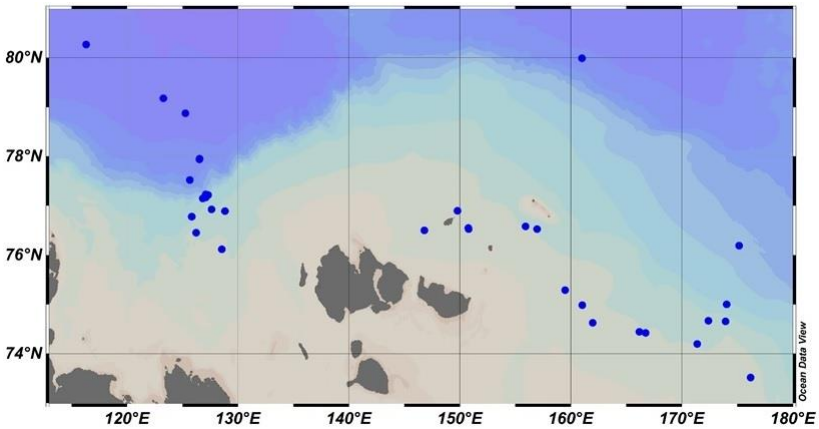
Stations where POC and DOC has been collected on Teflon filters, GFF and SPE from SWI- surface water.

Bottom water was sampled and filtered on high volume GF/F filters, for high volume SPE and 47 mm Teflon filters for 21 stations.



Stations where POC and DOC has been collected on Teflon filters, GFF and SPE from submersible pump – bottom water.

Plankton was sampled at 22 locations always directly from the stainless steel line of SWI.



Sampling locations of plankton

All stations that where SPE and Teflon filtration was carried out were also subsampled for TOC and DOC analysis on Shimadzu by Marcus Sundbom.

The SPE bond elut columns, will be brought back to Stockholm University and analyzed for d13C-DOC at the Stable Isotope Laboratory (SIL), Stockholm University, d14C-DOC at NOSAMS facility for AMS, solvent extractable lipids and CuO oxidation reaction products will be carried out at the Department of Applied Environmental sciences. Analysis is predicted to be carried out in the next 12 months.

Teflon filters will be extracted in CuO oxidation for analysis of reaction products such as lignin phenols and cutin acids. Analysis is predicted to be carried out in the next 12 months at Department of Applied Environmental Sciences.

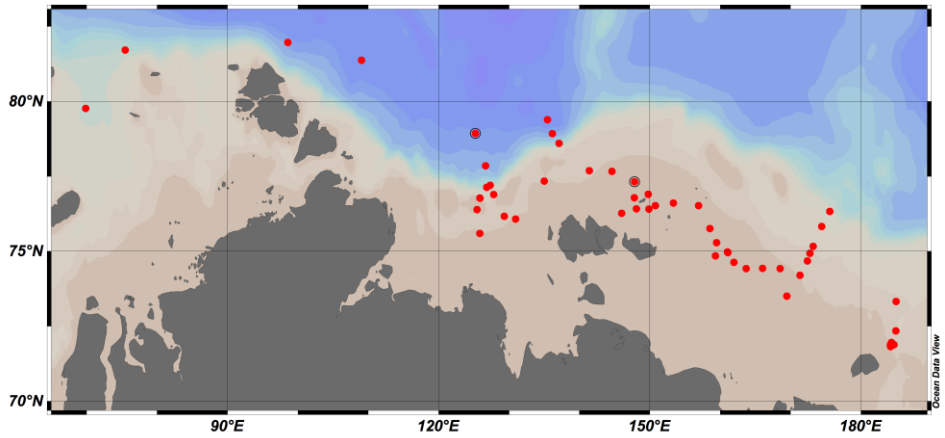
GF/F filters will be brought back to Department of Applied Environmental Science at Stockholm University for analysis within the next 12 months. Analysis will be d13C-POC at the Stable Isotope Laboratory (SIL), Stockholm University, d14C-POC at NOSAMS facility for AMS, and solvent extractable lipids.

Plankton samples will be taken back to Stockholm University for molecular and isotopic analysis. Subsamples will be acidified for reduction of DIC and sent off for carbon isotope analysis on AMS for 14C at NOSAMS (Woods Hole National Oceanographic Accelerated Mass Spectrometer facility) and to stable isotope laboratory (SIL), at Stockholm University for 13C on HR-irMS. Biomarker analysis will be carried out at the Department of Applied Environmental Science.

If there is enough material on SPE columns and on GF/F filters there might be compound specific isotope analysis carried out on these at the Department of Applied Environmental Analysis, Stockholm University.

The TOC and DOC samples were analyzed onboard.

In total 121 samples were taken for stable isotope analysis and FT-ICR-MS on bulk DOM (see map for stations), both from the SWI system as well as from Niskin bottles. Back in Stockholm the collected DOM will be eluted from the SPE columns with Methanol will be performed. We anticipate that the analyses of bulk DOM via Isotope Ratio Mass Spectrometry stable isotope analysis $\delta\ ^{13}C$, $\delta\ ^{15}N$, $\delta\ ^{2}H$ at SIL in Stockholm and FT-ICR-MS measurement will continue over the next 6-24 month.



Stations where samples for bulk DOM characterization were taken (stable isotope analysis and FT-ICR-MS)

Tracers for groundwater

Metadata description of collected sample set

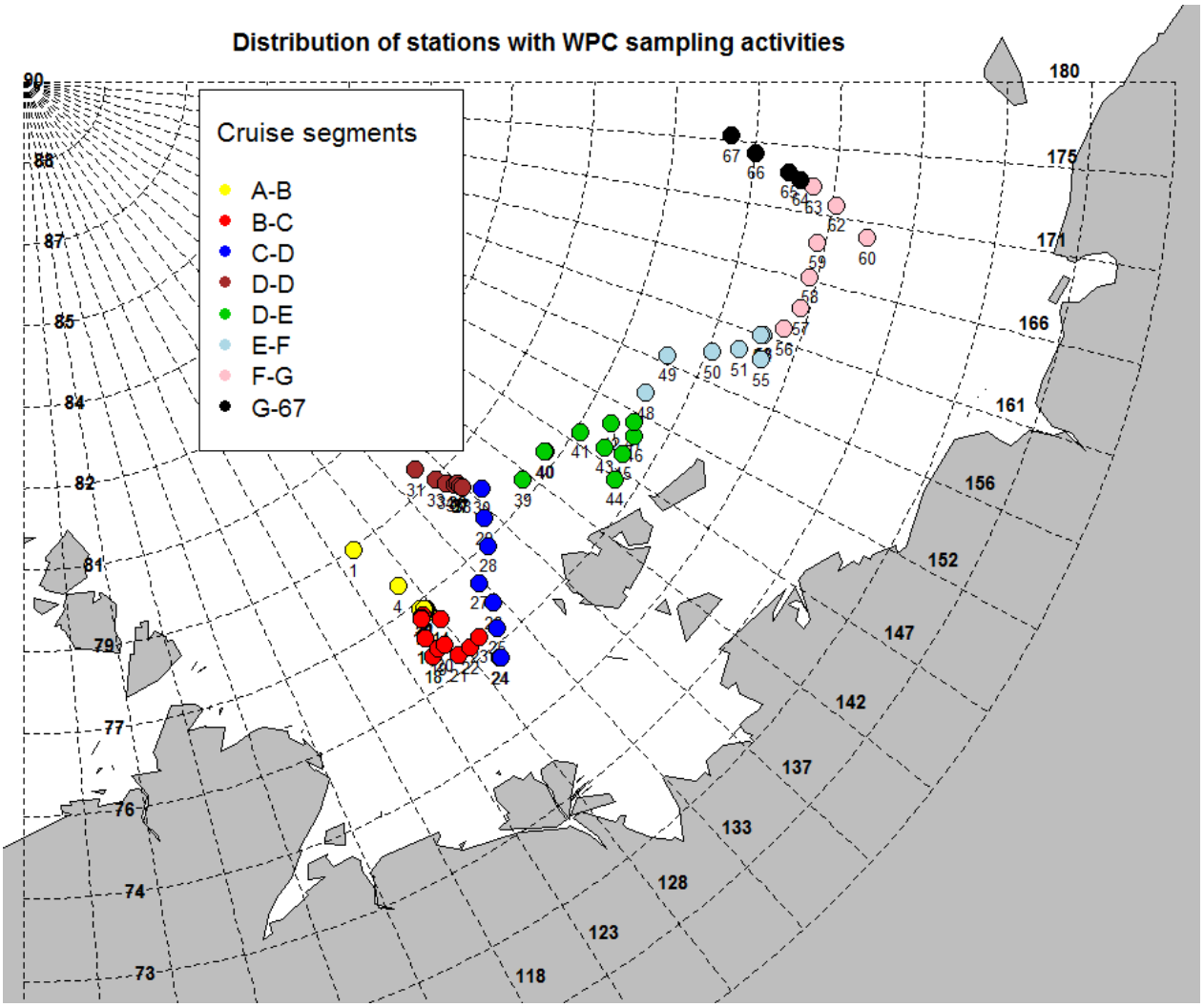
In total 93 water samples (more then 6000 liters) have been obtained for the ^{223}Ra, ^{224}Ra, ^{228}Ra and ^{226}Ra activity in the water column of Laptev and East-Siberian seas.

WP C Methane and other trace gases in the water column

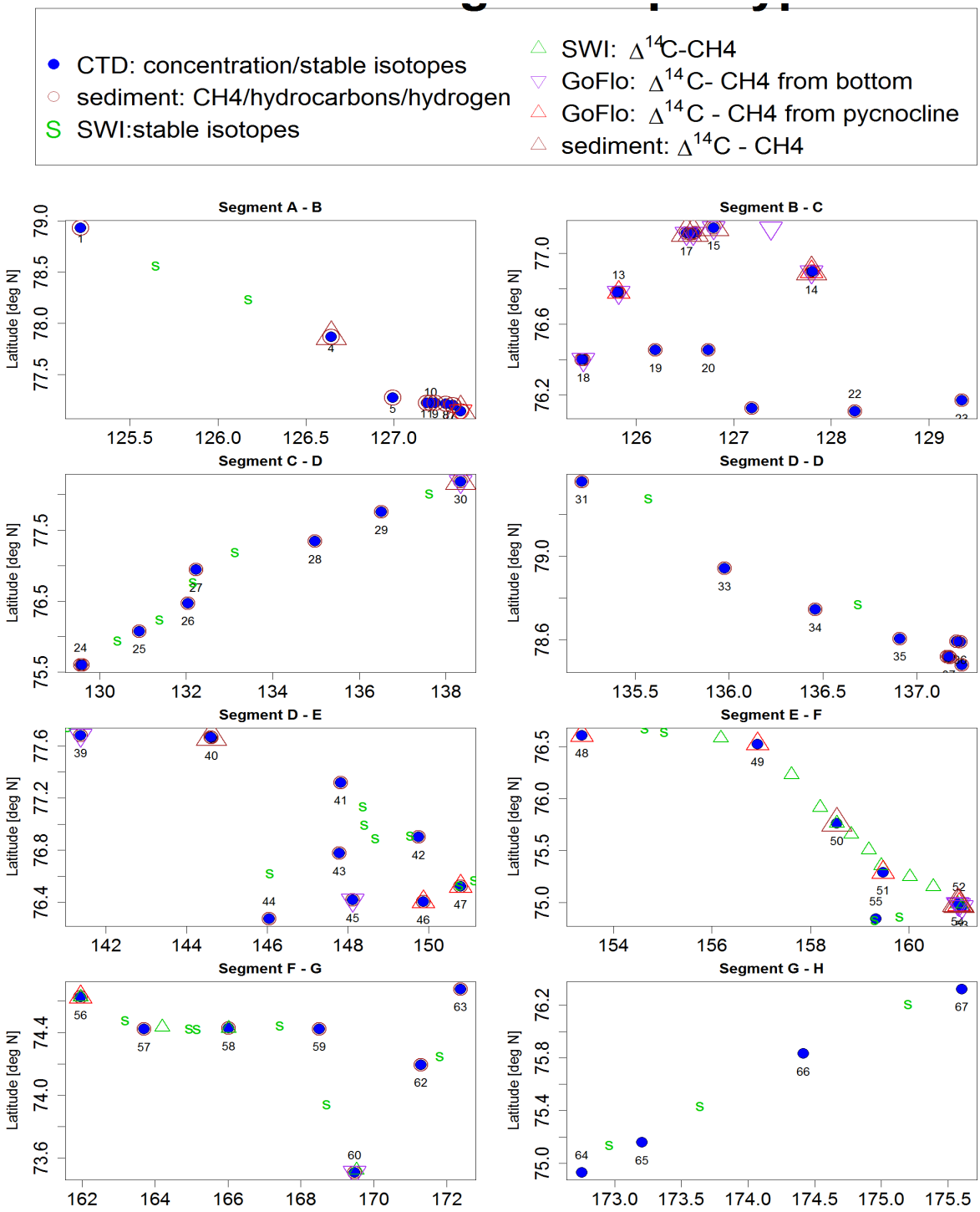
Overview

The sampling for WP C follows the positioning of stations along the Leg 1 cruise transects. The available data at the end of Leg 1 consist of concentration depth profiles for most stations, and sediment gas concentration data for many stations (ref. Denis Kosmach). All stations where Niskin bottles were used in the CTD casts were also sampled for stable isotope analysis of CH4. Close to 90 samples were taken for carbon-14 of methane at different depths, using both the SWI and GO-FLO casts.

- **Overview plot of sampling stations (p1)**



- **Detailed sample types in each cruise segment (p2)**



A table with all sample types taken at specific stations is available in the file Appendix WP_C_1_station log.xlsx, and is also presented here on the following two pages.

SWERUS WPC station log

Station Nr	Niskin I	Niskin II	Niskin III	GoFlo	SWI stable isotopes at station	SWI stable isotopes after station	SWI 14C at station	SWI 14C after station	Bottom water from sediment tube	Sediment, Denis	Sediment stripping	Segment	Comment
1	x	-	-	-	-	-	-	-	-	x	-	A-B	
2	-	-	-	-	-	x	-	-	-	-	-	A-B	
3	-	-	-	-	x	-	-	-	x	?	-	A-B	
4	x	-	-	-	-	-	-	-	?	x	x	A-B	
5	x	-	-	-	-	-	-	-	?	?	-	A-B	
6	(x)	-	-	x	-	-	-	-	?	x	x	A-B	CTD cast for Ra, no Ids. Did quickie from 3 depths. GoFlo 101nm @ 39m depth, 3 kegs
7	-	x	-	(x)	-	-	-	-	?	?	-	A-B	Goflo cast done for 14C sample, but not stripped because of low concentration
8	-	x	-	-	-	-	-	-	-	-	-	A-B	
9	-	-	-	-	-	-	-	-	-	-	-	A-B	
10	-	-	-	-	-	-	-	-	-	-	-	A-B	
11	-	-	-	-	-	-	-	-	-	-	-	A-B	
12	-	-	-	-	-	-	-	-	-	-	-	A-B	
13	x	-	x	x	x	-	x	-	-	x	x	B-C	cast I normal CTD, cast III- drag CTD (24 bottles filled, 8 measured with quick analysis) GoFlo profile: 2x samples from 60,50,20m and SWI + sediment. Also 14C-Co2 sample from 60 and 50m
14	x	x	-	x	x	-	x	-	?	x	?	B-C	GoFlo profile from 59, 25m and SWI (each x2) + sediment (this might be the only useful sediment sample from this HS)
15	x	x	-	x	-	-	x	-	-	x	-	B-C	2x GoFlo from bottom (445m)
16	x	x	-	x	-	-	-	-	?	x	x	B-C	GOFlo: 2x from bottom (360m) cast I: BGC CTD, cast II drag CTD, 10 bottles
17	x	x	-	x	-	-	-	-	?	x	x	B-C	GoFlo: 2x bottom (270m)cast II drag CTD, 10 bottles. Cast I: For most depth no syringes, data from serumbottles --> no CO2
18	x	x	-	x	-	-	-	-	?	x	?	B-C	GOFlo (2x bottom) cast II drag CTD, 10 bottles. Both casts no syringes, data from serumbottles --> no CO2
19	x	-	-	-	-	-	-	x	?	x	x	B-C	no syringe --> no CO2
20	x	-	-	-	-	-	-	-	?	x	x	B-C	
21	x	-	-	-	-	-	-	-	-	x	x	B-C	
22	x	-	-	-	-	-	-	-	-	x	-	B-C	
23	x	-	-	-	-	x	-	-	-	x	-	B-C	
24	x	-	-	-	-	x	-	-	-	x	-	C-D	
25	x	-	-	-	-	x	-	-	-	x	-	C-D	
26	x	-	-	-	-	x	-	-	-	x	-	C-D	
27	x	-	-	-	-	x	-	-	-	-	-	C-D	from here on new equilibration times for accurate analysis: 5min shaking, 15min rest
28	x	-	-	-	-	x	-	-	-	x	-	C-D	
29	x	-	-	-	-	x	-	-	-	x	-	C-D	
30	x	-	-	x	-	x	-	-	-	x	x	C-D	
31	x	-	-	-	-	x	-	-	-	x	-	D-D	
32	-	-	-	-	-	-	-	-	-	-	-	D-D	
33	x	-	-	-	-	-	-	-	-	x	-	D-D	
34	x	-	-	-	-	-	-	-	-	x	-	D-D	
35	x	-	-	-	-	-	-	-	-	x	-	D-D	
36	x	-	-	-	-	-	-	-	-	x	-	D-D	
37	x	x	x	-	-	-	-	-	-	x	-	D-D	Problems with Agilent GC (Romeo) during analysis of cast I. Quickies analysed on Geo-GC (Francesca)
38	x	-	-	-	-	x	-	-	-	x	-	D-D	CTD samples not analyzed because of GC problems, only quick analysis done

Station Nr	Niskin I	Niskin II	Niskin III	GoFlo	SWI stable isotopes at station	SWI stable isotopes after station	SWI 14C at station	SWI 14C after station	Bottom water from sediment tube	Sediment, Denis	Sediment stripping	Segment	Comment
39	x	-	-	x	-	-	-	-	-	x	x	D-E	CTD samples not analyzed because of GC problems, only quick analysis done
40	x	x	-	-	-	-	-	-	-	x	x	D-E	Goflo cast done for 14C sample, but not stripped because of low concentration (9nM).sediment sampling "new style" 2 jars with as much sediment as possible. From now on all GC measurement on Geo-GC --> no C2H6
41	x	-	-	-	-	x	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6
42	x	-	-	-	-	-	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6
43	x	-	-	-	-	-	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6
44	x	-	-	-	-	-	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6
45	x	-	-	x	-	-	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6. 4x GoFLo cast from20m @9nm, 2 traps, 1sample
46	x	-	-	x	-	-	-	-	-	x	-	D-E	GC measurement on Geo-GC --> no C2H6. 4x GoFLo cast from 20m @20nm, 2 traps, 1sample
47	x	-	-	x	-	x	-	x	-	x	-	D-E	no analysis of CTD cast, to be done from serumbottles (only quickies). GoFlo 3casts into 2 traps for 1 sample (20nm) + 5kegs from SWI after station
48	x	-	-	x	-	x	-	x	-	x	-	E-F	GC measurement back on Agilent GC, direct injection. Data quality not so convincing. 4x GoFlo for 2 traps (11-14nm)
49	x	-	-	x	-	x	-	x	-	x	-	E-F	GC measurement back on Agilent GC, direct injection. Data quality not so convincing. 2x GoFlo cast @ 20m, SWI on way to next station x2
50	x	-	-	-	x	x	x	x	-	x	x	E-F	GC analysis back to geo GC (no C2H6). Ice conditions don't allow GoFlo. SWI sample taken at station (but sample got destroyed), 2 14C-SWI samples on way to next station. Sediment sample 4 jars
51	x	-	-	x	-	x	-	x	-	x	-	E-F	GC analysis on geo GC (no C2H6). 2x GoFlo from 20m (2 traps), 2x SWI-14C on way to next station
52	x	-	-	x	x	-	x	-	-	x	x	E-F	GC analysis on geo GC (no C2H6). 2x GoFlo from 37 and 20m, 1x SWI-14C onapproach of station. Issue with 168 Ids should be checked
53	x	-	-	x	x	-	x	-	-	x	-	E-F	GC analysis on geo GC (no C2H6).GoFlo x 2from 41m (2 traps/samples)
54	x	-	-	x	x	x	x		-	x	x	E-F	GC analysis on geo GC (no C2H6).GoFLo x 2 close to bottom (36/41m, 2 traps/samples). Sediment 4 jars
55	x	-	-	-	x	x	-	x	-	x	-	E-F	GC analysis on geo GC (no C2H6).
56	x	-	-	x	x	x	x	-	-	x	-	F-G	GC analysis on geo GC (no C2H6). GoFLo x2 from 20m
57	x	-	-	x	x	x	-	x	-	x	-	F-G	GC analysis on geo GC (no C2H6).
58	x	-	-	-	x	x	x	-	-	x	-	F-G	GC analysis on geo GC (no C2H6).
59	x	-	-	-	-	x	-	x	-	x	-	F-G	GC analysis on geo GC (no C2H6). SWI sample taken on approach of station 60.
60	x	-		x		x				x		F-G	GC analysis on geo GC (no C2H6). GoFlo from bottom (35m), 89nm. 2 kegs filled and preserved with ZnCl
61	-	-	-	-	-	-	-	-	-	x	-	F-G	only sediments taken at this station, ice conditions didn't allow CTD
62	x	-	-	-	-	-	-	-	-	-	-	F-G	GC analysis on geo GC (no C2H6).
63	x	-	-	-	-	-	-	-	-	-	-	F-G	GC analysis on geo GC (no C2H6).
64	x	-	-	-	-	x	-	-	-	x	-	G- Barrow	GC analysis on geo GC (noC2H6)
65	x	-	-	-	-	x	-	-	-	x	-	G- Barrow	GC analysis on geo GC (noC2H6)
66	x	-	-	-	-	x	-	-	-	x	-	G- Barrow	GC analysis on geo GC (noC2H6)
67	x	-	-	-	-	-	-	-	-	x	-	G- Barrow	GC analysis on geo GC (noC2H6)

Results: concentration data for CH4, CO2 and C2H6 in the water column

Metadata description of observational dataset and collected sample set

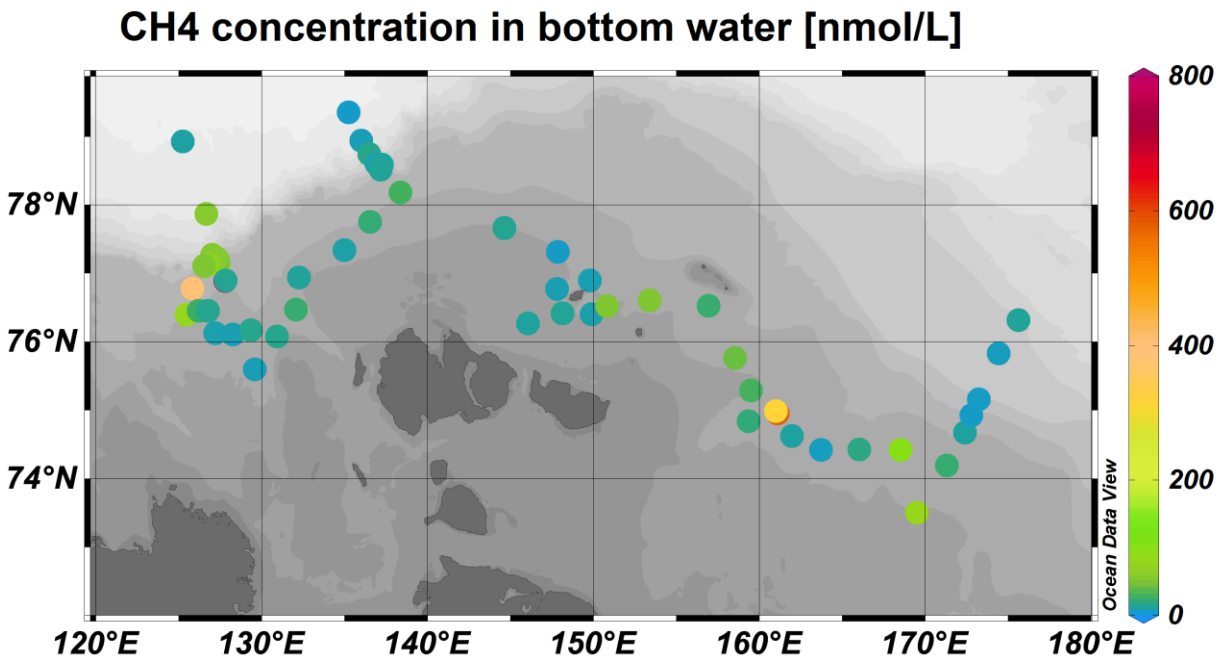
Depth profiles for methane have been measured for 64 out of 67 stations. Ethane data is lacking for 27 of the stations due to the problem with the Agilent GC-FID instrument, and will be produced from stored samples at the end of 2014 (which samples to be analyzed is evident from the file Appendix_WP_C_1_station log.xlsx). Additional data for GO-FLO casts and Quick Analysis can be found in the station-specific data files from the methane quantification using gas chromatography.

All concentration data file with from the water column can be found in Appendix C1. The full dataset, also containing station coordinates as well as temperature and salinity data from the CTD bottle files and coordinates is available in the file Appendix WP_C_2_concentrations.xlsx (1500 rows Excel spreadsheet). Data is also available in the Sample Record files and in the GC data files, as described in the methods section.

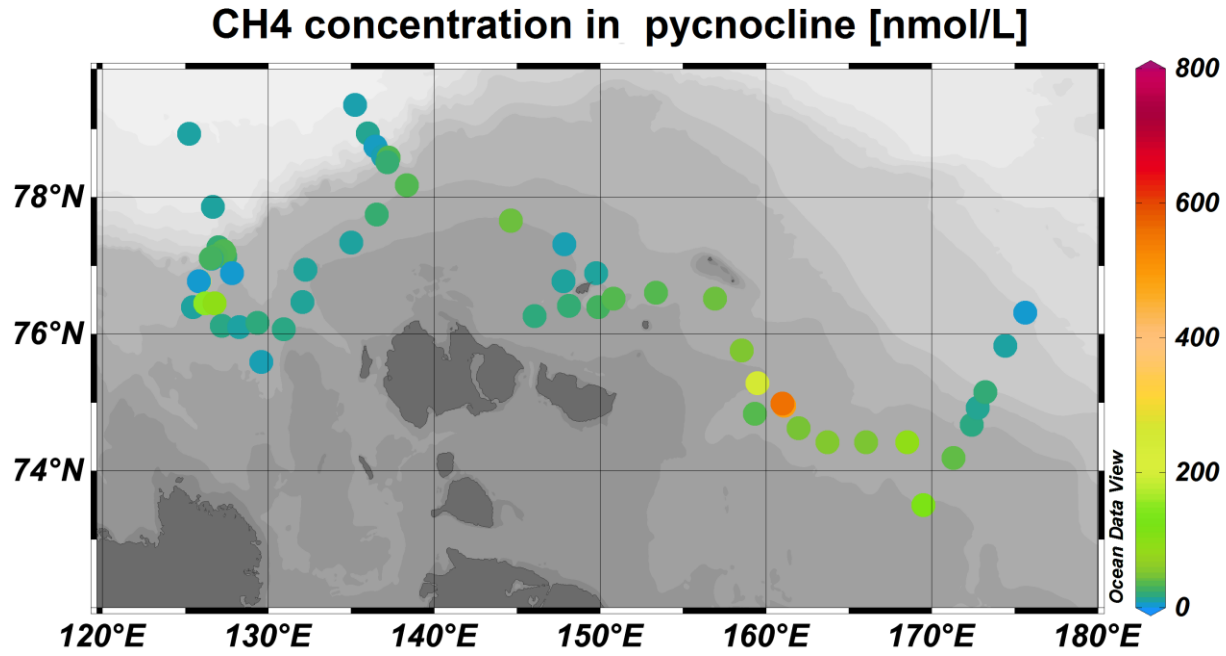
Data set broad features

The surface plots p3-p5 illustrate how the CH4 concentrations in seawater increase when going from the rise up on the slope and onto the shelf. The two hotspot areas stand out with observations of >300 nM CH4. However, it is also clear that elevated concentrations were found on the slope.

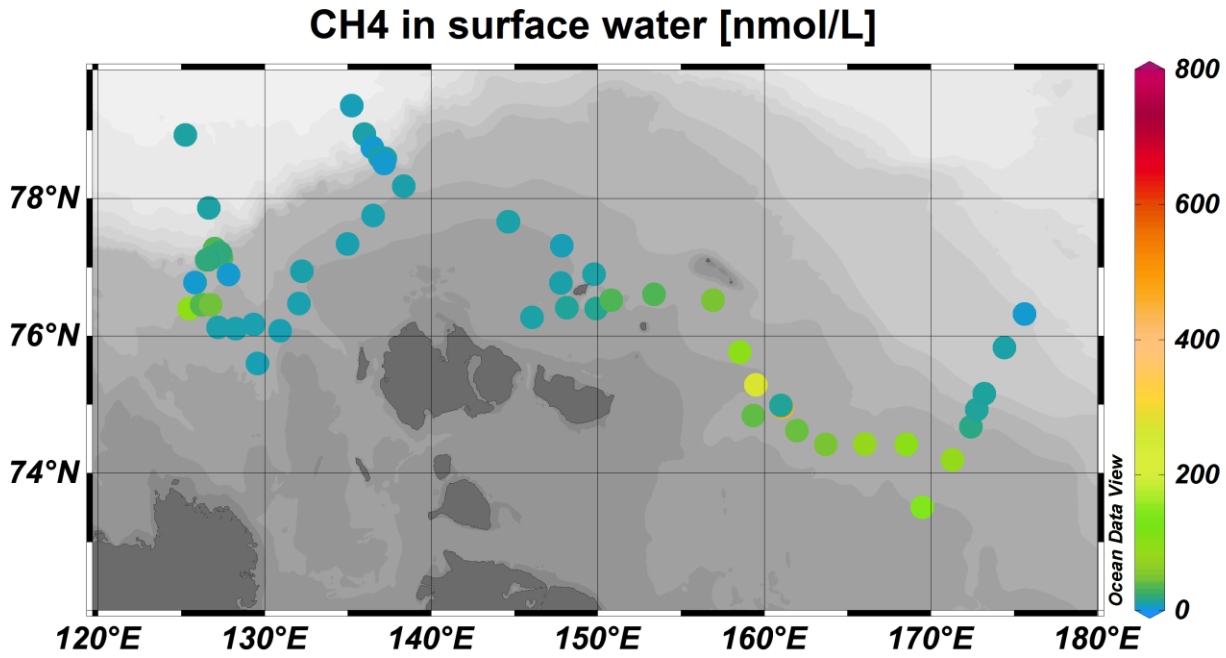
- **Overview over CH4 concentrations in bottom water (p3)**



- **Overview of CH4 concentrations at the pycnocline (p4)**

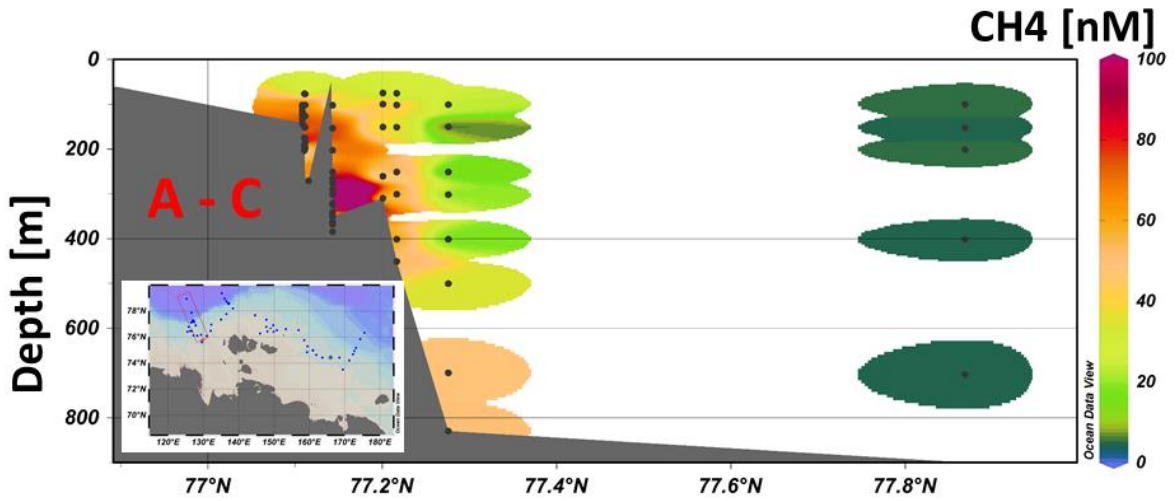


- **Overview of CH4 concentrations at the surface (p5)**

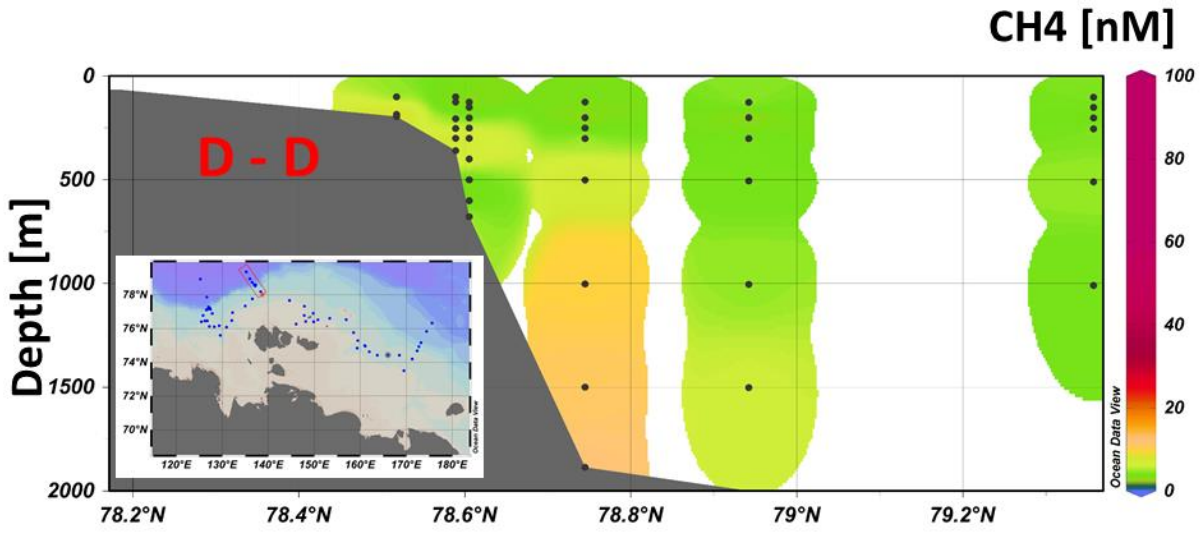


The more detailed plots of transects A-C, D-D, and F-H indicate that three sources types might exist separated by depth. Plot A-C show a local maxima in CH4 concentration about 2000 m, and another at 250 m. This may correspond to release of CH4 from deep sources (at 2000 m depth) and the upper methane hydrate stabilization level (250 m depth). The third local maxima, and potential source type, is found on the shelf at 50-100 m depth. These observations, combined with triple isotope data to come and existing geophysical data from the Oden sonar systems, has potential for the characterization of these potential CH4 sources to the water column.

