JAMSTEC Research Activities in the Northern North Pacific

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Dr. Masashi Kusakabe received his Ph.D. from Hokkaido University, Japan, in 1980. He worked at the Department of Geological Sciences, University of Southern from 1980 to 1992, studying behaviors of radioisotopes in the ocean. Dr. Kusakabe has been working at the Japan Marine Science and Technology Center (JAMSTEC) since 1992. Now he is Head of the Biogeochemistry Research Group of the Ocean Research Department of JAMSTEC. From 1992 to 1996, the target area of his research was the East China Sea. Although he misses the comfortable weather of the East China Sea, he is ready to proceed to the northern North Pacific.

The northern North Pacific, especially its western part, has been attracting attention of biogeochemists because of its importance in global biogeochemical cycle of carbon and its related substances. In addition, physical oceanographers have been interested in that region with respect to the formation of the North Pacific Intermediate Water. Despite its importance, there has been few systematic surveys to cover the temporal and spatial variation of biogeochemical processes in the area.

The Japan Marine Science and Technology Center (JAMSTEC) began a biogeochemical study of the northern North Pacific and its adjacent seas two years ago. However, the field campaign, which is expected to last at least 5 years, was not started until JAMSTEC obtained the new research vessel *Mirai* ("future" in Japanese) in the fall of 1997. The vessel is capable of winter operations in high latitudes (length of 130 m, gross tonnage of 8600 tons, service speed of 16 knots and capacity of 28 researchers and 18 technicians). She will enable us to fill data gaps in the high latitudes of the ocean.

Goals of the project are:

- To assess the spatial and temporal variation of flux of CO_2.
- To understand the mechanisms that control the biological pump and its role in the carbon cycle.
- To clarify transportation processes of dissolved materials in in relation to the formation of intermediate water.
- To evaluate the fluxes of carbon and other materials carried by particulate matter to the interior of the deep ocean, and their spatial and temporal variation.
- To determine the past change of ocean environments from records in sediments.

Due to the vast spatial and temporal variability of the biogeochemical processes in the northern North Pacific, JAMSTEC cannot be a sole player in the field, but must coordinate with the Japan JGOFS community, especially NPPS (North Pacific Process Study) group. In 1997, a new Ocean Time Series project in the western North Pacific was funded in Japan, which is an intensive study of seasonal and interannual variation of the processes occurring at station KNOT located at 44˚N and 155˚E (see PICES Press Vol. 6, No. 2, p. 32 for details of the project). JAMSTEC will also be one of the key players in the project. In addition, since *Mirai* cruises are open to scientists outside JAMSTEC, our project is inevitably complementary to other projects. In other words, the JAMSTEC project is within the framework of JGOFS and closely related to other on-going projects.

After the *Mirai* was launched in 1997, there were a series of the shakedown cruises until October 1998. The biogeochemistry group of JAMSTEC joined three cruises. Summary of the cruises is shown in *Table 1*.

Table 1. Summary of shakedown cruises.

Cruise	Date	Area	Activities
MR97-02	11/10/97 12/5/97	northwestern North Pacific	• Deployment of sediment traps (3 stations). • Sampling of bottom sediment by a piston corer and multiple corer. • Underway measurement of pCO_2 TCO_2, and nutrients in the surface water. • Hydrocasts at 13 stations for carbonate species, nutrients, DO, ^{14}C, radioisotopes (^{234}Th), trace metals (Fe), etc.
MR98-05	7/06/98 | 7/24/98	northwestern North Pacific	• Recovery and re-deployment of sediment traps. • Sampling of bottom sediment by a piston corer and multiple corer. • Hydrocasts at 4 stations for carbonate species. • Underway measurement of pCO_2, TCO2
MR98-06	7/30/98 | 9/10/98	northern North Pacific, Bering, Chukchi and Beaufort Seas	• Underway measurement of pCO_2, TCO2, and nutrients in the surface water • Hydrocasts at 25 stations for carbonate species, nutrients, DO, ^{14}C etc.

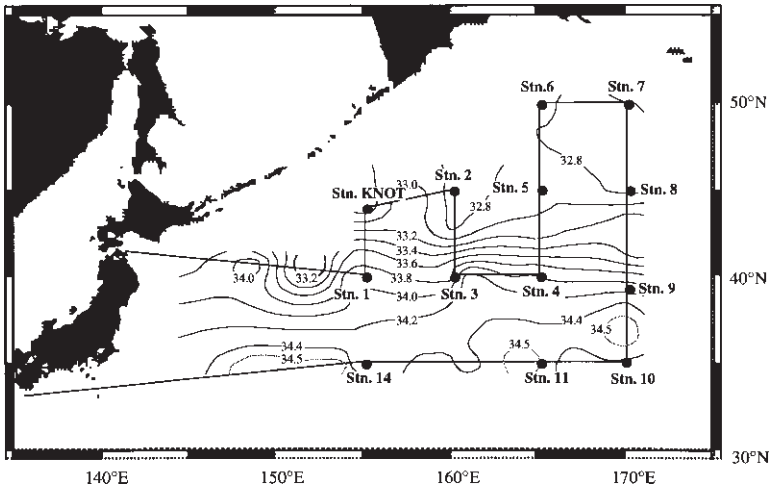

Fig. 1 Distribution of salinity in the surface water along the cruise track and sampling stations in Nov.-Dec., 1997 (MR97-02).

