The Amundsen Sea Expedition (ANA01C)

Chief Scientist: SangHoon Lee

IBRV Araon, 21 December 2010 – 23 January 2011
(King Sejong Station, The Antarctica to Christ Church, NZ)

Prologue

This is the cruise report of the first-ever field expedition in the frozen Southern Ocean, the Amundsen Sea. My team - 20 scientists and 2 technicians - spent 33 days onboard Araon, the very first Korean IBRV that was commissioned in 2009. Performance of both the ship and the crew was superb. The Amundsen cruise team occupied 30 stations during 19 work days, and their performance was even more superb - swift, effective, and flawless – which I believe is the result of their meticulous preparations made in the previous year. No one would have wanted to blemish the commemorable moment in the history of the Korean Antarctic Research Program. Besides the 30 stations, there were 2 sediment traps deployed for a year, 1 automatic weather stations set up in Bear Peninsular, 2 safety lectures, 5 situation briefings, 11 science seminars, numerous small-group discussions, and 2 big parties where most of the shipboard alcoholic beverages disappeared. By the time we have half-way gone through the expedition, people started calling ourselves the A-Team, and no one asked why or how.

Temperature is rising in the West Antarctic, and the Amundsen Sea is a drainage of the West Antarctic Ice Sheet. This area is experiencing the rapid loss of glacier and sea ice, which may further accelerate the collapse of ice shelf and glacier. Upwelling of the deep water should play some parts by warming the basal marine glacier, but it has to be a mixed impact from both ocean and atmosphere. Biological processes are often boosted, being associated with the melting of the ice, such as the elevated level of chlorophyll observed via satellite imagery in polynya area. Physical processes altered by the warming propagate through biological and biogeochemical ones, ultimately affecting the whole ecosystem.

Our Amundsen project is to assess the rapid changes of polar sea-ice dynamics and related physical, chemical, and biological processes under the current trend of climate change, by implementing an Earth observation system from space down to deep sea. The study looks into the physical mechanisms associated with opening and closing of the Amundsen polynya and its impacts on the biology and biogeochemistry in the region; the behaviors of the climate gases in and out of the ploynya and their roles in ecological processes; the spatial and temporal variability of the physical properties of sea ice that are important to air-sea interaction and to biological processes in the sea-ice zone. We wanted to examine the links between biogeochemical processes and food web structure, identify key functional groups, their roles and interactions, to name just a few.

This is to report our first step in to a series of field expeditions to come. I am indebted to those who help made the project exist and carried out.

2010/2011 Amundsen cruise chief scientist, SangHoon Lee

Contents

Chapter 1

Hydrographic survey

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1.1 Introduction

The Amundsen Sea sector is the most rapidly changing region of the Antarctic ice sheet (Walker et al., 2007). It has been claimed that the high rate of collapsing ice is primarily related to the intrusion of warm circumpolar deep water (CDW) as an oceanic heat source (Vaughan, 2008; Jenkins et al., 2010). The Amundsen shelf troughs are thought to be main conduits supplying heat flux onto the continental shelf, eroding the underside of the ice sheets and glaciers (Walker et al., 2007; Wahlin et al., 2010). Despite this importance of CDW in the continental shelf of the Amundsen Sea, vital information is still absent from the existing body of knowledge pertaining to spatial-temporal variability of CDW. This is mainly because the Amundsen Sea is remotely located and the extremely harsh weather and sea conditions limited the access to its inner shelf. The lack of data has impeded our evaluation and prediction of physical processes and associated biochemical processes in the Amundsen Sea. Therefore, it is necessary to timely addressed these processes. Based on the aforementioned rationale, the main objective of 2010/2011 expedition (ANA01C) is to understand the CDW's roles in controlling the hydrodynamics and related biochemical processes in the continental shelf of the Amundsen Sea. The specific objectives in the field of physical oceanography are:

- to reveal the spatial distribution and pathway of CDW in the vicinity of the Amundsen shelf trough;
- to characterize the temporal and spatial variability in water masses and their modification by bathymetry and mixing with ice-melting waters;
- to study the evolution in water column current field (e.g., velocity, circulation, and eddy formation)

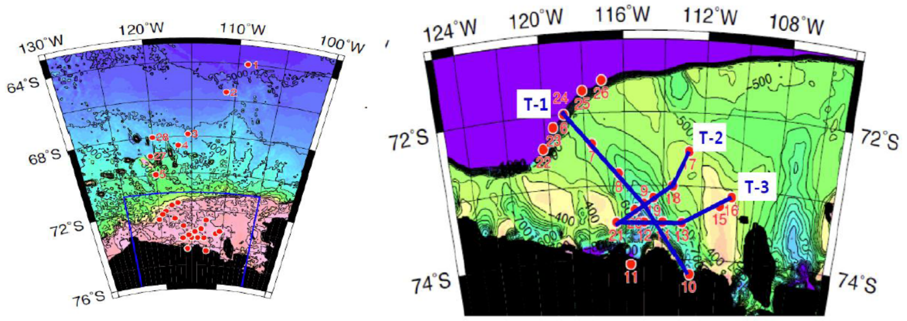

Figure 1.1: Map of study area. Red dots show the CTD stations during 2010/2011 expedition. The numbers indicates the station numbers. Three transects (T-1, T-2 and T-3) were given to reveal the spatial distribution of CDW (right panel).

1.2 Materials and methods

An intensive oceanographic survey was conducted in the period between December 21, 2010 and January 23, 2011 (Fig. 1.1). At each hydrographic station, the hydrocast of CTD/Rosette system with additional probes (e.g., transmissometer, altimeter, fluorometer, oxygen sensor, and etc.) was conducted to measure the profiles of salinity, temperature, depth, and other biochemical parameters. By means of traditional T-S diagram analysis, the mixing and transformation of water mass was revealed. During the CTD upcasting, water samples were collected at several depths, and then later analyzed in a laboratory to get the ground truth. The velocity structure in the water column was measured using a 38-kHz shipboard acoustic Doppler current profiler (SADCP; RDI) mounted on IBRV Araon. Considering the depth and flow velocity, the proper configuration and setup (e.g., bin size and sampling rate) were selected. With the bottom tracking mode, if needed, the profile of residual velocities between SADCP measurement and ship's velocity was measured with continuous resolution during the vessel operation. The vessel-mounted ADCP, however, has a constraint on the vertical sensing range, because the sound absorption by water and suspended matters causes undesirable noises with increasing distance from transducer. In order to improve the correlation at far distances, the frequent profiling for a 300-kHz lowered ADCP (LADCP; RDI) at each hydrographic station was deployed. The SADCP and LADCP can complement respective measurement in terms of the sensing range and spatial resolution.

For monitoring the sea ice dynamics, two SAMS buoys were installed on two ice stations (St. 17 and St. 26). The thermometer chain was lowered through a hole in sea ice to monitor the heat flux at the sea-ice-air interface.

1.3 Preliminary results

1.3.1 Water mass classification

Potential temperature (θ)-salinity (T) diagram shows that the Amundsen Sea has three distinct water masses: (1) CDW; (2) Modified CDW (MCDW); and (3) Antarctic Surface Water (AASW) (Fig. 1.2). CDW has much higher temperature, salinity than AASW, but the dissolved oxygen was depleted in CDW.

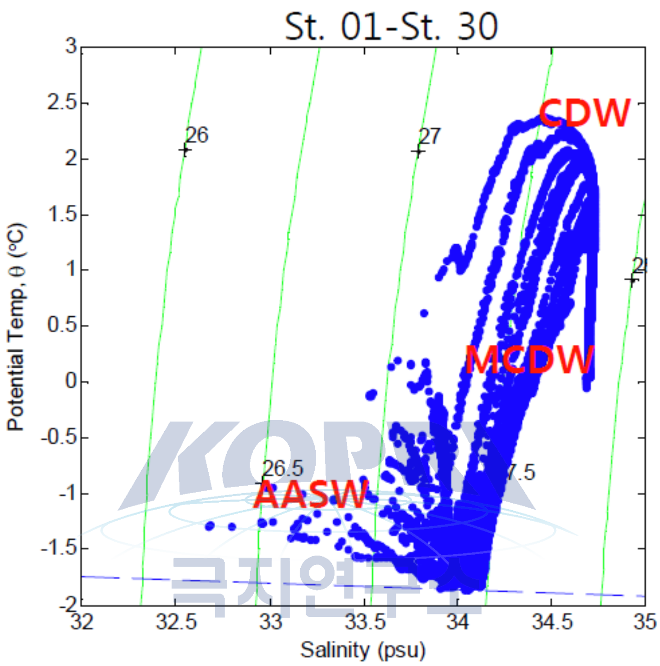

Figure 1.2: θ-S diagram for all data collected from St. 1 to St. 30. The blue dashed line indicates the freezing point, and the green lines are isopycnals. Three water masses were classified: CDW: Circumpolar Deep Water; MCDW: Modified Circumpolar Deep Water; AASW: Antarctic Surface Water.

1.3.2 Spatial distribution of CDW

During the expedition, a total of 30 CTD stations were occupied. The major axis of transect (T-1) is along the western trough in the Amundsen Shelf. In general, the warm CDW occupied a large volume off the continental slope. As it was transported onto the continental shelf, it was modified (i.e., cooled and freshened) to be MCDW by interacting with AASW (Fig. 1.3). In some stations covered by sea ice, the surface temperature was lower than other open areas. In the polynya (e.g., St. 9 and St. 10), the surface temperature was in the neighborhood of -0.8˜-0.4°C.

Two cross-transects (T-2 and T-3) clearly showed the intrusion tongue of warm CDW (Figs. 1.4 and 1.5). The existence of warm, dense water suggests that the trough geomorphology plays an important role in confining the flow

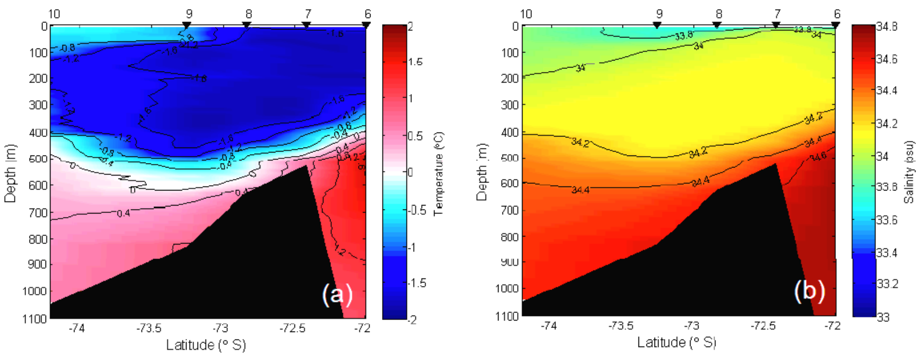

Figure 1.3: Spatial distribution of (a) temperature and (b) salinity along the trough (T-1). The triangles are the CTD stations with associated numbers (see Fig. 1.1).

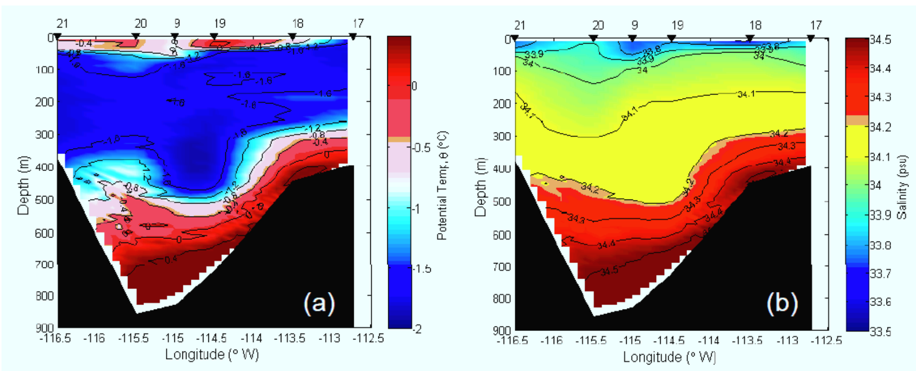

Figure 1.4: Spatial distribution of (a) temperature and (b) salinity cross the trough (T-2). The triangles are the CTD stations with associated numbers (see Fig. 1.1).

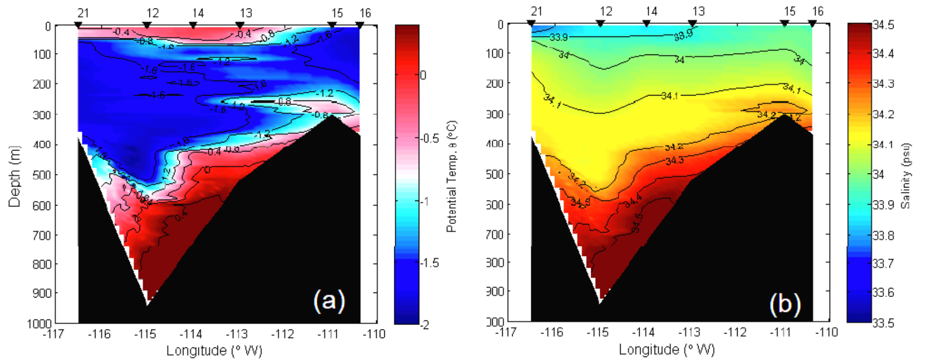

Figure 1.5: Spatial distribution of (a) temperature and (b) salinity cross the trough (T-3). The triangles are the CTD stations with associated numbers (see Fig. 1.1).

pattern of CDW within shelf areas. It is noticeable that a warm tongue was extended over the eastern flank of the trough, and that the eastern slope is slightly gentler than the western slope. At this time, it is not clear where this warm water on the eastern flank comes from, but it might be attributed to the branch of CDW flooded from the eastern trough. In tandem with hydrographic structures presented here, the data set of SADCP and LADCP recorded at each station can help clarify the magnitude and direction of flow near the eastern flank, and thus the complicated pathways of CDW will be understood. It was found that the cold core is located at the depth of 400 m of St. 9 and St. 19. The potential temperature is about -1.8°C.

Interestingly, the subsurface temperature maxima were found at the depths of 120 m and 260 m. Compared with overlying and underlying water column, the temperature increased 0.5~1°C. In addition, the dissolved oxygen profile clearly showed the abrupt decrease at the same depths. The interleaving of warm water mass with less oxygen was found only at the eastern part of trough (especially, St. 13 and St. 14). This suggests that a different water mass was transported into the upper mixed layer. The reason why the eastern part of channel has the interleaving structure should be further investigated. The distribution of biochemical tracer (e.g., nutrient, isotope) can provide a clue about the transport of warm water in the upper water column.

References

Jenkins, A., Dutrieux, P., Jacobs, S.S., McPhail, S.D., Perrett, J.R., Webb, A.T. and White, D., (2010) Observations beneath Pine Island Glacier in West Antarctica and implications for its retreat. Nature Geoscience, 3, 468-472.

Vaughan, D.G., (2008) West Antarctic Ice Sheet collapse-the fall and rise of a paradigm. Climate Change, 91, 65-79.

Wahlin, A.K., Yuan, X., Bjork, G. and Nohr, C., (2010) Inflow of warm circumpolar deep water in the central Amundsen Shelf. Journal of Physical Oceanography, 40, 1427- 1434.

Walker, D.P., Brandon, M.A., Jenkins, A., Allen, J.T., Dowdeswell, J.A. and

Evans, J., (2007) Oceanic heat transport onto the Amundsen Sea shelf through a submarine glacial trough. Geophysical Research Letters, 37(L02602), doi: 10.1029/2006GL028154.

Appendix: Daily Cruise Log (ANA01C)

See the following pages.