- **CH4 concentration over slope transect A-C (p6)**

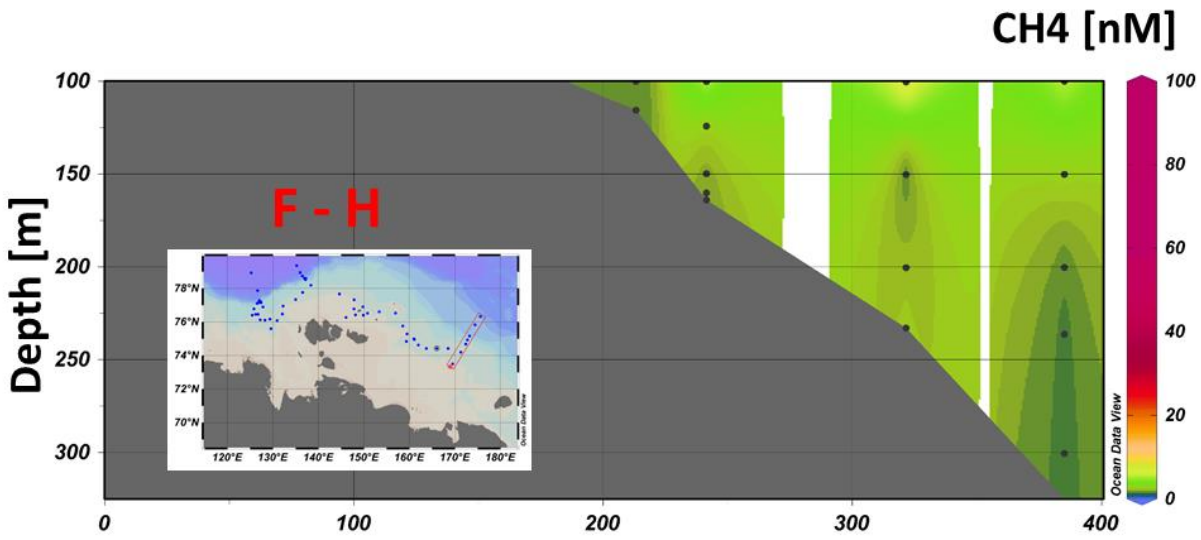


- **CH4 concentration over slope transect D-D (p7)**



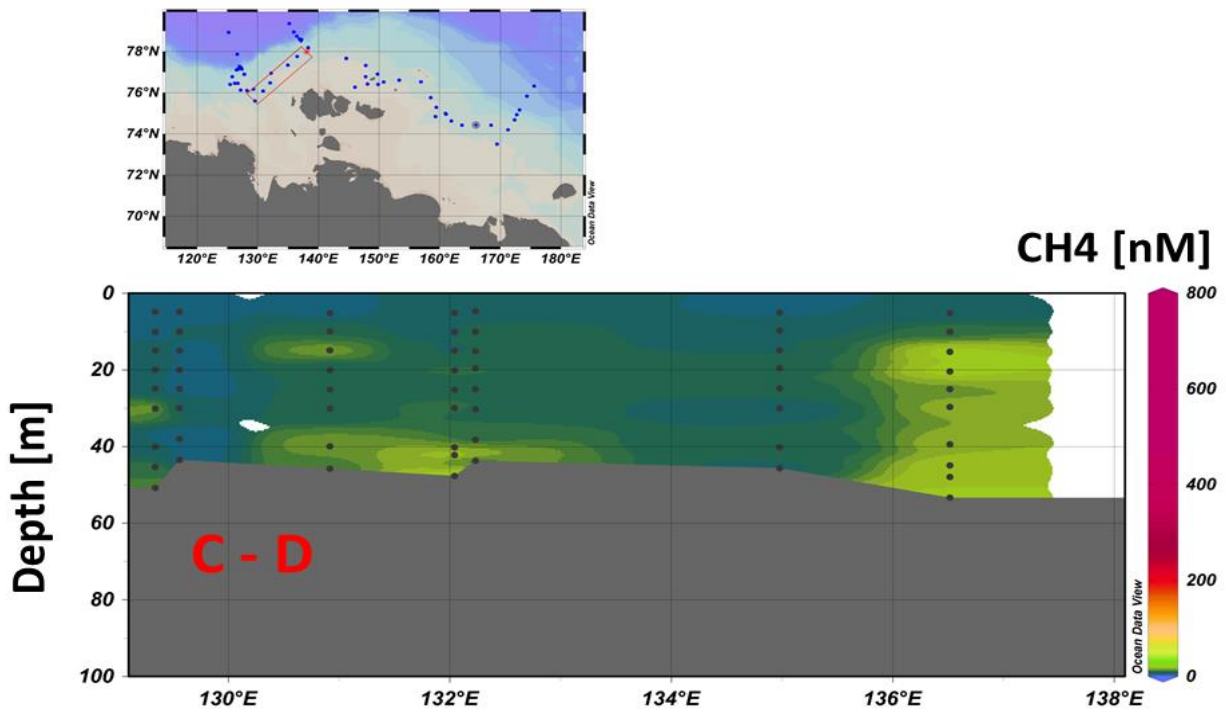
The 2D plot of transect F-H clearly shows a midwater plume of methane that seems to extend from a hotspot on the shelf (73.5 degrees N) out to deeper waters beyond the continental slope. Stable isotope data will aid the interpretation of the fate of the CH4 during this transport, and also verify its origin.

- **CH4 concentration over slope transect F-H (p7)**

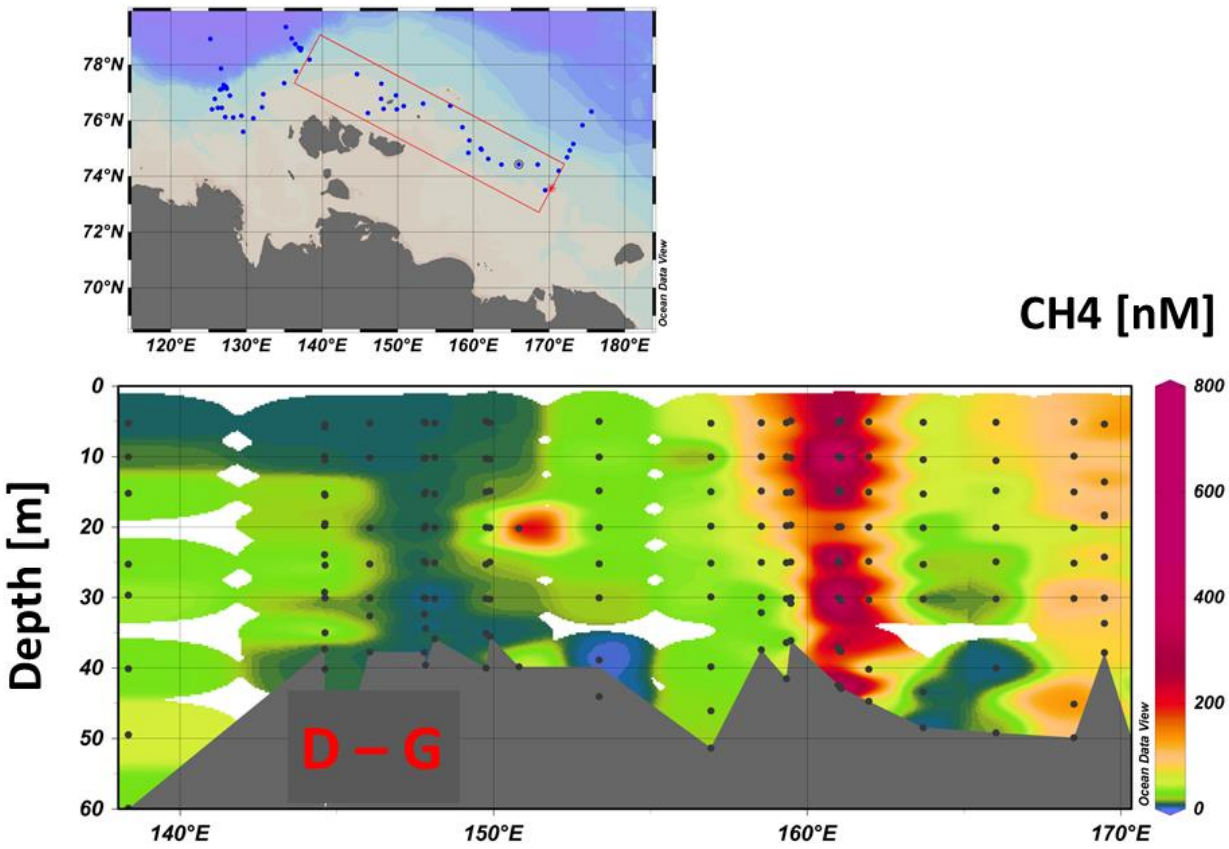


The 2D on-shelf transect plots show slightly to greatly elevated CH4 concentrations without any clear trends. The gradients in concentration can be very steep when approaching flare areas.

- **CH4 concentration over on-shelf transect C-D (p8)**

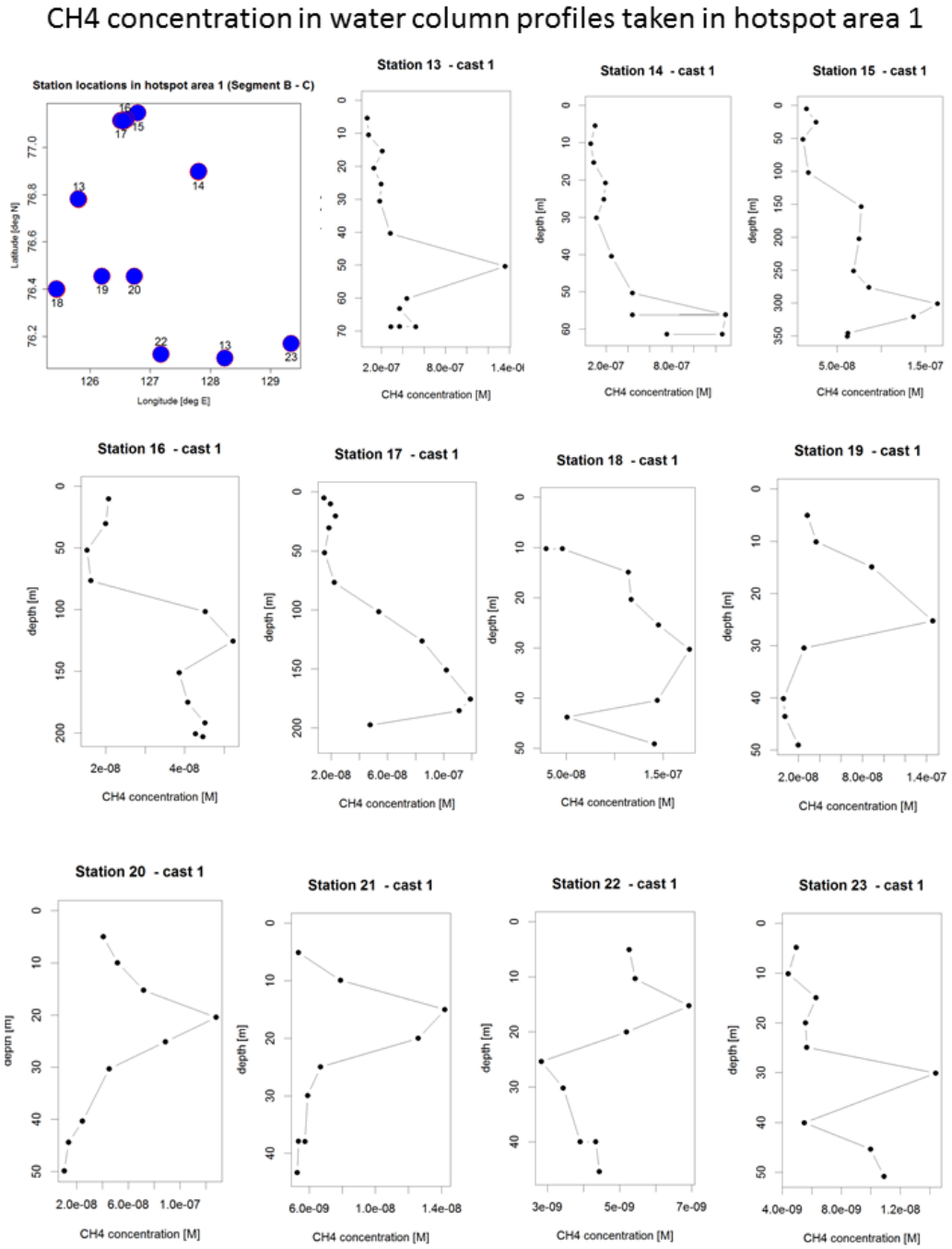


- **CH4 concentration over on-shelf transect D-G (p9)**



The vertical profiles for Hotspot Area 1 in the B-C segment indicate concentration maxima in the lower half of the water column. Several samples were taken here, in duplicate, to constrain the "megaflare" CH4 source signature for 14C and the stable isotopes of carbon and hydrogen.

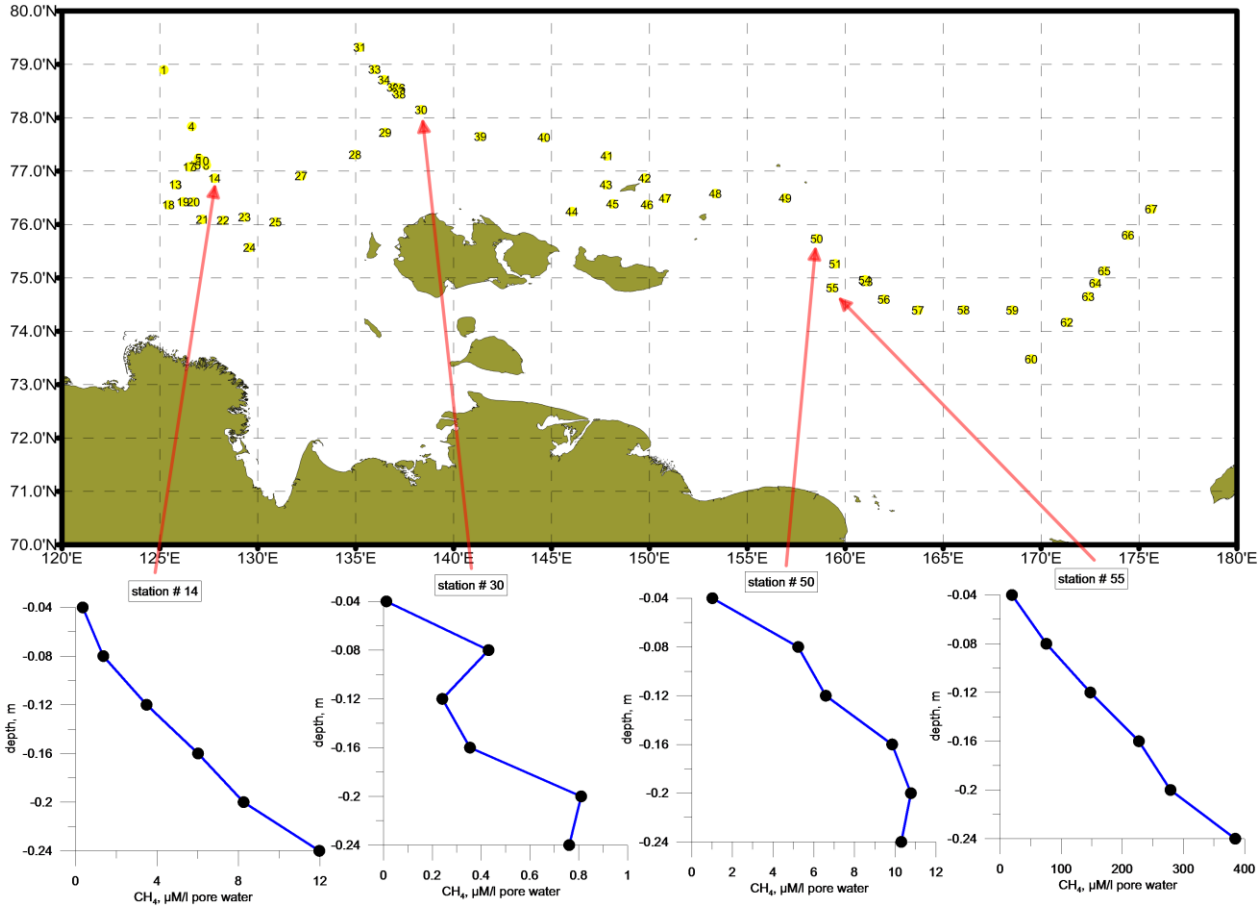
- **CH4 concentrations at Hotspot Area 1 (B-C segment), with depth profiles (p11)**



Results: concentration data for sediments

Metadata description of observational dataset

Sediment samples for concentration analysis were taken at all stations with MUC deployment, as illustrated in the following figure. Four examples of vertical concentration profiles are also shown. A full table with the sediment concentration data for CH4, H2 and C2H6 can be found in Appendix C2.



Dataset

The full data set for the measurements of gases in sediments will be made available in a separate file after clearance by Russian authorities. The file name is "Appendix_WP_C_3_sediment gas concentrations.xlsx".

Results: stored samples for stable isotope analysis of CH4 in the water column

Metadata description of collected sample set

Seawater samples for stable isotope analyses of CH4 were taken according to the description in the Methods section. Please refer to Appendix_WP_C_1_station log.xlsx and the plots in the Overview of this section for information of where samples where taken.

Timeframe for measurement data

A selection from these samples can be analyzed at the end of 2014 but the general time frame is 8-24 months for isotope analysis, considering the quantity of samples (approx. 530 samples in duplicates for stable isotopes of hydrogen and carbon, respectively).

Results: stored samples for carbon-14 analysis of CH4 in the water column

Metadata description of collected sample set

A full list of samples taken for 14C analysis, and their corresponding sample container IDs, can be found in Appedix C3, and in the file Appendix_WP_C_3_samples 14C.xlsx. Also refer to Appendix_WP_C_1_station log.xlsx and the plots in the Overview of this section for complementary information about locations for 14C sampling. Additional samples may come out of Leg 2, for which 18 kegs have been prepared for sampling.

The 86 U-traps that were available for carbon-14 sampling have been divided on in total 58 samples (some U-traps will be pooled to meet the limit of quantification for radiocarbon dating). Out of these 58 samples, 25 come from GO-FLO, 18 from SWI, and 15 from sediments.

Timeframe for measurement data

The timeframe for carbon-14 analysis of these samples is on the order of 4-12 months. Samples must be purified and converted to CO2 before analysis at NOSAMS or an equivalent facility for radiocarbon dating of microgram-sized samples.

WP D CH_4 and other trace gases in the atmosphere

Results: online monitoring systems

Ambient CH_4 and CO_2 observations from the profile system were made on the 1 second data stream from the instrument (LGR 13-0116). The data were tagged with ship's navigation and winds data and our SatNav gps/motion data (if satellite locks were not available then ship's location data were used) and written to archive files. Our automated processing would discard the first 50 seconds after a valve switch then calculate 70 second means and standard deviations, tag those data as above and write those data to files organized according to the height level being sampled. Target gases are handled in an identical way.

Target gases are used to correct the LGR raw mixing ratios for instrument drift. The average difference of the pairs of targets that bracket a 2 hour period from their calibrated mixing ratios are used to adjust the raw data. The average correction was -1.8 ppb (0.1%) for CH_4 and +2.75 (0.7%) for CO_2.

To help evaluate ambient conditions, the corrected data were filtered to remove potential ship interferences and for outliers. These data are used in the location maps of mixing ratios along the cruise track. The effects of these filters are summarized in the table that follows.

- Filter 1 (Flag1) wind must be coming from the forward quadrant of the ship, between 280° to 80°. 8682 (39%) of the observations were removed.
- Filter 2 (Flag2) the wind speed had to be greater than 2 m/s. An additional 504 observations were removed.
- Filter 3 (Flag3) tests for outliers. Any datum greater than 2x's the average standard deviation of the 70 sec averages is removed. An additional 157 observations were excluded.
- Filter 4 (Flag4) simply filters for those observations made while the ship is underway at a speed of greater than 2 knots. This further reduces chances of ship contamination.

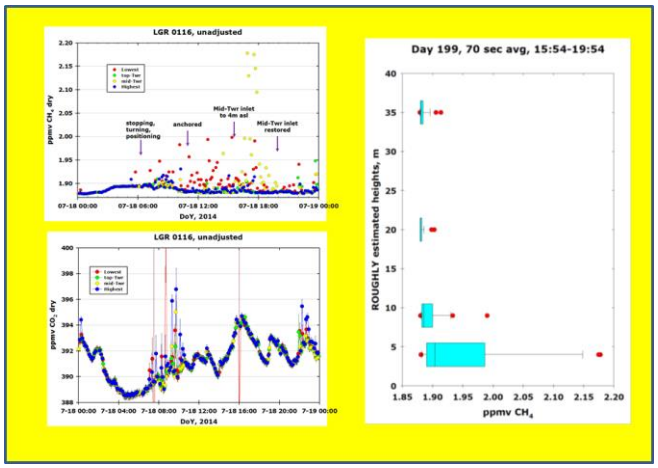
Summary table of the descriptive statistics of CH_4 and CO ambient mixing ratio data taken from 01:59 11 July to 07:03 15 August 2014 with LGR 116 is below. The table includes all levels combined. All numbers have ppm units except the counts.

	All obs	After Flag1	After Flag2	After Flag3	After Flag4
n CH_4	22170	13490	12986	12829	10595
%	100	61	59	58	48
max CH_4	3.6352	2.8849	2.8849	1.9964	1.9964
min CH_4	1.5723	1.6493	1.6493	1.6493	1.6493
max CO_2	704.40	664.45	401.93	401.93	401.93
minCO_2	352.71	352.71	352.71	365.23	365.23
mean CH_4	1.8863	1.8844	1.8842	1.8837	1.8837
median CH_4	1.8813	1.8806	1.8805	1.8804	1.8803
sd of the mean CH_4	0.0233	0.0173	0.0171	0.0109	0.0110
mean CO_2	391.48	391.32	391.29	391.30	391.18
median CO_2	391.83	392.12	392.11	392.11	391.91
sd of the mean CO_2	6.03	4.10	3.36	3.30	3.26

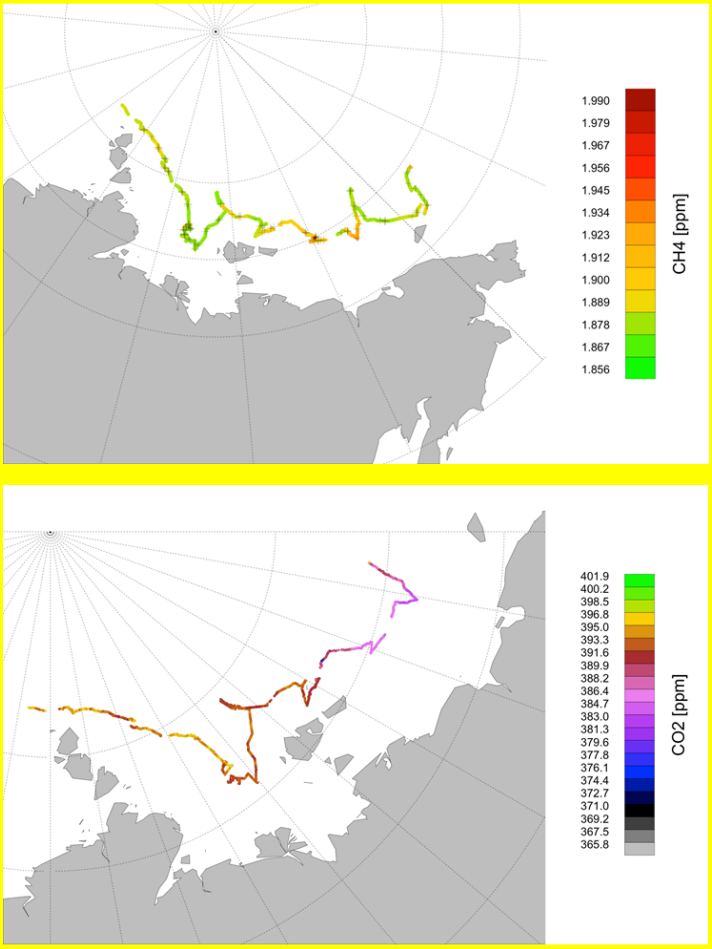
count CH_4	22170	13490	12986	12829	10595
count CO_2	22170	13490	12986	12944	10610

The flags are assigned when filter conditions are not met. Other known problems are that the data streams will sometimes give spurious values (either very high or very low), probably when a data frame is missed or slips. We attempt to recognize these and calculate around them. At his point it is highly probable that here are some of these events still included in these first evaluations of the data. All of the one second observations are archived and, of course, passed to our Russian colleagues.

The effects of the ship on the readings can be seen in the next figure. Notice the when the ship is underway early in the illustrated day there is minimal variability in the CH_4 or the CO_2. When the ship slows, turns and maneuvers later in the morning, ship contamination is easily seen in the increased variability in both CH_4 and the CO_2 (in particular). Once the anchor is set and the ship is riding downwind of a stiff breeze (>5 m/s) with its engines off, we are again able to make precise measurements and a gradient is evident. This was one day when we were able to lower one of our inlets to 4 m asl. Please note that these are raw data and are NOT corrected.



The broader patterns of CH_4 in the atmosphere can be seen in the graph below. There were no broad CH_4 enhancements during our transit of the Laptev Sea but there were persistently higher CH_4 values in the ESS, especially in the ice and very near the eastern-most hotspot.



Mixing ratios at measured at different locations while underway along the transect. These are adjusted and filtered data. Note that the discrete sampling locations for Tasks 1.4, 1.5 and 1.6 are marked on the CH_4 map. Maps kindly provided by Marc Geibel for CH_4 and Matt Shupe for CO_2.

Also note that there might be a broad anti-correlation with CO_2 which is higher over the Laptev Sea but lower to the east. Of course these are very preliminary speculations.

We will be pushing to complete a near final dataset within the next two months. Our Russian colleague the one second tagged Aerodyne QCL and LGR 0116 and the Preliminary corrected 70 second averaged dataset. It is this dataset that is ready for us to begin our discussions with our Russian friends of future activities. Metadata files will be included with the electronically transferred datafiles. We will archive all of the raw instrument data (much less useful) from both LGRs and the QCL at Stockholm University where they will be easily available.

Here is the ReadMe file text for the Aerodyne CH_4 Isotopes Data (Task 1.2)

These are data produced by the SU Aerodyne TDL Laser Spectrometer. There are 1Hz measurements of 12C-CH4, 13C-CH4, and CH3D concentrations. These files do NOT contain delta ratios commonly used in isotopic studies.

Data are provided as raw “stream” (.str) 1Hz files up until July 14th.

Spectral corrections have not been applied to this data.

These are ASCII text files. The separator is a space.

Starting time is provided in the header line and the filename.

First column is a relative time in seconds; absolute times can be calculated as offsets from these values.

Filename format is YEARMONTHDAY_HOURMINUTESECOND.stc

After 14 July, 1Hz tagged files containing the isotope concentrations and valve positions are provided.

They are ASCII text files, but can generally be treated as comma delimited files for loading into spreadsheets. Spectral corrections have been applied to this data.

Some ship navigational data and ambient information is included in the tagged files.

See file headers for more information.

All of the Aerodyne data is uncalibrated. For comparative use, the absolute concentration values provided here must be calibrated. Calibration gases were added every two hours (valve positions 6,2 and 6,8). Drift between calibrations must be accounted for at each data point.

Filenames of tagged data follow the format:

DAY-MONTH-YEAR_HOUR-MINUTE-SECOND_Aerodyne-tagged.txt

In comparison to the LGR data, the Aerodyne data are at least an order of magnitude more precise (in reality more); however without applying the frequent calibrations they are less accurate. Our first order of business (of course after the samples/data are approved for release) will be to run calibrations on our high level NOAA ESRL standards and to intercalibrate with our Utrecht University partner which is one of the premier laboratories in the world for ambient trace gas isotope measurements. This is especially true for CH_3D. Very few laboratories in the world do these measurements and even fewer do them well. These will be unique data and from an important region of the world.

Here is the Readme file for LGR 0117 10Hz data (Task 1.3)

The LGR 0117 is not frequently calibrated but the relative gain looks ok. For eddy covariance studies it is the relative dynamics around the mean that are important. The 10 Hz data from the instrument are taken directly into the data stream of our physical meteorologist partner Ian Brooks from Leeds University (WP I). We will be working with him to produce high quality CO2 and CH4 flux data within the context of their flow distortion and boundary layer dynamics studies. We will provide our Russian colleagues all the data that we collect here in the Triple Lab mainly for diagnostic purposes but we also collect the instrument raw data archive.

———————

The files in this folder are raw, uncorrected and uncalibrated 10Hz CH_4 and CO_2 data from the LGR FGGA system mounted behind the meteorological mast. These are the raw data produced by the LGR system. Air is sampled from a small inlet at the top (20 m asl) of the meteorological mast. These data are intended for eddy covariance studies.

Water vapor corrections have been applied to the CH_4(dry) and CO_2(dry) columns based on the water vapor measurements. No additional corrections have been applied.

The files are zipped ASCII text files.

Filename format is fgga_DATE_fINDEX.txt.zip

Samples selected for tasks 1.5, 1.6, 1.7 led by Dr C. Sapart.
See attached Excel file

Results: discrete air sampling

Data from discrete air sampling

Sample collection

In total 214 samples have been taken at this stage of the cruise (30 will be added to that on the way to Barrow): 117 samples in SS flasks, 71 in glass flasks and 25 in small sample bottles for $^{14}CO_2$ and $^{14}CH_4$ analysis. Fig. 5 shows the spatial distribution of the discrete sampling along the cruise path. It is overlying the continuous CH_4 mixing ratio measurements.

