

WHP P17N REVISIT DATA BOOK

Sub-Arctic Gyre Experiment (SAGE)



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Edited by

Hiroshi Uchida (JAMSTEC),

Masao Fukasawa (JAMSTEC)



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Sub-Arctic Gyre Experiment (SAGE)

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Edited by Hiroshi Uchida (JAMSTEC) and Masao Fukasawa (JAMSTEC)

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Preface

P17N is a WHP (WOCE Hydrographic Program) line which crosses the Gulf of Alaska in south-east to north-west direction and was occupied in 1993 by U.S (Chief Scientist: Dr. David Musgrave, University of Alaska). The Gulf of Alaska is an important oceanic region to understand physical characteristics of the North Pacific Sub-Arctic Gyre (NPSAG) because the Western Sub-Arctic Water (WSAW), which is the main water mass in NPSAG, re-circulates there with the meso-thermal water below to form a thick isothermal water mass at subsurface which is supplied to the Bering Sea, and to the Western Gyre again to form a new WSAW. Also the sub-tropical water breaks into the surface of the Gulf of Alaska along the west coast of the American Continent to discharge a considerable amount of heat and salt there. At the same time, it has been well known that the 'zero wind curl line' immigrates meridionally by much more larger magnitude over the Gulf of Alaska than over the Western Gyre of NPSAG. It has been of great interest of many oceanographers what the role the Gulf of Alaska plays to determine the oceanic structure or the stratification of whole North Pacific Sub-Arctic Gyre.

An ocean science program entitled "Sub Arctic Gyre Experiment" (SAGE) began in April 1997 funded by the Japan Science and Technology Agency. The goals of the program were:

1. To detect decadal changes in the structure of the North Pacific Sub-Arctic gyre.
2. To describe an overturn in the Sub-arctic North Pacific which leads to the formation of North Pacific Intermediate Water in the Sub-Tropical North Pacific.
3. To develop ocean numerical model tools including the assimilation of hydrographic data.

As a part of the SAGE field operations, P17N was reoccupied in 2001 collaboratively between the Japan Marine Science and Technology Center (JAMSTEC) and the Fisheries Agency on R/V Mirai of JAMSTEC. The main objectives of the cruise were 1) to inquire into a physical/chemical relation between the sub-surface water in the Gulf of Alaska and the Western Sub-Arctic Water, 2) to find changes in the inter-mediate and the sub-surface water mass structures of the Gulf of Alaska which may be associated with the marked development of the dico-theremal structure after 1985 and 3) to identify whether the decrease in volume of lower m-NADW, which was found along P1 in 1999, was common to all North Pacific basins.

The first leg of MR01K04 was assigned to P17N revisit cruise, and the cruise was the first experience for R/V Mirai to complete a WHP line. R/V Mirai is a big ship of 8,687 gross tonnages.

She can navigate at so fast speed as 15 knots with 40 scientists and technicians. So, there is a great possibility for her to complete even a long hydrographic line within a shorter time period with plural analytical teams. On the other hand, she has very high deck as 10m from the sea surface and has been regarded to be inappropriate for a hydrographic observation. As a solution to this problem, a new winch/crane system, DYNACON system, was introduced to R/V Mirai in 2001. From these points of view, the first leg of MR01K04 can also be regarded as a challenging cruise to make a big research vessel Mirai available for an observation with successive hydrographic casts like WHP.

This booklet contains cruise report, metadata and data collected from the P17N revisit cruise, because we hope and believe that the result of P17N revisit is useful for not only SAGE scientists but also many other researchers in the world.

Finally, we would like to express our gratitude to all participants and crew members of the R/V Mirai of JAMSTEC (Capt. Dr. Masaharu Akamine) for their assistance in carrying out this cruise. Our gratitude also extends to all the staff in supporting divisions in JAMSTEC to complete the cruise.

Masao Fukasawa
SAGE Principal Investigator
Japan Marine Science and
Technology Center
Yokosuka, Kanagawa, Japan

1 Cruise Narrative

1.1 Highlights

WOCE P17N+P17C (eight stations) revisit, R/V Mirai cruise in the Gulf of Alaska

Expedition designation (EXPOCODE): 49MR01K04_1

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Ship: R/V Mirai

Ports of call: Sekinehama, Japan to Dutch Harbor, U.S.

Cruise dates: 23 July 2001 to 27 August 2001

1.2 Cruise Summary

Number of stations

A total of 78 CTDO/rosette stations including two training stations. CTDO was equipped with LADCP and Transmission meter. A General Oceanics 36 bottle rosette was equipped with 36 12-liter Niskin-X water sample bottles.

Sampling

The following sample measurements were made: salinity, oxygen, phosphate, silicate, nitrate, nitrite and CFCs 11, 12 and 113, DIC, pH, total alkalinity and $\Delta^{14}\text{C}$. CTD salinity and oxygen were also measured.

Overview

The first leg of MR01K04 of R/V Mirai was assigned for WHP P17N revisit cruise. The cruise was planned under a Japanese ocean science program of Sub-Arctic Gyre Experiment (SAGE). SAGE re-occupied P1 (47N) in 1999 and reported preliminarily an evidence of bottom water warming, an anomalously strong intrusion of the meso-thermal water into the Gulf of Alaska and large scale up-welling and down-welling at the mid and deeper depths which was explainable as a local response of the ocean to changes in the wind curl field. The objectives of the cruise were, therefore, focused to detect changes in the bottom and deeper water property and in the temperature stratification at sub-surface compared to the results from P17N in 1993. Beside these physical interests, it was also very important objective of the cruise to collect carbon related parameters which were not measured in 1993.

The cruise started on 23 July 2001 at Sekinehama port in Mutsu (Figure 1.1). On the way to the southernmost our WHP revisit station, 64 XCTDs were casted by Japan Fisheries Agency. Also before the first WHP station, two CTD+ROSSET station were occupied for the training of participants. Reference sample water were also collected for radio-active species at one of these stations.

The observation along P17N (+8 stations of P17C) started at P17C_#26 at 19:25 on 6 August 2001. A new DO censer, SBE 43, was used in this cruise. The performance of the sensor was so good (Figure 1.2) that the calibration of the sensor using results from bottle DO measurements can be carried out much easier than before.

A new station of P17N_X01 was added between P17N_#64 and #65 (Figure 1.1) to occupy P1_#92 which is the crossover station of P17N and P1.

On 24 August, we encountered a big low after the station P17N_#83. The wave height exceeded 5m. R/V Mirai had to make a heaving there for more than 24 hours. This time loss resulted in the replacement of CTD lowering at P17N_#93, #95 and #97 with XCTD casting.

The last station of P17N was occupied at 20:52 on 25 August 2001. We made a port at Dutch Harbor on 27 August.

We would like to express our gratitude to Captain Akamine and all crews of Mirai. Also we would like to express our heartfelt thanks to all participants of this cruise.

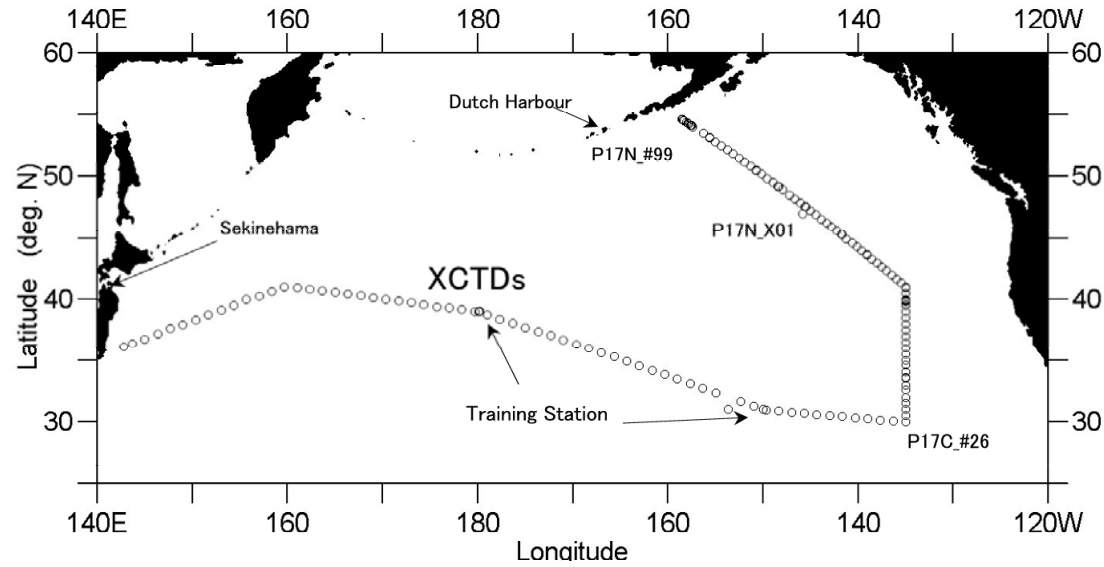


Figure 1.1: Station locations of MR01K04 Leg1.

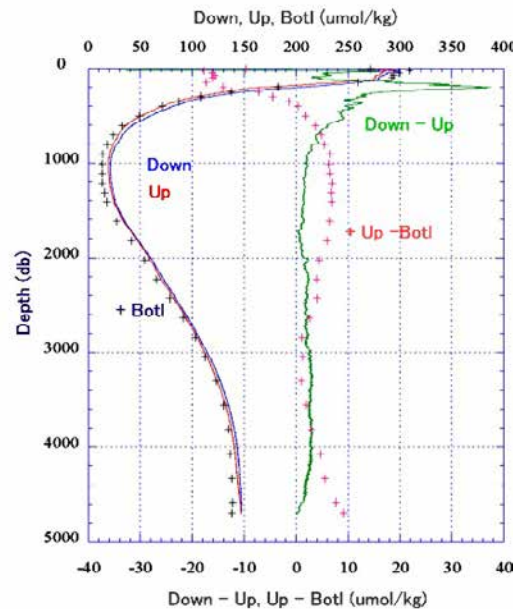
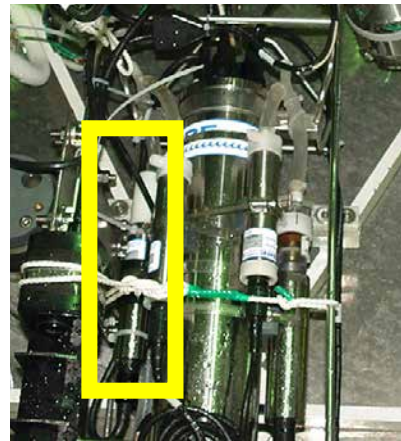


Figure 1.2: left: SBE43, right: Sensor outputs and bottle measured DO values.

1.3 List of Principal Investigators

The principal investigators responsible for the major parameters measured on the cruise are listed below. Also, the persons responsible for the tasks undertaken on the cruise are listed in Table 1.1.

Table 1.1: Principal investigators.

Principal investigator(s)	Person in charge	Responsibility
H. Uchida and M. Fukasawa (JAMSTEC)	S. Ozawa (MWJ)	CTD/O ₂
<i>huchida@jamstec.go.jp, fksw@jamstec.go.jp</i>	<i>satoshi@mwj.co.jp</i>	
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S. Watanabe (JAMSTEC)	A. Murata (JAMSTEC)	CFCs

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JAMSTEC: Japan Marine Science and Technology Center

MWJ: Marine Works Japan, Ltd.

GODI: Global Ocean Development, Inc.

TNFRI: Tohoku National Fisheries Research Institute

1.4 List of Cruise Participants

The members of the scientific party are listed in Table 1.2 along with their main tasks undertaken on the cruise.

Table 1.2: Cruise participants.

Name	Affiliation	Main tasks
Masao Fukasawa	JAMSTEC	LADCP
Yasushi Yoshikawa	JAMSTEC	LADCP
Hiroshi Uchida	JAMSTEC	LADCP
Takeshi Kawano	JAMSTEC	Salinity
Akihiko Murata	JAMSTEC	CFCs
Tomowo Watanabe	TNFRI	XBT/XCTD
Munehito Kimura	KANSO	Nutrients
Takashi Kitao	KANSO	TCO ₂ , CFCs
Nobuharu Komai	MWJ	Oxygen
Satoshi Ozawa	MWJ	CTD operations
Fuyuki Shibata	MWJ	Alkalinity, pH
Katsunori Sagishima	MWJ	Oxygen
Takeo Matsumoto	MWJ	Salinity
Ai Yasuda	MWJ	Nutrients
Mikio Kitada	MWJ	TCO ₂
Kenichiro Sato	MWJ	Nutrients
Keisuke Wataki	MWJ	Alkalinity, pH
Hiroshi Matsunaga	MWJ	CTD operations
Taeko Ohama	MWJ	Alkalinity, pH

Minoru Kamata	MWJ	TCO ₂ , CFCs
Junko Hamanaka	MWJ	Nutrients
Asako Kubo	MWJ	Nutrients
Yuichi Sonoyama	MWJ	Oxygen
Tomoko Miyashita	MWJ	Oxygen
Naoko Takahashi	MWJ	CTD operations
Shinya Iwamida	GODI	Meteorology, XBT/XCTD
Souichiro Sueyoshi	GODI	ADCP, Bathymetry, XBT/XCTD
Yosuke Inoue	Tokyo University of Fisheries	Water sampling
Hisami Suga	Hokkaido University	Water sampling
Tomokazu Hirata	Tokai University	Water sampling
Fuma Matsunaga	Kagoshima University	Water sampling
Satoko Katsuyama	Tokai University	Water sampling
Tae Yamamoto	Tokai University	Water sampling
Takahiro Miura	Tohoku University	Water sampling

JAMSTEC: Japan Marine Science and Technology Center

MWJ: Marine Works Japan, Ltd.

GODI: Global Ocean Development, Inc.

TNFRI: Tohoku National Fisheries Research Institute

KANSO: Kansai Environmental Engineering Center Co., Ltd.

2 Underway Measurements

2.1 Sea Bottom Topography Measurement

13 Mar 2002

(1) Personnel

Souichiro Sueyoshi (GODI): Operation Leader

Shinya Iwamida (GODI)

(2) Objectives

To obtain bathymetry data contributes to geophysical investigation, and supports for CTD and sea water sampling observation.

(3) Methods

The observation was carried out from 24 July 2001 to 26 August 2001. Bathymetry data were obtained continuously by SeaBeam2112.004 (SeaBeam, Inc., USA) 12kHz multi-narrow beam echo sounding system. In order to measure accurate depth, precise sound velocity profiles were calculated from the temperature profile of water column. During this cruise, XCTD/CTD data and SSV data were used to calculate the sound velocity profiles for most of stations.

(4) Data archive

The dataset obtained in this cruise will be submitted to the DMO (Data Management Office), JAMSTEC and will be archived there.

3 Hydrographic Measurement Techniques and Calibrations

3.1 Sample Salinity Measurements

15 Dec 2003

(1) Personnel

Takeshi Kawano (JAMSTEC)

Takeo Matsumoto (MWJ)

(2) Objectives

Bottle salinities were measured in order to be compared with CTD salinities to identify leaking bottles and calibrate CTD salinities.

(3) Instrument and Method

Salinity Sample Collection

The bottles in which the salinity samples are collected and stored are 250 ml Phoenix brown glass bottles with screw caps. Each bottle was rinsed three times with sample water and was filled to the shoulder of the bottle. The caps were also thoroughly rinsed. Salinity samples were stored at least 12 hours in the same laboratory as the salinity measurement was made.

Instruments and Method

The salinity analysis was carried out on two Guildline Autosal salinometers model 8400B (S/N 62556, 62827). The salinometer with serial number of 62827 was used at station P17N-56 to 59 and that with serial number of 62556 was used at the other stations. The salinometers were modified by addition of an Ocean Science International peristaltic-type sample intake pump and two Guildline

platinum thermometers model 9450. One thermometer monitored an ambient temperature and the other monitored a bath temperature. The resolution of the thermometers was 0.001 °C. The measurement system was almost same as Aoyama et al (2002). The salinometer was operated in the air-conditioned ship's laboratory at a bath temperature of 24 °C. An ambient temperature was about 23 °C and varied within ± 1 °C, while a bath temperature is varied from 23.940 to 23.954 day by day with the short term instability of ± 0.004 °C. This may be caused by the temperature difference between samples and the bath due to the insufficient time of storage.

A measure of a double conductivity ratio of a sample is taken as a median of thirty-one reading. Data collection was started after 5 seconds and it took about 10 seconds to collect 31 readings by a personal computer. Data were sampled for the sixth and seventh filling of the cell. In case the difference between the double conductivity ratio of this two fillings is smaller than 0.00003, the average value of the two double conductivity ratios was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). If the difference was greater than or equal to the 0.0003, we measured eighth filling of the cell. In case the double conductivity ratio of eighth filling did not satisfy the criteria above, we measured ninth and tenth filling of the cell and the median of the double conductivity ratios of five fillings are used to calculate the bottle salinity.

(4) Preliminary Result

Standard Seawater

From the stations P17C-26 to P17N-55, the STANDBY of the Autosal S/N 62556 was 6116 ± 0001 and ZERO was 0.00000 to 0.00001. Because the Autosal S/N 62556 became unstable after P17N-55, we measured the salinity by the salinometer S/N 62827 from P17N-56 to P17N-59. During this period, the STANDBY was 6147 ± 0001 and ZERO was 0.00000 to 0.00001. We used Autosal S/N 62556 again from P17N-60 to the last station after the cell was removed and washed thoroughly. Then the STANDBY was changed to 6118 ± 0001 and ZERO was 0.00000 to 0.00001.

We used IAPSO Standard Seawater batch P139 whose conductivity ratio was 0.99993 (double conductivity ratio is 1.99986) as the standard for salinity.

very stable as mentioned above, we made a linear correction at every station using the measured double conductivity ratio of SSW.

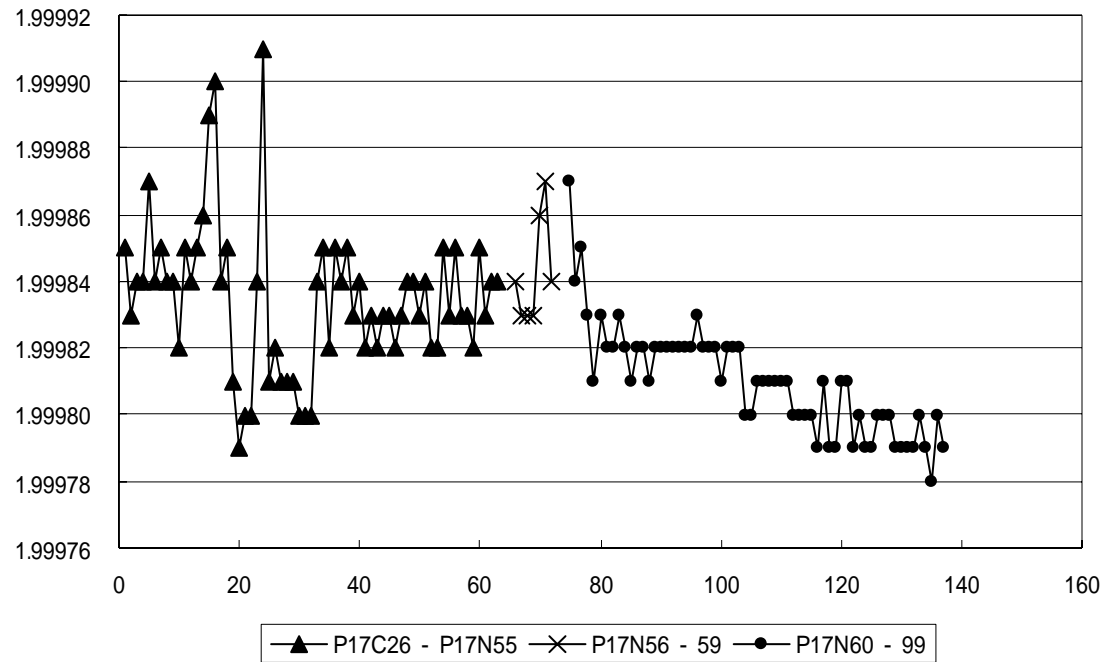


Figure 3.1.1: The history of the measured double conductivity ratio of SSW.

Figure 3.1.1 shows the history of the measured double conductivity ratio of SSW. During the measurement from the stations P17C-26 to P17N-55, we measured 63 ampoules of P139 and the average of the double conductivity ratio was 1.99983 and the standard deviation was 0.000022, which is equivalent to 0.0004 in salinity. During the measurement from the stations P17N-56 to P17N-59, we measured 7 ampoules and the average was 1.99984 and the standard deviation was 0.000016, which is equivalent to 0.0003 in salinity. During the measurement from the stations P17N-60 to P17N-99, we measured 63 ampoules and the average of the double conductivity ratio was 1.99981 and the standard deviation was 0.000016, which is equivalent to 0.0003 in salinity. Since the bath temperature was not

Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered by pore size of 0.45 micrometer and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measuring. It was measured every six samples in order to check the possible sudden drift of the salinometer. During the whole measurements, there was no detectable sudden drift of the salinometer.

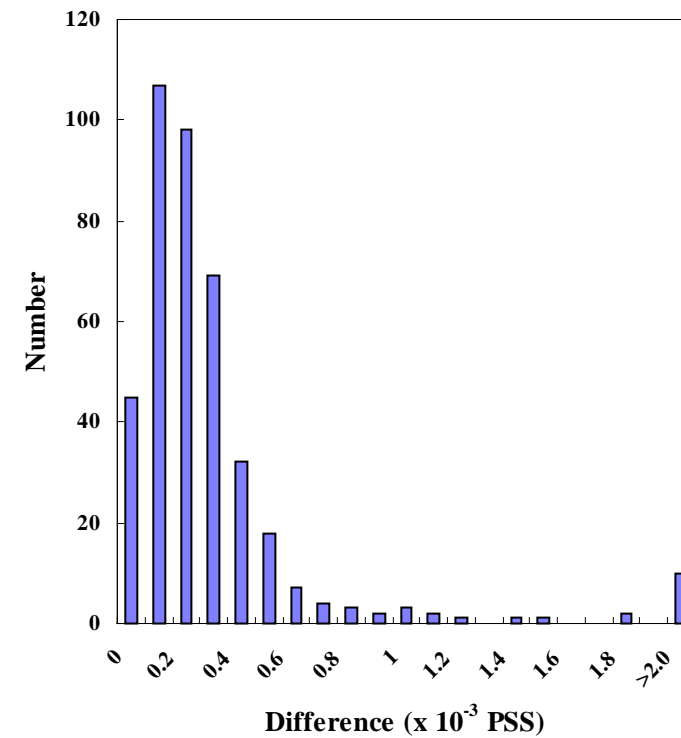


Figure 3.1.2: The histogram of the absolute difference between replicate samples.

Replicate Samples

406 pairs of replicate were measured. Figure 3.1.2 shows the histogram of all the absolute difference between replicate samples. When we consider measurements below 1,000m (263 pairs), the average and the standard deviation were 0.00020 and 0.00014, respectively in salinity.

(5) References

Aoyama, M., T. Joyce, T. Kawano and Y. Takatsuki: Standard seawater comparison up to P129.

Deep-Sea Research, I, Vol. 49, 1103-1114, 2002

UNESCO: Tenth report of the Joint Panel on Oceanographic Tables and Standards. UNESCO Tech.

Papers in Mar. Sci., 36, 25 pp., 1981

3.2 Sample Dissolved Oxygen Measurements

13 Mar 2002

10 Feb 2004 updated

(1) Personnel

Masao Fukasawa (JAMSTEC)

Nobuharu Komai (MWJ)

Katsunori Sagishima (MWJ)

(2) Equipment and techniques

Bottle oxygen samples were taken in calibrated clear glass bottle of 200 ml capacity before other samples were drawn. Each glass cap of sampling bottle has a column stem of 7cm long and 2cm diameter to make the fixing and the in-bottle titration easy. The bottle and the cap were dried up well before the sampling. Before the fixing, three bottles volume of the sea water was over flowed. The stem on the cap was not rinsed. The temperature of the water was measured at the time of the drawing for 12 of 36 Niskin bottles to check and to allow corrections for the change in density of the sampled water between the closure of the rosette bottle and the fixing of the dissolved oxygen. As for samples of which the water temperature was not measured, potential temperature calculated from CTD results was used after a correction based on the measured temperature data and CTD data. Analysis followed the whole bottle method. The thiosulfate titrations were carried out using two sets of titrators in a controlled environmental laboratory maintained at temperature between 24 °C and 27 °C. The normality of thiosulfate was set to be 0.07 when the regents were made up, and checked their changes every other day (Table 3.2.1). Replicate samples were taken from six bottles (deepest bottle and DO minimum bottle are always included) on every cast.

The end point of titration was determined by an electrode method following Culberson and Huang (1987) using a Metrohm Titrator and DOSIMAT (Switzerland) auto burette with 10 ml cylinder.

Titration volume were always smaller than 6 ml and the smallest increment from the burette was 1 micro liters.

The volume of oxygen dissolved in the water was converted to mass fraction by use of the factor 44.66 and an appropriate value of the density; corrections for the volume of oxygen added with reagents and for impurities in the manganese chloride were also made as described in the WOCE Manual of Operation and Methods (Culberson, 1991, WHPO 91-1).

Table 3.2.1: Concentration of tiosulfate used for DO titration.

Titrator A		Concentration				
Date	lot	KIO3	Vstd	Vblank	of Tiosulfate	
2001/8/6	10622	0.001668	1.409	-0.004	0.0707 St26-St19	
2001/8/8	10622	0.001668	1.401	-0.004	0.0711 St18-St44	
2001/8/12	10622	0.001668	1.409	-0.002	0.0708 St45-51	
2001/8/14	10622	0.001668	1.415	-0.002	0.0705 St52-68	
2001/8/16	10622	0.001668	1.409	-0.003	0.0708 St69-74	
2001/8/20	10622	0.001668	1.409	-0.003	0.0708 St75	
2001/8/22	10622	0.001668	1.410	-0.003	0.0707 St76-99	
2001/8/26	10622	0.001668	1.413	-0.004	0.0705 after analyse	
Stdev (N)					0.0002	
Average (N)					0.0708	
R.S.D (%)					0.3	

Titrator B		Concentration				
Date	lot	KIO3	Vstd	Vblank	of Tiosulfate	
2001/8/6	10622	0.001668	1.411	-0.005	0.0706 St26-St19	
2001/8/8	10622	0.001668	1.400	-0.005	0.0711 St18-St44	
2001/8/12	10622	0.001668	1.411	-0.005	0.0706 St45-51	
2001/8/14	10622	0.001668	1.413	-0.003	0.0706 St52-68	
2001/8/16	10622	0.001668	1.412	-0.002	0.0707 St69-74	
2001/8/20	10622	0.001668	1.412	-0.002	0.0707 St75	
2001/8/22	10622	0.001668	1.414	-0.005	0.0704 St76-99	
2001/8/26	10622	0.001668	1.411	-0.001	0.0708 after analyse	
Stdev (N)					0.0002	
Average (N)					0.0707	
R.S.D (%)					0.3	

(3) Repeatability of measurement

During the cruise 2420 samples were taken including 513 of replicates. Statistics on the replicates are given in Table 3.2.2. These statistics were estimated including both replicates samples and those collected from duplicate bottles. Taking numbers shown in Table 3.2.1 into account, it is possible to state that the accuracy of the bottle DO measurements was 0.24 $\mu\text{mol/kg}$ rms. The bottle DO measurement almost could achieve WOCE standard not only for the precision but also for the accuracy. Much more cares for the fixing procedure will be a great help to improve the repeatability of the measurement.

Table 3.2.2: Statistics of replicates and duplicate obtained during the cruise.

Number of replicates	mean difference	Oxygen concentration $\mu\text{mol/kg}$		%mean
		Std. dev		
473	0.28 $\mu\text{mol/kg}$	0.22 $\mu\text{mol/kg}$		0.19

(4) References

- Culberson, C.H. and S. Huang (1987): Automated Amperometric Oxygen titration, Deep-Sea Res., 34, 875-880.
- Culberson C.H. (1991): Dissolved oxygen, WOCE Operations Manual, WOCE Report No.68/91, Woods Hole, MA.

3.3 Nutrients

30 Apr 2004

(1) Personnel

Shuichi Watanabe (JAMSTEC)

Kenichiro Sato (MWJ)

Junko Hamanaka (MWJ)

Asako Kubo (MWJ)

Ai Yasuda (MWJ)

(2) Instruments and Methods

Nutrient analysis was performed on BRAN+LUEBBE TRAACS 800 system that has 4-channel analyzing lines for nitrate, nitrite, silicate and phosphate. The system was improved by BRAN+LUEBBE for seawater analysis. This analytical procedure recommended with BRAN+LUEBBE is similar to WOCE procedure.

a. Measured Parameters

Nitrite: Nitrite was determined by diazotizing with sulfanilamide and coupling with N-1-naphthyl-ethylenediamine (NED) to form a colored azo dye that was measured at absorbance of 550 nm using 5 cm length cell.

Nitrate: Nitrate in seawater is reduced to nitrite by reduction tube (Cd - Cu tube), and the nitrite determined by the method described above, but the flow cell used in nitrate analysis was 3 cm length cell. Nitrite initially present in the sample is corrected.

Silicate: The standard AAI molybdate-ascorbic acid method was used. The silicomolybdate produced is measured at absorbance of 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. The phospho-molybdate produced is measured at absorbance of 880 nm using a 5 cm length cell.

b. Nutrients Standard

Silicate standard solution, the silicate primary standard, is obtained from Kanto Kagaku Co., Ltd. This standard solution is 1000 mg per liter in 0.5 M KOH solution for atomic absorption spectrometry. Primary standard solution for nitrate (KNO_3), nitrite (NaNO_2) and phosphate (KH_2PO_4) was prepared from special grade reagents of Wako Pure Chemical Industries, Ltd.

c. Sampling and analytical Procedures

Samples were drawn into polypropylene 100 ml small mouth bottle. These were rinsed twice before filling. The samples were analyzed as soon as possible. Sets of 5 different concentrations of shipboard standards were analyzed at beginning.

(2) Precision and Accuracy

Standard deviations of Nitrate, phosphate and silicate concentrations are respectively 0.22, 0.01 and 0.43 $\mu\text{mol/kg}$, which obtained from difference between two samples collected two Niskin bottles at same layers. The flow designs of TRACCS are easy to be contaminated with last sample by heating bath that was used narrow tube. This flow designs caused sometime high contaminating values.

Concentration of each sample was calculated and corrected by marker sample following Bran-Luebbe method. This marker sample were put into every about 20 samples. The absorbance of marker sample was unstable, especially silicate analysis. This unstable absorbance value was caused irregular concentration by contamination, ambient temperature and others. In case of silicate analysis, this unstable absorbance and the correction of marker samples might be reached to low precision.

Nutrients measured twice for same sample in principle. In the case of large difference between two measurement values obtaining, one value was excepted after comparing with another nutrients

concentrations and dissolved oxygen content and checking vertical profiles of near stations.

Accuracy of our method depended on our standard concentration. The standard was prepared before analyzing. These prepared standard concentrations for each analysis might not be consistent. Silicate standard was prepared with diluting Kanto standard solution. This solution is diluted with 0.5M KOH. During preparation of working standard, solution's pH is adjusted. This procedure might cause decreasing of accuracy.

The obtained values are compared with WOCE data obtained in 1990s. Nitrate, phosphate, silicate and dissolved oxygen concentrations below 2000 dbar were used for this comparison. Trend between phosphate and dissolved oxygen obtained our work ($PO_4 = -0.0050 \times DO + 3.293$, $r^2 = 0.967$) is almost same to that of 1990s' data ($PO_4 = -0.0051 \times DO + 3.289$, $r^2 = 0.978$). Nitrate values of this work are 1.4 – 1.9% higher than those of 1990s. Trends of this work between nitrate/dissolved oxygen, and nitrate/phosphate are $NO_3 = -0.0644 \times DO + 46.41$ ($r^2 = 0.992$) and $NO_3 = 12.454 \times PO_4 + 5.13$ ($r^2 = 0.957$). Those of 1990s are $NO_3 = -0.0636 \times DO + 45.78$ ($r^2 = 0.969$) and $NO_3 = 12.223 \times PO_4 + 5.48$ ($r^2 = 0.985$). Values of this work differ about 7% from those of 1990s. This difference is large. Relations between silicate and dissolved oxygen concentrations below 2000dbar without three bottom layers are $SiO_2 = -0.00248 \times DO^2 + 0.4150 \times DO + 144.64$ ($r^2 = 0.60413$) and $SiO_2 = -0.00288 \times DO^2 + 0.4876 \times DO + 154.19$ ($r^2 = 0.58946$). Silicate concentration is not related with that of dissolved oxygen directly. However, difference between intercept values (about 10 $\mu\text{mol/kg}$) is larger than other cruise.

(3) References

Murphy, J. and J. P. Riley (1962): A modified single solution method for determination of phosphate in natural waters, *Anal. Chim. Acta.*, 27, 31-36.

3.4 Total alkalinity (A_T)

13 Mar 2002

(1) Personnel

Akihiko Murata (JAMSTEC)

Fuyuki Shibata (MWJ)

Keisuke Wataki (MWJ)

Taeko Ohama (MWJ)

(2) Sample collection

All sea water samples collected from depth using 12 liter Niskin bottles at every two stations. The sea water samples for A_T were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into high-density polyethylene (PE) bottles with an inner cup. The PE bottle was filled with sea water smoothly from the bottom after rinsing it twice with a small volume of sea water. The sea water samples were kept at 4 °C in a refrigerator until analysis. A few hours before analysis, the sea water samples were kept at 25 °C in a water bath.

(3) Instrument and technique

A sea water of approx. 100 ml was transferred into a tall beaker of 200 ml (open cell) from a PE bottle using a calibrated pipette (101.63 or 102.14 ml). The water temperature at pipetting was recorded to know transferred water volume.