Scientific Cruise Daily Log

Ship: R/V Araon **Cruise:** ANA01 **Leg:** C

Prepared by H.K. Ha (KOPRI) ha@kopri.re.kr

STN No.	Gear	Cast No.	Date (UTC)	Cast start (UTC)	Bottom or at depth (UTC)	Cast end (UTC)	Latitude	Longitude	Water depth (m)	Cast depth (m)	Cable payout (m)	No. of spl. depth Core length	Wind speed knot	Wind direction (°)	Ship speed knot	Heading (°)	Remarks	Device Driver
										Amundsen Sea								
CTD: CTD; ZOO: Zooplankton; PHY: Phytoplankton; BON: Bongo net; MOC: Mocness; MUC: multi-core; BOX: Box core; GVC: gravity core; PSC: piston core; ICE: work on sea-ice; IBY: ice buoy; OBY: ocean buoy; SUF: surface water; OCL: ocean color																		
	OCL	1	12-22-2010	15:45		16:10	63°32.16'S	65°22.95'W	2846	7							HPRO II, water sample	HC Kim
	OCL	2	12-23-2010	16:00		16:10	63°50.95'S	76°09.23'W	4033	7							Only water sample (2m, 7m)	HC Kim
	OCL	3	12-24-2010	16:01		16:11	63°50.88'S	86°36.96'W	4667	7							HPRO II, HR4000, water sample	HC Kim
	OCL	4	12-25-2010	16:00		16:10	63°53.86'S	97°45.98'W	4883	7			8.2	138	1.2	194	HPRO II	HC Kim
1	OCL	1	12-26-2010	17:00		17:10				20			7.1	183	0.5	265	HPRO II	HC Kim
1	PHY	1	12-26-2010	18:52		19:05				150		2					20 micron mesh	EJ Yang
1	ZOO	1	12-26-2010	19:17		19:34				200		1					200 micron mesh	DB Lee
1	OCL	2	12-26-2010	19:00		19:10	63°59.97'S	108°59.98'W	4996	30							HPRO II	HC Kim
1	CTD	1	12-26-2010	20:40		1:36	63°59.48'S	108°59.23'W	4990	4500		24	6	215	22.5	0.2	Winch problem during upcasting; Fluoscence meter malfunctioned (negative values)	HK Ha
1	CTD	2	12-27-2010	3:43		3:58	64°01.31'S	108°52.61'W	4971	100		24					6th bottle not closed	HK Ha
1	BON	1	12-27-2010	4:00		4:22				180	400	2					2.5 kt toward St. 2	DB Lee
1	BON	2	12-27-2010	4:30		5:10				180	400	2					2.5 kt toward St. 2	DB Lee
2	CTD	1	12-27-2010	20:10		23:50	65°41.19'S	111°15.89'W	4838	4500		24	10	160	0.2	168	Fluoscence meter still malfunctioned (dual deployed)	HK Ha
2	OCL	1	12-27-2010	20:30		20:40	65°41.17'S	111°15.97'W	4839	30		1	5.5	135	0.7	272	HPRO II, water sample	HC Kim
2	PHY	1	12-28-2010	0:30		0:41	65°40.62'S	111°16.61'W	4839	150			9.3		1.7		20 micron mesh	EJ Yang
2	BON	1	12-28-2010	0:50		1:01				130	200				1.7		vertical towing, fast drifting (1.7 kt)	DB Lee
2	BON	2	12-28-2010	1:08		1:18				130	200				1.7		vertical towing, fast drifting (1.7 kt)	DB Lee
2	CTD	2	12-28-2010	1:51		2:21	65°39.08'S	111°20.01'W	4848	100		24	9.1	145	0.5	178	Seasave upgraded from 7.19 to 7.219	HK Ha
2.5	OCL	1	12-28-2010	19:30		19:40	68°42.64'S	115°11.18'W	4557	70		2					HPRO II, water sample	HC Kim
2.5	PHY	1	12-28-2010	19:52		20:02	67°42.33'S	115°12.51'W	4532	150	150		6	280	0	214	20 micron mesh	DB Lee
3	OBY	1	12-28-2010	21:50													1st Satlink buoy with echosounder deployed	DH Kang
3	CTD	1	12-28-2010	22:14		22:32	67°52.27'S	115°29.15'W	4482	300		0	6.2	215	1.4	109	First casting failed due to winch problem, the second cast overwrite the first; Old CTD sensor used; No water sa	
4	CTD	1	12-29-2010	3:39		6:26	68°28.38'S	116°44.15'W	4000	3700		24	7.8	183	0.1	210	Bottle fire control not configured, so two separated files (up & down casting) were made: F	HK Ha
4	OCL	1	12-29-2010	6:30		6:40	68°26.93'S	116°44.70'W		70		4					HPRO II, water sample	HC Kim
4	PHY	1	12-29-2010	6:50		7:01	68°27.86'S	116°44.29'W	4007	150	150		5.9		1.3		20 micron mesh	EJ Yang
4	BON	1	12-29-2010	7:09		7:21				130	200						vertical towing	DB Lee
4	BON	2	12-29-2010	7:26		7:36				140	200						vertical towing	DB Lee
4	CTD	2	12-29-2010	8:52		9:14	68°26.43'S	116°46.75'W	4015	300		24					The second (shallow casting)'s filename: 04CTD3	HK Ha
5	CTD	1	12-29-2010	22:22		0:44	70°00.11'S	120°01.26'W	2920	2700		24	12	110	0.4	150		HK Ha
5	OCL	1	12-29-2010	1:00		1:10				100		4					HPRO II, water sample	HC Kim
5	PHY	1	12-30-2010	1:16		1:24				150	150						20 micron mesh	EJ Yang
5	BON	1	12-30-2010	1:32		1:42				130	200						vertical towing	DB Lee
5	BON	2	12-30-2010	1:48		1:58				130	200						vertical towing	DB Lee
5	CTD	2	12-30-2010	2:26		2:47	69°58.87'S	120°10.79'W	2700	150		24	12.1	138	1.2	9		HK Ha
6	CTD	1	12-30-2010	21:27		23:01	71°57.13'S	119°07.50'W	1451	1435		24	8	131	0.2	359	Only deep casting (no shallow)	HK Ha
6	OCL	1	12-30-2010	21:40		21:50				65		4					HPRO II, water sample	HC Kim
6	PHY	1	12-30-2010	23:19		23:30				150	150						20 micron mesh	EJ Yang
6	BON	1	12-31-2010	0:00		0:07				130	200						vertical towing	DB Lee
6	BON	2	12-31-2010	0:20		0:27	71°56.63'S	119°11.39'W	1520	130	200						vertical towing	DB Lee
7	CTD	1	12-31-2010	6:47		7:41	72°24.87'S	117°41.37'W	530	500		24	9.2	131	0.1	132		HK Ha
7	OCL	1	12-31-2010	8:00		8:10				55		3					HPRO II, water sample	HC Kim
7	BON	1	12-31-2010	8:10		8:18											vertical towing	EJ Yang
7	BON	2	12-31-2010	8:23		8:30											vertical towing	DB Lee
7	PHY	1	12-31-2010	8:39		8:46	72°24.84'S	117°41.52'W	536				11.6		0.9		20 micron mesh	DB Lee
7	CTD	2	12-31-2010	9:13		9:28	72°24.57'S	117°43.76'W	530	100		24	9.9	145	0	317		HK Ha
7	OBY	1	12-31-2010	10:47		12:06	72°24.08'S	117°45.66'W	530								1st sediment trap deployed (2 MicroCats + 2 RCMs); Ending GPS: 72°24.16'S, 117°43.34	DH Kang
8	CTD	1	12-31-2010	17:55		18:40	72°49.99'S	116°28.81'W	630	610		24	14.7	125	1.5	330	Only deep casting (no shallow)	HK Ha
8	OCL	1	12-31-2010	18:45		18:55			45			4					HPRO II, water sample	HC Kim
8	PHY	1	12-31-2010	19:20		19:27	72°50.07'S	116°25.73'W	651	150			8.7		0.4		20 micron mesh	EJ Yang
8	BON	1	12-31-2010	19:37		19:44				200							vertical towing	DB Lee
8	BON	2	12-31-2010	19:49		20:10				200							vertical towing	DB Lee
8	ICE	1	12-31-2010	20:20													Collect the floating ice	EJ Yang
9	CTD	1	1-1-2011	3:10		4:04	73°15.00'S	114°59.98'W	830	810		24	13	130			Altimeter 8 m	CS Hong
9	OCL	1	1-1-2011	4:10		4:20				35		3					HPRO II, water sample	HC Kim
9	PHY	1	1-1-2011	4:43		4:40			825	150			11.5		0.1		20 micron mesh	EJ Yang
9	BON	1	1-1-2011	4:50		5:00				160							vertial towing	DB Lee
9	CTD	2	1-1-2011	5:20		5:30	73°14.86'S	115°00.57'W	825	100		24						CS Hong
9	BON	2	1-1-2011	5:44		6:05				210							oblique towing	DB Lee
9	OBY	1	1-1-2011	8:04			73°16.31'S	114°58.19'W	830								2nd sediment rap deployed (1 Microcat)	DH Kang
10	AWS	1	1-1-2011	18:00			74°21.42'S	111°22.14'W									Bear Penninsula; Dispatch AWS team by heli	TJ Choi
10	OBY	1	1-1-2011	21:05			74°12.40'S	112°29.77'W	1050	0-400		24	9.7	164	0	198	Floating trap buoy deployed with 2nd Saltlink buoy	DH Kang

Scientific Cruise Daily Log

Ship: R/V Araon **Cruise:** ANA01 **Leg:** C

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Amundsen Sea

CTD: CTD; **ZOO**: Zooplankton; **PHY**: Phytoplankton; **BON**: Bongo net; **MOC**: Mocness; **MUC**: multi-core; **BOX**: Box core; **GVC**; gravity core; **PSC**: piston core; **ICE**: work on sea-ice; **IBY**: ice buoy; **OBY**: ocean buoy; **SUF**: surface water; **OCL**: ocean color

STN No.	Gear	Cast No.	Date (UTC)	Cast start (UTC)	Bottom or at depth (UTC)	Cast end (UTC)	Latitude	Longitude	Water depth (m)	Cast depth (m)	Cable payout (m)	No. of spl. depth Core length	Wind speed knot	Wind direction (°)	Ship speed knot	Heading (°)	Remarks	Device Driver
10	CTD	1	1-1-2011	21:27		22:41	74°12.40'S	112°29.77'W	1050	1040							Altimeter 3.5 m	HK Ha
10	PHY	1	1-1-2011	22:52		23:01												EJ Yang
10	BON	1	1-1-2011	23:05		23:23											vertical towing	DB Lee
10	OCL	1	1-1-2011	23:30		23:40				45		3					HPRO II, water sample	HC Kim
10	CTD	2	1-2-2011	0:03		0:20	74°12.38'S	112°29.86'W	1050	100		24	8.5	186	0	195		HK Ha
10	AWS	2	1-2-2011	0:15													Dispatch heli for picking up AWS team	SH Lee
10	BON	2	1-2-2011	2:35		2:59											oblique towing	DB Lee
10	ACS	1	1-2-2011	3:08		16:00											Ship speed at 6 kt for EK60 Krill monitoring(st.10-11); Bongo oblique towing (09:19-09:39)	DH Kang
11	CTD	1	1-2-2011	16:05		17:14	74°04.82'S	115°43.49'W	1060	1056		24	5.9	206	0.2	191	Altimeter 4.7 m (only deep casting)	HK Ha
11	OCL	1	1-2-2011	17:25		17:40				72		4					HPRO II, water sample	HC Kim
11	BON	1	1-2-2011	17:48		18:00	74°04.79'S	115°43.56'W	1070	140			6.7		1.2		vertical towing	DB Lee
11	PHY	1	1-2-2011	18:11		18:21				150							20 micron mesh	EJ Yang
11	BON	2	1-2-2011	18:30		18:52				220							oblique towing	DB Lee
12	CTD	1	1-2-2011	22:25		23:39	73°30.00S	115°00.03'W	942	937		24	1.9	260	0	342	Only deep casting	HK Ha
13	CTD	1	1-3-2011	4:05		4:46	73°29.97'S	113°00.15'W	523	518		24	11.4	142	0.1	170	First casting failed; LADCP was exposed to the air between first and second;	HK Ha
13	CTD	2	1-3-2011	5:56		6:20				485		24	12	138	0.1	145		HK Ha
13	CTD	3	1-3-2011	7:25		7:54	73°30.01'S	112°59.99'W	536	500		24						HK Ha
13	CTD	4	1-3-2011	9:36		10:10	73°30.01'S	112°59.99'W	533	500		24	11	130			Altimeter 22 m	HK Ha
13	OCL	1	1-3-2011	10:25		10:35				24								HC Kim
13	BON	1	1-3-2011	11:03		11:16				200							vertical towing	DB Lee
13	BON	2	1-3-2011	11:22		11:36				200							vertical towing	DB Lee
13	CTD	5	1-3-2011	12:00		12:31			538	500		24	10	123				HK Ha
13	CTD	6	1-3-2011	13:32		14:02			534	500		24	10	125	0	148		HK Ha
13	CTD	7	1-3-2011	15:29		15:52			535	500		24						HK Ha
13	CTD	8	1-3-2011	17:31		17:58	73°30.00'S	113°01.93'W	530	500		24						HK Ha
13	BOX	1																
13	CTD	9	1-3-2011	19:36		20:06	73°29.59'S	113°01.93'W	535	500		24	11	136			Altimeter 22 m	HK Ha
13	CTD	10	1-3-2011	21:38		22:09			534	500		24	12	133				HK Ha
13	OCL	1	1-3-2011	22:40		22:50				25		4					HPRO II, water sample	HC Kim
13	BON	3	1-3-2011	22:37		22:50				200							vertical towing	DB Lee
13	BON	4	1-3-2011	22:57		23:06				200							vertical towing	DB Lee
13	CTD	11	1-3-2011	23:34		0:04	73°29.46'S	113°02.50'W	539	500		24	9.5	130				HK Ha
13	CTD	12	1-4-2011	1:35		1:57			540	500		24						HK Ha
14	CTD	1	1-4-2011	3:57		4:37	73°30.00'S	113°59.96'W	728	706		24	3.6	117	0.1	137	Only deep casting, Altimeter 4.7	HK Ha
15	CTD	1	1-4-2011	9:50		10:15	73°15.05'S	111°00.10'W	303	294		24	2.6	141	0	133		HK Ha
16	CTD	1	1-4-2011	12:56		13:26	73°29.46'S	113°02.50'W	370	363		24	3	159	0	284	Ice #1, but conditions were not good for landing	HK Ha
17	CTD	1	1-4-2011	23:55		0:42	72°31.68'S	112°43.60'W	398	385							Ice #1 station	HK Ha
17	OCL	1	1-5-2011	4:30		5:00				140		3					HPRO II, ice water sample (3), ice core (4)	HC Kim
17	IBY	1	1-5-2011	3:50			72°31.59'S	112°44.03'W									SAMS Buoy (IMB 15)	HK Ha
17	ICE		1-5-2011														Ice core (10)	EJ Yang
17	ACS		1-5-2011														Acoustic survey for biomass distribution, trap installed for 12 hr observation	DH Kang
18	CTD	1	1-6-2011	0:12		0:57	72°59.59'S	113°29.99'W	448	440		24	5.9	255	0.7	199		HK Ha
18	OCL	1	1-6-2011	1:11		1:20				25		3					HPRO II, water sample	HC Kim
18	PHY	1	1-6-2011	1:21		1:32				150							vertical towing	EJ Yang
18	BON	1	1-6-2011	1:42		1:55				170							vertical towing	DB Lee
18	CTD	2	1-6-2011	2:15		2:38	72°59.59'S	113°29.91'W	447	200		24	5.9	265	1	104		HK Ha
18	BON	2	1-6-2011	2:50		3:06				230							oblique towing, Ship speed at 6kt at EK60 Krill monitoring(st. 18-21)	DB Lee
19	CTD	1	1-6-2011	6:36		7:17	73°10.00'S	114°29.98'W	727	708		24	7	245	0	240	Only deep casting	HK Ha
20	CTD	1	1-6-2011	11:02		11:59	73°20.00'S	115°29.94'W	857	839		24	6.5	257	0	261	Only deep casting	HK Ha
21	CTD	1	1-6-2011	15:35		16:04	73°30.00'S	116°30.00'W	376	368		24	5.8	275	0.1	244	Only deep casting	HK Ha
21	OCL	1	1-6-2011	16:23		16:40				21							HPRO II	HC Kim
21	PHY	1	1-6-2011	16:27		16:36				150							vertical towing	EJ Yang
21	BON	1	1-6-2011	16:44		16:55				170							vertical towing	DB Lee
21	BON	2	1-6-2011	17:09		17:31				180							oblique towing	DB Lee
22	CTD	1	1-7-2011	4:30		5:35	72°26.79'S	120°08.54'W	1360	1354		24	6.3	315	0	295	Only deep casting	HK Ha
22	OCL	1	1-7-2011	5:40		5:50				70							HPRO II	HC Kim
22	PHY	1	1-7-2011	5:59		6:08				150							vertical towing	EJ Yang
22	BON	1	1-7-2011	6:15		6:27				170							vertical towing	DB Lee
22	BON	2	1-7-2011	6:37		6:55				210							oblique towing, Ship speed at 6kt at EK60 Krill monitoring(st. 22-26),2 times of Bongo obli	DB Lee

Scientific Cruise Daily Log

Ship: R/V Araon **Cruise:** ANA01 **Leg:** C

Prepared by H.K. Ha (KOPRI) ha@kopri.re.kr

Amundsen Sea

CTD: CTD; **ZOO**: Zooplankton; **PHY**: Phytoplankton; **BON**: Bongo net; **MOC**: Mocness; **MUC**: multi-core; **BOX**: Box core; **GVC**; gravity core; **PSC**: piston core; **ICE**: work on sea-ice; **IBY**: ice buoy; **OBY**: ocean buoy; **SUF**: surface water; **OCL**: ocean color

STN No.	Gear	Cast No.	Date (UTC)	Cast start (UTC)	Bottom or at depth (UTC)	Cast end (UTC)	Latitude	Longitude	Water depth (m)	Cast depth (m)	Cable payout (m)	No. of spl. depth Core length	Wind speed knot	Wind direction (°)	Ship speed knot	Heading (°)	Remarks	Device Driver
23	CTD	1	1-7-2011	11:29		12:48	72°09.89'S	119°33.95'W	1299	1280		24	10	308	0	302	Only deep casting	HK Ha
24	CTD	1	1-7-2011	16:48		17:51	71°56.21'S	119°06.35'W	1450	1446		24	7.2	300	0.2	14	Only deep casting	HK Ha
25	CTD	1	1-8-2011	0:04		1:34	71°41.33'S	118°01.75'W	1255	1247		24	11.5	300	0	294	Only deep casting	HK Ha
25	OCL	1	1-8-2011	1:30		1:45				70							HPRO II, water sample	HC Kim
26	CTD	1	1-8-2011	7:22		8:31	71°33.54'S	117°04.95'W	1364	1352		24	9.7	280	0.2	267	Ice #2 station	HK Ha
26	OCL	1	1-8-2011	8:40		8:50				100							HPRO II, no water sample	HC Kim
26	BON	1	1-8-2011	8:58		9:06				170								DB Lee
26	BON	2	1-8-2011	9:11		9:19				170								DB Lee
26	PHY	1	1-8-2011	9:30		9:39				150								EJ Yang
26	IBY	1	1-8-2011	23:47													2nd SAMS buoy installed	HK Ha
26	OCL	2	1-9-2011	23:25		23:40				150							Sea ice	HC Kim
26	OCL	3	1-10-2011	17:20		17:30				70							Sea ice	HC Kim
27	CTD	1	1-11-2011	7:10		8:21	69°00.00'S	120°29.99'W	1140	1100		24	11	75	0	71		HK Ha
27	BON	1	1-11-2011	8:33		8:40				165								DB Lee
27	BON	2	1-11-2011	8:45		8:53				165								DB Lee
27	PHY	1	1-11-2011	8:59		9:10				150								EJ Yang
27	OCL	1	1-11-2011	9:30		9:45				103							HPRO II, no water sample	HC Kim
27	CTD	2	1-11-2011	9:39		9:52	69°00.25'S	120°30.85'W	4148	100		24						HK Ha
28	CTD	1	1-11-2011	16:14		17:04	67°59.99'S	120°00.05'W	4240	4280		24	9.5	65	0.1	91	Seasave stopped twice during casting, so three files should be merged; SBP depth is shal	HK Ha
28	BON	1	1-11-2011	19:29		19:36				170								DB Lee
28	BON	2	1-11-2011	19:40		19:48				170								DB Lee
28	PHY	1	1-11-2011	19:57		20:05				150								EJ Yang
28	OCL	1	1-11-2011	20:20		20:40				70							HPRO II, no water sample	HC Kim
29	CTD	1	1-12-2011	2:54		6:05	67°00.04'S	120°00.05'W	4520	4510		24	9.3	39	0	38		HK Ha
29	PHY	1	1-12-2011	6:15		6:23				150								EJ Yang
29	BON	1	1-12-2011	6:30		6:35				160								DB Lee
29	OCL	1	1-12-2011	6:55		7:10				110							HPRO II, no water sample	HC Kim
29	CTD	2	1-12-2011	7:08		7:24			4460	150		24						HK Ha
29	BON	2	1-12-2011	7:35		8:00				200								DB Lee
29	OBY	1	1-12-2011	8:30			67°00.39'S	120°00.64'W	4460								3rd Satlink buoy deployed	DH Kang
30	CTD	1	1-13-2011	16:10		19:39	64°54.67'S	131°15.96'W	4810	4800		24	7.5	34	0.1	34		HK Ha
30	BON	1	1-13-2011	19:48		19:57				165								DB Lee
30	BON	2	1-13-2011	20:02		20:08				165								DB Lee
30	PHY	1	1-13-2011	20:14		20:20				150								EJ Yang
30	OCL	1	1-13-2011	20:48		21:05				70		3					HPRO II, water sample	HC Kim
30	CTD	2	1-13-2011	21:06		21:23			4762	150		24						HK Ha
30	OBY	1	1-13-2011	21:30			64°54.32'S	131°15.88'W	4760								4th Satlink buoy deployed	DH Kang

Chapter 2

A long duration mooring for the observation of ocean current and sediment on continental shelf in the Amundsen Sea

2.1 current meter mooring

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요약문

2010년 12월 31일과 2011년 1월 1일, 아문젠해 대륙붕 해역2개 정점에서 해류계와 수온/염분측정기를 2 개 수심 (200m 층, 400m 층)에, 퇴적물 수집기는 400m 층에 설치하였다. 설치된 해류계와 수온/염분측정기는 1 년 혹은 그 이상의 장기간 동안 1 시간 간격으로 유향과 유속, 그리고 수온과 염분 및 수압을 기록하며, 선상에서 음향신호를 보내면 계류선 하부에 있는 음향분리기가 추와 분리되면서 설치된 장비들을 회수할 수 있다. 장기간 동안의 해류와 수온/염분 변화의 시계열 자료를 얻는데 성공한다면 아문젠해 대륙붕 해역으로 유입되는 남극순환심층수 (CDW) 의 특성과 결빙 해역에서 해수순환이 sea ice 를 녹이는 역할을 연구하는데 도움이 될 것으로 기대한다.

