

# **The 11th Seoul International Symposium on Polar Sciences**

## **"Patterns and Processes in Polar Oceans and Life : Signals and Responses from Molecules to System"**

**Seogwipo KAL Hotel, Jeju, Korea  
8-9 September 2004**

Editors : Yeadong Kim  
Hosung Chung  
Hyoung-Chul Shin



**Korea Polar Research Institute**



# PROGRAMME

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<b>Tuesday 7 September 2004</b>		
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## Poster presentation

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# ABSTRACT

A1

## **Interannual variability of the oceanic CO<sub>2</sub> and net community production in the seasonal ice zone of the Southern Ocean to the south of Australia**

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We have detected the long-term increase in the partial pressure of CO<sub>2</sub> in surface water ( $p\text{CO}_{2\text{sw}}$ ) in the Subantarctic Zone, Polar Frontal zone and Permanently Open Ocean Zone of the Southern Ocean to the south of the eastern Australia in austral summers between 1969 and 2002. The  $p\text{CO}_{2\text{sw}}$  has been increasing at a similar rate as the growth of the atmospheric CO<sub>2</sub>, showing that physical processes and the atmospheric CO<sub>2</sub> increase are the dominant factors controlling the trend of the oceanic CO<sub>2</sub> in these zones.

In the Seasonal Ice Zone, on the other hand, biological activity is also playing a crucial role for the variability in the oceanic CO<sub>2</sub>. In January 2002, we observed a large deficit in salinity-normalized TCO<sub>2</sub> (def-TCO<sub>2</sub>) (-30 to -120 mol/kg; 17 to 38 gC/m<sup>2</sup>) and a considerable CO<sub>2</sub> under-saturation ( $Dp\text{CO}_2$  : -20 to -150 atm) with an elevated chlorophyll level (50 to 420 mg/m<sup>2</sup>) in the zone close to the pack-ice margin (> 64S, 140E). In contrast, an intensive bloom was not observed and def-TCO<sub>2</sub> was less than 10 gC/m<sup>2</sup> in the same zone in January 1995. Such a large year-to-year variability in the net biological CO<sub>2</sub> uptake (net community production) demonstrates a large influence of biological activity on the flux of carbon between the atmosphere and the ocean as well as that from the surface to the interior of the ocean.

## A2

### Frontal Zone Mixing and Distribution of Water Masses around Antarctica

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To better understand the frontal structure in the Antarctic continental slope, the water masses around Antarctica are examined and their spatial distributions are described. Antarctic Surface Water over the Antarctic shelf regime is distinguished from underlying other water masses by a salinity, which varies from approximately 34.35 to 34.45, and is 34.40 on average. Shelf Water is defined as water over the Antarctic shelf regime with salinity greater than the cut-off salinity (about 34.4) and potential temperature less than -1.7°C. Low-salinity Shelf Water is distinguished from high-salinity Shelf Water by the maximum potential density of Lower Circumpolar Deep Water ( $\sigma_0 = 27.87 \text{ kg m}^{-3}$ ). Antarctic Slope Front Water is characterized by potential temperature between -1.7°C and about 0.2°C, and salinity greater than the cut-off salinity. Antarctic Slope Front Water, produced by isopycnal mixing of Lower Circumpolar Deep Water with low-salinity Shelf Water, is referred to as low-salinity Antarctic Slope Front Water. High-salinity Antarctic Slope Front Water, produced by diapycnal mixing of low-salinity Antarctic Slope Front Water with high-salinity Shelf Water, is observed with densities greater than the maximum density of Lower Circumpolar Deep Water ( $\sigma_0 = 27.87 \text{ kg m}^{-3}$ ). Antarctic Slope Front Water is observed everywhere around Antarctica except in the Bellingshausen-Amundsen sector (between 63° and 155° W). The different water masses over the Antarctic continental margin produce V-shaped double fronts: one between Lower Circumpolar Deep Water and Antarctic Slope Front Water, and the other between Shelf Water and Antarctic Slope Front Water. The former is referred to as the Antarctic Slope Front, which is found wherever Antarctic Slope Front Water exists.



A3

**Carbonate system across the Antarctic Polar Front in the Drake Passage**

Young Chul KANG<sup>1</sup>, JeongHee SHIM<sup>2</sup>, Dongseon KIM<sup>2</sup>, Sang Hwa CHOI<sup>3</sup>, Soo  
Jin SONG<sup>1</sup>, Hyoung Chul SHIN<sup>1</sup>

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*<sup>2</sup>Ocean Climate & Environment Research Division*

*<sup>3</sup>Data Management Section, KORDI*

Continuous determination of oceanic carbonate parameters was carried out across the Antarctic Polar Front in the Drake Passage during the 1998-1999, 2001-2002, 2002-2003, and 2003-2004 austral summers. A flowing pCO<sub>2</sub> system and an automated TA titration system were installed onboard of the Russian R/V Yuzhmorgeologiya for measuring pCO<sub>2</sub>, pH, TA, and TCO<sub>2</sub>. Sea surface pCO<sub>2</sub> was automatically measured every 2 minute by the flowing pCO<sub>2</sub> system, and TA values were determined every hour with the TA titration system. Water samples were also collected every hour to follow the changes in nutrients and chlorophyll concentrations along the cruise lines.

Sea surface temperature and salinity fluctuated greatly across the polar front. Strong variations were also observed in nutrient concentrations across the front. Silicate concentrations significantly increased traversing the frontal zone as well as increasing nitrate and phosphate concentrations toward the south. Higher surface pCO<sub>2</sub> values were observed along most of the cruise lines, while lower surface pCO<sub>2</sub> values were found at frontal zones in early Decembers. Clear correlation between pCO<sub>2</sub> and nutrients in the south of the Polar Front suggest that the biological removal of CO<sub>2</sub> is more efficient in the south of the front (the Silica Ocean) than in the north of the front (the Carbonate Ocean at least during the study periods).

