Preliminary Report
of
The Hakuho Maru Cruise
KH-12-5

7 October ～ 19 November 2012

Vancouver － San Diego － Tokyo

Atmosphere and Ocean Research Institute
The University of Tokyo
2013

Preliminary Report
of
The Hakuho Maru Cruise
KH-12-5

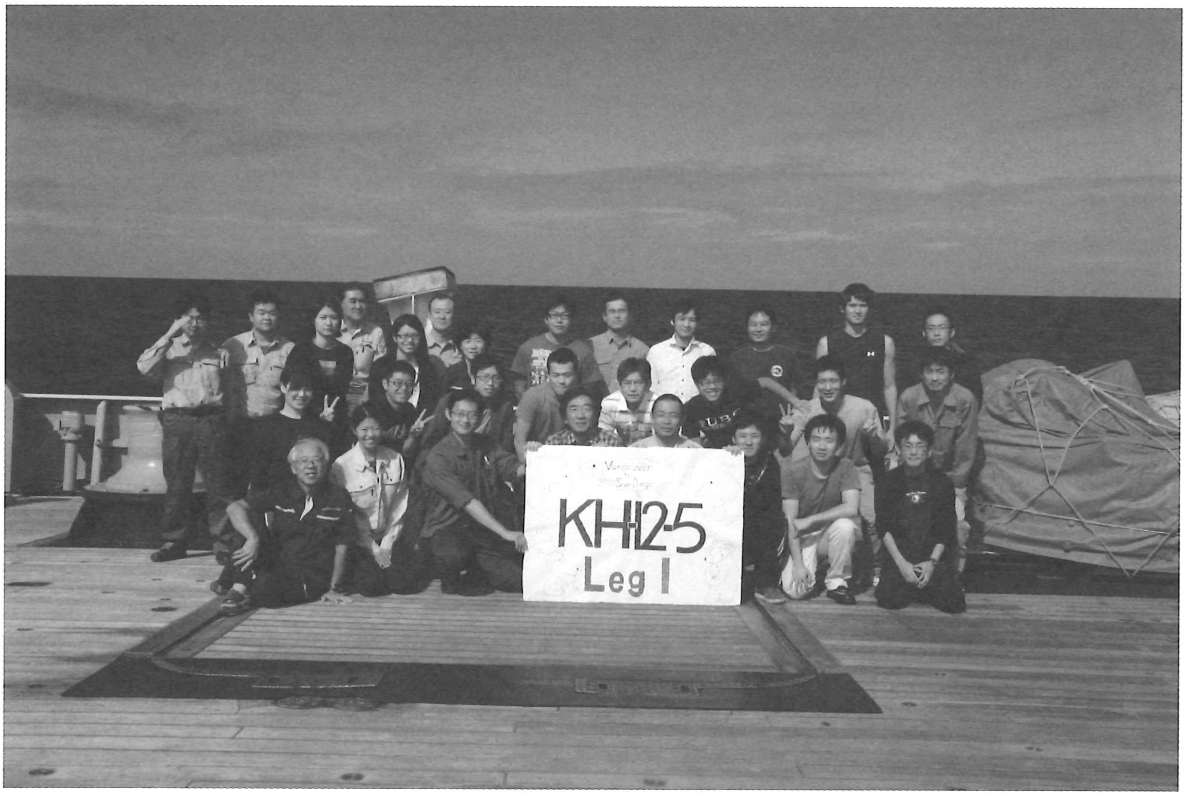
7 October ～ 19 November 2012

Vancouver － San Diego － Tokyo

Cruise for overturning circulation, turbulence, and subduction in the northeastern North Pacific
Part II

by
The Scientific Members of the Cruise

Edited by
Jiro YOSHIDA and Shinzou FUJIO


KH12-5
Leg 1


KH12-5
Leg 2
San Diego
Tokyo

CONTENTS

1. Outline of the KH-12-5 Cruise

The KH-12-5 cruise of R/V Hakuho-Maru was carried out for 44 days from October 7 to November 19 in 2012. The ship left Vancouver with a stop at San Diego from October 23 to October 28 composed of Leg 1 (Vancouver to San Diego) and Leg2 (San Diego to Tokyo). The observation was done by 24 scientists from 5 universities, 24 for Leg 1 and 22 for Leg 2.

The aim of this cruise is to study the overturning circulation of deep water and subduction of surface water in the northeastern North Pacific. This cruise is the second year cruise following the KH-11-8 cruise conducted in 2011. These two cruises were originally planned by Professor Masaki Kawabe, Atmosphere and Ocean Research Institute, the University of Tokyo (AORI), who passed away in January 2012.

The objectives of the KH-12-5 cruise are to study

1. deep circulation and upwelling of deep water (AORI)
2. time variation of deep circulation current (AORI)
3. surface subduction processes in the northeastern North Pacific (AORI; Tohoku University)
4. eddy diffusivity near the surface by the combination of density ratio and turbulent intensity observations (Tokyo University of Marine Science and Technology)
5. oceanic variability by deploying Argo Floats (Japan Agency for Marine-Earth Science and Technology)

Scheduled observation items were

$CTDO_2$ (Conductivity, Temperature, Depth and Oxygen profiler) with a carousel multi water sampler (CMS), LADCP (Lowered Acoustic Doppler Current Profiler), MicroRider (temperature microstructure), Water sampling for salinity, dissolved oxygen. and nutrients. (50 stations)

① Recovering of mooring systems (7 systems were moored in the KH-11-8 cruise)

② Turbomap (Turbulence Ocean Microstructure Acquisition Profiler) (13 stations)

③ Argo float (12 floats)

④ XCTD (Expendable CTD) (occasionally)

⑤ Shipboard ADCP, Short and long wave radiation meter (continually)

Recovering of the 7 mooring systems was scheduled in Leg 1. Throughout the cruise, $CTDO_2$ with a CMS measured water temperature, salinity and, dissolved oxygen. The CMS was equipped with 24 Niskin bottles to sample water to calibrate $CTDO_2$ salinity and dissolved oxygen sensors. Sampled water was also used to measure nutrients in the ocean. Upward and downward looking LADCPs were mounted on the CMS frame, and measured current velocity and echo intensity during their descending and ascending casts. MicroRider was also mounted on the frame and measured the temperature microstructure. In order to avoid the underwater instruments to touch and collide the sea bottom, we equipped the frame with an altimeter and a bottom-touch-switch. The altimeter monitored the distance of 40-70 m (80 m at several stations) from the sea bottom. The bottom-touch-switch hanging a 10-m string and a weight informed us that the instrument reached less than 10 m above the sea bottom, by ringing buzzer in a laboratory of the ship. At all CTDO2 stations, surface water was sampled by a bucket to measure surface temperature, salinity, dissolved oxygen, and nutrients. Twelve Argo floats were deployed occasionally in Leg 2. Beside these observations, near-surface turbulence observation by the Turbomap and XCTD observations were conducted. Shipboard ADCPs (Furuno Electric Co. and RD Instruments) were operated throughout the cruise to measure near-surface current velocity. Solar and infrared radiation meters were set on the upper deck to measure these radiations throughout the cruise. Temperature and salinity data measured by $CTDO_2$ and XCTD were transferred to the Japan Meteorological Agency (JMA) in quasi-real time base in TESAC format.

Leg 1 (Vancouver→San Diego)

Scientists (23 persons) arrived at Vancouver Airport about 10:30 on 5 October, and immediately moved to the Hakuho-Maru by agent cars. One scientist arrived the day before. We left Vancouver Port at 14:00 on 7 October after finishing the exit procedures.

Capt. Okubo informed us that the distribution of the atmospheric pressures in the North Pacific was a nearly typical wintertime pattern, and rough sea condition was predicted in our observation area. In fact, awful sea condition awaited us and the ship was frequently compelled to heave-to and to turn around to avoid the rough sea. Because of this, the recovering of mooring systems was started at the southernmost station on 11 October, and the final seventh mooring system (the northernmost station) was recovered on 18 October. The 1004^{th} current meter set by Mr. Shoji Kitagawa was also safely recovered. As for $CTDO_2$ and Turbomap observations, the condition of the sea was so rough that only three $CTDO_2$ casts (scheduled 28 casts) and two Turbomap casts (scheduled 6 casts) were conducted. Supplementary five XCTD observations were conducted. We tried a new instrument called a rotary joint (slip ring) to avoid twist of the armored cable. The slip ring was connected to a rotation meter and jointed to the armored cable. Three casts were conducted continuosly down to 500m depth. The instrument was good enough to protect the cable.

After recovering of the seventh mooring on 18 October, the ship sailed to San Diego. The rough sea was also predicted in the area near our scheduled observation area and the distance between the northernmost station to San Diego was so long, we gave up the scheduled observation off California coast. The Hakuho-Maru docked 10th Avenue Pier of San Diego Port at 15:00 on 23 October and the Leg 1 cruise was over. It was one day earlier before the scheduled day (24 October).

The instruments recovered were as follows.

Fluorometer (WetLab+Ocean Elec. Co.)	1
Moored CTD SBE-37 MicroCat (SeaBird)	14
Current meters	38
Aquadopp (NORTEX)	5
* due to the malfunction of real time clock inside, recordin was not started	1
RCM11 (Aanderra)	16
* water inside, impossible to data recover	1
* only half year records	1
URM (Union Engineering)	10
* Rotation record of rotor is 0	1
* Rotation record of rotor is 0 after 2589 hour was passed	1
SDCM (Union Engineering)	7
* Rotor was dropped immediately after deploying. Rotation record of rotor is 0 after 16 data was recorded.	1

Leg 2 (San Dieg→Tokyo)

We left San Diego port at 14:00 on 28 October, and Leg 2 of the cruise started. Because rough sea condition was also predicted throughout Leg 2, we reduced the number of planned CTDO$_2$ casts from 22 to 11 and those of Turbomap casts from 4 to 3. The successive Low Pressure literally pressed our ship, and the ship speed was not high enough to approach the first scheduled CTD station (36°N, 140°W) on time. We finally arrived there about noon on 3 November to start the Leg 2 observation. Because of high swell and wind waves, Turbomap observation was impossible at this station. The pressure of successive Low Pressure compelled the ship taking a south-westward detour route. While taking this detour route, XCTD observations were conducted at 30-minute interval in longitude, if sea condition was allowed us to go outside to the afterward deck.

Such action of the ship was frequently repeated, and the speed of the ship was not enough to occupy CTDO$_2$ stations afterward. Therefore, considering the long distance to Tokyo, we gave up CTDO$_2$ observation in Leg 2. The final observation was at 1:30 on 3 November (UTC). The total occupied CTDO$_2$

stations were only three. Irrespective of rough sea condition, XCTD observation was conducted at 30-minute interval in longitude mainly along 31°N line, and it was finished at 12:55 on 5 November at 32°01.52′ N、 157°00.01′ W. The ship continued to go westward, however, the sea condition has been still rough, and the ship speed is so low. Capt. Okubo considered all the matter about the maneuvering of the ship to Tokyo on time; he informed us that the scheduled arrival at Tokyo (16 November) was impossible and should be changed to 19 November. We accepted this change, and the ship kept going westward along 30°N line to avoid rough sea condition. After passing through the Date Line, the sea condition was gradually improved, and Turbomap observation was resumed at 22:00 on 9 November (UTC). After 10 November, Turbomap observation was done twice a day at 9:00 AM and 15:00 PM, if the sea condition was suitable for observation. At 05:00 on 14 November, the nineth Turbomap was finished, and all the observation in Leg 2 was finished.

Acknowledgement

The cruise KH-12-5 was carried out for 44 days. Because of rough weather throughout Leg 1 and Leg 2, the schedule was frequently changed and only four CTD casts was done. However, we conducted nine Turbomap stations and it was a great joy to recover all the mooring systems safe and sound. Therefore, I must say sincere thanks from the bottom of my heart to Capt. Suguru Okubo, the crew members of R/V Hakuho-Maru and the scientists and technical staff for the cooperation in the work throughout the cruise.

I thank Dr. Hiroshi Ogawa and Ms. Yoko Fujimoto (Department of Chemical Oceanography, AORI) for their kind help in the pre-cruise preparation of reagents for nutrients measurements. Thanks are also extended to Dr. Tadashi Inagaki (Office for Cruise Cooperation, AORI) for his help for arranging the cruise.

Finally, I must personally say my thanks to late Professor Masaki Kawabe for his longtime friendship and cooperation for 40 years from our university days. He greatly anticipated this cruise, so it is my great pleasure that we was able to recover all the moorings he deployed in KH-11-8.

Chief Scientist of the KH-12-5 cruise
Jiro Yoshida
Graduate School of Marine Science and Technology
Tokyo University of Marine Science and Technology

2. Summary of the Measurement and Correction

A. Water Sample

A1. Instrument

Seawater was sampled from 12-liter Niskin bottles mounted at 24 places on a Sea–Bird Electronics Carousel water sampler SBE32 for 24 bottles (Serial Number 3253585–0704).

