5. OCEAN OCEANOGRAPHY AND ASSOCIATED TASKS DURING MOSAIC LEG 3

Bin Kong[1], Janin Schaffer[2] (group leader), Natalia Sukhikh[3], Torsten Kanzow[2,3], Ying-Chih Fang[1] (on board Leg 1), Ilker Fer[4] (not on board), Mats Granskog[5] (not on board), Céline Heuzé[6] (not on board), Mario Hoppmann[1] (on board Leg 1), Markus Janout[1] (not on board), Yusuke Kawaguchi[7] (not on board), Ivan Kuznetsov[1] (on board Leg 2), Christian Mertens[3] (not on board), Benjamin Rabe[1] (on board Leg 2), Monika Rhein[3] (not on board), Kirstin Schulz[1] (on board Leg 4), Arild Sundfjord[5] (not on board), Sandra Tippenhauer[1] (on board Leg 4)

[1]CH.FIO
[2]DE.AWI
[3]DE.UBremen
[4]NO.UBergen
[5]NO.NPI
[6]SE.UGOT
[7]JP.UTokyo
[8]DE.UBremen

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A comprehensive summary of the physical-oceanographic measurements during all 5 cruise legs can be found in Rabe et al., 2022.

Objectives

General background and objectives of the physical oceanography within the MOSAiC project have been described in the expedition booklet, the reports by leg 1 and 2, and the individual proposals within team OCEAN. Major overarching aims are

1. To develop improved parametrizations for ocean boundary-layer mixing including treatment of brine rejection from sea-ice formation and the dissipation of surface momentum fluxes;
2. To better understand heat fluxes from the warm Atlantic water across the halocline; and
3. At the mesoscale, to develop a better understanding of the processes controlling eddies, upwelling and restratification at water mass fronts, and improve the model representation of these processes.

One specific focus of leg 3 was to study turbulent mixing in the near-surface ocean with respect to expected changes in the ice cover in the course of winter and spring. Studying this seasonal change is of major importance for a better understanding of the heat exchange between the ocean and the atmosphere and thus one of the main objectives within MOSAiC.

The leg 3 MOSAiC drift started off (after the handover with leg 2) on March 2nd in the Eurasian Basin, i.e., in the central Arctic Ocean. Between March 2nd and May 16, we drifted from the interior Amundsen Basin southward across the Gakkel ridge into the Nansen Basin (Figure 5.1). Detailed description of the Arctic Basins, their water masses, and the ocean circulation are described in the expedition report of MOSAiC leg 1 (PS122/1). In principle, waters in Amundsen and Nansen basin are present in a quiescent environment (far away from boundary current dynamics), where mixing is dominated by diffusive processes in the ocean interior and turbulent mixing close to the ocean surface.

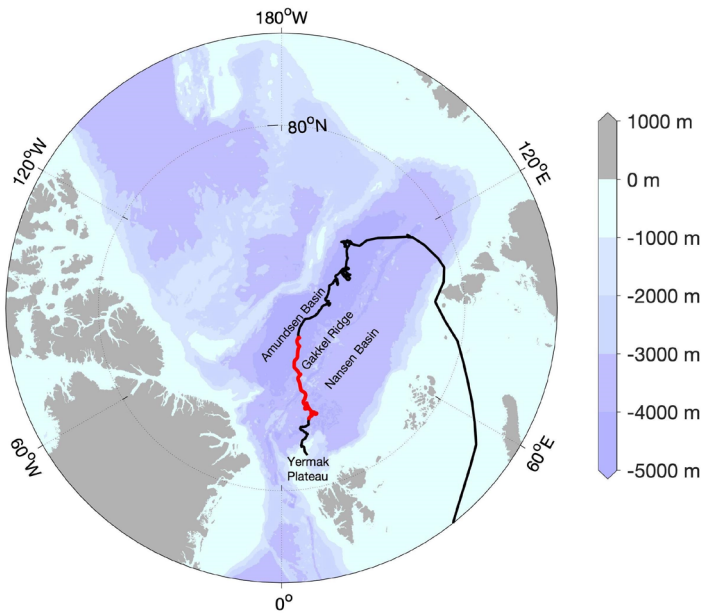

Fig. 5.1: *Bathymetric map of the Arctic Ocean highlighting ocean basins and ridges crossed during the drift of MOSAiC leg 3. The black line shows the cruise track of the entire MOSAiC campaign between 20 September 2019 and 31 May 2020. The red line highlights the time of the drift during leg 3 (2 March until 16 May 2020).*

Work at sea

CTD operations from Polarstern

Following up on MOSAiC leg 2, we operated a CTD/Rosette system with various additional sensors and 24 Niskin bottles (in the following referred to as CTD) through a hydrohole from the ship. The 3 x 3 m big hydrohole was established during MOSAiC leg 1 approximately 8 to 10 m away from the ship. An additional block on the cargo crane was used in order to operate the CTD with the ship's crane and winch. More details on the preparation of the hole and the CTD deployment using the cargo crane are given in the cruise report of leg 1.

During leg 2, teams BGC, ECO, and OCEAN installed a Weatherhaven tent on top of the hydrohole to reduce refreezing. An air heater powered by the ship was placed in the tent in order to keep the hole ice-free. Replacing the wooden lid (that had covered the hydrohole beforehand) by the Weatherhaven tent significantly decreased the amount of work time needed for ice hole maintenance in order to operate the Polarstern CTD. A submersible pump was used to mitigate ice growth in the hydrohole during CTD cast and net operations (taking each ~ 4 hours), i.e., when the tent did not cover the hole. Moving the tent next to and back to the hydrohole required 4 to 6 persons. A detailed description of the CTD deployment/recovery procedures are given in the cruise report of leg 2.

During MOSAiC leg 3, we planned to carry out weekly deep CTD casts (i.e., down to 10 m above the seafloor) on Thursdays, and shallow CTD casts (for water sampling mainly by team ECO) on Monday, Thursday, and Friday. However, this plan could not be realized due to various complications. First, the temperature limit of the cargo crane restricted CTD operations to air temperatures warmer -30°C, i.e., limiting the CTD operations in March. However, five CTD cast were carried out successfully in the first two weeks of March, during days when temperatures were close to -29°C (Figure 5.2).

On March 15, increased ice pressure caused the ship suddenly to be pushed several meters forward. As a result, not only anchor lines flipped but also the (uplifted) gangway hit the upper part of the Weatherhaven tent covering the CTD's hydrohole. This caused severe deformation of the tent's frame (Figure 5.2). Within the next hours, the ship was further pushed along the ice floe. As a consequence, the hydrohole ended up at the stern of the ship, i.e., inaccessible for any ship crane operations. Thus, team ECO took down the broken Weatherhaven tent (see Chapter 6). The tent was not reparable as some of the aluminium tent sticks were broken

and/or deformed and the tent cover was cut open at some points. The next day, the hydrohole ended up behind the stern of Polarstern where in the upcoming weeks an opening and closing lead deformed the ice considerably.

Fig. 5.2: Left: *CTD deployment from Polarstern. The CTD is covered with the red coat to prevent the sensors from freezing. Wooden bars protect the sides of the hydrohole. The Weatherhaven tent is moved away from the hole during CTD operations. Right: Deformed Weatherhaven tent (placed on top of the hydrohole) after the gangway hit the tent top on March 15.*

Due to the very dynamic ice conditions and ice ridging close to the ship's hull, a hydrohole could not be re-established during leg 3. A final deep CTD cast at the MOSAiC floe was carried out on May 16 before leaving the floe with Polarstern. Furthermore, one CTD cast was carried out on the Yermark Plateau, on May 30, while the ship needed to wait for the ice pressure to be released in order to be able to break through the ice again.

Ship-based CTD measurements

The Polarstern CTD/Rosette with 24 12-liter OTE-Niskin bottles had been assembled at the Alfred Wegener Institute in Bremerhaven. The standard SeaBird SBE9plus was equipped with dual sensors to measure temperature, conductivity, and oxygen, and single sensors measuring pressure, substance fluorescence (Chl-*a* and CDOM*),* irradiance, beam transmission, nitrate, and rhodamine (Table 5.1). An altimeter was mounted to monitor the distance to the seafloor. Additionally, a stand-alone recording, battery-powered Underwater Vision Profiler (UVP, see Team ECO chapter 6.2) was attached. During leg 2, a Turner Cyclops fluorometer for Rhodamine was attached to the CTD. However, due to time limitations and the very limited use of the Polarstern CTD, we did not add any Rhodamine in order to trace Polarstern's wastewater during leg 3.

We continued to use the sensor configuration handed over from the leg 2 team. All CTD profiles carried out in March were performed using configuration 1 given in Table 5.1. Before carrying out the CTD cast on May 16, we exchanged the Chl-a Fluorometer SN 725 (WET Labs ECO-AFL/FL) with the Chl-a Fluorometer SN1853 due to the following reason: During the time when the Polarstern CTD was not operational, the Chl-a Fluorometer SN 725 was used in the setup of the Ocean City CTD. After transportation back to Polarstern, we noticed scratches on the fluorometer surface. Thus, we decided to use another fluorometer (SN1853) for the CTD deployments in May from Polarstern (configuration 2).

Deep CTD casts were carried out to ~10 m above the seafloor. The actual water depth did not match the calculated and sound-speed corrected EK60 water depth during the profiles carried out in March (offset of about 50 m with the true depth being deeper than the EK60 depth). The echosounder started to receive an echo at ~20 m above the seafloor only. In contrast, during the two CTD casts carried out in the Nansen Basin and on the Yermak Plateau in May, the

performance of the altimeter was good: The altimeter received an echo at 70 and 50 m above the seafloor, and the actual water depth agreed well with the EK60 water depth.

The water budget plan for the ship-based water samplings was prepared during leg 3 by team ECO, i.e., the team requesting the largest amount of seawater from the Polarstern CTD. Team OCEAN required water samples for salinity calibrations, as well as water samples for CFC/SF6, helium, tritium, and density.

It was Team OCEAN's responsibility to prepare and operate the CTD/Rosette system. Maintenance of CTD hole and moving the Weatherhaven tent before/after CTD deployments was done by team ECO.

In total, 7 CTD casts were carried out from Polarstern, 3 of which were deep casts (see Table 5.21). Raw CTD data was pre-processed following standard procedures (based on the SBE Data Processing software and automized by using Manage CTD). Data was copied to the MCS, and the public server (//public/scientists/_CTDBackup/).

Tab. 5.1: *Sensor configuration (conf1) of the Polarstern CTD/Rosette system. Sn = serial number.*

Config. 1	**Temperature sensor**	**Conductivity sensor**	**Oxygen sensor**	**Pressure sensor**	**Turner Cyclops Fluorometer**
Primary	SBE3 sn #1338	SBE4 sn #3173	SBE43 sn #1834	sn #0321	sn #216K00138
Secondary	SBE3 sn #1374	SBE4 sn #3590	SBE43 sn #0467	-	-
Altimeter	**Transmissometer**	**Nitrate sensor**	**Chl-a Fluorometer**	**PAR/Irradiance sensor**	**CDOM Fluorometer**
Sn 47768	WET Labs C-Star sn #1198	Satlantics SUNA sn #0732	WET Labs ECO-AFL/FL sn #725	Biospherical/Li-cor sn #70257	WET Labs ECO CDOM sn #4531

Vessel-mounted current profiler

Polarstern is equipped with a vessel-mounted Acoustic Doppler Current Profiler (VMADCP) to monitor underway ocean currents. The Ocean Surveyor instrument sends and receives sound near 150 kHz (beam angle 30 degree) below the ship's hull from which to estimate vertical profiles of horizontal ocean velocity. Velocity vectors are measured relative to the moving ship whose velocity vector must be removed in order to measure water currents. To estimate the ship's velocity over ground, the vessel's GPS system was used. Furthermore, pitch, roll, and heading data are converted from the NMEA string. Current speed data were collected in beam coordinates to apply corrections during post processing.

During leg 3 we used the same configuration for the VMADCP as used during MOSAiC leg 2. The instrument was configured in narrowband mode and set up to use 8 m bin size covering a range from 15 m to about 240 m (latter depending mainly on the backscatter signals during the time of the drift). The software VmDas (Teledyne RD Instruments) was used to set the ADCP's operating parameters and to record the data. We used a long-term averaged interval of 20 min and a short-term averaged interval of 5 min. The Ocean Surveyor data conversion was done using Matlab routines (osheader.m, osdatasip.m, osrefine.m) last changed by Gerd Krahmann in 2015 (OSSI19). Herein the VMADCP data was corrected using a misalignment angle of 0.92318 and an amplitude factor of 1.0178.

The VMADCP was operated continuously during Leg 3 of MOSAiC but switched of twice during times when the echosounder (EK60) was calibrated (April 27, 11-17:30, and May 5, 9:15-13:40).

The post-processing will be done using the SADCP software developed at GEOMAR Helmholtz Centre for Ocean Research Kiel with minor changes implemented at AWI.

Work on the MOSAiC floe (Central Observatory)

Ocean City (OC) – devices, power supply, and final dismantling

The installation of the Ocean City tent and set-up of instruments inside Ocean City is described in detail in the cruise report of MOSAiC leg 1. The main devices operated inside the tent through the 1.5-m wide hydrohole were the CTD, a microstructure probe (MSS), a Laser In-situ Scatter Transmission meter (LISST), a vertical microstructure profiler (VMP), and nets (with the latter deployed by team ECO). In order to deploy the larger heavier instruments (i.e., the CTD, LISST, and nets), we used an A-frame (Figure 5.3). The CTD was deployed using winch and data cable belonging to the A-frame while the LISST and nets were deployed with the KC Denmark winch from NPI.

Fig. 5.3: *Pictures showing the interior of Ocean City 2.0 Weatherhaven tent. Upper panel: A-frame with winch and CTD rosette (left), CTD and winch electronics (middle), and CTD sampling with the rosette placed on top of 2 boards across the hole (right). Lower panel: KC Denmark winch, VMP winches, heater, and additional items (left), and MSS setup (right).*

Outside the Ocean City tent two PAR sensors were installed. They were mounted on the end of a telescope stick to position them above the uppermost peak of the tent (i.e., having a free sphere around the sensor) at the back of the tent (Figure 5.4). One of the two PAR sensors (SN20349) was already installed during the previous MOSAiC legs and connected to the deck unit of the CTD recording surface light measurements during each CTD cast. The second PAR sensor (SN20460) was installed during the handover with leg 2 aiming for time-continuous light measurements. The electronic setup was prepared during leg 2 (by Benjamin Rabe and the lab-electrician). Data were written daily on the Polarstern server (/Data01) using the fibre-optical/RadioLAN connection of the Ocean City power hub.

Fig. 5.4: *Pictures showing the 2 surface PAR sensors (left) and the respective deckunit placed inside the OC tent (right).*

During the entire time of leg 3, work in the OC tent was possible with few exceptions due to evacuation of the floe during cracks opening/ridging next to Polarstern and/or power shut downs. OC bear guarding was mainly carried out by the Logistic Team.

Power to Ocean City was supplied via one of the main power lines from Polarstern. The overall power distribution was set up as follows: Two main power lines were running from the starboard side of Polarstern to the main power hub in the log area. From there power was distributed to the different “cities” inside the Central Observatory with one power line running to the Ocean City power hub. During both previous legs power was continuously supplied without major interruptions. In contrast, several blackouts affected the work in Ocean City during the first half of leg 3 (i.e., in March). The blackouts were mainly a result of too strong tension on the power cables caused by forward/backward movements of Polarstern along the ice floe (i.e., several meters away from its original parking position) due to the ice pressure. The first major displacement of Polarstern occurred on March 20 when main power needed to be unplugged (controlled blackout). The second major event happened shortly after on March 22/23. This time the tension on the power cables was so strong that power cables were teared out of the main power hub causing the connectors to break (uncontrolled blackout). Plugs could not be unplugged in time due to the danger of flipping anchor lines. To avoid similar situations in the future, more slack was given on the power lines between the ship and the main power hub. In addition, the LOG team routinely checked that the cables would not be buried down deep into snow and/or get stuck into ice ridging next to the ship.

Table 5.2 lists all dates with power shutdowns affecting the power supply to Ocean City. In order to prevent sensors and other electronics from damages due to cold (during times when no power from Polarstern could be supplied), a Vanguard 16 HP (11.9 kW) generator was placed in front of Ocean City (Figure 5.5). When running both heaters in Ocean City on half power, the fuel lasted for a couple of hours. In order to provide a more continuous performance of the generator, a fuel barrel was connected to the generator. With this setup the generator would run for more than one day (i.e., filling up the generator with new fuel carried in canisters to Ocean City once per day was sufficient). However, during the first nights the generator stopped running causing the air temperatures inside Ocean City to drop well below 0°C. Adding a wooden cover over the generator to prevent it from snow blowing into the engine improved the performance of the generator. During all dates listed in Table 5.2, temperatures falling below 0°C may have caused damage to the electronics in Ocean City.

During the period when heaters were run on the generator, we regularly detached the MSS probe and the conductivity cells of the CTD and took them onboard Polarstern overnight to prevent damages due to potential freezing. Because it was planned to move the ship on March 30 to a new parking position, we dismantled the hole CTD unit on March 29 from the CTD rosette frame and took the CTD unit and the MSS probe onto the ship. However, due to changing ice conditions Polarstern did not change its parking position and the instruments were taken back to Ocean City the next day.

Fig. 5.5: *Left: Picture showing the Ocean City entrance with the palettes used to secure the door, and the sledge with generator (covered by wooden box) and fuel barrel used during blackouts for power. Right: Entrance of OC after the door was blown open in the night on March 27/28.*

Tab. 5.2: *Power shut-downs affecting power supply for heaters and work in Ocean City*

Date	**Description of the power shut down event**	**Instruments run on generator**	**Date when power was back**
March 20, evening	Power plugs from main power lines were unplugged on *Polarstern* due to ship displacement, generator was installed at OC, MSS and CTD conductivity cells were taken onboard in the night	MSS and MSS winch were run on same generator as heater (March 21), not very stable power supply	Power back (after one or two MSS profiles) in the late afternoon of March 21
March 22, night	Main power lines broke with plugs being teared out from the main power hub	MSS, LISST, nets were run on generators (used 3kW Honda generators for instruments and Vanguard for heaters only) in upcoming days	Plugs of the main power line needed to be repaired, power back on March 26 in the late afternoon
March 29	Controlled power shutdown because ship was expected to move on March 30 to a new parking position	(CTD unit and MSS taken to *Polarstern*, generator put on for heating of the tent)	Power remained because ship stayed, heaters reconnected to ship's power on March 30
April 2	While 2nd power line was reinstalled at the main power hub the fuse blew two or 3 times causing power shut downs lasting a couple of hours	CTD was run on generators	Afternoon of April 2nd

In order to run instruments in Ocean City during times of power shutdowns, we used different generators. The Vanguard 16 HP (11.9 kW) generator was used to run one heater (3kW) on full power or both heaters on half power (required to keep temperatures inside OC above 6°C). It was not desirable to run winches and instruments on the same generator as the heater due to peaks in the power supply. To run the CTD, we used the Vanguard 16 HP to supply power for the CTD winch (3.5 kW), a 2 kW Honda generator (from the HAVOC project) for the CTD Deckunit and Notebook, and a 3 kW Honda generator (borrowed from team ICE) to run a heater (2-3 kW). Most power supply is needed for deploying the LISST or nets because both the KC Denmark winch (2.2 kW) and the CTD winch were needed to run at the same time

(latter to have a depth reading). Both can be run in parallel on the Vanguard 16 HP when connected to two different phases.

Stability of and temperatures inside the Ocean City tent remained fine (temperatures about +8°C) even during several storms with winds gust of up to 25 m/s and low temperature (lowest air temperatures of -42°C, with wind-chill temperatures of about -60°C). In March, ice was growing at the sides of the hydrohole continuously. Thus, the hole needed to be largened every 10 to 14 days using an ice saw.

In the night of the 27th to the 28th March the door of the Ocean City tent was blown open. The door most likely remained open for several hours over night. In the morning, the entrance was full of snow (Figure 5.5, right) and temperatures inside the tent were well below the freezing point. Most likely, this event was the main reason for the bad performance of both oxygen cells attached to the CTD, while conductivity cells and the MSS sensors remained unaffected. To prevent the door to blow open again, we used 2 pallets to block the door in our absence (Figure 5.5, left).

During April, ice conditions remained more stable and there was no need to use generators again. Instead of ice growth, we experienced melting and a rising water level inside the OC hydrohole toward the end of April (when air temperatures were rising up to 0°C). The OC tent was sinking into the ice with the snow piling up around it (Figure 5.5, left). In the beginning of May, we measured the ice thickness in and around OC: The side of the OC hole facing the tent's door had about 60 cm (presumably due to the heavy winches standing at this side of OC). Measuring the ice thickness inside the hole toward the back side of the tent yielded 90 cm. Outside about 0.5 m away from the tent we measured an ice thickness of about 1.60 m.

In the end of leg 3, it was decided that Polarstern would leave the MOSAiC floe in order to bring all leg 3 participants to Svalbard. Thus, on May 10, we emptied the OC tent with the help of team ECO members. We dismounted the A-frame and tables and packed all small items into Zarges boxes carried to the ship via skidoo and sledge. Only three heavy/large devices remained inside the tent after tidying up: the CTD rosette (with Niskin bottles), the part of the A-frame containing the CTD winch, and the KC Denmark winch (Figure 5.6).

