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Cruise report CAGE 20-1

K-lander recovery and water column survey offshore Svalbard and in the Barents Sea

Longyearbyen – Tromsø 22-06-20 to 01-07-20



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Participants: Dimitri Kalenitchenko, Manuel Moser, Marie Stetzler, Truls Holm and Stormer Jensen

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# 2 CRUISE OBJECTIVES AND DEVIATIONS

The cruise was conducted from June 22nd to July 1th 2020 as part of the Centre of Excellence for Arctic Gas Hydrate, Environment and Climate (CAGE) at UiT – The Arctic University of Norway. The main objective of the research cruise was to recover one of our K-lander that was deployed for the 3rd time offshore Prins Karls Forland, on an extensive methane seepage area (area a in Figure 1). This includes incubation plates installed for Helge Niemann's team to study the biofilm that could developed on different types of polymers. The sub-objective in this area was to performed single and multibeam surveys around the lander in order to locate the origin of the signal seen in the collected data, as well as map the seepages to compare with our horizontally-looking multibeam mounted on the lander. In addition, we collected water from Niskin bottles during CTD casts to measure methane concentration in the water column along and across the lander.

The second objective of the cruise was to visit the site around the location called "MASOX" due to the former seafloor observatory deployed there for 2 years, in order to check the status of the flare activities (deeper part of area a in Figure 1).

We then decided to explore little known areas in search of a new "hot spots" and headed south to explore the Sørkapp area (Southern Svalbard, area b in in Figure 1) where we expected to see a large number of flares, based on Mau et al. 2017 and the flares located during CAGE 13-? (cruise leader Karin Andreassen). We started to perform a single and multibeam survey in the area, but the little activity there motivated us to change our plans and we decided to head to the pingo area (area c in in Figure 1), where the coming NorEMSO mooring will most likely be deployed next year. As time allowed, we headed to Kveithola were we suspect many more methane seepages than reported in Mau et al. (2017) and Bazzaro et al. (2020) (area d in in Figure 1).

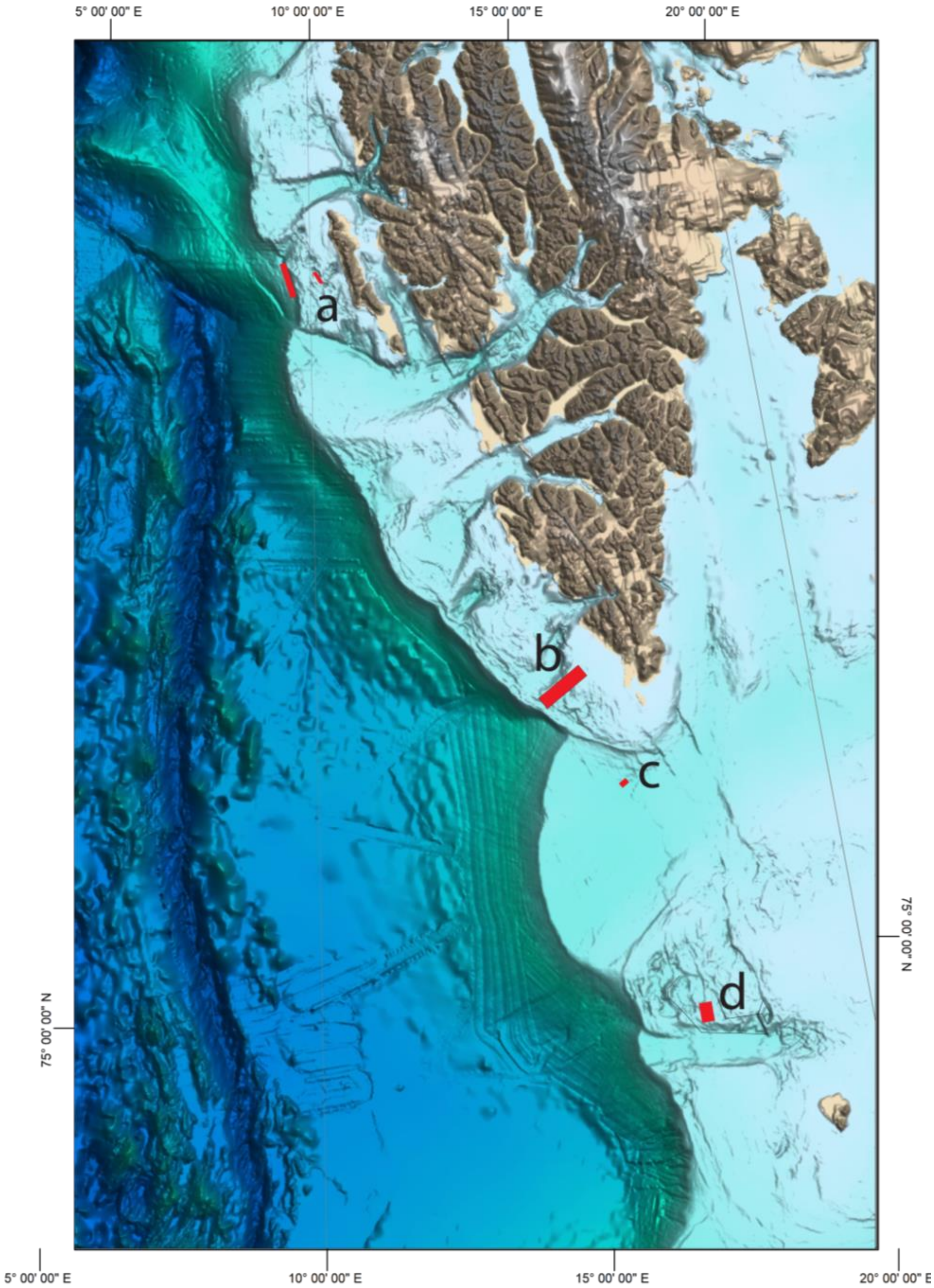



*Figure 1. Maps illustrating the working areas (red rectangles) where we performed single/multibeam surveys and CTD casts offshore Prins Karls Forland (PKF, ~100m depth) and MASOX area (~200-400m depth), Sørkapp (100m in average), pingo area and Kveithola.*

# 3 INVESTIGATED AREAS

## 3.1 Western Svalbard

The K-Lander observatory was deployed during CAGE 19-2 in July 2019 offshore Prins Karls Forland (PKF), Svalbard, which is part of the Forlandet moraine complex (Landvik et al., 2005) (Figure 2). The area is characterized by large bathymetric depressions (Landvik et al., 2005) and is known to discharge methane in the water column from hundreds of individual gas flares patchily distributed between 80 and 130 m depth (Sahling et al., 2014). The methane there has a microbial origin (Mau et al., 2017), and unlikely results from locally dissociating gas hydrate due to the shallow depths. It is instead suggested that lateral migration of methane from gas hydrate dissociation from deeper areas could fuel the shallow shelf seeps (Rajan et al., 2012, Sarkar et al. 2012). Despite the methane not reaching the atmosphere in summer 2017, little is known about the situation in colder seasons regarding transport of methane to the atmosphere. We hope that our K-lander can shed light to these uncertainties.

More than 1 000 flares were observed deeper offshore Western Svalbard region at ~400 m depth, corresponding to the present-day landward limit of hydrate stability (Berndt et al., 2014) (Figure 2). The flares there have been active for at least 3000 years (Berndt et al., 2014), and hydrates started dissociating even earlier (~8,000 yr ago) when rapid glacial isostatic uplift overcame the sea-level rise (Wallmann et al., 2018). Many previous studies surveyed the area, showing a constant activity. However, these previous observations were based in summer data, and Ferré et al. (2020) showed a strongly reduced activity during cold temperatures in May.