Objectives

To study of the characteristic of Circumpolar Deep Water (CDW) intruding along trough on continental shelf in the Amundsen Sea and the role of CDW circulation melts a sea ice in freezing area, and to collect long-term time series data, mooring was deployed during 1 year or more at 2 sites.

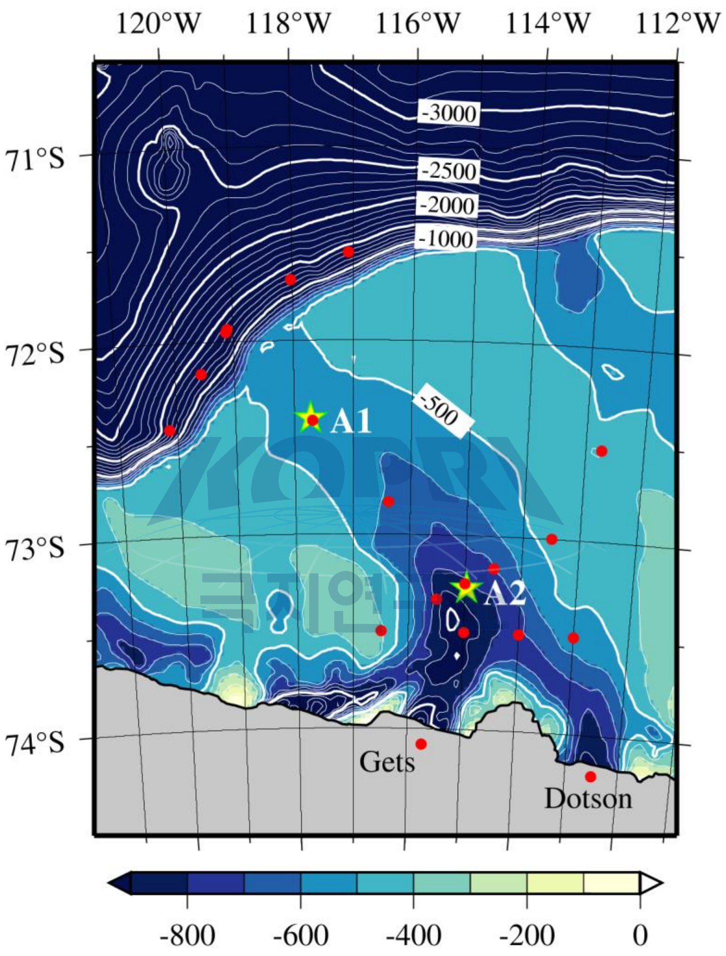

Figure 2.1: Location of 2 mooring sites (yellow stars) and CTD stations (red circles) during ANA01C in December 2010 and January 2011. Background is bottom topography (Nitsche et al. 2007).

Table 2.1: Location of anchor drop at 2 mooring sites

Station Name	Latitude (S)	Longitude (W)	Depth (m)	Date (YYYY/MM/DD)	Time (UTC)	CTD Station
A1	72° 24.163′	117° 43.341′	530	2010/12/31	12:06	7
A2	73° 16.28′	114° 58.23′	830	2011/01/01	08:00	9

Table 2.2: Information of Benthos acoustic releases

Model	Serial number	Frequency (kHz)		Command code		Mooring station
		Receive	Transmit	Enable	Release	
865-A-DB-13	839	9.5	12.0	A	B	A1
865-A-DB-13	840	9.5	12.0	C	D	A1
865-A-DB-13	841	9.5	12.0	E	F	A2
865-A-DB-13	842	9.5	12.0	G	H	A2

Work at sea and preliminary results

A long-term mooring that was deployed at 2 stations of trough and polynya area on continental shelf in the Amundsen Sea from December 31, 2010 to January 1, 2011 (Table 2.1, Figure 2.1) . The top of 2 moorings is the 3-ball glasses subsurface buoy with a flasher and RF- transmitter to search the buoy usefully in darkness and that is installed at depth about 230-250m (Figure 2.2 and 2.3). Mooring line is almost constructed with 8-millimeter steel cable jacketed a plastic to be protected from corrosion. 2 moorings are equipped with double Benthos acoustic releases to be safely recovered (Table 2.2). To observe during 1 year and over, 4 acoustic releases are used double lithium battery pack for 2 years made in Korea. Each mooring includes two acoustic current meters of Aanderaa which use Doppler backscatter measurement techniques, one or two conductivity, temperature and depth recorder (CTD) of Sea-Bird for mooring and one sediment trap (Figure 2.2 and2.3). Current meters and CTDs on the mooring are configured to record in memory at 1 hour intervals on time (Table 2.3, 2.4, and 2.5).

2.2 Sediment Trap

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요약 문

남극 아문젠해에서 유기탄소, 탄산칼슘, 생기원규소 연간 플러스를 알아보기 위해 폴리냐 외부 대륙사면 지역과 폴리냐 지역에 sediment trap 을 설치하였

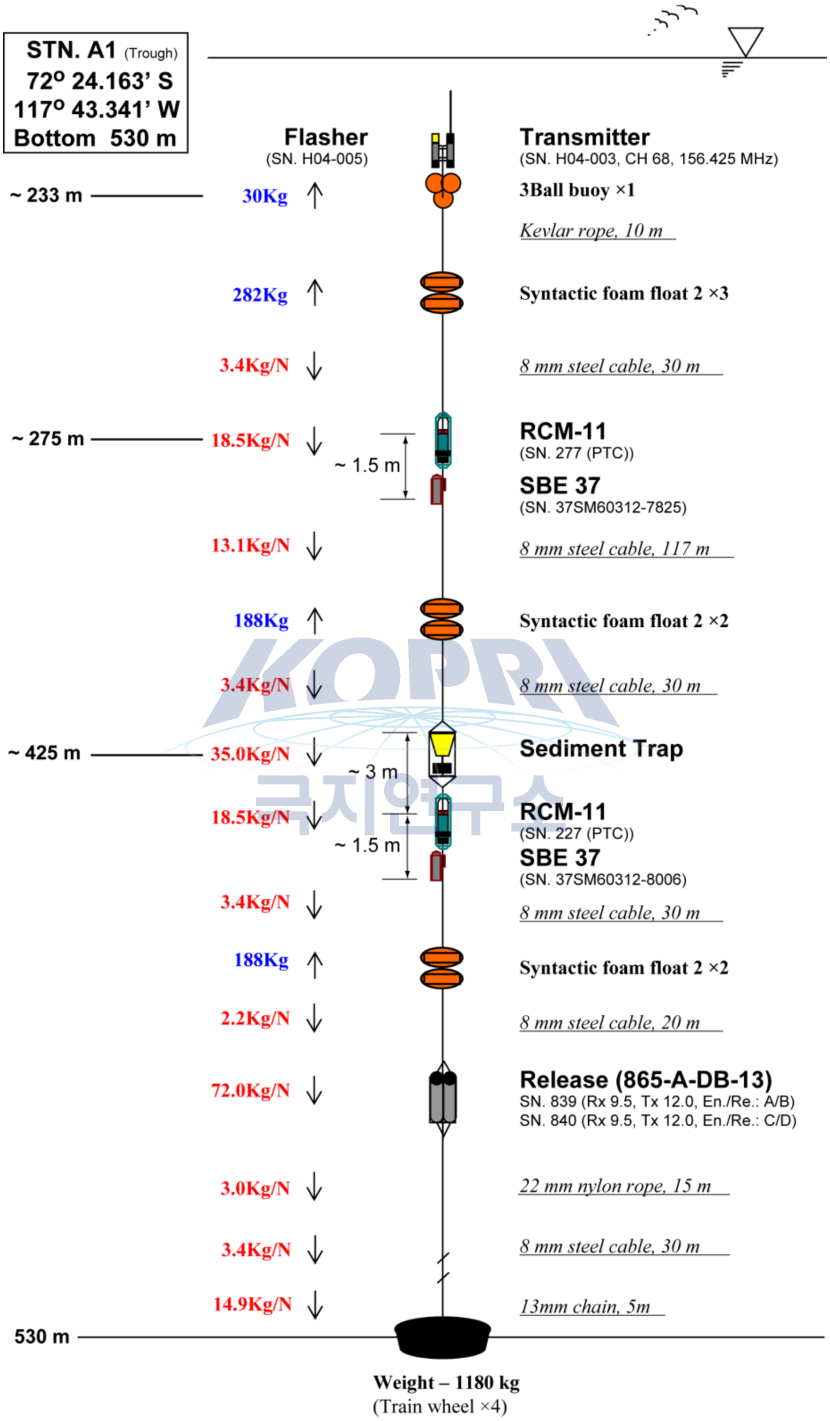

Figure 2.2: Mooring configuration at station of A1 (trough site).

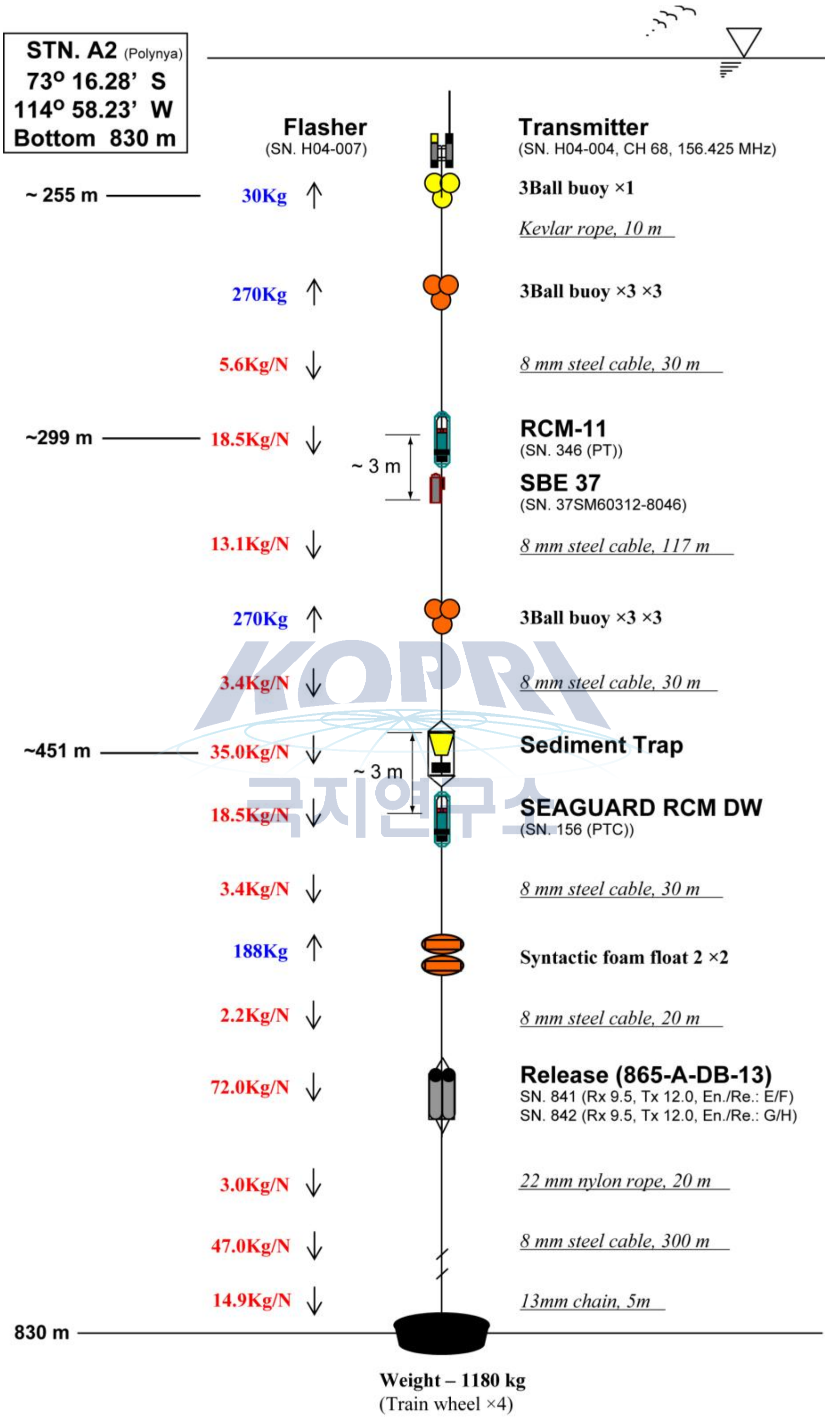

Figure 2.3: Mooring configuration at station of A2 (polynya site).

Table 2.3: Information of Aanderaa current meters (D:Direction, S:Speed, P:Pressure, T:Temperature, C:Conductivity, e:etc., CH:Channel; Arctic temperature mode range : - 3.01~5.92 deg.C)

Model	Serial number	Recording data						Press. range (m)	Temp. mode	CH	Ping mode	Sta.
		D	S	P	T	C	e					
RCM-11	277	•	•	•	•	•		2000	Arctic	6	Burst (600 pings)	A1
RCM-11	227	•	•	•	•	•		3500	Arctic	8	Burst (600 pings)	A1
RCM-11	346	•	•	•	•			6000	Arctic	6	Burst (600 pings)	A2
SEAGUARD RCM DW	156	•	•	•		•	•	6000	-	-	Burst (600 pings)	A2

Table 2.4: Information of storage unit and start time of current meters

Model	Serial number	Storage unit (SN, Date)	Start (restart)		Recording check	Sta.
			Date	Time (UTC)		
RCM-11	277	DSU 2990E (15681, 2007/06/13)	2010/12/30	08:00	OK	A1
RCM-11	227	DSU 2990E (15685, 2007/06/13)	2010/12/30	08:00	OK	A1
RCM-11	346	DSU 2990E ()	2010/12/30 (2010/12/30)	08:00 (16:00)	OK	A2
SEAGUARD RCM DW	156	SanDisk SD card, 2GB	2010/12/30 (2010/12/31)	08:00 (01:00)	OK	A2

Table 2.5: Information of Sea-Bird CTDs for mooring (P:Pressure, T:Temperature, C:Conductivity)

Model	Serial number	Recording data			Press. range (m)	Start		Sta.
		P	T	C		Date	Time (UTC)	
SBE37	37SM60312-7825	•	•	•	1000	2010/12/31	02:00	A1
SBE37	37SM60312-8006	•	•	•	1000	2010/12/31	02:00	A1
SBE37	37SM60312-8046	•	•	•	3500	2010/12/31	22:00	A2

다. 아직까지 아문젠해에서 유기물질의 플럭스에 관한 연구가 이루어지지 않아 현재 결과를 예상하기 어렵다. 1 년 후 트랩을 회수 후 샘플을 얻고 재계류하여 장기간의 유기탄소, 탄산칼슘, 생기원규소 플럭를 조사할 예정이다.

Objectives

The sinking particles by primary production drive sequestration of organic matters from euphotic zone to deep sea. The flux of the organic matters sinking to depth (1) is a major control on the inventory of carbon in the ocean, (2) represents new production, and (3) regulates the removal through burial of bioactive elements from the ocean. This process, therefore, has an important influence on the chemical composition of the deep sea and on global biogeochemical cycles. Furthermore, the process also is important in understanding the global carbon cycle. There have been very few measurements of the flux of organic matters in the Amundsen Sea, Antarctic Ocean. The objective of this survey is to understand the flux of organic matters such as particulate organic carbon (POC), CaCO3 and biogenic silica in the Amundsen Sea, Antarctic Ocean.

Work at sea and preliminary results

The interesting items through the study are to observe the annual flux of the organic matters and the local differences of the flux of organic matters. For the purposes, two sediment traps (Mark 78G) were separately deployed at 400 m depth at continental slope outer polynya and polynya center. The sediment trap consists of 21 bottles (see Fig. 2.4), operating time interval of the each bottles was 9, 15, and 30 days during summer, spring/autumn, and winter seasons, respectively (see Table 2.6). After 1 year, the sediment trap will be recovered and analyzed to understand annual flux of organic matters in the Amundsen Sea, Antarctic Ocean.

Additionally, for measuring short-term flux of organic matters below the sea ice, a small trap was separately deployed at 100 m at two sea ice stations during 12 - 22 hours (see Fig. 2.5). In the nearly future, the samples obtained from sea ice stations will be analyzed to know short-term flux of organic matters below the sea ice.

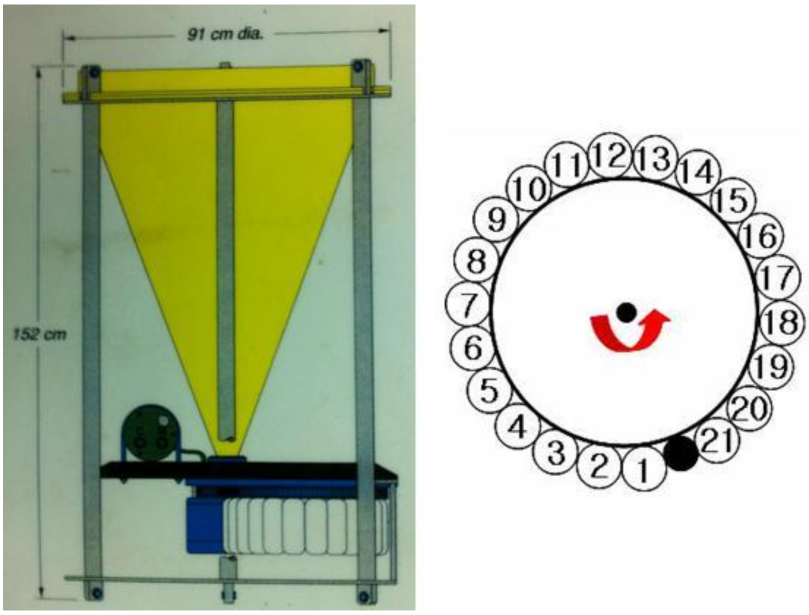

Figure 2.4: Sediment Trap schematic (model MARK 78G) and bottle rotation.