Measurement of A_T was made using a titration system which comprises of a titration manager (TIM900, Radiometer) and auto-burette (ABU901, Radiometer). A combination of a pH glass electrode (pHG201, Radiometer) and a reference electrode (REF201, Radiometer) was used to monitor changes of emf by titrating a sea water sample by an acid (0.1N HCl + 0.6N NaCl). The best combination of the electrodes was selected by checking titration curves of NaCl solutions titrated by

0.01N HCl. The titration was made in a thermostat bath kept at 25 °C, and was controlled by PC with a burette operation software (Tim Talk 9, Lab Soft).

Calculation of A_T was made based on a modified Gran approach.

(4) Calibration of acid titrant

Calibration of acid titrant was made by measuring A_T of 4 solutions of Na_2CO_3 in 0.7N NaCl solutions. The computed A_T s were approx. 0, 1000, 2000 and 2500 $\mu\text{mol kg}^{-1}$.

The measured values of A_T (calculated by assuming 0.1N) should be a linear function of the A_T contributed by the Na_2CO_3 . The line is fitted by the method of a least square. Theoretically, the slope should be unity. If the measured slope is not equal to one, the acid normality should be adjusted by dividing initial normality by the slope, and the whole set of calculations is repeated until the slope = 1 is obtained.

The normality of the acid titrant used was 0.098211N.

(5) Calibration of titrant dispensing tips

‘To deliver’ volumes of the auto-burette were calibrated with pure water. Volumes of 2, 3, 4 ml delivered by the auto-burette were calibrated.

Precision and accuracy

We collected replicate samples at an interval of 5 to 8 sampling depth, approx. 5 replicate samples for each water column. The average difference of field replicate analyses was calculated to be $2.6 \pm 2.6 \mu\text{mol kg}^{-1}$ (n = 181).

The CRMs (mostly Bach #54 and two Bach #53) were measured to remove biases between analyzed values of samples. The average difference between the analysed values of CRM and the certified value (2342.09 $\mu\text{mol kg}^{-1}$; Bach #45) was calculated to be $3.6 \pm 3.3 \mu\text{mol kg}^{-1}$ (n = 18).

All the values reported were recalibrated against certified values of CRMs.

(6) Comparison with the past P17 data

The A_T s obtained by the past P17 observation are shown in Figure 3.4.1, together with the A_T s obtained in this cruise. According to Lamb et al. (2002), 12 $\mu\text{mol kg}^{-1}$ was subtracted from the values of the past P17 observation.

From Figure 3.4.1, it is found that in the deep layers, A_T s obtained in this cruise accord well with the A_T s obtained in the past P17 cruise. However, further detailed investigations are necessary for evaluating accurate differences between the cruises.

(7) References

Lamb, M.F., Sabine, C.L., Feely, R.A., Wanninkhof, R., Key, R.M., Johnson, G.C., Millero, F.J., Lee, K., Peng, T.-H., Kozy, A., Bullister, J.L., Greeley, D., Byrne, R.H., Chipman, D.W., Dickson, A.G., Goyet, C., Guenther, P.R., Ishii, M., Johnson, K.M., Keeling, C.D., Ono, T., Shitashima, K., Tilbrook, B., Takahashi, T., Wallace, D.W.R., Watanabe, Y.W., Winn, C., and Wong, C.S. 2002. Consistency and synthesis of Pacific Ocean CO_2 survey data. *Deep-Sea Res. II*, **49**, 21-58.

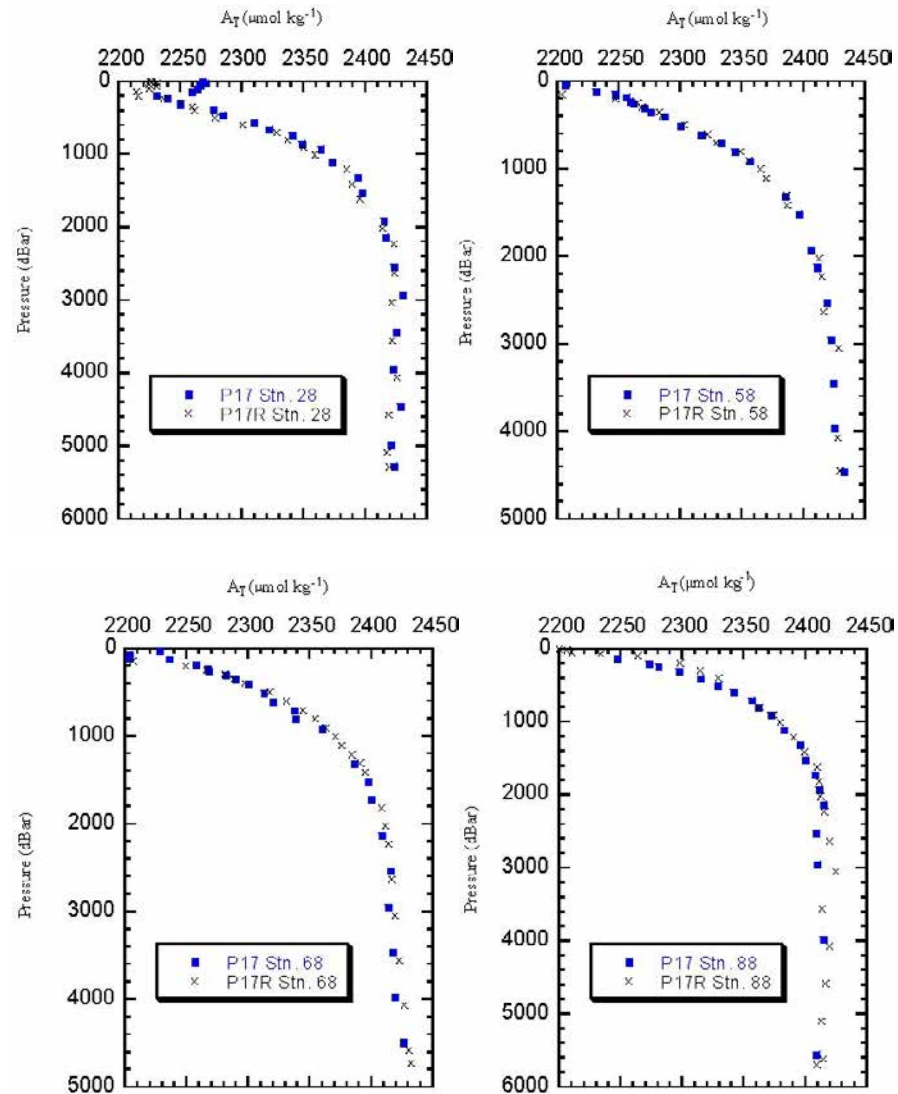


Figure 3.4.1: Vertical distributions of A_T obtained in the past P17 (solid squares) and in this cruise (crosses).

3.5 Total carbon (C_T)

13 Mar 2002

(1) Personnel

Akihiko Murata (JAMSTEC)

Mikio Kitada (MWJ)

Minoru Kamata (MWJ)

Takashi Kitao (KANSO)

(2) Sample collection

All sea water samples collected from depth using 12 liter Niskin bottles at every two stations. The sea water samples for C_T were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into 300 ml borosilicate glass bottles. The glass bottle was filled with sea water smoothly from the bottom following a rinse with a sea water of 2 full, bottle volumes. A head-space of approx. 1 % of the bottle volume was left by removing sea water using a plastic pipette. A saturated mercuric chloride of 50 μ l (later changed to 100 μ l) was added to poison the sea water samples. The glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd) ground glass stopper and the clips were secured. The sea water samples were kept at 4 °C in a refrigerator until analysis. A few hours before analysis, the sea water samples were kept at 20 °C in a water bath.

(3) Instrument and technique

Measurements of C_T were made with the total CO_2 measuring system (Nippon ANS, Ltd) installed in the R/V *Mirai* of JAMSTEC. The system comprises of a sea water dispensing system, a CO_2 extraction system and a coulometer (Model 5012, UIC Inc.).

The sea water dispensing system has an auto-sampler (6 ports), which takes sea water in a 300 ml borosilicate glass bottle and dispenses the sea water to a pipette of nominal 30 ml volume by PC control.

The pipette was kept at 20 °C by a water jacket, in which water from a water bath set at 20 °C was circulated.

CO₂ dissolved in a sea water sample was extracted in a stripping chamber of the CO₂ extraction system by adding phosphoric acid (10 % v/v). The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. To degas CO₂ as quickly as possible, heating wire kept at 40 °C is rolled from the bottom to a 1/3 height of the stripping chamber. The acid was added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out the right amount of acid. The pressurizing was made with nitrogen gas (99.9999 %). After the acid was transferred to the stripping chamber, a sea water sample kept in a pipette was introduced to the stripping chamber by the same method as in adding an acid. The sea water reacted with phosphoric acid was stripped of CO₂ by bubbling the nitrogen gas through a fine frit at the bottom of the stripping chamber. The CO₂ stripped in the chamber was carried by the nitrogen gas (flow rate of 130 ml min⁻¹) to the coulometer through a dehydrating module. The module consists of two electric dehumidifiers (kept at 1 °C) and a chemical desiccant (Mg(ClO₄)₂).

The measurement sequence such as system blank (phosphoric acid blank), 2 % CO₂ gas in a nitrogen base, sea water samples (4) was programmed to repeat. The measurement of 2 % CO₂ gas was made to monitor response of coulometer solutions (from UIC, Inc.).

(4) Calibration

Calibration was made using 6 Na₂CO₃ solutions of nominal 0, 500, 1000, 1500, 2000 and 2500 μmol dm⁻³. The slope of the linear regression equation ($R^2 = 1.00000$) was used as the calibration factor. Certified reference materials (CRM; Bach #54) provided by Prof. A.G. Dickson of SIO were measured when a coulometer solution was renewed. For a renewed coulometer solution, samples of two stations (approx. 80 samples) were measured. Reference materials (RM) produced by KANSO and JAMSTEC were measured subsequently to CRM and at about half a time of one coulometer span. All the values reported were recalibrated against the certified value of CRM.

(5) Stability of the measuring system

Changes of C_T due to changes of response of a coulometer were monitored by measuring 2 % CO₂ gas periodically; coulometer counts of the 2 % CO₂ gas at respective sample measurements were interpolated from the measured coulometer counts of the gas, which were obtained at every 6 measurements. Then, based on the count assigned to each sample measurement, C_{TS} were corrected so as to be measured at the coulometer response of CRM measurement.

The values of CRM measured during the operation of the system are plotted as a function of day (Figure 3.5.1). From this figure, it is found that there was a decreasing trend of measured values. We believe that this was caused by a contamination of a pipette.

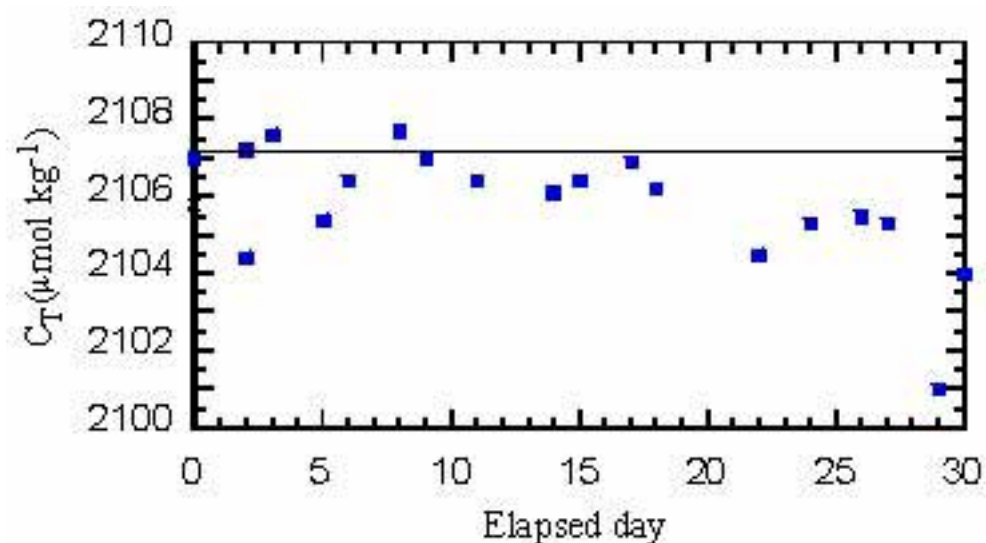


Figure 3.5.1: Plots of measured values of CRM (Bach #54) as a function of day during the cruise. The horizontal line indicates the certified value of 2107.35 μmol kg⁻¹.

(6) Uncertainty

We collected replicate samples at an interval of 5 to 8 sampling depth, approx. 5 replicate samples for each water column. The average difference of field replicate analyses was calculated to be $1.5 \pm 1.4 \mu\text{mol kg}^{-1}$ ($n = 183$).

The CRMs were measured twice from one bottle. The number of measurement was 38 (19 pairs) in total. The average value of the two analyses was used for CRM correction. The average difference between the average of the two CRM analyses and the certified value ($2107.35 \mu\text{mol kg}^{-1}$) was $1.5 \pm 1.5 \mu\text{mol kg}^{-1}$.

(7) Comparison with the past P17 data

The C_T s obtained by the past P17 observation are shown in Figure 3.5.2, together with the C_T s obtained in this cruise. $7 \mu\text{mol kg}^{-1}$ was subtracted from the values of the past P17 observation, according to Lamb et al. (2002). From the figures, it is found that in the deep layers, C_T s obtained in this cruise accord well with the C_T s obtained in the past P17 cruise. However, further detailed investigations are necessary for evaluating accurate differences between the cruises.

(8) References

Lamb, M.F., Sabine, C.L., Feely, R.A., Wanninkhof, R., Key, R.M., Johnson, G.C., Millero, F.J., Lee, K., Peng, T.-H., Kozy, A., Bullister, J.L., Greeley, D., Byrne, R.H., Chipman, D.W., Dickson, A.G., Goyet, C., Guenther, P.R., Ishii, M., Johnson, K.M., Keeling, C.D., Ono, T., Shitashima, K., Tilbrook, B., Takahashi, T., Wallace, D.W.R., Watanabe, Y.W., Winn, C., and Wong, C.S. 2002. Consistency and synthesis of Pacific Ocean CO_2 survey data. *Deep-Sea Res. II*, **49**, 21-58.

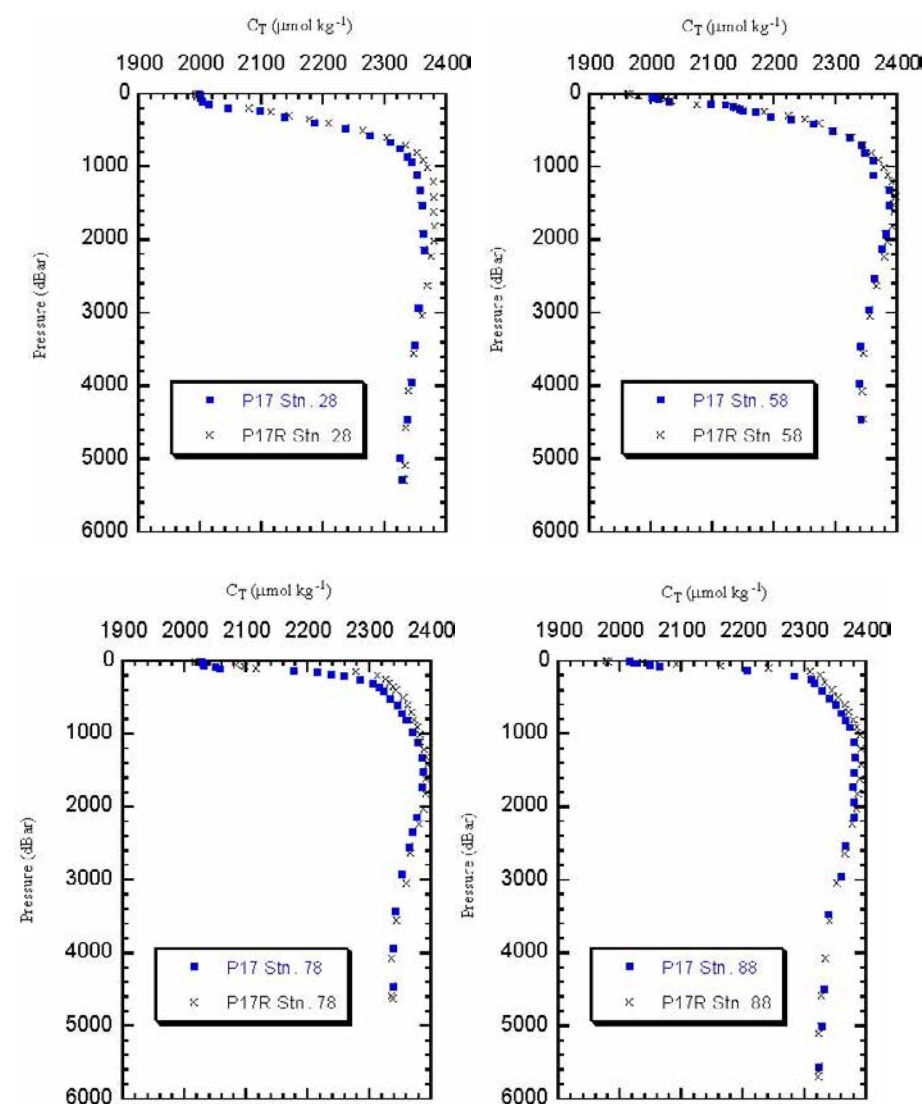


Figure 3.5.2: Vertical distributions of C_T obtained (solid squares) in the past P17 and (crosses) in this cruise.

3.6 pH

13 Mar 2002

(1) Personnel

Andray Andreev (JAMSTEC)

Akihiko Murata (JAMSTEC)

Taeko Ohama (MWJ)

(2) Sample collection

All seawater samples collected from depth using 12 liter Niskin bottles at every two stations. The seawater samples for pH were taken with a plastic drawing tube (PEA tubing connected to silicone rubber tubing) into high-density polyethylene (PE) bottles with an inner cup. The PE bottle was filled with seawater smoothly from the bottom after rinsing it twice with a small volume of seawater. Special care was given to allow no air space in the samples. The sea water samples were kept at 4 °C in a refrigerator until measurement. A few hours before measurement, the seawater samples were kept at 25 °C in a water bath.

(3) Instrument and technique

Separate glass (Radiometer PHG201) and reference (Radiometer REF201) electrodes were used. The emf of the glass / reference electrode cell was measured with a pH / Ion meter (Radiometer PHM95). In order not to have seawater sample exchange CO₂ with the atmosphere during pH measurement, closed glass container with water jacket was used. The temperature during pH measurement was monitored with temperature sensor (Radiometer T901) and controlled at 25 °C within ±0.1 °C.

(4) Calibration

To calibrate the electrodes the TRIS (pH=8.0936 pH unit at 25 °C; Delvalls and Dickson, 1998) and AMP (pH=6.786 pH unit at 25 °C; DOE, 1994) in the synthetic seawater (S=35 PSU) (total hydrogen scale) were applied.

pH_T of seawater sample (pH_{samp}) is calculated from the expression:

$$\text{pH}_{\text{samp}} = \text{pH}_{\text{TRIS}} + (E_{\text{TRIS}} - E_{\text{samp}}) / ER$$

where electrode response, ER, is calculated as follows:

$$ER = (E_{\text{AMP}} - E_{\text{TRIS}}) / (\text{pH}_{\text{TRIS}} - \text{pH}_{\text{AMP}})$$

ER value should be equal to the ideal Nernst value as follows:

$$ER = RT \text{LN}(10) / F = 59.16 \text{ mV} / \text{pH unit at } 25 \text{ }^\circ\text{C}.$$

(5) Precision and accuracy

At each station, 4 to 6 duplicate samples were measured, 180 pairs in total. The average difference was calculated to be 0.003 ± 0.003 pH unit.

(6) References

DelValls, T.A., and Dickson, A.G. 1998. The pH of buffers based on 2-amino-2-hydroxymethyl-1,3-propanediol ("tris") in synthetic seawater. *Deep-Sea Res.*, **45**, 1541-1554.

DOE. 1994. In: Dickson, A.G., and Goyet, C. (Eds.), Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water, version 2, ORNL/CDIAC-74.

3.7 CFCs

13 Mar 2002

(1) Personnel

Shuichi Watanabe (JAMSTEC)

Akihiko Murata (JAMSTEC)

(2) Sample collection

All sea water samples were collected from depth using 12 liter Niskin bottles at every two stations. Duplicate sea water samples were taken from each Niskin bottle following sampling for oxygen. The sea water samples were transferred with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) to glass ampoules of a volume of approx. 100 ml. The ampoule was filled with sea water smoothly from the bottom following a rinse with a sea water of 2 full, ampoule volumes. To prevent the samples from contamination from ambient air, the mouths of the ampoules were covered with a small glass container immediately after sampling. The ampoules were flame-sealed under nitrogen (99.9999 %) flow.

(3) Measurements

Analysis has not been finished yet (Feb 2004).

3.8 Carbon Isotope Ratios in dissolved inorganic carbon ($\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$)

25 Nov 2002

(1) Personnel

Yuichiro Kumamoto (JAMSTEC)

(2) Sample collection

The sampling stations and number of samples are summarized in Figure 3.8.1 and Table 3.8.1. A total of 715 samples, including 60 replicate samples, were collected at 21 stations. The samples were collected from surface (about 10 m depth) to near bottom using 12 liter Niskin bottles. The seawater was siphoned into a 250 ml glass bottle with enough seawater to fill the glass bottle 2 times. Immediately after sampling, 5 ml of seawater was removed from the bottle and poisoned by 50 μl of saturated HgCl_2 solution. Then the bottle was sealed by a glass stopper with Apiezon M grease and stored in a cool and dark space on board. The sampling procedure on board basically follows the method in WOCE Operation Manual (McNichol and Jones, 1991).

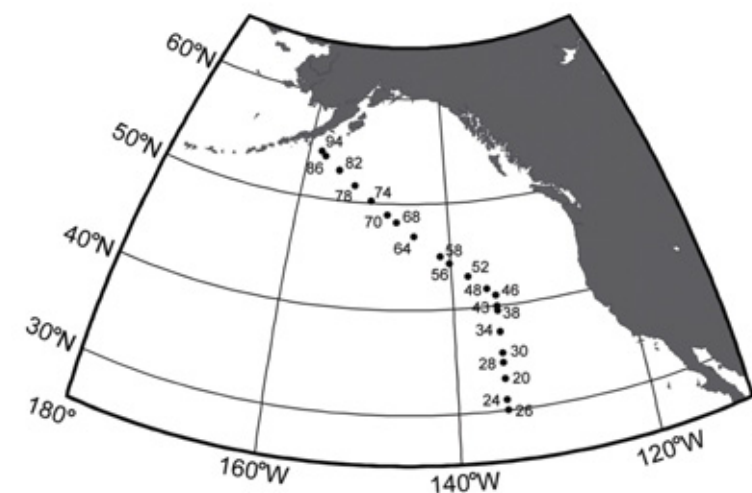


Figure 3.8.1: Sampling stations for carbon isotope ratios during P17N revisit cruise in August 2001.

Table 3.8.1: The sampling locations, date, number of samples, and maximum sampling pressure.

Station	Date	Latitude N degree	Longitude W degree	Number of samples	Number of replicate samples	Max. sampling pressure /db
26	8/06/01	30.000	134.995	32	3	4549
24	8/07/01	31.011	135.002	31	0	4705
20	8/08/01	33.003	135.003	30	3	4906
28	8/08/01	34.588	135.004	30	30	5288
30	8/09/01	35.504	135.010	30	0	5305
34	8/10/01	37.501	135.002	30	3	5309
38	8/11/01	39.504	135.011	30	0	4963
43	8/12/01	39.970	135.010	34	3	3742
46	8/12/01	40.991	134.987	32	0	4113
48	8/13/01	41.642	135.992	32	3	3949
52	8/14/01	42.966	138.053	32	0	4065
56	8/15/01	44.294	140.149	31	3	4445
58	8/15/01	44.949	141.231	31	0	4457
64	8/17/01	46.899	144.444	31	3	4742
68	8/18/01	48.208	146.685	31	0	4730
70	8/18/01	48.914	147.907	31	3	4846
74	8/19/01	50.171	150.137	31	0	4800
78	8/22/01	51.473	152.550	31	3	4635
82	8/23/01	52.788	155.016	31	0	4522
86	8/24/01	53.975	157.371	29	3	5620
94	8/25/01	54.374	158.105	35	0	2567
Total				655	60	

(3) Sample preparation

In our laboratory, dissolved inorganic carbon in the seawater samples were stripped cryogenically and split into three aliquots: Accelerator Mass Spectrometry (AMS) ^{14}C measurement (about 200 μmol),

^{13}C measurement (about 100 μmol), and archive (about 200 μmol). The extracted CO_2 gas for ^{14}C was then converted to graphite catalytically on iron powder with pure hydrogen gas. Details of these preparation procedures using an automated preparation system were described by Kumamoto *et al.* (2000).

(4) Measurements

$\delta^{13}\text{C}$ analyses

The $^{13}\text{C} / ^{12}\text{C}$ ratio of the extracted CO_2 gas (R_{sample}) was measured using Finnigan MAT252 mass spectrometer. The ratio of R_{sample} against the $^{13}\text{C} / ^{12}\text{C}$ ratio of the standard (R_{standard}) is expressed as $\delta^{13}\text{C}$ and calculated by the following equation:

$$\delta^{13}\text{C} (\text{‰}) = (R_{\text{sample}} / R_{\text{standard}} - 1) \times 1000. \quad (1)$$

Because the value of R_{standard} was validated with NIST RM8544 (NBS19), the measured $\delta^{13}\text{C}$ is the value against the VPDB standard. All of the $\delta^{13}\text{C}$ analyses have been finished. Except the replicate samples (see below), the individual $\delta^{13}\text{C}$ results were given by average of several time measurements with its error (standard deviation). These errors were less than 0.01 ‰.

The 60 replicate analyses are tabulated in Table 3.8.2. The table shows the error weighted mean and uncertainty for each set of replicates. The uncertainty is defined here as the larger of the standard deviation of the mean and the error weighted standard deviation. The simple average of the uncertainty, 0.02 ‰ is larger than the individual errors (standard deviation) because the uncertainty obtained for the replicate analyses includes errors due to sample collection and preparation.

$\Delta^{14}\text{C}$ analyses

The ^{14}C in the graphite sample was measured by AMS facilities at National Institute for Environmental Studies in Tsukuba, Japan (Tanaka *et al.* 2000) and Institute of Accelerator Analysis Ltd in Shirakawa, Japan. The ^{14}C results are reported as $\Delta^{14}\text{C}$. The equation for $\Delta^{14}\text{C}$ is:

$$\Delta^{14}\text{C} (\text{‰}) = \Delta^{14}\text{C} - 2 (\delta^{13}\text{C} + 25) (1 + \Delta^{14}\text{C} / 1000), \quad (2)$$

where

$$\Delta^{14}\text{C} (\text{‰}) = (R_{\text{sample}} / R_{\text{standard}} - 1) \times 1000, \quad (3)$$

where R_{sample} and R_{standard} denote, respectively, $^{14}\text{C} / ^{12}\text{C}$ ratios of the seawater sample and the NIST oxalic acid standard (HOxII) with corrections for isotopic fractionation and age correction to A.D. 1950 (Stuiver and Polach, 1977; Stuiver, 1983). All of $\Delta^{14}\text{C}$ analyses have been finished. Except the replicate samples (see below), the individual $\Delta^{14}\text{C}$ results were given by average of several time measurements with its error that was the larger of the standard deviation and the counting error.

The results of the $\Delta^{14}\text{C}$ replicates are also shown in Table 3.8.2. The definition of the uncertainty is same as that of the $\delta^{13}\text{C}$ analyses. The simple average of the uncertainty (3.4 ‰) is almost same as that of the individual errors (3.7 ‰), which suggests that errors due to sample collection and preparation were negligible during the AMS radiocarbon measurements.

Table 3.8.2: Summary of replicate analyses.

Station	Bottle	$\delta^{13}\text{C} / \text{‰}$				$\Delta^{14}\text{C} / \text{‰}$			
		$\delta^{13}\text{C}$	Error ^a	E.W.Mean ^b	Uncertainty ^c	$\Delta^{14}\text{C}$	Error ^d	E.W.Mean ^b	Uncertainty ^c
26	7	-0.05	0.01	-0.05	0.00	-254.3	3.2	-250.4	5.1
		-0.05	0.00			-247.2	2.9		
26	18	-0.36	0.01	-0.38	0.02	-230.6	2.9	-228.1	3.3
		-0.39	0.00			-225.9	2.8		
26	30	0.72	0.00	0.72	0.02	66.7	5.9	72.5	5.8
		0.70	0.01			74.8	3.8		
20	9	-0.07	0.01	-0.06	0.00	-243.9	3.3	-246.5	3.8
		-0.06	0.00			-249.2	3.4		

20	18	-0.44	0.01	-0.44	0.01	-224.4	3.5	-228.6	5.8
		-0.45	0.01			-232.6	3.4		
20	30	0.63	0.00	0.64	0.01	46.3	3.3	43.9	5.3
		0.65	0.00			38.9	4.7		
28	1	0.03	0.00	0.10	0.08	-229.5	2.7	-229.9	1.9
		0.14	0.00			-230.4	2.7		
28	2	0.16	0.00	0.14	0.02	-232.5	2.9	-228.7	5.1
		0.12	0.00			-225.4	2.7		
28	4	0.11	0.01	0.13	0.01	-224.7	2.8	-226.5	2.5
		0.13	0.00			-228.2	2.7		
28	6	0.07	0.00	0.07	0.01	-228.7	2.7	-232.1	5.1
		0.08	0.00			-235.8	2.8		
28	8	0.03	0.00	0.02	0.01	-237.2	2.7	-236.1	1.9
		0.02	0.00			-235.1	2.6		
28	10	-0.12	0.01	-0.11	0.01	-241.2	2.6	-243.4	3.5
		-0.10	0.00			-246.2	2.9		
28	12	-0.19	0.01	-0.19	0.00	-247.2	2.6	-248.6	2.0
		-0.19	0.00			-249.9	2.5		
28	14	-0.24	0.00	-0.27	0.04	-251.3	2.7	-250.9	1.8
		-0.29	0.00			-250.4	2.5		
28	15	-0.30	0.01	-0.31	0.01	-247.7	2.5	-247.7	1.8
		-0.32	0.00			-247.7	2.6		
28	16	-0.33	0.00	-0.33	0.01	-249.3	2.7	-246.1	4.4
		-0.35	0.01			-243.2	2.6		

28	17	-0.40	0.00	-0.38	0.04	-249.0	2.7	-246.7	3.3
		-0.35	0.01			-244.4	2.7		
28	18	-0.43	0.01	-0.42	0.00	-241.6	2.7	-240.5	1.9
		-0.42	0.00			-239.4	2.7		
28	19	-0.48	0.01	-0.48	0.00	-234.4	2.5	-233.4	1.8
		-0.47	0.01			-232.4	2.5		
28	20	-0.54	0.01	-0.54	0.01	-213.2	2.8	-215.0	4.0
		-0.53	0.00			-218.8	4.1		
28	21	-0.54	0.00	-0.54	0.01	-204.5	2.8	-203.3	2.0
		-0.55	0.00			-202.0	2.8		
28	22	-0.60	0.00	-0.59	0.05	-188.9	2.8	-187.4	2.2
		-0.53	0.00			-185.7	2.9		
28	23	-0.57	0.00	-0.56	0.01	-162.7	2.9	-162.5	2.1
		-0.55	0.00			-162.4	2.9		
28	24	-0.48	0.00	-0.48	0.00	-128.0	2.9	-131.8	5.4
		-0.48	0.00			-135.6	2.9		
28	25	-0.36	0.00	-0.35	0.01	-83.8	3.0	-85.0	2.2
		-0.34	0.00			-86.3	3.1		
28	26	-0.13	0.01	-0.13	0.00	-27.1	3.0	-29.2	3.1
		-0.13	0.01			-31.5	3.2		
28	27	-0.02	0.00	-0.01	0.01	-6.2	3.2	-4.6	2.3
		-0.01	0.00			-3.1	3.2		
28	28	0.16	0.01	0.16	0.00	21.9	3.0	22.3	2.1
		0.16	0.00			22.8	3.0		

28	29	0.33	0.00	0.32	0.03	39.8	3.1	42.5	3.9
		0.29	0.00			45.3	3.2		
28	30	0.69	0.00	0.70	0.03	47.8	3.0	46.2	2.5
		0.72	0.01			44.2	3.3		
28	31	1.02	0.01	1.06	0.03	51.4	3.3	52.3	2.2
		1.06	0.00			53.0	3.0		
28	32	1.49	0.01	1.52	0.02	57.6	3.2	52.6	7.0
		1.52	0.00			47.7	3.2		
28	33	1.58	0.01	1.59	0.01	55.5	3.2	57.1	2.3
		1.60	0.00			58.6	3.2		
28	34	1.68	0.00	1.72	0.04	48.9	3.3	49.5	2.3
		1.73	0.00			50.1	3.3		
28	35	1.77	0.01	1.78	0.01	36.7	3.3	41.5	6.7
		1.78	0.00			46.2	3.3		
28	36	1.75	0.00	1.76	0.01	54.3	3.3	51.5	3.9
		1.77	0.01			48.7	3.3		
34	2	0.12	0.00	0.13	0.01	-216.1	4.1	-218.9	7.7
		0.14	0.00			-226.9	7.0		
34	18	-0.54	0.00	-0.54	0.00	-229.2	5.0	-227.9	3.2
		-0.54	0.00			-227.0	4.1		
34	30	0.54	0.00	0.52	0.03	42.4	3.8	43.5	2.6
		0.50	0.00			44.5	3.5		
43	7	-0.20	0.00	-0.20	0.00	-250.5	5.3	-246.7	6.9
		-0.20	0.00			-240.8	6.7		

43	18	-0.57	0.00	-0.57	0.00	-230.4	4.9	-231.0	3.2
		-0.57	0.01			-231.5	4.2		
43	30	0.48	0.00	0.48	0.00	33.1	4.4	31.1	3.0
		0.48	0.00			29.4	4.0		
48	7	-0.20	0.00	-0.20	0.00	-245.2	6.6	-245.0	3.6
		-0.20	0.00			-244.9	4.3		
48	18	-0.59	0.00	-0.61	0.01	-227.4	5.5	-225.7	4.3
		-0.61	0.00			-223.0	6.9		
48	30	0.44	0.00	0.44	0.01	29.9	4.6	28.7	3.3
		0.43	0.01			27.4	4.8		
56	7	-0.11	0.01	-0.16	0.04	-240.8	3.0	-241.3	2.2
		-0.17	0.00			-242.0	3.2		
56	18	-0.69	0.00	-0.69	0.01	-218.3	2.9	-222.6	6.0
		-0.68	0.00			-226.9	2.9		
56	30	0.43	0.00	0.43	0.01	24.5	3.8	23.7	2.5
		0.41	0.00			22.9	3.4		
64	8	-0.10	0.01	-0.12	0.03	-239.1	2.4	-240.2	1.8
		-0.15	0.01			-241.6	2.6		
64	18	-0.65	0.00	-0.65	0.02	-229.6	2.8	-228.5	1.9
		-0.63	0.01			-227.6	2.6		
64	30	-0.13	0.01	-0.19	0.04	-36.1	2.6	-35.8	1.8
		-0.19	0.00			-35.6	2.6		
70	8	-0.09	0.00	-0.09	0.01	-235.3	2.6	-235.6	1.8
		-0.08	0.00			-235.9	2.5		

70	18	-0.62	0.00	-0.63	0.01	-221.6	2.8	-223.7	2.7
		-0.64	0.01			-225.4	2.5		
70	30	-0.35	0.01	-0.41	0.06	-58.7	3.2	-59.9	2.3
		-0.43	0.00			-61.1	3.2		
78	8	-0.16	0.01	-0.16	0.00	-239.2	3.5	-239.9	2.5
		-0.16	0.00			-240.6	3.6		
78	18	-0.62	0.00	-0.60	0.03	-228.8	3.6	-225.8	4.0
		-0.58	0.00			-223.1	3.4		
78	30	-0.73	0.00	-0.72	0.01	-88.7	4.1	-93.8	6.8
		-0.71	0.00			-98.4	3.9		
86	3	0.11	0.00	0.14	0.07	-207.7	3.3	-208.8	2.4
		0.21	0.01			-210.0	3.4		
86	18	-0.50	0.00	-0.51	0.01	-238.8	3.1	-238.8	2.2
		-0.51	0.00			-238.8	3.2		
86	30	-0.74	0.00	-0.75	0.02	-105.2	3.6	-106.5	2.5
		-0.76	0.00			-107.8	3.6		

a. Normal standard deviation of several time measurements

b. Error weighted mean reported with data set

c. Larger of the standard deviation of the mean and the error weighted standard deviation

d. Larger of the standard deviation and the counting error

(5) Quality control samples

During the sample measurements (Nov. 2001 – Aug. 2002), we synchronously carried out preparation and measurement of 19 quality control samples (QCS). The QCS was prepared by a large volume of surface seawater collected in open ocean and kept in our laboratory from 1999. The QCS results are shown in Table 3.8.3. The normal standard deviations of the simple average for $\delta^{13}\text{C}$ and

$\Delta^{14}\text{C}$ are 0.03 ‰ and 4.5 ‰, respectively. These standard deviations of the QCS replicates are estimates of the true error which includes errors due to the sample preparation and the measurement for the time frame over which all the samples were measured.

