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Cruise Report of NT03-07
(2003.7.5 – 2003.7.18)

JAMSTEC

MIO (Mutsu Institute for Oceanography)
HiLaTS (High Latitude Time Series observatory)

Dec. 2003

1. Outline of NT03-07

1.1 Cruise Summary

Hajime KAWAKAMI (JAMSTEC, Mutsu Institute for Oceanography)

This cruise was manly carried out in order to study the biogeochemistry in northwestern North Pacific by following institutes and universities.

Mutsu Institute for Oceanography (MIO) of Japan Marin Science Technology Center (JAMSTEC)
National Institute for Environmental Science (NIES)
National Institute of Advanced Industrial Science and technology (AIST)
Hokkaido University

R/V Natsushima left Yokosuka on 5 July. Because the weather of northwestern North Pacific was relatively good in early summer, we could advance the observations favorably.

Station KNOT (44N, 155E)

Hydrocast

We deploy water samplers (rossette multiple sampler with CTD sensor) 5 times (Hydrocast). Water samples taken were or will be used for the following chemical analysis.

- the routine chemical analysis (Sal, DO, SiO_2, PO_4, NO_3, NO_2, TDIC, TALK)
- Th-234, POC, PON, Chl. *a* analysis
- simulated *in situ* measurement of Primary production used by C-13

In situ pumping

In order to collect suspended particles in the water column, large volume pumping system (LVP) were used. 2 casts of LVP were practiced and 4 LVP were deployed at once for respective casts. The particulate samples from LVP were will be used for Th-234, POC and PON analysis.

Optical measurements

SeaWiFS Profiling Multichannel Radiometer (SPMR) was deployed in a free fall mode through the water column, so as to investigate the air and underwater light conditions and to determine depths for simulated *in situ* measurement of primary production.

However a flood trouble occurred at sea-cable of the rossette multiple sampler, we could repair during a few hours. Then, all observations we planned previously were successful, only a few hours late.

Station K2 (47N, 160E)

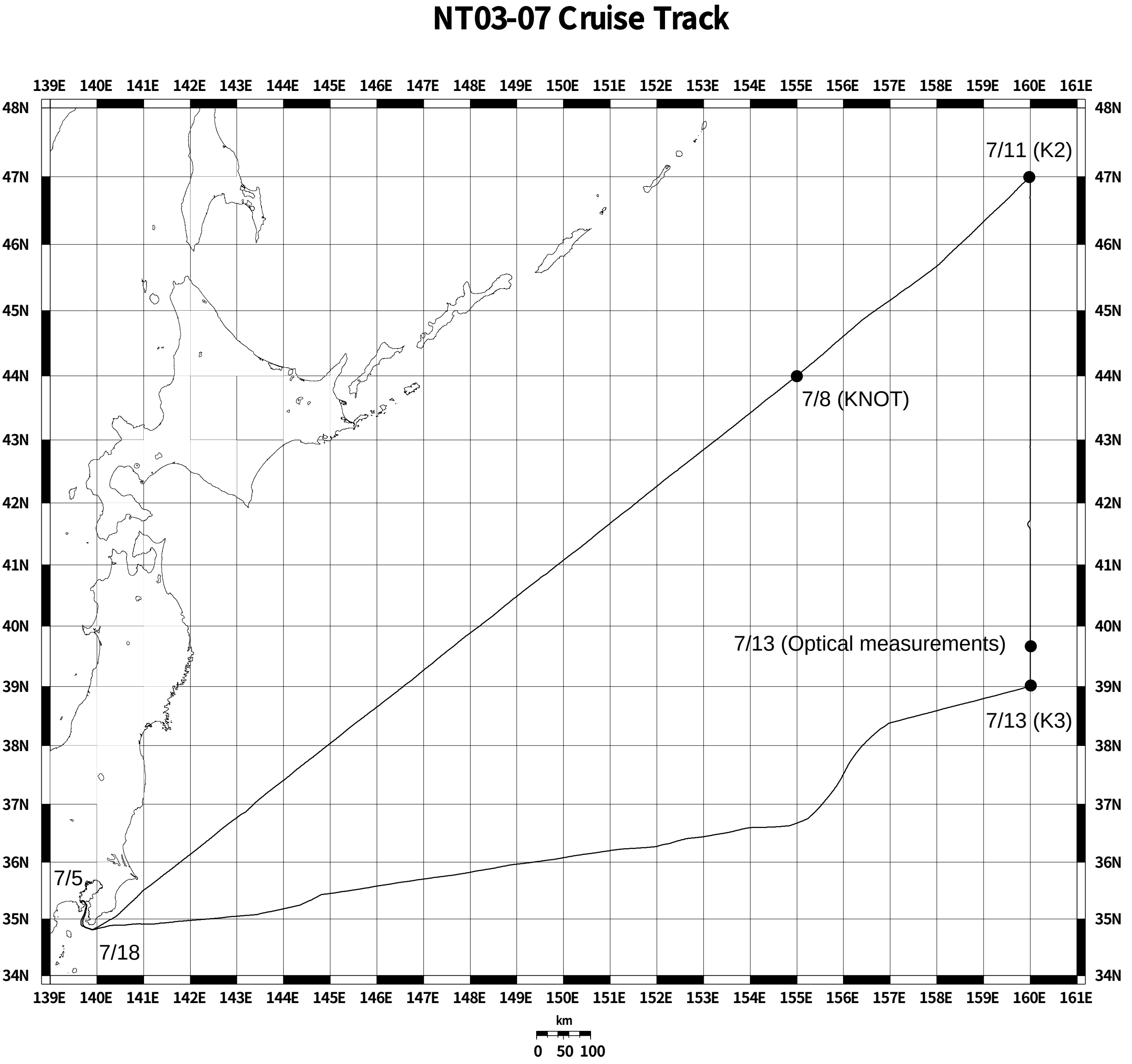
We could do the observations (same contents of St. KNOT) smoothly.

Stforation K3 (39, 160E)

We could also do the observations smoothly similarly to St. K2. But, we were in trouble for the bad weather after the observation of St. K3. Though the water bathes for simulated *in situ* measurement of primary production tumbled over during the incubation, we could recovery most of the samples of primary production.

However this cruise was first experiment of ocean research at R/V Natsushima, this cruise was nearly 100% successful. We would like to thank for the kind supports of the crew of R/V Natsushima and marine technicians of Marine Works Japan. Then, we expect to succeed in the next cruise (November, 2003) of R/V Natsushima.

1.2 Cruise track and schedule



JST		Position		Events
Date	Time	Lat.	Long.	
7.05	11:00	35-19N	139-39E	Departure from Yokosuka
7.08	06:20	44-00N	155-00E	Arrival at St. KNOT
7.08	23:50	44-00N	155-00E	Departure from St. KNOT
7.11	07:00	47-00N	160-00E	Arrival at St. K2
7.11	18:50	47-00N	160-00E	Departure from St. K2
7.13	10:00	39-40N	160-00E	Optical measurements
7.13	14:50	39-00N	160-00E	Arrival at St. K3
7.13	23:50	39-00N	160-00E	Departure from St. K3
7.18	15:30	35-19N	139-39E	Arrival at Yokosuka

1.3 List of Participants

Name	Affiliation	Address	Tel Fax E-mail
Hajime KAWAKAMI	JAMSTEC Mutsu Institute for Oceanography (MIO)		
Hiroaki SAKO	JAMSTEC MIO		
Kazuhiro HAYASHI	JAMSTEC MIO		
Ai YASUDA	Marine Works Japan Ltd. (MWJ)		
Yuichi SONOYAMA	MWJ		

2. Observation

2.1 Water sampling, CTD and salinity

Makio HONDA (Mutsu Institute for Oceanography: MIO)
Hiroaki SAKO (MIO)

(1) Water sampling system

Water sampling system for this cruise consists of a 12-position Rosette water sampler (General Oceanics Rosette model 1016), Falmouth Science Inc. CTD (ICTD-BP-702-SRD) and twelve Niskin Bottles of 12 litters. Water samples from surface to deep ocean (by 3500 m) were collected at three stations: KNOT, K2, and K3. Salinity was calculated with observed pressure, conductivity and temperature. .
Vertical profiles for potential temperature, salinity and sigma-theta in upper 500m are shown in Figure 2.1. It can be seen that subtropical water with high temperature and high salinity invaded into station KNOT. Salinity and water temperature in the surface water were complicated at station K3, which is indicative of that this point is located in the subarctic front. Data of salinity and water temperature at water sampling depth for respective casts is summarized in Appendix. In addition, CTD data obtained each 1 m are available as electric file.

(2) Salinity

Seawater samples were collected with the above system., and water sample for salinity were stored in 125ml brown glass bottles with screw caps. The bottle was stored more than 24 hours in the Autosal Room at JAMSTEC Yokosuka headquarter before starting the salinity measurement. The room temperature was set around 22 deg-C.

The salinity was measured with the laboratory salinometer (Guildline Instruments Ltd., Autosal Model 8400B S/N 60132;.), attached with an Ocean Science International peristaltic-type sample intake pump. A double conductivity ratio was defined as median of 31 readings of the salinometer. Data collection started after 5 seconds and it took about 10 seconds to collect 31 readings by a personal computer. The bath temperature of Autosal was set to 24 deg-C and standardized before and after sequence of measurement by IAPSO Standard Seawater (SSW) batch P141 (conductivity ratio : 0.99993, salinity: 34.997). The average and standard deviation of SSW salinity measured by our system were 34.9975 and 0.0004, respectively. We also used sub-standard seawater (SUB) which was deep-sea water filtered by Millipore filter (pore size of 0.45 µm). We measured SUB salinity every 6 - 10 samples in order to check the drift of Autosal. The average and standard deviation of SUB were 5.1035 and 0.0003, respectively.

The average of the difference between CTD data and data measured by Autosal (n = 28) was 0.017 and the standard deviation was 0.026. The average of difference between these for deep water samples (below 1,000m : n = 5) was 0.010 and the standard deviation was 0.010. It is well know that salinity measured by CTD does not always coincide with salinity measured by Autosal for water samples from the upper ocean because of difference in objective water.. Even taking into account for this point, however, these discrepancy were significantly large compared with that by MIRAI CTD / salinity observation system. (usually less than 0.005). There might be problems in small volume of water sample (125ml instead of 250 ml) and / or calibration of ICTD. Finally, We acknowledge Naoko Takahashi of MWJ for the measurement of salinity.

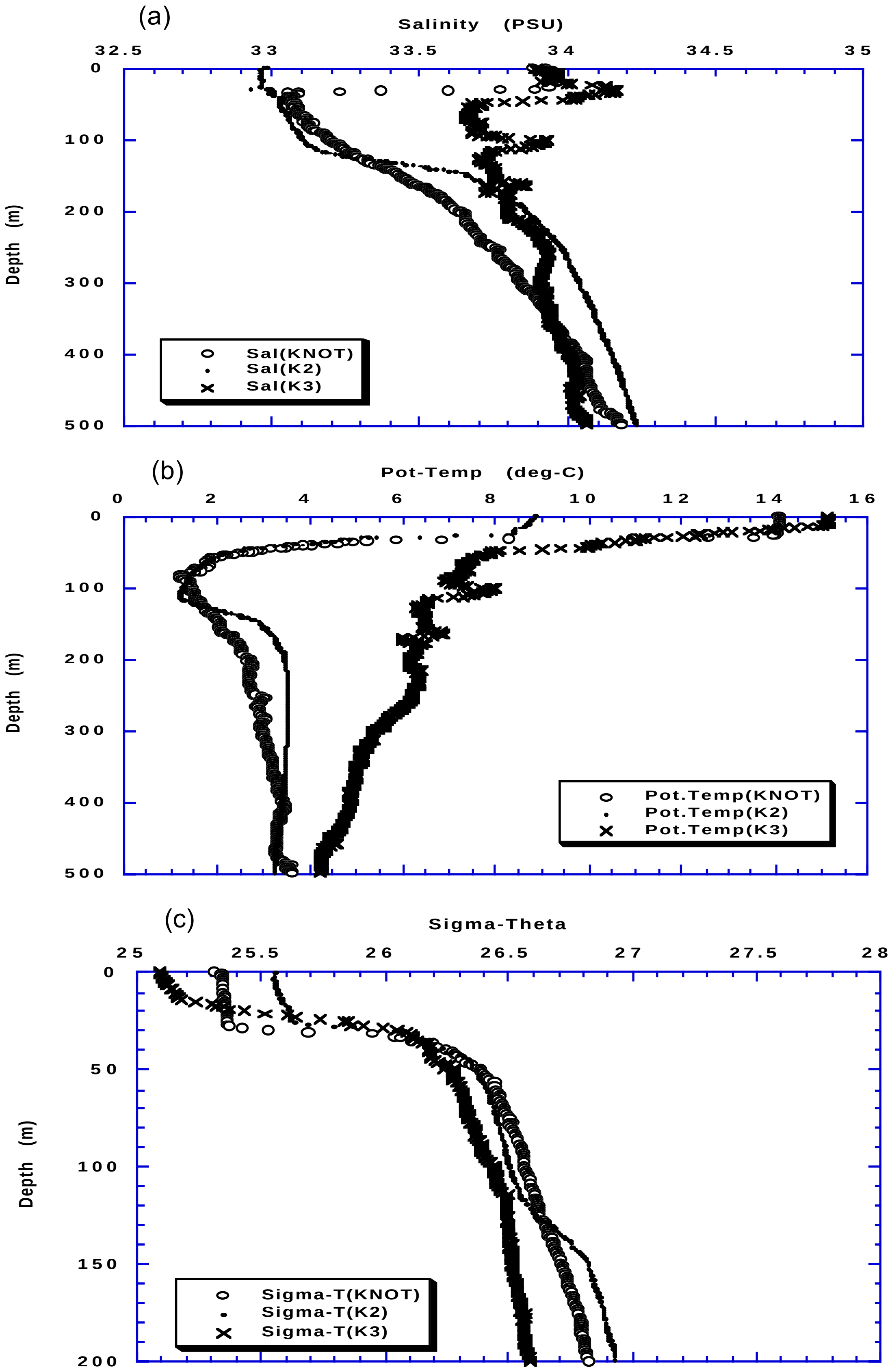


Figure 2.1 Vertical profiles for (a) salinity (b) potential temperature and (c) sigma theta.