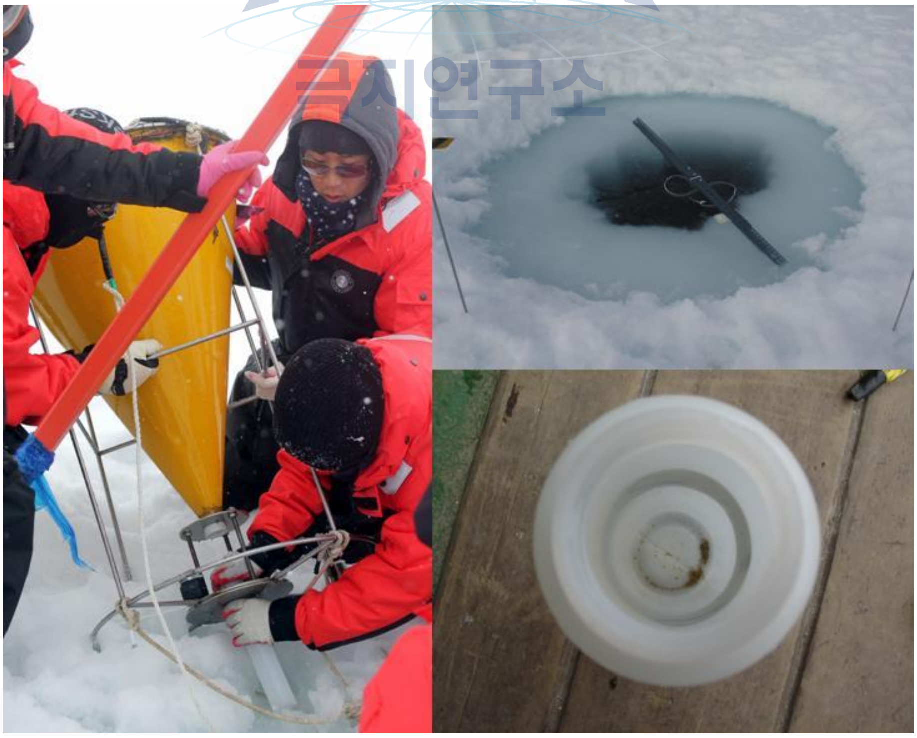

Figure 2.5: Deployment of small trap on the sea ice.

Table 2.6: Sediment trap time schedule.

St. 7	Date	St. 9	Date
1	2011.01.05 00:00:00	1	2011.01.14 00:00:00
2	2011.01.14 00:00:00	2	2011.01.23 00:00:00
3	2011.01.23 00:00:00	3	2011.02.01 00:00:00
4	2011.02.01 00:00:00	4	2011.02.10 00:00:00
5	2011.02.10 00:00:00	5	2011.02.19 00:00:00
6	2011.02.19 00:00:00	6	2011.03.01 00:00:00
7	2011.03.01 00:00:00	7	2011.03.16 00:00:00
8	2011.03.16 00:00:00	8	2011.04.01 00:00:00
9	2011.04.01 00:00:00	9	2011.05.01 00:00:00
10	2011.05.01 00:00:00	10	2011.06.01 00:00:00
11	2011.06.01 00:00:00	11	2011.07.01 00:00:00
12	2011.07.01 00:00:00	12	2011.08.01 00:00:00
13	2011.08.01 00:00:00	13	2011.09.01 00:00:00
14	2011.09.01 00:00:00	14	2011.10.01 00:00:00
15	2011.10.01 00:00:00	15	2011.11.01 00:00:00
16	2011.11.01 00:00:00	16	2011.11.16 00:00:00
17	2011.11.16 00:00:00	17	2011.12.01 00:00:00
18	2011.12.01 00:00:00	18	2011.12.10 00:00:00
19	2011.12.10 00:00:00	19	2011.12.19 00:00:00
20	2011.12.19 00:00:00	20	2011.12.28 00:00:00
21	2011.12.28 00:00:00	21	2012.01.06 00:00:00

Chapter 3

Inorganic Carbon System and Nutrients Survey

3.1 Inorganic carbon system observation

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요약문

총용존무기탄소 (Dissolved Inorganic Carbon; DIC), 총알칼리도 (Total Alkalinity; TA), pH, 용존이산화탄소 농도를 30 개 정점의 수층에서 채수한 400 여개 시료에서 분석하였다. DIC 는 인산을 이용하여 모두 이산화탄소로 산화시킨 후 이들 이산화탄소를 적정하는 쿨로메트릭 방법을 이용하였으며 TA 는 알고 있는 농도의 염산을 해수에 적정하여 적정점을 찾아 농도를 계산하였다. pH 는 분광법을 이용하여 분석하였으며 용존 이산화탄소는 니켈 촉매를 이용하여 메탄으로 환원시킨후 FID 로 분석하는 가스크로마토그래프를 이용하였다. 아문젠해에서 이제까지 이들 네 개의 무기탄소 인자를 분석하여 보고한 바는 없으며 이번 탐사에서 처음으로 수행하였다. 선상에서 관측된 초벌자료는 이제까지 해양에서 관측되는 전형적인 수직 분포 경향을 보여주었다.

Objectives

The Amundsen Sea has been spotlighted by the rapid melting of ice sheets in the region bounded along the coast. A body of scientific community suspects that the inflow of the circumpolar deep water to the shelf drives melting of the ice sheets (e.g., Jenkins et al., 2010). Retreat of ground line of ice sheet under the water supports this argument. Ice sheets would deliver trace metals and nutrients from the land to the sea, which will in turn stimulate biological activity in the sea, leading to absorbing atmospheric CO2 down to the sea floor. To understand the impact of melting ice sheets to the carbon flux in the water column of the Amundsen Sea, we investigated the inorganic carbon system, in particular focusing on the shelf region.

Table 3.1: Number of samples collected at the station for analyses of inorganic carbon system parameters

Station No.	DIC	TA	pH	CO_2
1	17	17	17	17
2	17	17	17	17
4	16	16	16	16
5	16	16	16	16
6	14	14	14	14
7	14	14	14	14
8	13	13	13	13
9	17	17	17	17
10	15	15	15	15
11	17	17	17	17
12	14	14	14	14
13	13	13	13	13
14	14	14	14	14
15	9	9	9	9
16	11	11	11	11
17	11	11	11	11
18	12	12	12	12
19	6	6	11	6
20	14	14	14	14
21	11	11	11	11
22	15	15	15	15
23	10	10	10	10
25	13	13	13	13
26	11	11	11	11
27	11	11	11	11
28	15	15	15	15
29	15	15	15	15
30	16	16	16	16
Total	377	377	382	377

Work at sea and preliminary results

Hydrographic survey was conducted in the Amundsen Sea by casting CTD/Rosette at 30 stations. The area covers the open ocean, sea-ice zone, and polynya. Inorganic carbon system was investigated by measuring dissolved CO2 (pCO2), pH, dissolved inorganic carbon (DIC), and total alkalinity (TA) in two dimensions, horizontal monitoring along the ship track and vertical profiling at the hydro-casting stations. pCO2 was measured using two different instruments: a non-dispersive infrared (NDIR) detecting system and a gas chromatographic system. The former was dedicated for measuring pCO2 underway whereas the latter was both for underway measurement and for analyzing discrete samples collected at the hydro-casting stations. Underway measurement of pCO2 was carried out by supplying uncontaminated seawater to a small Weiss-type equilibrator from which headspace air was delivered to the analytical system. For

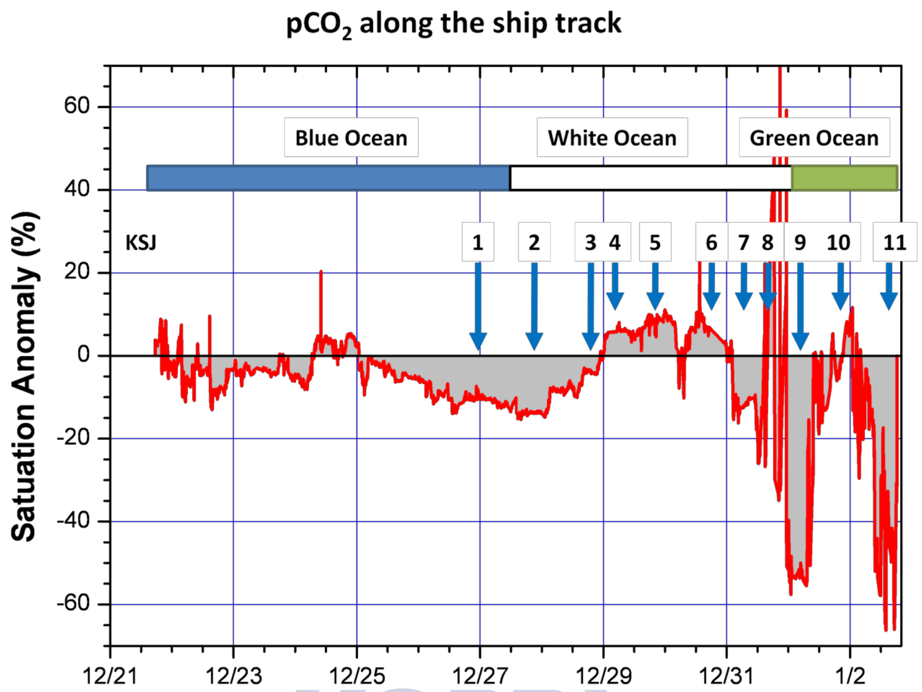

Figure 3.1: Saturation anomaly of pCO2 along the ship track

analyzing pCO2 in the seawater samples collected at the station, a specially designed glass bottle was used to avoid any contamination from the air during sampling and storage. Atmospheric CO2 in the marine boundary layer was also analyzed in a regular interval using the same instruments by pumping the ambient air. The pCO2 analyzing systems were calibrated using a series of standard gases. Dissolved inorganic carbon (DIC) was analyzed by coulometric titration using a system similar to SOMMA analyzer (Johnson et al., 1993). Total alkalinity (TA) was measured by potentiometric titration with HCl in an open cell. pH was determined using a spectrophotometric system which contains 1 m long cell measuring absorption at the wavelength of 400, 578, and 730 nm. The analytical system for DIC and TA was calibrated using a certified reference material provided by Andrew Dickson (Scripps Institution of Oceanography). To our knowledge, it is the first time to measure all inorganic carbon parameters at the same time in the Amundsen Sea. We will compare these 4 parameters in view of thermodynamic consistency in the nature. The number of samples collected at the hydro-casting stations is listed in Table 3.1.

The NDIR detecting system for pCO2 equips a streamline of software that provides the values in situ, while the gas chromatographic technique requires computation to determine pCO2 based on the calibration runs which were carried out between sample runs. Here we use preliminary data from the NDIR detecting system. In Figure 3.1 saturation anomaly against atmospheric concentration of CO2 are shown along the track. Positive values indicate supersaturation of CO2 with respect to the atmospheric CO2 above the seawater, thus emitting dissolved CO2 to the atmosphere and negative values for undersaturated surface seawater. In general, most of the surface seawaters along the cruse track until January 2, 2011 were undersaturated and act as a sink of atmospheric CO2. Supersaturated seawaters were encountered sea ice zone between the open ocean and polynya. This could be due to the recent retreat of sea ice in which dissolved CO2 would be trapped under the sea ice. Dissolved CO2 concentration appears to be extremely low in the polynya. In particular, the lowest value of dissolved CO2 was observed at the center of the polynya where large content of Chl-a was observed (personal commumication with E.J. Yang) Thus, biological pump seems to be the major factor controlling the sink strength of atmospheric CO2 in the polynya.

3.2 Nutrients suvey

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요약문

영양염류는 식물플랑크톤의 성장에 필수적인 요소로써 유광층 내의 영양염류 분포는 식물플랑크톤 종조성 및 분포에 영향을 미치는 제한 요소 (limitation factor)로 작용한다. 아문젠해 탐사기간 동안 모든 CTD 정점, 모든 채수 수심에서 영양염류 시료를 획득하여 영양염 자동 분석기 (Auto Analyzer)를 이용하여 규산염, 질산염+아질산염, 암모니아를 분석하였다. 모든 시료 분석은 채수 후 24 시간내에 이루어졌으며 추후 인산염 분석을 위하여 냉동 보관하였다. 이러한 영양염류 분석 결과는 아문젠해에서의 식물플랑크톤 분포를 이해하고 해석하는 화학인자로 쓰일 뿐 아니라 서로 다른 수괴의 혼합 및 분포를 해석하는 물리추적 인자로도 쓰일 수 있다.

Objectives

We investigate the spatial and temporal variations of the micro nutrients nitrate+nitrite, silicate, ammonium, and phosphate, through the contrasting oceanic regions along the cruise track between the King George Islands and New Zealand, especially focused on Amundsen Sea. These results will be use to understand the physical and chemical structures of the water columns.

Work at sea and preliminary results

Samples for dissolved inorganic nutrients were collected from the continuous underway pumping system and the CTD rosette in every station and placed in 50ml bottles and immediately stored in the fridge until analysis. The samples were analyzed with standard colorimetric methods using a Quatro AA (Auto Analyzer). The manifold layouts are illustrated in Figure 3.2.

The surface distributions of the three dissolved inorganic nutrients (nitrate+nitrite, ammonium, silicate) are shown in Figure 3.3. Dissolved inorganic nitrate+nitrite concentrations tend to decreased in the polynya stations. In contrast, higher silicate concentrations show in the polynya stations. Dissolved inorganic ammonium concentrations remained low throughout the region and some stations concentrations were found to be just above the level of detection.

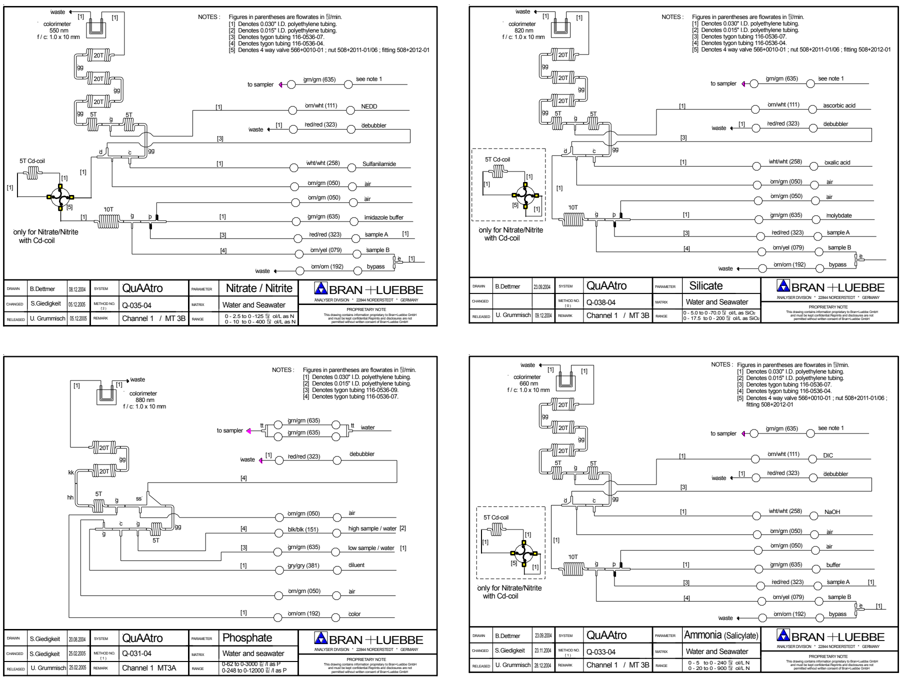

Figure 3.2: The manifold layout and flow chart of nutrient channels

As depth increased, the concentrations of nitrate+nitrite and silicate were increased, but Ammonium concentrations were highest around 50 to 100m. The vertical nutrients distribution indicate the mixing of different water masses in particular stations (see Figure 3.4).

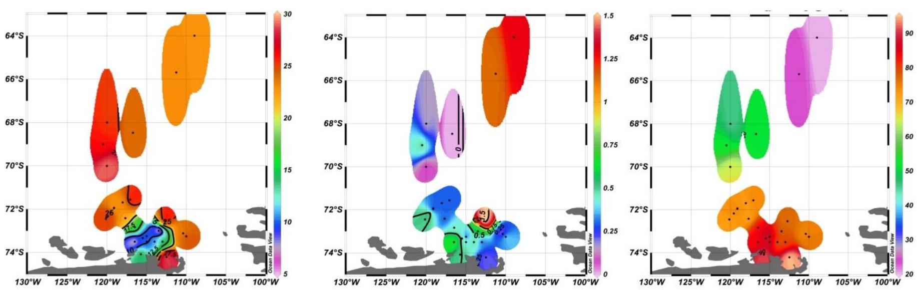

Figure 3.3: Surface distribution of dissolved inorganic nitrate+nitrite (left), ammonium (center), silicate (right)

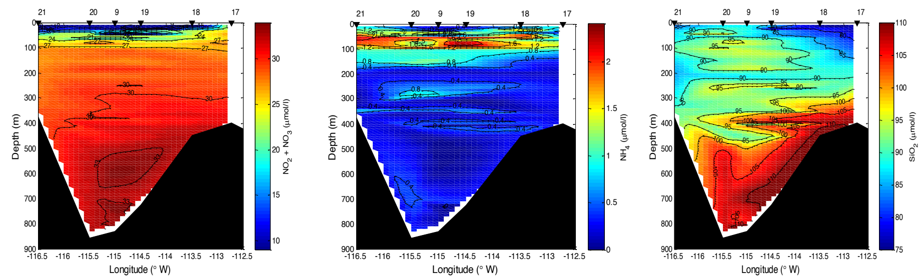

Figure 3.4: Vertical distribution of dissolved inorganic nitrate+nitrite (left), ammonium (center), silicate (right) along station 17 to 21 transect.

Chapter 4

Observation of Dissolved Gases

4.1 Water sampling for the measurement of noble gases

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Work at sea

The noble gases, especially helium isotopes (3He and 4He) in conjunction with tritium (3H), have been widely used to trace water mass movement due to their conservative behavior in the environment and to give time constraints (i.e., 3H-3He age) on physical and biological processes in the ocean (e.g., Jenkins, 2008). Another interesting application is to detect ice-related processes using their different partitioning behavior in water, sea-ice and glacier (e.g., Huhn et al., 2008). The hydrography of the Amundsen Sea is supposed to be in substantial change due to rapid loss of glacier ice sheet and sea-ice, occurring around the west Antarctica. Given the high resolving power of noble gases for ice-related processes, they will provide invaluable information on the influence of glacier and sea-ice loss of this area on the changes of its hydrography and, in turn, biological processes.

With the following two aims: (1) to quantify the input of glacial and sea-ice meltwater to the Amundsen Sea and (2) to determine the extend of such water masses along the trough that leads to the open ocean, water samples for noble gases were collected at 11 selected stations (red bull's eyes in Fig. 4.1) among the 30 stations covered during the cruise. We targeted the mouths of the glacier drainages in the Amundsen Sea such as Dotson (#10) and Getz (#11) to quantify the glacial meltwater input. Additionally, we collected water along the trough (#6 to #9) and sea-ice stations (#16, 17 and 26). We collected total 126 samples, including #1 and #4 not shown on the map.