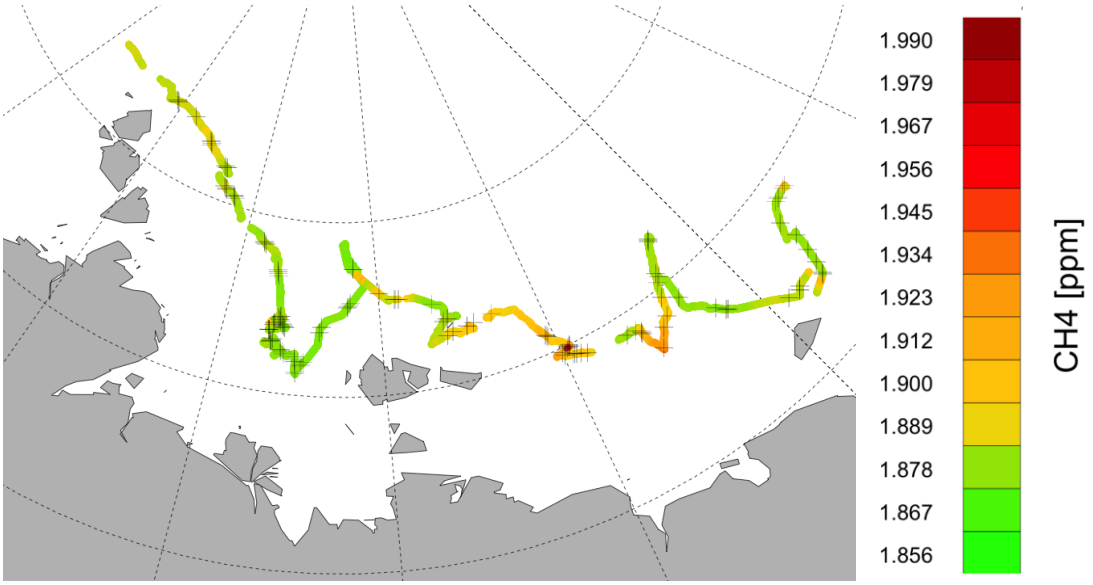


Fig. 5: Spatial distribution of atmospheric discrete sampling (crosses).

Sample post processing

SS flasks will be analyzed for CH_4, carbon dioxide and nitrous oxide mixing ratios and their stable isotope ratios. Glass flasks will be analyzed for carbon monoxide and molecular hydrogen mixing ratios and stable isotope ratios. The small sample bottles will be analyzed for $^{14}CO_2$ and $^{14}CH_4$ and for carbon stable isotope ratios of both gases for quality check.

Use of data

CH_4 and CO_2 mixing ratios, stable isotope ratios and radiocarbon data will be used to answer the research questions I and II. Nitrous oxide data will be used to answer research question III while Hydrogen data will be used to answer research question IV.

CO data will be used as a quality control to identify potential contamination from stack gas or any other combustion source in our samples. Stack gas samples have also been taken at the outlet of all

engines running on both gasoil and diesel in order to evaluate the isotopic signature of the potential contamination.

Table of all discrete samples taken by WP-D

Date	Time (UTC)	Bottle #	SAMPLE	Pressure (bar)	CO_2, CH_4, N_2O + stable isotopes	CO, H_2 + stable isotopes	$^{14}CH_4$, $^{14}CO_2$	North (degr.)	East (degr.)
2014-07-12	10:39	128	SW_1a_SS	3.50	1			81.9715	98.5127
2014-07-12	10:45	UU-1-4-248	SW_1a_GL	1.70		1		81.9715	98.5127
2014-07-12	10:59	U11	SW_1_^{14}C	1.02			1	81.9675	98.7873
2014-07-12	11:30	58	SW_1b_SS	3.50	1			81.9675	98.7873
2014-07-12	11:50	UU-1-8-590	SW_1b_GL	1.70		1		81.9670	99.0863
2014-07-12	20:26	no number	SW_2a_SS	3.50	1			81.8843	103.5925
2014-07-12	20:35	no number	SW_2a_GL	1.70		1		81.8843	103.5925
2014-07-13	0:00	UU-1-8-575	SW_4a_GL	1.70		1		80.9773	113.0205
2014-07-13	8:40	137	SW_3a_SS	3.50	1			81.4655	108.5855
2014-07-13	8:54	UU1-8-598	SW_3a_GL	1.70		1		81.4655	108.5855
2014-07-13	8:54	U8/U4(HSD)	SW_3_^{14}C	1.89			1	81.4548	108.7005
2014-07-13	9:21	no number	SW_3b_SS	3.70	1			81.4240	108.9330
2014-07-13	10:21	UU-1-8-574	Sw_3b_GL	1.70		1		81.3710	108.9317
2014-07-13	19:13	139	SW_4a_SS	3.50	1			80.9773	113.0205
2014-07-13	19:51	U2/U7(HSD)	SW_4_14C	1.88			1	80.9647	113.3258
2014-07-13	20:11	61	SW_4b_SS	3.50	1			80.9590	113.5263
2014-07-13	20:24	UU-1-8-570	SW_4b_GL	1.70		1		80.9590	113.5263
2014-07-14	8:46	65	SW_5a_SS	3.50	1			80.4607	114.0672
2014-07-14	9:15	UU-1-4-196	SW_5a_GL	1.70		1		80.4462	114.1935
2014-07-14	10:00	U26	SW_5_14C	2.18			1	80.4092	114.4848
2014-07-14	10:25	54	SW_5b_SS	3.50	1			80.3942	114.6107
2014-07-14	10:44	UU-1-8-591	SW_5b_GL	1.70		1		80.3732	114.6687
2014-07-14	15:26	143	SW_6a_SS	3.50	1			80.2800	116.2110
2014-07-14	15:35	UU-1-8-593	SW_6a_GL	1.70		1		80.2662	116.3052
2014-07-14	15:42	U34/U17(HSD)	SW_6_14C	1.49			1	80.2662	116.3052
2014-07-14	16:08	70,/670	SW_6b_SS	3.50	1			80.2382	116.4148
2014-07-14	16:32	UU-1-7-466	SW_6b_GL	1.70		1		80.2143	116.5675
2014-07-15	10:01	42	SW_7a_SS	3.50	1			79.24062	122.9415
2014-07-15	10:17	UU-1-5-334	SW_7a_GL	1.70		1		79.21742	123.0293
2014-07-15	10:25	U9	SW_7_14C	2.39			1	79.20713	123.0804
2014-07-15	10:49	63	SW_7b_SS	3.50	1			79.18283	123.2436
2014-07-15	11:05	UU1-8-559	SW_7b_GL	1.70		1		79.1617	123.3453
2014-07-16	8:49	71	SW_8a_SS	3.50	1			78.51211	125.7504
2014-07-16	9:05	UU-1-5-372	SW_8a_GL	1.70		1		78.47283	125.7975
2014-07-16	9:13	U33/U11(HD)	SW_8_14C	1.91			1	78.45676	125.8285
2014-07-16	9:37	no number on bottle	SW_8b_SS	3.50	1			78.39922	125.9157
2014-07-16	10:01	UU-1-8-561	SW_8b_GL	1.70		1		78.33724	126.0062
2014-07-17	16:00	1	SW_10c_SS		1			76.7776	125.8293
2014-07-17	19:30	2	SW_10d_SS		1			76.7773	125.8275
2014-07-18	0:25	68	SW_9a_SS	3.50	1			77.20745	127.1282
2014-07-18	0:33	UU-1-5-301	SW_9a_GL	1.70		1		77.1983	127.0782
2014-07-18	0:41	U46/U118(HSD)	SW_9_14C	2.51			1	77.18963	127.03
2014-07-18	1:13	44	SW_9b_SS	3.50	1			77.15462	126.834
2014-07-18	1:21	UU-1-10-723	SW_9b_GL	1.70		1		77.14544	126.7811
2014-07-18	14:40	4	SW_14d_SS		1			76.8937	127.7979
2014-07-18	15:37	41	SW_10a_SS	3.50	1			76.77753	125.8291

2014-07-18	15:45	UU-1-10-733	SW_10a_GL	1.70		1		76.77743	125.8291
2014-07-18	15:53	U14/U42(HSD)	SW_10_14C	2.40			1	76.7775	125.8295
2014-07-18	16:25	99	SW_10b_SS	3.50	1			76.77763	125.8295
2014-07-18	16:33	U-1-10-705	SW_10b_GL	1.70		1		76.77765	125.8288
2014-07-18	19:30	3	SW_14c_SS		1			76.8973	127.7979
2014-07-19	23:45	14	SW_11a_SS	3.50	1			76.92081	127.6294
2014-07-19	23:53	UU-1-10-676	SW_11a_GL	1.70		1		76.93251	127.5918
2014-07-20	0:01	U41/U49(HSD)	SW_11_14C	2.54			1	76.94445	127.5543
2014-07-20	0:25	U302	SW_11b_SS	3.50	1			76.9797	127.4435
2014-07-20	0:33	UU-1-7-478	SW_11b_GL	1.70		1		76.99124	127.4068
2014-07-20	1:21	U45/U1(HSD)	SW_12_14C	1.85			1	77.06195	127.1788
2014-07-20	1:45	U132	SW_12b_SS	3.50	1			77.0949	127.0595
2014-07-20	1:53	UU-temp-006	SW_12b_GL	1.70		1		77.1056	127.0187
2014-07-21	1:29	736	SW_13a_SS	3.50	1			77.01296	126.41
2014-07-21	1:37	UU-1-10-675	SW_13a_GL	1.70		1		76.99872	126.3879
2014-07-21	1:45	U44/U6(HSD)	SW_13_14C	2.43			1	76.98458	126.3663
2014-07-21	2:09	62	SW_13b_SS	3.50	1			76.9428	126.2991
2014-07-21	2:17	UU-1-10-711	SW_13b_GL	1.70		1		76.92898	126.2763
2014-07-21	3:00	5	SW_17c_SS		1			75.96	129.4
2014-07-21	3:10	6	SW_17c_SS		1			75.967	129.404
2014-07-21	16:01	57	SW_14a_SS	3.50	1			76.44725	126.2398
2014-07-21	16:09	UU-1-10-117	SW_14a_GL	1.70		1		76.45651	126.2036
2014-07-21	18:49	U308	SW_15a_SS	3.50	1			76.4651	126.2613
2014-07-21	18:57	UU-1-10-706	SW_15a_GL	1.70		1		76.4744	126.2855
2014-07-21	19:05	U21/U24(HSD)	SW_15_14C	?(25min pumping)			1	76.48511	126.3235
2014-07-21	19:29	U238	SW_15b_SS	3.50	1			76.51779	126.4391
2014-07-21	19:37	UU-1-10-728	SW_15b_GL	1.70		1		76.52875	126.4775
2014-07-22	10:39	U1184	SW_16a_SS	3.50	1			76.25188	127.5526
2014-07-22	10:41	UU-1-10-694	SW_16a_GL	1.70		1		76.24957	127.5641
2014-07-22	10:57	U25/U10(HSD)	SW_16_14C	1.85			1	76.23038	127.6571
2014-07-22	11:21	U310	SW_16b_SS	3.50	1			76.20194	127.7944
2014-07-22	12:09	UU-1-10-700	SW_16b_GL	1.70		1		76.1455	128.0669
2014-07-22	22:05	7	SW_B1a_SS		1			76.83	132.187
2014-07-22	22:08	8	SW_B1b_SS		1			76.85	132.196
2014-07-23	1:08	9	SW_B2a_SS		1			76.981	132.396
2014-07-23	1:15	10	SW_B2b_SS		1			76.996	132.452
2014-07-23	2:17	135	SW_17a_SS	3.50	1			76.09922	129.3663
2014-07-23	2:49	114	SW_17b_SS	3.50	1			76.0157	129.391
2014-07-23	8:33	U103	SW_18a_SS	3.50	1			75.62122	129.5891
2014-07-23	8:49	UU-1-4-255	SW_18a_GL	1.70		1		75.65454	129.5465
2014-07-23	10:33	U28/U35(HSD)	SW_18_14C	?			1	75.84784	130.0688
2014-07-23	10:57	156	SW_18b_SS	3.50	1			75.89172	130.2249
2014-07-23	11:29	UU-1-10-674	SW_18b_GL	1.70		1		75.94988	130.4309
2014-07-24	8:33	153	SW_19a_SS	3.50	1			77.55139	135.7446
2014-07-24	8:41	UU-1-8-567	SW_19a_GL	1.70		1		77.57016	135.8134
2014-07-24	8:49	U13/U29 (HSD)	SW_19_14C	1.7?			1	77.5891	135.8838
2014-07-24	9:13	151	SW_19b_SS	3.50	1			77.6466	136.0962
2014-07-24	9:29	UU-1-7-586	SW_19b_SS	1.70		1		77.68419	136.2367
2014-07-25	4:40	11	SW_B3a_SS		1			78.661	136.701
2014-07-25	4:45	12	SW_B3b_SS		1			78.661	136.701
2014-07-25	4:50	13	SW_B3c_SS		1			78.661	136.701
2014-07-26	3:35	14	SW_20c_SS		1			77.90668	140.2215
2014-07-27	3:21	120	SW_20a_SS	3.50	1			77.92752	140.1156
2014-07-27	3:29	142	SW_20b_SS	3.30	1			77.91488	140.1797
2014-07-27	10:01	50	SW_21a_SS	3.50	1			77.70907	142.0644

2014-07-27	10:09	UU-1-5-358	SW_21a_GL	1.70		1		77.70631	142.1792
2014-07-27	10:17	U16/U23(HSD)	SW_21_14C	1.54			1	77.70416	142.2932
2014-07-27	10:41	67	SW_21b_SS	3.50	1			77.69724	142.6392
2014-07-27	10:49	UU-1-5-317	SW_21b_GL	1.70		1		77.69518	142.7572
2014-07-27	21:29	85	SW_21c_SS	3.50	1			77.38887	146.9879
2014-07-28	6:16	15	SW_B4a_SS		1			76.4179	148.102
2014-07-28	6:25	16	SW_B4b_SS		1			76.4179	148.102
2014-07-28	14:24	168	SW_22a_SS	3.50	1			76.89299	148.6402
2014-07-28	14:32	UU-1-8-600	SW_22a_GL	1.70		1		76.88778	148.5388
2014-07-28	14:40	U38/U5(HSD)	SW_22_14C	2.45			1	76.88268	148.436
2014-07-28	15:12	14	SW_22b_SS	3.50	1			76.85521	148.0433
2014-07-28	15:28	UU-1-8-563	SW_22b_GL	1.70		1		76.81891	147.9146
2014-07-29	6:50	17	SW_B5a_SS		1			76.5415	150.7296
2014-07-29	6:55	18	SW_B5b_SS		1			76.5415	150.7296
2014-07-29	7:00	19	SW_B5c_SS		1			76.5415	150.7296
2014-07-29	10:56	A4/8	SW_23a_SS	3.50	1			76.49373	148.795
2014-07-29	11:04	UU-1-10-681	SW_23a_GL	1.70		1		76.49507	148.8852
2014-07-30	3:30	20	SW_B6a_SS		1			76.67546	154.1343
2014-07-30	3:40	21	SW_B6b_SS		1			76.67063	154.1773
2014-07-30	10:32	131	SW_23b_SS	3.50	1			76.59617	151.551
2014-07-30	10:48	UU-1-10-689	SW_23b_GL	1.70		1		76.58866	151.6108
2014-07-31	3:12	U135	SW_23c_SS	3.50	1			76.67632	154.0441
2014-08-01	2:34	22	SW_B7a_SS		1			74.87	160.0295
2014-08-01	2:41	23	SW_B7b_SS		1			74.87	160.007
2014-08-01	8:48	U222	SW_24a_SS	3.50	1			75.53812	159.095
2014-08-01	9:04	UU-1-8-551	SW_24a_GL	1.70		1		75.51556	159.1477
2014-08-01	9:12	U19(HSD)	SW_24_14C	?			1	75.5119	159.1727
2014-08-01	9:36	161	SW_24b_SS	3.50	1			75.47338	159.2288
2014-08-01	9:52	UU-1-1-068	SW_24b_GL	1.70		1		75.46004	159.3042
2014-08-02	11:40	U111	SW_25a_SS	3.50	1			74.99613	161.0711
2014-08-02	11:48	UU-temp-001	SW_25a_GL	1.70		1		74.98649	161.0639
2014-08-02	23:48	U206	SW_25b_SS	3.50	1			74.95873	161.0673
2014-08-03	0:08	UU-1-5-324	SW_25b_GL	1.70		1		74.95582	161.0279
2014-08-03	0:16	U48/U30(HSD)	SW_25_14C	2.60			1	74.95257	160.9819
2014-08-03	0:40	U109	SW_25c_SS	3.50	1			74.93833	160.8112
2014-08-03	0:48	UU-1-10-687	SW_25c_GL	1.70		1		74.93335	160.7474
2014-08-03	11:00	U130	SW_26a_SS	3.50	1			74.7725	160.1444
2014-08-03	11:16	UU-1-10-719	SW_26b_GL	1.70		1		74.77393	160.1475
2014-08-03	14:28	U150	SW_27a_SS	3.50	1			74.70644	161.0189
2014-08-03	14:52	UU-1-10-702	SW_27a_GL	1.70		1		74.69816	161.1686
2014-08-03	15:00	U27/U36(HSD)	SW_27_14C	?			1	74.69402	161.2212
2014-08-03	15:24	144	SW_27b_SS	3.50	1			74.67577	161.3702
2014-08-03	15:32	UU-1-10-684	SW_27b_GL	1.70		1		74.66914	161.4287
2014-08-03	16:32	66	SW_27c_SS	3.50	1			74.63057	161.8176
2014-08-03	16:40	UU-1-10-696	SW_27c_GL	1.70		1		74.62544	161.8632
2014-08-03	21:28	16	SW_27d_SS	3.50	1			74.55843	162.4452
2014-08-03	21:44	UU-1-10-701	SW_27d_GL	1.70		1		74.55555	162.5045
2014-08-04	3:07	24	SW_B8a_SS		1			74.4	168.099
2014-08-04	23:48	83	SW_28b_SS	3.50	1			74.42088	167.0759
2014-08-05	0:00	UU-1-10-730	SW_28b_GL	1.70		1		74.41664	167.1782
2014-08-05	5:00	25	SW_29e_SS		1			73.54933	169.593
2014-08-05	9:36	49	SW_29a_SS	3.50	1			74.3001	168.5903
2014-08-05	9:52	UU-1-10-682	SW_29a_GL	1.70		1		74.2776	168.5317
2014-08-05	10:00	26	SW_29f_SS		1			73.55013	169.598
2014-08-05	10:04	U39/U31(HSD)	SW_29_14C	?			1	74.26536	168.5347
2014-08-05	10:28	132	SW_29b_SS	3.50	1			74.23778	168.5345

2014-08-05	10:44	UU-1-10-692	SW_29b_GL	1.80		1		74.21179	168.5568
2014-08-05	23:40	26	SW_29c_SS	3.50	1			73.54063	169.5272
2014-08-05	23:48	45	SW_29d_SS	3.50	1			73.54635	169.5685
2014-08-06	8:40	10	SW_30a_SS	3.50	1			74.01816	170.7581
2014-08-06	8:48	612	SW_30b1_SS	3.50	1			74.028	170.7639
2014-08-06	20:15	27	SW_B9a_SS		1			75.1526	173.1067
2014-08-06	20:20	28	SW_B9b_SS		1			75.15381	173.1533
2014-08-06	20:32	40	SW_30b2_SS	3.50	1			74.22905	171.6798
2014-08-06	20:40	UU-1-10-732	SW_30b_GL	1.70		1		74.23887	171.7123
2014-08-07	11:48	23	SW_30c_SS	3.50	1			74.74371	172.4192
2014-08-07	12:00	UU-1-5-281	SW_30c_GL	1.70		1		74.76168	172.4348
2014-08-07	20:08	4	SW_30d_SS	3.50	1			75.15102	173.0545
2014-08-08	0:08	931	SW_30e_SS	3.50	1			75.38182	173.5103
2014-08-08	0:16	UU-1-1-90	SW_30e_GL	1.70	1			75.39364	173.5465
2014-08-08	14:20	674/7..	SW_31a_SS	3.50	1			76.20851	175.1939
2014-08-08	14:25	29	SW_B10a_SS		1			75.12688	173.7792
2014-08-08	14:30	30	SW_B10b_SS		1			75.12008	173.7961
2014-08-08	14:52	UU-1-5-276	SW_31a_GL	1.70		1		76.23949	175.2575
2014-08-08	15:08	U15/U50(HSD)	SW_31_14C	1.62			1	76.25048	175.3083
2014-08-08	15:32	55	SW_31b_SS	3.50	1			76.27816	175.3996
2014-08-08	15:40	UU-1-4-249	SW_31b_GL	1.70		1		76.28719	175.4267
2014-08-09	13:12	56	SW_31c_SS	3.50	1			75.26567	173.5872
2014-08-09	13:20	UU-1-4-195	SW_31c_GL	1.70		1		75.25248	173.5883
2014-08-09	22:52	74	SW_31d_SS	3.50	1			74.46278	173.8804
2014-08-09	23:16	UU-1-7-459	SW_31d_GL	1.70		1		74.4245	173.8889
2014-08-10	12:32	59	SW_32a_SS	3.50	1			73.5421	176.1217
2014-08-10	12:48	UU-1-5-371	SW_32a_GL	1.70		1		73.52397	176.1803
2014-08-10	19:24	52	SW_32c_SS	3.50	1			73.312	176.7635
2014-08-10	19:48	UU-1-7-455	SW_32c_GL	1.70		1		73.30371	176.855
2014-08-10	20:00	U40/U43(HSD)	SW_32_14C	2.40			1	73.29466	176.8926
2014-08-10	20:24	94	SW_32d_SS	3.50	1			73.27879	176.9844
2014-08-10	20:32	31	SW_B11a_SS		1			73.273	177.0073
2014-08-10	20:32	UU-1-5-328	SW_32d_GL	1.70		1		73.27316	177.0072
2014-08-11	11:32	75	SW_33a_SS	3.50	1			72.2885	-178.1034
2014-08-11	11:40	UU-1-4-232	SW_33a_GL	1.70		1		72.27795	-178.0602
2014-08-11	16:00	51/U181	SW_33b_SS	3.50	1			72.20031	-176.89
2014-08-11	16:08	UU-1-5-321	SW_33b_GL	1.70		1		72.20907	-176.8574
2014-08-11	16:16	U12/U20(HSD)	SW_33_14C	2.30			1	72.21752	-176.8257
2014-08-11	17:04	160	SW_33c_SS	3.50	1			72.26767	-176.6239
2014-08-11	17:20	UU-1-4-256	SW_33c_GL	1.70		1		72.28586	-176.5577
2014-08-12	12:43	101	SW_34a_SS	3.50	1			72.0033333	-174.3795
2014-08-12	23:40	32	SW_B12a_SS		1			73.277	-173.053
2014-08-13	2:01	33	SW_B13a_SS		1			73.36	-172.862
2014-08-13	12:52	UU-1-5-320	SW_34a_GL	1.70		1		72.0116667	-174.347
2014-08-13	13:12	U113	SW_34b_SS	3.50	1			72.0375	-174.283833
2014-08-13	13:19	UU-1-2-079	SW_34b_GL	1.70		1		72.0498333	-174.255333
2014-08-13	16:41	107	SW_34c_SS	3.50	1			72.3495	-173.86
2014-08-13	16:56	UU-1-4-176	SW_34c_GL	1.70		1		72.3845	-173.826667
2014-08-13	19:23	122	SW_34d_SS	3.50	1			72.7641667	-173.453
2014-08-13	19:33	UU-1-7-450	SW_34d_GL	1.70		1		72.7891667	-173.427
2014-08-13	23:48	U179	SW_34e_SS	3.50	1			73.2866667	-173.0605
2014-08-13	23:55	?	SW_34e_GL	1.70		1		73.2946667	-173.053667

2014-08-14	16:28	34	SW_B14a_SS		1			73.821	-173.166
2014-08-14	16:37	125	SW_35a_SS	3.50	1			73.842	-173.117833
2014-08-14	16:57	UU-1-5-355	SW_35a_GL	1.70		1		73.8743333	-173.0785
2014-08-14	21:27	170	SW_35b_SS	3.50	1			74.3226667	-171.632167
2014-08-15	0:35	176	SW_35c_SS	3.50	1			74.3363333	-171.21
2014-08-15	0:49	UU-1-7-449	SW_35b_GL	1.70		1		74.3435	-171.075333
2014-08-15	2:35	177	SW_35d_SS	3.50	1			74.3861667	-170.033833
2014-08-15	3:10	176	SW_35e_SS	3.50	1			74.3941667	-169.6905
2014-08-15	7:35	35	SW_B15a_SS		1			74.14602	-169.8223
2014-08-15	7:40	36	SW_B15b_SS		1			74.13809	-169.8236

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Proposed publication strategy

- Research questions I and II will be included in one paper lead by C.J. Sapart with the WP-D and in collaboration with the permit holder POI.
- Research questions III will be included in a second paper lead by the ULB group in collaboration with the permit holder POI.
    - Research questions IV will be included in a third paper lead by the IMAU group in collaboration with the permit holder POI.

Coring sites metadata

The map below (Figure E.9) shows the coring sites where sediment samples were collected during the first leg. Filled green dots are the MUC stations, black crosses are the Rumohr stations and red triangles are the gravity corer/piston corer stations. Additional information about the metadata is provided in Table E.1 below. Information about the Rumohr cores can be found in the WPF description.

MUC

Figure E.10 shows the average recoveries for the MUC. Sediment recoveries varied from 14 cm to 55 cm (Figure E.11). On average the rise sediments were characterized by relatively high recoveries while the Laptev shelf exhibited the lowest recovery. Along the shelf, recoveries increased going eastward. Table E.2 provides a detailed description of the different purposes and recoveries for all the tubes recovered with the MUC. This table shows the cores that have been sliced on board too. Table E1 shows the stations where footage of the seabed (underwater camera) is available.

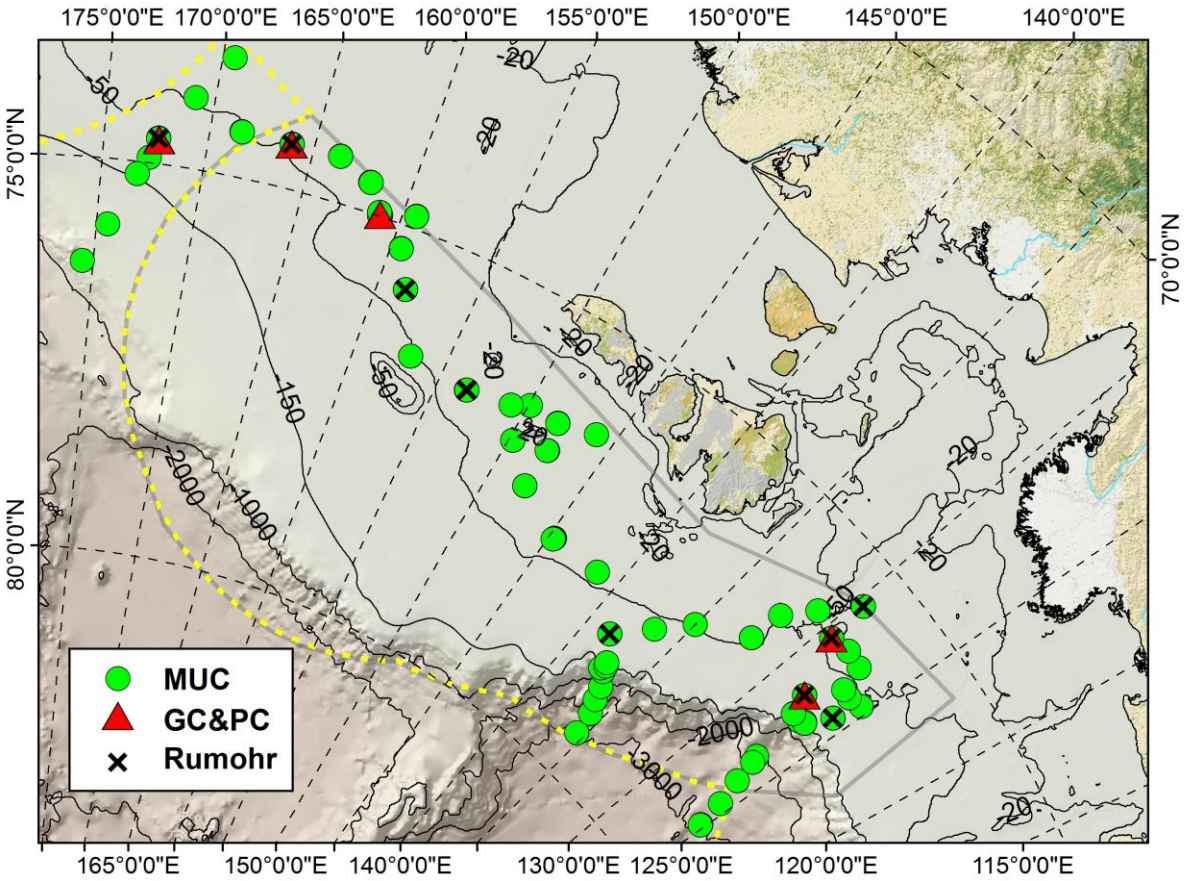


Figure E.9 . Map showing the coring sites during leg 1. Three different sample type are shown: MUC (mulitcorer), RUM (Rumohr corer), GC&PC (gravity corer and piston corer)

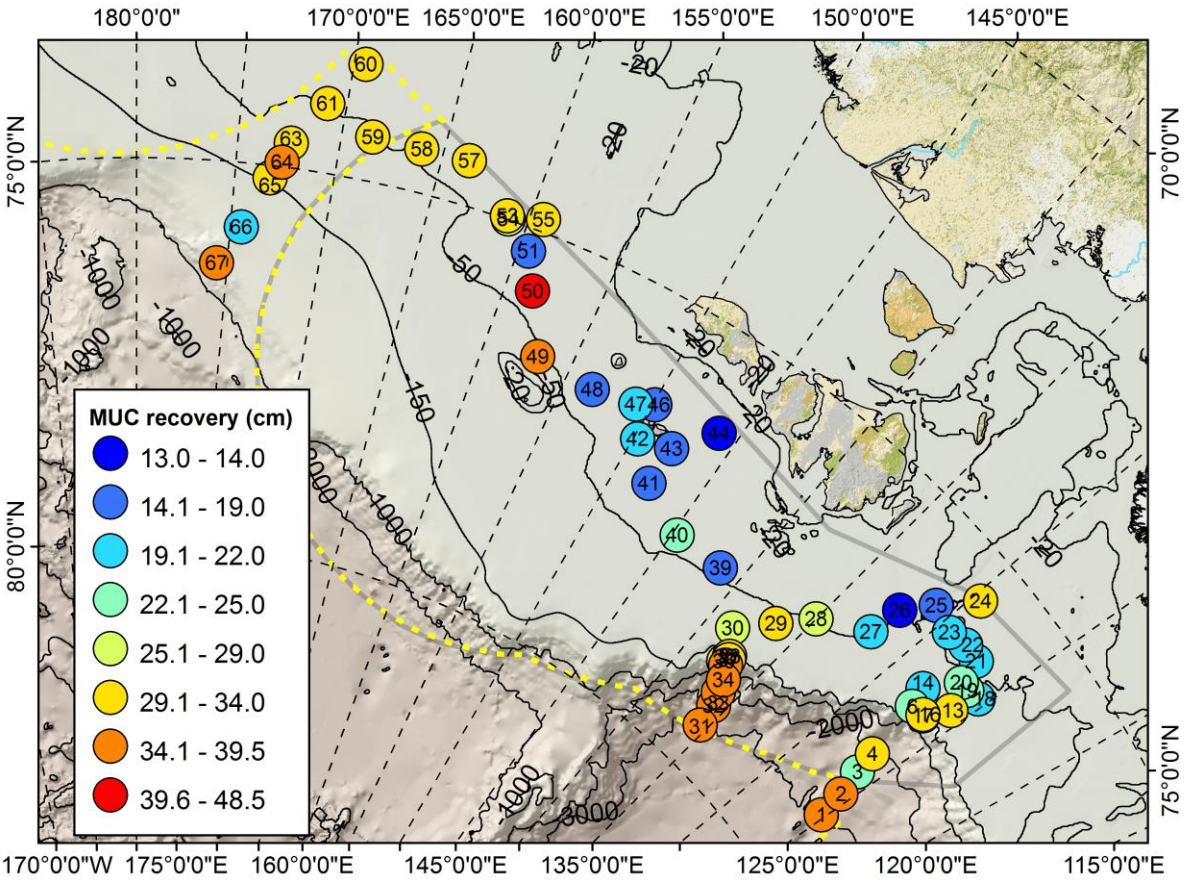


Figure E.10 . Map showing MUC recoveries. Numbers refer to the station number

Table E.1. Coring sites. Bold IDs are stations where footage of the seabed is available