On May 11, we opened the back of the tent to take the larger equipment out of the tent. The CTD rosette was carried out of the tent by 4-5 people and transported to the ship with skidoo and Nansen sledge. In order to get the heavy winches toward the ship, we used the Argo. We shuffled a ramp into the snow (the OC tent was about 1 m below the main snow/ice surface of the floe) to lower a Nansen sledge to the open side of the tent. We lifted the CTD winch/A-frame onto the sledge and pulled it out with the Argo. The most heavy and biggest device to transport out of the OC tent was the KC Denmark winch. It required at least 5 people to lift the winch onto the Nansen sledge plus one LOG person driving the Argo. All OC inventory (despite the KC Denmark winch) was packed inside the warm storage ICE container (AWIU223900-4) to be easily accessible for leg 4.

On May 12, we removed the power and LAN cables installed from the OC power hub toward the OC tent and the UiB instruments (75kHz ADCP and Cluster, see below). In the afternoon, the OC power hub was pulled with the Argo toward the ship (Figure 5.6, right). The UiB instruments were reprogrammed to run efficiently on batteries over the next days to weeks (see below for more details).

Fig. 5.6: *Left: Picture showing the Ocean City interior after emptying all small equipment. Right: Removal of the OC power hub with the Argo.*

Originally, we planned to handover the empty OC tent to the MOSAiC leg 4 team. However, a heavy storm on May 11/12 caused the break-up of the CO in many smaller ice floes. Several cracks also split up the logistics area and limited the access from the ship to OC considerably. The OC tent and Balloon Town were situated in the most stable part of the remaining smaller floe inside the CO. Still, we decided to dismantle the OC tent completely before leaving the floe for the leg 3/4 exchange (fearing more break-up events to happen during our absence).

The OC tent was dismantled on May 15 after repositioning of Polarstern on May 14. It required about 10 people (from teams ECO, OCEAN, DATA, and BGC) to dig out and free the tent from snow and ice with shuffles and ice picks (Figure 5.7). While digging, the ice got very wet and slushy. Most challenging was that the bottom-ends of the tent cover and parts of the tent straps were frozen into the ice. Some of these ropes frozen over deep down into the ice needed to be cut (but are easily replaceable for future operations). After about 2 hours the tent cover was loosened, lifted over the top and packed together. Next, the metal frame and the door were taken down. The pontons were not frozen in but rather loose with the hole platform floating on the slushy ice. Thus, we managed to pull the platform (wooden floor with pontons) with about 10 people from the OC hole onto the snow (Figure 5.7, right). Finally, the entire platform was pulled via skidoo to the ship. For storage reasons it was dismantled before lifted and stored on Polarstern.

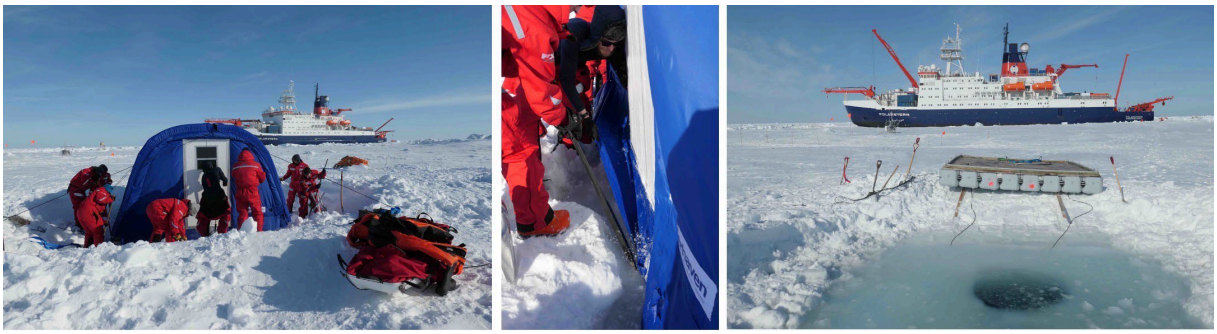

Fig. 5.7: *Left and Middle: Freeing the OC tent from snow and ice to take it down. Right: OC floor with pontons next to the former OC location clearly visible by the OC hydrohole. The entire underside of the OC tent was flooded with ocean water.*

CTD/Rosette casts in Ocean City

One major task was to carry out CTD casts in Ocean City. A standard SeaBird 9 plus system is mounted below twelve 5-liter OTE-Niskin bottles. The CTD is equipped with duplicate sensors to measure temperature, conductivity and oxygen, as well as sensors for fluorescence (Chl-*a* and CDOM*),* irradiance, beam transmission, nitrate, methane concentration/gas temperature, and rhodamine (see Table 5.3). The SBE9plus was connected via a Rochester (type A210124) 3.12 mm diameter conducting cable to an SBE11 surface unit. The custom-built winch can support safe ascending/descending speeds of ~0.2–0.5 m s^{-1}, and has a cable length of 1500 m. Mean lowering speeds were 0.4 m s-1, while to put the cable neatly back onto the drum needed some practice and was done with 0.3 to 0.35 m s^{-1} but reducing the speeds to < 0.1 m s^{-1} when approaching the sides of the drum. For deepest casts we left only one complete set of wire on the drum. This allowed us to reach maximum water depths of 1170 m. Such a deep profile took in total about ~3.5 hours. Once the Polarstern CTD could not be operated anymore, we carried out one deep cast in OC per week.

Overall, 67 CTD deployments were done in Ocean City. In order to supply teams BGC and ECO with larger amounts of water, several shallow casts closing all 12 bottles at 2 / 5 / 20 m were carried out in combination with casts down to 250 m and below the temperature maximum. BGC casts deployed at least down to 250 m were scheduled for Tuesday and Saturday. During these casts nutrient samples were taken by team BGC. Casts for team ECO to below the temperature maximum, 2 m, and 20 m were scheduled for Thursday. A “deep cast” in order to take salinity and oxygen samples but also CFC/He/Tri by team OCEAN was scheduled for Friday. While oxygen, CFC and He were not sampled in OC during legs 1 and 2, the OCEAN team member of leg 3 from University of Bremen set up a routine that allowed successful sampling for CFC and He in OC and a safe transport to the ship even in very cold conditions. More details are given below. Raw data were copied to the MCS, and the public server. Data were preprocessed using ManageCTD Matlab and SeaBird data processing software, and copied to the public server (/_CTDbackup).

Sensor configurations were changed comparably often during leg 3 due to sensor failures. We started off with the configuration used by leg 2 given in Table 5.3. However, no methane values were recorded as problems occurred when using the Rhodamine sensor on a custom-made split cable together with the Franatech methane sensor (data and power) and the SUNA (power only). Problems were related to the methane sensor needing two channels for output (methane concentration and temperature), and could not be solved. In order to test the performance of the methane and rhodamine sensor separately, we first detached the Rhodamine sensor (configuration 2). Using configuration 2, the methane sensor revealed reasonable data output for one cast, but failed during a second cast. Next, we detached the methane sensor and reattached the Rhodamine sensor (configuration 3). This resulted in reasonable output of data from the Turner Cyclops Fluorometer. However, because we did not release rhodamine as a tracer for wastewater during leg 3 we detached the rhodamine sensor as well as the methane sensor in all future sensor configurations (configuration 4).

The CTD sensors suffered from various temperature drops inside the tent (well below 0°C) during shut-downs of the main power lines (see Table 5.2). While we detached the conductivity cells to prevent them from cold, the oxygen membranes clearly showed bad performances. On March 29, we detached the entire CTD unit from the rosette and brought it to Polarstern (see above). Both SBE43 oxygen sensors were exchanged, resulting in a new sensor configuration (Table 5.4, configuration 5). While sensor SN0880 showed reasonable oxygen values, sensor SN2007 showed very noisy data. We suspected that the y-cable (shared with the PAR sensor) could be the problem for the poor performance of the sensor and tested various cables. However, this did not resolve the problem. In the meantime, we added the WET Labs ECO CDOM fluorometer (SN4531) from Polarstern to the OC CTD (configuration 6). In order to test the performances of the PAR sensor (SN70241) and the Chl-a fluorometer (SN1346), we replaced the PAR sensor with the one from Polarstern (SN70257) and added a second Chl-a fluorometer (SN725) using the free data input where the Rhodamine sensor has been detached earlier (configuration 7). As an outcome, the PAR sensor from Polarstern was kept in the OC setup. The Chl-a fluorometer did not provide data output via the attached cable. We

replaced the Chl-a fluorometer (SN1346) with the new one from Polarstern (SN725). Furthermore, we replaced the noisy oxygen sensor (SN2007) with a new sensor (SN1597) resulting in our final CTD configuration 8 given in Table 5.5 (used since station PS122-3_36-59 until the end of leg 3).

Tab. 5.3: *Sensor configuration 1 of the Ocean City CTD*

Config. 1	**Temperature sensor**	**Conductivity sensor**	**Oxygen sensor**	**Pressure sensor**	**Surface PAR**
Primary	SBE3 sn #4918	SBE4 sn #3549	SBE43 sn #1605	sn #0935	Biospherical/Licor sn #20349
Secondary	SBE3 sn #5110	SBE4 sn #3810	SBE43 sn #0743	-	-
Turner Cyclops Fluorometer	**Transmissometer**	**Nitrate sensor**	**Chl-a Fluorometer**	**PAR/Irradiance sensor**	**Methane sensor**
Sn # 216k00137	WET Labs C-Star sn #1220	Satlantics SUNA sn #1318	WET Labs ECO-AFL/FL sn #1346	Biospherical/Licor sn #70241	Franatech METS sn #1917

Tab. 5.4: *Sensor configuration 5 of the Ocean City CTD*

Config. 5	**Temperature sensor**	**Conductivity sensor**	**Oxygen sensor**	**Pressure sensor**	**Surface PAR**
Primary	SBE3 sn #4918	SBE4 sn #3549	SBE43 sn #2007	sn #0935	Biospherical/Licor sn #20349
Secondary	SBE3 sn #5110	SBE4 sn #3810	SBE43 sn #0880	-	-
Turner Cyclops Fluorometer	**Transmissometer**	**Nitrate sensor**	**Chl-a Fluorometer**	**PAR/Irradiance sensor**	**Methane sensor**
-	WET Labs C-Star sn #1220	Satlantics SUNA sn #1318	WET Labs ECO-AFL/FL sn #1346	Biospherical/Licor sn #70241	-

Tab. 5.5: *Final sensor configuration 8 of the Ocean City CTD*

Config. 8	**Temperature sensor**	**Conductivity sensor**	**Oxygen sensor**	**Pressure sensor**	**Surface PAR**
Primary	SBE3 sn #4918	SBE4 sn #3549	SBE43 sn #1597	sn #0935	Biospherical/Licor sn #20349
Secondary	SBE3 sn #5110	SBE4 sn #3810	SBE43 sn #0880	-	-
CDOM Fluorometer	**Transmissometer**	**Nitrate sensor**	**Chl-a Fluorometer**	**PAR/Irradiance sensor**	
WET Labs ECO CDOM sn #4531	WET Labs C-Star sn #1220	Satlantics SUNA sn #1318	WET Labs ECO-AFL/FL sn #725	Biospherical/Licor sn #70257	

Table 5.6 lists all file names of OC CTD casts with respective maximum water depth, configurations used, station numbers and comments related to sensor problems. In addition to the described sensor problems, some other events affected the performance of the CTD described as follows.

On March 22, we noted that an amphipode was stuck in the income of temperature sensor 1 (Figure 5.8), likely sucked into the sensor with the pump. Salinity values thus show a larger offset during the respective cast (dship action 32-77).

Fig. 5.8: *Left: Amphipode stuck in the CTD. Middle: Water entering the wire termination. Right: CTD wire when CTD is out of the water. In the future this part of the cable close to the white block may cause problems.*

Furthermore, we experienced problems with the communication to the water sampling unit from time to time. When turning on the CTD deck unit, the data acquisition run successfully, while the initialization of the water sampling failed. We believe that a loose connection was the main problem. Still, during cast 32-77 the bottles needed be fired via the deck unit as no connection with the Seasoft programme could be established.

On April 2nd, the data transfer from the CTD suddenly stopped during the downcast at 70 m depth. After checking for loose contacts, data transmission was shortly reestablished but failed again. The CTD was taken out of the water and all connections were checked. The winch and lab electricians of Polarstern found that the problem was water entering the wire termination (between winch wire and seacable) and fixed the problem the following day (Figure 5.8).

On May 1, the fuse at the OC power hub blew while the CTD was on its downcast at about 100 m depth. The fuse blew because the performance of the KC Denmark winch was tested in parallel to running the CTD system. The cast was restarted from the surface.

On May 5, the CTD wire got entangled by the ROV during the upcast of profile 39-16. The wire was dragged against the side of the hydrohole. The problem could be solved by radio communication.

At stations 34-67, 34-76, and 38-69 sensors from the fishing rod CTD were attached for sensor calibrations. During those casts, we first lowered the CTD to 70-100 m and back to the surface before we started the deep cast.

Filenames did not follow the filename convention during 3 casts, two on March 10 and one on April 4 (see Table 5.6 for details). Furthermore, bottles 2 and 11 did not close during various casts. The elastic rubber hose used to tighten the bottles before the CTD deployment broke of one bottle (presumable number 6) in the night from 30 April to May 1. We fixed this in a makeshift manner by tying two tubes together.

Last, we note that the CTD wire is not in a good shape at the part that is close to the white block when the CTD is not operated and placed on the floor (Figure 5.8).

Tab. 5.6: *List of all Ocean City CTD profiles giving file names, the respective maximum water depth, the configurations used, station numbers, and comments related to sensor problems*

Filename (PS122_3_yyyymmdd_tttttt)	Max. Depth (m)	Comments	Configuration	DShip station
PS122_3_20200225_063500	150	By leg 2 team, Rhodamine sensor attached by Ben, methane sensor gives no data	1	29-8
PS122_3_20200229_063500	100	Leg 2 trained leg 3 people	1	29-74
PS122_3_20200302_103900	225	Leg 3 people alone	1	30-9
PS122_3_20200305_052900	400		1	30-38
PS122_3_20200305_112100	2	Water for BGC/ECO	1	30-40
PS122_3_20200305_114900	2	Water for BGC/ECO	1	30-41
PS122_**2**_20200310_073000	420	Rhodamine sensor was detached, methane worked again, **conf2,** wrong leg number in file name!	2	31-18
PS122_**2**_20200310_111600	5	Water for BGC, wrong leg number in file name!	2	31-19
PS122_3_20200315_112100	200	Strong drift, wire at angle	2	31-81
PS122_3_20200317_122000	550	No methane data coming in	2	32-12
PS122_3_20200319_082000	5	No methane & rhodamine, btl 2 and 11 did not close, water for Jeff	2	32-38
PS122_3_20200322_080000	1000	No methane but rhodamine	3	32-75
PS122_3_20200322_120000	2	For ECO	3	32-76
PS122_3_20200322_133000	250	For BGC, Oxygen 1 spiky, water sampler unit does not initialize -> btls can be fired via deck unit only, + amphipode sucked into tem1!!! Do not use “first” sensors (sal1 totally off)!	3	32-77
PS122_3_20200327_120500	450	For ECO, both oxygen sensors look wrong, both oxygen sensors suffered most likely from cold (several power shut downs and one time door open over night)	3	33-69
PS122_3_20200327_143300	2	For ECO	3	33-70
PS122_3_20200327_151000	20	For ECO	3	33-71
PS122_3_20200328_093500	600	dismantled methane and rhodamine sensors, oxygen sensors do not work, test CFC sampling	4	33-80
PS122_3_20200328_123500	100	For BGC	4	33-82
PS122_3_20200331_092700	250	For BGC, both oxygen sensors replaced, btl 2 does not fire, connection to water sampler unit is lost, bottles fired remotely	5	34-17
PS122_3_20200402_074500		No oxygen 1 and PAR sensor (cable was checked on board *Polarstern*); at about 70 m data transfer failed, shortly came back, at 70 m no data transmission anymore, cast was cancelled and CTD taken out of the water, problem was water in the wire termination (winch to seacable) fixed by board electricians	5	34-38
PS122_3_20200404_080100	5	For Jeff, no ox1 & PAR	5	34-64
PS122_3_20200404_090300	20	For ECO, no ox1 & PAR	5	34-65
PS122_3_20200404_094100	2	For ECO, no ox1 & PAR	5	34-67

PS122_3_20200404_0102000	1170	Calibration for one fishing rod CTD, 70 m down then surface then deep down, CTF/He sampling, no ox1 & PAR	5	34-67
PS122_3_20200405_113000	251	Btl 11 did not close, calibration for both fishing rod CTDs, 110 m down – surface – deep down, CFC/He sampling, no ox1 & PAR	5	34-76
PS122_3_20200405_135500	75	no ox1 & PAR	5	34-77
PS122_3_20200407_075000	250	New cable for ox1 and PAR, ox1 still noisy, btl 11 did not close	5	35-25
PS122_3_20200409_074500	20	For ECO, added CDOM sensor	6	35-60
PS122_3_20200409_080000	2	For ECO	6	35-61
PS122_3_20200409_082500	20	For ECO	6	35-62
PS122_3_20200409_085500 + *_101500	500	For ECO (Tmax), forgot to fire btls 10-12 at 2 m, thus new file (PS122_3_20200409_101500) contains btl files for these bottles only!!!	6	35-63
PS122_3_20200410_074500	1173	CFC/He sampling	6	35-77
PS122_3_20200411_075000	251	For BGC	6	35-92
PS122_3_20200414_113500	150	exchanged PAR and added a second fluorometer (from PS CTD) attached, for Jeff	7	36-17
PS122_3_20200414_125000	5	For Jeff	7	36-18
PS122_3_20200414_130500	250	For BGC	7	36-19
PS122_3_20200416_082000	1170	Exchanged oxygen 1, placed second fluoremeter to first fluorometer AUX and removed first fluorometer	8	36-59
PS122_3_20200417_073000	385	For ECO (Tmax)	8	36-81
PS122_3_20200417_093000	20	For ECO	8	36-83
PS122_3_20200417_100000	2	For ECO	8	36-84
PS122_3_20200417_102500	20	For ECO	8	36-85
PS122_3_20200418_113000	250	For BGC	8	36-115
PS122_3_20200420_113000	250	File name has wrong date (21.4.), strong drift, Nd sampling	8	37-14
PS122_3_20200421_140000	250	For BGC, Strong drift	8	37-15
PS122_3_20200423_081500	450	Eco water sampling	8	37-45
PS122_3_20200423_102500	20	For eco	8	37-46
PS122_3_20200423_105000	2	For eco	8	37-47
PS122_3_20200425_073500	1172	CFC/He/S/rho sampling	8	37-88
PS122_3_20200425_120000	20	For ECO, recording started at 20 m	8	37-99
PS122_3_20200426_112000	250	For BGC	8	37-116
PS122_3_20200427_114000	450	For Clara and Jacqueline	8	38-5
PS122_3_20200428_073000	250	For BGC	8	38-31
PS122_3_20200430_073500	450	ECO water sampling	8	38-54
PS122_3_20200430_100500	20	Btl 2 did not close, for eco	8	38-55
PS122_3_20200430_103500	2	For ECO	8	38-56
PS122_3_20200501_114500	~100m	Fishing rod CTD calibration, i.e., down to 80 m, back to surface, then down again, Power shut down unexpectedly at 100 m, started deep cast again, spring of btl 6(?) broke overnight, was fixed with tubes and knots	8	38-69

PS122_3_20200501_121500	1173	Continue previous cast after power shut-down	8	
PS122_3_20200502_073000	259	For BGC	8	38-100
PS122_3_20200505_112500	500	For BGC, CTD entangled by ROV	8	39-16
PS122_3_20200507_072500	450	ECO water sampling	8	39-51
PS122_3_20200507_094500	35	For eco	8	39-52
PS122_3_20200507_101500	2	For eco	8	39-53
PS122_3_20200507_103200	20	For eco	8	39-54
PS122_3_20200508_074500	800	Too strong drift to go deeper down	8	39-69
PS122_3_20200508_111000	100	For BGC	8	39-70
PS122_3_20200509_073500	250	For BGC	8	39-82

Sampling for CFC/SF6, Helium/Neon, and Tritium

During MOSAiC Leg 3 research cruise, we collected 175 samples in total, 39 of them – from Polarstern and 136 samples from Ocean City. We sampled once a week according to the sampling strategy (for lab setup see Figure 5.9).