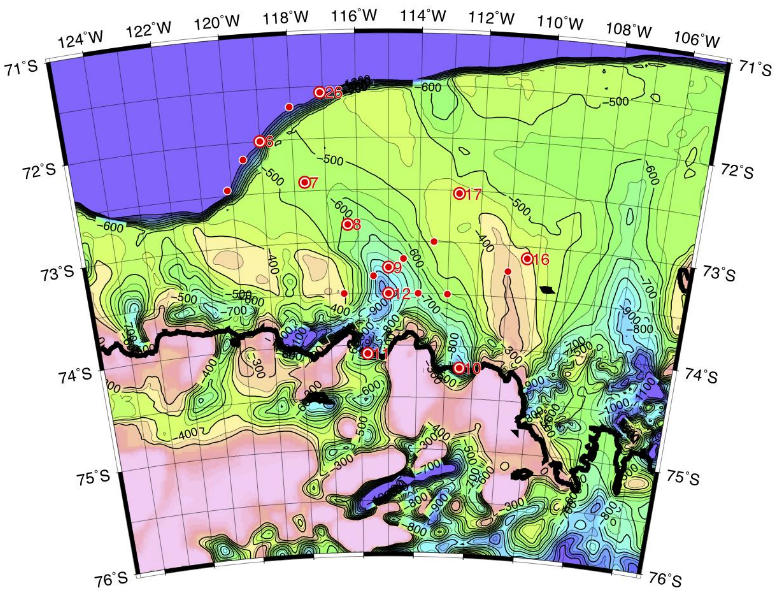

Figure 4.1: Map showing the stations where water samples for noble gases were collected (red bull's eyes with numbers).

4.2 Continuous O_2/Ar measurement as a proxy of net community production

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Work at sea

To determine the net community production underway, we adopted a continuous O2/Ar measurement system developed by Cassar et al. (2009). The so called 'equilibrator inlet mass spectrometer (EIMS)' is centered around a quadrupole mass spectrometer that measures dissolved gas molecules equilibrated with air in and supplied by an equilibrator. Unlike Cassar et al. (2009) who used a membrane contactor, we took advantage of a pre-installed Weiss-type equilibrator for the measurements of dissolved gases such as CH4 and N2O. Water temperature, salinity, oxygen and fluorescence were also obtained to help the interpretation of temporal and spatial variation of O2/Ar. Preliminary results show some spatial variation and supersaturation up to 30% in the Amundsen Sea (Fig. 4.2).

4.3 Determination of dissolved oxygen by spectrophotometric Winkler method

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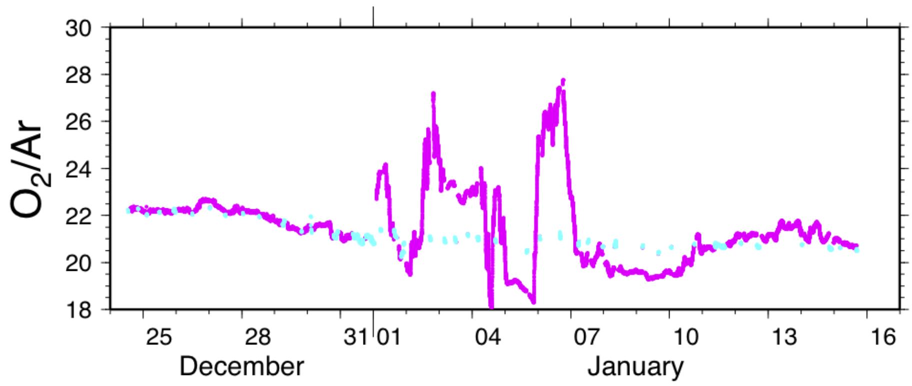

Figure 4.2: O2/Ar variation measured by the equilibrator inlet mass spectrometer.

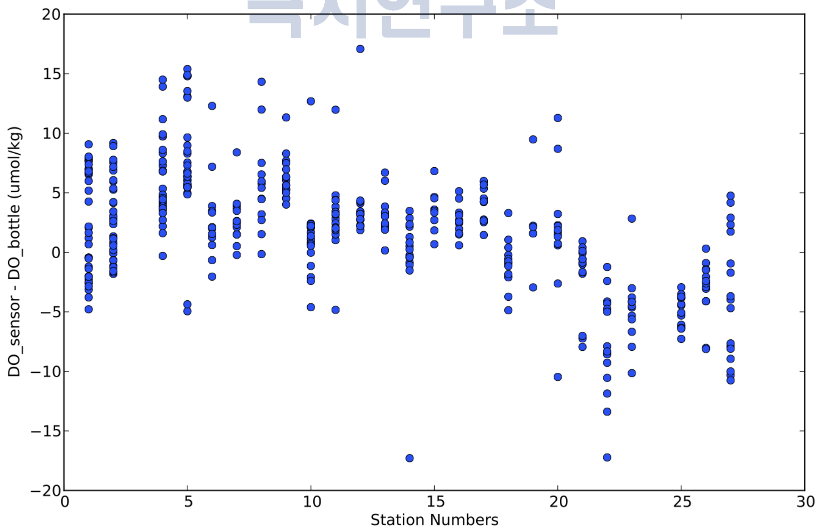

Figure 4.3: Dissolved oxygen concentration difference between SBE43 and flask measurements.

Work at sea

Due to its central role in biological redox reactions and the availability of reliable sensors, oxygen is one of the most common parameters in a sea-going observation. In the cruise, along with the oxygen sensor (SBE-43) attached to the CTD-rosette system, we determined oxygen concentration by spectrophotometric method (Labasque et al., 2004). The bottle oxygen measurements will be used to calibrate SBE-43 oxygen sensor, Annderra oxygen optode (No. 3835, part of O_2/Ar measurement system) and be paired with other chemical measurements such as nutrients, CH_4, N_2O and noble gases.

Our spectrophotometric measurement is a replication of Labasque et al. (2004) with the reagents prepared according to the WHP Reference Manual (Dickson, 1995). However, we reduced the volume of pickling reagents ($MnCl_2$ and alkaline iodine) to 0.5 mL, respectively because we used smaller volume of sample bottle (˜63 mL) than commonly used 120 mL bottles. We measured 545 samples collected at the 30 CTD stations and surface water (˜7 m depth) underway. The majority (65%) of duplicate analysis pairs give relative errors less than 0.5%, equivalent to analytical errors reported by Labasque et al. (2004). As shown in Fig. 4.3, the difference between the sensor and bottle concentration were bigger than the presumed analytical error and there is a hint of temporal drift of the oxygen sensor. The sensor calibration will be performed after careful re-determination of the KIO_3 standard on land.

References

Cassar, N., Barnett, B. A., Bender, M. L. , Kaiser, J. , Hamme, R. C. and Tilbrook, B. (2009). Continuous high-frequency dissolved O_2/Ar measurements by equilibrator inlet mass spectrometry. Analytical Chemistry, 81, 1855–1864.
Dickson, A. G. (1995) Determination of dissolved oxygen in seawater by Winkler titration. WOCE Operations Manual. WHP Office Report WHPO 91-1, 1995.
Huhn, O., Hellmer, H. H. , Rhein, M., Rodehacke, C., Roether, W. , Schodlok, M. P. and Schroeder, M. (2008). Evidence of deep- and bottom-water formation in the western weddell sea. Deep-Sea Research Part I, 55, 1098–1116.
Jenkins, W. J. , 2008. The biogeochemical consequences of changing ventilation in the Japan/East Sea. MarineChemistry, 108, 137–147.
Labasque, T., Chaumery, C., Aminot, A. and Kergoat, G. (2004). Spectrophotometric Winkler determination of dissolved oxygen: re-examination of critical factors and reliability. Marine Chemistry, 88, 53– 60.

Chapter 5

Phytoplankton Physiological Study

5.1 Phytoplankton pigment analysis (HPLC)

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요약문

조사 해역의 식물플랑크톤 색소 분석을 위한 시료를 총 22 개 정점에서 각 4 개 수층에서 획득하였다. 각 수층별 해수는 Whatman GF/F 여과지로 0.5˜3 liter 를 거른 후 -80°C 초저온 냉동고에 보관하였다. 시료는 추후 실험실에서 HPLC (High Performance Liquid Chromatography)를 이용하여 총 15 개의 보조색소를 분리한 후 CHEMTAX 프로그램을 이용 전체 엽록소 a 농도 중 규조류 (diatoms), 와편모조류(dinoflgellates), 후각편모조류(prymnesiophytes), 녹조류 (chlorophytes), 황색편모조류(chrysophytes), 은편모조류(cryptophytes) 이상 6 그룹 식물플랑크톤의 그룹별 농도 및 분율을 구할 예정이다. 이를 통하여 아문젠해의 식물플랑크톤 군집구조 및 우점종 분포를 알 수 있을 것이다.

Objectives

Universally all phytoplankton contain chlorophyll a, and the concentration of chlorophyll a in water masses directly indicates phytoplankton biomass. In addition to chlorophyll a phytoplankton contain different accessory pigments, for example other forms of chlorophyll, carotenoids and phycobilins. The diversity of accessory pigments between groups is considerable. Table 5.1 shows a summary of the principle (diagnostic) photosynthetic pigments among marine phytoplankton. High performance liquid chromatography (HPLC) is used to identify the different photosynthetic pigments present in organisms as taxonomic markers (Jeffery, 1997). The distribution of plankton and community structure in the water column of the Amundsen is not well known. Pigment analysis will allow us to understand the phytoplankton community structure and dominant species distribution in this area.

Table 5.1: The Major Photosynthetic Pigments of Marine Phytoplankton Groups

Phytoplankton Group	Major Photosynthetic Pigments*
Cyanobacteria	Monovinyl chlorophyll a and β-carotene
Prochlorophytes	Divinyl chlorophylls a and b
Diatoms	Fucoxanthin
Prymnesiophytes	19'-hexanoyloxyfucoxanthin
Pelagophytes	19'-butanoyloxyfucoxanthin
Chrysophytes	Fucoxanthin and Violaxanthin
Cryptophytes	Alloxanthin
Dinoflagellates	Peridinin
Prasinophytes	Prasinoxanthin
Chlorophytes	Lutein

Work at sea and preliminary results

In order to study the phytoplankton community, pigment samples were collected in 20 stations. Stations were chosen based on physio-chemical characteristics of the water environment. Water samples (1000 – 4000 ml) for the determination of pigment concentration were filtered onto Whatman GF/F filters (pore-size 0.7μm) under positive pressure. The filter was then placed in a plastic bag and stored in the freezer (80°C) for HPLC analysis. These samples will be identified based on their retention time compared with those of pure standards (chlorophyll a obtained from Sigma; chlorophyll c2 and c3, peridinin, 19'-butanoyloxyfucoxanthin, fucoanthin, 19'- hexanoyloxyfucoxanthin, diadinoxanthin, violaxanthin, prasinoxanthin, lutein, alloxanthin, zeaxanthin, β carotene, chlorophyll b, and divinyl chlorophyll a obtained from DHI, Denmark). This pigment data set (around 100 samples) will be complemented by comparison with other studies, such as CHEMTAX data set, physiological parameters and carbon flux process study.

5.2 Phytoplankton physiological parameters

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요약문

식물플랑크톤의 생리활성을 측정하기 위해 FIRe (Fluorescence Induction and Relaxation)를 이용하였다. 식물플랑크톤의 생리활성은 영양염, 미량금속, 빛, 혼합도 등 물리화학 환경과 밀접한 연관을 가지고 있으며 FIRe 로 측정한 다양한 생리활성 성분들은 이들 외부 환경에 의한 스트레스 정도를 이해하는데 도움을 줄 것이다.

Objectives

The phytoplankton physiological parameters were measured by FIRe system (personally developed by DR. Maxim Gorbunov, Rutgers University). The FIRe

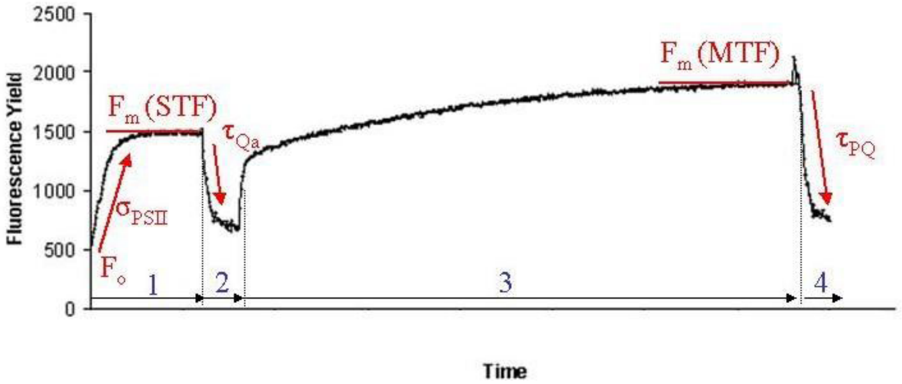

Figure 5.1: An example of FIRe measurement protocol

(Fluorescence Induction and Relaxation) System is the latest advance in biooptical technology to measure variable fluorescence in photosynthetic organisms (see Figure 5.1). The FIRe technique is based on active stimulation and highly resolved detection of the induction and subsequent relaxation of chlorophyll fluorescence yields on micro- and millisecond time scales. The aim of this study is investigatetheeffectsofthephysio-chemicalenvironment onphysiologicalparameters.

Work at sea and preliminary results

Discrete samples were collected for Fire measurements in selected stations. Such complementary measurements were likely to be important, particularly when collected in stratified waters, where vertical gradients in light may be accompanied by vertical gradients in phytoplankton physiology and taxonomy. Blank water samples were obtained by filtering a sub-sample through a GF/F. Samples were run on the highest gain setting that did not saturate the sample, with blanks run on matching gain settings to the associated sample. The photochemical efficiency was calculated as (Fm-F0)/Fm=Fv/Fm.

Populations on the polynya had high values of Fv/Fm (Figure 5.2). Relatively high values were associated with the subsurface chlorophyll maximum (SCM). The lowest photochemical efficiency was associated with the below SCM population in st.4 and 5.

References

Jeffery, S. W., and Vesk, M. 1997. Introduction to marine phytoplankton and their pigment signatures. in, S. W. Jeffery, R. F. C. Mantoura, and S. W. Wright, editors. Phytoplankton Pigments in Oceanography: A Guide to Advanced Methods. SCOR-UNESCO, Paris. Pages 127-166

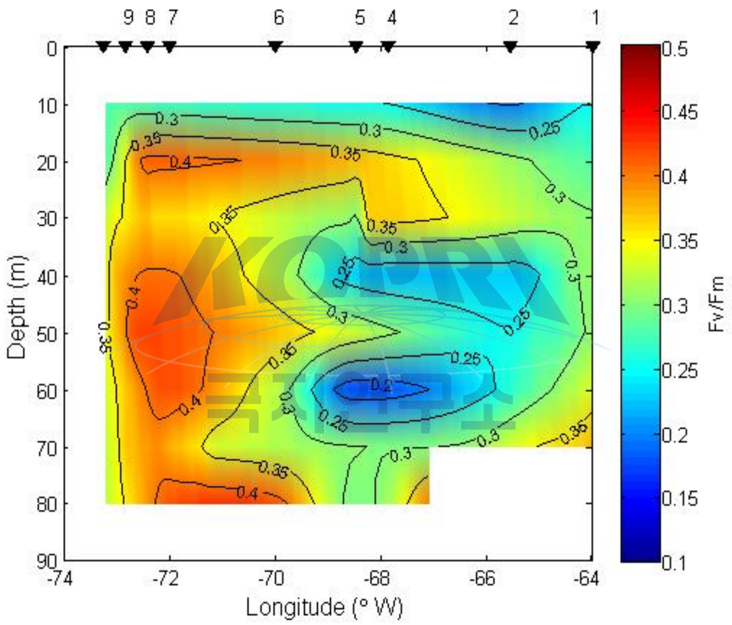

Figure 5.2: Vertical distribution of Fv/Fm between st.1 and st.10 transect.

Chapter 6

Pelagic Ecological study

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Objectives

The Amundsen Sea, which is historically known as a region of heavy ice, is undergoing sea ice recession within the last decades (Jacobs and Comiso, 1993), and extensive phytoplankton blooms near the coast have been observed (Smith and Comiso,2008). Change of ocean and sea ice condition in this area will profoundly alter ecosystem structure by changing pathways of energy flow and the spatial distribution and species composition of plankton. However, the Amundsen Sea is one of the least studied regions in the entire Southern Ocean. To understand the environmental impacts on plankton ecology and physiology and associated carbon flux via a variety of biological parameters in the various environmental conditions (e.g., open sea, marginal ice zone, sea ice, and polynya), we investigated primary production, phytoplankton community structure, protozoan community structure and grazing impact, assessment of mesozooplankton population, and trophic interaction among the planktons. The study on planktonic carbon flow in the pelagic ecosystem of the Amundsen area would contribute toward a more comprehensive understanding of climate effects on Southern Ocean pelagic carbon cycle. During this cruise, we observed biological parameters in total 29 stations

6.1 Phytoplankton community structure and Primary production

6.1.1 Background study

The Amundsen Seas are the most productive areas of the Southern Ocean, with annual primary production reaching up to 160 g C m-2 and chlorophyll concentrations exceeding >10 µg L-1 (Arrigo and van Djiken, 2003). The high productivity in these regions is attributed to the three most productive postpolynyas. The greatest phytoplankton blooms near the coast have been observed (Smith and Comiso,2008). The Amundsen Sea is far less studied than the Ross Sea, despite being one of the most productive areas of the Southern Ocean. In this cruise, our primary objective was to quantify the contemporary ranges of size-fraction phytoplankton distribution, phytoplankton composition, and primary productivity in different water masses, particular in the polynya.

6.1.2 Method

Size fraction chlorophyll-a and phytoplankton composition

Samples for the determination of total chlorophyll- a were filtered onto Whatman GF/F glass fiber filters (24 mm). Size-fractionated chlorophyll-a was determined on samples passed sequentially through 20 and 5 mm Nucleopore filters (47 mm) and 0.7 mm Whatman GF/F filters (47 mm). Concentrations of chlorophyll-a were measured on the board using a Turner Designs (Triology), which had been calibrated with commercially purified chlorophyll-a preparations. To determine the composition of phytoplankton, 120 ml water from the vertical profiles was preserved with glutaraldehyde (1% final concentration) and stored at 4° C.

Carbon and nitrogen uptake rates of phytoplankton

Daily carbon and nitrogen uptake rates were estimated from six light depths (100%, 50%, 30%, 12%, 5%, and 1% penetration of the surface photosynthetically active radiation, PAR), using a 13C–15N-dual isotope tracer technique. Each light depth was determined from an underwater PAR sensor lowered with CTD/rosette samplers. Seawater samples of each light depth were transferred from the Niskin bottles to 500mL polycarbonate incubation bottles, which were covered with stainless-steel screens for each light depth. Water samples were inoculated with labeled nitrate (K15NO3), ammonium (15NH4Cl), and carbon (NaH13CO3) substrates. Bottles were incubated in a deck incubator cooled with surface seawater. The 3–4 h incubations were terminated by filtration through pre-combusted (450 1C) GF/F glass–fiber filters (24 mm). The filters were immediately frozen and preserved for mass spectrometric analysis at the stable isotope laboratory

6.2 Grazing impacts and community structure of heterotrophic protists

6.2.1 Background study

Heterotrophic protists ingest a broad size spectrum of prey, from bacteria to microphytoplankton, and are themselves important prey items for mesozooplankton. Many researches suggest that heterotrophic protists contribute to the trophic linkage between phytoplankton and mesozooplankton and are important in the pelagic food webs of many oceanic waters. The importance of heterotrophic protists in pelagic ecosystems has become increasingly evident in the past two decades, and trophic interaction between heterotrophic protists and phytoplankton has been reported in various marine. However, there is no information on the relative importance of heterotrophic protists in the pelagic ecosystem of the Amundsen sea. In this study area, we investigated the mesoscale variations and structure of heterotrophic protist communities and grazing rates on phytoplankton in the various environmental conditions such as open ocean, sea ice zone and polynya.