2.2 Hydrocast

2.2.1 Dissolved Oxygen

(1) Personnel

Hajime Kawakami (JAMSTEC) Principal Investigator
Yuichi Sonoyama (Marine Works Japan Ltd.)
Ai Yasuda (Marine Works Japan Ltd.)

(2) Objective

Precise determination of dissolved oxygen (below D.O.) using the Winkler titration with potentiometric detection.

(3) Instruments and Apparatus

Titrator:

Metrohm Model 716 DMS Titrino, capable of titrating $Na_2S_2O_3$ solution for 0.001 ml.
Metrohm Pt Electrode 6.0401.100

Software:

Data acquisition/ Metrohm, Tinet 2.4

Sample flasks:

BOD flasks of 180ml nominal capacity with glass stoppers.

OPTIFIX:

Capable of dispensing 1ml pickling reagents.

Dispensers:

Metrohm Model 765 Multi Dosimat, capable of dispensing standard KIO_3 solution.

Eppendorf:

Capable of dispensing 1ml 5M H_2SO_4 and standard KIO_3 solution.

(4) Methods

Sampling and analytical methods were based on the WHP Operations and Methods (Culberson, 1991, Dickson, 1994).

(a) Sampling

Seawater were sampled from 12 litters Niskin bottles to the calibrated dry glass bottles at the stations whose name was KNOT, K2 and K3. At each stations, we had two casts that was “Deep” and “Shallow”. Deep cast was from 3600m to 200m, and shallow cast was from 200m to surface. Thus we collected seawater samples from 3600m to surface for 25 layers. During each sampling, 3 bottle volumes of seawater were overflowed to minimize contamination with atmospheric oxygen. After the sampling, $MnCl_2$ (aq.) 1ml and NaOH / NaI (aq.) 1ml were added into the glass bottle, and then shook well. After the precipitation was setteled, we shook the bottle vigorously to disperse the precipitation.

(b) Analytical methods

The samples were analyzed by 1 sets of Metrohm titrator with 10 ml piston burette and Pt electrode. Titration values was determined by the potentiometeric methods, and the endpoint for titration was evaluated by the software of Metrohm, Tinet 2.4. From the titration values, we calculated concentration of dissolved oxygen by WHP Operations and Methods (Culberson, 1991, Dickson, 1994).

(5) Result

(a) Precision of Winkler titration data

We took 14 duplicate samples for Winkler titration method in this cruise. The standard deviation of anlytical values was 0.35 µmol/kg-sw (Table 3.2.2) , and was satisfied WOCE precision (below 0.5µmol/kg-sw).

(b) Vertical profiles

The vertical profiles of dissolved oxygen were shown in Fig. 3.2.2.

(6) References

Culberson, C.H. (1991) Dissolved Oxygen, in WHP Operations and Methods, Woods Hole., pp1-15.

Culberson, C.H., G.Knapp, R.T.Williams and F.Zemlyak (1991) A comparison of methods for the determination of dissolved oxygen in seawater. (WHPO 91-2)

Dickson, A.G. (1994) Determination of dissolved oxygen in seawater by Winkler titration, in WHP Operations and Methods, Woods Hole., pp1-14.

Murray, N., J.P.Riley and T.R.S. Wilson (1968) The solubility of oxygen in Winkler regents used for the determination of dissolved oxygen, Deep-Sea Res.,15, 237-238.

Table 2.2.2 The standard deviations of the duplicate samples at each stations.

Station	Cast	Niskin Bottle	Pressure (dB)	Sample 1 (μmol/kg-sw)	Sample 2 (μmol/kg-sw)	Difference (μmol/kg-sw)
KNOT	1	1	201.6	161.36	160.54	0.82
	1	8	50.3	349.79	349.95	0.16
	1	12	10.0	274.89	275.14	0.25
	2	1	3556.9	146.26	146.00	0.26
K2	1	1	201.0	53.31	53.94	0.63
	1	8	49.1	345.27	345.06	0.21
	1	12	9.7	309.66	309.74	0.08
	2	1	3557.7	149.46	148.81	0.66
	2	8	607.4	16.37	16.12	0.25
K3	1	1	202.1	284.40	284.73	0.33
	1	8	51.3	281.64	281.17	0.47
	1	12	10.9	280.26	280.57	0.31
	2	1	3556.9	146.55	145.45	1.10
	2	8	605.5	49.83	49.81	0.02
					Stdev	0.35

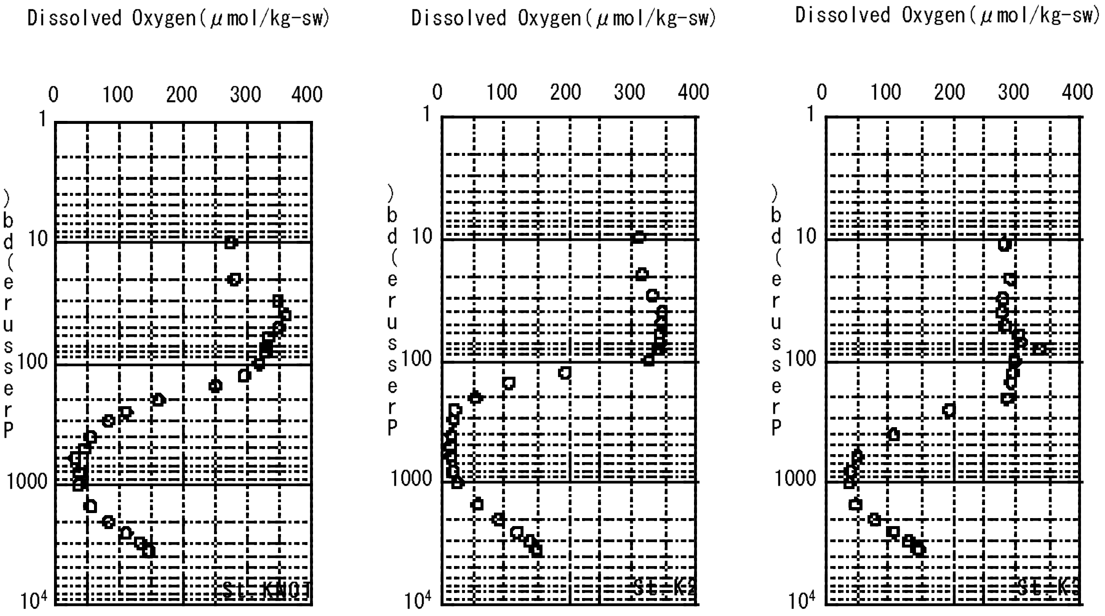


Figure 2.2.2 Vertical profiles of dissolved oxygen at each stations.

2.2.2 Nutrients

Yukihiro NOJIRI (National Institute for Environmental Science)
Kazuhiro HAYASHI (JAMSTEC MIO)
Mario HONDA (JAMSTEC MIO)

a. Sampling Procedures

Samples were drawn into polypropylene 100 ml small mouth bottles. These were rinsed twice before filling. The samples were quickly stored in a freezer under - 20 °C and kept by the day the nutrients analyses were conducted on land.

b. Instruments and Methods

The nutrients analyses were performed on BRAN+LUEBBE continuous flow analytical system Model TRAACS 800 (4 channels). The laboratory temperature was maintained between 20-25 deg C.

Nitrite: The nitrite is determined by diazitizing with sulfanilamide and coupling with N-1-naphthyl-ethylenediamine (NED) to form a colored azo dye which is measured at 550 nm using 5 cm length cell.

Nitrate: Nitrate in seawater is reduced to nitrite, which is determined by the method described above. Nitrite initially present in the sample is corrected.

Silicate: The standard AAII molybdate-ascorbic acid method was used. Tempreture of the sample was maintained at 45-50 deg C using a water bath to reduce the reproducibility problems encountered when the samples were analyzing at different temperatures. The silicomolybdate produced is measured spectrophotometrically at 630 nm using a 3 cm length cell.

Phosphate: The method by Murphy and Riley (1962) was used with separate additions of ascorbic acid and mixed molybdate-sulfuric acid-tartrate. Tempreture of the samples were adjusted to be 45-50 deg C using a water bath. The phospho-molybdate produced is measured at 880 nm using a 5 cm length cell.

Preliminary results

a. Precision of the analysis

We have made the repeat analysis of two layers' (about 100 m and 500 m depths) samples at each station. At those repeat analysis range of CV (concentration average to standard deviation) were 0.03 to 2.6 % in upper layer and 0.07 to 1.9 % in bottom layer except nitrite.

b. Distribution of nutrients

The results are shown in Appendix.

2.2.3 TCO2 and Alkalinity

Nubuo TSURUSHIMA
Kazuhiro HAYASHI
Mario HONDA

Sampling

We collected samples for on board measurements of total carbon dioxide (TC) and total alkalinity (TA). Water samples were collected with CTD rosette systems attached with Niskin bottles of 12 1 capacity. Sample waters for TC/TA were drawn from Niskin samplers into 250 (200 ?) ml glass bottles with plastic screw cap (Schott Duran). Sequentially, mercuric chloride solution (3 mg-$HgCl_2$ / 100 g-H_2O) of 0.05 cm^3 was added as preservative. Samples collected on board were kept in refrigerator by the day the analysis was conducted

Analysis

TC and TA in seawater were determined by the methods similar to DOE (1994) with new automatic measurement system (KIMOTO ELECTRIC Co., LTD.). This system contain two devices, device for extraction of carbon dioxide and a device for determination of TA by titration, each in a 50x60x40cm console. This system is coupled to a CO_2 coulometric detector (model 5012, supplied by UIC Coulometrics Inc.), an Autoburette (ABU901, supplied by RADIOMETER Co., LTD.), two cooling units to maintain the sample water at constant temperature, and a personal computer. All procedures except exchange of the samples and rinsing of TA titration cell are operated automatically. Sample water for TC analyses were controlled at constant temperature (10°C). A known volume (about 30 ml) of seawater sample is dispensed into the stripping chamber and acidified with 8.5% reagent grade phosphoric acid, converting all carbonate species to free CO_2. The evolved CO_2 is then extracted from seawater using ultra high purity nitrogen gas (99.9995%) for 10 minutes at a rate of 200 ml/min. The CO_2 gas is absorbed by a coulometer cell solution, containing ethanolamine, dimethylsulfoxide and thymolphthalein indicator, and quantified by coulometric titration. Seawater based reference materials were prepared by Hokkaido University used for calibration. The precision was 0.1%, which was obtaned from 10 replicate determinations on board the ship once a day. TA was determined by potentiometric titration. Sample water for determination of TA was controlled at constant temperature (20°C). A known volume (about 100 ml) of seawater sample is dispensed into closed titration cell containing two glass electrodes, a thermometer and a capillary tube that supplies acid from a burette. Sample seawater was titrated with 0.2 N hydrochloric acid past the carbonic acid endpoint. TA was calculated from titration data by the non-linear least-squares approach (DOE, 1994). The precision was 0.1%, which was obtained from 10 replicate determinations on board the ship once a day.

Results

The results of TC are shown in Appendix. The results of TA will be determined as soon as possible after this cruise.

Reference

DOE (1994): Handbook of methods for the analysis of the various parameters of the carbon dioxide system in seawater; version 2.0, A. G. Dickson and C. Goyet, editors, U. S. Department of Energy CO_2 Science Team Report.

2.2.4 Primary productivity

Ai YASUDA (Marine Works Japan LTD)
Hiroaki SAKO (Japan Marine Science and Technology Center MIO)
Makio HONDA (Japan Marine Science and Technology Center MIO)

Uptake rates of ^{13}C and ^{15}N (primary productivity) were measured by simulated *in-situ* incubation.

(1) Simulated in-situ incubation

We took three samples from the surface and other five depths at all stations. Water samples were collected by using a bucket for surface and CTD / RMS system for five pre-defined depths, which had 100%, 36%, 22.5% 7.2% 4.5% and 2% light intensity relative to the surface light irradiance: PAR) based on the optical profiles (see section “optical measurements”). On deck, sea water samples of 1 liter were sieved through Norpac filter with pore size of 200 mm to remove large-sized zooplankton and transferred into Nalgen polycarbonate bottles with screw caps.

As a chemical tracer (spike), 1 ml NaH^{13}CO$_3$ solution (0.202 mmol-C/ml: 17 g NaH^{13}CO$_3$ in 100 ml in buffered water) and 1 ml K^{15}NO$_3$ solution (0.1 mmol-N/ml) were spiked to two of three samples from each layer. Another one samples was not spiked for blank test. Sequentially, all bottles were put into light shield nets and placed into deck incubators with light shield filter adjusting to the light levels at respective depths. Although water temperatures for respective incubators were tried to be adjusted to those at respective water depth, water temperature was, unfortunately, not under control and most of those were approximately 3 – 4 ℃, while *in-situ* water temperature is often higher than 10℃ (see Table1). Samples were incubated for 24hours except station K3 (suspension after 19 hours). At the incubation, samples were filtered through glass fiber filters (Wattman GF/F 25mm o.d.) pre-combusted with temperature of 450 ℃ for at least 6 hours and the filters were frozen immediately until laboratory analysis are carried out on land.

(2) 13C and 15N Analysis

As result of 15N analysis is still under consideration, preliminary result of 13C analysis are reported here

1) 13C

On land, ^{13}C of samples were measured by using a mass spectrometer ANCA-SL system.
Before analysis, inorganic carbon of samples was removed by an acid treatment in a HCl vapor bath for 4-5 h. Table * shows total particulate organic carbon (POC) and concentrations of ^{13}C of POC for respective samples.

