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Cruise Report

Innovative study on regional high resolution imaging of glacier induced plankton dynamics in West-Greenland fjords - IOPD

R/V Sanna, Cruise No. 6,

28/06/2022 – 10/07/2022, Ilulissat (Greenland) –Uummannaq (Greenland)

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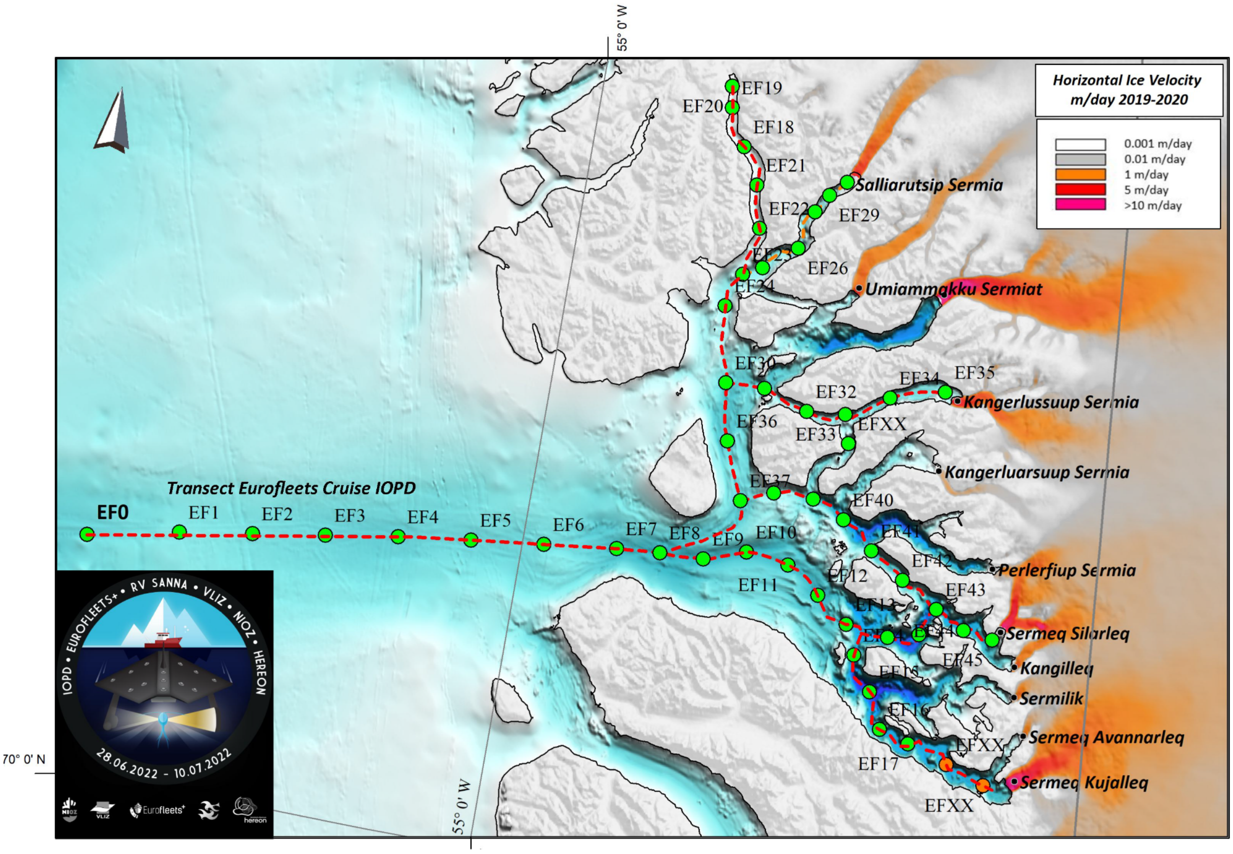
1 Summary

From 28/06/2022 till 10/07/2022, a multidisciplinary team of marine biologists, physical oceanographers and engineers went to the Uummannaq region to study the plankton and nutrient dynamics of West Greenland fjords and their oceanographic drivers. The good weather allowed the team to make optimal use of the ship's time and in total five fjords and the connecting shelf area were sampled. The team of early career researchers sailed from the shelf edge towards the head of the fjord or until icebergs blocked the way. To achieve their goal proven oceanographic equipment was used such as conductivity- temperature-depth profilers (Sea-Bird Scientific, RBR, Sea & Sun Technology), microstructure profilers (Rockland Scientific Inc.), plankton nets (Apstein, MultiNet and MIK net), Niskin bottles for water samples, and more. In addition, they made use of emerging technologies such as a Fast Repetition Rate Fluorometers (FastOcean), as well as towed and profiling plankton imaging sensors including a Video Plankton Recorder (VPR, towed system, SEASCAN INC) and a CPICS (CoastalVision) to get high spatial resolution images of the plankton community composition.



Background data from QGreenland.org; atlas-belgique.be; Greenland Ice Sheet velocity map from Sentinel-1, wintercampaign 2019/2020 [version 1.3]

Fig. 1.1 Working area and track chart of R/V Sanna Cruise 6.

2 Research Programme/Objectives

The West Greenland marine ecosystem forms a complex interaction between the marine areas along the West Greenland banks and the numerous fjords that drain meltwater from the Greenland Ice Sheet to the ocean. Marine ecosystem productivity is very differently regulated in fjords influenced by either land- or marine-terminating glaciers. Rising subsurface meltwater plumes originating from marine-terminating glaciers entrain large volumes of ambient deep water towards the surface. The resulting upwelling of nutrient-rich deep water sustains a high phytoplankton productivity throughout summer in the fjord with marine-terminating glaciers. In contrast, fjords with only land-terminating glaciers lack this upwelling mechanism, and are characterized by lower productivity (Meire *et al*., 2017). Due to the melting of the Greenland Ice Sheet, the fjords will shift to systems with more land- instead of marine-terminating glaciers. By sampling these two types of fjords, the consequences of climate change on the plankton community and marine ecosystem can be researched.

In this multidisciplinary study, two different fjord systems and the connecting shelf area were sampled with the aim of studying:

1) The plankton distribution within fjords and food web composition of the two fjord systems

2) The zooplankton - marine snow interaction and the carbon cycling within these fjords

3) The turbulence in the water column in fjords and the shelf area.

By making use of optical imaging devices this study wants to overcome the limits of traditional sampling methods. Innovative tools such as Video Plankton Recorder, Continuous Particle Imaging and Classification System, and Fast Repetition Rate Fluorometer will allow to analyze the phyto- and zooplankton dynamics and distribution with a high spatial resolution on a broad spatial scale. Together with CTD, turbidity, turbulence, nutrient, chlorophyll a, fatty acid and DNA measurements, the biotic, chemical as well as physical component of the water column were be sampled.

3 Narrative of the Cruise

Table 3.1 introduces an overview of the mobilisation/demobilisation, time/date of departure, and time/date of cruise finalisation. The detailed narrative of the cruise day by day with the description of the main activities performed onboard is also presented below. Hereafter, stations are labelled as EFXX where XX is the stations' number. All stations were performed chronologically respecting their respective stations' number, except station EF1 which was carried out first than EF00. Stations were also classified and grouped as CTD, focus, and super stations depending on the used devices and sampling in the respective station: CTD (only CTD cast), focus (CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, VPR+CPICS), or super station (CTD, Turbulence profiler, 2-3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS).

Table 3.1 Overview of the mobilisation/demobilisation, time/date of departure, and time/date of cruise finalisation.

Date	UTC Time	Location	Activities
26/06		Ilulissat	Arrival on board
27/06	18:15 (leaving harbour)	Ilulissat+transit	Mobilisation + transit to first station
28/06	11:22	EF01 and EF00	First and second sampling station
29/06 to 08/07		EF02-EF44	See Table 7.1.
09/07	10:22	EF45-EF47	Last sampling stations + packing equipment and cleaning labs

10/07	9:00	Uummannaq	Demobilisation

26/06/2022

Arrival of the scientists on board. Acquaintance with each other. Group meeting to reinforce the cruise's goals, planning of the activities, and to-do's for the next day.

27/07/2022

Mobilisation of the equipment by Blue Water Shipping. Equip the laboratories (e.g., FRRF, filtration systems). Arrange equipment on deck (e.g., VPR, VPR winch, MultiNet, MIKnet, Apstein net). The VPR winch was partly welded on deck. VPR and EARS systems were installed; and a weather station and GoPro camera were assembled at the whale-watching tower.

After lunch, the captain gave a safety briefing and demonstrated the utilisation of the survival suit.

RV Sanna started sailing to the Uummannaq area for the first sampling station.

28/07/2022

Arrival at the first sampling station (EF01; super station) around 11h20 (UTC, or 9h20 local time). The first MultiNet sampling, deployed through an A-frame did not close, possibly due to issues with the winch's depth sensor of the ship so that the desired depth was not reached (Failed MultiNets are not included in the 'Station List table'). Thereafter, the Multinet was used from the side of the ship with a depth analog counter which turned out to be suitable. The CPICS had battery issues. There were difficulties with pulling the VPR's termination through the A-frame, but this was solved with support from the crew. Water samples from the Niskin bottles were used for FRRF analyses and to collect information on nutrients, pigments, POC, DNA, DIC, primary production and bacteria. Technical issues were timely sorted out by the scientific team and crew. Overall, it was a smooth first sampling day.

29/06/2022

In total, four CTD stations (EF02, 03, 05, 06) and one focus station (EF04) were conducted on this day.. Because the fatty acid sample with dominant species from the previous day was defrosted and therefore no longer useble, it was decided to use a WP2 net in the surface layer in order to collect new specimens . This sample was stored in the freeze.

30/06/2022

CTD casts were taken at EF07, 09, 10 and 11. The CTD touched the bottom during one of the deployments, but no issues were encountered. At EF08, we conducted a super station. At this location, the MultiNet hit the bottom, nevertheless the samples were not impacted. The VPR software showed faulty behaviour displaying a white screen. This was resolved after careful cleaning of the FC connectors and cables. After towing the VPR aboard, a broken bulkhead connector of the main pod was replaced. In the evening, the VPR at EF12 was deployed. The rest of the sampling in EF12 was performed the next day.

01/07/2022

Began the day at focus station EF12 by deploying CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, and Apstein Net data (VPR+CPICS was done the previous day). From this day forward, whenever possible, turbulence profiles were also taken from the workboat. In this day, Daniel took the opportunity to join the workboat for conducting tests with the CPICS. Nevertheless, these were not successful due to the low plankton abundance. Back on the RV Sanna, a CPICS test with a plankton on a needle in a bucket was performed. As suggested by the later test, CPICS settings were changed. On the same day, CTD casts were taken at stations EF13 and EF14. At the end of the day, the super station EF15 was finalised.. Passed by Uummannaq, where we encountered more and more icebergs.

