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Data Report for R/V Shinsei-Maru Cruise: KS22-17

Dec 26, 2022 – Jan 5, 2023

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Ryuichiro Inoue
Chiho Sukigara
Mei Sato
Gloria Silvana Duran Gomez
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Abstract

The Kuroshio Current, one of the world's largest ocean currents, flows through the regions south of Kyushu exhibiting the characteristic stationary inverted S-shaped meandering path. Although it is a stationary meandering current, some temporal variations are observed. In particular, when the Kuroshio flowing through the Tokara Strait shifted northward, warm water intrudes into the north of Yakushima Island, and submesoscale cyclonic eddies are generated in the southwest of Yakushima Island and southeast of Tanegashima, which are expected to supply nutrients caused by upwelling and turbulent mixing. Further south of Yakushima, subduction of organic matter can be expected from the Kuroshio Current, which takes an inverted S-shaped meander. However, due to a lack of detailed interdisciplinary field observations, detailed physical mechanisms, how much nutrients can be supplied, and how the low trophic level ecosystem responds to the nutrient injection have still been elusive. In this study, free-fall tow-yo turbulence and biochemical cross-sectional observations are conducted near Yakushima and Tanegashima Islands in southern Kyushu to clarify the effects of the reverse S-shaped meandering and mixing phenomenon of the Kuroshio on nutrient supply, ecosystem response.

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1. Cruise Overview

1.1 Cruise Information

1. Cruise ID: KS22-17
2. Name of vessel: Shinsei-Maru
3. Title of cruise : Mixing processes and quasi-steady meandering of the Kuroshio south of Kyushu and their impacts on marine ecosystem
4. Chief Scientist: Takeyoshi Nagai [Tokyo University of Marine Science and Technology]
5. Cruise period: December 26, 2022, through January 5, 2023
6. Ports of departure / call / arrival: Kochi
7. Research area: Southwest-Southeast of Kyshu
8. Research map (figure 2.22)

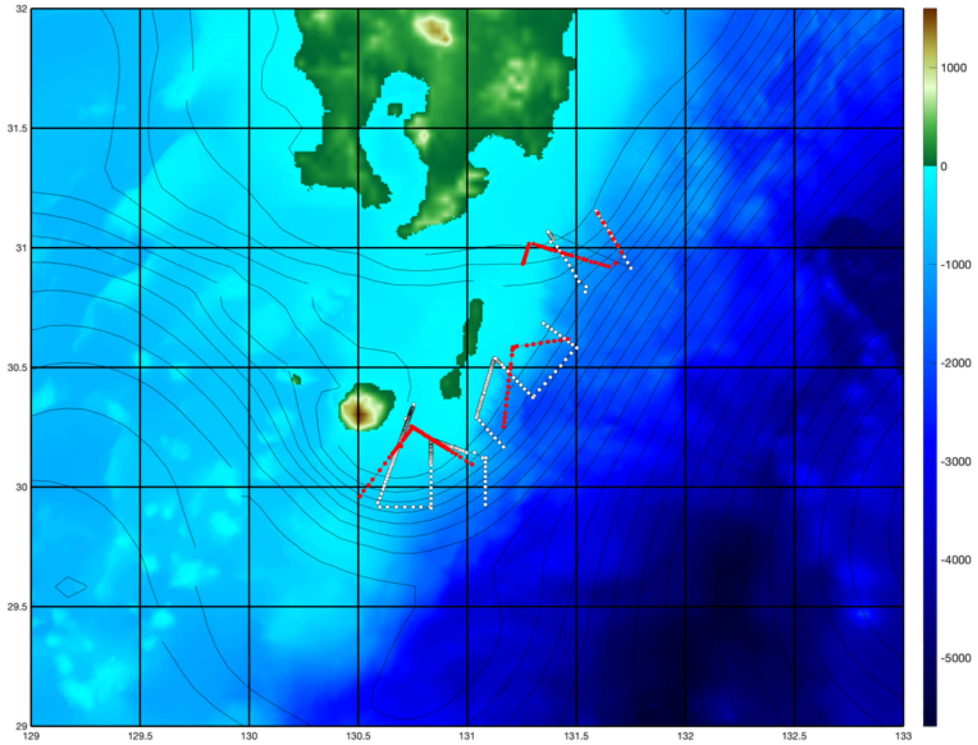

Figure 1.1: *Map of the observations. The circles indicate the ship track for (white) Underway-RINKO and (red) Underway-VMP and SUNADAYODACam tow-yo observations.*

1.2 Participants

The researchers participated in this cruise are listed as follows.

Table 1.1: *Participants. TUMSAT stands for Tokyo University of Marine Science and Technology. JAMSTEC stands for Japan Agency for Marine Earth Science and Technology. WHOI stands for Woods Hole Oceanographic Institution.*

Name	Affiliation	Title
Chief Scientist		
Takeyoshi Nagai	TUMSAT	Associate Professor
Onboard Scientists		
Ryuichiro Inoue	JAMSTEC	Senior Researcher
Chiho Sukigara	TUMSAT	Assistant Professor
Mei Sato	WHOI	Assistant Scientist
Ingibjorg Bjorgvinsdottir	TUMSAT	Doctoral Student
Gloria Silvana Duran Gomez	TUMSAT	Master Student
Eri Morikawa	TUMSAT	Master Student
Yuki Ikeda	TUMSAT	Master Student
Miku Okawa	TUMSAT	Master Student
Diego Andre Otero Huaman	TUMSAT	Research Student
Iara Andressa Torres Cabrera	TUMSAT	Research Student
Rubi Del Pilar Salazar	TUMSAT	Research Student
Kristinn Sigurdarson	TUMSAT	Research Student
Kou Morita	MWJ Ltd	Observation technicians

Figure 1.2: Group photo of KS22-17.

2. Research Activities

2.1 Background

The Kuroshio Current is known to be oligotrophic in the surface layer, but in the subsurface layer, it is a nutrient stream that carries nutrients downstream. The Kuroshio flows over seamounts in the Tokara Strait in the region southwest of Kyushu, where it exits the Okinawa Trough and turns its flow direction from northeast to southwest (e.g. Nagai et al. 2017), leading to intense turbulent mixing. More recent observations have also shown that the turbulent dissipation rate in the Tokara Strait, which is 100-1000 times larger than the surrounding area due to the formation of negative potential vorticity on the seamount slope, extends more than 100 km downstream as a strong turbulent streak (Nagai et al. 2021), enhancing the downstream subsurface chlorophyll maxima of east of Tane-gashima Island. However, little is known about how the nutrient supply associated with this intense turbulence and the increase in phytoplankton in the subsurface layer affects zooplankton and fish. Observations of high-resolution biological parameters have often been limited up to phytoplankton, and observations of their predators, the higher-order ecosystems, have been conducted primarily with nets. Therefore, it has been very difficult to compare the three-dimensional physical environment with the higher-order ecosystem. With the use of echo-sounders, it has become possible to obtain the same resolution for observations of higher-order ecosystems as for physical parameters (Sato et al. 2021), making it possible to quantitatively investigate the effects of turbulent mixing on the ecosystem. On the other hand, the Kuroshio Current, which flows northeastward through the Okinawa Trough, changes its flow to the southeast while riding up on shallows in the southwestern Kyushu region, and then changes its flow to the northeast again once it passes through the Tokara Strait due to rapid water depth increase. This forced reverse S-shaped meandering of the Kuroshio Current is quasi steady, and the convergence and divergence associated with the meander-ing is expected to form a quasi-steady vertical pathway of transport of matters. In addition, when the Kuroshio flows around the shallows in the southwestern Kyushu region, changing its direction from northeast to southwest, mixing is expected to occur within the Kuroshio. However, there are few examples of direct observations of turbulence and nutrients simultaneously, so it is unclear to what extent vertical mixing contributes to the nutrient supply to the regions south of

Kyushu. Furthermore, when the Kuroshio flows northward in the northern Tokara Strait, a part of the flow hits Yakushima Island, and numerical experiments by the principal investigator and others have shown that a submesoscale cyclonic eddy may form on the south of Yakushima Island, and satellite sea surface chlorophyll images often show an increase in chlorophyll-a concentrations, which may be due to the eddy upwelling effect. Thus, submesoscale cyclonic eddies along the Kuroshio in southern Kyushu generally tend to increase phytoplankton. The detailed mechanism, however, cannot be determined only from satellite observations at the sea surface. It is possible that the negative potential vorticity formed on the seamount slope can be stirred with the nutrient-rich submesoscale cyclonic eddies that form behind Yakushima and other islands, providing a efficient supply route of nutrients to sunlit layers, thereby increasing phytoplankton. Furthermore, three-dimensional physical and biochemical observations are needed to elucidate how this affects zooplankton and fish. In addition, when the Kuroshio passes through the Tokara Strait and changes its flow direction from southeast to northeast, a confluence (convergence) of currents can be expected, and subduction may occur in the meandering trough, injecting shelf water and water within the cyclonic eddy into the subsurface Kuroshio. The hypothesis that the submesoscale cyclonic eddies with nutrient-rich water and enhnaced diapycnal mixing work together to provide the nutrient into the upper layers and support biological production in the downstream areas. To test this hypothesis, this study will conduct three-dimensional density and current observations using a free-fall tow-yo Underway-CTD (UCTD) and ADCP in the southwest to south of Kyushu, where the Kuroshio meanders in an inverted S-shape on a regular basis. In addition, turbulence and nutrients will be observed using the Underway-VMP (UVMP), a free-fall tow-yo turbulence profiler, capable of cross-sectional observation of turbulent microstructure, and the SUNADAYODA, a free-fall tow-yo biochemical profiler capable of cross-sectional observation of nitrate concentration, chlorophyll fluorescence, and other parameters. In addition, an autonomous profiling float equipped with a turbulence sensor will be deployed along the Kuroshio Current to quantify turbulent mixing to just above the seafloor where UVMP cannot reach. Furthermore, we will attempt to quantify zooplankton and fish using the onboard Simrad EK60 fish finder of the Shinsei Maru. In conjunction with this, zooplankton and fish will be collected using a NORPAC net and IKMT net, and plankton and marine snow will be photographed using SUNADAYODACame, a high-resolution camera attached to SUNADAYODA. The purpose of this study is to clarify the effects of the reversed S-shape meandering and mixing of the Kuroshio Current on nutrient supply, the response of low trophic level ecosystems, and fish distribution in the southwestern region of Kyushu.

2.2 Cruise Log

On the first day of the cruise, the calibration of the echosounder was conducted in Kagoshima Bay and completed in a few hours. We then moved to Area 1, south of Yaku Island, and conducted free-fall tow-yo biochemical cross-sectional observations along a zigzag ship track. Free-fall tow-yo turbulence and biochemical parameter cross-sectional observations were also conducted. In addition, a CTD was deployed and water sampling was conducted, and a NORPAC Net was towed vertically. Also, the IKMET Net was towed to investigate what the echosounder captured. After observing area 1, we headed to area 2 south of Yaku Island and Tanegashima Island and conducted similar observations. After the area 2, we moved to the area 3, and deployed an autonomous microstructure float, FLAT. Then, the shipboard observations are repeated in the area 3 northeast of Tanegashima Island. While conducting the observations in the area 3, the float was recovered.

The cruise log is included as the following table.

Table 2.1: *Cruise log of KS22-17. The time is in JST. Longitude and latitude are in degree and minute.*

Date	Time	Lat (N).	Lon (E).	Station	Event	Depth [m]
12 27, 2022	12:40	31 27.71	130 33.14	EK1	CTD Start	282 m
12 27, 2022	13:02	31 27.71	130 33.14	EK1	CTD End	282 m
12 27, 2022	13:30	31 27.71	130 33.14	EK1	EK60 Calib1 Start	282 m
12 27, 2022	16:46	31 27.71	130 33.14	EK1	EK60 Calib1 End	282 m
12 28, 2022	08:00	31 27.71	130 33.14	EK1	EK60 Calib1 Start	288 m
12 28, 2022	09:20	31 27.71	130 33.14	EK1	EK60 Calib1 End	288 m

Table 2.2: *Continued Table from Table 2.1*

Date	Time	Lat (N).	Lon (E).	Station	Event	Depth [m]
12 28, 2022	20:10	30 4.1	130 44.0	IK1-1	IKMT Net Start	374 m
12 28, 2022	22:33	30 4.1	130 44.1	IK1-2	IKMT Net Start 382 m	
12 28, 2022	22:33	30 7.8	130 45.4	IK	IKMT Net End	382 m
12 29, 2022	00:00	30 20.1	130 45.0	Z1-1	URINKO Start	395 m
12 29, 2022	05:37	29 55.0	130 35.6	Z1-2	URINKO	425 m
12 29, 2022	09:11	29 54.6	130 50.0	Z1-3	URINKO	440 m
12 29, 2022	12:49	30 12.1	130 49.7	Z1-4	URINKO	460 m
12 29, 2022	15:43	30 7.4	131 5.1	Z1-5	URINKO	477 m
12 29, 2022	18:27	29 54.4	131 5.0	Z1-6	URINKO End	492 m
12 29, 2022	22:25	29 56.5	130 30.3	V1-1	CTD Start	531 m
12 29, 2022	23:43	29 56.6	130 32.6	V1-1	CTD End	533 m
12 30, 2022	00:11	29 56.5	130 30.3	V1-1	NORPAC Start	536 m
12 30, 2022	00:29	29 56.6	130 30.9	V1-1	NORPAC End	536 m
12 30, 2022	00:52	29 56.5	130 30.3	V1-1	UVMP Start	538 m
12 30, 2022	11:45	30 15.2	130 44.6	V1-2	UVMP	563 m
12 30, 2022	18:06	30 5.0	131 2.5	V1-2	UVMP End	585 m

Table 2.3: *Continued Table from Table 2.2*

Date	Time	Lat (N).	Lon (E).	Station	Event	Depth [m]
12 30, 2022	19:12	30 9.9	131 10.1	Z2-1	URINKO Start	592 m
12 30, 2022	21:06	30 17.6	131 2.4	Z2-2	URINKO End	603 m
12 30, 2022	21:21	30 17.5	131 2.5	Z2-2	CTD Start	603 m
12 30, 2022	22:30	30 17.9	131 3.9	Z2-2	CTD End	604 m
12 30, 2022	22:45	30 17.9	131 3.9	Z2-2	NORPAC Start	604 m
12 30, 2022	23:05	30 18.1	131 4.3	Z2-2	NORPAC End	604 m
12 30, 2022	23:23	30 18.1	131 4.4	IK2-1	IKMT Net Start	605 m
12 31, 2022	00:04	30 20.7	131 5.4	IK2-1	IKMT Net End	607 m
12 31, 2022	23:23	30 18.5	131 4.6	IK2-2	IKMT Net Start	610 m
12 31, 2022	00:04	30 22.6	131 6.2	IK2-2	IKMT Net End	614 m
12 31, 2022	02:50	30 17.6	131 2.6	Z2-2	URINKO Start	622 m
12 31, 2022	05:48	30 32.1	131 7.9	Z2-3	URINKO	639 m
12 31, 2022	09:10	30 22.4	131 17.8	Z2-4	URINKO	654 m
12 31, 2022	05:48	30 34.8	131 30.3	Z2-5	URINKO	670 m
12 31, 2022	05:48	30 42.0	131 19.6	Z2-6	URINKO	683 m
12 31, 2022	16:25	30 22.4	131 18.1	Z2-4	URINKO	654 m
12 31, 2022	18:53	30 32.4	131 7.6	Z2-3	URINKO End	720 m
12 31, 2022	21:45	30 32.4	131 7.6	F1	microALTO Deploy	746 m
12 31, 2022	22:05	30 10.2	131 10.1	F1	VMP Start	748 m
12 31, 2022	22:51	30 14.0	131 11.6	F1	VMP End	753 m
12 31, 2022	23:38	30 15.0	131 10.0	V2-1	UVMP Start	753 m
1 1, 2023	6:45	30 35.0	131 12.4	V2-2	UVMP	774 m
1 1, 2023	11:11	30 37.5	131 30.2	V2-3	UVMP End	790 m
1 1, 2023	11:38	30 36.3	131 29.3	V2-3	CTD Start	793 m
1 1, 2023	23:43	30 38.8	131 30.0	V2-3	CTD End	796 m
1 1, 2023	14:02	30 37.2	131 29.6	V2-3	NORPAC Start	536 m
1 1, 2023	14:23	30 38.0	131 29.8	V2-3	NORPAC End	536 m