Table 3.8.3: Summary of quality control samples (QCS).

QCS No.	$\delta^{13}\text{C} / \text{‰}$			$\Delta^{14}\text{C} / \text{‰}$		
	Measurement date	$\delta^{13}\text{C}$	Error	Measurement date	$\Delta^{14}\text{C}$	Error
15	11-Jun-02	0.12	0.00	30-Jul-02	88.5	4.3
17	28-May-02	0.09	0.00	02-Jul-02	82.4	3.5
27	23-Apr-02	0.11	0.01	23-May-02	81.6	3.2
29	19-Dec-01	0.10	0.00	04-Feb-02	87.1	3.8
34	19-Feb-02	0.09	0.00	05-Aug-02	86.6	4.2
38	10-Jun-02	0.15	0.00	30-Jul-02	83.7	4.4
51	24-Apr-02	0.09	0.00	23-May-02	79.9	4.2
57	18-Dec-01	0.08	0.00	04-Feb-02	86.8	3.4
58	07-Nov-01	0.14	0.01	04-Dec-01	83.6	3.8
60	08-May-02	0.10	0.00	02-Jul-02	79.7	3.0
66	14-Jun-02	0.12	0.01	20-Aug-02	81.4	4.3
73	28-Jun-02	0.14	0.00	20-Aug-02	90.1	3.1
75	22-Apr-02	0.16	0.00	23-May-02	79.7	3.4
78	10-May-02	0.11	0.01	02-Jul-02	78.6	3.2
85	26-Apr-02	0.11	0.00	23-May-02	82.3	4.0
86	12-Jun-02	0.15	0.00	05-Aug-02	82.0	4.0
95	14-Nov-01	0.13	0.00	01-Feb-02	80.1	3.2
99	20-Dec-01	0.08	0.00	25-Feb-02	91.2	3.7
113	07-Jan-02	0.07	0.01	28-Feb-02	94.9	3.8
	mean	0.11		mean	84.2	
	standard deviation	0.03		standard deviation	4.5	

(6) Quality control flag assignment

Quality flag values were assigned to all $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce *et al.*, 1994). Measurement flags of 2, 3, 4, 5, and 6 have been assigned (Table 3.8.4). For the choice between 2 (good), 3 (questionable) or 4 (bad), we basically followed a flagging procedure that described by Key *et al.* (1996) as listed below:

- On a station-by-station basis, a datum was plotted against pressure. Any points not lying on a generally smooth trend were noted.
- $\delta^{13}\text{C}$ ($\Delta^{14}\text{C}$) was then plotted against dissolved oxygen (silicate) concentration and deviant points noted. If a datum deviated from both the depth and dissolved oxygen (silicate) plots, it was flagged 3.
- Data below 1000 m depth were checked against the first visits of WHP P17N (1993) and P17C (1991). Deviant points were flagged 3.
- Vertical sections against depth (see section 6) were prepared using the Ocean Data View (Schlitzer, 2002). If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or from 3 to 4.

Table 3.8.4: Summary of assigned quality control flags

Flag	Definition	Number	
		$\delta^{13}\text{C}$	$\Delta^{14}\text{C}$
2	Good	571	562
3	Questionable	12	18
4	Bad	3	5
5	Not report (missing)	9	10
6	Replicate	60	60
Total		655	655

(7) Data Summary

Figure 3.8.2 shows vertical sections of $\delta^{13}\text{C}$ (upper) and $\Delta^{14}\text{C}$ (lower) against depth. $\delta^{13}\text{C}$ value is large in surface water and its minimum appears in mid layer (200 – 1000 m). This $\delta^{13}\text{C}$ profile is consistent with vertical profile of dissolved oxygen concentration, suggesting strong biological effect on the $\delta^{13}\text{C}$ vertical profile. $\Delta^{14}\text{C}$ vertical profile is similar with the $\delta^{13}\text{C}$ profile: larger value in surface and mid layer minimum (2000 – 2500 m). This profile, however, is controlled by “physical” factors, namely both intrusion of the bomb-produced ^{14}C in surface water and decrease due to the radioactive decay. On the other hands, slight increases of both $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ near bottom indicate bottom ventilation by “younger” Pacific Bottom Water in the eastern North Pacific.

In surface and intermediate waters (< 1000 m), comparison of $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ between the first visit in 1991 (Tsuchiya, 2002) & 1993 (Musgrave, 2002) and the revisit in 2001 will evaluate water circulation and air-sea gas exchange in the eastern North Pacific during the past decade. However, it is hard to discuss temporal change of $\delta^{13}\text{C}$, because the previous data in 1991 and 1993 were sparse. $\Delta^{14}\text{C}$ in surface water above 200 m depth decreased at all the stations in the past decade. At the northernmost stations in the Alaskan Stream, radiocarbon decrease was also observed in deeper layer. While radiocarbon increased in the mid layer around 35°N, in the other stations the intermediate radiocarbon decreased slightly or did not change. Further discussion about these $\Delta^{14}\text{C}$ changes will be described in other publications.

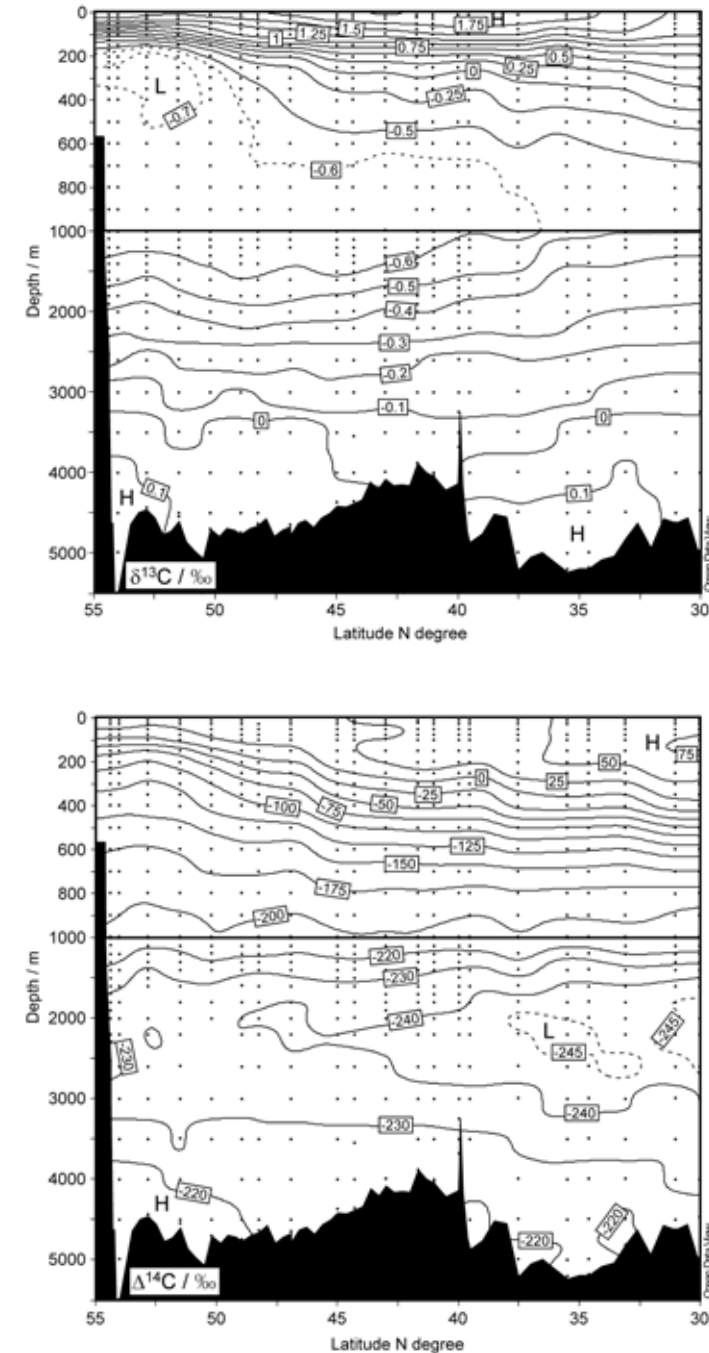


Figure 3.8.2: Vertical sections of $\delta^{13}\text{C}$ (upper) and $\Delta^{14}\text{C}$ (lower) against depth during P17N revisit cruise in August 2001.

(8) References

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3.9 CTD/O₂ Measurements

13 Mar 2002

(1) Personnel

Hiroshi Uchida (JAMSTEC)

Masao Fukasawa (JAMSTEC)

Satoshi Ozawa (MWJ)

(2) Winch arrangements

The CTD package was deployed using 4.5 Ton Traction Winch System (Dynacon, Inc., USA) which was installed to the R/V Mirai in April 2001. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc., USA) is designed to reduce cable stress resulted from loads variation caused by wave or vessel motion. The system is operated passively by providing a nodding boom crane that moves up or down in response to line tension variations. Primary system components include a complete CTD Traction Winch System with 10 km of 9.5 mm armored cable rocker and Electro-Hydraulic Power Unit, nodding-boom crane assembly, two hydraulic cylinders and two hydraulic oil/nitrogen accumulators mounted within a single frame assembly. The system also contains related electronic hardware interface and a heave compensation computer control program.

(3) Overview of the equipment

The CTD system, SBE 911plus system (Sea-Bird Electronics, Inc., USA), is a real time data system with the CTD data transmitted from a SBE 9plus underwater unit via a conducting cable to the SBE 11plus deck unit. The SBE 11plus deck unit is a rack-mountable interface which supplies DC power to the underwater unit, decodes the serial data stream, formats the data under microprocessor control, and passes the data to a companion computer. The serial data from the underwater unit is sent to the deck unit in RS-232 NRZ format using a 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK)

telemetry link. The deck unit decodes the serial data and sends them to a personal computer to display, at the same time, to storage in a disk file using SBE SEASOFT software.

The SBE 911plus system acquires data from primary, secondary and auxiliary sensors in the form of binary numbers corresponding to the frequency or voltage outputs from those sensors at 24 samples per second. The calculations required to convert from raw data to engineering units of the parameters are performed by the SBE SEASOFT in real-time. The same calculations can be carried out after the observation using data stored in a disk file.

The SBE 911plus system controls the 36-position SBE 32 Carousel Water Sampler. The Carousel accepts 12-liter water sample bottles. Bottles were fired through the RS-232C modem connector on the back of the SBE 11plus deck unit while acquiring real time data. The 12-liter Niskin-X water sample bottle (General Oceanics, Inc., USA) is equipped with two stainless steel springs externally. The external springs are ideal for applications such as the trace metal analysis because the inside of the sampler is free from contaminants from springs.

SBE's standard temperature (SBE 3F) and conductivity (SBE 4) sensor modules were used with the SBE 9plus underwater unit fixed by a single clamp and "L" bracket to the lower end cap. The conductivity cell entrance is co-planar with the tip of the temperature sensor's protective steel sheath. The pressure sensor is mounted in main housing of the underwater unit and is ported to outside through the oil-filled plastic capillary tube. A compact, modular unit consisting of a centrifugal pump head and a brushless DC ball bearing motor contained in an aluminum underwater housing pump (SBE 5T) flushes water through sensor tubing at a constant rate independent of the CTD's motion. Motor speed and pumping rate (3000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC.

The system used in this cruise is summarized as follows:

Under water unit:

SBE, Inc., SBE 9plus, S/N 79492

Temperature sensor (primary):

SBE, Inc., SBE 3-04/F, S/N 031464

Temperature sensor (secondary):

SBE, Inc., SBE 3-04/F, S/N 031524

Conductivity sensor (primary):

SBE, Inc., SBE 4-04/0, S/N 041203

Conductivity sensor (secondary):

SBE, Inc., SBE 4-04/0, S/N 041206

Oxygen sensor (primary):

SBE, Inc., SBE 13-04, S/N 130540 (from station 431 to P17N 30)

SBE, Inc., SBE 43, S/N 430069 (from station P17N 31 to P17N 99)

Oxygen sensor (secondary):

SBE, Inc., SBE 43, S/N 430069 (from station 431 to P17N 30)

SBE, Inc., SBE 13-04, S/N 130540 (from station P17N 31 to P17N 99)

Pump (primary):

SBE, Inc., SBE 5T, S/N 053118

Pump (secondary):

SBE, Inc., SBE 5T, S/N 050984

Altimeter:

Benthos, Inc., 2110-2, S/N 22

(from station 431 to P17N 29, and from station P17N 31 to P17N 33)

Benthos, Inc., 2110-2, S/N 206 (station P17N 30)

Datasonics, Inc., PSA-900D, S/N 396 (from station P17N 34 to P17N 99)

Fluorometer:

Seapoint sensors, Inc., S/N 2148

Transmissometer:

WET Labs, Inc., C-Star Transmissometer, S/N CST-207RD

Deck unit:

SBE, Inc., SBE 11plus, S/N 11P8010-0308 (from station 431 to P17N 70)

SBE, Inc., SBE 11plus, S/N 11P7030-0272 (from station P17N 71 to P17N 99)

Carousel Water Sampler:

SBE, Inc., SBE 32, S/N 3221746-0278

Water sample bottle:

General Oceanics, Inc., 12-litter Niskin-X

$$t1 = 29.92375$$

$$t2 = -2.63869e-04$$

$$t3 = 3.92132e-06$$

$$t4 = 1.35947e-09$$

$$t5 = 4.49704e-12$$

(The coefficients c1, c2, t1 and t2 were changed on December 6, 1999.)

Pressure coefficients are first formulated into

$$c = c1 + c2 * U + c3 * U^2$$

$$d = d1 + d2 * U$$

$$t0 = t1 + t2 * U + t3 * U^2 + t4 * U^3 + t5 * U^4$$

where U is temperature in degrees Celsius. The pressure temperature, U, is determined according to

$$U (^{\circ}\text{C}) = M * (\text{12 bit pressure temperature compensation word}) - B$$

The following coefficients were used in SEASOFT through software module SEACON:

$$M = 1.284934e-2$$

$$B = -8.388034$$

(in the underwater unit system configuration sheet dated on November 30, 1999)

Finally, pressure is computed as

$$P (\text{psi}) = c * [1 - (t0^2 / t^2)] * \{1 - d * [1 - (t0^2 / t^2)]\}$$

where t is pressure period (microsec). Since the pressure sensor measures the absolute value, it inherently includes atmospheric pressure (about 14.7 psi). SEASOFT subtracts 14.7 psi from computed pressure above automatically.

Pressure sensor calibration against a dead-weight piston gauge are performed at Marine Works Japan Ltd. in Yokosuka, Kanagawa, Japan, usually once in a year in order to monitor its time drift and the linearity. The pressure sensor drift is known to be primarily by an offset at all pressures rather than by a change of span slope. The pressure sensor hysteresis are typically 0.2 dbar. The following coefficients for the sensor drift correction were also used in SEASOFT through the software module

(4) Pre-cruise calibration

(4.1) Pressure

The Paroscientific series 4000 Digiquartz high pressure transducer (Paroscientific, Inc., USA) uses a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress with 0.01 per million of resolution over the absolute pressure range of 0 to 15,000 psia (0 to 10,332 dbar). Also, a quartz crystal temperature signal is used to compensate for a wide range of temperature changes at the time of an observation. The pressure sensor (MODEL 415K-187) has a nominal accuracy of 0.015 % FS (1.5 dbar), typical stability of 0.0015 % FS/month (0.15 dbar/month) and resolution of 0.001 % FS (0.1 dbar).

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in the SEASOFT through software module SEACON:

S/N 79492 October 27, 1999

$$c1 = -65706.8$$

$$c2 = -0.1758329$$

$$c3 = 2.04245e-02$$

$$d1 = 0.027146$$

$$d2 = 0.0$$

SEACON:

S/N 79492 April 24, 2001

slope = 0.99995898

offset = 1.78677

The drift-corrected pressure is computed as

Drift-corrected pressure (dbar) = slope * (computed pressure in dbar) + offset

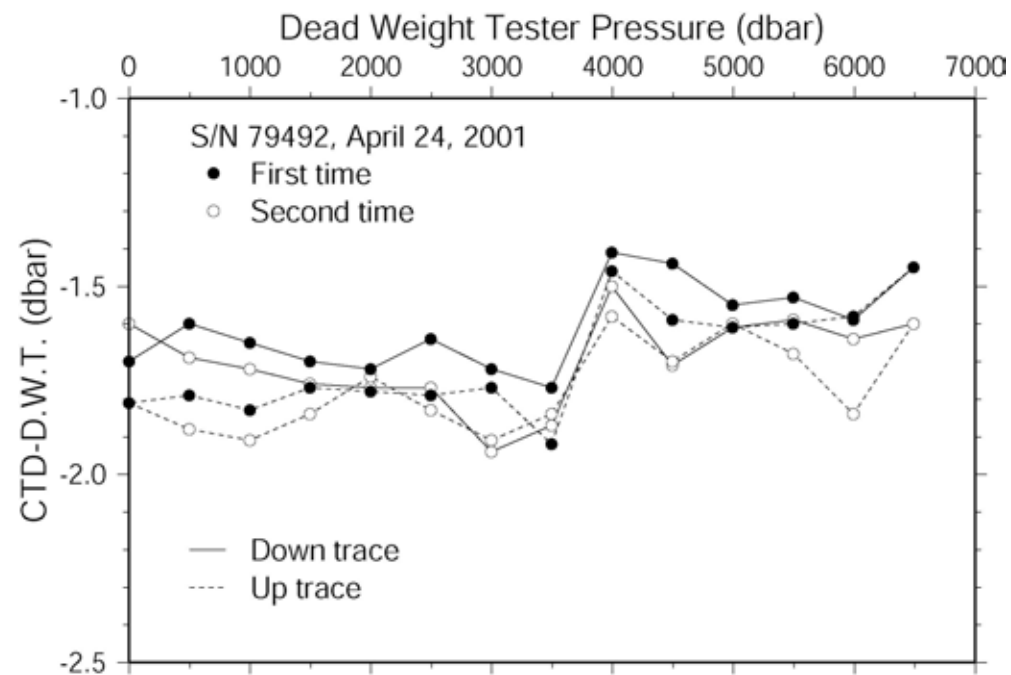


Figure 3.9.1: The residual pressures between the Dead Weight Tester and the CTD.

(4.2) Temperature (SBE 3F)

The temperature sensing element is a glass-coated thermistor bead in a stainless steel tube to provide a pressure-free measurement at depths up to 10,500 meters. The sensor output frequency ranges from approximately 5 to 13 kHz corresponding to temperature from -5 to 35 °C. The output frequency is inversely proportional to the square root of the thermistor resistance, which controls the

output of a patented Wien Bridge circuit. The thermistor resistance is exponentially related to temperature. The SBE 3F thermometer has a nominal accuracy of 0.001 °C, typical stability of 0.0002 °C/month and resolution of 0.0002 °C at 24 samples per second.

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in SEASOFT through the software module SEACON:

S/N 031464 (primary) June 16, 2001

g = 4.84394400e-03

h = 6.80848240e-04

i = 2.70328214e-05

j = 2.13867061e-06

f0 = 1000.000

S/N 031524 (secondary) June 16, 2001

g = 4.83484327e-03

h = 6.75462258e-04

i = 2.64451174e-05

j = 2.13440093e-06

f0 = 1000.000

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =

$$1 / \{g + h * [\ln(f_0 / f)] + i * [\ln^2(f_0 / f)] + j * [\ln^3(f_0 / f)]\} - 273.15$$

where f is the instrument frequency (kHz).

(4.3) Conductivity (SBE 4)

The flow-through conductivity sensing element is a glass tube (cell) with three platinum electrodes to provide in-situ measurements at depths up to 10,500 meters. The impedance between the center and the end electrodes is determined by the cell geometry and the specific conductance of the fluid within

the cell. The conductivity cell composes a Wien Bridge circuit with other electric elements of which frequency output is approximately 3 to 12 kHz corresponding to conductivity of the fluid from 0 to 7 S/m. The conductivity cell of SBE 4 has a nominal accuracy of 0.0003 S/m, typical stability of 0.0003 S/m/month and resolution of 0.00004 S/m at 24 samples per second.

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in SEASOFT through the software module SEACON:

S/N 041203 (primary) June 15, 2001

$$g = -4.05180978$$

$$h = 4.93348008e-01$$

$$i = 9.46008409e-05$$

$$j = 2.18812300e-05$$

$$CP_{cor} = -9.57e-08 \text{ (nominal)}$$

$$CT_{cor} = 3.25e-06 \text{ (nominal)}$$

S/N 041206 (secondary) June 15, 2001

$$g = -4.28945276$$

$$h = 5.03354673e-01$$

$$i = 1.03033274e-04$$

$$j = 2.08217238e-05$$

$$CP_{cor} = -9.57e-08 \text{ (nominal)}$$

$$CT_{cor} = 3.25e-06 \text{ (nominal)}$$

Conductivity of a fluid in the cell is expressed as:

$$C \text{ (S/m)} = (g + h * f^2 + i * f^3 + j * f^4) / [10 (1 + CT_{cor} * t + CP_{cor} * p)]$$

where f is the instrument frequency (kHz), t is the water temperature (°C) and p is the water pressure (dbar). The value of conductivity at salinity of 35, temperature of 15 °C (IPTS-68) and pressure of 0 dbar is 4.2914 S/m.

(4.4) Oxygen (SBE 13)

The SBE 13 dissolved oxygen sensor uses a Beckman polarographic element to provide in-situ measurements at depths up to 10,500 meters. The sensor is included in the path of pumped sea water. The oxygen sensor determines the dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through a membrane. By knowing the flux of oxygen and the geometry of the diffusion path, the concentration of oxygen can be computed. The permeability of the membrane to oxygen is a function of temperature and ambient pressure. The interface electronics outputs voltages proportional to oxygen flux (oxygen current) and membrane temperature (oxygen temperature). Oxygen temperature is used for internal temperature compensation. Computation of dissolved oxygen in engineering units is done in SEASOFT software. The range for dissolved oxygen is 0 to 15 ml/l; nominal accuracy is 0.1 ml/l; resolution is 0.01 ml/l.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N 130540 June 18, 2001

$$m = 2.4424e-07$$

$$b = -4.2986e-10$$

$$k = 8.9712$$

$$c = -6.8923$$

$$Soc = 2.2237$$

$$Boc = -0.0143$$

$$tcor = -0.033$$

$$pcor = 1.50e-04$$

$$\tau = 2.0$$

$$wt = 0.67$$

The use of these constants in linear equations of the form $I = m * V + b$ and $T = k * V + c$ yield the oxygen current and the oxygen temperature (with a maximum error of about 0.5 °C), respectively. These scaled values of the oxygen current and the oxygen temperature are used in the SEASOFT

processing stream.

The oxygen sensor of S/N 130540 was used with primary temperature and conductivity sensors at stations from 431 to P17N 30 and used with secondary temperature and conductivity sensors at station from P17N 31 to P17N 99.

(4.5) Oxygen (SBE 43)

The SBE 43 oxygen sensor uses a Clark polarographic element to provide in-situ measurements at depths up to 7,000 meters. Calibration stability is improved by an order of magnitude and pressure hysteresis is largely eliminated in the upper ocean (1,000 m). Continuous polarization eliminates the wait-time for stabilization after power-up. Signal resolution is increased by on-board temperature compensation. This Sensor is also included in the path of pumped sea water. This oxygen sensor determines the dissolved oxygen concentration also by counting the number of oxygen molecules per second (flux) that diffuse through a membrane, where the permeability of the membrane to oxygen is a function of temperature and ambient pressure. Computation of dissolved oxygen in engineering units is done in SEASOFT software through almost the same way as for the case of SBE 13. The range for dissolved oxygen is 120 % of surface saturation in all natural waters; nominal accuracy is 2 % of saturation; typical stability is 2 % per 1000 hours.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N 430069 July 6, 2001

$$\text{Soc} = 0.3268$$

$$\text{Boc} = 0.0184$$

$$\text{TCor} = 0.0004$$

$$\text{PCor} = 1.500\text{e-}04$$

$$\text{Offset} = -0.6181$$

$$\text{tau} = 0$$

Oxygen (ml/l) is computed as

$$\text{Oxygen (ml/l)} = [\text{Soc} * \{(\text{v} + \text{offset}) + (\text{tau} * \text{doc/dt})\} + \text{Boc} * \exp(-0.03 * \text{t})]$$

$$* \exp(\text{TCor} * \text{t} + \text{PCor} * \text{p}) * \text{Oxsat}(\text{t}, \text{s})$$

$$\text{Oxsat}(\text{t}, \text{s}) = \exp[\text{A1} + \text{A2} * (100 / \text{t}) + \text{A3} * \ln(\text{t} / 100) + \text{A4} * (\text{t} / 100)$$

$$+ \text{s} * (\text{B1} + \text{B2} * (\text{t} / 100) + \text{B3} * (\text{t} / 100) * (\text{t} / 100))]$$

where p is pressure in dbar, t is absolute temperature and s is salinity in psu. Oxsat is oxygen saturation value minus the volume of oxygen gas (STP) absorbed from humidity-saturated air. Its coefficients are as follows;

$$\text{A1} = -173.4292$$

$$\text{A2} = 249.6339$$

$$\text{A3} = 143.3483$$

$$\text{A4} = -21.8482$$

$$\text{B1} = -0.033096$$

$$\text{B2} = -0.00170$$

The oxygen sensor of S/N 130540 was used with secondary temperature and conductivity sensors at stations from 431 to P17N 30 and used with primary temperature and conductivity sensors at station from P17N 31 to P17N 99.

(4.6) Altimeter

The Benthos 2110 Series Altimeter (Benthos, Inc., USA) follows the basic principal of most echo ranging devices. That is, a burst of acoustic energy is transmitted and the time until the first reflection is received is determined. In this unit, a 400 microsecond pulse at 100 kHz is transmitted twice a second; concurrent with the transmission, a clock is turned off, thus the number of pulses out relates directly to the distance of the target from the unit. The internal ranging oscillator has an accuracy of approximately 5 % and is set assuring a speed of sound of 1,500 m/s. Thus the unit itself, neglecting variations in the speed of sound, can be considered accurate to 5 % or 0.1 meter, whichever is greater. The unit is rated to a depth of 12,000 meters.

The Datasonics PSA-900 Programmable Sonar Altimeter (Datasonics, Inc., USA) determines the distance of the target from the unit in almost the same way as the Benthos 2110. PSA-900 also uses the nominal speed of sound as 1,500 m/s. But, PSA-900 compensates for sound velocity errors due to temperature. In a PSA-900 operating at a 350 microsecond pulse at 200 kHz, the jitter of the detectors can be as small as 5 microseconds or approximately 0.4 centimeters total distance. Since the total travel time is divided by two, the jitter error is 0.25 centimeters. The unit is rated to a depth of 6,000 meters.

The following scale factors were used in SEASOFT through the software module SEACON:

$$\text{FSVolt} * 300 / \text{FSRange} = 0.5$$

$$\text{Offset} = 0.0$$

(4.7) Fluorometer

The Seapoint Chlorophyll Fluorometer (Seapoint sensors, Inc., USA) is a high-performance, low power instrument to provide in-situ measurements of chlorophyll-a at depths up to 6,000 meters. The instrument uses modulated blue LED lamps and a blue excitation filter to excite chlorophyll-a. The fluorescent light emitted by the chlorophyll-a passes through a red emission filter and is detected by a silicon photodiode. The low level signal is then processed using synchronous demodulation circuitry which generates an output voltage proportional to chlorophyll-a concentration.

The following coefficients were used in SEASOFT through the software module SEACON as user defined polynomial:

S/N 2148 (unknown calibration date)

$$A0 = 0.0$$

$$A1 = 5.0$$

Chlorophyll-a concentration is computed as

$$\text{Chlorophyll-a } (\mu\text{g/l}) = A0 + A1 * \text{Voltage}$$

(4.8) Transmissometer

The C-Star Transmissometer (WET Labs, Inc., USA) measures light transmittance at a single wavelength over a known path. In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the receiver to the amount originating at the source is known as the beam transmittance. Suspended particles, phytoplankton, bacteria and dissolved organic matter contribute to the losses sensed by the instrument. Thus, the instrument provides information both for an indication of the total concentrations of matter in the water as well as for a value of the water clarity.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N CST-207RD March 19, 1998

$$M = 19.6415$$

$$B = -1.3945$$

$$\text{Path length (m)} = 0.25$$

The beam transmittance (Tr) is computed as

$$\text{Tr (\%)} = M * \text{voltage} + B$$

(5) Data Collection and Processing

(5.1) Data collection

CTD/O₂ measurements were made using a SBE 9plus CTD equipped with two pumped temperature-conductivity (TC) sensors and dissolved oxygen sensor pair. The TC pairs were monitored to check drift and shifts by examining the differences between the two pairs. Also a newly developed oxygen sensor (SBE 43) was compared with a Beckman type oxygen sensor (SBE 13).

The SBE 9plus CTD/O₂ (sampling rate of 24 Hz) was mounted in a 36-position frame. Auxiliary sensors included altimeter, fluorometer and transmissometer. Water samples were collected using a 36-bottle SBE 32 Carousel Water Sampler with 12-liter Niskin-X bottles.

The package was lowered into the water from the board side and was held 10 m beneath the surface for about one minute in order to activate the pump. After the pump was activated the package was lowered at a rate of 0.5 m/s to 100 m then the package was stopped in order to operate the heave compensator of the crane. The package was lowered again at a rate of 0.8 m/s to 300 m, 1.0 m/s to 500 m, and 1.2 m/s to the bottom. The position of the package relative to the bottom was monitored by the altimeter reading. Also the bottom depth was monitored by the SEABEAM multibeam sounder on the board. For the up cast, the package was heightened at a rate of 1.2 m/s except for a time when sampling water at a rate of 0.5 m/s. At 100 m deep from the surface, the package was stopped in order to stop the heave compensator of the crane.