A4

**Surface  $p\text{CO}_2$  distribution and its controlling factors on the Drake Passage  
and the Scotia Sea in December 2001**

JeongHee Shim<sup>1</sup>, \*, Young Chul Kang<sup>2</sup>, Dongseon Kim<sup>1</sup>, and Sang-Hwa Choi<sup>3</sup>

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Surface measurements of  $p\text{CO}_2$ ,  $\text{TCO}_2$ , alkalinity, and nutrients were made on the Drake Passage and the Scotia Sea in December 2001. Surface  $p\text{CO}_2$  concentration along the Scotia Sea Line (WS-Line) ranged from 370-420  $\mu\text{atm}$  and increased across the Polar and Scotia Fronts by about 10-20  $\mu\text{atm}$ , while the surface  $p\text{CO}_2$  along the Drake Passage Line (DP-Line) ranged from 380-400  $\mu\text{atm}$  and have no significant change across the front. Seasonal warming from winter to the study period forced an increase of 0.08 to 0.27  $\mu\text{atm d}^{-1}$  in surface  $p\text{CO}_2$ ; the higher values were observed at the stations close to the Polar Front. The air-sea exchange decreased surface  $p\text{CO}_2$  along the WS-Line but increased surface  $p\text{CO}_2$  along the DP-Line. It suggests that the area around the WS-Line supposed to be a weak  $\text{CO}_2$  source, while the area around the DP-Line acted as a  $\text{CO}_2$  sink during the study period. The surface  $p\text{CO}_2$  changes by biological production were several times higher at the WS-Line than those at the DP-Line. Physical mixing also promoted an increase of surface  $p\text{CO}_2$  along both lines. South of Scotia Front, mixing was the dominant process of surface  $p\text{CO}_2$  change. It suggests the possibilities of lateral and vertical transport of  $\text{CO}_2$ -rich water masses from the Weddell Sea and the deep ocean to the surface. Our results suggest that the major factors affecting the surface  $p\text{CO}_2$  distribution were the biological production and physical mixing at the WS-Line, while seasonal warming at the DP-Line during the study period.

A5

## Methane in the Siberian and Alaskan land-shelf system: a factor of global significance?

Natalia Shakhova<sup>1</sup>, Igor Semiletov<sup>2</sup>, Vladimir Romanovsky<sup>3</sup>

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<sup>3</sup>*Geophysical Institute, UAF*

Carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) are the most abundant and most important greenhouse gases in the atmosphere. Recent evidence that atmospheric CH<sub>4</sub> is increasing globally has made it an urgent necessity to understand the natural processes, both physical and biological, which control methane concentrations (Rassmussen and Khalil, 1984; Steele et al., 1987; Blake and Rowland, 1988; Cicerone and Oremland, 1988). At the current rate of increase, warming due to CH<sub>4</sub> is about 38% of the warming due to CO<sub>2</sub>. *At present, the maximum atmospheric CH<sub>4</sub> is located over Arctic/Subarctic; the value of CH<sub>4</sub> over the Arctic exceeds that over Antarctica by 8-10%. A comparison of the Antarctic (Vostok) and Greenland (GRIP) ice core data shows that the pole-to-pole gradient of atmospheric CH<sub>4</sub> (by 8-10%) and CO<sub>2</sub> (by 1-2%) in warm epochs is decreased to practically negligible values during glacial epochs.* **Our hypothesis is that** this is a complex consequence of linkages between climate change and permafrost conditions: in cold periods the northern ecosystems accumulate organic carbon in permafrost (because the rates of photosynthesis decrease more slowly with a drop in temperature than do the decomposition rates), while in warm periods the buried carbon in the form of CH<sub>4</sub> and CO<sub>2</sub> is released (pumped back) into the atmosphere. It may therefore be hypothesized that during global warming the North is a source of both greenhouse gases into the atmosphere. We suggest that during the Holocene and previous "warm stages", the formation and evolution of thaw lakes and disturbance of gas hydrates are the best candidates to explain the resulting increase in the atmospheric CH<sub>4</sub>.

Results of observations in the Siberian and Alaskan Arctic regions may confirm the hypothesis, though additional studies are required.

**B1**

**Ecological and biogeochemical response of Antarctic ecosystems on iron fertilization and implications on global carbon cycle**

Ulrich Bathmann \*

Several experiments have demonstrated that iron supply leads to enhanced primary production in the Southern Ocean as in other high-nutrient-low chlorophyll (HNLC) open ocean areas. But in all *in situ* experiments for determining processes to follow such iron supply, the long-term fate of the carbon fixed additionally remained unknown. Contrary to the common assumption that zooplankton play a minor role in plankton productivity of Southern Ocean HNLC areas, zooplankton structure and influence phytoplankton development and thus alter carbon flux, as we will show from results of 2 iron fertilization experiments EisenEx and EIFEx in the Atlantic sector of the Southern Ocean. After EIFEx was successful of stimulating a phytoplankton bloom in a closed oceanic eddy located in the Antarctic Polar Front, we also could follow the fate of the accumulated carbon into the ocean interior and to the deep-sea sediments between January and April 2004. Consequences for carbon sequestration in the Southern Ocean will be discussed.

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## B2

**Phytoplankton community structure in the Drake Passage between the Magellan Strait and the Bransfield Strait during the Austral summer of 2001/02**

Sung-Ho Kang, Jae-Shin Kang, Jung-Eun Choi, Hyung-Min Joo, Ji-Soo Park

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During the Austral summer of 2001/02, phytoplankton biomass and species distribution were measured in the Drake Passage between the Magellan Strait and the Bransfield Strait region. Size-fractionated chlorophyll *a* (chl *a*) concentrations with species information were measured to investigate the relations between physico-chemical factors and phytoplankton community structure. Chl *a* values ranged from 0.14 to 2.42 mg chl *a* m<sup>-3</sup> (mean of 0.93 mg chl *a* m<sup>-3</sup>) in the overall surface stations. The highest values of the chl *a* concentrations (1.08 - 2.42 mg chl *a* m<sup>-3</sup>) were found in the Magellan Strait and near Falkland Island in the Sub-Antarctic. Nanoplanktonic (<20 µm) phytoflagellates were the important contributors for the increase of the chl *a* in the pelagic region. The nano-sized phytoflagellates accounted for more than 80% of the total chl *a* biomass in the pelagic regions of the Sub-Antarctic and the Antarctic. Mean chl *a* concentration in the Sub-Antarctic (0.92 mg chl *a* m<sup>-3</sup>) was 0.05 mg chl *a* m<sup>-3</sup> lower than in the Antarctic (0.97 mg chl *a* m<sup>-3</sup>). The phytoplankton community of the diatom (>20 µm) dominated-bloom in the Sub-Antarctic was different with phytoflagellate (<20 µm) dominated-bloom formed in the Antarctic. Autotrophic pico- and nanoplankton contributed >80% to total chl *a* in regions with low chl *a* concentrations, but microplankton contributed >50% in regions where phytoplankton biomass accumulated (Magellan Strait region, Falkland Island region). As expected, chlorophyll stocks in the open waters of the Sub-Antarctic and ACC region were monotonously low (<1.0 mg chl *a* m<sup>-3</sup>) throughout the study, while a negligible build-up (<0.5 mg chl *a* m<sup>-3</sup>) of phytoplankton biomass was observed in association with Polar Front region (PFR). In striking contrast to this unexpected poverty of the PFR, phytoplankton increases (>1.0 mg chl *a* m<sup>-3</sup>), dominated by diatoms and *Cryptomonas* species, accumulated in coastal regions of the Sub-Antarctic (Magellan Strait and Falkland Island regions) and the Antarctic (Bransfield Strait and Maxwell Bay regions), respectively. The higher chl *a* concentrations in the Sub-Antarctic zone of the Atlantic Ocean may be caused by the higher deposition rate in the aeolian supply of dust (Fe input) from the Patagonian desert, more favorable light conditions and vertical