Based on the balance of ^{13}C, assimilated organic carbon (ΔPOC) is expressed as follows (Hama *et al.*, 1983):

$$^{13}C_{(POC)} * POC = {}^{13}C_{(sw)} * \Delta POC + (POC - \Delta POC) * {}^{13}C_{(0)}$$

This equation is converted to the following equation;

$$\Delta POC = POC * ({}^{13}C_{(POC)} - {}^{13}C_{(0)}) / ({}^{13}C_{(sw)} - {}^{13}C_{(0)})$$

where $^{13}C_{(POC)}$ is concentration of ^{13}C of particulate organic carbon after incubation, *i.e.*, measured value (%).

$^{13}C_{(0)}$ is that of particulate organic carbon before incubation, *i.e.*, that for sample as a blank.

$^{13}C_{(sw)}$ is concentration of ^{13}C of ambient seawater with a tracer. This value for this study was determined to be 10.17 % based on the following calculation;

$$^{13}C_{(sw)}\ (\%) = [(0.002 * 0.011) + 0.000202] / (0.002 + 0.000202) * 100$$

where 0.002 is assumed concentration of total dissolved inorganic carbon (TDIC: mol l^{-1}) and 0.011 is concentration of ^{13}C of natural seawater (1.1 %). 0.000202 is added ^{13}C (mol) as a tracer.

Taking into account for the discrimination factor between ^{13}C and ^{12}C (1.025), primary productivity (PP) was, finally, estimated by

$$PP = 1.025 * \Delta POC$$

Table 1 also shows estimated primary productivity. The precision (repeatability) for the deepest sample (n = 3) ranged from 2 % to 5 % and, however, the average of that for other samples (n = 14) was 0.7 %. Fig. 1 shows the vertical profile of primary productivity for respective stations. Unlike we expected, the maximum of primary productivity did not appear at surface. Instead of that, peaks of primary productivity were observed at approximately 15 m and 30 m.

On the other hand, primary productivity in the euphotic layer (> 1 % light level: upper 48 m) were integrated assuming that primary productivity at 48 m is 0 mg m^{-3} day^{-1} (Table 1). Integrated primary productivity were estimated to be approximately 270 mg m^{-3} day^{-1} for station KNOT, 365 mg m^{-3} day^{-1} for station K2, and 230 mg m^{-3} day^{-1} for station K3. Primary productivity at station KNOT was previously observed and that in summer ranged from approximately 150 to 280 (average: 227) mg m^{-3} day^{-1} (Imai *et al.*, 2002). Result in this observation was comparable to that.

However simulated *in-situ* incubation methods during this cruise had problem in the light and water temperature control. Especially there is much possibility that the light for surface sample was partly shielded. The peak appeared at approximately 30 m might be artifact because of the above problem. Water temperatures for respective incubators were much lower than *in-situ* water temperature. Therefore primary productivity observed during this cruise might be underestimated. More precise experiment is requested in future.

References

Allen *et al.* (1996): New production and photosynthetic rates within and outside a cyclonic mesoscale eddy in the North Pacific subtropical gyre. Deep-Sea Research I 43, 917-936.

Hama *et al.* (1983): Measurement of photosynthetic production of a marine phytoplankton population using a stable ^{13}C isotope. Marine Biology 73, 31-36.

Imai *et al.* (2002): Time series of seasonal variation of primary productivity at station KNOT (44°N, 155°E) in the sub-arctic western North Pacific. Deep-Sea Research 49, 5395-5408.

Table 2.2.5 Results of ^{13}C

light level	Depth(m)	in-situ Temp(°C)	incubator Temp(°C)	POC (µg l^{-1})	$^{13}C_{(POC)}$ (%)	PP (µg l^{-1} day^{-1})	Integrated PP (mg m^{-2} day^{-1})	(0 - 48 m) (mg m^{-2} day^{-1})
KNOT #1	Blank ^{13}C: 1.084							
2.0%	40	4.340	3	125.74	1.495	5.83	23.34	266.36
4.5%	31	5.652	4	396.08	1.363	12.45	82.27	
7.2%	26	14.012	3	139.20	1.310	3.56	40.01	
22.5%	14	14.066	4	151.02	1.429	5.88	56.64	
36.0%	8	14.087	3	147.22	1.392	5.11	32.98	
100.0%	0		3	166.85	1.226	2.68	31.14	
KNOT #2	Blank ^{13}C: 1.084							
2.0%	40	4.340	3	110.71	1.480	4.95	19.80	269.25
4.5%	31	5.652	4	140.33	1.902	12.95	80.54	
7.2%	26	14.012	3	138.40	1.321	3.70	41.62	
22.5%	14	14.066	4	157.62	1.425	6.07	58.61	
36.0%	8	14.087	3	144.74	1.424	5.56	34.88	
100.0%	0		3	159.26	1.245	2.89	33.80	
K2 #1	Blank ^{13}C: 1.084							
2.0%	39	4.314	3	85.76	1.905	7.94	35.74	380.54
4.5%	31	5.812	4	105.85	2.356	15.20	92.55	
7.2%	26	7.265	3	120.42	1.482	5.41	51.51	
22.5%	13	8.459	4	135.37	1.647	8.60	91.06	
36.0%	8	8.710	3	144.98	1.724	10.46	47.65	
100.0%	0	9.037	3	168.49	1.349	5.04	62.02	
K2 #2	Blank ^{13}C: 1.084							
2.0%	39	4.314	3	84.49	1.676	5.64	25.39	352.92
4.5%	31	5.812	4	127.97	2.090	14.52	80.65	
7.2%	26	7.265	3	124.31	1.439	4.97	48.73	
22.5%	13	8.459	4	125.10	1.679	8.39	86.86	
36.0%	8	8.710	3	153.35	1.709	10.80	47.99	
100.0%	0	9.037	3	166.59	1.351	5.02	63.30	
K3 #1	Blank ^{13}C: 1.087							
2.0%	41	9.495	3	71.15	1.336	2.00	7.00	227.71
4.5%	32	10.675	3	82.49	1.952	8.05	45.23	(19 hr. incubation)
7.2%	26	12.215	3	110.77	1.293	2.58	31.89	(without 0 -8m)
22.5%	13	15.146	3	170.48	1.541	8.74	73.58	
36.0%	8	15.158	3	189.90	1.382	6.33	37.67	
100.0%	0		3	174.83	1.176	1.76	32.35	
K3 #2	Blank ^{13}C: 1.087							
2.0%	41	9.495	3	61.43	1.522	3.02	10.55	214.27
4.5%	32	10.675	3	109.57	1.718	7.80	48.65	(19 hr. incubation)
7.2%	26	12.215	3	108.30	1.365	3.40	33.60	(without 0 -8m)
22.5%	13	15.146	3	174.06	1.551	9.11	81.31	
36.0%	8	15.158	3	192.04	1.408	6.95	40.15	

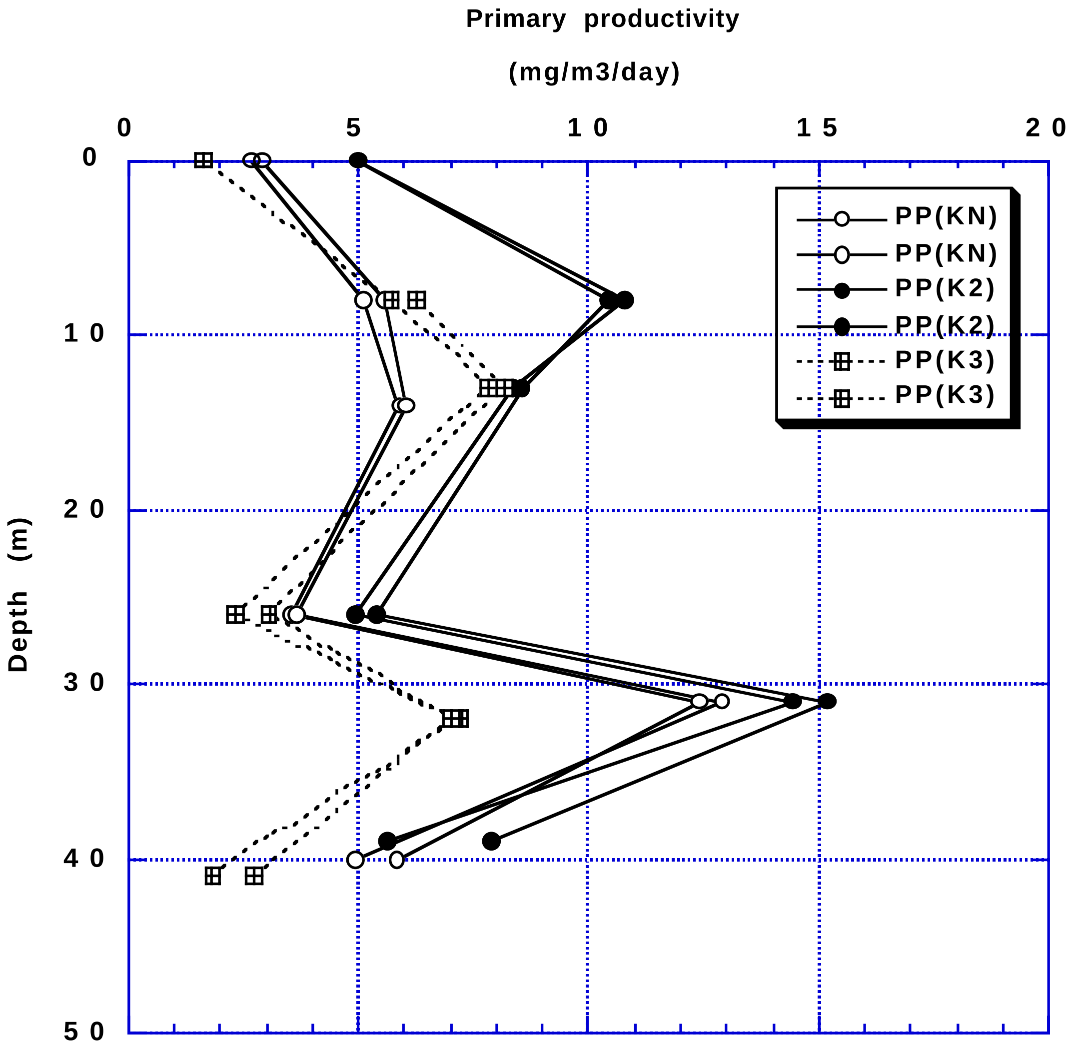


Figure 2.2.5 Vertical profile of primary

2.2.5 Chlorophyll *a*

Hajime KAWAKAMI (JAMSTEC, Mutsu Institute for Oceanography)

(1) Sampling location

Seawater samples are collected from Station KNOT, K2 and K3 in this cruise used 12 L Niskin sampling bottles with CTD-RMS. (Th-234 cast)

(2) Experimental procedure

The concentration of chlorophyll *a* in seawater samples is measured by fluorometric determination. The method used here utilizes the Turner fluorometer as suggested by Parsons et al. (1984).

Seawater samples (500 ml) are filtered through a glass fiber filter at 1/2 atmospheric pressure. Filters are used Whatman GF/F glass fiber filters (25 mm diameter).

The filters are extracted by 7 ml of *N, N'* -dimethylformamide between overnight in a dark and cold (-20 ℃) place.

The extracts of the samples are measured the fluorescence by Turner fluorometer (10-AU-005, TURNER DESIGNS) with a 340-500 nm bound excitation filter and a >665 nm bound emission filer, before and after acidification. The acidification is carried out with 2 drops of 1 N HCl and the second measurement made 1 minutes after the acidification.

The amount of chlorophyll *a* is calculated from the following equation;

$$\mu\text{g chlorophyll } a \text{ / L} = (fo - fa) / (F_{Ch} - F_{ph}) \quad * \; v/V$$

where fo and fa are the fluorescence before and after the acidification, respectively, F_{Ch} and F_{ph} are the fluorescent factor of chlorophyll *a* and phaeophytine *a*, respectively, v is the volume of *N, N'* -dimethylformamide extract, and V is the volume of seawater.

The method is calibrated against a known concentration of chlorophyll *a* as determined by the spectrophotometric method (Porra et al., 1989).

A precision based on replicate measurements is usually less than 5%.

(3) Preliminary result

The preliminary results were shown in Table 2.2.6 and Figures 2.2.6

(4) References

Parsons Timothy R, Yoshiaki Maita and Carol M Lalli. 1984. "A manual of chemical and biological methods for seawater analysis" (Pergamon Press), pp. 101-112.

Porra R. J., W. A. Thompson and P. E. Kriedemann. 1989. Biochim. Biophys. Acta, 975, 384-394.

Table 2.2.6 The concentrations of Chlorophyll *a* ($\mu g\ l^{-1}$) at NT03-07.