Niskin-X bottle sampled water for analysis of salinity, dissolved oxygen, inorganic nutrients, CFCs, DIC, ¹⁴C, pH and total alkalinity. The 36-position frame and Niskin-X bottles were periodically wiped with acetone in order to prevent water samples from contamination. Niskin-X bottle's caps and O-rings were re-arranged and wiped with acetone when a bottle leaking was found.

The SBE 11plus deck unit received the data signal from the CTD. Digitized data were forwarded to a personal computer prepared for SEASAVE module of the SEASOFT acquisition and processing software of which version was 4.249. Temperature, salinity, oxygen and descent rate profiles were displayed in real-time with the package depth and altimeter reading.

(5.2) Data collection problems

At station P17N 29, altimeter reading was not stable and altimeter was replaced after the cast. At station P17N 30, the replaced altimeter did not work correctly and the altimeter which was removed at P17N 29 was used again. At station P17N 33, altimeter did not work and replaced with other one after the cast.

At station P17N 36, SEASAVE data acquisition software was restarted during the package was holding at 10 m depth because of incorrect setting of the software. Therefore, data shallower than 10 m were lost.

At station P17N 47, up cast CTD data was very noisy and sensor connectors were checked and cleaned after the cast. At station P17N 71, bottle #1 fired unwillfully at 900 m depth during the down cast and the first cast was aborted. On the second cast, communication error was detected at 90 m depth during the down cast and the cast was aborted. CTD cable was checked electrically and some of connectors were replaced. Also the deck unit was replaced to complete the third cast.

At station P17N 76, 78, 82, 83 and 86, the down cast was started without holding at 10 m depth because of bad weather. At station P17N 77, the package was lowered and stopped at 20 m depth because the pump did not work at 10 m depth. So the down cast was started from 20 m depth.

At station P17N 94, descent rate exceeded 3 m/s for unknown reason and the package was stopped at 326 m deep. Then the down cast was restarted checking the heave motion mechanism of the crane. A communication error was detected when the package was lowered faster than 0.8 m/s. Therefore, the package had to be lowered at slower rate than 0.8 m/s to the bottom. During the up cast, bottle #1 did not fire. Hence, the deck unit and SEASAVE data acquisition software were restarted at 100 m above bottom and the up cast restarted at the 10 m above bottom. After the cast, the end of the CTD cable was cut about 50 m. At station P17N 96, sensor error was detected at 80 m depth during the down cast and the cast was aborted. After the cast, sensor connectors were checked.

(5.3) Other incidents of note

Before the first CTD station of this cruise, load test of CTD cable was performed on the deck up to 4.5 ton load. At station 431, CTD package was lowered to 100 m deep before the down cast in order to regulate CTD winch system. Also on the second cast at station 431, CTD package was lowered further 70 m after firing all bottles at 3000 m deep in order to regulate CTD winch system. After the station P17N 76, the CTD cable was cut 50 m from the end and load test of CTD cable was performed on the deck up to the load of 3.3 ton. After the station P17N 94, the CTD cable was cut 23 m from the end and load test of CTD cable was performed on the deck up to the load of 4 ton.

On the fourth cast at station 431, stainless steel weight of 60 kg (10 kg * 6) were attached to the

water sampler frame in order to increase the tension of the CTD cable near the surface. After the CTD cast at station P17N 40, more stainless steel weight of 60 kg (10 kg * 6) were added to the water sampler frame so that the CTD package stops rotating horizontally during down casts. But the rotation rate of the package checked from the LADCP data still to be about 0.5 revolutions per minute. Therefore, at station P17N 64 and 67, the package was stopped one hour at 100 m above bottom in order to untwist the cable before the up cast.

At station P17N 69, the package was stopped 20 minutes at 100 m deep in the down cast in order to supply nitrogen gas to the Heave Compensation System. The CTD package was stopped a few minutes in order to stabilize the heave motion during down casts at station P17N 66 (1545 m), P17N 67 (350 and 1450 m), P17N 70 (1000 m), P17N 73 (1363 and 1611 m), P17N 80 (940 m), P17N 90 (723 m) and P17N 92 (1365 m).

Since the new oxygen sensor SBE 43 was recognized as a surprisingly good sensor compared to the old oxygen sensor SBE 13, the new sensor was used as primary sensor and the old sensor was used as secondary sensor after P17N 31.

CTD casts at station P17N 41 and 91 have been scheduled to be skipped. The station P17N X01 was located at the same geographical position as station 92 of WHP-P01, where CTD casts were carried out in 1985 by R/V Thomas Thompson and in 1999 by R/V Mirai and R/V J.P. Tully.

The CTD cast at station P17N 76 was delayed about 2 days than the plan because sea and weather were too severe for a CTD operation. For this reason, the station P17N 85 and 89 were canceled and the station P17N 95 and 97 were replaced with XCTD casts.

(6) Data processing

SEASOFT consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment and is designed to work with an IBM or compatible personal computer. Raw data are acquired from instruments and are stored as unmodified data. The conversion module DATCNV uses the instrument configuration and calibration coefficients

to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. Each SEASOFT module that modifies the converted data file adds proper information to the header of the converted file permitting tracking of how the various oceanographic parameters were obtained. The converted data is stored in either rows and columns of ascii numbers. The last data column is a flag field used to mark scans as good or bad.

The following are the SEASOFT-Win32 (Ver. 5.21 or 5.23) processing module sequence and specifications used in the reduction of CTD/O₂ data in this cruise. Some modules are originally developed for additional processing and post-cruise calibration.

DATCNV converted the raw data to scan number, pressure, temperatures, conductivities, oxygen current (SBE 13), oxygen temperature (SBE 13), oxygen voltage (SBE 43), chlorophyll-a concentration, transmissometer voltage and altitude. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The first scan was set to 2 seconds prior to the confirm bit and the duration was set to 4 seconds.

ROSSUM created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Pressure, temperatures, conductivities, oxygen current (SBE 13), oxygen temperature (SBE 13), oxygen voltage (SBE 43), chlorophyll-a concentration, transmissometer voltage and altitude were averaged over 4 seconds.

ALIGNCTD converted the time-sequence of conductivity and oxygen sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9 CTD with the ducted temperature and conductivity sensors and a 3,000 rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary conductivity for 1.73 scans ($1.75/24 = 0.073$ seconds). As the result, the secondary conductivity was advanced 0.073 seconds relative to the temperature. Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. As for the temperature and the conductivity, this delay was compensated by 5 seconds

advancing oxygen sensor outputs relative to the pressure.

WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 48 scans. Data greater than two standard deviations were flagged. The second pass computed a standard deviation over the same 48 scans excluding the flagged values. Values greater than 10 standard deviations were marked bad. This process was applied to pressure, temperatures, conductivities, oxygen and altimeter outputs. For oxygen voltage (SBE 43), values within displacement of 0.006 V from the mean were not marked bad. For oxygen current (SBE 13), values within displacement of 0.0015 microA from the mean were not marked bad. For oxygen temperature (SBE 13), values within displacement of 0.055 °C from the mean were not marked bad. For the data at stations of P17N 47 and P17N 71 cast 1, this process was applied twice in order to remove remaining spikes.

CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values were used for thermal anomaly amplitude ($\alpha = 0.03$) and the time constant ($1/\beta = 9.0$).

FILTER performed as a low pass filter on pressure with a time constant of 0.15 seconds. In order to produce zero phase lag (no time shift) the filter runs forward first then backwards.

WFILTER performed as a median filter to remove spikes in Fluorometer and Transmissometer data. A median value was determined by 49 scans of the window.

WHPHEADER (original module) added information in header record correspondingly to the WHP CTD data (EXPOCODE, WHP-ID, STNNBR, CASTNO, DATE, INSTRUMENT NO. and SAMPLING RATE).

SECTION selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be a starting time when the CTD package was beneath the sea-surface after the activation of the pump. The maximum number was set to be an ending time when the package came up from the surface. (Data to check the CTD pressure drift were prepared before SECTION.)

LOOPEDIT marked scans where the CTD was moving less than the minimum velocity of 0.0 m/s

(traveling backwards due to ship roll).

DERIVE was used only to compute the time derivative of oxygen (for the term dc/dt of SBE 13) with a time window size of 2.0 seconds.

BINAVG averaged the data into 1 dbar pressure bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record exists every dbar.

DERIVE was re-used to compute salinity, depth, potential temperature, σ_t and σ_θ .

SPLIT was used to split data into the down cast and the up cast.

(7) CTD/O2 Post-Cruise Calibration

(7.1) Pressure calibration

The CTD pressure sensor drift in the period of this cruise is estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor has to be powered for at least 10 minutes before the operation and carefully temperature equilibrated. However, CTD system was powered only several minutes before the operation at most of stations. Only “pre-cast on deck CTD pressure” data with longer aging time than two minutes were selected and were averaged over one minute to prepare calibration data for the pre-cast pressure sensor drift. As for the calibration data for the post-cast pressure sensor drift, the CTD deck pressure is averaged over last one minute to get a calibration data. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) is subtracted from the CTD pressure. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and averaged over one minute for a meteorological data.

The CTD pressure sensor drift is estimated from the deck pressure obtained above. An average of the pre- and the post-casts data over the whole period of this cruise gave an estimation of -0.61 dbar and the root-mean-square difference of 0.14 dbar. Since the cruise period (August 2001) was 4 months later from the pre-cruise calibration (April 2001), the typical drift was expected about 0.6 dbar. The

estimated drift (0.61 dbar) is comparable to the typical drift in the specification of the present pressure sensor. Finally the CTD pressure is calibrated as

$$\text{Calibrated pressure (dbar)} = p + 0.61$$

where p is the CTD pressure in dbar.

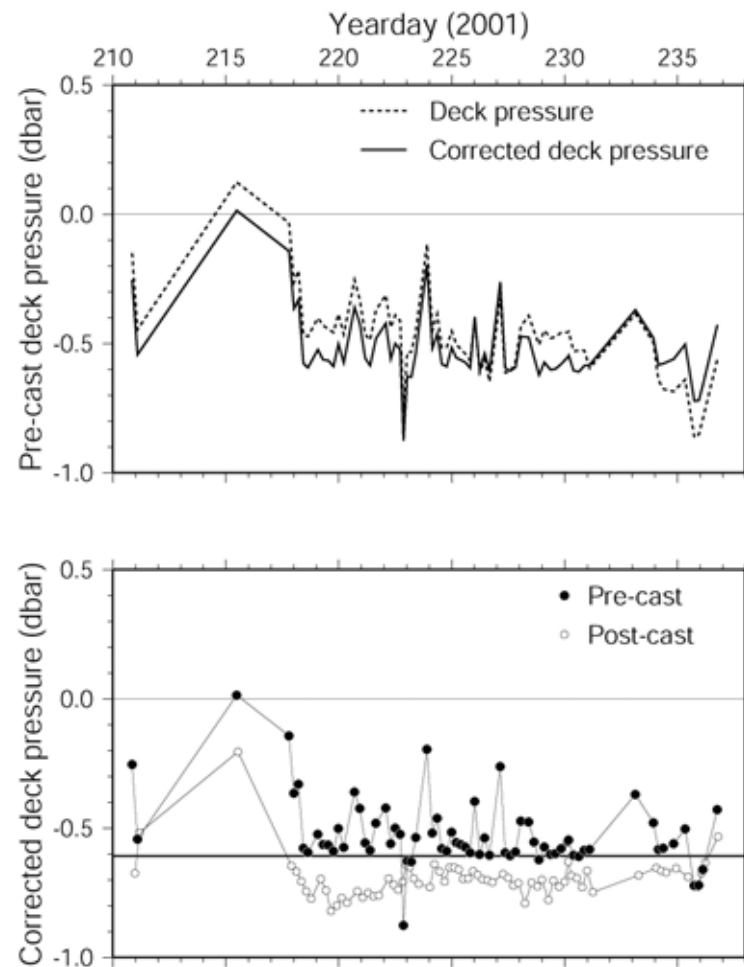


Figure 3.9.2: Time series of the CTD deck pressure. Upper panel shows the pre-cast deck pressure (dotted line) and the corrected deck pressure subtracting the atmospheric pressure deviation from the pre-cast deck pressure (solid line). Lower panel shows the corrected deck pressure for the pre- and post-cast.

(7.2) Temperature calibration

Post-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were the results.

S/N 031464 September 25, 2001

$$g = 4.84437595e-03$$

$$h = 6.81426982e-04$$

$$i = 2.72899771e-05$$

$$j = 2.17701451e-06$$

$$f0 = 1000.000$$

S/N 031524 September 25, 2001

$$g = 4.83461183e-03$$

$$h = 6.75115071e-04$$

$$i = 2.62742100e-05$$

$$j = 2.10734809e-06$$

$$f0 = 1000.000$$

These temperature sensor drifts are traced since 1994 based on laboratory calibrations performed at SBE, Inc. The mean absolute residuals between the bath temperature and the CTD temperature at 11 calibration points show almost linear tendency in time for the primary temperature sensor (about 1 m°C per year). The CTD temperature drift during each period of observation is estimated lineally using the pre- and post-cruise laboratory calibration equations. The CTD temperature calibration was carried out by subtracting the corresponding estimated drift from in-situ temperature readings.

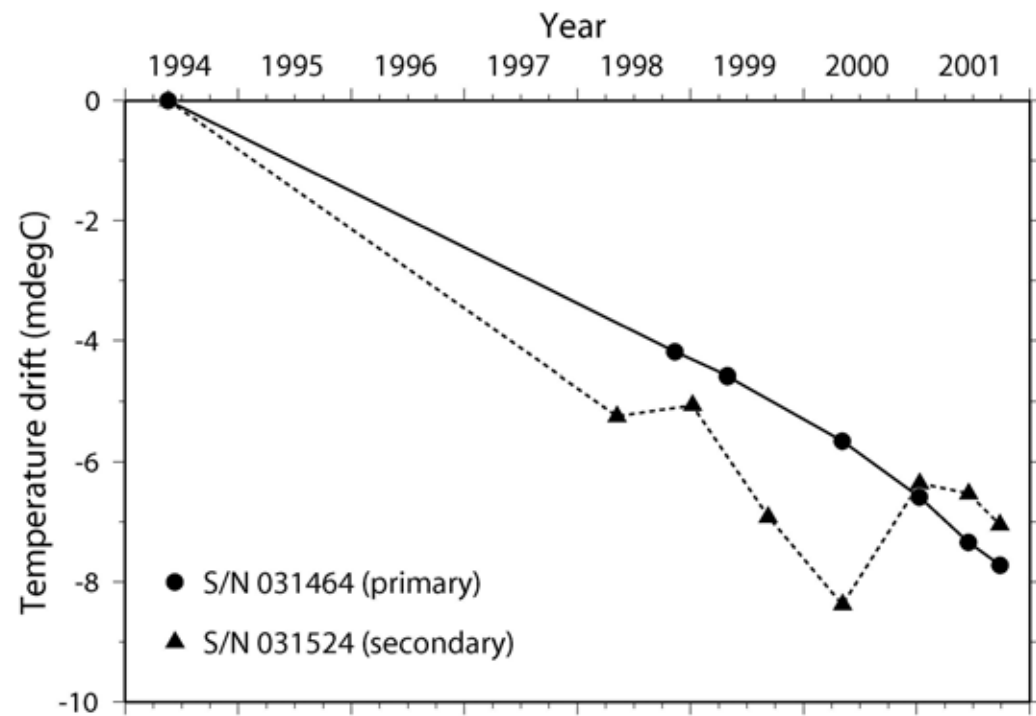


Figure 3.9.3: Temperature sensor drift based on laboratory calibrations performed at SBE, Inc.

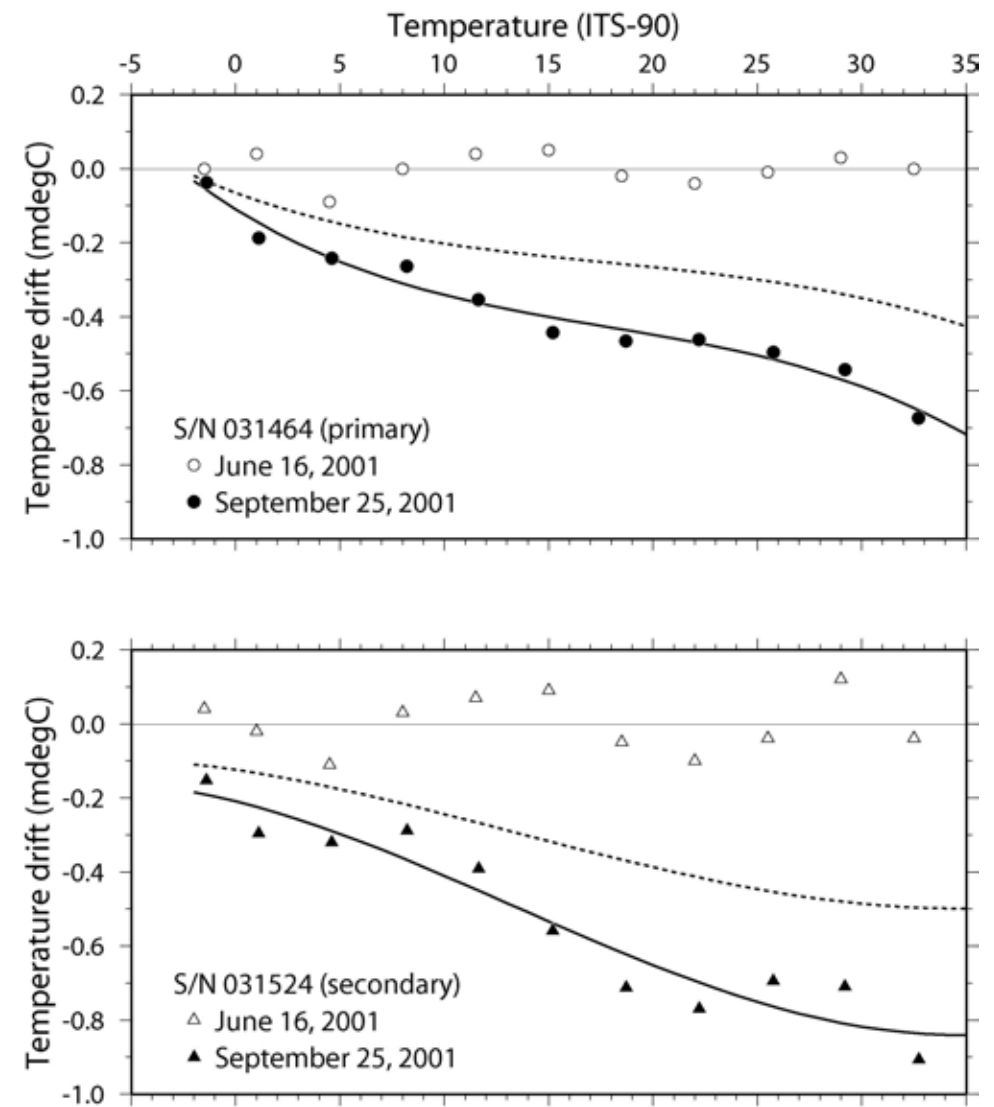


Figure 3.9.4: Temperature sensor drift between the pre-cruise calibration and the post-cruise calibration. Dotted line shows estimated drift at August 15, 2001. Upper panel is for the primary sensor and lower panel is for the secondary sensor.

(7.3) Salinity calibration

The discrepancies of the CTD salinity from the bottle salinity showed each linear behavior against the pressure at the depths upper and lower than about 2,000 dbar, separately. Therefore the CTD salinity can be calibrated as

$$\begin{aligned} \text{Calibrated salinity} &= s - (a_0 + b_0 * p) \quad [\text{when } p < p_r] \\ &= s - (a_1 + b_1 * p) \quad [\text{when } p \geq p_r] \\ a_0 + b_0 * p_r &= a_1 + b_1 * p_r \end{aligned}$$

where s is CTD salinity, p is CTD pressure in dbar, p_r is the bordering pressure in dbar (i.e. about 2,000 dbar) and a_0 , b_0 , a_1 and b_1 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation from the bottle salinity data. Fortran routine MEDFIT in the Numerical Recipes (Press et al., 1992) is used with a slight modification to determine the sets. The coefficients of a_1 and b_1 are determined first then the coefficients of a_0 and b_0 are determined with a restriction that the two equations take same value at a pressure of p_r .

The p_r is set to 2,000 dbar. The coefficients are determined for each station. For the station P17N 96, 98 and 99, only coefficients of a_0 and b_0 are determined with no restriction because the maximum pressure is shallower than 2,000 dbar. The CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD pressure and temperature. The calibration is performed for the CTD salinity calculated from the primary temperature and the primary conductivity sensor data. For depths where the vertical salinity gradient calculated from the up cast CTD data as greater than 0.003 (per dbar), bottle salinity data are not used for calibration because of the ambiguity resulted from the vertical separation of the bottles and CTD sensors. Nevertheless, for the station P17N 98 and 99, the threshold is enlarged to 0.01 and 0.03, respectively, because vertical salinity gradients greater than 0.003 (per dbar) at most of depths of observation.

The calibration coefficients, the mean absolute deviation (dev) from the bottle salinity and the number of the data (n) used for the calibration are shown in Table 3.9.1.

Table 3.9.1: Calibration coefficients for CTD salinity.

		[P < pr]				[p >= pr]				
Station		a0	b0	dev	n	a1	b1	dev	n	
P17C	26	1	-0.00323796359	8.36601939e-07	0.0037	19	-0.00271393877	5.74589528e-07	0.0002	11
P17C	25	1	-0.00257052449	8.82155636e-07	0.0014	16	-0.00132877162	2.61279201e-07	0.0002	13
P17C	24	1	-0.00331067064	1.16289883e-06	0.0016	16	-0.00184117328	4.28150144e-07	0.0003	12
P17C	23	1	-0.00382368966	1.40692913e-06	0.0015	16	-0.00179434874	3.92258671e-07	0.0001	12
P17C	22	1	-0.00326188564	1.41985481e-06	0.0007	15	-0.00096517101	2.71497497e-07	0.0002	12
P17C	21	1	-0.00319830505	1.43389220e-06	0.0017	17	-0.00147579046	5.72634908e-07	0.0003	11
P17C	20	1	-0.00261318529	1.00304935e-06	0.0011	15	-0.00138810474	3.90509077e-07	0.0002	12
P17C	19	1	-0.00202409855	1.25230270e-06	0.0029	14	-0.00004195469	2.61230772e-07	0.0003	15
P17C	18	1	-0.00283864140	1.71584117e-06	0.0026	13	+0.00002441331	2.84313809e-07	0.0001	15
P17N	28	1	-0.00112514634	7.56885977e-07	0.0021	15	-0.00055319685	4.70911231e-07	0.0002	15
P17N	29	1	-0.00370425677	2.22804475e-06	0.0029	12	+0.00017592133	2.87955697e-07	0.0002	15
P17N	30	1	-0.00280488879	1.69012529e-06	0.0036	16	-0.00044555799	5.10459893e-07	0.0002	15
P17N	31	1	-0.00098135226	9.06224203e-07	0.0010	16	+0.00022851796	3.01289096e-07	0.0002	15
P17N	32	1	-0.00126321674	8.70164912e-07	0.0013	18	-0.00005488577	2.65999429e-07	0.0002	14
P17N	33	1	-0.00100392508	7.57475347e-07	0.0017	17	-0.00017721020	3.44117904e-07	0.0002	15
P17N	34	1	-0.00210535284	1.44937246e-06	0.0022	14	+0.00024544860	2.73971739e-07	0.0001	15
P17N	35	1	-0.00100620500	8.98826507e-07	0.0021	19	+0.00009644912	3.47499447e-07	0.0002	13
P17N	36	1	-0.00084307915	8.22056902e-07	0.0011	17	+0.00003336582	3.83834416e-07	0.0002	12
P17N	37	1	-0.00206571751	1.65780681e-06	0.0008	14	+0.00086308272	1.93406694e-07	0.0002	12
P17N	38	1	-0.00274848175	1.90594484e-06	0.0027	18	+0.00043136806	3.16019935e-07	0.0001	13
P17N	39	1	-0.00219115023	1.59192468e-06	0.0015	16	+0.00043326578	2.79716674e-07	0.0002	13

P17N 40 1 -0.00480874195 2.84841427e-06 0.0018 20 -0.00002631819 4.57202389e-07 0.0001 10	P17N 66 1 -0.00433764720 3.06272946e-06 0.0013 15 +0.00089342267 4.47194522e-07 0.0002 13
P17N 42 1 -0.00364456318 2.16124869e-06 0.0028 21 -0.00103968629 8.58810246e-07 0.0001 10	P17N 67 1 -0.00363321500 2.68804962e-06 0.0012 16 +0.00062632815 5.58278049e-07 0.0002 12
P17N 43 1 -0.00187164002 1.22702118e-06 0.0030 16 -0.00104440142 8.13401881e-07 0.0001 10	P17N 68 1 -0.00289688175 2.50376971e-06 0.0009 16 +0.00124164132 4.34508177e-07 0.0002 11
P17N 44 1 -0.00301327646 1.75063559e-06 0.0020 18 -0.00049127870 4.89636713e-07 0.0001 11	P17N 69 1 -0.00206561032 1.82391954e-06 0.0010 17 +0.00011845680 7.31885980e-07 0.0002 13
P17N 45 1 -0.00221023727 1.31971058e-06 0.0009 18 -0.00081721950 6.23201692e-07 0.0002 11	P17N 70 1 -0.00652305713 4.20119396e-06 0.0027 16 +0.00083172904 5.23800872e-07 0.0001 11
P17N 46 1 -0.00351928388 2.21918435e-06 0.0029 20 +0.00018003287 3.69525974e-07 0.0001 11	P17N 71 3 -0.00516241726 3.52364120e-06 0.0021 16 +0.00078813535 5.48364888e-07 0.0002 13
P17N 47 1 -0.00149713124 1.16861624e-06 0.0013 20 +0.00022286518 3.08618031e-07 0.0001 8	P17N 72 1 -0.00260120648 2.47380727e-06 0.0010 19 +0.00164166493 3.52371566e-07 0.0003 13
P17N 48 1 -0.00739143072 4.18611668e-06 0.0035 22 -0.00003244765 5.06625144e-07 0.0006 9	P17N 73 1 -0.00091898367 1.55554863e-06 0.0007 17 +0.00125905785 4.66527870e-07 0.0002 14
P17N 49 1 -0.00274069485 1.72223501e-06 0.0015 21 -0.00020164018 4.52707674e-07 0.0001 10	P17N 74 1 -0.00371667927 3.38154846e-06 0.0014 14 +0.00243689634 3.04760658e-07 0.0002 10
P17N 50 1 -0.00179353576 1.30327572e-06 0.0010 20 +0.00005565780 3.78678942e-07 0.0001 10	P17N 75 1 -0.00486364697 3.37219811e-06 0.0017 16 +0.00041573837 7.32505441e-07 0.0003 14
P17N 51 1 -0.00236921437 1.71007795e-06 0.0019 18 +0.00036073481 3.45103364e-07 0.0002 10	P17N 76 1 -0.00424812495 3.16531365e-06 0.0010 17 +0.00140274108 3.39880636e-07 0.0001 14
P17N 52 1 -0.00431883257 2.60325069e-06 0.0010 15 -0.00009230456 4.89986690e-07 0.0001 10	P17N 77 1 -0.00277322927 2.49874131e-06 0.0018 18 +0.00157255241 3.25850470e-07 0.0002 14
P17N 53 1 -0.00389149710 2.36791128e-06 0.0021 22 -0.00051017140 6.77248430e-07 0.0003 11	P17N 78 1 -0.00317585841 2.74326963e-06 0.0014 18 +0.00144148287 4.34598993e-07 0.0001 11
P17N 54 1 -0.00656862167 3.92821012e-06 0.0033 18 +0.00040671843 4.40540072e-07 0.0001 10	P17N 79 1 -0.00069385904 1.56374525e-06 0.0007 17 +0.00186176145 2.85935009e-07 0.0001 12
P17N 55 1 -0.00395174000 2.47307957e-06 0.0016 17 +0.00006997511 4.62222014e-07 0.0003 12	P17N 80 1 -0.00456970497 3.72415366e-06 0.0015 18 +0.00232147753 2.78562409e-07 0.0002 12
P17N 56 1 -0.00424859112 2.54919462e-06 0.0037 16 -0.00045596387 6.52880998e-07 0.0001 9	P17N 81 1 -0.00211883577 2.35442232e-06 0.0012 17 +0.00188724978 3.51379543e-07 0.0001 12
P17N 57 1 -0.00632590758 3.78120284e-06 0.0024 18 +0.00072592490 2.55286594e-07 0.0003 9	P17N 82 1 -0.00027518314 1.34440570e-06 0.0009 17 +0.00155926357 4.27182341e-07 0.0001 9
P17N 58 1 -0.00391224558 2.51015183e-06 0.0010 18 -0.00023526510 6.71661595e-07 0.0002 12	P17N 83 1 -0.00075817689 1.78319230e-06 0.0008 17 +0.00238703497 2.10586372e-07 0.0001 11
P17N 59 1 -0.00648368908 4.00245706e-06 0.0030 18 +0.00115609924 1.82562902e-07 0.0006 10	P17N 84 1 -0.00172366742 2.10642746e-06 0.0014 19 +0.00166914832 4.10019591e-07 0.0002 10
P17N 60 1 -0.00619373052 3.53760486e-06 0.0018 17 -0.00012297052 5.02224860e-07 0.0002 12	P17N 86 1 -0.00082332938 1.83224240e-06 0.0017 13 +0.00233071217 2.55221624e-07 0.0001 14
P17N 61 1 -0.00287315314 2.23506005e-06 0.0011 19 +0.00064993799 4.73514483e-07 0.0002 13	P17N 87 1 -0.00292921563 2.98581447e-06 0.0013 14 +0.00254923496 2.46589172e-07 0.0002 14
P17N 62 1 -0.00579580478 3.62060307e-06 0.0011 17 +0.00042784185 5.08779752e-07 0.0002 12	P17N 88 1 -0.00107680266 2.10124760e-06 0.0008 12 +0.00279254161 1.66575462e-07 0.0002 17
P17N 63 1 -0.00380900743 2.34187157e-06 0.0019 20 -0.00102612201 9.50428857e-07 0.0002 13	P17N 90 1 -0.00083228193 1.91158460e-06 0.0019 18 +0.00230746930 3.41708982e-07 0.0001 12
P17N 64 1 -0.00557255381 3.40483902e-06 0.0015 18 +0.00002883384 6.04145195e-07 0.0002 12	P17N 92 1 -0.00074134491 1.76061628e-06 0.0015 20 +0.00198020219 3.99842728e-07 0.0001 10
P17N X01 1 -0.00492856194 3.33574011e-06 0.0011 14 +0.00087074293 4.36087680e-07 0.0002 14	P17N 93 1 0.001337410210 9.21610307e-07 0.0012 21 +0.00174232110 7.19154863e-07 0.0001 9
P17N 65 1 -0.00672411653 4.32041464e-06 0.0015 16 +0.00107943845 4.18637148e-07 0.0002 13	P17N 94 1 -0.00031490228 2.00050960e-06 0.0010 22 +0.00270481639 4.90650267e-07 0.0001 6

P17N 96 2 -0.00195391654 4.17750848e-06 0.0011 16
P17N 98 1 -0.00137970523 2.52920668e-06 0.0023 11
P17N 99 1 -0.00993932076 4.01977009e-06 0.0056 6

The mean absolute deviation averaged over all stations is as follows:

0.0018 [p < 2,000 dbar]

0.0002 [p >= 2,000 dbar]

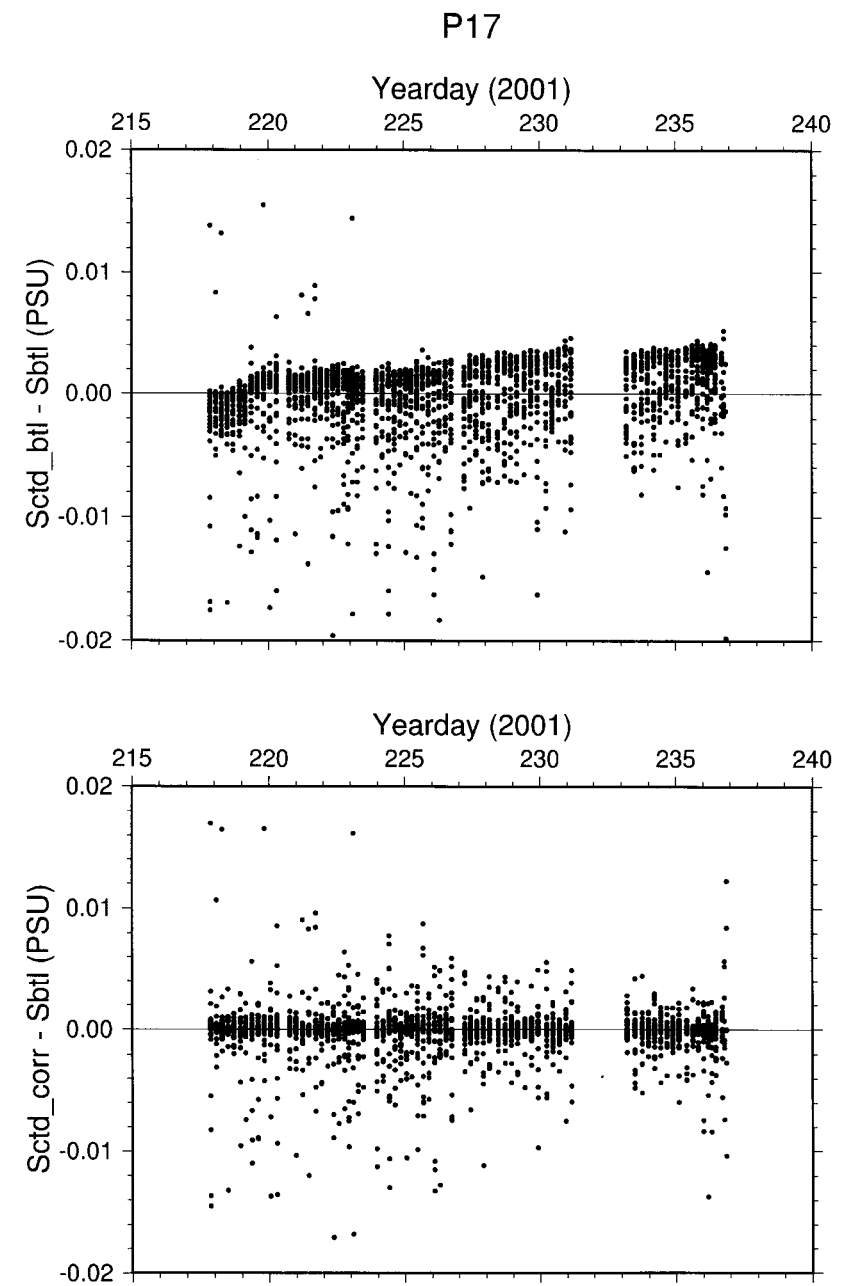


Figure 3.9.5: Time series of salinity residuals before (upper panel) and after (lower panel) the calibration.