stability and a virtual absence of larger grazers. The monotonously low biomass levels of the Polar Front region seems to be maintained by the combination of low growth rates due to deep mixing, lower iron availability and high grazing pressure.

**B3****Krill feces as a key vehicle of the downward particle flux in Southern Ocean**Hyoung-Chul SHIN<sup>\*1</sup>, Dongseon KIM<sup>2</sup>, Dong-Yup KIM<sup>1</sup>, Yoon-Hee JUNG<sup>1</sup><sup>1</sup>*Korea Polar Research Institute, KORDI, Ansan, Seoul 425-600 Korea*<sup>2</sup>*Ocean climate and environment research division, KORDI, Ansan, Seoul 425-600 Korea*

A preliminary analysis of materials from an Antarctic sediment trap was undertaken. The analyzed samples were part of the year-round collections (from December 1999 to December 2000) obtained from two depths (678m and 1678m), south of Elephant Island, Antarctica. To filter sequentially through a series of sieves proved to be the simple, least destructive method to sort the trap material by the origin. The upper trap material was dominated by zooplankton feces during summer. Most of the feces of Antarctic krill could be retained by a 180  $\mu\text{m}$  mesh, and were by far the most significant contributor, reaching 60% by mass. Smaller pellets of other origins were of much less importance, and the contribution of flocculent material could hardly be quantified. On the other hand, the lower trap material was dominated by a fraction that passed through a 32  $\mu\text{m}$  mesh, and could not be attributed to zooplankton feces, but to more lithogenic origin. The krill feces recovered from the trap contained significantly more carbon and biogenic silica than in finer sized fraction. The krill feces fraction contained broken cells of large diatom species whereas the fine sized fraction contained more of less damaged cells of much smaller species. The density of krill fecal strings in the trap was lower than measured for fresh pellets of other euphausiid species but sufficiently high so that the pellets sink quite rapidly and reach the upper trap within a few days. The downward flux of carbon and biogenic silica mediated by krill feces should be substantial. This suggests that the grazing pressure of krill, the removal of diatom cells from the upper water column in particular, might be more intense than previously thought. It also implies that the abundance and the distribution of large grazers such as krill and salps can be critical in determining the downward carbon flux.

**B4**

**Do different grazing mechanisms make any difference in the DMSP release to seawater?**

Nobue KASAMATSU<sup>1</sup>, So KAWAGUCHI<sup>2,5</sup>, Shuichi WATANABE<sup>3</sup>, Tsuneo ODATE,  
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Dimethylsulfide (DMS) is the most abundant form of volatile sulfur in the ocean and may influence planetary climate by altering the global radiation balance. DMS is produced in seawater by the breakdown of dimethylsulfoniopropionate (DMSP) produced by phytoplankton. Zooplankton grazing can release DMSP from phytoplankton cells into seawater. Antarctic krill, *Euphausia superba*, and the tunicate, *Salpa Thompsoni*, are both dominant macrozooplankton groups in the Southern Ocean. Krill break phytoplankton cells in their mandibles before ingestion causing the release of organic matter to seawater while salps ingest whole phytoplankton, transferring the ingested chemicals into rapidly sinking pellets. Because of their different grazing mechanisms and their importance as consumers of primary producers in the Southern Ocean, we aimed at to compare the contribution of krill and salps to DMSP release into this ocean system. In February 2002, shipboard incubation experiments were conducted using these two dominant macrozooplankton species. During the incubation experiments, both animals fed on phytoplankton. DMSP release into seawater was linearly related to phytoplankton ingestion of krill. However, salps released negligible amounts of DMSP. The fecal pellets of krill contained broken phytoplankton cells whereas those of salps contained unbroken cells. The production rate of dissolved DMSP+DMS by krill grazing was 2.96 nmol ind<sup>-1</sup> h<sup>-1</sup>. This production rate of krill is comparable to those of copepods as previously reported. Our results indicate that grazing mechanism of krill is an efficient way to release DMSP into seawater.



B5

**Time-series study of lipid storage of dominant copepod *Calanoides acutus* in the Antarctic Ocean**

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Time-series observations of lipid storage of herbivorous copepod *Calanoides acutus* were conducted on RSV Aurora Australis in November 2001, Hakuho Maru in January 2002 and RV Tangaroa in February 2002 along a transect on 140E between 61 and 66S. It is widely accepted that *C. acutus* has a one-year life span, and accumulates lipid as an energy reserve during the productive season, and then migrates to deeper waters for overwintering. In this study, copepodite V (CV) stage, which is major overwintering stage, was dominant at the surface in November and ranged from 10 to 40% of the total population. They must have not developed from eggs produced that spring, but have overwintered, and had not been able to mature at depth prior to ascending to the surface. Furthermore, the dry weight of the CV stage in January was double that of those of November, while the lipid weight did not change dramatically. Thus, the CV stages after overwintering had stored lipid as an energy reserve, and maintained high lipid contents during summer months. The population in February could be divided into two groups, based on their dry weight, with the difference being over 600g. The difference between the two groups was 2.0 times by dry weight, and 1.5 times by lipid weight. Therefore, a first-year group of lipid-poor individuals developed from eggs in the current spring co-existed in autumn with a second-year group, lipid-rich individuals with high lipid contents that had already overwintered once as a CV stage.