Depth (m)	St. KNOT	St. K2	St. K3
0	0.495	0.472	0.553
10	0.616	-	0.739
20	0.543	0.737	0.817
40	0.651	0.849	0.433
60	0.783	0.445	0.322
80	0.078	0.134	0.258
100	0.057	0.055	0.073
150	0.018	0.020	0.019
200	0.025	0.016	0.012

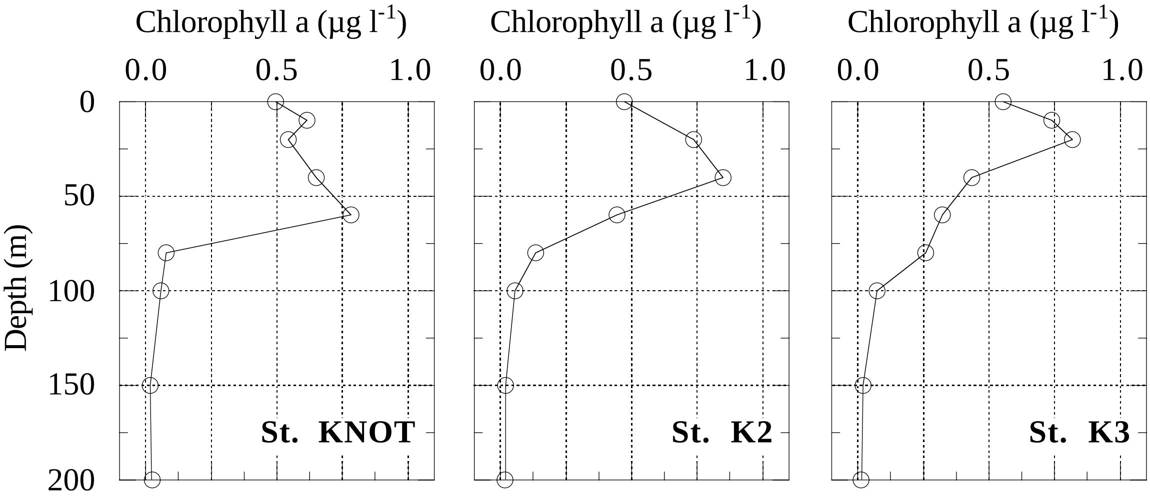


Figure 2.2.6 The vertical distributions of Chlorophyll *a* at NT03-07.

2.2.6 Th-234 and export flux

Hajime KAWAKAMI (JAMSTEC, Mutsu Institute for Oceanography)

(1) Purpose of the study

The fluxes of POC were estimated from Particle-reactive radionuclide (^{234}Th) and their relationship with POC in the northwestern North Pacific Ocean.

(2) Sampling

Seawater sampling for ^{234}Th and POC: 3 stations (St. KNOT, K2, and K3) and 8 depths (10m, 20m, 40m, 60m, 80m, 100m, 150m and 200m) at each station.

Seawater samples (20–30 L) were taken from Hydrocast at each depth. The seawater samples were filtered with 47mm GF/F filter on board immediately after water sampling.

In situ filtering samples were taken from large volume pump sampler (LVP) at same depths as Hydrocast. The filter samples (150mm GF/F filter) were divided for ^{234}Th, POC and PON.

(3) Chemical analyses

Dissolved ^{234}Th was separated using anion exchange method on board; all Hydrocast samples. Particulate ^{234}Th from LVP samples were separated in land-based laboratory. Separated samples of ^{234}Th were absorbed on 25mm stainless steel disks electrically, and were measured by β-ray counter.

The determinations of POC and PON were used CHN analyzer in land-based laboratory.

(4) Preliminary result

The distributions of dissolved and particulate ^{234}Th will be determined as soon as possible after this cruise. This work will help further understanding of particle dynamics at the euphotic layer.

2.3 Surface underway observations

2.3.1 Continuous pCO_2 measurement

Yukihiro NOJIRI (National Institute for Environmental Science)
Kazuhiro HAYASHI (JAMSTEC MIO)
Mario HONDA (JAMSTEC MIO)

Introduction

The surface seawater pCO_2 is controlled by the percentage of gaseous carbon dioxide concentration to its solubility in seawater. The four major controlling mechanisms of oceanic pCO_2 are SST (surface seawater temperature), biological activities (photosynthesis and decomposition of organic matter), vertical mixing and gas exchange. The NT03-07 cruise included the subarctic north Pacific with intensive cooling and vertical mixing of surface seawater.

Because the oceanic pCO_2 varies with time and space, the response time of the underway measurement on board a ship should be as short as possible. The popular types of pCO_2 systems are using showerhead type equilibrator. Because it usually has large ratio of air to water in the equilibrator, the system needs circulating pass to achieve the gas-water equilibrium to have enough contact with gas and seawater. This usually makes the response time of the pCO_2 measurement in the order of hour. The oceanic pCO_2 sometime changes very sharply with the rapid change of SST at frontal regions. Sharp spatial change is also observed in the spring bloom season, when the patch of highest productivity is commonly observed in the subarctic and coastal regions.

In this cruise, we used the continuous flow type of equilibrator, which facilitate the rapid response measurement of pCO_2.

Method

The surface seawater taken from the sea chest of R/V Natsushima was supplied to an air-liquid equilibrator having Tandem design, which is a combination of bubbling and mixer equilibrators. Seawater is supplied from the inlet locating the top of the equilibrator and run down. As the inlet diameter is 20 mm, it is never clogged by plankton and nekton. Cylinder air having natural CO_2 concentration is supplied from the bottom of the bubbling equilibrator at 350 ml/min flow rate and ascends in the cylindrical tube. The air is equilibrated to the CO_2 concentration in seawater at the overflow surface of the cylindrical tube. Because of the surface tension in the bubbling air makes the inside pressure of air bubble increase, the resulted pCO_2 of the bubble has slightly lower pCO_2 than the true seawater pCO_2 which is estimated about 0.8% of the total pCO_2 in seawater. The supplied air then passes through the mixer equilibrator with a splasher inside. The air is accurately equilibrated by the second equilibrator and then flows out from the equilibrator. 200 ml/min of the air overflows at a separator, and 150 ml/min of the air is aspirated to a CO_2 measurement system with NDIR.

The NDIR is calibrated with 4 working standard gases have already been critically calibrated against NIES-95 standard gas scale. The calibration was dons at 0 and 12 of GMT. The calibration takes 40 minutes and atmospheric CO_2 was measured after each calibration for 10 minutes. The NDIR output signal was logged with 10 seconds interval for standard gases and with 1minute interval for atmosphere and seawater measurement. Then, we had 2 series of 670 minutes (11 hour and 10 minutes) of continuous pCO_2 measurement of 1 minutes date logging in a day.

The NDIR mV output are corrected with pressure effect with pressure gage at the outlet of NDIR cell and then calibrated by the standard gas readings.

Result

After leaving the last station, K3, and on the way back to Yokosuka, sea condition became worse and the sea chest was outcropped in the air. Therefore the continuous pCO2 measurement could not but be suspended. Except this period, temporal and spatial variability in surface pCO2 was successfully observed continuously.

2.3.2 Underway sampling for Particulate matter

Kazuhiro HAYASHI (Mutsu Inst. for Oceanography, JAMSTEC)

Objectives

Understanding the seasonal variation of the trace metals in the particle matter at the ocean surface is important for study of export fluxes by them. The contents of trace elements in particulate matter differ by dominant phytoplankton communities. The objectives of this investigation are to understand the seasonal variation relationship between chemical tracers and primary production at the northwestern Pacific, and obtain more knowledge of characteristics of the particulate matter and phytoplankton communities in this area.

Sampling

Underway samples were collected by continuous seawater pump on R/V Natushima. Underway seawater was passed through temperature and salinity sensor (Themosalinograph model 316SM), and introduced to stainless steel filter holder (SUS 316) for 142mm filters. Particulate matter was collected by Nuclepore (0.4µm), Versopor (0.8µm), Millipore-HA (0.45µm) and GF/F filtes, respectively (Table 2.3.2-1). Filtered volume was counted by flowmeter. After filtrated, each filter was rinsed 3 times by milli-Q water. Nuclepore, Versopor and Millipore HA filters were moved to acid clean centrifuge tubes, which were stored in the refrigerator. GF/F filter was wrapped by organic free aluminum foil, and stored in the freezer.

Seawater samples were collected in 280 ml after filtration, and were acidified in pH ~2 by adding 8M-HNO_3. After acidification, samples were stocked in plastic bag and stored in the refrigerator. Table 2.3.2-2 showed sampling list of surface seawater, and Figure 2.3.2 illustrated distribution of temperature and salinity.

Analytical method

Nuclepore, Versopor and Millipore HA filters are cut in half size by plastic cutter in the clean food, one is digested by using microwave digestion system (Ethoth: Milestone) with HNO_3 and HF. Dissolved samples are transferred to 50ml centrifuge tube. For ICP-AES samples, uptake of 5ml, add Sc as an internal standard, which take for major elements. These samples will be measured by ICP-AES (Optima 3300DV: Perkin-Elmer). After divided for ICP-AES, almost 45ml sample is added spikes, transferred to Teflon beaker, and evaporated to small drop. Teflon beaker wall is rinsed by conc. HNO_3 3 or 4 times. Sample will be measured by ICP-MS with dessolvator (modified Cullen *et al.*, 2001). GF/F filter is dried by vacuum freeze drier, and cut a of quarter size. One is introduced to CHNS analyzer (NCS 2500: FiniganMAT) for determination of total Carbon and Nitrogen. Another one is for determination of inorganic Carbon contents by Coulometer.

Seawater samples are brought out 1ml, added Sc for internal standard, and diluted by 10% HNO3. Diluted samples are introduced to ICP-AES and analyze Ca, Sr, and Mg.

Reference

Cullen *et al.*, (2001) Determination of elements in filtered suspended marine particulate material by sector field HR-ICP-MS, J. Anal. At. Spectrom. , 2001, 16, 1307-1312

Table 2.3.2-1 Filteration sample list.

		Start				End				Filteration volume /L
No.	Type	Lot	Long	Salinity	Temp. (ºC)	Lot	Long	Salinity	Temp. (ºC)	
1	GF/F	37.07.07	143.31.73	34.216	20.928	37.24.37	143.59.44	34.341	21.162	211.8
2	Versopor	37.26.68	144.03.30	34.349	21.243	37.37.61	144.19.92	34.291	21.072	112.6
3	Nuclepore	37.42.75	144.28.21	34.234	20.496	37.47.49	144.36.18	34.213	20.708	3.1
4	Nuclepore	37.49.08	144.38.80	34.267	20.792	38.19.65	145.27.20	34.305	20.140	13.9
5	GF/F	39.16.34	147.00.15	33.596	18.139	39.38.64	147.36.15	32.718	15.512	182.7
6	Versopor	39.40.05	147.38.46	32.764	15.345	40.00.38	148.12.47	34.266	21.091	56.6
7	Nuclepore	40.02.19	148.15.41	34.270	21.117	40.22.65	148.48.69	33.007	16.286	11.2
8	Nuclepore	40.26.21	148.54.63	33.211	16.402	40.51.90	149.39.05	33.975	15.822	1.3
9	GF/F	41.52.26	151.10.19	32.729	13.119	42.24.28	152.13.74	32.680	13.842	203.7
10	Versopor	42.25.96	152.16.79	33.316	13.910	42.38.43	152.38.64	32.985	14.392	58.9
11	Nuclepore	42.39.91	152.41.24	32.989	14.408	42.55.26	153.07.98	33.044	14.498	11.4
12	Nuclepore	42.55.26	153.07.98	33.070	14.494	43.25.14	153.59.70	32.690	13.023	16.5
13	GF/F	44.00.03	154.59.93	33.584	15.101	44.00.01	155.00.00	33.597	15.237	171.9
14	Versopor	44.00.05	155.00.04	33.601	15.262	44.00.05	154.59.78	33.775	15.299	59.8
15	Nuclepore	44.00.07	154.59.73	33.801	15.299	44.00.07	154.59.73	33.805	15.399	11.6
16	GF/F	44.57.06	156.34.84	32.809	12.166	45.27.18	157.35.07	32.814	11.180	275.9
17	Versopor	45.28.75	157.38.09	32.788	11.081	45.50.16	158.14.50	32.809	10.979	113.6
18	Nuclepore	46.02.93	158.34.26	32.781	10.562	46.14.85	158.52.18	32.776	10.600	14.2
19	GF/F	46.59.97	160.00.09	32.820	10.307	47.00.05	160.00.00	32.820	10.886	180.7
20	Versopor	47.00.05	160.00.00	32.821	10.841	46.59.92	160.00.17	32.814	10.798	74.5
21	Nuclepore	46.59.92	160.00.17	32.814	10.798	46.44.36	159.59.89	32.798	10.669	6.6
22	GF/F	46.04.03	159.59.99	33.020	11.975	44.36.66	160.00.04	32.903	11.820	306.7
23	Versopor	44.29.42	160.00.02	32.903	11.820	43.50.21	160.00.00	33.686	13.721	308.4
24	Nuclepore	43.46.27	159.59.94	33.711	13.756	43.34.02	159.99.98	33.627	13.442	12.2
25	GF/F	43.31.37	160.00.01	33.566	13.265	43.11.47	160.00.03	33.517	13.033	164.4
26	Versopor	43.08.52	159.59.97	33.488	13.107	42.50.82	159.52.92	33.213	13.100	95.9
27	Nuclepore	42.48.67	160.00.04	33.198	13.173	42.38.06	159.59.97	33.836	15.100	12.79
28	GF/F	42.35.95	160.00.00	33.563	14.454	42.05.13	160.00.01	33.987	15.676	121.2
29	Versopor	42.02.87	160.00.01	33.798	15.612	41.46.67	159.59.98	33.897	15.472	65.1
30	Nuclepore	41.43.20	159.59.87	33.990	16.185	41.37.95	159.57.66	34.186	16.896	3.3
31	GF/F	41.35.92	159.59.25	34.218	17.159	40.01.50	160.00.01	33.667	15.355	100.6
32	Versopor	39.57.85	160.00.02	33.548	15.097	39.43.11	160.00.07	33.567	15.660	24.7
33	Nuclepore	39.40.21	159.59.98	33.458	15.129	39.40.15	159.59.92	33.441	15.072	1.8
34	GF/F	39.40.49	159.59.76	33.433	15.102	38.59.96	160.00.01	33.861	16.758	103.8
35	Versopor	39.00.12	159.59.93	33.863	16.732	39.00.12	159.59.93	33.719	16.225	24.4
36	Nuclepore	39.00.03	159.59.84	33.724	16.327	39.00.03	159.59.84	33.769	16.414	1.7
37	GF/F	39.00.06	159.59.88	33.772	16.453	39.00.06	159.59.88	33.772	16.453	99.7
38	Versopor	38.57.56	159.48.06	33.588	16.023	38.33.08	157.48.11	34.229	19.689	47.7
39	Nuclepore	38.31.95	157.42.32	34.258	19.686	38.29.00	157.28.07	34.237	19.571	1.2
40	GF/F	38.28.57	157.25.74	34.220	19.553	38.28.57	157.25.74	34.220	19.553	59.1

Table 2.3.2-2 Surface seawater sampling list.