A2. Conductivity

Conductivity of water samples was measured with a salinometer Guildline Autosal Model 8400B, S/N 68806, which was standardized by IAPSO Standard Seawater (Ocean Scientific International Ltd.) of Batch P154 (K_{15} = 0.99990). The measurement was done in Laboratory 5 in which air temperature was controlled to be a little lower (≈ 2°C) than water temperature in the salinometer water bath being 27°C.

A3. Dissolved Oxygen

Dissolved oxygen of water samples was measured with an automatic recording titrator Metrohm 888 Titrando (S/N 1888001002201). We used 0.02 mol l^{-1} Sodium Thiosulfate Solution (Wako Pure Chemical Industries Ltd.) (factor = 1.00) for titration.

A4. Nutrients

We analyzed nitrate, nitrite, silicate, and phosphate using an auto analyzer BLTEC SWAAT. Nitrate, nitrite, and phosphate standard solutions were prepared in laboratory before the cruise. Silicate standard solution was 1,000 ppm Silicon Standard Solution for atomic absorption spectrometry (Wako Pure Chemical Industries, Ltd.). For working standards and baseline solution, we used natural seawater of low nutrients which was filtered and analyzed in laboratory before the cruise.

B. $CTDO_2$

B1. Instrument

The $CTDO_2$ was a Sea-Bird Electronics instrument for 6800 dbar (SBE9plus). The sensor of conductivity was manufactured by Sea-Bird Electronics, Inc. (SBE4) who claimed a resolution of 0.00004 S m^{-1} (0.0004 mmho cm^{-1}) and an accuracy of ±0.0003 S m^{-1} (±0.003 mmho cm^{-1}). The sensor of water temperature was manufactured by Sea-Bird Electronics, Inc. (SBE3) who claimed a resolution of 0.0002°C and an initial accuracy of ±0.001°C. The sensor of pressure was manufactured by Paroscientific Digiquartz (Model 4xK) with a resolution of 0.001 % of full scale and an accuracy of ±0.015 % of full scale (6000 dbar range). The sensor of dissolved oxygen was manufactured by Sea-Bird Electronics, Inc. (SBE43) who claimed an accuracy of 2 % of saturation.

We used a set of the $CTDO_2$ underwater instrument. It was CTD SBE9plus (S/N 55807-0951) equipped with conductivity sensor SBE4 (S/N 0518), temperature sensor SBE3 (S/N 4378), pressure sensor (S/N 114746), oxygen sensor SBE43 (S/N 0628), pump SBE5T (S/N 5304), and a fluorometer manufactured by Seapoint Sensors Inc. (S/N 2363).

B2. Data Collection

Full signals of frequency digitized 24 times per second and sent from the underwater CTD unit SBE9plus were received with the onboard unit SBE11plus and converted to output sequences of RS232C. The data were collected with the Sea-Bird Electronics CTD operating software SEASOFT, using a personal computer EPSON Endeavor MR6700, whose operating system is Windows. Then, the Windows version of software was used. The full signals of frequency were stored in the hard disc during the downcast and upcast of CTD and then were copied in DVD-RAM discs after the recovery of CTD.

B3. Calibration

The sensors of conductivity and temperature were calibrated by Sea-Bird Electronics, Inc. in April 2012. The sensor of dissolved oxygen was calibrated by Sea-Bird Electronics, Inc. in June 2011. The pressure sensor was calibrated by Sea-Bird Electronics, Inc. in July 2009. The obtained coefficients were used in the CTD operating software SEASOFT.

a. Pressure

Pressure data were corrected by subtracting 0.482 dbar for C000-C004 and 0.534 dbar for C005-C007, which are the pressure sensor values under the standard air pressure P_0 (= 10.1325 dbar). We observed the atmospheric pressure P and the CTD pressure sensor values p on deck simultaneously for 15 minutes, and calculated the correction value of pressure by $P_0 - P + p$.

b. Conductivity

Conductivity data were calibrated using water-sample data. The ratio of conductivity from water sample to that from CTD (CF) was calculated. Vertical change of CF was expressed with polynomials of pressure P (dbar) such as

$$CF = 1 + a + bP + cP^2 + dP^3.$$

The sensor value of conductivity was multiplied by CF computed from the above equation and the following coefficients *a~d* for each of the station groups.

1) C001~C004
   a~d = 1.286E-04, -3.843E-08, -8.748E-13, 1.425E-15
2) C005~C007
   a~d = 1.167E-04, 5.130E-09, -1.773E-11, 3.181E-15

c. Dissolved Oxygen

Oxygen data were obtained with the method in the World Ocean Circulation Experiment (WOCE) Operations Manual, WOCE Hydrographic Programme Office Report WHPO 91-1, WOCE Report No. 68/91.

For SBE43, dissolved oxygen was calculated from the polarographic oxygen sensor electric voltage with the algorithm

$$O_x = S_{oc}\,(1 + AT + BT^2 + CT^3)\left[V + V_{\text{offset}} + \tau(P,T)\frac{dV}{dt}\right]\exp\left(\frac{E\cdot P}{273.15 + T}\right)\,O_x^*(T,S)$$

where O_x is the concentration of dissolved oxygen (ml l^{-1}), V the oxygen electric voltage, T, S, and P are water temperature (°C), salinity (pss78), and pressure (dbar) measured with CTD, and $O_x^*(T,S)$ the saturated oxygen for T and S by Garcia and Gordon (1992; *Limnology and Oceanography*, 37, 1307-1312). Sensor time constant is a function of P and T: $\tau(P,T) = \tau_{20}\exp[D_1P + D_2(T - 20)]$, where we used nominal dynamic coefficients for D_1 and D_2.

After applying the hysteresis correction to voltage V (Sea-bird Application Note No. 64-3, 2010), the seven coefficients S_{oc}, A, B, C, V_{offset}, τ_{20}, and E were determined with a nonlinear least squares fitting to the oxygen of water samples. The result of the coefficients is as follows.

1) C001~C004
   S_{oc}~E = 0.488, -2.83E-02, 2.74E-03, -7.22E-05, -0.515, 1.14, 0.0358
2) C005~C012
   S_{oc}~E = 0.490, -2.70E-02, 2.33E-03, -5.58E-05, -0.513, 1.09, 0.0355,

C. XCTD

We used probes of TSK XCTD-1. The depth of a falling probe was computed with the equation that

$$z = 3.42543\cdot t - 0.00047026\cdot t^2.$$

The data were recorded with TSK MK-130 (Tsurumi Seiki Co., Ltd. S/N 06456 for XC01-XC07, and S/N 06889 for XC09-XC36).

D. Shipboard ADCP

D1. ADCP (Furuno Electric Co., Ltd.)

Current velocities at three depths of 20 m, 50 m, and 100 m were measured at an interval of 15 seconds. The data were averaged for every minute and recorded with Doppler Sonar Current Profiler System CI-20H.

D2. ADCP (RD Instruments)

Current velocities at 80 levels at an interval of 16 m from 32-m depth down to about 1300 m were measured with Broadband 38 kHz ADCP and recorded every minute.

Misalignment of shipboard transducer decreases accuracies of the measured flow direction relative to the ship head and the measured velocity components.

According to Joyce (1989; *Journal of Atmospheric and Oceanic Technology*, 6, 169-172), the correct velocity (u_w, v_w) is given from a ship speed (u_s, v_s) and a measured ADCP velocity (u_d, v_d) as

$$u_w = u_s + (1+\beta)\,(u'_d \cos\alpha - v'_d \sin\alpha)$$
$$v_w = v_s + (1+\beta)\,(u'_d \sin\alpha + v'_d \cos\alpha),$$

where α is the error in orientation of transducer, and $1+\beta$ is the scale factor.

The values of α and β were estimated by comparing the ship speed obtained from bottom tracking with that from the Global Positioning System. For the comparison, 1153 ensemble data were used. The result is

$$\alpha\ (\text{rad}) = 0.0061,\ \beta = -0.0021.$$

The current velocity data from the RDI ADCP should be corrected with the above equations and coefficients.

E. Lowered ADCP

An ADCP instrument of 300 kHz Workhorse manufactured by RD Instruments was attached to the frame of the SBE Carousel water sampler and used as a lowered ADCP in order to obtain vertical profiles of horizontal velocity. Two transducers were set downward at the bottom (S/N 14797) and upward at the top (S/N 14626) of the water sampler frame, and a battery package was mounted on the frame. We selected 1 ping per a second and 4-meter bins.

Data were stored in the underwater ADCP unit and recovered on the deck after the cast. Noises and an influence of vertical move and rotation of the ADCP unit must be removed from the original data. Further processes of data should be made after the cruise to obtain correct data of current velocity.

F. Altimeter

An altimeter PSA-916T (S/N 47446) manufactured by BENTHOS Inc. was attached to the water sampler frame. It indicated the distance from the sea bottom being 40~70 m. Owing to the use of the altimeter, we could observe safely to just above the sea bottom.

G. TurboMAP

TurboMAP (Turbulence Ocean Microstructure Acquisition Profiler), manufactured by JFE Alec Electronics, Kobe, Japan, is 2.426 m in length, 0.405 m in diameter, 43 kg on deck, and 0.6~0.9 kg in water. This instrument is equipped with two shear probes and FPO7 temperature, conductivity, chlorophyll, turbidity, acceleration and pressure sensors. See the KH-04-4 Preliminary Report for the details.

TurboMAP is lowered freely with adjusted ballasts at 0.6~0.7 m s^{-1}. Sea cable is attached at an opposite side of sensors, and is connected to a personal computer through the portable winch system. Data is transferred through output sequence of USB. The sampling rate is 512 Hz, and transferring rate is 115.2 kbps. TurboMAP must be operated freely without tension to measure velocity shear correctly. When the observation is finished, TurboMAP is recovered by the portable winch.

The shear data are fitted on to the Nasymth spectral form to check the validity of data quality. Energy dissipation, scaled dissipation rate, and eddy diffusivities of heat and salt are calculated by using the shear data as well as the density ratio calculated from the temperature and salinity data obtained from TurboMAP.

H. MR6000

MR6000 (Micro Rider 6000), manufactured by Rockland Scientific International, Inc., was mounted to the water sampler frame. MR6000 is an internally recording instrument equipped with microstructure sensors, such as the shear probe, FP07 thermistor and micro conductivity sensor, as well as a pressure sensor, a 3-axis accelerometer. The sampling rates of these sensors are 512Hz. MR6000 also supports acquisition from Sea-Bird temperature and conductivity sensors of the CTD.

The data acquisition is started automatically upon MR6000's power up and is stopped by removing the power from the instrument after the recovery of CTD. Energy dissipation rates are estimated using the microstructure shear, temperature and conductivity data sampled during the downcast of CTD.