Table 2.4: *Continued Table from Table 2.3*

Date	Time	Lat (N).	Lon (E).	Station	Event	Depth [m]
1 1, 2023	14:43	30 37.6	131 29.5	IK3-1	IKMT Net Start	801 m
1 1, 2023	15:24	30 40.5	131 28.1	IK3-1	IKMT Net End	801 m
1 1, 2023	16:07	30 37.6	131 29.7	IK3-2	IKMT Net Start	808 m
1 1, 2023	17:09	30 41.7	131 28.2	IK3-2	IKMT Net End	809 m
1 1, 2023	21:21	30 54.3	131 39.7	V3-2	CTD Start	822 m
1 1, 2023	22:30	30 55.7	131 41.0	V3-2	CTD End	823 m
1 1, 2023	22:45	30 55.2	131 40.5	V3-2	NORPAC Start	824 m
1 1, 2023	23:05	30 55.7	131 41.0	V3-2	NORPAC End	824 m
1 1, 2023	23:23	30 55.1	131 40.4	IK4-1	IKMT Net Start	826 m
1 1, 2023	00:04	30 58.3	131 40.3	IK4-1	IKMT Net End	827 m
1 1, 2023	23:23	30 55.0	131 40.5	IK4-2	IKMT Net Start	832 m
1 1, 2023	00:04	30 58.5	131 40.0	IK4-2	IKMT Net End	835 m
1 2, 2023	08:55	30 46.3	131 38.9	F2	microALTO Recover	894 m
1 2, 2023	11:45	30 54.7	131 14.9	V3-1	UVMP Start	918 m
1 2, 2023	17:54	30 57.0	131 32.6	V3-1	UVMP Terminated	940 m
1 2, 2023	18:28	30 56.5	131 29.8	V3-O	CTD Start	944 m
1 2, 2023	19:56	30 56.2	131 30.1	V3-O	CTD End	944 m
1 2, 2023	20:10	30 56.3	131 29.7	V3-2	NORPAC Start	945 m
1 2, 2023	20:25	30 56.2	131 29.8	V3-2	NORPAC End	947 m
1 2, 2023	20:38	30 56.1	131 29.8	IK5-1	IKMT Net Start	945 m
1 2, 2023	21:17	30 55.9	131 28.0	IK5-1	IKMT Net End	947 m
1 2, 2023	21:36	30 56.2	131 29.9	IK5-2	IKMT Net Start	949 m
1 2, 2023	23:00	30 56.3	131 27.3	IK5-2	IKMT Net End	954 m
1 2, 2023	23:27	30 57.2	131 31.9	V3-1	UVMP Restart	958 m
1 3, 2023	02:59	30 55.0	131 40.0	V3-2	UVMP	975 m
1 3, 2023	06:10	31 10.0	131 35.0	V3-3	UVMP	982 m
1 3, 2023	09:52	30 48.9	131 32.6	Z3-2	URINKO Start	1008 m
1 3, 2023	13:10	31 4.2	131 22.1	Z3-1	URINKO End	1026 m
1 3, 2023	14:05	30 58.0	131 27.5	IK5-3	IKMT Net Start	1034 m
1 3, 2023	14:43	30 59.5	131 26.3	IK5-3	IKMT Net End	1036 m
1 3, 2023	15:03	30 57.8	131 27.6	IK5-4	IKMT Net Start	1038 m
1 3, 2023	16:22	31 1.3	131 27.2	IK5-4	IKMT Net End	1042 m
1 3, 2023	18:16	30 54.8	131 45.1	Z3-3	URINKO Start	1060 m
1 3, 2023	21:16	31 10.5	131 34.7	Z3-4	URINKO End	1075 m

2.3 Underway Observations

Figure 2.1: One of two winches that were used for towing UVMP and SUNADAYODACam during KS22-17.

2.3.1 Instrumentation

We use three different tow-yo profilers, including Underway-VMP, Underway-RINKO, and SUNADAYODACam. The Underway-VMP (UVMP), which consists of a Vertical Microstructure Profiler 250 (VMP250, Rockland Scientific International, Victoria, B.C., Canada) and an Underway-CTD winch (Teledyne Oceanscience, CA, USA) was used in the study area. The VMP250 carries two shear probes, two FP07 thermistors, a pressure sensor, an accelerometer, and a conductivity-temperature-depth (CTD) package. The VMP250 measured temperature, conductivity, and pressure at 64 Hz, turbulent shear, microscale temperature gradient, and acceleration components of the instrument at 512 Hz. The data were used only for the downcast while the VMP250 descended roughly at a quasi-free fall speed of 0.7 ms^{-1} on average. The tow-yo UVMP observations were conducted with a ship speed relative to the water at 1–2 ms^{-1}. The VMP250 reaches approximately 300 m depth after 7 minutes, depending on the current, and recovering it to the surface takes about 7–8 minutes, which enabled us to profile every 15 minutes with a lateral resolution of 0.9–1.8 km. Above the seamounts with shallower bottom depths, the profiling required shorter duration, and the lateral resolution became correspondingly higher. Underway-RINKO (URINKO, JFE-Advantech) carries, JFE-CTD, chlorophyll a and turbidity, and oxygen sensor. We tow-yo Underway RINKO at 6 knots allowing us to deploy it down to 400 m every 15 minutes. SUNADAYODA carries YODA-Profiler (JFE-Advantech), which has the same sensors of URINKO. We mounted Deep-SUNA (Sea-Bird) on the YODA-Profiler, that we call SUNADAYODA to measure nitrate concentration. Also, we attached the camera to record 4K videos of marine aggregates and plankton (SUNADAYODACam) while its descending period.

2.3.2 Underway-VMP Observations

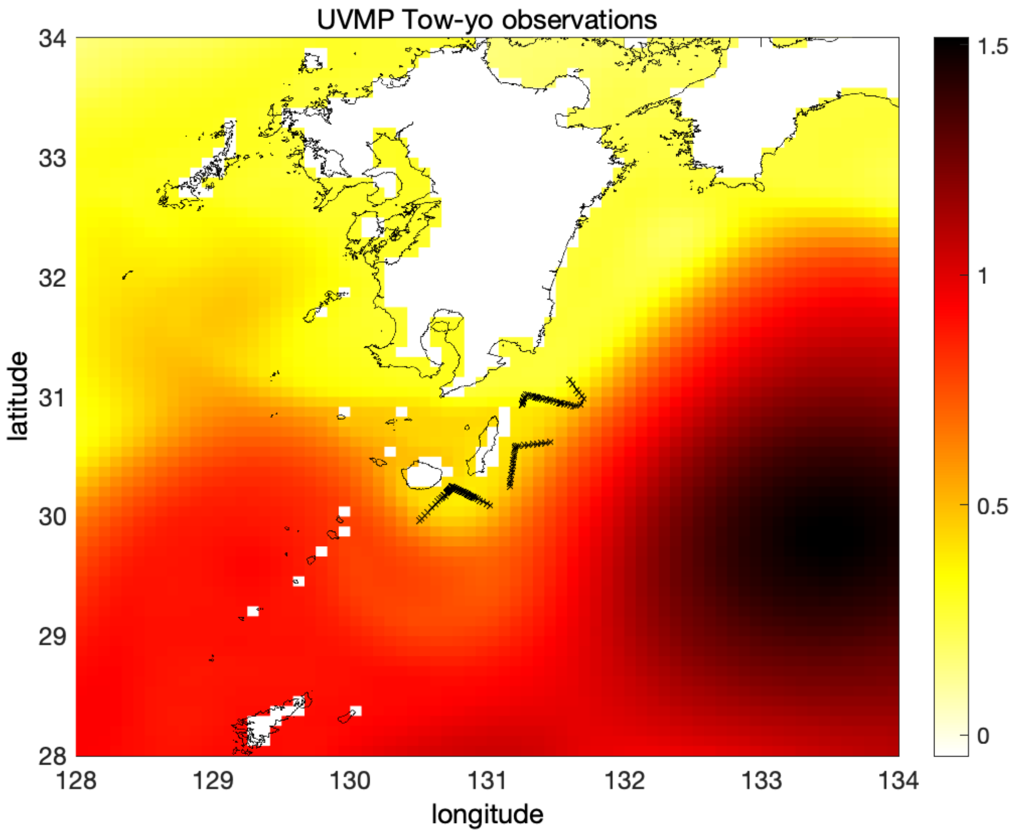

Figure 2.2: Underway-VMP tow-yo lines during KS22-17. Red shading represents average sea surface height (CMEMS) during Dec. 28-Jan 3.

Underway-VMP (UVMP) observations were carried out in 3 different observation sites; the first one is south of Yakushima Island (site 1), the second one is south of Tanegashima Island (site 2), and the last one is east of Tanegashima Island (site 3) (Figure 2.2). The detailed log for the UVMP is as follows.

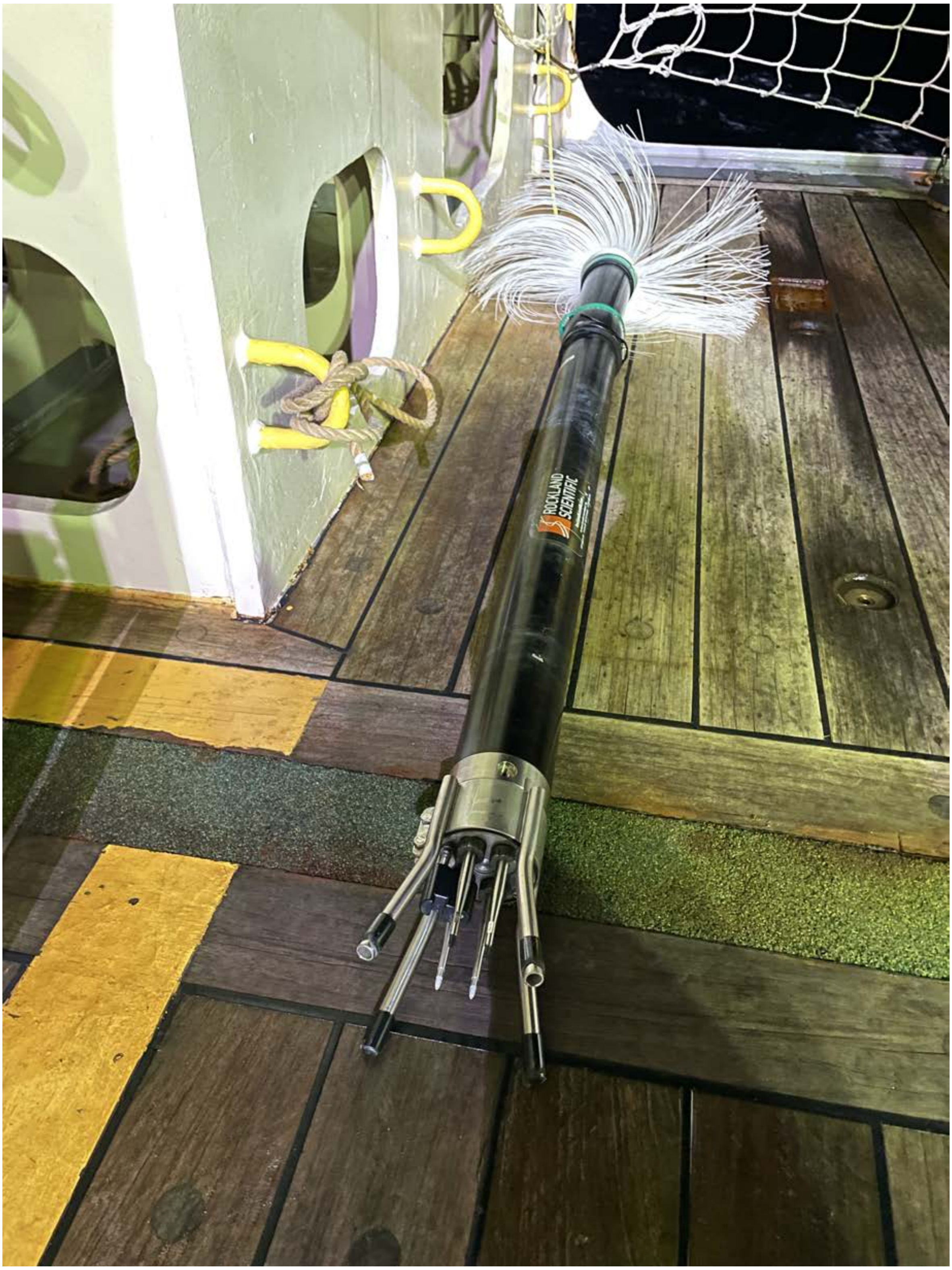

Figure 2.3: *VMP250 tow-yoed during KS22-17.*

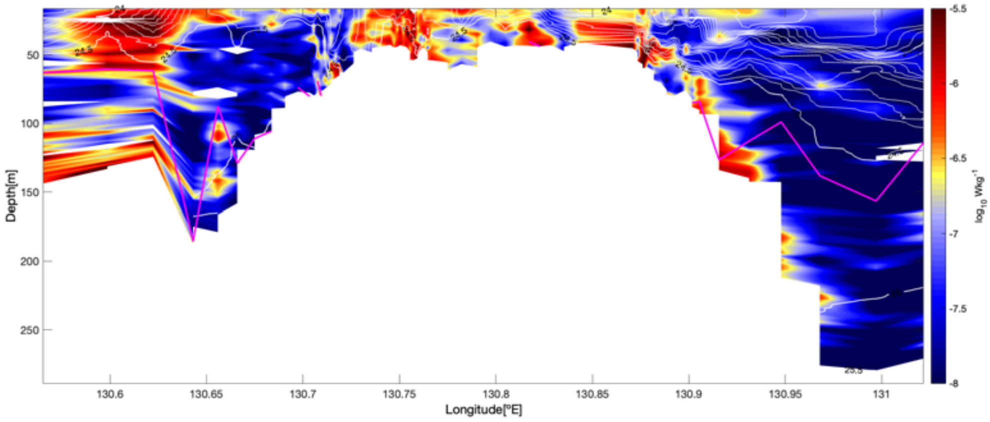

Figure 2.4: *Turbulent Kinetic Energy (TKE) dissipation rates measured using the Underway-VMP for site 1 (eastern most observation site in Figure 2.2). The magenta line shows mixed layer depth.*

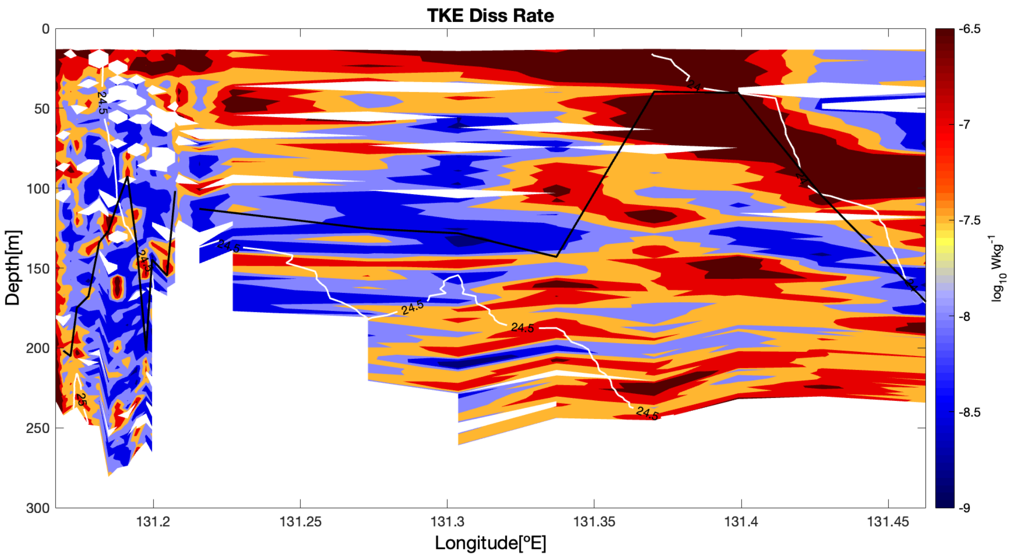

Figure 2.5: *Turbulent Kinetic Energy (TKE) dissipation rates measured using the Underway-VMP for site 2 (middle observation site in Figure 2.2). The black line shows mixed layer depth.*