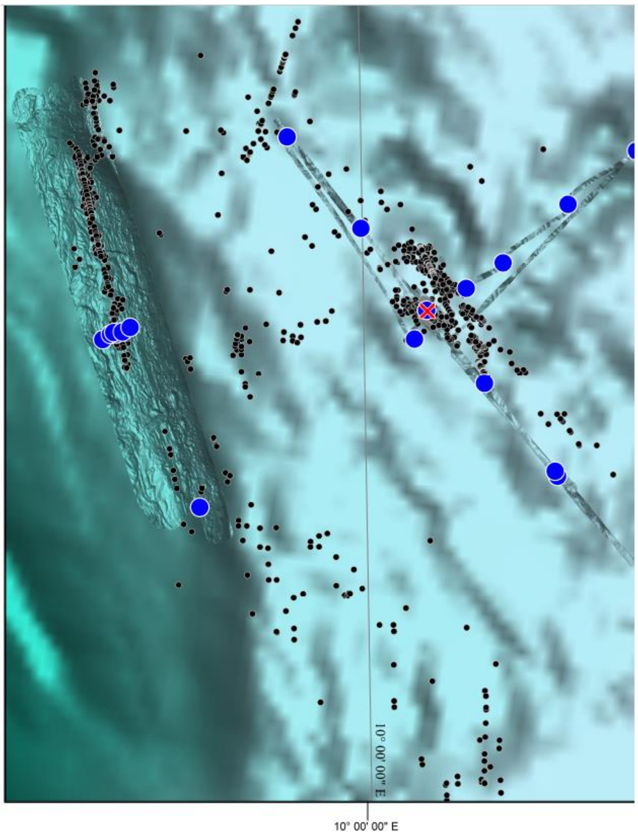



*Figure 2. Maps of the areas with CTD stations (blue circles) with EK/multibeam surveys visible from the sharper areas offshore Prins Karls Forland (PKF, ~100m depth) and MASOX area (~200-400m depth). The lander location is indicated with the red cross, known flares locations are represented in black dots.*

## 3.2 Sørkappbanken

Located on the south continental shelf of Svalbard, Sørkappbanken is influenced by cold Arctic surface water coming from Storfjorden, known for significance production of dense water of brine origin produced through ice formation in polynyas (e.g. Fer et al. 2006). It extends from 60 to ~230m depth. Multiple flares have been reported by Mau et al. (2017) on two survey lines, but also on one survey line reported in CAGE 13-?? (cruise leader Karin Andreassen). We suspect that this area covers an extended amount of flares elsewhere on the shelf (Figure 3).

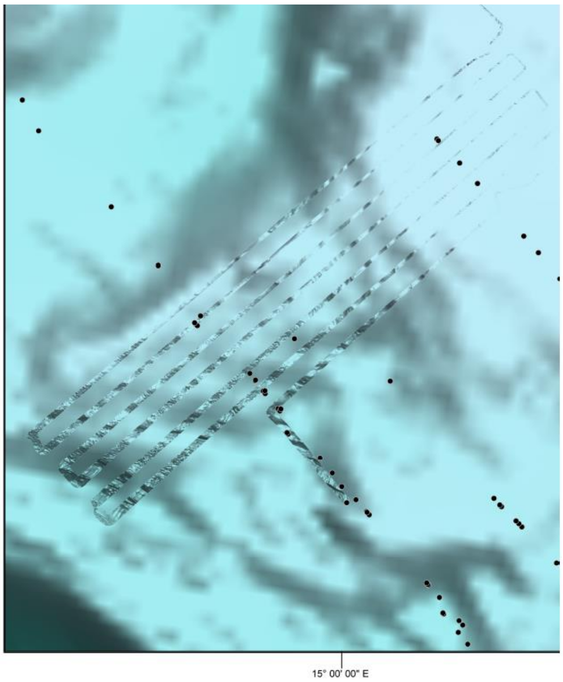



*Figure 3. Maps of the EK/multibeam surveys at Sørkapp, visible from the sharper areas. Kown flares locations are represented in black dots.*

## 3.3 Pingo area

The pingo area is located in Storfjordrenna around 16°E 76°N at ~390m depth, and is characterized by circular morphologic features ~280-450m in diameter and 8-10m high (Serov et al., 2016). They formed after the retreat of the last ice sheet (Serov et al., 2016). The pingo area has been visited during many research cruises (CAGE 15-2; CAGE 15-5; CAGE 15-6; CAGE 15-7; CAGE 18-5), mainly to perform seismic, sediment and water sampling, as well as mapping and imaging. However, no water column data exist as the new multibeam echosounder was installed on Helmer Hansen in 2017, and CAGE 18-5 was on Kronprins Håkon and no water column data was recorded with the multibeam. In order to locate all the flares, we decided to map the area, extending the edges we already know. We also performed CTD casts with water sampling for methane concentration.

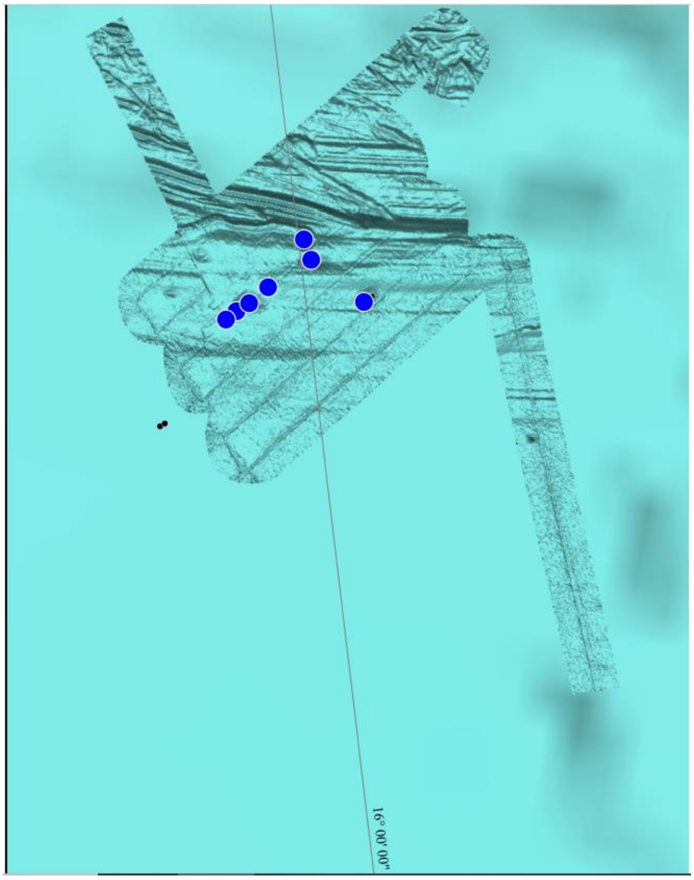



*Figure 4. Maps of the EK/multibeam surveys at pingo area, visible from the sharper areas. Blue dots locate the CTDs, covering the flares.*

## 3.4 Kveithola

The last area we explored was Kveithola, glacially-carved U-shape depression with an East-West orientation in the Barents Sea, north from Bjørnøya. The through is ~15 km wide and 100 km long, with water depth from 200 to 400 m. It is covered with sediments derived from ice rafting and meltwater plumes (Lucchi et al., 2013). Previous expeditions (as reported in Lucchi et al., 2016; Mau et al., 2017 and Weniger et al., 2019) observed a few single methane seepage along the northern edge of the though from thermogenic origin (Weniger et al., 2019).

