REPORT OF THE RESEARCH EXPEDITION IN THE SEA OF OKHOTSK FOR 2007

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1. INTRODUCTION

The Research Expedition in the Sea of Okhotsk for 2007 has been carried out in the period from 5 August to 15 September in 2007 by *R/V Professor Khromov* of Far Eastren Regional Hydrometeorological Research Institute (FERHRI), Vladivostok, Russia. This expedition was a collaborative research activity between following 4 institutes, FERHRI, Research Institute of Humanity and Nature (RIHN), Institute of Low Temperature Science, Hokkaido University (ILTS) and Ocean Research Institute, University of Tokyo (ORI).

The purposes of this research expedition were to understand the present transport processes of land-derived materials, especially iron, from Amur River to the Sea of Okhotsk and Pacific Ocean and their historical variability, with special emphasis on the intermediate water ventilation along east coast of Sakhalin and the vertical mixing process around Kuril straits. This research expedition had following subjects.

1) To clarify the vertical and horizontal distribution of iron and related substances in water masses of the Sea of Okhotsk, especially in areas of Amur River mouth, northern and eastern continental shelves and slopes off Sakhalin, and the area around Kuril straits.

2) To quantify the physical processes, which transport iron and related substances from Amur River to Pacific Ocean, such as shelf tidal mixing, intermediate water formation, East Sakhalin current and turbulent mixing processes around Kuril straits.

3) To reconstruct historical changes in the budget and the deposition rates of iron and related substances to the sediment on slope and deep basin of the western Sea of Okhotsk, together with past changes in water temperature & salinity in both of shelf bottom and offshore surface waters.

4) To infer the contribution of aerosol, which supply iron from atmosphere to the surface water, in the Sea of Okhotsk.

2. PROGRAM OF THE EXPEDITION AND ITS IMPLEMENTATION

2.1. CTD observations, Water Chemistry and Biogeochemistry

2.1.1. CTD observations

Purpose. The purpose of CTD (Conductivity, Temperature and Depth probe) casts was to examine the water characteristics in the Sea of Okhotsk from the Sakhalin Bay and around Sakhalin Island through the Kuril Straits (especially Bussol' Strait), in order to

elucidate the influence of the Amur River water and dense shelf water on the Okhotsk Sea water-masses and on bio-chemistry in the Sea of Okhotsk and the North Pacific.

Data Acquisition. The CTD/Carousel water sampling system was used to acquire water samples and CTD data (pressure, temperature and conductivity). The CTD is Sea-Bird 911 plus system, and Seabird Carousel bottle release systems were used. The CTD/rosette held twelve 10-liter Niskin bottles with Teflon coating for iron measurements. The CTD instruments were equipped with a dissolved oxygen sensor (Sea-bird SBE43), transmissiometer (Wet lab C-Star) and altimeter (Data sonic PSA-900D). The CTD-frame was deployed via the right-side A-frame at the sites described in Figure 1, 2.