C1

**An Introduction of NOAA's Polar Programs**

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The National Oceanic and Atmospheric Administration (NOAA) supports the concept of the International Polar Year (IPY) and expects to play a leading role in its implementation, both nationally and internationally. From a NOAA perspective, there are several themes that seem appropriate for the IPY, and these are 1) to initiate sustained effort to assess environmental change and variability of the polar region 2) to create observing networks and improve science infrastructure; 3) to study the coupled human-natural systems in the Arctic, and 4) to explore new frontiers in the polar research, such as polar ocean exploration and polar influence on impacts of space weather. Each of these themes will consist of a series of NOAA efforts and activities in supporting science programs across all of NOAA agencies. This presentation will give an overview of NOAA's perspective on the IPY, along with an inventory of current and planned NOAA programs on the polar science and research.

## C2

**The up-to-now research progress of CHINARE-2003**

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Marine science investigations in Bering Sea, Chukchi Sea and Canada Basin had been successfully conducted during the Second Chinese National Arctic Research Expedition (CHINARE-2003) from July 15 to September 26, 2003, involving 53 Chinese scientists, technicians and 13 overseas scientists.

The objectives of this expedition was to get further understanding of the Arctic response and feedbacks to global change and to get better understanding of the influence of the Arctic change to the climate change in China. The field work of CHINARE-2003 covered a large area of south to north 3000 km and east to west 900 km, finishing the multi-disciplinary survey at 209 stations including 175 oceanographic stations, 13 floating sea ice stations and 21 Helicopter supported observation stations. This presentation will show the up to now major research progress of CHINARE-2003 in Oceanography, Marine chemistry, Marine biology, Marine geology and geochemistry.

C3

**Detecting decadal-scale oxygen trends in the Southern Ocean**

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Trends of dissolved oxygen in the ocean can be a powerful tool to understand changes in the coupled physical and biogeochemical ocean system. The oceanic oxygen budget is furthermore a crucial constraint on the current anthropogenic CO<sub>2</sub> budget. Here we estimate decadal-scale oxygen trends in the Southern Ocean, where several general circulation models predict substantial trends in circulation and the dissolved oxygen budget in response to anthropogenic climate change. These predicted changes, if substantiated by observations, would have considerable implications for deepwater ventilation as well as oceanic heat and CO<sub>2</sub> uptake. We estimate decadal-scale changes in dissolved oxygen in the Southern Ocean since the 1960s using the World Ocean Database 2001. We test previously used data analysis methods using positive and negative controls and develop correction techniques to account for potential spatial and temporal sampling biases. We find significant decreases in oxygen concentration in deep waters of the Southern Ocean during the past four decades. The estimated oxygen trends are spatially heterogeneous, suggesting that previous conclusions based on assumed homogeneous patterns may have to be revisited. The estimated oxygen trends can be used to assess the skill of the general circulation models to reproduce the observed changes in the Southern Ocean.

C4

## **Technology and Some Results of Ice Engineering Survey on the Shelf of Arctic Seas for Needs of Oil and Gas Producing Companies**

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Ice cover in Arctic seas is a very important factor of environmental conditions. Construction and trouble-free exploitation of structures and communication lines on the shelf, as well as rational planning and conducting of transport operations, organization of environment protection measures are impossible without taking into account of this factor.

In the course of the recent years, the Arctic and Antarctic Research Institute developed and successfully realized technology of information collection in the regions of oil and gas structures in the Barents Sea.

Annual cycle of works consists of conducting of multi-disciplinary expeditions in the period of maximum development of ice cover and summer expeditions in the ice free water area.

In the winter period these works at ice stations are conducted on an ice floe near ship board and by means of helicopter landing operation on ice floes and icebergs located at some distance from research vessel.

The following works are carried out at the ice stations:

- topographic survey of the upper surface of the ice cover with determination of sizes and location of above-water parts of ridges and icebergs;
- sonar survey of the ice cover bottom surface with determination of sizes and draft of keels of ridges and grounded ridges (stamukhas);
- study of the underwater part of the ridges and grounded ridges, data verification of the sonar survey by direct measurements, submarine video- and photography by skin-divers;
- through drilling of the ridges and grounded ridges, ratio determination sail/keel, packing coefficient of ridge sails and keels, ridge internal structure , determination and estimation of vertical and horizontal sizes of the

- consolidated part of the ridges;
- obtaining of temperature, salinity and density profiles of flat and deformed sea ice and icebergs, ice classification according to structural-genetic types;
- determination of breaking points of the flat and deformed sea ice and icebergs using small specimens;
- conducting of large-scale tests of ice strength;
- estimation of ice dynamics characteristics with the help of satellite navigation system;
- observation and record of under-ice current parameters;
- registration of sea level oscillations;
- observations for energy balance and standard meteorological observations.

The remote observations include:

- aerial photography;
- laser profiling of the upper surface of the ice cover;
- photography of separate ridges and ice reconnaissance for required tracks;
- sonar survey of the bottom surface of the ice cover;
- observations using self-contained drifting buoys deployed on ice and icebergs.

The emphasis of the summer expeditions is on collection of information about bottom scouring processes by keels of ridges and stamukhas, iceberg formation at glacier tongues of Arctic archipelagoes.

Large-scale Russian companies (Gasprom, Gasflot, Rosshelf, LUKOIL, Varandineftgas, Sevmorneftgas, Murmansk steamship company, etc.), as well as foreign companies (CONOCO, Norsk Hydro, StatOil, Fortum, Kverner Masa-Yards, Neste, etc.) were customers of these research works in the years 1998-2003.

C5

**Temperature and salinity distributions in the Southern Oceans from autonomous profiling floats**

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As a part of the International ARGO Program, KORDI has been deploying autonomous profiling floats across the Drake Passage since 2001, and to the south of Australia since 2002. The Southern Oceans are rather poorly observed areas and the profiles and trajectories from the floats will be useful information. The data from the ARGO Project is open to the public and one can download necessary data from the ARGO Data Center through the Internet. We have utilized data collected from the ARGO Data Center in addition to those from the floats deployed by KORDI to investigate temperature and salinity distributions as well as deep flows in the Southern Oceans in the Lagrangian point of view. In addition, we will introduce the roles of KORDI in the international ARGO Program for the Southern Oceans.

