Preliminary Report of The Hakuho Maru Cruise KH-01-3

(Southern Pacific and Southern Ocean)

November 27, 2001 - March 1, 2002

Studies on the biological production and biogeochemical cycles in the central Southern Pacific and Southern Ocean and Geophysical Study of Australia-Antarctic Ridge

Ocean Research Institute
University of Tokyo

2003

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by
The Scientific Members of the Expedition
Edited by
Makoto TERAZAKI, Hiroshi OGAWA and Kensaku TAMAKI

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Preface

The KH-01-3 cruise of R/V Hakuho Maru was conducted un the title" Studies on the biological production and biogeochemical cycles in the central Southern Pacific and Southern Ocean and Geophysical Study of Australia-Antarctic Ridge" in the central south Pacific and the Australian sector of the Southern Ocean from November 27, 2001 to March 1, 2002. A total 55 scientists and supporting staffs from 19 organizations in japan and the United State of America. This expedition is conducted under the international programs such as JGOFS, SO-GLOBEC, ODP and Inter Ridge.

Many works on the productivity of the Antarctic Ocean have been published elsewhere, however, most works are based on a single observation on one cruise in particular time of year. Time-series works are necessary for understanding a real process happening in water. environmental change. In 2001/2002 austral summer, the time series observations by several research vessels, that is, Aurora Australis(Cruise leader: Dr. H. Marchant, ANARE-AAD:October-December 2001), RV Hakuho Maru (january 2001), Tangaroa(Cruise leader: Dr. T. Odate, JARE-NIPR: February 2002), and Shirase(Cruise leader: F. Nishio, JARE-Chiba University: March 2002)were successfully completed. Major target area in 2001/2002 austral summer was south of 61° S along 140° E, where a CTD observation as one of WOCE lines has been repeated by the ANARE(Australian National Antarctic Research Program).

The community structure and process-oriented studies, and biogeochemical cycles related dynamics of plankton communities and primary production patterns, role of microbial loop, rate process study on feeding and growth of main zooplankton, and size distribution and chemical composition of dissolved and particulate organic matter , were conducted at 25 stations located in the central Southern Pacific and Southern Ocean .

In order to evaluate the exchange of materials between ocean and atmosphere, distribution of pCO_2 and biogenic gases, and distribution and chemical composition of atmospheric aerosol particles, was surveyed. Study of crustal structure by Ocean Bottom

Seismometers, bathy metric survey by Sea-Beam, and high resolution measurements of sea-floor spreading rate by deep-sea magnetometer were conducted in the Australia-Antarctical Ridge.

The main topics of the studies were as follows;

1)Clarification of primary production

2)Clarification of communities and biomass of marine organisms

3)Evaluation of inter relationship between planktons by the measurement of feeding, respiration and growth rates

4)Evaluation of the exchange of materials between ocean and atmosphere, such as greenhouse gases, anthropogenic pollutants and terrestrial particles

5)Evaluation of the role of microbial food chain in the biogeochemical cycle

6)Evaluation of the relationship between the distribution of trace elements and biological production

7)Further evaluation of biogeochemical cycles from the dynamics of organic matter such as origin and processes of production, accumulation, settling, and decomposition

8)The slow down of Australia plate will be examined by obtaoining high resolution sea-floor spreading rates by deep-sea magnetometer survey

9)The true mantle density structure beneath Australia-Antarctica Ridge will be determined by obtaining crustal structure with Ocean Bottom Seismometer

Finally, I would like to appreciate the memmbers of cruise planning committee (Mr. Hiroshi HASUMOTO, Drs. Hiroshi OGAWA, Kyoko OKINO, Masahiko NISHIMURA and Jun NISHIKAWA) to advance and complete this Expedition.

Makoto TERAZAKI

Chief Scientist

Center for International Cooperation
Ocean Research Institut
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* Chief Scientist (Leg. 1 - Leg. 3)
**Acting Chief Scientist (Leg. 4)

KH-01-3 TRACK CHART

KH-01-3 Leg.1 TRACK CHART

KH-01-3 Leg.2 TRACK CHART

KH-01-3 Leg.3 TRACK CHART

KH-01-3 Leg.3 TRACK CHART

KH-01-3 Leg.4 TRACK CHART

KH-01-3

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11/27/01 (Tue.)	Tokyo Harumi														14:00 leave port Harumi Tokyo		16:29 Sunset					20:52 Sonde1		
11/28/01 (Wed.)		00:39 Sonde2	01:28 Sonde2				05:58 Sunrise		07:45 Sonde3						14:20 Sonde4	Surface W	16:09 Sunset							Sonde5 23:01
11/29/01 (Thu.)							05:37 Sunrise				Surface W					15:47 Sunset					Sonde6 20:56		GMT+10→→→	
11/30/01 (Fri.)							06:07 Sunrise				Surface W			13:20 Sonde7			16:27 Sunset					21:18 Sonde8		
12/1/01 (Sat.)			GMT+11→→→				06:39 Sunrise			09:28 Sonde9 09:49 Sonde10	Surface W			13:23 Sonde11				17:05 Sunset			20:18 Sonde12			Sonde13 23:01
12/2/01 (Sun.)							06:10 Sunrise				Surface W 09:55 Sonde14						16:44 Sunset			19:51 Sonde15				
12/3/01 (Mon.)							GMT+12→→→ 06:42 Sunrise	07:11 Sonde16			Surface W							17:39 Sonde17 17:26 Sunset						Sonde18 23:09
12/4/01 (Tue.)						05:12 Sonde19	05:57 Sonde19 06:16 Sunrise				Surface W 10:28 Sonde20					15:41 Sonde21		17:17 Sunset		19:08 XC01 19:16 XC01A 19:25 XC01B		21:53 XC02 22:00 XC02A 21:16 Sonde22		
12/4'/01 (Tue.)	GMT-12→→→	ARGOCTD****** 01:05 ARGO1					06:16 XC03 06:26 Sonde23 05:55 Sunrise 07:03 Sonde23			09:08 XC04	Surface W		12:08 XC05 12:27 Sonde24			14:54 XC06 15:04 XC06A		17:49 XC07 17:06 Sunset	18:19 Sonde25		20:48 ARGO2 20:51 XC08			
12/5/01 (Wed.)	00:05 XC09	01:15 Sonde26		03:03 XC10			05:57 XC11 05:43 Sunrise	06:58 Sonde27		08:53 XC12	Surface W		11:55 XC13 12:02 XC13A 12:10 XC13B	13:35 Sonde28	15:19 XC14	15:14 ARGO3	16:52 Sonde29	17:04 Sunset	18:20 XC15					GMT-11→→→ 20:06 XC16
12/6/01 (Thu.)							06:09 Sunrise		07:41 Sonde30		Surface W			13:26 Sonde31				17:47 Sunset			20:58 Sonde32			
12/7/01 (Fri.)					04:31 Sonde33		05:48 Sunrise				Surface W 10:36 Sonde34							17:04 Sonde35 17:37 Sunset						
12/8/01 (Sat.)	CTDD1********** St.1 00-00.06N 160-00.16W					Multi corer**********	05:27 Sunrise			CTDS1***** 09:42 Sonde36	MTD**********				CTDD2**********		Norpac	VMPS**********			CTDS2***			RMT********
12/9/01 (Sun.)	MTD**********				CTDS3		05:31 Sunrise				09:20 Sonde37				14:03 Sonde38			17:42 Sunset	18:40 Sonde39				St.2 05-00.00S 159-59.89W	CTD
12/10/01 (Mon.)	CTD********* 00:00 Sonde40 Norpac		RMT*********				05:20 Sunrise				08:39 Sonde41				12:36 Sonde42			17:51 Sunset	18:13 Sonde43		St.3 10-00.07S 160-00.01W			Sonde44 23:30 VMPS****
12/11/01 (Tue.)	*****	CTD********** Norpac*			RMT**********		05:14 Sunrise				09:48 Sonde45				13:30 Sonde46			17:31 Sonde47 18:00 Sunset				21:10 Sonde48		
12/12/01 (Wed.)	St.4 15-00.07 S 160-00.63 W		02:21 Sonde49 RMT**********			XCTD	05:04 Sunrise				09:20 Sonde50				13:38 Sonde51 13:54 Sonde51				18:04 Sonde52 18:09 Sunset			21:16 Sonde53		
12/13/01 (Thu.)	St.5 19-59.90S 160-00.19W			CTDD1**********		Multi corer**********	04:53 Sunrise			CTDS1*** 09:41 Sonde54	MTD**********			RMT**********			CTDD2**********		Norpac****** 18:14 Sunset			CTDS2**		ORI side MTD**********

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	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
12/14/01 (Fri.)	******	CTDS3				04:53 Sunrise	06:04 Sonde55				09:40 Sonde56			13:30 Sonde57				17:07 Sonde58	St.6 24-59.99S 159-59.98W 18:23 Sunset			CTD********** 21:16 Sonde59 Norpac		RMT*
12/15/01 (Sat.)	*********		Multi corer**********			04:43 Sunrise					09:59 Sonde60			13:23 Sonde61 Gravity meter Calibration**********					17:46 Sonde62 18:34 Sunset					22:21 Sonde63
12/16/01 (Sun.)	St.7 29-59.98S 160-00.01W		CTD********** 02:27 Sonde64 Norpac		RMT********* 04:33 Sunrise			VMPS*********					12:36 Sonde65				16:25 Sonde66				19:46 Sonde67			Sonde68 23:33
12/17/01 (Mon.)			St.8 35-00.03S 160-00.21W		CTDD1********** 04:21 Sunrise			Multi corer**********			09:30 Sonde69	CTDS1**			MTD**********				CTDD2**********		Norpac		CTDS1***	ORI Side MTD**
12/18/01 (Tue.)	**********			CTDS3	RMT********* 04:20 Sunrise			CTDS2**		VMPS*********					14:21 Sonde70				17:50 Sonde71 18:57 Sunset					22:25 Sonde72
12/19/01 (Wed.)			01:35 Sonde73		St.9 40-02.10S 160-02.72W 04:08 Sunrise	RMT*******			VMPS*******		09:16 Sonde74	CTD********** 10:08 Sonde75 Norpac				15:52 Sonde76					19:52 Sonde77	20:51 Sonde78		Sonde79 23:26
12/20/01 (Thu.)				03:03 Sonde80	03:53 Sunrise		06:16 Sonde81				10:11 Sonde82			St.10 47-00.07S 160-00.14W	CTDD2********** 14:28 Sonde83				Multi corer**********		19:34 Sunset		MTD**********	ORI side
12/21/01 (Fri.)	**********		CTDS2***		RMT**********							CTDS1***	MTD**********						CTDD1**********		Norpac 19:35 Sunset		RMT*********	
12/22/01 (Sat.)	VMPS*********			03:40 Sunrise					08:13 Sonde84											18:51 Sonde85 19:53 Sunset				
12/23/01 (Sun.)					04:10 Sunrise				08:46 Sonde86											18:47 Sonde87	20:19 Sunset			
12/24/01 (Mon.)									08:43 Sonde88					13:01 Sonde89								20:36 Sunset		
12/25/01 (Tue.)						05:21 Sunrise																20:53 Sunset		
12/27/01 (Wed.)	GMT+13→→→					05:49 Sunrise					10:00 a call Wellington													
1/2/02 (Wed.)															14:00 leave port Wellington							21:07 Sunset		
1/3/02 (Thu.)							05:50 Sunrise				Surface W										GMT+12→→→	20:48 Sunset(2nd)		
1/4/02 (Fri.)						04:52 Sunrise			Surface W															
1/5/02 (Sat.)	GMT+11→→→										Surface W											Proton Survey**********		
1/6/02 (Sun.)	Proton Survey**********			03:42 Sunrise							Surface W										Sea-Beam Survey**********			

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	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1/7/02 (Mon.)	Sea-Beam Sarvey********** CTD Photo CTD CTDS3********** Proton Survey********** Norpac C-Net Proton Survey********** C-Net 02:14 Sunrise St.11 63-06.88S 149-55.89E
1/8/02 (Tue.)	CTD CTD CTD*** Norpac ORI side Proton Survey********** 03:21 Sunrise St.12 65-00.07S 140-00.08E RMT********** MTD*******
1/9/02 (Wed.)	CTDD1******** CTDS1*** ********** C-Net IKMT********** MTD********** VMPS********* VMPS********* VMPS*
1/10/02 (Thu.)	CTDB1* CTDB2 St.12B 65-41.29S 140-08.32E CPR-Net********** ****** Norpac IKMT**********
1/11/02 (Fri.)	********* 03:57 Sunrise
1/12/02 (Sat.)	St.13 64-00.15S 139-57.59E CTDS2 CTD********** CTDD1********* Float.trap L. Photo Sediment Trap*** Photo C-NET Multi corer********* C-NET Photo Norpac
1/13/02 (Sun.)	* CTDD2********** CTDS1** CTDD1********** CTDS1** ORI Side Surface W Flost.trap R. CPR-Net********** Norpac ORI side CPR-Net RMT********** Photo St.14 63-00.00S 140-00.04E RMT********** C-Net
1/14/02 (Mon.)	CTDD1********** CTDS1** CTDS2 CTDD1********** CPR-Net********** Norpac ORI side CPR-Net********** Float.trap L St.15 62-00.20S 149-00.28E RMT********* C-Net* St.16 61-00.38S 140-00.05E Photo Norpac MTD********
1/15/02 (Tue.)	CTDS1** CTDD2********** CTDS3 Photo VMPS****** Photo Float.trap R Photo ********** 04:40 Sunrise C-Net C-Net MTD********** VMPS******** C-Net VMPS*****
1/16/02 (Wed.)	CTDD1********** ORI side CPR-Net ********** Norpac Multi corer********** Proton Survey********** RMT********** C-Net 04:46 Sunrise St.17 60-00.02S 140-00.12E
1/17/02 (Thu.)	CTDD1********** Proton Survey********** Piston Corer********* Multi corer********** 05:23 Sunrise St.18 54-44.11S 140-02.68E Norpac
1/18/02 (Fri.)	CTDS1*** C-Net ORI side CPR-Net ********** VMPS RMT********* 05:37 Sunrise
1/19/02 (Sat.)	CTDD1********** CTDS1**** C-Net St.20 47-00.76S 139-59.80E Norpac Multi Corer********** ORI side CPR-Net********** St.19 50-00.37S 140-00.14E 05:59 Sunrise RMT********** VMPS MTD
1/20/02 (Sun.)	CTDD1********** CTDS1 ORI side C-Net Norpac MTD********** RMT********* 06:12 Sunrise MTD**********
1/21/02 (Mon.)	Flowmeter Calib. 06:03 Sunrise
1/22/02 (Tue.)	10:00 a Call Hobart
1/27/02 (Sun.)	14:00 leave port Hobart Proton Survey******
1/28/02 (Mon.)	Proton Survey********** 06:21 Sunrise

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	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1/29/02 (Tue.)	Proton Survey**********						06:58 Sunrise																	
1/30/02 (Wed.)	00:51 XCTD Proton Survey**********							07:23 Sunrise																
1/31/02 (Thu.)	Proton Survey**********														Proton Survey**********									
2/1/02 (Fri.)	Proton Survey**********							07:20 Sunrise				OBS1		OBS2		OBS3	OBS4	OBS5		Air-Gun Set Streamer L		Air-Gun********** Passed OBS5		
2/2/02 (Sat.)	Air-Gun**********	Passed OBS4		Passed OBS3		Passed OBS2		Passed OBS1 07:31 Sunrise								Passed OBS3								Passed OBS2
2/3/02 (Sun.)	Air-Gun**********				Streamer R Air-Gun on Deck Passed OBS1		OBS1 R****	07:28 Sunrise	OBS2 R*****			OBS3 R****			OBS4 R***		OBS5 R***		St.21 49-54.01S 124-48.95E	CTD**********			Proton Survey B1S	
2/4/02 (Mon.)	Proton Survey**********					Passed B1N Passed B2N		07:30 Sunrise				Passed B2S Passed B3S						Passed B3N Passed B4N						Passed B4S B5S
2/5/02 (Tue.)	Proton Survey**********								Deep tow Proton**********															
2/6/02 (Wed.)	Deep tow Proton**********						Proton Survey**********																	
2/7/02 (Thu.)	Proton Survey**********					Passed B9N Passed B10N		07:39 Sunrise	Passed B10C		Passed B6C			Passed B3N Passed B6N									Passed B3NN	
2/8/02 (Fri.)	Proton Survey**********						St.22 45-00.62S 130-00.57E			08:21 XCTD IKMT**********			Proton Survey**********											
2/9/02 (Sat.)	Proton Survey**********															St.23 41-44.31S 140-02.72E				IKMT**********			CTD*********	
2/10/02 (Sun.)							06:47 Sunrise																	
2/11/02 (Mon.)							06:23 Sunrise														19:54 Sunset			
2/12/02 (Tue.)							06:25 Sunrise				10:00 a call Sydney													
2/16/02 (Sat.)															14:00 leave port Sydney									
2/17/02 (Sun.)							06:24 Sunrise														19:26 Sunset			
2/18/02 (Mon.)					GMT+10→→→		05:29 Sunrise				Surface W								18:19 Sunset					

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	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2/19/02 (Tue.)							05:36 Sunrise												18:12 Sunset					
2/20/02 (Wed.)				Surface W			05:41 Sunrise												18:08 Sunset					
2/21/02 (Thu.)							05:51 Sunrise												18:12 Sunset					
2/22/02 (Fri.)							06:10 Sunrise					St.24 02-30.08N 151-31.83E		CTD*******					18:09 Sunset					
2/23/02 (Sat.)							06:10 Sunrise												18:10 Sunset		GMT+9→→→			
2/24/02 (Sun.)				St.25 12-33.95N 148-59.91E		CTD****** 05:22 Sunrise												17:16 Sunset						
2/25/02 (Mon.)							05:36 Sunrise				Surface W							17:21 Sunset						
2/26/02 (Tue.)							05:49 Sunrise											17:32 Sunset						
2/27/02 (Wed.)							06:04 Sunrise											17:35 Sunset						
2/28/02 (Thu.)							06:13 Sunrise																	
3/1/02 (Fri.)											10:00 a call Tokyo													

Oceanographic condition of the Australasian sector of the southern ocean during the summer of 2002 (KH01-3 : Leg.2)

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Hydrographic observations were carried out in January during austral summer of 2002, in the Australasian sector of the Southern Ocean, south of Australia. This was a part of the research cruise KH01-3 of RV Hakuho-maru.