02/07/2022

One CTD station (EF16) and one focus station (EF17: 2x CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS) were performed. Notice that EF17 is the only station in the entire cruise with 2 CTD casts. The second profile focused on shallow waters to support the further interpretation of the turbulence profile. One MultiNet didn't close because the depth of the water column had changed since the start of the station.

03/07/2022

One super station (EF18) and two CTD stations (EF19 and EF20) were performed. EF18 represented the first VPR deployment without any issues.

04/07/2022

Two CTD stations (EF21 and EF23), one focus station (EF22), and one super station were carried out. At EF22, a part of the starting mechanism of net 1 from the MultiNet broke. For the remainder of the cruise 4 instead of 5 nets of the MultiNet were used to collect plankton samples. The VPR operated smoothly during this day.

05/07/2022

Four CTD stations (EF25, EF26, EF28, EF29) and one super station (EF27) were accomplished that day. Since EFXX was located in the vicinity of the glacier front, the team seized the opportunity to take additional samples of Turbulence, Niskin bottles, 1x MultiNet for zooplankton and Apstein Net.

06/07/2022

Four CTD stations (EF30, EF31, EF33, and EF34), one super station (EF32), and one focus station (EF35) were conducted.

07/07/2022

Three CTD stations (EF36, EF38, EF39), one super station (EF37), and one focus station (EF40) were sampled. Technical issues with the VPR arose at EF40, obliging us to interrupt the sampling and bring the VPR back on deck.

08/07/2022

Three CTD stations (EF41, EF42, EF44) and one super station (EF43) were sampled. Metal bucket for Apstein sampling was lost during the deployment Further sampling was performed with a plastic bucket.

09/07/2022

One super station (EF45), one CTD station (EF46), and one focus station (EF47) were sampled.

In the evening the team started to pack everything and clean the lab.

10/07/2022

Further packing of all the equipment. All used laboratories and cabins were cleaned. Demobilisation on land.

4 Preliminary Results

4.1 Underway Hydroacoustics

The on board hydro acoustic system was actively monitoring throughout the whole cruise. It consists of three EK80 sounders with frequencies of 333 kHz, 120 kHz and 38 kHz respectively.

About 3.5 TB of acoustic data have been gathered and will be analysed with a focus on the VPR/CPICS tows and possible conclusions that can be gathered from the comparison between VPR/CPICS Data and the acoustic data with different frequencies.

It was observed that the ship's navigational sounders interfered with the scientific sounders, but these are repetitive distributions which can be filtered during the data processing steps. Data analysis will be done using the EchoView software (Echoview Software Pty Ltd).

4.2 CTD sample collection and processing

CTD sample collection took place through two different devices: (i) Seabird SBE 19plus CTD deployed individually at all stations, and (ii) Seabird SBE 49 CTD deployed at selected stations coupled to the VPR system. The post-processing and preliminary analyses of the casts from both devices were conducted in near real-time, onboard R/V Sanna. The effort to perform near real-time processing was necessary for improvements in the original cruise plan in order to provide a better representation of the hydrographic system of the sampled region. In this section, we provide details on the CTD sample collection, including other sensors coupled to the CTD frames. We also introduce the sampling approach and present the collected data through preliminary diagnostics.

4.2.1 Seabird 19+ CTD system

Besides conductivity, temperature, and pressure, the GCRC's CTD system had other coupled sensors to sample oxygen, fluorescence, turbidity, and irradiance. Sensors on the CTD cage included:

- Seabird SBE 19plus V2 SeaCAT Profiler CTD
- Seabird SBE 43 dissolved oxygen sensor
- Fluorescence and Turbidity (Seapoint)
- Irradiance (Biospherical QSP- 2350L Scalar)

Operationally, the ship assets (winch, crane, and taglines) and CTD performed smoothly. Not a single kink was observed in the tagline during the entire cruise. In total, 47 casts were collected so that all EF-IODP stations counted with one cast. The exception is station EF17 in which a second (shallow-water) cast was performed along an extra turbulence sampling. Both the R/V Sanna crew and the scientific team participated in the operation of the CTD system. The first, operating the winch and crane, and the second, manipulating tagline, monitoring depth through an analog counter, ensuring appropriate descent speed, and stowing after deployment. The CTD cage was lowered and lifted from the starboard side of the ship facing sunlight to optimize the functioning of the irradiance sensor.

Once in the water, the CTD was first lowered to about 5 m and kept at this depth for 5 minutes for initialization and stabilization of all sensors, as well as to allow standing water to flush out of the CTD plumbing system. From the surface to the bottom of the pycnocline, the descent was controlled to be slower than 1 m/s to ensure a proper representation of the strong vertical gradients in this part of the water column. Deeper than that, the descent speed was around 1 m/s to provide about 4 measurements per meter (CTD's sampling rate is 4Hz). Due to the capacity of the CTD system, there was no sampling deeper than 1000 m. However, this limitation had a negligible impact on the cruise plan since only two stations (EF15 and EF46) was in waters deeper than the referred threshold. In practical terms, all profiles reached depths near the bottom but respecting a safe distance of 10-20 m, depending on the wave conditions and dragging by the currents, to avoid collision with the seafloor.

Since the CTD had no instantaneous communication with computers aboard, the profiles were stored in the CTD unit as binary files and, afterward, downloaded for quality checking and processing. The first step in the data processing was to convert binary files through the Seabird Seasoft V2 software. In the second step, Seasoft V2 corrected mismatches caused by alignment due to sensor response times and transit time of sample water passing through the CTD plumbing system. After this point, Seasoft V2 was unable to deal with further steps in the processing, such as the removal of all spurious data generated during the stabilization period in which the CTD was kept near the surface. The data processing was so conducted with python scripts coded aboard by the scientific team. The final products from the CTD casts are 1 m-binned vertical profiles (see Fig. 4.1). It is worthwhile saying that other steps in the data processing might be required, mainly for oxygen, fluorescence, and turbidity. These variables showed to be somehow spiky in a few stations.

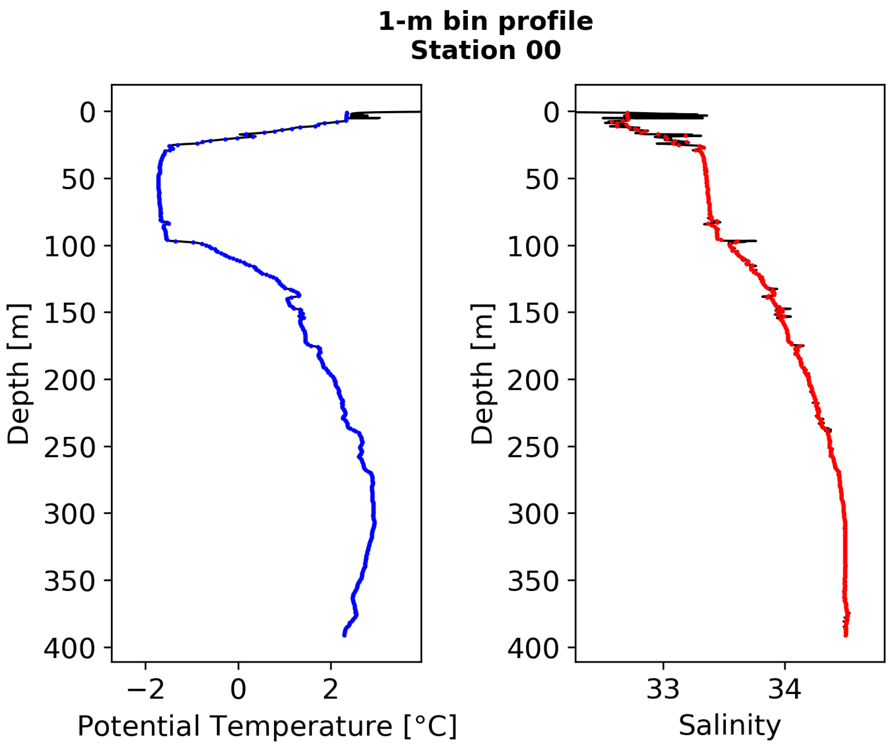


Fig. 4.1 Potential temperature (left) and salinity (right) profiles outputted by Seasoft V2 after the alignment step in the data processing (black lines). The 1 m-binned generated profiles with the python scripts are displayed as blue (potential temperature) and red (salinity) dots.

Based on the binned profiles, a preliminary set of results was generated through two diagnostics. Namely, temperature-salinity (TS) diagrams, for an indication of water masses properties, and vertical transects connecting the fjords with the offshore region. Figure 4.2 shows the TS diagram for stations EF00 to EF17. Likewise, Figs. 4.3, 4.4, and 4.5 show how potential temperature, salinity, and potential density are vertically distributed between the most offshore station (EF00) and along the Uummannaq Fjord (EF17). Vertical slices for oxygen, fluorescence, turbidity, and irradiance are plotted in Figs. 4.6, 4.7, 4.8, and 4.9, respectively, for the same EF00-EF17 transect. A careful analysis of the preliminary results, complemented by other metrics, diagnostics, and analyses, will be conducted in the upcoming months by the participating institutions.