Fig. 5.9: *Left: Complete set up of the frame for the flame sealing of CFC glass ampules and thermostat. Right: Equipment prepared for the sampling in Ocean City: Styrofoam box with CFC glass ampules, copper tubes and bucket with salt water and plastic tubes for He/Ne samples, bucket with freshwater and equipment for CFC samples, yellow boxes to store CFC ampules.*

The first week of March was spent inspecting lab installations for flame sealing of glass ampules. The leakage from Nitrogen bottle was fixed, the frame for flame sealing was installed. At the beginning of the Leg 3 two heaters were installed near the Polarstern CTD. After the first station we decided to take them out as samples warmed up too fast and started dissolving. The first sampling of Leg 3 was done from the deep Polarstern CTD cast on 6th of March. During flame sealing of glass ampules suspicious water flow coming from metal tubes for nitrogen was detected. Some ampules were destroyed due to this issue. On 7th of March the additional sampling from shallow Polarstern CTD cast was performed. This time, during flame sealing the heating spiral connecting the metal tubes (coming from the nitrogen bottle) and the glass ampule was blocked. All samples were lost. Problems with the heating spiral were fixed on 12th of March after communication with home institution and several tests with the spiral. Most probably, the reason for the blocking was incorrect use of the equipment during Leg 2. The metal tubes were stored in a bucket with water, which allowed water to flow through the tubes inside the heating spiral. The heating spiral is filled with molecular sieve for additional cleaning of the nitrogen from the bottle. Incorrect storage in water caused the molecular sieve got wet and blocked the spiral's tubes. We carried out several tests heating the spiral up to temperatures of 50˚C, 100˚C, 150˚C, 200˚C and 300˚C (checked with a thermostat) in order to dry the molecular sieve. This solved the problem.

Between stations 31_59 and 32_76 the sampling procedure was successfully tested for Ocean City (Figure 5.10). We tested sampling and transportation procedures in Ocean City. For transportation the black styrofoam box and gray plastic tubes for CFC glass ampules were used. All boxes and tubes were carefully packed in a pulka. Skidoos were not used for transportation because this option would not have been safe enough for the fragile glass ampules. Gray plastic tubes were partially destroyed during previous legs which reduced the amount of possible samples from Ocean City. Helium/Neon samples were performed with copper tubes. Tritium water probes were sampled into plastic bottles. Latter were also transported inside the styrofoam box to prevent freezing during sampling in Ocean City. All sampling procedures are described in the SOP and Cruise Reports of Leg 1 and Leg 2.

Sampling strategy was changed from Leg1/Leg2 according to the sampling strategy approved by the University of Bremen. The focus of our work was on the upper 400 m and the mixed layer. Replicate samples for CFC was taken from 10 m depth, for He – 50 m. Tritium samples were taken every second week. Numbers of stations and performed sampling is described in Table 5.7. Total amount of samples is in Table 5.8. We changed firing sequence in order to close all bottles on one side of the tent.

Fig. 5.10: *Left: Helium sampling in Ocean City. Middle: CFC glass ampules in Ocean City. Right: Flaming of a CFC glass ampule in the lab onboard Polarstern.*

Table 5.7: *CTD stations with performing sampling during MOSAiC Leg 3*

Station number	Date	Coordinates	CFC/SF6	He/Ne	Tr	PS/OC
30_53	06.03.2020	88˚6.058'N / 29˚36.920'E	×	×	×	PS
31_59	14.03.2020	87˚8.864'N / 17˚25.312'E	×	×	-	PS
32_76	22.03.2020	86˚13.620'N / 15˚43.425'E	×	×	×	OC
33_80	28.03.2020	85˚47.906'N / 13˚24.499'E	×	×	-	OC
34_67	04.04.2020	84˚39.983'N / 12˚53.812'E	×	×	×	OC
35_77	10.04.2020	84˚23.512'N / 14˚39.164'E	×	×	-	OC
36_59	16.04.2020	84˚19.031'N / 13˚7.813'E	×	×	×	OC
37_88	25.04.2020	84˚1.159'N / 15˚38.989'E	×	×	-	OC
38_69	01.05.2020	83˚55.197'N / 17˚41.143'E	×	×	×	OC
39_69	08.05.2020	83˚51.326'N / 15˚17.126'E	×	×	×	OC

Table 5.8: *Amount of samples collected during MOSAiC Leg 3*

Samples	Amount		Total	Number of stations		Total
	from PS	from OC		from PS	from OC	
CFC/SF6	15	53	68	2	8	10
He/Ne	16	53	69			
Tr water	8	30	38			
Tr snow	-		18	-		9

For leg 3, the loss rate of CFC ampules is 24%. The highest loss was caused by problems with the heating spiral and water in the connecting tubes.

All collected samples are sent to home institution for further processing. The samples will be analyzed with mass-spectrometer according to the priority list on the Oceanography Department of the University of Bremen.

Snow samples for tritium probes should be done every second week according to the sampling strategy. No snow samples were taken during Leg 1 and samples from only 2 stations were taken during Leg 2. Thus, we collected samples from some additional stations to increase the number of samples. Snow samples were taken in large distance to the ship to avoid contamination sources with the help of Teams ICE and BGC. Preferably, we collected fresh surface snow which was melted and stored in plastic bottles. An overview of all collected Tritium snow samples is given in Table 5.9. All collected snow samples are sent to the home institution for further processing and analysis.

Table 5.9: *Stations of Tritium snow samples performed during MOSAiC Leg 3*

Date	Coordinates	Tr snow station number	Location	Number of samples
04.03.2020	N 88˚5.230’ / E 30˚2.721’	3	Dark site	2
08.03.2020	N 88˚0.717’ / E 25˚0.009’	4	Dark site	
21.03.2020	N 86˚15.241’ / E 15˚18.541’	5	First Year Ice	
06.04.2020	N 84˚32.034’ / E 14˚18.619’	6	Dark site	
13.04.2020	N 84˚17.747’ / E 14˚58.232’	7	Snow1	
15.04.2020	N 84˚19.585’ / E 14˚01.294’	8	Snow2	
25.04.2020	N 84˚00.185’ / E 15˚35.718’	9	L1	
30.04.2020	N 83˚56.036’ / E 17˚28.903’	10	L2	
06.05.2020	N 83˚55.292’ / E 17˚40.354’	11	L3	

T-POP deployment (PI: C. Heuze)

The T-POP is a football-sized autonomous temperature instrument that sits at the bottom of the ocean for a pre-set time, taking measurements every hour. It then automatically burns its anchoring link to float back to the surface and send its data by satellite. These sensors are part of the project "*Why is the deep Arctic Ocean Warming? (WAOW)*" of the University of Gothenburg. The aim is to quantify for the first time the high-frequency, seasonal, and interannual variability of the deep Arctic Ocean temperature. Team OCEAN had deployed four T-POPs (out of a total of ~25) in leg 3 (Table 5.10). Preparation was done by one person and deployment by two persons.

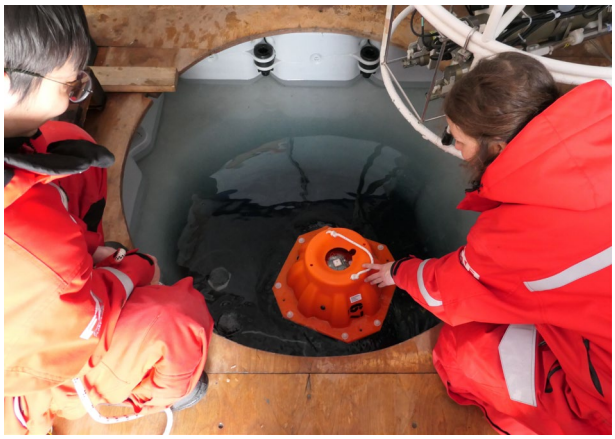

Fig. 5.11: *Deployment of T-POP in the Ocean City hydrohole.*

The first T-POP was deployed after a deep CTD profile from the CTD hole next to *Polarstern*. Because of the ice dynamics, we lost the ship CTD hole. Thus, the other T-POPs were deployed at OC before one of the "deep" Ocean City CTD casts going down to approx. 1170 m (Figure 5.11).

Tab. 5.10: *T-POP deployments during MOSAiC Leg 3*

Dship-action	Timestamp	Latitude (deg)	Longitude (deg)
PS122/3_38-56	2020-04-30 11:20	83,56145	017,27962
PS122/3_37-88	2020-04-25 07:20	84,01159	015,38989
PS122/3_36-85	2020-04-17 07:16	84,24801	013,40964
PS122/3_31-59	2020-03-14 11:40	87,08085	017,25743

Microstructure profiling at Ocean City

During MOSAiC Leg 3, the microstructure turbulence profiler MSS 90-S IOW 55 was used to perform measurements of microstructure temperature, salinity, velocity shear, oxygen, and chlorophyll-a concentrations. All sensors and measured parameters are described in Table 5.11.

Tab. 5.11: *MSS 90-S 55 sensor configuration*

Probe ID	Sampling Rate	Pressure	Shear 1	Shear 2	Temperature (PT100)	Temperature (NTC)
MSS 90-S IOW 55	1024Hz	PA7-100 (1000m) PA7-25 (250m)	PNS 18	PNS 19	-2…36°C	FP07
Conducti-vity	**Micro conductivity**	**Tilt**	**Acceler ation**	**Oxygen optode**	**Turbidity**	**Chlorophyll-a**
0…70 mS/cm	-	ADXL 203	-1…1 m/s^2	SST-DO	SST-Turb	-

Profiling was performed in Ocean City. Due to mobile ice conditions in March, we often took the microstructure profiler back on board *Polarstern* during night. We followed the procedure described in the Cruise Report of Leg 2 during the deployment of the microstructure profiler.

We did at least 3 profiles during one station. Observations cover a depth range between 1 and 420 meters. The mean vertical sinking velocity was 0.6 m/s.

Several times the GPS navigation did not work in Ocean City or started with a delay during the first profile. During our last station carried out on May 07, data transmission stopped working after 3 profiles. We found that the problem was caused by damages on the cable (which can be expected after the extensive usage of the MSS winch/cable since leg 1). Since the problem was not found within the first meters of the cable and we needed to pack up for leaving the MOSAiC floe, the problem could not be solved during leg 3.

Fig. 5.12: *Microstructure profiling in Ocean City.*

Current profiler at Ocean City

Following up on the measurements installed during leg 2, a 300 kHz ADCP was mounted temporarily in the Ocean City hydrohole in order to record data of currents and turbulence in the mixed layer concurrently (Figure 5.13). The device was mounted in a steel frame that kept the heading of the ADCP fixed relative to the heading of the floe. The ADCP gathered reliable data in the upper 50 m and was deployed in the hydrohole nearly the entire time. However, during deployments of the CTD and the LISST profiler the ADCP was removed from the ice hole. Further gaps in the time series were caused by gaps in the power supply and during times when we changed the memory cards (once per week).

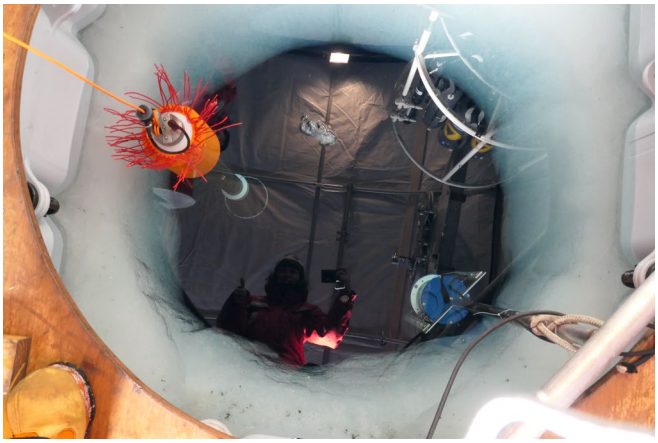

Fig. 5.13: *MSS (upper left corner) and downward looking ADCP (lower right corner) deployed in the Ocean City hydrohole.*

Microstructure profiling with VMP250 Upriser (UiB, PI: Ilker Fer)

In total, we collected 15 profiles with VMP250 Upriser during 4 stations (Table 5.12) as a part of the AROMA project from University of Bergen. The aim with using the uprising vertical microstructure profiler was to record dissipation rates of turbulent kinetic energy in the upper 80 m up to the ice-water interface in order to resolve the under-ice boundary layer and to better quantify the ocean heat fluxes in the upper water column. All data was sent to the University of Bergen via Keppler data transfer.

We followed the deployment procedure described in the Cruise Report of Leg 2. In the beginning of leg 3, the setup file (setup.cfg) was changed to (i) correct the configurations for both shear sensors and (ii) fix the offset between the dissipation rate profiles from both shear sensors. Furthermore, we detached the light sensor following instructions by the PI.

In March, fast drift speeds of about 0.5 knots did not allow us to deploy the VMP. According to the recommendations from Leg 2, we waited for better conditions, i.e., slow drift speeds, for the first deployment of the VMP in Ocean City. In April and May, we performed in total 4 stations. Drift speeds during all stations were 0.1 to 0.2 kn causing a horizontal displacement of the VMP of about 10 to 20 m. During the first station the full setup from Leg 2 was used. Post-processing of the data showed increased rising velocities of about 0.8 m/s. We added one more brush (using 3 brushes in total) to stabilize the profiler rising with a desired velocity of 0.6 m/s. During each deployment, we waited for 5 minutes after lowering the VMP to about 80 to 90 m and before releasing the VMP to rise under the ice surface in order to avoid an artificially increased turbulence signal generated by the device itself. The battery package was changed from the original to a rechargeable one.

We deployed the VMP250 six times during our last station (station 39_10) to increase the total number of profiles. However, when checking the data in the lab we found that after the fourth profile the VMP detected power problems and stopped recording data (an extraction of the logfile is given below in Table 5.13). The problems also affected the data download from the device. According to the recommendations in the manual, the battery voltage was measured with a multimeter at the 2-pin Molex connector on the deck cable. We measured a value of 14.85 V (i.e., above the expected threshold of 13 V). After charging the VMP batteries for 2 hours, we measured 16 V and were able to download the data from the VMP. The reason why the VMP stopped recording remained unknown. The first profile from the four recorded ones at that day cannot be used for data processing: The rope of the VMP winch made several loops around the VMP profiler (probably, because of changing drift direction) and thus disturbed the upward movement of the VMP250.

Tab. 5.12: *VMP250 Upriser stations during MOSAiC Leg 3*

Station number	Date	Coordinates	Max. depth, m	Number of profiles	Vertical velocity, m/s	Location
35_10	06.04.2020	84˚31.869'N / 14˚21.689'E	70	3	0.8	Ocean City
36_2	13.04.2020	84˚17.586'N / 14˚57.417'E	75	4	0.6	
38_9	27.04.2020	83˚55.428'N / 15˚37.589'E	75	4	0.6	
39_10	04.05.2020	83˚54.269'N / 18˚20.527'E	76	6	0.6	

Tab. 5.13: *Extraction of the logfile from the VMP250 Upriser documenting battery problems occurring on May 04, 2020*

```
5eaffae9 05 0000 unknown --- Mon May  4 11:22:17 2020 - "power good signal received"
5eaffaeb 05 0000 unknown --- Mon May  4 11:22:19 2020 - "power good signal received"
5eaffaf7 0b 0000 dat_038.p --- Mon May  4 11:22:31 2020 - "acquisition start" Setup File:'SETUP.CFG'
5eb00d15 04 121e dat_038.p --- Mon May  4 12:39:49 2020 - "power is bad"
5eb00d15 0c 121e dat_038.p --- Mon May  4 12:39:49 2020 - "acquisition stop" power is bad
```

Laser In-situ Scatter Transmission meter (LISST)

The LISST is a Laser In-situ Scatter Transmission meter that was used in order to measure underwater distribution of particle sizes. The ultimate goal of this project is to estimate the export and sequestration of particles beneath the sea ice and consequently impacts on the sensitive ecosystems over the central Arctic as introduced in the cruise report of Leg 1. The task of Leg 3 was to extend the observations through the spring season aiming for covering a complete annual cycle. Measurements from this instrument were taken within the framework of a project of the Polar Research Institute of China (PRIC) in order to collect time series of particle sizes in the upper 500 to 1000 m of the ocean throughout the entire MOSAiC drift.

The LISST was deployed in OC once a week down to 800 m. It required two or three persons (approximately 2 hours), and 1 bear guard. The set-up of LISST deployment was continued similar to the Leg 2 set-up (described in the Leg 2 cruise report). We used the wire of the KC Denmark winch to lower the LISST together with a Seacat (SBE19) mobile CTD (Figure 5.14). The wire was laid over the A-frame of the OC CTD in order to get a depth reading from the CTD winch. During Leg 3, 10 LISST casts were completed (Table 5.14, Figure 5.15). We planned to deploy the LISST to 800 m every cast. However, due to a number of floe evacuations (due to lead openings) some profiles were interrupted and deployment depth were shallower.

During leg 3, we experienced two trouble-shootings while LISST deployments. First, the small block which is mounted on the A-frame (Figure 5.14) occasionally stopped spinning. This problem occurred predominantly when the angle of the wire going down into the water became very large (i.e. during strong drift speeds). A quick solution was to change the direction of the A-frame to lower the angle and thereby the tension between the cable and the small block. The second trouble shooting was caused by the KC Denmark winch itself. The winch stopped running properly during the upcast of the last deployment of the LISST on April 29. While lifting the LISST upwards, the emergency stop caused the winch to turn off when the speed of the winch was increased. Thus, the LISST could only be lifted up to the surface with very slow winch speeds and it took more than 2 hours to finish the cast. While searching for the reason of trouble shooting from the winch, several error messages were displayed on the motor (Kollmorgen, AKD) when driving the winch. We detected loose contacts. Furthermore, an overheating of the winch by the installed heaters might have caused parts of the problem. The winch was inspected and tested by an engineer from the ship's crew. The problem could be solved but it remained unclear what exact fix solved the problem.

Tab. 5.14: *LISST deployments during MOSAiC Leg 3*

Dship-action	Timestamp	Latitude (deg)	Longitude (deg)	Depth (m)
PS122/3_38-41 LISSTDeep_4047	2020-04-29 07:34:46	84,01494	017,13192	827
PS122/3_37-29 LISSTDeep_4047	2020-04-22 07:57:54	84,08345	015,53092	832
PS122/3_36-44 LISSTDeep_4047	2020-04-15 07:30:00	84,19585	014,01294	829
PS122/3_35-36 LISSTDeep_4047	2020-04-08 08:15:30	84,28949	014,38140	830
PS122/3_34-28 LISSTDeep_4047	2020-04-01 13:46:35	85,05885	015,31512	822
PS122/3_33-36 LISSTDeep_4047	2020-03-25 08:34:14	86,07604	014,14247	619
PS122/3_32-51 LISSTDeep_4047	2020-03-20 11:30:17	86,19967	014,47213	531
PS122/3_31-29 LISSTDeep_4047	2020-03-11 07:54:45	87,40553	024,42797	840
PS122/3_30-26 LISSTDeep_4047	2020-03-04 06:25:35	88,06156	030,23762	200
PS122/3_29-75 LISSTDeep_4047	2020-02-29 14:08:42	88,16163	031,45032	511

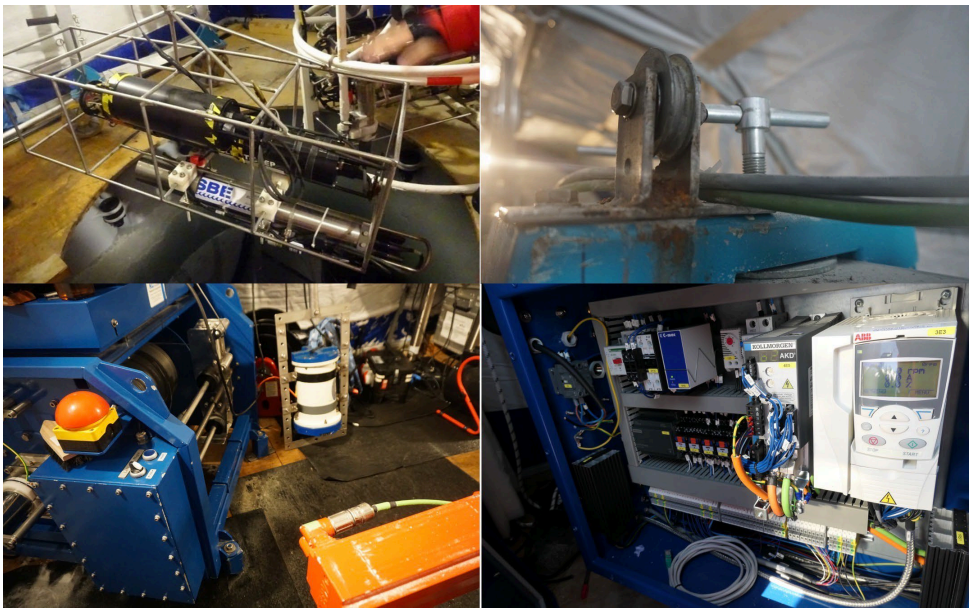

Fig. 5.14: *Top left: LISST and Seacat (SBE19) mobile CTD during deployment in Ocean City. Top right: Small block on the CTD A-frame that did not spin properly. Bottom left: KC Denmark winch used for the deployment of the LISST. Bottom right: Inside electronics of the KC Denmark winch showing the display of the motor where errors were displayed.*

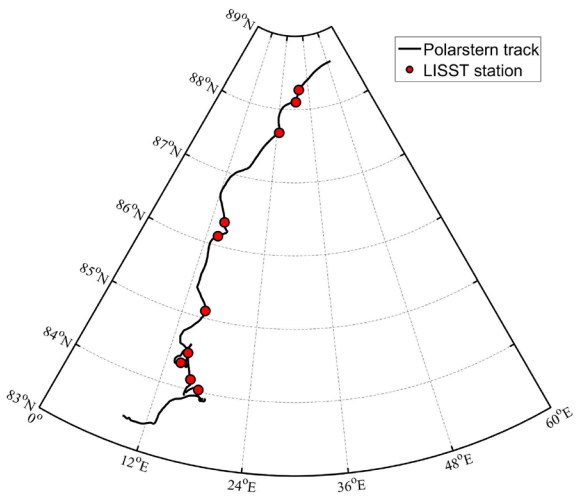

Fig. 5.15: *LISST stations during Leg 3*

Permanent velocity measurements on the main MOSAiC floe (AROMA project, PI: Ilker Fer)

Within the AROMA project, three permanent installations were installed on the main ice floe during leg 1: (1) a Tchain with a Microrider, (2) the UiB ADCP Longranger mooring, and (3) the UiB Cluster with 3 cluster packages consisting each of a S1000 ADCP, a SBE37 MicroCAT, and a SAMI pCO2 sensor (see cruise report from leg 1 for more details). These autonomous, continuous recording systems were planned to be operative in all legs. During leg 3, regular data downloads with subsequent backups to the MCS and on the public server were carried out from all systems following up on the instructions given by leg 2. Data gaps were caused due to shut downs of the main power supply and broken data glasfibre cables caused by the movements of *Polarstern* along the MOSAiC floe (due to strong ice pressure). After the glasfibre cable broke several times, team data installed RadioLAN antenna's allowing data downloads from the ship.