Observation line was taken along the meridian of 140° E between 45° to 65° 41.9' S. Casts of CTDO (Sea-Bird's 911 plus) with carousel Multi-Sampler (Sea-Bird's 32) were made at 10 hydrographic stations (Station 12B, 12, 13, 14, 15, 16, 17, 18, 19, 20) to collect data on water temperature, salinity, and dissolved oxygen from surface to bottom. Another set of data of dissolved oxygen(Winkler Method), salinity (Guildline Autosal 8400A) and nutrients were measured from bottle water samples.

The exact locations of the Subantarctic Front and Polar Fronts were not clear because observation stations were few and far apart, especially between 45° to 60° S. There are three distinct water massed located south of Antarctic Front in a vertical manner. They are, Antarctic Surface Water, the Circumpolar Deep water and Antarctic Bottom Water(Deacon 1937).

The Antarctic Surface Water is represented by temperature minimum and salinities below about 34.5 PSU. The temperature minimum layer is believed to be a remnant of winter-time convection and is termed the Antarctic Winter Water (Mosby 1934).

The Circumpolar Deep Water is characterized by a thick layer of water with temperature maximum higher than 1.5° C and the salinity maximum higher than 34.7 PSU. The Antarctic Bottom Water occupies the lower portion of the water column and is generally recognized by temperature below 0° C and salinity from 34.60 to 34.72 PSU (Gorden 1971a).

Figures 1 and 2 show the temperature and salinity vertical profiles and figure 4 shows

surface temperature and salinity profiles along 140° E.

Around 49° to 49.5° S, a steep horizontal gradient in surface temperature and salinity was observed (Fig.4). This was recognized as the Subantarctic Front, which is characterized by a steep thermal gradient in upper 400m of the water column with a drop in surface salinity.

The area south of the Polar Front is called the Antarctic Zone. This zone is characterized by subsurface water with temperature lower than 2° C and salinity less than 34.0 PSU. In this area, temperature minimum layer gradually becomes shallow southward, from depth of 200m around the Polar Front to 50m in vicinity of 65° S. A steep gradient in surface temperature was observed around 54.5° S. Northern limit of subsurface temperature minimum (2° C) was observed at 200m depth in the same area. The existence of the Polar Front, which is marked by these features was recognized around 54.5° S.

An upwelling of water with warmer temperature (>1° C) and higher salinity (34.5 PSU) was observed around 63.8° S forming the Antarctic Divergence.

South of the Antarctic Divergence, was indication of a sinking water mass, which may be the major source of Antarctic Bottom Water.

The Circumpolar Deep Water characterized by the temperature maximum more than 1.5° C and the salinity maximum more than 34.7 PSU was present forming a thick layer of water mass which extended down to a depth of nearly 3000m.

Fig. 1. Vertical section of temperature (℃) along 140° E line made from CTDO.

Fig. 2. Vertical section of salinity (psu) along 140° E line made from CTDO.

Fig. 3. Vertical section of oxygen (ml/l) along 140° E line made from CTDO.

Fig. 4 Sea surface temperature and salinity along 140° E line made from surface T.S. meter.

Studies of microbial population in the Pacific, sub-Antarctic and Antarctic Oceans.

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Studies on marine microbes show that not only degradation but also production is closely related to microbial activities in the oceans. So it is of importance to clarify ecological roles of marine bacteria and their contribution to bio-element cycling in the marine ecosystems. To understand their ecological roles, microbial abundance and community structure are the basic parameters to be primarily assessed. The aim of "Microbial Ecology" group is to examine microbial abundance and their community structure in the Pacific, sub-Antarctic and Antarctic waters. The experimental approach consists of flow-cytometric analyses of marine bacteria, genetic analyses of microbial communities based on 16S ribosomal DNA, and bacterial isolation from marine environments by conventional non-selective plating techniques.

Flow cytometric analyses of marine bacteria:

Water samples were fixed with a combination of 1-% paraformaldehyde and 0.01-% glutaraldehyde, followed by the staining of SYBR Green I . After 30 min of staining, samples were loaded into the flow-cytometer, Pas-Ⅲ(Partec GmbH). A part of samples were stained and analyzed without fixation. In addition, Live/Dead staining was carried out in order to estimate the proportion of actively growing bacteria to a total community. Though the marine bacteria in the open oceans are known to be far smaller than the detection limit of the flow-cytometers that have been used before, using a Pas-Ⅲ model flow-cytometer on board and SYBR Green I staining, we could estimate marine bacteria in the open oceans with good accuracy. In some samples, we succeeded in differentiating actively growing bacteria from dormant ones by means of Live/Dead staining.

Genetic analyses of microbial communities:

Water samples were collected at some important stations in the present cruise for this

purpose. One liter of water collected from the depths of 20m, 200m, 500m and 1000m were concentrated on Sterivex-GS filter units in order to trap marine bacteria present. Each filter unit was washed in SET buffer, and stored in deep freezer for further experiments. To learn of microbial community structures and their diversity, microbial DNAs will be extracted, purified and would be subjected to genetic analyses using 16S rDNA as target.

Bacterial isolation from marine environments:

We tried to isolate marine bacteria from water samples and from antarctic krill. Water samples were spread on ZoBell 2216E agar plates and incubated at 20℃ and 4℃ to isolate the mesophilic as well as psychrophilic bacterial counts. Representative colonies were picked up and transferred to agar slants of the same medium. The slants were brought back to the laboratory and stocked for further study.

Fig. 1. Flow-cytometric analysis of seawater samples taken from the surface during the cruise KH-01-3. A sample was collected at Stn. 10 and stained with SYBR Green I for counting total bacterial number (A), Collected at Stn. 12 and stained with LIVE/DEAD stains for analyzing actively growing bacterial number (B).

Phytoplankton population dynamics and primary productivity in the South Pacific and the Southern Ocean.

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Primary production in the Southern Ocean on the whole has been characterized by low to moderate productivity, with large meso-scale temporal and spatial variations. Spatially restricted studies indicated that absolute levels of productivity vary over three orders of magnitude. However, the controlling factors of these variations are far from certain. Seasonal variability in physical, chemical and biological conditions in surface waters is large particularly in the areas with seasonal ice cover. Spatial variability is also large because of the convergences and divergences of waters associated with the sub-polar and polar fronts. A complete understanding of the phytoplankton population dynamics and variation in primary productivity in the Southern Ocean will require systematic seasonal observations in various oceanographic regimes.

In this study, we investigated spatial variations of phytoplankton community structure and primary productivity during austral summer in the South Pacific and the Southern Ocean. The results obtained from this cruise will be examined together with those obtained by other cruises (Aurora V3 by R/V Aurora Australis, Nov.-Dec. 2001 and JARE43 by R/V Tangaroa, Feb.-Mar. 2002) to understand seasonal variability along 140°E line in the Southern Ocean.

1. Biomass and community structure of phytoplankton

The analysis of class-specific biomarker pigment and flow cytometric analysis of picophytoplankton were made to deduce spatial variations in biomass and composition of phytoplankton assemblage in the South Pacific and the Southern Ocean.

Algal chlorophylls, xantophylls and carotenoids

Seawater samples (2 liter) were filtered through Whatman GF/F filter under a vacuum of 150 mmHg. The filters were frozen in liquid nitrogen and stored at –80°C for analyses of chlorophylls, xantophylls and carotenoids by HPLC (Zapata et al., 2000).

Phycoerythrin

Cyanobacteria, that possess phycoerythrin as the major light-harvesting phycobiliproteins, are the dominant group of phytoplankton assemblage in the oligotrophic and temperate ocean. For the analysis of phycoerythrin in seawater along 160°W, water sample (1 liter) was filtered through 0.4 μm Nuclepore filter and cells on the filter were resuspended in 50% glycerol for 10-30 minutes under dark condition *In vivo* fluorescence of phycoerythrin was then determined using a Turner Design TD700 fluorometer. Samples were also fixed in 2% glutaraldehyde and filtered through 0.2 μm cellulose acetate filters for cell counting under a fluorescent microscope.

Phycoerythrin contains two types of chromophores, phycourobilin (PUB) and phycoerythrobilin (PEB). Each strain of cyanobacteria has different PUB/PEB ratio and the ratio also changes with optical conditions. Thus, we examined the PUB/PEB ratio along a transect of 160°W during Leg. 1 by measuring excitation and emission spectra using Shimadsu RF-540 spectrofluorometer.

Concentration of phycoerythrin in the surface water ranged from 0.003 to 0.26 μg l^{-1} (Fig. 1). At the stations between 20°S and 40°S, phycoerythrin concentrations were low and uniform, while the equatorial station exhibited high phycoerythrin concentrations in the upper 70 m. Similar or slightly higher phycoerythrin concentrations were also found at 40-50m depths at 10°S. The ratio of PUB/PEB increased with depth at 10°S, suggesting adaptation of cyanobacteria to the light field dominated by blue light in the deeper layer (Fig. 2). This is because PUB has an absorption peak at blue light, while PEB absorbs longer wavelength light than PUB. On the other hand, PUB/PEB ratio at equator showed constant value in the upper 150 m, in accordance with our previous study on PUB/PEB ratio along east-west transect in the equatorial Pacific.

Flow cytometric analysis of picophytoplankton

For enumeration and size analysis of picophytoplankton by flow cytometry, samples were fixed in formaldehyde, frozen in liquid nitrogen and stored at –80°C.

2. Phytoplankton photosynthesis and productivity

Photosynthesis-irradiance relationship

Photosynthesis vs. irradiance curve (P-E curve) was obtained for phytoplankton assemblages collected at 10 m and at chlorophyll *a* maximum depth. Uptake of ^{14}C-bicarbonate was measured using a photosynthetron (Lewis and Smith, 1983). Samples were incubated at *in situ* temperature under the white light with 22 different light intensities

ranging from 0 to 1300 μmol $m^{-2}s^{-1}$. After 30 min of incubation, photosynthesis was terminated by an addition of HCl, and radioactivity was measured by liquid scintillation counter with the external standard channel ratio method.

Primary production will be calculated based on chlorophyll *a* normalized absorption coefficient (a*), the underwater light field, vertical profiles of chlorophyll *a* and photosynthetic parameters obtained from the P-E curves (Morel, 1991).

Absorption spectra of phytoplankton

Absorption spectra of phytoplankton were measured by QFT method (Mitchell, 1990). Samples were filtered through Whatman GF/F filter and stored at –80°C. Optical density of phytoplankton and detritus were measured using spectrophotometer, and absorption coefficients of phytoplankton, $a_{ph}(\lambda)$ were obtained.

For precise estimation of maximum quantum yield from absorption coefficient, correction of light absorption by photoprotective pigments, which do not contribute to photosynthesis, is needed. Absorption spectra of photosynthetic pigments will be constructed by subtracting the absorption of photoprotective pigments using the result of algal pigments analysis by HPLC.

3. Effect of iron enrichment on community structure and photosynthetic activity of phytoplankton

In high-nitrate, low-chlorophyll regions of the Southern Ocean, growth of phytoplankton, especially large diatoms, have been considered to be limited by iron deficiency. To elucidate the effect of iron supply on community structure and photosynthetic activity of phytoplankton, an iron enrichment experiment was conducted at station 13.

Water samples were collected from 5 m depth using an acid-cleaned pump with Teflon tubing. Acid-cleaned 4-liter polycarbonate incubation bottles were filled with the sample water under low light condition. In this experiment, three control and three Fe-enriched bottles were prepared. Total Fe concentration of the initial sample was 0.62 nM and the Fe treatment received an addition of 1 nM $FeCl_3$. The bottles were sealed in three plastic bags and incubated on deck in running surface seawater baths to maintain surface seawater temperatures for 7 days. One bottle was recovered for each treatment after 2, 4 and 7 days of incubation for the analyses of total Fe, P-E curve, algal pigments and phytoplankton cell counting. All treatments and sub-samplings were carried out in a Class-100 clean-air laminar flow hood in a cold room (No. 10 laboratory).

Sampling depths and measured parameters of each station were summarized in Table 1.

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Table 1 Sampling station, depth and measured parameters.

Station	P-E curve	Absorption spectrum	Algal Pigments		Picophytoplankton by flow cytometry
			by HPLC	Phycoerythrin	
Tokyo - St 1*			0m	0m	
1	10m, 50m	0-150m (11)***	0-150m (11)	0-150m (11)	0-150m (11)
2		0-150m (9)	0-150m (9)	0-150m (9)	0-150m (9)
3		0-150m (9)	0-150m (9)	0-150m (9)	0-150m (9)
5	10m, 140m	0-150m (11)	0-150m (11)	0-150m (11)	0-150m (11)
6		0-150m (9)	0-150m (9)	0-150m (9)	0-150m (9)
7		0-150m (9)	0-150m (9)	0-150m (9)	0-150m (9)
8	10m, 120m	0-150m (11)	0-150m (11)	0-150m (11)	0-150m (11)
9		0-150m (9)	0-150m (9)	0-150m (9)	0-150m (9)
10	10m, 50m	0-150m (11)	0-150m (11)	0-150m (11)	0-150m (11)
12		0-200m (9)	0-200m (9)		0-200m (9)
12B		0-200m (9)	0-200m (9)		0-200m (9)
13 **	5m, 10m, 40m	0-200m (9)	0-200m (9)		0-200m (9)
14		0-200m (10)	0-200m (10)		0-200m (10)
15		0-200m (10)	0-200m (10)		0-200m (10)
16	10m, 80m	0-200m (10)	0-200m (10)		0-200m (10)
18	10m, 80m	0-200m (8)	0-200m (8)		0-200m (8)
19	10m, 50m	0-200m (9)	0-200m (9)		0-200m (9)
20		0-200m (13)	0-200m (13)		0-200m (13)

* Surface water sample was collected once a day at 10 AM between Tokyo and St, 1.
** Iron enrichment experiment was performed using water sample from 5m depth.
***Number of sampling depth.

Fig. 1 Distribution of phycoerythrin concentration (μg l^{-1}) along 160°W during Leg. 1.

Fig. 2 Distribution of the ratio of phycourobilin (PUB) and phycoerythrobilin (PEB) along 160°W during Leg. 1.

Photosynthetic activity in the surface water during Leg. 2 cruise of KH-01-3

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Photosynthetic activity of phytoplankton community in the surface water of the Southern Ocean, which was pumped up from the ship bottom (scientific seawater), was frequently measured by means of a PAM (Pulse-Amplitude-Modulation) chlorophyll fluorometer during the Leg. 2 cruise of KH 0103. The pumped up water was allowed in a dark bottle for ca. 1.5 hr to be the sample dark adapted at the same surface water temperature, then several fluorescence parameters were determined to know the degree of photo-physiological stresses and photosynthesis-irradiance relationships of the phytoplankton community. Similar experiments were carried out on R/V Tangaroa in February to evaluate the temporal changes of these photosynthetic parameters.

Fig. 1 shows the points where the experiments were conducted. On the Leg. 2, 16 and 21 experiments have been done from Wellington to St. 11 and from St. 12 to St. 19, respectively, that those were covered from Sub-Antarctic to Antarctic Ocean zones. The results will be presented in near future when the analytical works will be completed.

Fig. 1 Locations where photosynthetic activity of phytoplankton communities in the surface water were measured by means of a PAM chlorophyll fluorometer in the Leg. 2 of KH 0103 and Tangaroa cruise.

Composition of photosynthetic products and sinking particles in the South Pacific and the Southern Ocean.

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Introduction

Organic matter in the sea is mainly produced by natural phytoplankton populations, and this process makes the bases of fundamental material and energy flow. Thus the primary production of natural phytoplankton population is one of the most important processes in the biogeochemical cycle in the sea.

The photosynthetic products by phytoplankton are comprised of various organic matter and change according to the surrounded environment and/or physiological state. They vary in biological and chemical reactivity due to the difference in molecular structure, then are different in the contribution to biogeochemical cycle. The measurements of organic carbon flux in organic compound level as well as in bulk carbon, thus, are valuable to study the carbon cycle in oceanic environments.

Methods

The incubation experiments were done at Stas.1, 5, 8, 10, 13 and 16. The water samples for the incubation experiments were collected from 6 or 7 layers (100, 50, 25, 12.5, 6, 3, and 1% of the surface irradiance decided in the euphotic zone before dawn, and transferred into 9l polycarbonate bottles. After addition of ^{13}C-$NaHCO_3$ (^{13}C concentration in the dissolved inorganic carbon was about 14%), the bottles were incubated in an on-deck water tank circulating seawater with corresponding light irradiance controlled by the neutral density filters. Incubation experiments was started just before sunrise and continued for 24h. The concentration of POC and chl.*a* and the production rate of POC were measured. Composition of photosynthetic products, carbohydrate, protein and lipid, was measured by the ^{13}C and gas chromatography-mass spectrometry (^{13}C-GC-MS).

To evaluate difference of contribution to sinking materials among organic matters, the

sediment trap experiments were done at Stas. 13 and 16 using floating buoy as a cooperative study with Drs. Hiroshi Sasaki (Senshu University of Ishinomaki) and Sakae Kudoh (National Institute of Polar Research). Sinking materials of POM, chl.*a*, carbohydrate, protein and lipid were measured.

To evaluate the process of produce of DOM from POM produced by phytoplankton, dissolution and decomposition experiment was done using the surface water of Sta.18. After incubation to label the photosynthetic products with ^{13}C, water sample was placed in dark condition, and subsamples were recovered at some intervals. Particulate and dissolved carbohydrate of subsample was measured.

Results

The concentration of chl.*a* was high at St.16 (Fig.1), but low concentration with a litter vertical change was found in other station. Primary production was highest at the surface of St.16 (Fig.2), but it decreased as increasing depth. Primary production of St.1 was high even in deeper depth.

The ratio of sinking flux to standing stock was relatively low at St.13 (Table1), but it was very high at St.16.

The detailed composition of primary products and sinking particles will be measured.