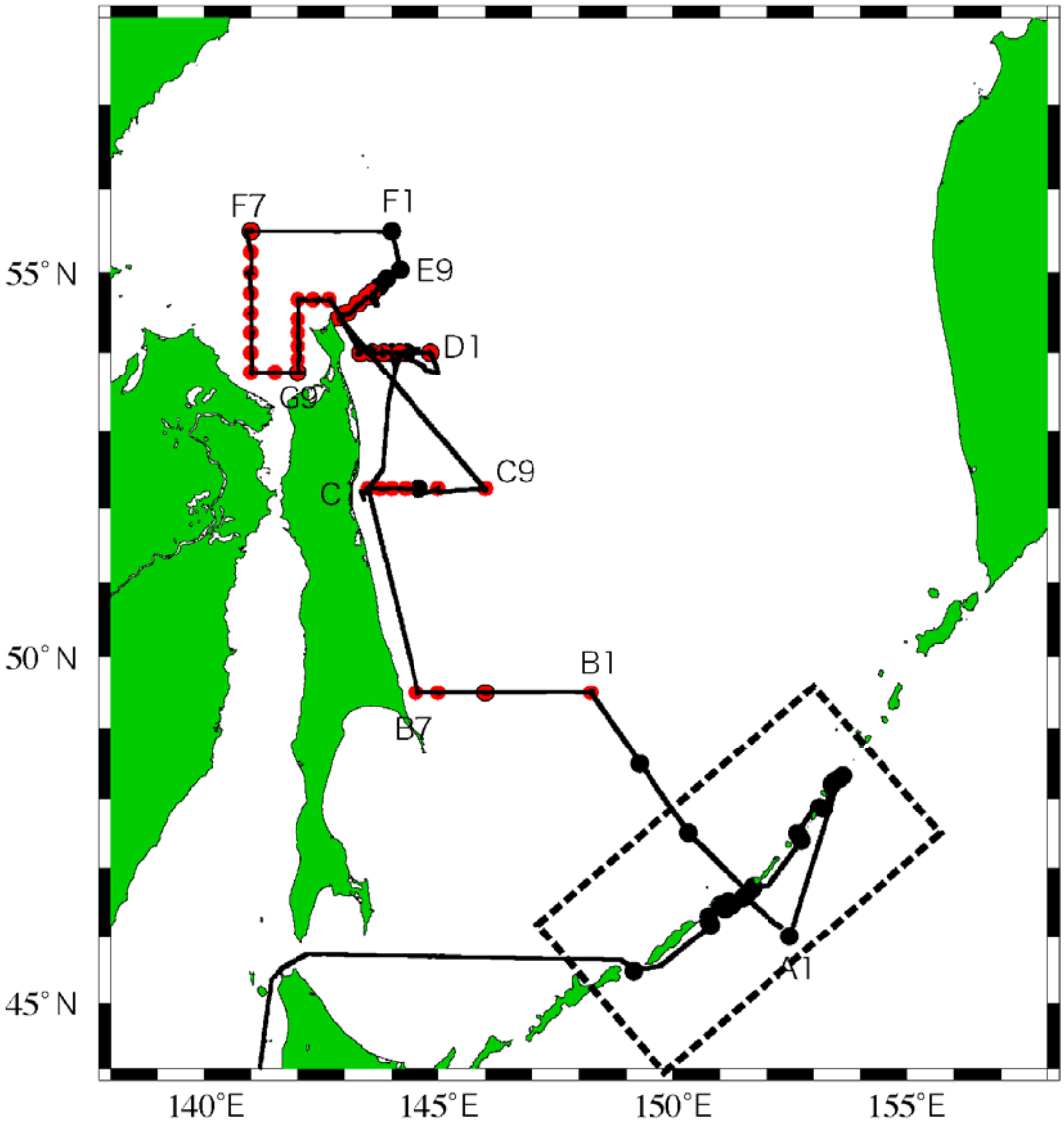

Figure 1. Cruise Track of the Research Expedition for 2007 (Whole area)

Water samples were drawn for dissolved oxygen and salinity at most of the CTD casts. However, in Kuril strait areas, water samples were analyzed for dissolved oxygen and salinity only about once a day to calibrate the CTD and DO senser. The samples of dissolved oxygen

were analyzed by Winkler method using an automated titration system with a colorimeter. Salinities were analyzed with a Guildline Portsal 8410A salinometer, using a computer interface and software. IAPSO Standard Seawater, batch P-146, served as the standard.

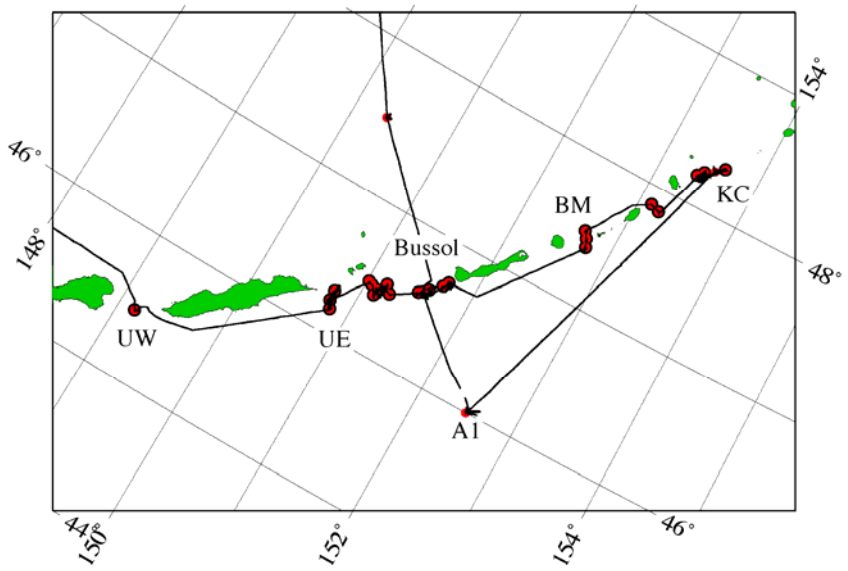

Figure 2. Cruise Track of the Research Expedition for 2007 (Kuril straits area)

Data Processing. Conductivities and dissolved oxygen obtained by CTD sensors at each bottle level will be merged with the results from bottle salinity and oxygen analyses. Bottle salinity and oxygen concentrations will be calculated and compared with the CTD data. CTD performance will be monitored by means of these comparisons. Final processing of CTD data will be completed at a later date.