Ocean thermistor chain and microrider mooring

In the beginning of leg 3, a glasfibre cable installed between the Tchain and the ship allowed data downloads from the thermistor chain and microrider on board *Polarstern*. Data from the four CTDs were recorded internally only and thus could not be accessed during the time of deployment. Already during leg 2, data from the thermistor chain suggested sensor failures with only one remaining sensor giving reasonable temperature data. Thermistor data was downloaded with the Ruskin software, Microrider data was downloaded regularly using WinSCP.

After March 9 no connection to the Tchain was reached any longer. (However, all data was downloaded from the data logger after recovery of the Tchain on May 9.) After the glasfibre cable was broken due to the ship's movement along the ice floe, we downloaded data directly from the main power hub.

On March 27, the remote sensing hut was moved right next to the Tchain. On April 27, a crack opened in the logistics area between the ship and the remote sensing hut/Tchain (with the main power hub remaining on the ice floe directly accessible from *Polarstern*). The power cable to the Tchain needed to be unplugged suddenly from the main power hub. Afterwards, we reconnected power and data cable from the Tchain inside the Remote sensing hut instead of in the main power hub. Problems occurred when reconnecting with the Microrider. While power seemed to be connected, the host could not be found when starting WinSCP for data download. First, we solved the problem be exchanging the data cable. However, the same problem occurred again the next week. We connected once to the *Polarstern* server and afterwards tried again to establish communication with the MR. This solved the problem.

Before the MOSAiC leg 3 team left the MOSAiC floe, the Tchain has been recovered from the ice on May 9 (Figure 5.16). Drilling close to the mooring revealed an approximate ice thickness of 1,60 m. In order to recover the 200 m long mooring line with all instrumentation, we mainly used a chainsaw with 1 m blade, ice screws, a crowbar, a 10-inch auger, a tripod, and a skidoo. First, a grid was cut with the chainsaw into the ice to pull out ice cubes of approx. 30x30x60 cm with the ice screws (loosened beforehand with crowbar). The total area cut around the mooring was about 1x1.5 m. The metal chain (i.e., the upper part of the deployed Tchain) was freed from ice by using a hammer and secured to the ice surface by using ice screws. After cleaning the hole, a second grid was cut into the ice (leaving a little step on all sides) to deepen the hole. As a third step, the auger drill was used to drill 4 to 5 predrilled points around the metal chain. Finally, the hole was flooded with ocean water by drilling through one of the drill points. In order to free the mooring completely from the ice, we drilled holes through all predrilled points. To see were to drill we removed ice and stirred the water with two sieves. Once the mooring line was free, we set up a tripod with a small block (borrowed from the bosun) over the hole. A rope was attached to the mooring chain and connected via the block to a skidoo. As the metal chain could not be run over the block it was lifted bit by bit until the mooring cables (Tchain and MR cable) were reached. Then, we could run the Tchain cable over the block slowing down at each thermistor. However, damage of the cable/sensors might be well possible. The MR cable was entangled around the Tchain cable (both cables were attached to another but needed to be detached for recovery). Thus, the recovery needed 3 people at the hole plus one skidoo driver to ensure a save recovery of all sensors.

The recovery was done in air temperatures of about -5°C. CTD sensors were stored at site in an isolating box to prevent freezing. The MR was slightly too large to be stored in the box and was carried immediately after recovery to the ship. All CTD sensors and the MR were recovered without any damage. While recovering the second last CTD, the tension on the mooring line suddenly dropped. We believe that the 30 kg anchor weight placed at the bottom of the mooring line broke free at that time because it was missing in the end of the recovery. The shackle where the anchor weight should have been attached looked eroded. The hole recovery took one working day (about 6 to 7 hours). Data of the Tchain data logger and all CTDs was read out on board using the Ruskin software and copied to the MCS.

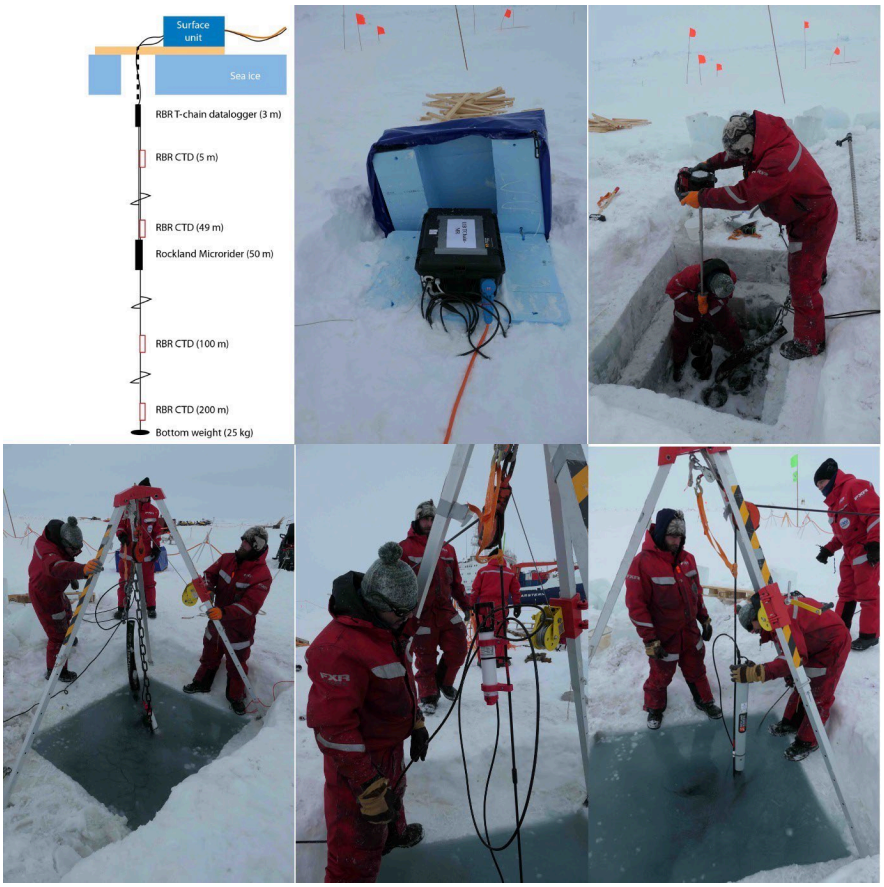

Fig. 5.16: *From top left to bottom right: Sketch of the Tchain with MR; Surface unit of the Tchain; Drilling a hole for Tchain recovery; Setting up the tripod; Recovery of the thermistor chain with clamped RBR CTD and MR cable entangled around it; MR recovery.*

UiB ADCP Longranger mooring

The UiB 75kHz ADCP has been deployed on leg 1 in the vicinity of Ocean City with power supply and data connection using the Ocean City power hub. In the beginning of leg 3, a glasfibre cable ensured continuous data downloads from the 75 kHz ADCP on board Polarstern. In mid-March, several power shut-downs due to the ship movements along the flow (causing interruptions in the power supply from Polarstern onto the floe, Table 5.2) presumably affected a continuous data record by the 75 kHz ADCP. At the same times, the glasfibre cable broke several times, i.e. data transfer to the notebook located in the lab on Polarstern was interrupted. Since team DATA installed a RadioLAN connection on the Ocean City power hub, data downloads run fluently again to the board computer once power was reconnected.

In the evening of May 11, we reprogrammed the 75 kHz ADCP (following the PI's instructions; RDI75_20min_dep.txt). Since Polarstern was leaving the floe and the ADCP was supposed to be left on the ice, it was setup to sample less frequently and for our absence on its own batteries. On May 12, power and LAN connections were unplugged. A severe storm on May 13, caused the break-up of the MOSAiC floe. Thus, it was decided that we would recover the ADCP before leaving the floe with Polarstern.

The UiB ADCP was recovered on May 15. We used the same practice (Figure 5.17) as described above in detail for the Tchain. Ice thickness around the ADCP was 1,60 to 1,70 m. The ADCP was recovered within one day without any damage and stored onboard Polarstern.

Fig. 5.17: *Recovery of the UiB ADCP Longranger on May 15. Left: Sketch of the mooring setup. Middle: Drilling the hole. Right: Recovery of the ADCP (in the picture just under the water surface) with a tripod.*

UiB Cluster mooring

The UiB Cluster mooring has been deployed during leg 1 in the vicinity of Ocean City and the UiB ADCP Longranger (see cruise report from leg1). Each of the 3 clusters consists of a S1000 ADCP, a SBE37 MicroCAT, and a SAMI pCO2 sensor. Data was downloaded about every second week from board Polarstern (via glasfibre cable and later RadioLAN antenna installed on the Ocean City power hub).

Already during the handover with leg 2, CTD data from the SBE37 could not be downloaded. Furthermore, no download of data from the bottom pCO2 was possible. Data from the two other pCO2 sensors and the 3 ADCPs was downloaded every 2nd to 3rd week and saved on the MCS and the public server. Data download for pCO2 data was done running the software SAMI Client. It took at least one hour to download data from one pCO2 sensors due to software problems causing very long waiting times between the different download procedure steps (see manual provided by leg 2 team: from_UiB_Cluster_CO2.docx). Data records may be affected by blackouts interrupting the power supply from Polarstern (Table 5.2).

Before leaving the MOSAiC floe on May 16, we reprogrammed instruments, and added additional batteries and floatation for the time of Polarstern being absent from the MOSAiC floe. We downloaded all accessible data, erased it from the instruments, and reprogrammed the ADCPs following the instructions by the PI of the project (Ilker Fer) on May 11. In order to prolong the data records, we added 4 batteries in an additional box (using the cover of the Tchain surface unit and a wooden box build by the ship's crew) placed next to the UiB Cluster surface unit and connected to the 2 battery packages inside the UiB cluster surface unit (Figure 5.18). Additional floatation (orange-colored fenders from the ship) was borrowed from the bosun (Figure 5.18).

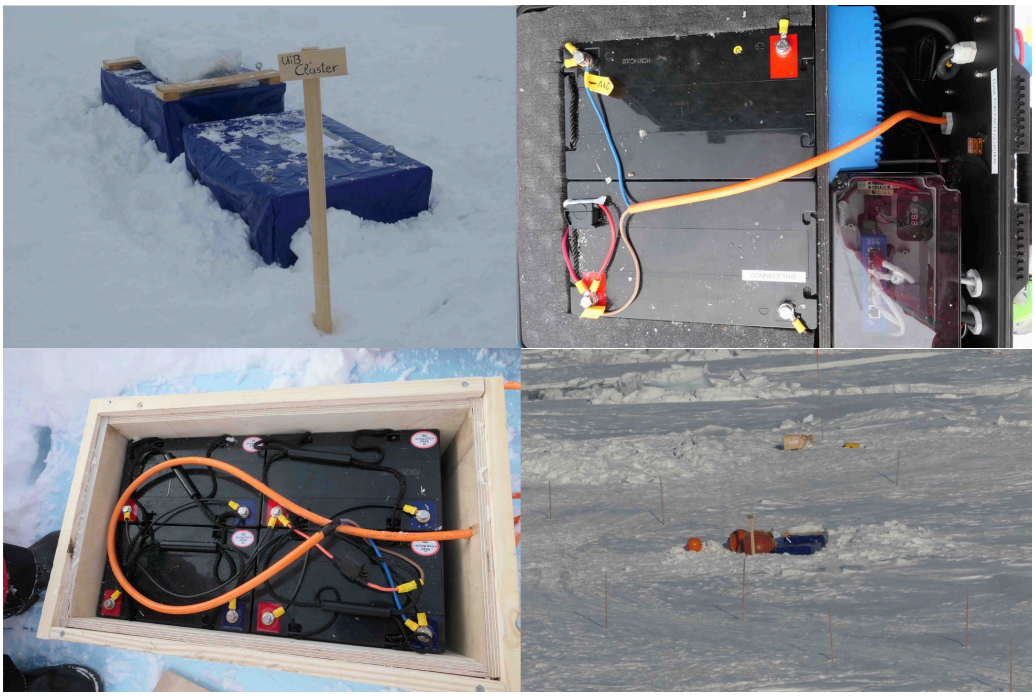

Fig. 5.18: *UiB Cluster mooring when leg 3 left the MOSAiC floe in mid-May. Top left: Surface unit plus a package with additional batteries (below blue cover in the back) to ensure a continuing data record without power supply from Polarstern. Top right: Battery connection in the main surface unit. Bottom left: Setup of additional battery packages and connections. Bottom right: Surface units with additional floatation attached to the UiB Cluster when leg 3 team left the floe on May 16.*

Ocean permanent measurements at Fort Ridge (HAVOC program, PI: Mats Granskog)

As part of the HAVOC project, two ADCP/CTDs were installed at Fort Ridge by team ICE (taking the lead) and team OCEAN during leg 2. During leg 3, team OCEAN took care of data monthly downloads from the instruments. We followed instructions from leg 2 in order to download the ADCP data with subsequent backups to the MCS. CTD data was installed internally only and could not downloaded without instrument recovery.

Due to very cold (-30°C) weather conditions in the first weeks of March, we did not try to download data in the beginning of leg 3 (Figure 5.19). We visited the instrumentation at Fort Ridge during leg 3 for the first time on March 23. To access Fort Ridge via the common road, we needed to climb 2 ridges. The region had experienced strong shear and more ridging events in the previous weeks. We found that part of the team ICE instruments were deformed by ridging and only found one ADCP/CTD package. Reconsidering the ice movements, we believed that. The second ADCP/CTD sight presumably was moved during shearing several tens of meters away from its original position. However, we were not able to find the instruments in this heavily ridged area.

Fig. 5.19: *Fort Ridge instruments on March 23. Left: Instruments tilted in the ridge, ADCP in the background on the right of the red flag. Right: GPS recorder (left, white cylinder), Buoyancy of the CTD (middle, orange balls), and ADCP (right, left cylinder with green cables) with battery package stored in a table. For data downloads from the ADCP next to a toughbook a generator and a cooler with heating packs (to keep the Toughbook warm) has been used.*

While a search mission in April did not succeed to find back the lost second ADCP/CTD, a ROV dive on May 2nd found the instruments back by chance (Figure 5.20). The movies showed that both the ADCP and CTD were pushed down and tilted (i.e., “eaten up”) under a ridge. Unfortunately, the exact positions could not be inferred due to navigational problems on that specific ROV dive.

Fig. 5.20: *ADCP (left) and CTD (right) lost at Fort Ridge in mid-March and found by the ROV (inaccessible) on May 2nd.*

Data were successfully downloaded from the remaining ADCP. Following the advices from leg 2, we took precaution that the battery of the toughbook used for data download would not die quickly from the cold. We stored the notebook with two hot-water bottles in a cooler borrowed by team ECO for the transport on site and left the notebook half-open in the box during data download (Figure 5.18). We did not experience any problems with running low in battery during data recoveries.

We visited Fort Ridge the second time on April 24. Instead of crossing ridges, this time we were challenged by crossing open cracks in order to reach the ADCP/CTD. Data was again downloaded successfully and stored on the MCS.

On May 6 we visited Fort Ridge for the third and last time. We downloaded the ADCP data successfully again. Furthermore, we exchanged the ADCP batteries (in the field) and recovered and redeployed the CTD (Figure 5.21). The ice thickness was about 1,60 m. We used a chain saw and a 10-inch auger drill to make a hole for the recovery. The CTD was successfully recovered, the data record downloaded and checked in the field, and subsequently we redeployed the CTD (not changing the setups). In total, with 3 persons (2

making the hole and 1 downloading ADCP data and changing ADCP batteries) we took less than a day (having the lunch break on the ship) for the described actions.

Fig. 5.21: *Series of pictures showing the recovery and redeployment of the CTD at Fort Ridge on May 6. The bottom panel shows the site when we left it on May 6 (left) and from the ship when leaving the floe on May 16.*

Operation of a small ("fishing rod") CTD at different locations on the MOSAiC floe

During MOSAiC Leg 3, we used two SST 48M CTD (by Sea&Sun Technology) for 3 main tasks: (1) calibration with the Ocean City CTD, (2) measuring temperature and salinity under the ice at L- and M-sites for further comparison with buoys' data, and (3) investigation of ocean circulation during lead events. We used two sensors with serial numbers 1459 and 1495.

The deployment procedure is described in cruise report of Leg 2. Two buoyancy rings were attached to the lowered sensor (Figure 5.22). We chose the continuous mode of the recording with ca. 1 second time interval. The speed of the fishing line was about 0.5 m/s. The fishing line was cleaned during the upcast with a brush to prevent damaging of the line by the ice (Figure 5.22). Calibration casts were carried out in Ocean City since the Polarstern CTD could not be operated during most times of leg 3 (because the hydrohole was lost, see above).

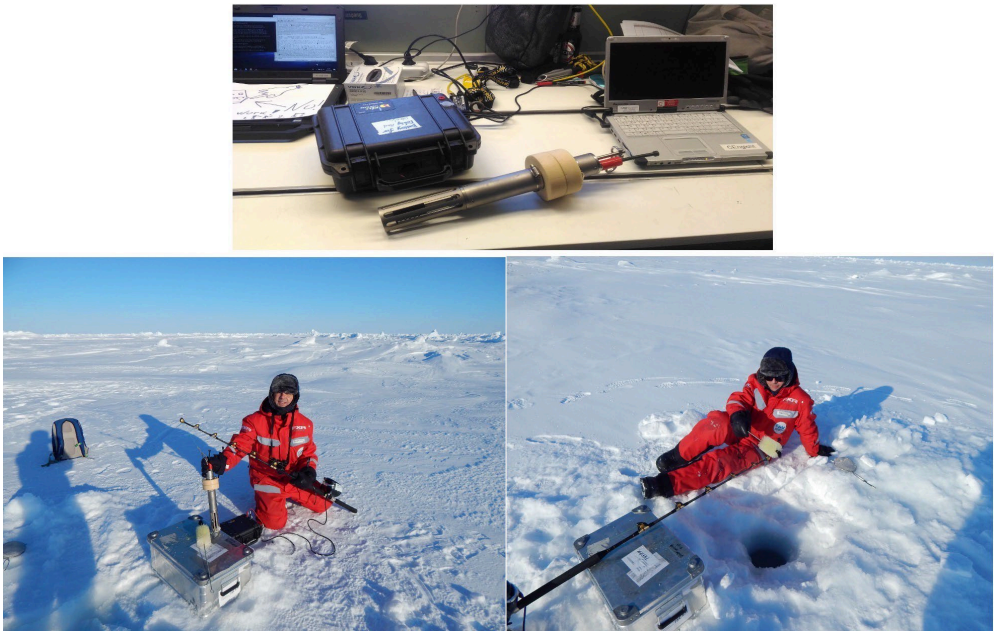

Fig. 5.22: *Top: Fishing rod CTD and external battery package. Bottom left: Full set up of fishing rod profiler at L- and M-sites. Bottom right: Cleaning the fishing line from ice at L- and M-sites.*

Tab. 5.15: *Fishing Rod CTD casts for calibration during MOSAiC Leg 3*

CTD station number	Date	Coordinates	Pro-files	Depth, m	CTD SN	Location
33_80	28.03.2020	85˚36.641‘N/13˚18.387‘E	1	600	# 1459 # 1495	Ocean City
34_38	02.04.2020	84˚58.586‘N/15˚09.017‘E	1	100	# 1459	
			4	70	# 1495	
			1	6		
			3	70		
34_67	04.04.2020	84˚39.983‘N/12˚53.812‘E	1	1200	# 1459 # 1495	
34_76	05.04.2020	84˚34.710‘N/13˚24.430‘E		250		
34_77		84˚34.578‘N/13˚31.326‘E		80		
38_69	01.05.2020	83˚55.197‘N/17˚41.143‘E		1200		

We performed 4 calibration experiments by attaching the sensors to the Ocean City CTD (Table 5.15). On Saturday, 28-03-2020, the first calibration cast was performed. Both fishing rod CTDs were attached to the frame of the Ocean City CTD and deployed to a maximum depth of 600 m (Figure 5.23). We found an offset in the recorded temperatures and conductivities for both fishing rod CTDs compared to the data from the OC CTD (Figure 5.23). We also found an offset in the pressure sensors of both fishing rod CTDs. Furthermore, we detected an unexpected behavior of the conductivity sensors in the mixed layer.