All the observations listed in the table were carried out by JAMSTEC scientists. During the shakedown cruises, we not only tested equipment on board and trained ourselves and technicians, but also carried out a reconnaissance survey in the northern North Pacific.

During the first cruise (MR97-02) in 1997, we occupied 13 stations for hydrocasts (*Figure 1*). In addition, sediment traps were deployed at three stations and bottom sediments were collected. Working in the northern North Pacific in November, the *Mirai* proved to be operable in rough weather. The following are some results obtained during the cruise:

The survey area has clear latitudinal variation. *Figure 2* displays a T-S diagram for all the stations occupied. Water mass structure in the region has three distinct characteristics: (1) the subarctic zone (Stns. 2, 5, 6, 7, 8, KNOT) (2) transition zone (Stns. 1, 3, 4, 9) and (3) subtropical zone (Stns. 10, 11, 14). Chemical constituents also change accordingly. Vertical profiles of nutrients and carbonate species such as alkalinity and total CO_2 show a downward increase with significant influence of upwelling in the subarctic region (see nitrate + nirite profiles in *Figure 3* as an example).

Distributions of atmospheric and surface seawater pCO_2 in latitudes 35˚N - 50˚N along the 170˚E meridian are shown in *Figure 4*, together with the distribution of sea surface temperature (SST), salinity and wind speed. Surface seawater pCO_2 generally increases northward while SST and salinity decrease. In addition to the overall tendency, meso-scale variability of surface seawater pCO_2 was also found. Surface seawater pCO_2 reveals up-down fluctuations associated with SST and salinity in latitudes 38˚N - 44˚N, where the Kuroshio and Oyashio meets (Interfrontal Zone). In fact, surface seawater pCO_2 in the area is well formulated by a multiple linear regression equation with SST (T) and salinity (S) (see *Figure 4*). Thus the meso-scale variability in surface seawater pCO_2 can be attributed to water mixing by the currents. The area south of 45˚N acted as a sink for atmospheric CO_2, while surface seawater pCO_2 in the latitudes north of 45˚N was almost in equilibrium with the atmosphere.

The second cruise (MR98-05) was mainly focused on the sediment trap recovery and redeployment, and bottom sediment sampling (*Table 1*). The sediment traps were successfully recovered and redeployed. Most of the cores taken by a piston corer were more than 15 m in length. The longest one was approximately 17 m (a Japanese record!).

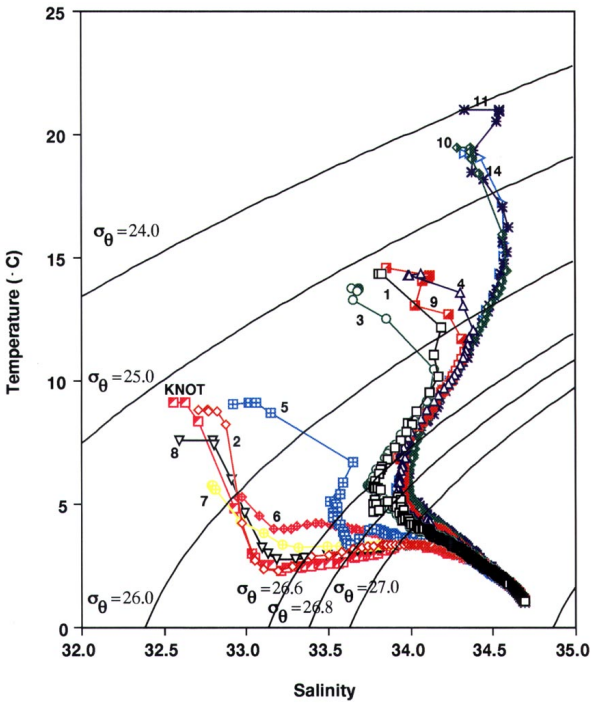

Fig. 2 T-S diagram (MR97-02 cruise). Numbers represent stations.