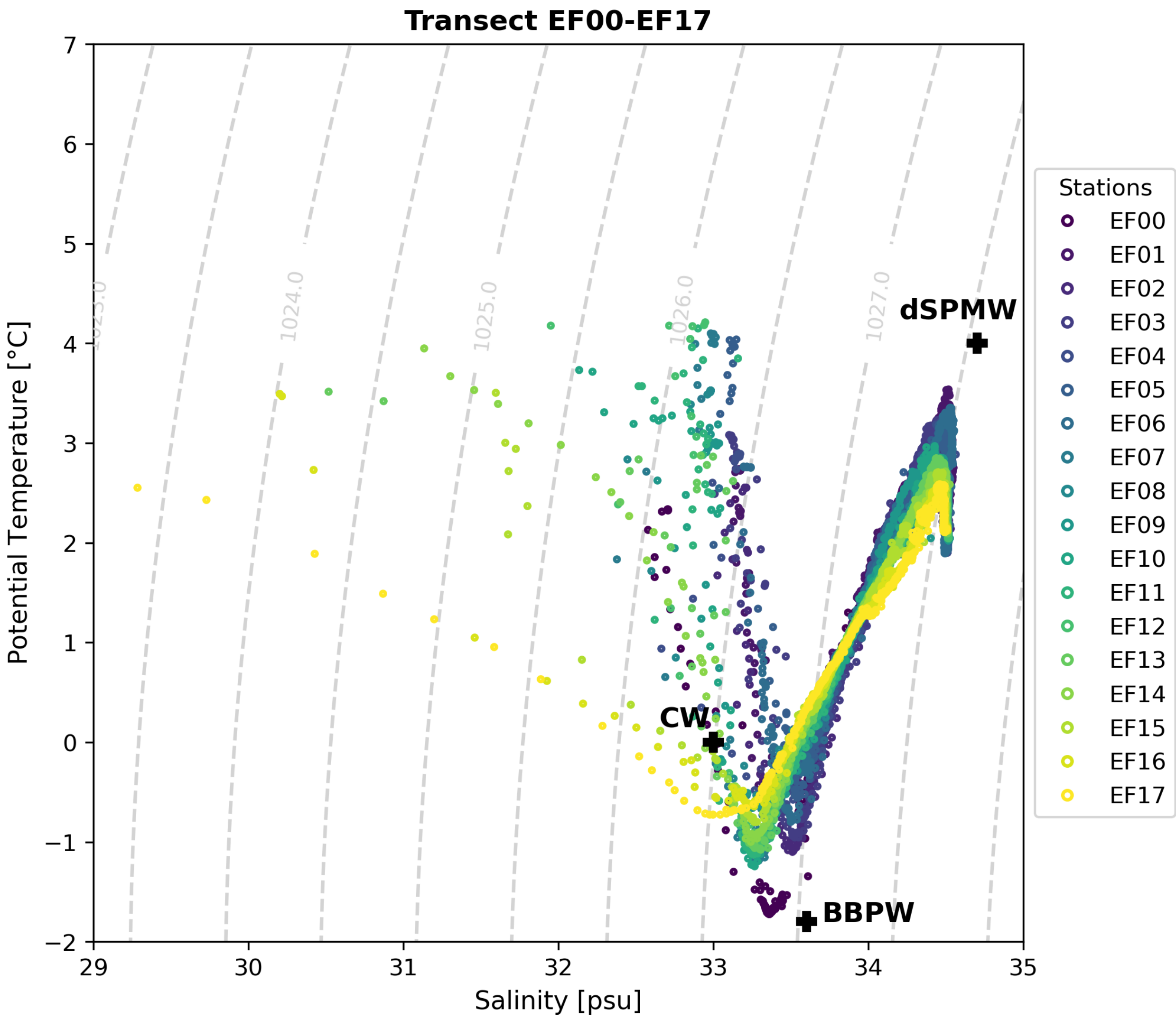


Fig. 4.2 Temperature-salinity diagram (colourful circles) plotted for the transect covering the Uummannaq Fjord and the adjacent offshore region. EF00 is the most offshore station and EF17 is the innermost station in the fjord. Isopycnals are plotted as dashed grey lines. Suggested indices for water masses are indicated by crosses, as follows: Baffin Bay winter mode water (BBPW), coastal water (CW), and diluted subpolar mode water (dSPMW).

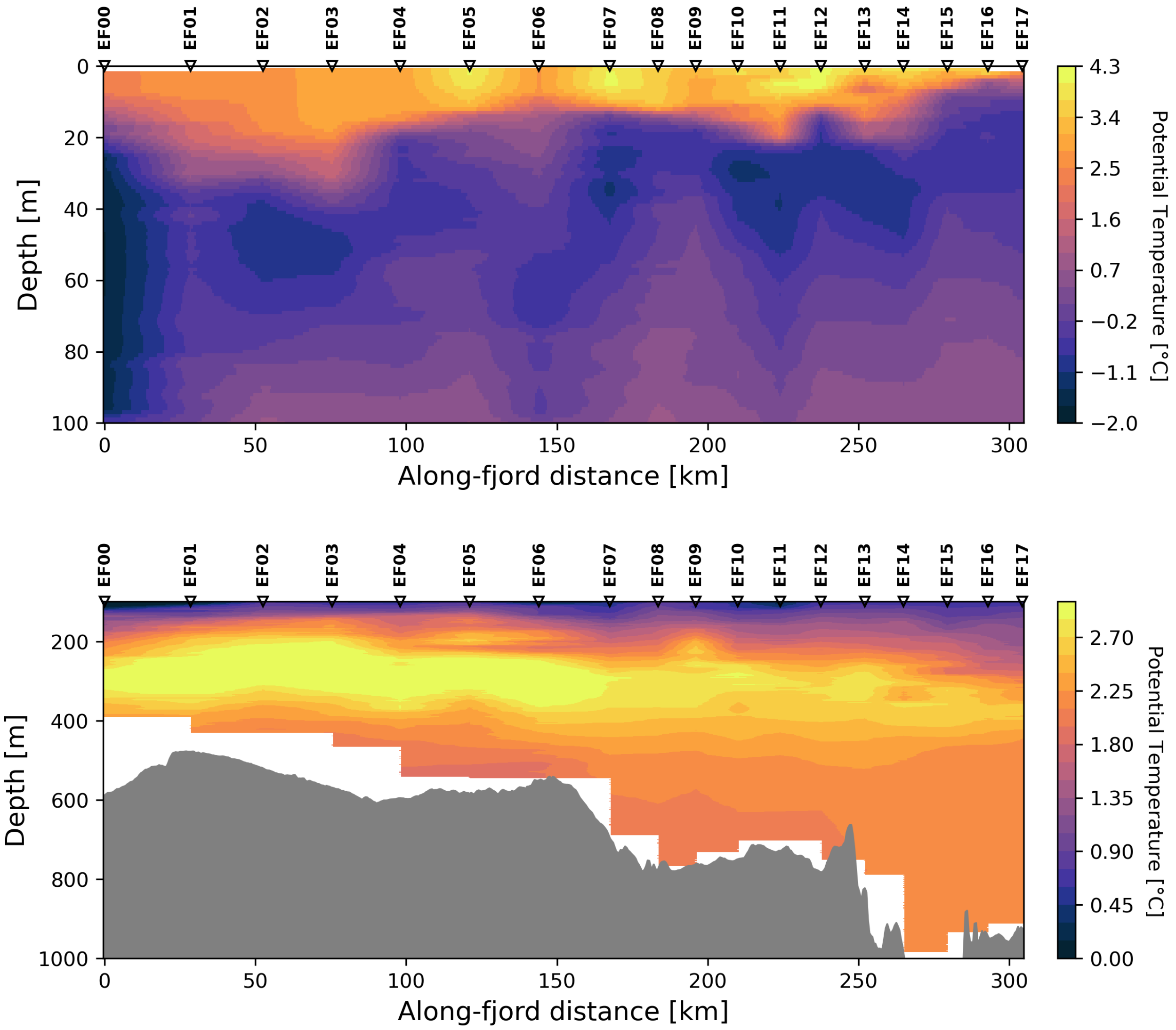


Fig. 4.3 Vertical distribution of potential temperature connecting the most offshore station (EF00) and the innermost station in the Uummannaq Fjord (EF17). The top panel focuses on the first 100 meters of the water column, while the bottom panel represents depths deeper than 100 meters to the seafloor. The bathymetry is indicated by the grey-filled area.

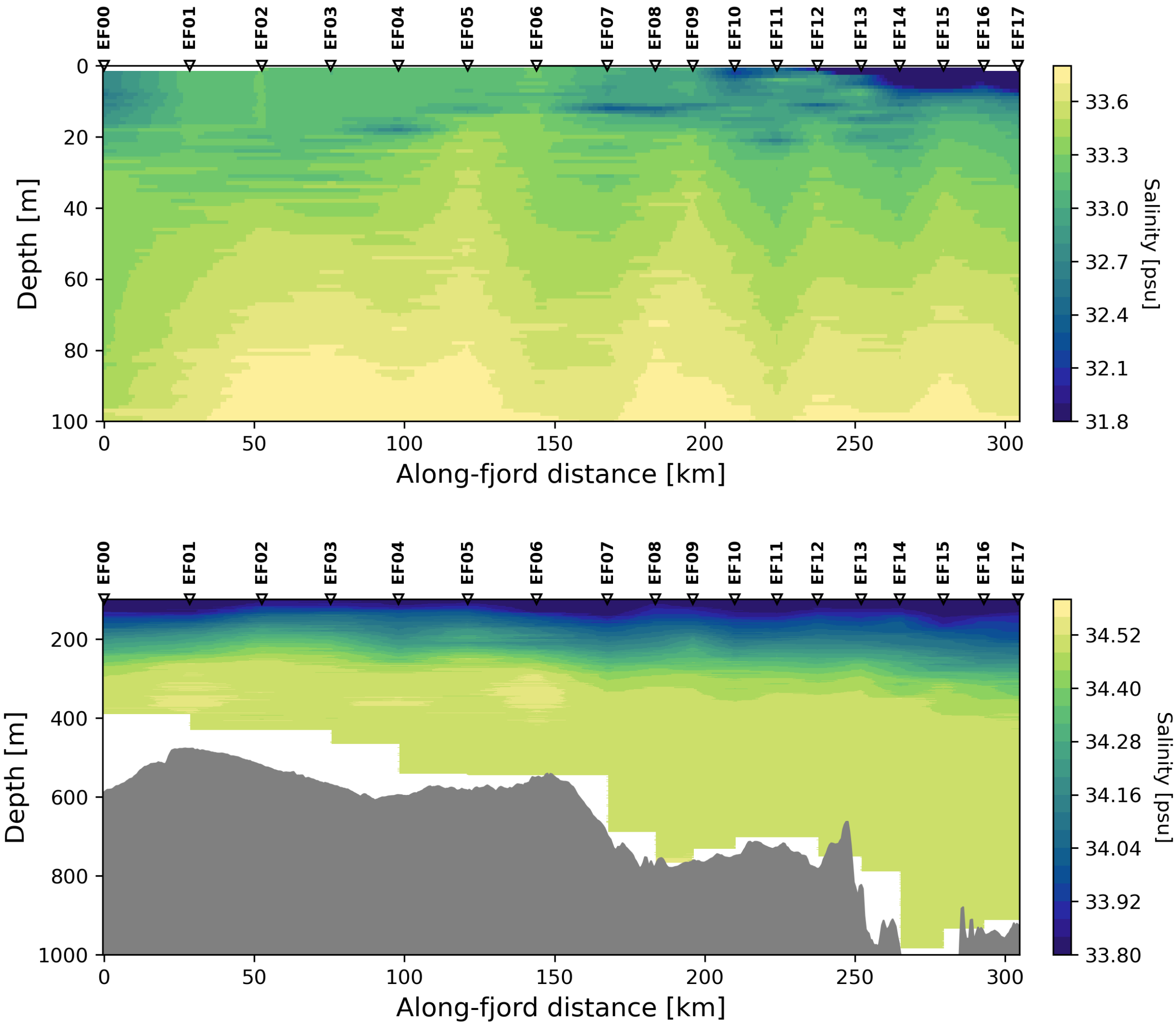


Fig. 4.4 Same as Fig. 4.3, but for salinity.