No.	Sampling data					trace metal	Nuts*		Auto Sal.	Remark
	Date	Lot	Long	Salinity	Temp. (°C)		(MAG)	(MIO)	psu	
1	7/6/2003	37.16.47	143.46.47	34.334	21.243		o	o	34.5236	
a	7/6/2003	37.27.55	144.04.68	34.383	22.039	o		o		
2	7/6/2003	37.49.08	144.38.80	34.260	20.761		o	o		
3	7/6/2003	38.19.65	145.27.20	34.305	20.140		o	o		
4	7/7/2003	39.05.95	146.44.26	34.383	20.195	o	o	o	34.2101	
5	7/7/2003	39.44.96	147.46.19	33.618	17.598		o			
b	7/7/2003	40.02.19	148.15.41	34.270	21.117	o		o		
6	7/7/2003	40.22.65	148.48.69	33.007	16.286		o			
7	7/8/2003	40.57.35	149.50.88	33.913	15.440		o			
8	7/8/2003	41.46.57	151.10.19	32.756	13.264		o	o		
9	7/8/2003	42.20.34	152.07.17	32.991	14.163		o	o	33.1317	
c	7/8/2003	42.25.96	152.16.79	33.316	13.910	o		o		
10	7/8/2003	42.55.26	153.07.98	32.065	14.494		o	o		
11	7/8/2003	43.26.92	154.02.74	32.689	12.609		o			
12	7/9/2003	44.00.03	154.59.93	33.582	15.102		o	o		KNOT
13	7/9/2003	44.00.05	155.00.04	33.601	15.262		o	o	33.7418	KNOT
14	7/9/2003	44.00.07	154.59.73	33.801	15.269	o	o			KNOT
15	7/10/2003	44.57.06	156.34.84	32.830	12.457		o			
16	7/10/2003	45.28.75	157.38.09	32.793	10.632		o		32.9428	
17	7/10/2003	46.02.93	158.34.26	32.781	10.562		o			
18	7/10/2003	46.29.98	159.14.88	32.799	10.307		o			
19	7/11/2003	46.59.97	160.00.09	32.820	10.337		o			K2
20	7/11/2003	47.00.05	160.00.00	32.821	10.841		o			K2
21	7/11/2003	46.59.92	160.00.17	32.814	10.798		o			K2
22	7/11/2003	46.04.03	159.59.99	33.020	11.975	o	o			
23	7/12/2003	44.36.66	160.00.04	32.903	11.820		o			
24	7/12/2003	43.50.21	160.00.00	33.686	13.721		o			
25	7/12/2003	43.27.86	159.59.99	33.502	12.755		o		33.6547	
26	7/12/2003	43.08.52	159.59.97	33.488	13.107		o			
27	7/12/2003	42.48.67	160.00.04	33.198	13.173		o			
28	7/12/2003	42.35.95	160.00.00	33.563	14.454		o			
29	7/12/2003	42.17.66	160.00.01	34.067	15.858		o			
30	7/12/2003	42.02.87	160.00.01	33.790	15.612		o			
31	7/12/2003	41.43.20	159.59.87	33.990	16.185		o			
32	7/13/2003	40.01.50	160.00.01	33.667	15.355		o			
33	7/13/2003	39.40.21	159.59.98	33.472	15.176		o			
34	7/13/2003	39.10.27	160.00.01	33.962	17.112		o		34.1148	
35	7/13/2003	39.00.12	159.59.93	33.859	16.646		o			K3
36	7/13/2003	39.00.06	159.59.88	33.747	16.301		o			K3
37	7/13/2003	38.31.95	157.42.32	34.258	19.686		o			

* Nutrients samples were stored by 2 methods. MIO was poisoning by using $HgCl_2$. MAG was stored by frozen.

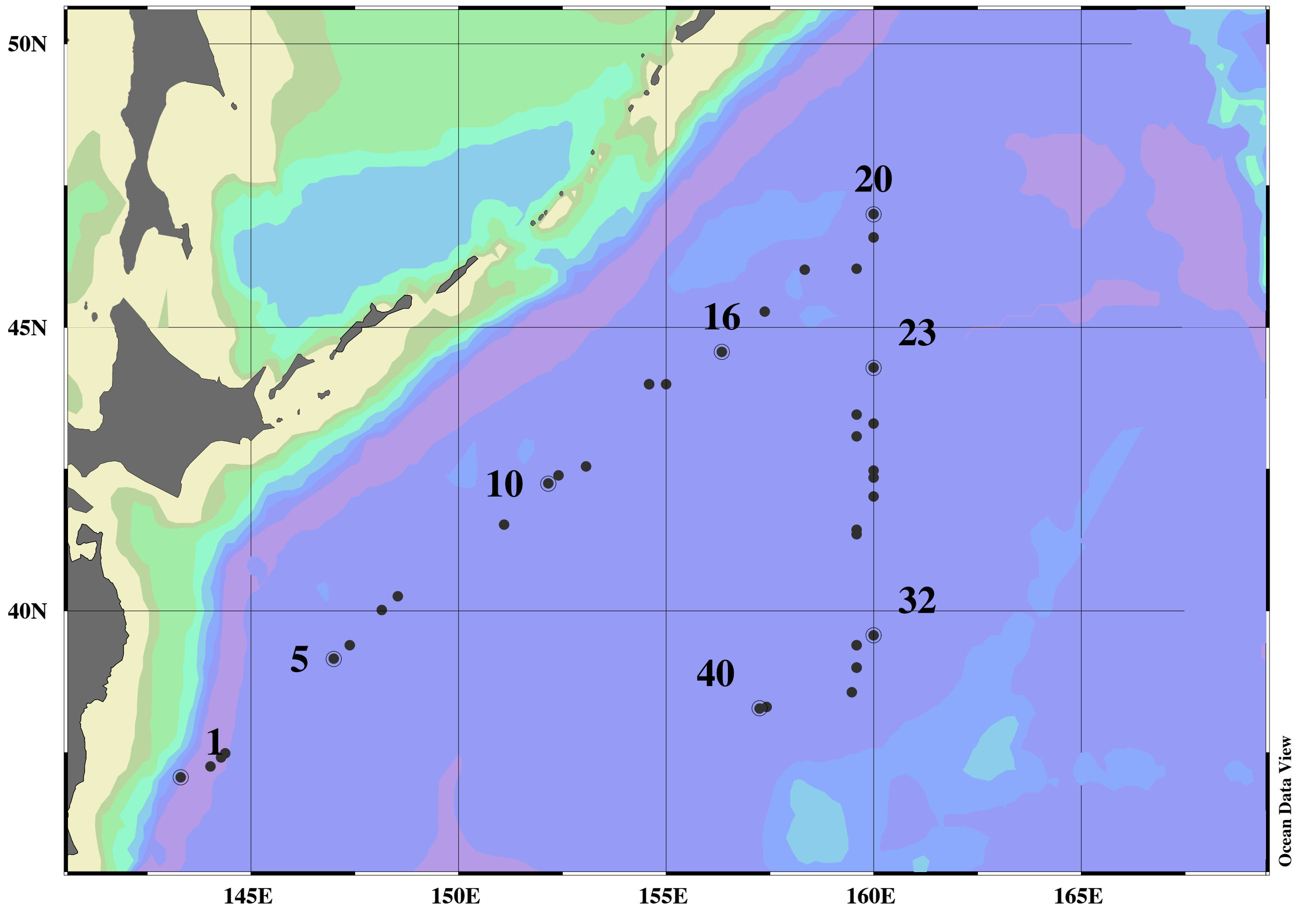


Figure 2.3.2 Sampling map

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C:/ODV_data/NT03_07/Cruese report/Filter_map_STATION_2Win.cfg

Administrator 8/18/2003 17:21:03

2.3.3 Barium as a tracer of dust input and biogeochemical cycle in the western North Pacific

Hisashi NARITA (Hokkaido University)

Objectives

It is well known that the vertical profiles of barium in the ocean well are similar to those of silicate. The objective of this study is to understand seasonal variation in surface water and spatial distribution of barium concentration in the western North Pacific in relation to biological production and dust inputs.

Sampling

Surface waters for barium analysis were collected during this cruise through underway surface water sampling. In addition, Seawater samples for barium analysis were also collected using Niskin bottles mounted on the CTD/RMS system. The samples for barium analysis were collected into 10 ml polyethylene vials after pre-rinsing with the sample. The external joints between caps and bodies were wrapped in Parafilm to minimize evaporation, and the unacidified samples were enclosed in plastic bags to store. All samples were stored at room temperature till analysis in Hokkaido University.

Analytical method

Barium concentrations will be determined by isotope dilution-inductively coupled plasma quadrupole mass spectrometry (ID-ICPMS) in a manner similar to that described by Klinkhanner and Chen (1990). Briefly, 1 ml of seawater sample was spiked with an equal volume of 135Ba-enriched solution (Oak Ridge National laboratories) and diluted 100-flod in 0.16 N ultra pure HNO3. Samples were introduced into ICP-MS (HP 4500).

2.4 Optical Measurements

Hiroaki SAKOH (JAMSTC Mutsu Institute for Oceanography)

(1) Objective

The objective of this measurement is to investigate the air and underwater light conditions at respective stations and to determine depths for simulated *in situ* measurement of primary production using labeled 15N-nitarate and inorganic 13C-carbon.

(2) Description of instruments deployed

The instrument consisted of the SeaWiFS Profiling Multichannel Radiometer (SPMR; and SeaWiFS Multichannel Surface Reference (SMSR). The SPMR was deployed in a free fall mode through the water column. The profiler has a 13 channel irradiance sensor (Ed), a 13 channel radiance sensor (Lu), tilt sensor, and fluorometer. The SMSR has a 13 channel irradiance sensor (Es), tilt meter. These instruments observed the vertical profiles of visible and ultra violet light and chlorophyll concentration.

Fig1. Profiler configuration

Table 2.4-1. Center wavelength of the SPMR/SMSR

Es	379.5	399.6	412.2	442.8	456.1	490.9	519.0	554.3	564.5	619.5	665.6	683.0	705.9
Ed	380.0	399.7	412.4	442.9	455.2	489.4	519.8	554.9	565.1	619.3	665.5	682.8	705.2
Lu	380.3	399.8	412.4	442.8	455.8	489.6	519.3	554.5	564.6	619.2	665.6	682.6	704.5

The profiler was deployed twice at respective stations to a depth of 200 m. The reference (SMSR) was mounted on the compass deck and was never shadowed by any ship structure. The profiler descended at an average rate of 1.1 m/s with tilts of less than 3 degrees.

These measurements provide data for the computation of quantities of photosynthetically available radiation (PAR).

The preliminary results were shown in Figures 2.4-1, 2.4-2 and 2.4-3.

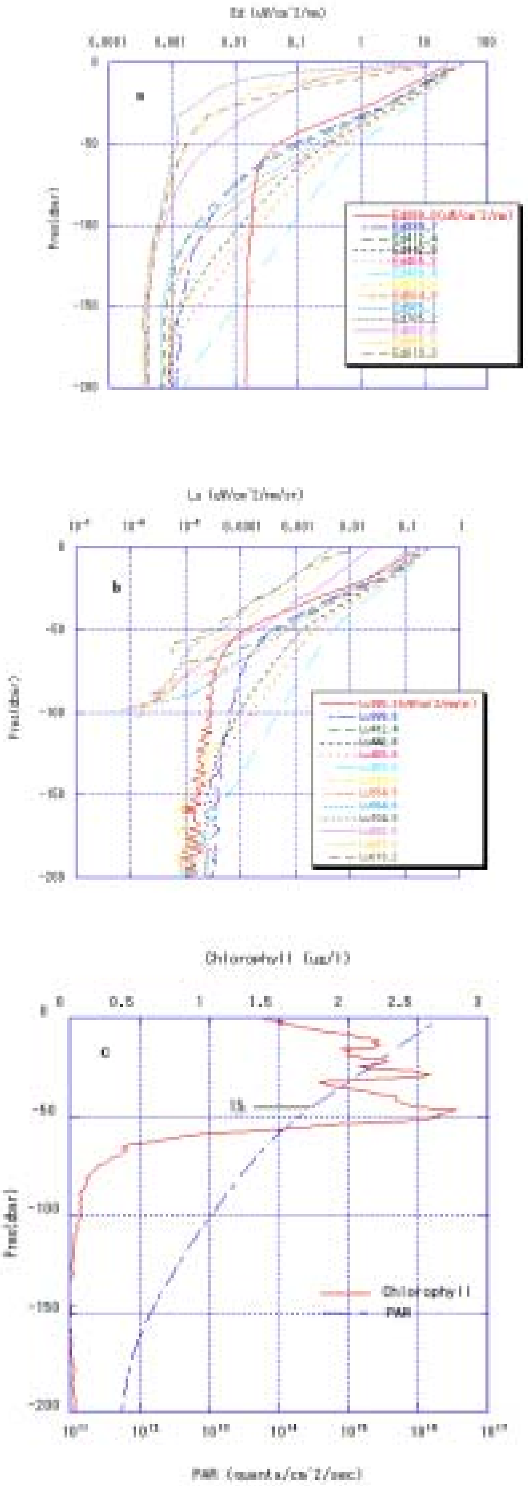

Figure 2.4-1. Vertical profiles of underwater light field at station KNOT.

a: downwelling spectral irradiance

b: upwelling spectral radiance

c: calculated chlorophyll concentration and photosynthetically available radiation (PAR)