ID	LAT_DD	LONG_DD	DATE	TIME (UTC)	DEPTH (m)	Recovery
01-MC/I	78.942	125.243	7/15/2014	7:53:55 PM	-3146	
01-MC/II	78.950	125.232	7/15/2014	11:00:35 PM	-3120	35
02-MC/I	78.581	125.607	7/16/2014	6:58:34 AM	-2900	36
03-MC/I	78.238	126.150	7/16/2014	11:58:35 AM	-2601	25
4-MC/I	77.855	126.664	7/16/2014	5:06:06 PM	-2106	
4-MC/II	77.938	126.518	7/16/2014	9:08:15 PM	-2186	30
6-MC/I	77.142	127.378	7/17/2014	10:02:27 AM	-89	
6-MC/II	77.150	127.352	7/17/2014	10:42:25 AM	-92	23
13-MC/I	76.777	125.830	7/18/2014	11:20:47 AM	-74	30
13-MC/II	76.778	125.830	7/18/2014	12:58:14 PM	-73	
13-MC/III	76.778	125.830	7/18/2014	1:46:22 PM	-72	
13-RU/I	76.778	125.830	7/18/2014	2:40:24 PM	-72	
14-MC/I	76.894	127.798	7/19/2014	12:09:11 PM	-64	22
14-MC/II	76.894	127.798	7/19/2014	1:23:13 PM	-64	
14-MC/III	76.894	127.799	7/19/2014	2:18:59 PM	-64	
14-PC	76.893	127.795	7/19/2014	7:55:30 PM	-64	
14-RU/I	76.894	127.799	7/19/2014	3:13:00 PM	-64	
15-MC/I	77.144	126.807	7/20/2014	10:31:33 AM	-330	?
16-MC/I	77.100	126.596	7/20/2014	3:56:00 PM	-236	31
17-MC/I	77.110	126.539	7/20/2014	8:28:42 PM	-208	17
18-MC/I	76.399	125.460	7/21/2014	9:39:45 AM	-52	22
19-MC/I	76.456	126.211	7/21/2014	5:34:06 PM	-51	24
20-MC/I	76.454	126.742	7/21/2014	11:14:47 PM	-52	24
21-MC/I	76.126	127.190	7/22/2014	7:03:52 AM	-46	20
22-MC/I	76.108	128.241	7/22/2014	1:03:58 PM	-48	20
23-MC/I	76.171	129.333	7/22/2014	11:27:40 PM	-56	21
23-MC/II	76.171	129.333	7/22/2014	11:52:26 PM	-56	
23-MC/III	76.171	129.333	7/23/2014	12:23:53 AM	-56	
23-PC/I	76.171	129.337	7/22/2014	21:06:40	-56	
23-RU/I	76.171	129.332	7/23/2014	1:02:05 AM	-56	38
23-RU/II	76.171	129.332	7/23/2014	1:10:48 AM	-56	42
23-RU/III	76.171	129.332	7/23/2014	1:20:21 AM	-56	
24-MC/I	75.599	129.558	7/24/2014	5:45:49 AM	-46	31
24-RU/I	75.600	129.566	7/24/2014	6:20:00 AM	-46	62
24-RU/II	75.600	129.567	7/24/2014	6:26:00 AM	-46	32
25-MC/I	76.077	130.916	7/23/2014	12:55:49 PM	-53	18.5
26-MC/I	76.473	132.044	7/23/2014	6:34:50 PM	-52	13
27-MC/I	76.943	132.229	7/23/2014	11:19:50 PM	-44	
27-MC/II	76.941	132.229	7/23/2014	11:53:35 PM	-44	20
28-MC/I	77.342	135.007	7/24/2014	6:25:50 AM	-49	29
29-MC/I	77.753	136.545	7/24/2014	11:02:27 AM	-57	30
30-MC/I	78.182	138.355	7/24/2014	3:55:32 PM	-69	27
30-MC/II	78.181	138.354	7/24/2014	4:27:42 PM	-69	

30-RU/I	78.181	138.357	7/24/2014	4:56:00 PM	-69	
31-MC/I	79.396	135.497	7/25/2014	11:54:14 AM	-3056	38
32-MC/I	79.093	135.760	7/25/2014	4:18:33 PM	-2540	37
33-MC/I	78.927	136.178	7/25/2014	9:19:12 PM	-2264	39
34-MC/I	78.758	136.501	7/26/2014	1:52:14 AM	-1880	39
35-MC/I	78.600	137.061	7/26/2014	6:41:12 AM	-541	38
36-MC/I	78.581	137.338	7/26/2014	8:54:05	-360	30
37-MC/I	78.521	137.170	7/26/2014	16:28:34	-205	33
38-MC/I	78.481	137.274	7/26/2014	21:21:57	-118	31
39-MC/I	77.681	141.370	7/27/2014	6:30:00	-45	18
40-MC/I	77.666	144.643	7/27/2014	15:20:31	-45	
40-MC/II	77.670	144.668	7/27/2014	15:48:20	-45	
40-MC/III	77.681	144.690	7/27/2014	16:20:00	-47	23
41-MC/I	77.320	147.830	7/27/2014	22:54:30	-43	
41-MC/II	77.320	147.830	7/27/2014		-40	18
42-MC/I	76.900	149.755	7/28/2014	8:51:11	-44	
42-MC/II	76.902	149.751	7/28/2014	10:06:07	-44	21
43-MC/I	76.780	147.791	7/28/2014	16:12:46	-42	19
43-MC/II	76.786	147.814	7/28/2014		-40	
44-MC/I	76.273	146.034	7/28/2014	22:39:15	-43	14
45-MC/I	76.416	148.115	7/29/2014	5:41:22	-40	
45-MC/II	76.418	148.104	7/29/2014	6:06:26	-40.5	
46-MC/I	76.403	149.878	7/29/2014	13:05:28	-40	16
47-MC/I	76.521	150.809	7/29/2014	21:37:10	-41	21
48-MC/I	76.616	153.365	7/30/2014	19:37:40	-40	17
48-MC/II	76.615	153.345	7/30/2014	19:54:16	-49	
48-RU/I	76.613	153.338	7/30/2014	20:25:20	-48.5	
48-RU/II	76.612	153.335	7/30/2014	20:37:55	-49.2	
48-RU/III	76.612	153.349	7/30/2014	20:48:06	-49	
49-MC/I	76.526	156.924	7/31/2014	13:31:59	-47	39.5
49-MC/II	76.526	156.924	7/31/2014	14:02:28	-47	
50-MC/I	75.763	158.529	8/1/2014	3:08:08	-44	48.5
50-MC/II	75.764	158.529	8/1/2014	3:31:53	-44	
50-MC/III	75.764	158.529	8/1/2014	3:58:40	-44	
50-MC/IV	75.765	158.531	8/1/2014	4:25:05	-44	
50-RU/I	75.763	158.529	8/1/2014	3:08:08	-44	48.5
50-RU/I	75.763	158.529	8/1/2014	3:08:08	-44	48.5
51-MC/I	75.296	159.474	8/1/2014	14:54:16	-39	
51-MC/II	75.297	159.477	8/1/2014	3:13:20 PM	-39	19
52-MC/I	74.998	161.025	8/2/2014	6:43:00 AM	-46	
52-MC/II	75.001	161.032	8/2/2014	7:08:20 AM	-46	
52-PC	74.984	161.012	8/2/2014	4:39:29 AM	-48	33
53-MC/I	74.957	161.088	8/2/2014	3:31:54 PM	-47	
53-MC/II	74.957	161.090	8/2/2014	15:59:24	-48	30
54-MC/I	74.990	160.995	8/2/2014	9:47:15 PM	-48	27
55-MC/I	74.845	159.327	8/3/2014	7:13:00 AM	-49.6	32

55-MC/II	74.846	159.325	8/3/2014	7:34:57 AM	-49	
56-MC/I	74.630	161.948	8/3/2014	6:32:10 PM	-48	
56-MC/II	74.632	161.943	8/3/2014	6:55:01 PM	-48	
57-MC/I	74.425	163.692	8/4/2014	2:03:45 AM	-52	34
57-MC/II	74.427	163.691	8/4/2014	2:27:00 AM	-53	
58-GC/I	74.444	166.064	8/4/2014	3:00:45 PM	-55.5	200
58-GC/II	74.444	166.065	8/4/2014	4:17:32 PM	-54	
58-MC/I	74.439	166.047	8/4/2014	12:34:05	-54	32
58-MC/II	74.440	166.050	8/4/2014	12:58:55 PM	-54	
58-MC/III	74.441	166.053	8/4/2014	1:21:32 PM	-55	
58-RU/I	74.441	166.053	8/4/2014	1:21:32 PM	-55	
58-RU/II	74.441	166.053	8/4/2014	1:21:32 PM	-55	
59-MC/I	74.426	168.493	8/5/2014	6:33:25 AM	-54	32
59-MC/II	74.427	168.490	8/5/2014	6:57:01 AM	-54	
60-MC/I	73.520	169.460	8/5/2014	10:53:28 PM	-43	31
61-MC/I	74.106	170.901	8/6/2014	12:58:54 PM	-51	31
63-GC/I	74.699	172.331	8/7/2014	9:36:55 AM	-68	
63-GC/II	74.704	172.325	8/7/2014	10:33:41 AM	-69	
63-MC/I	74.682	172.369	8/7/2014	6:51:22 AM	-64	30
63-MC/II	74.685	172.361	8/7/2014	07:14:30-60	-67	
63-RU/I	74.686	172.357	8/7/2014	7:44:45 AM	-66.5	54
63-RU/II	74.687	172.355	8/7/2014	7:42:23 AM	-67	
63-RU/III	74.688	172.352	8/7/2014	7:51:49 AM	-69	51
64-MC/I	74.941	172.694	8/7/2014	5:23:58 PM	-120	38
65-MC/I	75.163	173.191	8/7/2014	9:15:47 PM	-170	31
66-MC/I	75.838	174.409	8/8/2014	8:59:25 AM	-239	21
67-MC/I	76.333	175.579	8/8/2014	7:22:25 PM	-468	36

Table E. 2. MUC core purpose and recovery

ID	1		2		3		4		5		6		7		8		Sliced
	Purpose	**cm**	**Purpose**	**cm**	**purpose**	**cm**	**purpose**	**cm**	**purpose**	**cm**	**purpose**	**cm**	**purpose**	**cm**	**purpose**	**cm**	
01-MC/I	WPF	35	WPF	34	WPF	35	WPF	37	CH4	23	O2	23	EC	10	x	0	
01-MC/II	OG	25	**OG**	35	X	0	*OG*	24	SED	20	EC	16	EC	17	EC	10	1x
02-MC/I	EC	17	O2	34	**OG**	36	*OG*	31	EC	31	OG	32	EC	22	SED	17	1x
03-MC/I	O2	23	14C-CH4	23	**OG**	25	*OG*	23	SED	24	EC	23	OG	24	EC	22	1x
04-MC/I	WPF	30	WPF	31	WPF	32	WPF	33	O2	24	EC	22	x	0	CH4	17	
04-MC/II	OG	28	OG	29	14C-CH4	28	SED	27	**OG**	30	EC	28	EC	28	EC	27	1x
06-MC/I	WPF	14	WPF	16	CH4	19	O2	17	WPF	19	CH4	17	x	0	x	0	
06-MC/II	**OG**	23	*OG*	20	OG	22	14C-CH4	22	SED	22	EC	23	EC	22	EC	22	1x
13-MC/I	**OG**	30	OG	25	EC	24	SED	23	OG	28	14C-CH4	28	CH4	27	14C-CH4	27	1x
13-MC/II	WPF	23	WPF	24	WPF	22	WPF	23	WPF	24	WPF	22	O2	22	WPF	0	
13-MC/III	WPF	14	WPF	13	WPF	17	WPF	13	WPF	14	WPF	13	WPF	15	O2	15	
14-MC/I	OG	21	14C-CH4	20	14C-CH4	18	CH4	21	**OG**	22	*OG*	21	EC	21	SED	20	1x
14-MC/II	WPF	16	WPF	17	WPF	17	WPF	15	WPF	16	WPF	14	WPF	16	O2	16	
14-MC/III	WPF	22	WPF	23	WPF	24	WPF	23	WPF	22	WPF	22	WPF	24	O2	24	
15-MC/I	X		X		X		x		x		SED		SED		SED		
16-MC/I	CH4	17	EC	22	OG	24	**OG**	31	OG	25	O2+SED	22	14C-CH4	22	14C-CH4	20	1x
17-MC/I	EC	6	14C-CH4	12	14C-CH4	9	CH4	18	**OG**	17	OG	15	OG	12	O2	8	1x
18-MC/I	EC	10	OG	14	14C-CH4	15	**OG**	22	14C-CH4	25	OG	22	CH4	17	SED	14	1x
19-MC/I	SED	17	OG	20	OG	19	**OG**	24	14C-CH4	22	14C-CH4	22	CH4	20	EC	19	1x
20-MC/I	OG	23	**OG**	24	EC	22	CH4	23	SED	20	OG	21	14C-CH4	23	14C-CH4	25	1x
21-MC/I	O2	12	CH4	13	EC	14	14C-CH4	18	SED	20	**OG**	20	OG	19	14C-CH4	17	1x
22-MC/I	EC	19	OG	18	CH4	23	SED	24	14C-CH4	21	14C-CH4	19	**OG**	20	OG	18	1x
23-MC/I	WPF	24	WPF	26	WPF	25	WPF	26	WPF	24	WPF	25	WPF	26	O2	26	
23-MC/II	SED	19	EC	19	*OG*	20	**OG**	21	**OG**	21	EC	20	CH4	21	OG	21	2x
23-MC/III	WPF	22	WPF	24	WPF	23	WPF	23	WPF	23	WPF	24	WPF	23	WPF	24	
24-MC/I	OG	30	**OG**	31	*OG*	31	O2+SED	30	CH4	32	EC	29	14C-CH4	29	14C-CH4	29	1x
25-MC/I	14C-CH4	17	CH4	18	OG	18	**OG**	19	**OG**	18	EC	18	OG	18	SED	17	2x
26-MC/I	**OG**	13	CH4	16	OG	17	14C-CH4	16	EC	12	SED	10	OG	12	EC	12	1x
27-MC/I	WPF	21	WPF	19	WPF	20	WPF	20	WPF	20	WPF	19	WPF	20	O2	20	
27-MC/II	SED	18	EC	19	EC	19	CH4	18	OG	19	**OG**	20	OG	20	OG	19	1x
28-MC/I	OG	20	CH4	29	OG	27	EC	26	EC	29	SED	28	OG	26	**OG**	29	1x
29-MC/I	EC	28	**OG**	30	CH4	28	OG	27	OG	24	OG	20	SED	21	EC	21	1x
30-MC/I	14C-CH4	25	14C-CH4	24	CH4	26	SED	27	OG	27	*OG*	26	**OG**	27	OG	27	1x
30-MC/II	WPF	25	X	0	O2	27	WPF	27	WPF	27	WPF	27	WPF	26	WPF	27	
31-MC/I	SED	32	EC	30	**OG**	38	CH4	34	*OG*	35	OG	31	OG	33	EC	36	1x
32-MC/I	SED	29	OG	28	**OG**	37	*OG*	30	CH4	28	OG	36	EC	27	EC	26	1x
33-MC/I	CH4	33	EC	24	SED	30	EC	30	OG	31	*OG*	33	**OG**	39	OG	37	1x
34-MC/I	EC	32	O2	33	SED	31	OG	39	CH4	41	**OG**	39	OG	38	OG	33	1x
35-MC/I	OG	30	O2+SED	29	**OG**	38	*OG*	38	CH4	40	OG	38	EC	34	EC	32	1x
36-MC/I	OG	32	**OG**	30	EC	29	CH4	35	OG	35	EC	28	OG	30	SED	26	1x
37-MC/I	OG	26	EC	13	*OG*	31	**OG**	33	CH4	33	O2+SED	31	OG	28	EC	25	1x
38-MC/I	EC	25	EC	24	SED	22	CH4	27	**OG**	31	*OG*	27	OG	25	OG	23	1x

39-MC/I	EC	10	EC	12	OG	13	OG	12	CH4	17	**OG**	18	OG	19	SED	16	1x
40-MC/I	X	0	X	0	X	0	14C-CH4	14	SED	17	14C-CH4	11	x	0	CH4	16	
40-MC/II	EC	8	X	0	WPF	19	O2	17	x	0	EC	7	EC	10	WPF	18	
40-MC/III	OG	19	OG	19	WPF	16	**OG**	23	WPF	18	OG	20	WPF	17	WPF	18	1x
41-MC/I	EC	?	X		x		x		x		x		x		x		
41-MC/II	CH4	15	OG	16	**OG**	18	**OG**	17	14C-CH4	16	x	0	14C-CH4	17	SED	16	2x
42-MC/I	X		X		x		x		x		x		x		x		
42-MC/II	OG	21	**OG**	21	OG	19	EC	19	OG	18	x	0	SED	19	x	0	1x
43-MC/I	X	0	WPF	12	x	0	O2	13	WPF	16	WPF	19	WPF	11	WPF	11	
43-MC/II	EC	14	CH4	13	OG	15	**OG**	16	OG	14	OG	15	CH4	12	SED	14	1x
44-MC/I	EC	11	EC	11	OG	13	**OG**	14	CH4	13	**OG**	14	OG	12	SED	12	2x
45-MC/I	WPF	11	WPF	12	O2	12	WPF	14	WPF	10	WPF	12	WPF	13	WPF	9	
45-MC/II	OG	19	OG	20	OG	19	**OG**	19	EC	18	SED	19	CH4	19	EC	17	1x
46-MC/I	EC	15	EC	14	OG	14	OG	16	SED	14	**OG**	16	CH4	18	OG	16	1x
47-MC/I	OG	20	**OG**	21	EC	19	SED	16	CH4	19	EC	19	OG	19	OG	19	1x
48-MC/I	EC	17	SED	16	OG	17	OG	17	**OG**	17	OG	17	CH4	16	EC	16	1x
48-MC/II	WPF	20	WPF	20	O2	19	WPF	19	WPF	18	WPF	19	WPF	19	WPF	19	
49-MC/I	CH4	33	EC	34	OG	39	**OG**	40	OG	38	OG	36	SED	33	EC	31	1x
49-MC/II	14C-CH4	37	14C-CH4	38	14C-CH4	33	14C-CH4	34	EC	?	EC	?	EC	?	EC	?	
50-MC/I	EC	46	OG	47	**OG**	49	OG	48	EC	48	OG	48	CH4	44	SED	45	1x
50-MC/II	WPF	49	WPF	48	O2	47	x	0	WPF	47	WPF	49	WPF	49	WPF	50	
50-MC/III	WPF	26	WPF	25	WPF	28	WPF	27	WPF	26	WPF	27	WPF	25	WPF	28	
50-MC/IV	14C-CH4	30	14C-CH4	32	14C-CH4	26	14C-CH4	20	EC	21	EC	20	EC	26	EC	22	
51-MC/I	OG	16	**OG**	19	OG	16	OG	16	EC	13	EC	13	CH4	15	SED	15	1x
51-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
52-MC/I	SED	29	OG	30	**OG**	33	OG	30	OG	32	EC	24	EC	25	CH4	29	1x
52-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
53-MC/I	CH4	22	SED	21	EC	19	EC	23	14C-CH4	26	14C-CH4	29	14C-CH4	28	14C-CH4	24	
53-MC/II	OG	29	OG	30	**OG**	30	OG	30	O2	29	EC	29	EC	30	EC	27	1x
54-MC/I	14C-CH4	25	14C-CH4	26	14C-CH4	24	14C-CH4	25	EC	24	EC	25	EC	25	EC	25	
55-MC/I	OG	31	EC	30	CH4	31	OG	31	EC	31	**OG**	32	OG	32	SED	31	1x
55-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
56-MC/I	OG	21	CH4	18	OG	19	EC	15	SED	15	**OG**	18	**OG**	21	OG	21	2x
56-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
57-MC/I	CH4	31	EC	33	**OG**	34	OG	34	OG	29	EC	30	SED	29	OG	31	1x
57-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
58-MC/I	OG	31	OG	31	OG	31	CH4	31	SED	30	EC	30	EC	30	**OG**	32	1x
58-MC/II	WPF	38	O2	36	WPF	34	WPF	33	WPF	31	WPF	34	WPF	35	WPF	38	
58-MC/III	WPF	34	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	
59-MC/I	OG	30	**OG**	32	EC	32	SED	32	CH4	31	EC	31	EC	31	OG	30	1x
59-MC/II	14C-CH4	?	14C-CH4	?	14C-CH4	?	14C-CH4	?	EC	?	EC	?	EC	?	EC	?	
60-MC/I	OG	32	OG	32	SED	32	CH4	30	EC	31	EC	30	**OG**	31	OG	31	1x
61-MC/I	OG	30	OG	31	SED	32	EC	31	EC	30	CH4	31	**OG**	31	OG	31	1x
63-MC/I	EC	29	OG	29	EC	29	SED	25	OG	26	CH4	30	**OG**	29	**OG**	30	2x
63-MC/II	WPF	24	O2	36	WPF	30	WPF	33	WPF	31	WPF	32	WPF	34	WPF	36	
64-MC/I	EC	37	OG	37	SED	34	CH4	35	EC	37	EC	32	**OG**	38	OG	36	1x

65-MC/I	CH4	33	EC	32	EC	31	**OG**	31	OG	32	OG	32	SED	32	EC	32	1x
66-MC/I	OG	1	OG	21	CH4	17	OG	17	SED	17	x	0	EC	17	**OG**	21	1x

CH4	Denis Kosmach
WPF	Volker Bruchert
EC	Ecology, Aleksandr Gukov
O2	Lisa Broder
SED	Sedimentology, Oleg Dudarev
OG	Organic Geochemistry
OG	Sliced core for OG
OG	Split core for OG
X	no recovery
14C-CH4	Julia Steinbach for 14C methane

Piston cores and gravity cores

Two piston cores were recovered in the Laptev Sea (64 and 56 meter sea water) along with one piston core and two gravity cores in the East Siberian Sea (48, 54 and 69 msw).

- PC-14 recovered 413cm of sediment but appeared to have hit the top of the counterweight and fallen over. The sediment recovered is likely to have been 'hoovered' up from the surface layer by the action of the piston during recovery.
- PC-23 recovered 421.7cm and seemed to have stopped at the Holocene erosive transgressive surface or even low stand deposits as suggested by the presence of harder shale in the core cutter. 22cm of sand from the bottom of the core was sucked up the core liner during recovery but the core remained relatively undisturbed (Figure E.12).
- PC-52 was stopped by a compacted 'rubber' layer of sand and silt and only recovered 84cm.
- GC-58 also stopped at the rubber layer and GC-63 suffered from sediment loss past the core catcher during recovery.

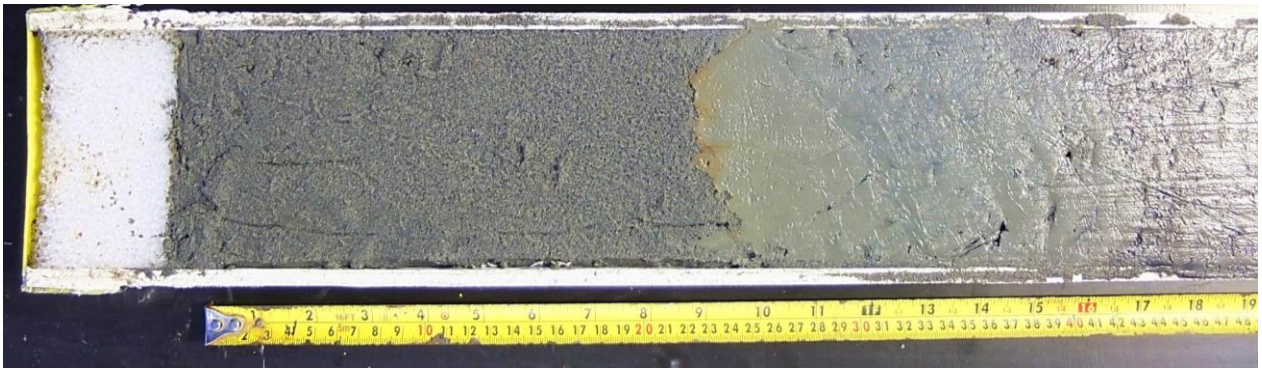


Figure E.12. Layer of sand that was pulled from the bottom sandy unit due to the backpressure in the liner. The red/brown color should correspond to the oxidized top layer as observed in the MUC collected at the same station

Table E.3. Summary table with all PC and GC collected

	PC-14	PC-23	PC-52	GC-58	GC-63
Lat	76.893	76.171	74.984	74.444	74.7042
Long	127.795	129.337	161.012	166.065	172.325
Date	7/19/2014	7/22/2014	8/2/2014	8/4/2014	8/7/2014
Time (UTC)	7:55:30 PM	21:06:40	4:39:29 AM	4:17:32 PM	10:33:41 AM
Depth (m)	-64	-56	-48	-54	-69
Recovery (cm)	413	421.7	84	77.8	100.2
Section I (cm)	125	134.2			
Section II (cm)	150	137			
Section III (cm)	138	150.5			
Top probe	#1854458 (6.43m)	#1854459 (6.39m)	#1854459 (6.4m)		
Middle probe	#1854459 (3.42m)	#1854476 (3.38m)	#1854476 (3.38m)		
Bottom probe	#1854476 (0.26m)	#1854458 (0.35m)	#1854458 (0.35m)		
Head Weight (Kg)	900	900	900	1215	1215
Barrel Length (m)	9	9	9	6	6
Counter Weight (Kg)	90	90	90		
Free fall (m)	1	2	2		

Multisensor core logger

All the piston/gravity cores were logged to determine the bulk density and magnetic susceptibility. For the MUC, at least one tube per station was logged but the cores were too short to obtain reliable magnetic susceptibility. MUC tubes were logged at 0.4 cm resolution while longer cores (PC and GC) were logged at 1 cm resolution. The figure below (Figure E.12) shows an example of gamma attenuation (CPS) and magnetic susceptibility (SI) data for station 23 (both MUC and PC)

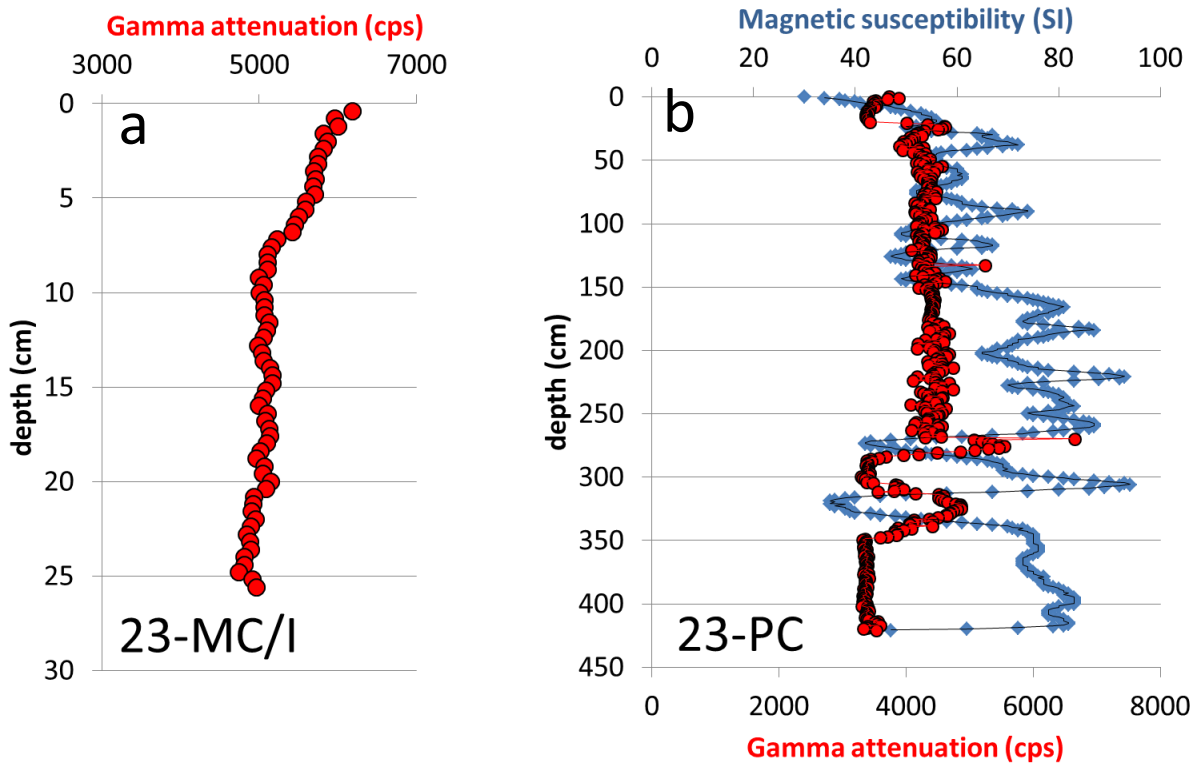


Figure E.12. MSCL data for station 23, (a) multicorer and (b) piston corer

Bottom water and sediment temperature (ANTARES logger)

The temperature in bottom water (50 cm above the seabed) and surface sediment was measured in 47 stations. Data are presented in Table E.4 and Figures E.13 and E.14. In general, the two temperatures correlate with each other. The highest differences were measured in the upper slope likely due to local changes in the bottom current due to the irregular bottom morphology.