## 3.5 Hydrography

The Norwegian Atlantic Current (NwAC) carries Atlantic Water (AW) (S >34.9 and T >3 °C). Following a northward direction, this current is then called West Spitsbergen Current (WSC) which carries warm and less saline Atlantic Water (AW) on the slope and continental shelf of Svalbard (Aagaard et al., 1987). The East Spitsbergen Current (ESC) brings colder and low saline Arctic surface water (ASW) from Eastern Svalbard, following the southern coasts of Svalbard and continuing northward over the shelf (Saloranta and Svendsen, 2001). Sørkappbanken is therefore crossed by low salinity water (Mau et al., 2017). The ESC is then known as the Coastal Current (CC).

Offshore Svalbard, meanders of the WSC render the area very dynamic and complex, flooding the coast and bathymetric depressions with heavier AW (Nilssen et al., 2008; Silyakova et al., 2020). This warm aerobic methanotrophs-free AW replaces the cold water rich in aerobic methanotrophs within a few days (Steinle et al., 2015), implying reduced methane consumption during this current setting.

# 4 METHODS AND PRELIMINARY RESULTS

## 4.1 Retrieve of K-lander

We could visualize the K-lander on the seafloor from the EK60 signal surrounded by flares (figure 2).

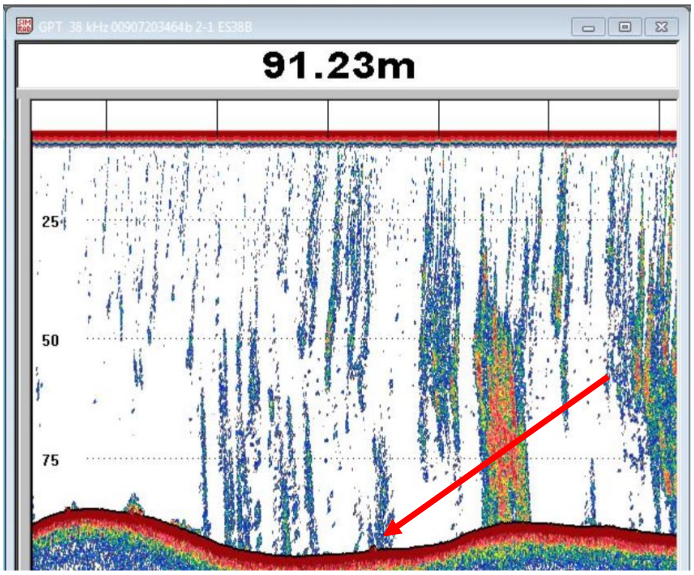
5. 


*Figure 5. Echosounder signal showing intense flare activity. Lander location is marked with the red arrow.*

We started the process of retrieving the lander by placing the transponder in the water at 12:00 on June 23rd. The first frequency did not work so we tried the other c-node frequency, working on its own battery. It took about 25 min for the K-lander to be on deck from the time the dinghy was placed in the water. Unfortunately, the quick observation of the general state of the lander revealed that the DPU (data processing unit, where the data are stored) was wide open, exposing all cables and the harddrive. It seems that the head of one of the cables created a reaction with the platinum casing of the DPU, coroding everything touching it. The DPU shows signs that it was open for a long time based on the damages and the melting of cables and harddrive (figure 3).

*Figure 6. Observations after recovery: left: the DPU was already open after recovery. Right: what was left of the hard drive containing the data.*

## 4.2 Singlebeam EK60 and multibeam EM302 for flare observation

Single beam echo sounders are common among all types of ships with the main purpose of detecting fish. Here, the Simrad EK60 scientific echosounder system was used at 18 KHz, 38 KHz and 120 KHz to identify active seeps. In a single beam echo sounder, the transducer projects a sound pulse through water in a controlled direction and the reflected wave is received. The depth is calculated from the travel time of the sound pulse. EK60 helps us quickly identify flares (example in Figure 5).

We also used the upgraded SIMRAD EM302 high-resolution multibeam system, including a maximum of 864 beam compared to the previous version only including 135. This new system also maps the water column and detect a broader area than the singlebeam echosounder, allowing to visualize more flares (Example Figure 7). The multibeam was used with a 90° angle at a speed of 5kn during most surveys, except at Kveithola where the angle was open at 120° to cover a larger area.

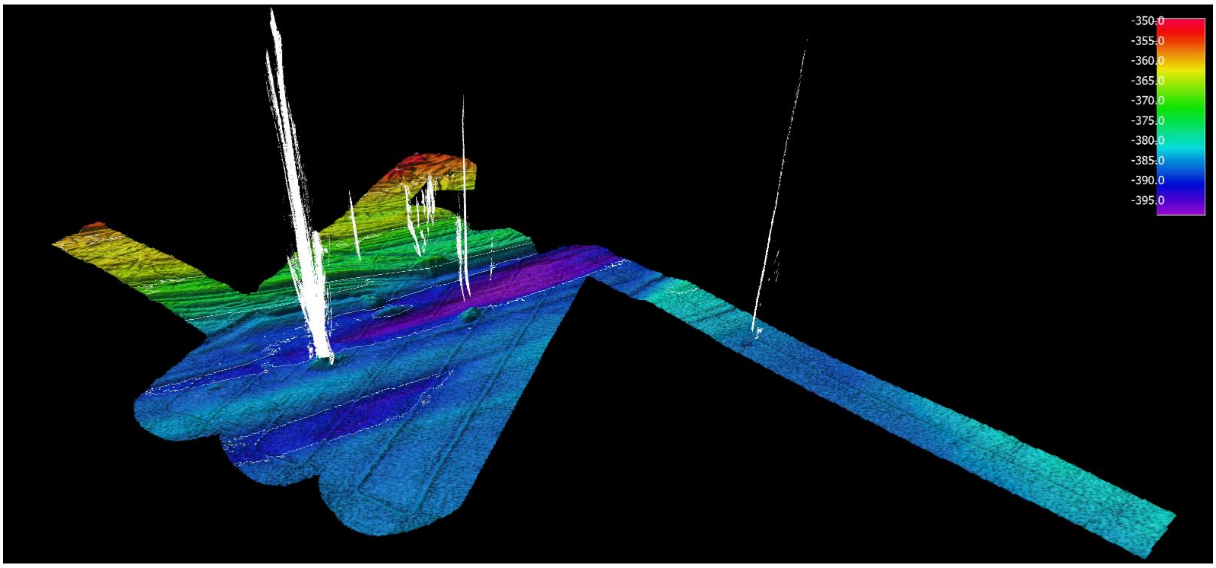



*Figure 7. Example of flares in the pingo area seen by the multibeam ecosounder*

## 4.3 ADCP

The ship is equipped with a traditional "Ocean Surveyor" Acoustic Doppler Current Profiler (ADCP) from Teledyne RD, operating at 75 kHz. The setup consists of an ADCP transducer / receiver mounted on the lowered keel, 7 meters below the sea surface, a deck unit, communicating with the device and a standard PC in the Instrument room. The ADCP provides current amplitude and direction, as well as backscatter information.

## 4.4 CTD

CTD (Conductivity, Temperature, Depth) sensors measure the physical properties of seawater. In addition to measuring the conductivity, temperature and pressure (from which depth is calculated), the CTD sensors can measure or calculate salinity of seawater, density, P-wave velocity, turbidity, fluorescence/chlorophyll, and oxygen content. R/V Helmer Hanssen uses SBE 911plus CTD to produce vertical profiles of seawater properties. A winch lowers the CTD system into the water at 1 m/s. The CTD sensors record data at a rate of 24 samples per second. A total of 12 × 5-liters Niskin bottles are attached to the CTD instrument set up to collect water samples from chosen depth. A single conductor cable supplies power to the system and transmits data from and to the CTD system in real time.