Table 2.5: *Deployment log of UVMP.*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	30	0:55	29	57.6715	130	30.4084	455	7′	V1-1
12	30	1:14	29	59.023	130	31.5441	466.9	7′	V1-1
12	30	1:34	30	0.5064	130	32.8137	416.7	7′	V1-1
12	30	1:51	30	1.8391	130	33.9269	348.5	7′	V1-1
12	30	2:22	30	4.2196	130	35.916	287.1	5′	V1-1
12	30	2:45	30	5.9148	130	37.3408	269	"4′50"""	V1-1
12	30	3:09	30	7.3803	130	38.5824	248	"4′20"""	V1-1
12	30	3:31	30	8.2942	130	39.3522	231	"3′30"""	V1-1
12	30	3:51	30	8.9894	130	39.9549	214	4′	V1-1
12	30	4:11	30	9.6421	130	40.4957	188	"2′50"""	V1-1
12	30	4:30	30	10.274	130	41.0217	167	"2′20"""	V1-1
12	30	4:48	30	10.7572	130	41.4422	158	"2′05"""	V1-1
12	30	5:04	30	10.2288	130	41.8422	144	"1′50"""	V1-1
12	30	5:20	30	11.6693	130	42.2094	137	2′	V1-1
12	30	5:26	30	11.8226	130	42.3435	135	"1′50"""	V1-1
12	30	5:30	30	11.948	130	42.4494	132	"1′50"""	V1-1
12	30	5:35	30	12.084	130	42.5674	128	"1′50"""	V1-1
12	30	5:39	30	12.2162	130	42.6753	123	"1′45"""	V1-1
12	30	5:43	30	12.3465	130	42.7752	117	"1′40"""	V1-1
12	30	5:47	30	12.478	130	42.8709	111	"1′40"""	V1-1
12	30	5:51	30	12.6404	130	43.0176	105	"1′30"""	V1-1
12	30	5:55	30	12.7695	130	43.1321	98	"1′30"""	V1-1
12	30	6:00	30	12.9221	130	43.2557	92	"1′25"""	V1-1
12	30	6:10	30	13.283	130	43.5757	79.9	1′	V1-1
12	30	6:18	30	13.5659	130	43.8063	79.9	"45"""	V1-1
12	30	6:25	30	13.7663	130	43.9859	79	"45"""	V1-1
12	30	6:31	30	13.9454	130	44.1323	77.6	"45"""	V1-1
12	30	6:39	30	14.1704	130	44.3157	76.3	"25"""	V1-1
12	30	6:45	30	14.3741	130	44.4906	76.4	"20"""	V1-1
12	30	6:45	30	14.6575	130	44.7219	76.3	"20"""	V1-1
12	30	7:00	30	14.8788	130	44.9275	75.7	"30"""	V1-1
12	30	11:45	30	15.2108	130	44.5898	71.1	1′	V1-2
12	30	11:48	30	15.1544	130	44.7049	72.9	1′	V1-2
12	30	11:51	30	15.087	130	44.8256	75	1′	V1-2
12	30	11:54	30	15.0311	130	44.9277	75.7	1′	V1-2
12	30	11:56	30	14.9863	130	45.0269	76.1	1′	V1-2
12	30	11:58	30	14.9267	130	45.1221	77.6	1′	V1-2
12	30	12:01	30	14.868	130	45.222	77.3	1′	V1-2
12	30	12:04	30	14.8049	130	45.3328	80.6	"1′10"""	V1-2
12	30	12:06	30	14.75	130	45.45	85.5	"1′10"""	V1-2
12	30	12:09	30	14.6723	130	45.5656	86.3	"1′10"""	V1-2
12	30	12:12	30	14.6198	130	45.6833	75.4	1′	V1-2
12	30	12:15	30	14.5618	130	45.7807	78.4	1′	V1-2
12	30	12:17	30	14.5001	130	45.8792	85.8	"1′10"""	V1-2
12	30	12:20	30	14.4314	130	46.003	81.4	"1′10"""	V1-2
12	30	12:31	30	14.1516	130	46.5018	90.9	"1′30"""	V1-2
12	30	12:41	30	13.9126	130	46.931	87.5	"1′50"""	V1-2
12	30	12:52	30	13.6482	130	47.4251	88.8	"1′20"""	V1-2
12	30	13:01	30	13.3944	130	47.8252	85.3	1′	V1-2
12	30	13:14	30	13.1223	130	48.2916	76.8	1′	V1-2
12	30	13:22	30	12.9251	130	48.6175	72.1	1′	V1-2
12	30	13:31	30	12.7153	130	49.0289	69.1	1′	V1-2
12	30	13:39	30	12.535	130	49.3623	72.6	1′	V1-2
12	30	13:47	30	12.3148	130	49.6887	79.5	1′	V1-2
12	30	13:57	30	12.0592	130	50.1156	83.2	"1′10"""	V1-2
12	30	14:05	30	11.8106	130	50.5882	77.1	1′	V1-2
12	30	14:14	30	11.5823	130	51.0053	66.1	"40"""	V1-2
12	30	14:20	30	11.3914	130	51.3313	57.2	"40"""	V1-2
12	30	14:23	30	11.2932	130	51.5005	46.2	"20"""	V1-2
12	30	14:24	30	11.25	130	51.5819	52.8	"30"""	V1-2
12	30	14:26	30	11.2072	130	51.6559	53.6	"30"""	V1-2
12	30	14:27	30	11.1564	130	51.7501	55	"30"""	V1-2
12	30	14:29	30	11.1063	130	51.8361	58.2	"30"""	V1-2
12	30	14:31	30	11.0464	130	51.9377	65.7	"40"""	V1-2
12	30	14:32	30	10.9922	130	52.0201	69.5	"40"""	V1-2
12	30	14:34	30	10.9266	130	52.1367	72.8	"40"""	V1-2
12	30	14:37	30	10.8557	130	52.2598	79	1′	V1-2
12	30	14:40	30	10.7629	130	52.4066	83.8	"1′10"""	V1-2
12	30	14:43	30	10.6705	130	52.5645	89.1	"1′20"""	V1-2
12	30	14:46	30	10.5608	130	52.7364	93.8	"1′20"""	V1-2
12	30	14:50	30	10.4611	130	52.9137	98.3	"1′30"""	V1-2
12	30	14:54	30	10.3493	130	53.1298	102.1	"1′30"""	V1-2
12	30	14:58	30	10.2562	130	53.3094	106.3	"1′40"""	V1-2
12	30	15:02	30	10.1306	130	53.5393	108.7	"1′40"""	V1-2
12	30	15:07	30	10.0178	130	53.7441	109.3	"1′40"""	V1-2
12	30	15:10	30	9.9147	130	53.9033	112.5	"1′40"""	V1-2

Table 2.6: *Continued table from Table 2.5*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	30	15:14	30	9.8011	130	54.0974	127.7	"1’50"""	V1-2
12	30	15:19	30	9.6783	130	54.3262	127.3	2’	V1-2
12	30	15:33	30	9.322	130	54.94	137.7	2’	V1-2
12	30	15:54	30	8.7746	130	55.8743	172.5	"3’10"""	V1-2
12	30	16:16	30	8.2082	130	56.8707	246	"5’10"""	V1-2
12	30	16:43	30	7.4819	130	58.0759	350	7’	V1-2
12	30	17:15	30	6.5088	130	59.8188	524	7’	V1-2
12	30	17:43	30	5.6844	131	1.3024	709.9	7’	V1-2
12	31	23:39	30	15.0844	131	9.9977	1378	7’	V2-1
1	1	23:25	30	16.3645	131	10.1636	1462	7’	V2-1
1	1	0:14	30	17.4709	131	10.3095	1501	7’	V2-1
1	1	0:30	30	18.5437	131	10.4368	1470	7’	V2-1
1	1	0:59	30	20.4153	131	10.6743	1359	7’	V2-1
1	1	1:28	30	22.128	131	10.8946	1293	7’	V2-1
1	1	1:56	30	23.6367	131	11.0813	1203	7’	V2-1
1	1	2:24	30	25.0607	131	11.265	1240	7’	V2-1
1	1	2:55	30	26.6969	131	11.4713	990	7’	V2-1
1	1	3:24	30	28.2313	131	11.6552	601	7’	V2-1
1	1	3:53	30	29.7737	131	11.8495	527	7’	V2-1
1	1	4:10	30	30.7425	131	11.9728	440	7’	V2-1
1	1	4:55	30	33.0828	131	12.2769	234	4’	V2-1
1	1	5:12	30	34.429	131	12.4433	212	"3’35"""	V2-1
1	1	6:46	30	34.9965	131	12.513	170	"2’40"""	V2-2
1	1	6:52	30	35.0476	131	12.9382	185	"3’10"""	V2-2
1	1	7:18	30	35.2844	131	13.6213	239	"4’20"""	V2-2
1	1	7:42	30	35.5303	131	16.3776	305	"5’40"""	V2-2
1	1	8:08	30	35.8157	131	18.219	505	7’	V2-2
1	1	8:38	30	36.1234	131	20.2259	585	7’	V2-2
1	1	9:08	30	36.3993	131	22.2201	757	7’	V2-2
1	1	9:39	30	36.6253	131	23.9343	845	7’	V2-2
1	1	10:09	30	36.8583	131	25.6466	1003	7’	V2-2
1	1	10:39	30	37.1618	131	27.7693	1188	7’	V2-2
1	2	12:05	30	55.9836	131	15.3411	100.9	"1’30"""	V3-1
1	2	12:09	30	56.2265	131	15.4173	100.6	"1’30"""	V3-1
1	2	12:13	30	56.4621	131	15.4945	101.4	"1’30"""	V3-1
1	2	12:17	30	56.7133	131	15.5799	101.2	"1’30"""	V3-1
1	2	12:21	30	56.9609	131	15.6682	100	"1’30"""	V3-1
1	2	12:31	30	57.571	131	15.8746	101.9	"1’30"""	V3-1
1	2	12:42	30	58.1734	131	16.0724	101.9	"1’30"""	V3-1
1	2	12:53	30	58.8553	131	16.2942	106	"1’30"""	V3-1
1	2	13:04	30	59.5116	131	16.5226	105	"1’30"""	V3-1
1	2	13:16	31	0.1777	131	16.7361	108	"1’30"""	V3-1
1	2	13:29	31	0.9253	131	16.9955	113	"1’40"""	V3-1
1	2	13:48	31	0.9495	131	18.2523	117	"1’30"""	V3-1
1	2	14:00	31	0.566	131	19.3707	124	"1’40"""	V3-1
1	2	14:12	31	0.3235	131	20.2525	134	2’	V3-1
1	2	14:27	31	0.0369	131	21.2484	143	2’	V3-1
1	2	14:35	30	59.9102	131	21.7039	152	"2’20"""	V3-1
1	2	14:41	30	59.8189	131	22.0642	205	"3’20"""	V3-1
1	2	14:49	30	59.6823	131	22.5801	259	5’	V3-1
1	2	15:01	30	59.4954	131	23.3163	523	7’	V3-1
1	2	15:18	30	59.214	131	24.3133	598.4	7’	V3-1
1	2	15:47	30	58.7625	131	26.0082	739.4	7’	V3-1
1	2	16:04	30	58.516	131	26.939	804	7’	V3-1
1	2	16:21	30	58.262	131	27.8195	860	7’	V3-1
1	2	16:38	30	57.9987	131	28.8662	920	7’	V3-1
1	2	17:06	30	57.5329	131	30.6005	1014	7’	V3-1
1	2	17:35	30	57.2073	131	31.9577	1089	7’	V3-1
1	2	23:28	30	57.1682	131	31.939	1085	7’	V3-1
1	2	23:44	30	56.9525	131	32.7296	1139	7’	V3-1
1	3	0:12	30	56.5174	131	34.0002	1227	7’	V3-1
1	3	0:39	30	56.2739	131	35.2209	1266	7’	V3-1
1	3	1:08	30	55.9459	131	36.5279	1308	7’	V3-1
1	3	1:36	30	55.6072	131	37.7085	1302	7’	V3-1
1	3	2:04	30	55.2972	131	38.9205	1394	7’	V3-1
1	3	3:14	30	56.1502	131	40.7602	1497	7’	V3-2
1	3	4:00	30	58.8358	131	42.4515	1471	7’	V3-2
1	3	4:18	31	0.5649	131	41.3038	1378	7’	V3-2
1	3	4:36	31	2.1856	131	40.2322	1319	7’	V3-2
1	3	4:54	31	3.7156	131	39.1956	1153	7’	V3-2
1	3	5:24	31	6.3487	131	37.4522	983	7’	V3-2
1	3	5:53	31	8.6041	131	35.9239	904	7’	V3-2

2.3.3 SUNADAYODACam Observations

Figure 2.6: *SUNADAYODACam tow-yoed during KS22-17.*

SUNADAYODACam was alternatively deployed wit the UVMP from one of 2 winches mounted on the stern of the ship. Thus the deployments were carried out also in the same 3 observation sites; the first one is south of Yakushima Island, the second one is south of Tanegashima Island, and the last one is east of Tanegashima Island (Figure 2.2). The detailed log for the SUNADAYODACam is as follows. During the tow-yo profiling at the final observation line, the winch was suddenly stopped or even reversed dram's spin while we were recovering the SUNADAYODACam. But we could recover it to the surface. Right after this incidence, we brought the instrument back on deck and found out that the battery pack for SUNA is detached from the mounting clump and connected to YODA Profiler only with a cable between the battery and the SUNA. It is suspected that the battery pack was bit by a shark (Figure 2.7).

Figure 2.7: *SUNADAYODACam after the shark attack.*

Table 2.7: Log of SUNADAYODACam

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Y	Min.	Deg.	Min.	m	Minute	Name
12	30	2:11	30	3.3799	130	35.1954	302.4	"3’30"""	V1-1
12	30	2:34	30	5.1397	130	36.7083	273	4’	V1-1
12	30	2:59	30	6.8243	130	38.0866	258	4’	V1-1
12	30	3:21	30	7.8733	130	39.0002	238	4’	V1-1
12	30	3:41	30	8.6748	130	39.6993	223	4’	V1-1
12	30	4:00	30	9.3159	130	40.2275	203	4’	V1-1
12	30	4:20	30	9.9126	130	40.717	178	4’	V1-1
12	30	4:37	30	10.4614	130	41.182	163	4’	V1-1
12	30	4:53	30	10.9008	130	41.547	152	4’	V1-1
12	30	5:09	30	11.3706	130	41.9575	141	4’	V1-1
12	30	6:06	30	13.1628	130	43.4586	78	1’	V1-1
12	30	6:14	30	13.4312	130	43.6913	80	"1’10"""	V1-1
12	30	6:21	30	13.6677	130	43.8971	79	"1’10"""	V1-1
12	30	6:28	30	13.8437	130	44.0508	78.3	"1’10"""	V1-1
12	30	6:36	30	14.1023	130	44.2531	76.8	"42"""	V1-1
12	30	6:41	30	14.2423	130	44.377	75.6	"1’05"""	V1-1
12	30	6:51	30	14.5324	130	44.6346	75.3	"1’05"""	V1-1
12	30	6:56	30	14.7322	130	44.7921	76.4	"1’05"""	V1-1
12	30	12:24	30	14.3224	130	46.3	86.1	1’	V1-2
12	30	12:35	30	14.0422	130	46.7066	86.7	"1’15"""	V1-2
12	30	12:44	30	13.8221	130	47.1152	91.5	"2’20"""	V1-2
12	30	12:56	30	13.562	130	47.5654	86.9	2’	V1-2
12	30	13:07	30	13.2699	130	48.0511	80.5	"1’55"""	V1-2
12	30	13:17	30	13.0344	130	48.4352	75.7	"1’30"""	V1-2
12	30	13:25	30	12.8352	130	48.7924	71.6	"1’30"""	V1-2
12	30	13:34	30	12.6321	130	49.1851	67.8	"1’30"""	V1-2
12	30	13:42	30	12.4639	130	49.4828	75.1	"1’40"""	V1-2
12	30	13:51	30	12.2151	130	49.8453	82.5	"1’50"""	V1-2
12	30	14:00	30	11.9742	130	50.2769	81.7	"1’50"""	V1-2
12	30	14:09	30	11.7091	130	50.7815	173.4	"1’40"""	V1-2
12	30	14:16	30	11.4803	130	51.1773	59.7	"1’10"""	V1-2
12	30	15:24	30	9.5424	130	54.552	129.2	"3’10"""	V1-2
12	30	15:43	30	9.0543	130	55.402	152	"4’10"""	V1-2
12	30	16:02	30	8.5586	130	56.2668	182	5’	V1-2
12	30	16:28	30	7.8857	130	57.4135	286	5’	V1-2
12	30	17:04	30	6.8533	130	59.2386	450	"4’15"""	V1-2
12	30	17:33	30	5.9812	131	0.8151	650	"4’10"""	V1-2
12	30	18:00	30	5.1887	131	2.18	822.3	4’	V1-2
1	1	0:48	30	19.6849	131	10.5951	1464	"4’15"""	V2-1
1	1	1:17	30	21.4895	131	10.8203	1324	"4’15"""	V2-1
1	1	1:45	30	23.0691	131	11.0261	1222	"4’15"""	V2-1
1	1	2:13	30	24.4777	131	11.1895	1176	"4’15"""	V2-1
1	1	2:43	30	26.0452	131	11.388	1215	"4’15"""	V2-1
1	1	3:12	30	27.6067	131	11.5906	840	"4’15"""	V2-1
1	1	3:41	30	29.1362	131	11.7835	589	"4’15"""	V2-1
1	1	4:28	30	31.8569	131	12.1093	320	"4’15"""	V2-1
1	1	4:39	30	32.4388	131	12.1784	268	"4’15"""	V2-1
1	1	5:00	30	33.6671	131	12.351	224	"4’15"""	V2-1
1	1	7:01	30	35.122	131	13.4787	204	"4’15"""	V2-2
1	1	7:30	30	35.4212	131	15.4929	260	"4’15"""	V2-2
1	1	7:57	30	35.7192	131	17.411	408	"4’15"""	V2-2
1	1	8:27	30	35.9977	131	19.4181	596	"4’15"""	V2-2
1	1	8:56	30	36.2952	131	21.4678	838	"4’15"""	V2-2
1	1	9:28	30	36.5499	131	23.3304	792	"4’15"""	V2-2
1	1	9:58	30	38.7861	131	24.9811	937	"4’15"""	V2-2
1	1	10:28	30	37.0426	131	26.9158	1139	"4’15"""	V2-2
1	1	10:59	30	37.381	131	29.9381	1319	"4’15"""	V2-2
1	2	12:25	30	57.2004	131	15.756	100	"2’20"""	V3-1
1	2	12:35	30	57.7854	131	15.9411	101.7	"2’30"""	V3-1
1	2	12:46	30	58.4408	131	16.1671	103.9	"2’30"""	V3-1
1	2	13:00	30	59.2475	131	16.4277	105	"2’30"""	V3-1
1	2	13:09	30	59.7856	131	16.6146	106	"2’30"""	V3-1
1	2	13:21	31	0.4903	131	16.8381	110	"2’30"""	V3-1
1	2	13:40	31	1.2135	131	17.5902	117	"2’20"""	V3-1
1	2	13:52	31	0.8059	131	18.6376	119	"2’40"""	V3-1
1	2	14:05	31	0.4509	131	19.7694	128	3’	V3-1
1	2	14:18	31	0.1994	131	20.6314	138	"3’20"""	V3-1
1	2	15:34	30	58.9664	131	25.2535	695.8	"4’15"""	V3-1
1	2	16:55	30	57.7125	131	29.9087	976	"4’15"""	V3-1
1	2	17:24	30	57.3064	131	31.6304	1066	"4’15"""	V3-1
1	3	0:01	30	56.7429	131	33.551	1183	"4’15"""	V3-1
1	3	0:29	30	56.4097	131	34.7563	1250	"4’15"""	V3-1
1	3	0:57	30	56.0673	131	36.0054	1295	"4’15"""	V3-1
1	3	1:25	30	55.7452	131	37.2264	1280	"4’15"""	V3-1
1	3	1:53	30	55.4131	131	38.4213	1350	"4’15"""	V3-1
1	3	2:21	30	55.1083	131	39.5824	1449	"4’15"""	V3-1
1	3	3:02	30	55.2676	131	40.1826	1534	"4’15"""	V3-2
1	3	5:12	31	5.3022	131	38.1535	1057	"4’15"""	V3-2
1	3	5:42	31	7.7819	131	36.4867	922	"4’15"""	V3-2

2.3.4 Underway-RINKO Observations

In above 3 observation sites, we deployed Underway-RINKO to map the three-dimensional temperature, salinity, density, chlorophyll, turbidity, and dissolved oxygen distributions, prior or after the UVMP-SUNADAYODACam tow-yo surveys (Figure 2.8).