In order to correct the calibration coefficient of both fishing rod CTDs, we used the following procedure: First, we calculated the temperature and conductivity offsets from the respective profiles. Second, we calibrated the pressure sensors on air pressure with the SDA software. Third, we changed the offset calibration coefficients for both CTDs (Table 5.16) and checked the new calibration coefficients on the next Ocean City CTD calibration casts (carried out on 04-04-2020 and 05-04-2020).

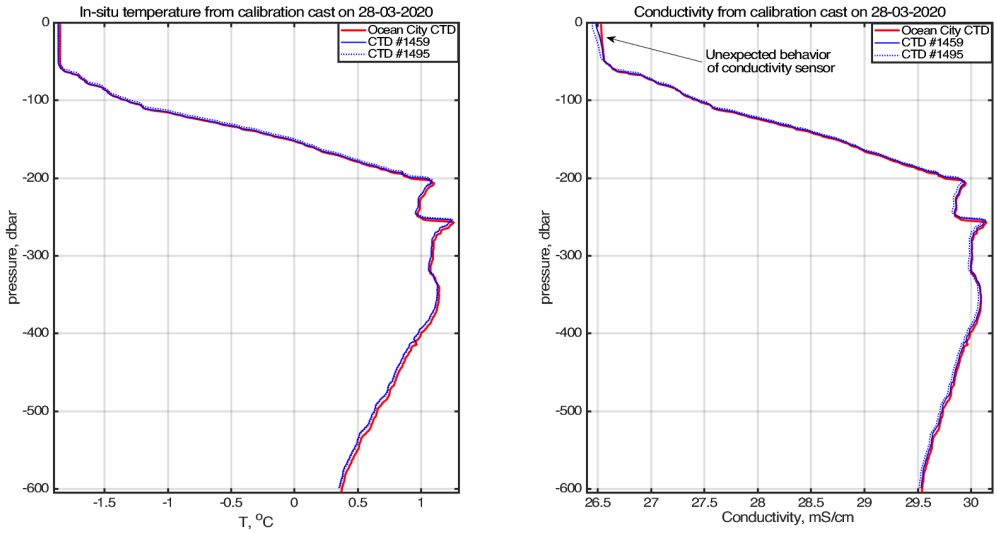

***Fig. 5.23**: In-situ temperature and conductivity profiles during the first calibration cast in Ocean City on 28.03.2020.*

***Tab. 5.16**: Calibration coefficients after calibration cast on 28-03-2020*

Fishing Rod CTD 1459			
Calibration Coefficient	**Previous value**	**Changed value on 01-04-2020**	**Comments**
Pressure (Air pressure compensation)	0	-2.44242492E+0.0	Air pressure compensation (software)
Temperature (A0)	-2.52307	-2.50687(+0.0162)	Matlab calculation of Ocean City CTD
Conductivity (A0)	-2.16359E-1	-2.11559E-1(+0.0048)	Matlab calculation of Ocean City CTD
Fishing Rod CTD 1495			
Calibration Coefficient	**Previous value**	**Changed value on 01-04-2020**	**Comments**
Pressure (Air pressure compensation)	0	-3.66197626E+0.0	Air pressure compensation (software)
Temperature (A0)	-2.38192	-2.37152(+0.0104)	Matlab calculation of Ocean City CTD
Conductivity (A0)	-2.117897E-1	-1.86187(+0.0256)	Matlab calculation of Ocean City CTD

To improve the performance of the fishing-rod CTDs in the mixed layer, we performed three different tests with fishing rod CTD #1495 in Ocean City on 02-04-2020 aiming for a better understanding of the T/C-offsets and, most important, the adjustment time of the fishing rod CTD in the mixed layer. For the first test, we carried out 4 fishing rod CTD profiles in the Ocean City hydrohole. For the second test, we deployed the fishing rod CTD for 15 minutes at a constant depth of 6 m. For the third test, we first stored the CTD sensor for 10 minutes outside to adjust to the cold environment before we deployed the “cold” sensor. We repeated this test 3 times.

In conclusion, we found that conductivity sensors from both probes showed non-realistic behavior in the mixed layer due to slow adjustment times. Furthermore, “cold” CTD sensors need more time for adjustment to the surrounding water. In turn, we decided to increase the time of sensors’ adjustment by performing additional 100 m profile each time at the beginning of a fishing rod CTD station. We recommend the following procedure to record a trustworthy profile: (1) The fishing rod CTD is lowered to 100 m. (2) The probe is lifted back to the water surface. (3) The planned “real” fishing rod CTD cast is performed. This procedure should also be followed for calibration casts.

On 04.04.2020, both fishing rod CTDs were attached to Ocean City CTD frame during the deep cast (1200 m). Next day (05.04.2020) two more casts (BGC 250 m and ECO 80 m) were performed. Finally, data from fishing rod CTDs were compared with data from Ocean City CTD during all 3 casts (figures are not included here). Comparison of the fishing rod CTD data with data from the OC CTD showed a better performance with changed calibration coefficients compared to the default ones. Still, we changed the calibration coefficients for fishing rod CTD #1495 once more (Table 5.17). Profiles from the last calibration cast on 01.05.2020 did not show any significant offsets (Figure 5.24). All calibration coefficients were saved to the SDA software project.

On 25.04.2020 air pressure compensation coefficient was changed to -2.37261301 for probe # 1459. Last Ocean City CTD calibration cast was performed on 01.05.2020 (Figure 5.24). The profiles did not show a significant offset.

Tab. 5.17: *Calibration coefficients after calibration casts on 04-04-2020 and 05-04-2020 for Fishing Rod CTD 1495*

Calibration Coefficient	**Previous value**	**Changed value on 09-04-2020**	**Comments**
Pressure (Air pressure compensation)	0	-3.66197626E+0.0	Air pressure compensation (software)
Temperature (A0)	-2.38192	-2.37182(+0.0101)	Matlab calculation of Ocean City CTD
Conductivity (A0)	-2.117897E-1	-2.048897E-1(+0.0069)	Matlab calculation of Ocean City CTD

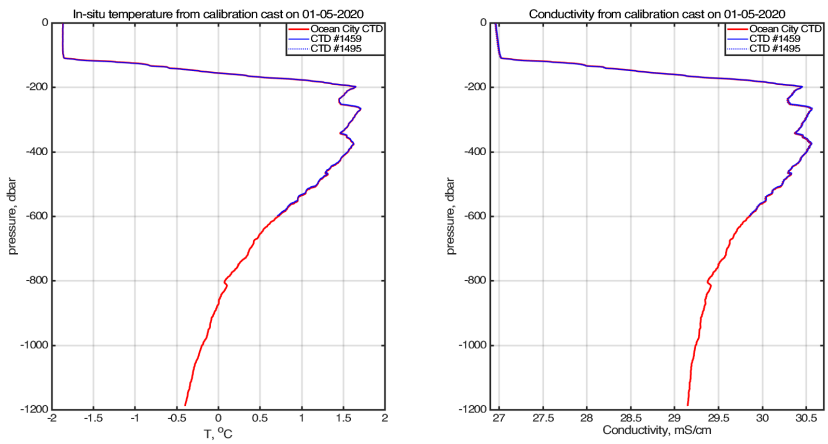

Fig. 5.24: *In-situ temperature and conductivity profiles during the calibration cast in Ocean City on 01.05.2020 with applied calibration coefficients.*

We used the fishing rod CTD to carry out hydrographic measurements on L and M sites (see blow), across a lead at the stern of *Polarstern* (see below), at Fort Ridge and on the Yermark Plateau (Table 5.18).

Tab. 5.18: *Fishing Rod CTD casts carried out at Fort Ridge and on the Yermak Plateau*

CTD sta-tion	Date	Coordinates	Pro-files, CTD SN	Depth in m	Location
39_32	06.05.2020	83˚55.295'N/17˚40.321'E	2, # 1459	20	Fort Ridge
39_33		83˚55.392'N/17˚39.163'E	1, # 1459	200	
42_14	26.05.2020	82˚19.092'N/08˚08.959'E	1, # 1459	400	Yermak Plateau
42_13	27.05.2020	82˚23.556'N/08˚20.435'E		800	
42_20		82˚23.601'N/08˚19.620'E		400	

Distributed Network

Fishing Rod CTD inter-calibration casts at L and M sites

For inter-calibration of data recorded by ITPs at all three L site and T/S chain buoys at the M sites, we carried out fishing-rod CTD profiles at each site. At all sites, we performed temperature-salinity profiles with the fishing rod CTD #1459 for comparison with timeseries data collected by the deployed instruments. In total, 10 profiles were performed at different sites. The procedure of deployment is described in the Cruise Report Leg 2. An overview of all stations is given in Table 5.19. First results showing the recorded data is given below (see Preliminary Analysis).

The M4 site was not found while mashed ice, ridges, and leads covered the area. Thus, the fishing rod CTD profile was carried out at 0.3 nm away from the coordinates of the M4 buoys. On 24.03.2020, the fishing rod CTD profile at L1 site needed to be aborted at the downcast at 100 m depth due to changing weather conditions (fog patches) requiring the helicopter to fly back to the ship.

Data from buoys were transferred via satellite and stored at meereisportal. During Leg 2 downloading data on regular base to the Polarstern were established (see cruise report leg 2) which were continued during leg 3.

Tab. 5.19: *Fishing Rod CTD casts at L and M sites during MOSAiC Leg 3. At each position one profile was recorded with CTD SN#1495*

CTD station number	Date	Coordinates	Depth, m	Location
33_24	24.03.2020	86˚11.369'N/15˚28.301'E	200	L2 site
33_25		86˚11.284'N/15˚25.640'E		L1 site, close to the ridge
37_71	24.04.2020	84˚03.086'N/15˚53.226'E	220	L1 site
37_72		84˚02.966'N/15˚52.595'E		L2 site
37_73		84˚02.847'N/15˚52.013'E		L3 site
37_119	26.04.2020	83˚55.282'N/15˚30.439'E	250	M3 site

37_120		83˚55.151'N/15˚30.754'E		M5 site
38_101	02.05.2020	83˚54.191'N/17˚34.172'E		M1 site
38_102		83˚54.049'N/17˚34.200'E		near M4
38_103		83˚53.924'N/17˚34.289'E		M6 site

Data recovery at L1 (PI: Richard Krishfield, WHOI)

Since data from the IPT at L1 stopped data transmission during leg 2, we tried to download data from the ITP at site on April 8. We managed to reach the data cable (making a hole into the styrofam (Figure 5.25) and could connect to the data recorder with our toughbook. Still, mounting failed and we were not able to download data. However, the ITP started sending data back home to *Woodshole* again shortly after our visit.

Fig. 5.25: *Surface unit of the ITP at L1 (left) and data cable digged out of the styrofoam.*

Recovery of FIO fixed-layer buoy from L1

The FIO fixed-layer buoy was deployed on October 5, 2019. This buoy carries four CT sensors which are at the depth of 10, 20, 50, 200 m. And one CTD sensor at 100 m. Due to the satellite communication problem, the buoy did not transmit data anymore. So, we decided to recovery it in Leg 3. The recovery activity happened on May 4 and the coordinates of the buoy is about 83°45′N, 19°28′E. Sea ice thickness around the buoy was more than 2 m, which led to a whole day of recovery activity. At last, all parts of the buoy were recovered at 15:00 UTC.

Fig. 5.26*: FIO fixed-layer buoy recovery.*

Lead measurements

We investigated the lead at the stern side of the Polarstern. It opened and closed several times during leg 3. At the beginning, the set up was tested at the lead opened between Balloon Town and Dark site on 23-03-2020. At the stern lead measurements were performed at the four main ice hole (in order from the open part of the lead): open lead part, refrozen part of the lead (50-80 cm ice thickness), ADCP ice hole separated from the lead with the ridge (ice thickness 2.5 m), mechanics ice hole close to the ROV tent (ice thickness 1.5 m) (Figure 5.27). In total, 3 main lead experiments were performed. Description of dataset is in Table 5.20. The profiles are shown in the preliminary analyses (below).

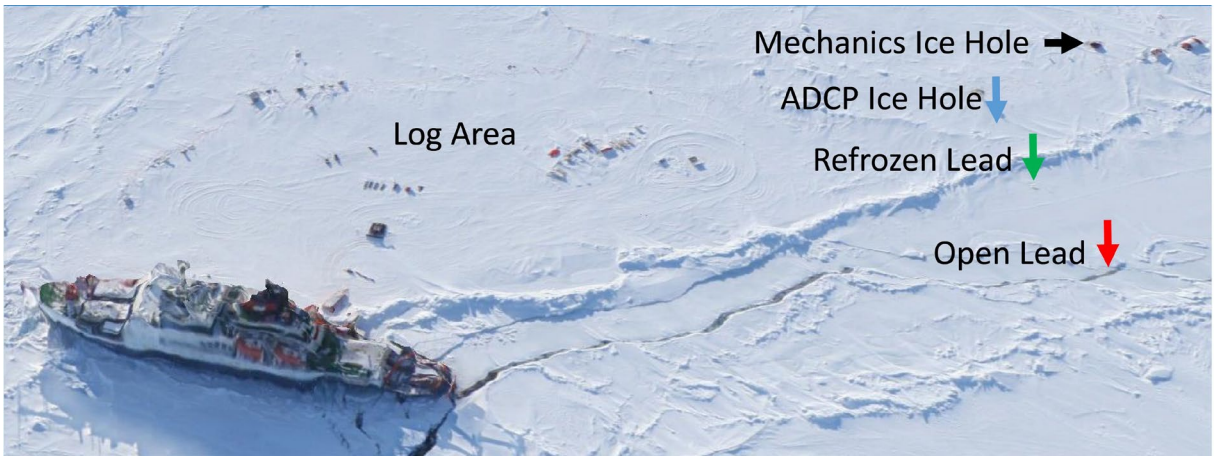

Fig. 5.27: *Positions of ice holes for lead investigation (photo from Manuel Ernst).*

Tab. 5.20: *Fishing Rod CTD casts carried out for lead sampling during MOSAiC Leg 3 with CTD SN#1495*

CTD sta-tion	Date	Coordinates	Pro-files, CTD SN	Depth in m	Location
33_3	23.03.2020	86˚12.600‘N/15˚48.448‘E	1, # 1495	200	Lead between Balloon Town and Dark Site
33_4			1, # 1459		
33_5		86˚12.575‘N/15˚48.279‘E	1, # 1459	200	ca. 5 m from the Lead between Balloon Town and Dark Site
36_56	16.04.2020	86˚19.013‘N/13˚07.891‘E	1, # 1459	200	Stern Lead, Mechanics Ice Hole
36_89	17.04.2020	84˚25.070’N/13˚41.684’E	1, # 1459	220	ADCP Ice Hole
36_90		84˚25.206’N/13˚42.700’E			Refrozen Stern Lead
36_91		84˚25.468’N/13˚44.663’E			Mechanics Ice Hole
38_10	28.04.2020	83˚56.004’N/15˚38.038’E	1, # 1459	220	Open Stern Lead
38_11			5, # 1459	20	

38_12		83˚56.207'N/15˚38.674'E	1, # 1495	2	
38_13		83˚56.217'N/15˚38.713'E	4, # 1459	20	Refrozen Stern Lead
38_14		83˚56.425'N/15˚39.403'E			ADCP Ice Hole
38_15		83˚56.566'N/15˚39.942'E	2, # 1459		Open Stern Lead

In addition to carrying out fishing rod CTD profiles, we aimed to measure dissipation rates of kinetic energy with the MSS and ocean currents with a 600kHz-ADCP. The ADCP was deployed in a hole next to the refrozen lead (Figure 5.27, ADCP hole, and Figure 5.28) aiming to measure the circulation for future events when the lead would open up again. However, after recording data for 2 days and checking its quality, we discovered that one beam of the ADCP did not work properly and thus the data could not be used. We did not find a fix for the problem. The instrument has been sent home after leg 3.

For measuring dissipation rates, we tested the self-recording MSS46 provided by IOW. Since this is still a prototype, we needed to overcome many problems before the first deployment. After 1.5 profiles carried out in the hole of the refrozen lead (Figures 5.27 and 5.28) communication failed. We did not manage to run the MSS in an operational mode. If time would have allowed, MSS and ADCP regularly used in Ocean City could have been used for our lead experiment. However, due to a lack of time this has not been realized during leg 3.

Fig. 5.28: *ADCP hole and MSS46 deployment in the hole of the refrozen lead at the stern of Polarstern (map in Figure 5.27)*

Installations from Team OCEAN left on the MOSAiC floe after leg 3 (DN not included)

Polarstern left the MOSAiC floe on May 16 for the exchange of people from leg 3 to leg 4 in Svalbard. The following installations from team OCEAN remained in the CO:

- the UiB Cluster mooring (Figure 5.18) belonging to the ARMOA project by Ilker Fer,
- one ADCP and one CTD (Figure 5.21) at Fort Ridge belonging to the HAVOC project by Mats Granskog,
- two GPS and one thermistor chain buoy at Fort Ridge belonging to a project lead by Yusuke Kawaguchi (see cruise report from leg 2), and
- one Aural acoustic recorder (PI: Olaf Boebel) and one Microcat CTD chain (PI: Benjamin Rabe) at the Dark Site (see cruise reports from leg 1 and 2).

Preliminary results

Hydrographic properties and enhanced dissipation rates measured during leg 3

Our drift track shows that we started off in the Amundsen Basin and crossed the Gakkel Ridge in the end of March at about 85.5°N (Figures 5.1). We continued to drift further south into the Nansen Basin where we expect hydrographic properties to be largely influenced by waters of Atlantic origin as observed. CTD profiles taken in Ocean City reveal a shift towards more saline and warmer Atlantic water properties (found between about 200 and 800 m) during the leg 3 drift (Figure 5.29 and 5.30). At the same time salinities in the mixed layer increased from about 32.7 end of February to 34.3 in beginning of May. Both, more saline mixed layer properties and a warmer Atlantic water layer are indicative for a transition to Atlantic water properties as expected to find in the Nansen Basin.

At the same time, we found a deepening of the mixed layer and a steeper slope of the thermocline evolving throughout the leg 3 drift (Figure 5.31). A first thickening of the mixed layer from about 53 +/- 10 m in March to 74 +/- 5 m between 5th and 22nd April may be related to our drift into the Nansen Basin. A second strong increase in mixed layer depth occurred in mid-April after a strong storm (driving enhanced dissipation rates of kinetic energy throughout the entire mixed layer) passed the MOSAiC flow on April 21 (Figures 5.29 and 5.31). Subsequently, we observed mixed layer depth of 115 +/- 6 m between April 28 and May 7.