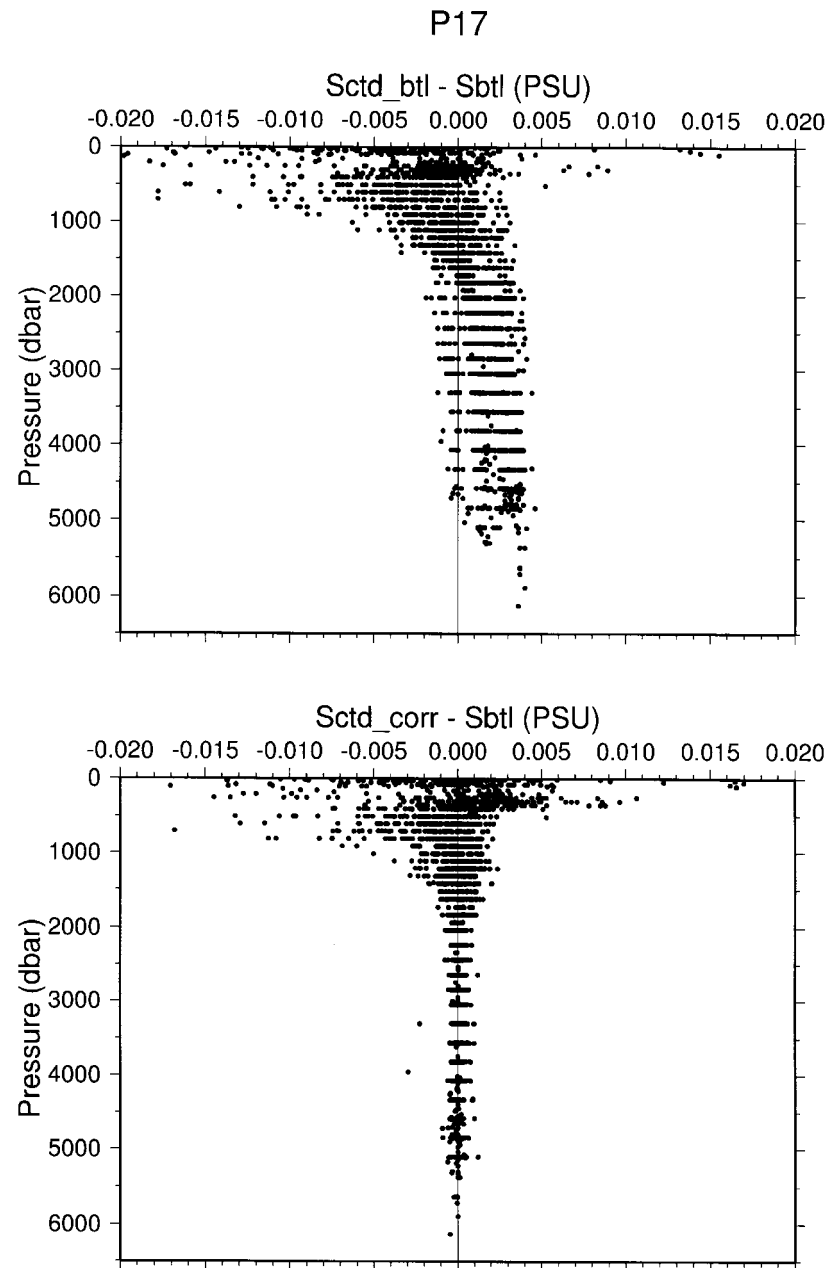


Figure 3.9.6: Vertical distribution of salinity residuals before (upper panel) and after (lower panel) the calibration.

(7.4) Oxygen calibration

The discrepancies of the CTD oxygen (SBE 43) from the bottle oxygen show linear behavior against the bottle oxygen values at depths shallower than about 3,000 dbar and against the pressure deeper than about 3,000 dbar. Therefore the CTD oxygen is calibrated as

$$\text{Calibrated oxygen} = (a_0 + b_0 * o) - (a_1 + b_1 * p)$$

$$a_1 = 0, b_1 = 0 \quad [\text{when } p < pr]$$

$$a_1 + b_1 * pr = 0$$

where o is CTD oxygen in $\mu\text{mol/kg}$, p is CTD pressure in dbar, pr is the bordering pressure (about 3,000 dbar) in dbar and a_0 , b_0 , a_1 , b_1 are the calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviations from the bottle oxygen data. Fortran routine MEDFIT in the Numerical Recipes (Press et al., 1992) is used with a slight modification to determine the coefficients. The coefficients a_0 and b_0 are determined first then the coefficients a_1 and b_1 are determined with a restriction that the two equations take same value at a pressure of pr .

A calibration with the coefficients a_0 and b_0 in above equation may correspond to that with the coefficients of Soc and Offset (see 4.4 and 4.5) in the oxygen model. Although a calibration with Soc and Offset should be essential, the pressure dependency mentioned above could not be retrieved with sufficient accuracy through such a calibration. Therefore the simple linear calibration equations are used to calibrate the CTD oxygen.

The pr was set to 2,500 dbar or 3,000 dbar. The coefficients are determined at each station. The deviation of CTD oxygen from the bottle oxygen at depth shallower than 800 dbar is too large to determine a proper sets of the coefficients since the vertical oxygen gradient is strong in the regions. So the coefficients a_0 and b_0 are determined using the data in the pressure range from 800 dbar to pr . Nevertheless, for the station P17N 96, 98 and 99, the coefficients of a_0 and b_0 are determined using the data in the whole pressure range because the numbers of bottle oxygen data were small. The down cast CTD data were used after the post-cruise calibration for CTD pressure, temperature and salinity. For depths where the vertical oxygen gradient calculated from the down cast CTD data as greater than 5

μmol/kg, bottle oxygen data are not used for calibration because of the ambiguity resulted from the vertical separation of the bottles and CTD sensors.

The pr, the calibration coefficients, the mean absolute deviation from the bottle oxygen and the number of available data for the calibration are shown in Table 3.9.2.

Table 3.9.2: Calibration coefficients for CTD oxygen.

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dev and n: the mean absolute deviation and the number of the data [p < 800 dbar]
dev0 and n0: the mean absolute deviation and the number of the data [pr > p >= 800 dbar]
dev1 and n1: the mean absolute deviation and the number of the data [p >= pr]
-----
Station  pr  a0      b0      dev  n  dev0 n0  a1      b1      dev1 n1
-----
P17C 26 1 3000 -6.099360405 1.040369946 6.86 13 0.94 14 -10.9299107 0.00364330357 0.35 7
P17C 25 1 3000 -8.971520275 1.075145280 7.44 12 0.42 13 -14.4504841 0.00481682805 0.50 8
P17C 24 1 3000 -5.529627844 1.028365598 4.53 14 0.68 14 -6.77747736 0.00225915912 0.40 7
P17C 23 1 3000 -7.386595950 1.047246541 4.23 12 0.28 11 -7.53960919 0.00251320306 0.22 6
P17C 22 1 3900 -7.305887486 1.049203595 4.80 14 0.50 11 -8.46202316 0.00282067439 0.35 8
P17C 21 1 3000 -9.059589750 1.070725686 5.07 14 0.84 14 -12.5271348 0.00417571159 0.70 6
P17C 20 1 2500 -7.576914038 1.062166023 3.99 12 0.65 10 -7.26808020 0.00290723208 0.27 9
P17C 19 1 3000 -6.888153605 1.050814179 3.54 14 0.87 11 -10.0069168 0.00333563892 0.34 10
P17C 18 1 2500 -8.676846720 1.091437969 7.52 12 0.44 08 -10.2718365 0.00410873459 0.55 10
P17N 28 1 2500 -8.949509795 1.095178051 6.29 13 0.24 10 -11.7304995 0.00469219980 0.83 12
P17N 29 1 2500 -10.71553764 1.108806876 6.21 11 1.10 08 -13.9391875 0.00557567501 0.80 12
P17N 30 1 3000 -9.991639224 1.076033076 2.98 12 0.31 10 -13.9476730 0.00464922434 0.41 10
P17N 31 1 3000 -8.781873275 1.059551905 8.41 13 0.31 11 -12.3603037 0.00412010122 0.67 10

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P17N 32 1 3000 -7.409800688 1.031783329 4.84 11 0.50 13 -6.89646032 0.00229882011 0.68 9
P17N 33 1 3000 -8.873530679 1.060111768 6.25 14 0.62 11 -13.8277935 0.00460926451 0.43 10
P17N 34 1 3000 -10.31154992 1.091510132 8.47 12 0.75 11 -19.6614446 0.00655381487 0.70 10
P17N 35 1 3000 -9.084332713 1.046265000 5.97 14 0.57 13 -8.88625332 0.00296208444 0.43 8
P17N 36 1 3000 -9.399049595 1.056992029 6.70 11 0.64 13 -11.9565125 0.00398550416 0.46 7
P17N 37 1 3000 -8.364248414 1.042942612 2.91 10 0.35 12 -8.37163711 0.00279054570 0.62 6
P17N 38 1 3000 -10.13053131 1.073233270 4.53 12 0.79 12 -16.4941999 0.00549806665 0.52 9
P17N 39 1 3000 -9.434457480 1.055735385 7.58 11 0.73 14 -12.2868186 0.00409560619 0.47 8
P17N 40 1 3000 -8.422725258 1.043201281 5.09 11 0.82 17 -10.8458844 0.00361529479 0.48 5
P17N 42 1 3000 -10.24374321 1.058984335 4.74 11 0.93 18 -16.0869251 0.00536230838 0.31 3
P17N 43 1 3000 -9.382698183 1.062958957 5.26 11 0.49 14 -18.7986256 0.00626620852 0.53 5
P17N 44 1 3000 -9.981734298 1.061992123 5.80 14 0.29 16 -12.6278156 0.00420927187 0.20 6
P17N 45 1 3000 -10.58694741 1.067900558 3.96 11 0.49 15 -14.4999088 0.00483330294 0.29 6
P17N 46 1 3000 -8.581704444 1.035389951 7.26 14 0.53 14 -6.65999935 0.00221999978 0.40 6
P17N 47 1 3000 -9.576965449 1.050655685 5.16 14 0.69 14 -8.81065801 0.00293688600 0.28 5
P17N 48 1 3000 -9.473259386 1.047975147 8.31 11 0.52 16 -7.72022568 0.00257340856 0.34 5
P17N 49 1 2500 -9.834545198 1.081214717 6.36 14 0.41 14 -11.3991842 0.00455967368 0.26 6
P17N 50 1 2500 -10.10495099 1.095254233 8.22 09 0.37 11 -13.5234429 0.00540937715 0.90 6
P17N 51 1 2500 -9.638736644 1.081947704 2.00 11 0.43 12 -11.3137098 0.00452548393 0.49 7
P17N 52 1 3000 -8.121769450 1.044767285 6.81 09 0.61 13 -11.1193260 0.00370644201 0.38 3
P17N 53 1 3000 -9.604492361 1.067672633 5.95 13 0.68 16 -15.5654310 0.00518847700 0.73 5
P17N 54 1 3000 -10.28221502 1.064388502 4.91 10 0.83 13 -11.5592357 0.00385307857 0.45 4
P17N 55 1 3000 -8.215101362 1.056469182 2.18 11 0.95 14 -15.7699668 0.00525665560 0.42 7
P17N 56 1 3000 -9.791078427 1.057042803 2.86 12 0.73 15 -10.5405558 0.00351351859 0.24 6
P17N 57 1 3000 -10.66876483 1.080050297 5.21 12 0.35 13 -16.4940112 0.00549800374 0.54 6
P17N 58 1 2500 -10.76470289 1.100402187 5.59 14 0.71 11 -13.8494455 0.00553977820 0.66 9

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P17N 59 1 2500 -10.53793839 1.092647127 5.34 14 0.65 13 -12.2999378 0.00491997513 0.72 9	P17N 84 1 3000 -9.985211184 1.057807940 5.17 12 0.43 13 -12.9007483 0.00430024945 0.39 8
P17N 60 1 3000 -9.836038299 1.064379433 2.11 13 0.34 13 -12.3644234 0.00412147447 0.69 7	P17N 86 1 3000 -10.19567244 1.043387069 5.30 09 0.56 10 -15.2588930 0.00508629768 0.83 10
P17N 61 1 3000 -9.408143455 1.056110095 5.71 12 0.35 14 -10.7805048 0.00359350161 0.26 8	P17N 87 1 2500 -9.730194504 1.057040862 9.18 09 0.38 09 -9.91423923 0.00396569569 0.56 14
P17N 62 1 3000 -9.923429623 1.073515852 3.87 11 0.64 13 -15.2642608 0.00508808694 0.35 8	P17N 88 1 2500 -10.41733909 1.063737279 16.76 11 0.23 09 -12.4798272 0.00499193089 1.00 14
P17N 63 1 3000 -9.557855591 1.048627293 6.34 14 0.28 13 -11.5186339 0.00383954465 0.33 7	P17N 90 1 2500 -12.56598991 1.124036761 3.03 12 0.67 10 -19.9885598 0.00799542391 1.32 10
P17N 64 1 3000 -9.740348640 1.088424387 4.00 13 0.31 13 -21.7283223 0.00724277409 0.41 7	P17N 92 1 3000 -8.952500275 1.027299076 11.14 13 0.78 16 -1.61467574 0.00053822525 0.56 5
P17N X01 1 3000 -8.371952559 1.038180592 8.83 13 0.60 09 -9.78801865 0.00326267288 0.69 9	P17N 93 1 3000 -9.686243469 1.043885543 7.03 14 0.78 17
P17N 65 1 3000 -9.551040280 1.079632823 11.09 11 0.60 11 -19.3524499 0.00645081664 0.76 8	P17N 94 1 3000 -10.52427791 1.049230691 8.71 17 0.48 16
P17N 66 1 3000 -10.27693516 1.091416152 6.31 11 0.53 13 -21.3706714 0.00712355714 0.44 8	P17N 96 2 3000 -10.54840239 1.091405576 * * 1.59 20
P17N 67 1 3000 -9.412121367 1.075727953 3.39 13 0.55 12 -16.9440724 0.00564802414 0.43 7	P17N 98 1 3000 -11.10571481 1.094795619 * * 3.15 17
P17N 68 1 3000 -8.714350922 1.060143438 7.42 10 0.57 14 -13.7545611 0.00458485371 0.31 6	P17N 99 1 3000 -14.02518652 1.104887956 * * 6.22 10
P17N 69 1 3000 -9.408301211 1.071835344 8.02 13 0.78 14 -15.8136664 0.00527122215 0.53 8	-----
P17N 70 1 3000 -10.32013012 1.076201596 6.76 11 0.56 12 -15.4215410 0.00514051366 0.41 7	
P17N 71 3 3000 -8.919832027 1.050925439 4.18 10 0.45 13 -11.2263973 0.00374213242 0.20 8	
P17N 72 1 3000 -9.052916259 1.047460170 8.98 14 0.49 14 -11.6939781 0.00389799269 0.18 8	
P17N 73 1 3000 -9.219642560 1.073557224 6.08 12 0.61 13 -17.2527649 0.00575092164 0.58 9	
P17N 74 1 3000 -8.775778186 1.060304930 6.37 11 0.25 11 -13.9816700 0.00466055667 0.20 7	
P17N 75 1 3000 -9.997667857 1.075134400 5.43 12 0.51 12 -16.9202792 0.00564009308 0.61 9	
P17N 76 1 3000 -8.990971722 1.042222397 7.76 14 0.40 13 -15.4331625 0.00514438751 1.16 9	
P17N 77 1 3000 -9.710916843 1.060383262 3.41 11 0.47 13 -13.6283141 0.00454277136 0.29 9	
P17N 78 1 3000 -8.568935573 1.044311498 4.35 11 0.47 12 -12.0664230 0.00402214101 0.23 8	
P17N 79 1 3000 -8.738046345 1.043973027 4.87 13 0.50 14 -13.4045628 0.00446818759 0.38 7	
P17N 80 1 3000 -8.097798952 1.043270916 4.01 10 0.54 14 -12.2593489 0.00408644964 0.34 8	
P17N 81 1 3000 -9.233743802 1.053771754 3.80 14 0.68 12 -16.4023224 0.00546744080 0.29 8	
P17N 82 1 3000 -8.881406499 1.051434887 7.17 11 0.28 13 -15.1862347 0.00506207823 0.24 7	
P17N 83 1 3000 -7.975074171 1.028412310 4.26 10 0.47 13 -6.97467826 0.00232489275 0.26 7	

The mean absolute deviation averaged over all stations is as follows:

5.90 $\mu\text{mol/kg}$ [p < 800 dbar]

0.68 $\mu\text{mol/kg}$ [pr > p >= 800 dbar]

0.49 $\mu\text{mol/kg}$ [p >= pr]

(8) References

Press, W. H., S. Teukolsky, T. W. Vetterling and B. P. Flannery (1992): Numerical Recipes in Fortran, Cambridge University Press, 2nd edition.

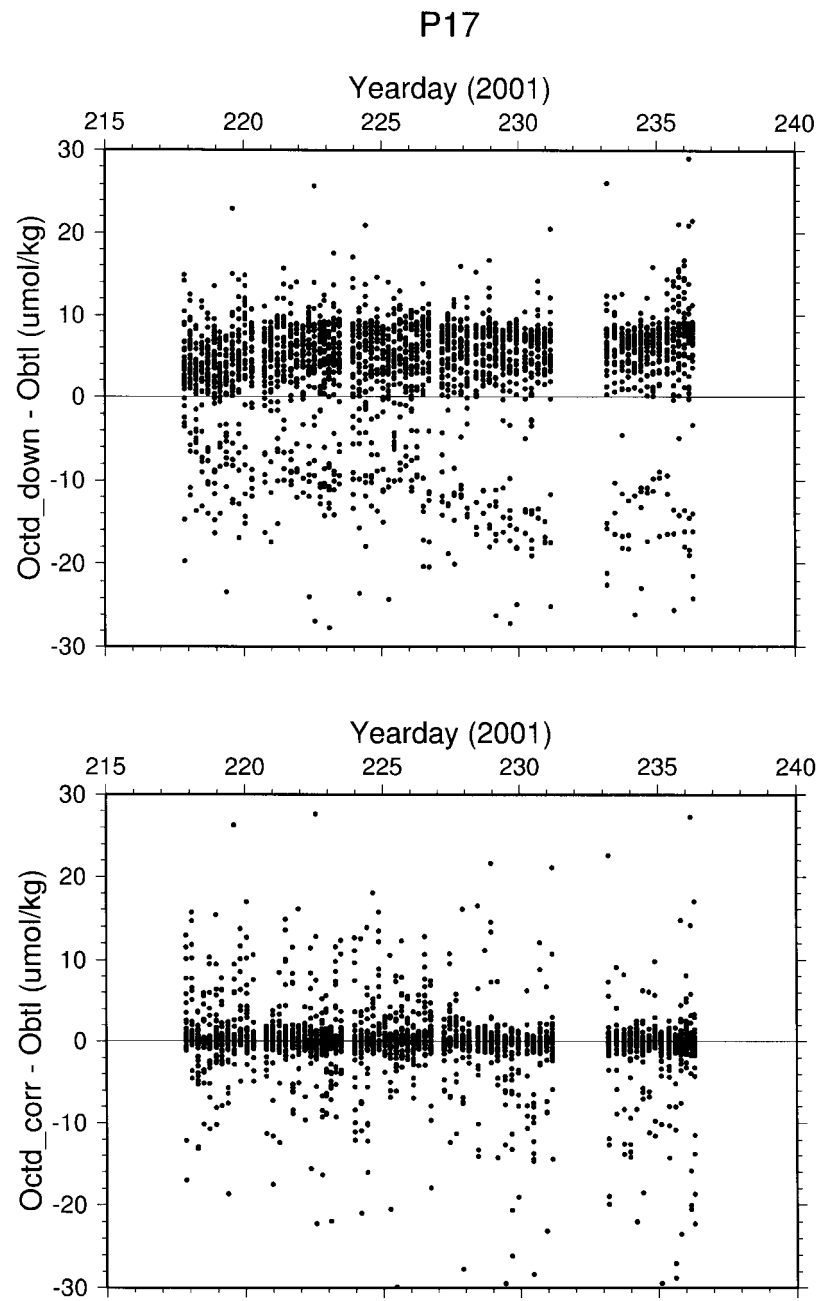


Figure 3.9.7: Time series of oxygen residuals before (upper panel) and after (lower panel) the calibration.

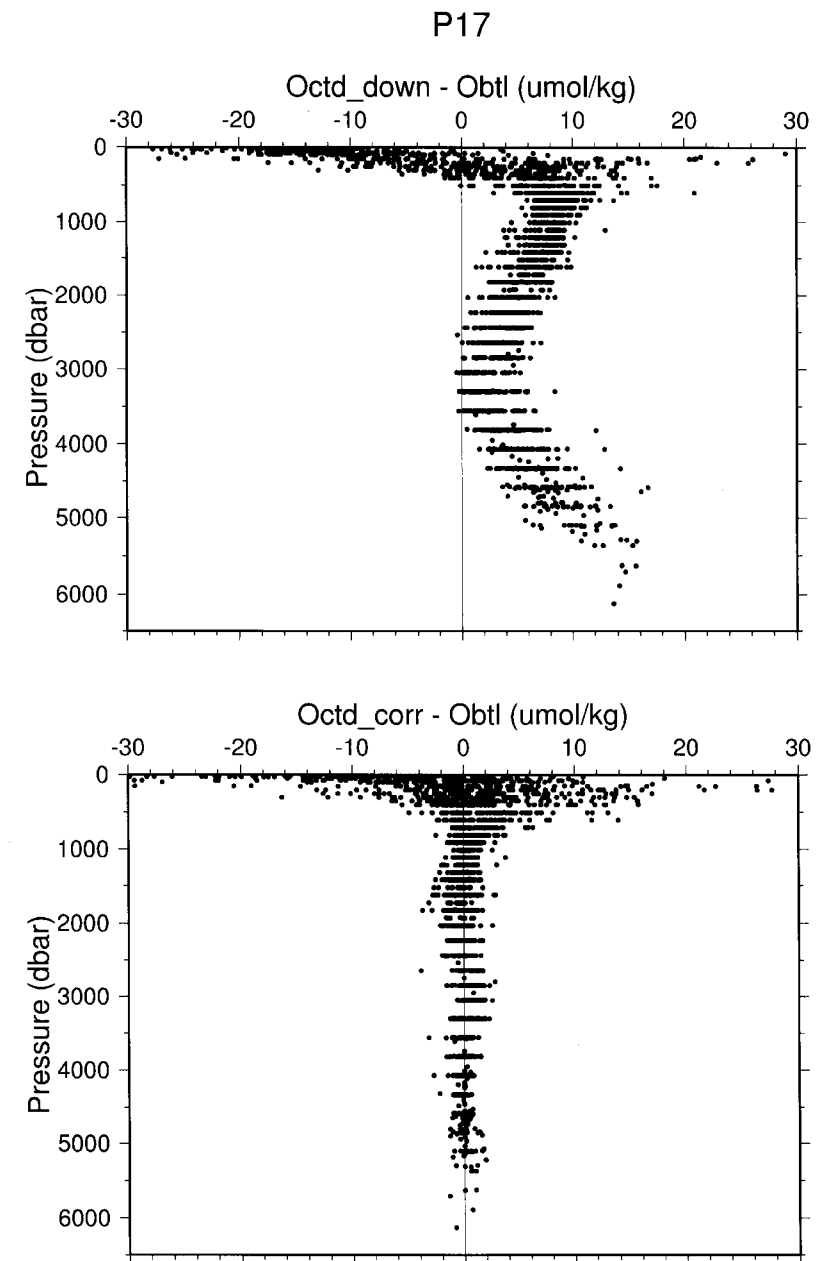


Figure 3.9.8: Vertical distribution of oxygen residuals before (upper panel) and after (lower panel) the calibration.

49MR01K04_1	P17C	18	1	ROS	080801	1248	BE	34	03.97	N	135	00.03	W	GPS	-9	5101				36		LADCP	
49MR01K04_1	P17C	18	1	ROS	080801	1409	BO	34	04.16	N	134	59.86	W	GPS	-9	5091	12	4984	5177			1-8,23,24,26,27	
49MR01K04_1	P17C	18	2	XCT	080801	1548	DE	34	04.47	N	134	59.78	W	GPS	-9	5058						S/N 01075612 (2000M TEST)	
49MR01K04_1	P17C	18	1	ROS	080801	1605	EN	34	04.60	N	134	59.77	W	GPS	-9	5056						BITL#21 O-RING(L) LEAK	
49MR01K04_1	P17N	28	1	ROS	080801	1823	BE	34	35.07	N	135	00.02	W	GPS	-9	5211				36		LADCP	
49MR01K04_1	P17N	28	2	BIO	080801	1901	BE	34	35.24	N	135	00.17	W	GPS	-9	5201						UV PHOTOMETER (100M)	
49MR01K04_1	P17N	28	2	BIO	080801	1910	EN	34	35.21	N	135	00.19	W	GPS	-9	5203							
49MR01K04_1	P17N	28	3	BIO	080801	1910	BE	34	35.21	N	135	00.19	W	GPS	-9	5203						BIO. BUCKET SAMPLING	
49MR01K04_1	P17N	28	3	BIO	080801	1916	EN	34	35.23	N	135	00.21	W	GPS	-9	5204							
49MR01K04_1	P17N	28	1	ROS	080801	1944	BO	34	35.26	N	135	00.25	W	GPS	-9	5191	13	5099	5288			1-8,12,23,24,26,27	
49MR01K04_1	P17N	28	4	XCT	080801	2134	DE	34	35.22	N	135	00.17	W	GPS	-9	5212						S/N 01045094 DEPTH 1036M	
49MR01K04_1	P17N	28	1	ROS	080801	2150	EN	34	35.20	N	135	00.14	W	GPS	-9	5209							
49MR01K04_1	P17N	28	5	XCT	080801	2156	DE	34	35.42	N	135	00.15	W	GPS	-9	5194						S/N 01075617 (1000M TEST)	
49MR01K04_1	P17N	29	1	ROS	080801	2345	BE	34	59.89	N	135	00.01	W	GPS	-9	5213				36		LADCP	
49MR01K04_1	P17N	29	2	BIO	080801	2359	BE	34	59.79	N	135	00.04	W	GPS	-9	5216						BIO. BUCKET SAMPLING	
49MR01K04_1	P17N	29	2	BIO	080901	0011	EN	34	59.71	N	135	00.09	W	GPS	-9	5209							
49MR01K04_1	P17N	29	1	ROS	080901	0119	BO	34	59.52	N	135	00.33	W	GPS	-9	5209	14	5102	5293			1-6	ALTIMETER ERROR (PARTIALLY)
49MR01K04_1	P17N	29	3	XCT	080901	0249	DE	34	59.36	N	135	01.01	W	GPS	-9	5273						S/N 01075617 (2000M TEST)	
49MR01K04_1	P17N	29	1	ROS	080901	0307	EN	34	59.35	N	135	01.04	W	GPS	-9	5294						BITL#33 MISS TRIP (NO DO SAMPLING)	
49MR01K04_1	P17N	30	1	ROS	080901	0534	BE	35	30.00	N	135	00.16	W	GPS	-9	5267				36		LADCP, REPLACED ALTIMETER (BENIHOS)	
49MR01K04_1	P17N	30	1	ROS	080901	0657	BO	35	30.23	N	135	00.57	W	GPS	-9	5229	42	5155	5306			1-8,12,23,24,26,27	ALTIMETER ERROR, HT_ABOVE_BOTTOM MEASURED BY LADCP BOTTOM PING
49MR01K04_1	P17N	30	1	ROS	080901	0859	EN	35	30.77	N	135	00.87	W	GPS	-9	5127						BITL#34 LEAK (NO DO, CFCs, DIC, PH, ALK, 14C SAMPLING)	
49MR01K04_1	P17N	31	1	ROS	080901	1656	BE	36	00.00	N	135	00.18	W	GPS	-9	5134				36		LADCP, RETURNED ALTIMETER, SWAPPED DO SENSORS	
49MR01K04_1	P17N	31	1	ROS	080901	1815	BO	35	59.95	N	135	00.80	W	GPS	-9	5174	11	5079	5215			1-6	
49MR01K04_1	P17N	31	1	ROS	080901	2005	EN	35	59.95	N	135	01.33	W	GPS	-9	5116							
49MR01K04_1	P17N	32	1	ROS	080901	2229	BE	36	29.93	N	135	00.01	W	GPS	-9	5008				36		LADCP	
49MR01K04_1	P17N	32	1	ROS	080901	2352	BO	36	29.94	N	135	00.43	W	GPS	-9	5040	10	4910	5091			1-8,23,24,26,27	
49MR01K04_1	P17N	32	2	XCT	081001	0126	DE	36	30.01	N	135	00.68	W	GPS	-9	5067						S/N 01075613 (2000M TEST)	
49MR01K04_1	P17N	32	1	ROS	081001	0143	EN	36	30.01	N	135	00.73	W	GPS	-9	5073							
49MR01K04_1	P17N	33	1	ROS	081001	0408	BE	37	00.16	N	135	00.08	W	GPS	-9	5059				36		LADCP	
49MR01K04_1	P17N	33	1	ROS	081001	0531	BO	37	00.19	N	135	00.52	W	GPS	-9	5055	58	4919	5096			1-6	ALTIMETER ERROR, HT_ABOVE_BOTTOM MEASURED BY LADCP BOTTOM PING
49MR01K04_1	P17N	33	1	ROS	081001	0719	EN	37	00.45	N	135	01.37	W	GPS	-9	5078							
49MR01K04_1	P17N	34	1	ROS	081001	0941	BE	37	29.92	N	135	00.06	W	GPS	-9	5244				36		LADCP, REPLACED ALTIMETER	
49MR01K04_1	P17N	34	1	ROS	081001	1102	BO	37	30.08	N	135	00.13	W	GPS	-9	5281	10	5126	5308			1-8,12,23,24,26,27	
49MR01K04_1	P17N	34	2	BIO	081001	1153	BE	37	30.31	N	135	00.16	W	GPS	-9	5266						BIO. BUCKET SAMPLING	
49MR01K04_1	P17N	34	2	BIO	081001	1213	EN	37	30.40	N	135	00.14	W	GPS	-9	5259							
49MR01K04_1	P17N	34	3	XCT	081001	1238	DE	37	30.50	N	135	00.14	W	GPS	-9	5251						S/N 01045089 DEPTH 1036M	
49MR01K04_1	P17N	34	1	ROS	081001	1255	EN	37	30.60	N	135	00.13	W	GPS	-9	5213							
49MR01K04_1	P17N	34	4	XCT	081001	1258	DE	36	30.01	N	135	00.68	W	GPS	-9	5213						S/N 01075605 (1000M TEST)	
49MR01K04_1	P17N	35	1	ROS	081001	1540	BE	37	59.90	N	135	00.06	W	GPS	-9	4546				36		LADCP	
49MR01K04_1	P17N	35	1	ROS	081001	1656	BO	38	00.04	N	135	00.62	W	GPS	-9	4545	12	4509	4603			1-6	
49MR01K04_1	P17N	35	2	BIO	081001	1726	BE	38	00.18	N	135	00.67	W	GPS	-9	4520						BIO. BUCKET SAMPLING	
49MR01K04_1	P17N	35	2	BIO	081001	1732	EN	38	00.17	N	135	00.68	W	GPS	-9	4524							
49MR01K04_1	P17N	35	3	XCT	081001	1818	DE	38	00.34	N	135	00.99	W	GPS	-9	4520						S/N 01075614 (2000M TEST)	
49MR01K04_1	P17N	35	1	ROS	081001	1841	EN	38	00.42	N	135	01.23	W	GPS	-9	4505							
49MR01K04_1	P17N	36	1	ROS	081001	2110	BE	38	30.00	N	135	00.05	W	GPS	-9	4484				36		LADCP, SYSTEM RESTARTED AT 10M DEEP	
49MR01K04_1	P17N	36	1	ROS	081001	2217	BO	38	30.24	N	135	00.29	W	GPS	-9	4542	9	4456	4602			1-8,23,24,26,27	
49MR01K04_1	P17N	36	2	XCT	081001	2331	DE	38	30.41	N	135	00.39	W	GPS	-9	4573						S/N 01045090 DEPTH 1036M	
49MR01K04_1	P17N	36	1	ROS	081001	2351	EN	38	30.40	N	135	00.44	W	GPS	-9	4553							
49MR01K04_1	P17N	36	3	XCT	081001	2357	DE	38	30.56	N	135	00.47	W	GPS	-9	4589						S/N 01075602 (1000M TEST)	
49MR01K04_1	P17N	37	1	ROS	081101	0215	BE	38	59.98	N	135	00.00	W	GPS	-9	4772				36		LADCP	