2.1.2. Water Chemistry and Biogeochemistry

Purpose. One of the most important goals of this cruise is to grasp direct evidences of the tight connections between land and ocean ecosystems through material transports via river and shelf systems. Main targets are riverine iron and related substances, which are dissolved and/or suspended in the water of the Sea of Okhotsk. In order to clarify the spatial distributions of iron and related substances, water samplings were performed during all of the CTD casts from the areas near Amur River mouth to Pacific Ocean. Suspended particles were also collected using “in-situ large volume water filtering systems” at several CTD stations.

Water Samplings and Sample Treatments. Waters were collected during the CTD casts. In addition, surface water was continuously analyzed for nitrate concentration using underway waters supplied from engine room, although the nitrate analyzer did not work well during the cruise. Water samples during CTD casts were distributed into various sizes of clean bottles for on-board and/or on-shore analyses. Some water samples were directly filtered through filtration unit attached to the Niskin bottles to collect dissolved forms of chemical components. Particle samples were also collected using the “in-situ large volume

water filtering system" besides the CTD/water sampling at various water depths, especially focusing on the dense shelf water and its outflow to slope and basin areas around Sakhalin Island. The in-situ filtration was conducted by WTS-LV system (McLANE Inc.) with 1.0 μm pore size polycarbonate filters at the stations mainly on the slope and shelf areas..

Water and Particle Analyses. The distributed waters and filter samples are to be measured on the following list of chemical and biogeochemical parameters. Some of them have been analyzed on board, and the rests are to be analyzed on shore.

Substance	Number of water samples *	Analytical Method or Instrument	Measurement Remarks
Basic properties			
Salinity	All, except for Kuril strait areas	Guildline Port-Sal	On board
Dissolved Oxygen	All, except for Kuril strait areas	Winkler method (Titrated by Oxidation –Reduction Electrode)	On board
Nutrients	All	Continuous Flow type of Auto Analyzer	On shore
Biogeochemical parameters			
Iron (dissolved and total)	All except for Kuril strait areas	Chemiluminescence method (Kimoto-Denshi, EN-701)	On shore (partly on board)
Chlorophyll a	All, but only shallow layers at some stations	Fluorescence Spectrophotometer (Turner, 10-AU)	On board
Chromo-Dissolved Organic Matter	Almost all, except for Kuril strait areas	3D-fluorescence method	On shore
Carbon chemistry			
Dissolved Inorganic Carbon	Almost all, except for Kuril strait areas	CO_2 coulometer	On shore
Dissolved Organic Carbon	Almost all, except for Kuril strait areas	High Temperature Combustion method	On shore
Other Properties Metal Composition (Particles)	Mainly on slope and shelf	Atomic Absorption and/or ICP/MS	On shore

* "Number of water samples" indicates that how much water samples collected by CTD/carousel systems are applied for the analyses of the corresponding substances.

2.2. Shear Probe Observations

Purpose. Around the Kuril Islands in the Okhotsk Sea, tidal currents are strong and the vertical mixing is expected to be large and to contribute to the material circulation and resulting biological activity as well as the physical processes. However the mixing activity has not been directly measured. Measurements of turbulence and microstructure were performed at sites around the Kuril Islands shown in Figure 2.

Instruments and observation. A real time system of VMP2000 (Vertical Microstructure Profiler for 2000m casts) and VMP500 (smaller type for 500m casts) manufactured in Rockland Scientific Service (Victoria Canada) were used with the hydraulic motor, winch and line puller system. The fish deploys and recoveries were from the stern using A-frame and capstan. During the profiling, the ship moved as slowly as possible against the surface currents or winds in order the ship to be away from the cable and to avoid the cable cut by ship propeller.

Data acquisition and processing. Shear probe, micro-temperature probe and acceleration data were obtained in 512Hz, and the pressure and Sea-Bird temperature and conductivity were obtained in 64Hz. These were used to obtain the turbulent kinetic energy dissipation rate during 2 seconds from velocity shear spectra. Very preliminary data of diapycnal mixing coefficients of density in the interval of 1dbar were processed during the cruise. But the careful treatments are necessary to make final data because the probes are quite sensitive and the Sea-Bird sensors had troubles with water invasion and also because the data is frequently influenced by various matters.