Fig.1 Vertical changes in chl.*a*

Fig.2 Vertical changes in primary production

Table1 The ratio of production rate and flux to standing stock at 20m depth

	Production/Standing stock	Vertical flux/Standing stock		
	POC	chl.*a*	PON	POC
St.13	0.0591	0.0026	0.0044	0.0047
St.16	0.0307	0.0110	0.0174	0.0152

Study on assemblage and isotopic and chemical features of planktonic foraminifera in the Pacific

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Introduction

The Pacific is the largest ocean in the world. It has played an important role in global marine carbon cycle. Therefore in recent years, significant international efforts have been made to investigate biological pump in relation to climatic change in the equatorial to southern oceans in the Pacific. Since planktonic foraminifera are dwelling in the shallow water, stable isotope data of their skeletons provide a good record of hydrography such as temperature, salinity and nutrients' level in the surface ocean.

In fact, the stable isotope ratios of planktonic foraminifera have been used frequently in climatological studies of marine sedimentary cores. Especially, quantitative estimates of temperature variation have been made from isotopic data. However, there has been much debate as to whether or not planktonic foraminifera build their test in equilibrium with the ambient seawater. Most authors find a small deviation from the isotopic equilibrium with a constant offset, suggesting that the oxygen isotope ratios in the test should reflect the $\delta^{18}O$ values of the seawater and its temperature .

On the other hand, carbon isotope data are controlled by $\delta^{13}C$ of total dissolved inorganic carbon in seawater and physiological processes such as respiration and symbiont photosynthesis. They are used to infer change in the ocean's biological pump influencing atmospheric CO_2 concentrations and to reveal shifts in the carbon reservoirs between the terrestrial and oceanic biosphere. However, the complexity of the carbon isotopic signal of foraminiferal test is as yet not well understood, as it is governed by unknown vital effects and depends on the ontogentic stage of the specimens and their habitat depth.

In order to learn more about physiological and ecological effects which control the variations in foraminiferal shell $\delta^{18}O$ and $\delta^{13}C$ of the different species, plankton net-tow investigations and comparison of these values between surface ocean and surface sediments have been extensively carried out. However, these collected foraminiferal shells originated from certain range of water

depth. Therefore, stable isotopic values of these shells recorded integrated calcification. Therefore it is important to collect planktonic foraminifera by pumping seawater at the water depth of 4 m at a latitudinal transect.

Field work and Laboratory analysis

Plankton samples were collected during the R/V Hakuhou-maru 2001-2002 cruise. A continuous set of samples was obtained by a pump method, filtering approximately 2 cubic m of seawater twice per day through a 150 micro-m sieve, from 4 m depth. The samples were preserved in 40 % ethanol. These samples were analyzed for assemblage and then were completely dried under the vacuum and were served for the stable isotope analysis. Most samples were 500-250 micro-m in size because larger size foraminifera were seldom obtained.

Isotope measurements will be carried out at AIST. The foraminiferal samples of 10-20 micro-g were reacted with 100% H_3PO_4 at 90°C in an automated carbonate device (Multiprep) coupled with a Micromass Optima mass spectrometer. The internal precision was 0.03per mil and 0.04 per mil for $\delta^{13}C$ and $\delta^{18}O$, respectively, based on repeated measurements of NBS-19 calcite standard (n= 6). Data are reported as per mil deviations relative to PDB (Peedee Belemnite).

Biological and ecological studies of meso-, macrozooplankton and micronekton in the south Pacific and the Southern oceans

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1. Distributional ecology of chaetognath (Travis Johnson, Makoto Terazaki)

Chaetognath collection during legs 1 and 2 of the KH01-3 cruise was largely centered around the species *Eukrohnia hamata* and had 3 main objectives. The first was to collect quantitative data on a linear north-south transect depicting the tropical submergence of *E. hamata*. The second was acquisition of specimens for future DNA work comparing *E. hamata* from differing locales throughout the Pacific Ocean in order to assess the degree of similarity between far removed individuals. The third was to obtain data on the feeding and ontogenetic distribution of *E. hamata* in the Southern Ocean, in addition to general chaetognath community structure and species composition, for a comparative study against the KH94-4 cruise.

The nets utilized for the collection of chaetognath samples were the MTD (0.33mm mesh), VMPS (0.33 mm mesh), and Norpac (twin type, 0.1/0.33mm mesh). Both the MTD and VMPS nets covered the 0-1000m water column, sampling in discrete layers. The Norpac net covered the 0-200m water column. Samples intended for DNA analysis were immediately fixed with ethanol, while all other samples were fixed with a 10% buffered formalin/seawater solution.

Examination of the samples is currently pending. The tropical submergence of *E. hamata* will be studied using MTD samples from stations 1, 5, 8, 10, 12, 16, and 20, plus VMPS samples from stations 1, 3, 7, 8, 9, 10, 12, and 16. Southern Ocean data for comparison against cruise KH94-4 will be limited to MTD samples from stations 12, 16, and 20, and VMPS samples from stations 12 and 16.

DNA analysis will utilize 217 *E. hamata* individuals separated out from all three nets: the 800, 900, and 1000m depth MTD samples from stations 1, 5, 8, and 10; Norpac samples from stations 12, 12B, 14, 16, and 18; and VMPS samples from incomplete hauls at stations 7

and 19.

2. Study of taxonomy, biogeography and reproductive patterns of crustacea in the South Pacific and Southern Ocean with special reference to color pattern of living copepoda and amphipoda (Kazuyoshi Hashizume)

The planktonic copepoda and amphipoda are very dominant zooplankton in the world ocean, however the biology of oceanic species (excluding to the species of subarctic and subantarctic upwelling area and so on) has scarcely studied except for the basic study such as taxonomy and horizontal distribution. The study about the reproductive patterns (mature size, spawning pattern, brood size, egg volume and so on), and specific identifications of the larval stages are very important for estimate biomass in the ocean, however their study are very few in the oceanic zone. Consequently we have researched on the horizontal and vertical distributions, and reproductive patterns of copepoda (mainly Euchaetidae) in the South Pacific and Southern Oceans, by NORPAC (0-150m, vertically) , RMT (0-1500m, obliquely), MTD (0, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000m, synchronized horizontally) and VMPS (0-50, 50-100, 100-200, 200-300, 400-500, 500-600, 600-800 and 800-1000m, vertically) nets. The genus *Euchaeta* and *Paraeuchaeta* (Euchaetidae) were widely distributed from tropical to Antarctic zone also from surface to mesopelagic water, many species were collected especially in the equator zone. Moreover mature female of both genus were frequently carrying egg mass. I prepare to study the relation of the distribution of euchaetid copepods with water temperature, salinity, chlorophyll *a* concentration and total plankton wet weight. On the other hand, the specific identifications of larval stages of copepoda are very difficult, because the sexual organs are important character for distinguish the species of copepoda. I detected specific color patterns of copepoda (especially Calanidae, Eucalanidae, Calocalanidae, Aetideidae, Euchaetidae, Phaennidae, Scolecithricidae, Temoridae, Lucicutiidae, Augaptilidae, Candaciidae, Corycaeidae) by a digital camera (Nikon, COOLPIX950). Also the color patterns of the copepodid stages were frequently similar to the adult stage, therefore they are good character for specific identification the larvae. Aetideidae (especially *Gaetanus*), Euchaetidae (especially *Euchaeta* and *Paraeuchaeta*) and Scolecithricidae (especially *Scottcalanus*) were having diverse color patterns among species in same gunus. Furthermore Palacalanidae (especially *Palacalanus*), Clausocalanidae (especially *Clausocalanus*), Metridinidae (especially *Metridia* and *Pleuromamma*) , Heterorhabdidae (especially *Heterorhabdus*) and Acartiidae (especially *Acartia*) were

characteristic arrangement of pigment nevertheless similarly color patterns. On the other hand, planktonic amphipoda (especially *Cyphocaris*, *Eupronoe*, *Hyperoides*, *Hyperuetta*, *Paraphronima*, *Vibilia*) also were having diverse color patterns. Consequently their investigations contribute possibly to study the resource-partitioning of oceanic species of the planktonic copepoda and amphipoda.

3. Study on the latitudal variations in biomass, community structure, and biodiversity of zooplankton (Jun Nishikawa)

In general, biodiversity of various organisms tends to lower in higher latitudes (e.g. Gaston 2000). However, this trend may not be applied to the marine plankton (Rutherford et al. 1999). There have been many hypothesis to explain the trend, however, little study have been made on mesozooplankton. In this cruise, zooplankton sampling was made by the RMT which covers from equator to 65°S at 1 to 10 degree intervals. Samples will be analysed to know the latitudal trend in the biomass, community structure, and biodiversity of zooplankton.

4. Feeding rhythm of the pelagic tunicate, *Salpa thompsonii*in the Southern Ocean (Jun Nishikawa, Makoto Terazaki)

Feeding rhythm of the pelagic tunicate, *Salpa thompsonii* was investigated as a part of studies on these animal to clarify the reason for their high monospecific stocks in the Southern Ocean offshore regions. Several successive samplings were carried out at stn 16. Salps were sorted out, their body length mesured, and the pigments of gut contents were extracted in N, N-Dimethylformamide. Concentration of chlorophyll a and phaeopigments in the extracts was measured with a fluorometer on board.

5. Study on biomass and metabolism of mesopelagic shrimps (Sean Toczko)

I am studying the abundance and biomass of pelagic micronektonic crustaceans (euphausiids, decapods, and mysids) along two transects: one from the equitorial Pacific to 50°S lat. (Leg 1); and a second in the Southern Ocean from 65°S lat. to 47°S lat., along 140°E long (Leg 2). A third series will be taken south of the Australian Bight (Leg 3), time permitting. Samples were collected at 19 stations via a combination of 2 nets: IKMT and RMT 8+1. Discrete layer sampling was conducted at 5 stations via MTD. The IKMT and RMT nets were used in oblique tows from ca. 1500m w/o, while the MTD nets collected samples over ca. 100m depth intervals from 1000m to the surface both day and night.

Combined with abundance and biomass, two other characteristics are being studied: respiration (via ETS) and trophic partitioning (via stable isotope). Samples for these studies, including POM samples for each station, have been deep-frozen (-84°C) and will be processed in the lab. Abundance and biomass samples have been preserved in 10% buffered formalin. It is hoped that this study will help clarify: (1) the trophic positioning and metabolic requirements for these crustaceans; and (2) the biomass of decapods and mysids in the Australian sector of the Southern Ocean.

Changes in lipid composition and metabolism of major copepods associated with diet and environmental conditions in the Indian sector of the Southern Ocean

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Objective

Antarctic zooplankton generally have a high lipid content. The fatty acid composition of wax esters and triacylglycerols is generally species specific but can be modified through dietary variability and metabolic process. We measured metabolic rate (respiration rate, ammonia excretion and phosphate excretion) and lipid composition of the major copepods in order to deduce the relationship between changing conditions to their dietary preferences and life-strategies of copepods.

In addition, we measured the possible impact of the copepod grazing on DMSPd and DMS production in order to understand and to estimate the biological activity relating to the production of greenhouse gases. This section is part of an international multi-ship program.

Sampling and methods

Lipid composition

Copepods were collected at 9 stations (Table 1) by a NORPAC twin net (mesh size: 330 μm, mouth diameter: 0.45 m) equipped with a flow meter. The net was hauled vertically from an approximate depth of 150 m. For each lipid sample only live and intact specimens were selected under a stereomicroscope according to species and stages (CV and females). All samples were immediately transferred into petri dishes and stored at –80℃ freezer.

DMS experiment

Copepods were collected at 3 stations (Table 1) by a NORPAC twin net. The three copepod species examined were *Calanoides acutus*, *Calanus propinquus* and *Metridia gerlachei*. 20 individuals were washed and incubated in 2L polycarbonate bottles with a little headspace for 12h at ca. 0℃ in a darkened roller incubator in the low temperature room of the ship. Control bottles without specimens were prepared concurrently. End samples for chlorophyll a concentration and DMS(P) analysis were taken after incubation.

Table 1. Details of C-net sampling, and the description of the experiment done (+).

Date	Station	Position		Lipid content	DMS experiment
		Latitude	Longitude		
Jan. 7, 2002	11	62° 30.0'S	150° 00.0'W	+	
Jan. 9, 2002	12	65° 00.0'S	140° 00.0'W	+	+
Jan. 12, 2002	13	64° 00.0'S	140° 00.0'W	+	
Jan. 13, 2002	14	63° 00.0'S	140° 00.0'W	+	
Jan. 14, 2002	15	62° 00.0'S	140° 00.0'W	+	+
Jan. 15, 2002	16	60° 00.0'S	140° 00.0'W	+	+
Jan. 18, 2002	18	54° 44.0'S	140° 00.0'W	+	
Jan. 19, 2002	19	50° 00.0'S	140° 00.0'W	+	
Jan. 20, 2002	20	47° 00.0'S	140° 00.0'W	+	

Continuous Plankton Recorder (CPR) Survey

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The Continuous Plankton Recorder (CPR) has been very successful in the monitoring zooplankton communities in the North Sea and North Atlantic Ocean over the past seventy years. Plankton samples are collected between two sheets of silk gauze (270μm), which then rolled into a preservation bath, giving approximately 450 nautical miles (830km) of continuous zooplankton records during a single tow. Therefore in a short period, it is ideal for sampling in large areas and mapping for the distribution of zooplantkon in relation to ocean environments such as frontal zones typically found through the Southern Ocean.

During the 2001/02 shipping season, the Southern Ocean CPR survey was conducted through the use of 4 research vessels, *Aurora Australis* (Australian Antarctic Division), *Shirase* (NIPR: National Institute of Polar Research), *Hakuho Maru* (Tokyo University) and *Tangaroa* (on charter to NIPR from NIWA, NZ). The 4 ships were involved in repeat tows along longitude 140° E, between 47 and 65° S, to look at temporal variation of surface zooplankton community and abundance on a fixed spatial scale.

sampling

Two CPR tows along longitude 140° E were successively conducted northward cruise between station 12 to 17, and station 18 to 20 (Table 1). First CPR tows stopped every one degrees of latitude for the purpose of CTD casts and other sampling. Similarly, second CPR tows were interrupted for routine CTD casts and NORPAC net sampling. The CPR was towed at 10m depth and towing speed was between 15 to 16 knots. After sampling, zooplankton samples retained between silk gauzes were preserved in a 10% v/v buffered formalin solution.

Table 1. Details of CPR tows conducted on *Hakuho Maru* in January 2002.

CPR Run #	Start Date (GMT)	Start Time (GMT)	Start Position Latitude	Start Position Longitude	End Date (GMT)	End Time (GMT)	End Position Latitude	End Position Longitude
1	Jan. 10, 2002	05:42	65° 33.8'S	140° 07.2'W	Jan. 10, 2002	14:00	64° 00.7'S	139° 59.0'W
	Jan. 12, 2002	23:53	63° 59.6'S	139° 57.1'W	Jan. 13, 2002	04:00	63° 00.0'S	140° 00.0'W
	Jan. 13, 2002	12:02	63° 00.1'S	140° 00.9'W	Jan. 13, 2002	16:17	62° 00.2'S	140° 00.3'W
	Jan. 14, 2002	00:42	62° 00.3'S	140° 01.3'W	Jan. 14, 2002	04:50	61° 00.3'S	140° 00.1'W
	Jan. 15, 2002	16:11	60° 56.4'S	139° 56.8'W	Jan. 15, 2002	20:19	60° 00.0'S	140° 00.1'W
2	Jan. 17, 2002	18:10	54° 42.2'S	139° 56.7'W	Jan. 18, 2002	12:58	50° 00.1'S	140° 00.1'W
	Jan. 19, 2002	00:40	49° 58.5'S	139° 55.7'W	Jan. 19, 2002	12:25	47° 00.6'S	139° 59.8'W

A study on the early life history of Notothenids (Teleost).

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Introduction

Fishes of the suborder Notothenioidei exhibited a great deal of adaptive radiation in the Antarctic region, comparable to the Cottidae of Lake Baikal(Sideleva, 1980) and Cichlidae of African Rift Lakes(Ribbink, 1991). Currently, 5 families and 122 species are recognized in Notothenioidei (Gon and Heemstra, 1990). Recently, rearing experiments at Port of Nagoya Public Aquarium conducted by curator Yasuo Hirano, has revealed numerous interesting early life history traits of this suborder: egg incubation period as well as pelagic larval period extending two hundred days or more, providing new and unique insight into the adaptive mechanism of this unique Teleost group to the Southern Ocean. Wild field caught specimens of eggs and larvae of Notothenids are not well represented in museum or institutional collections, and eggs and larvae of Notothenids were not described in detail facilitating early life history studies. Leg 2 of research cruise KH01-3 provided a golden opportunity to collect valuable specimens for early life history study of Notothenids. Teleost eggs, larvae and juveniles were collected in order to elucidate the ontogeny of this very unique Teleost suborder.

Materials and Methods

RMT net, IKMT net (1 mm mesh) and ORI nets were used to collect Teleosts. For details of sampling conducted, refer to Plankton Net Record of the cruise.

Telesot eggs, larvae and juveniles were sorted from the net samples immediately after capture. Most specimen were frozen, while some were fixed and preserved in 10 % buffered sea water formalin.

Specimens were examined under a binocular microscope after being thawed. Drawings and measurements were made with a drawing tube attached to a binocular microscope. Biomass in weight was measured to the nearest 0.1 mm g with an electronic balance.

Results

Preliminary results based on Teleosts collected using RMT-8 net is presented here. 18 families of Teleosts were collected during Leg 2 of the cruise. Family composition as well as biomass expressed as weight per 1000 cubic liters of water is presented in Table 1.

A pelagic egg, 3.4 mm in diameter possessing a single prominent lipid droplet 1.0 mm in diameter surrounded by seven smaller 0.1 mm diameter lipid droplets was collected at St.12. A positive identification of this egg to species level is not currently possible.

Two types of juvenile Notothenids were collected at St. 12. Bathydraconidae sp. and Artedidraconidae sp. (Fig. 1A, 1B). Three larval specimens tentatively identified as members of Notothenioidei were also collected at St. 12. Further observation and analysis is necessary to identify these specimens to species level.

Both Bathydraconidae sp. and Artedidraconidae sp. larvae swam actively inside an aquaria after capture, indicating their high swimming capability.

Discussion

Current knowledge of early life history of Notothenids is very scarce and limited(e.g. Stevens, Watson and Matarese, 1984). Eggs, larvae and juveniles of this unique Teleost suborder collected during the Leg 2 of the Research Cruise KH01-3 of RV Hakuhomaru is certain to provide valuable information on the biology of this unique group of Teleost.