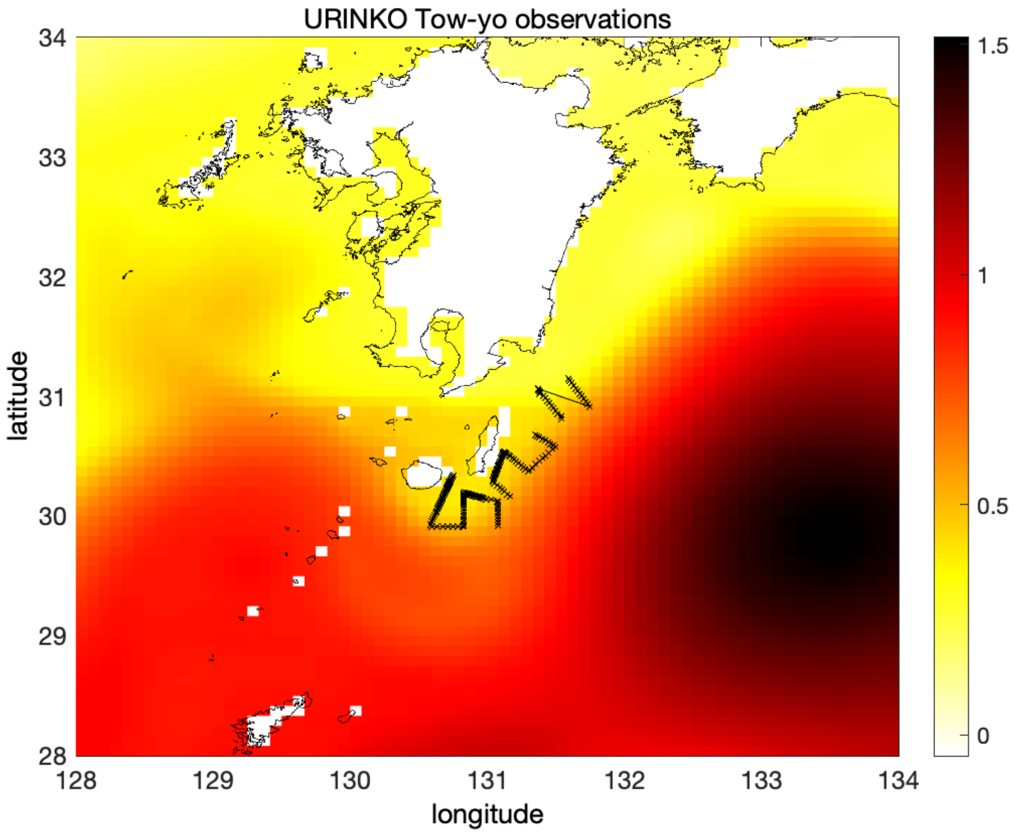

Figure 2.8: Underway-RINKO tow-yo lines during KS22-17. Red shading represents average sea surface height (CMEMS) during Dec. 28-Jan 3.

Table 2.8: *Log of URINKO.*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	28	23:58	30	20.6679	130	45.281	64.7	"15"""	Z1-1
12	29	0:07	30	19.9731	130	44.999	69.1	"16"""	Z1-1
12	29	0:08	30	19.8472	130	44.949	58.7	"15"""	Z1-1
12	29	0:10	30	19.6561	130	44.881	49.7	"15"""	Z1-1
12	29	0:11	30	19.5658	130	44.8475	50.2	"15"""	Z1-1
12	29	0:13	30	19.4579	130	44.8004	51.9	"15"""	Z1-1
12	29	0:14	30	19.3477	130	44.751	51.3	"15"""	Z1-1
12	29	0:15	30	19.2459	130	44.7031	52.4	"15"""	Z1-1
12	29	0:17	30	19.09	130	44.6352	52.2	"15"""	Z1-1
12	29	0:18	30	18.981	130	44.5891	51.9	"15"""	Z1-1
12	29	0:19	30	18.8673	130	44.5396	52	"15"""	Z1-1
12	29	0:20	30	18.7719	130	44.5003	51.9	"15"""	Z1-1
12	29	0:21	30	18.666	130	44.4577	52.2	"15"""	Z1-1
12	29	0:23	30	18.5246	130	44.4026	51.1	"15"""	Z1-1
12	29	0:24	30	18.4199	130	44.3592	51.1	"15"""	Z1-1
12	29	0:25	30	18.2984	130	44.3092	48.7	"10"""	Z1-1
12	29	0:26	30	18.212	130	44.2747	48	"10"""	Z1-1
12	29	0:27	30	18.1431	130	44.2471	48.5	"10"""	Z1-1
12	29	0:28	30	18.0549	130	44.2131	51.9	"10"""	Z1-1
12	29	0:29	30	17.9697	130	44.1828	53.3	"10"""	Z1-1
12	29	0:30	30	17.8849	130	44.1528	54	"10"""	Z1-1
12	29	0:31	30	17.8125	130	44.1267	54.7	"10"""	Z1-1
12	29	0:32	30	17.7175	130	44.0925	58	"15"""	Z1-1
12	29	0:33	30	17.6244	130	44.059	59.1	"15"""	Z1-1
12	29	0:34	30	17.5285	130	44.0231	60.2	"15"""	Z1-1
12	29	0:36	30	17.4266	130	43.983	61.1	"15"""	Z1-1
12	29	0:37	30	17.3258	130	43.941	61.8	"15"""	Z1-1
12	29	0:38	30	17.2221	130	43.8352	62.6	"15"""	Z1-1
12	29	0:39	30	17.122	130	43.0533	62.7	"15"""	Z1-1
12	29	0:40	30	17.0223	130	43.8121	63.2	"15"""	Z1-1
12	29	0:42	30	16.9232	130	43.7724	63.8	"15"""	Z1-1
12	29	0:43	30	16.7737	130	43.7126	65.2	"18"""	Z1-1
12	29	0:45	30	16.6467	130	43.6625	66.3	"18"""	Z1-1
12	29	0:46	30	16.5186	130	43.6134	67	"18"""	Z1-1
12	29	0:48	30	16.386	130	43.5643	67.5	"20"""	Z1-1
12	29	0:50	30	16.2445	130	43.511	68.3	"20"""	Z1-1
12	29	0:51	30	16.1094	130	43.4585	69.6	"20"""	Z1-1
12	29	0:53	30	15.9618	130	43.3991	70.8	"20"""	Z1-1
12	29	0:55	30	15.8252	130	43.343	72.2	"20"""	Z1-1
12	29	0:57	30	15.6287	130	43.2615	74.4	"20"""	Z1-1
12	29	0:58	30	15.5005	130	43.2104	74.8	"20"""	Z1-1
12	29	1:01	30	15.272	130	43.1218	73.4	"20"""	Z1-1

Table 2.9: *Continued table from 2.8*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	29	1:03	30	15.1424	130	43.0673	72.8	"20"""	Z1-1
12	29	1:05	30	14.9814	130	43	75.1	"20"""	Z1-1
12	29	1:06	30	14.8415	130	42.9413	74.5	"20"""	Z1-1
12	29	1:08	30	14.713	130	42.8886	73.6	"20"""	Z1-1
12	29	1:10	30	14.5762	130	42.8329	73.7	"20"""	Z1-1
12	29	1:13	30	14.3049	130	42.7266	74.5	"20"""	Z1-1
12	29	1:14	30	14.1667	130	42.6721	75	"22"""	Z1-1
12	29	1:17	30	13.9792	130	42.6017	75.7	"22"""	Z1-1
12	29	1:18	30	13.8459	130	42.5528	76.3	"22"""	Z1-1
12	29	1:20	30	13.7152	130	42.4984	76.9	"22"""	Z1-1
12	29	1:21	30	13.5799	130	42.4407	76.9	"22"""	Z1-1
12	29	1:23	30	13.421	130	42.375	76	"22"""	Z1-1
12	29	1:25	30	13.2725	130	42.3169	82.9	"25"""	Z1-1
12	29	1:27	30	13.0891	130	42.2477	89.8	"25"""	Z1-1
12	29	1:29	30	12.9131	130	42.1846	97.9	"30"""	Z1-1
12	29	1:31	30	12.7241	130	42.1155	107	"30"""	Z1-1
12	29	1:34	30	12.4753	130	42.0131	116.9	"35"""	Z1-1
12	29	1:36	30	12.2421	130	41.908	121	"35"""	Z1-1
12	29	1:38	30	11.9976	130	41.8004	126.4	"35"""	Z1-1
12	29	1:41	30	11.7648	130	41.7094	132.9	"40"""	Z1-1
12	29	1:44	30	11.4996	130	41.6033	137.2	"40"""	Z1-1
12	29	1:47	30	11.1889	130	41.4827	141.9	"45"""	Z1-1
12	29	1:50	30	10.8787	130	41.3599	148.8	"45"""	Z1-1
12	29	1:53	30	10.5657	130	41.2205	159.5	"45"""	Z1-1
12	29	1:56	30	10.29	130	41.108	162.9	"50"""	Z1-1
12	29	2:00	30	9.9506	130	40.9742	173.9	1’	Z1-1
12	29	2:04	30	9.555	130	40.8154	188	"1’05"""	Z1-1
12	29	2:09	30	9.1019	130	40.635	206.3	"1’10"""	Z1-1
12	29	2:14	30	8.6134	130	40.444	222.9	"1’20"""	Z1-1
12	29	2:19	30	8.1919	130	40.2764	232.4	"1’25"""	Z1-1
12	29	2:25	30	7.6402	130	40.0592	242.2	"1’30"""	Z1-1
12	29	2:30	30	7.1558	130	39.874	247.6	"1’30"""	Z1-1
12	29	2:36	30	6.6659	130	39.6694	256.4	"1’40"""	Z1-1
12	29	2:43	30	6.1249	130	39.4585	270.9	"1’50"""	Z1-1
12	29	2:50	30	5.5782	130	39.2441	288	2’	Z1-1
12	29	2:57	30	4.9736	130	38.9802	288.3	2’	Z1-1
12	29	3:05	30	4.337	130	38.7374	294.9	"2’05"""	Z1-1
12	29	3:13	30	3.8153	130	38.5453	304.8	"2’15"""	Z1-1
12	29	3:22	30	3.2088	130	38.3021	321.1	"2’20"""	Z1-1
12	29	3:30	30	2.6716	130	38.069	334.4	"2’30"""	Z1-1
12	29	3:40	30	1.9987	130	37.7955	355.1	"2’30"""	Z1-1
12	29	3:50	30	1.2787	130	37.52	387.1	"3’10"""	Z1-1
12	29	4:03	30	0.3715	130	37.1486	409.4	"3’20"""	Z1-1
12	29	4:16	29	59.4087	130	36.8081	434.1	4’	Z1-1
12	29	4:32	29	58.363	130	36.358	454.2	4’	Z1-1
12	29	4:48	29	57.2423	130	35.9068	471.5	4’	Z1-1
12	29	5:04	29	56.089	130	35.4392	492.6	4’	Z1-1
12	29	5:39	29	55.0072	130	35.9267	567.6	4’	Z1-2
12	29	5:54	29	54.9912	130	38.1014	513.2	4’	Z1-2
12	29	6:10	29	54.9957	130	40.4493	639.7	4’	Z1-2
12	29	6:26	29	54.997	130	42.8297	795.2	4’	Z1-2
12	29	6:42	29	54.9914	130	45.1337	842.9	4	Z1-2
12	29	6:57	29	55.0023	130	47.2801	932.5	4’	Z1-2
12	29	7:13	29	55.0002	130	49.6446	1028.5	4’	Z1-2
12	29	9:12	29	54.6689	130	50.0323	1083.8	4’	Z1-3
12	29	9:27	29	55.8478	130	50.0318	1009.9	4’	Z1-3
12	29	9:43	29	57.15	130	50.0155	876.5	4’	Z1-3
12	29	9:59	29	58.4107	130	50.0129	788.1	4’	Z1-3
12	29	10:14	29	59.7237	130	49.9937	660.4	4’	Z1-3