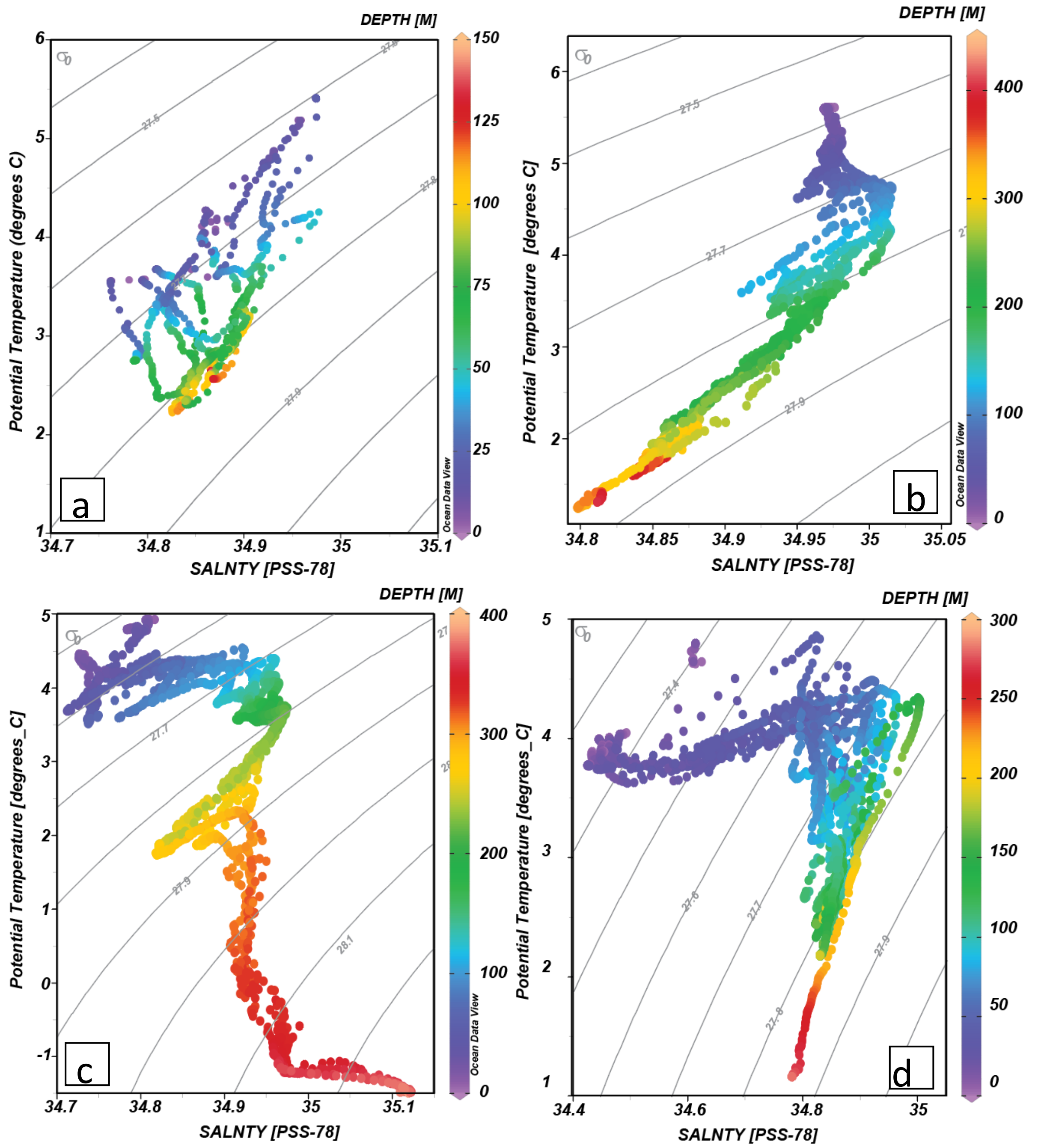



*Figure 8. Temperature –Salinity diagram a) offshore Prins Karls Forland, b) in the MASOX area, c) pingo area and d) Kveithola colored by the depth*

Water masses are dominated by Atlantic water (T>3°, S ~34.65 psu) in all settings. Intrusion of Transformed Atlantic Water occurred offshore PKF near the seabed that resulted from heat loss to the atmosphere and freshening due to meltwater from glaciers, snow and sea ice (Cottier et al. 2005) (Figure 8). Pure Atlantic water was found in the MASOX area, with influence from intermediate water near the seafloor. The water was stratified with a strong pycnocline around 70m in the shallow area and between 20 and 30m in the MASOX area.

The hydrography presents very different features over the pingo site, showing a clear sign of brine formation near the seafloor (e.g. Fer et al., 2003) (Figure 8c). The upper 200m is composed of warm AW, with lower salinity due to mixing with East Spitsbergen water. Over Kveithola the water column is characterized by surface water up to 50, Atlantic Water down to 100m depth and Polar Front signature (mixture of Atlantic water and Arctic Water) down to the sea floor (Harris et al., 1998) (Figure 8d).

## 4.5 Microbiology: Lander' incubators

The aim of the field incubations is to expose different polymer types to the marine environment and compare the biofilms that have developed over time on the plastics. We also want to investigate whether UV treatment of the polymer influences the microbial community.

The white plastic plate attached to the lander frame (called incubation holder, Figure 9) contains small cartridges, which return contain a metal disc that is covered with the different plastic polymers tested. After holders were recovered and brought back on the ship with the lander, they have been processed in the lab. The cartridges with the Samples metal discs were taken out of the holder, and the discs were subsampled (3 samples in total). (i) One subsample was stored in a tube with RNAlater, (ii) one was wrapped in aluminum foil and subsequently frozen for lipid and surface analyses and (iii) one was fixed in 4% formaldehyde solution and finally stored in PBS/Ethanol for FISH (Fluorescent in-situ hybridization).

*Figure 9. Incubation holders installed on the frame of the lander.*

## 4.6 Water sampling at CTD location

### 4.6.1 Methane concentration

To prepare water samples for measurements of methane concentrations we applied the conventional headspace gas extraction technique. Water samples were collected bubble free into 120 mL crimp seal bottles, and poisoned with 1 mL NaOH solution (Figure 10. Bottles were kept in the fridge (5 degrees C) until analysis back in Tromsø with the GC.

*Figure 10. Sampling team: Manuel Mosser on the left sampling water from Niskin bottles, and Marie Stetzler on the right poisening the water samples with NaOH.*

### 4.6.2 Svalbard community analysis

We aim to setup incubation experiments using bottom and surface waters communities retrieved from Svalbard waters exposed to methane. We collected 24 L of water from 371 m (Figure 11) and 5 m below the sea surface at station 284 above Pingo 3 (76°06.421N 15°58.079E). 20L of water were concentrated on a GFF 142mm filter and added to 4L of in situ water. This ‘filter soup’ is kept at 4ºC until further processing at NIOZ (Netherland).