Both Bathydraconidae and Artedidraconidae are benthic families. The pelagic juveniles of the two families collected during this cruise, with its developed body structure and high swimming ability indicates an adaptation for prolonged pelagic life during early life history. Planned examination of otolith microstructure (ring patterns) and resultant analysis on daily growth information will most certainly shed light on this unique aspect of Notothenid early life history.

Acknowledgements

I am greatly indebted to the kind cooperation, support and help obtained from the researchers and crew on board Hakuhoumaru during the research cruise KH01-3. My special thanks goes to Makoto Terazaki, Hiroshi Hasumoto, Jun Nishikawa, Toshiaki Miura, Kazuyoshi Hashizume, Sean Toczko and Travis Johnson for their help and support during net sampling.

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Table 1. Biomass in grams of Teleosts colleced with RMT-8 net during Leg 2 of Hakuhomaru Cruise KH01-3

All sampling was conducted using RMT-8 net with wire out of 1500m, net reaching ca. 1000m depth. Oblique tow.

St. No.	12	12(300m)	13	14	15	16	18	19	20
Total weight (g/1000m3)	21.37	6.94	17.60	2.19	3.77	22.84	20.93	11.77	14.03
Family name									
Congridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
Leptocephalus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
Bathylagidae	2.85	0.00	6.34	0.06	0.40	4.28	0.55	0.00	0.02
Searsiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00
Gonostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.52	0.26
Cyclothone spp	0.00	0.00	0.00	0.14	0.00	0.00	0.19	1.72	2.83
Sternoptychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Chauliodontidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stomiidae	0.00	0.00	0.00	0.00	1.65	0.00	0.34	0.00	0.00
Astronesthidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Paralepididae	7.92	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.01
Myctophidae	9.97	0.00	10.99	2.00	1.72	9.45	19.85	0.92	9.67
Macrouridae	0.00	0.00	0.00	0.00	0.00	6.19	0.00	0.00	0.00
Melamphaidae	0.00	0.00	0.00	0.00	0.00	2.93	0.00	0.00	0.00
Bathydraconidae	0.23	4.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artedidraconidae	0.40	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gempiridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Pentacerotidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00
Unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08

Figure 1: Sketches of juvenile Notothenoidei collected during research cruise KH01-3.
A: Artedidraconidae sp. B: Bathydraconidae sp.

Surface drifter experiments at St. 13 (64° S, 140° E) and St. 16 (61° S, 140° E)

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To collect the sediment from the surface water (euphotic surface) within a day and to estimate in situ primary production, the surface drifter experiments were carried out at St. 13 and 16 on 12 and 14 January 2002, respectively. St. 13 located at the northern edge of seasonal sea ice zone, and the St. 16 was the area where permanently open water was observed in the studied Antarctic Ocean. Sediment traps were set at 5 different depths and in situ incubation bottles were allocated at 6 different depths from the near surface to the euphotic bottoms (Fig. 3). These experimental results will be presented by OOI (in situ production) and IWADATE (traps).

Fig. 2 A design of the mooring array which was installed at St.13.

作成日：2001／10／01

表層トラップ（Type－1）

Fig. 3　Design of the surface drifter

Mooring experiment at St. 13 (64°S, 140°E) in the Antarctic Ocean

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To evaluate the biological production and the vertical flux of sediments at the Antarctic Ocean during austral summer, a mooring array was installed at St. 12 (ca. 3700 m depth) on 12 January, and the array was retrieved on R/V Tangaroa on 20 February 2002. The design of the mooring array is in Fig.2.

Four time-serial sediment traps were set at 1200, 1500, 2200 and 3200 m depths, and collected the sediment in separate bottles for a few days interval. Currents data at several depths were recorded at the same time. Unfortunately, the sediment trap at 3200 m was accidentally stopped before the array retrieval, but rest of all instruments (traps and current meters) worked completely. Related samplings and experiments about the sedimentation processes were carried out by IWADATE, and explained in elsewhere by her in the other section of this report.

Export of particulate organic matter in the epipelagic and mesopelagtic layers in the Sealonally Ice-covered Zone (SIZ) of the Southern Ocean.

Hiroshi Sasaki , Yumi Iwadate

Ishinomaki Senshu University

Introduction

A spike or pulse like increase of primary production during a short summer period can be a main source of organic material in the epipelagic and mesopelagic layers of the Antarctic marine ecosystem. To evaluate the production and downward transport processes of particulate organic matter in these layers, temporal and spatial variabilities in the flux of sinking particles were observed in the Seasonally Ice-covered Zone (SIZ) during a austral summer in 2002.

Surface drifting experiments of sediment traps

Five sediment traps were suspended at 20,40,70,100 and 200m depths for 24hs. Two types of sediment traps; twin-traps and quadruplet-traps were used. One of the twin trap used in the upper 100m has a cylindrical shape with a mouth diameter of 15.2cm, and the other of the quadruplet traps suspended at 200m has a cylindrical shape with a mouth diameter of 16cm. The surface drifting buoy with traps was deployed at 64.00° S, 140.00° E on January 12-13, and deployed at 61.00° S, 140.00° E at 17:40 local time on January 14-15 (Table 1).

Collected particle samples were split into four aliquots, among which three quarters were used for determinations of particulate organic carbon (POC), and stable carbon isotopes and microscopic observations (Senshu U. Ishinomaki). The rest of aliquot was used for organic matter analyses (U. Tsukuba). Collected particles samples at 200m were used for analyses of ^{234}Th, and POC. Zooplankton swimmer were removed manually before later analyses. Particle samples were filtered through pre-ignited Whatman GF/F glass fiber filter and used for determinations of POC and PON after decalcification with acid fumes (HCl). The data on POC flux in terms of mg m^{-2} d^{-1} were shown in Table 2. The radionuclide analyses of these samples is now in process at National Institute of Radiological Sciences.

Table 1. The Date and positions of sediment trap deployments in January 2002 in the Antarctic Ocean.

Station No.	Lat. S	Lon. E	Deploy Time (start)	Recovery Time (end)	Period day
13	64	140	2002/1/12/ 8:25	2002/1/13 8:04	0.985
16	61	140	2002/1/14/ 17:40	2002/1/15 15:59	0.93

Table 2. Data on the flux of particulate organic carbon (POC) at station 13 and station16.

Station No.	Lat. S	Lon. E	Depth (m)	POC Flux (mg/m2/d)
13	64	140	20	46.4
			40	56.2
			70	34.5
			100	36.6
			200	62.0
16	61	140	20	43.8
			40	70.9
			70	70.2
			100	66.2
			200	45.4

Mooring experiment of deep sediment traps.

To know the temporal change of organic particle flux into mesopelagic and bathypelagic layers, bottom-tethered, time-series sediment traps were deployed at the depth of 1200, 1500, 2200 and 3200 m at 61.00° S, 140.00° E (sea depth 3724 m) on January 12, 2002. The mooring array with traps was recovered on February 20, 2002 during the cruise of Tangaroa.

Vertical distribution of organic particles

At sites where surface drifting experiments were made, sea water samples were collected from twelve layers (0,10,20,40,75,100,150,200,500,1000,2000,3000m) to obtain vertical distributions of POC, PON, $\delta^{13}C$ and $\delta^{15}N$. in the water collums Sea water was filtered through pre-ignited Whatman GF/F glass fiber filters. These filter samples were stored in a freezer and were used for later analyses after removal of carbonate with fumes of concentrated HCl, and dried immediately at 80℃ for 8h.

Organic matter dynamics and microbial processes in the South Pacific and the Southern Ocean.

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Introduction

In the last decade, the study of organic matter dynamics and microbial processes in the ocean, in terms of their roles in the oceanic carbon cycle, has progressed markedly. Particularly the dual survey using chemical and biological approaches has developed, which is necessary for better understanding the biogeochemical cycles in the ocean. In 1990s, the North Atlantic, the equatorial Pacific and the subtropical North Pacific have been a typical area in which this kind of research was tested, whereas few studies has intended for the South Pacific and the Southern Ocean. On this cruise, which covered these areas, we tried to investigate the vertical and horizontal distribution of dissolved organic components, including dissolved organic carbon (DOC) and nitrogen (DON), and colloidal particles and microbial community including viral particles, bacteria and heterotrophic nanoflagellates (HNF). In addition, we conducted chemical characterization of dissolved organic matter (DOM) and colloidal organic matter, including the size distribution and amino acids composition, and determination of biological activity of virus and bacteria, and culture experiments to investigate the interaction of colloidal particles and microbial community and the response of viruses to the exposure to UV of natural sunlight. Most of these measurements and/or the data processing are now under way. Here we compile the chemical and biological parameters that we are to obtain from samples collected during this cruise (mainly in Leg.1, Leg.2) and some experiments to elucidate microbial processes in the surface ocean.

Biological approaches for microbial processes (Fukuda & Imada)

The latitudinal variation of microbial organisms (viruses, bacteria and nanoflagellates) and colloidal particles (0.5-1.0 μm in diameter) were surveyed along the transect during Leg. 1 and Leg. 2. In addition, viral and bacterial production rate in surface mixed layer (0 and 10 m) were estimated from tritiated thymidine incorporation rate at all of official sampling stations during Leg. 1 and Leg. 2. Figure 2 shows that latitudinal distribution of Chlorophyll *a* (Chl. *a*) concentration, bacterial abundance and number of colloidal particle (1.0 μm in diameter) in the surface survey during Leg. 1. The variation of Chl. *a* had three parts with the increase of latitude; i) the decrease phase (from the equatorial region to 13°S), ii) no notable variation with the change of latitude in sub-tropical and temperate region (from 10°S to 35°S), and iii) the increase phase In sub-arctic region (from 35°S to 48°S). While the latitudinal variation of Chl. a correlate with that of their nutrients, latitudinal variations of bacterial abundance and number of colloidal particles (CPN) had the difference from that of phytoplankton (Chl. a), which supplies organic substrates for bacteria and constituents to colloidal fraction (Fig. 2).

In bacterial abundance, significant decrease was not observed in the decrease phase of Chl. *a* and notable peak was observed at 40°S, while correlation between Chl. *a* and bacterial abundance in large-scale comparison was statistically significant ($R = 0.740$, $n = 37$). Above differences in latitudinal variation may be originated from the differences in species composition of phytoplankton and following food web structure. We will conduct minute analysis about this problem by comparing the data set on the production rates (bacteria and viruses) or abundance (viruses and nanoflagellates).

The latitudinal distribution of CPN had an especially different feature from Chl. *a* or bacterial abundance. In PCN, a significant increase was not observed in sub-arctic region except for a point at 47°S. Correlation coefficient, also, between CPN and Chl. *a* or bacterial abundance ($R = 0.353$, $n = 38$) were weaker than the relationship between Chl. *a* and bacterial abundance (see above). In contrast, other studies on PCN in the western North Pacific shows that PCN is related to Chl. *a*. This difference also affected by not only species composition of phytoplankton but also that of other organisms because heterotrophic plankton release and consume colloidal particles. And still more, input from atmosphere must be considered as the controlling factor on the latitudinal variation of PCN.

Chemical approaches for organic matter dynamics (Ogawa & Takeuchi)

Distribution of DOC and DON

Seawater samples for the vertical distribution of DOC and DON were collected from each depth layer at nine stations (Stn. 1,2,3,5,6,7,8,9,10) on transect of 160° W in Leg.1. In order to survey detailed horizontal distribution of DOC and DON, surface waters were collected using a clean pump-up system kept on the ship at approximately one degree interval between 0° and 48° S along 160° W line. Temperature, salinity and nutrients in a series of surface waters were measured on board (Fig.1). Temperature varied from 11.6 °C at the subantarctic site to 29.1 °C at the equatorial station. Salinity varied 34.3 at the subantarctic site 35.9 at the subtropical station. Nutrients concentrations were minimum in the subtropical area (ca. 20° S - 30° S) with values below the determination limits (NO_3: < 0.1μM, NO_2: < 0.02 μM, NH_4: < 0.05 μM, SiO_2: < 0.5 μM) except for PO_4 which were 0.04 μM at the minimum, while they have double maxima at the equatorial (0° - 6° S) and subanatarctic (43° S - 48° S) region (NO_3: 4-7μM, NO_2: 0.1-0.5 μM, NH_4: 0.1-0.2 μM, PO_4: 0.5-0.6 μM) except for SiO_2 which indicated single maximum of 1.5-2 μM at the equatorial region. Overall the distribution of chlorophyll a followed those of nutrients (Fig.2). Thus, it is clearly shown that there is a large variation of both physical and biological properties along this transect. The concentrations of DOC and DON in these samples will be determined by high temperature combustion (HTC) method. It is expected that DOC and DON concentrations would vary significantly with changes in physical and/or biological factors.

Size spectrum of DOM

Some samples were used for the size fractionation of DOM by ultrafiltration method. Seawaters from typical areas and depths on 160° W line in Leg.1 were collected for this purpose, i.e. 10, 100, 500 and 4000m at St.5 (20° S: subtropical) and St.10 (47° S: subantactic), and 10 and 4000m at St.1 (0° : equatorial) and St.8 (35° S: temperate). DOM was fractionated into the four size fractions of > 100k Da, 10-100k Da, 1-10k Da and < 1k Da using ultrafiltration membranes with nominal molecular weight cutoffs of 100k Da, 10k Da and 1k Da. The concentrations of DOC, DON and total amino acids will be measured in each size fraction. Consequently, the size spectrum of DOM and C:N ratio, amino acids content and amino acids composition in each size fraction will be determined.

Fig.1 Distribution of temperature, salinity and nutrients (NO^{3-}, NO^{2-}, NH^{4+}, PO_4^{3-}, SiO_2) in surface water on the transect of 160°W in the South Pacific (Leg.1).

Fig.2 Distribution of chlorophyll a, bacterial abundance and particle counts at 1μm (Leg.1).

Chemical properties and dynamics of dissolved and particulate organic matter in the South Pacific and the Southern Ocean.

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Introduction

Most of organic matter in the ocean is thought to be originated from marine organisms. However, chemical properties of marine organic matter have not well understood yet, so that we do not have enough knowledge about behavior of organic matter in the ocean.

In KH-01-03 cruise, we researched to know biogeochemical behavior of organic matter in the ocean at elemental level and chemical properties of marine particulate and dissolved matter at molecular level. The experiments and observations performed are shown below.

1. Experiments and observations

1.1 The horizontal and vertical distribution of particulate and dissolved organic carbon

Carbon in seawater occurs in living or dead particulate forms and in dissolved forms. Carbon is introduced into the sea by various mechanisms (air-sea CO2 exchange, river flow and transport of terrestrial substances etc.). In terms of the entire ocean, photosynthesis is the most important mechanism by which organic carbon is formed. Organic carbon is initially produced by the fixation of carbon dioxide by phytoplankton (conversion of the oxidized carbon into reduced carbon). The marine organisms consume organic carbon as energy sources and finally convert organic (reduced) carbon to inorganic (oxidized) carbon. Carbon in seawater is partitioned into dissolved inorganic and organic carbon and particulate carbon and the relationship among them should be reflected in their concentrations.

In this cruise, we collected samples for dissolved and particulate organic carbon in surface layer (<500m depth) in all station of Leg.1 and 2. Samples for dissolved

inorganic carbon were collected by Dr. Ishii (MRI) in same stations and depths.

Compared with the horizontal and vertical distributions of DIC, POC and DOC in the South Pacific and the Southern Ocean, we clarify "carbon partitioning in the ocean" and biogeochemical dynamics of carbon.

1.2 Culture experiments for specifying source organisms of particulate and dissolved organic matter.

The living biomass, non-living detritus and dissolved organic matter exist together in the ocean. The marine organism is composed by the amino acid, sugar, their polymer and lipids. To clarify the chemical structures of non-living particles and dissolved organic matter at the polymer level is the most effective approach to specify source organisms of organic matter in seawater.

In this cruise, we set up the culture experiment system on the second deck of Hakuho-Maru. The carbon stable isotope (13C-sodium bicarbonate) and/or the mixture solution of inorganic nutrients were added in the polyethylene cubitainers filled with surface seawater. Photosynthetic 13C labeled organic material was made by phytoplankton proliferation. We monitored them during about one month. After that, cubitainers were preserved in dark at room temperature and monitored during six months. The analyses of particulate and dissolved organic matter are as follows.

1. Carbon and nitrogen	HTCO-IRMS
2.Hydrolyzable amino acids	HPLC-OPA, GC-C-IRMS
3.Protein	2D-electrophoresis, AA sequence, GC-C-IRMS
4.Polysaccharide	CFF, ^{13}C, ^{15}N-NMR
5.Lipid	TLC-FID/FPD, ^{1}H&^{13}C-NMR, GC-C-IRMS

1.3 Chemical characterization of particulate combined amino acids and dynamics of particulate proteins in the surface water.

The particulate organic matter (POM) in surface water is a complex mixture of living biomass and non-living detritus. The largest identified fraction of POM is the particulate combined amino acids (PCAAs), which are liberated by hydrolysis of bulk POM. Almost amino acids in living organisms are in the form of proteins. The PCAAs collected from seawater are a mixture of cellular proteins and detrital combined amino acids. It is not clear how much protein amino acids contribute to PCAAs and what

non-proteinaceous PCAA is in terms of chemical form. Among the proteins detected so far, a limited number of proteins (specific proteins) were prominent in POM. It has been thought they survive and accumulate as consequence of their resistant nature to degradation. Chemical characterization of PCAAs and identification of the specific proteins will provide clue for better understanding of degradation process of POM.

Samples of POM were collected by filtration of the surface waters on GF/F glass fiber filters during the cruise, included various areas from oligotrophic to productive and from tropical to Antarctic Oceans. Two-dimensional electrophoresis (2DE) is a powerful technique for separating protein molecules from complex mixture. The particulate proteins will be effectively separated from the non-proteinaceous PCAAs. The proteins separated by 2DE will be determined N-terminus amino acid sequence or subjected to mass spectrometric analysis to identify source organism(s). The non-proteinaceous PCAAs will be also characterized by directly analyses of (oligo) peptides and other chemical nature after enzymatic hydrolysis.

Biogeochemical evaluation of marine organic matter in the central South Pacific and the Antarctic Ocean, by means of biomarkers and their carbon and nitrogen stable isotopic compositions.