Table 2.10: Continued table from 2.9

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	29	10:29	30	1.1269	130	49.9818	587.8	4'	Z1-3
12	29	10:45	30	2.54	130	49.9923	488	4'	Z1-3
12	29	11:01	30	4.0178	130	49.9944	417.3	4'	Z1-3
12	29	11:16	30	5.4761	130	49.9836	323.3	"2'20"""	Z1-3
12	29	11:25	30	6.3556	130	49.9676	250	"1'30"""	Z1-3
12	29	11:32	30	6.8961	130	49.9781	196.1	"1'30"""	Z1-3
12	29	11:37	30	7.4489	130	49.9918	189	"55"""	Z1-3
12	29	11:41	30	7.7736	130	50.0028	182	"50"""	Z1-3
12	29	11:44	30	8.0876	130	50.013	176	"45"""	Z1-3
12	29	11:48	30	8.3941	130	50.0227	156	"40"""	Z1-3
12	29	11:51	30	8.6735	130	50.015	151	"35"""	Z1-3
12	29	11:54	30	8.9022	130	50.0138	141	"30"""	Z1-3
12	29	11:56	30	9.1009	130	50.013	136	"30"""	Z1-3
12	29	11:58	30	9.2964	130	50.0132	129	"30"""	Z1-3
12	29	12:01	30	9.5963	130	50.016	128.5	"30"""	Z1-3
12	29	12:04	30	9.8872	130	50.0133	120	"30"""	Z1-3
12	29	12:07	30	10.1129	130	50.0097	120	"30"""	Z1-3
12	29	12:09	30	10.3028	130	50.0059	112.9	"30"""	Z1-3
12	29	12:12	30	10.4976	130	50.0097	108.2	"30"""	Z1-3
12	29	12:14	30	10.7085	130	50.0169	97.5	"20"""	Z1-3
12	29	12:16	30	10.9176	130	50.0236	96.7	"20"""	Z1-3
12	29	12:17	30	11.0209	130	50.0231	92.1	"20"""	Z1-3
12	29	12:19	30	11.167	130	50.0216	90.4	"20"""	Z1-3
12	29	12:20	30	11.3099	130	50.0191	89.2	"15"""	Z1-3
12	29	12:22	30	11.4576	130	50.0157	89.1	"30"""	Z1-3
12	29	12:25	30	11.7771	130	50.0053	87.7	"35"""	Z1-3
12	29	12:54	30	11.9014	130	50.256	82.9	"20"""	Z1-4
12	29	12:55	30	11.8534	130	50.4014	81.3	"20"""	Z1-4
12	29	12:56	30	11.8073	130	50.5261	77.7	"20"""	Z1-4
12	29	12:58	30	11.7534	130	50.6807	74.2	"20"""	Z1-4
12	29	12:59	30	11.6932	130	50.8564	69.2	"16"""	Z1-4
12	29	13:01	30	11.6286	130	51.0736	63	"10"""	Z1-4
12	29	13:02	30	11.5929	130	51.163	57.2	"10"""	Z1-4
12	29	13:02	30	11.5604	130	51.2578	56.2	"10"""	Z1-4
12	29	13:03	30	11.5218	130	51.375	53.3	"10"""	Z1-4
12	29	13:05	30	11.4775	130	51.4808	51.3	"10"""	Z1-4
12	29	13:05	30	11.4425	130	51.5826	49.9	"10"""	Z1-4
12	29	13:06	30	11.4048	130	51.6844	50.5	"10"""	Z1-4
12	29	13:07	30	11.3709	130	51.7645	52.5	"10"""	Z1-4
12	29	13:08	30	11.3389	130	51.8589	52	"10"""	Z1-4
12	29	13:09	30	11.3017	130	51.9703	59.8	"15"""	Z1-4
12	29	13:10	30	11.2596	130	52.1154	65.5	"15"""	Z1-4
12	29	13:11	30	11.2155	130	52.2558	69.7	"15"""	Z1-4
12	29	13:12	30	11.1735	130	52.3902	73.1	"20"""	Z1-4
12	29	13:14	30	11.1082	130	52.5871	77.7	"15"""	Z1-4
12	29	13:15	30	11.0649	130	52.7325	81.4	"20"""	Z1-4
12	29	13:17	30	10.9961	130	52.9415	85.3	"22"""	Z1-4
12	29	13:19	30	10.9279	130	53.1613	89	"25"""	Z1-4
12	29	13:21	30	10.8565	130	53.3756	92.1	"25"""	Z1-4
12	29	13:23	30	10.777	130	53.6072	95.5	"25"""	Z1-4
12	29	13:25	30	10.7041	130	53.8487	99.7	"30"""	Z1-4
12	29	13:27	30	10.6226	130	54.0705	103.6	"30"""	Z1-4
12	29	13:30	30	10.536	130	54.3224	107.2	"34"""	Z1-4
12	29	13:32	30	10.4513	130	54.586	109.2	"35"""	Z1-4
12	29	13:35	30	10.3555	130	54.8582	110	"35"""	Z1-4
12	29	13:37	30	10.2584	130	55.143	110.5	"35"""	Z1-4
12	29	13:40	30	10.1621	130	55.4434	118.1	"35"""	Z1-4
12	29	13:43	30	10.0698	130	55.7565	125.2	"35"""	Z1-4
12	29	13:46	30	9.9879	130	56.5854	128	"40"""	Z1-4
12	29	13:49	30	9.896	130	56.4342	136.2	"42"""	Z1-4
12	29	13:52	30	9.7753	130	56.796	145.3	"45"""	Z1-4
12	29	13:55	30	9.6367	130	57.1909	159.2	"52"""	Z1-4
12	29	13:59	30	9.472	130	57.668	174.4	"55"""	Z1-4
12	29	14:03	30	9.2957	130	58.1602	194.7	"1'10"""	Z1-4
12	29	14:07	30	9.0715	130	58.7272	291.6	"2'05"""	Z1-4
12	29	14:16	30	8.6656	130	59.7618	417.7	4'	Z1-4
12	29	14:32	30	8.6459	131	1.9502	564.9	4'	Z1-4
12	29	14:49	30	7.2926	131	4.2581	953.3	4'	Z1-4
12	29	15:43	30	7.3662	131	5.0482	1023	4'	Z1-5
12	29	16:00	30	6.2193	131	5.0009	977	4'	Z1-5
12	29	16:16	30	5.1159	131	5.0102	890	4'	Z1-5
12	29	16:33	30	3.8433	131	4.9951	1042	4'	Z1-5
12	29	16:49	30	2.5586	131	5.0065	1119	4'	Z1-5
12	29	17:05	30	1.3579	131	4.9967	1255	4'	Z1-5
12	29	17:21	30	0.0318	131	4.9919	1342	4'	Z1-5
12	29	17:39	29	58.522	131	4.9929	1383	4'	Z1-5
12	29	17:55	29	57.117	131	4.9947	1449	4'	Z1-5
12	29	18:12	29	55.587	131	5.0029	1449	4'	Z1-5

Table 2.11: *Continued table from 2.10*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	30	19:13	30	10.0179	131	9.9807	1228	4’	Z2-1
12	30	19:29	30	11.169	131	8.8371	1235	4’	Z2-1
12	30	19:45	30	12.3175	131	7.6808	1199	4’	Z2-1
12	30	20:01	30	13.3961	131	6.5754	1201	4’	Z2-1
12	30	20:17	30	14.4473	131	5.5127	1219	4’	Z2-1
12	30	20:34	30	15.6669	131	4.2867	1080	4’	Z2-1
12	30	20:50	30	16.7376	131	3.2747	609	4’	Z2-1
12	31	2:50	30	17.5526	131	2.5591	272.5	"1’50"""	Z2-2
12	31	2:57	30	18.2533	131	2.7636	200.4	"1’20"""	Z2-2
12	31	3:04	30	18.7772	131	2.9318	192.5	1’	Z2-2
12	31	3:08	30	19.106	131	3.0429	190	1’	Z2-2
12	31	3:12	30	19.4528	131	3.1573	190	1’	Z2-2
12	31	3:16	30	19.7915	131	3.2649	189.3	1’	Z2-2
12	31	3:20	30	20.1565	131	3.389	182.4	"50"""	Z2-2
12	31	3:24	30	20.564	131	3.5302	193.3	1’	Z2-2
12	31	3:28	30	20.9413	131	3.6621	197.8	1’	Z2-2
12	31	3:33	30	21.3553	131	3.8009	198.9	1’	Z2-2
12	31	3:37	30	21.7687	131	3.9301	197.2	1’	Z2-2
12	31	3:41	30	22.1231	131	4.0452	202.4	"1’20"""	Z2-2
12	31	3:47	30	22.6204	131	4.209	195.2	"1’15"""	Z2-2
12	31	3:53	30	23.212	131	4.4193	199.7	1’	Z2-2
12	31	3:57	30	23.5497	131	4.5241	201.7	1’	Z2-2
12	31	4:01	30	23.7041	131	4.6384	204.8	1’	Z2-2
12	31	4:07	30	24.519	131	4.8517	208.6	1’	Z2-2
12	31	4:12	30	24.9092	131	4.9853	228.6	"1’10"""	Z2-2
12	31	4:17	30	25.3445	131	5.1362	212.8	"1’20"""	Z2-2
12	31	4:21	30	25.7974	131	5.2964	218.7	"1’10"""	Z2-2
12	31	4:27	30	26.3168	131	5.4724	225.6	"1’15"""	Z2-2
12	31	4:32	30	26.8035	131	5.617	227.2	"1’20"""	Z2-2
12	31	4:38	30	27.3691	131	5.8012	225.4	"1’15"""	Z2-2
12	31	4:44	30	27.8836	131	5.9697	249	"1’25"""	Z2-2
12	31	4:51	30	28.5596	131	6.2101	230	"1’10"""	Z2-2
12	31	4:56	30	29.0662	131	6.3762	244	"1’20"""	Z2-2
12	31	5:02	30	29.6293	131	6.5524	229	"1’10"""	Z2-2

Table 2.12: *Continued table from 2.11*

Time (JST)			Latitude		Longitude		Depth	Duration	Station
Month	Day	hr:mn	Deg.	Min.	Deg.	Min.	m	Minute	Name
12	31	5:07	30	30.1038	131	6.7071	150	"35"""	Z2-2
12	31	5:10	30	30.4061	131	6.8098	153	"35"""	Z2-2
12	31	5:13	30	30.6535	131	6.8922	152	"35"""	Z2-2
12	31	5:15	30	30.9247	131	6.9851	150	"35"""	Z2-2
12	31	5:18	30	31.1582	131	7.0645	141	"35"""	Z2-2
12	31	5:20	30	31.3899	131	7.1431	143	"35"""	Z2-2
12	31	5:23	30	31.6254	131	7.2265	143	"35"""	Z2-2
12	31	5:25	30	31.8768	131	7.3174	139	"30"""	Z2-2
12	31	5:27	30	32.0984	131	7.3959	138	"30"""	Z2-2
12	31	5:29	30	32.3122	131	7.4693	136	"30"""	Z2-2
12	31	5:49	30	32.0404	131	7.9915	148	"35"""	Z2-2
12	31	9:11	30	22.532	131	18.0565	1911	4’	Z2-4
12	31	9:16	30	22.9238	131	18.4177	1933	4’	Z2-4
12	31	9:32	30	24.3942	131	19.8704	2007	4’	Z2-4
12	31	9:48	30	25.9378	131	21.35	1727	4’	Z2-4
12	31	10:04	30	27.4908	131	22.7826	1838	4’	Z2-4
12	31	10:20	30	28.9534	131	24.2322	1652	4’	Z2-4
12	31	10:35	30	30.4273	131	25.6808	1717	4’	Z2-4
12	31	10:51	30	31.9277	131	27.0971	1735	4’	Z2-4
12	31	11:07	30	33.547	131	28.6082	1666	4’	Z2-4
12	31	11:48	30	34.8861	131	30.16	1510	4’	Z2-5
12	31	12:04	30	35.684	131	28.9666	1386	4’	Z2-5
12	31	12:20	30	36.4603	131	27.796	1269	4’	Z2-5
12	31	12:35	30	37.2178	131	26.6696	1082	4’	Z2-5
12	31	12:50	30	38.0432	131	25.442	880	4’	Z2-5
12	31	13:05	30	38.8158	131	24.2619	625	4’	Z2-5
12	31	13:20	30	39.589	131	23.1265	997	4’	Z2-5
12	31	13:35	30	40.3035	131	22.0556	619	4’	Z2-5
12	31	13:50	30	41.0411	131	20.938	507	4’	Z2-5
12	31	16:25	30	22.4384	131	18.052	1942	4’	Z2-3
12	31	16:41	30	23.5968	131	16.8375	1673	4’	Z2-3
12	31	16:56	30	24.6224	131	15.7656	1291	4’	Z2-3
12	31	17:11	30	25.5673	131	14.7958	1050	4’	Z2-3
12	31	17:27	30	26.5468	131	13.7441	1200	4’	Z2-3
12	31	17:41	30	27.4701	131	12.7758	829	4’	Z2-3
12	31	17:56	30	28.5225	131	11.6881	617.3	4’	Z2-3
12	31	18:03	30	28.9961	131	11.1772	442.2	"3’15"""	Z2-3
12	31	18:18	30	29.9849	131	10.131	356.6	"2’30"""	Z2-3
12	31	18:27	30	30.6086	131	9.483	315	"2’30"""	Z2-3
12	31	18:36	30	31.2605	131	8.771	161.9	"50"""	Z2-3
12	31	18:40	30	31.4933	131	8.5406	156.3	"40"""	Z2-3
12	31	18:42	30	31.6975	131	8.3291	157.3	"40"""	Z2-3
12	31	18:45	30	31.906	131	8.114	152	"40"""	Z2-3
12	31	18:48	30	32.0845	131	7.9312	147.6	"40"""	Z2-3
12	31	18:51	30	32.2906	131	7.7201	140	"35"""	Z2-3
1	3	9:52	30	48.9437	131	32.535	1309	4’	Z3-2 to Z3-1
1	3	10:08	30	50.2571	131	32.6519	1229	4’	Z3-2
1	3	10:24	30	51.5956	131	30.7216	1191	4’	Z3-2
1	3	10:40	30	52.9048	131	29.8442	1118	4’	Z3-2
1	3	10:56	30	54.2777	131	28.8952	971	4’	Z3-2
1	3	11:11	30	55.5601	131	28.0307	915	4’	Z3-2
1	3	11:26	30	56.8843	131	27.1217	845	4’	Z3-2
1	3	11:42	30	58.1027	131	26.3035	750	4’	Z3-2
1	3	11:58	30	59.2534	131	25.5082	710	4’	Z3-2
1	3	12:12	31	0.3526	131	24.7501	651	4’	Z3-2
1	3	12:29	31	1.4641	131	23.0015	330	"2’30"""	Z3-2
1	3	12:36	31	2.0941	131	23.5651	168	1’	Z3-2
1	3	12:42	31	2.4391	131	23.3557	164	"40"""	Z3-2
1	3	12:45	31	2.6226	131	23.3381	161	"40"""	Z3-2
1	3	12:48	31	2.8095	131	23.0985	159	"40"""	Z3-2
1	3	12:50	31	2.9995	131	22.9611	158	"40"""	Z3-2
1	3	12:53	31	3.1979	131	22.8145	156	"40"""	Z3-2
1	3	12:56	31	3.3778	131	22.6877	155	"40"""	Z3-2
1	3	12:59	31	3.5866	131	22.5372	154	"40"""	Z3-2
1	3	13:01	31	3.7801	131	22.4012	152	"40"""	Z3-2
1	3	13:04	31	3.9928	131	22.2541	150	"40"""	Z3-2
1	3	18:18	30	54.9043	131	45.0457	1704	4’	Z3-3
1	3	18:32	30	56.3043	131	44.1148	1716	4’	Z3-3
1	3	18:47	30	57.7103	131	43.1998	1534	4’	Z3-3
1	3	19:02	30	59.0714	131	42.3116	1472	4’	Z3-3
1	3	19:17	31	0.3649	131	41.4178	1385	4’	Z3-3
1	3	19:32	31	1.6925	131	40.5806	1326	4’	Z3-3
1	3	19:46	31	2.9278	131	39.7218	1279	4’	Z3-3
1	3	20:01	31	4.267	131	38.855	1110	4’	Z3-3
1	3	20:16	31	5.6026	131	37.9342	1045	4’	Z3-3
1	3	20:31	31	6.8435	131	37.1002	939	4’	Z3-3
1	3	20:45	31	8.0531	131	36.2754	934	4’	Z3-3
1	3	21:00	31	9.2268	131	35.5171	854	4’	Z3-3