49MR01K04_1 P17N	37	1	ROS	081101	0328	BO	38	59.86	N	135	00.52	W	GPS	-9	4823	8	4705	4841	1-6	
49MR01K04_1 P17N	37	1	ROS	081101	0512	EN	38	59.79	N	135	00.68	W	GPS	-9	4839					
49MR01K04_1 P17N	38	1	ROS	081101	0737	BE	39	30.02	N	135	00.24	W	GPS	-9	4912				36	LADCP
49MR01K04_1 P17N	38	1	ROS	081101	0852	BO	39	30.21	N	135	00.67	W	GPS	-9	4892	11	4847	4963	1-8,12,23,24,26,27	
49MR01K04_1 P17N	38	1	ROS	081101	1032	EN	39	30.60	N	135	01.23	W	GPS	-9	4980					
49MR01K04_1 P17N	39	1	ROS	081101	1218	BE	39	37.01	N	134	59.97	W	GPS	-9	4735				36	LADCP
49MR01K04_1 P17N	39	1	ROS	081101	1336	BO	39	37.17	N	135	00.58	W	GPS	-9	4725	11	4687	4808	1-6	
49MR01K04_1 P17N	39	2	XCT	081101	1503	DE	39	37.17	N	135	01.20	W	GPS	-9	4761					S/N 01075610 (2000M TEST)
49MR01K04_1 P17N	39	1	ROS	081101	1522	EN	39	37.26	N	135	01.30	W	GPS	-9	4756					
49MR01K04_1 P17N	40	1	ROS	081101	1718	BE	39	48.96	N	135	00.01	W	GPS	-9	3993				36	LADCP, INCREASED WEIGHT BY 60KG
49MR01K04_1 P17N	40	1	ROS	081101	1827	BO	39	48.90	N	135	00.28	W	GPS	-9	4034	11	3878	4020	1-6	
49MR01K04_1 P17N	40	1	ROS	081101	2009	EN	39	48.78	N	135	01.08	W	GPS	-9	4207					
49MR01K04_1 P17N	42	1	ROS	081101	2107	BE	39	54.99	N	135	00.18	W	GPS	-9	3332				36	LADCP
49MR01K04_1 P17N	42	1	ROS	081101	2203	BO	39	54.86	N	135	00.83	W	GPS	-9	3324	10	3237	3296	1-6	
49MR01K04_1 P17N	42	1	ROS	081101	2327	EN	39	54.91	N	135	01.76	W	GPS	-9	3404					
49MR01K04_1 P17N	43	1	ROS	081201	0059	BE	39	58.12	N	135	00.26	W	GPS	-9	3732				36	LADCP
49MR01K04_1 P17N	43	1	ROS	081201	0201	BO	39	58.21	N	135	00.60	W	GPS	-9	3786	12	3602	3742	1-8,12,23,24,26,27	
49MR01K04_1 P17N	43	1	ROS	081201	0332	EN	39	58.62	N	135	00.66	W	GPS	-9	3866					
49MR01K04_1 P17N	44	1	ROS	081201	0521	BE	39	59.96	N	135	00.21	W	GPS	-9	4157				36	LADCP
49MR01K04_1 P17N	44	2	BIO	081201	0544	BE	39	59.98	N	135	00.41	W	GPS	-9	4171					BIO. BUCKET SAMPLING
49MR01K04_1 P17N	44	2	BIO	081201	0555	EN	40	00.02	N	135	00.43	W	GPS	-9	4176					
49MR01K04_1 P17N	44	1	ROS	081201	0625	BO	40	00.01	N	135	00.45	W	GPS	-9	4166	10	4047	4214	1-6	
49MR01K04_1 P17N	44	1	ROS	081201	0757	EN	39	59.91	N	135	00.88	W	GPS	-9	4157					
49MR01K04_1 P17N	45	1	ROS	081201	1013	BE	40	30.12	N	135	00.01	W	GPS	-9	4196				36	LADCP
49MR01K04_1 P17N	45	1	ROS	081201	1118	BO	40	30.19	N	135	00.10	W	GPS	-9	4218	10	4077	4239	1-6	
49MR01K04_1 P17N	45	1	ROS	081201	1300	EN	40	30.36	N	135	00.24	W	GPS	-9	4257					
49MR01K04_1 P17N	46	1	ROS	081201	2154	BE	40	59.86	N	134	59.86	W	GPS	-9	4074				36	LADCP
49MR01K04_1 P17N	46	1	ROS	081201	2302	BO	40	59.45	N	134	59.20	W	GPS	-9	4039	10	4030	4113	1-8,12,23,24,26,27	
49MR01K04_1 P17N	46	2	XCT	081301	0029	DE	40	58.83	N	134	58.60	W	GPS	-9	4103					S/N 01075611 (2000M TEST)
49MR01K04_1 P17N	46	1	ROS	081301	0056	EN	40	58.46	N	134	58.45	W	GPS	-9	4102					
49MR01K04_1 P17N	47	1	ROS	081301	0326	BE	41	18.97	N	135	29.95	W	GPS	-9	3985				36	LADCP
49MR01K04_1 P17N	47	1	ROS	081301	0428	BO	41	19.00	N	135	29.84	W	GPS	-9	3974	11	3876	4031	1-6	REMARKABLE NOISE IN CTD DATA (UP CAST)
49MR01K04_1 P17N	47	1	ROS	081301	0556	EN	41	19.01	N	135	29.60	W	GPS	-9	3943					
49MR01K04_1 P17N	48	1	ROS	081301	0852	BE	41	38.93	N	135	59.91	W	GPS	-9	3926				36	LADCP, REPAIRED CTD CONNECTOR
49MR01K04_1 P17N	48	1	ROS	081301	0956	BO	41	38.49	N	135	59.50	W	GPS	-9	4063	11	3845	3949	1-8,12,23,24,26,27	BTL#15 MISFIRE
49MR01K04_1 P17N	48	1	ROS	081301	1129	EN	41	38.59	N	135	58.96	W	GPS	-9	4081					
49MR01K04_1 P17N	49	1	ROS	081301	1358	BE	41	58.91	N	136	30.06	W	GPS	-9	4144				36	LADCP
49MR01K04_1 P17N	49	2	BIO	081301	1404	BE	41	58.87	N	136	30.08	W	GPS	-9	4143					BIO. BUCKET SAMPLING
49MR01K04_1 P17N	49	2	BIO	081301	1415	EN	41	58.79	N	136	30.10	W	GPS	-9	4143					
49MR01K04_1 P17N	49	1	ROS	081301	1510	BO	41	58.91	N	136	30.06	W	GPS	-9	4146	12	4041	4198	1-6	
49MR01K04_1 P17N	49	1	ROS	081301	1648	EN	41	58.63	N	136	29.54	W	GPS	-9	4143					
49MR01K04_1 P17N	50	1	ROS	081301	1910	BE	42	19.89	N	137	00.93	W	GPS	-9	4138				36	LADCP
49MR01K04_1 P17N	50	2	BIO	081301	1919	BE	42	19.79	N	137	00.82	W	GPS	-9	4140					BIO. BUCKET SAMPLING
49MR01K04_1 P17N	50	2	BIO	081301	1926	EN	42	19.70	N	137	00.77	W	GPS	-9	4139					
49MR01K04_1 P17N	50	3	BIO	081301	1926	BE	42	19.70	N	137	00.77	W	GPS	-9	4139					UV PHOTOMETER (100M)
49MR01K04_1 P17N	50	3	BIO	081301	1934	EN	42	19.61	N	137	00.67	W	GPS	-9	4141					
49MR01K04_1 P17N	50	1	ROS	081301	2021	BO	42	19.48	N	137	00.89	W	GPS	-9	4139	10	4058	4194	1-8,23,24,26,27	
49MR01K04_1 P17N	50	1	ROS	081301	2154	EN	42	19.33	N	137	01.28	W	GPS	-9	4140					
49MR01K04_1 P17N	51	1	ROS	081401	0011	BE	42	38.11	N	137	32.07	W	GPS	-9	4143				36	LADCP
49MR01K04_1 P17N	51	2	BIO	081401	0021	BE	42	38.16	N	137	32.05	W	GPS	-9	4147					BIO. BUCKET SAMPLING
49MR01K04_1 P17N	51	2	BIO	081401	0033	EN	42	38.22	N	137	32.03	W	GPS	-9	4145					

49MR01K04_1	P17N	51	1	ROS	081401	0119	BO	42	38.28	N	137	32.03	W	GPS	-9	4148	10	4040	4201	1-6	
49MR01K04_1	P17N	51	1	ROS	081401	0248	EN	42	38.11	N	137	32.56	W	GPS	-9	4123					
49MR01K04_1	P17N	52	1	ROS	081401	0501	BE	42	58.10	N	138	03.00	W	GPS	-9	4042				36	LADCP
49MR01K04_1	P17N	52	1	ROS	081401	0604	BO	42	57.94	N	138	03.16	W	GPS	-9	3977	11	3909	4063	1-8,12,23,24,26,27	
49MR01K04_1	P17N	52	1	ROS	081401	0736	EN	42	57.78	N	138	03.43	W	GPS	-9	3668					
49MR01K04_1	P17N	53	1	ROS	081401	0953	BE	43	18.08	N	138	34.05	W	GPS	-9	4201				36	LADCP
49MR01K04_1	P17N	53	1	ROS	081401	1058	BO	43	18.03	N	138	34.09	W	GPS	-9	4197	10	4089	4255	1-6	
49MR01K04_1	P17N	53	1	ROS	081401	1234	EN	43	18.03	N	138	34.46	W	GPS	-9	4201					
49MR01K04_1	P17N	54	1	ROS	081401	1452	BE	43	37.27	N	139	05.04	W	GPS	-9	4098				36	LADCP
49MR01K04_1	P17N	54	1	ROS	081401	1602	BO	43	37.79	N	139	04.63	W	GPS	-9	4136	14	4075	4166	1-8,23,24,26,27	
49MR01K04_1	P17N	54	1	ROS	081401	1742	EN	43	38.44	N	139	03.51	W	GPS	-9	4181					
49MR01K04_1	P17N	54	2	XCT	081401	1753	DE	43	38.73	N	139	04.03	W	GPS	-9	4157					S/N 01075601 (1000M TEST)
49MR01K04_1	P17N	55	1	ROS	081401	1959	BE	43	57.09	N	139	37.02	W	GPS	-9	4332				36	LADCP
49MR01K04_1	P17N	55	1	ROS	081401	2106	BO	43	57.45	N	139	37.05	W	GPS	-9	4330	11	4235	4389	1-6	
49MR01K04_1	P17N	55	1	ROS	081401	2242	EN	43	57.46	N	139	37.76	W	GPS	-9	4332					
49MR01K04_1	P17N	56	1	ROS	081501	0059	BE	44	17.25	N	140	09.18	W	GPS	-9	4382				36	LADCP
49MR01K04_1	P17N	56	1	ROS	081501	0212	BO	44	17.62	N	140	08.94	W	GPS	-9	4386	10	4294	4444	1-8,12,23,24,26,27	
49MR01K04_1	P17N	56	1	ROS	081501	0347	EN	44	18.04	N	140	08.08	W	GPS	-9	4385					
49MR01K04_1	P17N	57	1	ROS	081501	0556	BE	44	35.95	N	140	38.86	W	GPS	-9	4419				36	LADCP
49MR01K04_1	P17N	57	1	ROS	081501	0705	BO	44	35.97	N	140	38.24	W	GPS	-9	4422	10	4344	4479	1-6	
49MR01K04_1	P17N	57	1	ROS	081501	0844	EN	44	35.81	N	140	37.50	W	GPS	-9	4418					
49MR01K04_1	P17N	58	1	ROS	081501	1116	BE	44	56.98	N	141	13.97	W	GPS	-9	4391				36	LADCP
49MR01K04_1	P17N	58	1	ROS	081501	1227	BO	44	56.93	N	141	13.88	W	GPS	-9	4396	11	4276	4456	1-8,12,23,24,26,27	
49MR01K04_1	P17N	58	2	BIO	081501	1302	BE	44	56.93	N	141	13.61	W	GPS	-9	4409					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	58	2	BIO	081501	1326	EN	44	57.03	N	141	13.52	W	GPS	-9	4422					
49MR01K04_1	P17N	58	1	ROS	081501	1412	EN	44	57.11	N	141	13.80	W	GPS	-9	4399					
49MR01K04_1	P17N	59	1	ROS	081501	1621	BE	45	15.96	N	141	44.11	W	GPS	-9	4504				36	LADCP
49MR01K04_1	P17N	59	1	ROS	081501	1735	BO	45	15.94	N	141	43.93	W	GPS	-9	4505	10	4484	4564	1-6	
49MR01K04_1	P17N	59	2	BIO	081501	1827	BE	45	15.99	N	141	43.51	W	GPS	-9	4501					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	59	2	BIO	081501	1832	EN	45	16.00	N	141	43.45	W	GPS	-9	4504					
49MR01K04_1	P17N	59	3	BIO	081501	1832	BE	45	16.00	N	141	43.45	W	GPS	-9	4504					UV PHOTOMETER (100M)
49MR01K04_1	P17N	59	3	BIO	081501	1838	EN	45	16.01	N	141	43.36	W	GPS	-9	4504					
49MR01K04_1	P17N	59	1	ROS	081501	1922	EN	45	16.10	N	141	42.82	W	GPS	-9	4503					
49MR01K04_1	P17N	59	4	XCT	081501	1934	DE	45	16.40	N	141	43.49	W	GPS	-9	4499					S/N 01045085 DEPTH 1035M
49MR01K04_1	P17N	60	1	ROS	081601	0400	BE	45	34.96	N	142	16.05	W	GPS	-9	4554				36	LADCP
49MR01K04_1	P17N	60	1	ROS	081601	0512	BO	45	34.54	N	142	16.22	W	GPS	-9	4560	10	4492	4626	1-8,23,24,26,27	
49MR01K04_1	P17N	60	1	ROS	081601	0700	EN	45	34.22	N	142	17.11	W	GPS	-9	4562					
49MR01K04_1	P17N	61	1	ROS	081601	0913	BE	45	55.05	N	142	48.08	W	GPS	-9	4582				36	LADCP
49MR01K04_1	P17N	61	1	ROS	081601	1026	BO	45	55.09	N	142	48.17	W	GPS	-9	4581	10	4466	4652	1-6	
49MR01K04_1	P17N	61	1	ROS	081601	1210	EN	45	54.88	N	142	47.70	W	GPS	-9	4595					
49MR01K04_1	P17N	62	1	ROS	081601	1431	BE	46	14.94	N	143	20.04	W	GPS	-9	4592				36	LADCP
49MR01K04_1	P17N	62	1	ROS	081601	1548	BO	46	14.64	N	143	20.07	W	GPS	-9	4593	9	4483	4661	1-8,23,24,26,27	
49MR01K04_1	P17N	62	1	ROS	081601	1741	EN	46	14.18	N	143	20.62	W	GPS	-9	4595					
49MR01K04_1	P17N	63	1	ROS	081601	2003	BE	46	33.94	N	143	53.99	W	GPS	-9	4628				36	LADCP
49MR01K04_1	P17N	63	1	ROS	081601	2130	BO	46	33.65	N	143	53.82	W	GPS	-9	4630	5	4519	4703	1-6	
49MR01K04_1	P17N	63	1	ROS	081601	2315	EN	46	33.06	N	143	53.84	W	GPS	-9	4635					
49MR01K04_1	P17N	63	2	XCT	081601	2323	DE	46	33.24	N	143	54.13	W	GPS	-9	4630					S/N 01075600 (1000M TEST)
49MR01K04_1	P17N	64	1	ROS	081701	0132	BE	46	54.01	N	144	26.10	W	GPS	-9	4680				36	LADCP
49MR01K04_1	P17N	64	1	ROS	081701	0251	BO	46	53.91	N	144	26.66	W	GPS	-9	4679	10	4568	4741	1-8,12,23,24,26,27	STOPPED 1H AT 100M ABOVE BOTTOM (UP CAST)
49MR01K04_1	P17N	64	1	ROS	081701	0552	EN	46	53.75	N	144	27.52	W	GPS	-9	4682					
49MR01K04_1	P17N	X01	1	ROS	081701	0952	BE	47	00.00	N	145	48.50	W	GPS	-9	4811				36	LADCP, WHP P01 CROSSOVER (SINNER 92)

49MR01K04_1	P17N	X01	1	ROS	081701	1106	BO	46	59.73	N	145	48.96	W	GPS	-9	4812	9	4705	4881	1-8,23,24,26,27	
49MR01K04_1	P17N	X01	1	ROS	081701	1255	EN	46	59.43	N	145	49.68	W	GPS	-9	4811					
49MR01K04_1	P17N	65	1	ROS	081701	1542	BE	47	14.09	N	144	59.95	W	GPS	-9	4729				36	LADCP
49MR01K04_1	P17N	65	1	ROS	081701	1701	BO	47	13.61	N	145	00.43	W	GPS	-9	4727	9	4669	4798	1-6	
49MR01K04_1	P17N	65	2	BIO	081701	1747	BE	47	13.33	N	145	00.66	W	GPS	-9	4727					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	65	2	BIO	081701	1806	EN	47	13.24	N	145	00.76	W	GPS	-9	4729					
49MR01K04_1	P17N	65	3	BIO	081701	1806	BE	47	13.24	N	145	00.76	W	GPS	-9	4729					UV PHOTOMETER (100M)
49MR01K04_1	P17N	65	3	BIO	081701	1816	EN	47	13.21	N	145	00.85	W	GPS	-9	4722					
49MR01K04_1	P17N	65	1	ROS	081701	1900	EN	47	13.10	N	145	01.19	W	GPS	-9	4735					
49MR01K04_1	P17N	66	1	ROS	081701	2110	BE	47	33.09	N	145	33.18	W	GPS	-9	4822				36	LADCP
49MR01K04_1	P17N	66	1	ROS	081701	2226	BO	47	33.03	N	145	33.09	W	GPS	-9	4824	12	4697	4893	1-8,23,24,26,27	
49MR01K04_1	P17N	66	1	ROS	081801	0012	EN	47	32.41	N	145	32.68	W	GPS	-9	4825					
49MR01K04_1	P17N	67	1	ROS	081801	0245	BE	47	52.93	N	146	06.93	W	GPS	-9	4565				36	LADCP
49MR01K04_1	P17N	67	1	ROS	081801	0402	BO	47	52.61	N	146	06.85	W	GPS	-9	4566	9	4458	4630	1-6	STOPED 1H AT 100M ABOVE BOTTOM (UP CAST)
49MR01K04_1	P17N	67	1	ROS	081801	0655	EN	47	52.05	N	146	06.51	W	GPS	-9	4556					
49MR01K04_1	P17N	68	1	ROS	081801	0916	BE	48	12.99	N	146	40.89	W	GPS	-9	4661				36	LADCP
49MR01K04_1	P17N	68	1	ROS	081801	1027	BO	48	12.48	N	146	41.07	W	GPS	-9	4654	10	4583	4730	1-8,12,23,24,26,27	
49MR01K04_1	P17N	68	1	ROS	081801	1216	EN	48	12.21	N	146	41.70	W	GPS	-9	4653					
49MR01K04_1	P17N	69	1	ROS	081801	1437	BE	48	31.93	N	147	15.04	W	GPS	-9	4707				36	LADCP
49MR01K04_1	P17N	69	1	ROS	081801	1618	BO	48	31.50	N	147	15.13	W	GPS	-9	4718	10	4602	4790	1-6	STOPED 20MIN AT 100M DEEP (DOWN CAST)
49MR01K04_1	P17N	69	1	ROS	081801	1816	EN	48	31.33	N	147	15.05	W	GPS	-9	4717					
49MR01K04_1	P17N	69	2	XCT	081801	1824	DE	48	31.57	N	147	15.54	W	GPS	-9	4718					S/N 01075599 (1000M TEST)
49MR01K04_1	P17N	70	1	ROS	081801	2051	BE	48	55.00	N	147	55.03	W	GPS	-9	4767				36	LADCP
49MR01K04_1	P17N	70	1	ROS	081801	2209	BO	48	54.81	N	147	54.42	W	GPS	-9	4718	10	4677	4845	1-8,12,23,24,26,27	
49MR01K04_1	P17N	70	1	ROS	081801	2355	EN	48	54.55	N	147	53.41	W	GPS	-9	4686					
49MR01K04_1	P17N	71	1	ROS	081901	0202	BE	49	12.17	N	148	24.05	W	GPS	-9	4726				36	LADCP
49MR01K04_1	P17N	71	1	ROS	081901	0247	EN	49	12.01	N	148	23.87	W	GPS	-9	4721			940		ABORTED (BTL#1 FIRED AT 900M DEEP), CTD NO DATA
49MR01K04_1	P17N	71	2	ROS	081901	0342	BE	49	12.15	N	148	24.35	W	GPS	-9	4732				36	LADCP, CHECKED CTD CABLE AND CONNECTOR
49MR01K04_1	P17N	71	2	ROS	081901	0352	EN	49	12.13	N	148	24.26	W	GPS	-9	4733			89		ABORTED (COMMUNICATION ERROR), CTD NO DATA
49MR01K04_1	P17N	71	3	ROS	081901	0425	BE	49	12.18	N	148	24.26	W	GPS	-9	4731				36	LADCP, REPLACED DECK UNIT, CHECKED CTD CONNECTOR
49MR01K04_1	P17N	71	3	ROS	081901	0547	BO	49	12.19	N	148	23.33	W	GPS	-9	4715	10	4655	4798	1-6	
49MR01K04_1	P17N	71	3	ROS	081901	0738	EN	49	12.51	N	148	21.86	W	GPS	-9	4675					
49MR01K04_1	P17N	72	1	ROS	081901	0956	BE	49	31.97	N	148	57.98	W	GPS	-9	4716				36	LADCP
49MR01K04_1	P17N	72	1	ROS	081901	1111	BO	49	31.51	N	148	57.57	W	GPS	-9	4699	9	4637	4792	1-8,23,24,26,27	
49MR01K04_1	P17N	72	1	ROS	081901	1301	EN	49	30.55	N	148	57.84	W	GPS	-9	4704					
49MR01K04_1	P17N	73	1	ROS	081901	1516	BE	49	48.99	N	149	34.14	W	GPS	-9	4787				36	LADCP
49MR01K04_1	P17N	73	2	BIO	081901	1522	BE	49	48.97	N	149	34.21	W	GPS	-9	4787					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	73	2	BIO	081901	1530	EN	49	48.90	N	149	34.17	W	GPS	-9	4788					
49MR01K04_1	P17N	73	1	ROS	081901	1659	BO	49	48.74	N	149	34.33	W	GPS	-9	4791	9	4669	4864	1-6	
49MR01K04_1	P17N	73	3	BIO	081901	1729	BE	49	48.69	N	149	34.31	W	GPS	-9	4788					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	73	3	BIO	081901	1738	EN	49	48.68	N	149	34.22	W	GPS	-9	4787					
49MR01K04_1	P17N	73	4	BIO	081901	1738	BE	49	48.68	N	149	34.22	W	GPS	-9	4787					UV PHOTOMETER (100M)
49MR01K04_1	P17N	73	4	BIO	081901	1748	EN	49	48.68	N	149	34.24	W	GPS	-9	4787					
49MR01K04_1	P17N	73	1	ROS	081901	1857	EN	49	48.54	N	149	34.17	W	GPS	-9	4788					
49MR01K04_1	P17N	74	1	ROS	081901	2121	BE	50	10.87	N	150	09.01	W	GPS	-9	4702				36	LADCP
49MR01K04_1	P17N	74	2	BIO	081901	2123	BE	50	10.85	N	150	08.99	W	GPS	-9	4703					BIO. BUCKET SAMPLING
49MR01K04_1	P17N	74	2	BIO	081901	2137	EN	50	10.69	N	150	08.81	W	GPS	-9	4708					
49MR01K04_1	P17N	74	1	ROS	081901	2238	BO	50	10.24	N	150	08.24	W	GPS	-9	4720	10	4699	4800	1-8,12,23,24,26,27	
49MR01K04_1	P17N	74	1	ROS	082001	0017	EN	50	09.80	N	150	07.95	W	GPS	-9	4710					
49MR01K04_1	P17N	75	1	ROS	082001	0239	BE	50	29.91	N	150	43.93	W	GPS	-9	5079				36	LADCP
49MR01K04_1	P17N	75	1	ROS	082001	0400	BO	50	29.50	N	150	43.32	W	GPS	-9	5050	9	4976	5162	1-6	

49MR01K04_1	P17N	93	1	ROS	082501	0641	BE	54	21.62	N	158	02.67	W	GPS	-9	2928				36	LADCP	
49MR01K04_1	P17N	93	1	ROS	082501	0742	BO	54	21.61	N	158	03.29	W	GPS	-9	2997	14	2892	2999		1-6	
49MR01K04_1	P17N	93	1	ROS	082501	0850	EN	54	21.51	N	158	03.84	W	GPS	-9	2938						
49MR01K04_1	P17N	93	2	XCT	082501	0859	DE	54	21.65	N	158	03.99	W	GPS	-9	2921						S/N 01075598 (1000M TEST)
49MR01K04_1	P17N	94	1	ROS	082501	0947	BE	54	22.49	N	158	05.33	W	GPS	-9	2557				36	LADCP, COMMUNICATION ERROR (DOWN CAST), BIL#1 DID NOT FIRE	
49MR01K04_1	P17N	94	1	ROS	082501	1105	BO	54	22.43	N	158	06.29	W	GPS	-9	2572	16	2492	2566		1-8,12,23,24,26,27	SYSTEM RESTARTED AT BOTTOM
49MR01K04_1	P17N	94	1	ROS	082501	1211	EN	54	22.08	N	158	07.05	W	GPS	-9	2622						
49MR01K04_1	P17N	95	1	XCT	082501	1325	DE	54	29.00	N	158	18.00	W	GPS	-9	1937						S/N 01075596 (1000M TEST)
49MR01K04_1	P17N	96	1	ROS	082501	1423	BE	54	31.75	N	158	22.32	W	GPS	-9	1327				26	LADCP, CUT WIRE END (23M)	
49MR01K04_1	P17N	96	1	ROS	082501	1432	EN	54	31.68	N	158	22.52	W	GPS	-9	1406			80		ABORTED (SENSOR ERROR), CTD NO DATA	
49MR01K04_1	P17N	96	2	ROS	082501	1634	BE	54	32.17	N	158	21.86	W	GPS	-9	1413				26	LADCP, CHECKED CTD CONNECTOR	
49MR01K04_1	P17N	96	2	ROS	082501	1702	BO	54	32.30	N	158	22.34	W	GPS	-9	1274	7	1289	1313		1-6	
49MR01K04_1	P17N	96	2	ROS	082501	1742	EN	54	32.47	N	158	22.83	W	GPS	-9	1218						
49MR01K04_1	P17N	97	1	XCT	082501	1808	DE	54	33.90	N	158	26.90	W	GPS	-9	1026						S/N 01045087 DEPTH 1036M
49MR01K04_1	P17N	98	1	ROS	082501	1836	BE	54	35.93	N	158	30.12	W	GPS	-9	482				20	LADCP	
49MR01K04_1	P17N	98	1	ROS	082501	1854	BO	54	35.92	N	158	30.15	W	GPS	-9	547	13	509	530		1-8,23,24,26,27	DESCENDED 10M AFTER FIRING BIL#1
49MR01K04_1	P17N	98	1	ROS	082501	1916	EN	54	36.00	N	158	30.57	W	GPS	-9	535						
49MR01K04_1	P17N	99	1	ROS	082501	2033	BE	54	36.98	N	158	34.04	W	GPS	196	200				36	LADCP, DEPTH MEASURED BY FURUNO DOPPLER SONAR	
49MR01K04_1	P17N	99	1	ROS	082501	2041	BO	54	36.92	N	158	34.21	W	GPS	196	200	10	191	196		1-8,27	DEPTH MEASURED BY FURUNO DOPPLER SONAR
49MR01K04_1	P17N	99	1	ROS	082501	2052	EN	54	36.82	N	158	34.38	W	GPS	195	199						DEPTH MEASURED BY FURUNO DOPPLER SONAR

1=Sal, 2=DO, 3=SiO2, 4=NO2, 5=NO3, 6=PO4, 7=CFC11, 8=CFC12, 12=C14, 13=C13, 23=DIC, 24=Alk, 26=pH, 27=CFC113

Figure caption

- Figure 1 Station location with bottom topography based on Smith and Sandwell (1997). Station of X01 is crossing-over station with WHP P01.
- Figure 2 Potential temperature ($^{\circ}\text{C}$) cross section calculated using CTD temperature and salinity data calibrated by bottle salinity measurements. Vertical exaggeration of the 0-6000 m section is 1000:1. Expanded section of the upper 1000 m is made with a vertical exaggeration of 2500:1.
- Figure 3 CTD salinity (psu) cross section calibrated by bottle salinity measurements. Vertical exaggeration is same as Figure 2.
- Figure 4 Same as Figure 3 but with SSW batch correction using values¹ reported by Aoyama et al. (2002) and Aoyama et al. (2004).
- Figure 5 Density (σ_0) (kg/m^3) cross section calculated using CTD temperature and calibrated salinity data with SSW batch correction. Vertical exaggeration is same as Figure 2.
- Figure 6 Same as Figure 5 but for σ_4 (kg/m^3).
- Figure 7 Cross section of bottle sampled dissolved oxygen ($\mu\text{mol/kg}$). Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 8 Silicate ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 9 Nitrate ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration of the upper 1000 m section is same as Figure 2.
- Figure 10 Nitrite ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 11 Phosphate ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 12 Total Alkalinity ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 13 Total Carbon ($\mu\text{mol/kg}$) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 14 pH cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 15 Sampling points for CFCs. Vertical exaggeration is same as Figure 2.
- Figure 16 $\Delta^{14}\text{C}$ cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 17 $\delta^{13}\text{C}$ cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 2.
- Figure 18 Difference in potential temperature ($^{\circ}\text{C}$) between results from 2001 and 1993 (as for P17C, 1991). Red and blue areas show areas where potential temperature increased and decreased in 2001, respectively. On white areas differences in temperature do not exceed the detection limit of 0.002°C . Vertical exaggeration is same as Figure 2.
- Figure 19 Difference in salinity (psu) between results from 2001 and 1993 (as for P17C, 1991). Red and blue areas show areas where salinity increased and decreased in 2001, respectively. On white areas differences in salinity do not exceed the detection limit of 0.002 psu. Vertical exaggeration is same as Figure 2.

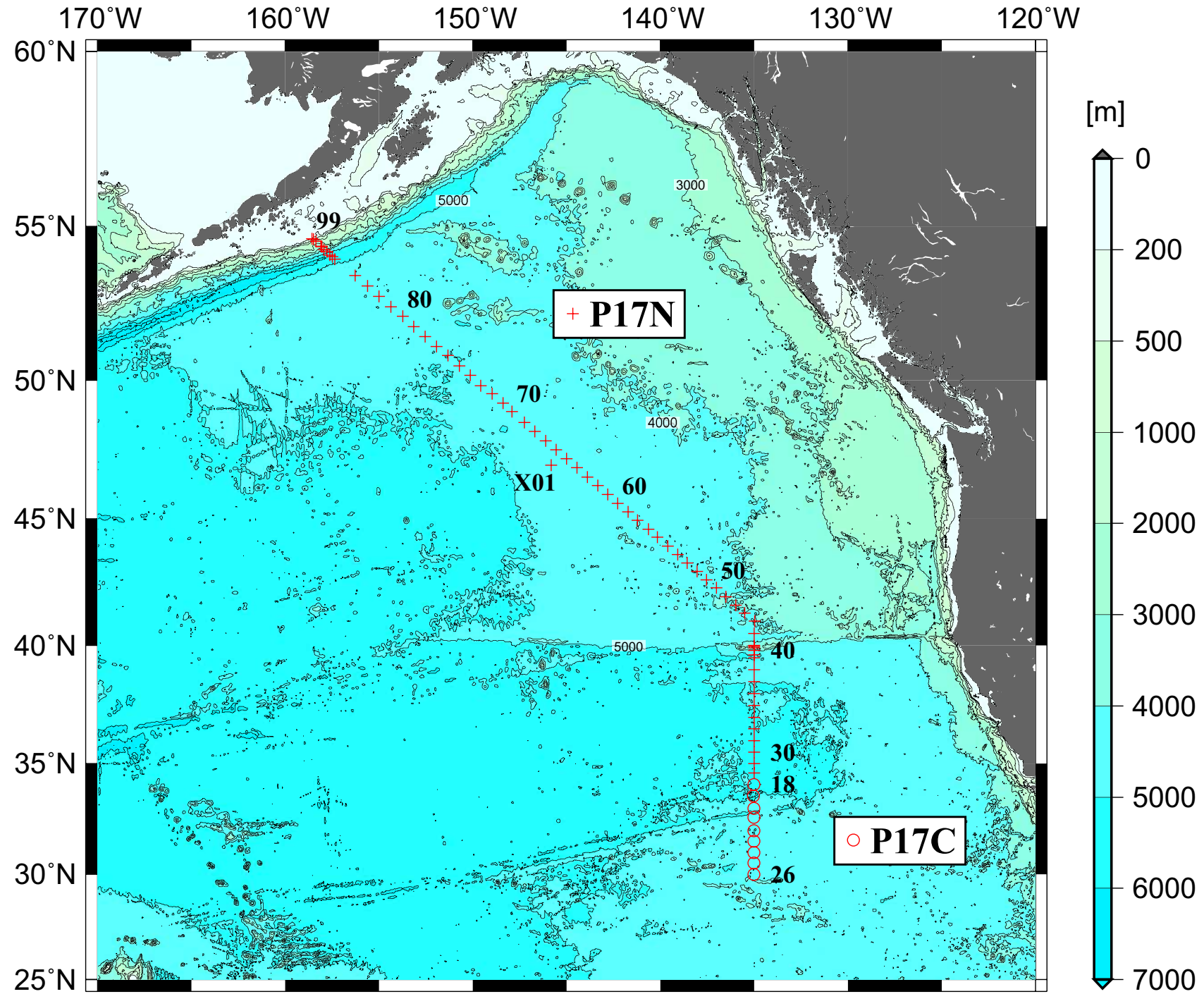
Note

1. As for the traceability of SSW to Mantyla's value, the offsets for the batches P114 (P17C_91), P122 (P17N_93) and P139 (P17N_01) are +0.0007, -0.0009 and -0.0010, respectively.