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Introduction

The purpose of this study is to evaluate chemical tracers found in marine organic matter as available proxies for marine production and material cycling in the central South Pacific and the Antarctic Ocean. The carbon and nitrogen stable isotopic compositions, hereafter presented as $\delta^{13}C$ and $\delta^{15}N$, respectively, of particulate organic matter (POM) in surface water vary with reflecting various environmental factors such as primary productivity, dissolved carbon dioxide, nutrient concentration and so on. Such isotopic signals are well preserved in organic matter of surface sediment, although isotopic effect on diagenesis is still remained as an unavoidable factor. Therefore these tracers would be useful to evaluate marine biogeochemical conditions in present and past. The isotopic compositions in bulk organic matter, however, might be interfered by the signal of terrestrial organics like land plants. Hence, because it is necessary to estimate contribution of terrestrial organics, we will measure various biomarkers from both marine plankton and land plants (e.g., alkenones, sterols, fatty acids, hydrocarbons, lignin phenols and pigments) to assess the origin of organic matter in particles and sediments. Furthermore, we intend to use such biomarkers as proxies for reconstructing paleoproduction and paleoclimate. It is also expected that $\delta^{15}N$ of nitrate in seawater will become a good parameter on nutrient budget and its utilization in this study areas. We reported here preliminary results of $\delta^{13}C$ and $\delta^{15}N$ of bulk organics in particles and surface sediments collected from transects in the central South Pacific and the Antarctic Ocean.

Materials and Methods

POM were collected on a glass-fiber filter (GF/F) from seawater from various water depths and were stored at –20°C. The filtrates were preserved in bottles with HCl for isotope

analysis of nitrate. Surface sediments were collected by multiple core samples and were stored at –20°C. For isotope analyses, POM and surface sediments were decarbonized by 12M HCl vapor for POM and 1M HCl for sediments, respectively. The $\delta^{13}C$ and $\delta^{15}N$ were analyzed by the flow-injection method using a Finnigan MAT 252 mass spectrometer connected with a Fisons NA1500 elemental analyzer. POM and surface sediments were treated by organic solvents to extract lipid fractions for biomarker analyses. Each purified lipid fraction will be finally introduced in a gas-chromatography system fitted with mass spectrometer.

Preliminary results of isotope analyses

Analytical results of POM in surface water and total organic matter (TOM) in surface sediments at Sts 1, 6, 8, 10, 13, 17, 18 and 19 were listed in Tables 1 and 2, respectively. POC ranged from 37 to 239 μg/l and showed maximum at St 13 where was the closest station to the Antarctica. The C/N atomic ratios of POM varied between 6.3 and 10.3 and showed higher values at Sts 6 and 8 where nitrate concentration was scarce in surface water. But this trend was not found in surface sediments. It is necessary to carry out further research to describe vertical profiles of each station, diagenesis effect and etc.

Latitudinal variations on $\delta^{13}C$ of POC and TOC were shown in Fig. 1. The $\delta^{13}C$ ranged from –27.5 to –20.4 ‰ and from –24.8 to –19.3 ‰ for POC and TOC, respectively, and showed lower values in Antarctic region. The $\delta^{13}C$ of POC would be controlled by relatively large isotope discrimination probably due to higher dissolved CO_2 in seawater. Generally, $\delta^{13}C$ of POC showed latitudinal trend reflecting $[CO_2]_{aq}$ and the growth rate of phytoplankton (Goericke and Fry, 1994). The result of this study seems to be consistent with those trends, except for considerable high value at St 10. Moreover $\delta^{13}C$ of TOC fitted more clearly, although those values were significantly affected by diagenesis.

Latitudinal variations on $\delta^{15}N$ of PN and TN were shown in Fig. 2. The $\delta^{15}N$ ranged from –1.9 to 8.0 ‰ and from 4.2 to 10.1 ‰ for PN and TN, respectively. The $\delta^{15}N$ of phytoplankton depends not only the isotopic fractionation during uptake of substrates (NO_3^-, NO_2^- and NH_4^+) but also on the isotopic composition of nitrogen compound and the degree of nutrient utilization. Altabet and Francois (1994) suggested that large latitudinal variations in $\delta^{15}N$ should be occurred reflecting relative nitrate utilization and depletion in surface layer in the south Indian Ocean and the equatorial Pacific. Fig. 3 showed $\delta^{15}N$ of PN and TN versus surface $[NO_3^-]$. The $\delta^{15}N$ in both PN and TN were strongly correlated with surface $[NO_3^-]$ (R^2

= 0.83 and 0.94, respectively). Hence $\delta^{15}N$ signal seems to be closely related to surface nitrate conditions, although isotopic effect on diagenesis is not negligible as well as in the case of POC. We will further examine this feature by analyzing $\delta^{15}N$ of nitrate in seawater from same water samples.

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Table 1. Results of isotopic and elemental analyses of POM in sea surface.

Station	Latitude	Longitude	Water depth (m)	POC (μg/l)	PN (μg/l)	C/N (mol/mol)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
1	S00	W160	5142	71	9.7	8.5	-23.2	4.9
6	S25	W160	5074	40	4.5	10.3	-24.2	8.0
8	S35	W160	5113	37	4.2	10.2	-24.9	6.8
10	S47	W160	5118	103	17.8	6.7	-20.4	2.0
13	S64	E140	3700	239	44.2	6.3	-25.7	1.7
17	S60	E140	4486	46	8.0	6.8	-27.5	-1.1
18	S54	E140	3458	55	9.3	6.9	-25.8	-1.9
19	S50	E140	3658	73	12.6	6.7	-24.0	-1.0

Table 2. Results of isotopic and elemental analyses of TOM in surface sediment.

Station	Latitude	Longitude	Water depth (m)	TOC (%)	TN (%)	C/N (mol/mol)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
1	S00	W160	5142	0.38	0.066	6.8	-19.3	8.9
6	S25	W160	5074	0.32	0.069	5.4	-20.1	9.4
8	S35	W160	5113	0.29	0.067	5.1	-20.2	10.1
10	S47	W160	5118	0.45	0.087	6.0	-20.5	7.9
13	S64	E140	3700	0.35	0.060	6.7	-24.8	5.6
17	S60	E140	4486	0.31	0.052	6.9	-22.5	5.0
18	S54	E140	3458	0.27	0.039	8.0	-20.5	4.2
19	S50	E140	3658	0.27	0.041	7.6	-20.4	7.0

Fig. 1. Latitudinal variations on $\delta^{13}C$ of POC and sedimentary TOC.

Fig. 2. Latitudinal variations on $\delta^{15}N$ of PN and sedimentary TN.

Fig. 3. $\delta^{15}N$ of PN and sedimentary TN versus surface $[NO_3^-]$.

Marine geochemistry of rare earth elements in the South Pacific

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Introduction

Rare earth elements (REEs) represent a spectrum of elements (atomic numbers:57-71) which have similar chemical properties. However, REEs show different behavior systematically because their atomic size of trivalent ions shrinks smoothly with increasing atomic number (i.e., lanthanide contraction). This unique systematics among REEs allow them, as a group, to be used as a chemical tracer in the field of marine geochemistry.

For the purpose of understanding REEs behavior in all over the Pacific Ocean, we'll reveal the distributions of REEs in the South Pacific and discuss the geochemical cycles of REEs by comparing the previous studies in the North Pacific.

Samples

Seawater samples for vertical profiles were collected using Niskin bottles mounted on a CTD/Carousel array. Surface seawater samples were taken once a day from the ship's research seawater supply. The samples were transferred to previously acid-washed cubic containers and immediately filtered using a Stera Disk filter of 0.2 μm porosity in the clean room (No4. lab.). They are acidified to pH<1.8 with ultra pure HC and carried to the ORI for analysis.

CTD sampling

Station No. ; St.1, St.5, St.8, St.10

Depth [m] ; 20, 50, 70, 100, 150, 200, 250, 300, 500, 700, 800, 1000, 1250, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000

Analytical method

The analysis of REEs and Y in the seawater is performed by the ICP mass spectrometric method described in Shabani et al. (1990) and Zhang and Nozaki (1996). REEs and Y were preconcentrated and purified from 1 L samples of seawater by solvent extraction

and back extraction using HDEHP (2-ethylhexyl hydrogen phosphate) and H_2MEHP (2-ethylhexyl dihydrogen phosphate) in heptane. Indium is used as an internal standard to monitor the stability of the ICP-MS determination.

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Ce and Nd isotope ratios in the Pacific and the Southern Ocean

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Introduction

About one third of the ^{138}La decays produce ^{138}Ce with a β-decay constant of $\lambda_\beta=2.33\times10^{-12}$ yr^{-1}. This results in a change over time in the $^{138}Ce/^{142}Ce$ ratios in various terrestrial materials, the rate of change being a function of the La/Ce ratio. Both La and Ce belong to the rare-earth element group but their ratio varies in the Earth due to fractionation by various geochemical processes. It is also possible to use the $^{138}Ce/^{142}Ce$ ratio as a tracer of geochemical processes on the Earth analogous to the $^{143}Nd/^{144}Nd$ ratio in the ^{147}Sm-^{143}Nd system. In the ocean, the mean residence time of Ce(IV) is much shorter than that of Nd and other REE(III)s, and therefore the $^{138}Ce/^{142}Ce$ ratios in seawater and marine deposits should be less homogenized by oceanic mixing than that of $^{143}Nd/^{144}Nd$ in the world oceans.

The measurement of the cerium isotope in seawater is difficult due to the extremely low Ce concentration, generally of the order of 10^{-12}mol/kg. For the Ce isotope measurement, ca.10^3 to 10^4L of seawater is required, which is two to three orders of magnitude larger than for neodymium isotope measurement. In order to collect Ce and Nd from large volumes of seawater efficiently, the MnO_2-impregnated fiber method was employed in this study.

Experiments

1. On shipboard

The seawater was transferred by using a built-in pumping system from an inlet at the bottom of the ship (~5m below sea level). This seawater was passed directly through MnO_2 fiber after 1μm pre-filter. Ce and Nd isotopes were strongly adsorbed on the fiber. The normal sample size is about 3000L for Ce isotope measurement.

2. On land

After leaching the MnO_2 fiber with HCl and H_2O_2, REEs were separated by solvent extraction with HDEHP. The REEs fraction was further purified standard ion exchange methods. Ce and Nd were separated from the REE fraction using an AG50W-X8 resin

column with α-hydroxy-iso-butyric acid eluents. The solution containing Nd was also purified to remove Sm by Ln resin. The purified Ce and Nd fractions were loaded on a Re double filament, respectively.

The isotopic compositions were measured as CeO^+ and Nd^+ using a Finnigan MAT 262 thermal ionization mass spectrometer.

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Distribution and speciation of trace elements in the South Pacific and the Southern Ocean

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The distribution and speciation of trace elements in seawater are controlled by various physical, chemical and biological processes. Our object is to reveal the behavior of trace elements (Fe, Co, Ni, Zn, Zr, Nb, Hf, Ta, W, etc.) in seawater samples collected with a CTD carrousel sampler.

Distribution of trace bioelements in seawater

Martin *et al.* reported the distribution of iron and affirmed that iron deficiency is limiting phytoplankton growth in high-nutrient and low-chlorophyll (HNLC) areas such as the subarctic northeast Pacific and the Antarctic[1,2]. Moreover, they suggested that oceanic iron fertilization aimed at the enhancement of phytoplankton production may turn out to be the most feasible method of stimulating the active removal of atmospheric CO_2. Concerning this hypothesis, many studies have been carried out and controversies have occurred[3,4]. The possibility of zinc limitation has also been reported. However, the data on the trace bioelements are very limited spatially and temporally. We have developed a novel simultaneous determination method for trace bioelements (Fe, Co, Ni, Cu, Zn, Cd, etc.). Our method is superior to previous methods in that many bioelements can be determined with a small volume of seawater (250 ml). We are going to measure the concentrations of the trace bioelements and to clarify their spatial and temporal variations.

Method: Immediately after sampling, we filtered 250 ml of seawater using a closed filtration system in a clean room (No. 4 laboratory). The filtered seawater samples were acidified with hydrochloric acid and brought back to our laboratory. The seawater sample will be adjusted to pH 4 with ammonium acetate buffer and passed through a column of 8-quinolinol immobilized fluoride containing metal alkoxide glass (MAF-8HQ). The trace bioelements collected on MAF-8HQ will be eluted with 25 ml of 0.5 M nitric acid containing 10^{-3} M hydrogen peroxide. The eluents will be analyze with a ICP-mass spectrometer (ELAN-DRC II, Perkin-Elmer).

Distribution of second and third transition series elements in seawater

Our knowledge on the distribution of trace elements in the ocean has greatly advanced in recent years. This is due to the improvement of clean techniques and analytical methods. However, the data on second and third transition elements are still few. We are investigating the marine chemistry of elements of groups 4, 5 and 6 (Zr, Nb, Hf, Ta and W). We will obtain the profiles of these elements in the South Pacific and the Southern Ocean on this cruise. The dissolved species of the elements are presumed to be $Zr(OH)_4$, $Nb(OH)_5$, $Hf(OH)_4$, $Ta(OH)_5$ and WO_4^{2-}. These elements are not thought to be essential to organism, and their distributions may not be significantly influenced by the active uptake of primary producers. The chemistry of the second and third transition series elements in the same group is very similar, because their ionic radii are close to each other owing to lanthanoid contraction. We expect that comparing the distribution and circulation of these elements will improve our knowledge on the chemical and physical process which fractionate the elements in the ocean.

Method: The unfiltered seawater sample were acidified with hydrochloric acid and hydrofluoric acid and brought back to our laboratory. The trace bioelements collected on MAF-8HQ will be eluted with 25 ml of 0.5 M nitric acid containing 10-3 M hydrogen peroxide. The eluents will be analyze with a ICP-mass spectrometer (ELAN-DRC Ⅱ, Perkin-Elmer).

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Geochemical study for dissolved biogenic gases in the South Pacific and the Antarctic Ocean.

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1. Introduction

We investigated the distribution of biogenic gases (CH_4, N_2O, DMS/DMSP) in order to determine the marine productions and emissions. Methane (CH_4), nitrous oxide (N_2O), and dimethyl sulphide (DMS)/dimethylsulphoniopropionate (DMSP) concentrations in the water column were focused to understand the nature and genesis of these biogenic gases in the biologically active South Pacific and the Southern Ocean, and each objective, method and result in detail are reported below.

2. Methane (CH_4)

Osamu Yoshida, Shizuo Tsunogai, Shuichi Watanabe and Shinichiro Noriki

2.1 Objective

Methane in atmosphere, one of greenhouse effect gases, is increasing with about 1% per year (e.g. Khalil and Rasmussen, 1983; Blake and Rowland, 1988). Since methane could be important in global warming, the global methane budget is the subject of active investigation. While large inventories of methane are present in anoxic marine sediment and anoxic water columns, the ocean is considered to be a minor source in the global methane budget (e.g. Cicerone and Oremland, 1988; Khalil and Rasmussen, 1990; Wang *et al.*, 1990; Taylor *et al.*, 1991). The oceanic source is estimated chiefly based on the methane contents in the open oceans water slightly supersaturated with respect to the atmospheric methane (Ehhalt, 1974),

which ranges from 0.005% to about 3% of the total input (e.g. Conrad and Seiler, 1988; Cicerone and Oremland, 1988; Bange *et al.*, 1994). To estimate an accurate amount of the methane exchange from ocean to atmosphere, it is necessary to research widely and vertically not only the surface water of the open sea. Several reports showed that vertical profile of methane concentration has the maximum at subsurface layer in the Ocean. The origin of the subsurface methane maximum is unclear. Suggestion includes advection from nearby sources in shelf sediments, diffusion and/or advection from local anoxic environments, and *in situ* production by methanogenic bacteria, presumably in association with suspended particulate material. Some observations suggested that biogenic methane production occurred in the subsurface layer. In the water column, although only the methanogenic bacteria produce methane, they cannot survive under any traces of oxygen. Therefore, these bacteria are thought to probably live in the anaerobic microenvironments supplied by organic particles or guts of zooplankton (e.g. Alldredge and Cohen, 1987). Recently, it is reported that some amount of methane is released by zooplankton-phytoplankton co-culture in the laboratory. But, there was few data that prove environmental subsurface methane production. So, we investigate in detail profile of methane concentration and distribution in the water column. In addition, we undertake a study of methane distribution in the interstitial water and overlying water collected with multiple corer in order to evaluate the magnitude of discharging and diffusion to the water column and obtain clues to the mechanism responsible for production and consumption in anoxic environment. To distinguish between biogenic methane and thermogenic methane, we also measure the carbon and hydrogen isotope of methane ($^{13}CH_4$ and CH_3D). Moreover, we address the seasonal variation at same transect in Antarctic area, expedition are performed on three cruise (aboard R/V Hakuho-Maru, RSV Aurora Australis, and R/V Tangaroa).

2.2 Materials and Methods

Seawater samples are taken by CTD-CAROUSEL system attached Niskin samplers of 12 L at all layers and surface layer taken by plastic bucket at all the water sampling stations. 30 ml of water sample for the concentration measurement of the methane are introduced into a glass vial and 125 ml for the isotope (carbon and hydrogen) measurement are introduced into 2 glass vials together with 20 μl of mercury chloride being out of contact with the air respectively. The vials are sealed with butyl rubber and aluminum cap. They are preserved at low temperature, and are analyzed on board or in the laboratory on land. Seawater samples are into a purge unit and bubbled with a flow of ultra pure helium gas for 10 minutes.

Methane purged out is collected in the column cooled with dry ice ethanol (~-78°C). This column is warmed with water bath of about 95°C and methane sweep into a gas chromatograph (SHIMADZU GC-8A) equipped with Flame Ionization Detector. The precision for 8 replicate determinations of methane was about 5% at the concentration level of about 5 nmol kg^{-1} and the detection limit was 0.05 nmol kg^{-1}. The standard gases are used those containing 2.02, 19.6, and 38.4 ppmv methane in ultra pure nitrogen gas those were calibrated by Nippon Sanso Co. Ltd. Approximately 1,000 samples in total are obtained in this cruise. In addition, about 100 surface water samples for concentration of methane and methane isotope are obtained while going from Sydney to Tokyo.