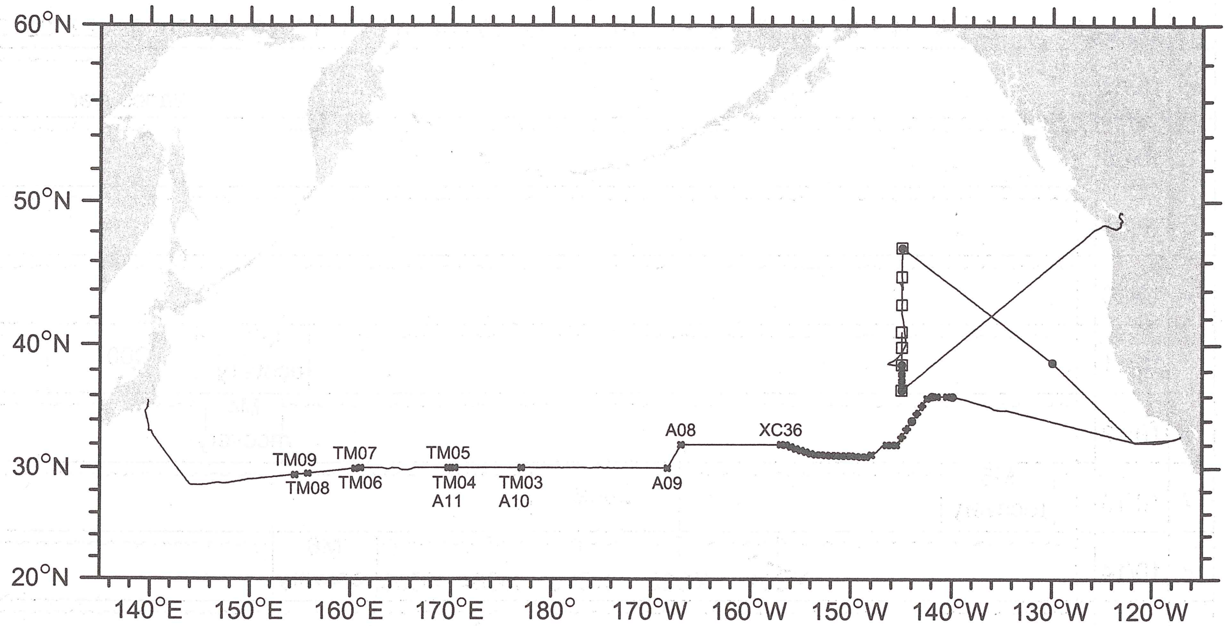
3. List of Scientists Aboard

Name	Phone	E-Mail
Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo 108-8477		
Jiro Yoshida	03-5463-0459	jiroy@kaiyodai.ac.jp
Haruka Nakano	03-5463-0459	m113033@kaiyodai.ac.jp
Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology, 2-1-6 Etchujima, Koto-ku, Tokyo 135-8533		
Masafumi Kimizuka	03-5245-7458	d122006@kaiyodai.ac.jp
Faculty of Marine Science, Tokyo University of Marine Science and Technology 4-5-7 Konan, Minato-ku, Tokyo 108-8477		
Mai Ishikawa	03-5463-0459	s091008@kaiyodai.ac.jp
Toshiki Kajiura	03-5463-0459	s091018@kaiyodai.ac.jp
Akihiro Tanaka	03-5463-0459	s091054@kaiyodai.ac.jp
Atmosphere and Ocean Research Institute, The University of Tokyo 5–1–5 Kashiwanoha, Kashiwa, Chiba, 277-8564		
Shinzou Fujio	04-7136-6061	fujio@aori.u-tokyo.ac.jp
Daigo Yanagimoto	04-7136-6043	daigo@aori.u-tokyo.ac.jp
Shoji Kitagawa	04-7136-8192	kitagawa@aori.u-tokyo.ac.jp
Maki Nagasawa	04-7136-8176	maki@aori.u-tokyo.ac.jp
Ryo Aruga	04-7136-6055	aruga-r@aori.u-tokyo.ac.jp
Hidetaka Kobayashi	04-7136-4382	hidekoba@aori.u-tokyo.ac.jp
Sam Sherrifftadano	04-7136-4404	tadano@aori.u-tokyo.ac.jp
Faculty of Environmental Earth Science, Hokkaido University N10 W5, Kita-ku, Sapporo, 060-0810		
Genta Mizuta[1]	011-706-2357	mizuta@ees.hokudai.ac.jp
Graduate School of Environmental Science, Hokkaido University N10 W5, Kita-ku, Sapporo, 060-0810		
Tsukasa Tekuramori	011-706-2620	tekuramori@ees.hokudai.ac.jp
Graduate School of Science, Tohoku University 6-3 Aoba, Aoba-ku, Sendai, 980-8578		
Katsuya Toyama	022-795-6529	katsuya@pol.gp.tohoku.ac.jp
Shun Ohishi	022-795-6528	ohishi@pol.gp.tohoku.ac.jp
Yu Shibata	022-795-6528	y-shibata@pol.gp.tohoku.ac.jp
Yasuharu Seo	022-795-6528	seo@pol.gp.tohoku.ac.jp
Kaori Hikobe	022-795-6528	hikobe@pol.gp.tohoku.ac.jp
Ryosuke Sasaki	022-795-6745	sasaki@ocean.caos.tohoku.ac.jp
Shinichi Murase	022-795-6745	murase@ocean.caos.tohoku.ac.jp
Graduate School of Marine Science, Tokai University 3-20-1, Orido, Shimizu-ku, Shimizu, Shizuoka, 424-8610		
Suguru Kameda[1]	054-337-0196	2btgd001@mail.tokai-u.jp
Marine Works Japan Ltd. 3-54-1, Oppama-higashimachi, Yokosuka, Kanagawa, 237-0063		
Shinichiro Yokogawa	046-869-0045	yokogawa@mwj.co.jp

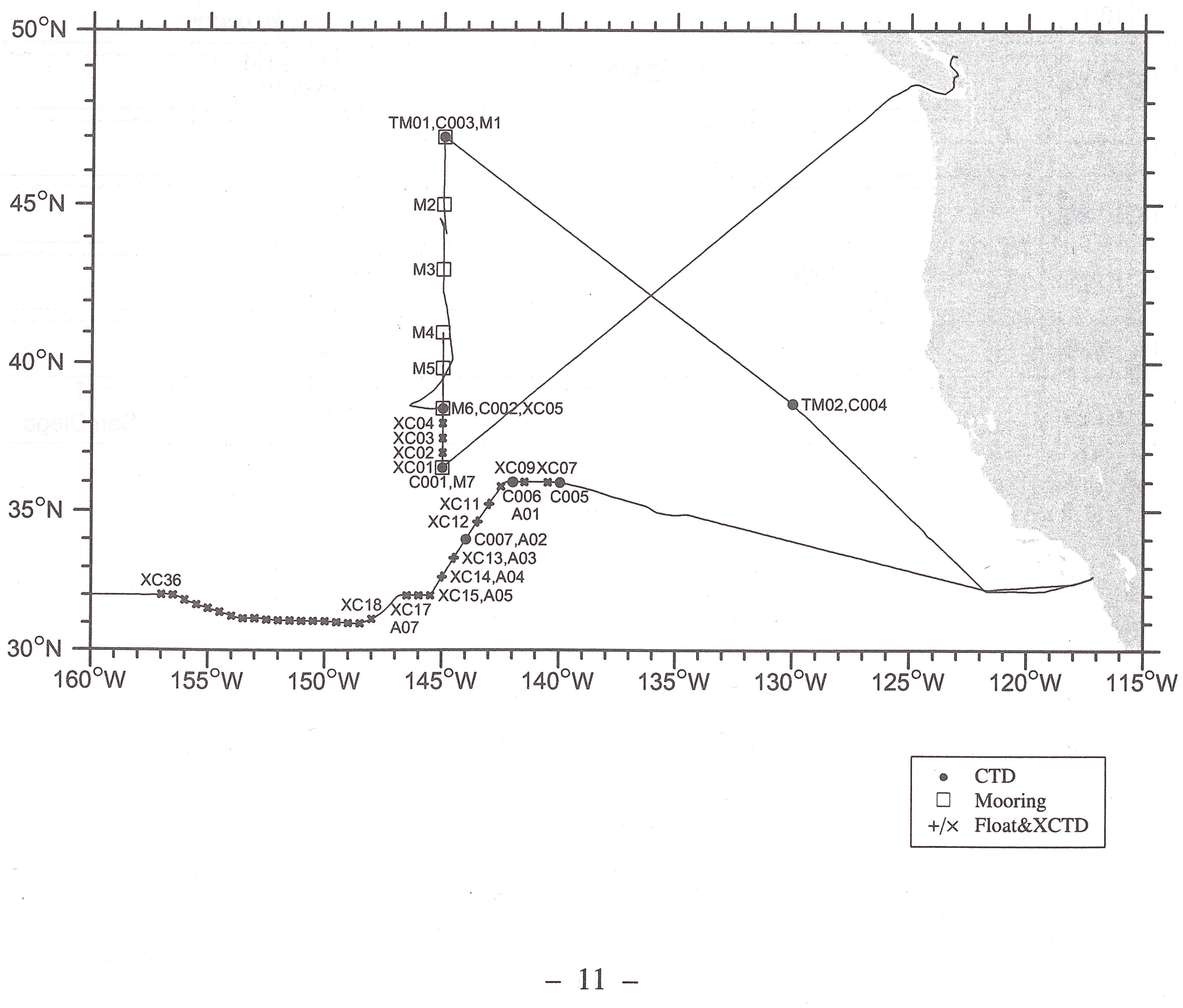
[1] only Leg-1

4. Track Chart

The whole area



The eastern part



5. Time Table

Leg 1

No.	Date	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	10/07																						↑ Vancouver			
2	10/08																									
3	10/09																									
4	10/10																									
5	10/11																		M7 recovery				C001			
6	10/12																			M4 recovery						
7	10/13		M5 recovery									C002														
8	10/14							↑ XC01		↑ XC02		↑ XC03		↑ XC04		↑ XC05		M6 recovery								
9	10/15																									
10	10/16																M3 recovery									
11	10/17																			M2 recovery						
12	10/18										C003							M1 recovery	TM 01							
13	10/19																									
14	10/20																									
15	10/21				TM 02		C004																			
16	10/22																									
17	10/23																						↑ San Diego			

Leg 2

	Date	TIME (UTC) 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1	10/28	San Diego
2	10/29	
3	10/30	
4	10/31	
5	11/01	C005
6	11/02	XC07 XC09 C006 A01 XC10 XC11 XC12 C007
7	11/03	C007 A02 A03 A04 XC15 A05 XC16 A06 XC17 A07 XC18
8	11/04	XC19 XC20 XC21 XC22 XC23 XC24 XC25 XC26 XC27 XC28 XC29
9	11/05	XC30 XC31 XC32 XC33 XC34 XC35 XC36
10	11/06	A08
11	11/07	A09
12	11/08	
13	11/09	TM 03 A10
14	11/10	TM 04 A11
15	11/11	TM 05
16	11/12	
17	11/13	TM 06 TM 07 TM 08
18	11/14	TM 09
19	11/15	
20	11/16	
21	11/17	
22	11/18	
23	11/19	Tokyo

6. Summary of Observation Stations

STN: Station number
TYPE: CTD=CTDO only, ROS=CTDO plus water sampler, MOR=Mooring, XCTD=XCTD, TMAP=TurboMAP, FLT=Float
CODE: BE=Beginning of cast or work, EN=End of work, BO=Bottom
DE=Deployment of instruments, RE=Recovery of instruments
DEPTH: Uncorrected water depth in meters
MAXP: Maximum pressure in decibars
PARAM: Sampling parameters
1=Salinity, 2=Dissolved oxygen, 3-6=Nutrients (NO_3,NO_2,SiO_2,PO_4),
LADCP=Lowered ADCP
COMMENTS are included in the columns of MAXP/PARAM

Leg 1

STN	TYPE	DATE	GMT	CODE	LATITUTE	LONGITUDE	DEPTH	MAXP	PARAM	*COMMENTS*
M7	MOR	101112	1747	BE	36°29.44'N	145°00.84'W	5316			*3 RCM11, 3 CM, 2 MicroCAT*
M7	MOR	101112	1855	RE	36°29.24'N	145°01.11'W	5319			*Transmitter 43.528MHz, A/R 3E*
C001	ROS	101112	1939	BE	36°29.05'N	145°00.74'W	5317			MR6000,LADCP
C001	ROS	101112	2122	BO	36°28.70'N	145°00.64'W	5320	5421	1-6	*SBE9p951 CTDO*
C001	ROS	101112	2250	EN	36°28.44'N	145°00.63'W	5312			
M4	MOR	101212	1827	BE	40°59.99'N	145°00.81'W	4715			*1 AQD, 2 RCM11, 2 CM, 2 MicroCAT*
M4	MOR	101212	1920	EN	40°59.83'N	145°00.65'W	4702			*Transmitter 43.528MHz, A/R 3A*
M5	MOR	101312	0145	BE	39°49.71'N	144°59.71'W	5683			*1 AQD, 3 RCM11, 3 CM, 2 MicroCAT*
M5	MOR	101312	0300	EN	39°49.09'N	145°00.42'W	5602			*Transmitter 43.528MHz, A/R 3D*
C002	ROS	101312	0857	BE	38°32.02'N	144°59.71'W	5101			MR6000,LADCP
C002	ROS	101312	1035	BO	38°31.91'N	144°59.40'W	5115	5230	1-6	*SBE9p951 CTDO*
C002	ROS	101312	1202	EN	38°31.93'N	144°59.24'W	5090			
XC01	XCTD	101412	0647	DE	36°30.12'N	145°00.02'W	5303			*TSK XCTD-1*
XC02	XCTD	101412	0855	DE	37°00.07'N	144°59.99'W	5222			*TSK XCTD-1*
XC03	XCTD	101412	1103	DE	37°30.11'N	144°59.94'W	5217			*TSK XCTD-1*
XC04	XCTD	101412	1309	DE	38°00.08'N	145°00.00'W	5069			*TSK XCTD-1*
XC05	XCTD	101412	1516	DE	38°30.05'N	144°59.98'W	5095			*TSK XCTD-1*
M6	MOR	101412	1645	BE	38°29.93'N	144°59.92'W	5093			*1 AQD, 2 RCM11, 3 CM, 2 MicroCAT*
M6	MOR	101412	1743	EN	38°30.36'N	145°00.64'W	5073			*Transmitter 43.528MHz, A/R 3C*
M3	MOR	101612	1552	BE	43°00.33'N	145°00.12'W	4588			*FLC, 1 AQD, 1 RCM11, 2 CM, 2 MCAT*
M3	MOR	101612	1643	EN	43°01.29'N	145°00.00'W	3943			*Transmitter 43.528MHz, A/R 3B*
M2	MOR	101712	1821	BE	44°59.82'N	145°00.37'W	4741			*3 RCM11, 2 CM, 2 MicroCAT*
M2	MOR	101712	1911	EN	45°00.20'N	145°01.68'W	4572			*Transmitter 43.528MHz, A/R 3H*
C003	ROS	101812	0756	BE	46°57.35'N	144°59.40'W	4710			MR6000,LADCP
C003	ROS	101812	0926	BO	46°57.59'N	144°59.86'W	4713	4775	1-6	*SBE9p951 CTDO*
C003	ROS	101812	1050	EN	46°58.14'N	145°00.16'W	4716			
M1	MOR	101812	1625	BE	46°59.38'N	144°58.88'W	4719			*1 AQD, 2 RCM11, 2 CM, 2 MicroCAT*
M1	MOR	101812	1711	EN	46°59.78'N	144°58.82'W	4719			*Transmitter 43.528MHz, A/R 3G*
TM01	TMAP	101812	1758	BE	46°59.65'N	144°58.72'W	4719			*476 TurboMAP*
TM01	TMAP	101812	1811	BO	46°59.47'N	144°58.66'W	4718			
TM01	TMAP	101812	1823	EN	46°59.31'N	144°58.58'W	4719			
TM02	TMAP	102112	0307	BE	38°39.71'N	129°59.99'W	4291			*TurboMAP*
TM02	TMAP	102112	0320	BO	38°39.51'N	129°59.93'W	4294	500		
TM02	TMAP	102112	0329	EN	38°39.39'N	129°59.90'W	4281			