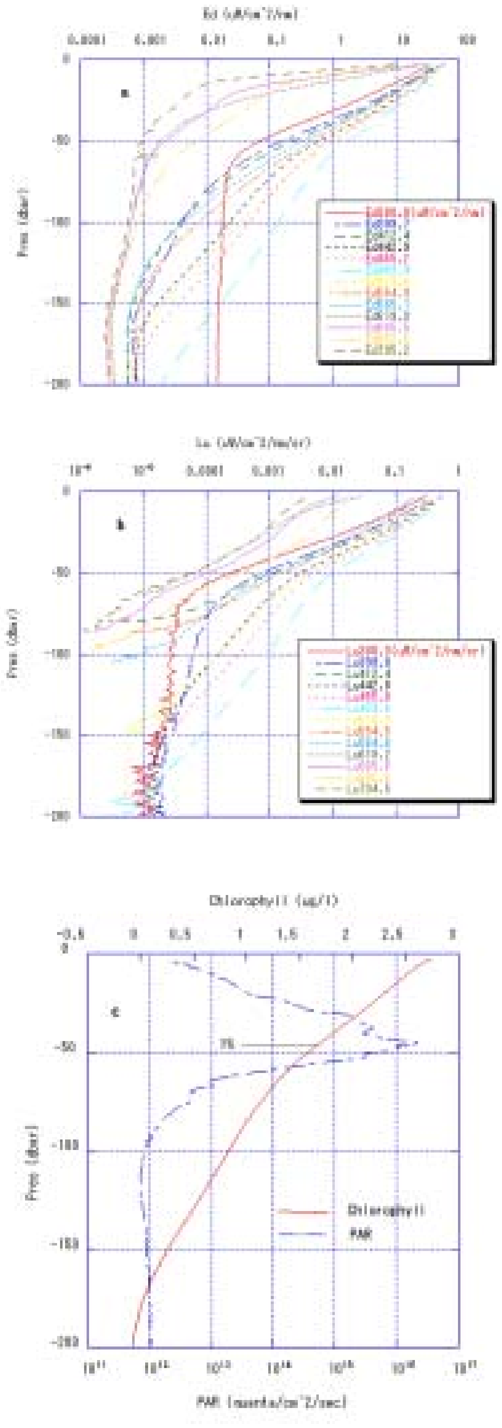

Figure 2.4-2. Vertical profiles of underwater light field at station K2.

a: downwelling spectral irradiance

b: upwelling spectral radiance

c: calculated chlorophyll concentration and photosynthetically available radiation (PAR)

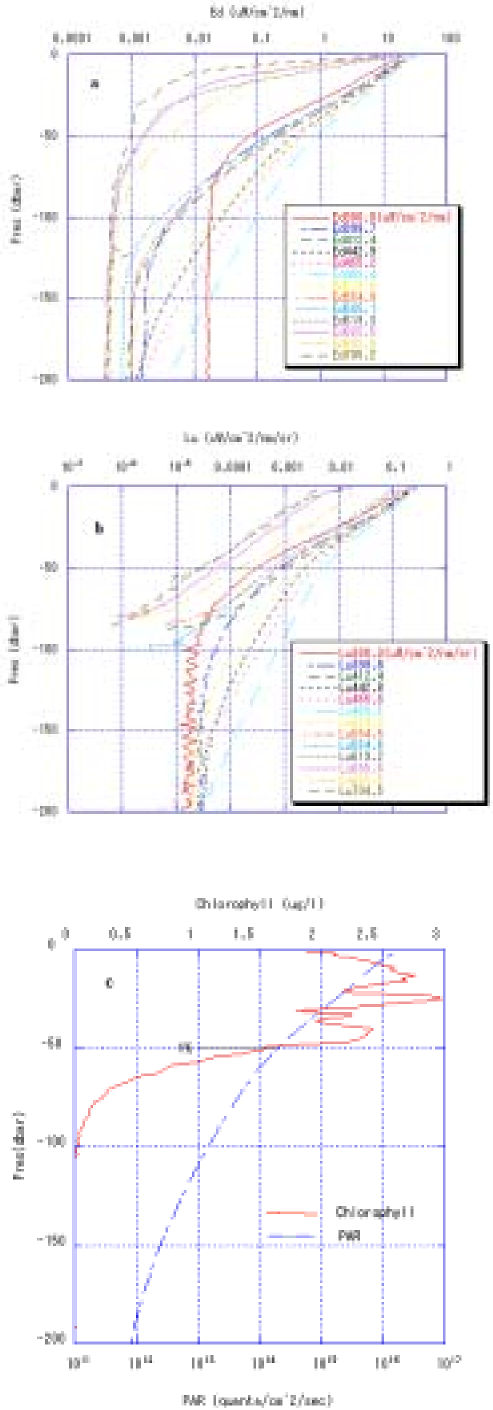

Figure 2.4-3. Vertical profiles of underwater light field at station K3.

a: downwelling spectral irradiance

b: upwelling spectral radiance

c: calculated chlorophyll concentration and photosynthetically available radiation (PAR)

(3) Optical characteristics

Makio HONDA (JAMSTEC MIO)

In the northwestern North Pacific (NWNP), our group (JAMSTEC-MIO / WHOI-JPAC) have been conducting time-series observation with using mooring systems. On these mooring systems, optical sensor package called BLOOM are installed. The BLOOM measures spectral downwelling irradiance and upwelling radiance for three wavelengths (443 nm, 490 nm and 555 nm), and chlorophyll. On the other hand, our group has never observed light condition by using optical sensors at time-series stations in the NWNP. Another objective of optical observation during this cruise was to know the optical characteristics and to contribute to the evaluation of observed values by BLOOM.

1) *Extinction rate for respective wave lengths and PAR for respective stations*

Figure 2.4-4 shows spectral downwelling irradiance (Ed) at several depths observed at station K2. It can be seen that the extinction of Ed with depth is larger for wavelengths from 600 to 700 nm than for that from 450 to 550 nm. It is indicative of that the wavelength of ~ 480 m, which is blue ~ green light, can penetrate to deeper depth. Figure 2.4-5 shows vertical profile in photosynthetically available radiation (PAR) at stations KNOT, K2 and K3. PAR at station K2 was the strongest followed by station KNOT. The extinction coefficient (K) is one of index of extinction intensity and expressed as

$$I_z = I_0 \, e^{-kz} \qquad (1)$$

where I_z and I_0 are irradiance at z m and 0 m water depth, respectively. With using PAR data at upper 50 m, K at stations KNOT, K2 and K3 were estimated to be 0.095, 0.094 and 0.089, respectively, resulting that extinction coefficient at station K3 located in the subarctic-subtropical boundary and governed by the Kuroshio related water was slightly smaller than other stations.

2) ***Calculation of PAR***

Quantum yield between two wavelengths ($\lambda 1$ and $\lambda 2$) ($Q_{((\lambda 1/\lambda 2))}$) are estimated with Ed of respective wavelengths ($Ed_{(\lambda 1)}$ and $Ed_{(\lambda 2)}$) and the following equation:

$$Q_{((\lambda 1/\lambda 2))} \text{ (quanta cm}^{-2}\text{ sec}^{-1}\text{)}$$
$$= (Ed_{(\lambda 1)} + Ed_{(\lambda 2)}) * ((\lambda 2) - (\lambda 1)) / 2 * 10^{-6} \; / \; h / c * ((\lambda 1) + (\lambda 2)) / 2 * 10^{-9} \qquad (2)$$

where $Ed_{(\lambda 1)}$ and $Ed_{(\lambda 2)}$ are irradiance of wave length of $\lambda 1$ and $\lambda 2$ nm, respectively. Therefore $(Ed_{(\lambda 1)} + Ed_{(\lambda 2)}) * ((\lambda 2) - (\lambda 1)) / 2 * 10^{-6}$ is integrated Ed (W·cm^{-2} or joule·cm^{-2}) between wavelength of $\lambda 1$ and $\lambda 2$ nm. $((\lambda 1) + (\lambda 2)) / 2 * 10^{-9}$ is average wavelength (m). The h and c are the Planck constant and light velocity, and $6.626 * 10^{-34}$ joule·sec·m^{-1} and $3.0 * 10^{8}$ m·sec^{-1}, respectively.

Based on the above equation, PAR which is integrated quantum yield between 400 and 700 nm were calculated. Estimated PAR coincided well with PAR computed by software “Satlantic PROSOFT6” dedicated to this optical sensor system within 1 % deviation.

3) *The ratio of quantum yield between 443 and 555 nm to PAR*

As described above, BLOOM installed at approximately 45 m below surface on our mooring system measures Ed of three wavelengths; 443 nm, 490 nm, 555 nm. In order to understand the ratio of quantum yield between 443 and 555 nm ($Q_{(443/555)}$) to PAR, $Q_{(443/555)}$ was calculated with equation (2). Figure 2.4-6 shows the ratio of $Q_{(443/555)}$ to PAR against the light level relative to surface light level. The ratio in air was approximately 38 % and decreased with light level. At 40 m, where light level is approximately 2 % and BLOOM is deployed, the ratio was approximately 78 %. Therefore $Q_{(443/555)}$ estimated with BLOOM data can be suspected to be approximately 80 % of PAR at that depth. It is noted that $Q_{(443/555)}$ estimated with Ed of three wave lengths (443, 490, 555) coincided well with $Q_{(443/555)}$ estimated with Ed of five wave lengths (443, 455, 490, 520, 555) within 5 % deviation.

4) *Daily PAR*

Although we can observe optical condition such as PAR several times a day by BLOOM, total daily PAR is often requested for estimation of net primary productivity. In addition, satellite provides us a daily PAR data (often weekly composite). Therefore how to estimate daily PAR with temporally observed PAR should be considered.

The following empirical equation is proposed for the estimation of diurnal change in PAR ($PAR_{(T)}$);

$$PAR_{(T)} = PAR_{(max)} * (\sin(\pi / I * T))^3 \quad \text{(for sunny day in summer)} \qquad (3)$$
$$PAR_{(T)} = PAR_{(max)} * (\sin(\pi / I * T))^2 \quad \text{(for other day)} \qquad (4)$$

(Kaiyo Kansoku Shishin, 1990)

where PAR(max) is PAR at meridian passage time, I is an insolation duration and T is an elapsed time from sunrise. During this cruise, optical observation was carried out around noontime. Assuming that observed PAR in air is PAR at meridian passage time and insolation duration at stations KNOT, K2 and K3 are approximately 15.3, 15.5 and 14.8 hours, respectively, diurnal change in PAR was suspected by using equation (3) and daily PAR was estimated by integrating $PAR_{(T)}$ for respective stations. Based on suspected diurnal change in PAR in Figure 2.4-7, integrated PAR, *i.e.*, daily PAR, were estimated to be approximately 22, 17 and 11 mol quanta m^{-2} day^{-1} at station K2, KNOT and K3, respectively. Table 2.4-2 shows statistics of daily PAR in July 1998/1999 observed by VISSR (Visible and Infrared Spin Scan Radiometer) aboard Japanese GMS- (Honda, 2001). Compared our data with these data, our data were slightly smaller. This might be attributed to that PAR observation was not always conducted at meridian passage time and days for observation were cloudy. However estimated daily PAR does not differ from previous data critically.

Finally, it is likely that the estimation of PAR dedicated to the estimation of primary productivity with BLOOM data is not simple and many assumptions are needed. However the above consideration will be helpful for the interpretation of BLOOM data. In addition, more optical observation is strongly recommended at our time-series stations in future.

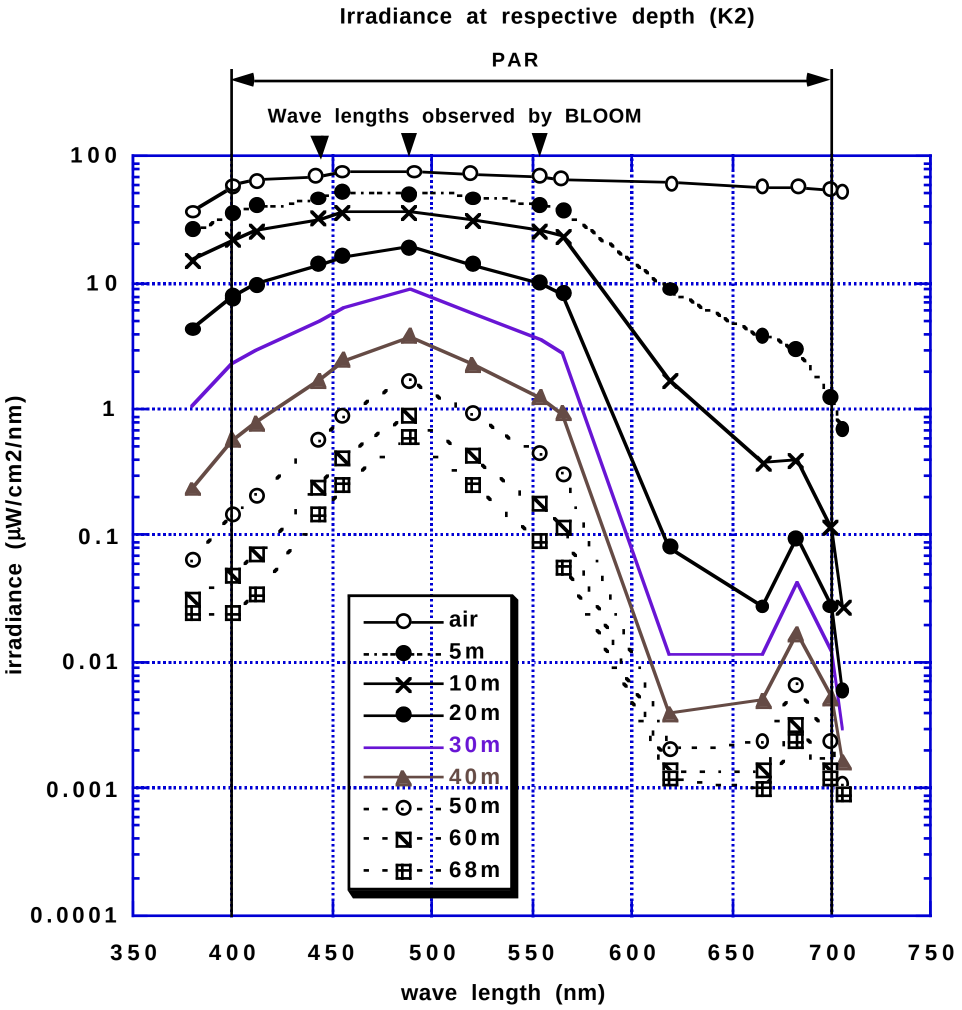

Figure 2.4-4 spectral downwelling irradiance at various wavelengths for respective depths