2.3 Results

The methane concentrations obtained from the water column observation are shown in Fig. 1 for the South Pacific section (along 160°W) and Fig. 2 for the Southern Ocean section (along 140°E). The degree of saturations, expressed in % (i.e. 100% = equilibrium), were also calculated as a ration of the concentration of observed CH_4 concentration C_w and an expected equilibrium water concentration C_a, derived from the ambient air dry mole fraction using the solubility equation of Wiesenburg and Guinasso (1979). We used the mean atmospheric methane concentration was 1.8 ppmv (e.g. Houghton *et al.*, 1996).

$$CH_4 \text{ Saturation} = 100\ C_w/C_a$$

In South Pacific section, the methane concentration was higher in the surface 300 m layer (1.9-3.8 nmol kg^{-1}). This higher concentration may be caused by its active biological production in the anaerobic microenvironments. The mean degree of saturation in the surface was 153% in this section. In Southern Ocean section, the higher methane concentration was observed in the surface 200 m layer and decreased with increasing depth drastically. The surface 100 m concentration (2.0-4.7 nmol kg^{-1}) and surface saturation (106-139%) were greater in the higher latitudes except 50°S and 47°S. The methane maximum in the surface corresponded to the chlorophyll *a* maximum at high latitude station (Fig. 3). This result indicates the formation of methane is related to the photosynthetic process, and its production is thought to be active within guts of zooplankton.

Fig.1. Methane concentration along 160°W.

Fig.2. Methane concentration along 140°E.

Fig.3. Plot of methane concentration against chlorophyll *a* at Station 13, 14 and 15.

3. Nitrous Oxide (N_2O)

Osamu Yoshida, Chiho Asahi, Shizuo Tsunogai, Shuichi Watanabe and Shinichiro Noriki

3.1 Objective

Nitrous oxide is an important trace gas in the atmosphere. It is an active greenhouse effect gas in the troposphere and it has a large radiative forcing about 200 times that of CO_2 on a per molecule basis (IPCC, 1995). It also controls ozone concentration in the stratosphere through nitric oxide production (Khalil and Rasmussen, 1992). Atmospheric nitrous oxide has both natural and anthropogenic sources, but their relative contributions are unclear. Oceans are believed to contribute up to 20% of the total annual input of about 15 Tg per year (IPCC, 1995). Nitrous oxide is produced in the ocean as a byproduct of nitrification and an intermediate of denitrification processes. However, in suboxic waters nitrous oxide is consumed by the process of denitrification (Yoshinari, 1976; Yoshida et al., 1989; Naqvi and Noronha, 1991; Mantoura et al., 1993). We investigate the distribution of nitrous oxide, particularly in relation to denitrification in the subsurface layers. To distinguish between nitrous oxide by the process of nitrification and denitrification, we also measure the nitrogen isotope of nitrous oxide ($^{15}N_2O$). Moreover, we address the seasonal variation at same transect in Antarctic area, expedition are performed on three cruise (aboard R/V Hakuho-Maru, RSV Aurora Australis, and R/V Tangaroa).

3.2 Materials and Methods

Seawater samples are taken by CTD-CAROUSEL system attached Niskin samplers of 12 L at all layers and surface layer taken by plastic bucket at all the water sampling stations. 125 ml of water samples for the concentration and isotope measurement of the nitrous oxide are introduced into a glass vial with 20 μL of mercury chloride being out of contact with the air respectively. The vials are sealed with butyl rubber and aluminum cap. They are preserved at low temperature, and are analyzed in the laboratory on land. Seawater samples are into the purge unit and bubbled with the flow of ultra pure nitrogen gas for 10 minutes. Nitrous oxide purged out is collected in the PolaPak Q column cooled with dry ice ethanol (~-78°C). This column is warmed with water bath of about 95°C and nitrous oxide sweep into a gas chromatograph (SHIMADZU GC-8A) equipped with Electron Capture Detector. The precision (1 sigma value for 11 determinations) is about 1.3% at the concentration level of about 70 nmol kg^{-1} and detection limit is 0.05 nmol kg^{-1}. The standard gas is used that

containing 5.01 ppmv nitrous oxide in ultra pure nitrogen gas that ware calibrated by Taiyo Toyo Sanso Co. Ltd. Approximately 1,000 samples in total are obtained in this cruise. In addition, about 100 surface water samples for concentration of nitrous oxide and nitrous oxide isotope are obtained while going from Sydney to Tokyo.

4. DMS/DMSP

Nobue Kasamatsu, Shizuo Tsunogai, Shuichi Watanabe and Shinichiro Noriki

Dimethylsulfide (DMS) is the most abundant biogenic sulfur-bearing compounds emitted from the ocean to the atmosphere. DMS is formed from its precursor dimethylsulfonio-propionate (DMSP) which is produced by a marine phytoplankton. This observation is conducted to improve our basic knowledge on production DMS in the South Pacific and the Antarctic Ocean. We also measured DMS and DMSP in the experiment of DMSP ingestion of copepods and krill.

Water samples were collected with CTD/CAROUSEL systems attached Niskin samplers of 12 L capacity and a plastic bucket from surface to 200 m water depth at Stn.1-18 except Stn.11. The sample water was transferred to a 100 ml glass syringe and kept at about 4°C in the dark until analysis. All the samples for DMS were analyzed within 12 hours after the sampling. For DMS measurement, an aliquot of 8-14 ml of was purged in the glass purge chamber with stoppers at each mouth. The concentration of DMS in the seawater samples was determined using a purge-and-trap system followed by a gas chromatograph equipped with a flame photometoric detector (Shimadzu GC-14B). For DMSPt (total DMSP) measurement, an aliquot of 2-14 ml of seawater sample was injected into 30 ml vial containing 4ml of 6N NaOH to cleave DMSPt (dissolved DMSP and particulate DMSP) into gaseous DMS. For dissolved DMSP (DMSPd), an aliquot of 2-14 ml seawater sample was injected through a Whatman GF/F filter into the vial. Vials were stored at 4°C for at least 24 hours in dark. DMSP samples were sparged in the vials. The particulate DMSP (DMSPp) concentrations can be determined by subtracting the DMS and DMSPd values from DMSPt values. The analytical error for each mesurement was 11%.

In Leg-1 DMS concentrations ranged c.a. 2–18 nmol l^{-1} in upper 50 m. DMSPp concentrations were higher in the south than those in the north of Leg-1. Subsurface maxima were clearly observed at Stn. 9 and Stn. 10 (Fig. 4). In Leg-2, High concentration of DMS was observed at 65°S (c.a. 48 nmol l^{-1}). DMS concentrations were higher in the

south than those in the north part of Leg-2. DMS concentrations increased dramatically at 65°S.

Fig. 4. DMS(P) distribution along 160°W.

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Atmospheric and oceanic CO_2 observations

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Objectives

We intended to describe the temporal and spatial variation of the oceanic CO_2 in the North and the South Pacific and in the Southern Ocean. The purposes include (1) to investigate the long-term increase in the partial pressure of CO_2 (pCO_2) in surface water due to the anthropogenic CO_2 invasion, (2) to describe the temporal variation in the oceanic CO_2 system in the central equatorial Pacific in association with the El Niño-Southern Oscillation phenomena (3) to describe seasonal variation in the oceanic CO_2 system in the subtropics under the condition of nutrient-depletion, and (4) to evaluate the net community production and its importance for the seasonal variation of the pCO_2 in the seasonal ice zone of the Southern Ocean.

Parameters

In the course of leg 1 (Tokyo – Wellington) and leg 2 (Wellington – Hobart), we made underway measurements of CO_2 concentration in the atmosphere (xCO_2air) and in surface seawater (xCO_2sw), and total inorganic carbon (TCO_2) in surface seawater. We also made measurements of TCO_2 and pH (total hydrogen ion concentration scale) in the water column at hydrographic stations (stn.1 – stn. 19).

Methods

(1) Underway measurements of CO_2 concentration in the air and in surface seawater

Underway measurements of CO_2 concentration (mole fraction of CO_2 in dry air) in marine boundary air (xCO_2air) and in the air equilibrated with the large excess of seawater (xCO_2sw) were made using the automated air-sea CO_2 analyzer equipped with a non-dispersive infrared (NDIR) gas analyzer (LI-COR 6251) as a detector and a shower-type equilibrator (Inoue, 1999). Its design is basically the same as that equipped in the international intercomparison experiment

held on board the R/V *Meteor* in June 1996 in the subtropical and subarctic North Atlantic (Körtzinger et al., 1999, 2000).

We continuously operated the automated analyzer in 90-minutes cycles. The first 24 minutes in each cycle was allocated to the analyses of the four reference gases. Repeated analyses of seawater (14 minutes and 12 minutes), repeated analyses of marine boundary air (6 minutes for each analysis) and again repeated analyses of seawater followed it. All NDIR output voltages were recorded under the ambient pressure while stopping the air stream temporarily.

A suite of reference gases (CO_2 in air; 271.36ppm, 330.10ppm, 359.73ppm, 404.64ppm) prepared by Nippon Sanso Co. was used for the calibration of the NDIR's output voltages. These reference gases were calibrated against the MRI's primary standard gaseson land before and after the cruise, and no drift in the concentration was detected. Compatibility of MRI's primary standards has been examined in the round-robin experiments organized by the World Meteorological Organization.

For xCO_2air analysis, marine boundary air was pumped continuously from the deck above the bridge (about 13 m above sea level), and an aliquot of the air (250 cm^3 min^{-1}) was dried with an electric cooling unit and a magnesium perchlorate before introducing it into the NDIR gas analyzer. The first xCO_2air datum in each 90-minutes cycle was flagged (flag=1) because the slight indication of imperfect substitution of air samples in the NDIR gas analyzer was detected.

For xCO_2sw analysis, seawater was drawn continuously from the seachest located *ca.* 5m depth by a pumping system of the ship. It was then introduced into a shower-type equilibrator and its water jacket where the seawater was equilibrated with air in closed circuit. The seawater-equilibrated air was dried in the same way as the marine boundary air.

Partial pressure of CO_2 (pCO_2) was calculated from xCO_2 with total barometric pressure (P) and saturated vapor pressure of seawater (p_{sw}) (Weiss and Price, 1980) taken into account:

$$pCO_2 = xCO_2 \cdot (P - p_{sw})$$

In this report, pCO_2 was calculated under the condition of P = 1013.25 hPa.

Calibration of thermometer (Pt-100Ω) equipped in the equilibrator and measurement of seawater warming in transiting from the sea surface up to the equilibrator were also performed. Temperature of seawater in the equilibrator (t_{eq}) is expressed as a quadratic function of *in situ* temperature (t):

$$t_{eq} / °C = 0.59 + 0.985\, t + 0.00022\, t^2 \qquad (0.6\ °C \leq t \leq 29.5°C)$$

or t / °C = -0.60+ 1.016 t_{eq} - 0.00023 t_{eq}^2 (1.2 °C ≤ t_{eq} ≤ 29.8°C)

Standard deviation (1s) from the regression line is 0.10 °C (n=24).

Correction of pCO_2sw in the equilibrator to the *in situ* pCO_2sw for seawater warming was made using the equation given by Copin-Montégut (1988, 1989). Ranges of correction was between 5.0 and 10.9 μatm in leg 2 depending on the pCO_2sw and t. Difference in the correction due to the different coefficients for the different TCO_2/TA ratio was within 0.23 μatm in leg 2. In this report, coefficients for 0.93 ≤ TCO_2/TA ≤ 0.98 was applied to the correction of pCO_2sw to the south of 49.5 °S, and coefficients for 0.83 ≤ TCO_2/TA ≤ 0.93 was applied to the correction in other regions.

In leg 1, measurement was quitted at 30°S, 160°W because of the trouble in the computer of the system.

(2) Analysis of total inorganic carbon

Total inorganic carbon in seawater (TCO_2) was determined using a handmade automated sample processor with coulometric detection of the CO_2 extracted from acidified samples. A description of MRI-automated sample processor can be found in Ishii et al.(1998). Commercially available coulometer (Model 5012, UIC) with Teledyne's VF converter was used, and its photometric detector was improved so that it became less sensitive to the change in the ambient temperature. Less than 36 samples were analyzed in each run of the coulometric cathode- (125 cm^3) and anode-solutions. Procedures and a method of calculation of TCO_2 concentration were essentially identical to those described in DOE (1994).

A batch of reference material prepared in MRI (MRI-RM batch-R) in a similar method to that of Dickson (1992) and bottled in 250 cm^3 glass bottles was also used for quality control at sea. Calibration of the coulometric system was made with a suite of sodium carbonate solutions as can be found in Ishii et al. (2000) before and after the cruise. Offset of the calibration, usually less than 0.2%, and TCO_2 of MRI-RM determined were corrected using the difference between the analytical results and certified value of Certified Reference Material #54 provided by Dr. Andrew Dickson in Scripps Institution of Oceanography. During the cruise, MRI-RM was usually analyzed at the beginning and at the end in each run of the coulometric cathode- and anode-solutions unless extraordinary result was obtained. Standard deviation of TCO_2 in MRI-RM(R) was ±1.3 μmol kg^{-1} (1s) (n=73) during the cruise (leg 1 and leg 2) after rejecting

some extraordinary results. Data of TCO_2 in sample seawater with its adjacent MRI-RM analytical results exceed ±2.6 μmol kg^{-1} (±2s) were flagged as flag=5. Data of TCO_2 were flagged as flag=1 when blank level (C_b) of coulometer is $0.05 \leq C_b$ / μgC $min^{-1} < 0.10$, and they were flagged as flag = 2 when $0.10 \leq C_b$ / μgC min^{-1}.

Underway measurement of TCO_2 in surface seawater was operated in 60-minutes cycles that started every nn:44. The first 15 minutes in each cycle was assigned to the analyses of coulometric blank (blank count when purging the 10% phosphoric acid solution). The next 15 minutes were assigned to the analysis of surface seawater. At nn+1:00, surface seawater was drawn into the water-jacketed pipette (23 cm^3) of the system from the flow-bottle and provided for the subsequent TCO_2 analysis. No operation was conducted in the rest 30 minutes in each cycle. The source of seawater for the underway TCO_2 measurements is the same as that for the underway pCO_2 measurements.

Salinity of seawater supplied for these underway measurements (S_u) was recorded in 1-minute intervals. These values were corrected for on the basis of the salinity of water taken from 10m at each hydrographic station. The corrected salinity (S_c) is expressed as:

$$S_c = 35.0154 + 0.9827\times(S_u\text{-}35.000) + 0.00410\times(S_u\text{-}35.000)^2 \qquad (33.5 \leq S_u \leq 35.6)$$

When standard deviation of S_c of 7 data from nn:57 to nn+1:03 was larger than 0.024, TCO_2 in the corresponding water was flagged as flag=8.

At each hydrographic station except stns. 4, 17 and 20, discrete samples for TCO_2 analysis were taken from 10L-Niskin bottles mounted on CTD/carousel sampler. They were stored in 250cm^3 ground glass stoppered borosilicate glass bottles lubricated with Apiezon-L grease after poisoning with 0.1 cm^3 of a saturated mercury(II) chloride solution. They were analyzed at 20.0°C usually within 24 hours of the sampler's arrival on deck.

(3) Analysis of pH

Index of the hydrogen ion concentration (pH) in the total hydrogen ion concentration scale was measured spectrophotometrically with *m*-cresol purple as a indicator dye (DOE 1994) using a UV-VIS spectrophotometer (JASCO V-550) equipped with a custom-made temperature controlling unit.

At each hydrographic station except stns. 4, 17 and 20, discrete samples for pH analysis were taken and stored in the same way as the samples for TCO_2 analysis. They were transferred

into a ground glass stoppered photometric cell (8 cm light-pass length) lubricated with Apiezon-L grease before analysis. After measuring the base-line spectrum, 0.2 cm^3 of indicator-dye solution was added to the sample and a spectrum was again observed. Once every 8 samples, addition of the 0.2 cm^3 indicator-dye solution to the same sample and the measurement of the spectrum was repeated in order to evaluate the effect of the addition of the indicator-dye solution on the pH of the sample sea water. Analyses were made at 20.0°C.

Results

Increase in pCO_2sw resulted from the increase in $NTCO_2$ due to the effect of equatorial divergence was observed in the equatorial region (5°N-10°S) (Fig.1). The value of pCO_2sw and $NTCO_2$ at S=35 reached 450.0 μatm and 2017 μmol kg^{-1}, respectively, at 0°N.

In the subtropics in both hemispheres and in the Sub-Antarctic Zone of the Southern Ocean, pCO_2sw was lower than the pCO_2air. Under-saturation of CO_2 in these zones are ascribed to the decreasing temperature and somewhat to the increasing NTA toward the higher latitude that are partly compensated for by the increasing $NTCO_2$.

In the Polar Frontal Zone and in the Permanently Open Ocean Zone in the Southern Ocean (between 61°S and 54°S in the southbound cruise and between 61°S and 50°S in the northbound cruise along 140°E), $NTCO_2$ was elevated enough for pCO_2sw in surface water becomes close to pCO_2air in the overlying atmosphere. However, in the Seasonal Ice Zone (to the south of 61°S), significant decrease in pCO_2sw due primarily to the biological drawdown of $NTCO_2$ was observed (Fig.1 and Fig.2). Values of TCO_2 in the preceding winter mixed layer was evaluated from the properties in the remnant T_{min} layer, and the deficit in TCO_2 in the summer surface water reached 38.1 gC m^{-2} at 64°S (Table I).

Table I. Chl.*a* and deficit in TCO_2 in the summer surface water and the thickness of the SSW.

Stn.(latitude)	12B1(65.69°S)	12(65°S)	13(64°S)	14(63°S)	15(62°S)	16(61°S)
Date in 2002	Jan. 8	Jan. 10	Jan. 11	Jan.13	Jan.13	Jan.14
Thickness of the SSW / m	45	70	41	63	79	93
T_{min} / °C	-1.36*	-1.42	-1.20	-1.09	-0.73	-0.44
Salinity at T_{min}	34.331*	34.315	34.031	33.985	33.945	33.930
TCO_2 at T_{min} / μmol kg^{-1}	2206.1*	2207.2	2175.1	2170.3	2165.6	2166.5
Def(TCO_2) / gC m^{-2}	19.7	38.1	17.4	13.7	10.1	8.7
Chl. *a* / mg m^{-2}	405	346	114	74	32	24

* at the top of the T_{min} layer.

Fig.1. Meridional distributions of partial pressure of CO_2 in the atmosphere and in seawater, total inorganic carbon, total alkalinity, temperature, and salinity in surface seawater. A: northbound cruise in leg 2 to Hobart, B: southbound cruise in leg 2 from Wellington, C: leg 1 from Tokyo to 48°S, 160°W.