6.2.2 Method

Abundance and community composition of heterotrophic protists

To determine the abundance of heterotrophic protists, a CTD-Niskin rosette sampler was used to take water samples from the following 7 depths. For ciliates and sarcodina, 1,000 ml water from the vertical profiles was preserved with 1% acid Lugol's iodine solution these samples were then stored in darkness. For heterotrophic nanoflagellates and heterotrophic dinoflagellates smaller than 20 µm, 500 ml of water was preserved with glutaraldehyde (0.5% final concentration) and stored at 4° C.

Grazing experiments

Grazing rates of heterotrophic protists were determined by the dilution method (Landry and Hassett 1982). Water for grazing experiments was collected from 3 depth (surface, SCM, 1% light depth) of each station, and gently filtered through a 200-µm mesh. At each station, 30L seawater were collected in a Niskin bottle and transferred to a polycarbonate carboy. Part of this water was filtered through the 0.22-µm filtration system. Dilution series were set up in ten 1.3-l PC bottles. Ten bottles were used to establish a nutrient-enriched dilution series consisting of replicate bottles with 11, 28, 50, 75, and 100% natural seawater. The bottles were incubated on deck for 24 – 48 h at ambient sea surface temperatures and screened to the ambient light level with neutral density screening. Subsamples were collected from replicate bottles at 0 and 24-48h to determine chlorophyll-a concentrations.

6.3 Assessment of mesozooplankton population and feeding rates

6.3.1 Background study

Copepod is the most abundant mesozooplankton taxon in Southern Ocean. They believed to play key roles in the planktonic food web consuming organic energy produced by primary producers and as energy linker to the higher trophic levels. Feeding behavior plays an important role in the adaptive strategies of marine organisms. Feeding is the main route for the transfer of energy and material from lower to higher trophic levels within communities. Therefore, its quantification will be a key factor when trophic interactions are studied. Two different approaches are generally used to estimate grazing impact: gut pigment analysis and food clearance rate measurements. Gut content analysis provide information on mesozooplankton feeding with a tool sensitive enough to measure chlorophyll a and derived pigments in zooplankton guts. This method is useful because of its analytical simplicity and the fact that it provides data directly from field zooplankton samples and does not require incubations. It has been especially useful to make quantitative comparisons of feeding rates on phytoplankton in the field. The food removal methods involves incubating zooplankton in bottles with food for fixed time, measuring the decrease in food concentration compared to that in control bottles with no grazers, and thus calculating the feeding rate. This approach is the simplest direct method and the longest in use. The main goal of our study was, 1) to estimate the food selectivity of major copepods and Euphausia superba (krill) 2) to evaluate the grazing impacts of major copepods and krill on the phytoplankton community.

6.3.2 Material and methods

Zooplankton samples were collected with a Bong net (333 µm and 505 µm mesh) at 20 stations. The net was towed twice vertically or obliquely within the upper 200 m of the water column. From the First-towed samples, healthy individuals were immediately sorted out and transferred into 20 ml vials containing filtered seawater. These vials were frozen at -80°C using the deep freezer for the gut content analyses. Sample from the second tow was preserved with buffered formalin for quantitative analyses. Filtering efforts (clearance rate, volume swept clear by each individual copepod per unit time) was measured in the laboratory. Freshly caught healthy individuals were immediately sorted out and transferred to 10 l polycarbonate bottles on the site. Undamaged healthy adult females of the copepods from the 10 l bottles were transferred into 2.2 l polycarbonate bottles filled with a 200 µm prescreened seawater. The experimental bottles (2 or 3 replicates per experiment) with copepods and a control bottle (2 replicates per experiment) without copepods were placed in the dark for 24 h in the incubator at in situ seawater temperatures. Seawater of 500-2000 ml were taken from each bottle before and after 24 h incubation and filtered onto GF/F filters for the HPLC analyses.

References

Arrigo, K. R., van Dijken, G. L. 2003. Phytoplankton dynamics within 37 Antarctic coastal polynyas, Journal of Geophysical Research 108: doi:10.1029/2002JC001739.
Jacobs, S. S., Comiso, J. C. 1993. A recent sea-ice retreat west of the Antarctic Peninsula. Geophysical Research Letters 20: 1171-1174.
Smith, W. O. Jr., Comiso, J. C. 2008. Influence of sea ice on primary production in the Southern Ocean: a satellite perspective. Journal of Geophysical Research 113 doi:10.1029/2007JC004251.

Chapter 7

Antarctic krill acoustics

7.1 Krill acoustics from shipboard measurement

요약문

남극 아문젠해 polynya 인근 해역에서 음향 조사를 통한 남극해 크릴(Antarctic krill, Euphausia superb)의 공간적, 수직적 분포 특성을 조사하였다. Polynya 내부의 지역별 크릴 분포 특성을 파악하기 위하여 총 3 개의 정선 조사를 실시하였다. 사용된 음향 시스템은 선저 설치형 EK60으로 3개의 주파수 가운데 센서 보정이 실시된 120 kHz 자료를 표층에서 수심 400m 까지 수신하였으며, 전체 자료 가운데 선속에 따른 음향 자료의 안정성을 고려하여 6 노트 미만의 자료만을 사용하였다. 음향 정선 조사와 함께 네트를 이용한 수직, 사선, target trawling 을 통해 음향 산란층 내의 생물을 채집하였다. 가상 에코그램 분석법을 이용한 예비 분석 결과, polynya 가장 안쪽과 중앙 정선에서 크릴 음향 산란층이 50 – 200 m 수층에서 강하게 나타났으며, 북쪽 사면 지역에서는 상대적으로 약한 음향 산란층이 분포하는 것으로 나타났다. 향후, 네트를 이용한 채집 자료와 음향 자료의 수신 강도로부터 종 분리를 실시하며, 각 정선에서 우점종별 분포 밀도를 계산할 예정이다. 또한 이들 분포 밀도와 식물플랑크톤, 해빙 분포 등 환경 자료와의 상관성을 비교 분석할 예정이다.

Objectives

The primary objective of the shipboard hydroacoustic survey is to know spatial/vertical distribution and density of Antarctic krill (Euphausia superba) in the polynya around Amundsen Sea, Antarctic Ocean. Additional objective is to describe the relationships between E. superba and key environmental variables such as bathymetry, phytoplankton, sea-ice distribution, and temperature/salinity.

Work at sea and preliminary results

Hydroacoustic data were collected using a multi-frequency echo sounder (EK60, Simrad) configured with down-looking 38, 120, and 200 kHz split-beam transducers mounted in the hull of R/V Araon. Among 3 frequency transducers, a 120 kHz transducer was calibrated using standard sphere while the ship was stopped at steady station in the sea ice zone. For the reason, only 120 kHz acoustic data

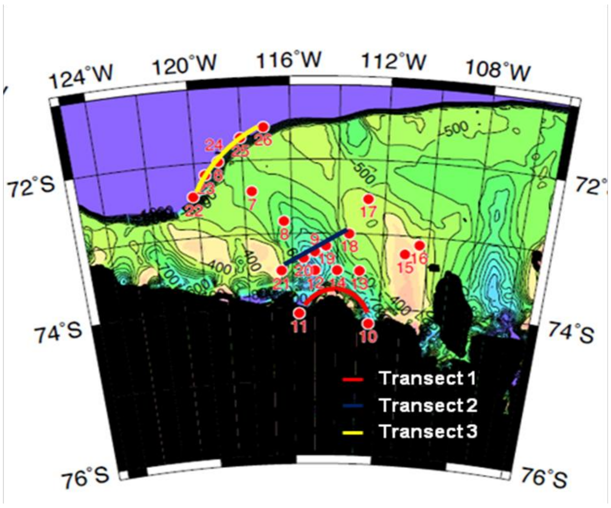

Figure 7.1: Hydroacoustic transect around polynya in Amundsen Sea, Antarctic Cruse, 2010/2011 Austral summer.

were used to interpret krill distribution. During the surveys, acoustic pulses were transmitted with synchronization system, and the pulse duration was 1 millisecond. Because of stability of the acoustic data, confined data with ship speed below 6 knots were used. Acoustic surveys of the water in the polynya, Amundsen Sea were divided into three transects (See Figure 7.1): (1) 85 mile along between polynya and ice wall (transect 1); (2) 65 mile across the north-east side of the polynya (transect 2); (3) 110 mile along continental shelf outer polynya (transect 3). Delineation of the Antarctic krill and other zooplankton was based on the volume backscattering strength and net sampling data. All acoustic data of the three transects were compressed using virtual echogram technique (Echoview, SonarData) with 30 seconds and 1 meter depth. As a preliminary results, high concentrations of krill were found on the transect 1 and 2. On the contrary, krill patch along the transect 3 was restively low strength than that of transect 1, and 2 (See Figure 7.2). The main distributed depth of the krill along transect 1 was between surface and 200 m depth, whereas the main depth of the biological scatter along transect 2 was between surface and 100 m depth. In the nearly future, krill density for each transect will be estimated from length-weight relationship with net sampling and volume backscattering strength data. Simultaneously, the relationships between E. superba and key environmental variables such as bathymetry, phytoplankton, sea-ice distribution, and temperature/salinity will be described.

7.2 Acoustic measurements on the sea ice

요약문

남극해 유빙은 남극 크릴에게 악줘한 서식 공갂을 제공하며, 또한 ice algae 를 먹이로 제공하는 것으로 알려지고 있다. 따라서, 남극해 연안의 유빙(sea ice) 발달 정도는 남극해 크릴 뷴포 및 크릴 밀도와 직· 갂접적으로 연결되어 있다.

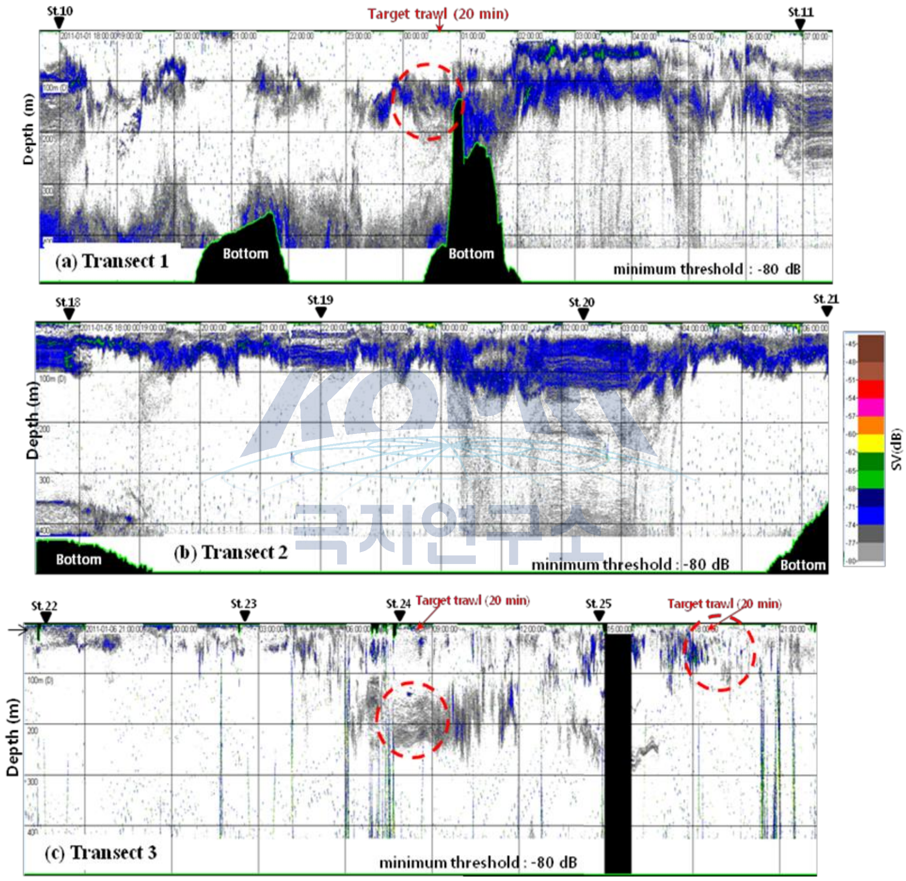

Figure 7.2: Compressed acoustic signal (120 kHz) at the transect 1, 2, and 3.

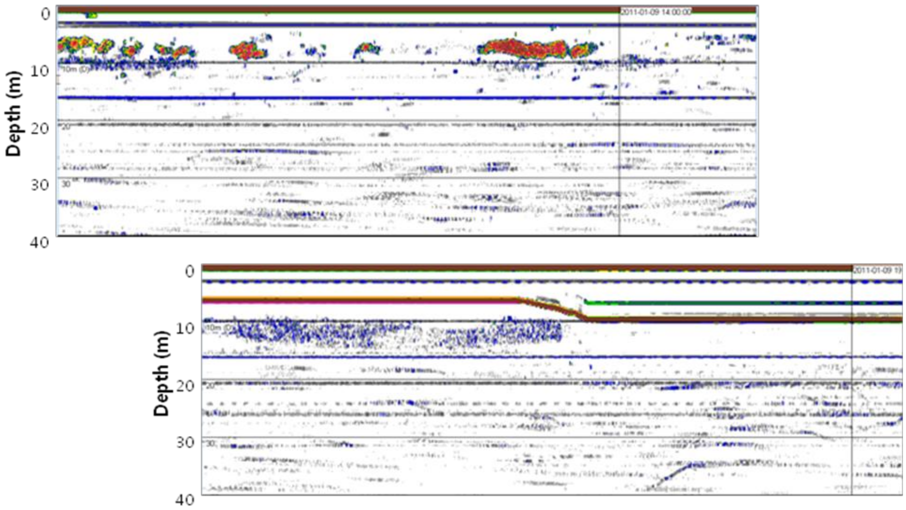

Figure 7.3: The example of hydroacoustic signal on the sea ice station (120 kHz).

본 조사에서는 우리나라에서 처음으로 남극해 해빙 하부의 음향 산란체 분포 자료를 얻기 위한 현장 조사를 시도하였다. 총 2 지점의 해빙 위에서 120 kHz 음향 센서를 설치하여 각각 19, 18 시간에 걸친 연속 자료를 얻었다. 예비 분석 결과, 제 1 지점의 해빙 하부에서는 전혀 음향 신호가 없어 생물체가 없었으나, 제 2 지점의 해빙 하부에서는 시간에 따라 음향 산란체에 의한 신호가 탐지되어 해빙 하부에 생물체가 존재함을 알 수 있었다. 특히 특정 시간대에서는 생물에 의한 강한 음향 신호가 수신되어 해빙 하부에서 음향 산란체의 시변동성을 보여주고 있다.

Objectives

The objective of the hydroacoustic measurement on the sea ice is to know presence of biological scatter, especially Antarctic krill (Euphausia superba), from acoustic method. If the scatter present under the sea ice, the density or distribution of the biological scatter will be compared with that of surrounding open water.

Work at sea and preliminary results

As a pilot study, hydroacoustic data on the sea ice were collected using a multi-frequency echo sounder (EK60, Simrad) configured with down-looking 120 kHz split-beam transducers. For the purpose, two sea ice stations were separately selected and thickness of the sea ice was about 70 – 90 cm. Acoustic measuring time was 19 and 18 hours for sea ice station 1 and 2, respectively. As a preliminary result, acoustic signal at the sea ice station 1 was very weak, whereas the signal at the station 2 was varied with time and depth. The signal shows that biological scatter under the sea ice was presented and have some temporal variation (See Figure 7.3). In the nearly future, strength of the acoustic signal will be estimated, and compared with acoustic signal at the open ocean.

Chapter 8

Diversity and function analysis of microbial community in Amundsen sea: Sample collection

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요약문

지구 물질순환에 Procaryotes(세균 및 고세균)는 매우 중요한 기능을 한다. 특히, 해양에서는 물질순환에 새로운 기능을 하는 많은 미생물들의 발견이 끊임없이 보고되고 있다. 남극은 인간의 접근이 어려워 미생물에 관한 연구가 미진하나 지구기후변와 관련하여 매우 중요한 지역이다. 아문젠해 크루즈를 통하여 남극의 아문젠해에서의 Polynya 의 발달을 연구하고자 하였으며, 관련하여 대양으로부터 해빙해양, polynya 로 이어지는 극지해양환경에서의 Procaryotes 의 다양성을 연구하고자 한다. 나아가, 분자생태기술을 이용하여 온난화가스 (N2O, 메탄)의 생성과 분해에 관련된 미생물의 활성과 분포 및 다양성을 연구하고자 하며, 배양을 통하여 이러한 과정에 중요한 기능을 하는 미생물 자원을 확보하고자 한다. 크루즈기간동안 구체적으로 수행한 일은 1) 중요한 정점에 대하여 깊이별로 해수 샘플링 후 필터를 통하여 바이오매스를 확보하였다. 해빙 정점에서는 코어를 녹인 후 해빙속의 바이오매스를 확보하였다. 바이오매스를 함유하고 있는 필터는 DNA/RNA 가 분해되지 않게 보존할 수 있는 용액에 담군 후 바로 동결시켰다. 2) 배양을 통한 활성 측정 및 신규 미생물의 확보을 위하여 해수샘플도 확보하여 냉장보관하였다. 특히, 메탄산화활성을 가지는 미생물의 다양성 분석 및 자원의 확보를 위하여, 선상에서, 메탄을 함유한 액체배지에 해수를 직접 접종 하여 배양하였다. 앞으로, 확보한 시료로부터 DNA/RNA 를 추출하여 Procaryotes 의 rRNA 및 그 유전자의 Pyrosequencing 을 통한 다양성 분석을 실시하고자 한다. 나아가, realtime PCR 을 통한 온난화가스 전환 관련 기능유전자의 정량 및 다양성 분석을 실시하고, 이를 토대로 신규 생물자원의 존재와 확보를 시도하고자 한다.

Objectives

Global biogeochemical cycles are essentially mediated by diverse prokaryotic microorganisms. The antarctica has been focused as an important region in the aspect of global climate change. In this cruise, we collected seawater samples in the Amundsen sea area which includes polynya and their surrounding seaice environments. Polynya is annual melt area with large bloom event. There aer various procaryotes involved in nitrogen cycles: nitrogen fixation and nitrification which might be tightly related with polynya bloom. We are going to study key players of the nitrogen cycle in the polynya region. Further, we are interested in the diversity, activity, and abundance of procaryotes involved in the generation and consumption of non-CO2 greenhouse gas, i.e., nitrous oxide and methane. Nitrous oxide is known to be produced by nitrification process which is mediated proteobacteria and archaea. Methane consumption is mediated by aerobic methanotrophs in water column. For this purpose, first, we are going to take a census of procaryotes using sequencing of rRNA or its gene in the Amundsen area (sea ice area, polynya, ice margin, open ocean). Second, diversity and expression of functional genes involved in nitrogen cycles (such as nifH and amoA) and the transformation of greenhouse gases (such as nirK, and pmoA) will be studied in representative stations. Third, candidate microorganisms of essential and abundant biogeochemical function in the Amundsen sea suggested from the studies above molecular survey will be cultivated in the laboratory. The results obtained from these studies will be crucial for understanding the biogeochemical cycles involved in the polynya bloom and concurring greenhouse gas dynamics, which will give insight into climate change in the antarctic area.