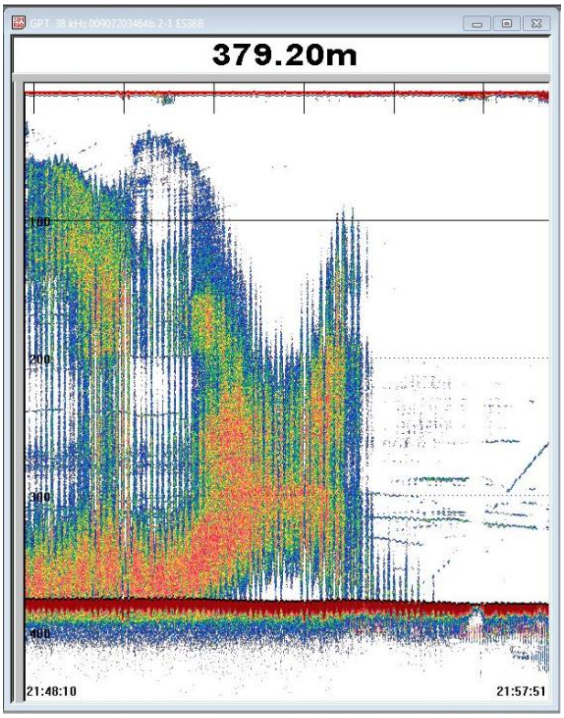



*Figure 11. Visual of the CTD track in the EK60 signal (line on the right side), illustrating that the water sample was taken from the plume.*

# 5 Cruise narrative

| Date | Time (UTC) | |
|---|---|---|
| *22.06* | 23:00 | Departure from Longyearbyen |
| *23.06* | 06:30 | Arrival on site, single/multibeam survey around the K-lander |
| | 11:40 | CTD above the lander |
| | 12:00 | Recovery of the lander (10 8,08686 E / 78 33,8127) (on deck at 13:00) |
| | 14:40 | Single/Multibeam survey where missing data (4 lines were not recording) |
| | 16:00 | CTD across and along the lander |
| | 23:00 | Single/multibeam line on along CTDs |
| *24.06* | 02:00 | Transect to MASOX site |
| | 02:40 | multibeam survey |
| | 21:00 | CTD survey |
| *25.06* | 02:20 | redo failed MASOX lines |
| | 07:40 | Transit to Sørkapp |
| | 19:43 | Sørkapp survey |
| *26.06* | 18:00 | transit to pingo |
| | 23:00 | pingo CTD |
| *27.06* | 04:40 | pingo survey |
| | 08:00 | transit to Kveithola |
| | 14:15 | Kveithola exploration |
| *28.06* | 00:50 | Kveithola survey |
| *29.06* | 12:10 | Kveithola CTD |
| | 18:20 | Kveithola survey |
| *30.06* | 23:44 | Transit to Tromsø |
| *01.07* | | arrive in Tromsø |

## 4.7 Acknowledgements

We thank the engineers (Truls Holm and Stormer Jensen), the captain and his crew of R/V Helmer Hanssen of the University of Tromsø for their excellent support before and during the oceanographic survey and the deployment of the landers. This part of the cruise was conducted under the framework of the Centre of Excellence on Gas Hydrates, Environment and Climate (CAGE) (Norwegian Research Council (NFR) project number 223259/F5 at the University of Tromsø.

## 4.8 Reference

Aagaard, K., et al. (1987). The West Spitsbergen Current: disposition and water mass transformation. Journal of Geophysical Research: Oceans, 92(C4), 3778-3784.

Berndt, C., et al. (2014). Temporal constraints on hydrate-controlled methane seepage off Svalbard. Science, 343(6168), 284-287. Fer et al., 2003

Fer, I. 2006 Scaling turbulent dissipation in an Arctic fjord, Deep-Sea. Res. II, 53, 77–95.

Ferré, B. et al. 2020. 'Reduced methane seepage from Arctic sediments during cold bottom-water conditions', Nature Geoscience.

Harris, C.L., Plueddemann, A.J., Gawarkiewicz, G., 1998. Water mass distribution and Polar Front structure in the western Barents Sea. J. Geophys. Res. 103, 2905–2917.

Landvik, J. Y., Ingolfsson, O., Mienert, J., Lehman, S. J., Solheim, A., Elverhøy, A., & Ottesen, D. (2005). Rethinking Late Weichselian ice-sheet dynamics in coastal NW Svalbard. Boreas, 34(1), 7-24.

Mau, S. et al. (2017). Widespread methane seepage along the continental margin off Svalbard-from Bjørnøya to Kongsfjorden. Scientific reports, 7, 42997.

Nilsen, F. et al. (2008). Fjord–shelf exchanges controlled by ice and brine production: the interannual variation of Atlantic Water in Isfjorden, Svalbard. Continental Shelf Research, 28(14), 1838-1853.

Rajan et al., 2013. Gas hydrate systems in petroleum provinces of the SW-Barents Sea. Mar. Petrol. Geol., 46, pp. 92-106

Saloranta, T. and H.Svendsen. 2001. 'Across the Arctic front west of Spitsbergen: high-resolution CTD sections from 1998–2000', Polar Research, 20: 177-84.

Serov et al. 2016. Postglacial response of Arctic Ocean gas hydrates to climatic amelioration, PNAS

Silyakova, A. 2020. 'Physical controls of dynamics of methane venting from a shallow seep area west of Svalbard', Continental Shelf Research, 194: 104030.

Skogseth, R. et al. 2005. Watermass transformations in Storfjorden. Cont. Shelf Res. 25, 667–695.

Steinle, L. et al. Water column methanotrophy controlled by a rapid oceanographic switch. Nat. Geosci. 8, 378–382 (2015).

Wallmann, K. et al. Gas hydrate dissociation off Svalbard induced by isostatic rebound rather than global warming. Nat. Commun. 9, 83 (2018).