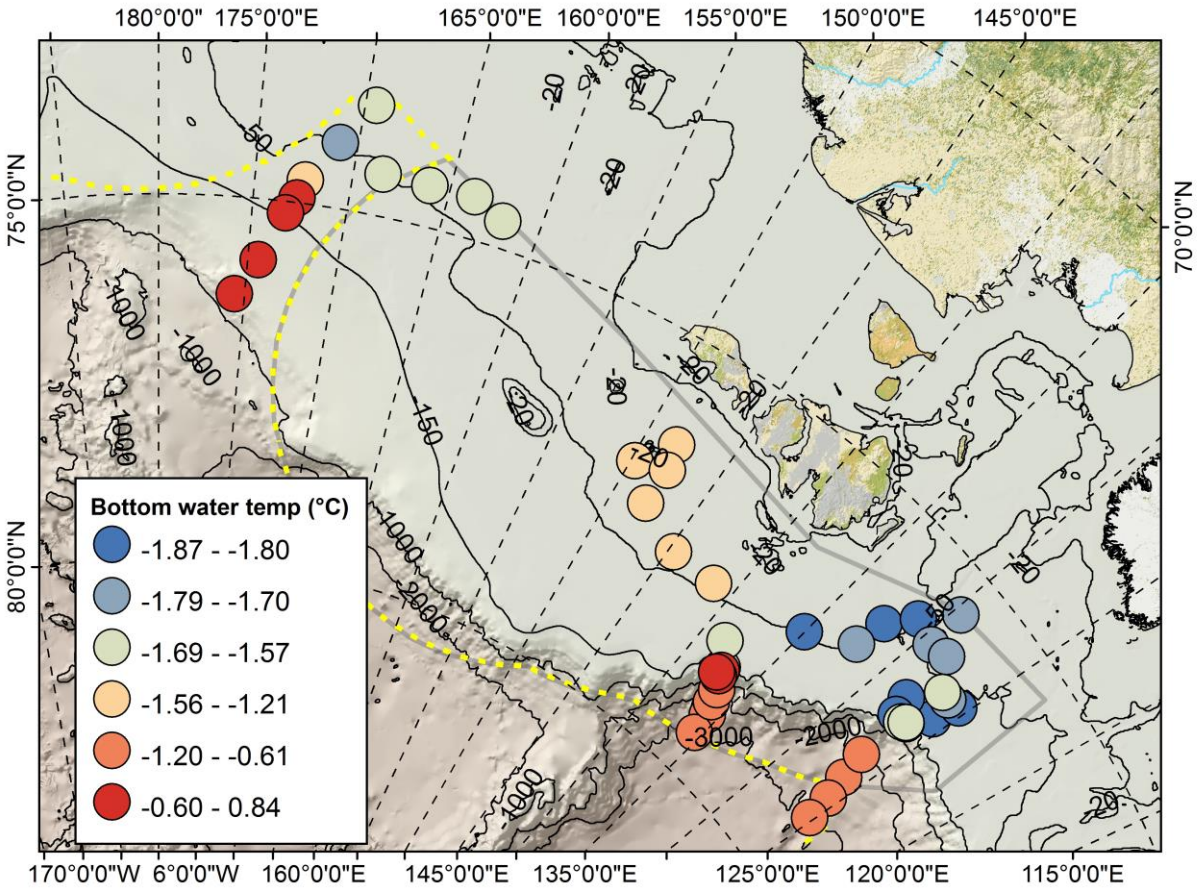


Figure E.12. Temperature in bottom waters (50 cm above the seabed)

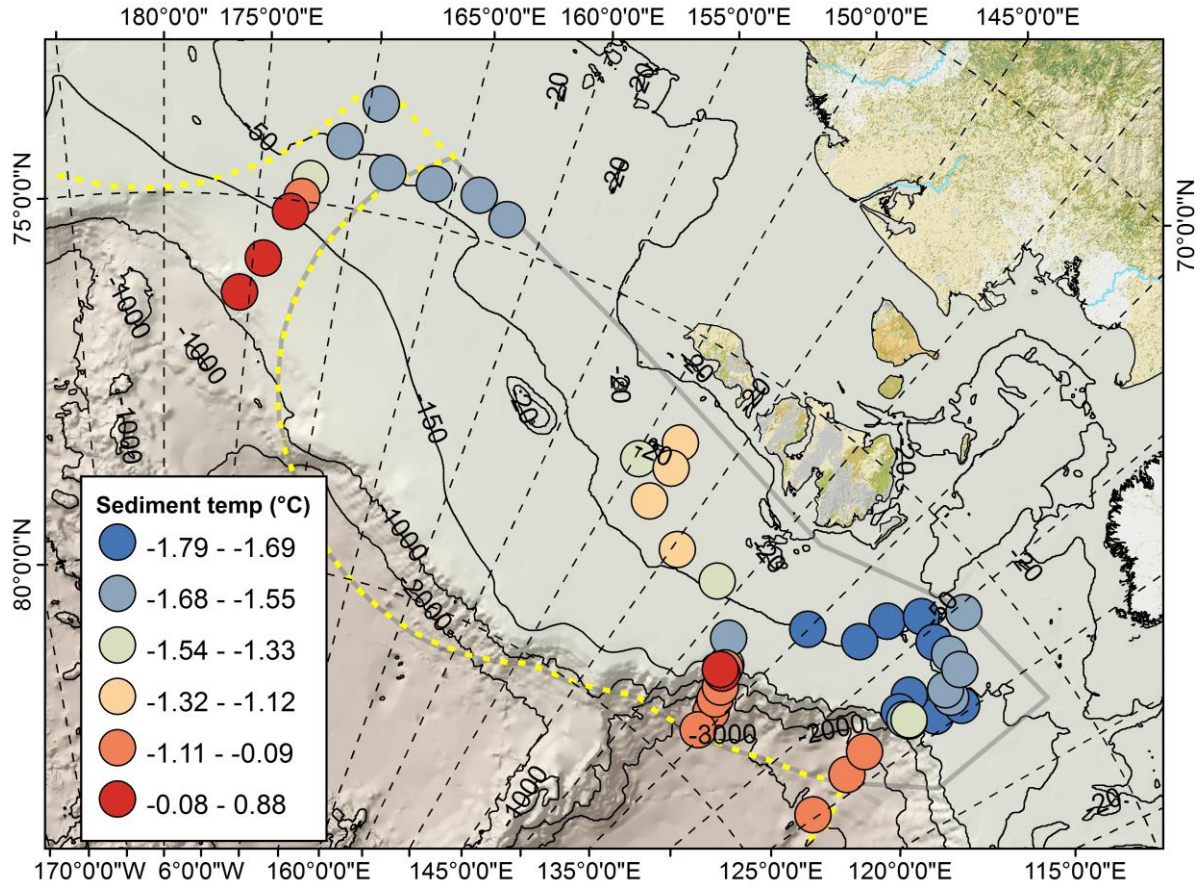


Figure E.13. Temperature in surface sediments

Table E.4. Temperature in bottom waters (50 cm above the seabed) and surface sediments

STATION	CAST	LAT_DD	LONG_DD	DATE	TIME (UTC)	DEPTH (m)	temp bottom water (°C)	temp sediment (°C)
01	MC/I	78.942	125.243	7/15/2014	7:53:55 PM	-3146	-0.768	-0.704
02	MC/I	78.581	125.607	7/16/2014	6:58:34 AM	-2900	-0.779	
03	MC/I	78.238	126.150	7/16/2014	11:58:35 AM	-2601	-0.806	-0.757
4	MC/I	77.855	126.664	7/16/2014	5:06:06 PM	-2106	-0.789	-0.751
6	MC/I	77.142	127.378	7/17/2014	10:02:27 AM	-89	-1.834	-1.729
13	MC/I	76.777	125.830	7/18/2014	11:20:47 AM	-74	-1.872	-1.789
14	MC/II	76.894	127.798	7/19/2014	1:23:13 PM	-64	-1.848	-1.775
15	MC/I	77.144	126.807	7/20/2014	10:31:33 AM	-330	-1.681	-1.652
16	MC/I	77.100	126.596	7/20/2014	3:56:00 PM	-236	-1.677	-1.405
17	MC/I	77.110	126.539	7/20/2014	8:28:42 PM	-208	-1.683	-1.564
18	MC/I	76.399	125.460	7/21/2014	9:39:45 AM	-52	-1.840	-1.788
19	MC/I	76.456	126.211	7/21/2014	5:34:06 PM	-51	-1.704	-1.660

20	MC/I	76.454	126.742	7/21/2014	11:14:47 PM	-52	-1.569	-1.546
21	MC/I	76.126	127.190	7/22/2014	7:03:52 AM	-46		-1.616
22	MC/I	76.108	128.241	7/22/2014	1:03:58 PM	-48	-1.706	-1.621
23	MC/I	76.171	129.333	7/22/2014	11:27:40 PM	-56	-1.763	-1.697
24	MC/I	75.599	129.558	7/24/2014	5:45:49 AM	-46	-1.714	-1.627
25	MC/I	76.077	130.916	7/23/2014	12:55:49 PM	-53	-1.801	-1.763
26	MC/I	76.473	132.044	7/23/2014	6:34:50 PM	-52	-1.822	-1.781
27	MC/I	76.943	132.229	7/23/2014	11:19:50 PM	-44	-1.753	-1.694
28	MC/I	77.342	135.007	7/24/2014	6:25:50 AM	-49	-1.806	-1.744
30	MC/I	78.182	138.355	7/24/2014	3:55:32 PM	-69	-1.636	-1.568
31	MC/I	79.396	135.497	7/25/2014	11:54:14 AM	-3056	-0.771	-0.716
32	MC/I	79.093	135.760	7/25/2014	4:18:33 PM	-2540	-0.801	-0.759
33	MC/I	78.927	136.178	7/25/2014	9:19:12 PM	-2264	-0.760	-0.702
34	MC/I	78.758	136.501	7/26/2014	1:52:14 AM	-1880	-0.613	-0.572
35	MC/I	78.600	137.061	7/26/2014	6:41:12 AM	-541	0.409	0.445
36	MC/I	78.581	137.338	7/26/2014	8:54:05 AM	-360	0.840	0.878
37	MC/I	78.521	137.170	7/26/2014	4:28:34 PM	-205	0.295	-0.180
38	MC/I	78.481	137.274	7/26/2014	9:21:57 PM	-118	-1.681	-1.459
39	MC/I	77.681	141.370	7/27/2014	6:30:00 AM	-45	-1.369	-1.328
40	MC/I	77.666	144.643	7/27/2014	3:20:31 PM	-45	-1.314	-1.277
41	MC/I	77.320	147.830	7/27/2014	10:54:30 PM	-43	-1.222	-1.163
42	MC/I	76.900	149.755	7/28/2014	8:51:11 AM	-44	-1.430	-1.357
43	MC/I	76.780	147.791	7/28/2014	4:12:46 PM	-42	-1.208	-1.119
45	MC/I	76.416	148.115	7/29/2014	5:41:22 AM	-40	-1.335	-1.297
56	MC/I	74.630	161.948	8/3/2014	6:32:10 PM	-48	-1.649	-1.609
57	MC/I	74.425	163.692	8/4/2014	2:03:45 AM	-52	-1.654	-1.594
58	MC/I	74.439	166.047	8/4/2014	12:34:05 PM	-54	-1.675	-1.635
59	MC/I	74.426	168.493	8/5/2014	6:33:25 AM	-54	-1.675	-1.617
60	MC/I	73.520	169.460	8/5/2014	10:53:28 PM	-43	-1.691	-1.635
61	MC/I	74.106	170.901	8/6/2014	12:58:54 PM	-51	-1.723	-1.661
63	MC/I	74.682	172.369	8/7/2014	6:51:22 AM	-64	-1.437	-1.461
64	MC/I	74.941	172.694	8/7/2014	5:23:58 PM	-120	-0.040	-0.087
65	MC/I	75.163	173.191	8/7/2014	9:15:47 PM	-170	0.322	0.364
66	MC/I	75.838	174.409	8/8/2014	8:59:25 AM	-239	0.519	0.564
67	MC/I	76.333	175.579	8/8/2014	7:22:25 PM	-468	0.513	0.533

Macrobenthos

The following table summarizes the preliminary data from the ecology program that focused on macrobenthos is surface sediments (Table E.4). During the wet sieving, a serious of nodules (likely iron/manganese oxides and carbonate concretions) were found. Their record is in a separate table shown below (Table E.5).

Table E.5

PRELYMINARY DATA OF DISTRIBUTION OF BOTTOM BIOCOENOSES BY STATION DURING SWERUS- C3 EXPEDITION. (accordingly macrobenthos samples).

Biocoenoses	**Station**
Ophiocten sericeum	12, 13, 23. ,41
Ophiocten sericeum + Polychaeta	20
Nuculana pernula	14, 21, 43 59
Hydrozoa	16
Maldane sarsi	51
Polychaeta	15.30,33,35,36,38,40,46,52,58,63
Polychaeta + Briozoa	37
Ophiocantha bidentata	19
Arctinula groenlandica	42
Portlandia arctica	22, 28 ,53
Leionucula belotti	25 ,26, 27
Musculus niger	44
Tridonta borealis	45

Table E.6. Nodules found during the wet sieving of surface sediments

Station	number of samples found	downcore (cm)	Diameter (cm)	Sediment type	Comments
14	2	3	3, 1	Silt	
15	4	5	2, 2.5, 3, 5	Silt	
22	14	5	3.5	Silt	3 by shells Triodonta Borealis; 11 by tube of Polichaeta
24	1	10	3.5	Clay	
42	15	5	7.5 (x4), 4(x4), 3(x4), 3(x3)	Silt	
43	1	2	3.5	Silt	
66	1	14	3.8	Clay	
67	8	5	1.5(x1), 0.3-0.6(x7)	Silt	

Planned analyses and future activities.

The organic geochemistry program has the overarching objective to understand the fate of permafrost carbon upon its entry into the Arctic Ocean taking into account fundamental processes like transport, degradation and burial at different time scales (modern, centennial, millennial). In parallel, the ecology program (macrobenthos) aims at understanding the effect of ocean acidification on the benthic Arctic community. In order to address the aforementioned points, a series of analyses have been planned as part of the post-cruise activities. The table below lists the different parameters that will be measured after the expedition.

Table E.5. Planned analyses

	Analyses	Method/instrument	Expected time
Bulk measurenments	elemental carbon and nitrogen	CHN-IRMS	1 year
	carbon stable and nitrogen stable isotopes	CHN-IRMS	1 year
	radiocarbon analyses of bulk organic carbon	AMS	1-2 years
Biomarkers			
	Lignin phenols and cutin-derived products	Cuo alaknine oxidation/GC-MS	1-2 years
	HMW n-alkanes, HMW n-alkanoic acids, HMW n-alkanols	Solvent extraction/GC-MS	1-2 years
	Glycerol dialkyl glycerol tetraethers and bacteriohopanepolyols	Solvent extraction/HPLC-APCI-MS	1-2 years
Compound specific radiocarbon analyses (CSRA)	HMW alkanes and HMW n-alkanoic acids	PG-GC/AMS	1-3 years
Compound specific isotope analyses (CSIA; deuterium)	HMW alkanes and HMW n-alkanoic acids	Solvent extraction/GC-IRMS	1-3 years
Dating	210Pb	gamma spectrometer	1 year
	137Cs	gamma spectrometer	1 year
	radiocarbon analyses of CaCO3	AMS	1 year
Sediment properties	grain size	sedigraph	1-2 years
	minerals surface area	SA analyzer	
Biocoenoses	Identification of the macrobenthos	microscope	1-2 years

F. 3. Results WP F Microbial biogeochemistry

F.3.1. Results for water column studies on microbial methane and nitrous oxide dynamics

Table F.3.1 Summary table of sampling stations with sample numbers per station for nitrous oxide analysis

Station ID	Coordinates		Station depth	Number of sampling depths	sampling date
Station 1	78°55.88'	125°13.16'N	3125	14	150714
Station 4	77°56.27 N	126°38.68 E	2000	14	160714
Station 5	77°16.56/ N	126°59.65 E	700	13	170714
Station 8	77°12.96 N	127°17.45 E	450	14	170714
Station 13	76°46.65 N	125°49.48 E	60	12	180714
Station 14	76°N53.60 N	127°48.31 E	50	11	190714
Station 15	77°08.59 N	126°47.73 E	345	12	200714
Station 18	76°23.99 N	125°27.40 E	48	9	210714
Station 19	76°27.29 N	126°12.01 E	49	9	210714
Station 20	76°27.25 N	126°44.53 E	52	9	210714
Station 21	76°07.54 N	127°11.17 E	46	9	220714
Station 22	76°10.48 N	129°20.14 E	48	9	220714
Station 23	76°10.48 N	129°20.14 E	54	9	220714
Station 24	75°35.96 N	129°33.69 E	44	9	230714
Station 25	76°04.63 N	130°54.95 E	48	9	230714
Station 26	76°28.33 N	132°02.53 E	49	9	230714
Station 27	76°56.59 N	138°13.81 E	45	9	230714
Station 28	77°20.48 N	134°58.72 E	48	9	240714
Station 29	77°45.38 N	136°30.88 E	57	9	240714
Station 30	78°00.16 N	138°33.86 E	65	10	240714
Station 31	79°21.45 N	135°13.07 E	3052	24	250714
Station 39	77°40.90 N	141°22.23 E	45	8	270714
Station 40	77°39.85 N	144°37.78 E	38	9	270714
Station 42	76°53.97 N	149°45.31 E	43	8	280714
Station 43	76°46.64 N	147°47.19 E	39	8	280714
Station 45	76°24.96 N	148°70.07 E	38	8	290714
Station 46	76°24.17 N	148°52.68 E	38	8	290714
Station 47	76°31.34 N	150°47.76 E	42	8	290714
Station 48	76°35.54 N	153°21.72 E	45	8	300714
Station 49	76°31.54 N	156°55.45 E	55	8	310714
Station 50	75°45.79 N	150°31.77 E	43	8	10814
Station 51	75°17.41 N	159°28.44 E	38	8	10814
Station 52	74°58.86 N	161°10.01 E	46	8	20814
Station 53	74°57.44 N	161°04.52 E	45	8	20814
Station 54	74°59.38 N	160°58.90 E	46	8	20814
Station 55	74°50.59 N	159°19.75 E	44	8	30814
Station 57	74°25.34 N	163°41.53 E	51	8	40814
Station 58	74°25.62 N	166°01.12 E	53	8	40814
Station 59	74°25.40 N	168°30.22 E	52	8	40814
Station 63	74°40.67 N	172°23.15 E	62	8	70814

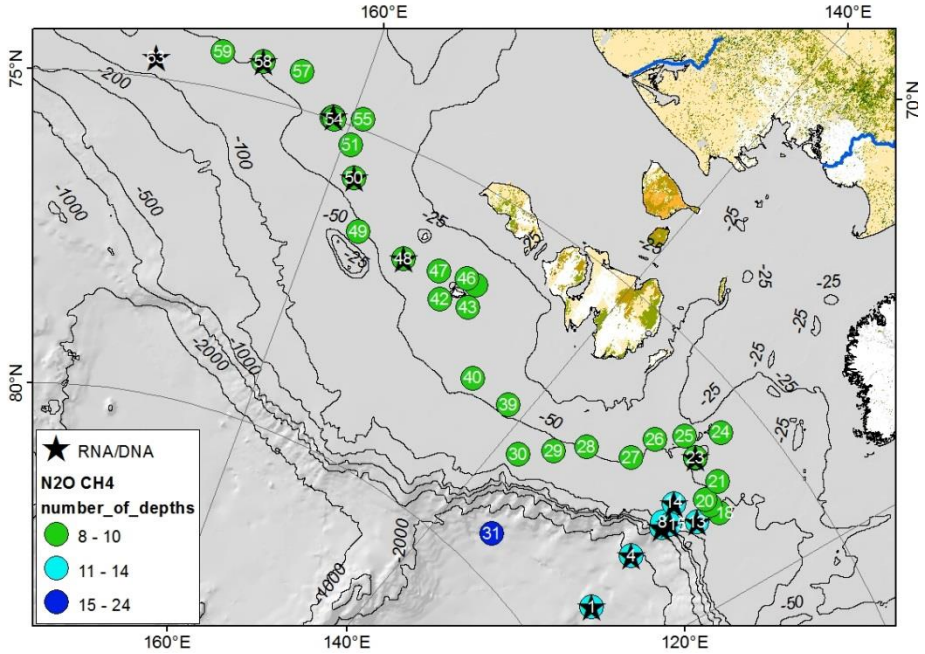


Figure 3.1. Map of stations where samples for N_2O analyses were taken.

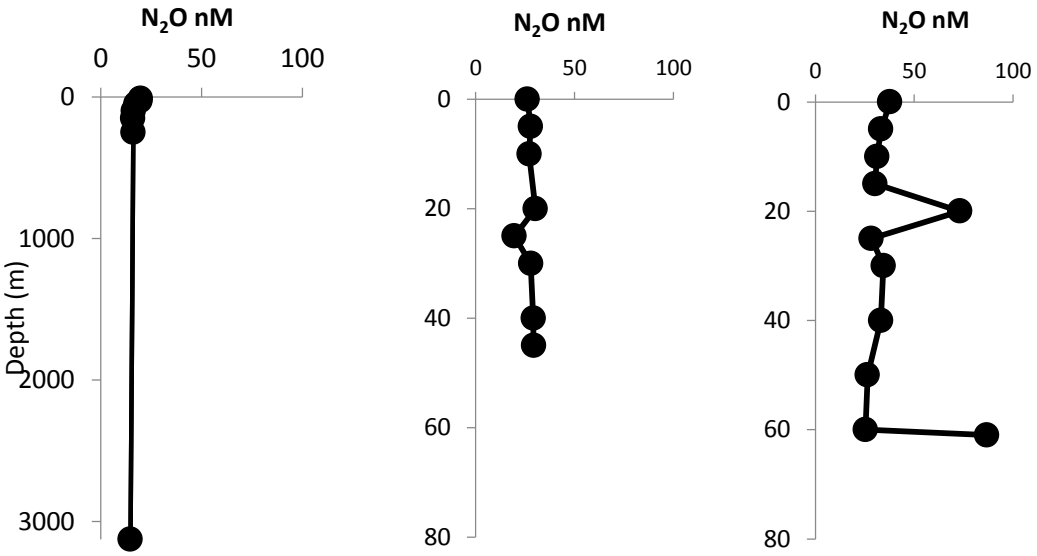


Figure 3.2. Preliminary results of concentrations of N_2O determined in the water column at the Nansen Laptev rise – Station 1 (a) depth 3125 m, Outer Laptev Sea shelf, Station 13 (b) depth 60 m and (c)

Preliminary results of N_2O concentrations indicate concentrations near artmospheric equilibrium with slight oversaturation in surface waters. On the shelf, concentrations were elevated and showed a bottom water maximum at Station 13 suggesting increased nitrification/dentrification activity.

Further analysis of water column samples will be conducted at Stockholm University within the next 6 months.

F.3.2. Results of microbial community studies in the water column

F.3.2.1. Sampling and fixation of water samples for DNA/RNA extraction

Water samples were collected from the CTD Rosette sampler at 12 chosen stations (Table 1) at four different depths, one in the top 10 m, one at the bottom, and two in the mid-waters. Water was collected into the 1L Schott Duran bottles. 1 L of sample was filtered through 0.2 µm Millipore filter using Millipore filtration unit. Millipore filtration unit was sterilized with ethanol and RNAse free solution before sample filtration. Filtration was done within 5 hours after samples collection and filteres were frozen at -80°C within 20 minutes after filtration to avoid RNA degradation. The analysis of these samples will take several years. Selected results will be available in the next 6 – 24 months.

F.3.2.2. Fixation for DNA/RNA for stable isotope probing

Water samples from selected sites and depths were taken into 1L glass bottles, closed without head space with butyl rubber stopper and screw caps, and injected with ^{13}C-CH_4 to the final concentration of ^{13}C-CH_4 of 1000 nM. Samples were incubated for 1 week at low (0.5-1.5C) ambient temperature in a dark temperature-insulated container. After that 5ml subsample of water was transferred to 20 ml pre-evacuated vial and acidified as it is described in previous section. Enrichment of DIC in these samples with ^{13}C will be measured in the UGA laboratory. 1L of water was filtered through 0.2 micrometer Sterivex filter with peristaltic pump and stored frozen at -80^{o} C. Enrichment of specific fractions of organic matter in these samples with ^{13}C will be measured in UGA for characterizing aerobic methanotrophic microbial community. Results will be available in the next 6 – 24 months.

F.3.2.3 Aerobic methane oxidation

^{13}C-aerobic methane oxidation

Enrichment of DIC with ^{13}C will be measured at University of Georgia, Athens laboratory in the next 6 months and potential MOX rates will be calculated.

^{3}H-aerobic methane oxidation

Potential methane oxidation rates will be measured in the University of Georgia Athens laboratory using methane labeled with tritium (^{3}H-CH_4) in water samples with low CH_4 and ^{14}C (^{14}C-CH_4) in samples with high methane concentrations. The results will be available in the 6 months.

Table F.3.2 List of methane oxidation rate experiments in the water column

Station	Sample #	Depth (m)	Volume (l)	Shore-based ^{3}H-Methane oxidation	Shore-based ^{14}C-Methane oxidation	On-board incubation of ^{13}C-Methane oxidation	On-board incubation of ^{13}C-stable isotope probing of DNA
13	13/1	bottom	0.5	X	X	X	X
	13/7	50	0.5	X	X	X	X
	13/16	15	0.5	X	X	X	X
	13/interface		1	X	X	X	X
14	14/2	60	0.5	X	X	X	X
	14/8	50	0.5	X	X	X	X
	14/18	15	0.5	X	X	X	X
	14/interf		1	X	X	X	X
15	15/2	249	0.5	X	X		
	15/14	200	0.5	X	X		
	15/16	150	0.5	X	X		
	15/18	100	0.5	X	X		
	15/20	50	0.5	X	X		
	15/22	25	0.5	X	X		
23	23/2		0.5	X	X	X	X
	23/7		0.5	X	X	X	X
	23/10		0.5	X	X	X	X
	23/16		0.5	X	X	X	X
26	26/1		0.5	X	X		
	26/3		0.5	X	X		
	26/4		0.5	X	X		
	26/7		0.5	X	X		
30	30/1	65	0.5	X	X		
	30/3	50	0.5	X	X		
	30/5	30	0.5	X	X		
	30/8	15	0.5	X	X		
48	48/13	bottom	0.5	X	X		
	48/16	30	0.5	X	X		
	48/19	20	0.5	X	X		
	48/23	5	0.5	X	X		
	48 interf		0.5	X	X		
50	50/7	bottom	0.5	X	X		X
	50/10	30	0.5	X	X		X
	50/14	20	0.5	X	X		X
	50/20	5	0.5	X	X		X
	50 interf		0.5	X	X		
52	52/13	bottom	0.5	X	X		
	52/16	30	0.5	X	X		
	52/19	20	0.5	X	X		
	52/23	5	0.5	X	X		
	52 interf		0.5	X	X		
53	53/13	bottom	1	X	X		X
	53/16	30	1	X	X		X
	53/19	20	1	X	X		X
	53/23	5	1	X	X		X
	53 interf		0.5	X	X		

F.3.3 Results from sediment studies

Table F.3.3. Summary of activities on sediment in work package F

Station	Lat	Long	O_2 micro-electrode profiling	Porewater chemical profiles	^{35}S-sulfate reduction rates	Benthic flux experiments	Sediment methane cycle expts	RNA/DNA studies
1	78.942	125.243	x	x	x			x
2	78.581	125.607	x		x			x
3	78.238	126.150	x					
4	77.855	126.664	x	x	x			
6	77.142	127.378	x	x	x			x
13	76.778	125.830	xx*	x	x	x	x	x
14	76.894	127.799	xx*	xx*	x	x	x	x
16	77.110	126.539	x					
19	76.456	126.211	x					
23	76.171	129.333		x	x	x	x	x
24	75.599	129.558	x	x	x			
27	76.943	132.229	x	x	x			x
30	78.181	138.354	x	x	x			x
31	79.396	135.497	x					
35	78.600	137.061	x					
37	78.521	137.170	x					
40	77.670	144.668	x	x	x			
43	76.780	147.791	x					
45	76.416	148.115	x	x	x			
48	76.615	153.345	x	x	x			
50	75.764	158.529	x	x	x	x	x	x
53	74.957	161.090	x	x	x	x	x	x
58	74.440	166.050	x	x	x			
63	74.685	172.361	x	x	x	x		x

*** performed on two different casts with the Multicorer within several meters distance while vessel was anchored**

3.3.1. Results for porewater chemical analysis

Porewater analyses have been performed for porewater methane concentrations. Complete analysis of all porewaters has not been completed. Fig F.3.2.5. shows porewater concentrations of methane from 8 stations. General features are the comparably low concentrations in the sediment compared to other shelf systems with known methane seeps. However, clear signals were observed at Stations 13, 14, and 23, which all showed steep increases in methane below 15 cm depth, but concentrations were several order of magnitude below below saturation (about 8.5 mm) at 50 m water depth.

3.3.2. Dissolved ions

Porewaters were collected from Multicore tubes and Rumohr core tubes for chemical analysis of dissolved nutrients, dissolved inorganic carbon, dissolved metals, sulfate, sulfide, and chloride. Station locations and maximum extraction depths are shown in Table F.3.2.1 and Figure F.3.2.1.

Table F.3.4. Summary of porewater sampling program

Station	Coring type	Maximum extraction depth (cm)	Sample number
1	MUC	33	1-19
4	MUC	30	20-38
6	MUC	16.5	39-49
13	MUC	20.5	50-63
14	MUC	21.5 / 15.5	64-78 / 79-89
23	MUC / RUM	24 / 32.5	97-111 / 90-96
24	RUM	55	112-122
27	MUC / RUM	18.5	123-134
30	MUC / RUM	22.5 / 47.5	145-159 / 135-142
40	MUC	15.5	160-179 (w/duplicates)
45	MUC	16.5	181-192
48	MUC / RUM	16 / 47	193-209 / 210-219
50	MUC / RUM	49.5	220-240
53	MUC / RUM	20.5	241-254
58	MUC / RUM / GRA	32.5 / 63 / 37.5	255-274 / 276-288 / 275
63	MUC / RUM	29 / 45	289-307 / 308-317

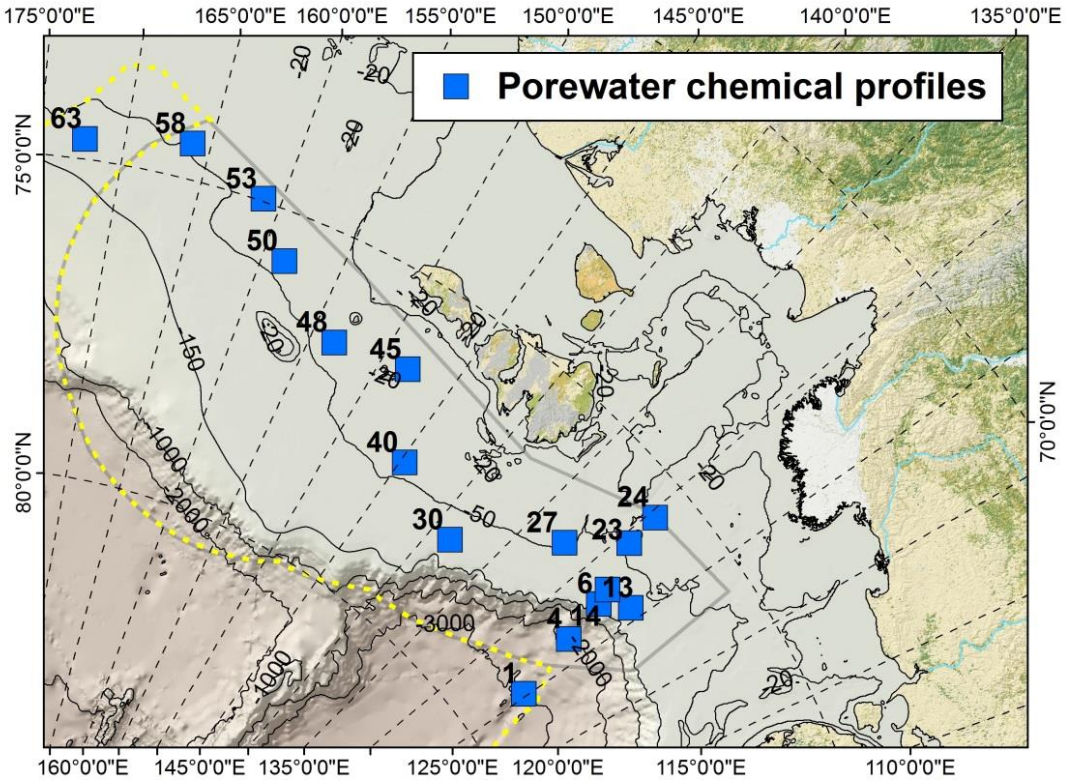


Figure F.3.3.Map of stations where porewaters were extracted from sediment

3.3.3. Dissolved methane

Table 3.5 lists the stations and maximum sampling depths of methane in sediment.