## D1

### **Extremophiles from Antarctica: biodiversity and biotechnological potential**

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Recently there has been a rapid accumulation of knowledge of microbial life in cold and frozen ecosystems. This understanding has revealed the extensive diversity of psychroactive prokaryotes. Cultivation-based and molecular-based surveys have been performed in Antarctic habitats ranging from glacial ice to continental shelf sediments. Results indicate that psychroactive taxa permeate throughout the Bacteria while they represent a more mysterious element of diversity in the Archaea owing to a notable lack of cultured strains. In certain ecosystems the diversity of psychroactive populations reach levels comparable to the richest temperature equivalents. Within these communities must exist tremendous genetic diversity that is potentially of fundamental and of practical value? So far this genetic pool has been hardly explored. Only recently have genomic data become available for various psychroactive prokaryotes and more is required. This owes to the fact that psychroactive microbes possess manifold mechanisms for cold adaptations, which not only provide enhanced survival and persistence but probably also contributes to niche specialisation. These mechanisms, including cold-active and ice-active proteins, polyunsaturated lipids and exopolysaccharides also have a great interest to biotechnologists. Interestingly, cold adaptation mechanisms are heterogenous in distribution and closely related bacteria, even in the same genus, can have quite different means of coping with low temperature and related environmental hurdles such as extremes of osmolarity. This heterogenous pattern could be a consequence of the recent evolution of prokaryotes to cold ecosystems. Some recent evidence is available that horizontal gene transfer has resulted in acquisition of some of these adaptations.



D2

## Molecular Systematics of Arctic Bacteria

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The Arctic is a representative cold habitat that offers good sources of useful enzymes with activity at low temperature. We isolated soil and marine samples from around Korean Arctic Research Station Dasan located at Ny-Ålesund, Svalbard, Norway (79N, 12E), on 2002 and 2003 summer. The collected samples were inoculated and colonies were successfully cultured on suitable agar plates at 4 ~ 10°C. Genomic DNA was extracted from liquid-cultured strains and 16S rDNA fragments were amplified by PCR. Phylogenetic analysis using 16S rDNA sequences indicated that the soil bacteria belong to *Achromobacter*, *Arthrobacter*, *Flavobacterium*, *Pedobacter*, *Pseudomonas* and *Psychrobacter*. On the other hand, the marine bacteria belong to *Aequorivita*, *Ahrensia*, *Algoriphagus*, *Carnobacterium*, *Cellulophaga*, *Cobetia*, *Colwellia*, *Exiguobacterium*, *Flavobacterium*, *Glaciecola*, *Hydrogenophaga*, *Hyphomicrobium*, *Leifsonia*, *Loktanella*, *Marinobacter*, *Marinomonas*, *Paracoccus*, *Pibocella*, *Plantibacter*, *Planococcus*, *Polaribacter*, *Pseudoaltermonas*, *Pseudomonas*, *Psychrobacter*, *Psychroserpens*, *Roseobacter*, *Shewanella*, *Sulfatobacter*, *Vibrio* and *Zobellia*. Among the Arctic bacteria, *Psychroserpens burtonensis* seems to be universal in seashore around Korean Arctic Research Station Dasan. We found several candidates for new species or genus. We also screened protease- or chitinase-producing bacteria, L-ribose-utilizing bacteria and UV-resistant bacteria. We expect that these Arctic bacteria can be used to develop new industrial enzymes or UV-resistant substances.

D3

**Diversity, viability, and activity potential of the bacterial cells preserved in ancient Antarctic glacial ice**

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Bacterial 16S rRNA sequence diversities were obtained via direct PCR amplification and cloning of the genes in total genomic DNA extracted from two Antarctic glacial ice samples. Their ages were minimum 100,000~300,000 years and 7.3 million years old, respectively, as determined by a cosmogenic-nuclide exposure-dating method and stable isotope analyses of in situ volcanic ash deposits. The ice samples were from the Dry Valleys; the younger ice (DLE9812) from Mullins Valley, and the older ice (EME9803) from upper Beacon Valley, and the latter is the oldest known ice on Earth. The 16S sequence data revealed many distinct phylotypes that are far-related to the currently catalogued species, yet best matched to those already documented from similar environments. Aliquots of ice melt water, aseptically prepared from the interior of the ice samples, were incubated at 4°C with nutrient enrichment. Optical density (OD<sub>600</sub>) of the liquid cultures was monitored as a proxy of cell density, and subsamples were taken as OD<sub>600</sub> increased. Portions of the subsamples were spread on plate media of the same enrichment for the isolation of viable cells. We also obtained 16S sequence diversities of the liquid cultures with the method described earlier. Certain enrichment types apparently stimulated the growth, as indicated by OD<sub>600</sub> increase, in both EME9803 (older) and DLE9812 (younger). We isolated viable cells of a few different colony types from DLE9812 after ca. 2 months of incubation. Further isolation and subsequent identification via 16S sequencing are under way. Only a few different phylotypes were found from DLE9812 liquid culture, which implies a much simpler diversity than in the original ice community. As for the EME9803 liquid culture, direct PCR amplification of the 16S genes was not successful due probably to the low cell density, and no colonies formed yet, either. We also investigated the potential metabolic capacity of the frozen ancient bacterial cells by incubating the freshly melt water at 4°C with radio-labelled substrates (3H TdR, 3H

leucine,  $^{14}\text{C}$  glucose). Sizable activities were measured from days of the incubation. This study provided valuable information on diversity and molecular phylogeny of ice-encased ancient bacteria, and their evolutionary relationships to current relatives. Further sequencing of genomic DNA should characterize the functional genes from millions years ago, which might give clues as to the evolution rates and the source of the host cells. Sustained viability over a geological time frame may address the role of prokaryotes in the propagation of life forms, potentially up to an inter-planetary scale.

## D4

### **Antarctic Actinomycetes for Biotechnological Application as Bio-demulsifier**

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We isolated soil actinomycete strains near from Sejong Station in Antarctic region. We tested demulsification ability of the actinomycete spores to develop biological demulsification technique. One isolate, identified as *Streptomyces* sp. on the basis of 16S rDNA sequences, produced hydrophobic aerial spores. The aerial spores demulsified an emulsion of kerosene/0.2% Triton X-100 (2:1, v/v) to 50% and 95% within 1 min. Hydrophobicity of the spores from the solid culture was correlated with both culture time and demulsification activity. However, demulsifying activity was not detected with neither mycelia nor spores from the liquid cultures, and the submerged spores displayed low hydrophobicity. Spore surface of liquid culture contained similar composition of amino acids as that of solid culture. But the content of glucose from liquid cultured spores was higher than that from solid culture. Demulsifying device was proposed for pre-treatment of oil-water separation. It could be developed as bio-demulsifier for separation of oil and water at oil spill.