Fig. 2. Vertical sections of temperature, salinity and TCO_2 in the top 300m to the south of 60°S along 140°E observed in leg 2.

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Marine Aerosols

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1. Observations of atmospheric aerosol constituents and their mixing states in the marine boundary layer of Pacific Ocean and Antarctic Ocean.

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Introduction: Atmospheric aerosol particles play critical roles in atmospheric chemistry and radiation budgets. Recently, direct/indirect climate impact by atmospheric aerosols has become one of great interest. However, there seems to be a matter of opinion in the contribution of direct (climate) effect by aerosols because of a large uncertainty. This large uncertainty is due to (1) large spatial and time variability of aerosols and (2) a few or less information of mixing states of aerosol constituents in each individual particle and chemical processes on aerosol particles. For better understanding of their roles, we need spatial distribution of aerosol constituents and their mixing states. In order to obtain the knowledge about spatial distributions and mixing states of aerosol constituents such as water soluble and some organic constituents in the marine boundary layer (MBL), aerosol observation was carried out during the KH01-3 Leg 1~Leg 4.

Sample and Analysis: Atmospheric aerosol particles, acidic gases and ammonia were collected in the front side on upper deck of R/V Hakuho. Aerosol samples and gaseous samples for chemical (bulk) analysis were continuously made using a 2-stage mid-volume impactor with back-up filter, impregnated filter and annular denuder. Each aerosol and gaseous constituents were determined with ion chromatography after extraction by ultra pure water (Milli-Q water, 18.3 MΩ). Aerosol samples for individual aerosol particle analysis were

collected using a PIXE impactor once or twice a day. Individual aerosol particles are observed/analyzed with both electron microscopy and energy dispersive X-ray analysis after some treatment and laser microprobe mass spectrometry.

Results and Future plans: Figure 1 shows spatial distribution of particulate $CH_3SO_3^-$ (methane sulfonate) and oxalate in the MBL. The concentration of $CH_3SO_3^-$ increased in the higher latitude than 40°S and slightly increased in low latitude region (0~20°S). Particulate $CH_3SO_3^-$ is one of products of biogenic sulfur species (such as DMS and DMSO) emitted from sea surface through biogenic activity in the sea. Considering higher chlorophyll-a concentration in high latitude and slight increase in low-latitudes during the KH01-3 cruise [preliminary cruise report KH01-3, 2002], spatial variation of $CH_3SO_3^-$ has probably a close relationship to oceanic biogenic activity and atmospheric chemical processes. For better understanding of the contribution of oceanic biogenic species to each aerosol processes such as heterogeneous reactions and new particle formation in the MBL, we are going to discuss them together with physical aerosol observation (e.g., size distribution).

Figure 1. Spatial distribution of particulate $CH_3SO_3^-$ and oxalate in the marine boundary layer.

On the other hand, particulate oxalate in the MBL can be released from (1) anthropogenic activities, (2) oceanic biogenic activity and (3) biomass burning. Higher oxalate concentration than 0.5 nmol m^{-3} in coastal area may be due to anthropogenic activity. Although oxalate concentration indicated background levels in the remote MBL, the concentration increased in low latitude regions (0~20°S). In the low latitude regions, the concentrations of $CH_3SO_3^-$, non-sea-salt (nss-) K^+, and NO_3^- also increased. As mentioned above, $CH_3SO_3^-$ can be used as tracer for oceanic biogenic activity, whereas nss-K^+, and NO_3^- can be released from biomass

burning. Particulate organic species such as oxalate were often internally mixed with sea-salt particles in low latitudes during the KH01-3 Leg-1 cruise as well as that in Antarctic Ocean. This suggests (1) heterogeneous oxalate formation on sea-salt particles from biogenic and biomass-burning species and/or (2) enrichment of organic species in sea-salt particles and seawater by oceanic biogenic activity. In order to know the contribution of each other, we must compare that with the mixing states of oxalate/organics, the observations of carbonaceous aerosol particles and air mass history in near future.

2. Number-Size distributions of atmospheric aerosol particles in marine boundary layer

Chiharu. Nishita, Keiichiro Hara, Atsushi Ooki, Naoki Kaneyasu, Kazuhiko Miura[5], Kazuo Osada[3], and Gen Hashida[2]

Introduction: Number-Size distributions of atmospheric aerosol particles between 5 nm and 5 μm in diameter were measured in marine boundary layer of the Pacific Ocean and the Antarctic Ocean during the KH-01-03 cruse of R/V Hakuhou-Maru. Measurements of number-size distribution of aerosol particles provide a basic parameter of atmospheric chemistry over the ocean.

Methods: Number-size distribution of aerosols was measured by a Scanning Mobility Particle Sizer (SMPS, model3936, TSI, size range 5<D<124 nm) and two Optical Particle Counters (OPC, model KC18, RION, 0.1<D<0.5 μm and model KC01D, RION, 0.3<D<5 μm) placed on an upper deck of the ship. Basic principle of sample air handling was described in Miura et al. (1996), although details were improved a lot. Some instrumental troubles occurred during the voyage: (1) SMPS data were missing between the latitude of 28°N and 18°S in Leg 1 because of water dew condensation in the SMPS, (2) flow rate of the KC18 decreased gradually after Leg 2 and that of the SMPS also decreased during Leg 2, and (3) the SMPS data were missing in Leg 4 because of a shortage of consumables.

Preliminary Results and Future Works: Figure 2 shows the typical examples of size distributions observed by the SMPS in the Pacific Ocean and the Antarctic Ocean. The distributions observed in Pacific Ocean show almost always Aitken mode at about 40 nm (Fig. 2a). In the Antarctic Ocean, bi-modal distributions were frequently observed (Fig. 2b). Figure 2(c) shows nucleation mode below 10 nm in diameter, which observed only twice under south

of 60° in the Antarctic Ocean. In the future, we would like to investigate about relationships among meteorological conditions, precursor concentrations and aerosol size distributions.

Figure 2 Number-size distributions of atmospheric aerosol particles observed in (a) the Pacific Ocean, and (b, c) the Antarctic Ocean.

Reference

Miura, K. et al., *Proc. NIPR Symp. Polar Meteorol. Glaciol.*, **10,** 102-110, 1996

3. Size fractionated aerosols for inorganic components and particulate carbon in the marine air

Atsushi Ooki

Introduction: Non-sea-salt sulfate, sea-salt, and particulate carbon are the dominant components of marine aerosols. It is essential to estimate their contributions to the particle number concentrations in the accumulation mode range. To investigate the relationships between their mass concentrations and particle number concentrations, ionic components for the size fractionated aerosols and particulate carbons were measured over the Pacific Ocean.

Size fractionated inorganic components: Size fractionated aerosol samples (18 sets) were collected by low-pressure impactor having 50% cut off diameters of 0.06, 0.13, 0.22, 0.33, 0.52, 0.76, 1.25, 2.5, 3.9, 5.7, 8.5, and 12.1 μm. Ambient air was pumped at a flow rate of 20 LPM for 3 days when wind blew from the bow in order to avoid the influence of the ship itself. Inorganic components of aerosol samples will be analyzed by ion chromatography.

Particulate carbon: Organic carbon (OC) is mainly derived from the anthropogenic sources, however, the contribution of natural sources (marine biological sources) would not be negligible over the remote ocean. Elemental carbon (EC) is mainly derived from the land

sources such as biomass burning and fuel combustion, and would be a useful indicator of land influences. The concentrations of OC and EC (Fig. 1) were measured by thermal method. The concentrations of OC (0.2 μg m^{-3}) and EC (0.05 μg m^{-3}) were measured over the remote ocean in the South Pacific during Leg-1, and would be the background levels of them. We expected that the OC concentrations would be increased over the high productive region in the Antarctic Ocean (65°S), however, high concentration peak was not found.

Figure 3 The concentrations of particulate carbons (OC and EC).

4. Optical properties of aerosols in the marine boundary layer

Naoki Kaneyasu, Keiichiro Hara, Atsushi Ooki, and Gen Hashida[2]

Introduction: The impact of continental originated air pollutants to the atmospheric constituents over pristine oceanic atmosphere has increasingly been recognized recent years . The optical properties of aerosol in the marine boundary layer are accordingly influenced by the fossil fuel burning, biomass burning, and soil-related particles transported long-distance from lands. This study investigates the change in the optical properties of aerosols according as the change in their chemical composition.

Methods: Hourly concentration of particulate Black Carbon (BC) was measured by an Aethalometer (Magee Scientific, AE-16U). Aerosol scattering and absorption coefficient were measured by an Integrating Nephelometer (Radiance Research, M903) and a

Particle/Soot Absorption Photometer (PSAP, Radiance Research), respectively. Time resolution of these instruments was 5 minutes. When the weather permitted, aerosol optical depth was measured manually by a Sun-Photometer (Eko, MS-120, 4-weavelenghs). A 13-stage low-pressure impactor (Tokyo Dylec, LP-20) was operated to measure the size distribution of black carbon and particulate organics. The sampled air volume of this measurements were normally 80 m^3 for each measurement. Glass plates were used as sampling substrate for the impactor.

Preliminary Result: Although the analyses of aerosol samples and recorded data are still underway, preliminary analysis exhibited a suggestive result on the absorption nature of aerosols at different area. Figure 4 shows the relation between absorption coefficient measured by the PSAP and "BC concentration" measured by the Aethalomenter.

Figure 4 Relation between absorption coefficients measured by PSAP and BC concentrations (raw data) measured by Aethalometer.

The data shown in left panel are measured at the Northwest Pacific close to Mainland Japan during the Leg-1 cruise. When the research vessel was in the area influenced by the Asian continent or Mainland Japan, there is a perfect correlation between these two values. Taking the "raw" BC concentration indicated by the Aethalometer, we can calculate the apparent specific mass absorption coefficient to be 8.9 m^2 g^{-1}, which is precisely in consistent with the previous studies regarding the BC absorption. While the vessel was in the relatively "clean" Trade Wind zone and South Pacific Ocean, the correlation of those two values decreased In addition, even taking into account that the PSAP measured absorption coefficient below 10^{-7} m^{-1} is not reliable, the specific mass absorption appeared to be low compared to that over the NW Pacific. The difference in the two panels in Figure 4 reflected the difference in

detection wavelengths adopted by PSAP and Aethalometer, 565 nm and 880 nm, respectively. The difference in the absorption nature of these "polluted" and "clean" aerosols further arises the subject whether the absorber in the "clean" aerosol is really BC or not. Additional analyses are currently underway regarding the data collected in the other region of the cruise track. Further results on the aerosol optical properties (scattering coefficient, single scattering albedo) and their relation with the chemical composition will be presented along.

Acknowledgement: We are grateful to Profs. Terazaki, Ogawa, Uematsu, and the staff members of R/V Hakuho for help of aerosol measurements during the KH01-3 cruise.

A meridional scan of the stratosphere over the ocean in 2001 (MeSSO2001)

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1. Introduction

It has been well known that atmospheric gravity waves play an important role to determine global-scale thermal and wind structure in the middle atmosphere by transporting momentum mostly vertically. For quantitative evaluation of their role, it is necessary to estimate momentum fluxes as a function of phase velocity. The momentum fluxes associated with gravity waves in the real atmosphere have been estimated by using MST radars such as the MU radar (e.g. Sato, 1994) and by using high-resolution operational radiosonde data (SPARC gravity wave initiative, R.A.Vincent). However, our knowledge on gravity waves over the ocean is limited.

As the atmosphere over the ocean is free from topography, gravity waves with non-zero phase velocities that are excited by convection, fronts and jet stream would be clearly observed there. Recent development of computer technology allows us to resolve gravity waves by high-resolution global climate models to examine their global characteristics (e.g. O'Sullivan and Dunkerton, 1995; Sato et al., 1999). However, gravity waves having horizontal scales smaller than several tens kilometers are hardly examined. Satellite observations with the GPS occultation technique provide fine vertical temperature profiles over the globe. However, the horizontal resolution is a few hundreds km, restricting the analysis to gravity waves having horizontal scales greater than several hundred kilometers. It is also noted that momentum fluxes are hardly estimated with temperature data only.

In our project, we made an attempt to obtain wind and temperature profiles with fine

resolution in both horizontal and vertical directions in the atmosphere over the ocean to examine gravity wave characteristics in a wide range of latitude, by launching radiosondes successively over a research vessel. Details of the observation were described in Section 2. Gravity wave energy and vertical wavenumber spectrum are examined as a function of latitude and altitude, and compared with climatology by Vincent et al. (2002) in Section 3. During the observation period, an inertia-gravity wave packet originated from the ITCZ region is observed over 6 days in the wide latitudinal region propagating from the Northern Hemisphere to the Southern Hemisphere. Details are described in Section 4.

2. Observations

The observation period is about one month from November 27 through December 25, 2001. To measure horizontal winds, temperature and humidity, Vaisala RS80-15GH radiosondes were launched at almost the same latitude interval of 1 degree in the latitude range of 28N to 48S over Hakuho-maru research vessel that is operated by Ocean Research Institute in the University of Tokyo. The observed locations are shown in Figure 1. Although several trials were failed in the beginning of the campaign period due to a trouble of receiving system, seventy observations in the troposphere and lower stratosphere reaching the altitude above 24 km were successfully performed.

Figure 1: Observation points

3. Gravity wave characteristics as a function of latitude

In order to examine the dynamical characteristics of gravity waves, we extracted fluctuation components defined as perturbation from the third

Figure 2: Gravity wave energy as a function of latitude in the height range of 18-25km (bottom) and 24-31km (top).

order polynomial fit for a particular altitude range extending over 7 km, following the SPARC gravity wave project. The gravity wave energy is largest around the equator just above the tropopause, but it seems that the energy peak spreads to higher latitudes at higher altitudes (Fig. 2). The peak values are several times as large as the climatology in land regions shown by SPARC gravity wave initiative. The vertical wavenumber (m) spectra are steep and close to the shape proportional to m^{-3} in the equatorial region while they become shallower at higher latitude regions. An interesting result obtained by the following detailed analysis is that the energy peak observed in the equatorial region is due to an inertia-gravity wave packet propagating from the Northern to Southern Hemispheres.

4. Meridional propagation of an inertia-gravity wave generated at ITCZ

In the meridional cross sections of winds and temperature, phase and energy propagation of a wave packet is observed in the latitude region from 7N to 20S, even though each profile was obtained at different time (Fig. 3). In particular the phase structure is clear in the latitude region of 11S to 19S. Thus we performed hodograph analysis for each vertical profile in this region with a theoretical constraint of phase relation of an inertia-gravity wave between winds and temperature components. The temperature amplitude estimated from wind amplitudes and obtained wave parameters accords well with the observation, indicating that wave packets are due to an inertia-gravity wave. The inertia-gravity wave propagates southeastward with a horizontal wavelength of about 1500km and vertical wavelength of about 4.5km. These estimated wave parameters explain well the phase structure and energy propagation observed in the meridional cross sections. The reason why the wave packet propagation is nicely detected by this cruise observation is that the ship speed is almost the same as the meridional group velocity of the inertia-gravity wave. A satellite IR picture is examined when the wave packet is located at the tropopause (z=17km) when the ship is located at 7N on December 6, 2001. A clear structure of ITCZ was observed at this particular time and location. Thus it is likely that the observed gravity wave is excited by vigorous convection at ITCZ.

Figure 3: A meridional cross-section of meridional winds. A clear upward and southward propagation of a monochromatic wave packet is seen.

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Late Quaternary paleoceanographic changes in the Polar Front zone in the Southern Ocean.

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Introduction

Martin (1990) proposed the "iron hypothesis," indicating that iron is a limiting factor to control the phytoplankton productivity and consequent CO_2 drawdown from the atmosphere. To evaluate whether the past marine productivity was enhanced in the Southern Ocean during the glacial periods, several approaches have been performed using inorganic chemical tracers, microfossils, and biomarkers (e.g., Mortlock et al., 1991; Charles et al., 1991; Shemesh et al., 1993; Kumar et al., 1995; Nürnberg et al., 1997, Ikehara et al., 2000). The Southern Ocean is characterized by a high-nutrient and low-chlorophyll (HNLC) surface waters (e.g., Martin, 1990; Coale et al., 1996), development of the polar zonation surrounding Antarctica, sea-ice distributions, and deep convection to form intermediate and deep waters.

On the basis of the study of alkenones in a Southern Ocean sediment core from the Tasman Plateau, Ikehara et al. (1997) reported, for the first time, variations of sea surface temperatures (SSTs) and showed that the amplitude of paleo-SSTs are 4°-5°C from the glacials (Last Glacial Maximum and marine isotope stage 6) to the interglacials (early Holocene and the Eemian). Marine biological productivity was increased during the glacial periods in the subantarctic surface waters (Ikehara et al., 2000). Changes in SSTs and productivity in the subantarctic ocean may have been influenced by the Antarctic Polar Front (APF) and sea-ice coverage. However, the past positions of the APF and maximum sea-ice extent are not clearly reconstructed during the glacial and interglacial climate cycles. Therefore a deep-sea sediment core was collected from the Southeast Indian Ridge, where the modern APF is located.

Material and methods

A piston core SIR-1PC was collected from the Southeast Indian Ridge during the KH01-3 cruise of the R/V *Hakuho-Maru* (Table 1 and Figure 1). Surface sediments were also recovered from latitudinal transect along 140°E (Table 1 and Figure 1). Sediments of SIR-1PC are mainly composed of calcareous foraminifera-nannofossil ooze and siliceous ooze. Changes in physical properties of sediments such as natural gamma ray, bulk density, magnetic susceptibility and P-wave velocity were routinely measured by every 2 cm using the Multi Sensor Core Logger (MSCL) system in order to study lithostratigraphic and sedimentological characteristics. X-ray computed tomography (CT) images of the core were also captured by a medical CT scanner (HITACHI RADIX PRATICO) to observe sedimentary structures. Sediment color was measured by every 1 cm using a CM-2022 (Minolta) Spectorophotometer. Sediments below 936 cm are thought to be a flow-in section, based on visual structure analyses by X-ray CT images.