### 4.8.1 Appendix: Stations

| Location | Station Id | Date | Time (UTC) | Lat. [N] Long. [E] | Bottles fired [#] | Water Depth [m] | Notes |
|---|---|---|---|---|---|---|---|
| Prins Karls Forland | CAGE20-1-HH-257-CTD | 23.06.2020 | 09:40 | 78°33.823' 10°08.198' | 8 | 94 | The number refers to the number of levels taken |
| Prins Karls Forland | CAGE20-1-HH-259-CTD | 23.06.2020 | 15:32 | 78°37.463' 10°33.385' | 8 | 77 | |
| Prins Karls Forland | CAGE20-1-HH-260-CTD | 23.06.2020 | 16:02 | 78°36.349' 10°26.557' | 8 | 118 | |
| Prins Karls Forland | CAGE20-1-HH-261-CTD | 23.06.2020 | 16:38 | 78°34.926' 10°17.958' | 8 | 126 | |
| Prins Karls Forland | CAGE20-1-HH-262-CTD | 23.06.2020 | 17:13 | 78°34.391' 10°13.575' | 8 | 159 | |
| Prins Karls Forland | CAGE20-1-HH-263-CTD | 23.06.2020 | 18:24 | 78°37.118' 09°53.698' | 8 | 122 | |
| Prins Karls Forland | CAGE20-1-HH-264-CTD | 23.06.2020 | 18:51 | 78°38.320' 09°50.419' | 8 | 129 | |
| Prins Karls Forland | CAGE20-1-HH-265-CTD | 23.06.2020 | 19:29 | 78°36.030' 09°59.518' | 8 | 106 | |
| Prins Karls Forland | CAGE20-1-HH-266-CTD | 23.06.2020 | 20:23 | 78°32.083' 10°14.890' | 8 | 124 | |
| Prins Karls Forland | CAGE20-1-HH-267-CTD | 23.06.2020 | 21:02 | 78°29.697' 10°23.851' | 8 | 105 | |
| Prins Karls Forland | CAGE20-1-HH-268-CTD | 23.06.2020 | 21:02 | 78°29.699' 10°23.837' | 8 | 104 | |
| MASOX | CAGE20-1-HH-271-CTD | 24.06.2020 | 08:19 | 78°29.209' 09°38.786' | | 342 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MASOX | CAGE20-1-HH-272-CTD | 24.06.2020 | 19:27 | 78°33.216' 09°26.932' | 8 | 405 | |
| MASOX | CAGE20-1-HH-273-CTD | 24.06.2020 | 20:15 | 78°33.290' 09°28.132' | 8 | 393 | |
| MASOX | CAGE20-1-HH-274-CTD | 24.06.2020 | 21:05 | 78°33.314' 09°28.915' | 8 | 392 | |
| MASOX | CAGE20-1-HH-275-CTD | 24.06.2020 | 21:40 | 78°33.391' 09°28.545' | 8 | 390 | |
| MASOX | CAGE20-1-HH-276-CTD | 24.06.2020 | 22:21 | 78°33.435' 09°29.275' | 8 | 386 | |
| MASOX | CAGE20-1-HH-277-CTD | 24.06.2020 | 23:01 | 78°33.565' 09°30.764' | 8 | 367 | |
| Sørkapp | CAGE20-1-HH-279-CTD | 25.06.2020 | 17:47 | 76°41.450' 15°22.071' | | 56 | |
| Sørkapp | CAGE20-1-HH-281-CTD | 25.06.2020 | 21:17 | 76°32.674' 14°29.636' | | 172 | |
| Pingo | CAGE20-1-HH-283-CTD | 26.06.2020 | 21:20 | 76°06.432' 15°57.946' | 8 | 379 | |
| Pingo | CAGE20-1-HH-284-CTD | 26.06.2020 | 22:04 | 76°06.415' 15°58.004' | 8 | 376 | |
| Pingo | CAGE20-1-HH-285-CTD | 26.06.2020 | 22:50 | 76°06.323' 15°57.249' | 8 | 385 | |
| Pingo | CAGE20-1-HH-286-CTD | 26.06.2020 | 23:33 | 76°06.536' 15°58.521' | 8 | 387 | |
| Pingo | CAGE20-1-HH-287-CTD | 27.06.2020 | 00:14 | 76°06.836' 15°59.996' | 8 | 383 | |
| Pingo | CAGE20-1-HH-288-CTD | 27.06.2020 | 00:57 | 76°06.714' 16°00.480' | 8 | 383 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pingo | CAGE20-1-HH-289-CTD | 27.06.2020 | 01:42 | 76°06.303' 16°01.916' | 8 | 379 | |
| Kveithola | CAGE20-1-HH-291-CTD | 27.06.2020 | 12:14 | 75°10.796' 16°38.745' | | 242 | |
| Kveithola | CAGE20-1-HH-295-CTD | 29.06.2020 | 04:56 | 74°52.276' 17°05.815' | 8 | 285 | |
| Kveithola | CAGE20-1-HH-296-CTD | 29.06.2020 | 10:09 | 74°57.886' 17°05.118' | 8 | 153 | |
| Kveithola | CAGE20-1-HH-297-CTD | 29.06.2020 | 10:45 | 74°59.294' 17°05.072' | 8 | 158 | |
| Kveithola | CAGE20-1-HH-298-CTD | 29.06.2020 | 11:23 | 75°00.784' 17°05.262' | 7 | 166 | |
| Kveithola | CAGE20-1-HH-299-CTD | 29.06.2020 | 12:02 | 75°00.733' 16°59.138' | 7 | 138 | |
| Kveithola | CAGE20-1-HH-300-CTD | 29.06.2020 | 12:32 | 74°59.271' 16°59.076' | 7 | 161 | |
| Kveithola | CAGE20-1-HH-301-CTD | 29.06.2020 | 13:02 | 74°57.673' 16°59.044' | 8 | 194 | |
| Kveithola | CAGE20-1-HH-302-CTD | 29.06.2020 | 13:34 | 74°57.552' 16°52.904' | 8 | 188 | |
| Kveithola | CAGE20-1-HH-303-CTD | 29.06.2020 | 14:08 | 74°59.253' 16°52.994' | 8 | 171 | |
| Kveithola | CAGE20-1-HH-304-CTD | 29.06.2020 | 14:37 | 75°00.818' 16°53.034' | 7 | 155 | |
| Kveithola | CAGE20-1-HH-307-CTD | 29.06.2020 | 16:34 | 75°00.776' 17°11.128' | 8 | 191 | |
| Kveithola | CAGE20-1-HH-308-CTD | 29.06.2020 | 17:16 | 74°59.268' 17°11.058' | 8 | 175 | |
| Kveithola | CAGE20-1-HH-309-CTD | 29.06.2020 | 17:56 | 74°57.948' 17°10.987' | 8 | 170 | |

| Location | Line ID | Date | Time (UTC) START | Lat. [N] Long. [E] START | Time (UTC) STOP | Lat. [N] Long. [E] STOP | Pulse mode | Shot Rate (HZ) | Ship Speed (kn) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Prins Karls Forland | CAGE20-1-HH-001-MB | 23.06 | 05:30 | 78°33.342' 10°08.490' | 00:00 | | | | 5.5 | EK60 survey lander area + MB 0015-0027 10 Lines |
| Prins Karls Forland | CAGE20-1-HH-002-MB | 23.06 | 08:06 | 78°33.660' 10°09.780' | 08:16 | 78°34.159' 10°07.015' | | | 4,5 | MB0028 |
| Prins Karls Forland | CAGE20-1-HH-003-MB | 23.06 | 08:22 | 78°34.201' 10°07.158' | 08:32 | 78°33.686' 10°09.939' | | | 4,5 | MB0030 |
| Prins Karls Forland | CAGE20-1-HH-004-MB | 23.06 | 08:38 | 78°33.720' 10°10.080' | 08:48 | 78°34.201' 10°07.420' | | | 4,5 | MB0031-MB0032 (about the four last minutes of MB0031) |
| Prins Karls Forland | CAGE20-1-HH-005-MB | 23.06 | 08:55 | 78°34.254' 10°07.424' | 09:05 | 78°33.741' 10°10.248' | | | 4,5 | MB0034 |
| Transit1 | CAGE20-1-HH-006-MB | 23.06 | 15:24 | 78°37.684' 10°35.207' | 15:49 | 78°36.435' 10°26.286' | | | | MB 0049 |
| Transit2 | CAGE20-1-HH-007-MB | 23.06 | 16:08 | 78°36.435' 10°26.286' | 16:21 | 78°35.149' 10°17.930' | | | | ADCP off, MB0051 |
| Transit3 | CAGE20-1-HH-001-MB | 23.06 | 16:39 | 78°35.149' 10°17.930' | 16:53 | 78°34.381' 10°13.052' | | | | MB0053 |
| Transit4 | CAGE20-1-HH-002-MB | 23.06 | 17:13 | 78°34.359' 10°13.151' | 17:30 | 78°33.180' 10°06.243' | | | | MB0057 |
| Transit5 | CAGE20-1-HH-003-MB | 23.06 | 17:50 | 78°33.072' 10°06.050' | 18:35 | 78°38.252' 09°50.631' | | | | MB0059-MB0060 |
| Transit6 | CAGE20-1-HH-004-MB | 23.06 | 18:51 | 78°38.322' 09°50.432' | 19:15 | 78°35.911' 09°59.853' | | | | MB0062 |
| Transit7 | CAGE20-1-HH-005-MB | 23.06 | 19:29 | 78°35.911' 09°59.853' | 20:08 | 78°31.956' 10°15.141' | | | | MB0064-MB0065 |
| Transit8 | CAGE20-1-HH-006-MB | 23.06 | 20:23 | 78°31.956' 10°15.141' | 20:50 | 78°29.587' 10°24.215' | | | | MB0067 |