2.4 CTD Observations

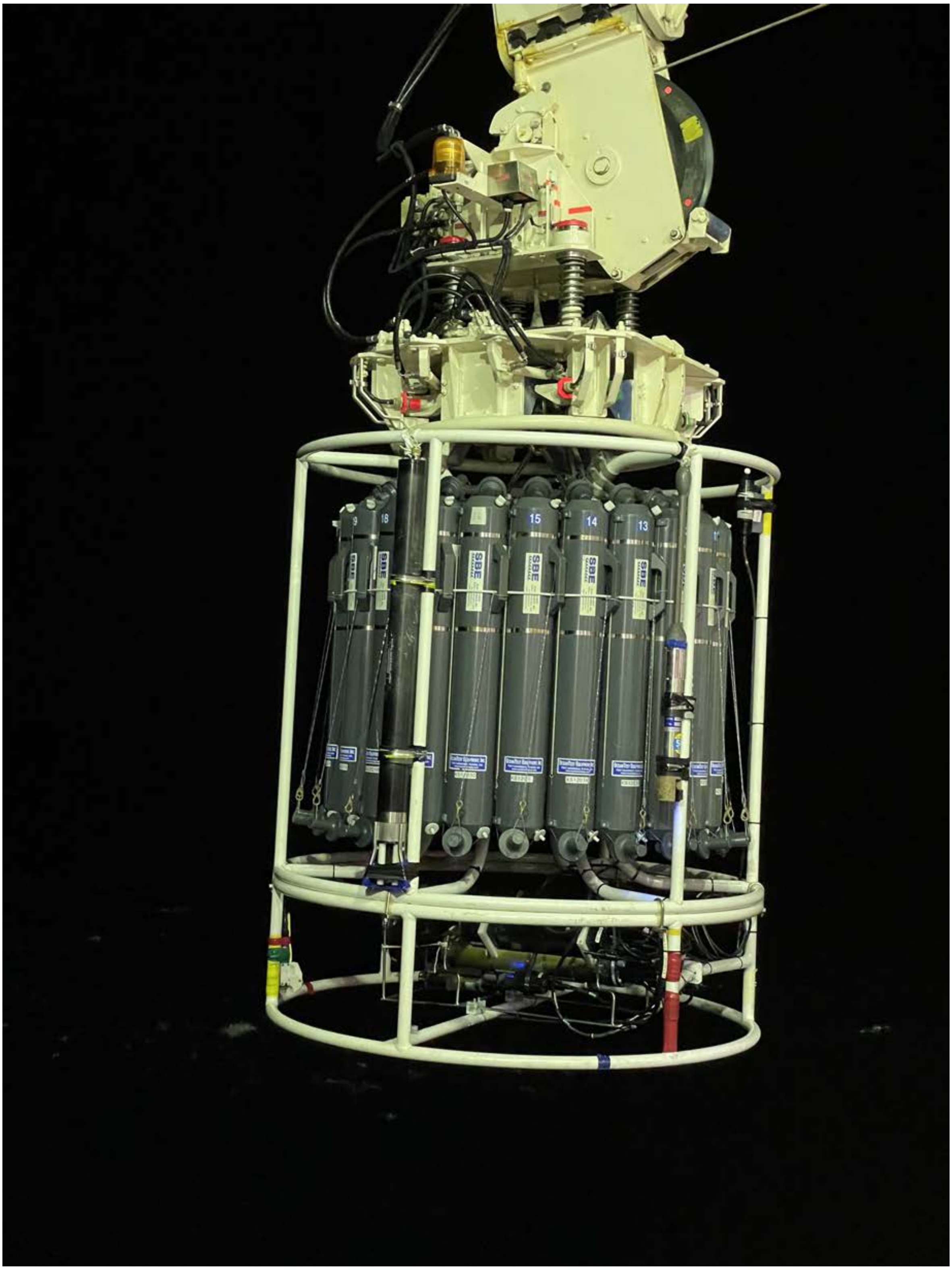

Figure 2.9: CTD SBE 911 plus of R/V Shinsei-Maru

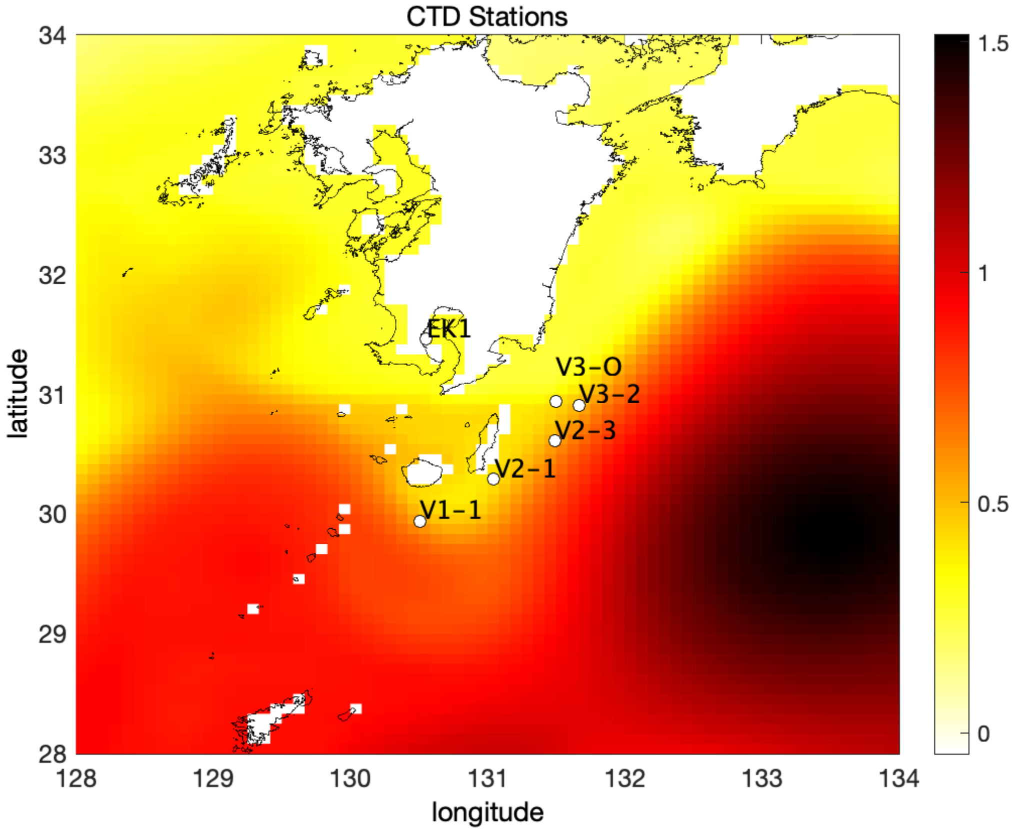

Figure 2.10: *CTD Stations during KS22-17. Red shading represents average sea surface height (CMEMS) during Dec. 28-Jan 3.*

Most of the CTD casts made during the KS22-17 cruise, were conducted at 1-3 stations along the UVMP observation lines, although the waves were too high at some locations where we canceled the CTD observations (Figure 2.17). The station EK1 is inside the Kagoshima Bay, in which a CTD cast was made for acquiring the temperature and salinity data to calculate sound velocity, which is needed for the echosounder calibration.

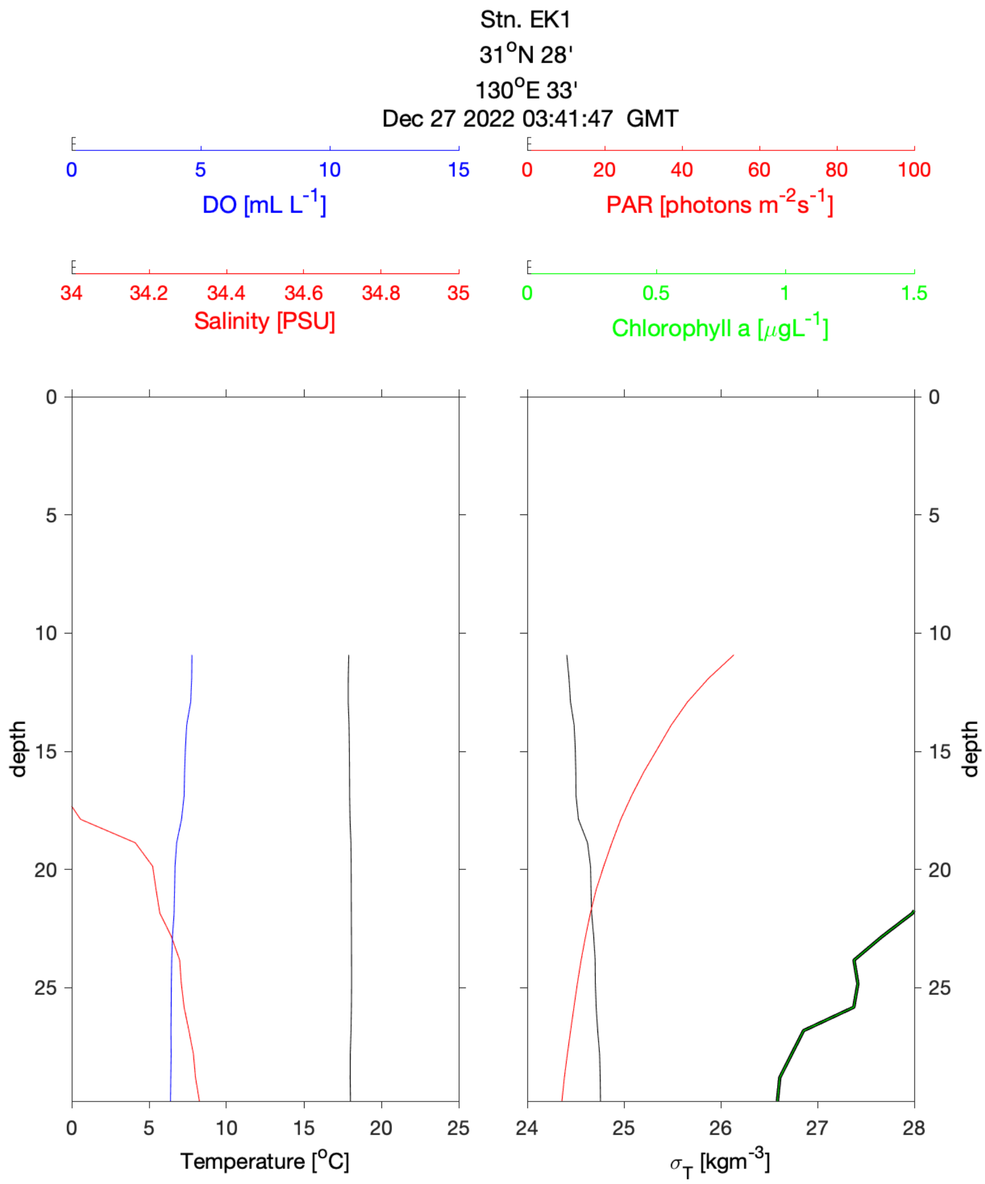

Figure 2.11: CTD vertical profile at Stn. EK1.

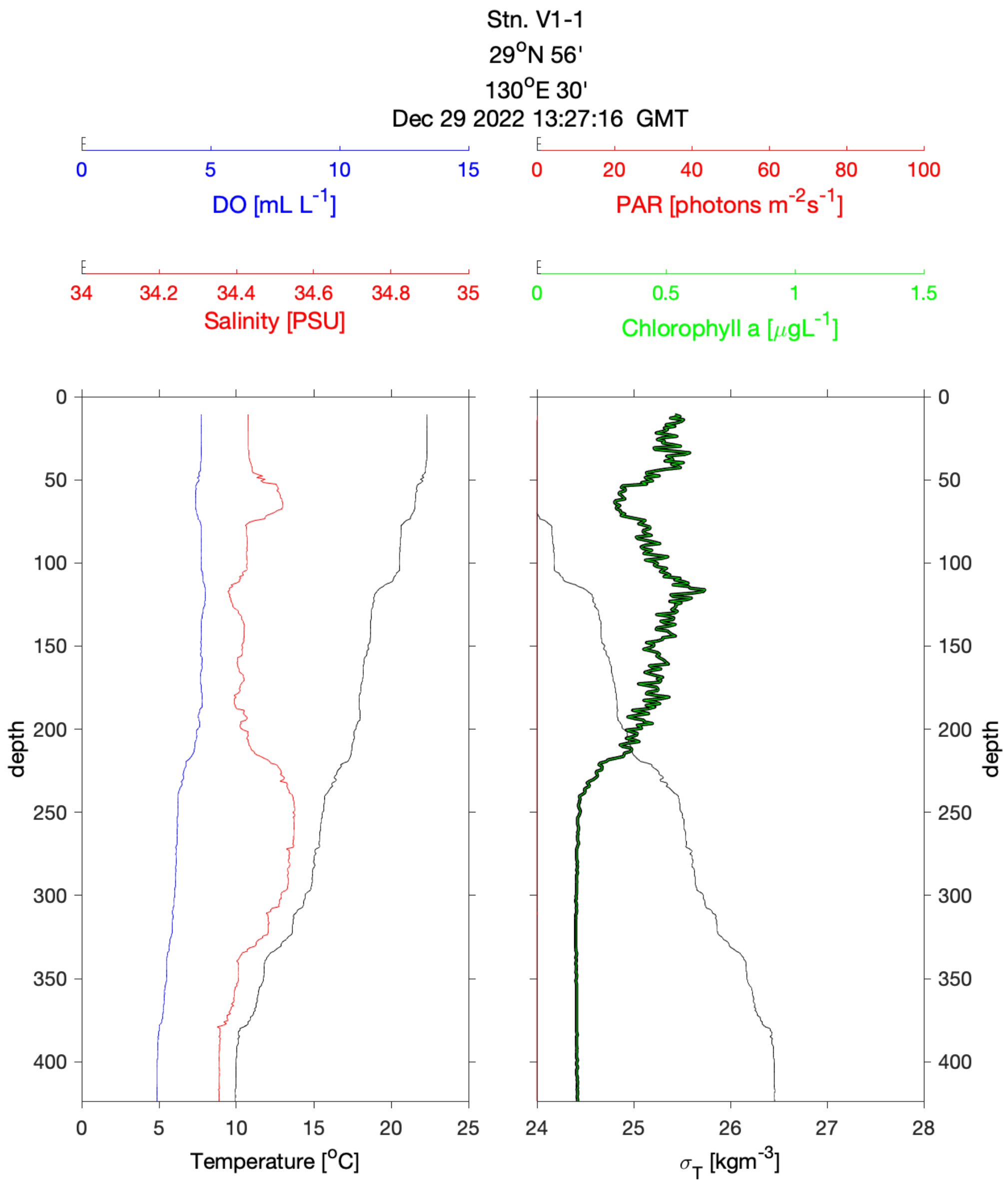

Figure 2.12: CTD vertical profile at Stn. V1-1.

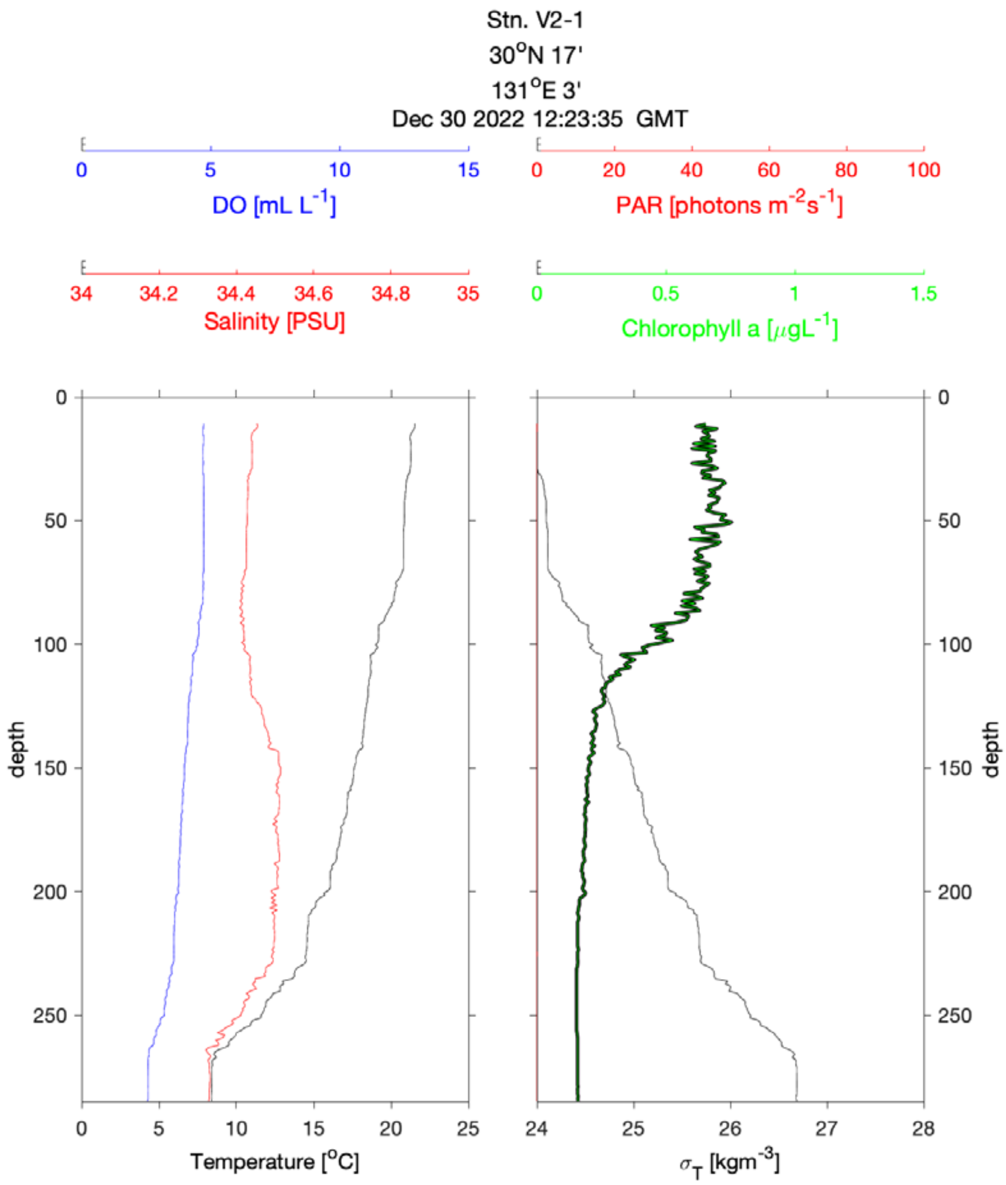

Figure 2.13: CTD vertical profile at Stn. V2-1.