Work at sea and preliminary results

Water samples were collected at discrete depths using a 24-bottle conductivity-temperature- depth rosette sampler (Table 5.1). Samples for nucleic acid extraction were collected from the rosette in 2–4 l sterile plastic bottles. Cells were harvested by vacuum filtration onto 47 mm filters housed in Millipore filter holders; first through a 10 μm pore size polyester pre-filter (Whatman) and then a 0.2 μm Supor filter (Pall). For simultaneous DNA/RNA extraction, 2–4 l volumes were filtered and frozen with the addition of 1 ml RNA Later solution prior to freezing. About 20 liters of underlying seatwaters were filtered at the ice stations for comprehensive analysis of the prokaryotic community by pyrosequencing of the metagenomic DNA. Further, microorganisms in ice core were collected from melt water of sectioned ice core layers showing algal bloom which was indicated by yellow pigment in the corresponding layers.

From each depth of biomass collection, 30 ml water was collected and stored in refrigerator before activity analysis. For the analysis of the activity and diversity of methanotrophs, 1 ml water sample from a few depths of representative stations was inoculated into 10 ml of methanotroph media. For determination of nitrite concentration, 1 ml of filtered seawater was transferred into an ependorf tube and frozen before analysis. Other information about nutrient and greenhouse gas concentration will be obtained from other scientists of this cruise team for decision of target stations and depths for comprehensive studies.

Table 8.1: Number of samples collected at the station for collection of biomass and seawater, nitrite determination, and methanotroph test.

Station No.	Depth No.	Water sample (30 ml) No	Nitrite sample (1 ml) No	Methanotroph Incubation No	Note
1	12	12	12	4	
2	12	12	12	no	
4	12	12	12	4	
5	10	no	10	no	
7	10	no	10	no	
8	10	10	10	3	
10	12	no	10	3	
11	10	10	7	4	
13	12	12	10	4	
16	8	1	4	no	
17	5	4	5	1	Ice station
	4	no	no	no	Ice core
	Underlyingwater (20 l)	no	no	no	
24	12	12	3	3	
26-1	5	5	5	1	Ice station
	15	155	no	6	Ice core
	Underlying water (20 l)	no	no	no	
27	2	2	no	no	
28	3	3	no	no	
29	3	3	no	no	
30	12	12	8	4	

Chapter 9

Calibration/validation of satellite remote sensing ocean color data

9.1 Bio-optical properties observation

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요약문

인공위성을 이용하여 관측한 해색 (ocean color)은 해수 중에 존재하는 유기물 (algal)과 무기물 (non algal) 등의 입자들이 흡광 (absorption)과 산란 (scatter)을 함으로서 나타나는 광스펙트럼의 형태를 경험식을 바탕으로 유추한 chlorophyll-a 의 양이다. 그러나, 해수면 아래에서 일어나는 생물-광 신호의 변화를 인공위성에서 감지하는 데는 여러 가지 해결해야 할 문제가 있다. 특히 극지역의 경우 중위도권에 비해 낮은 태양고도에 의한 해수면 반사도의 특수성과, 현장검증을 위한 조사를 수행하기 어려운 곳이라는 점 등에 의해 해색 원격탐사 부분에서 해결해야 할 숙제가 많은 곳이다. 이번 아문젠해 조사를 통해 총 28 개의 각기 다른 정점(Figure 9.1)에서 수층 별 3 개 수심에서 108 개의 흡광도, 즉, 식물플랑크톤에 의한 흡광 (aph), 부유물질에 의한 흡광 (ass), 용존유기물에 의한 흡광 (aCDOM)을 측정하였다. 각 흡광의 계수를 계산하기 위해 엽록소 (chlorophyll-a) 농도 및 부유성 입자(suspended sediments; SS)의 농도를 측정하였다. 동시에 수심별 광스펙트럼 변화를 350~800nm 의 스펙트럼에서 측정 가능한 hyper-spectrometer profoler (HPROII, Satlantic inc., Figure 9.3)를 이용해서 관측하였다. 또한, 쇄빙선 아라온호 선수에 장착한 해수면 반사도 측정기 (above water spectro-radiometer, HSAS, Satlantic inc., Figure 9.4)를 이용하여 아라온 항적을 따라 매 15 분 마다, 해수면 반사도 (350-800nm) 및 해수면 온도 (Infrared)를 측정하였다.

Objectives

Satellites borne ocean color sensors, such as Sea-viewing Wide Field-of-View Sensor (SeaWiFS), Moderate Resolution Imaging Spectrometer (MODIS), and

Medium Resolution Imaging Spectrometer (MERIS), can provide synoptic global-scale observation of the oceanic phytoplankton. However, high latitude oceans, e.g. Amundsen Sea, have not been studied in as much detailed as temperature or tropical oceans, due to location and cold environment which are not easy to assess. Hence, through Amundsen Sea expedition, we try to get bio-optical relationship to improve ocean color data quality by observing 1) inherent optical properties (IOPs) of water such as absorption by phytoplankton, suspended sediment, and dissolved organic meters, and 2) apparent optical properties (AOPs) of water such as downward irradiances (Ed) and upwelling radiance (Lu) over spectrum range of 350-800nm.

Work at sea

With hydrographic survey, such as CTD/Rosette, we sampled 108 waters at 28 stations (Figure 9.1) with 3 depths of surface, subsurface chlorophyll maximum depth (SCM), and bottom euphotic depth (see below station map, 4 stations added before Amundsen sea hydrographic station). To measure inherent optical properties (IOPs) of water, seawater volumes of 500 ml were filtered on 25 mm glass-fiber filters (Whatman GF/F). For absorption by CDOM, seawater volumes of 50 ml were filtered onto disposable syringe filter unit of Advantec (cellulose acetate 0.45 um). Optical densities of total particulate matters were measured directly on the wet filters by methods of Truper and Yentch (1967) with a double-beam recording spectroradiometer of Simatsu UV1800 in spectral range 350-900nm (spectrum resolution was 0.5nm) the filter was placed in front of a diffusing windows adjacent to an end-on photomultiplier of large surface area. For a reference blank and baseline variations, an unused wetted filter was taken as were automatically corrected. After the measurement of optical density of total pigments, the spectral absorption by nonalgal material was measured separately with method of Kishino et al.(1985). The filter was placed in absolute methanol for 1˜1.5 hr in order to extract pigments. For the measuring of apparent optical properties (AOPs) of water, we deployed hyper-spectroradiometer of Satlantic Inc. (HPRO II, Figure 9.3), which is free-fall type (0.5m per second) with 350- 800nm of downward irradiance (Ed) and upwelling radiance (Lu). For reference as ambient irradiance variation, downward irradiance (Es) was measured on deck, where is no shaded place of R/V ARAON. At the same time, through whole expedition we observed above water reflectance every 15 minutes by using 'Above water spectroradiometer of Satlantic Inc.(HyperSAS, Figure 9.4)', mounted on a head of vessel to continuous monitoring of ocean color along the ship's track. This data will be used to calibration/validation currently operated remote sensed ocean color data.

References

Truper, H. G. and C.S. Yentsch, 1967. Use of glass fiber filters for the rapid preparation of in vivo absorption spectra of photosynthetic bacteria. J. Bact.94, 1255-1256.

Kishino, M., N. Okami, M. Takahashi, and S. Ichimura, 1986. Light utilization efficiency and quantum yield of phytoplankton in a thermally stratified sea. Limnol. Oceangr., 31, 557-566.

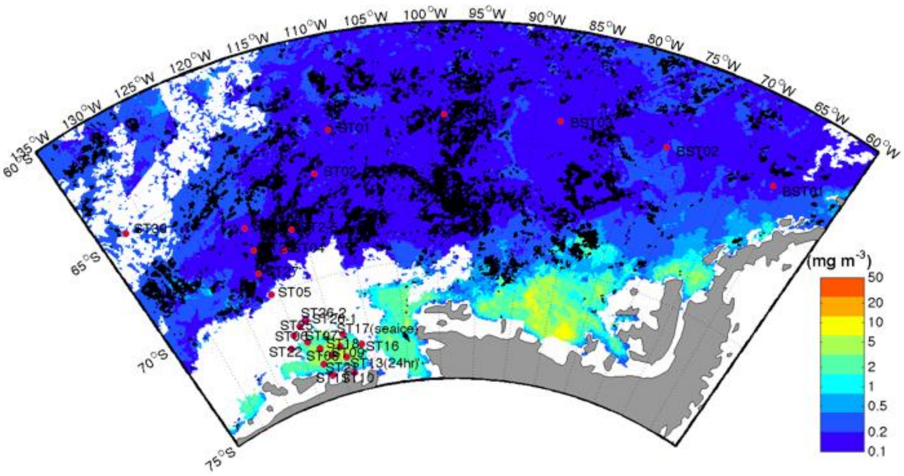

Figure 9.1: Station Map of Remote sensing CAL/VAL data sampled: 4 stations added before Amundsen Sea expedition (BST1, BST2, BST3, BST4).

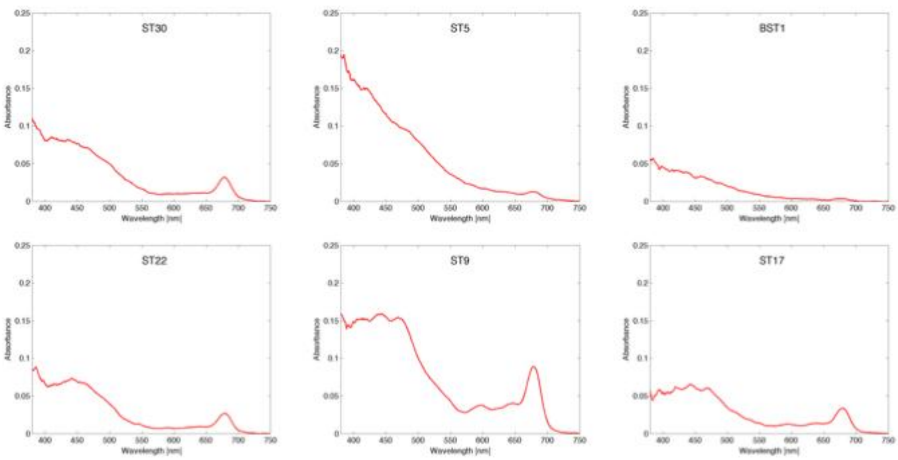

Figure 9.2: Examples of total pigments absorbance (before processing)

Figure 9.3: Hyper-spectroradiometer profiler (HPRO II, Satlantic Inc.,right figure) deployed in water(left figure).

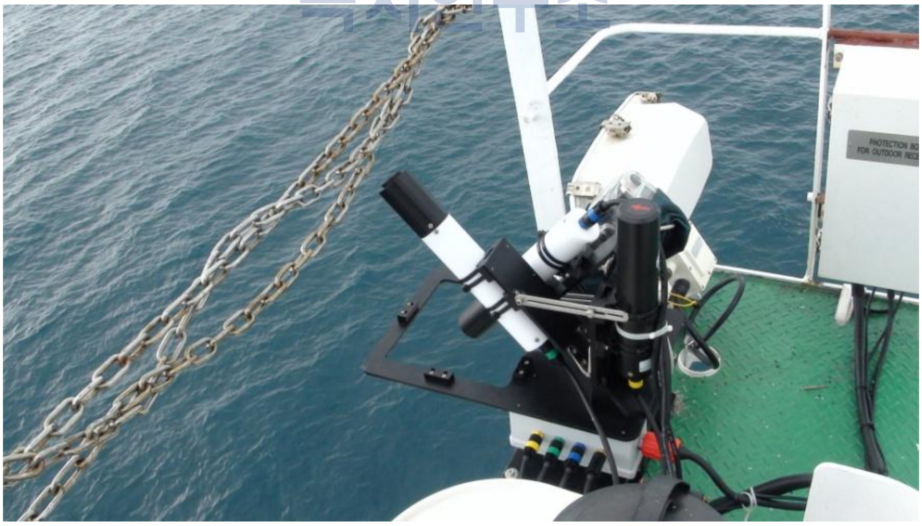

Figure 9.4: Station Map of Remote sensing CAL/VAL data sampled: 4 stations added before Amundsen Sea expedition (BST1, BST2, BST3, BST4).

Chapter 10

Activity related with Atmospheric Research

10.1 Setup of an automatic weather station

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요약문

서남극 지역 기후변화 원인 규명을 위한 현장 관측 자료 획득을 위해 서남극 아문젠 해에 위치한 Bear Peninsula 내의 Moore Dome 에 2011 년 1 월 1 일 자동기상관측장치(AWS)가 설치되었다. 세 명의 연구 직이 헬기를 이용하여 쇄빙연구선 아라온에서 현장으로 이동하였다. 풍향, 풍속, 기온, 습도 및 기압이 관측되어 자료 집록기에 저장되며, 이리듐 위성 통신을 이용하여 원격 자료 송수신이 가능하게 하였다. 전원 공급을 위해 배터리와 태양 전열판이 이용되었다. 한편, 적설 관측을 위해 2 m 길이의 대나무 봉 10개를 AWS를 중심으로 북서-남동 방향으로 설치하여, 표면으로부터의 높이 및 좌표를 기록해두었다. 1 월 2 일 아라온에서 이리듐 통신을 통해 Bear Peninsula 에 설치된 AWS 에 접근하여 하루 동안 저장된 자료를 수신하였다. 한 시간 평균된 자료에 의하면 풍속은 2 ~ 8 m/s, 기온은 -5 ~ - 10, 기압은 90.4 kPa 전후이었다.

Objectives

Warming on West Antarctica is debated (Thompson and Solomon, 2002, Steig et al., 2009, O'Donnel et al., 2010). One of the major reasons about the issue should be due to the lack of in- situ measurements. Therefore, additional installation of automatic weather stations (AWSs) and long-term operation of them should be helpful to better understand warming on West Antarctica. Research program stats in 2011 to better understand the role of southern annual mode (SAM) in the climate variability on West Antarctica over last 100 – 200 years. As a first step, AWS at doom area in the Bear Peninsula was setup. Data from the AWS will be used for site selection for ice coring (to reconstruct SAM during

Figure 10.1: The hole for the installation of AWS

Figure 10.2: The base of the AWS tower in the hole

Figure 10.3: The automatic weather station at Moore dome, Bear Peninsula on January 1, 2011

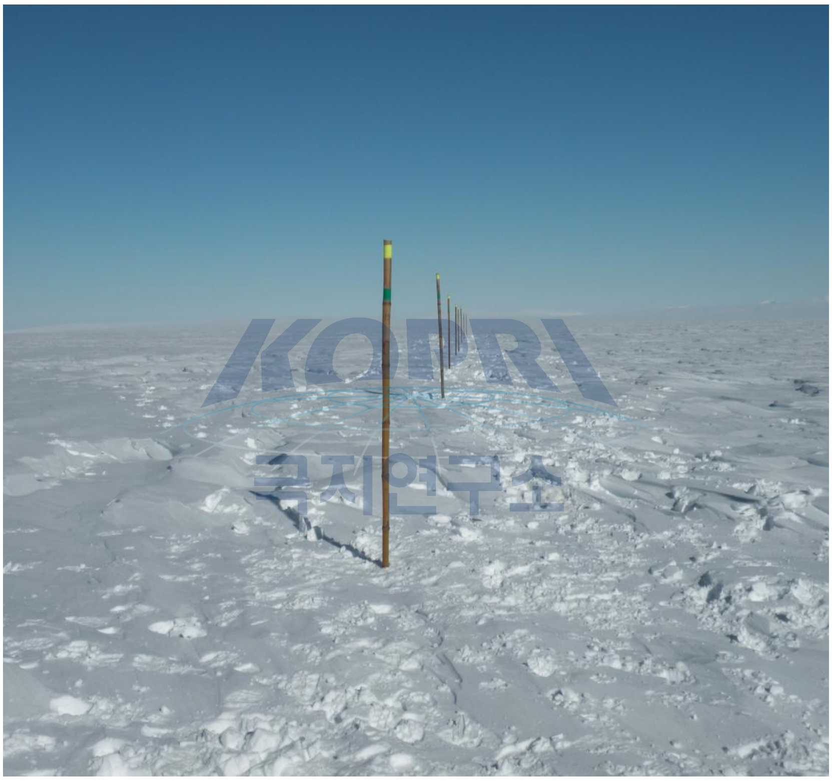

Figure 10.4: Bamboo bars for the measurement of snow accumulation

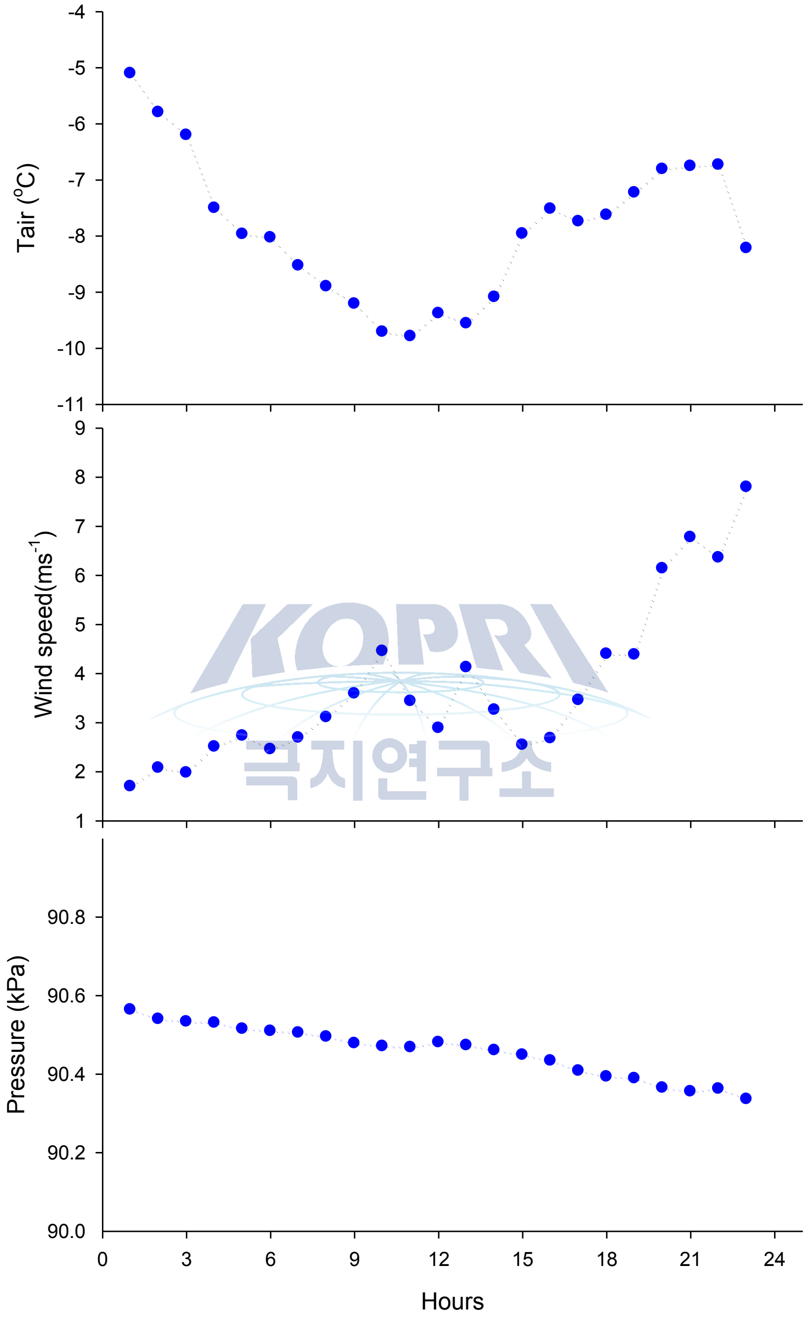

Figure 10.5: Diel variations of air temperature (top), wind speed (middle) and air pressure (bottom)

the last 100 – 200 years) as well as for climate study related with SAM on West Antarctica.