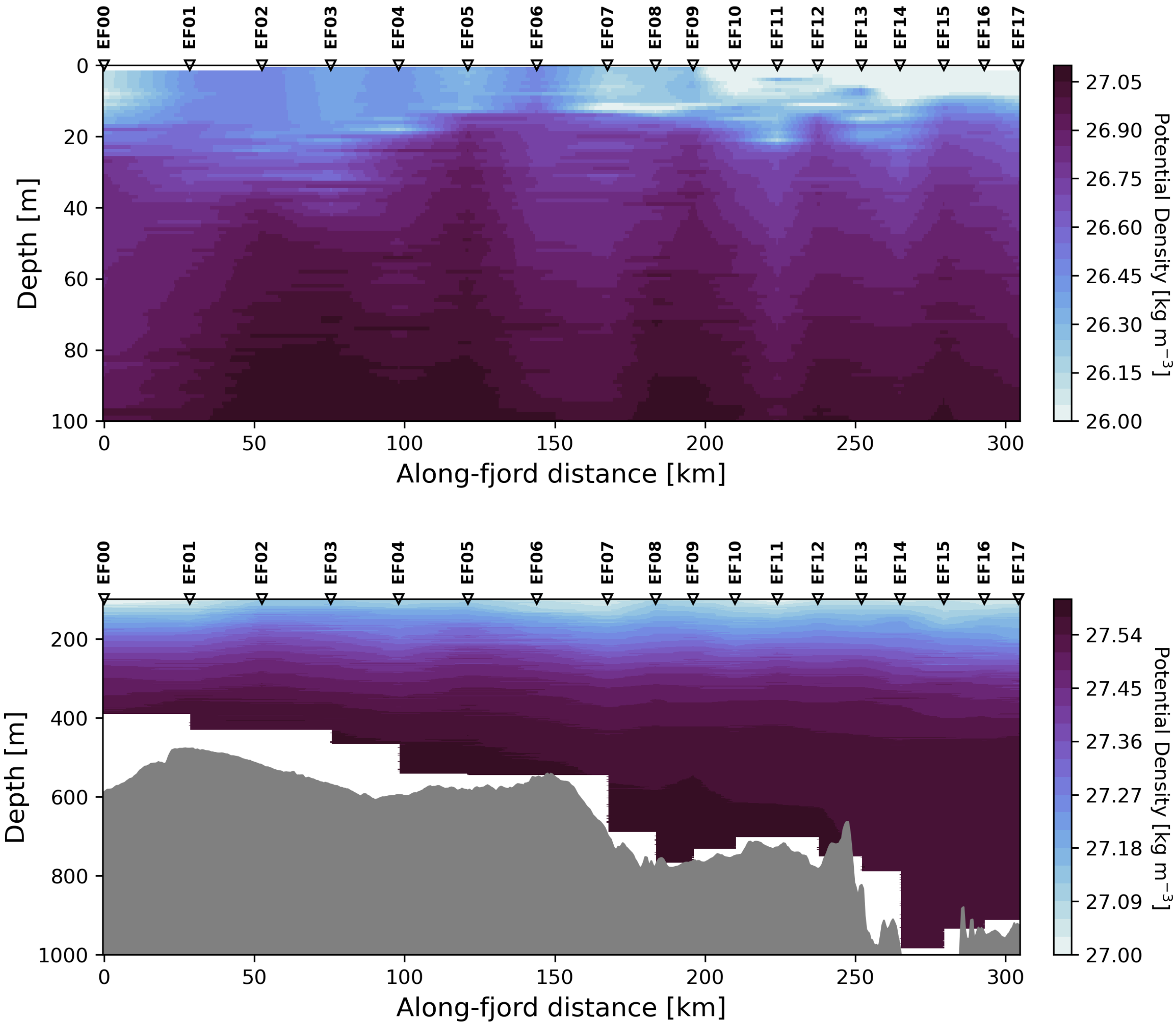


Fig. 4.5 Same as Fig. 4.3, but for potential density.

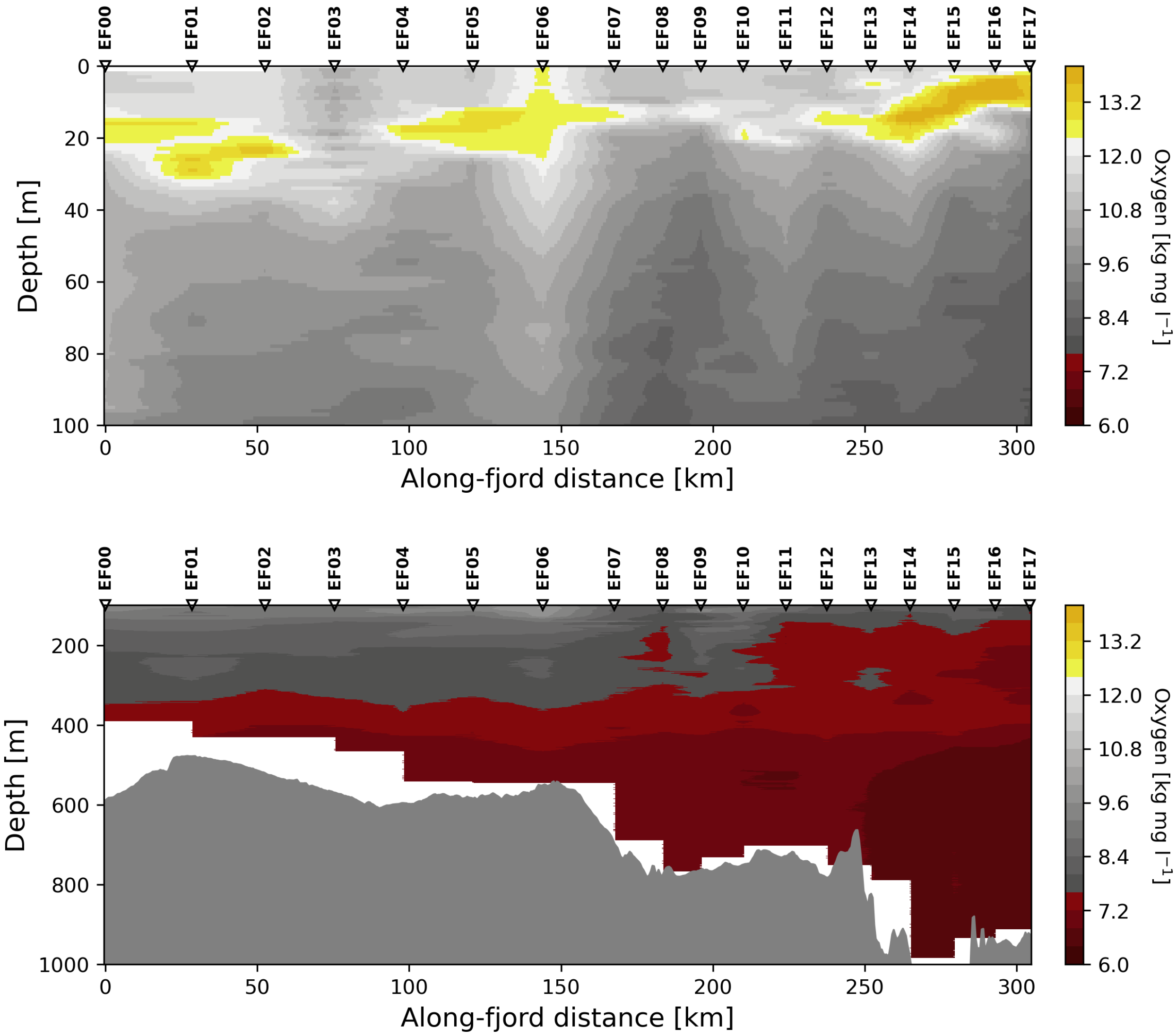


Fig. 4.6 Same as Fig. 4.3, but for dissolved oxygen.

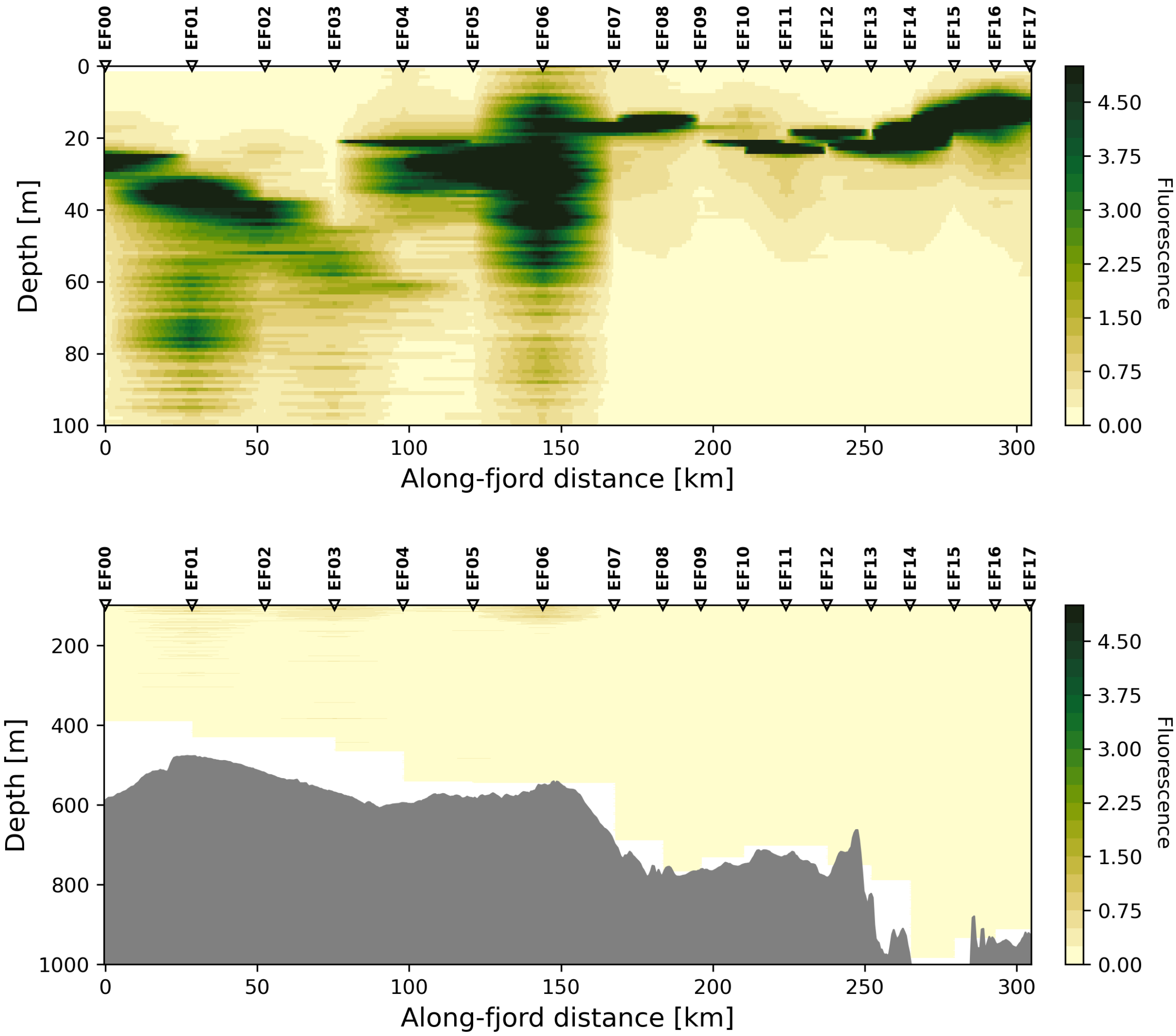


Fig. 4.7 Same as Fig.4.3, but for fluorescence.