C004A	CTD	102112	0425	BE	38°39.18′N	129°59.79′W	4275		MR6000,LADCP	
C004A	CTD	102112	0445	BO	38°39.00′N	129°59.91′W	4266	502		*SBE9p951 CTDO*
C004A	CTD	102112	0506	EN	38°38.88′N	130°00.07′W	4264			
C004B	CTD	102112	0507	BE	38°38.88′N	130°00.08′W	4266		MR6000,LADCP	
C004B	CTD	102112	0526	BO	38°38.78′N	130°00.27′W	4269	501		*SBE9p951 CTDO*
C004B	CTD	102112	0547	EN	38°38.63′N	130°00.46′W	4266			
C004C	CTD	102112	0548	BE	38°38.63′N	130°00.46′W	4266		MR6000,LADCP	
C004C	CTD	102112	0607	BO	38°38.60′N	130°00.60′W	4267	500		*SBE9p951 CTDO*
C004C	CTD	102112	0629	EN	38°38.53′N	130°00.73′W	4276			

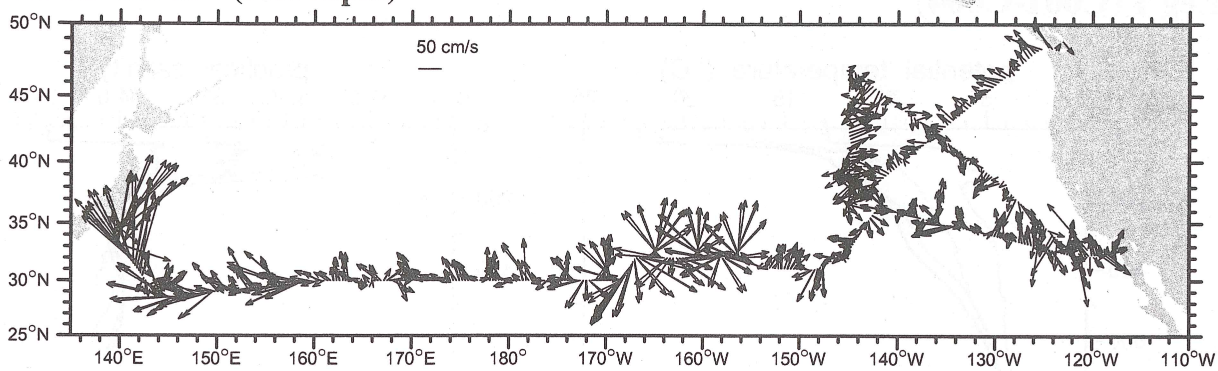
Leg 2

STN	TYPE	DATE	GMT	CODE	LATITUTE	LONGITUDE	DEPTH	MAXP	PARAM	*COMMENTS*
C005	ROS	110112	1906	BE	35°59.54′N	139°58.93′W	5234		MR6000,LADCP	
C005	ROS	110112	2049	BO	35°58.96′N	139°58.65′W	5224	5359	1-6	*SBE9p951 CTDO*
C005	ROS	110112	2223	EN	35°58.67′N	139°58.62′W	5282			
XC07	XCTD	110212	0031	DE	35°59.59′N	140°30.17′W	5396			*TSK XCTD-1*
XC09	XCTD	110212	0403	DE	36°00.06′N	141°30.12′W	5423			*TSK XCTD-1*
C006	ROS	110212	0620	BE	36°00.20′N	141°59.99′W	5326		MR6000,LADCP	
C006	ROS	110212	0812	BO	36°00.15′N	141°59.70′W	5310	5418	1-6	*SBE9p951 CTDO*
C006	ROS	110212	0943	EN	35°59.77′N	141°59.22′W	5334			
A01	FLT	110212	0956	DE	35°59.83′N	141°59.28′W	5324			*ARVOR, S/N 11JAP-APL-15, ID 112244*
XC10	XCTD	110212	1244	DE	35°50.74′N	142°30.04′W	4550			*TSK XCTD-1*
XC11	XCTD	110212	1555	DE	35°14.05′N	143°00.12′W	5367			*TSK XCTD-1*
XC12	XCTD	110212	1902	DE	34°37.03′N	143°30.06′W	5367			*TSK XCTD-1*
C007	ROS	110212	2226	BE	34°00.00′N	144°00.08′W	5462		MR6000,LADCP	
C007	ROS	110312	0018	BO	33°59.92′N	143°59.04′W	5452	5575	1-6	*SBE9p951 CTDO*
C007	ROS	110312	0153	EN	33°59.89′N	144°00.14′W	5416			
A02	FLT	110312	0200	DE	33°59.89′N	144°00.25′W	5460			*ARVOR, S/N 11JAP-APL-12, ID 112241*
XC13	XCTD	110312	0530	DE	33°20.23′N	144°30.10′W	5380			
A03	FLT	110312	0537	DE	33°19.39′N	144°30.97′W	5372			*ARVOR, S/N 11JAP-APL-17, ID 112246*
XC14	XCTD	110312	0852	DE	32°40.17′N	145°00.03′W	5500			*TSK XCTD-1*
A04	FLT	110312	0859	DE	32°39.44′N	145°00.60′W	5488			*ARVOR, S/N 12JAP-APL-01, ID 112351*
XC15	XCTD	110312	1219	DE	31°59.92′N	145°30.06′W	5496			*TSK XCTD-1*
A05	FLT	110312	1225	DE	31°59.36′N	145°30.51′W	5465			*ARVOR, S/N 12JAP-APL-03, ID 112353*
XC16	XCTD	110312	1420	DE	32°00.00′N	146°00.07′W	5606			*TSK XCTD-1*
A06	FLT	110312	1425	DE	32°00.00′N	146°00.94′W	5634			*ARVOR, S/N 11JAP-APL-16, ID 112245*
XC17	XCTD	110312	1616	DE	32°00.01′N	146°30.20′W	5609			*TSK XCTD-1*
A07	FLT	110312	1622	DE	32°00.02′N	146°31.00′W	5758			*ARVOR, S/N 12JAP-APL-02, ID 112352*
XC18	XCTD	110312	2344	DE	31°09.12′N	148°00.71′W	5370			*TSK XCTD-1*
XC19	XCTD	110412	0159	DE	30°59.65′N	148°30.01′W	5186			*TSK XCTD-1*
XC20	XCTD	110412	0403	DE	31°00.29′N	149°00.01′W	5092			*TSK XCTD-1*
XC21	XCTD	110412	0625	DE	31°02.21′N	149°30.05′W	5142			*TSK XCTD-1*
XC22	XCTD	110412	0912	DE	31°04.37′N	150°00.06′W	5142			*TSK XCTD-1*
XC23	XCTD	110412	1142	DE	31°05.03′N	150°30.05′W	5229			*TSK XCTD-1*
XC24	XCTD	110412	1342	DE	31°05.15′N	151°00.04′W	5492			*TSK XCTD-1*
XC25	XCTD	110412	1539	DE	31°05.88′N	151°30.04′W	5211			*TSK XCTD-1*
XC26	XCTD	110412	1735	DE	31°06.51′N	152°00.00′W	5402			*TSK XCTD-1*
XC27	XCTD	110412	1928	DE	31°07.70′N	152°29.99′W	5334			*TSK XCTD-1*
XC28	XCTD	110412	2157	DE	31°10.82′N	153°00.07′W	5482			*TSK XCTD-1*
XC29	XCTD	110412	2349	DE	31°10.36′N	153°30.09′W	5456			*TSK XCTD-1*
XC30	XCTD	110512	0143	DE	31°15.72′N	154°00.03′W	5659			*TSK XCTD-1*
XC31	XCTD	110512	0340	DE	31°24.37′N	154°30.07′W	5474			*TSK XCTD-1*
XC32	XCTD	110512	0531	DE	31°32.39′N	155°00.05′W	5622			*TSK XCTD-1*

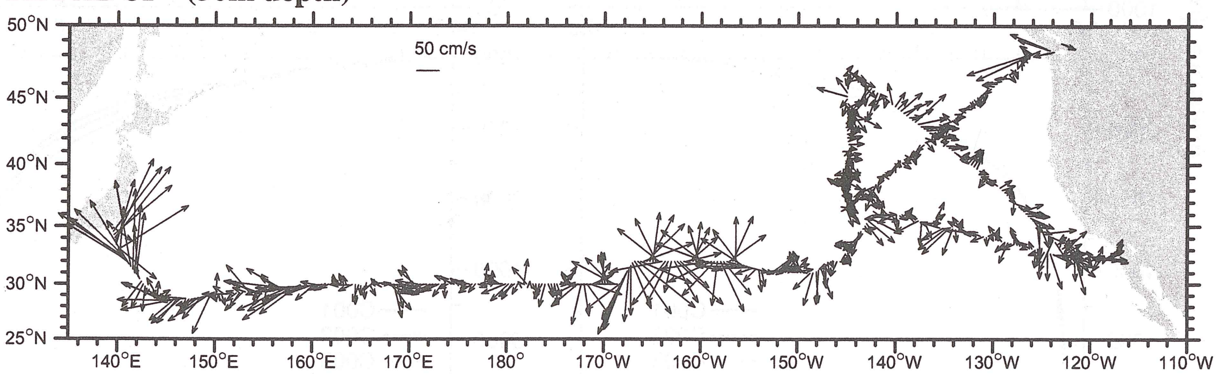
XC33	XCTD	110512	0718	DE	31°40.27'N	155°30.10'W	5625		*TSK XCTD-1*
XC34	XCTD	110512	0907	DE	31°50.00'N	156°00.04'W	5858		*TSK XCTD-1*
XC35	XCTD	110512	1102	DE	32°00.36'N	156°30.08'W	5812		*TSK XCTD-1*
XC36	XCTD	110512	1255	DE	32°01.52'N	157°00.01'W	5958		*TSK XCTD-1*
A08	FLT	110612	2357	DE	31°59.75'N	167°00.11'W	5865		*ARVOR, S/N 11JAP-APL-14, ID 112243*
A09	FLT	110712	0903	DE	29°59.94'N	168°19.91'W	5525		*ARVOR, S/N 11JAP-APL-19, ID 112248*
TM03	TMAP	110912	2202	BE	30°00.06'N	177°00.11'E	5128		*TurboMAP*
TM03	TMAP	110912	2219	BO	30°00.02'N	177°00.20'E	5089	685	
TM03	TMAP	110912	2227	EN	30°00.02'N	177°00.19'E	5085		
A10	FLT	110912	2245	DE	29°59.83'N	176°59.88'E	5166		*ARVOR, S/N 12JAP-APL-04, ID 113354*
TM04	TMAP	111012	2219	BE	30°00.56'N	170°21.97'E	5553		*TurboMAP*
TM04	TMAP	111012	2229	BO	30°00.95'N	170°22.02'E	5541	393	
TM04	TMAP	111012	2239	EN	30°01.24'N	170°22.07'E	5548		
A11	FLT	111012	2300	DE	30°01.73'N	170°21.87'E	5546		*ARVOR, S/N 11JAP-APL-10, ID 112239*
TM05	TMAP	111112	0151	BE	30°00.23'N	169°42.80'E	5656		*TurboMAP*
TM05	TMAP	111112	0203	BO	30°00.45'N	169°42.95'E	5656	434	
TM05	TMAP	111112	0212	EN	30°00.54'N	169°43.06'E	5654		
TM06	TMAP	111312	0331	BE	30°00.37'N	161°00.32'E	5831		*TurboMAP*
TM06	TMAP	111312	0346	BO	30°00.31'N	161°00.05'E	5829	550	
TM06	TMAP	111312	0355	EN	30°00.40'N	160°59.89'E	5827		
TM07	TMAP	111312	0613	BE	29°57.63'N	160°27.98'E	5728		*TurboMAP*
TM07	TMAP	111312	0628	BO	29°57.73'N	160°27.67'E	5725	550	
TM07	TMAP	111312	0638	EN	29°57.79'N	160°27.49'E	5726		
TM08	TMAP	111312	2318	BE	29°31.58'N	155°46.77'E	5754		*TurboMAP*
TM08	TMAP	111312	2331	BO	29°31.88'N	155°46.83'E	5754	525	
TM08	TMAP	111312	2340	EN	29°32.06'N	155°46.90'E	5756		
TM09	TMAP	111412	0512	BE	29°24.42'N	154°27.48'E	5850		*TurboMAP*
TM09	TMAP	111412	0525	BO	29°24.63'N	154°27.73'E	5847	516	
TM09	TMAP	111412	0536	EN	29°24.64'N	154°27.92'E	5846		