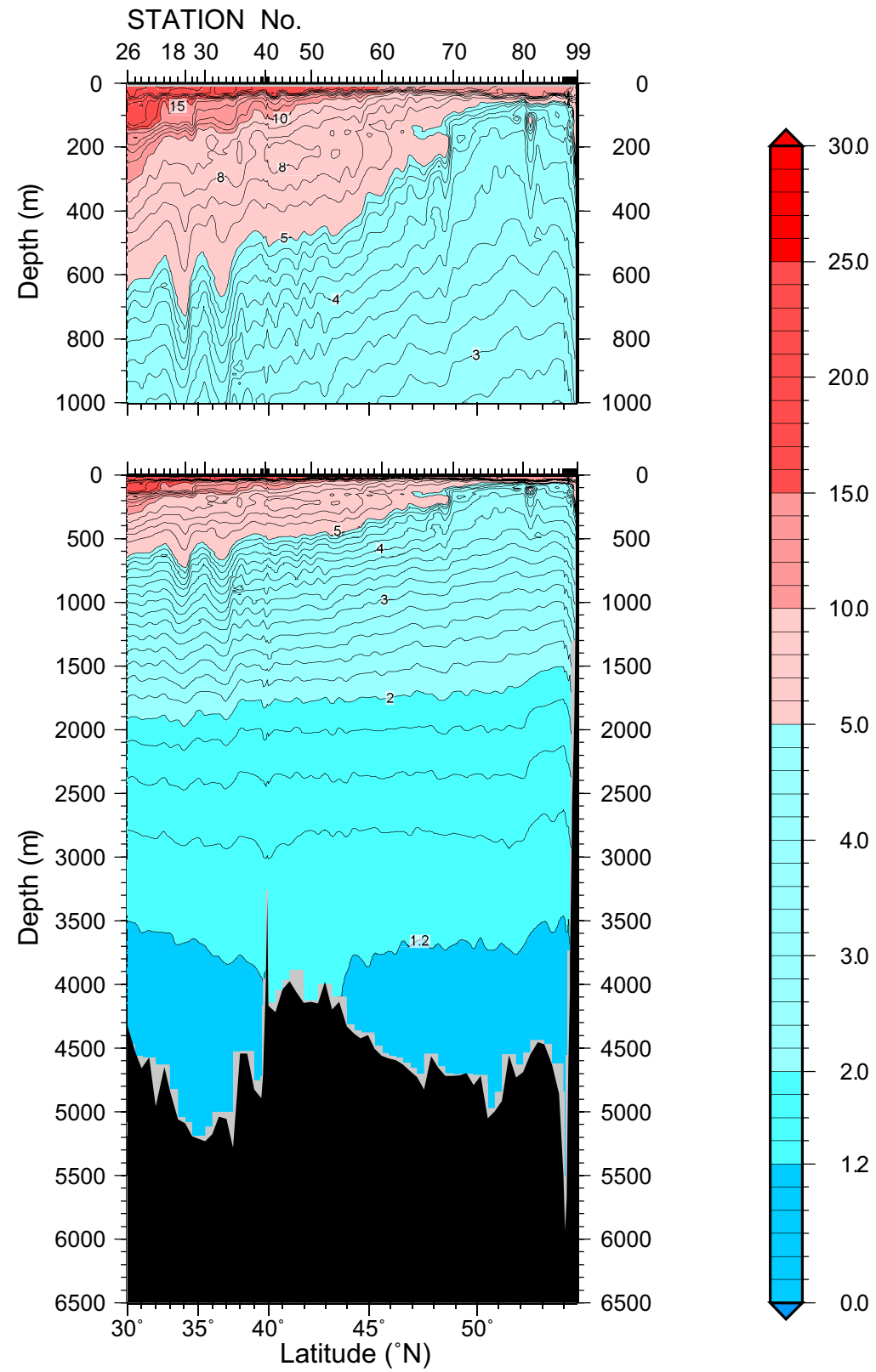
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Figure 1



STATION LOCATIONS FOR WHP P17N REVISIT IN 2001



POTENTIAL TEMPERATURE [°C]

Figure 3

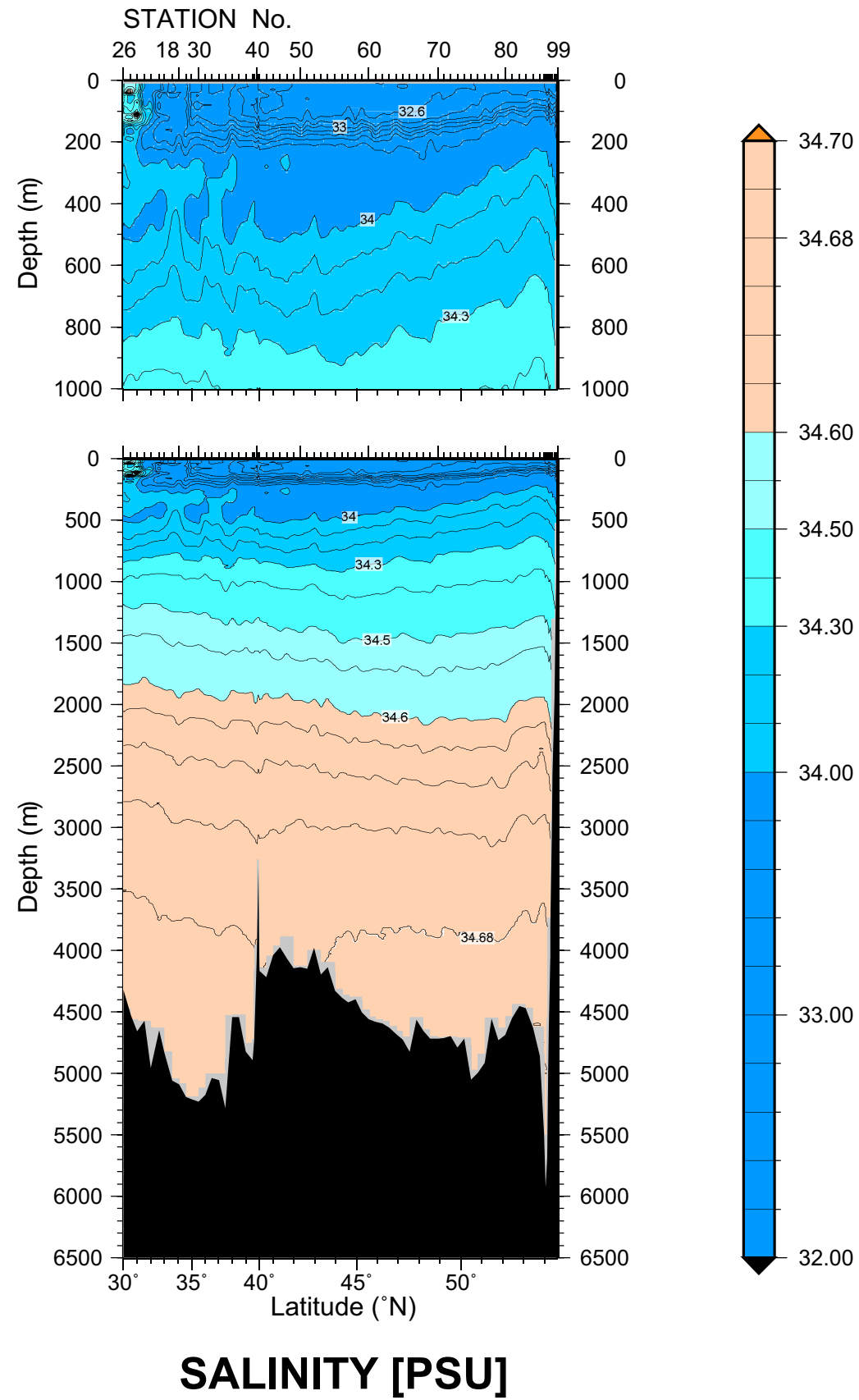
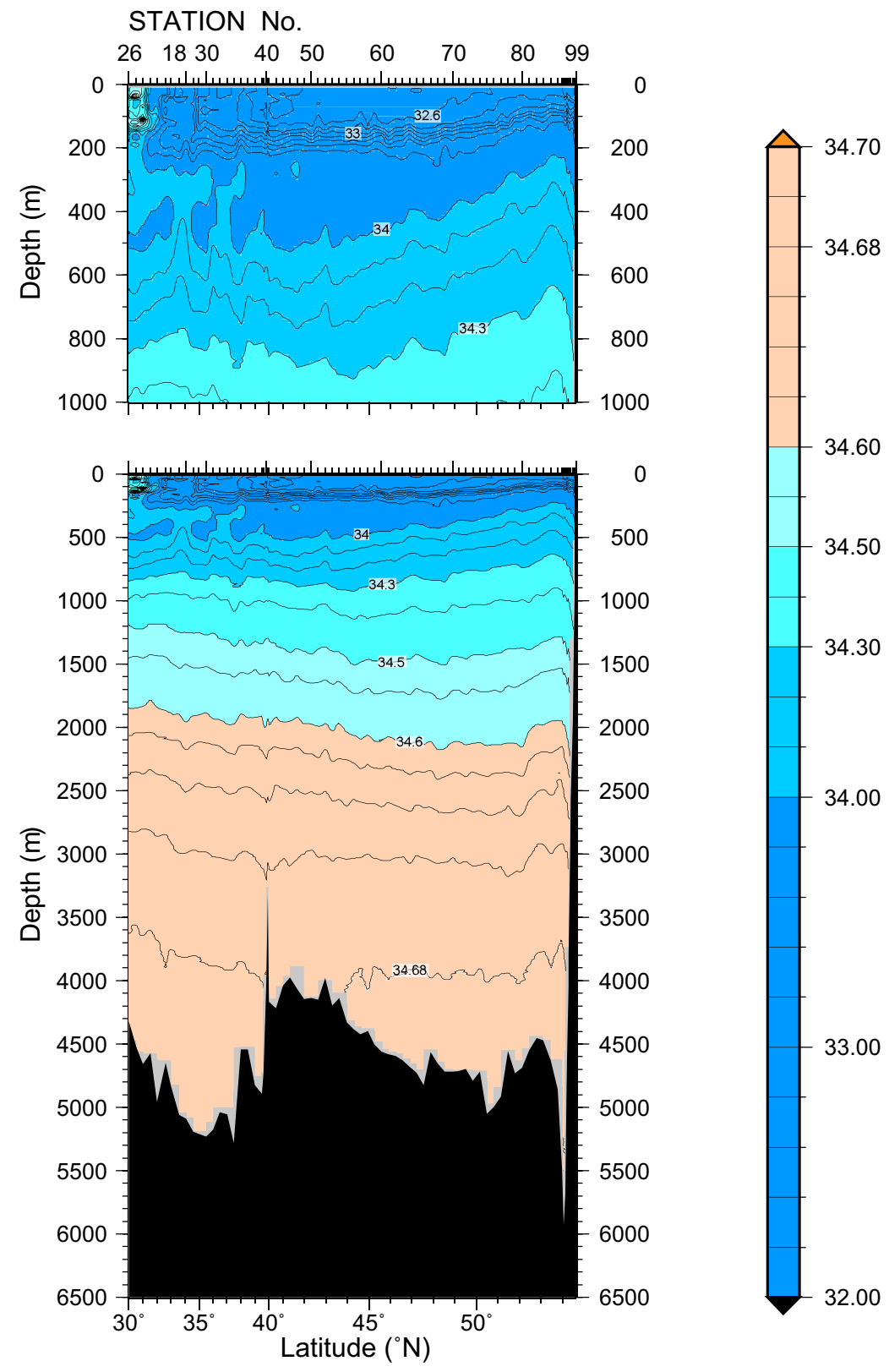


Figure 4



SALINITY (WITH SSW CORRECTION) [PSU]

Figure 5

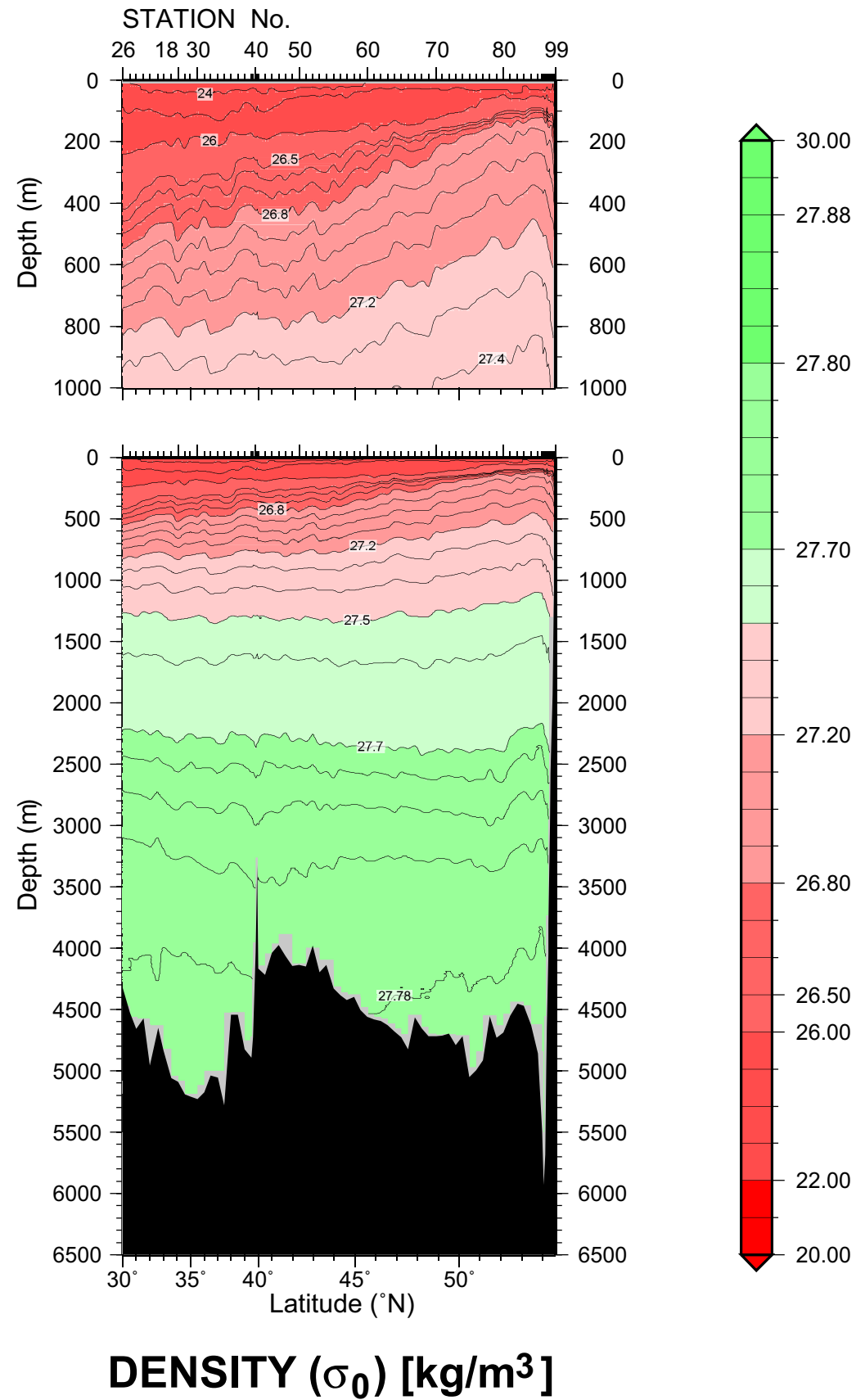


Figure 6

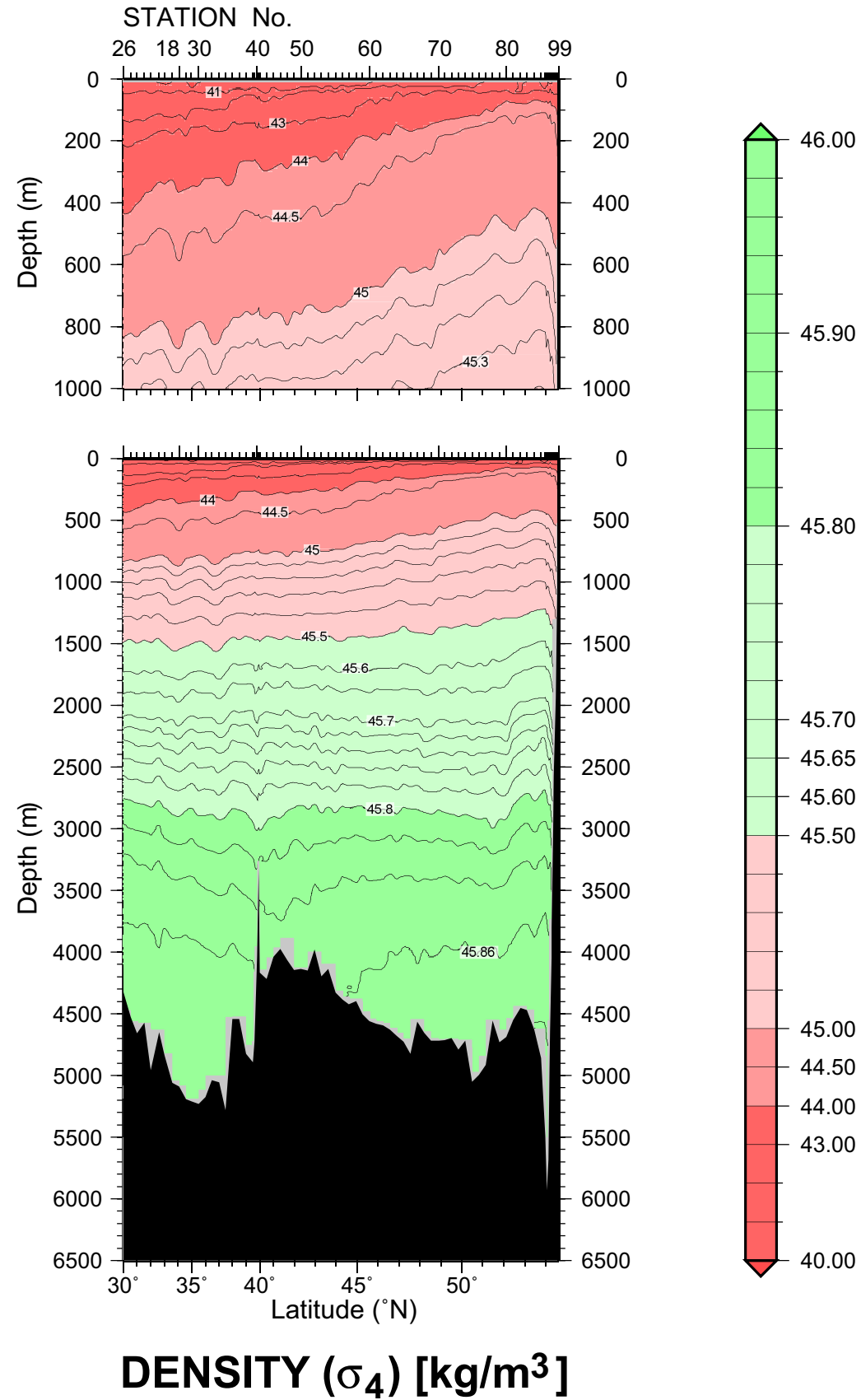


Figure 7

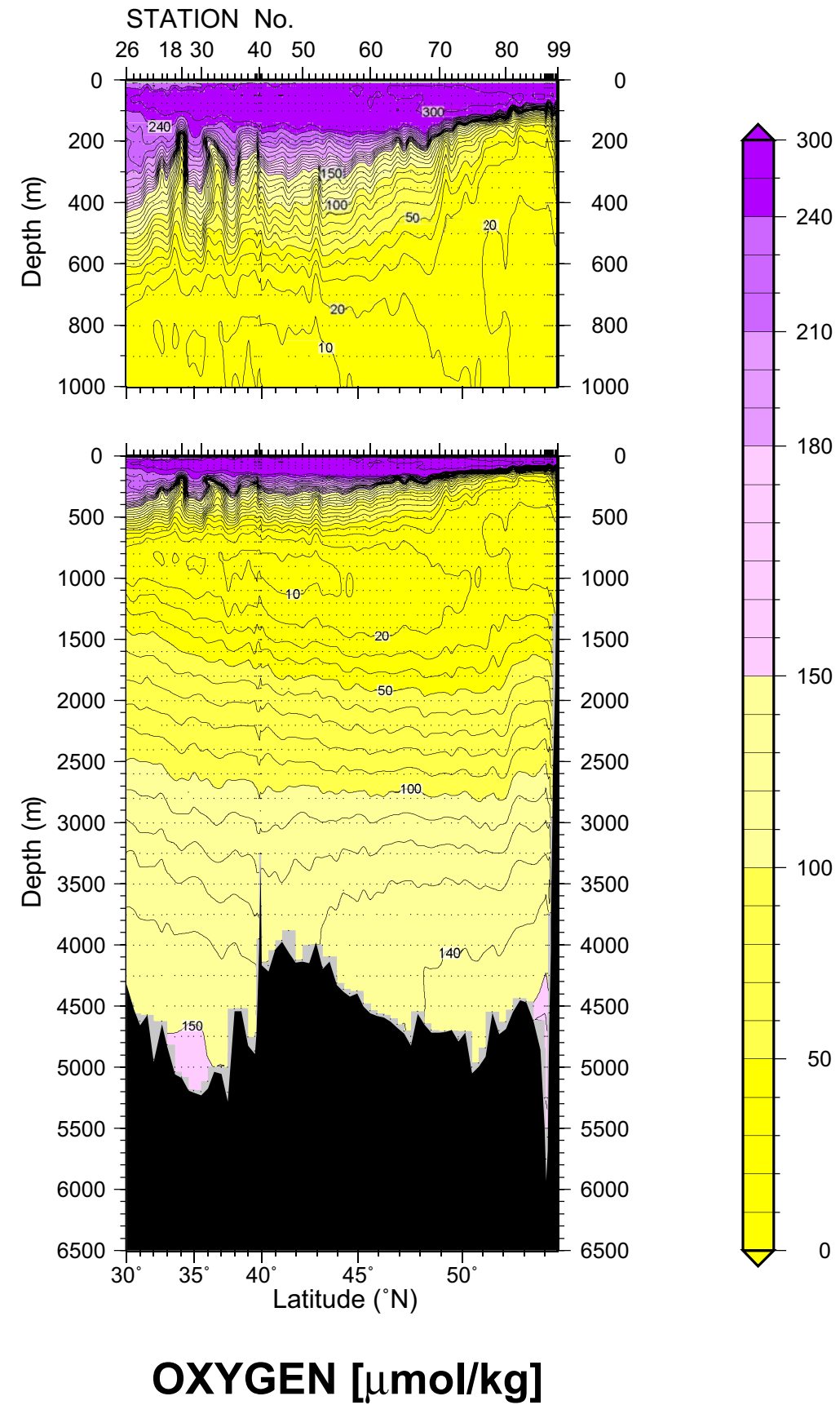


Figure 8

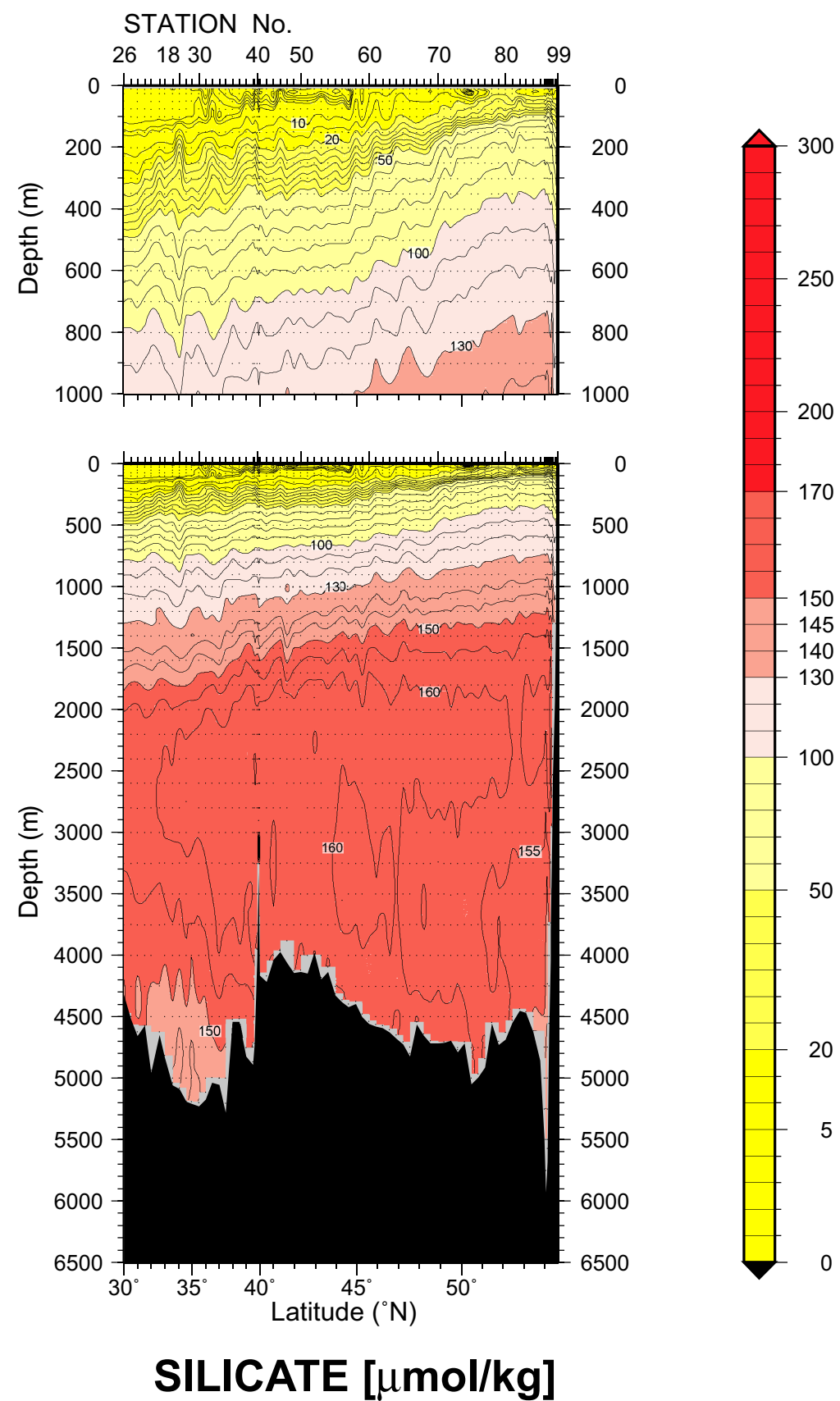
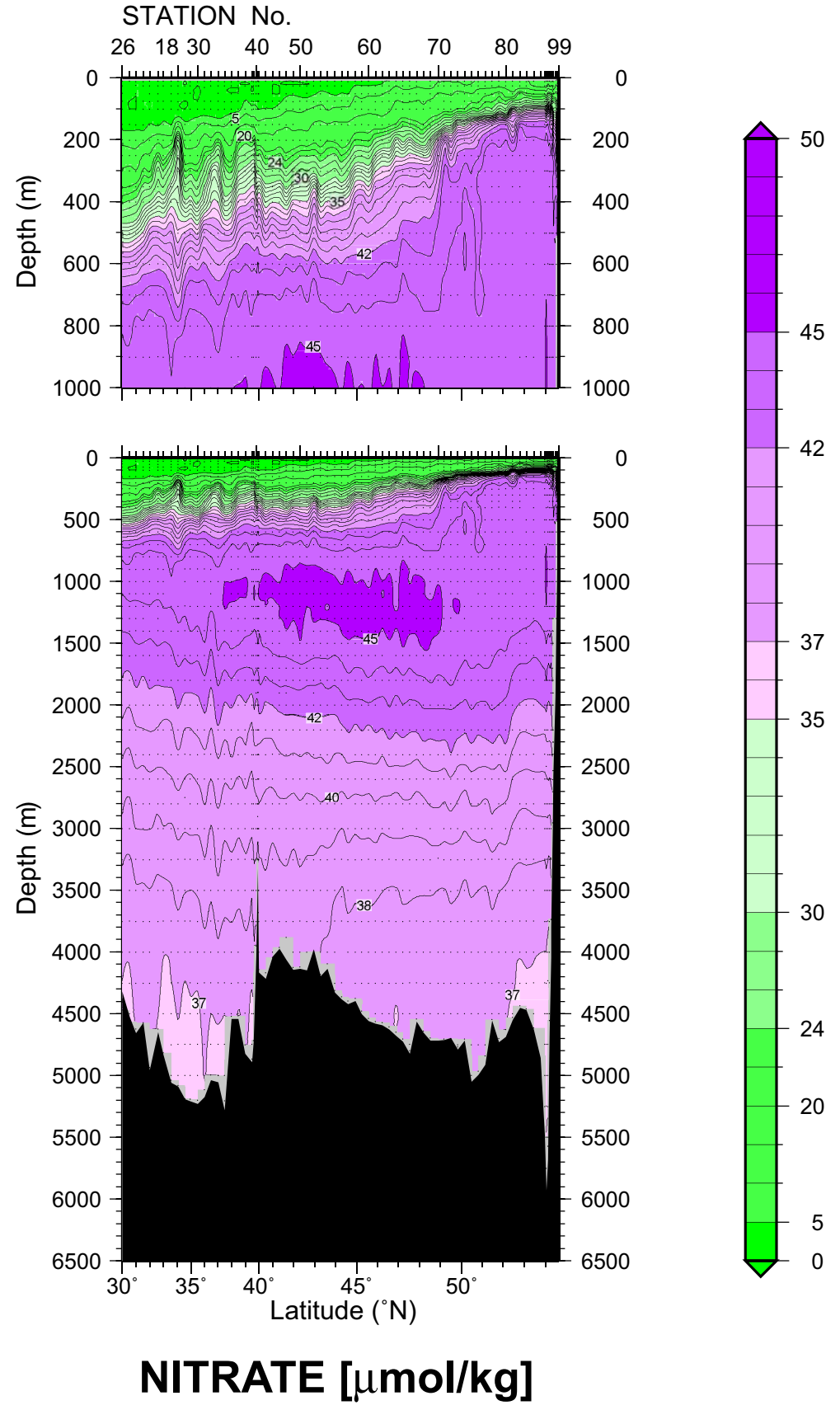
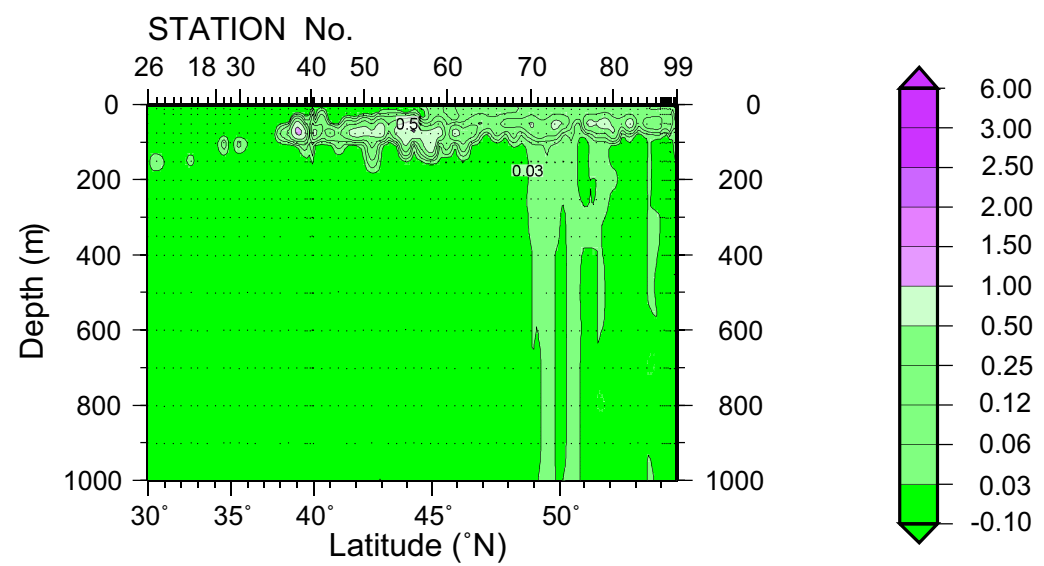


Figure 9





NITRITE [$\mu\text{mol/kg}$]