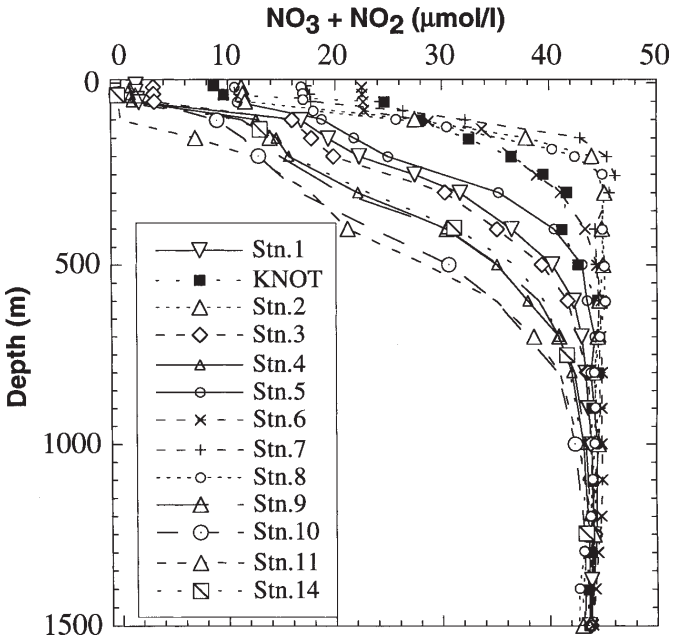

Fig. 3 Vertical distributions of nitrate + nitrite (MR97-02). Data provided by Dr. C. Saito.

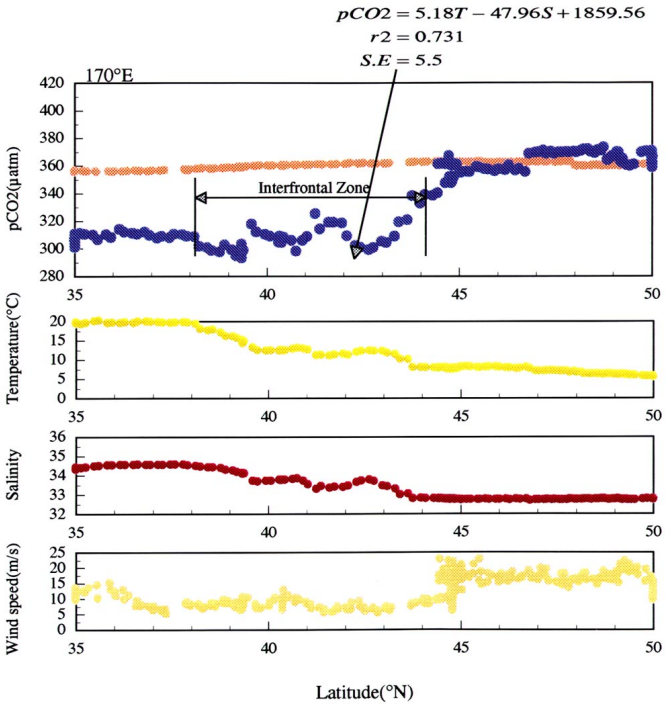

Fig. 4 Latitudinal distribution of pCO_2, surface temperature, surface salinity and wind speed along the 170˚E line (MR97-02). Data provided by Dr. A. Murata.

Since then, we have been working hard to decipher chemical and biological codes embedded in the sediments, though it may take years to clarify the paleoenvironment of the high latitude seas.

In the summer of 1998, surface seawater pCO_2, SST, salinity and wind along the transect from Japan to the Arctic Seas were measured (*Table 1*). The results are displayed in *Figure 5*. During the observations, the research vessel was moving northeastward from 45˚N to 50˚N, and surface seawater pCO_2 was measured with a new membrane-type equilibrator and alternately with a traditional shower-head-type one. As found from *Figure 5*, the pCO_2 values by the membrane-type equilibrator followed the values by the shower head-type. This successful measurement by the new equilibrator encourages us to detect meso-scale variations in surface seawater pCO_2, because the membrane-type equilibrator has a shorter equilibrium time. A distinct feature of the pCO_2 distribution during the summer cruise was that surface seawater pCO_2 was extremely high (frequently greater than 400 µatm) in longitudes from 162˚E to 177˚W along latitudinal zones of 45˚30'N - 47˚30'N. Since the atmospheric CO_2 was about 355 µatm during the cruise, the area acted as a source for atmospheric CO_2. Historical data (e.g., T. Takahashi's data by volunteer ships) revealed that summer surface seawater in the subarctic North Pacific Ocean is undersaturated with atmospheric CO_2 due to biological utilization. Therefore the situation observed in the summer of 1998 is unusual. We speculate that