7. Chart of Surface Current

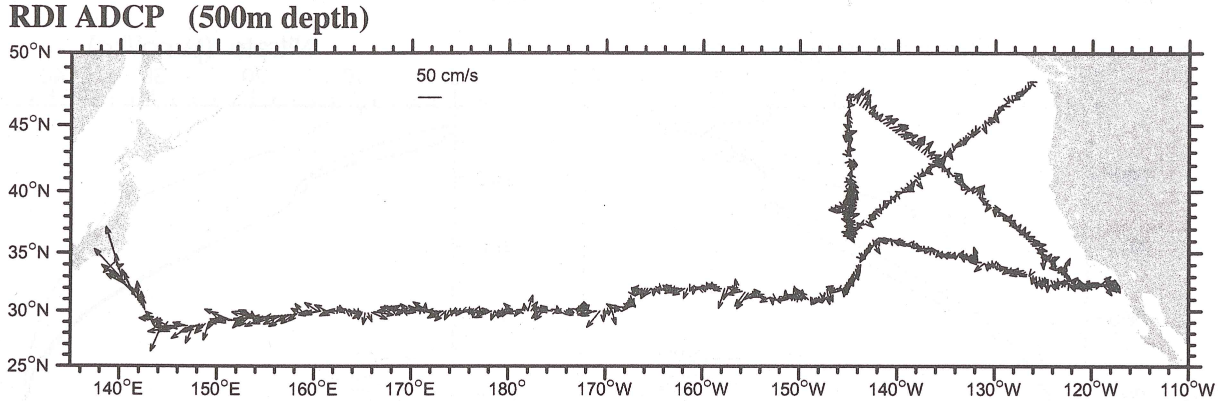
Furuno ADCP (50m depth)



RDI ADCP (50m depth)

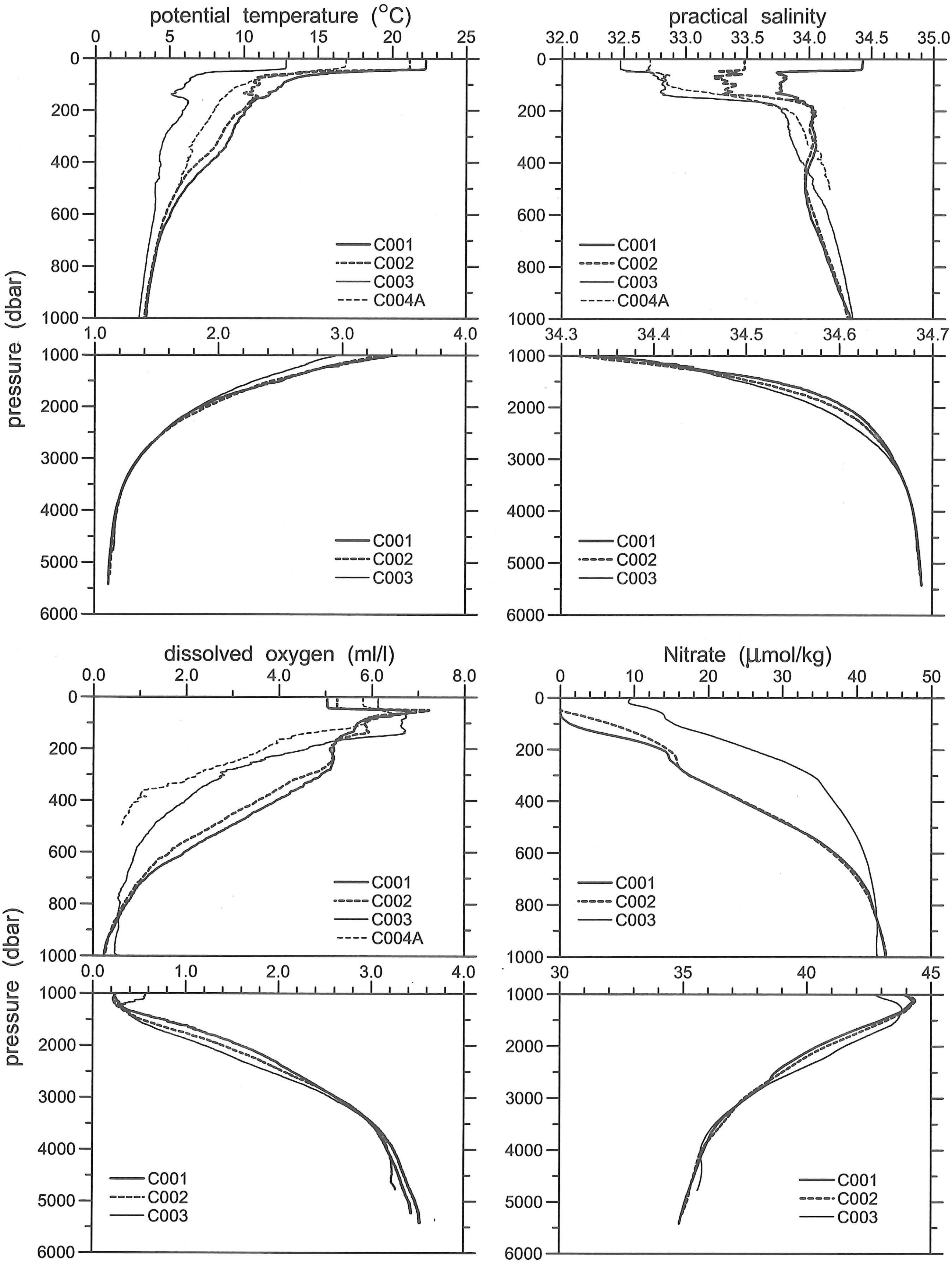


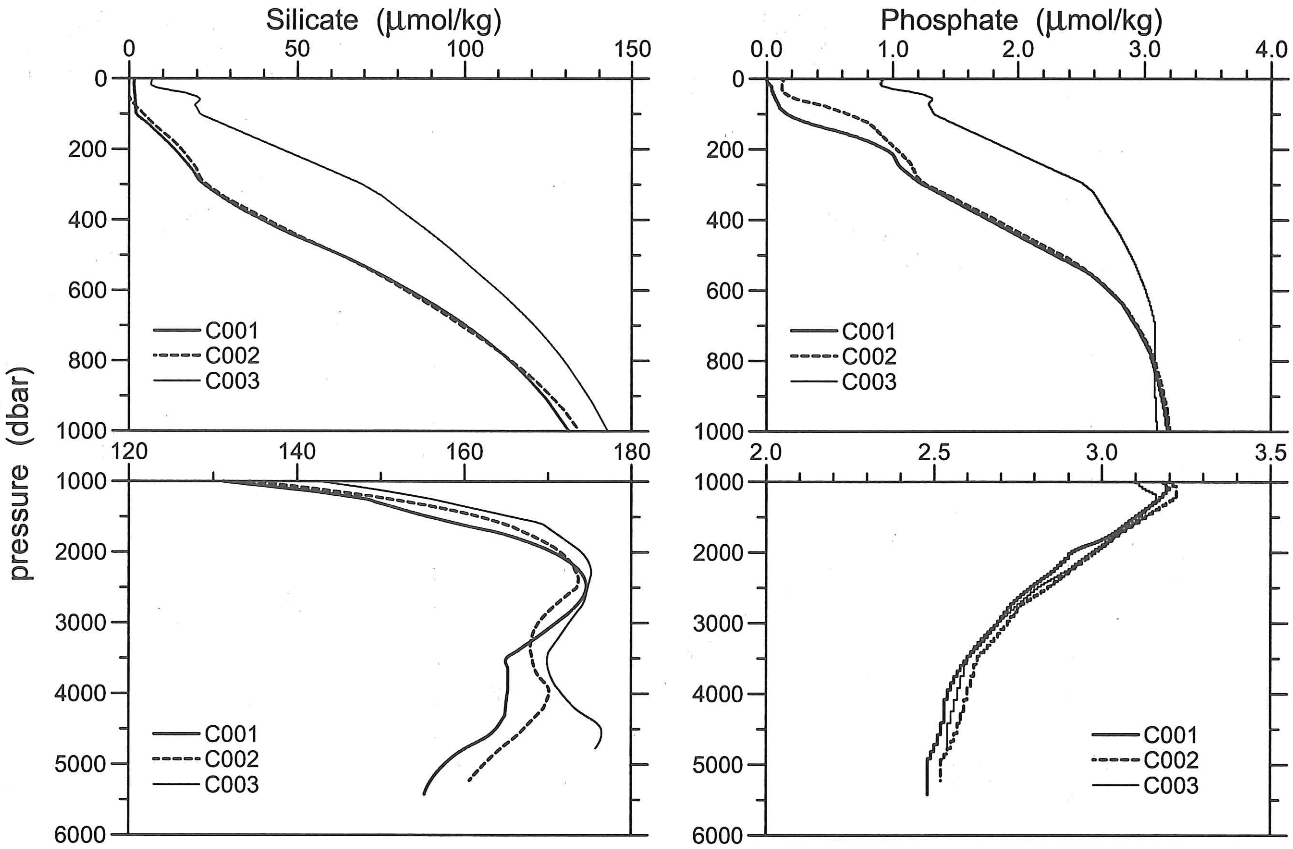
RDI ADCP (500m depth)



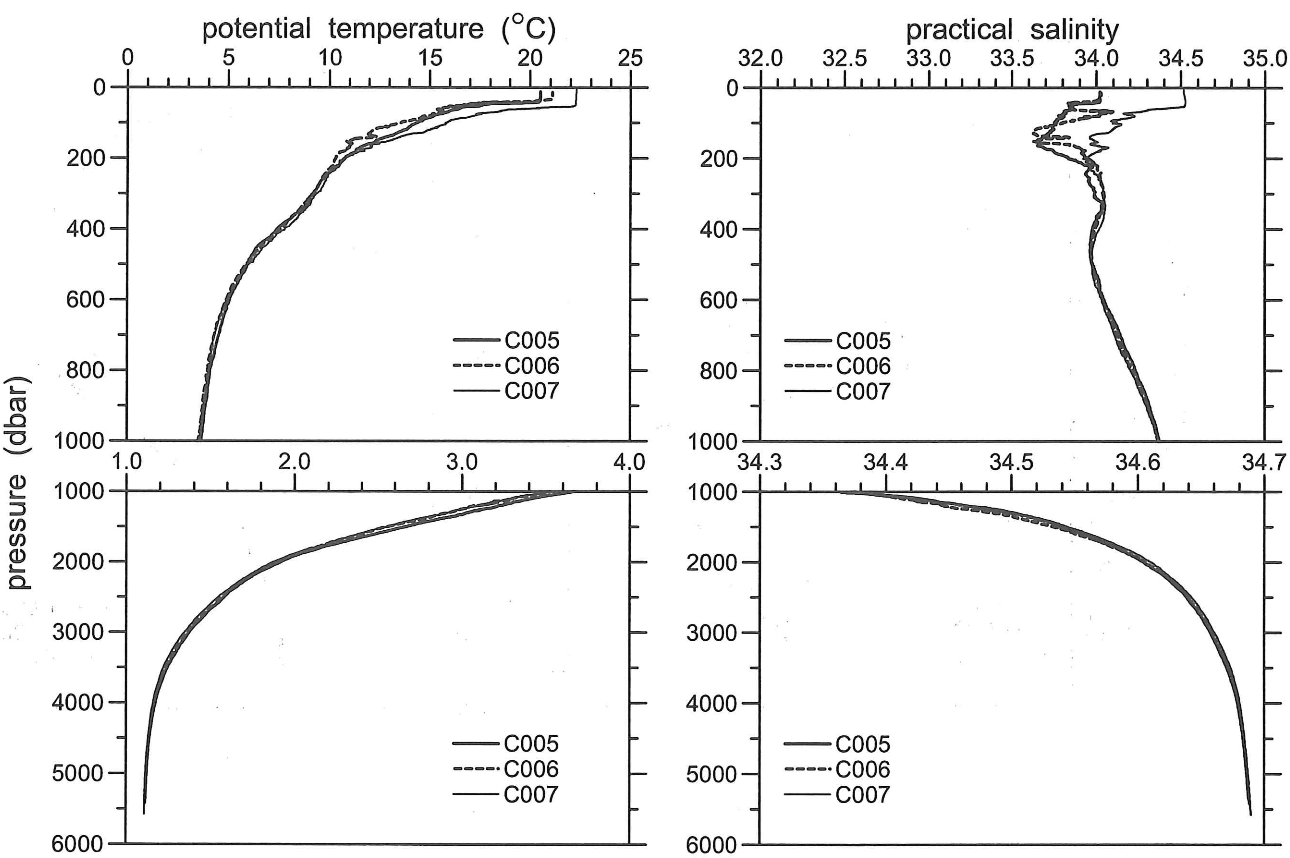
8. Vertical Profiles of $CTDO_2$ and Nutrient Data