D5

**Phylogeny and biogeography of representative red algae from the Antarctic**Han-Gu Choi<sup>\*1</sup>, Ji Hee Kim<sup>2</sup> and Hosung Chung<sup>2</sup><sup>1</sup> Institute of Natural Sciences, Kangnung National University, Kangnung 210-702, Korea<sup>2</sup> Korea Polar Research Institute, Ansan 426-744, Korea

The aim of the current investigation has been to test the general convention that phylogeny and biogeography of algae from the Antarctic are closely related to each other. Phylogeny and biogeography of representative red algae from King George Islands in the Antarctic and south Chile were investigated. Three bangialean, one ballialean, five coralline, one palmariacean and twelve Ceramiales algae were compared in terms of morphology, biogeography, nuclear rDNA and plastid *rbcL*-S sequence data among each order worldwide. Phylogenetic relationships among over 70 bangialean species based on nuclear SSU rDNA and plastid *rbcL* sequence data indicate that *Porphyra endivifolium* and *P. plocamioides* have evolved independently from other ancestors in the north Pacific and north Atlantic, respectively. *Palmaria decipiens* was also included to the north Pacific and north Atlantic palmariacean clade inferred from nuclear ITS rDNA sequence data of 12 species with 24 populations in the Palmariaceae. *Ballia callitricha* and the Australian species grouped together based on nuclear SSU rDNA sequence data of over 500 red algal species. Our SSU data also indicate that five coralline and four ceramiales algae were closely related to each relative taxa from south Australia, South Africa and south Chile consistent with their biogeography. Phylogeny and biogeography of each taxa will be discussed in detail.

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D6

**Can Antarctic microalgae produce ice-binding proteins?**

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Attempts to use natural antifreeze proteins to protect cells and tissues from freezing damage have had mixed results. Some success has been achieved in preventing hemolysis of red blood cells and maintaining sperm motility. There is some evidence that the protective effect of the antifreeze proteins is due to their ability to inhibit the recrystallization of ice. Ice-binding proteins (IBPs; formerly called ice-active substances, or IASs) from an Antarctic sea ice diatom and other Antarctic photosynthetic organisms can inhibit the recrystallization of ice at concentrations in the microgram ml<sup>-1</sup> range. At natural concentrations in seawater, the IBPs cause pitting and other changes in the habit of ice crystals, which are an indication that they adsorb to the ice surface. Other evidence of ice-binding by IBPs is their preferential incorporation in the ice phase of partially frozen solutions and incorporation in ice hemispheres. Unlike antifreeze proteins, the IBPs do not significantly lower the freezing point. Rather their function appears to be prevention of damage in the frozen state as they have been shown to increase survival of diatoms subjected to a freeze-thaw cycle. These results encouraged us to evaluate the ability of an algal IBP to reduce freezing damage to another cell type, red blood cells.

D7

**Evolutionary history of the Antarctic sea, *Sterechinus neumayeri***

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The Antarctic sea urchin *Sterechinus neumayeri* is the most abundant regular sea urchin in shallow Antarctic waters showing circum-Antarctic distribution. Because of its abundance, easy availability and wide distribution, this organism has been used as a model system in many fields of the Antarctic biology. Yet, little is known about its evolutionary history and whether its evolution was correlated with separation of continents between the Antarctica and the South America. In the present study, an attempt was made to infer the molecular phylogeny of the Antarctic sea urchin in relation to the two southernmost South America sea urchins *Loxechinus albus* and *Pseudechinus magellanicus* and to compare the divergence time with tectonic events in the southern hemisphere. The phylogenies were reconstructed with mitochondrial DNA sequences of 12S rDNA-tRNA(gln) region (877nt) and cytochrome oxidase subunit I (COI, 1079nt) including not only the three species but also a species of Parechinidae *Paracentrotus lividus* and three species of Strongylocentrotidae *Strongylocentrotus purpuratus*, *S. intermedius*, and *Hemicentrotus pulcherrimus*. The phylogenetic trees reveal that *L. albus* and *P. lividus* form a closest relative cluster and *S. neumayeri* branches off from the lineage as a sister taxon. This group of three species makes a clear distinction from the species of Strongylocentrotidae. *P. magellanicus* comes as the most distantly related species. The divergence time of the species were estimated from the trees after the rate of sequence evolution was calibrated using the time of separation between Parechinidae and Strongylocentrotidae (35-50m.y.a.) as a reference time frame. The divergence between *S. neumayeri* and *L. albus* seems to occur 24-35 million years ago coincident with separation of the Antarctica from the South America. The result suggests that speciation of the Antarctic sea urchin must have been provoked by the tectonic event in this southern region.

D8

### **Bacterial Diversities in Canada Basin**

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Denaturing gradient gel electrophoresis (DGGE) profiles of PCR amplified V3 regions of 16S rRNA gene were used to assess the diversity of bacterial assemblages in Canada Basin, the Arctic Ocean. DGGE fingerprint showed the characteristic band patterns for each depth. Deep waters tended to contain more *-Proteobacteria* and fewer *-Proteobacteria* than superficial waters. Moreover, the sequences derived directly from seawater samples presented more distinguishable DGGE bands in the separation patterns than that retrieved from the same samples after cultivation. All of sequences derived from the samples fell into four major lineages of the domain *Bacteria*: -, *Proteobacteria*, the CFB group and *Acidobacteria* groups (high G+C, Gram-positive bacteria). Sequences obtained in this study were most closely related to the sequences of cultivated isolates and uncultured bacterial clones from marine environment in database, especially the Antarctic and Arctic marine environments.