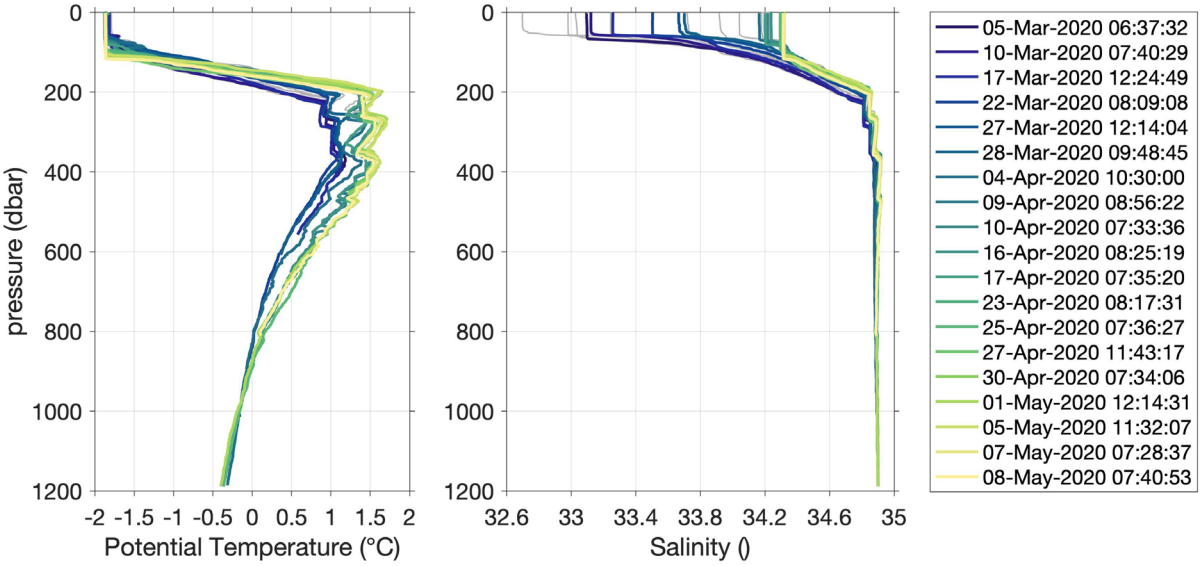

Fig. 5.29: *Potential temperature (left) and salinity (right) profiles collected during leg 3 with the CTD in Ocean City. Color indicated the evolution in time with all colored profiles deployed deeper than 350 m. Grey profiles were shallower 350 m.*

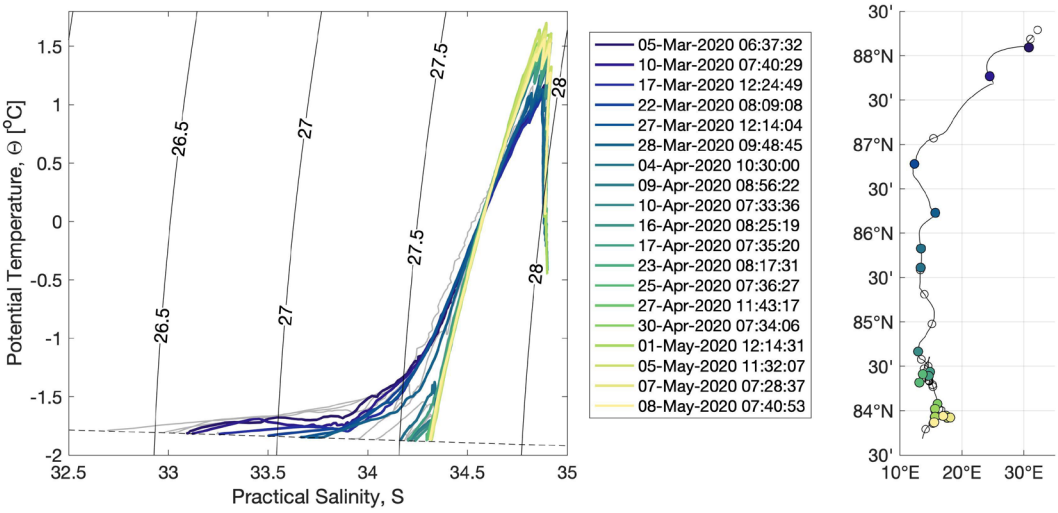

Fig. 5.30: *TS-diagram and geographical position along the leg 3 drift for the profiles shown in Figure 5.29 (using the same colorbar).*

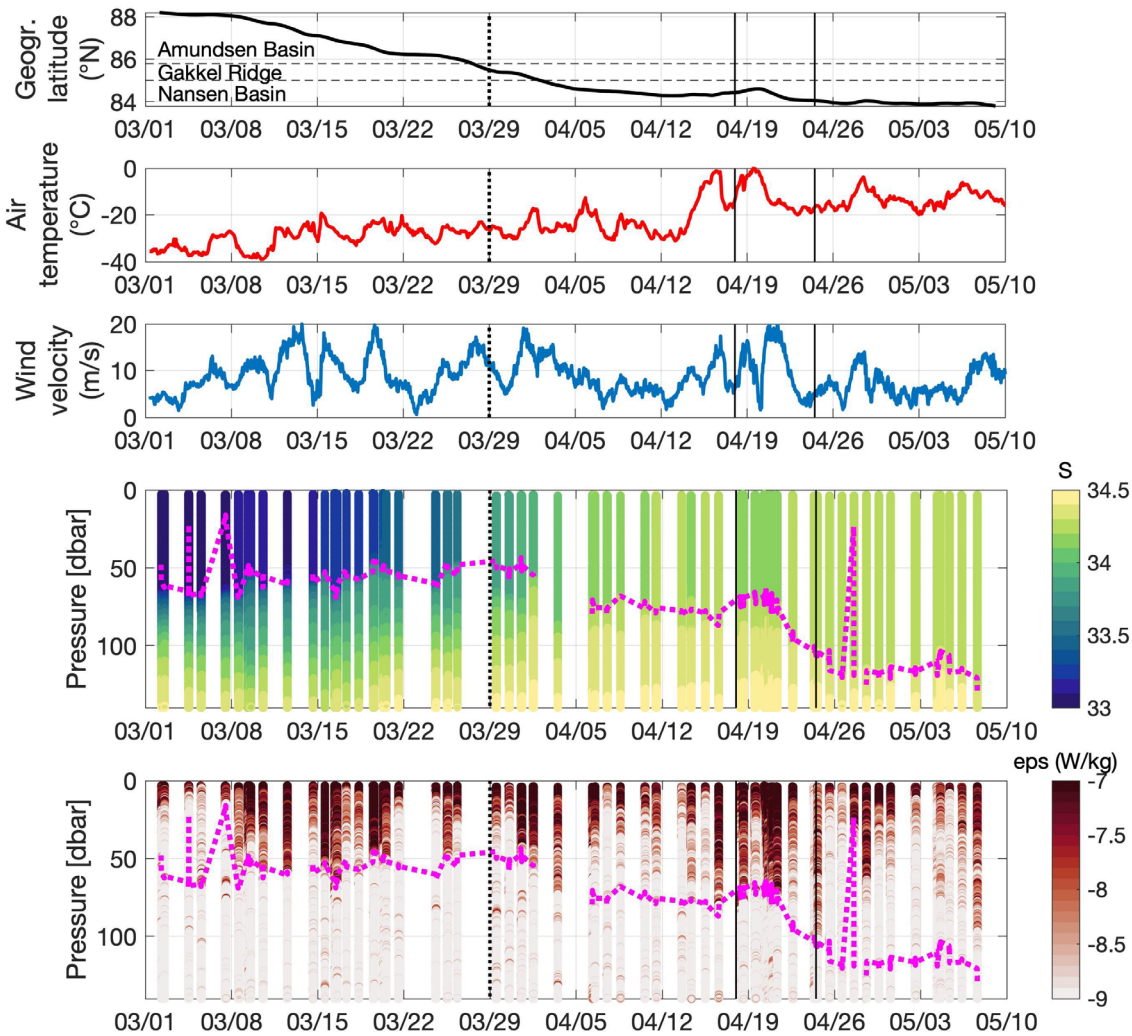

Fig. 5.31: *From top to bottom: Position (Latitude), air temperatures, wind speeds, and salinities and dissipation rates in the upper 150 m measured with the MSS during MOSAiC leg 3. Marked are the time of crossing Gakkel ridge (black dotted line), the time period around April 21 when a storm passed the floe (black lines), and the mixed layer depth (pink dotted line).*

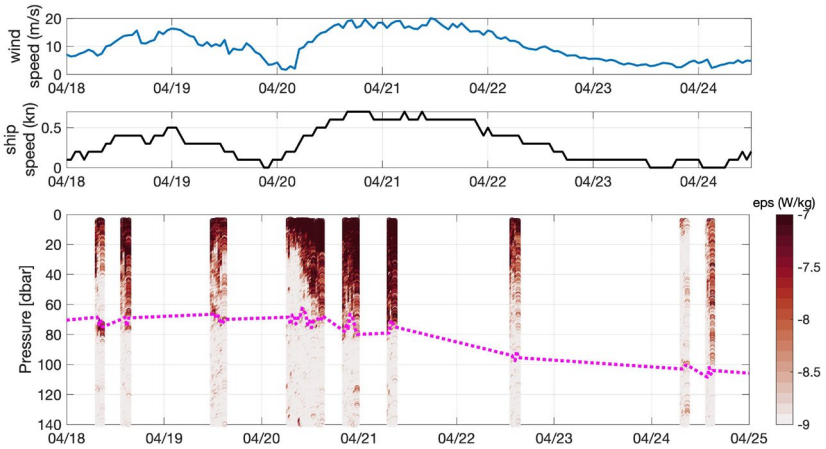

Fig. 5.32: *Wind speeds (top), drift speeds (middle), and dissipation rates (bottom) measured before, during and after a storm passing the MOSAiC floe on April 21.*

Figure 5.32 illustrates the simultaneous increase in wind speeds, drift speed of the floe, and enhanced dissipation rates reaching increasingly down to the base of the mixed layer on April 20. Dissipation rates remain enhanced over the entire depth of the mixed layer during the storm but decrease completely once the wind calms down to wind speeds close to zero on April 24. We believe that the enhanced turbulence triggered by the storm can be explained as follows: enhance wind velocities drive a faster ice drift. In turn, the water below the is dragged away as well. This will trigger strong velocity gradients in the upper water column. The combination of a strong vertical velocity gradient and a weakly stratified mixed layer will lead to Kelvin-Helmholtz instabilities driving enhanced turbulence in the mixed layer.

Evolution of the mixed layer depth (leg 1 to leg 3)

A comparison of hydrographic measurements carried out throughout the MOSAiC drift from beginning of November 2019 until the beginning of May 2020 (leg 1 to leg 3) based on CTD profiles in Ocean City shows reveals first indications of seasonal variations. During the entire drift from November until late March measurements were carried out within the inner part of Amundsen basin, i.e., in a quiescent environment (far away from boundary current dynamics). Mixed layer depths were shallowest at the beginning of the drift, i.e. before the onset of winter (Figures 5.33 and 5.34). Freshest surface waters with mean salinities in the mixed layer of 31.5 were observed in mid-January (Figure 5.34). Throughout February and March, the temperature gradient between the mixed layer and the underlying Atlantic water weakens. At the same time, the mixed layer depth increases from 28 +/- 7 m between Nov 1 and Feb 1 to 59 +/- 4 m in March. Increased surface salinities and warmer Atlantic waters are prominent in April and May since we drifted into the Nansen basin.

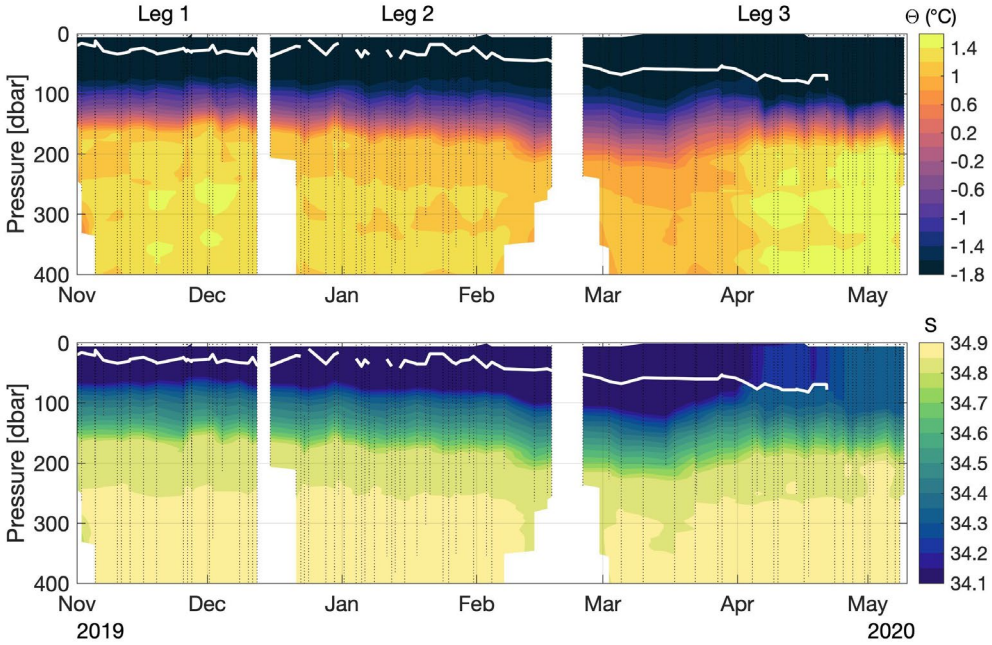

Fig. 5.33: *Top panel: Potential temperature (left) and salinity (right) section interpolated based on Ocean City CTD profiles collected during legs 1, 2 and 3. The white line indicates the mixed layer depth. Black dotted lines indicate the timing and deployment depth of each profile.*

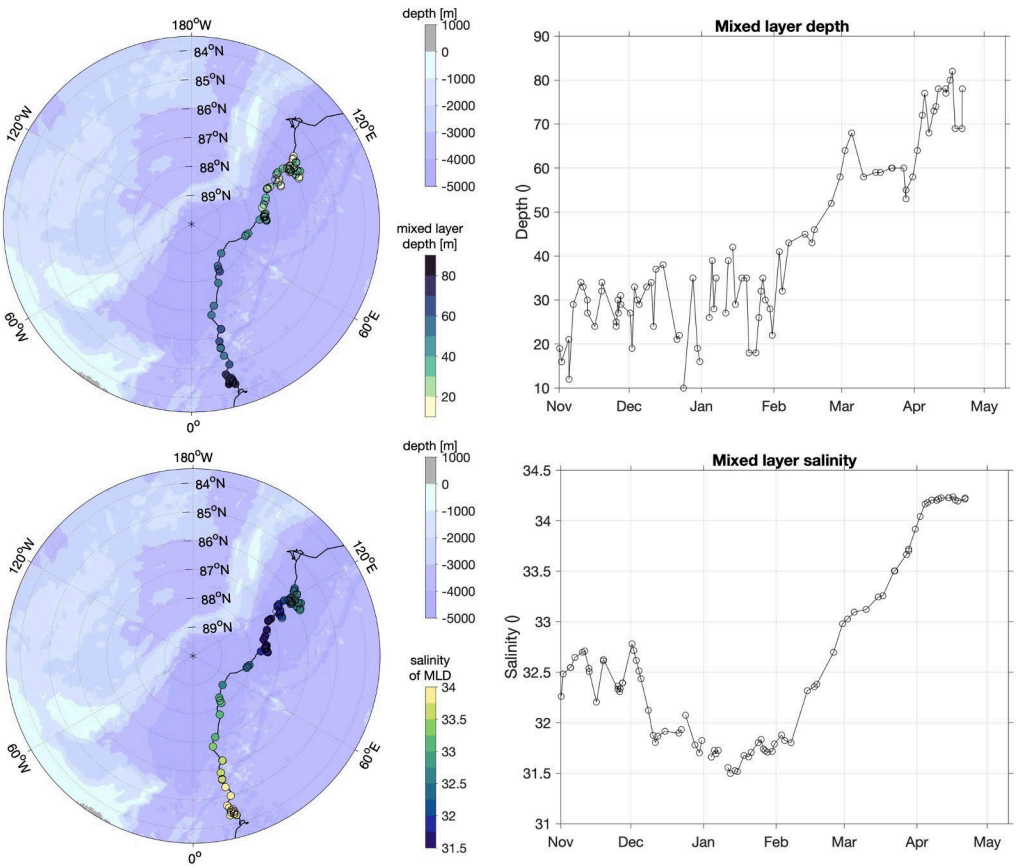

Fig. 5.34: *Top panel: Mixed layer depth computed based on Ocean City CTD profiles collected during legs 1, 2 and 3 and plotted along the MOSAiC drift track (left) and time (right). Bottom panel: Mean salinity in the mixed layer along the drift trach (left) and time (right).*

Ocean currents along the drift track of leg 3 (VMADCP)

Processing of MOSAiC Leg 3 VMADCP data was carried out with the Matlab® ADCP toolbox by GEOMAR. VMADCP data indicates that the current speeds during Leg 3 were typically <0.1 m/s, with occasionally stronger currents peaking at ~0.2 m/s. Figure 5.35 depicts the current velocity time series of March. First analysis point to the occurrence of internal waves at the inertial period, visible especially at the end of March. A comparison of wind directions and ocean currents averaged over 20-70 m (i.e., covering the mean mixed layer depth) indicates that the upper ocean generally follows the winds (Figure 5.36) based on Ekman dynamics. Current velocities are clearly enhanced around March 19, April 20, and May 13 when storm systems passed the MOSAiC floe.

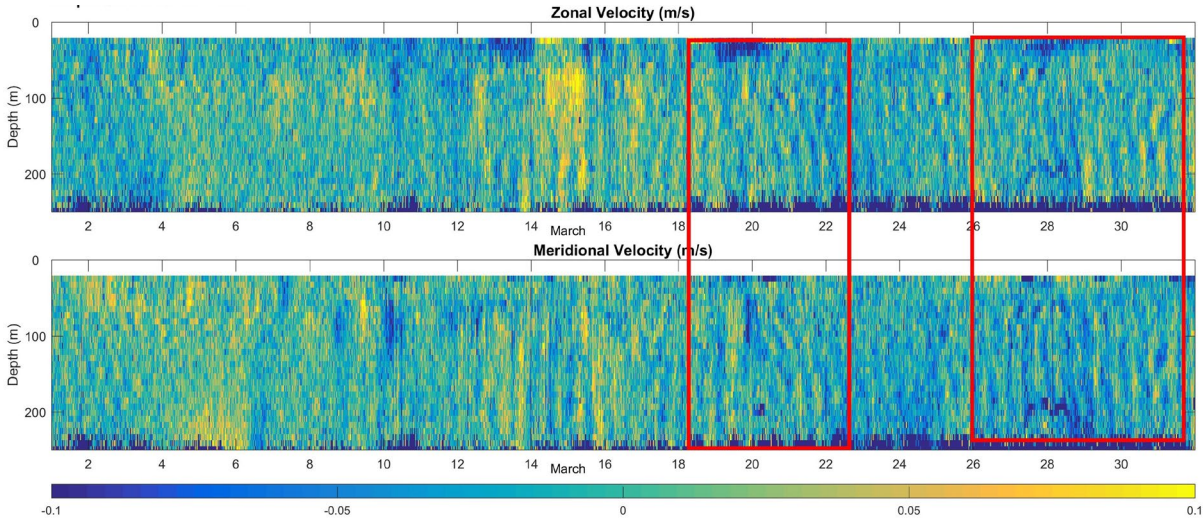

***Fig. 5.35**: Ocean velocity components (top: in East-West direction, bottom: in North-South direction) recorded by the 150 kHz VMADCP below Polarstern in March 2020. The red boxes indicate patterns of internal waves at the inertial period.*

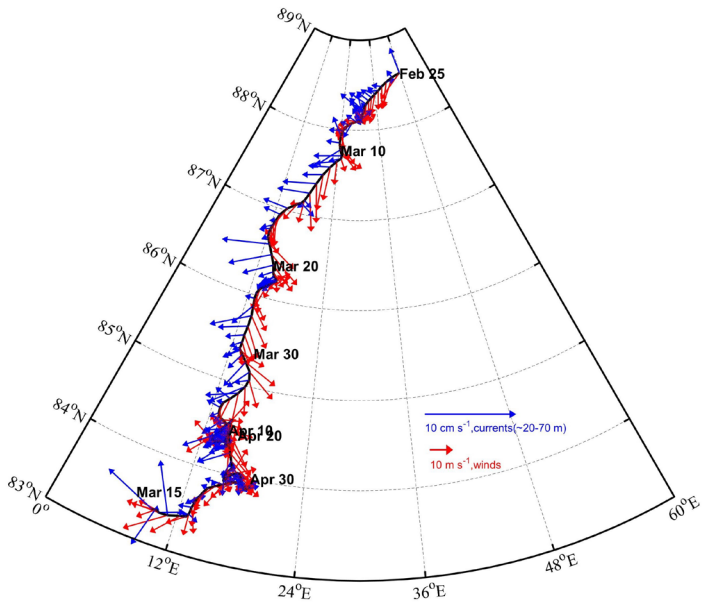

***Fig. 5.36:** Ocean currents in the mixed layer (averaged over 20-70 m, blue vectors) and the winds (red vectors) along the MOSAiC drift between 24 February and 16 May. Black line denotes the drifting trajectory.*

Particle volume concentrations in April (LISST)

The particle volume concentration distribution of suspended particulate matter captured by the LISST is shown in Figure 5.37. The data reveal that the average level of total particle volume concentration in the water column exceeded 1 µl/l and the particles are evenly distributed throughout the entire depth profile from the surface down to 800 m on 1 April. The results imply that the particle concentration in the early Arctic spring was about an order of magnitude higher than that in the winter. This is expected as the biota becomes more active again mainly because of the light reappearing in the high latitude central Arctic Ocean.

On April 22, particles suspended in the water show an average of total particle volume concentration exceeding 2.4 µl/l (Figure 5.37, right). Compared to early April the suspended particles have more than doubled throughout the first three weeks in April. Higher values mainly occur in the upper layer (< 200m) which may be indicative for an increased phytoplankton biomass density in the upper water column.

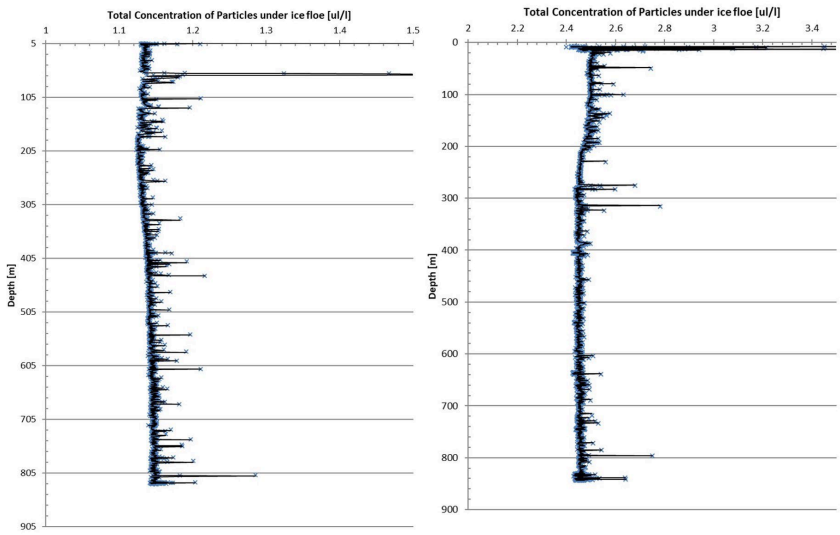

Fig. 5.37: *Profile of total particle volume concentration distribution performed on 1st April (left) and 22 April (right).*

Hydrographic profiles at L and M-sites

Preliminary analysis of the fishing-rod CTD profiles collected at L- and M-sites shows the temporal and spatial changes in the water masses' properties in the upper ocean (Figure 5.38). Data from the upper 5 m showing high salinity and temperature gradients should be used with care. We believe that these data were caused by measuring through our drilled ice hole in which the water started to refreeze during profiling with the fishing rod CTD.