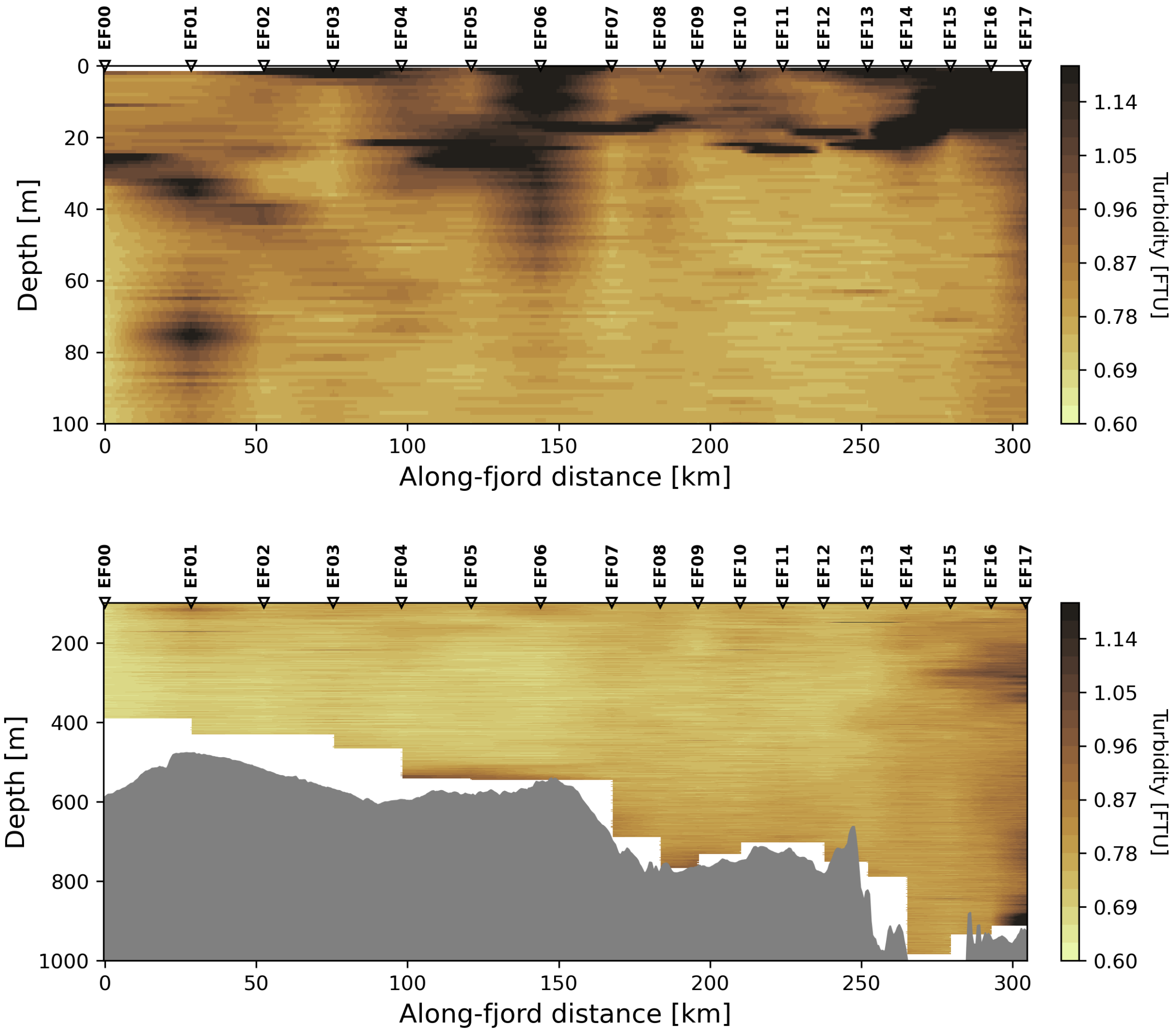


Fig. 4.8 Same as Fig. 4.3, but for turbidity.

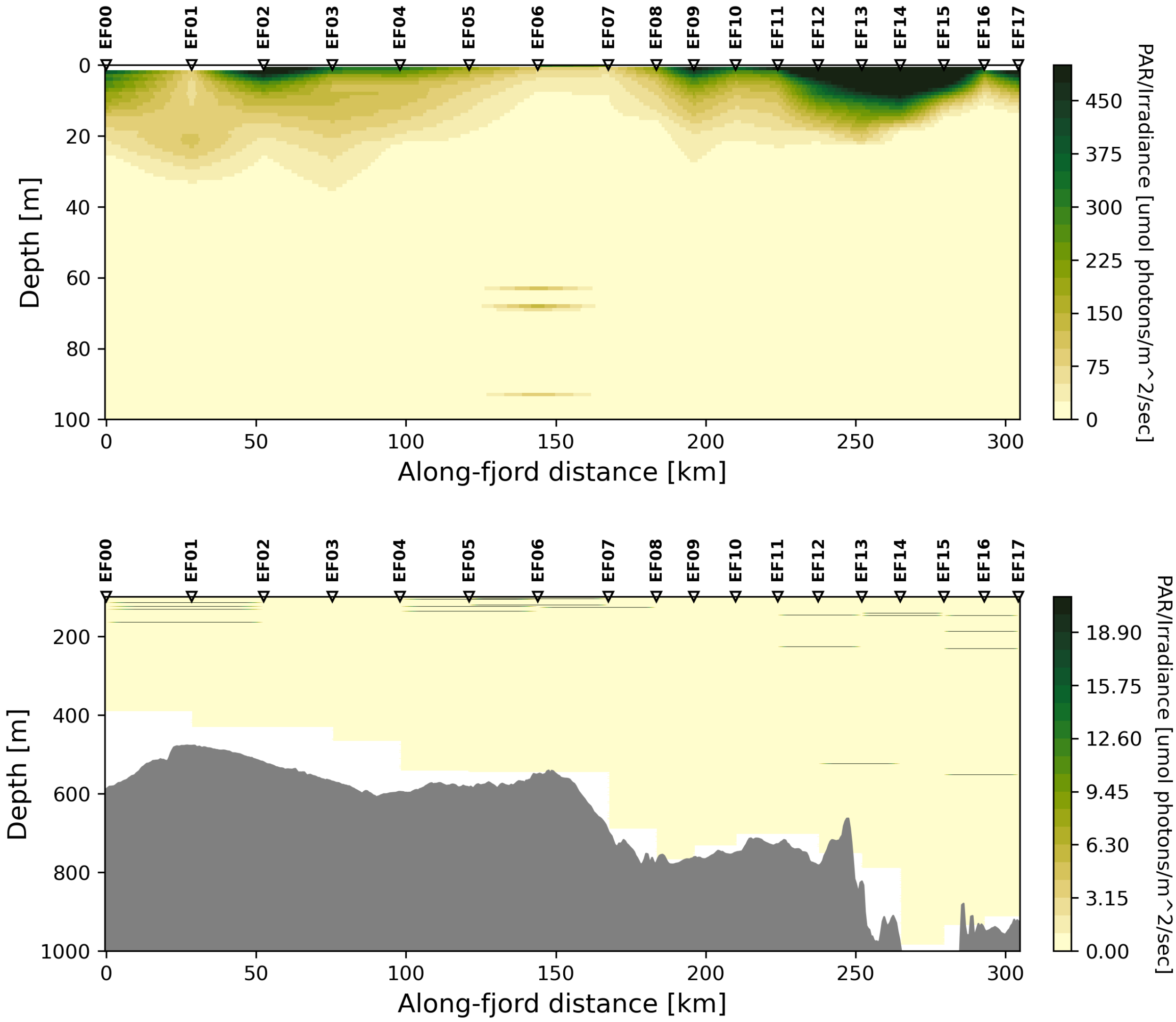


Fig. 4.9 Same as Fig. 4.3, but for irradiance.

4.2.2. CTD system synchronized with the VPR

A second CTD system was deployed at focus and super stations during the EF-IOPD cruise. This system was coupled and synchronized with the VPR device and, therefore, was towed from R/V Sanna in continuous up and down diagonal movements in the water column. Sensors on the CTD frame included:

- Seabird SBE 49 CTD.
- Wetlabs FLNTURT (S/N 4840):
    - fluorescence at 470 nm wavelength, sensitivity 0.025 µg/l Chl, range 0–50 µg/l Chl
    - turbidity at 700 nm wavelength, sensitivity 0.01 NTU, range 0-25 NTU
- MEMSIC CXTA02-T tilt & roll sensor

The CTD scans were collected at a frequency of 25 Hz. As for the first CTD device, the processing was conducted aboard with python scripts coded by the scientific team. After the removal of spurious data, the final CTD cast was binned at every second and saved as ascii files for further analyses. Figures 4.10 and 4.11 (left panels) exemplify the vertical movement of the CTD over time and display the respective temperature (Fig. 4.10) and salinity (Fig. 4.11) values. In addition, the presence of two CTDs aboard was useful for cross-validating both systems. Figures 4.10 and 4.11 (left panels) compare the data sampled by both systems. Even though differences are expected since the samplings were not synchronized in time, and also because the CTD installed in the VPR was operating with the vessel in movement, it is still striking the correspondence between the temperature and salinity values and gradients between the data sampled by both devices.