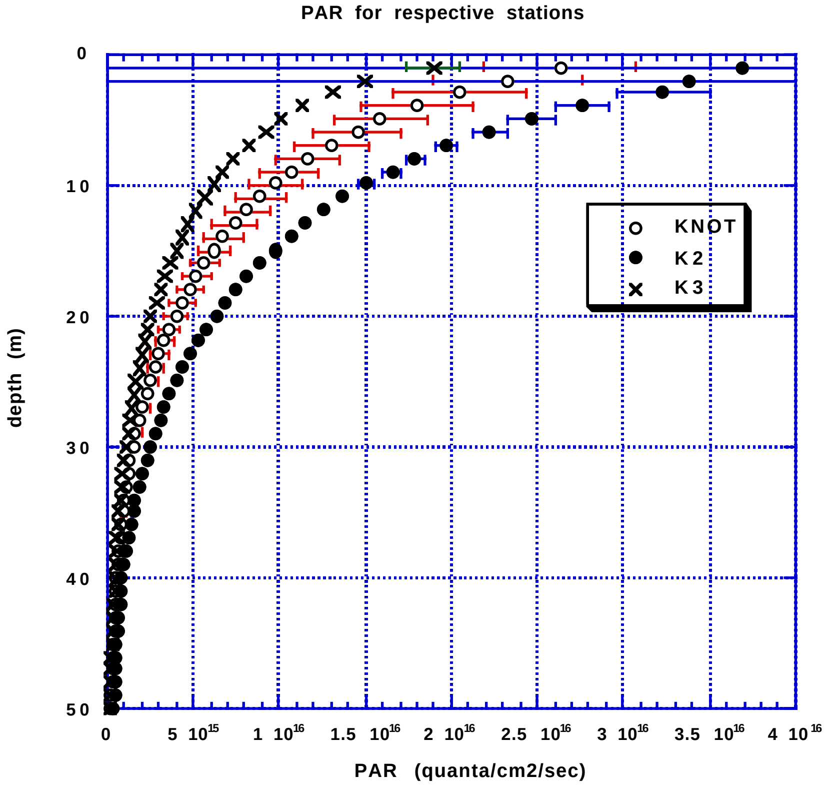

Figure 2.4-5 Vertical profile in PAR for resprctive stations

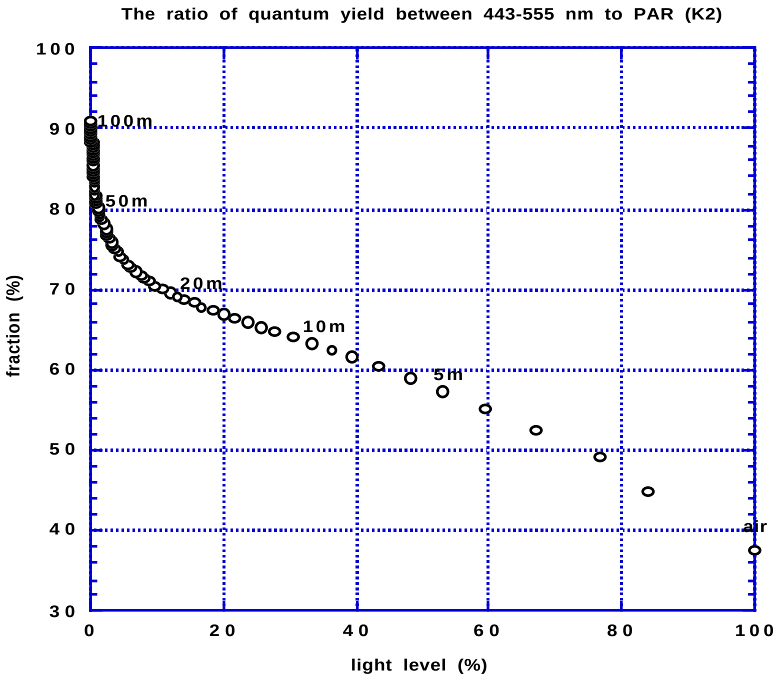

Figure 2.4-6 Ratios of quantum yield from 443 to 555 nm to PAR

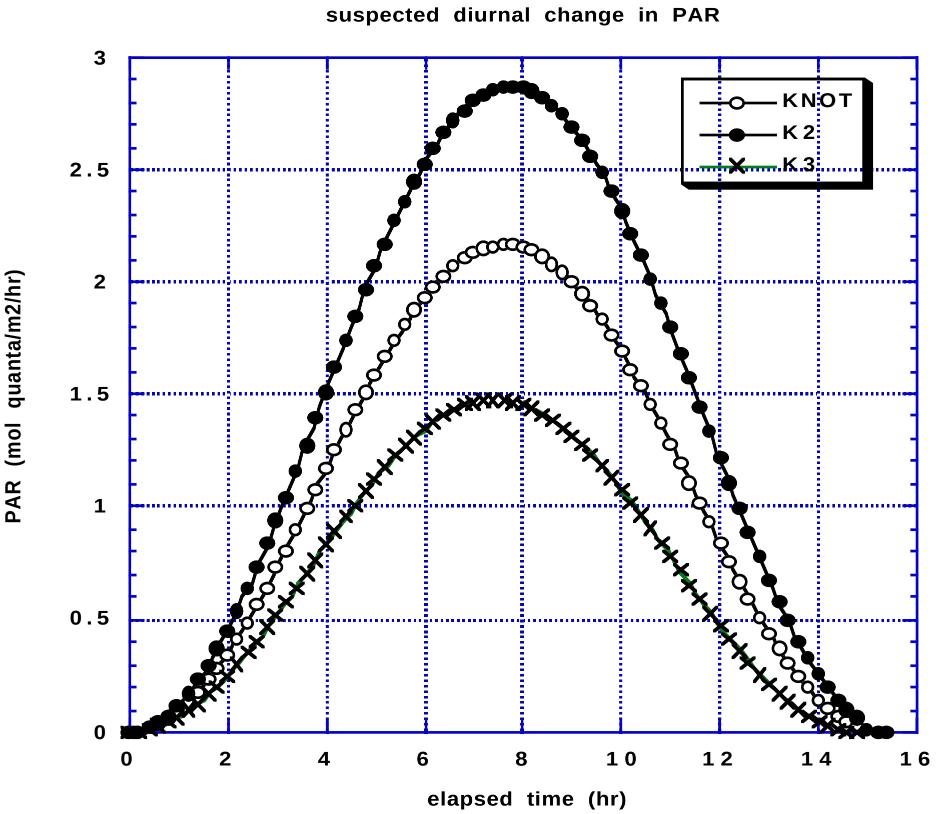

Figure 2.4-7 Diurnal change in PAR for respective

Table 2.4-2 PAR in July 1998 / 1999 at stations 50N (50°N, 165°E), KNOT (44°N, 155°E) and 40N (40°N, 165°E)

PAR in July (mol quanta/m2/day)

stations	50N	KNOT	40N
average	31.8	30.0	36.5
max	56.0	56.0	54.0
min	10.0	10.0	14.0
stdev	10.1	9.1	11.5

3. Appendix

List of Hydrocast

Hydrocast for Routine

>200m	1	200
	2	150
	3	125
	4	100
	5	80
	6	70
	7	60
	8	50
	9	40
	10	30
	11	20
	12	10
>3500m	1	3500
	2	3000
	3	2500
	4	2000
	5	1500
	6	1000
	7	800
	8	600
	9	500
	10	400
	11	300
	12	250

Hydrocast for Th

upper 4	1	60
	2	60
	3	60
	4	40
	5	40
	6	40
	7	20
	8	20
	9	20
	10	10
	11	10
	12	10
lower 4	13	200
	14	200
	15	200
	16	150
	17	150
	18	150
	19	100
	20	100
	21	100
	22	80
	23	80
	24	80

LVP for Th

upper 4	1	10
	2	20
	3	40
	4	60
lower 4	5	80
	6	100
	7	150
	8	200

Hydrocast for Productivity

<100m

Station: KNOT

	Start	End
Date/Time:	2003.7.9 10:23	2003.7.9 10:45
Lat.:	43-59.883	43-59.870
Long.:	155-00.080	155-00.095
Depth (m):	5310.0	5310.0

Remarks: Cast for Routine SHALLOW

			CTD data				Autosal	Chemical analysis (uncorrected data)						
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	201	202	2.418	33.585	26.814	98	33.587	161.36		2247.6	0.05	35.21	2.64	76.28
								160.54						
2	151	152	2.163	33.416	26.693	97	33.427	250.65		2188.5	0.06	28.17	2.18	55.65
3	126	127	1.847	33.278	26.624	96	33.303	296.22		2161.1	0.06	25.51	2.01	47.44
4	100	101	1.606	33.164	26.543	95	33.206	319.36		2147.2	0.07	24.60	1.97	43.38
5	80	81	1.377	33.112	26.504	94	33.129	328.31		2141.0	0.77	24.81	1.98	42.53
6	70	70	1.617	33.073	26.466	93	33.103	331.68		2140.0	0.00	23.75	1.97	40.74
7	61	61	2.125	33.078	26.434	92	33.092	334.24		2128.4	0.70	22.02	1.93	37.15
8	50	50	3.133	33.075	26.329	91	33.081	349.79		2092.3	0.42	18.61	1.73	25.78
								349.95						
9	40	40	3.838	33.064	26.245	90	33.066	361.53		2063.6	0.34	16.60	1.58	17.50
10	30	30	7.422	33.194	25.950	89	33.128	349.49		2027.3	0.24	10.39	1.14	11.07
11	20	20	13.698	33.698	25.242	88	33.691	280.53		2029.9	0.16	4.43	0.56	12.37
12	10	10	13.970	33.742	25.221	87	33.746	274.89		2023.6	0.16	3.98	0.51	12.77
								275.14						
bucket	0	0	14.025	33.733	25.203	99	33.740	-		2027.0	0.17	3.76	0.50	12.56

	Start	End
Date/Time:	2003.7.9 21:47	2003.7.9 23:46
Lat.:	44-00.055	44-00.059
Long.:	154-59.881	155-00.218
Depth (m):	5351	5351

Remarks: Cast for Routine DEEP
Precision of Salinity #86 determined by Autosal is low.

			CTD data				Autosal	Chemical analysis (uncorrected data)						
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	3492	3557	1.471	34.673	27.749	86	34.717	146.26		2331.9	0.00	36.33	2.50	147.93
								146.00						
2	2993	3045	1.525	34.662	27.736			132.06		2343.8	0.00	37.16	2.61	151.33
3	2495	2535	1.640	34.640	27.711			110.51		2357.2	0.00	38.51	2.74	157.09
4	1996	2025	1.854	34.603	27.663			82.04		2371.0	0.00	40.35	2.87	159.89
5	1497	1517	2.175	34.528	27.580			54.04		2377.1	0.00	41.91	3.01	156.84
6	997	1009	2.628	34.413	27.450	85	34.417	35.67		2374.4	0.00	42.62	3.06	145.97
7	798	807	2.950	34.350	27.371			36.30		2367.9	0.00	42.46	3.06	134.36
8	598	605	3.078	34.208	27.247			29.95		2357.1	0.00	43.02	3.07	125.15
9	501	506	3.547	34.173	27.173			44.31		2339.6	0.00	41.51	2.96	111.93
10	400	404	3.316	34.019	27.071			53.99		2328.0	0.00	41.60	3.00	104.32
11	299	302	2.976	33.824	26.957			82.27		2306.6	0.00	40.12	2.93	95.15
12	249	251	2.811	33.737	26.893	84	33.747	110.59		2283.3	0.00	38.03	2.80	85.58

	Start	End
Date/Time:	2003.7.9 8:51	2003.7.9 9:05
Lat.:	44-00.019	44-00.067
Long.:	155-00.005	155-00.035
Depth (m):		

Remarks: Cast for Th/POC Upper (Kawakami)

	CTD data				
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	59	60	2.711	33.095	26.368
2	59	60	2.726	33.088	26.368
3	60	61	2.728	33.094	26.366
4	40	40	3.787	33.064	26.266
5	40	40	3.978	32.976	26.266
6	40	40	3.991	33.029	26.266
7	20	20	13.843	33.733	25.236
8	20	20	13.907	33.708	25.236
9	20	20	13.923	33.725	25.236
10	9	9	13.952	33.729	25.211
11	10	10	13.956	33.729	25.211
12	10	10	13.960	33.728	25.211

	Start	End
Date/Time:	2003.7.9 6:16	2003.7.9 6:35
Lat.:	44-00.072	44-00.089
Long.:	154-59.957	154-59.890
Depth (m):		

Remarks: Cast for Th/POC Lower (Kawakami)

Bottle #	CTD data Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	200	202	2.464	33.606	26.820
2	200	202	2.465	33.611	26.820
3	201	203	2.466	33.610	26.823
4	150	151	2.062	33.413	26.694
5	150	151	2.062	33.410	26.694
6	150	151	2.060	33.410	26.694
7	99	100	1.448	33.209	26.576
8	99	100	1.448	33.208	26.576
9	99	100	1.448	33.209	26.576
10	79	80	1.509	33.166	26.531
11	79	80	1.516	33.159	26.531
12	80	81	1.514	33.162	26.533

	Start	End
Date/Time:	2003.7.9 20:48	2003.7.9 21:08
Lat.:	43-59.990	44-00.017
Long.:	154-59.834	154-59.880
Depth (m):	5310	

Remarks: Cast for Primary Productivity

	CTD data				
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	201	203	2.519	33.599	26.805
2	150	151	1.847	33.351	26.661
3	125	126	1.572	33.250	26.599
4	79	80	1.498	33.103	26.503
5	70	71	1.651	33.083	26.460
6	59	60	2.023	33.069	26.414
7	51	51	2.901	33.051	26.344
8	40	40	4.340	33.170	26.244
9	32	32	5.652	33.115	26.080
10	26	26	14.012	33.928	25.378
11	14	14	14.066	33.950	25.355
12	8	8	14.087	33.950	25.356
bucket	0	0			

Station: K2

	Start	End
Date/Time:	2003.7.11 10:33	2003.7.11 10:53
Lat.:	47-00.240	47-00.351
Long.:	160-00.024	160-00.059
Depth (m):	5189.0	5189.0

Remarks: Routine SHALLOW
Precision of Salinity #81 determined by Autosal is low.