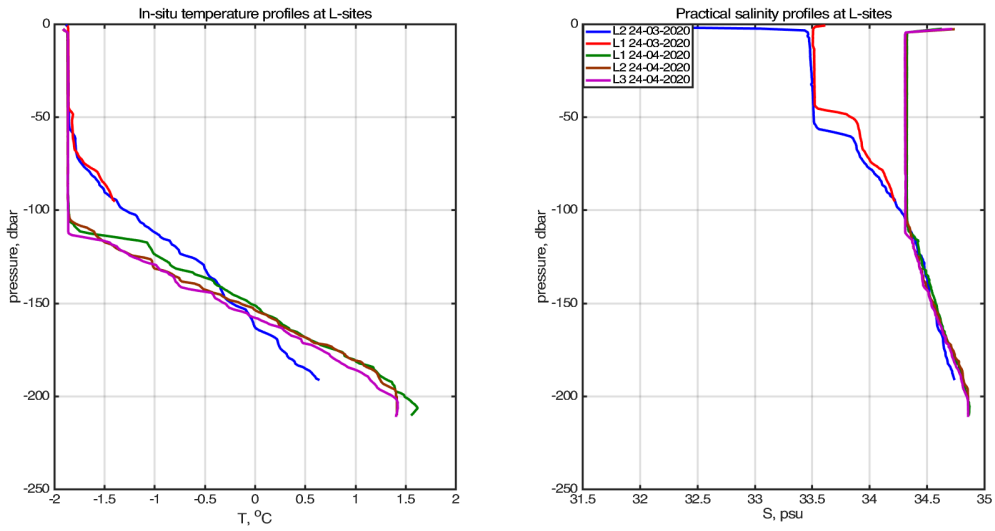

Fig. 5.38: *Overview of temperature and salinity profiles collected at L1, L2 and L3 sites on 24.03.2020 and 24.04.2020.*

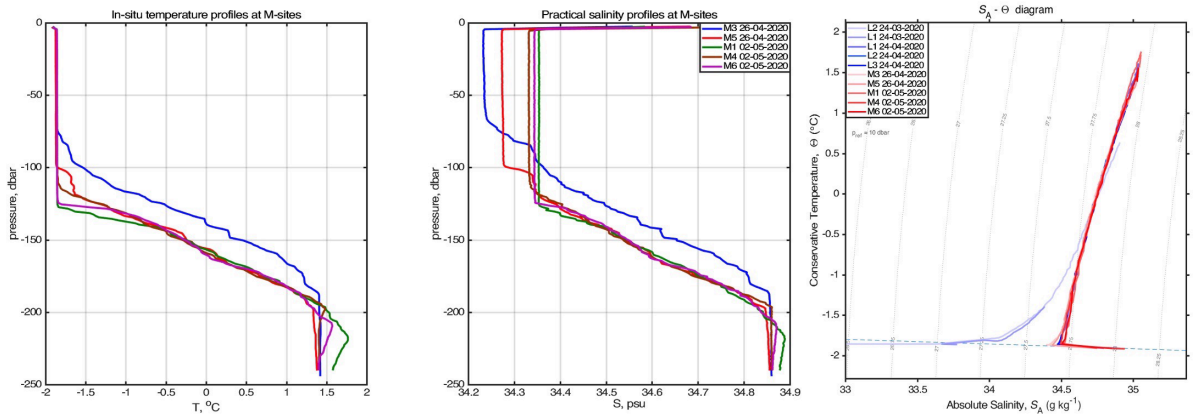

Fig. 5.39: *Overview of temperature (left) and salinity (middle) profiles collected at M1, M3, M4, M4 and M6 sites on 26.04.2020 and 02.05.2020. Right: Overview of TS properties of water masses at L- and M-sites.*

Hydrographic profiles at the stern lead

Figure 5.40 nicely illustrates different hydrographic properties measured in open and refrozen parts of the stern lead, compared to properties measured through holes further apart from the lead (see map in Figure 5.27).

Hydrographic profiles recorded with the fishing rod CTD on the Yermak Plateau

During the transit to Svalbard, 3 CTD profiles were performed with the fishing rod CTD in the area of the Yermak Plateau (Figure 5.41). Profiles were made from Polarsterns' stern while the ship engines were stopped. The first profile was carried out in the evening of May 26. Stations numbers were changed in d-ship system afterwards due to problems with software (Table 5.18). Two more profiles were collected on 27.05.2020. Profiling down to 800 m caused compression of the buoyancy rings. Datasets are stored at the \\mcs.fs-polarstern.de\platforms\pack_ice\ice_ps\ctd_48m_1459.

According to our measurements freshening of the mixed layer is observed. This might be caused by general circulation of permanent currents in the regions or by ice melting.

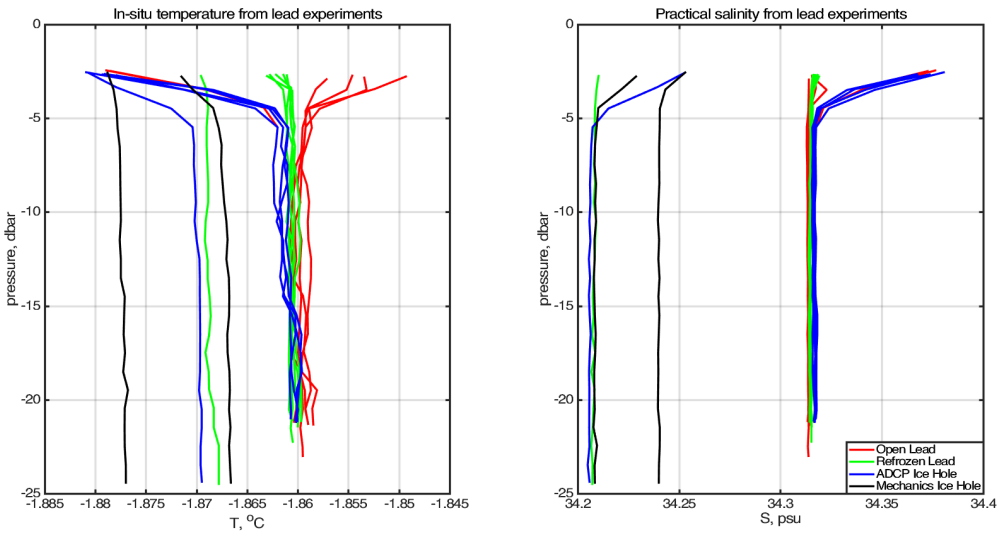

Fig. 5.40: *Overview of temperature and salinity profiles during stern lead investigation.*

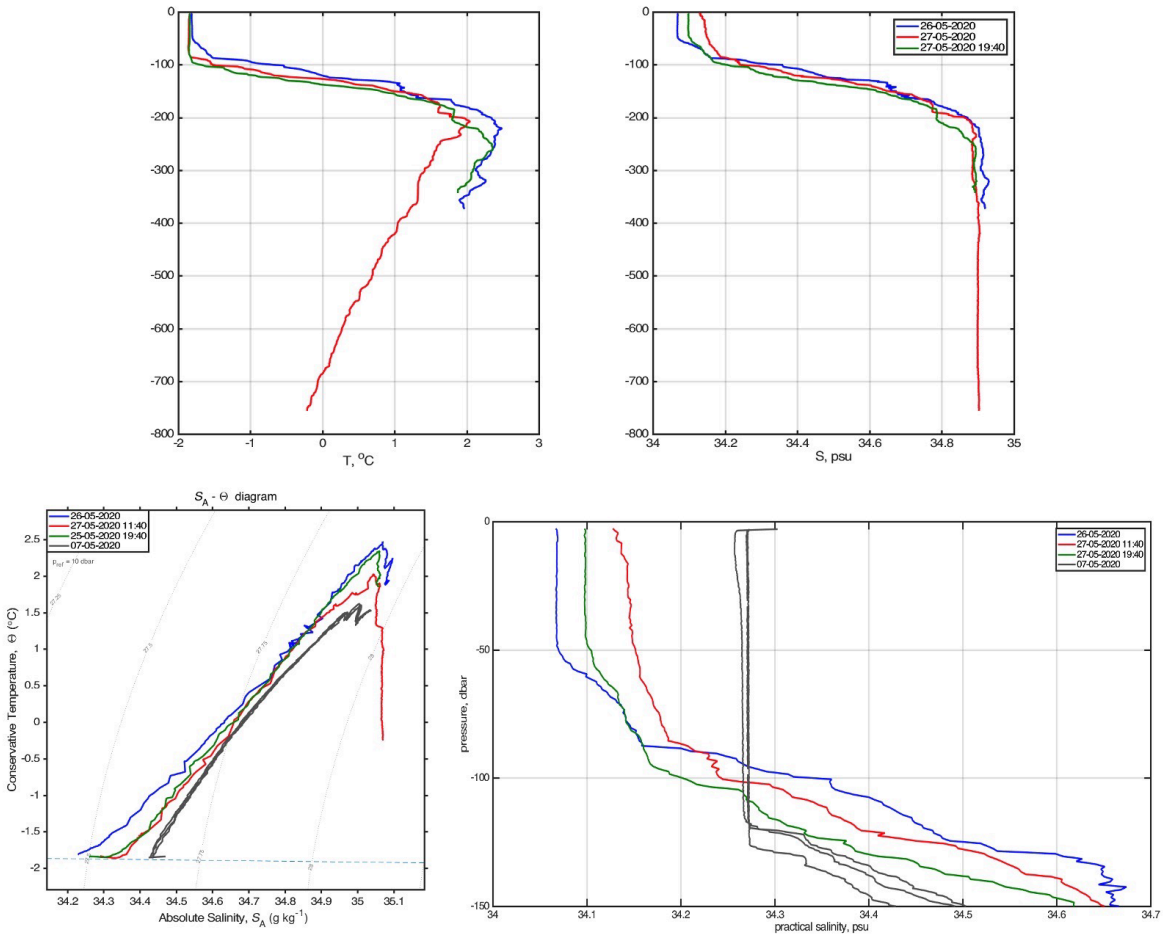

Fig. 5.41: *Top panel: Temperature and salinity profiles collected on the Yermak Plateau on 26.05.2020 and 27.05.2020. Bottom panel: T-S properties (left) and salinity profiles (right) on the Yermak Plateau compared to measurements from the MOSAiC floe on 07.05.2020.*

Data management

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

References

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Appendix

Tab. 5.21: *CTD casts using the ship-based CTD/Rosette system from Polarstern.*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_30-53	2020-03-06	11:07	CTD AWI-OZE	station start	88° 06.059' N	029° 38.042' E	4230.9
PS122/3_30-53	2020-03-06	11:08	CTD AWI-OZE	in the water	88° 06.059' N	029° 38.003' E	4244.3
PS122/3_30-53	2020-03-06	11:14	CTD AWI-OZE	lowering	88° 06.059' N	029° 37.183' E	4226.1
PS122/3_30-53	2020-03-06	12:46	CTD AWI-OZE	max depth/on ground	88° 06.023' N	029° 25.710' E	4228.2
PS122/3_30-53	2020-03-06	12:48	CTD AWI-OZE	hoisting	88° 06.022' N	029° 25.461' E	4249.0
PS122/3_30-53	2020-03-06	14:50	CTD AWI-OZE	on deck	88° 05.919' N	029° 11.235' E	4234.9
PS122/3_30-64	2020-03-07	6:30	CTD AWI-OZE	in the water	88° 04.641' N	027° 17.615' E	4414.1
PS122/3_30-64	2020-03-07	6:30	CTD AWI-OZE	lowering	88° 04.640' N	027° 17.566' E	4414.1
PS122/3_30-64	2020-03-07	6:48	CTD AWI-OZE	max depth/on ground	88° 04.611' N	027° 15.611' E	4414.2
PS122/3_30-64	2020-03-07	6:50	CTD AWI-OZE	hoisting	88° 04.607' N	027° 15.355' E	4414.3
PS122/3_30-64	2020-03-07	7:11	CTD AWI-OZE	at surface	88° 04.570' N	027° 13.025' E	4414.4
PS122/3_30-64	2020-03-07	7:25	CTD AWI-OZE	on deck	88° 04.547' N	027° 11.515' E	4414.5
PS122/3_31-39	2020-03-12	7:11	CTD AWI-OZE	in the water	87° 33.849' N	022° 04.777' E	4415.9
PS122/3_31-39	2020-03-12	7:13	CTD AWI-OZE	lowering	87° 33.840' N	022° 04.615' E	4415.9
PS122/3_31-39	2020-03-12	7:29	CTD AWI-OZE	max depth/on ground	87° 33.714' N	022° 02.506' E	4415.8
PS122/3_31-39	2020-03-12	7:30	CTD AWI-OZE	hoisting	87° 33.705' N	022° 02.352' E	4415.8
PS122/3_31-39	2020-03-12	7:58	CTD AWI-OZE	at surface	87° 33.495' N	021° 58.863' E	4415.8
PS122/3_31-39	2020-03-12	8:09	CTD AWI-OZE	on deck	87° 33.415' N	021° 57.568' E	4415.7
PS122/3_31-59	2020-03-14	6:49	CTD AWI-OZE	station start	87° 08.890' N	017° 25.743' E	4029.2
PS122/3_31-59	2020-03-14	6:55	CTD AWI-OZE	in the water	87° 08.871' N	017° 25.432' E	4033.4
PS122/3_31-59	2020-03-14	7:01	CTD AWI-OZE	lowering	87° 08.853' N	017° 25.101' E	4040.7
PS122/3_31-59	2020-03-14	8:28	CTD AWI-OZE	max depth/on ground	87° 08.634' N	017° 20.483' E	4145.4

PS122/3_31-59	2020-03-14	8:30	CTD AWI-OZE	hoisting	87° 08.629' N	017° 20.369' E	4184.9
PS122/3_31-59	2020-03-14	10:29	CTD AWI-OZE	on deck	87° 08.309' N	017° 14.778' E	4398.3
PS122/3_31-63	2020-03-14	12:37	CTD AWI-OZE	in the water	87° 07.930' N	017° 08.266' E	4399.2
PS122/3_31-63	2020-03-14	12:39	CTD AWI-OZE	lowering	87° 07.927' N	017° 08.214' E	4399.3
PS122/3_31-63	2020-03-14	13:00	CTD AWI-OZE	max depth/on ground	87° 07.864' N	017° 07.114' E	4399.3
PS122/3_31-63	2020-03-14	13:03	CTD AWI-OZE	hoisting	87° 07.857' N	017° 06.988' E	4399.3
PS122/3_31-63	2020-03-14	13:33	CTD AWI-OZE	on deck	87° 07.779' N	017° 05.586' E	4399.7
PS122/3_40-36	2020-05-16	10:44	CTD AWI-OZE	station start	83° 23.511' N	009° 06.694' E	4084.5
PS122/3_40-36	2020-05-16	12:43	CTD AWI-OZE	in the water	83° 23.478' N	009° 06.664' E	4084.5
PS122/3_40-36	2020-05-16	12:45	CTD AWI-OZE	lowering	83° 23.477' N	009° 06.662' E	4084.5
PS122/3_40-36	2020-05-16	12:50	CTD AWI-OZE	profile start	83° 23.475' N	009° 06.659' E	4084.5
PS122/3_40-36	2020-05-16	14:09	CTD AWI-OZE	max depth/on ground	83° 23.439' N	009° 06.579' E	4084.8
PS122/3_40-36	2020-05-16	15:55	CTD AWI-OZE	profile end	83° 23.375' N	009° 06.431' E	4084.7
PS122/3_40-36	2020-05-16	15:57	CTD AWI-OZE	on deck	83° 23.374' N	009° 06.430' E	4084.7
PS122/3_42-32	2020-05-30	8:57	CTD AWI-OZE	station start	81° 56.627' N	009° 23.336' E	807.5
PS122/3_42-32	2020-05-30	9:03	CTD AWI-OZE	in the water	81° 56.617' N	009° 23.474' E	807.7
PS122/3_42-32	2020-05-30	9:03	CTD AWI-OZE	lowering	81° 56.616' N	009° 23.481' E	807.9
PS122/3_42-32	2020-05-30	9:39	CTD AWI-OZE	max depth/on ground	81° 56.553' N	009° 24.283' E	809.3
PS122/3_42-32	2020-05-30	9:40	CTD AWI-OZE	hoisting	81° 56.552' N	009° 24.295' E	809.4
PS122/3_42-32	2020-05-30	10:20	CTD AWI-OZE	station end	81° 56.473' N	009° 25.143' E	811.9
PS122/3_42-32	2020-05-30	10:20	CTD AWI-OZE	station end	81° 56.472' N	009° 25.150' E	811.9

Tab. 5.22: *CTD casts in Ocean City*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_29-8	2020-02-25	12:23	Ocean City CTD	deployed	88° 33.597' N	045° 39.081' E	4414.4
PS122/3_29-74	2020-02-29	6:45	Ocean City CTD	deployed	88° 17.374' N	032° 14.069' E	4415.8
PS122/3_30-9	2020-03-02	11:34	Ocean City CTD	deployed	88° 11.204' N	031° 04.666' E	4416.2
PS122/3_30-38	2020-03-05	6:25	Ocean City CTD	deployed	88° 05.446' N	030° 48.292' E	4415.1
PS122/3_30-40	2020-03-05	10:33	Ocean City CTD	deployed	88° 05.553' N	030° 49.203' E	4415.3
PS122/3_30-41	2020-03-05	11:14	Ocean City CTD	deployed	88° 05.573' N	030° 49.212' E	4415.3
PS122/3_31-18	2020-03-10	7:44	Ocean City CTD	deployed	87° 45.967' N	024° 29.151' E	4415.6
PS122/3_31-19	2020-03-10	11:17	Ocean City CTD	deployed	87° 44.637' N	024° 38.764' E	4416.6
PS122/3_31-81	2020-03-15	11:22	Ocean City CTD	deployed	87° 04.149' N	015° 22.809' E	4401.2
PS122/3_32-12	2020-03-17	12:26	Ocean City CTD	deployed	86° 46.722' N	012° 18.061' E	4397.2
PS122/3_32-38	2020-03-19	8:20	Ocean City CTD	information	86° 34.217' N	013° 02.705' E	4619.6
PS122/3_32-75	2020-03-22	8:24	Ocean City CTD	deployed	86° 13.753' N	015° 41.238' E	3271.7
PS122/3_32-76	2020-03-22	12:03	Ocean City CTD	deployed	86° 13.620' N	015° 43.425' E	3221.8
PS122/3_32-77	2020-03-22	13:41	Ocean City CTD	deployed	86° 13.583' N	015° 44.579' E	3147.1
PS122/3_33-69	2020-03-27	12:20	Ocean City CTD	deployed	85° 49.625' N	013° 22.905' E	3509.2
PS122/3_33-70	2020-03-27	14:33	Ocean City CTD	deployed	85° 48.279' N	013° 24.052' E	3482.0
PS122/3_33-71	2020-03-27	15:10	Ocean City CTD	deployed	85° 47.906' N	013° 24.499' E	3412.1
PS122/3_33-80	2020-03-28	9:54	Ocean City CTD	deployed	85° 36.641' N	013° 18.387' E	2661.9
PS122/3_33-82	2020-03-28	12:35	Ocean City CTD	deployed	85° 35.110' N	013° 14.867' E	2758.9