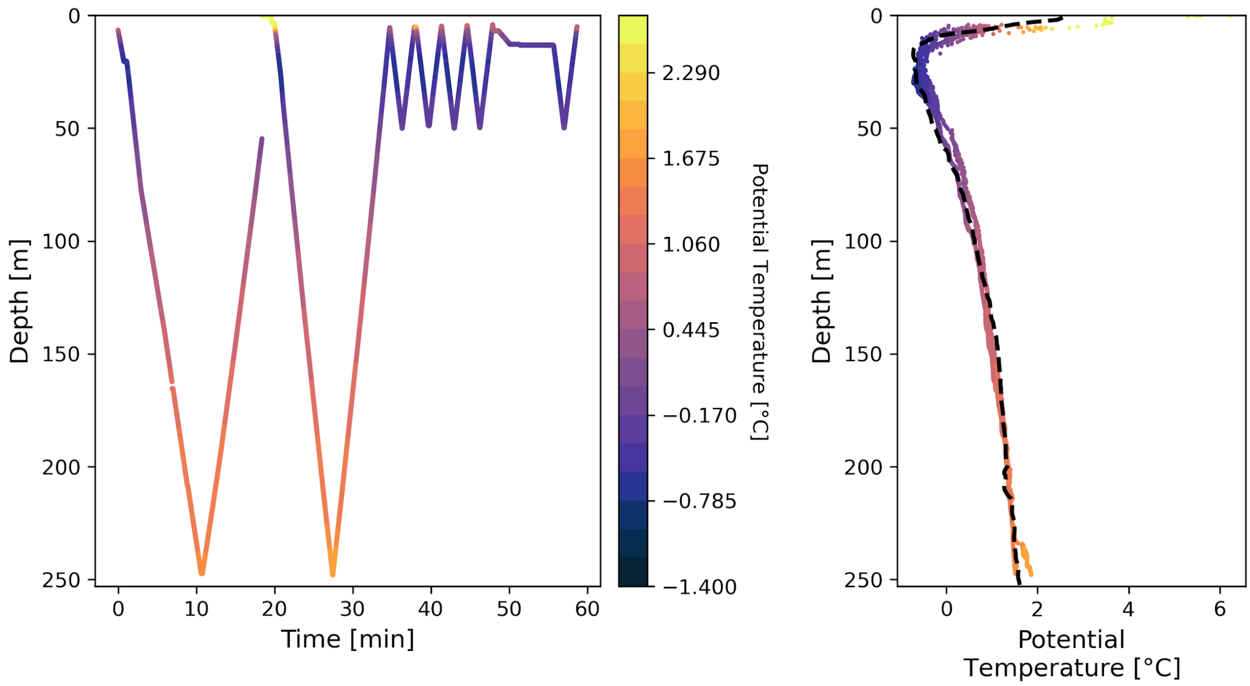


Fig. 4.10 Vertical profiles of potential temperature sampled in station EF17. (Left panel) Vertical movement of the CTD over time and respective potential temperature values represented according to the colorbar. (Right panel) profiles of potential temperature sampled by the CTD installed in the VPR system (colourful dots) compared against the potential temperature cast sampled by the individual CTD.

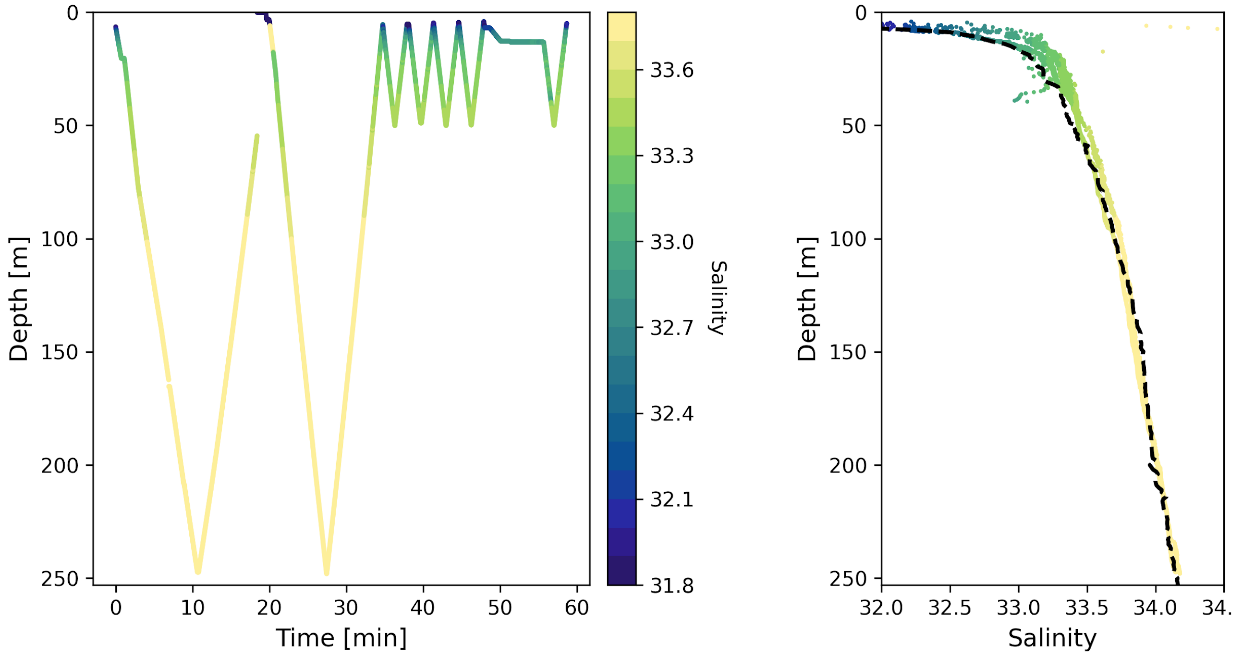


Fig. 4.11: Vertical profiles of salinity sampled in station EF17. (Left panel) Vertical movement of the CTD over time and respective salinity values represented according to the colorbar. (Right panel) profiles of temperature sampled by the CTD installed in the VPR system (colourful dots) compared against the temperature cast sampled by the individual CTD.

4.3 Imaging devices

4.3.1 Video Plankton Recorder

A VPR was used to collect zooplankton, CTD (see section 4.1.2), fluorescence and turbidity data. At almost all stations, with the exception of EF18, 22 ,24 and 45, the VPR encountered technical issues which could always be quickly solved on the station itself so that valuable data collection was still possible. The device functioned well in the Artcic waters and due the low turbidity of the water column, no turbidity issues were present and good plankton images could be captured (+- 90% of the images are plankton). A total of 66.000 images were collected.

Through the glass fibre cable on the winch, image and environmental data was sent onboard in real time. The live data collection indicated that on the shelf and fjords larger plankton species were present in the top layer, and smaller ones in the deeper layers. Inside the fjords a layer around 10-20m depth (depending on station) with high fluorescence values was present. This layer seemed to separate a more abundant and larger plankton community in the top layer from the less dense and smaller sized plankton in the deeper layers. On the first stations the VPR undulated between the surface and the maximum depth determined by the length of the winch cable (the winch cable itself is 250m). Because most plankton was observed in the top layer, it was decided to first do two undulations until the max depth and then subsequently undulate between 0-50m to collect more data on this plankton rich zone from station EF 17 onwards. The next processing step is to validate the images and identify the plankton taxa captured. An overview of some of the collected VPR images can be found in figure 4.12.

Fig. 4.12 Collage or recorded plankton images by the Video Plankton Recorder during the cruise.

4.3.2 CPICS

The CPICS (Continuous Particle Imaging and Classification System, Coastal Ocean Vision Inc. USA) was used to complement the VPR for optical sampling of the zooplankton and particle abundance as well as distribution patterns. It was deployed in two modes: In the first set up the CPICS was attached to the VPR's tow body below the v-fin for simultaneous sampling. To allow correlation of the data it was spliced into the VPR's CTD to merge both datastreams. Additionally, in the second mode of deployment, vertical hauls were performed within a protective cage including a CTD and turbidity sensor.

To yield the best possible results the camera was calibrated submerged in a tank on deck, where a copepod attached to string was used. Although the tests and deployments went well they resulted in only a limited number of images due to the small sampling volume of less than 1ml/s and the low abundances of zooplankton in the water column. However, the image quality was good as shown in figure 4.13.

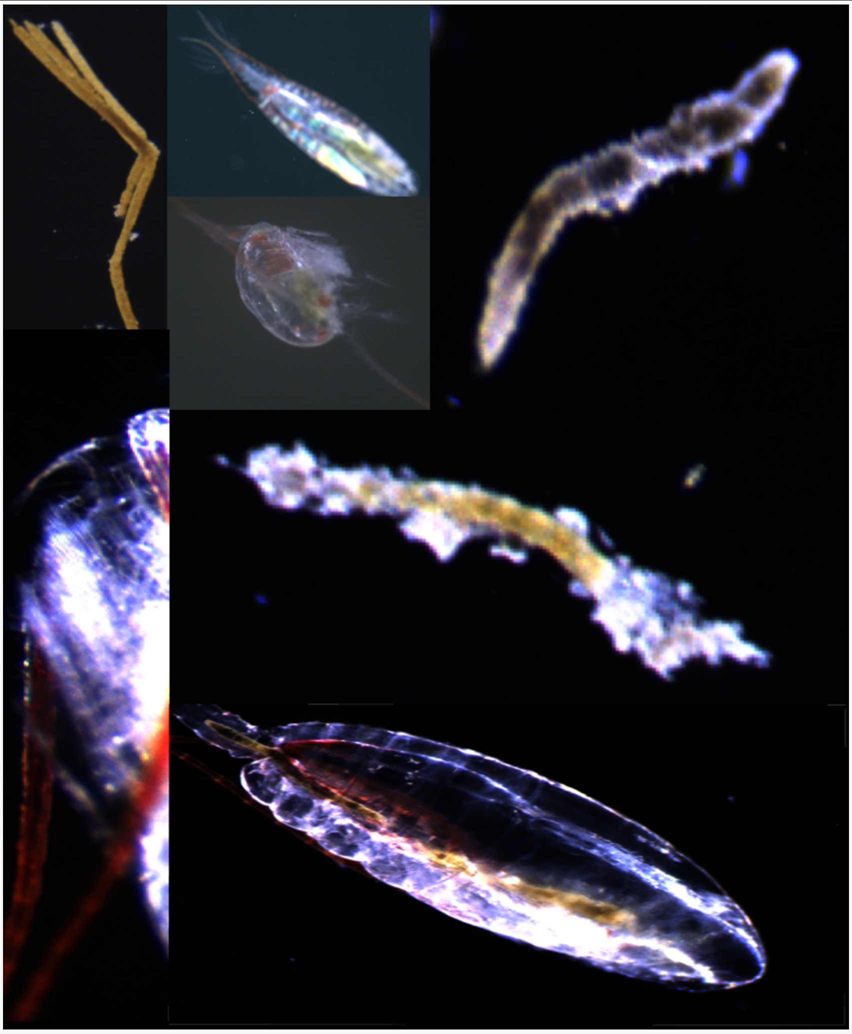


Fig. 4.13 Example Images of CPICS

4.4 Plankton nets

Physical plankton samples were collected by means of a 20 µm Apstein net, a 50 µm MultiNet and a MIK net. The Apstein net collects phytoplankton, whereas the MultiNet collects micro en mesozooplankton in depth intervals. The MIK net was used to collect larger zooplankton specimens. The plankton in the net samples will further be processed and identified by means of a FlowCam, ZooScan or through microscopy.