Bottle #	Depth [m]	Pressure [db]	CTD data Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Autosal Salinity (psu)	Chemical analysis (uncorrected data) DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	200	201	3.452	33.867	26.934	80	33.858	53.31		2316.9	0.05	43.07	3.07	94.16
								53.94						
2	150	151	2.965	33.676	26.829			106.63		2281.6	0.06	39.90	2.87	82.57
3	124	125	2.081	33.405	26.683			195.06		2224.5	0.06	34.34	2.56	66.64
4	100	100	1.313	33.105	26.508			325.22		2138.0	0.07	25.30	2.00	43.29
5	80	80	1.526	33.070	26.465			340.69		2128.8	0.77	23.17	1.92	39.77
6	71	71	1.705	33.056	26.442	81	33.070	342.10		2124.1	0.00	22.64	1.90	39.11
7	60	60	1.965	33.029	26.401			342.73		2119.5	0.70	22.59	1.87	39.28
8	49	49	3.351	33.037	26.266			345.27		2113.4	0.42	20.87	1.79	36.63
								345.06						
9	40	40	4.751	32.999	26.114			345.62		2093.2	0.34	18.79	1.63	33.42
10	29	29	8.030	32.936	25.670			330.60		2075.7	0.24	16.97	1.52	32.62
11	20	20	8.595	32.877	25.580			314.10		2066.2	0.16	15.28	1.39	31.21
12	10	10	8.744	32.960	25.562	82	32.966	309.66		2063.5	0.16	15.04	1.39	30.85
								309.74						
bucket	0	0	8.925	32.847	25.445	83	32.973	-		2067.1	0.17	15.06	1.39	30.62

	Start	End
Date/Time:	2003.7.11 14:41	2003.7.11 16:01
Lat.:	47-00.00	
Long.:	160-00.304	
Depth (m):		

Remarks: Routine DEEP I
CTD obervation stopped accidentally after 2000 m water sampled.

Bottle #	CTD data						Autosal	Chemical analysis (uncorrected data)						
	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	3509	3558	1.460	34.671	27.753	77	34.678	149.46		2327.1	0.00	36.24	2.53	147.24
								148.81						
2	3008	3046	1.493	34.663	27.743			138.21		2338.3	0.00	36.85	2.59	149.17
3	2507	2536	1.580	34.645	27.724			119.76		2348.2	0.00	37.80	2.69	154.58
4	2006	2026	1.749	34.612	27.688			90.58		2365.8	0.00	39.62	2.81	160.29

	Start	End
Date/Time:	2003.7.11 16:05	2003.7.11 16:37
Lat.:		46-59.973
Long.:		160-00.145
Depth (m):		

Remarks: Routine DEEP II

Bottle #	CTD data						Autosal	Chemical analysis (uncorrected data)						
	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
5	1504	1517.4	2.018	34.556	27.618			57.82		2385.0	0.00	41.60	2.98	161.48
6	1002	1010.0	2.456	34.447	27.494	78	34.454	25.65		2388.2	0.00	43.26	3.12	156.35
7	803	809.1	2.722	34.381	27.419			18.85		2380.5	0.00	43.75	3.13	147.70
8	603	607.4	3.019	34.293	27.325			16.37		2370.6	0.00	43.85	3.14	135.18
								16.12						
9	502	505.2	3.183	34.235	27.264			15.25		2368.2	0.00	43.75	3.15	128.31
10	402	403.7	3.355	34.160	27.188			16.60		2357.6	0.00	43.97	3.16	120.58
11	301	302.5	3.481	34.069	27.099			20.10		2345.0	0.00	43.95	3.15	112.56
12	252	252.8	3.521	34.003	26.723	79	34.008	21.90		2340.5	0.00	44.13	3.17	104.91

	Start	End
Date/Time:	2003.7.11 9:48	2003.7.11 9:58
Lat.:	47-00.025	47-00.046
Long.:	160-00.111	160-00.123
Depth (m):	5189	

Remarks: Cast for Th/POC Upper (Kawakami)

Bottle #	CTD data Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	61	61	2.039	32.999	26.399
2	61	61	2.046	33.035	26.399
3	61	61	2.069	32.999	26.399
4	40	40	3.489	33.015	26.253
5	40	40	3.583	33.029	26.253
6	40	40	3.770	33.023	26.253
7	20	20	8.289	32.965	25.653
8	19	19	8.144	32.936	25.653
9	20	20	8.255	32.947	25.653
10	10	10	8.665	32.963	25.569
11	10	10	8.677	32.961	25.569
12	10	10	8.677	32.964	25.569

	Start	End
Date/Time:	2003.7.11 7:28	2003.7.11 7:44
Lat.:	46-59.945	46-59.957
Long.:	160-00.294	160-00.301
Depth (m):	5189	

Remarks: Cast for Th/POC Lower (Kawakami)

	CTD data				
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	202	203	3.434	33.850	26.925
2	201	202	3.436	33.851	26.925
3	201	202	3.444	33.852	26.925
4	150	151	2.953	33.672	26.838
5	150	151	2.953	33.671	26.838
6	150	151	2.955	33.671	26.838
7	100	100	1.296	33.118	26.531
8	100	100	1.294	33.118	26.531
9	100	101	1.296	33.124	26.531
10	81	81	1.482	33.070	26.476
11	81	81	1.491	33.087	26.476
12	80	80	1.521	33.077	26.473

	Start	End
Date/Time:	2003.7.11 18:24	2003.7.11 18:39
Lat.:	46-59.909	46-59.538
Long.:	160-00.144	160-00.149
Depth (m):	5189	5189

Remarks: Cast for Primary Productivity

Bottle #	CTD data				
	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	101	101	1.381	33.097	26.487
2	101	102	1.378	33.095	26.487
3	101	101	1.393	33.093	26.487
4	101	101	1.390	33.096	26.487
5	101	101	1.390	33.096	26.487
6	101	101	1.388	33.089	26.487
7	40	40	4.272	33.008	26.166
8	40	40	4.314	32.990	26.166
9	30	30	5.812	33.032	26.032
10	27	27	7.265	32.973	25.825
11	13	13	8.459	32.965	25.602
12	8	8	8.710	32.962	25.566
bucket	0	0	9.037	32.870	25.445

Station: K3

	Start	End
Date/Time:	2003.7.13 15:53	2003.7.13 16:12
Lat.:	39-00.053	39-00.013
Long.:	159-59.977	159-59.971
Depth (m):	5488	5488

Remarks: Routine SHALLOW

			CTD data				Autosal	Chemical analysis (uncorrected data)						
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	200	202.1	6.068	33.757	26.555	75	33.755	284.40		2,117.6	0.06	16.79	1.32	27.26
								284.73						
2	150	150.8	6.471	33.757	26.509			291.93		2,108.1	0.06	15.32	1.21	24.07
3	125	126.1	6.520	33.723	26.478			294.40		2,104.6	0.06	15.16	1.20	23.65
4	100	100.9	6.843	33.696	26.411			296.58		2,101.3	0.07	14.68	1.18	23.17
5	80	80.5	7.185	33.681	26.358			334.44		2,092.1	0.51	13.66	1.13	22.46
6	70	70.5	7.187	33.650	26.335	74	33.645	305.97		2,090.2	0.55	13.04	1.13	22.47
7	60	60.6	7.702	33.695	26.290			302.64		2,086.2	0.47	12.49	1.08	21.66
8	51	51.3	9.348	33.995	26.315			281.64		2,085.3	0.31	12.26	0.99	20.00
								281.17						
9	40	40.1	9.947	34.009	26.205			277.56		2,081.9	0.41	11.17	0.91	18.54
10	31	30.7	11.168	34.138	26.105			279.03		2,069.8	0.52	9.42	0.81	16.45
11	21	21.0	13.132	33.870	25.694			290.19		2,029.3	0.23	5.14	0.55	12.50
12	11	10.9	15.280	33.998	25.143	73	33.992	280.26		2,002.5	0.14	1.80	0.31	9.58
								280.57						
bucket	0	0.0	15.504	33.988	25.081	76	34.001	-		1,998.0	0.14	1.64	0.29	9.31

	Start	End
Date/Time:	2003.7.13 21:43	2003.7.13 23:38
Lat.:	39-00.035	38-59.987
Long.:	159-59.897	159-59.875
Depth (m):	5488	5488

Remarks: Routine DEEP

			CTD data				Autosal	Chemical analysis (uncorrected data)						
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]	Sal B/N	Salinity (psu)	DO umol/kg	TA umol/kg	TDIC umol/kg	NO2 umol/kg	NOx umol/kg	PO4 umol/kg	SiO4 umol/kg
1	3496	3556.9	1.483	34.673	27.750	70	34.677	146.55		2336.2	0.00	36.37	2.58	149.37
								145.45						
2	2999	3046.5	1.551	34.660	27.735			130.35		2349.6	0.00	37.39	2.67	152.65
3	2497	2534.0	1.677	34.637	27.708			108.69		2357.9	0.00	38.70	2.78	156.79
4	1998	2025.4	1.917	34.593	27.655			77.71		2375.9	0.00	40.59	2.93	159.30
5	1500	1517.9	2.299	34.518	27.564			48.46		2385.2	0.00	42.14	3.07	154.91
6	1000	1010.9	2.967	34.392	27.404	71	34.419	37.30		2368.4	0.00	42.28	3.09	136.73
7	800	808.3	3.451	34.319	27.298			40.46		2349.8	0.00	41.50	3.03	122.98
8	600	605.5	3.901	34.166	27.136			49.83		2322.7	0.00	40.54	2.98	106.41
								49.81						
9	500	504.2	4.174	34.059	27.031			No data		2304.4	0.00	38.86	2.88	93.29
10	399	402.9	4.817	34.003	26.910			107.58		2255.9	0.00	34.44	2.50	76.02
11	300	302.6	5.614	33.917	26.752			222.02		2137.0	0.00	19.33	1.46	37.81
12	250	251.6	6.325	33.912	26.668	72	33.911	194.97		2175.7	0.00	24.24	1.79	44.28

	Start	End
Date/Time:	2003.7.13 15:25	2003.7.13 15:35
Lat.:	39-00.124	39-00.125
Long.:	159-59.916	159-59.932
Depth (m):	5488	

Remarks: Cast for Th/POC Upper (Kawakami)

			CTD data		
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [° C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	61	61	7.774	33.750	26.299
2	62	62	7.771	33.718	26.299
3	61	61	7.839	33.724	26.299
4	41	41	9.769	34.046	26.194
5	42	42	9.975	34.008	26.199
6	41	41	10.058	34.058	26.194
7	21	21	12.696	34.149	25.679
8	20	20	13.160	34.092	25.618
9	21	21	13.545	34.038	25.679
10	11	11	15.250	33.991	25.137
11	10	10	15.236	33.996	25.143
12	10	10	15.269	34.001	25.143

	Start	End
Date/Time:	2003.7.13 14:48	2003.7.13 15:02
Lat.:	39-00.013	38-59.961
Long.:	160-00.054	160-00.061
Depth (m):	5488	

Remarks: Cast for Th/POC Lower (Kawakami)

	CTD data				
Bottle #	Depth [m]	Pressure [db]	Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	201	203	6.500	33.819	26.548
2	200	202	6.514	33.823	26.548
3	200	202	6.472	33.830	26.548
4	150	151	6.669	33.777	26.501
5	150	151	6.669	33.779	26.501
6	150	151	6.669	33.780	26.501
7	101	102	6.859	33.677	26.415
8	99	100	6.903	33.688	26.394
9	100	101	6.870	33.680	26.401
10	81	82	7.268	33.694	26.354
11	80	81	7.297	33.698	26.352
12	80	81	7.300	33.692	26.352

	Start	End
Date/Time:	2003.7.13 19:20	2003.7.13 19:35
Lat.:	39-00.026	39-00.011
Long.:	159-59.946	159-59.913
Depth (m):	5488	

Remarks: Cast for Primary Productivity

Bottle #	Depth [m]	Pressure [db]	CTD data Pot-Temp. [。C]	Salinity [PSU]	Sigma-θ [kg/m^3]
1	101	102	7.715	33.899	26.769
2	101	102	7.724	33.906	26.769
3	101	102	7.720	33.906	26.769
4	100	101	7.724	33.906	26.444
5	101	102	7.723	33.907	26.769
6	101	102	7.719	33.906	26.769
7	100	101	7.695	33.898	26.444
8	41	41	9.495	33.946	26.189
9	33	33	10.675	34.149	26.171
10	25	25	12.215	34.074	25.886
11	13	13	15.146	33.973	25.156
12	8	8	15.158	33.928	25.106