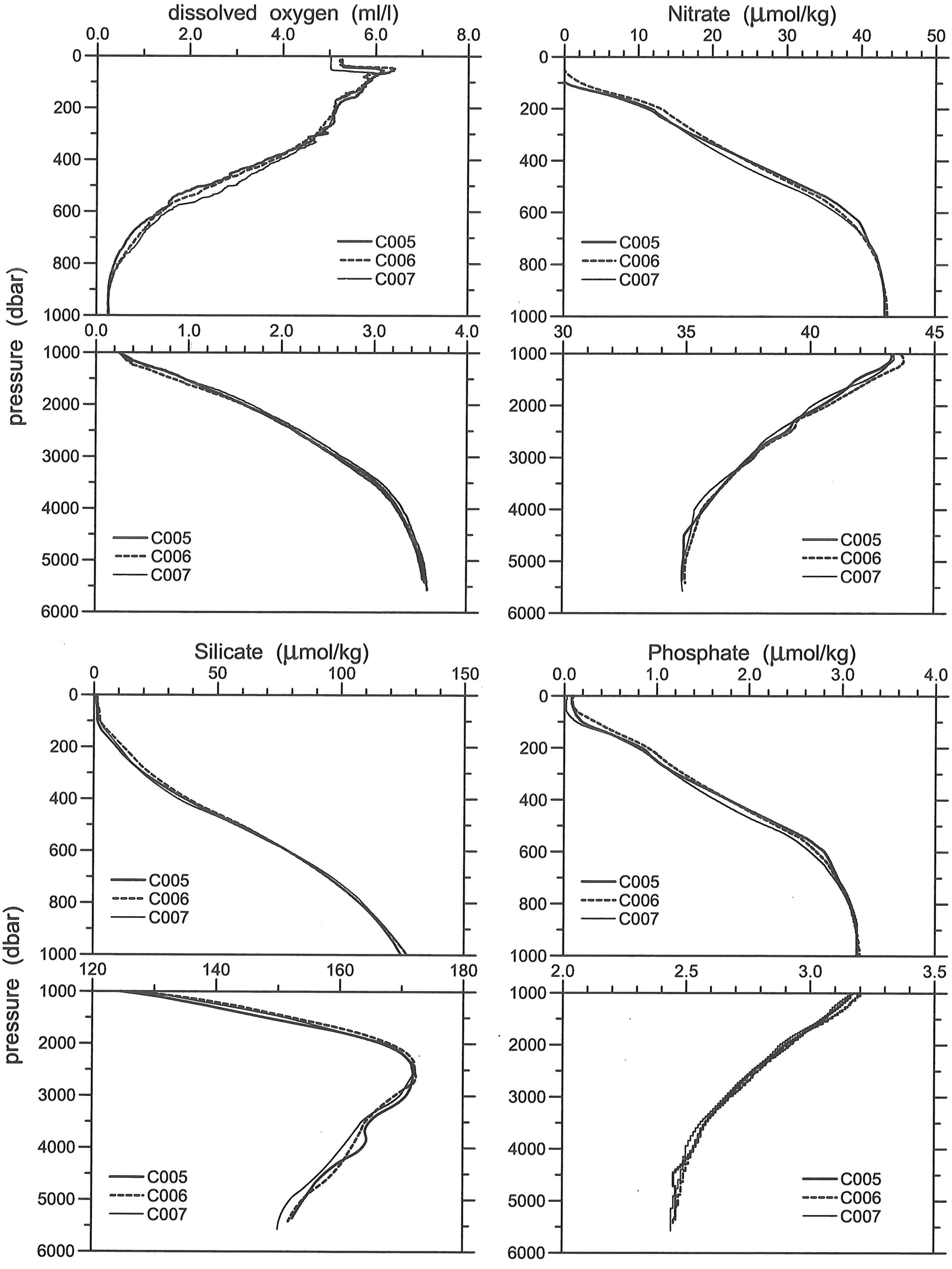
Leg 1 (C001-C004)





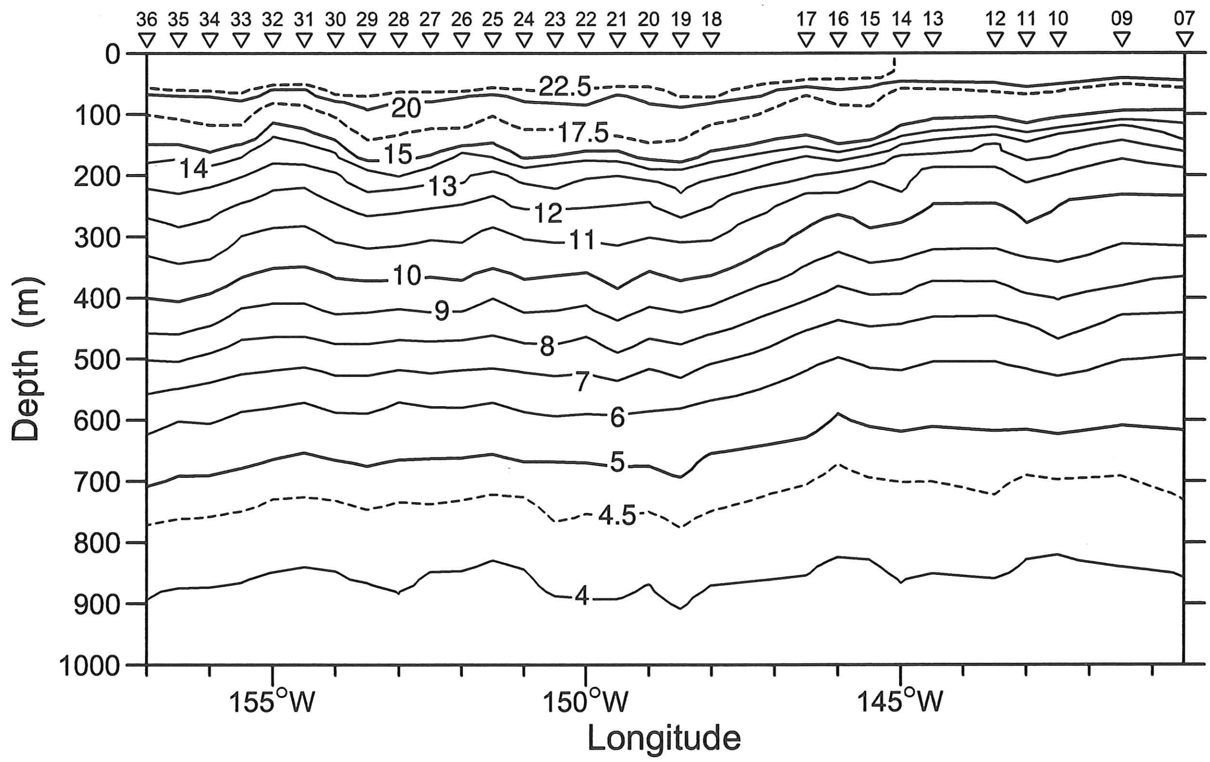
Leg 2 (C005-C007)



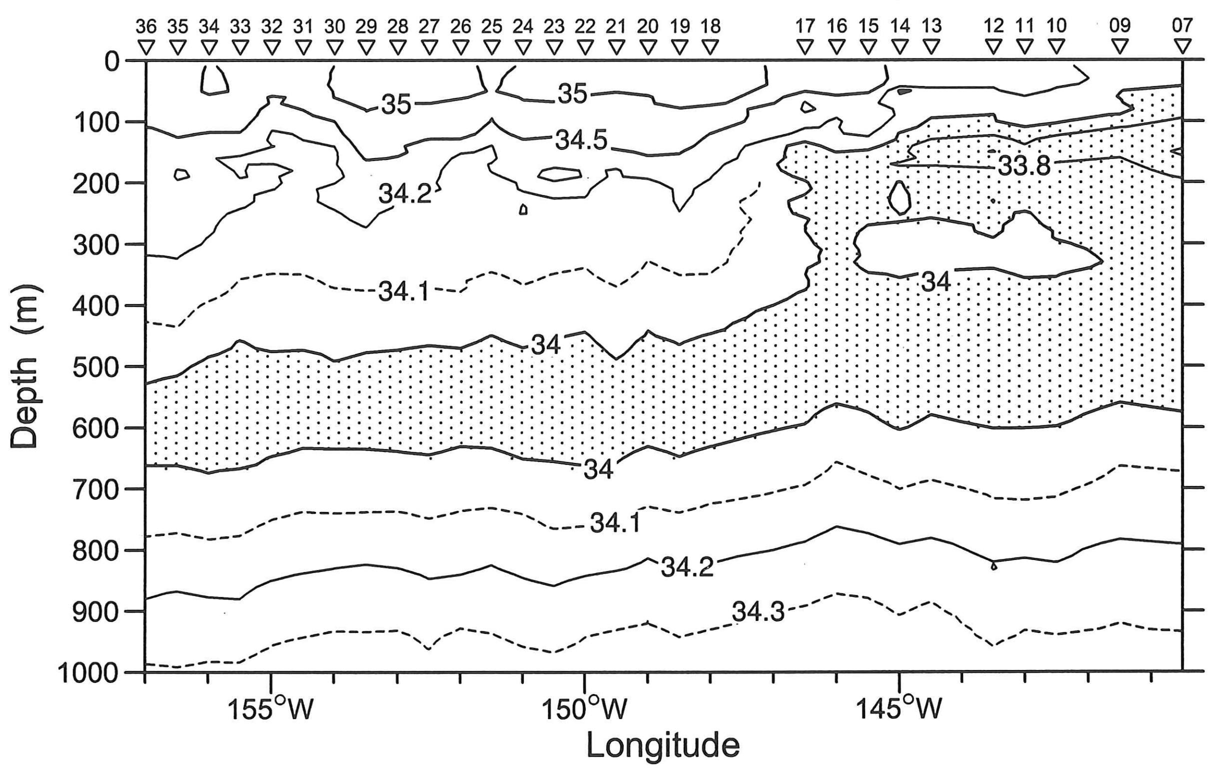

dissolved oxygen (ml/l)
Nitrate (μmol/kg)
Silicate (μmol/kg)
Phosphate (μmol/kg)
pressure (dbar)
C005
C006
C007