Results and discussion

(a) Sedimentary color variations

Lightness (L*) of sediments at SIR-1PC exhibits rhythmic variations throughout the core (Fig. 2). Values in the L* range from 33 to 76. Low values in the L* are occurred at about 50 cm, 400 cm, 540 cm, and 800 cm, whereas high values are shown at 360 cm, 760 cm, and 930 cm (Fig. 2). Lightness of deep-sea sediments is changed depending on the amount of carbonate (e.g., Ortiz et al., 1999), which was increased during the interglacial periods in the Southern Ocean (Howard and Prell, 1994). Therefore the sections with higher L* values at SIR-1PC was deposited during the interglacial periods. Based on the relationship between L* variations and oxygen isotope stacked curve (Martinson et al., 1987), the marine isotope stages (MIS) were estimated in SIR-1PC (Fig. 2). Positive L* peak may corresponds to the last interglacial MIS 5e.

(b) Variations of L* and magnetic susceptibility

Fig. 3 show the relationship between L* and magnetic susceptibility (MS) at SIR-1PC. MS values increased in each darker section with lower L* values, which are estimated to glacial stages. Bareille et al. (1994) reported that MS values were extremely increased during the glacial periods in the Southern Ocean. These MS fluctuations may have been influenced by time-series input variations of eolian dust and/or ice-rafted debris (IRD). IRD is used as a proxy to reconstruct past changes of ice sheet instability and sea-ice distribution in the

high-latitudinal oceans. Based on preliminary analyses on the SIR-1PC sediments, IRD grains (>150μm) increase during the enhanced MS intervals. Therefore, it is estimated that sea-ice distributions were expanded to the core location (~55°S) during the glacial periods.

Table 1. Core list

Station	Core Name*	Latitude	Longitude	Water depth (m)	Recovery (cm)
St.18	**SIR-1PC**	54°44.25'S	140°02.20'E	3358	984.0
St.13	**St.13MC**	63°59.30'S	139°57.04'E	3698	18.0
St.17	**St.17MC**	59°58.58'S	139°56.93'E	4483	51.0
St.18	**SIR-1MC**	54°43.81'S	140°03.31'E	3429	27.0
St.19	**St.19MC**	50°01.08'S	139°59.98'E	3755	30.0

*PC indicates piston core and MC means multiple core.

Fig. 1. Location map of deep-sea sediment cores during the KH01-3 cruise.

Fig. 2. Color signals in core SIR-1PC.

Fig. 3. Variations in lightness (L*) and magnetic susceptibility (MS) of core SIR-1PC. Shaded areas indicate the intervals of increased MS.

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Tectonics of the Australian-Antarctic Discordance

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1 Swath Bathymetric Survey by SeaBeam2120

1.1 Introduction

During Leg 3 of KH-01-3 (R/V Hakuho-maru) we conducted a detailed swath bathymetry survey of the B-3 segment of the Australian-Antarctic Discordance (AAD) zone, the Southeast Indian Ridge between 124°E and 125°15'E, using the SeaBeam 2120 system (Fig. 1). Additional isolated survey lines were completed in the area where OBS units were deployed (segment B-4), the northern part of the segment B-4, and also in the area of recent ODP drilling (Leg 187) site on the way to the survey area from Hobart. The mail objective of the survey in the Leg 3 is to clarify the on- and off-axis morphology of the unmapped segment B-3 and to study the crustal accretion process at the AAD.

1.2 System configuration of SeaBeam 2120

The system was operated at 0 dB, 110 degree manual swath mode, for the average depth of the survey area is about 4000 m where the swath width is switched from 120° mode to 90°mode in case of automatic swath mode. Bathymetry data comprised ~110 pings per beam, average ping interval is 10 seconds. Ship speed averaged 14 knots in B-3 segment area. Depth resolution is estimated to be 70 to 120 m. Positioning was accomplished using two shipboard GPS navigation devices and the SeaBeam internal GPS navigation system. Data quality is quite good in the B-3 segment area, on the other hand the quality is relatively not good because of higher heave and pitch of the ship. The data from the outer beams are also noisy when we set the 110°swath manually at the depths deeper than 4000m. Sea surface sound velocities were measured continuously by measured the sonic characteristics of seawater sampled during surveying.

1.3 Processing of the data

The sound velocity correction was completed in real-time during the survey using

appropriate XCTD and CTD data. The velocity profiles used during the survey are listed below.

2002.1.27 12:25 : CTD St.20 (leg2) data

2002.1.29 14:33 : XCTD (2002.1.29. 43°30'S, 129°11'E) for ~1000m,
CTD St.20 for 1000 m~

2002.2.3 10:55 : CTD St.21 (2002.2.3. 49°54'S, 124°49'E) data

2002.2.6 0:20- : XCTD (2002.2.6. 49°34'S, 124°03'E) for ~1000m,
CTD St.21 for 1000m~

To delete the erroneous data we applied a filter using mbclean program in MB system, however we did not do manual picks of erroneous depths onboard. The preliminary grid data is created for checking data quality and for this onboard report. The grid size of 0.001° * 0.0015° (approximately 100 m * 100m) is chosen for the onboard processing.

Fig.1 Track line of SeaBeam2120 in KH01-3 Leg3.

1.4 Mapping of the B-3 segment in the AAD

SeaBeam swath bathymetry measurements were done continuously while the ship in the survey area and on the way of transits from ports to the survey area. The most intensive survey was done in the B-3 segment in the AAD with a track spacing of 5 nm (9 km). The survey covered the axial valley of the rift system, and 40 nm. (72 km) of the off-axis abyssal hills and rift flanks toward the both sides, where the magnetic anomaly chron is estimated as Anomaly 2. The B-3 segment is divided into two lower order segments, B-3W and B-3E, by a non-transform discontinuity (Fig. 2). The spreading axis is characterized with 4500m deep rift valley though the spreading rate here is 76 mm/year. In the B-3E segment the bathymetry pattern is quite anomalous, e.g. asymmetry about the axial rift and the mullion structure at the inside corner of the eastern part. On the contrary, the normal abyssal hill pattern is dominant in the B-3W segment, therefore the recent anomalous crustal accretion is occurred along the limited area of B-3E and B-4.

1.5 Mapping of the other areas

Single swath line crosses the recent ODP drilling site near 130°E, where is the mantle isotopic boundary. It is important to clarify the relationship among the isotopic boundary of rock geochemistry, the boundary of different morphological characters (normal, well-ordered abyssal hills and chaotic seafloor), and the depth anomaly. Along our swath line, the seafloor is characterized with well-ordered abyssal hills and no chaotic or mullion-like structure is found.

We also mapped the northern part of segment B-4 between 47°10'S and 45°35'S. The well-ordered east-west trending abyssal hills are dominant in this area, however a few small scale mullion-like structures are found near the B4-B5 boundary discontinuities..

1.6 Summary

We successfully conducted swath mapping survey at the AAD rift system with the new 20kHz/1-degree narrow multibeam survey. The data quality is satisfactory in spite of the rough sea condition. The onboard processed map revealed fine structures of the Segment B-3 and provided important morphological information on the ODP site and the northern B-4 segment. Further processing the swath bathymetry data will firmly provide a new model of evolution of the BV-3 segment and the tectonics of the AAD. The fully correction of ping data will be done by noise filtering of ping bathymetries and GPS position data. The following research plans were proposed through the discussion of the concerned scientists on board.

Fig. 2 Shaded relief map of the Segment B-3 in the AAD.

2. Gravity measurement

The measurement of sea surface gravity had been carried out using the NIPR-ORI gravimeter. Free-air anomalies during Leg 3 are obtained along the almost all ship's tracks except for those during extreme rough sea condition. The profiles of free-air anomalies around the AAD zone after drift correction are shown in Figure 3. Negative free-air anomalies are observed around the almost entire AAD zone during Leg 3. Figure 4 indicates the gray scale image of free-air anomalies around the B-3 segment of the AAD zone. Clear negative free-air anomalies with the strike of WNW-ESE are detected along the ridge axis of the B-3 segment. Further analysis with the sea floor topography, such as mantle Bouguer analysis, will reveal the structure of the crust and mantle, and provide constraints for the dynamics of AAD rift system.

Fig. 3 The profiles of free-air anomalies around the AAD zone. Positive Anomalies are shaded.

Fig. 4 The gray scale image of free-air anomalies around the B-3 segment of the AAD zone. The scale of image is shown in upper center. The contour interval is 5 mgal.

3 Measurement of total intensity geomagnetic field

3.1 Surface-tow proton magmetometer measurement

Total intensity of geomagnetic filed had been obtained using the proton precession magnetometer along the ship's track except for the observation lines of seismic experiment. Magnetic anomalies are obtained by subtracting the IGRF 2000. Magnetic anomaly profiles in the B3 segment are shown in Fig. 5. The profiles almost cover the magnetic anomaly lineations from Brunhes to anomaly No. 2A. Complicated evolution of the ridge axis in B3 segment is suggested.

Fig. 5 Magnetic anomaly profiles in Segment B-3.

3.2 Deep-tow magnetic measurement

We conducted a 16-hours deep-towed magnetic survey at Segment B-3 in the AAD during Leg3. The deep-towed system can provide us a short-wave length magnetic anomaly data which cannot be detected by using surface magnetometer and lead us better understanding of the detailed history of seafloor spreading at the AAD.

We use an off-line deep-towed magnetometer system developed by ORI (Sayanagi et al., 1994). The system consists of two main units, magnetometer and depth (pressure) meter. The magnetometer unit consists of a sensor (2kg) and a pressure case including a control unit, memory and battery. The sensor is towed 15 m after the pressure case. The depth meter is fixed to the magnetometer pressure case. The whole system is towed behind the ship with 100 kg weight. The deep-towed magnetic survey line is as follows.

DTP-S : 48°24.8'S, 125°11.0E

DTP-E : 49°11.0'S, 124°47.0'E

The total length of the survey line is 48 mile and the direction is NNE-SSW which is approximately parallel to the relative plate motion vector. The line is planned to obtain the magnetic anomaly variation from the Anomaly 2 on the Australian Plate to the ridge axis.

Unfortunately, no depth data was logged after 2002/02/04 19:02 when the unit was still on deck. It is due to the loose connection among the logger unit of the depth meter. The magnetic measurement was recorded through the survey, however the data include high amplitude noises and offset after the wire length is over a few hundreds meters. It may be attributed to the unstable towfish attitude due to unappropriate towing configuration. The data will be carefully analyzed to investigate the origin of the erroneous data.

Seismic structure survey for the uppermost mantle and crust in the segment B4, the AAD using OBS and MCS

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1. Introduction

The Australian-Antarctic Discordance (AAD) is an anomalously deep and rugged zone of the Southeast Indian Ridge (SEIR) between 120°E and 128°E (Fig. 1). The AAD is also defined by the intersection of the SEIR and Australian-Antarctic Depression (Veevers, 1982) which is associated with a V-shaped trend of residual depth anomalies (e.g. Marks *et al.*, 1990) and a saddle-shaped low in the geiod (Weissel and Hayes, 1974). The SEIR south of Australia is devided into three distinct zones (Weissel and Hayes, 1974). Zone B indicates the AAD itself. The anomalous large depths within the AAD are interpreted to result from an unusually cold underlying mantle that yields a low melt supply to spreading plate boundary (e.g. West *et al.*, 1994). The AAD is also associated with distinct geochemical boundaries. The eastern AAD area is a distinctive boundary between Indian-type and Pacific-type upper mantle provinces (Klein *et al.*, 1988).

The AAD has unusual geometry with altering north- and south-offset spreading sections of the spreading center (Vogt et al., 1984). There are five sections denoted as B1 - B5. At the spreading centers within the AAD, relatively thin oceanic crust may be formed by a low melt supply. The crust with a total thickness of 4.5 km is found in the B5 (Tolstoy *et al.*, 1995). Their results indicates that the Oceanic Layer 2 is -3 km thick, whereas the Oceanic Layer 3 is unusually thin (- 1.2 km). From the multibeam bathymetric mapping, westernmost Zone A has normal seafloor characterized by axis-parallel abyssal hills. In B5 area, normal seafloor terrain occupies a west-pointing V-shaped region that is symmetrical about the spreading axis (Christie *et al.*, 1998). In B4 area and outside of the V-shaped region in B5, the sea floor terrain is unusually choatic. In the Zone A and within the V-shaped region of the B5,

Pacific-type mantle source rocks were dredged. In the other hand, all samples from the B4 area are Indian-type mantle source. (Pyle et al, 1992). The previous seismic experiment was carried out within the V-shaped region in the B5. The crustal and uppermost mantle structure of choatic seafloor topography area is not known yet.

Fig. 1. Batjymetric map of Southeast Indian Ridge showing the location of the AAD. A gray dash line shows the plate boundary. Contour interval is 1000m.

During the Hakuho-maru KH01-03 cruise Leg 3, we carried out the seismic experiment using large capacity airguns, Ocean Bottom Seismometer (OBS) and Multi Channel Streamer

(MCS) in the segment B4 where the sea floor topography is choatic and Indian-type mantle source rocks were dredged.

2. Instruments

2.1 OBS

We used a pop-up type OBS (Fig. 2) equipped with flashing light, radio beacon and transponder. This OBS has one vertical component and two horizontal components velocity sensor with a natural frequency of 4.5 Hz (Mark Products L25B or L28B) on a gimbals mechanism. The seismic signal is sent to pre-amp and 16 bits AD converter, and sent to a Digital Audio Tape (DAT) for continuous and compressed data recording. We set 100 Hz data sampling each channel for this experiment.

Fig. 2. Photograph of the OBS used in this study.

2.2 Airgun

We used two Bolt 1500C type airguns;the airgun with a 17-liter chamber on the starboard side, and the airgun with a 20-liter chamber on the port side (Fig. 3). The air pressure was set at 1500 lb/IN^{2}G, and airguns were shot every 20 or 60 seconds.

Fig. 3. Assembly of an airgun on the deck of the R/V Hakuho-maru before the cruise. Capacity of the chamber is 1000 cubic inchs (approximately 17 liters).

2.3 MCS

We used an Innovative Transducers Inc. solid-cable 24 channel analogue hydrophone streamer as receivers. The group interval was 25 meters, and each group consists of 5 hydrophone sensors. An approximately 300 m long nylon rope was attached at the tail in order to stabilize the streamer cable.

The Syntron MultiTRAK system was used to handle streamer positioning. Two MTUs (MultiTRAK Units) were mounted at the head and the tail of the streamer cable. These units control the cable depth by moving a set of motor driven wings. The MTUs were also equipped with a two-axis fluxgate magnetometer, and measured the horizontal components of the Earth's magnetic filed. Given their mounted locations on the streamer cable, the host computer calculated its shape.

Geoscope StrataView was used as a data logger. It converted analogue signals from the hydrophones to digital data, and recorded the data on 4 mm DAT tapes.

3. Operations

3.1 OBS

We deployed five OBSs on the seafloor at spacing 20km to observe seismic waves from airgun source as shown in Fig. 4. Positions and time-adjustment data of all OBS are listed in Table 1 and 2. The OBS-airgun survey line crosses the ridge axis in the B4 segment. Although we planned to use ten OBSs, we could deploy five OBSs due to a bad sea condition (Fig. 5). After the shooting, we retrieved all OBS.

Fig.4. Bathmetry obtained during KH01-03 Leg 3 by the Sea Beam 2100 on the Hakuho-maru and the positions of deployed OBSs. A black solid line indicates the OBS profile where the airguns were shot every 60s. Gray lines are the MCS profiles.

OBS#	Deployment		Retrieval		Depth (m)
	Latitude(S)	Longitude(E)	Latitude(S)	Longitude(E)	
1	49° 24.70'	125° 42.66'	49° 24.83'	125° 42.71'	3916
2	49° 34.93'	125° 36.89'	49° 34.98'	125° 37.17'	3571
3	49° 44.99'	125° 31.21'	49° 44.95'	125° 31.19'	4136
4	49° 55.11'	125° 25.38'	49° 54.99'	125° 25.54'	3314
5	50° 05.27'	125° 19.64'	50° 05.18'	125° 19.79'	3456

Table 1. OBS position information

OBS#	time offset at deployment (UTC)	time offset at retrieval (UTC)
1	2002 01 31 23 05 50 +0.183 s	2002 02 02 20 51 30 +0.606 s
2	2002 01 31 23 09 00 +0.247 s	2002 02 02 23 27 10 +0.597 s
3	2002 02 01 03 09 50 +0.255 s	2002 02 03 01 54 30 +0.567 s
4	2002 02 01 04 31 40 +0.277 s	2002 02 03 04 07 00 +0.650 s
5	2002 02 01 05 55 40 –0.031 s	2002 02 03 05 27 30 +0.148 s

Table 2 OBS time-adjustment data

Fig. 5. Deployment of an OBS during a rough sea condition.

3.2 MCS

Once the streamer was deployed, and all the configurations on the MTUs and StrataView were set up, nothing particular was required to be done. The watch standers were asked to visually confirm current MTU locations and increments of the recorded File Number every 30 minutes.

The MTUs were programmed to maintain the streamer depth at 10 m below the sea surface. The sampling interval of the seismic reflection data was 4 msec. Their record

lengths were either 20 seconds or 16 seconds; 20 seconds during shooting the first OBS-inline profile at a 60-second interval, and 16 seconds otherwise. The data were stored in SEGD 8058 rev.1 format.

4. Post cruise research plan

We will make analyses of the OBS data by conventional and other methods including ray tracing technique, seismic tomography, seismic imaging of reflectors and/or scatters and so on. The OBS data may give us information of microseismicity in spite of short observation period. The MCS data will be also processed using the conventional method to image beneath the profiles. These analyses will bring us knowledge about a structure of uppermost mantle and crust in the segment B4 of the AAD. We try to reveal the complicated tectonics of the AAD through comparison between the structure in the AAD and those of other ridge systems.

5. Summary

We successfully carried out the seismic experiment to obtain detailed crustal and uppermost mantle structure in the segment B4 of the AAD. The main profile is perpendicular to the spreading center and has a length of 100km. Five OBS were deployed at an interval of 25 km on the main profile and all OBS were recovered. In addition, MCS survey was performed on the main profile and additional five profiles.

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Appendix. Geophysics research team of KH01-03 Leg 3

Back row: left to right, K. Matsuda, T. Yamada, K. Mochizuki, Y. Nogi, C. Igarashi, D. M. Chirstie. Front row: left to right, K. Koizumi, K. Nakahigashi, M. Shinohara. K. Okino.