Station	Coring type	Core length MUC/Rumohr/Gravity core	Vial number
1	MUC	32	1-17
4	MUC	34	18-34
6	MUC	18	35-44
13	MUC	18	45-54
14	MUC cast 2 / MUC cast 3	22 / 16	55-66 / 67-75
23	MUC / RUM	24 / 37	76-88 / 96-104
24	RUM	28	89-95
27	RUM	18	105-114
30	RUM	22	115-125
45	MUC / RUM	16 / 55	126-134 / 135-146
48	MUC / RUM	18	147-156
50	MUC / RUM	46 / 52.5	171-194 / 159-170
53	MUC	22.5	195-206
58	MUC / RUM /GRA	28 / 51 / 40	207 - 220 / 221-232 / 233-243
63	MUC / RUM	29 / 48	265-280 / 281-290

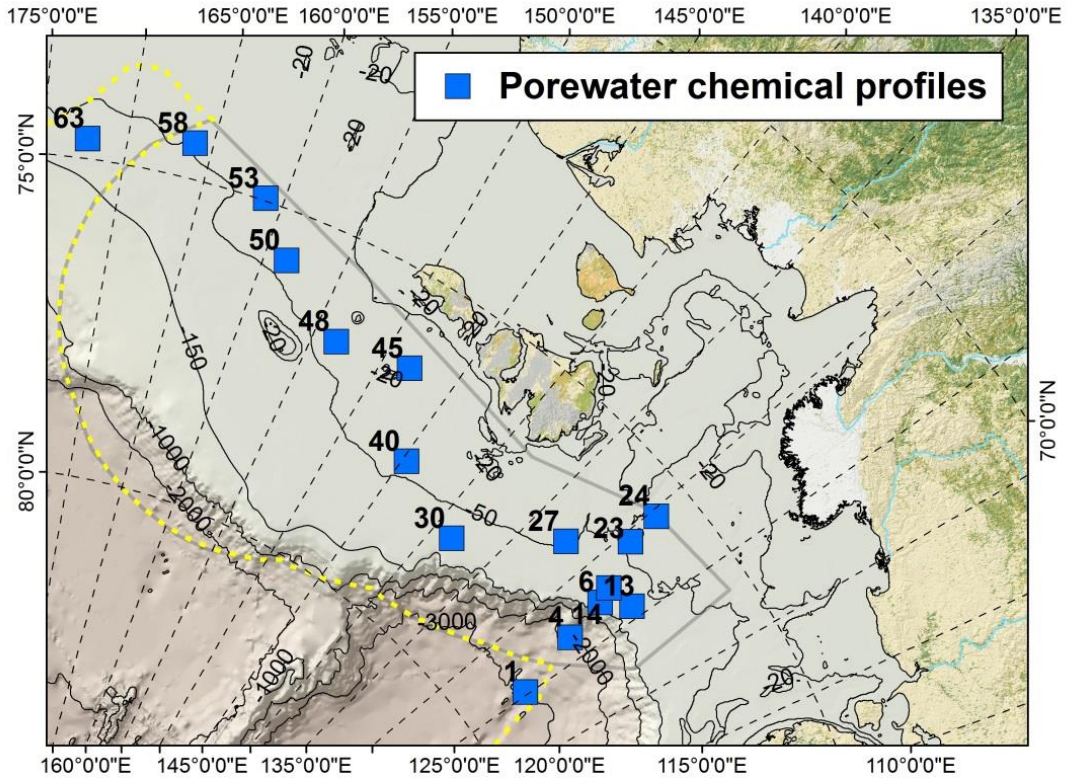


Fig.F.3.4 Map of sampling stations with high-resolution porewater methane sampling

3.4.Results of high-resolution O_2 profiling

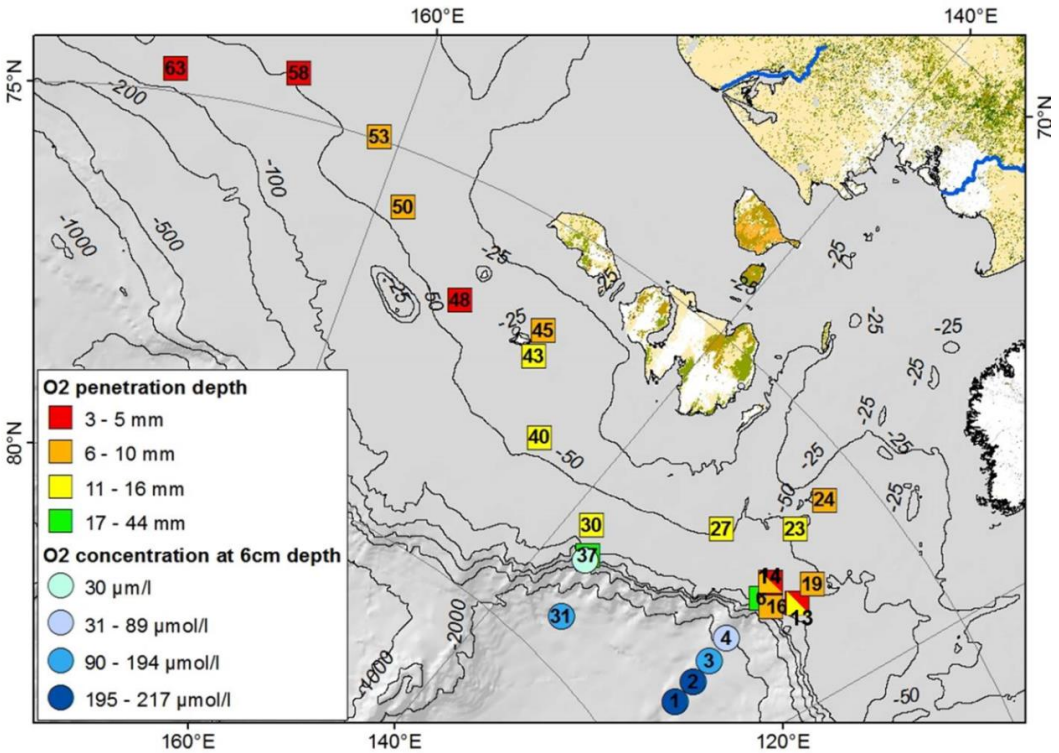


Figure F.3.5. Overview of preliminary oxygen penetration depths in the working area

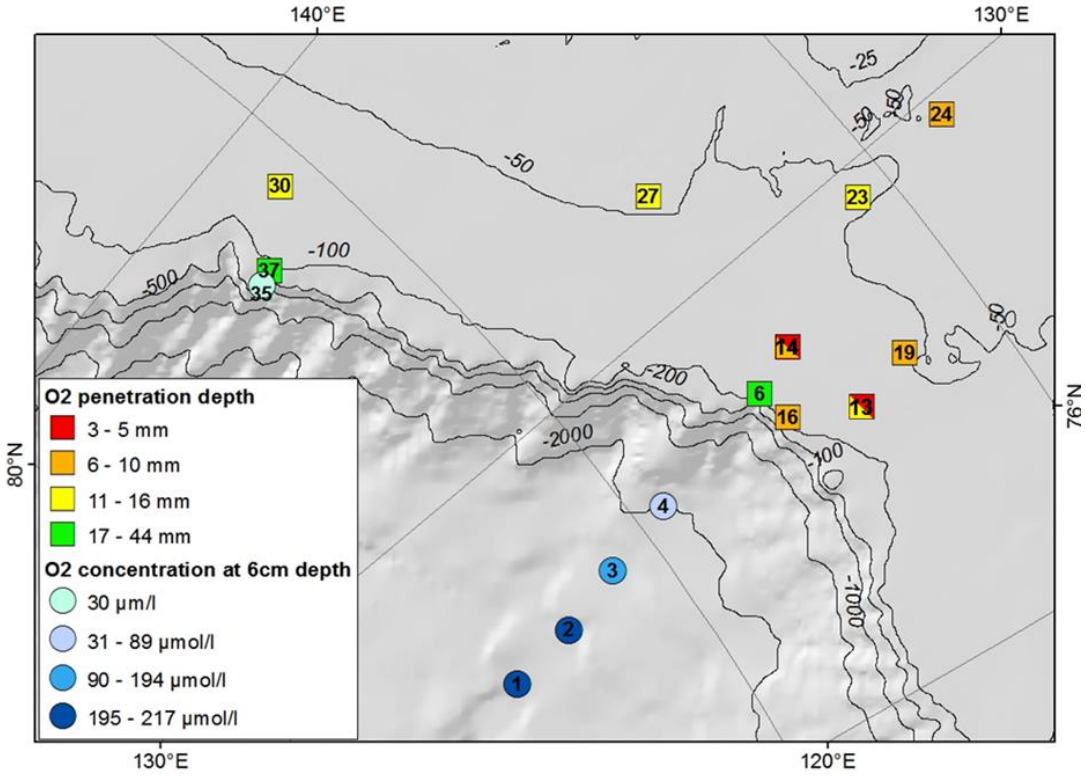


Figure F.3.6. Overview of preliminary oxygen penetration depths in the Laptev Sea

Table 3.6. Summary of preliminary microelectrode measurement results

Station	cast	Latitude N	Longitude E	date	time	depth (m)	mean O_2 penetration depth (mm)	mean O_2 conc @ 60mm depth (µmol/l)	comments
1	1	78.942	125.243	2014-07-15	19:53:55	-3146	> 60	217	
2	1	78.581	125.607	2014-07-16	06:58:34	-2900	> 60	213	
3	1	78.238	126.150	2014-07-16	11:58:35	-2601	> 60	194	
4	1	77.855	126.664	2014-07-16	17:06:06	-2106	> 60	89	
6	1	77.142	127.378	2014-07-17	10:02:27	-89	36	0	
13	2	76.778	125.830	2014-07-18	12:58:14	-73	13	0	Measurements on sediment from two MUC casts
13	3	76.778	125.830	2014-07-18	13:46:22	-72	5	0	Measurements on sediments from two MUC casts
14	2	76.894	127.798	2014-07-19	13:23:13	-64	9	0	
14	3	76.894	127.799	2014-07-19	14:18:59	-64	3	0	
16	1	77.100	126.596	2014-07-20	15:56:00	-236	*7*	0	high variability: 5-13mm
19	1	76.456	126.211	2014-07-21	17:34:06	-51	10	0	
23	1	76.171	129.333	2014-07-22	23:27:40	-56	13	0	
24	1	75.599	129.558	2014-07-24	05:45:49	-46	10	0	
27	1	76.943	132.229	2014-07-23	23:19:50	-44	16	0	
30	2	78.181	138.354	2014-07-24	16:27:42	-69	*16*	0	high variability: 9-23mm
31	1	79.396	135.497	2014-07-25	11:54:14	-3056	> 60	194	
35	1	78.600	137.061	2014-07-26	06:41:12	-541	> 60	*30*	highly variable: 16 - 59µmol/l
37	1	78.521	137.170	2014-07-26	16:28:34	-205	44	0	
40	2	77.670	144.668	2014-07-27	15:48:20	-45	12	0	
43	1	76.780	147.791	2014-07-28	16:12:46	-42	13	0	
45	1	76.416	148.115	2014-07-29	05:41:22	-40	10	0	
48	2	76.615	153.345	2014-07-30	19:54:16	-49	5	0	
50	2	75.764	158.529	2014-08-01	03:31:53	-44	9	0	
53	1	74.957	161.088	2014-08-02	15:31:54	-47	10	0	
58	2	74.440	166.050	2014-08-04	12:58:55	-54	3	0	
63	2	74.685	172.361	2014-08-07	07:14:30	-67	4	0	

Preliminary results of microprofles indicate clear slope-to-shelf gradients in oxygen penetrations depths and a slight decrease in oxygen penetration depth from the Laptev to the Chukchi Sea suggestive a stronger influence of more easily degradable carbon to the East.

O_2 profiling was conducted in two cores each from different Multicorer casts in the area of methane seeps. Steep gradients were found in sediments with free hydrogen sulfide indicating oxygen consumption by micobial sulfide oxidation suggesting enhanced anaerobic microbial activity in the seep area. The data will be analyzed in detail by diagenetic modelling to determine microbial respiration rates and to calculated the contribution of bioturbating and biorirrigating meio and macrofauna to the oxygen consumption. Results will be available in the next 6 to 24 months.

3.5. Results anaerobic carbon transformation experiments

The only anaerobic carbon transformation rate experiments conducted on board were rate measurements of bacterial sulfate reduction rates with ^{35}S-sulfate tracer using the whole-core incubation method of Jørgensen (1978). Due to time constraints, no other experiments were started on board. Instead, material was collected from 5 stations for detailed analysis on-shore. The planned analysis include measurements described in section 3.4.2.

3.5.1 Intact-core ^{35}S-sulfate reduction rates

The total amount of ^{35}S-labeled reduced inorganic sulfur will be determined using the single cold step distillation method by Kallmeyer et al. (2004) in the laboratory at Stockholm University within the next 6 months. The sulfate reduction rate is then calculated using the following equation (Jørgensen, 1978):

$$^{35}S - SRR = \frac{TRI^{35}S}{^{35}SO_4^{2-} + TRI^{35}S} * \frac{\left[SO_4^{2-}\right]}{T} * 1.06$$

where $[SO_4^{2-}]$ is the pore water sulfate concentration that corrected by porosity ($[SO_4^{2-}] = SO_4^{2-} \times \phi$), $TRI^{35}S$ and $^{35}SO_4^{2-}$ are the activities (Bq) of sulfate and total reduced sulfur species, respectively. T is the incubation time. 1.06 is an estimated fractionation factor between ^{35}S and the natural isotope ^{32}S. The sulfate reduction rate is calculated as nmol day^{-1} cm$^{-3.}$ The detection limit of the rate measurement is 0.01 nmol cm^{-3} day^{-1}.

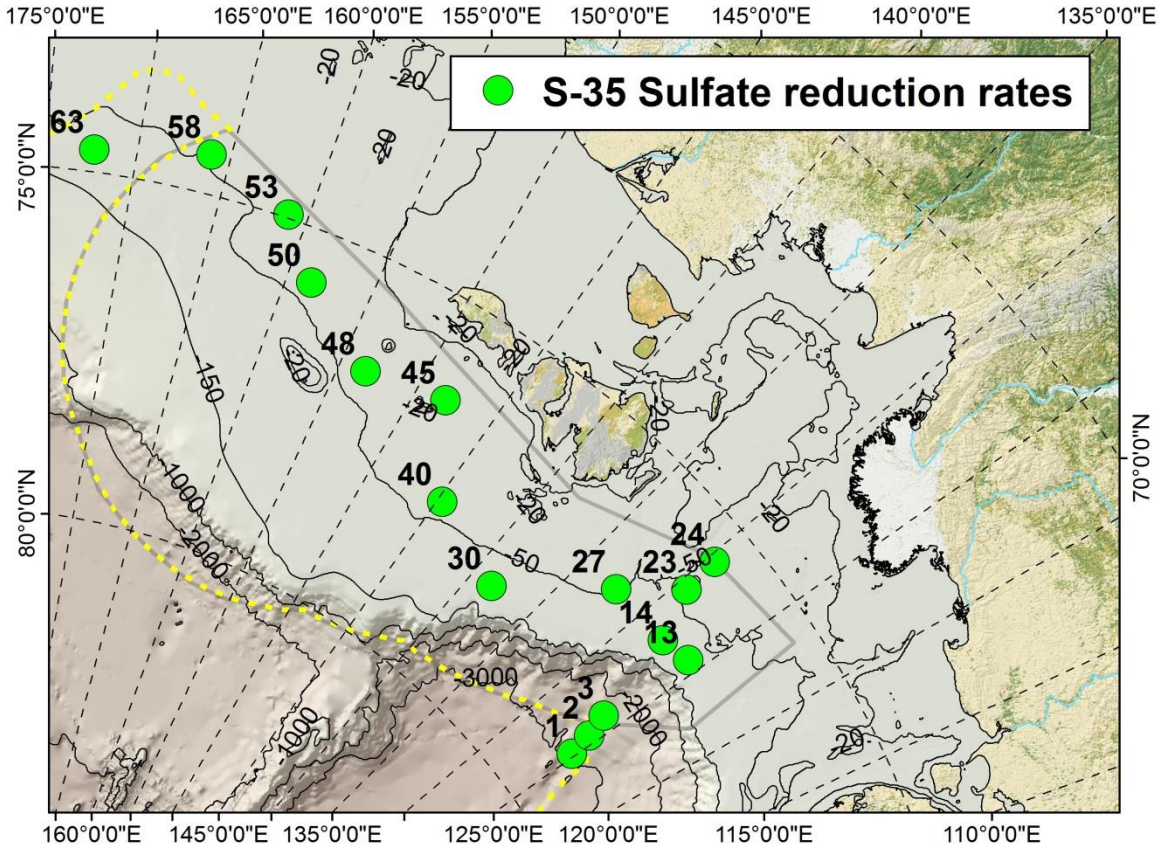


Figure F.3.7. Map of stations where sulfate reduction rate experiments were conducted with intact sediment cores

3.5.2 Shore-based experiments

The rates of microbial processes are important parameters for quantifying and modelling of methane cycling in the sediments. Aerobic and anaerobic methane oxidation (with ^{14}C-methane), sulfate reduction (with ^{35}S-sulfate) and methanogenesis (with ^{14}C-bicarbonate, 2-^{14}C-acetate, ^{14}C-methylamine and ^{14}C-methanol) will be measured in sediment samples that were collected during the cruise from the seep and control sites in Laptev and East-Siberian seas using standard techniques in the UGA laboratory. Sediment cores were sliced into 2-3cm intervals, placed into oxygen protective plastic bags with Anaerocult oxygen absorber, and stored at 4^{o} C. Results will be available in the next 6 months.

Table F.3.7. Summary table of sediment collected for methane cycling experiments

	Depth zones	Experiments	Expriments	Experiments
Station 13	0-0.5 ; 0.5-3.5; 3.5-7; 7-11 cm		Aerobic methane oxidation; Sulfate reduction; anaerobic methane oxidation	Methanogenesis: Bicarbonate reduction; methylamine cleavage, acetaclastic methanogenesis; methanol cleavage
Station 14	0-2; 2-4; 4-6; 6-8; 8-10; 10-13; 13-16; 16-18; 18-21cm	^{15}N-labeling experiments	Aerobic methane oxidation; Sulfate reduction; anaerobic methane oxidation	Methanogenesis: Bicarbonate reduction; methylamine cleavage, acetaclastic methanogenesis; methanol cleavage
Station 23	0-2; 2-4; 4--8; 8-12; 12-16; 16-20 cm	Temperature regulation and ^{15}N-labeling experiments	Aerobic methane oxidation; Sulfate reduction; anaerobic methane oxidation	Methanogenesis: Bicarbonate reduction; methylamine cleavage, acetaclastic methanogenesis; methanol cleavage
Station 50	0-2; 2-5; 5-10; 10-15; 15-20; 20-25; 25-30; 30-35; 35-40; 40-45; 45-50 cm	Temperature regulation experiments; ^{15}N-labeling experiments;	Aerobic methane oxidation; Sulfate reduction; anaerobic methane oxidation	Methanogenesis: Bicarbonate reduction; methylamine cleavage, acetaclastic methanogenesis; methanol cleavage
Station 53	0-1; 1-3; 3-5; 5-10; 10-15; 15-20; 20-25 cm	Samples for reactive Fe determination (frozen)	Sulfate reduction; anaerobic methane oxidation	Methanogenesis: Bicarbonate reduction; methylamine cleavage, acetaclastic methanogenesis; methanol cleavage

3.6. Results of intact core incubations: Benthic exchange measurements

Table 3.8. Station list of benthic flux experiments

	Experimental conditions	**Time period**	**Samples for**
Station 13	4 cores, 3 optodes	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC
Station 14	4 cores, 3 optodes	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC
Station 23	4 cores, 2 optodes	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC
Station 50	4 cores, 3 optodes	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC
Station 53	1 core, O_2 initial/O_2 final	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC
Station 63	3 cores, 3 optodes	48 hours	CH_4, N_2O, dissolved metals, nutrients, sulfate, DIC

3.7 Results from intact core incubation experiments

Figure F.3.5.2 shows the data record of the oxygen sensors for Station 23 cast 2 for two cores. After regression on the time trend of oxygen concentrations, areal fluxes across the sediment were calculated for dissolved oxygen. Analysis of the other components at the beginning and the end of the incubation will be performed on land.

3.8. Results sediment RNA/DNA studies

3.8.1 Molecular community and functional gene analysis

We will compare microbial community composition and functional gene distributions with our biogeochemical rate measurements. We will identify genes which may be indicators of respiration and methane metabolisms - methanogenesis - methyl co-enzyme M reductase (*mcrA*) and methane monooxygenase for aerobic methane oxidation. For sulfate reduction, we will target the genes dissimilatory sulfite reductase (*dsrA*) and adenylyl phosphosulfate reductase (*APSR*). First results from these studies will be available in the next 6-24 months, but data analysis will continue beyond this time.

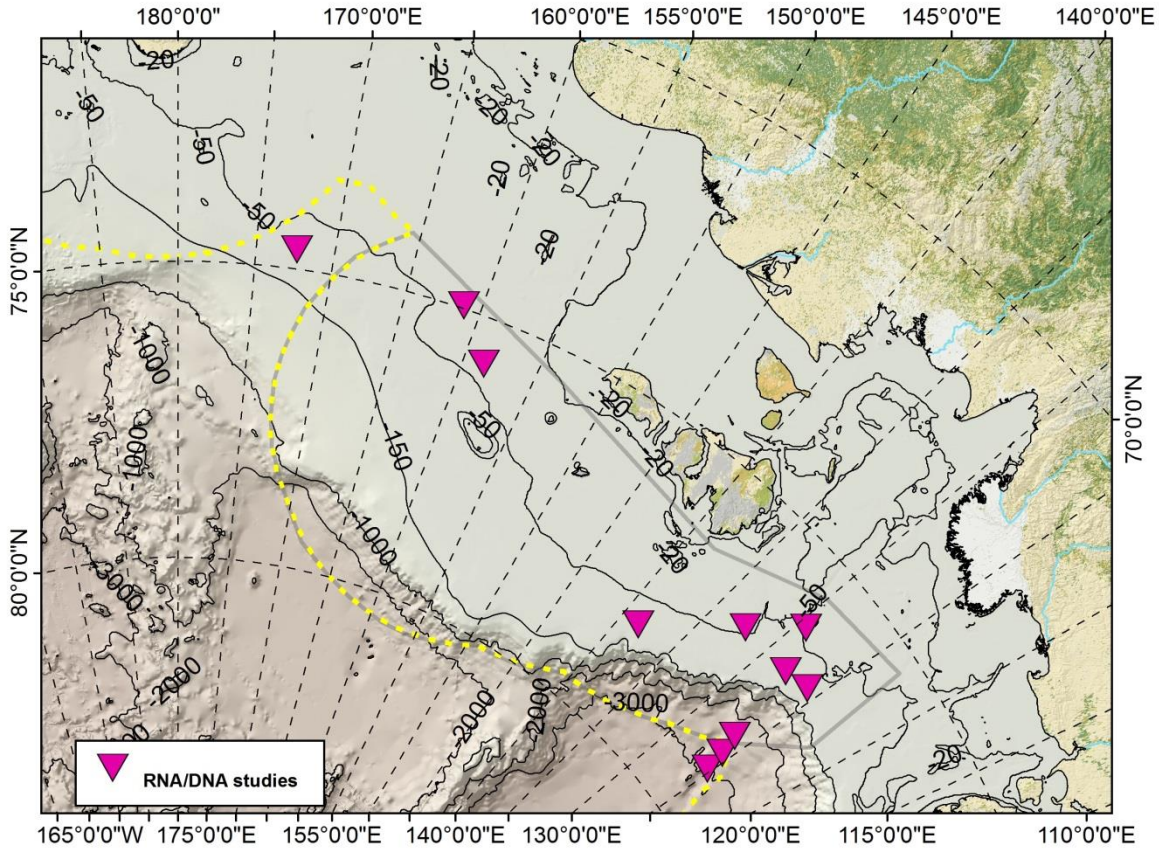


Figure F.3.8 Station map for sediment RNA/DNA studies

Table F.3.9. RNA/DNA sediment samples were collected at 12 stations listed in the table.

Station ID	Coordinates		Station depth (m)	Sampling date
Station 1	78°55.88'	125°13.16'N	3125	150714
Station 4	77°56.27 N	126°38.68 E	2000	160714
Station 5	77°16.56/ N	126°59.65 E	700	170714
Station 13	76°46.65 N	125°49.48 E	60	180714
Station 14	76°53.60 N	127°48.31 E	50	190714
Station 15	77°08.59 N	126°47.73 E	345	200714
Station 23	76°10.48 N	129°20.14 E	54	220714
Station 48	76°35.54 N	153°21.72 E	45	300714
Station 50	75°45.79 N	150°31.77 E	43	10814
Station 53	74°57.44 N	161°04.52 E	45	20814
Station 58	74°25.62 N	166°01.12 E	53	40814
Station 63	74°40.67 N	172°23.15 E	62	70814

3.8.2. Stable isotope probing

Oxic surface sediments (0-1cm) from 3 stations (Station 13, 50, 53) were collected into 5cm^3 cutoff syringes in triplicates closed with butyl rubber stoppers, then injected with 25 microliters of ^{13}C-CH_4 that was diluted with nitrogen to give final 1 micromolar concentration of dissolved CH_4 in pore water. The samples were incubated for one week at ambient temperature (0-1.5^o C). After that time samples were frozen at -80^o C. Further processing of samples will be conducted at UGA laboratory. Results will be available in the next 6 to 24 months.

WP G CTD-Niskin/Physical Oceanography

Metadata description of observational dataset

Positions and other types of basic information for the CTD stations are presented in Table G1. See also figure G2. The ADCP data was only screened onboard to ensure that the instruments worked properly. These data will be processed further and finalized after the cruise.

Table G1. Time, position and depth for SWERUS leg1 CTD stations. Column "Type" shows type of cast N=Normal cast, D=Drift cast (see methods WP G for further information). Column "ADCP" shows collected ADCP data, where U=Upward looking and D=Downward looking instrument.

Station	Cast	Date	Time (UTC)	Latitude (Dec. deg.)	Longitude (Dec. deg.)	Sounder depth (m)	Type	ADCP
1	1	20140715	16.21	78.9312	125.2192	3120	N	UD
4	1	20140716	17.56	77.8685	126.6440	2088	N	UD
5	1	20140717	05.04	77.2758	126.9937	798	N	UD
6	1	20140717	09.59	77.1412	127.3813	87	N	UD
7	1	20140717	12.28	77.2018	127.3347	282	N	UD
7	2	20140717	14.02	77.2007	127.3365	316	N	UD
8	1	20140717	16.42	77.2157	127.2962	495	N	UD
8	2	20140717	18.27	77.2165	127.2952	491	N	UD
9	1	20140717	21.01	77.2217	127.2363	618	N	UD
10	1	20140717	21.54	77.2240	127.2092	758	N	UD
11	1	20140717	22.44	77.2252	127.1872	663	N	UD
12	1	20140717	23.32	77.2253	127.1695	615	N	UD
13	1	20140718	10.04	76.7788	125.8197	72	N	UD
13	2	20140718	17.04	76.7788	125.8197	72	N	
13	3	20140718	22.33	76.7803	125.8078	72	D	UD
14	1	20140719	09.57	76.8943	127.7968	64	N	UD
14	2	20140719	21.46	76.8973	127.8105	66	D	D
15	1	20140720	08.54	77.1430	126.7933	360	N	UD
15	2	20140720	13.45	77.1430	126.7942	380	D	UD
16	1	20140720	16.51	77.1108	126.5818	208	N	UD
16	2	20140720	19.09	77.1153	126.6025	275	N	UD
17	1	20140720	21.10	77.1115	126.5148	220	N	UD
17	2	20140720	23.54	77.1083	126.5530	175	D	UD
18	1	20140721	09.35	76.3997	125.4563	52	N	UD
18	2	20140721	11.18	76.4010	125.4437	51	D	UD
19	1	20140721	17.19	76.4547	126.1993	51	N	UD
20	1	20140721	23.11	76.4540	126.7422	52	N	D
21	1	20140722	06.57	76.1255	127.1847	46	N	UD
22	1	20140722	12.55	76.1083	128.2443	48	N	UD
23	1	20140722	17.56	76.1705	129.3400	54	N	D
24	1	20140723	05.49	75.5990	129.5587	45	N	UD

24	2	20140723	07.43	75.5992	129.5978	47	N	
25	1	20140723	12.56	76.0772	130.9158	50	N	UD
26	1	20140723	18.25	76.4718	132.0417	51	N	UD
27	1	20140723	23.06	76.9432	132.2303	45	N	UD
28	1	20140724	05.34	77.3412	134.9783	48	N	UD
29	1	20140724	10.11	77.7563	136.5143	55	N	UD
30	1	20140724	15.01	78.1832	138.3480	67	N	UD
31	1	20140725	08.14	79.3573	135.2157	3052	N	UD
33	1	20140725	18.40	78.9420	135.9770	2347	N	UD
34	1	20140725	23.41	78.7447	136.4582	1871	N	UD
35	1	20140726	05.27	78.6052	136.9092	690	N	UD
36	1	20140726	08.04	78.5888	137.2318	370	N	UD
36	2	20140726	10.14	78.5912	137.2130	400	N	UD
37	1	20140726	15.03	78.5177	137.1615	198	N	UD
37	2	20140726	17.17	78.5152	137.1768	202	D	
37	3	20140726	19.26	78.5180	137.1722	189	N	
38	1	20140726	20.59	78.4778	137.2407	118	N	D
39	1	20140727	06.31	77.6815	141.3702	42	N	UD
40	1	20140727	15.16	77.6635	144.6198	46	N	D
40	2	20140727	17.19	77.6685	144.6060	46	N	UD
41	1	20140727	22.52	77.3185	147.8282	42	N	UD
42	1	20140728	08.58	76.8995	149.7550	43	N	UD
43	1	20140728	16.01	76.7768	147.7868	40	N	UD
44	1	20140728	22.32	76.2718	146.0470	40	N	UD
45	1	20140729	05.35	76.4160	148.1180	38	N	UD
46	1	20140729	13.05	76.4023	149.8790	38	N	UD
47	1	20140729	21.55	76.5213	150.8027	42	N	UD
48	1	20140730	23.36	76.6092	153.3623	46	N	UD
49	1	20140731	13.06	76.5255	156.9235	56	N	UD
50	1	20140801	02.38	75.7632	158.5295	40	N	UD
51	1	20140801	13.11	75.2900	159.4737	39	N	
52	1	20140802	03.05	74.9808	161.0168	45	N	UD
53	1	20140802	13.47	74.9573	161.0750	45	N	UD
54	1	20140802	20.16	74.9897	160.9815	46	D	UD
55	1	20140803	06.46	74.8432	159.3292	44	N	UD
56	1	20140803	17.44	74.6263	161.9568	48	N	UD
57	1	20140804	01.42	74.4223	163.6920	50	N	UD
58	1	20140804	10.45	74.4270	166.0185	51	N	UD
59	1	20140805	05.22	74.4232	168.5037	52	N	UD
60	1	20140805	20.19	73.5055	169.4762	39	N	D
62	1	20140806	18.20	74.1945	171.2955	52	N	UD
63	1	20140807	05.58	74.6775	172.3868	64	N	UD
64	1	20140807	16.04	74.9287	172.7538	118	N	UD
65	1	20140807	20.48	75.1582	173.2053	166	N	UD
66	1	20140808	08.20	75.8318	174.4143	242	N	UD
67	1	20140808	17.17	76.3215	175.6062	468	N	UD

Dataset

The surface and near bottom temperature/salinity for all CTD stations are shown in figure G2. The open ice free waters of the northern Laptev Sea was characterized by relatively warm surface water with temperatures up to 7 ^{o}C while the ESS was ice covered with surface temperature near the freezing point. The surface salinity was generally much lower (down to about 22 psu) in the Laptev Sea compared with the ESS showing influence of the Lena River. The bottom salinity was higher in the Laptev Sea than in the ESS which in combination with low surface salinity gave a much stronger density stratification and therefore also high stability.

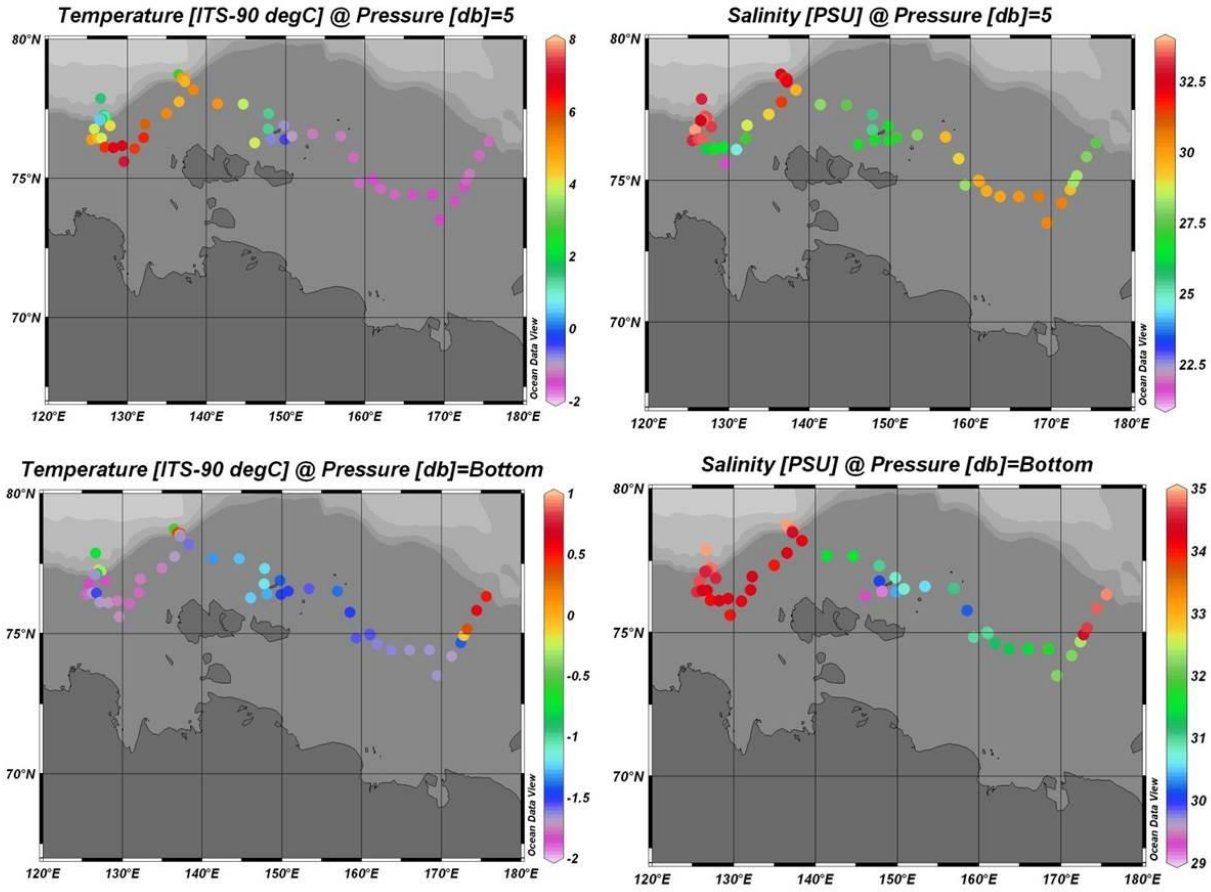


Figure G2. Surface and bottom temperature/salinity for all CTD stations.