**P1****Deep currents in the Bransfield Strait, Antarctica**

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The Bransfield Strait is a semi-enclosed sea bounded between the Antarctic Peninsula and the South Shetland Islands, and is connected to the Weddell Scotia Confluence in the northeast. From January 1999, four RCM current meters have been moored annually at two sites in east and central basins in the Bransfield Strait. Relevant structures of the time series obtained during 1999-2002 are presented focused on the variability of the deep flow and water properties. In the east basin, the main feature of the flow pattern is the barotropic lunar fortnightly tidal current with its maximum amplitude about 50 cm/sec. The southwestward flow is dominant in the residual current indicating the high correlation with the bottom topography. The monthly mean current velocity shows a seasonal variation with a maximum in August and a minimum in December. While, in the central basin, the fortnightly current pattern does not appear suggesting that the deep flow is influenced strongly by the eastward Bransfield Current. For the residual current, the eastward component is dominant but the flow variability with the period over 10 days is significant. The monthly mean current velocity does not show a typical trend. Seawater temperature shows a clear seasonal variation with a slight increase until the austral winter and a decrease during the period from August to October in the both basins. However, intensity and phase differ inter-annually with the maximum seasonal variation about 0.3 °C and over 0.7 °C in the east and central basins, respectively. The seasonal variation of salinity is less clear but parts of data indicate a good correlation with the temperature variation, especially in the central basin. Overall features of time series data analyzed suggest that further modification of schematic current pathway is needed in the east basin region from those suggested by Gordon et al. (2000, 2001) and von Gyldenfeldt et al. (2002).

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P2

**Effect of Soil Temperature on the fluxes of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O in Boreal  
Forest,  
Central Alaska**

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We have measured the fluxes of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O using the dynamic chambers and soil temperatures at three depths (5, 10, and 20 cm) in burned and unburned black spruce forest of Caribou Poker Creek Research Watershed (CPCRW), central Alaska during the growth period of 1999 to 2002. The prescribed FROSTFIRE burning experiment was occurred in 1999 for focus on the large-scale ecological consequences of fire. As a result, the fluxes of CO<sub>2</sub> and N<sub>2</sub>O have a significant temperature dependence at soil depths of 5, 10, and 20 cm in burned and unburned black spruce forest soils, demonstrating that the effect of soil temperature elucidates a maximum of 50%, 40%, and 35% of the variability of annual Q<sub>10</sub> values for both fluxes, respectively. However, CH<sub>4</sub> fluxes show a weak exponential correlation with soil temperature at three soil depths.

Therefore, soil temperature is one of the significant factors determining the soil-originated fluxes in boreal forest.

P3

### **Japanese-Australian time-series observations along 140 ° East in the Antarctic Ocean**

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Most previous work on Antarctic Ocean productivity is based on observations from a single cruise. Time series studies are required to elucidate the processes happening in the water column to better understand the impacts of climate change. Japanese and Australian researchers carried out time-series observations with employing a multi-ship operation in the 2001/2002 austral summer, using several vessels: RSV Aurora Australis (October-December 2001), RV Hakuho Maru (January 2002), RV Tangaroa (February 2002), and Shirase (March 2002). Further research was undertaken on TS Umitaka Maru (January 2003), RV Tangaroa (February-March 2003), and Shirase (March 2003) in the 2002/2003 austral summer. The major field area in both summers was south of 61° S along 140° E, where biological oceanographic studies have been repeatedly undertaken in the Australian Antarctic program. On the four cruises in 2001/2002 and the three cruises in 2002/2003, several key measurements using standard methods between voyages were repeated to address the following issues 1) Biogeochemical cycles between the lower atmosphere and ocean surface, 2) DMS(P) production/formation in biological processes, 3) Vertical flux, and 4) The role of sea-ice variation and Antarctic Bottom Water formation in the global climate system. Samples and data are still being processed. Preliminary results will be presented. Sea ice conditions were markedly different between the summers. In February 2002, the sea ice had retreated to the Antarctic coast while in February-March 2003 the study area was still ice covered. The difference in sea ice conditions appears to affect the phytoplankton as well as the zooplankton community structure. In particular, in the 2002/2003 summer, the zooplankton community was characterized by less salps, which predominated in the 2001/2002 summer. Preliminary evidence indicates the differences in biological community structures may result in variations of biogeochemical cycles.

P4

**Year to year variability of *Salpa thompsoni* population along 140° E in the Antarctic Ocean**

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Poster session

Distribution and abundance of *Salpa thompsoni* were investigated along 140°E off east Antarctica in two austral summers of 2002 and 2003. The populations of *S. thompsoni* with contrasting abundance were found between two summers: *S. thompsoni* was abundantly collected between 60°S and 65°S with the maximum density of 368 individuals per 1000m<sup>3</sup> at 62°S in 2002 summer, while the abundance in 2003 summer was less than 16 individuals per 1000m<sup>3</sup> throughout the sampling area. In 2002 summer, population of aggregate forms was composed of mainly large (>35mm) spent individuals in the southern area between 63°S and 65°S, but small individuals (<15mm) with early reproductive stages (Stage 0 and 1) dominated north of 62°S. In 2003 summer, small with early reproductive stage aggregates were predominant throughout the survey area. Percentage of aggregate forms with empty (dead) embryos, which indicate the lack of sexual reproductive ability, was higher in 2003 (16.5%) than that in 2002 (1.5 %). These results suggest that one of the main reason causing decline in overall numerical abundance of *S. thompsoni* in 2003 summer is attributed to the incompetency of alternation of generation by the defection of genetic activity of salps.

P5

**Relations between environmental changes involved with sea-ice retreat and development of copepods off Enderby Land, Antarctica**

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Over the past decade, a number of studies suggested that sea-ice plays a key role in the Antarctic marine ecological processes. However, there has been little information about the effects of sea-ice on the life cycles of copepods in the Antarctic Ocean. This study aimed to examine the effect of sea ice recession on the reproductive process of large dominant calanoid copepods off Enderby Land in the Indian sector of the Antarctic Ocean.

Zooplankton samples were collected with a vertical haul of the NORPAC standard net (sampling depth: 0-152; 0.33mm mesh) during the Japanese Antarctic Research Expedition from 1972 to 1995 in mid-February to early March. A total of 76 samples and 61 environmental data were selected in the present study.

*Chl.a* abundance was higher between 0 and 20 days after sea-ice recession. Abundance of females of three calanoids (*Metridia gerlachei*, *Calanus propinquus*, and *Calanoides acutus*) increased between 20 and 39 days after sea-ice recession. The abundance and composition of younger copepodites increased with receding ice edge. The oil storages of *Calanoides acutus* and *Rhincalanus gigas* decreased when sea-ice recession progressed, it may be influenced by prey availability, and it increases in high productivity regions and/or under blooming conditions. We suggest that copepods reproduce mainly during sea-ice retreat periods. There were differences, however, in the timing of reproduction among the species within the same season. These differences might represent life-strategies adaptations.