9. Vertical Sections of XCTD Data

Temperature

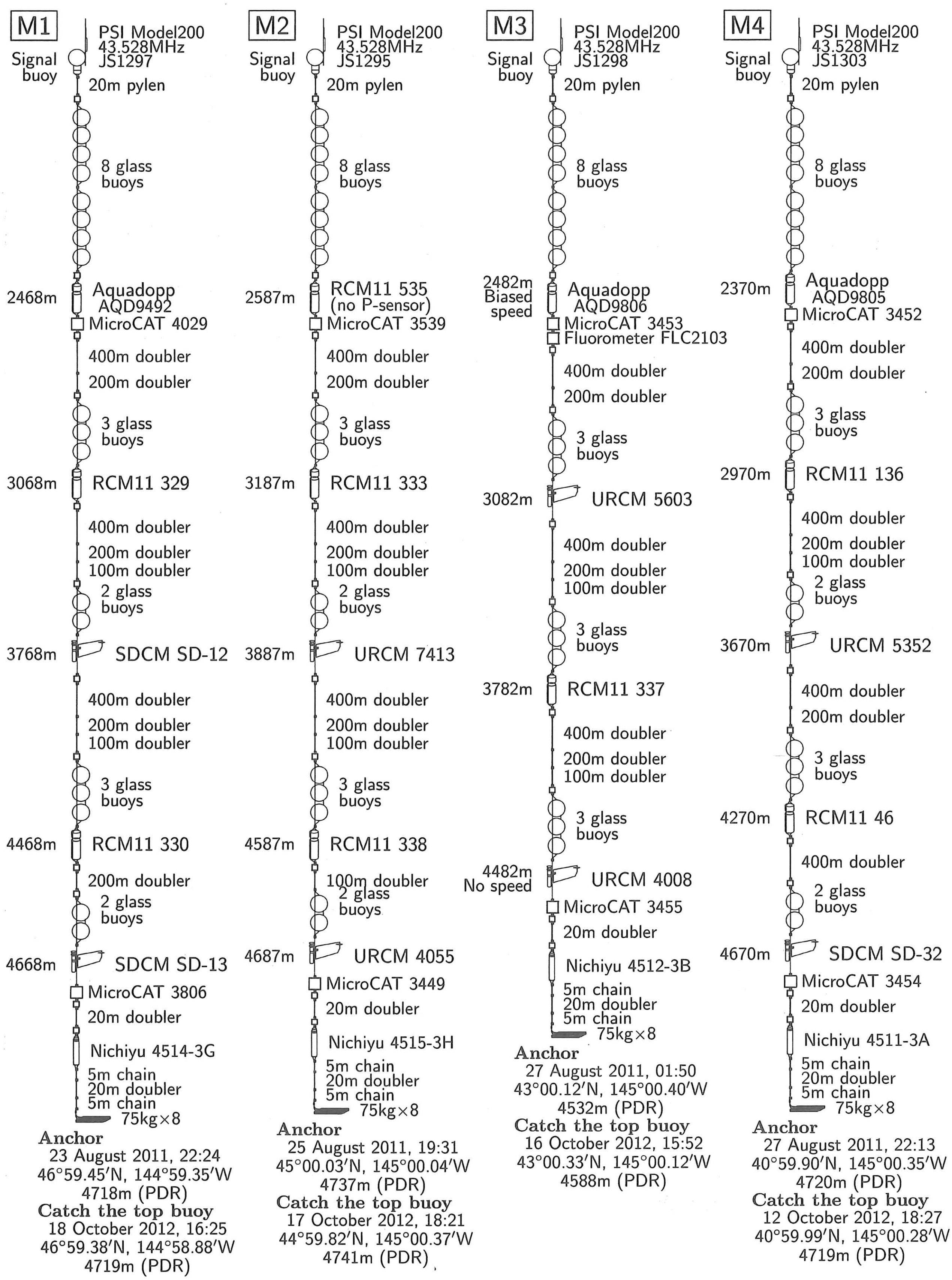


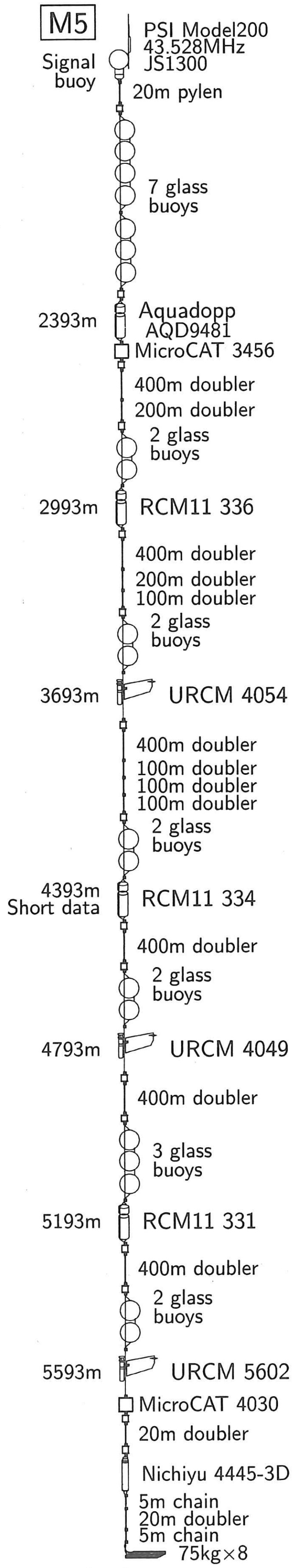
Salinity (pss78)



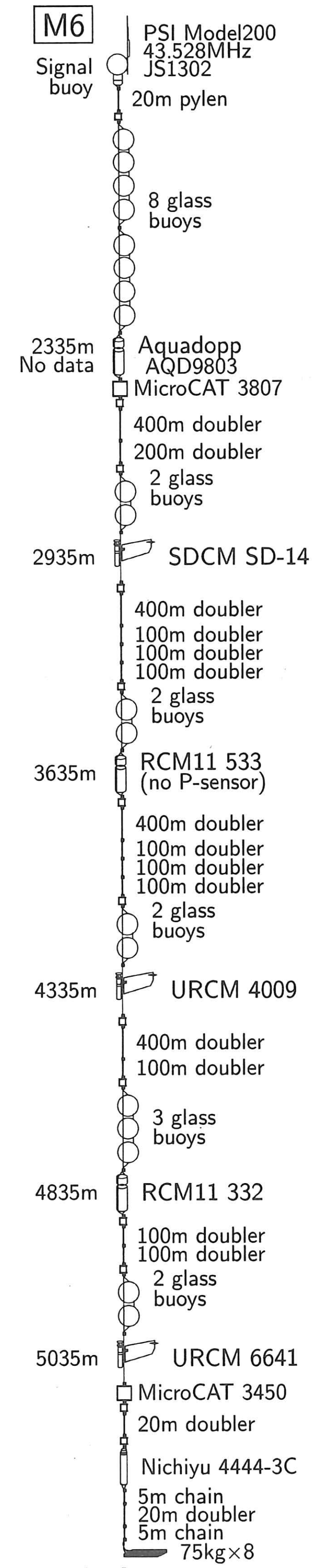
10. Mooring Systems

Recovered Systems at 145°W

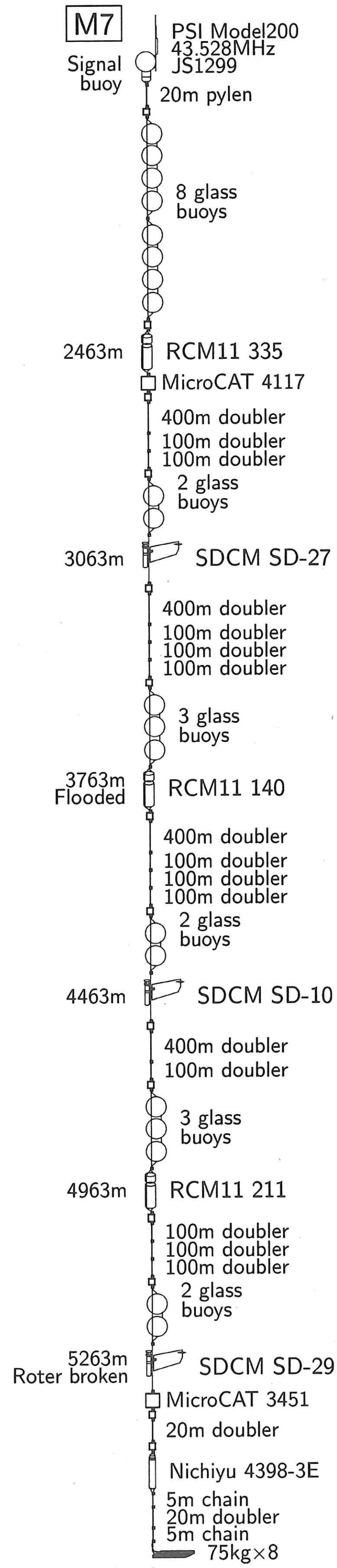




Anchor
28 August 2011, 18:44
39°50.21′N, 145°00.01′W
5643m (PDR)
Catch the top buoy
13 October 2012, 01:45
39°49.71′N, 144°59.71′W
5662m (PDR)