Many of the shelf stations had a well-developed bottom boundary layer with well mixed conditions as reflected by constant temperature and salinity with depth near the bottom (see figure G3 for examples). The turbulence in this layer is apparently intense enough to lift the bottom sediments as shown by the enhanced turbidity values.

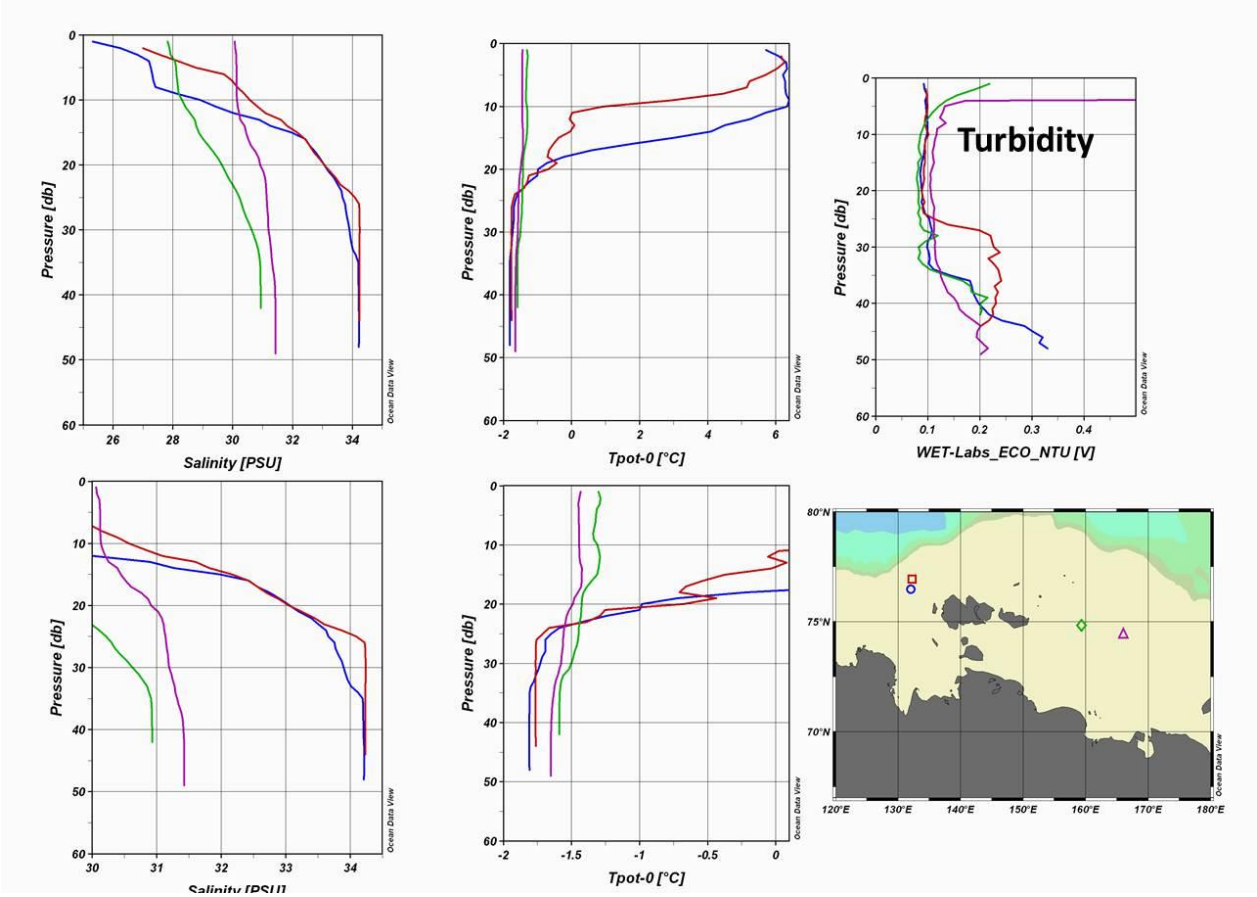


Figure G3. Examples of shelf stations with well mixed bottom layer and enhanced turbidity.

WP H Acoustics

By Riko Noormets, Nina Kirchner, Denis Chernykh and Alexey Khortov

Metadata description of observational dataset

Three hull-mounted echosounders (EM122, SBP120 and EK60) have been continuously recording data throughout the cruise (Fig. H1).

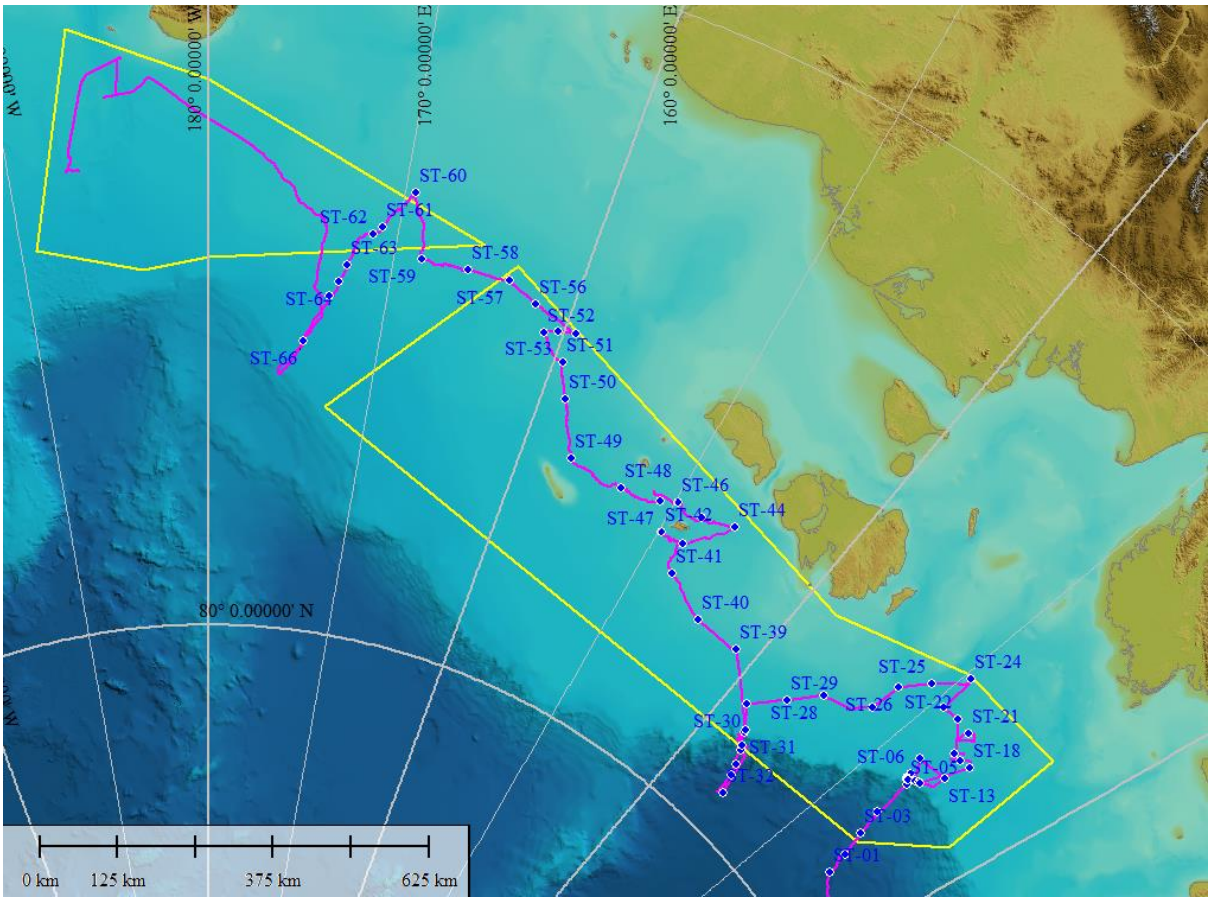


Fig. H1. Track of the IB Oden along which acoustic data were acquired. Indexed dots refer to sampling locations and the yellow polygons mark the areas of permit in the Russian EEZ.

In selected key areas full-coverage multibeam seabed site surveys were conducted in order to map the distribution of seafloor gas flares, gas-related acoustic features in the sediments, or to aid the selection of seabed sampling locations (Fig. H2).

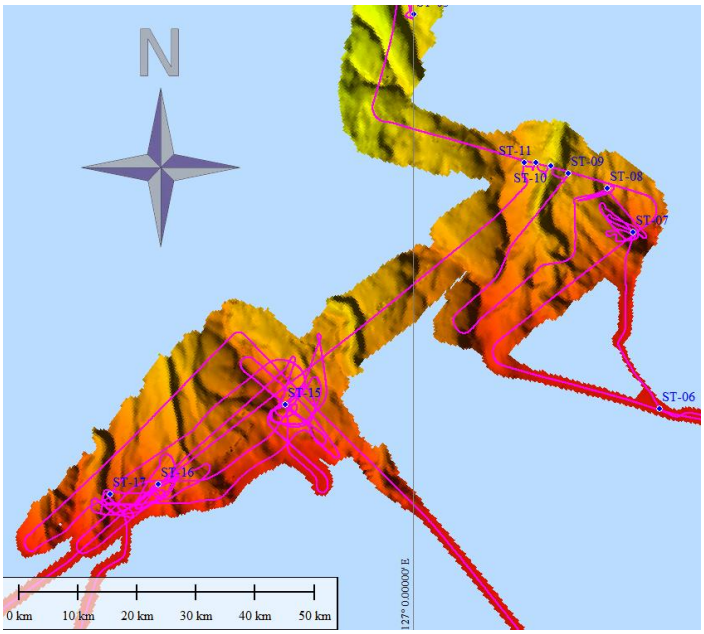


Fig. H2. Example of lines surveyed for seabed morphology and sediment structure on the upper continental slope of the Laptev Sea while mapping and sampling the active seeps. Water depth varies from c. 200 m in the southern part of the multibeam coverage to c. 60 m in the northern part. Pink lines mark the ship's track and blue indexed dots are sampling stations. Numerous gullies and canyons dissect the upper slope in this area.

In addition, small launch "Skidbladner" was deployed on 22. July and c. 2x2 km area was mapped with EM2040 multibeam echosounder and EK400 subbottom profiler at Station 23 (Fig. H3).

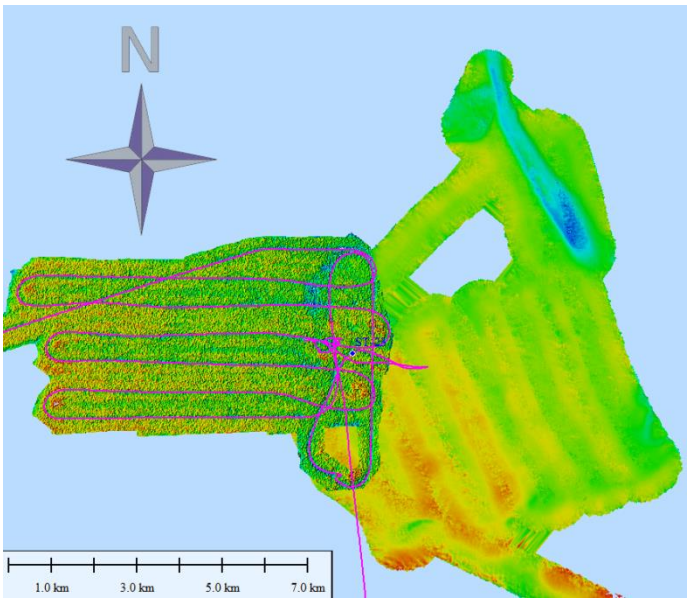


Fig. H3. Multibeam coverage at the Station 23 in the northern Laptev Sea. Pink lines show the Oden track and the respective swath coverage underneath. Area to the east of it (without ship's tracks) is the area surveyed with Skidbladner. Note the c. 0.5 m deep elongated depression in the northeastern part of the area.

Dataset

The **Kongsberg EM122** multibeam echosounder provides primarily high-resolution water depth measurements along ship's track covering a band with width equal to c. 4x the water depth. In addition, the amplitude and shape of the full reflected waveform in the EM122 datagram allows analysis of bottom character or sediment type as well as the acoustic backscatter from the water column (*Fig. Screenshot of SIS with these 3 data types presented*)

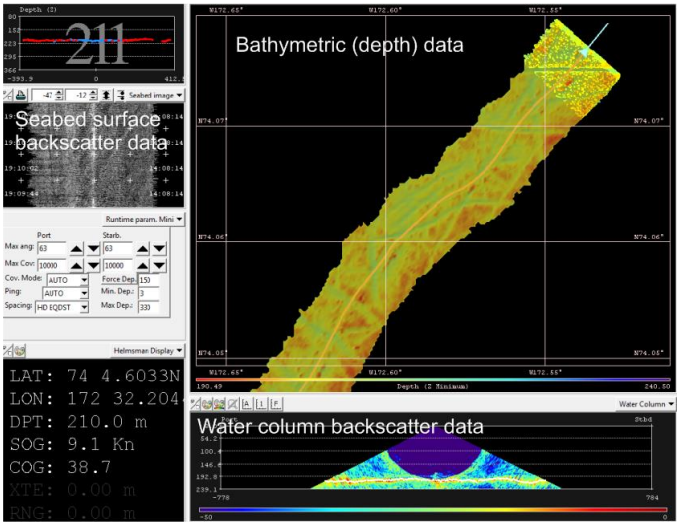


Fig. H4. Screenshot of SIS operating software demonstrating the three data types available from the EM122 datagram: bathymetric (depth), seabed surface backscatter and water column backscatter data. On the bathymetric data display one can clearly distinguish numerous iceberg scour marks.

The multibeam data quality varied considerably depending on the sea and ice conditions. Increasing deterioration of the data quality with heavier ice conditions was obvious. Also, site surveys of the seabed seeps did not always result in a regular grid of survey lines as the vessel maneuvering was significantly impeded by the sea ice.

The most prominent seabed morphological features observed on the bathymetric data were the gully-canyon systems on the continental slope (Fig. H2), and the iceberg scour marks on the continental shelf (Figs H4and H5).

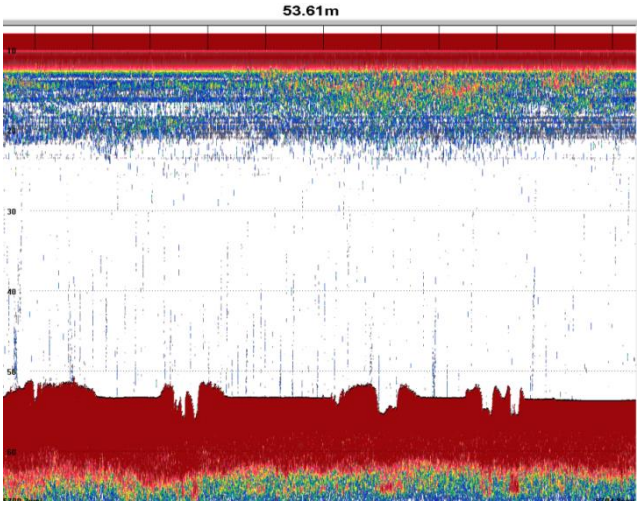


Fig. H5. Screenshot of EK60 record demonstrating the iceberg scours on the seabed and water column backscatter data. One can clearly distinguish numerous iceberg scour marks on the seabed.

SBP120 operation is coupled with the EM122 in terms of the synchronized transmit-receive cycle. As a slave to EM122, the data quality of SBP120 is dependent on the bottom detection of the latter.

Loss of reception of return signal of EM122, and subsequent delay of the transmit pulse, results also in loss of subbottom data. Examples of different sedimentary environments are given below. (*Fig. image of nice sediment structures (Canyon, shelf edge, shelf regional reflector, gaps in subbottom data, gas flares*)

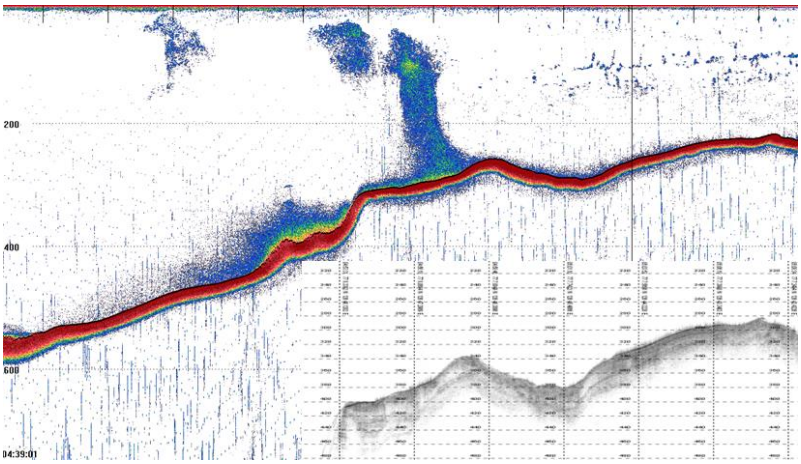


Fig. H6. An example of EK60 and subbottom profiler (inset in lower right corner) records from the continental slope. Note the interrupted subsurface acoustic reflector in the areas of active seabed seepage.

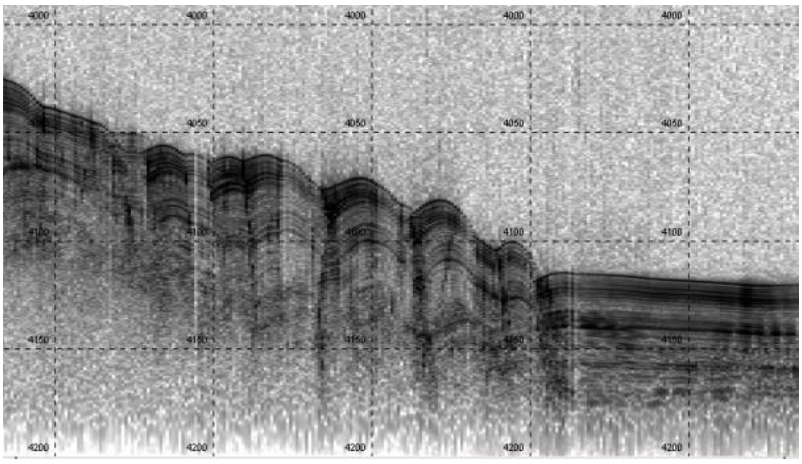


Fig. H7. An example of subbottom profiler record from the lower continental slope. The example shows thick stratified succession of marine deposits.

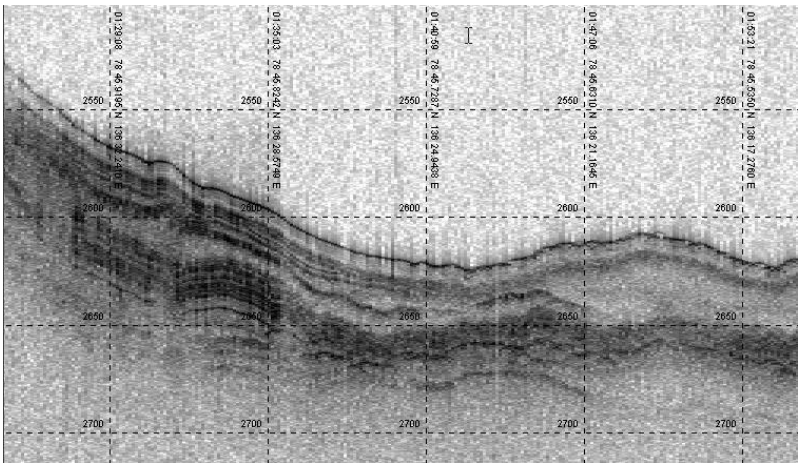


Fig. H8. An example of subbottom profiler record from the continental slope dissected by gullies. The example shows alternating acoustically transparent sediment mass flow deposits and stratified intervals of marine sedimentation.

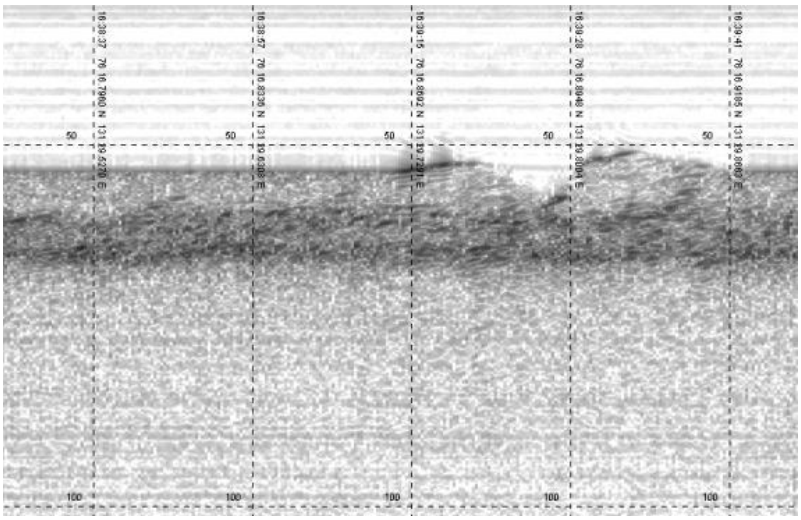


Fig. H9. An example of typical 2-layered acoustic structure of the sediments on the shallow continental shelf of East Siberia. Note the large iceberg scour mark on the seabed.

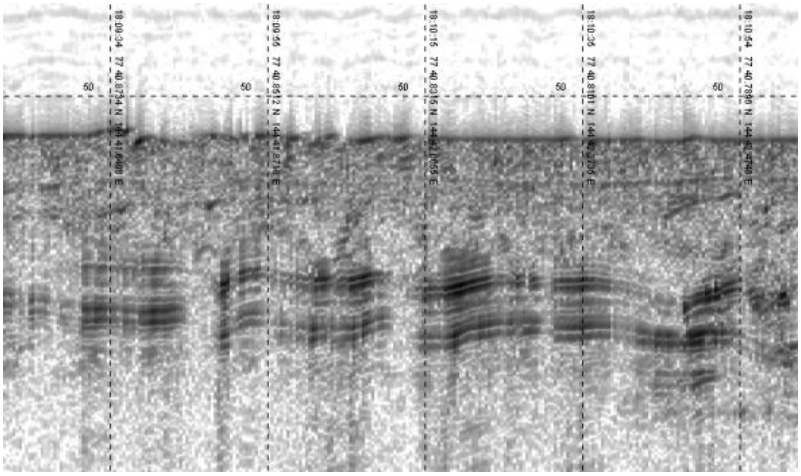


Fig. H10. An example of gas chimneys penetrating the subsurface acoustically stratified sediments. Such chimney-like acoustic structures are indicative of gas migration paths in the sediments.

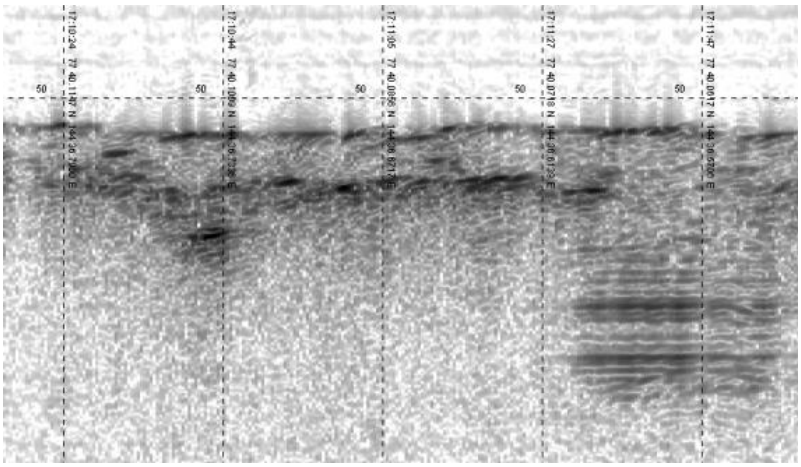


Fig. H11. An example of gas blanking on the subbottom profiler record. Gas accumulation in the upper part of the sediment succession blanks out the underlying sediment structures due to its physical properties that prevent the propagation of acoustic energy.

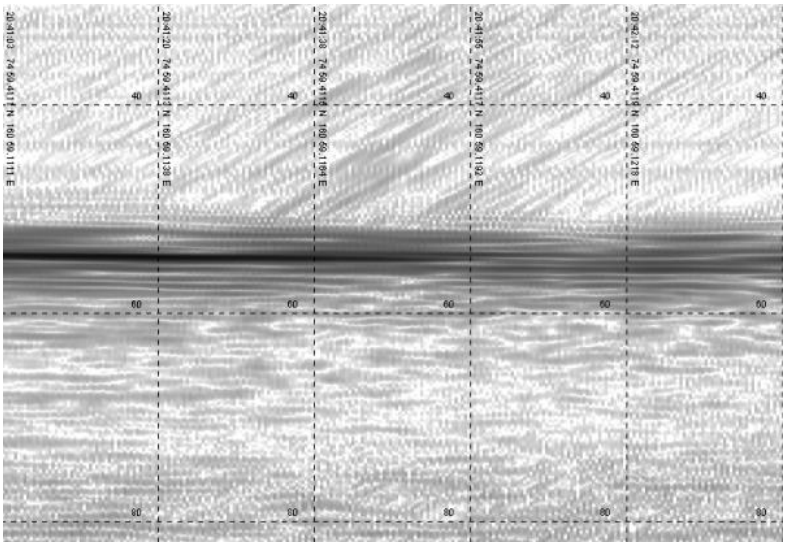


Fig. H12. An example of gas flares in the water column in one of the 'hot spots' of seafloor gas seeps.

EK60 (fish finder) was a primary tool for detection and mapping of gas bubbles and provided superb data on the water column structure throughout the expedition.

The performance of EK60 was somewhat less affected by the noise generated during the ice breaking than the other instruments, although occasionally considerable amount of disturbance was recorded.

C. 460 active seeps were recorded on the continental slope and shelf of ESSS, of which c. 260 were previously unknown.

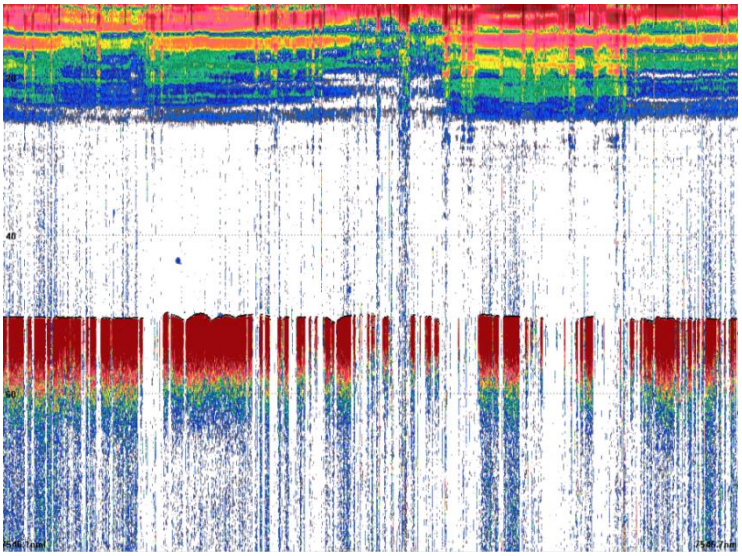


Fig. H13. An example of noisy EK60 record due to heavy ice conditions.

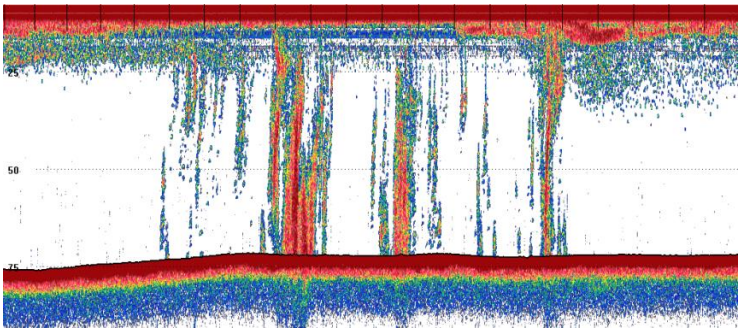


Fig. H14. A series of gas flares on the continental shelf along the survey track.

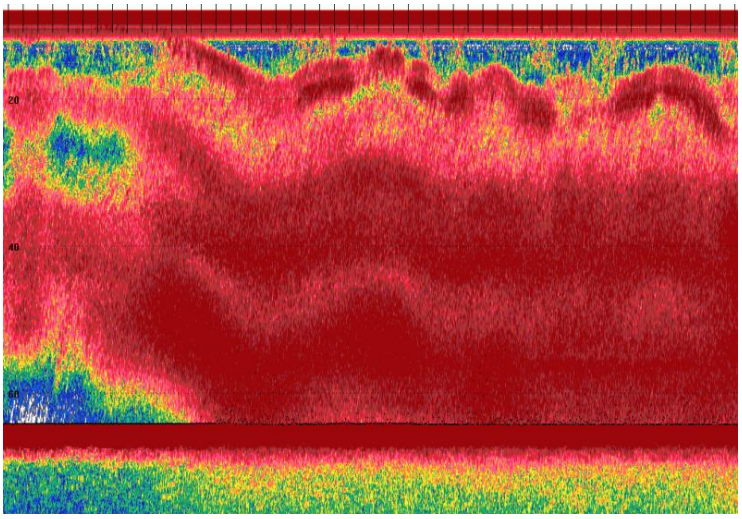


Fig. H15. Water column backscatter in one of the of methane seep 'hot spots' in the Laptev Sea.

Collectively, the subbottom, bathymetric and water column data will shed light on the sediment thickness and structure, seabed morphological features and their link to the active gas seepage from the seabed into the water column along the ship's track across different physiographic and sedimentary environments from the deep basin, through continental rise and slope to the shallow

shelf of the Siberian Laptev and East Siberian Seas. These data, when combined with the deep seismic and geological drilling data, can also yield information about the potential source rocks that the gas may ultimately originate from. This is crucial information for mapping of the distribution and size of potential reservoir, and provides basis for assessment of potential release of the carbon gases in various geological settings and climate scenarios.

WP I ACSE – Boundary Layer Meteorology

The description below follows the same structure as the description of the observations above. The pertinent science results often comes from combinations of several sensors; hence one example of a result is given at the end where the analysis is based on several observations/sensors.

Metadata description of observational datasets sample sizes

The weather station data are sampled at 1Hz and made together into two hourly files, one for the actual weather station and one for the GPS, and two daily files, one for visibility and one for cloud base heights; the logged voltages are also available separately. For the weather station itself data is available both as binary (Campbell logger style) and ASCII; the daily volume total volume of data is ~50 MB and in total for Leg 1 ~2.5 GB. The visibility and ceilometer data is only available as ASCII files; in total for both 20 MB.

Soundings are first performed in standard format, and then reprocessed to a "research mode" sounding, with higher resolution and less rigorous control; hence each sounding (4 per day, at 00, 06, 18 & 12 UTC) is stored in two different versions. The results are stored as WMO standard TEMP and PILOT messages (only for the standard sounding, 4 of each), ASCII output files (2 version of each mode) and as Vaisalla's own internal binary files (2 files). Total amount for Leg 1 is ~2GB.

Surface flux observations

The surface flux data requires post-processing; it needs to be first corrected for ships motion, the for flow distortion around the ship and this will happen after the cruise. The turbulence sensors are sampled at 20Hz, the motion sensors at 40Hz while the mean T/RH sensors are sampled at 1Hz.

The raw data from the sensors are stored both in binary and ASCII files from the two sonic anemometer instruments, the Licor gas analyzer and the CLASP aerosol sampler; for the motion sensors only binary files exist. The daily volume of data is 256MB for the sonic anemometers, 152MB for the Licor, 88MB for the CLASP and ~600MB for the motion sensors. Total for Leg 1 is 78GB. In addition, the mean temperature and humidity sensors collocated with the turbulence systems are stored as both binary and ASCII files, for T/RH and GPS separately and the total amount of data is 1.5GB.

Surface based remote sensing

W-band Cloud Radar**:** Many files are produced each day including hourly raw Doppler spectra, Doppler moments, instrument health messages, and output from the positioning system for the motion stabilized platform. Total data volume for Leg #1 is: 60 GB (moments); 900 GB (spectra); 9 GB (logs).