4.5 Water samples with Niskin bottles

Water sampling was conducted using 10 L Niskin bottles. At every station, water samples for Chl a analysis were collected at 1, 5, 10, 20, 40, 50 m and DCM (Deep chlorophyll maximum) depths. 500 ml was filtered through 25 mm Whatman GF/F filters (0.7 µm pore size) and frozen at -80°C. Water for nutrient analysis (nitrite, nitrate, ammonium, phosphate and silicate) was sampled from all depths and filtered through 0.45 µm Millipore filters (Q-Max GPF syringe) and stored frozen at -20°C. At focus stations, water was sampled for flow cytometry analysis. Water was collected at 1, 5, 10, 20, 30, 40, 100, and 200 m, directly from the Niskin bottle into 5 ml cryogenic vials. These were preserved with glutaraldehyde (Sigma-Aldrich) at 1% final concentration, left for ~1 hour in a refrigerator at 4°C and then frozen at -80°C. Suspended particulate matter (SPM) was collected by filtering ~1-2 L water from 1, 10, 20, 30, 40, 100, and 200 m and the deepest sampled depth, onto pre-combusted and pre-weighed 25 mm GF/F filters (0.7 µm pore size). Filtration continued until the filters were clogged. For all samples, visible zooplankton were removed with tweezers and filters were then stored at

-80°C. For DNA analysis, filter samples were taken through 0.45 µm nitrocellulose filters (500 to 1000 mL). Unfiltered water from 1, 10, 20, 50, 100, 200 and the deepest sampled depth was transferred by gastight Tygon tubing to 12.5 mL Exetainers (Labco, UK) for dissolved inorganic carbon (DIC) analysis. Exetainers were left to overflow and samples were preserved by adding 0.02 % saturated HgCl2 solution. Samples were stored in darkness at 4 ◦C until further analysis.

Primary production was measured using the 14C incubation method (Nielsen, 1952). Incubation bottles were filled with 60 mL unfiltered seawater and spiked with 100 µL NaH14CO3 and incubated for 2 h in an incubator. The samples were filtered onto GF/F filters (Whatman) and 100 µL of 1M HCl was added to remove excess NaH14CO3, and then the filters were left open for 24 h in the fume hood.

For FRRF measurements water was always collected from depths of 1, 10, 20, 40 and 50 m. During the first days of the cruise, a depth of 5 m was sampled as well. It was soon decided not to sample a depth of 5 m anymore and instead take a sample from the depth corresponding to the DCM based on the fluorescence signal from a CTD. Blank measurements were used to determine the background fluorescence of a mixture of all water samples at a given location filtered through 0.2 µm mixed cellulose ester filters with a diameter of 25 mm (Advantec Membrane Filter). Blank measurements were performed for each location and the FRRF was cleaned after each day of sampling with a 30% bleach solution.

4.6 Vertical microstructure profiler (VMP250)

Vertical profiles of turbulent microstructure were obtained with a stand-alone VMP250, Rockland Scientific Inc.. The probe was equipped with two air-foil shear probes (SH1: serial number M1854, SH2: serial number M1857), two fast responding FP07 thermistors (T1: T1568, T2: T1637, swapped to T1639 on July 2, 21:45 UTC), a JAC CTD, and a CLTU sensor to measure chl-a fluorometer and turbidity.

Measurements were carried out at 23 stations, with one station comprising between 3 and 10 individual profiles. In total 122 profiles were measured. The profiler was operated preferably in a workboat, in some 100m distance from Sanna, or directly from Sanna if the operation of the workboat was not feasible. GPS coordinates were noted at the beginning of each profile.

List of measurements (all times in UTC):

Station 1 (June 28, from Sanna) - **EF01:** 1. 70.713168°N, -57.909204°W 11:24; 2. 70.710645°N, -57.917488°W 11:38; 3. 70.708493°N, -57.924484°W 11:49; 4. 70.706590°N, -57.931943°W 12:00; 5. 70.704400°N, -57.941137°W 12:13

Station 2 (June 29, from Sanna) - **EF04:** 1. 70.826336°N, -56.102092°W 13:42; 2. 70.823745°N, -56.106137°W 13:54; 3. 70.821848°N, -56.110122°W 14:05

Station 3 (June 30, from Sanna) - **EF08:** 1. 70.914502°N, -53.775646°W 11:29; 2. 70.913476°N, -53.772044°W 11:41; 3. 70.912375°N, -53.767931°W 11:54; 4. 70.911179°N, -53.764029°W 12:07

Station 4 (July 1, from workboat, using dyneema, whale present) - **EF12:** 1. 70.857917°N, -52.423849°W 9:45; 2. GPS data missing; 3. 70.857916°N, -52.425472°W 10:13; 4. 70.857919°N, -52.426062°W 10:27; 5. 70.857851°N, -52.426528°W 10:41; 6. 70.857687°N, -52.426932°W 10:54; 7. 70.857402°N, -52.427429°W 11:07; 8. 70.857077°N, -52.427615°W 11:19; 9. 70.856747°N, -52.428350°W 11:34; 10. 70.856262°N, -52.428555°W 11:48

Station 5 (July 1, from workboat, using dyneema, lots of icebergs around) - **EF15:** 1. 70.607943°N, -51.851499°W 17:54; 2. 70.608001°N, -51.849461°W 18:05; 3. 70.607935°N, -51.847038°W 18:16; 4.

70.607825°N, -51.844128°W 18:28; 5. 70.607778°N, -51.841520°W 18:40; 6. 70.607713°N, -51.841957°W 18:53; 7. 70.607711°N, -51.839805°W 19:05; 8. 70.607684°N, -51.843624°W 19:19; 9. 70.607794°N, -51.842281°W 19:30

Station 6 (July 2, from Sanna) – **EF17;** 1. 70.464689°N, -51.474450°W 11:44; 2. 70.466347°N, -51.474174°W 11:59; 3. 70.467672°N, -51.475410°W 12:12; 4. 70.468854°N, -51.476334°W 12:25

Station 7 (July 2, from Sanna, after connector cap cleaning and new O-Ring) -**no EF#** 1. 70.471350°N, -51.493557°W 17:12; 2. 70.471160°N, -51.493201°W 17:27; 3. 70.470870°N, -51.492933°W 17:41; 4. 70.470830°N, -51.493988°W 17:54

! July 2 21:45: swapped T2 sensor, from T1637 to T1639

Station 8 (July 3, from workboat, a little bit of sea ice around) **– no EF #:** 1. 72.090831°N, -53.619207°W 12:45; 2. 72.090001°N, -53.615994°W 12:59; 3. 72.089272°N, -53.613174°W 13:11; 4. 72.088424°N, -53.609837°W 13:25; 5. 72.087732°N, -53.607291°W 13:37

Station 9 (July 3, from Sanna) - **EF18:** 1. 72.201914°N, -53.770418°W 19:46; 2. 72.201822°N, -53.771526°W 19:57; 3. 72.201725°N, -53.772182°W 20:07

Station 10 (July 3, from Sanna) **- EF19:** 1. 72.264654°N, -53.804209°W 21:25; 2. 72.264783°N, -53.804738°W 21:34; 3. 72.264916°N, -53.806283°W 21:44; 4. 72.264978°N, -53.806418°W 21:54

Station 11 (July 4, from workboat) **- EF22:** 1. 71.872528°N, -53.369938°W 12:07; 2. 71.872581°N, -53.369584°W 12:22; 3. 71.872756°N, -53.369492°W 12:37; 4. 71.872937°N, -53.369688°W 12:53; 5. 71.873319°N, -53.370248°W 13:09; 6. 71.873697°N, -53.371395°W 13:22; 7. 71.874106°N, -53.371761°W 13:36

Station 12 (July 4, from workboat) **- EF24:** 1. 71.637003°N, -53.564759°W 19:08; 2. 71.637552°N, -53.564196°W 19:21; 3. 71.638015°N, -53.562937°W 19:34; 4. 71.638474°N, -53.561737°W 19:48

Station 13 (July 5, from workboat) **- EF26:** 1. 71.938362°N, -52.867583°W 11:48; 2. 71.937940°N, -52.868322°W 12:04; 3. 71.937728°N, -52.868704°W 12:18; 4. 71.937465°N, -52.869543°W 12:33; 5. 71.937142°N, -52.869688°W 12:47; 6. 71.936632°N, -52.870581°W 13:00; 7. 71.936220°N, -52.871407°W 13:13; 8. 71.935720°N, -52.872159°W 13:26; 9. 71.935164°N, -52.873377°W 13:39

Station 14 (July 5, from Sanna, lots of icebergs) **- EF27:** 1. 72.035913°N, -52.616148°W 18:54; 2. 72.036292°N, -52.616789°W 19:09; 3. 72.036562°N, -52.615920°W 19:23; 4. 72.036765°N, -52.615043°W 19:37

Station 15 (July 5, from Sanna) **- EF28:** 1. 72.036807°N, -52.615185°W 21:49; 2. 71.990736°N, -52.765443°W 22:03; 3. 71.990835°N, -52.766936°W 22:15; 4. 71.990785°N, -52.768022°W 22:29

Station 16 (July 6, from workboat) – **EF32(?):** 1. 71.375611°N, -52.692894°W 12:20; 2. 71.375905°N, -52.693611°W 12:33; 3. 71.376180°N, -52.693543°W 12:48; 4. 71.376377°N, -52.694120°W 13:02; 5. 71.376605°N, -52.694204°W 13:16; 6. 71.376763°N, -52.694242°W 13:29; 7. 71.376888°N, -52.693957°W 13:43

Station 17 (July 6, from workboat, without Kiki) ! Careful, coordinates not in decimal degree – **EF35?:** 1. 71° 28.615 N, - 51° 29.619 W 22:07; 2. 71° 28.657 N, - 51° 29.645 W 22:22; 3. 71° 28.687 N, - 51° 29.632 W 22:37 [WP116]; 4. 71° 28.714 N, - 51° 29.644 W 22:51 [WP117]; 5. 71° 28.618 N, - 51° 29.423 W ??:?? [WP119]; 6. 71° 28.644 N, - 51° 29.443 W ??:?? [WP120]

Station 18 (July 7, from workboat, wavy, icebergs breaking) **- EF37:** ! Careful, issues with some location data. For 4 profiles, available time / GPS pairs are: 71.101756°N, -53.185210°W 11:40; 71.098758°N, -53.189340°W 11:56; 71.097501°N, -53.191467°W 12:10

Station 19 (July 7, from workboat) **- EF40:** 1. 71.081741°N, -52.306013°W 20:47; 2. 71.082990°N, -52.306598°W 21:07 [relocation]; 3. 71.083003°N, -52.306644°W 21:25; 4. 71.083446°N, -52.309221°W 21:39; 5. 71.083225°N, -52.311551°W 21:55; 6. 71.084287°N, -52.311460°W 22:11

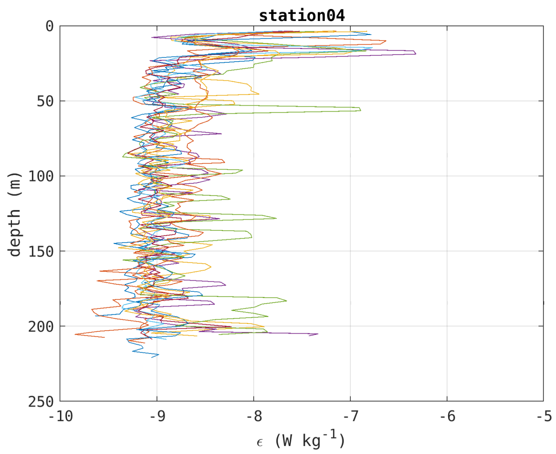
Station 20 (July 8, from workboat) **- EF43:** 1. 70.864320°N, -51.363807°W 12:00; 2. 70.864366°N, -51.361931°W 12:16; 3. 70.864506°N, -51.360396°W 12:31; 4. 70.864653°N, -51.359467°W 12:45; 5. 70.864692°N, -51.359212°W 12:59; 6. 70.864703°N, -51.358062°W 13:13; 7. 70.864707°N, -51.356998°W 13:27