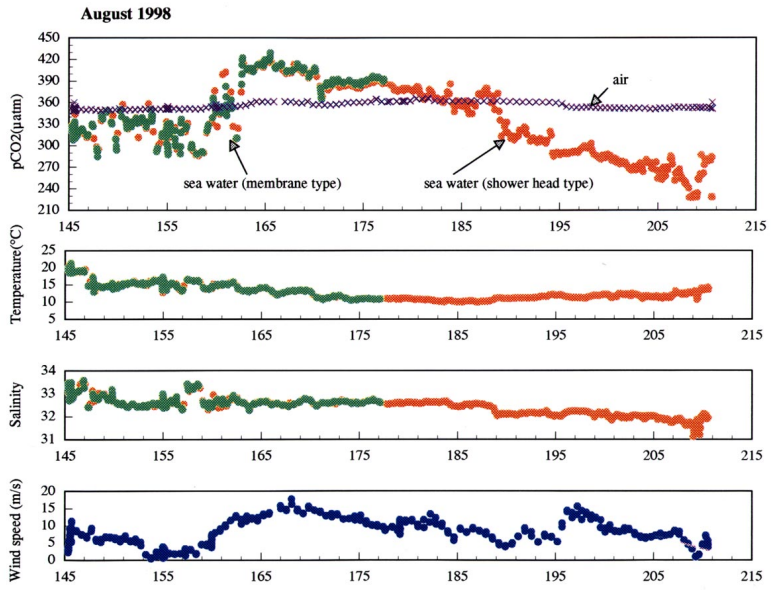

Fig. 5 Longitudinal distribution of pCO_2, surface temperature, surface salinity and wind speed along the 45-50˚E line in Aug. 1998 (MR98-06). Data provided by Dr. A. Murata.

the extremely high surface seawater pCO_2 caused by: (1) weak biological activity due to lack of sufficient light; and (2) mixing of surface water with subsurface water by atmospheric disturbance. The first speculation comes from the consistent cloudy weather during the cruise. High wind speeds may have raised subsurface waters rich in CO_2 into the sea surface layer.

From November 1998, the cruises will be in full swing. In addition to JAMSTEC scientists, scientists from elsewere will join the cruises. Cruise plans have been made based on the results obtained during the shakedown cruises. Summary of the future cruises relevant to the biogeochemical study is shown in *Table 2*, which includes research that will be done by JAMSTEC scientists and "outside" scientists as well. The participants for cruises in 1998 and 1999 were already selected. However, participants and details of cruises from May 2000 are yet to be determined. JAMSTEC will invite applications for the cruise in the spring of 1999 and the application dead line will be the summer of 1999. Application procedure can be found at http://www.jamstec.go.jp/.

The JAMSTEC research activity in the northern North Pacific has just begun. By utilizing the *Mirai*, we (and I believe the whole Japanese scientific community too) are looking forward to doing research on a long term basis in the area, and hopefully in the Okhotsk and Bering Seas. ***Mirai is our future.***

Table 2. Summary of future cruises.

Cruise	Date	Participants	Activities
MR98-K1	11/2/98 12/16/98	26 scientists and students (9 research groups from 4 research institutes and 4 universities)	(1) Hydrocasts (DO, nutrients, carbonate species, ^{13}C, ^{14}C, chlorophyll, trace metals, gases, radioisotopes), (2) Underway measurements of surface pCO_2, T, S, nutrients, TCO_2, (3) Bottom sediments, (4) Drifting sediment trap, (5) Aerosol sampling, (6) Primary productivity, (7) Plankton, (8) XBT and XCTD, (9) CTP-ALACE Float
MR99-K2	5/2/99 6/1/99	29 scientists and students (9 research groups from 3 research institutes and 3 universities)	(1) Hydrocasts (DO, nutrients, carbonate species, ^{13}C, ^{14}C, chlorophyll, trace metals, gases, radioisotopes) (2) Underway measurements of surface pCO_2, T, S, nutrients, TCO_2, (3) Bottom sediments, (4) Moored sediment traps and drifting sediment trap, (5) Aerosol sampling, (6) Primary productivity, (7) Plankton, (8) XBT and XCTD, (9) CTP-ALACE Float, (10) In situ adsorber (Dioxin, PCB etc)
MR00-K1	1/3/00 2/6/00	22 scientists and students (6 research groups from 2 research institutes and 2 universities)	(1) Hydrocasts (DO, nutrients, carbonate species, ^{13}C, ^{14}C, chlorophyll, trace metals, gases, radioisotopes), (2) Underway measurements of surface pCO_2, T, S, nutrients, TCO_2, (3) Bottom sediments, (4) Drifting sediment traps, (5) Aerosol sampling, (6) Primary productivity, (7) Plankton, (8) XBT and XCTD
MR00-K3	5/8/00 6/9/00	JAMSTEC will invite applications for this cruise in the spring of 1999. Application forms can be found at http://www.jamstec.go.jp/.	