PS122/3_34-17	2020-03-31	9:45	Ocean City CTD	deployed	85° 18.697' N	013° 55.527' E	4609.7
PS122/3_34-38	2020-04-02	7:52	Ocean City CTD	deployed	84° 58.586' N	015° 09.017' E	3040.1
PS122/3_34-64	2020-04-04	8:15	Ocean City CTD	deployed	84° 40.737' N	012° 53.328' E	1791.2
PS122/3_34-65	2020-04-04	9:23	Ocean City CTD	deployed	84° 40.398' N	012° 53.411' E	0.0
PS122/3_34-66	2020-04-04	9:41	Ocean City CTD	deployed	84° 40.316' N	012° 53.466' E	0.0
PS122/3_34-67	2020-04-04	10:49	Ocean City CTD	deployed	84° 39.983' N	012° 53.812' E	3563.6
PS122/3_34-76	2020-04-05	11:39	Ocean City CTD	deployed	84° 34.710' N	013° 24.430' E	3625.1
PS122/3_34-77	2020-04-05	13:59	Ocean City CTD	deployed	84° 34.578' N	013° 31.326' E	3491.1
PS122/3_35-25	2020-04-07	7:55	Ocean City CTD	deployed	84° 30.154' N	014° 32.062' E	2922.5
PS122/3_35-60	2020-04-09	7:41	Ocean City CTD	deployed	84° 26.423' N	014° 50.751' E	4060.2
PS122/3_35-61	2020-04-09	8:09	Ocean City CTD	deployed	84° 26.348' N	014° 50.471' E	4060.2
PS122/3_35-62	2020-04-09	8:29	Ocean City CTD	deployed	84° 26.296' N	014° 50.265' E	4060.1
PS122/3_35-63	2020-04-09	8:59	Ocean City CTD	deployed	84° 26.209' N	014° 49.914' E	4060.1
PS122/3_35-77	2020-04-10	7:35	Ocean City CTD	deployed	84° 23.512' N	014° 39.164' E	4061.8
PS122/3_35-92	2020-04-11	8:10	Ocean City CTD	deployed	84° 19.889' N	014° 44.949' E	4061.7
PS122/3_36-17	2020-04-14	11:35	Ocean City CTD	deployed	84° 20.324' N	014° 40.450' E	4062.9
PS122/3_36-18	2020-04-14	12:50	Ocean City CTD	deployed	84° 20.430' N	014° 36.980' E	4063.6
PS122/3_36-19	2020-04-14	13:05	Ocean City CTD	deployed	84° 20.444' N	014° 36.319' E	4063.7
PS122/3_36-59	2020-04-16	8:26	Ocean City CTD	deployed	84° 19.031' N	013° 07.813' E	3758.9
PS122/3_36-81	2020-04-17	7:15	Ocean City CTD	deployed	84° 24.715' N	013° 39.352' E	3956.3
PS122/3_36-83	2020-04-17	9:25	Ocean City CTD	deployed	84° 24.758' N	013° 40.828' E	3953.1
PS122/3_36-84	2020-04-17	10:00	Ocean City CTD	deployed	84° 24.800' N	013° 40.963' E	3951.9
PS122/3_36-85	2020-04-17	10:00	Ocean City CTD	deployed	84° 24.801' N	013° 40.964' E	3951.9
PS122/3_36-115	2020-04-18	11:36	Ocean City CTD	deployed	84° 28.276' N	013° 51.072' E	3250.1
PS122/3_37-14	2020-04-21	12:02	Ocean City CTD	deployed	84° 17.494' N	015° 14.376' E	3904.3
PS122/3_37-15	2020-04-21	13:57	Ocean City CTD	deployed	84° 16.361' N	015° 18.819' E	3778.4
PS122/3_37-45	2020-04-23	8:02	Ocean City CTD	deployed	84° 04.618' N	016° 03.393' E	4069.9
PS122/3_37-46	2020-04-23	8:02	Ocean City CTD	deployed	84° 04.618' N	016° 03.392' E	4069.9
PS122/3_37-47	2020-04-23	10:48	Ocean City CTD	deployed	84° 04.415' N	016° 02.046' E	4070.1
PS122/3_37-88	2020-04-25	7:17	Ocean City CTD	deployed	84° 01.159' N	015° 38.989' E	4069.0
PS122/3_37-99	2020-04-25	11:59	Ocean City CTD	deployed	84° 00.024' N	015° 35.362' E	4068.4
PS122/3_37-116	2020-04-26	11:28	Ocean City CTD	deployed	83° 55.652' N	015° 30.581' E	4072.4
PS122/3_38-5	2020-04-27	11:41	Ocean City CTD	deployed	83° 55.957' N	015° 37.968' E	0.0
PS122/3_38-31	2020-04-28	7:28	Ocean City CTD	deployed	84° 01.228' N	016° 17.455' E	4070.3
PS122/3_38-54	2020-04-30	7:31	Ocean City CTD	deployed	83° 56.479' N	017° 24.366' E	4061.3
PS122/3_38-55	2020-04-30	10:05	Ocean City CTD	deployed	83° 56.197' N	017° 27.470' E	4060.5
PS122/3_38-56	2020-04-30	10:32	Ocean City CTD	deployed	83° 56.145' N	017° 27.962' E	4058.8
PS122/3_38-69	2020-05-01	11:43	Ocean City CTD	deployed	83° 55.197' N	017° 41.143' E	4068.1
PS122/3_38-100	2020-05-02	7:28	Ocean City CTD	deployed	83° 54.591' N	017° 33.613' E	4068.9
PS122/3_39-16	2020-05-05	11:30	Ocean City CTD	deployed	83° 55.325' N	018° 06.442' E	0.0
PS122/3_39-51	2020-05-07	7:26	Ocean City CTD	deployed	83° 56.263' N	016° 57.516' E	4068.9
PS122/3_39-52	2020-05-07	9:58	Ocean City CTD	deployed	83° 56.157' N	016° 47.853' E	4069.9
PS122/3_39-53	2020-05-07	10:13	Ocean City CTD	deployed	83° 56.140' N	016° 46.914' E	4069.9
PS122/3_39-54	2020-05-07	10:32	Ocean City CTD	deployed	83° 56.120' N	016° 45.745' E	4070.0

PS122/3_39-69	2020-05-08	7:41	Ocean City CTD	deployed	83° 52.168' N	015° 31.017' E	4069.8
PS122/3_39-70	2020-05-08	11:08	Ocean City CTD	deployed	83° 51.280' N	015° 16.162' E	4069.8
PS122/3_39-82	2020-05-09	7:36	Ocean City CTD	deployed	83° 47.445' N	014° 07.696' E	4072.4

Tab. 5.23: *MSS casts (one action represents a day with several casts) in Ocean City*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_29-1	2020-02-24	11:44	MSS 46	deployed	88° 35.327' N	054° 30.159' E	4413.0
PS122/3_29-5	2020-02-25	8:10	MSS 46	deployed	88° 34.053' N	047° 03.412' E	4414.5
PS122/3_29-20	2020-02-26	7:10	MSS 46	deployed	88° 30.287' N	040° 59.938' E	4413.4
PS122/3_29-41	2020-02-27	7:17	MSS90L	deployed	88° 25.518' N	037° 17.371' E	4412.5
PS122/3_29-42	2020-02-27	7:17	MSS 46	deployed	88° 25.518' N	037° 17.352' E	4412.5
PS122/3_29-52	2020-02-28	6:15	MSS90L	deployed	88° 21.517' N	034° 25.164' E	4415.0
PS122/3_29-53	2020-02-28	7:33	MSS 46	deployed	88° 21.296' N	034° 17.690' E	4414.8
PS122/3_29-55	2020-02-28	11:28	MSS 46	deployed	88° 20.615' N	033° 53.804' E	4414.7
PS122/3_29-76	2020-02-29	10:53	MSS 46	deployed	88° 16.692' N	031° 57.275' E	4416.4
PS122/3_29-85	2020-03-01	7:53	MSS 46	deployed	88° 13.685' N	031° 24.998' E	4417.0
PS122/3_30-8	2020-03-02	7:12	MSS_55_IOW	deployed	88° 11.710' N	031° 10.805' E	4416.6
PS122/3_30-27	2020-03-04	11:28	MSS_55_IOW	deployed	88° 05.783' N	030° 29.639' E	4380.9
PS122/3_30-39	2020-03-05	6:43	MSS_55_IOW	deployed	88° 05.452' N	030° 48.393' E	4415.1
PS122/3_30-68	2020-03-07	10:39	MSS_55_IOW	deployed	88° 04.193' N	026° 52.558' E	4415.2
PS122/3_30-90	2020-03-08	12:39	MSS_55_IOW	deployed	88° 00.686' N	024° 59.502' E	4417.0
PS122/3_31-3	2020-03-09	7:45	MSS_55_IOW	deployed	87° 55.002' N	024° 05.897' E	4416.3
PS122/3_31-20	2020-03-10	12:15	MSS_55_IOW	deployed	87° 44.277' N	024° 41.206' E	4416.9
PS122/3_31-50	2020-03-12	11:28	MSS_55_IOW	deployed	87° 31.816' N	021° 30.931' E	4414.9
PS122/3_31-73	2020-03-14	13:33	MSS_55_IOW	deployed	87° 07.778' N	017° 05.573' E	4399.7
PS122/3_31-82	2020-03-15	13:35	MSS_55_IOW	deployed	87° 03.376' N	014° 58.078' E	4399.6
PS122/3_32-2	2020-03-16	8:22	MSS_55_IOW	deployed	86° 55.297' N	013° 00.364' E	4386.7
PS122/3_32-10	2020-03-17	7:33	MSS_55_IOW	deployed	86° 47.868' N	012° 23.470' E	4397.6
PS122/3_32-23	2020-03-18	7:25	MSS_55_IOW	deployed	86° 42.497' N	012° 07.221' E	4374.2
PS122/3_32-43	2020-03-19	11:23	MSS_55_IOW	deployed	86° 32.654' N	013° 16.092' E	4156.0
PS122/3_32-50	2020-03-20	7:15	MSS_55_IOW	deployed	86° 21.815' N	014° 40.756' E	3748.9
PS122/3_32-62	2020-03-21	13:01	MSS_55_IOW	deployed	86° 15.321' N	015° 16.620' E	3842.1
PS122/3_33-26	2020-03-24	13:42	MSS_55_IOW	deployed	86° 11.383' N	015° 28.748' E	2718.7
PS122/3_33-43	2020-03-25	11:34	MSS_55_IOW	deployed	86° 06.802' N	013° 58.318' E	3911.3
PS122/3_33-51	2020-03-26	7:46	MSS_55_IOW	deployed	86° 01.294' N	013° 07.826' E	3556.0
PS122/3_33-96	2020-03-29	11:29	MSS_55_IOW	deployed	85° 25.684' N	013° 12.724' E	3689.5
PS122/3_34-3	2020-03-30	12:03	MSS_55_IOW	deployed	85° 22.545' N	013° 12.445' E	4540.1
PS122/3_34-18	2020-03-31	12:00	MSS_55_IOW	deployed	85° 17.836' N	014° 03.447' E	4366.8
PS122/3_34-27	2020-04-01	11:16	MSS_55_IOW	deployed	85° 07.171' N	015° 30.549' E	3131.7
PS122/3_34-55	2020-04-03	12:22	MSS_55_IOW	deployed	84° 47.233' N	013° 27.765' E	3976.0
PS122/3_35-2	2020-04-06	7:13	MSS_55_IOW	deployed	84° 32.555' N	014° 09.986' E	2634.3
PS122/3_35-26	2020-04-07	11:14	MSS_55_IOW	deployed	84° 29.968' N	014° 32.225' E	2968.3
PS122/3_35-41	2020-04-08	14:28	MSS_55_IOW	deployed	84° 28.504' N	014° 44.967' E	3816.1

PS122/3_35-78	2020-04-10	13:34	MSS_55_IOW	deployed	84° 22.482' N	014° 37.217' E	4063.7
PS122/3_35-93	2020-04-11	11:11	MSS_55_IOW	deployed	84° 19.484' N	014° 44.804' E	4062.5
PS122/3_36-3	2020-04-13	13:12	MSS_55_IOW	deployed	84° 17.635' N	014° 58.129' E	4061.9
PS122/3_36-20	2020-04-14	7:15	MSS_55_IOW	deployed	84° 19.704' N	014° 50.394' E	4061.4
PS122/3_36-39	2020-04-15	11:25	MSS_55_IOW	deployed	84° 19.585' N	013° 54.535' E	4063.4
PS122/3_36-62	2020-04-16	13:19	MSS_55_IOW	deployed	84° 20.523' N	013° 05.425' E	3939.7
PS122/3_36-114	2020-04-18	7:23	MSS_55_IOW	deployed	84° 27.153' N	013° 48.968' E	3431.3
PS122/3_36-116	2020-04-18	13:39	MSS_55_IOW	deployed	84° 29.048' N	013° 53.793' E	3114.8
PS122/3_36-147	2020-04-19	11:38	MSS_55_IOW	deployed	84° 35.320' N	014° 43.137' E	3806.5
PS122/3_36-149	2020-04-19	13:21	MSS 46	deployed	84° 35.654' N	014° 45.335' E	3946.3
PS122/3_37-3	2020-04-20	6:24	MSS_55_IOW	deployed	84° 34.869' N	014° 39.093' E	3688.9
PS122/3_37-9	2020-04-20	20:13	MSS_55_IOW	deployed	84° 26.959' N	014° 40.571' E	4059.2
PS122/3_37-11	2020-04-21	7:11	MSS_55_IOW	deployed	84° 20.410' N	015° 05.349' E	3982.1
PS122/3_37-28	2020-04-22	14:00	MSS_55_IOW	deployed	84° 06.756' N	015° 58.982' E	4068.5
PS122/3_37-69	2020-04-24	7:15	MSS_55_IOW	deployed	84° 03.655' N	015° 58.323' E	4069.3
PS122/3_37-100	2020-04-25	13:06	MSS_55_IOW	deployed	83° 59.737' N	015° 34.850' E	4068.5
PS122/3_37-117	2020-04-26	13:36	MSS_55_IOW	deployed	83° 55.343' N	015° 30.391' E	4073.1
PS122/3_38-6	2020-04-27	13:21	MSS_55_IOW	deployed	83° 56.249' N	015° 38.810' E	0.0
PS122/3_38-32	2020-04-28	13:27	MSS_55_IOW	deployed	84° 02.344' N	016° 35.041' E	4070.1
PS122/3_38-53	2020-04-29	13:40	MSS_55_IOW	deployed	84° 00.015' N	017° 13.693' E	4068.8
PS122/3_38-83	2020-04-30	12:14	MSS_55_IOW	deployed	83° 55.939' N	017° 29.615' E	3994.8
PS122/3_38-99	2020-05-02	12:08	MSS_55_IOW	deployed	83° 54.154' N	017° 34.188' E	4068.9
PS122/3_39-9	2020-05-04	7:13	MSS_55_IOW	deployed	83° 53.793' N	018° 18.787' E	4069.2
PS122/3_39-17	2020-05-05	7:09	MSS_55_IOW	deployed	83° 55.420' N	018° 11.566' E	3816.3
PS122/3_39-31	2020-05-06	7:14	MSS_55_IOW	deployed	83° 54.766' N	017° 45.939' E	4066.7
PS122/3_39-50	2020-05-07	13:36	MSS_55_IOW	deployed	83° 55.853' N	016° 34.554' E	4070.4

Tab. 5.24: *VMP casts (one action a day with several casts) in Ocean City*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_29-84	2020-03-01	7:51	VMP250 upriser	deployed	88° 13.688' N	031° 24.999' E	4417.0
PS122/3_35-10	2020-04-06	13:38	VMP250 upriser	deployed	84° 31.869' N	014° 21.689' E	2743.7
PS122/3_36-2	2020-04-13	11:29	VMP250 upriser	deployed	84° 17.586' N	014° 57.417' E	4061.8
PS122/3_38-9	2020-04-27	7:48	VMP250 upriser	deployed	83° 55.428' N	015° 37.589' E	4073.2
PS122/3_39-10	2020-05-04	11:12	VMP250 upriser	deployed	83° 54.269' N	018° 20.527' E	4069.2

Tab. 5.25: *Fishing-rod CTD at various locations*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_29-82	2020-02-29	13:20	CTD SST 48M_1495 fishing-rod	deployed	88° 16.292' N	031° 47.680' E	4416.6
PS122/3_33-3	2020-03-23	13:34	CTD SST 48M_1495 fishing-rod	deployed	86° 12.613' N	015° 48.472' E	2701.1
PS122/3_33-4	2020-03-23	14:01	CTD SST 48M_1459 fishing-rod	deployed	86° 12.600' N	015° 48.448' E	2700.4
PS122/3_33-5	2020-03-23	14:54	CTD SST 48M_1459 fishing-rod	deployed	86° 12.575' N	015° 48.279' E	2700.2

PS122/3_33-24	2020-03-24	13:55	CTD SST 48M_1459 fishing-rod	deployed	86° 11.369' N	015° 28.301' E	2732.9
PS122/3_33-25	2020-03-24	15:03	CTD SST 48M_1459 fishing-rod	deployed	86° 11.284' N	015° 25.640' E	2810.5
PS122/3_36-56	2020-04-16	8:22	CTD SST 48M_1459 fishing-rod	deployed	84° 19.013' N	013° 07.891' E	3744.8
PS122/3_36-89	2020-04-17	12:27	CTD SST 48M_1459 fishing-rod	deployed	84° 25.070' N	013° 41.684' E	3931.2
PS122/3_36-90	2020-04-17	13:17	CTD SST 48M_1459 fishing-rod	deployed	84° 25.206' N	013° 42.700' E	3919.3
PS122/3_36-91	2020-04-17	15:07	CTD SST 48M_1459 fishing-rod	deployed	84° 25.468' N	013° 44.663' E	3851.3
PS122/3_37-71	2020-04-24	12:53	CTD SST 48M_1459 fishing-rod	deployed	84° 03.086' N	015° 53.226' E	4069.6
PS122/3_37-72	2020-04-24	14:02	CTD SST 48M_1459 fishing-rod	deployed	84° 02.966' N	015° 52.595' E	4070.0
PS122/3_37-73	2020-04-24	15:26	CTD SST 48M_1459 fishing-rod	deployed	84° 02.847' N	015° 52.013' E	4069.8
PS122/3_37-119	2020-04-26	14:08	CTD SST 48M_1459 fishing-rod	deployed	83° 55.282' N	015° 30.439' E	4073.2
PS122/3_37-120	2020-04-26	15:34	CTD SST 48M_1459 fishing-rod	deployed	83° 55.151' N	015° 30.754' E	4073.5
PS122/3_38-10	2020-04-27	11:58	CTD SST 48M_1459 fishing-rod	deployed	83° 56.004' N	015° 38.038' E	0.0
PS122/3_38-11	2020-04-27	12:33	CTD SST 48M_1459 fishing-rod	deployed	83° 56.111' N	015° 38.329' E	0.0
PS122/3_38-12	2020-04-27	13:08	CTD SST 48M_1495 fishing-rod	deployed	83° 56.207' N	015° 38.674' E	0.0
PS122/3_38-13	2020-04-27	13:11	CTD SST 48M_1459 fishing-rod	deployed	83° 56.217' N	015° 38.713' E	0.0
PS122/3_38-14	2020-04-27	14:07	CTD SST 48M_1459 fishing-rod	deployed	83° 56.425' N	015° 39.403' E	0.0
PS122/3_38-15	2020-04-27	14:43	CTD SST 48M_1459 fishing-rod	deployed	83° 56.566' N	015° 39.942' E	0.0
PS122/3_38-101	2020-05-02	11:43	CTD SST 48M_1459 fishing-rod	deployed	83° 54.191' N	017° 34.172' E	4069.1
PS122/3_38-102	2020-05-02	13:21	CTD SST 48M_1459 fishing-rod	deployed	83° 54.049' N	017° 34.200' E	4068.8
PS122/3_38-103	2020-05-02	14:49	CTD SST 48M_1459 fishing-rod	deployed	83° 53.924' N	017° 34.289' E	4068.7
PS122/3_39-32	2020-05-06	12:30	CTD SST 48M_1459 fishing-rod	deployed	83° 55.295' N	017° 40.321' E	4068.4
PS122/3_39-33	2020-05-06	13:36	CTD SST 48M_1459 fishing-rod	deployed	83° 55.392' N	017° 39.163' E	4068.0
PS122/3_42-14	2020-05-26	19:43	CTD SST 48M_1459 fishing-rod	deployed	82° 19.092' N	008° 08.959' E	916.4
PS122/3_42-13	2020-05-27	11:03	CTD SST 48M_1459 fishing-rod	deployed	82° 23.556' N	008° 20.435' E	1103.7
PS122/3_42-20	2020-05-27	19:03	CTD SST 48M_1459 fishing-rod	deployed	82° 23.601' N	008° 19.620' E	1121.4

Tab. 5.26: *LISST casts in Ocean City*

Station	Date	Time	Gear	Action	PositionLat	PositionLon	Waterdepth (m)
PS122/3_29-75	2020-02-29	14:08	PRIC LISST-Deep particel size analyser	deployed	88° 16.163' N	031° 45.032' E	4416.6
PS122/3_30-26	2020-03-04	6:25	PRIC LISST-Deep particel size analyser	deployed	88° 06.156' N	030° 23.762' E	4413.3
PS122/3_31-29	2020-03-11	7:54	PRIC LISST-Deep particel size analyser	deployed	87° 40.553' N	024° 42.797' E	4416.8
PS122/3_32-51	2020-03-20	11:30	PRIC LISST-Deep particel size analyser	deployed	86° 19.967' N	014° 47.213' E	3713.4
PS122/3_33-36	2020-03-25	8:34	PRIC LISST-Deep particel size analyser	deployed	86° 07.604' N	014° 14.247' E	3644.8
PS122/3_34-28	2020-04-01	13:46	PRIC LISST-Deep particel size analyser	deployed	85° 05.885' N	015° 31.512' E	2871.6
PS122/3_35-36	2020-04-08	8:15	PRIC LISST-Deep particel size analyser	deployed	84° 28.949' N	014° 38.140' E	3552.9
PS122/3_36-44	2020-04-15	7:30	PRIC LISST-Deep particel size analyser	deployed	84° 19.585' N	014° 01.294' E	4063.1
PS122/3_37-29	2020-04-22	7:57	PRIC LISST-Deep particel size analyser	deployed	84° 08.345' N	015° 53.092' E	4016.6
PS122/3_38-41	2020-04-29	7:34	PRIC LISST-Deep particel size analyser	deployed	84° 01.494' N	017° 13.192' E	4069.8