Figure 11

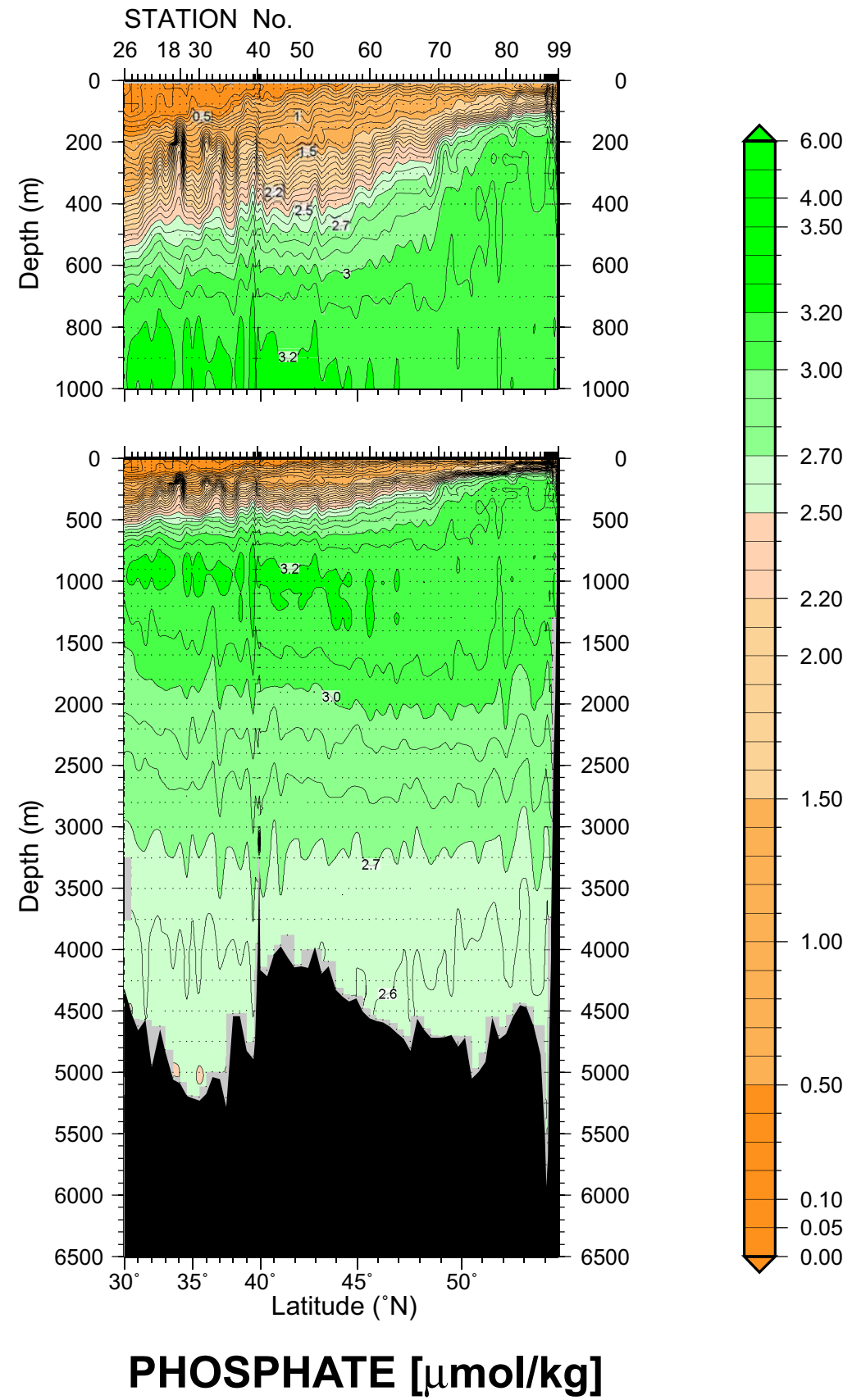
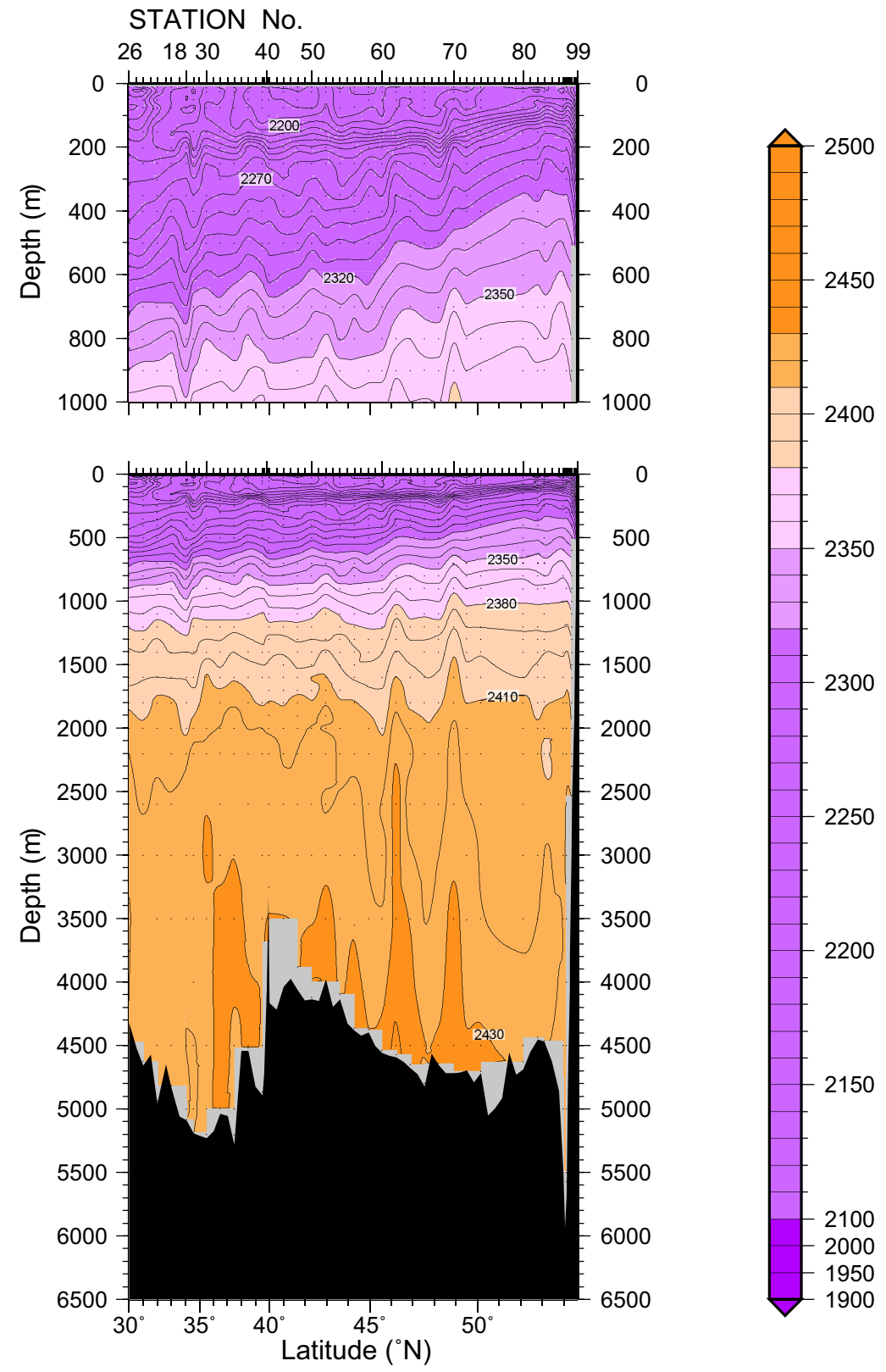
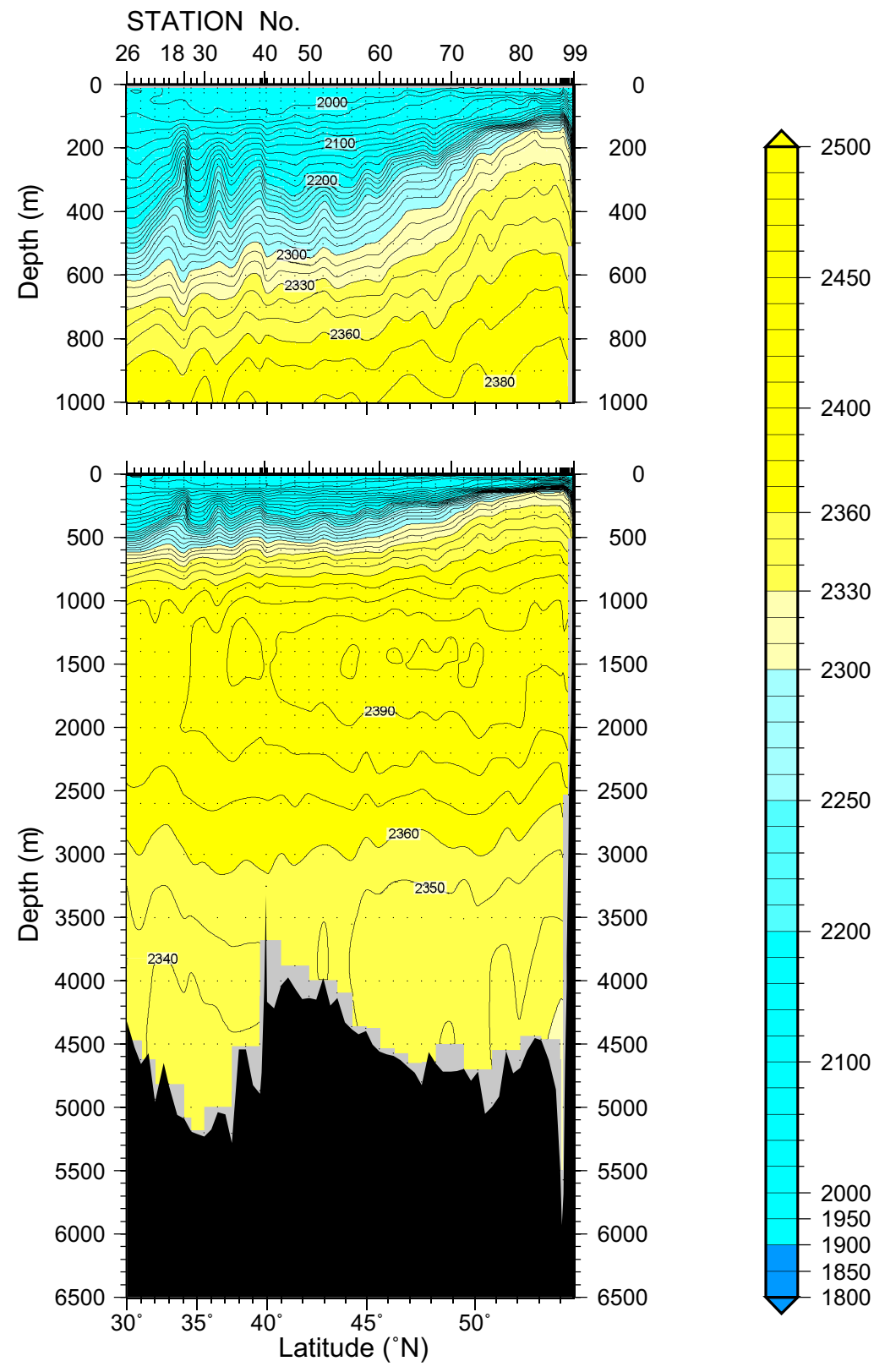


Figure 12

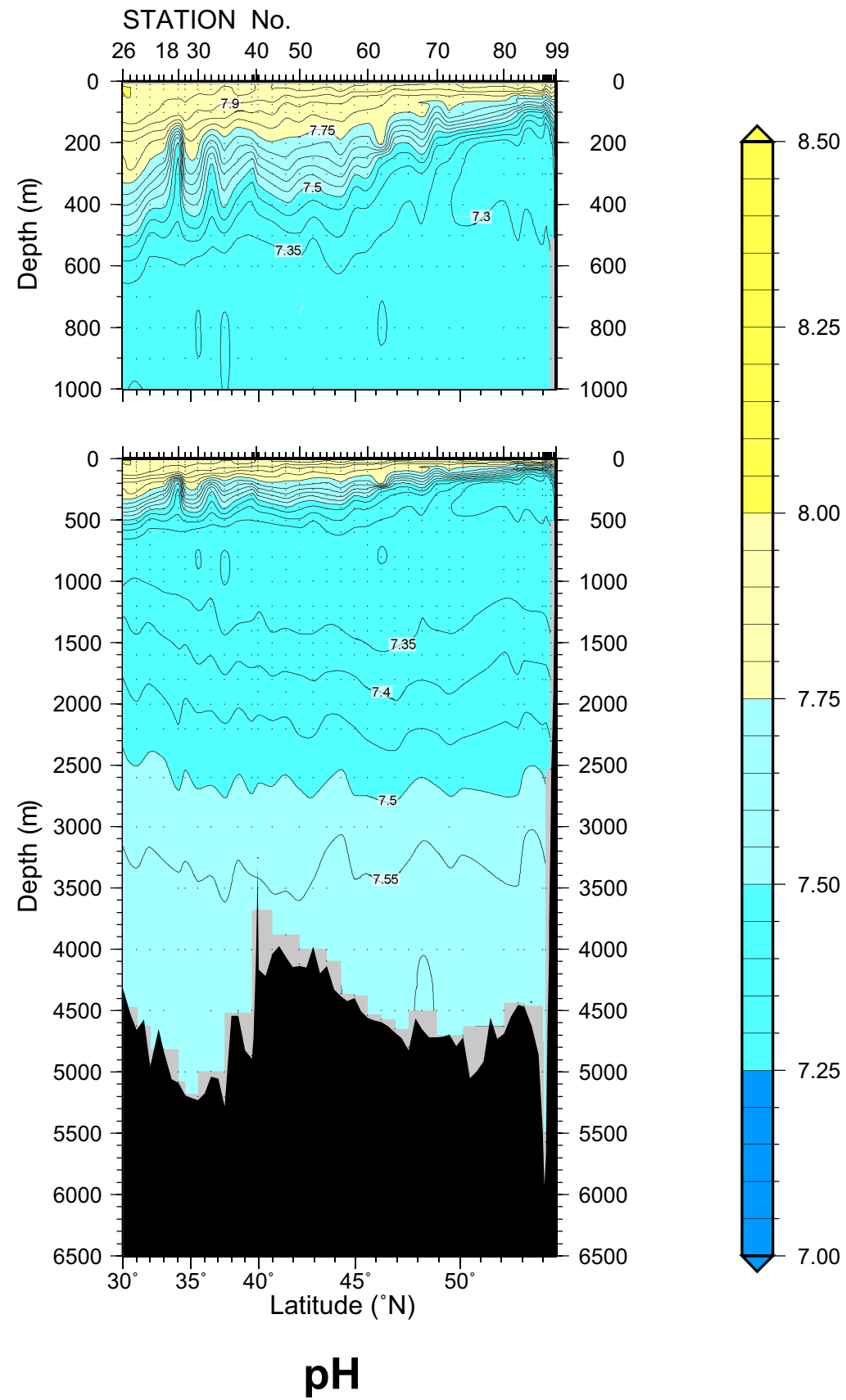


TOTAL ALKALINITY [$\mu\text{mol/kg}$]

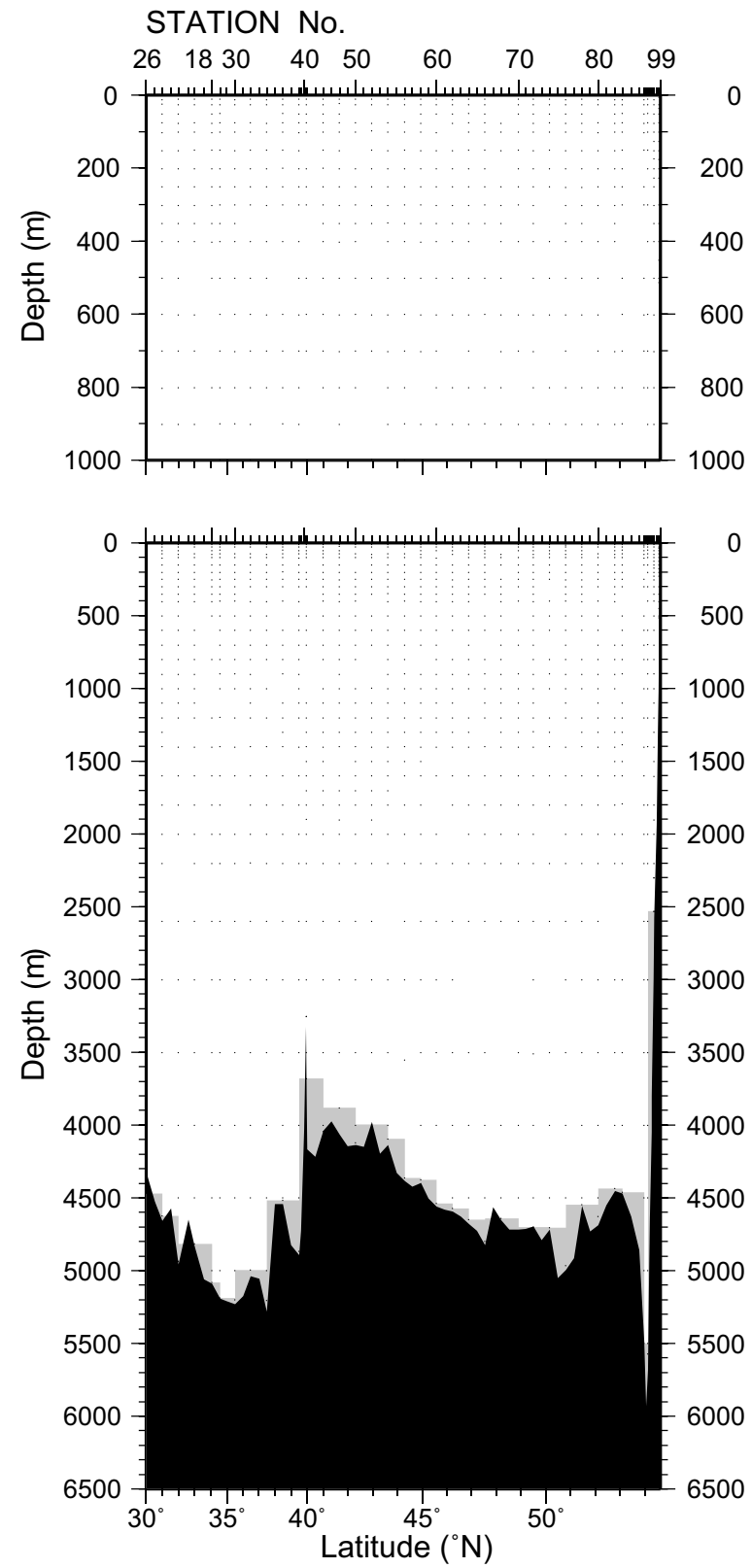


TOTAL CARBON [$\mu\text{mol/kg}$]

Figure 14



pH



CFCs (SAMPLING POINTS)

Figure 16

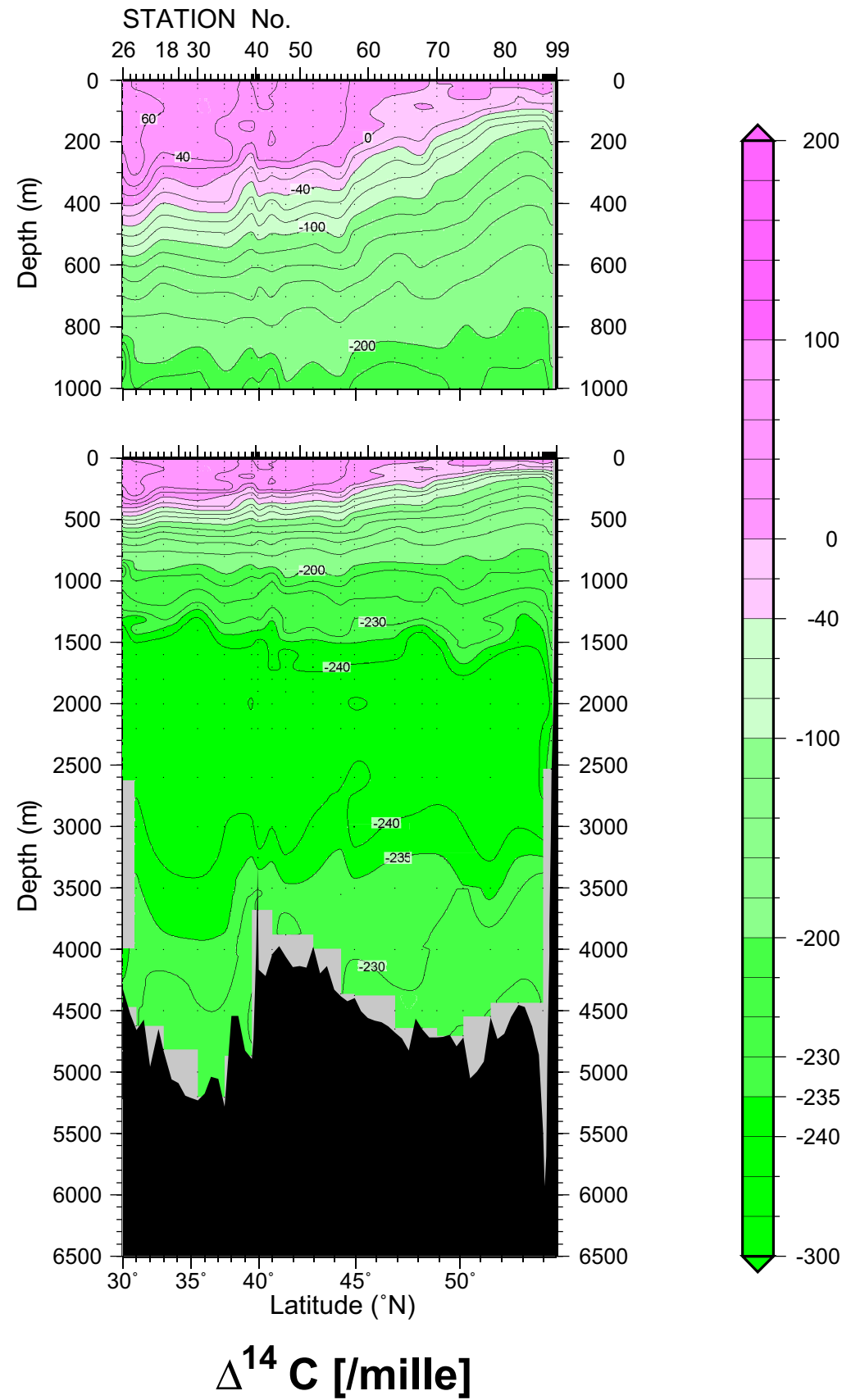
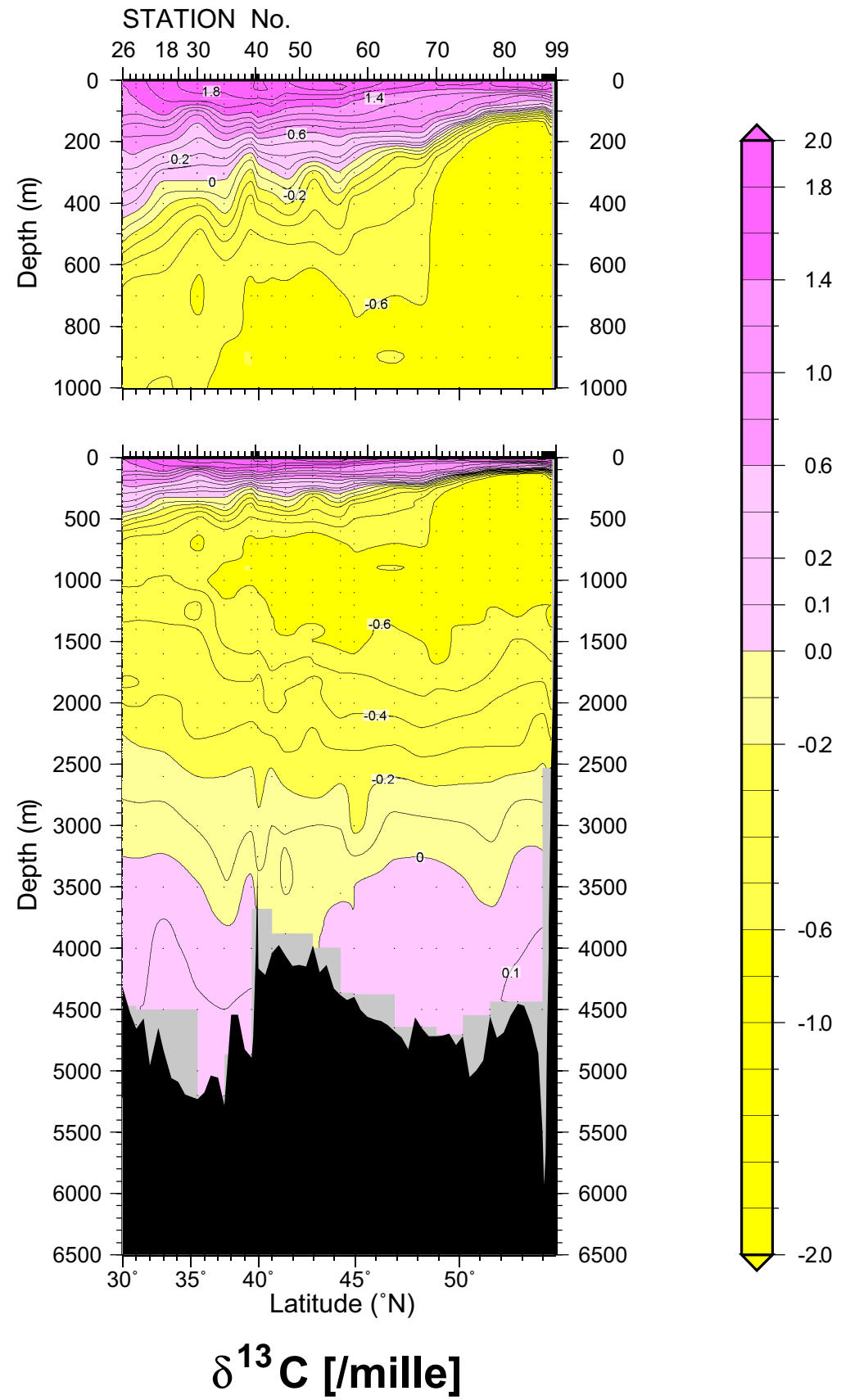
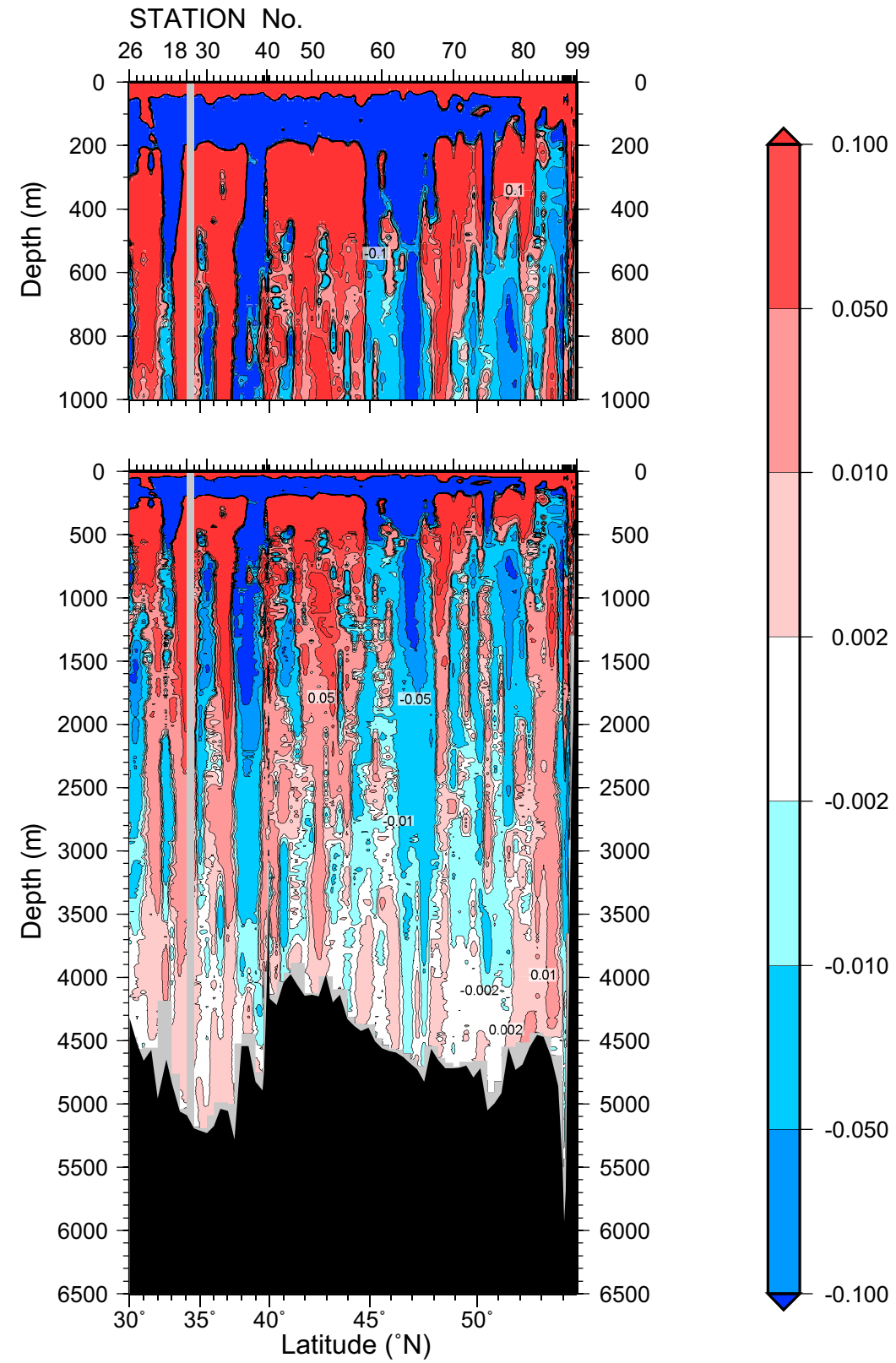
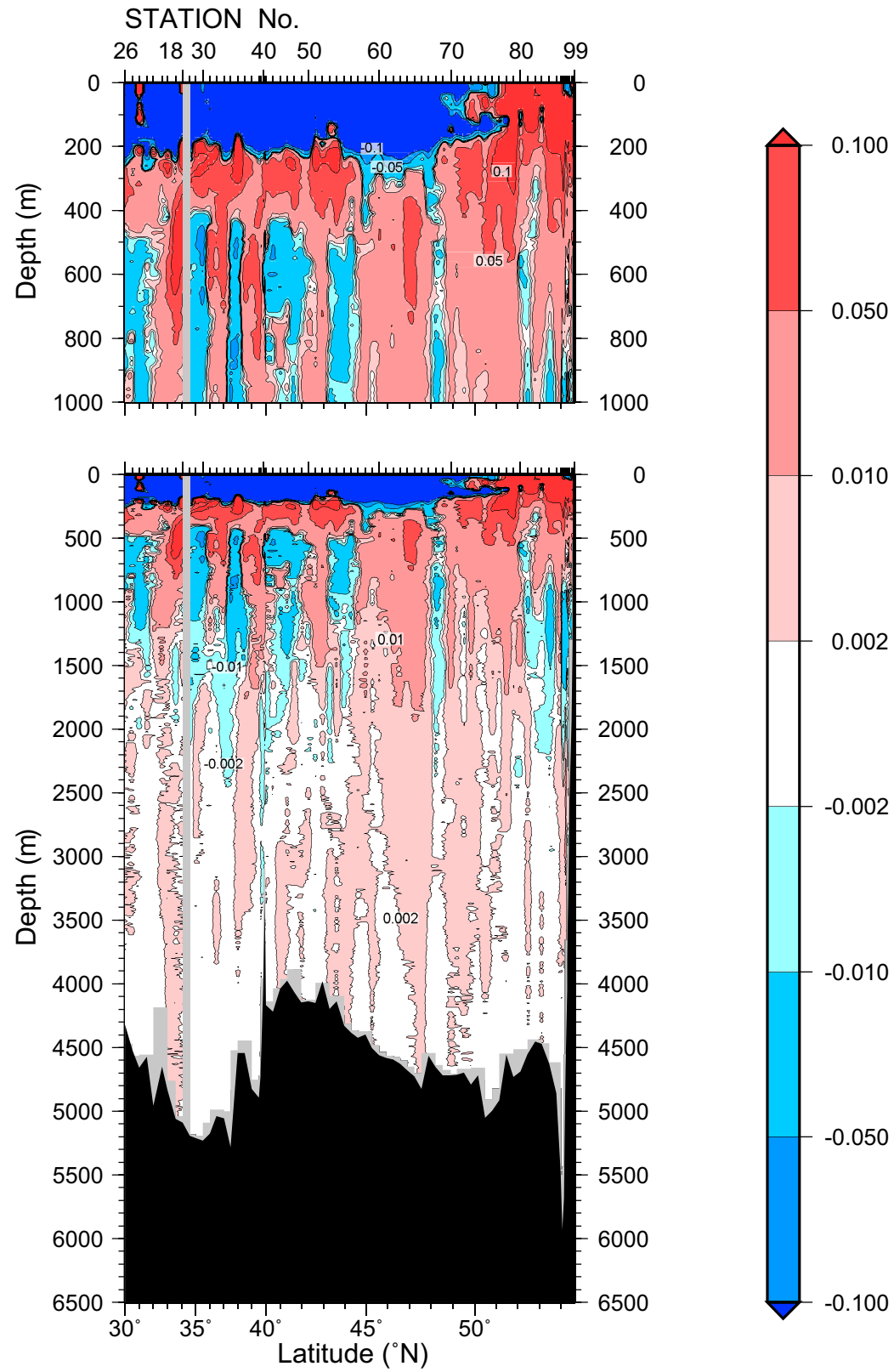


Figure 17





POTENTIAL TEMPERATURE DIFFERENCE BETWEEN 2001 AND 1993 (1991) [°C]



SALINITY DIFFERENCE BETWEEN 2001 AND 1993 (1991) [PSU]