2.3. Sediment Coring and Surface Sediment Samplings

Purpose. Although the present situations on the transport of iron and related substances from the Amur River and their influences on the biogeochemistry in the Sea of Okhotsk and the northwestern North Pacific Ocean can be addressed in the physical and biogeochemical oceanographic studies in this expedition, the situations must have varied largely in the past. Especially, impacts of climate changes and anthropogenic activities on the material transports through the Amur River and the Sea of Okhotsk should be understood carefully by paleoceanographic studies using sediment cores and related materials in order to predict future changes in the biogeochemical linkages between land and ocean in this region. There are two parts of the paleoceanographic studies in this expedition. One major part is to collect several meters (5-7m) of sediment cores from 8 sites on the continental slope and basin off Sakhalin in the western Sea of Okhotsk and analyze chemical properties of the sediment cores for reconstruction of past environmental changes, especially changes in material transport processes from Amur River, during Holocene and the last glacial period. The other minor part is to collect modern and past molluskan shells from continental shelf sediments around Sakhalin and analyze their chemical compositions, especially stable oxygen

isotope ratios, for estimation of past seasonal and inter-annual variations in temperature and salinity of the shelf bottom waters which is affected by seasonal sea-ice formation and Amur River discharge.

Sediment Samplings. Three types of sediment samplers (Smith-Macintyre Type of Grab Sampler, "Ashura" type of Multiple Corer (60cm of core pipe length) and a Piston Corer (8m of core pipe length)) were applied in this research expedition. Sediment cores were collected using both of the Multiple Corer and the Piston Corer at 8 stations on the slope and basin areas off east and north coast of Sakhalin. Surface sediments were collected for mollusk shell samplings using the Grab Sampler at many sites on the shelf areas.

Sample Treatments. Piston Core samples, most of which consisted of 5-7 m lengths of sediment, were divided into 1m length of core on board immediately after recovery and stored in the refrigerator until the precise sub-samplings and chemical analyses on shore. Multiple Core samples collected at the same locations as Piston Core were sliced at 1cm intervals on board, packed in plastic bags and stored in refrigerator or freezer until the chemical analyses on shore. Surface sediments collected by the Grab sampler were sieved using 5mm mesh to separate larger size of mollusk shells from sedimentary particles immediately after samplings and only the mollusk shells were stored for further species identification and chemical analyses on shore.

Chemical Analyses. Piston Core and Multiple Core samples are to be analyzed on the items such as major sediment components (total organic carbon, carbonate, biogenic silica, lithogenic silica), C/N ratio, terrestrial and marine organic molecules, major element compositions measurable by XRF, ice-rafted debris, ^{14}C contents and magnetic susceptibility for core chronology. Mollusk shells in surface sediments are to be identified of their precise species names and analyzed further for micro-scale distributions of the stable oxygen isotopic ratios across growth lines of typical large specimen.

2.4. Aerosol Samplings

Purpose. In general, land-derived iron is believed to be supplied to ocean surface via atmosphere by aerosol. Because the Sea of Okhotsk is located on the eastern end of Eurasia continent, huge amount of aerosol containing iron must be supplied to this area by the strong westerly. In order to estimate the relative importance of the iron from Amur River, it is necessary to monitor and quantify the iron load from atmosphere in the Sea of Okhotsk Therefore, aerosol samplings were conducted in this research expedition.

Observation. Aerosol samples were collected with a High Volume Sampler during the cruise (Aug. 9 – Sep. 11). Wind direction was continually monitored and the sampler was turned off if there was any risk of contamination by exhaust from the ship's stack. The

samples were collected on the 90 mm Teflon filter and the filters were changed when total volume reached over 100 m^3.

Sample analyses. Teflon filters with collected aerosol samples are to be used for analyzing major ions (Na^+, Ca^{2+}, SO_4^{2-}, NO_3^-) and trace metals (Fe, Al) at on-shore laboratory. Soluble major ions and trace metals are to be extracted from the filters and analyzed by ion chromatography and ICP-AES.

3. CONCLUDING REMARKS

In general, the program of this expedition was successfully completed with the combined efforts of Russian and Japanese specialists. In particular, it is notable that clean water samplings were successfully performed on *R/V Professor Khromov* in this expedition as well as last year. The quality of collected waters was monitored during the cruise by on-board analyses of trace amount of iron, and apparent contaminations of iron from the vessel have never been identified. This success is greatly owing to Russian efforts to clean up the vessel before the cruise and Japanese carefulness to avoid any kind of contaminations at all procedures during the samplings of water.

In this cruise, the piston core operations were successfully carried out at many sites to collect long sediment core samples, besides the water column observation. These successes clearly indicate the wider applicability of *R/V Professor Khromov* to the areas of oceanographic observations other than hydrometeorological studies.

4. ACKNOWLEDGEMENTS

This expedition was successfully completed with the effort and patience of many peoples, and with the good weather condition throughout the cruise. We would like deeply to appreciate Captain Alexander D'YACHENKO of the R/V Professor Khromov and his fine crews for their outstanding works during this cruise; without them, none of this expedition would have been possible.

5. LIST OF PARTCIPANTS

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