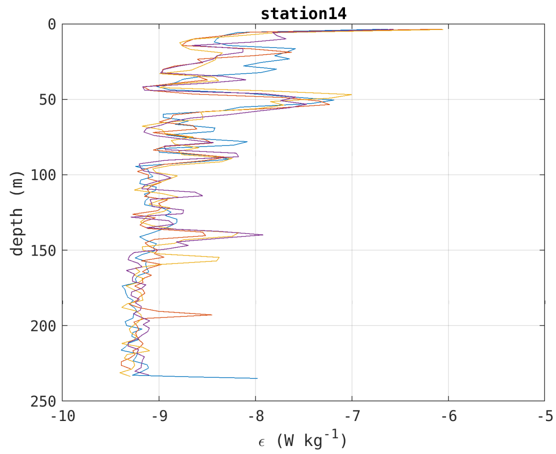
Station 21 (July 8, from Sanna) **- EF44:** 1. 70.810052°N, -51.093214°W 21:48; 2. 70.810274°N, -51.091302°W 22:02; 3. 70.810395°N, -51.090500°W 22:15; 4. 70.810693°N, -51.089417°W 22:28

Station 22 (July 9, from Sanna) **- EF45:** 1. 70.789743°N, -50.852762°W 10:37; 2. 70.789976°N, -50.853007°W 10:46; 3. 70.790201°N, -50.852502°W 10:54; 4. 70.790136°N, -50.851721°W 11:03

Station 23 (July 9, from workboat) **- EF47:** 1. 70.765528°N, -51.758494°W 16:40; 2. 70.765516°N, -51.758636°W 16:54; 3. 70.765415°N, -51.758410°W 17:08; 4. 70.765224°N, -51.758055°W 17:21; 5. 70.765105°N, -51.757691°W 17:35

Preliminary processing was done using the default setting in the ODAS matlab package by the instrument manufacturer. Rates of turbulent kinetic energy dissipation are generally low below the surface mixed layer, in the order of 10^-9 W kg^-1. At station 14 (EF27) and, less pronounced, at station 18 (EF37), a thin layer of enhanced dissipation rates was present around 50m depth. At both stations, icebergs were present. At station 4 (EF12), some thin, unconnected patches of enhanced turbulence were visible, which might or might not be related to the presence of a whale very close by. In the profiles obtained at stations 10 (EF19) and 20 (EF43), turbulence was enhanced towards the lower end of the profile, indicative of a turbulent bottom boundary layer. The only station with slightly elevated (half an order of magnitude) levels of turbulence throughout the whole water column was 17 (EF35), which was the closest station to the glacier front.





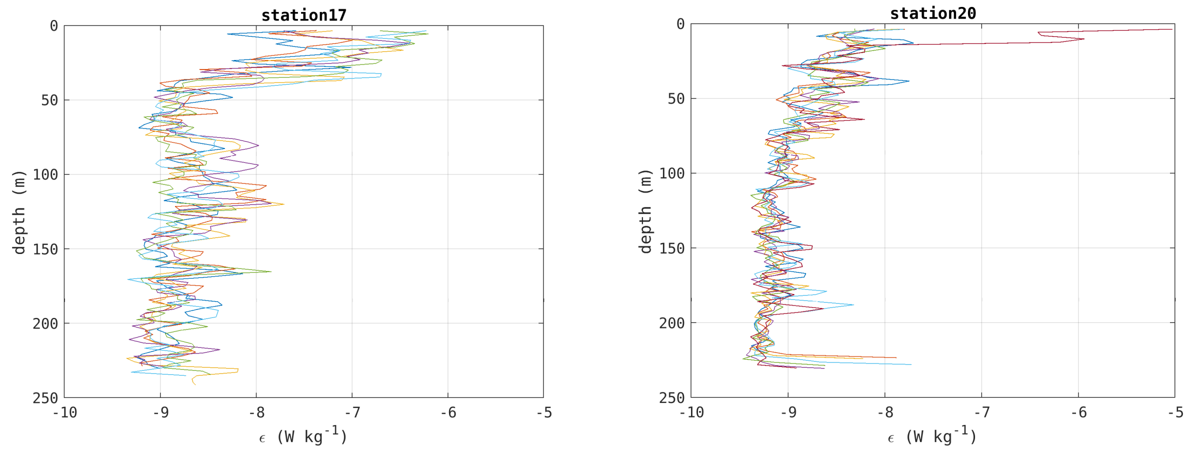


Fig 4.14 Vertical profiles of the turbulent dissipation rate epsilon (W kg-1) at four example stations.

5 Data and Sample Storage / Availability

All collected data were backed up on a hard drive during the cruise, and the files are now also uploaded to a data archive. All datasets are available to the partners.

6 Participants

Table 6.1 Participant list

No.	Name (Funded by EF+ = *)	Early career (Y/N)	Gender	Affiliation	On-board tasks (End responsibility = °)
1	Daniel Blandfort*	Y	M	HEREON	CPICS°, VPR
2	Wieter Boone*	Y	M	VLIZ	Chief scientist, CTD°
3	Roeland Develter*	Y	M	VLIZ	VPR°, Apstein net°, CTD
4	Lorenz Meire*	Y	M	NIOZ	Niskin°, filtrations°, MIK net°
5	Anouk Ollevier*	Y	F	VLIZ	VPR, MultiNet°, FA°
6	Koen Planken*	Y	M	NIOZ	FRRF°
7	Leandro Ponsoni*	Y	M	VLIZ	Turbulence profiles, CTD, data processing°
8	Kirstin Schulz*	Y	F	UT Austin	Turbulence profiles and data processing°, filtrations

HEREON	Helmholtz-Zentrum Hereon, Geesthacht, Germany
VLIZ	Flanders Marine Institute, Oostende, Belgium
NIOZ	Royal Netherlands Institute for Sea Research, Yerseke, the Netherlands
UT Austin	University of Texas at Austin, Austin, United States

Table 6.2 Remote participants, their tasks and role in processing the data/samples

No.	Name	Early career (Y/N)	Gender	Affiliation	Remote tasks
1	Klas Ove Möller	N	M	HEREON	Processing CPICS data
2	Dick van Oevelen	N	M	NIOZ	Processing FRRF data

7 Station List

Table 7.1 Station list

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear
	2022	[UTC]	[°N]	[°W]	[m]	
EF00	28.06	22:35:23	70.6483	-58.6888	592	CTD
EF01	28.06	11:22:15	70.71483	-57.9463	485	CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF02	29.06	9:11:33	70.75503	-57.3019	524	CTD
EF03	29.06	11:11:21	70.79507	-56.6915	569	CTD
EF04	29.06	13:14:04	70.83283	-56.0917	603	CTD, Turbulence profiler, 2x MultiNet, 1x WP2 net, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF05	29.06	21:42:35	70.85907	-55.4694	584	CTD
EF06	29.06	23:32:35	70.88528	-54.8368	559	CTD
EF07	30.06	1:21:56	70.90722	-54.1954	707	CTD
EF08	30.06	9:14:09	70.90925	-53.7591	785	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF09	30.06	17:23:23	70.91567	-53.4269	778	CTD
EF10	30.06	18:56:51	70.95442	-53.0625	760	CTD
EF11	30.06	20:27:45	70.93357	-52.6819	736	CTD
EF12	30.06 - 1.07	21:55:37	70.85585	-52.4179	785	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, VPR+CPICS
EF13	1.07	14:31:36	70.78743	-52.113	829	CTD
EF14	1.07	16:04:33	70.70368	-52.0228	987	CTD
EF15	1.07	17:48:13	70.6004	-51.8445	1024	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF16	2.07	9:11:43	70.50317	-51.725	955	CTD
EF17	2.07	11:03:46	70.47038	-51.4759	929	2x CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF18	3.07	19:25:46	72.08782	-53.5959	376	CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF19	3.07	21:09:23	72.20187	-53.7703	208	CTD
EF20	3.07	10:36:35	72.26472	-53.8037	200	CTD
EF21	4.07	11:57:40	71.99765	-53.4482	453	CTD
EF22	4.07	17:49:21	71.87168	-53.3585	440	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, VPR+CPICS
EF23	4.07	19:04:33	71.73537	-53.453	473	CTD
EF24	4.07	9:10:02	71.64107	-53.5604	425	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF25	5.07	10:20:38	71.76038	-53.2821	505	CTD
EF26	5.07	11:51:22	71.83087	-52.9797	500	CTD

EF27	5.07	18:30:08	71.9407	-52.8756	445	CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF28	5.07	21:20:41	72.03627	-52.6173	287	CTD, Turbulence profiler, 1x MultiNet, Niskin bottles, Apstein Net
EF29	5.07	9:12:45	71.99272	-52.7569	294	CTD
EF30	6.07	10:26:15	71.42045	-53.4438	590	CTD
EF31	6.07	12:15:10	71.42197	-53.1085	681	CTD
EF32	6.07	18:48:07	71.37677	-52.7049	427	CTD, Turbulence profiler, 3x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF33	6.07	20:19:33	71.37895	-52.3629	527	CTD
EF34	6.07	22:03:12	71.43938	-52.0007	553	CTD
EF35	6.07	9:04:12	71.47625	-51.4983	339	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, VPR+CPICS
EF36	7.07	11:04:49	71.25363	-53.3855	640	CTD
EF37	7.07	17:32:23	71.11	-53.1972	635	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF38	7.07	18:58:31	71.12817	-52.9052	445	CTD
EF39	7.07	20:43:27	71.12732	-52.5298	686	CTD
EF40	7.07	9:05:25	71.08378	-52.3024	986	CTD, Turbulence profiler, 2x MultiNet, CPICS, Niskin bottles, Apstein Net, VPR+CPICS
EF41	8.07	10:30:26	71.00517	-51.9747	688	CTD
EF42	8.07	12:06:05	70.93022	-51.6816	647	CTD
EF43	8.07	12:06:05	70.86205	-52.3579	945	CTD, Turbulence profiler, 3x MultiNet, Niskin bottles, Apstein Net, 2x MIK net, VPR+CPICS
EF44	8.07	21:00:24	70.97555	-51.0966	943	CTD
EF45	9.07	10:22:34	70.78985	-50.8513	213	CTD, Turbulence profiler, 2x MultiNet, Niskin bottles, Apstein Net, MIK net, VPR+CPICS
EF46	9.07	14:57:32	70.78395	-51.4923	1100	CTD
EF47	9.07	17:25:27	70.764366 67	-51.7593	1295	CTD, Turbulence profiler, 2x MultiNet, Niskin bottles, Apstein Net, MIK net, VPR+CPICS

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9 References

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