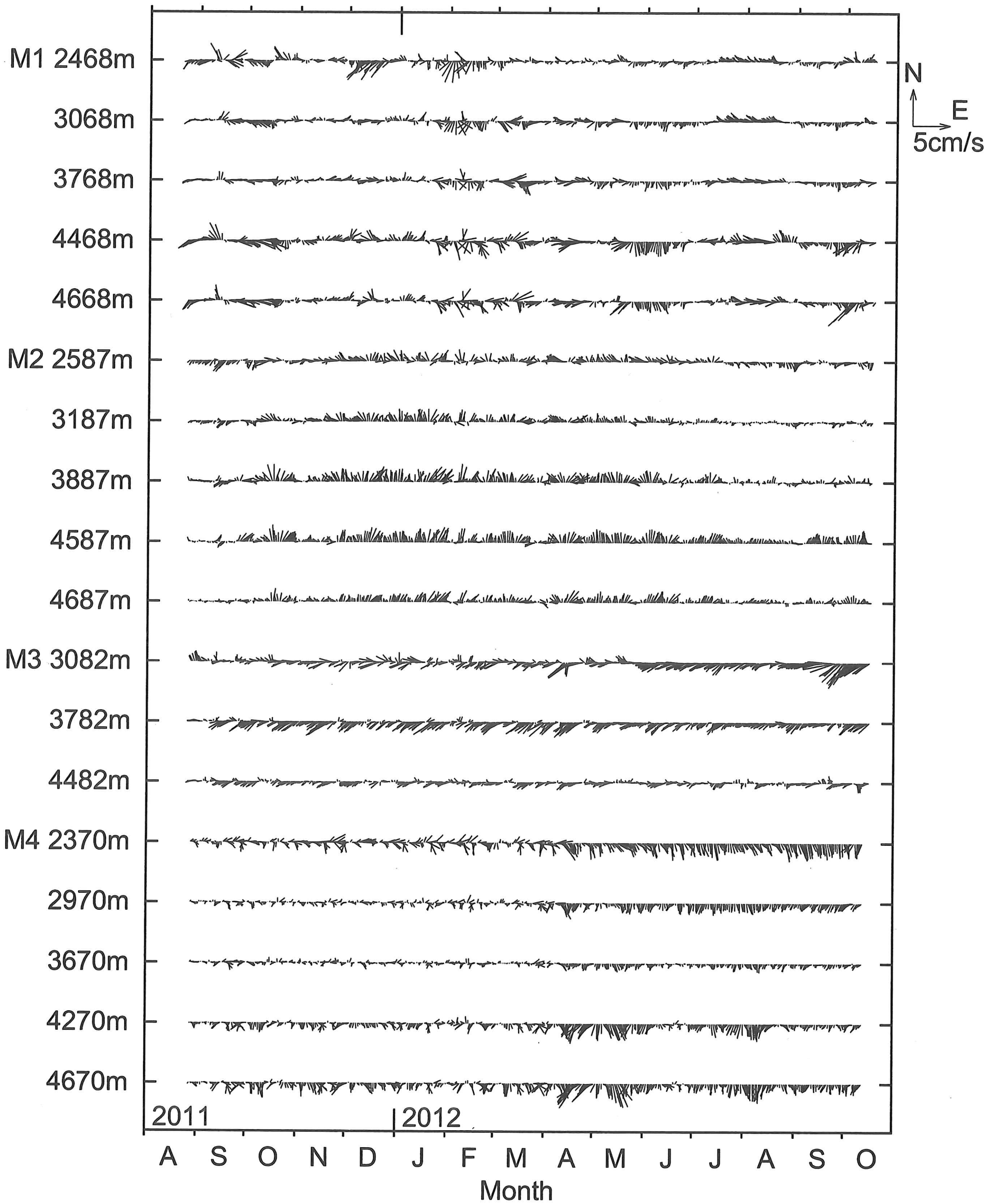


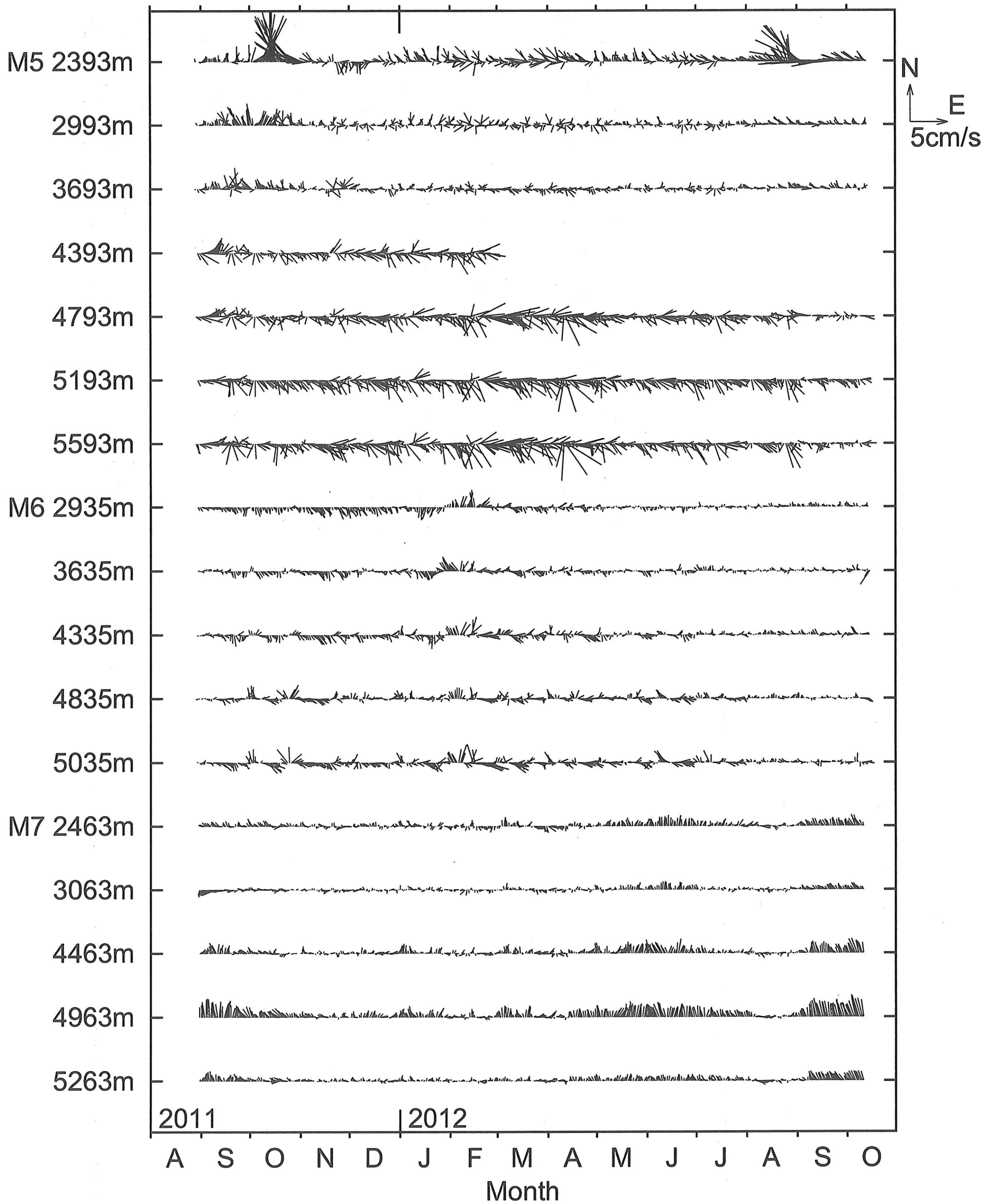
Anchor
29 August 2011, 01:31
38°30.01′N, 144°59.94′W
5085m (PDR)
Catch the top buoy
14 October 2012, 16:45
38°29.93′N, 144°59.92′W
5093m (PDR)



Anchor
30 August 2011, 19:02
36°29.60′N, 145°00.82′W
5313m (PDR)
Catch the top buoy
11 October 2012, 17:47
36°29.45′N, 145°00.85′W
5316m (PDR)

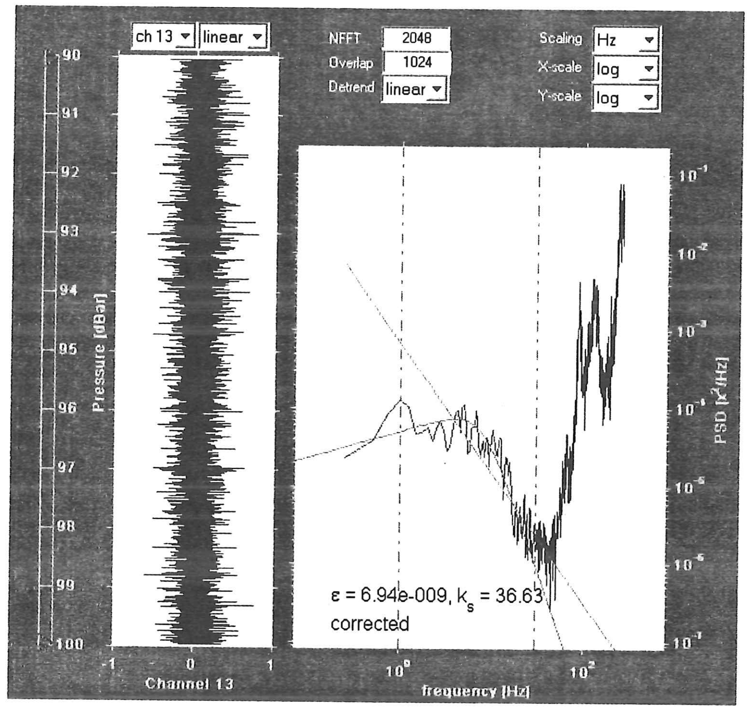
11. Results of Moored Current Meters

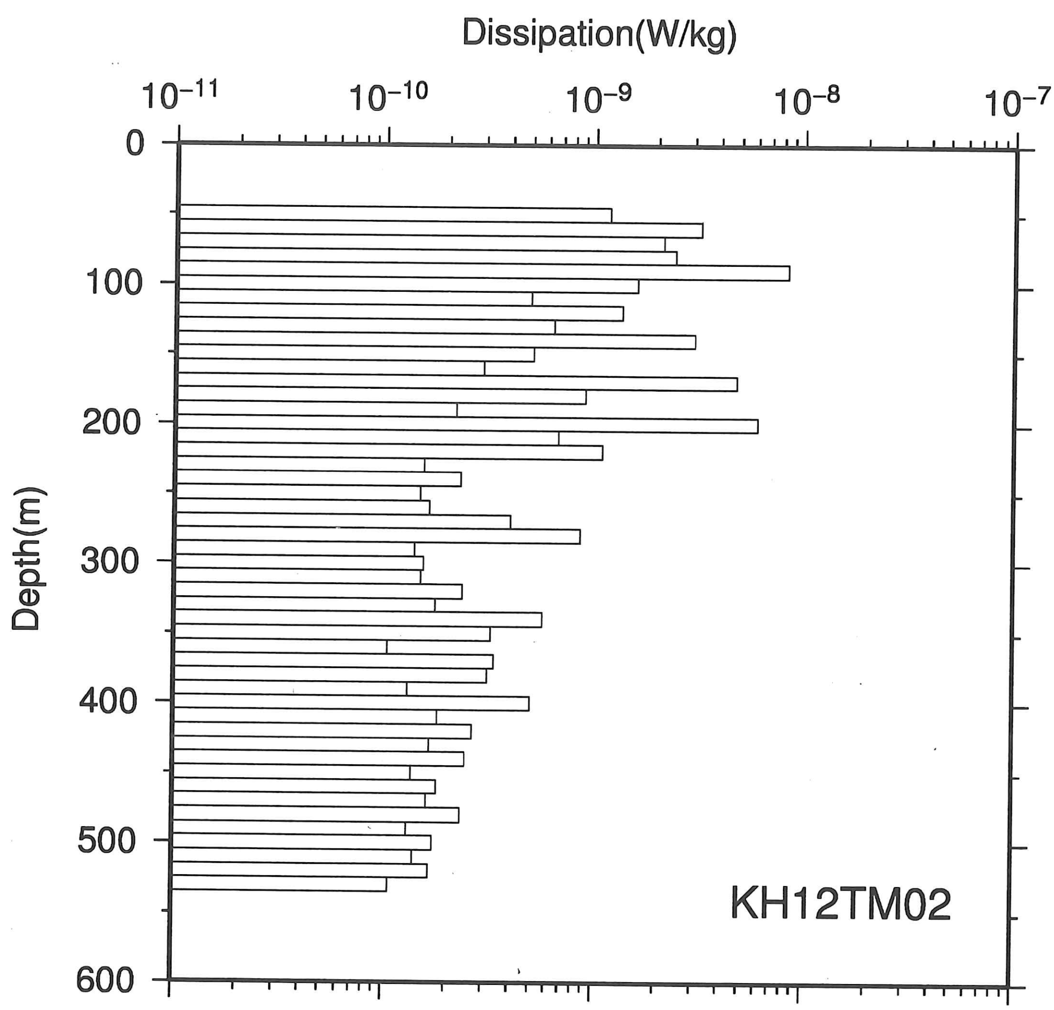



M5 2393m
2993m
3693m
4393m
4793m
5193m
5593m
M6 2935m
3635m
4335m
4835m
5035m
M7 2463m
3063m
4463m
4963m
5263m
N
E
5cm/s
2011
2012
A S O N D J F M A M J J A S O
Month

12. Sample Results of TurboMap Observation

Leg 1 (TM02)





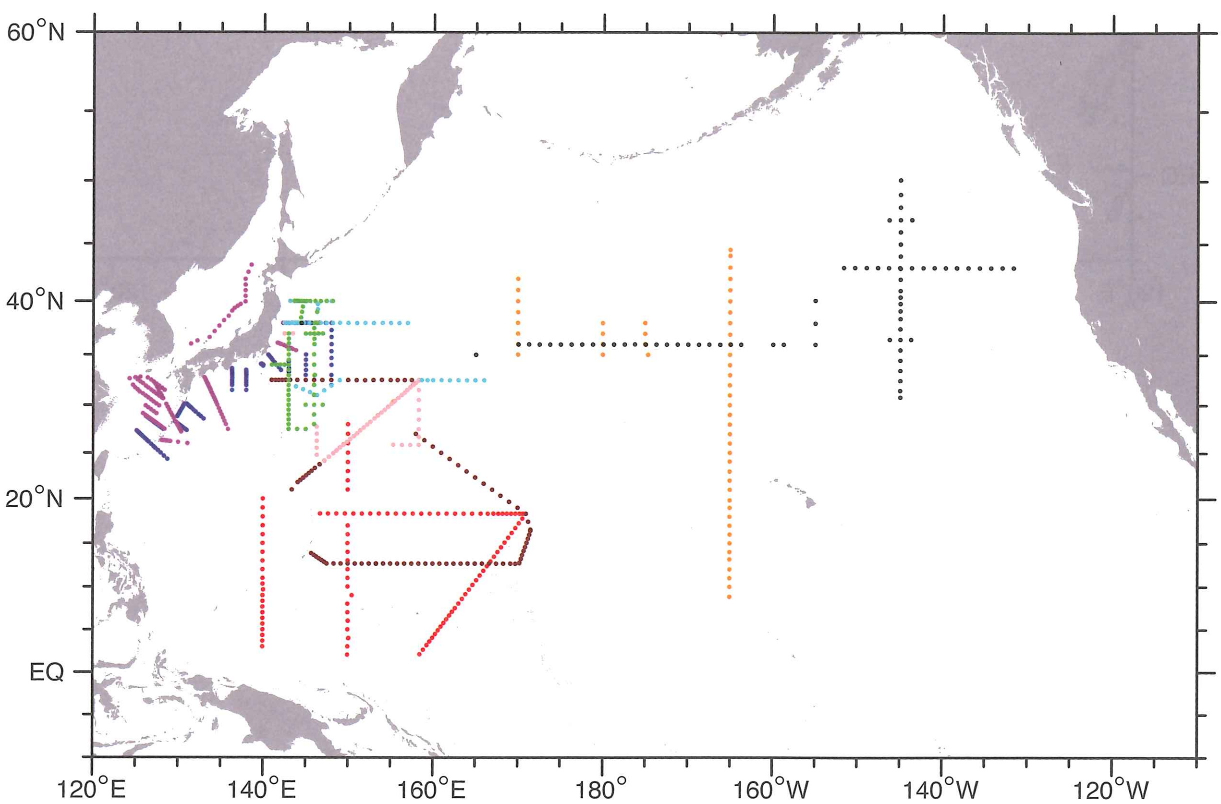
Appendix

Hakuho-Maru cruises directed by late Masaki Kawabe as Chief Scientist

Masaki Kawabe, a professor of Atmosphere and Ocean Research Insitutute, the University of Tokyo, died on January 29, 2012. He led many research cruises of R/V Hakuho Maru as their chief scientist in recent two decases, and the present KH-12-5 cruise was planned by him before his sudden death. The main objective of their cruises was to research the general circulation of the North Pacific. To honor his leadership we compile the observation stations.

CTD stations

KH-96-4, KH-99-1, KH-02-3, KH-03-1 Leg 1&2, KH-04-4,
KH-05-4, KH-07-1 Leg 2, KH-08-3 Leg 1, KH-11-8



Mooring stations