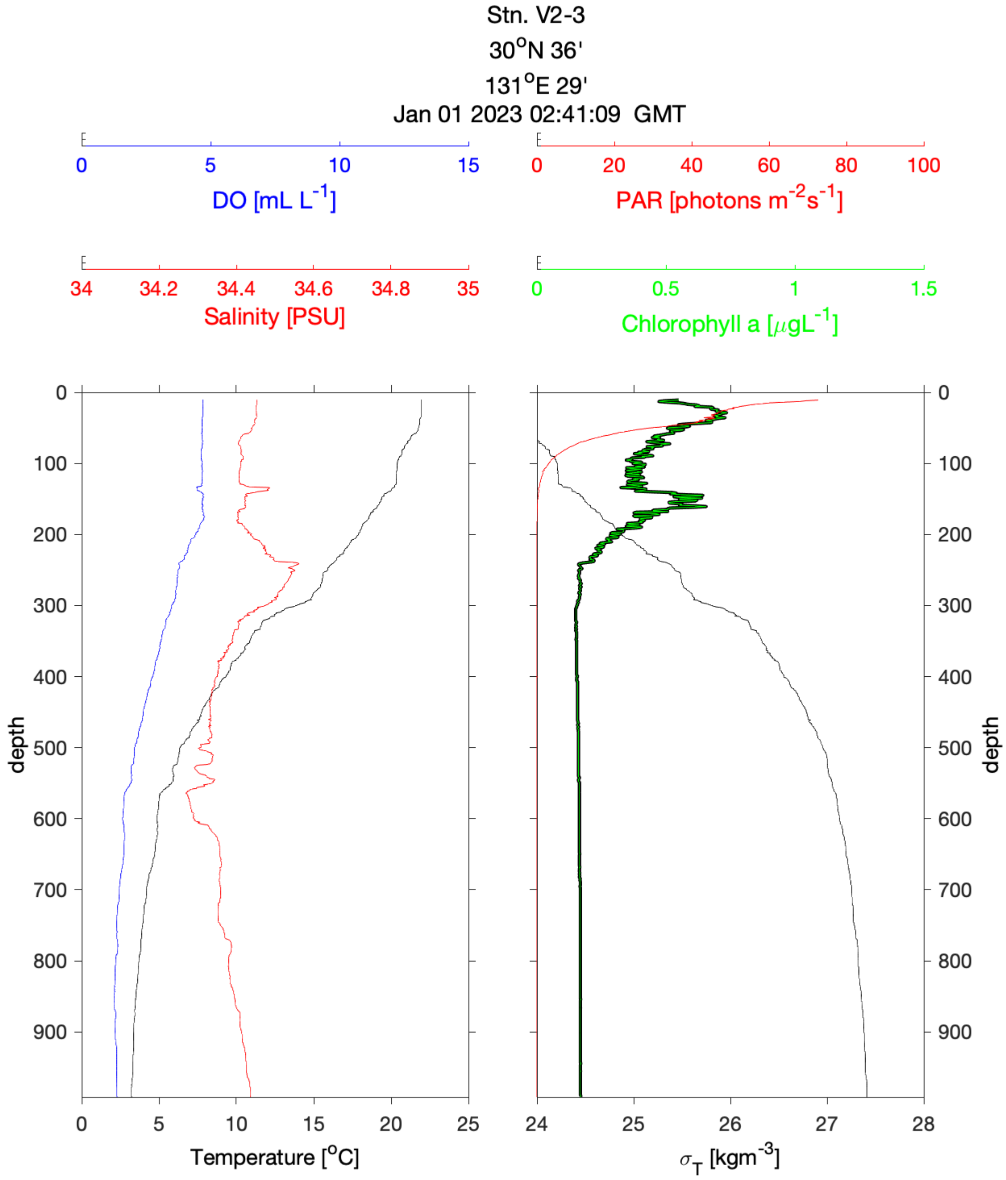

Figure 2.14: *CTD vertical profile at Stn. V2-3.*

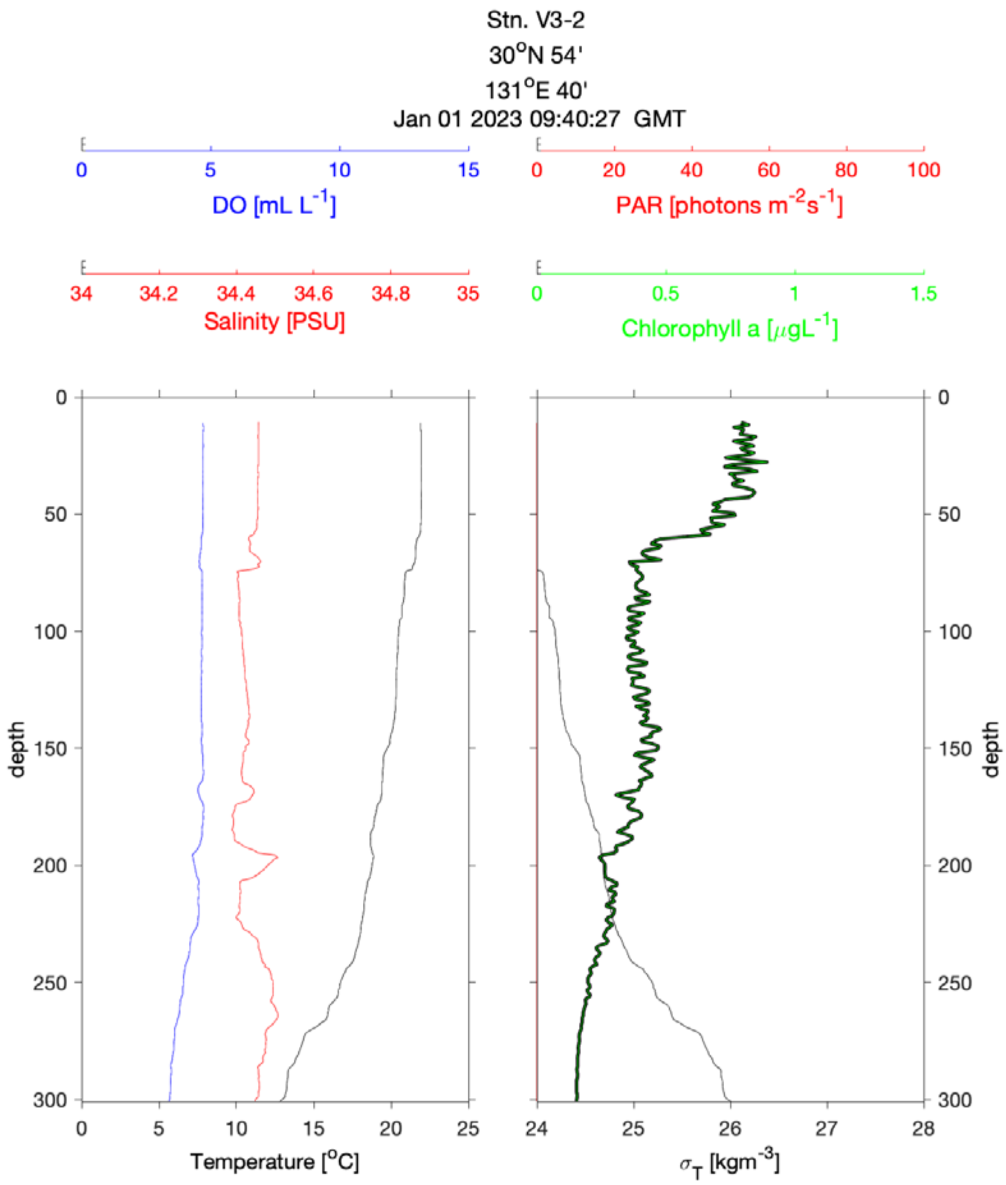

Figure 2.15: *CTD vertical profile at Stn. V3-2.*

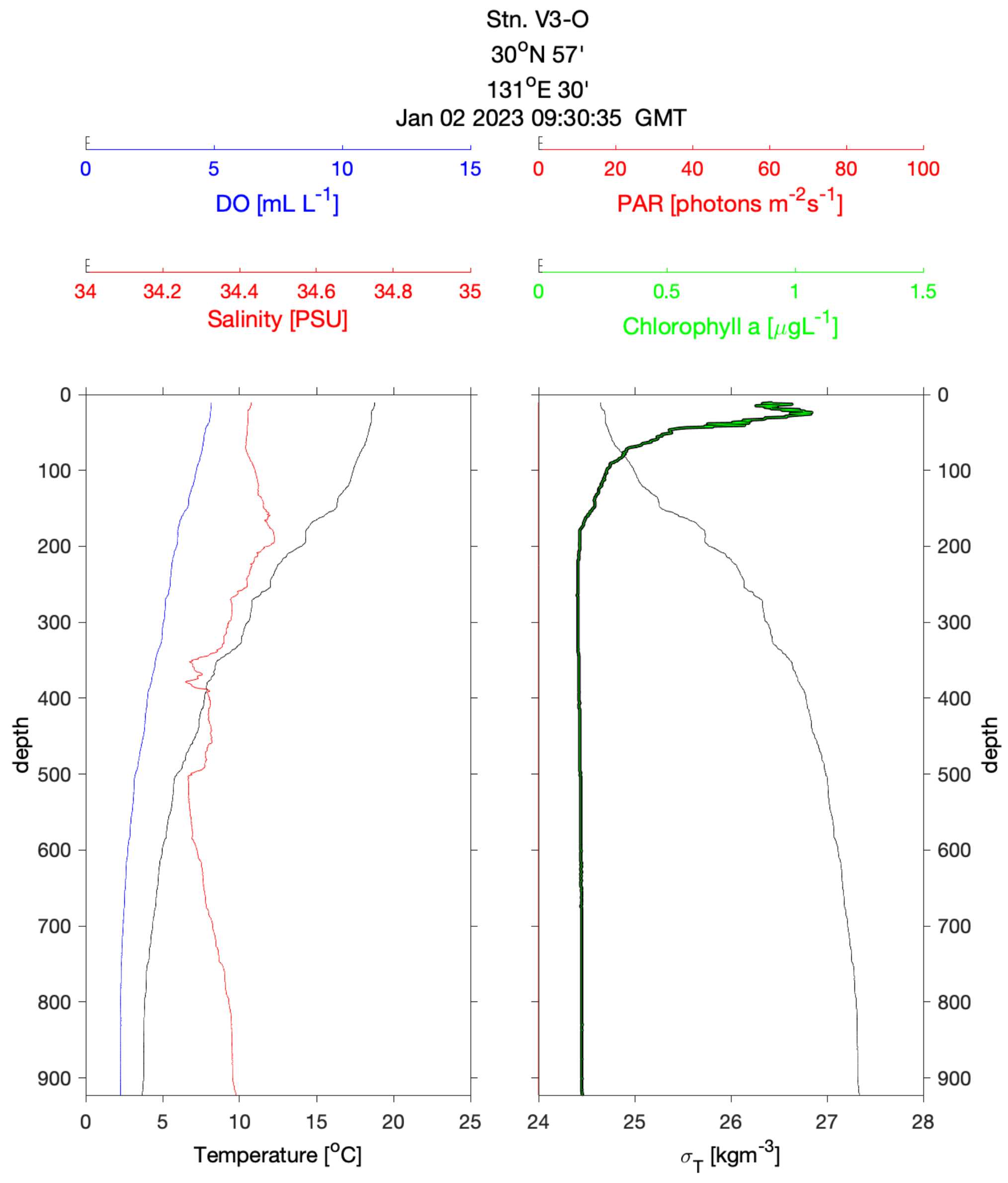

Figure 2.16: *CTD vertical profile at Stn. V3-O.*

2.5 CTD observation and water sampling

2.5.1 Purpose, background

To reveal the vertical structure of the water mass, CTD observations and water samplings were conducted. The data are used to estimate the distributions of biogeochemical parameters and the depth of the euphotic layer in the water column. Also, these data are used to calibrate towing sensors.

2.6 Observation, sampling, development

We conducted CTD (SBE 11 plus, Sea-Bird Scientific, USA) observations and water sampling with a rosette equipped with twenty-four 12-L Niskin bottles, a CTD sensor (11 PLUS, Sea-Bird Scientific, USA), an oxygen sensor (SBE43, Sea-Bird Scientific, USA), a chlorophyll fluorescence sensor (WETLabs, USA), and a photosynthetically active radiation (PAR) sensor (LI-COR Biospherical PAR sensor, Biospherical Instruments Inc., USA). Water samplings for salinity, dissolved oxygen (DO), nutrient (nitrate, nitrite, phosphate, and silicate), chlorophyll (Chl a), and particulate organic carbon (POC). The water samples for salinity measurements were also collected from a number of Niskin bottles at each station.

2.6.1 Methods, instruments

The DO concentrations in sampled water were measured by Winkler method (Carpenter, 1965; Japan Meteorological Agency, 1999) with an onboard titration unit (Titrino 888: Metrohm Japan, Japan). The water samples for Chl a concentration was poured into light-shielding bottle and filtered through grass fiber filters. The Chl a on the filter was extracted immediately in dimethylformamide in a freezer at -30°C. The extracted Chl a was measured onboard using a fluorometer (10-AU, Turner Designs, USA). The water samples for measurements of nutrient concentrations were immediately frozen at -30 °C and are kept in a freezer until the nutrient concentrations will be measured with an autoanalyzer. The seawater samples for measurement of POC concentration were filtered through pre-combusted (450 °C for 4 hours) Grade GF/F Whatman 47-mm grass fiber filters (Cytiva Life Sciences, USA). Filters were stored in pre-combusted aluminum foil at -30°C for chemical analysis with an elemental analyzer.

2.6.2 Results

The values of CTD oxygen sensor were matched to the DO concentrations determined from water sampling and titration. The relationship between the two values is obtained by the following equation: [Titration DO, μmol O2 kg^{-1}] = 1.00 × [CTD DO, μmol O_2 kg^{-1}] + 5.92, ($n = 98$, $r^2 = 0.99$). The values of CTD chlorophyll sensor showed the following relationship with Chl a concentrations determined from water sampling and pigment extraction: [extracted Chl *a*, μg L^{-1}] = -1.14 × [FISP, CTD]^2 + 1.88 × [FISP, CTD] – 0.20, ($n = 56$, $r^2 = 0.86$).

Salinity Measurements

Figure 2.17: *Salinity analysis at the Atmosphere and Ocean Research Institute on February 21, 2023.*

Salinity measurements were made at the Atmosphere Ocean Research Institute of the University of Tokyo after the cruise on February 21, 2023. The Autosal was set up from a day before to set the bath temperature at 24°C. The measured twice the conductivity ration and calculated salinity values are listed in the following table.

Table 2.13: *AUTOSAL measurements*

Station	Bottle Number	Condactivity ratio x 2	Temperature	Mean Condactivity ratio x 2	Salinity
V1-1	8	1.96686	24	1.96687	34.348
		1.96686	24		
		1.96688	24		
V1-1	9	1.96899	24	1.96898	34.3904
		1.96898	24		
		1.96898	24		
V1-1	10	1.97578	24	1.97579	34.5242
		1.97581	24		
		1.9758	24		
V1-1	11	1.97652	24	1.97655	34.539
		1.97656	24		
		1.97656	24		
V1-1	12	1.96898	24	1.96894	34.3896
		1.96893	24		
		1.96893	24		
V1-1	13	1.96944	24	1.96944	34.3995
		1.96944	24		
		1.96944	24		
V1-1	14	1.96804	24	1.96804	34.3721
		1.96805	24		
		1.96805	24		
V1-1	15	1.9683	24	1.96841	34.3793
		1.96841	24		
		1.96842	24		
V1-1	16	1.97029	24	1.97029	34.4163
		1.97031	24		
		1.97029	24		
V1-1	17	1.9739	24	1.97390	34.487
		1.97391	24		
		1.9739	24		
V1-1	18	1.97147	24	1.97147	34.4392
		1.97147	24		
		1.97146	24		
V1-1	19	1.97052	24	1.97052	34.4208
		1.97052	24		
		1.97052	24		
V1-1	20	1.97052	24	1.97051	34.4206
		1.97052	24		
		1.9704	24		
V1-1	21	1.97055	24	1.97057	34.4215
		1.97058	24		
		1.97058	24		
V1-1	22	1.97059	24	1.97059	34.4221
		1.9705	24		
		1.97059	24		
V1-1	23	1.97052	24	1.97052	34.4208
		1.97052	24		
		1.97052	24		
V1-1	24	1.97058	24	1.97057	34.4215
		1.97056	24		
		1.97058	24		

Table 2.14: *Continued from Table 2.13*

Station	Bottle Number	Conductivity ratio x 2	Temperature	Mean Conductivity ratio x 2	Salinity
V2-1	11	1.96648	24	1.96646	34.3410
		1.96646	24		
		1.96645	24		
V2-1	12	1.9750	24	1.97499	34.5084
		1.9750	24		
		1.97496	24		
V2-1	13	1.97439	24	1.97437	34.4962
		1.97437	24		
		1.97437	24		
V2-1	14	1.97486	24	1.97485	34.5056
		1.97485	24		
		1.97485	24		
V2-1	15	1.97156	24	1.97154	34.440
		1.97154	24		
		1.97154	24		
V2-1	16	1.97004	24	1.97004	34.4112
		1.97005	24		
		1.97004	24		
V2-1	17	1.96951	24	1.96951	34.4007
		1.9695	24		
		1.96951	24		
V2-1	18	1.97	24	1.97000	34.4104
		1.96998	24		
		1.97002	24		
V2-1	19	1.97042	24	1.97042	34.4187
		1.97042	24		
		1.97042	24		
V2-1	20	1.97073	24	1.97072	34.4247
		1.97073	24		
		1.97072	24		
V2-1	21	1.97098	24	1.97098	34.4296
		1.97098	24		
		1.97099	24		
V2-1	22	1.97184	24	1.97183	34.4463
		1.97181	24		
		1.97184	24		
V2-1	23	1.97188	24	1.97187	34.4472
		1.97188	24		
		1.97188	24		
V2-1	24	1.97187	24	1.97187	34.4470
		1.97187	24		
		1.97187	24		
V3-O	1	1.96886	24	1.96885	34.387
		1.96883	24		
		1.96886	24		
V3-O	2	1.96852	24	1.96851	34.3812
		1.96849	24		
		1.96851	24		
V3-O	3	1.96785	24	1.96784	34.3680
		1.96783	24		
		1.96785	24		