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|---|---|---|---|---|---|---|---|---|---|---|
| MB_AcrossLander + masox(night survey) | CAGE20-1-HH-007-MB | 23.06 | 21:15 | 78°29.234'<br>10°25.536' | 00:00 | | | | | MB0069-101 |
| masox Line 4 | CAGE20-1-HH-008-MB | 24.06 | 00:00 | | 13:13 | 78°28.921'<br>09°35.720' | | | | |
| masox Line 5 | CAGE20-1-HH-009-MB | 24.06 | 13:30 | 78°29.018'<br>09°34.111' | 15:44 | 78°39.381'<br>09°17.961' | | | | MB 0103-105 |
| masox Line 6 | CAGE20-1-HH-010-MB | 24.06 | 15:53 | 78°39.025'<br>09°16.525' | 18:13 | 78°28.929'<br>09°32.587' | | | | MB ???-113 |
| masox transit + gapfill | CAGE20-1-HH-011-MB | 24.06 | 18:13 | 78°28.929'<br>09°32.587' | 19:00 | 78°33.194'<br>09°26.819' | | | | MB0114-MB0115-MB0116 |
| Redro Masox 2,5 lines | CAGE20-1-HH-012-MB | 24.06 | 23:34 | 78°33.436'<br>09°28.907' | 05:40 | 78°28.070'<br>09°35.717' | | | | MB0128-MB0140 |
| Transit Sørkapp | CAGE20-1-HH-013-MB | 25.06 | 05:40 | 78°28.070'<br>09°35.717' | 17:43 | 76°41.401'<br>15°22.132' | | | 10 | MB0141-165 |
| Sørkapp line 1 | CAGE20-1-HH-014-MB | 25.06 | 18:00 | 76°41.125'<br>15°22.125' | 21:03 | 76°32.728'<br>14°29.693' | | | 4.5 | MB0167-173 |
| Sørkapp line 2 | CAGE20-1-HH-015-MB | 25.06 | 21:28 | 76°32.335'<br>14°31.303' | 00:30 | 76°40.610'<br>15°23.140' | | | 4.5 | MB 0177-0183 |
| Sørkapp line 3 | CAGE20-1-HH-016-MB | 26.06 | 00:30 | 76°40.610'<br>15°23.140' | 03:55 | 74°31.434'<br>14°34.075' | | | 4.5 | MB 0184-0190 |
| Sørkapp line 4 | CAGE20-1-HH-017-MB | 26.06 | 03:55 | 74°31.434'<br>14°34.075' | 07:04 | 76°39.706'<br>15°25.219' | | | 4.5 | MB 0191-0197 |
| Sørkapp line 5 | CAGE20-1-HH-018-MB | 26.06 | 07:12 | 15°26.148' | 10:18 | 76°30.850'<br>14°35.384' | | | 4.5 | MB 0199-205 |
| Sørkapp line 6 | CAGE20-1-HH-019-MB | 26.06 | 10:33 | 76°30.427'<br>14°36.802' | 13:44 | 76°38.803'<br>15°27.577' | | | 4.5 | MB 0207-0213 |
| Sørkapp line 7 | CAGE20-1-HH-020-MB | 26.06 | 13:52 | 76°38.374'<br>15°28.853' | 15:59 | 78°32.719'<br>14°54.519' | | | 4.5 | MB 0215-0219 |

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| Sørkapp line 8 | CAGE20-1-HH-021-MB | 26.06 | 15:59 | 78°32.719'<br>14°54.519' | 18:00 | 76°23.017'<br>15°55.529' | | | 6 | MB 0220-0226 , heading SouthEast |
| Transit to Pingo | CAGE20-1-HH-022-MB | 26.06 | 18:00 | 76°23.017'<br>15°55.529' | 20:50 | 76°06.460'<br>15°57.919' | | | ~9 | MB 0227-0231 |
| Pingo line 1 | CAGE20-1-HH-023-MB | 27.06 | 02:28 | 76°08.129'<br>16°04.018' | 03:06 | 76°06.532'<br>15°54.398' | | | 4.5 | MB0241 |
| Pingo line 2 | CAGE20-1-HH-024-MB | 27.06 | 03:10 | 76°06.291'<br>15°54.986' | 03:42 | 76°07.630'<br>16°03.338' | | | 4.5 | MB 0243-0244 |
| Pingo line 3 | CAGE20-1-HH-025-MB | 27.06 | 03:47 | 76°07.349'<br>16°03.838' | 04:20 | 76°05.988'<br>15°55.686' | | | 4.5 | MB 0246-0247 |
| Pingo line 4 | CAGE20-1-HH-026-MB | 27.06 | 04:25 | 76°05.696'<br>15°56.230' | 04:58 | 76°07.040'<br>16°04.486' | | | 4.5 | MB 0249-0250 |
| Pingo line 5 | CAGE20-1-HH-027-MB | 27.06 | 05:02 | 76°06.765'<br>16°05.023' | 05:36 | 76°05.381'<br>15°56.843' | | | 4.5 | MB 0252-0253 |
| Pingo line 6 | CAGE20-1-HH-028-MB | 27.06 | 05:41 | 76°05.087'<br>15°57.407' | 06:12 | 76°06.575'<br>16°06.349' | | | 4.5 | MB 0255-0256 |
| Transit line + CTD at end | CAGE20-1-HH-029-MB | 27.06 | 06:12 | 76°06.575'<br>16°06.349' | 12:16 | 75°10.758'<br>16°38.734' | | | ~10 | MB 0257-0269 |
| Kveithola line (explore) | CAGE20-1-HH-030-MB | 27.06 | 12:16 | 75°10.758'<br>16°38.734' | 22:51 | 75°02.072'<br>17°01.739' | | | 8 | MB 0270-0295 , stnr0292 |

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| Kveithola line 1 | CAGE20-1-HH-031-MB | 27.06 | 22:51 | 75°02.072'<br>17°01.739' | 23:44 | 74°56.677'<br>17°01.662' | | | 6 | MB 0296-0297 |
| Kveithola line 2 | CAGE20-1-HH-032-MB | 27.06 | 23:48 | 74°56.631'<br>17°00.296' | 00:44 | 75°01.888'<br>16°59.967' | | | 6 | MB 0299-0300 |
| Kveithola line 3 | CAGE20-1-HH-033-MB | 28.06 | 00:44 | 75°01.888'<br>16°59.967' | 01:38 | 74°56.679'<br>17°00.008' | | | 6 | MB 0300-0302 |
| Kveithola line 4 | CAGE20-1-HH-034-MB | 28.06 | 01:42 | 74°56.607'<br>16°59.103' | 02:37 | 75°01.926'<br>16°59.223' | | | 6 | MB 0304-0305 |
| Kveithola line 5 | CAGE20-1-HH-035-MB | 28.06 | 02:40 | 75°01.944'<br>16°58.409' | 03:37 | 74°56.610'<br>16°58.302' | | | 6 | MB 0307-0308 |
| Kveithola line 6 | CAGE20-1-HH-036-MB | 28.06 | 03:41 | 74°56.577'<br>16°57.402' | 04:37 | 75°01.922'<br>16°57.510' | | | 6 | MB 0310-0311 |
| Kveithola line 7 | CAGE20-1-HH-037-MB | 28.06 | 04:40 | 75°01.935'<br>16°56.691' | 05:36 | 74°56.589'<br>16°56.588' | | | 6 | MB 0313-0314 |
| Kveithola line 8 | CAGE20-1-HH-038-MB | 28.06 | 05:40 | 74°56.556'<br>16°55.741' | 06:34 | 75°02.059'<br>16°55.752' | | | 6 | MB 0316-0317 |
| Transit to kveithola del2 | CAGE20-1-HH-039-MB | 28.06 | 06:34 | 75°02.059'<br>16°55.752' | 06:54 | 75°01.950'<br>17°02.766' | | | 6 | MB 0318-0320 |
| Kveithola line 9 | CAGE20-1-HH-040-MB | 28.06 | 06:54 | 75°01.950'<br>17°02.766' | 07:44 | 74°56.711'<br>17°02.790' | | | 6 | MB 0321-0323 |
| Kveithola line 10 | CAGE20-1-HH-041-MB | 28.06 | 07:48 | 74°56.757'<br>17°03.581' | 08:47 | 75°02.385'<br>17°03.521' | | | 6 | MB 0324-0326 |
| Mini transit west | CAGE20-1-HH-042-MB | 28.06 | 08:47 | 75°02.385'<br>17°03.521' | 09:15 | 75°01.825'<br>16°54.858' | | | 6 | continue del1 MB 0327 |
| Kveithola line 11 | CAGE20-1-HH-043-MB | 28.06 | 09:15 | 75°01.825'<br>16°54.858' | 10:03 | 74°56.540'<br>16°54.772' | | | 6 | MB 0329-330 |
| Kveithola line 12 | CAGE20-1-HH-044-MB | 28.06 | 10:08 | 74°56.569'<br>16°53.924' | 11:20 | 75°01.920'<br>16°53.992' | | | 6 | MB 0332- speed reduced to 5kn 10:34 |
| Kveithola line 13 | CAGE20-1-HH-045-MB | 28.06 | 11:25 | 75°01.916'<br>16°53.168' | 12:19 | 74°56.580'<br>16°53.027' | | | 5 | MB -0037 |