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### **Distribution Pattern of *Deschampsia antarctica*, a Flowering Plant Newly Colonized around King Sejong Station in Antarctica**

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As a base line survey for long-term monitoring on environmental change around the Antarctic King Sejong Station, distribution pattern of *Deschampsia antarctica* Desv., a flowering plant newly colonized were investigated qualitatively and quantitatively in both austral summer 2002-2003. Dispersal of the seeds and vegetative leaves by skuas might lead to the colonization into this area from neighbors in Maxwell Bay. The pioneer populations were observed around ponds and a stream of the Sejong Point in January 2002, and the maximum dispersal area was four times expanded after a year. Most of the populations were formed on the stable and well-drained substrate, which consisted of moss carpet of *Sanionia georgico-uncinata* (65%) and pebbles (25%), while only a few young individuals were observed on the unstable and watertight silt-sandy area. Especially, *S. georgico-uncianta* was being effectively utilized as their primary substrate with the soft, coarse and water-contained leaves. Also the perennial mature plants of *D. antarctica* were mainly formed on the moss carpet rather than pebbles. A few individuals were grown on other mosses of *Polytrichastrum alpinum*, *Bryum pseudotriquetrum*, *Pohlia cruda*, and *Conostomum magellanicum* and on a liverwort of *Cephaloziella varians*. We expect that dispersal of *D. antarctica* and the following succession to grass field will be continuously and dynamically proceeded in this area, with the characteristics of ecological niche against the initial moss populations, on the similar continuity of environmental change of micro-habitat, e.g. the water content and nutrients of soil and the underground temperature and permafrost.

P7

### **Recent results of bio-logging Science from Antarctica**

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Novel technique to monitor diving behavior of the Antarctic seals and environment of their dive path has been developed. Animal borne TDR (Time Depth Recorder) system has revealed much about their diving behavior in last several decades. Recent advanced microelectronic technologies enabled us to develop further advanced system, which allowed us to conduct direct observation on the complexity of Antarctic marine ecosystem through foraging behavior of the top predators in Antarctica. We developed new bio-logging systems to measure three dimensional dive paths of the animals and prey distribution along their dive paths simultaneously. We applied this technique to the weddells seals in Syowa and Macmurdo Stations in 2002 to understand their foraging strategies. The system is composed of two data loggers. One is able to measure two axis of acceleration and three axis of magnetic fields to calculate three dimensional underwater position of the seals in every second. This system also gives us simultaneous information on flipper movements, swim speed and their posture or body angles. The other one takes image data for prey abundance analysis by digital still camera. Weddell seals dived mostly deeper than 200m and foraged near bottom where much prey was distributed. To dive deeper waters seals dived and returned to the breathing holes selecting straight pathways, while they strayed around bottom area for prey. The prey type of the weddell seals was small fish like *Pleurograma*, which appeared forming small patches.



P8

**Antarctic fish through the artist's eye**Mitsuo Fukuchi<sup>1</sup>, Harvey Marchant<sup>2</sup>, Tetsuo Iwami<sup>3</sup><sup>1</sup>*National Institute of Polar Research, Japan*<sup>2</sup>*Australian Antarctic Division, Australia*<sup>3</sup>*Tokyo Kasei Gakuin University, Japan*

The Antarctic fish fauna evolved following the break up of Gondwana to form the southern continents. While Antarctic fish have been intensely studied and numerous scientific papers and books published on them, there is little appreciation by the general public of their diversity and behaviour. We wish to bring the diversity of Antarctic fish to public attention by producing a book, illustrated by "Gyotaku". Gyotaku (gyo = fish, taku = impression or print) is a distinctively Japanese way of illustrating nature. In its simplest form (the direct method) paint is applied to a fish, shell or plant and a print is taken of the object onto paper or cloth. The indirect method of gyotaku requires much greater skill. Fine paper is moistened and applied to the surface of a fish, plant or other object. Coloured inks are then used to colour the imprint of the organism on the paper. The result is an anatomically exact copy of the organism coloured either as it is in nature or as the artist chooses. While this technique works well on 2 dimensional objects, accurately representing three dimensional subjects is a challenge. Boshu NAGASE has over 30 years experience of producing gyotaku by the indirect method and is regarded as perhaps the principal exponent of this art form. He has had several exhibitions and his work is on permanent display in several organizations including the University of Maine, Australian Institute of Marine Science, the Australian Antarctic Division, the Monaco Oceanographic Museum and insert a Japanese gallery or two. The gyotaku would be used to illustrate a large format book on Antarctic Fish edited by Mitsuo Fukuchi and Harvey Marchant. This would be the first time Antarctic fish have been illustrated in this way. We expect the book to be launched at the 25th anniversary of CCAMLR in 2006.

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### **Seasonal and interannual variations of particle fluxes in eastern Bransfield Strait, Antarctica**

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Time-series sediment traps were deployed to investigate the temporal evolution of particle fluxes in eastern Bransfield Strait over three years, from December 1998 to December 2001. Particle fluxes showed large seasonal and interannual variations. In 1999 and 2000, a seasonal trend of mass fluxes was characterized by highly elevated mass fluxes over  $300 \text{ mg m}^{-2} \text{ d}^{-1}$  during the summer season, of which summer fluxes were two orders of magnitude higher than winter mass fluxes, but such high summer fluxes were not observed in 2001, and seasonality was significantly reduced. The large interannual variation in particle fluxes is closely related with related with year to year changes in sea ice cover in eastern Bransfield Strait, which seems to act to limit the phytoplankton productivity in the surface waters. There is a lag of about one month between the surface water productivity and the export production in eastern Bransfield Strait. An average biogenic silica:organic carbon (Si:C) ratio of 1.5 is obtained at the trap material collected at a depth of 678 – 1034 m, of which ratio is lower than the results obtained in the marginal winter sea ice zone of the Atlantic section and the Antarctic zone of the Pacific section, but is similar to those observed in the Antarctic Polar Frontal zone of the both section. A three-year mean of annual organic carbon fluxes measured in eastern Bransfield Strait is  $4.21 \pm 3.16 \text{ gC m}^{-2}$ , which is about two times higher than that ( $2.84 \pm 3.33 \text{ gC m}^{-2}$ ) in central Bransfield Strait and a order of magnitude higher than that ( $0.35 \text{ gC m}^{-2}$ ) in western Bransfield Strait.