Table 2.15: Continued from Table 2.14

Station	Bottle Number	Conductivity ratio x 2	Temperature	Mean Conductivity ratio x 2	Salinity
V3-O	4	1.96547	24	1.96547	34.3215
		1.96547	24		
		1.96547	24		
V3-O	5	1.96319	24	1.96319	34.2768
		1.96319	24		
		1.96319	24		
V3-O	6	1.96488	24	1.96488	34.31
		1.96489	24		
		1.96488	24		
V3-O	7	1.9656	24	1.96558	34.3239
		1.96558	24		
		1.96558	24		
V3-O	8	1.96517	24	1.96517	34.315
		1.96517	24		
		1.96517	24		
V3-O	9	1.96288	24	1.96288	34.2708
		1.96286	24		
		1.96290	24		
V3-O	10	1.96741	24	1.96742	34.3599
		1.96743	24		
		1.96743	24		
V3-O	11	1.96978	24	1.96978	34.4061
		1.969789	24		
		1.96977	24		
V3-O	12	1.97327	24	1.97326	34.4744
		1.97324	24		
		1.97327	24		
V3-O	13	1.97330	24	1.97330	34.4754
		1.97330	24		
		1.97330	24		
V3-O	14	1.97242	24	1.97242	34.457
		1.97242	24		
		1.97242	24		
V2-1	15	1.97176	24	1.97174	34.4446
		1.97173	24		
		1.97174	24		
V2-1	16	1.97065	24	1.97077	34.425
		1.97069	24		
		1.97097	24		
V3-O	17	1.96995	24	1.96994	34.4093
		1.96994	24		
		1.96995	24		
V3-O	18	1.96995	24	1.96994	34.4093
		1.96993	24		
		1.96995	24		
V3-O	19	1.97012	24	1.97011	34.4127
		1.97012	24		
		1.97011	24		
V3-O	20	1.97028	24	1.97029	34.4161
		1.97028	24		
		1.97031	24		

Table 2.16: Continued from Table 2.15

Station	Bottle Number	Conductivity ratio x 2	Temperature	Mean Conductivity ratio x 2	Salinity
V3-O	21	1.97042		1.97042	34.4185
		1.97042			
		1.97041			
V3-O	22	1.97062		1.97061	34.4224
		1.97061			
		1.97061			
V3-O	23	1.97069		1.9706	34.4232
		1.97063			
		1.97063			
V3-2	24	1.97062		1.97061	34.4224
		1.97059			
		1.97063			
V3-2	10	1.97161		1.97161	34.4422
		1.97161			
		1.97161			
V3-2	11	1.97415		1.97415	34.4919
		1.97415			
		1.97415			
V3-2	12	1.97322		1.97320	34.4733
		1.97320			
		1.97320			
V3-2	13	1.96930		1.96929	34.3965
		1.96927			
		1.96929			
V3-2	14	1.97083		1.97082	34.4266
		1.97085			
		1.97082			
V3-2	15	1.97035		1.97037	34.4178
		1.97038			
		1.97039			
V3-2	16	1.96971		1.96971	34.4048
		1.96971			
		1.96971			
V3-2	17	1.96958		1.96958	34.4022
		1.96957			
		1.9696			
V3-2	18	1.97147		1.97147	34.4393
		1.97147			
		1.97147			
V3-2	19	1.97207		1.97208	34.4512
		1.97208			
		1.97208			
V3-2	20	1.97191		1.97190	34.4478
		1.97188			
		1.97191			
V3-2	21	1.97181		1.97178	34.4455
		1.97177			
		1.97178			
V3-2	22	1.97188		1.97189	34.4476
		1.9719			
		1.97188			

Table 2.17: *Continued from Table 2.16*

Station	Bottle Number	Conductivity ratio x 2	Temperature	Mean Conductivity ratio x 2	Salinity
V3-2	23	1.97185	24	1.97187	34.4472
		1.97185	24		
		1.9719	24		
V3-2	24	1.97185	24	1.97186	34.447
		1.97188	24		
		1.97185	24		
V2-3	1	1.97127	24	1.97131	34.4361
		1.97130	24		
		1.97136	24		
V2-3	2	1.96995	24	1.97001	34.4106
		1.96995	24		
		1.97015	24		
V2-3	3	1.96859	24	1.96857	34.3825
		1.96858	24		
		1.96856	24		
V2-3	4	1.96716	24	1.96717	34.3549
		1.96717	24		
		1.96717	24		
V2-3	5	1.96451	24	1.96450	34.3025
		1.96449	24		
		1.96449	24		
V2-3	6	1.96307	24	1.96304	34.2740
		1.96303	24		
		1.96303	24		
V2-3	7	1.96585	24	1.96584	34.3288
		1.96583	24		
		1.96583	24		
V2-3	8	1.96635	24	1.96635	34.3389
		1.96637	24		
		1.96635	24		
V2-3	9	1.96849	24	1.96848	34.3806
		1.96848	24		
		1.96848	24		
V2-3	10	1.97171	24	1.97171	34.4440
		1.97171	24		
		1.97171	24		
V2-3	11	1.97655	24	1.97654	34.5388
		1.97654	24		
		1.97654	24		
V2-3	12	1.97112	24	1.97112	34.4324
		1.97112	24		
		1.97113	24		
V2-3	13	1.96941	24	1.96941	34.3988
		1.96941	24		
		1.9694	24		
V2-3	14	1.97113	24	1.97113	34.4326
		1.97113	24		
		1.97113	24		
V2-3	15	1.97029	24	1.97027	34.4157
		1.97025	24		
		1.97028	24		

Table 2.18: Continued from Table 2.17

Station	Bottle Number	Conductivity ratio x 2	Temperature	Mean Conductivity ratio x 2	Salinity
V2-3	16	1.9695	24	1.96950	34.4005
		1.96951	24		
		1.9695	24		
V2-3	17	1.97019	24	1.97016	34.4136
		1.97015	24		
		1.97015	24		
V2-3	18	1.96951	24	1.96956	34.4018
		1.96958	24		
		1.9696	24		
V2-3	19	1.97113	24	1.97115	34.433
		1.97116	24		
		1.97116	24		
V2-3	20	1.97151	24	1.97151	34.4401
		1.97151	24		
		1.97151	24		
V2-3	21	1.97221	24	1.97221	34.4538
		1.97221	24		
		1.97222	24		
V2-3	22	1.97215	24	1.97214	34.4525
		1.97212	24		
		1.97215	24		
V2-3	23	1.97215	24	1.97215	34.4527
		1.97215	24		
		1.97215	24		
V2-3	24	1.97218	24	1.97217	34.4530
		1.97217	24		
		1.97218	24		

2.7 Autonomous Microstructure Profiling Float

Continuous and autonomous turbulence measurements in the strong current can be efficiently achieved if the autonomous float can measure turbulence as well as typical CTD.

Figure 2.18: *The micro-ALTO float deployed and recovered during KS22-17.*

2.7.1 Method

In this cruise, one micro-ALTO float (MRV, Figure 2.18) was deployed and measured turbulent shear and temperature gradient.

2.7.2 Deployment and recovery

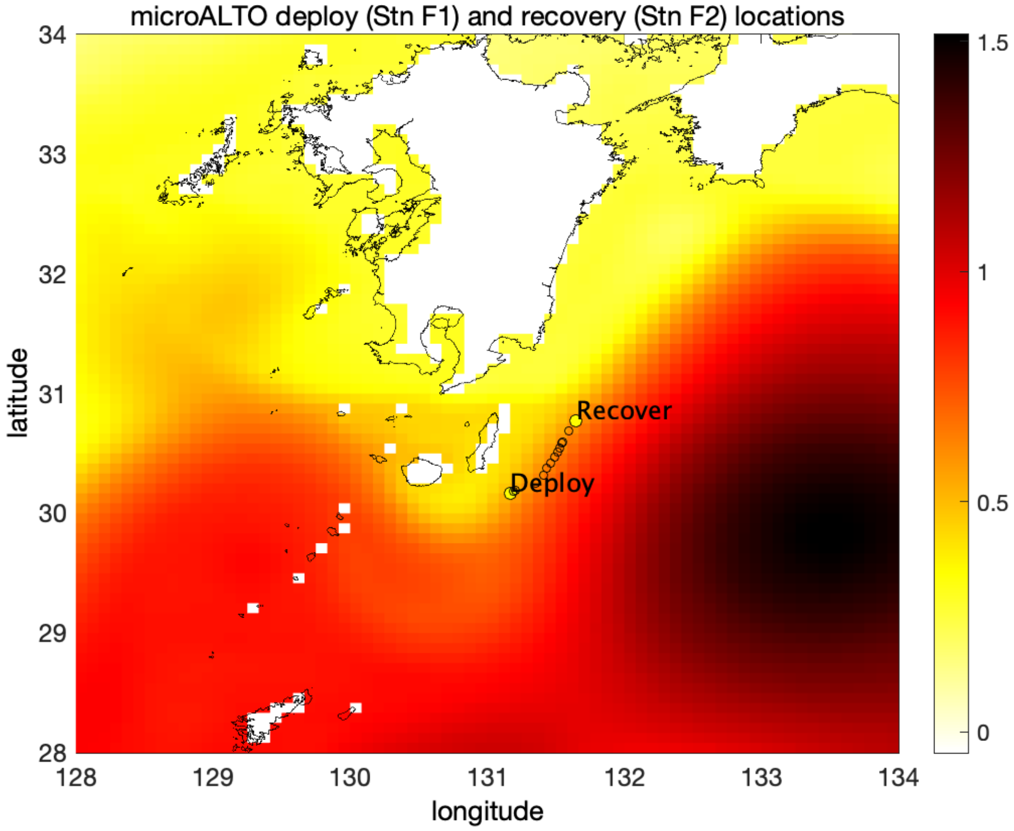

Figure 2.19: microALTo float deployment and recovery positions during KS22-17. Red shading represents average sea surface height (CMEMS) during Dec. 28-Jan 3.

Deployment
December 31, 2022, 12:45 (UTC) 30°N 10", 131°E 10"

Recovery
January 1, 2023, 23:55 (UTC) 30°N 46", 131°E 39" See Figure 2.19.

2.8 Calibration of echosounders

During the KS22-17 cruise, the shipboard echosounder EK60 continuously measure the echo intensity at 6 different frequencies to investigate the ecosystem responses to the nutrient injection in the upstream Kuroshio. To accurately quantify fish biomass in the ocean, the shipboard echosounder needs to be well calibrated. We conducted the calibration of EK60s after anchoring the ship in Kagoshima Bay on December 27-28, 2022.

2.8.1 Methods

We setup the fishing poles at the predetermined locations of the vessel (i.e., 1 on the starboard side, 2 on the port side). A calibration sphere was attached to the three fishing lines and deployed it at 20m depth under the EK60 transducers.

2.8.2 Calibration

We completed the calibration of all frequencies. It was a very successful operation. Based on the calibration results, there were errors on the 200 and 333 kHz suggesting the possible damage on the transducers themselves. I recommend contacting the manufacturer for repair.

1. Dec. 27, 2022 03:24 UTC CTD cast to calculate average temperature and salinity at 5-22m depth
   (approximate distance between the ship's transducers and calibration sphere)
2. Dec. 27, 2022 04:50 UTC Deploy the calibration sphere (tungsten carbide: 38.1mm in diameter)
3. Dec. 27, 2022 05:18 UTC start calibration of 120kHz, 120kHz, 70kHz, 200kHz, 18kHz, 38kHz, 120kHz,
   333kHz (using a calibration sphere of 22.0mm in diameter; tungsten carbide)
4. Dec. 27, 2022 00:07 UTC Completed the calibration

After the calibration, we collected the echosounder throughout the cruise.

2.9 IKMT net

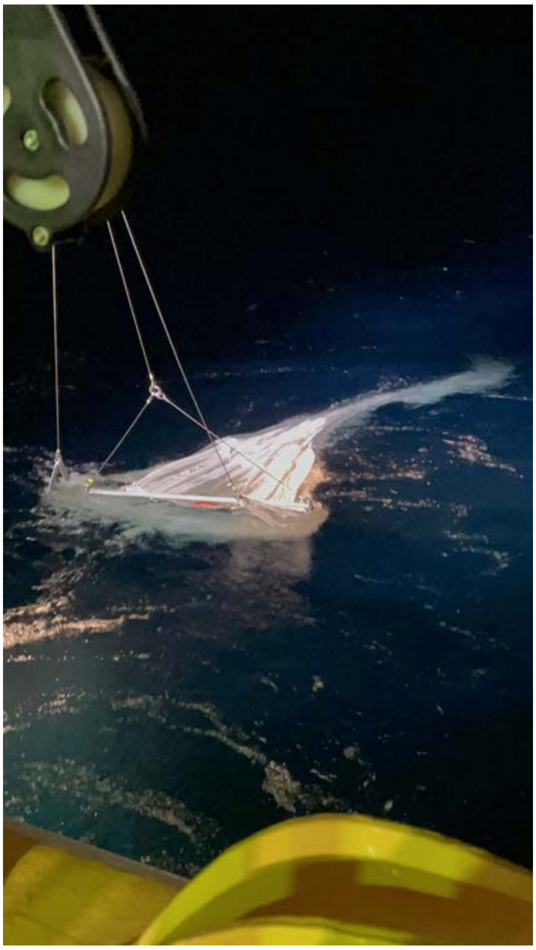

Figure 2.20: *IKMT Net towing during KS22-17.*

To know what the echosounder EK60 detected are, we towed a IKMT net to directly sample the micronewtons. IKMT net was towed within survey areas 1-3. Based on the scattering layers observed in the echosounder, we monitored the trawl depth using the Scanmer (real-time depth sensor) to target the specific layers to identify species composition of those layers.

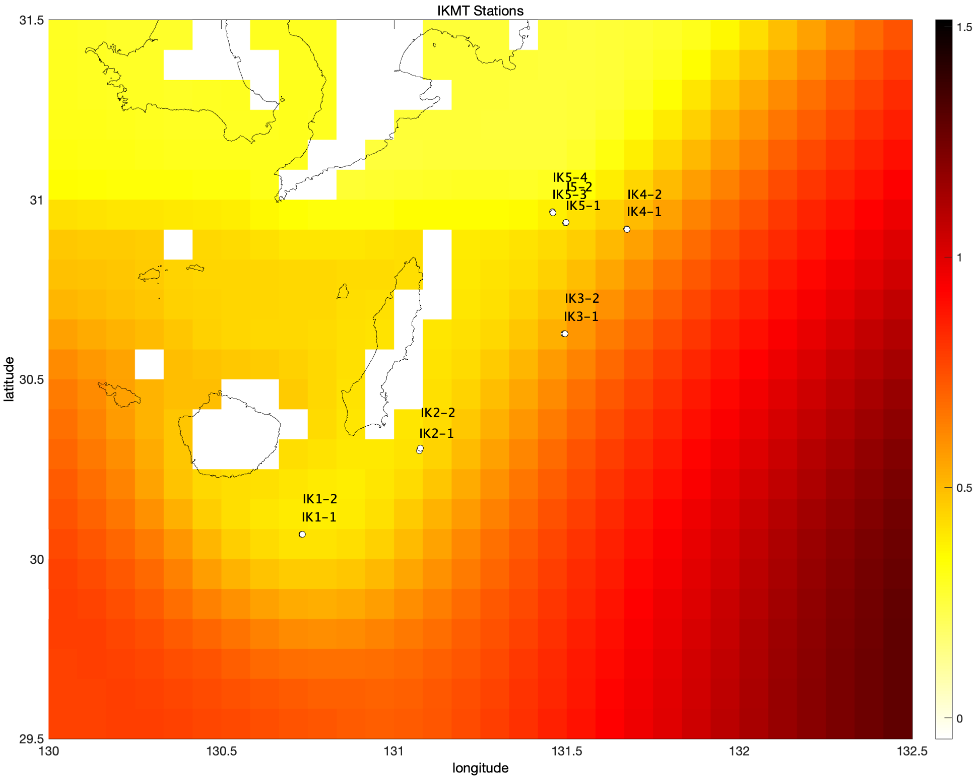

Figure 2.21: *IKMT Net stations during KS22-17. Red shading represents average sea surface height (CMEMS) during Dec. 28-Jan 3.*

2.9.1 Method

The mesh size of the IKMT net was 5.0 mm. The Scanmer (real-time depth sensor) was attached on the bridle and net. The net was towed from the ship stern. After reaching the target depth, the net was towed continuously over 30 minutes.

2.9.2 IKMT Net towing

We could tow the net at the following positions and time.

Figure 2.22: One of the samples caught by the IKMT Net during KS22-17.

1. Net 01: 12/28/2022 11:13UTC; 30 04.6398N, 130 44.1975E
2. Net 02: 12/28/2022 12:28UTC; 30 04.1174N, 130 44.1386E
3. Net 03: 12/30/2022 14:27UTC; 30 18.5462N, 131 04.5927E
4. Net 04: 12/30/2022 23:30UTC; 30 18.6995N, 131 04.6435E
5. Net 05: 1/1/2023 05:44UTC; 30 37.8352N, 131 29.4338E
6. Net 06: 1/1/2023 07:09UTC; 30 37.8424N, 131 29.6224E
7. Net 07: 1/1/2023 11:16UTC; 30 55.5618N, 131 40.3617E
8. Net 08: 1/1/2023 12:32UTC; 30 55.3247N, 131 40.421E
9. Net 09: 1/2/2023 11:41UTC; 30 56.1230N, 131 29.5175E
10. Net 10: 1/2/2023 12:38UTC; 30 56.1479N, 131 29.6255E

11. Net 11: 1/3/2023 05:07UTC; 30 58.1456N, 131 27.3939E
12. Net 12: 1/3/2023 06:06 UTC; 30 57.9755N, 131 27.5339E

3. Acknowledgements

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