449-MHz Wind Profiler**.** The system produces two daily raw files and two daily, first-estimate wind profile files. Total data volume for Leg 1: 46 GB.

LIDAR: Data volume approximately 1GB per day (processed output) + 19GB per day (raw binary data files).

Scanning Microwave Radiometer: Approximate data volume: 123MB per day, 5.7GB total.

Microwave Radiometer (MWR)**:** Data are provided in a suite of 5 ASCII files (lv0, lv1, lv2, tip, ser), all containing header information that describes the fields, measurement units, operational modes, etc. "ser" files are instrument logs, "tip" files contain calibration information, "lv0" files contain raw voltage measurements, "lv1" files contain brightness temperature measurements, and "lv2" files contain the first-estimated retrievals of geophysical parameters. Total data volume for leg #1: 750 MB.

Ceilometer**:** A single daily ASCII file is produced in standard Viasalla formats with naming convention CYMMDDhh.DAT, where Y is the last digit of the current year, MM is the month, DD is the day, hh is the hour. Total data volume for leg #1: 1 GB.

Miscellaneous observations

Surface skin temperature IR: Houry ASCII files, data volume: 11MB per day.

Sea surface temperature "Sea Snake": Total data volume for leg #1: 3.3 MB

Surface imagery: Data volume: approximately 250GB

Waverider: Only deployed a few times; total data volume: 250kB (binary).

Results

All systems have mostly worked well, although there has of course been down periods for different sensors for different reasons: sensor failure, logger or computer failure or human error. The scientific results will depend on quality controlled and post-processed data and can only be estimated at this time. A rough outline can be presented only from some data. The statistics below is an example, showing the frequency of occurrence of the lowest base and visibility. Common to many other Arctic datasets, low cloud were common and here the lowest cloud base was often below 100 m; clear conditions existed 20% of the time. Visibility statistics shows roughly the expected bimodal distribution, with peaks below 1 km (fog) and above 30 km; there is an additional weaker peak a little more than 10 km that requires further study. One may speculate that the distribution of open water and sea ice may have caused this; open water is more likely than ice to produce the type of large (sea salt) aerosols that can swell to form haze.

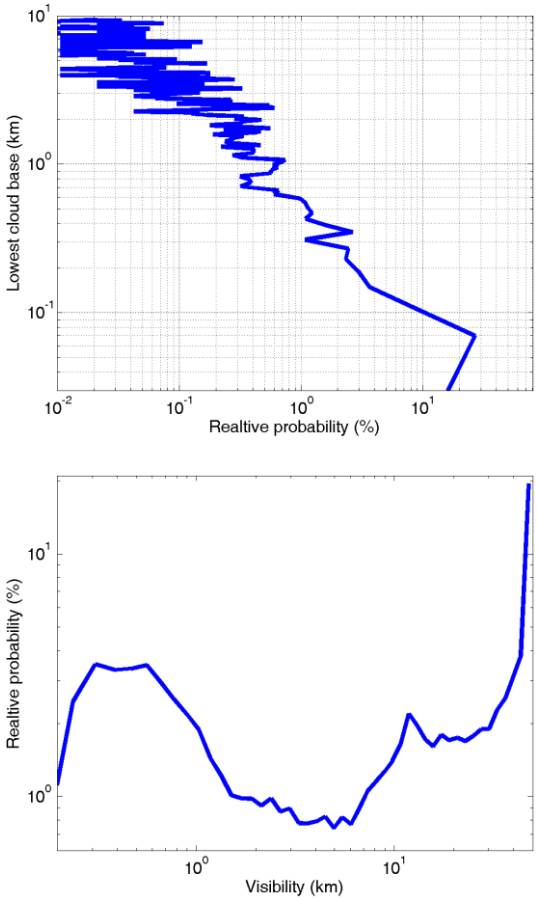


Figure MT1. Statistics for frequency of occurrence of (left) lowest cloud base and (right) visibility.

The really valuable results usually stems from combining data from several sensors for a complete picture of the atmospheric state and how it developed over time/space. Here one such example is described. During the period DoY 210 – 224 Oden was in the ice southeast of Bennett Island; during this whole time foggy conditions prevailed; see time series from visibility and cloud base sensors below. For a period the visibility was so poor it became an issue for navigation through the ice; on DoY 214 Oden actually stopped and waited for better visibility.

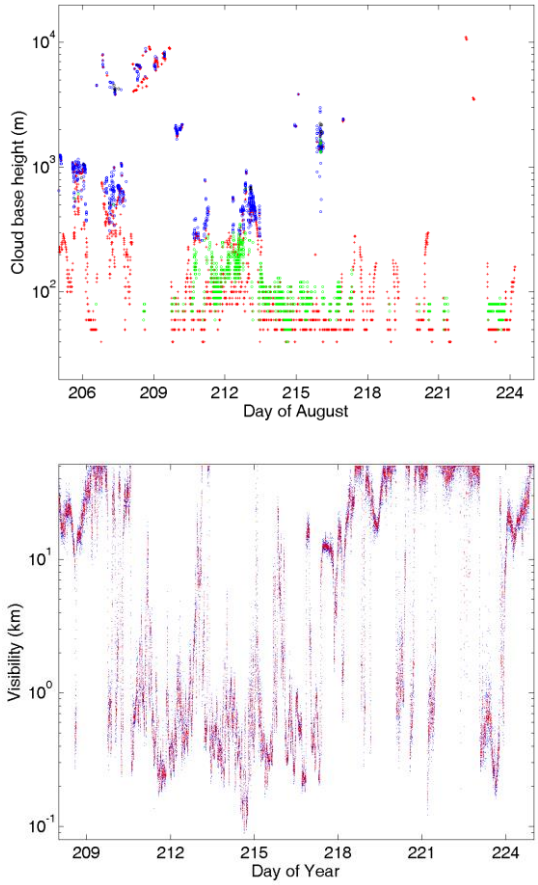


Figure MT2. Time series of (left) cloud base heights and (right) visibility.

Although fog occurred already from DoY 209, or thereabouts, the time period from DoY 213 to 218 was particularly interesting. The atmospheric flow then was from warm and moist conditions first over land and then open water. As this air entered over the ice, the melting ice cooled it from below and this generated a very strong surface inversion in which the absolute moisture content of the atmosphere increased with height; see results from soundings below. Temperatures at only a few hundred meters were close to 20 degrees warmer than at the surface; this was quite extreme conditions.

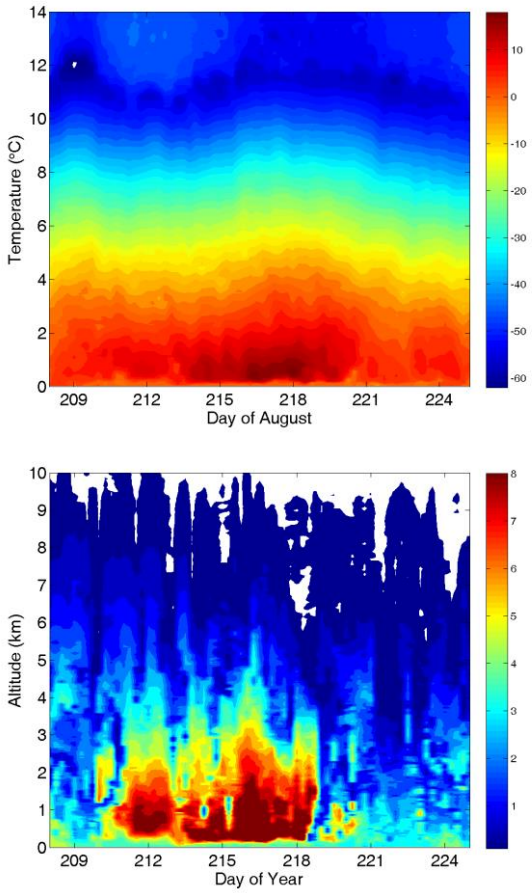


Figure MT3. Time-height cross section of (left) temperature and (right) water-vapor mixing ratio.

The time-height cross-sections show the warm and moist air aloft; temperatures reaching almost to 20 ^{o}C at 400 to 800 meter, with the corresponding increase in water vapor mixing ratio. The fog is here the key element; a liquid water fog is a good blackbody emitter of thermal radiation, only here the radiation from the fog comes from a much warmer layer than the surface temperature; hence a large and positive longwave radiation balance at the surface, that more than compensated for the loss of solar heating, which is small over the ice due to the high surface albedo. Below the statistics for the surface-radiation balance is estimated.

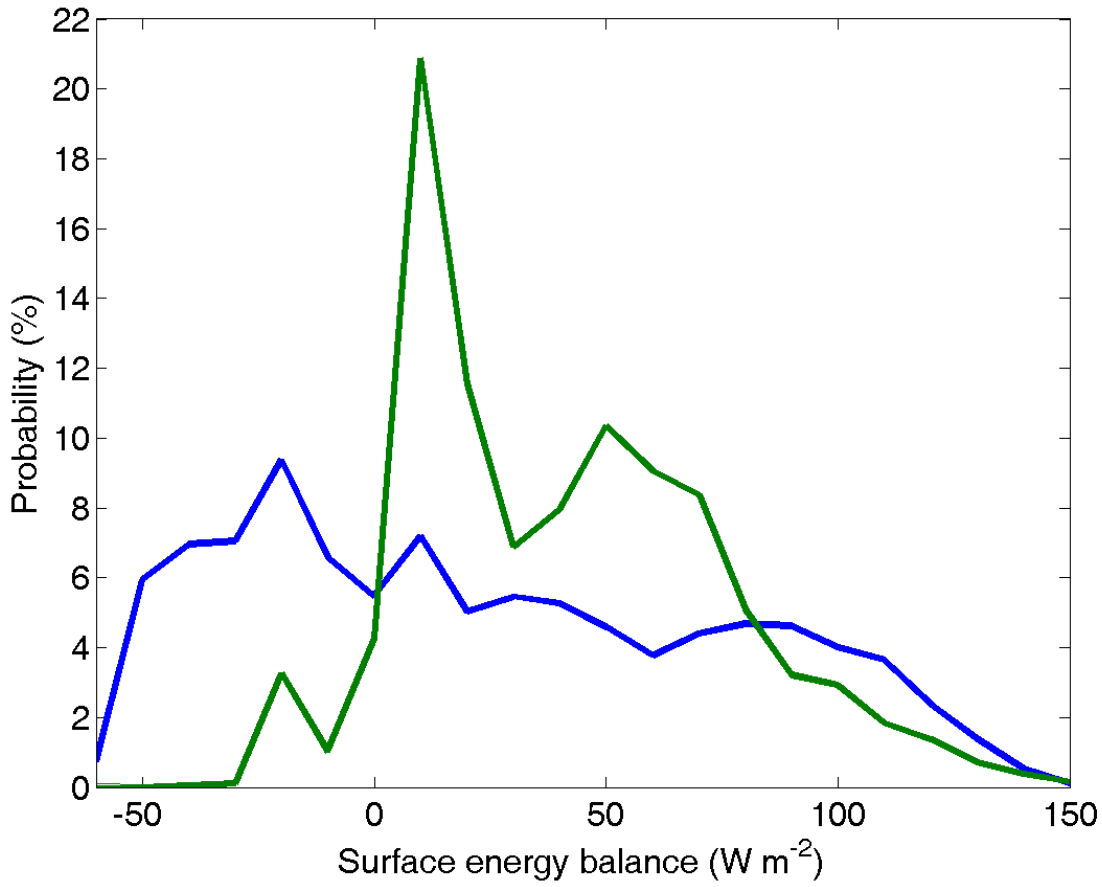


Figure MT4. Frequency of occurrence of the surface net radiation balance for (blue) two-day foggy periods before and after (green) the warm fog event.

This was estimated assuming a surface albedo of 70%; this is uncertain and can change the values but likely not the comparison between the periods. The upwelling longwave radiation was estimate using a surface emissivity of 0.98, which is another uncertainy; again values can change resulting in a horizontal shift of the curves but likely by the same amount. Finally, the turbulent heat flux and conduction through the ice needs to be accounted for; this can only happen in the post-expedition analysis, but these fluxes are typically much smaller than the radiation fluxes.

During most periods the energy balance goes through a diurnal cycle, with negative values at night, when the sun is weak and large positive values during the day. Here the negative values dominate, but the magnitude of the high values provides a positive mean budget (median value is ~10 W m^{-2}). However, during the warm fog event, the surface radiation balance almost never becomes negative; hence the median value is more than twice as large; ~25 W m^{-2}. This evenet clearly illustrates the importance of combining different sensors; also it shows how a long-range transport event of warm air interacts locally with fog formation to generate conditions that facilitate enhanced sea ice melt.

References

Kessler and Reeburgh (2005): Preparation of natural methane for stable isotopes and radiocarbon analysis, Limnol. Oceanogr.: Methods, 3, p. 408-418.

Rothman, L.S. The HITRAN2012 molecular spectroscopic database, J. Quant. Spect. Rad. Trans. 130 (2013) 4-50.

Appendix A – Example Station Activity Plan

Summary information segment between waypoints F → G Part 1 of 2

- **Setting, conditions and strategy:** We are breaking up the massive F to G segment – the Grand Finale of SWERUS-C3 Leg 1 – into two parts for the planning. This is because it is an extensive investigation and because ice conditions place uncertainties on timing and location of the second part. The F→ G core area is centered around a putative methane hotspot area in the East Siberian Sea. In the original Leg 1 cruise plan, we had the ambitions of thee hotspot areas. We sailed with cruise plan A2, where we reduced to two areas. We have detailed one hotspot on the Laptev Sea shelf and now aim to complete SWERUS Leg 1 with characterizing a second shelf methane focus area.

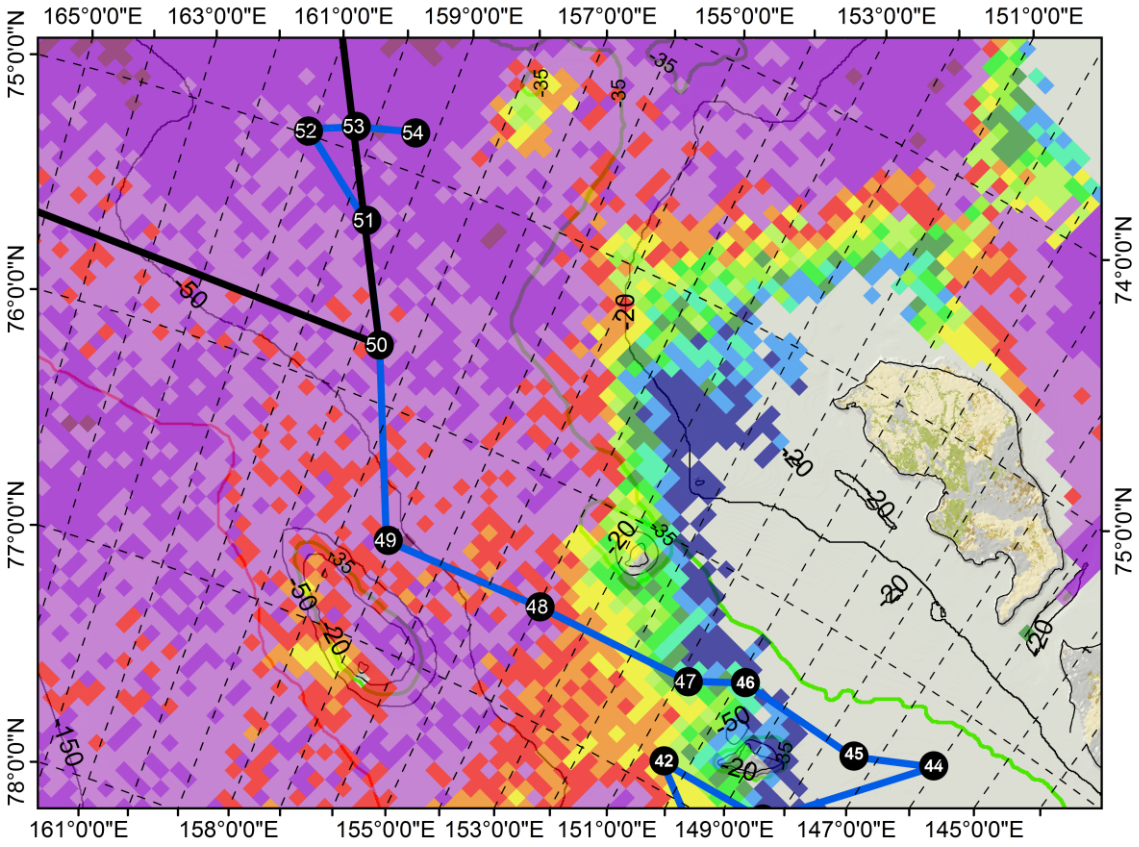
  The first stretch of the F→ G part 1 of 2 extends an extremely valuable long transect cutting across the West to Central East Siberian Sea, all the way from shelf break (waypoint D) to the target hotspot area (starting around stations 52-54, below). This will provide unique and rare opportunities to study biogeochemical processes of carbon and methane in both sediments, water and overlying air. Several of our earlier studies have documented a transition zone in the water and sediment geochemistry around the 155 E cutting across the ESS; related to the larger-scale circulation and a frontal zone between the Siberian Coastal Current (Lena plume) and the Pac influenced waters on the east. Swerus_C3 expedition (i.e. us) will characterize this in greater detail.

  Since about halfway along D to F segment, we are observing slowly but steadily increasing methane levels both in SWI and in a subsurface maximum centered right below the pycnocline. Such subsurf maximum was observed for 500-600 km in a more easterly region of the ESS during ISSS-08. How extensive is this? Where are the roots?

  Hence, some of the key objectives for this segment includes researching the input and fate of terrestrial (permafrost/erosion) carbon; cross-shelf transport and processing of terrestrial organic matter across the ~155E transition zone. Continue our strong continuous monitoring discrete-sampling programs of air and surface seawater; map shelf transition zones of sediment methane releases. Detail the subsurface maxima and in-depth study of the central ESS methane hotspot area. Since we may pass in and out of ice, this may provide a good opportunity for the ACSE program to gather data to investigate the role of sea ice on cloud formation and tropospheric boundary layer dynamics. There may be some requests to anchor for a megastation (same w Skidbladner operation).

  We are right now taking a more northerly route to eventually hit the central CH4 area (stns 52-54) with stations spaced some 40-50 nm apart along the transit.

- **Time points.**
  - Stn 48: 25 nm to go at 12:45 Wednesday 30 July, ETA: 19:00 (uncertain)


165°0'0"E
163°0'0"E
161°0'0"E
159°0'0"E
157°0'0"E
155°0'0"E
153°0'0"E
151°0'0"E
75°0'0"N
76°0'0"N
77°0'0"N
78°0'0"N
74°0'0"N
75°0'0"N
161°0'0"E
158°0'0"E
155°0'0"E
153°0'0"E
151°0'0"E
149°0'0"E
147°0'0"E
145°0'0"E
52
53
54
51
50
49
48
47
46
45
44
42
35
50
20
150

OVERVIEW ACTIVITY PLAN

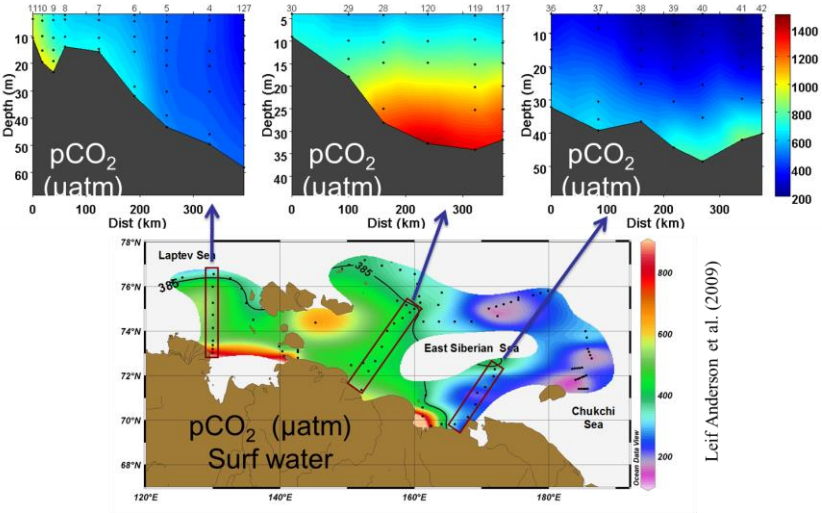
WAYPOINTS F to G part 1 of 2 ver 140730/kl 09

							BOW DECK	(nr of casts)				REDWINCH/DAVIT			AFT DECK (nr of casts)				BOAT		OTHER
Station ID ^	**OLD STN id**	**LAT**	**LON**	**approx depth, m**	**nm to next stn**		**CTD - no Niskin sampling**	**CTD BGC+Ra**	**CTD CH4/Ra isotopes +/- incub water**	**CTD CH4 only**		**GoFlo**	**Subm pump**		**Coring - multicorer**	**Coring - long gravity**	**Coring Piston**		**Skidbladner**		Plankton-net; Secchi; Snake; Waverider
real 47	at ice/night stop	76 31,25	150 48,48	40	44			1				0-4	0		1	0			if "CH4 mega"		
48	along NE nav	76 31,92	153 57,04	41	44			1				0-4	1		2				or PC opp		
49	nav wp Nmax	76 32,6	157 05,6	40	52			1				0-4			1	0			if "CH4 mega"		
50	Seism start	75 45,6	158 35,96	-43	33			1				0-4	1		4	0			or PC opp		
51	50	75 16.08	159 35.26	39	28			1				0-4			1	0			if "CH4 mega"		
52	51; ISSS96	74 59.05	161 02.59	45	13			1				0-4			1	0	1		or PC opp		
53	52; ISSS113	74 53.73	160 18.37	44	16			1				0-4	1		1	1			if "CH4 mega"		
54	53; ISSS112	74 49.96	159 19.81	41				1				0-4			4	0			or PC opp		

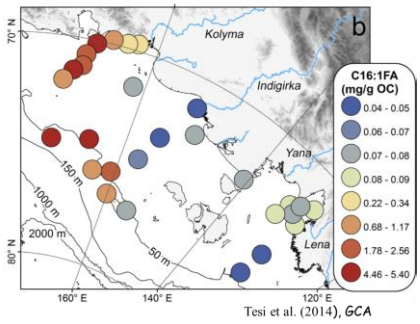
^ May ask for anchor if do a megastation focused on constrained area

* long gravity core either at stn 53 or 54

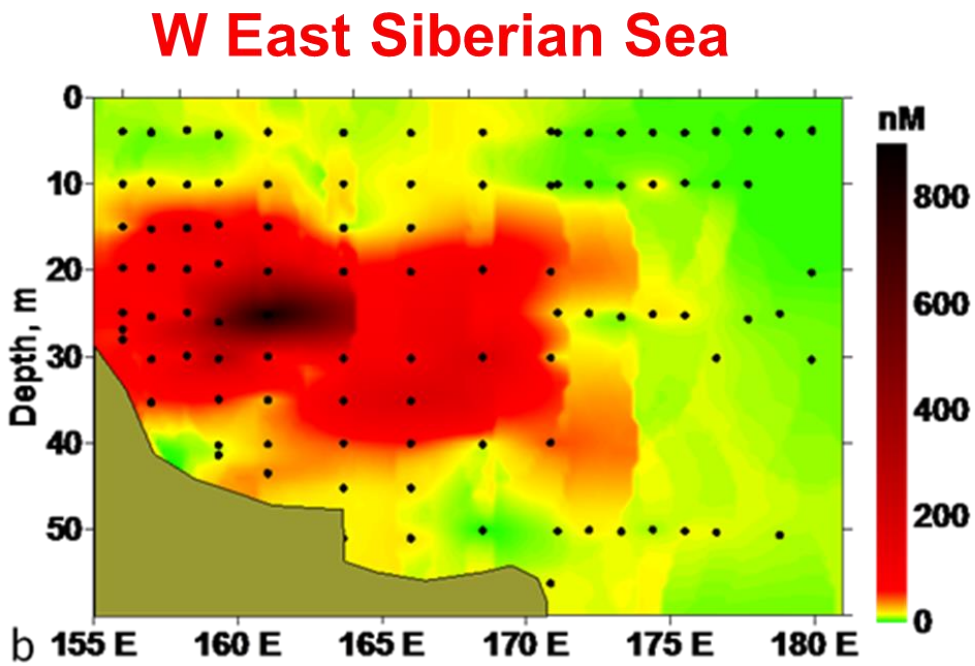
Examples of biogeochemical transition zone around 155 E in the ESS



Phytoplankton biomarker in surf sed: ~155°E transition



Mid-water methane plume observed in ISSS-08 around F to G region:



Shakhova et al. (2014)

Stn nr:	53	(stn nr in Segment Plan, if different):													
Stn activity plan						BOW DECK	(nr of casts)			REDWINCH		AFT DECK			BOAT
Station ID	old Station_ID	Lat	Long	approx depth, m	nm to next stn	CTD - no water	CTD BGC+Ra	CTD CH4/Ra isotopes +/- incub water	CTD CH4/He/Ra bw drift	GoFlo	Subm pump	Coring - multicorer	Coring - Rumohr	Coring Piston	Skidbladner
53	new!						1		0	0-4	0	2	0	0	if hi CH4 and low sea state

Arr stn area:		Parked:	00:00	departure:						
	Date	HH:MM	LAT	LON			Date	HH:MM	LAT	LON
Stn Start:	2014-08-02	13:45	74 57,49	161 03,86		Dep. stn:	2014-08-02			

Ship repositioning during station		Start time	Stop time	new start position	new stop position
Repositioning before Go-Flo		14:40	15:30	74 57,42	161 05,42

Hard to part

depth: 49m

Bottom SSE corner of survey circle.

Sampling deployments

Planned order:	
1	CTD/BGC+Ra
2	MUC1-2
2	GoFlo , if hi CH4
2	
anytime	
	Secchi disc
	Sea snake
	Plankton net
P	

Multicorer	down	up
MUC cast 1	15:30	15:39
MUC cast 2	16:00	16:05

Rumohr	down	up

Piston corer	down	up

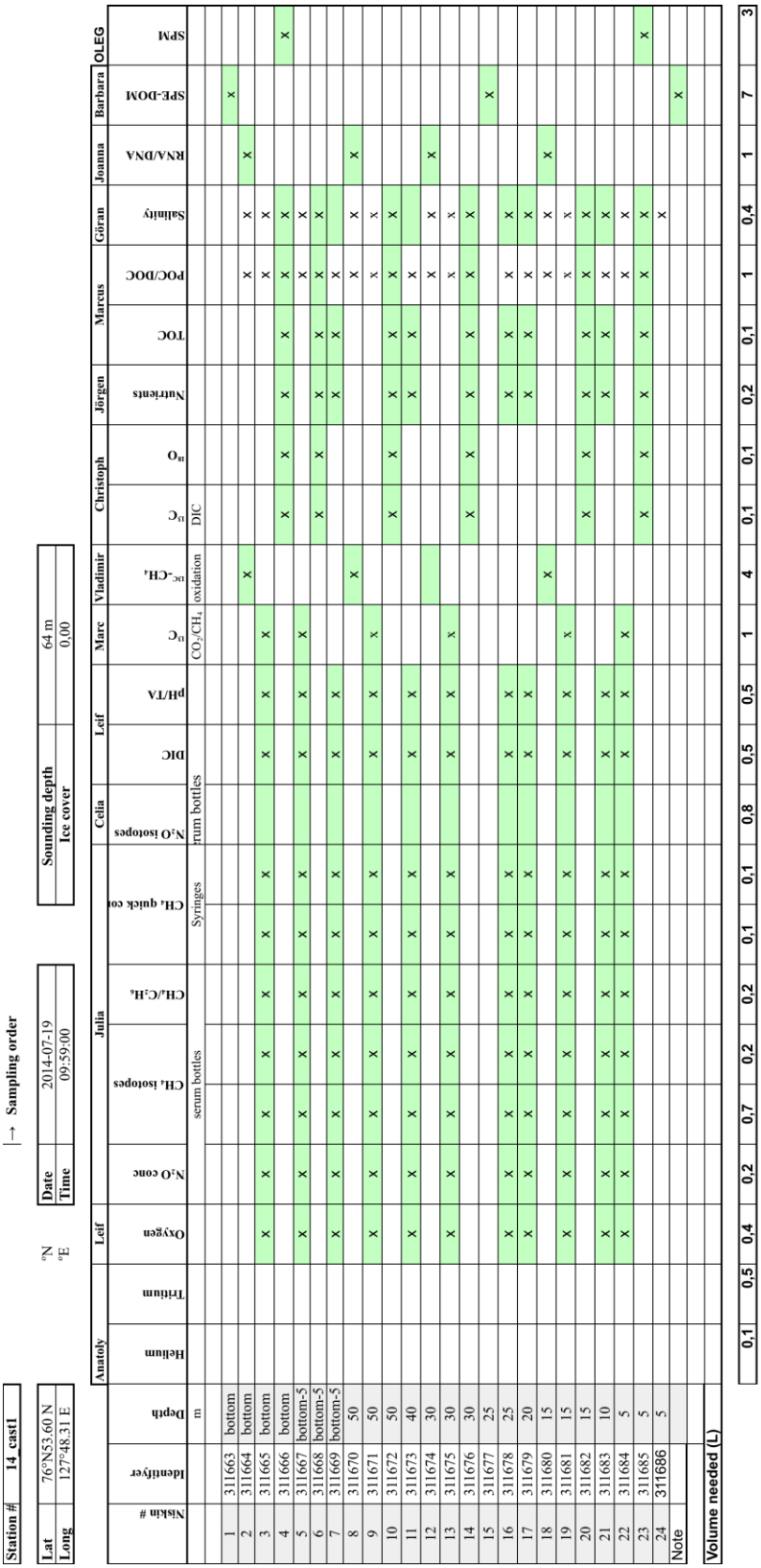
CTD	down	up
CTD 1 BGC	13:45	14:10

bw d13C-CH4 heavy - - 35 per mil; SWI was -60 per mil!
SWI: 500 nM
20m 500 nM
bw: 500 nM
SWI also taken for 14C-CH4

Go-Flo	down	up
Go-Flo 1, if hi CH4	16:20	16:26
Go-Flo 2, if hi CH4	16:35	16:40

Other	down	up
Plankton net		
Secchi	Yes	

Appendix C – Example Wet Deck Sheet



Station # 14 cast1

Lat	76°N53.60 N
Long	127°48.31 E

→ Sampling order

°N
°E

Date	2014-07-19
Time	09:59:00

Sounding depth	64 m
Ice cover	0,00

Niskin #	Identifyer	Depth	Anatoly		Julia				Leif	Celia	Leif	Marc	Vladimir	Christoph		Jörgen	Marcus		Göran	Joanna	Barbara	OLEG
		m	Helium	Tritium	Oxygen	N_2O conc	CH_4 isotopes	CH_4/C_2H_6	CH_4 quick con	N_2O isotopes	DIC	pH/TA	^{13}C	^{13}C-CH_4	O_{18}	Nutrients	TOC	POC/DOC	Salinity	RNA/DNA	SPE-DOM	SPM
							serum bottles		Syringes	rum bottles			CO_2/CH_4	oxidation	DIC							
1	311663	bottom																				
2	311664	bottom			x	x	x	x	x		x	x	x		x			x	x	x	x	
3	311665	bottom																				
4	311666	bottom			x	x	x	x	x		x	x			x	x	x	x	x			x
5	311667	bottom-5			x	x	x	x	x		x	x			x	x	x	x	x			
6	311668	bottom-5																				
7	311669	bottom-5			x	x	x	x	x		x	x			x	x	x	x	x			
8	311670	50											x									
9	311671	50			x	x	x	x	x		x	x						x	x	x		
10	311672	50													x	x	x	x	x			
11	311673	40			x	x	x	x	x		x	x				x	x					
12	311674	30																x	x	x		
13	311675	30			x	x	x	x	x		x	x	x					x	x			
14	311676	30													x	x	x	x	x			
15	311677	25																			x	
16	311678	25			x	x	x	x	x		x	x				x	x	x	x			
17	311679	20			x	x	x	x	x		x	x				x	x	x	x			
18	311680	15											x					x	x	x		
19	311681	15			x	x	x	x	x		x	x						x	x			
20	311682	15													x	x	x	x	x			
21	311683	10			x	x	x	x	x		x	x				x	x	x	x			
22	311684	5			x	x	x	x	x		x	x						x	x			
23	311685	5													x	x	x	x	x			x
24	311686	5																	x			
Note																						
Volume needed (L)																						
			0,1	0,5	0,4	0,2	0,7	0,2	0,1	0,1	0,8	0,5	0,5	1	4	0,1	0,1	0,2	0,1	1	0,4	1	7	3