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| Kveithola line 14 | CAGE20-1-HH-046-MB | 28.06 | 12:24 | 74°56.558'<br>16°51.725' | 13:01 | 74°59.646'<br>16°51.773' | | | 5 | MB 0338-0339 |
| Kveithola line 15 | CAGE20-1-HH-047-MB | 28.06 | 13:06 | 74°59.655'<br>16°50.615' | 13:45 | 74°56.557'<br>16°50.560' | | | 5 | MB 0341-0342 |
| Kveithola line 16 | CAGE20-1-HH-048-MB | 28.06 | 13:50 | 74°56.589'<br>16°49.484' | 14:34 | 74°59.626'<br>16°48.373' | | | 5 | MB 0344-0345 |
| Kveithola line 17 | CAGE20-1-HH-049-MB | 28.06 | 14:34 | 74°59.626'<br>16°48.373' | 15:13 | 74°56.561'<br>16°48.380' | | | 5 | MB 0345-0347 |
| Kveithola line 18 | CAGE20-1-HH-050-MB | 28.06 | 15:17 | 74°56.586'<br>16°47.184' | 15:55 | 74°59.627'<br>16°47.267' | | | 5 | MB 0348-0350 |
| Kveithola line 19 | CAGE20-1-HH-051-MB | 28.06 | 16:01 | 74°59.659'<br>16°46.118' | 16:41 | 74°56.555'<br>16°45.937' | | | 5 | MB 0352-0353 |
| Kveithola line 20 | CAGE20-1-HH-052-MB | 28.06 | 16:45 | 74°56.604'<br>16°44.952' | 17:24 | 74°59.760'<br>16°44.956' | | | 5 | MB 0355-0356 |
| Kveithola line 21 | CAGE20-1-HH-053-MB | 28.06 | 17:29 | 74°59.819'<br>16°43.794' | 18:15 | 74°56.153'<br>16°44.030' | | | 5 | MB 0358-0359 |
| Kveithola line 22 | CAGE20-1-HH-054-MB | 28.06 | 18:15 | 74°56.153'<br>16°44.030' | 19:09 | 74°56.549'<br>17°04.326' | | | 5 | MB 0361-0365 Trouble with EM could not find transducers |
| Kveithola line 23 | CAGE20-1-HH-055-MB | 28.06 | 19:09 | 74°56.549'<br>17°04.326' | 20:15 | 75°02.069'<br>17°04.416' | | | 5 | MB 0366-0368 |
| Kveithola line 24 | CAGE20-1-HH-056-MB | 28.06 | 20:20 | 75°01.974'<br>17°05.225' | 21:19 | 75°56.585'<br>17°05.168' | | | 5 | MB 0370-0371 |
| Kveithola line 25 | CAGE20-1-HH-057-MB | 28.06 | 21:26 | 74°56.753'<br>17°06.017' | 22:31 | 75°01.954'<br>17°05.937' | | | 5 | MB 0373-0375 |
| Kveithola line 26 | CAGE20-1-HH-058-MB | 28.06 | 22:39 | 75°01.934'<br>17°06.818' | 23:30 | 74°56.607'<br>17°06.831' | | | 5 | MB 0377-0379 |
| Transit + hole covering | CAGE20-1-HH-059-MB | 28.06 | 23:30 | 74°56.607'<br>17°06.831' | 00:25 | 74°53.637'<br>17°05.780' | | | 6 | MB 0380-0382 |
| Kveithola line 27 | CAGE20-1-HH-060-MB | 28.06 | 00:25 | 74°53.637'<br>17°05.780' | 02:29 | 74°51.960'<br>17°44.724' | | | 5 | MB 0383-0387 |

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| Kveithola line 28 | CAGE20-1-HH-061-MB | 29.06 | 02:43 | 74°50.926' 17°44.534' | 04:46 | 74°52.713' 17°06.198' | | | 5 | MB 0389-0393 |
| Kveithola line 29 | CAGE20-1-HH-062-MB | 29.06 | 05:19 | 74°52.289' 17°06.262' | 07:14 | 74°50.433' 17°44.598' | | | 5 | MB 0396-399 |
| Kveithola line 30 | CAGE20-1-HH-063-MB | 29.06 | 07:39 | 74°52.382' 17°45.057' | 09:40 | 74°54.137' 17°05.821' | | | 5 | MB 402-406 |
| Transit to CTD stations | CAGE20-1-HH-064-MB | 29.06 | 09:40 | 74°54.137' 17°05.821' | 10:06 | 74°57.795' 17°04.706' | | | ~10 | MB 0407 |
| CTDs + transits between | CAGE20-1-HH-065-MB | 29.06 | 10:06 | 74°57.795' 17°04.706' | 15:05 | 74°59.857' 17°01.214' | | | ~8 | MB 0408-0417 stnr 296, 297, 298, 299, 300, 301, 302, 303, 304 |
| GapFill1 | CAGE20-1-HH-066-MB | 29.06 | 15:05 | 74°59.857' 17°01.214' | 15:23 | 74°58.260' 17°01.192' | | | 5 | MB 0418, stnr305 |
| GapFill2 | CAGE20-1-HH-067-MB | 29.06 | 15:30 | 74°58.089' 17°02.209' | 15:48 | 74°59.533' 17°02.212' | | | 5 | MB 0420, stnr305 |
| Transit to CTD + line | CAGE20-1-HH-068-MB | 29.06 | 15:48 | 74°59.533' 17°02.212' | 16:19 | 75°01.946' 17°11.047' | | | | MB 0421-0422 |
| Kveithola line 31 | CAGE20-1-HH-069-MB | 29.06 | 16:19 | 75°01.946' 17°11.047' | 00:00 | 74°56.689' 17°11.009' | | | | MB 0423- stnr306 , CTD stnr 307, 308, 309 |
| Kveithola line 32 | CAGE20-1-HH-070-MB | 29.06 | 18:30 | 74°56.736' 17°10.141' | 19:21 | 75°01.765' 17°10.107' | | | 7 | MB -00430 |
| Kveithola line 33 | CAGE20-1-HH-071-MB | 29.06 | 19:23 | 75°01.750' 17°09.405' | 20:07 | 75°56.705' 17°09.284' | | | 7 | MB 0432-0433 |
| Kveithola line 34 | CAGE20-1-HH-072-MB | 29.06 | 20:10 | □ | 20:58:00 | □ | | | 7 | MB 0435-04036 |
| Kveithola line 35 | CAGE20-1-HH-073-MB | 29.06 | 21:00 | □ | 21:43:00 | □ | | | 7 | MB 0438-0439 |
| Gap filler, manuel line, transit | CAGE20-1-HH-074-MB | 29.06 | 21:44 | □ | | □ | | | | |