Work at sea and preliminary results

An automatic weather station (AWS) was established at Moore dome in Bear Peninsula (74°21'28.20' S, 111°2010 W, ˜ 700 m m.s.l.) on January 1 in 2011. Two helicopters were used for the transportation for three people and cargo from the Araon, which accessed a point ˜ 500 m away from ice shelf of Bear Peninsula. The site was flat with a fetch of several kilometers. The surface at the site was covered with snow and ice-covered area was not found. To setup the AWS at the snow, a hole with a size of ˜ 1.0 (length) x 1.0 (width) x 0.9 (depth) m was digged (Figure 10.1). The surface at a depth of ˜ 0.9 m in the hole was relative harder. A monopole-type tower with a height of 3 m was used for the installation of instruments (Figure 10.2). Three sets of guy wires were used to support the tower. An anemometer (05103, RM Young) at a height of 2.87 m and a temperature-humidity probe (HMP45D, Vaisala) at a height of 2.45 was attached to the tower (Figure 10.3). A pressure sensor (PTB100, Vaisala) was put in a box with a datalogger (CR1000, Campbell Scientific Inc.), which was put in a depth of 0.3 m. Data were sampled at an interval of one minute and hourly mean and standard deviation of the data were stored in the data logger in UTC. To determine true north, two locations with GPS coordinates were used ˜ 50 m away from each other (Figure 10.4). To operate the AWS, a 300 AH lithium battery and 40 AH gel-type batter with solar panel of 15 W was used. For data retrieval, a modem for iridium satellite was used. The modem was scheduled to be activated from 0800 to 0900 every day in UTC to save power consumption. To examine snow accumulation, ten bars of bamboo in 2 m long were set up at an interval of 2 or 3 m from northwest to south east. GPS coordinate for all of them and the height from the surface were documented. Based on the hourly data retrieved through iridium satellite at the Araon one day later, air temperature ranged from -5 to -10 °C, wind speed was in the range of 2 – 8 m/s. Air pressure was 90.4 kPa on average (Figure 10.5).

10.2 On-board eddy flux measurements

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요약문

에디 공분산 관측은 다른 미기상학적 방법과는 달리 가정 없이 직접적으로 연직 플럭스를 관측할 수 있다는 큰 장점이 있다. 하지만 움직이는 연구선 등에서의 에디 공분산 관측을 이용하여 해양 경계층에서의 난류와 대기-해양 교환 과정 연구에 있어서 연구선의 움직임은 관측의 불확도에 기여하는 주요한 원인이다. 따라서 이에 대한 실시간 또는 후처리 과정을 통한 교정이 필요하다. 본 연구 항해 동안 이 교정 방법을 개발하기 위한 첫 단계로 아라온의 foremast 에 에디 공분산 시스템과 배의 움직임이 에디 공분산 관측에 미치는 영향을 교정하기 위해 motion sensor 를 함께 설치하여 자료를 수집하였다. 아울러 에디 공분산 관측 자료 해석 및 motion sensor 값의 평가를 위해 아라온에서 상시 관측되는

위경도, heading 방향, 배의 속도, pitch/ roll/heave 의 각도 등의 자료를 수집하여 정리하였다. 향후 교정 방법이 확정되면, 다양한 배의 움직임 상황이 에디 공분산 관측에 미치는 영향이 정량화될 예정이며, 이에 근거하여 이번 항해 동안의 대기-해양 간의 에너지 교환에 대한 정량적인 평가를 수행할 예정이다.

Objectives

Fluxes of heat, water vapor and CO_2 between the atmosphere and the sea can be quantified by direct eddy covariance flux measurement without assumption. The motion of ships is, however, a major source of uncertainty in measurements of turbulence and air-sea interaction in the marine atmospheric boundary layer. (Edson et al., 1998, Miller et al., 2008). The purpose of the study during the cruise was to collect turbulence data from on board eddy flux system with data from motion sensor to develop on-line and post process algorithms to correct the motion effect on the eddy flux data. In addition, data related with ship motion such as pitch and roll angles, ship speed or heading were monitored and archived to understand the environment that the flux measurement is made.

Work at sea and preliminary results

A 3-D sonic anemometer (CSAT3, Campbell Scientific Inc.) was installed at the foremast of the ARAON on November 27, 2010 with a 6-degrees-of-freedom inertial motion sensor (Motion Pak II, Systron-Donner). A fast response CO_2/H_2O analyzer (LI-7500, LI-COR) was added next to the sonic anemometer on December 27, 2010 (Figure 10.6). The sampling rate of turbulence (u, v, w, T, CO_2 and H_2O) and motion data (three angular rates and three accelerations) was 20 Hz. All raw and half-hourly averaged turbulence data (not motion-corrected) were stored at a Desktop computer in the atmospheric science laboratory for post-processing. Raw data were splitted on half-hourly basis and time series of each variable was plotted to check up the system (Figure 10.7 and 10.8). The data related with the ship motion such as the angles of rolling, pitching, heading and ship speed measured routinely at the Araon are available at an interval of one second. Time series of the data were also plotted half-hourly basis (Figure 10.9 and 10.10) and archived for the analysis of turbulence data later.

Based on the daily averaged wind speed and air temperature, wind speed ranged from 2 to 8 ms- 1. For air temperature, it was in the rage of -2.5 - -0.8 °C during the cruise (Figure 10.11). For wind direction, wind from southeast was dominant with ~ 30 % of the period (Figure 10.12). Mean, maximum and minimum wind speed, air temperature, air pressure and solar radiation were summarized in Table 10.1. During the cruise eddy covariance system seemed to work without mechanical problems based on the time series of turbulence data and their diagnostic values. The magnitude of data looked reasonable. (Co)spectra can be used to check up the eddy flux system. Figure 10.13 shows the normalized power spectral density of vertical wind speed at 0130-0200 on January 1, 2011. Different from spectra at fixed platform, the power spectral density of vertical wind velocity showed significant peak at the frequency of 0.2, which resulted from the ship motion. Contaminated peak due to ship motion is a typical characteristic in turbulence data at moving platform (e.g., Miller et al., 2009).

Figure 10.6: Eddy covariance system with motion sensor at the foremast of Araon

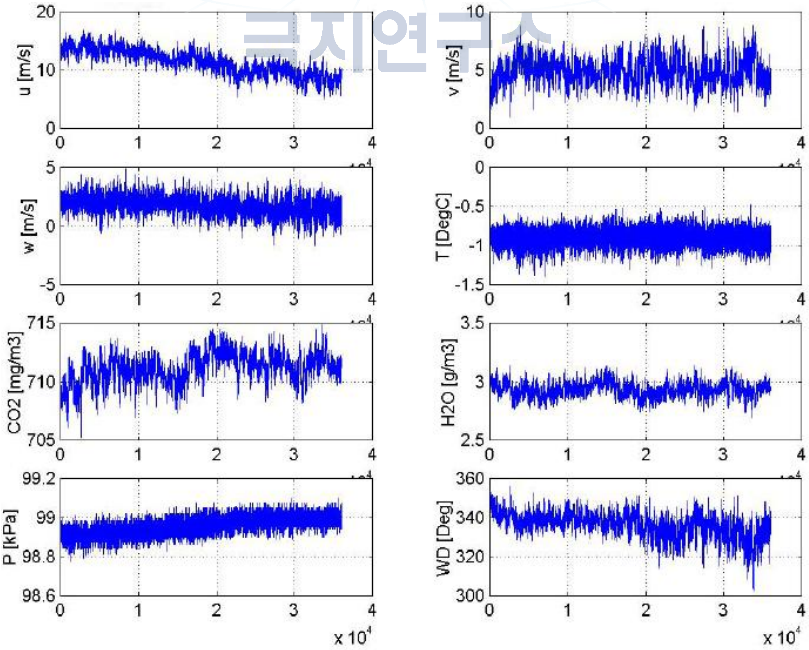

Figure 10.7: Eddy covariance system with motion sensor at the foremast of Araon

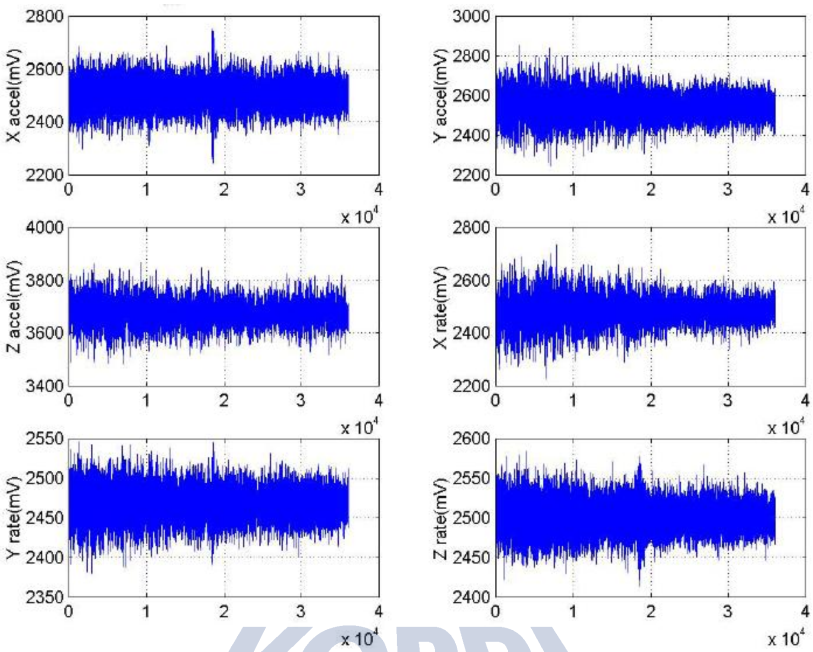

Figure 10.8: Eddy covariance system with motion sensor at the foremast of Araon

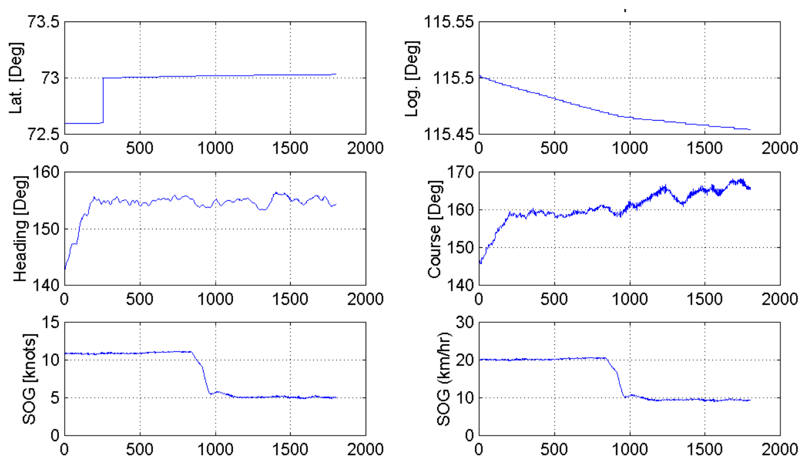

Figure 10.9: Eddy covariance system with motion sensor at the foremast of Araon

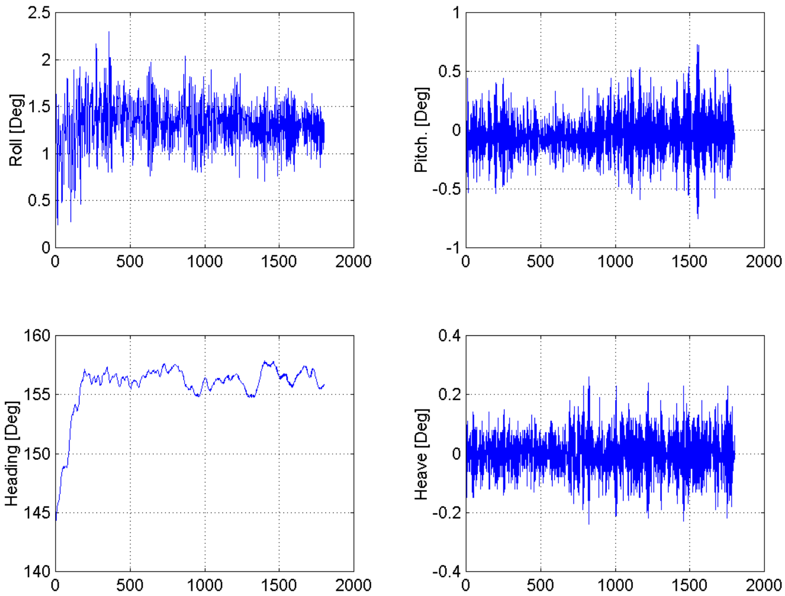

Figure 10.10: Eddy covariance system with motion sensor at the foremast of Araon

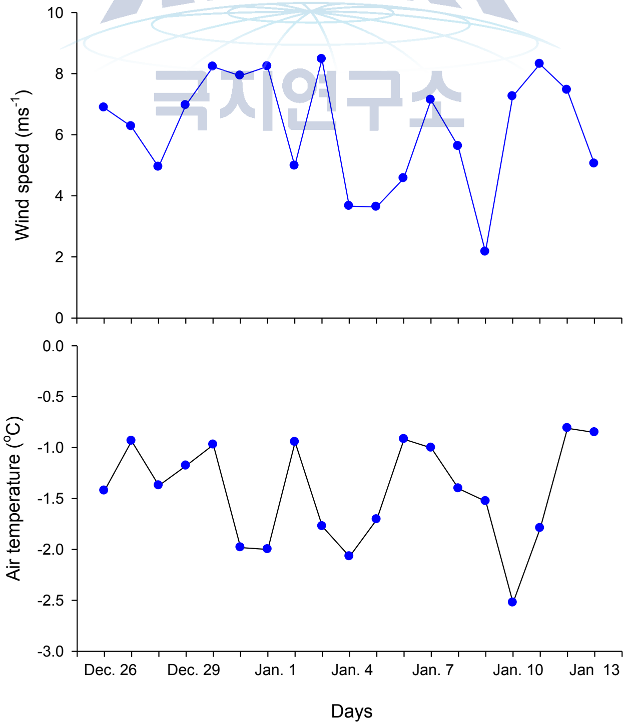

Figure 10.11: Eddy covariance system with motion sensor at the foremast of Araon

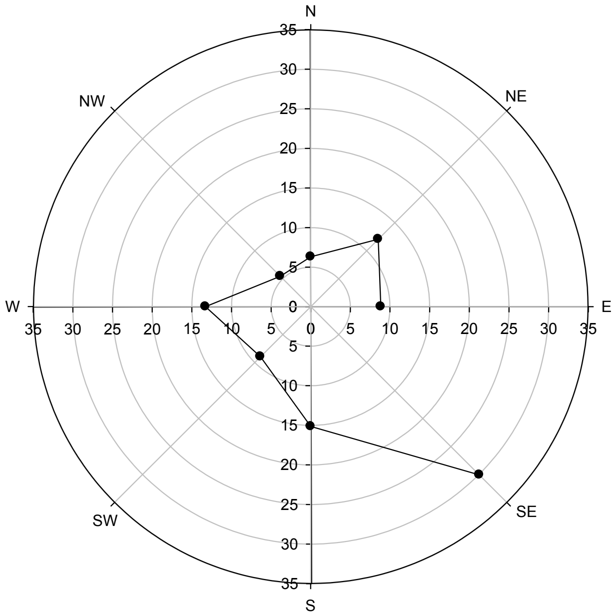

Figure 10.12: Eddy covariance system with motion sensor at the foremast of Araon

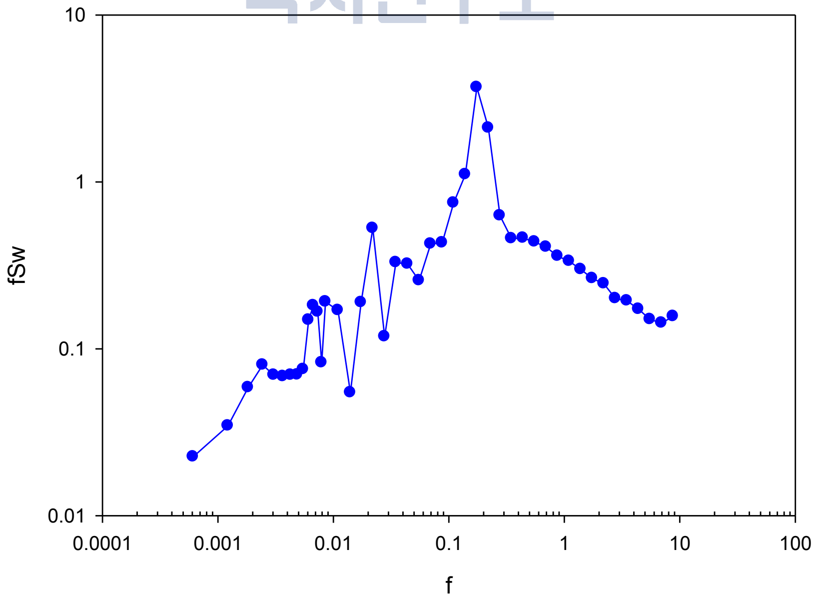

Figure 10.13: Eddy covariance system with motion sensor at the foremast of Araon

Table 10.1: Meteorological data based on half-hourly basis during the cruise.

	Mean	Maximum	Minimum
Wind speed (ms-1)	6.5	22.5	0
Air temperature(oC)	-1.4	1.8	-4.1
Air pressure (kPa)	98.5	99.5	97.0
Solar radiation (Wm-2)	178	714	0

References

Edson, J.B., A.A. Hinton, K.E. Prada, J.E. Hare, and C.W. Fairall, 1998, Direct covariance flux estimates from mobile platform at sea. J. Atmos. Oceanic Technology, 15, 547-562.

Miller, S.D., T.S. Haristov, J.B. Edson, and C.A. Friethe, 2008, Platform motion effects on measurements of turbulence and air-sea exchange over the open ocean. J. Atmos. Oceanic Technology, 25, 1683-1694.

Steig, E.J., D. P. Schneider, S.D. Rutherford, M.E. Mann, J.C. Comiso and D.T. Shindell, 2009, Warming of the Antarctic ice-sheet surface since the 1957 Iternational Geophysical Year, Nature, 457(22), 459-463. Thompson, D., S. Solomon, Interpretation of recent southern hemisphere climate change, Science, 296(5569), 895-899, 2002.