Interaction between the northern North Pacific and its marginal seas: current activities of JAMSTEC in the PICES region

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Dr. Takatoshi Takizawa is Head of the Arctic and Subarctic research group of the Ocean Research Department at the Japan Marine Science and Technology Centre. His recent activities include: (1) Arctic oceanographic research (a cooperative program with Woods Hole Oceanographic Institution) using a fully automated Ice-Ocean Environmental Buoy (IOEB) to understand oceanic structure of the upper Arctic Ocean, to evaluate air-sea interaction processes, and to investigate biogeochemical cycle in the Arctic Ocean; (2) study of water exchange and modification processes through the island chains (during last several summers Dr. Takizawa has been working in the Bering Sea and Aleutian Island region aboard the R/V Alpha Helix of the University of Alaska); and (3) implementation of the Sea of Okhotsk observational project.

1. Introduction

The North Pacific has two important marginal seas: the Bering Sea and the Okhotsk Sea which affect the Subarctic Gyre. They are the site of more active thermohaline forcing than the North Pacific. The cooling, sea ice production and river runoff in these seas contribute to water mass formations and modifications of the surface and intermediate water properties of the northern North Pacific.

The marginal Seas border island chains and communicate with the North Pacific through straits or passes. The Subarctic Gyre has strong flows along the North Pacific flank of these island chains. The thermohaline and biogeochemical structure of these seas are linked to the North Pacific, but little is known about the rates and their variations of mass and property exchanges. Even less is known about the processes that control flow through the passes. Recent observations indicate that the flows of the Subarctic Gyre are highly variable as eddies and meanders frequently occur. Furthermore, transport through the straits/passes can vary considerably in response to wind stress fluctuations, flow variations in the gyre and tidal currents.

Our study focuses on the interaction between the North Pacific and Bering and Okhotsk Seas, in particular water exchange and modification through the island chains. This note describes the physical setting of the study area and the current status of JAMSTEC's subarctic program.

2. Bering Sea

Exchange between the North Pacific and the Bering Sea occurs through passes comprising the Aleutian Island arc. The Alaskan Stream, the northern limb of the Subarctic Gyre, flows westward along the south side of Amchitka Pass (*Fig. 1*). A portion of this current flows northward through the pass and, on the Bering Sea side, turns eastward to flow along the north side of the Aleutian Islands as the North Aleutian Current (NAC). Observations from the Bering Sea indicate that these currents are quite variable as eddies and meanders

frequently occur. Similarly, transport through some of the passes can change markedly in response to wind stress fluctuations or flow variations in the Alaskan Stream.

Figure 2 indicates monthly maps of the SSHa (sea surface height anomaly) field showing the Alaskan Stream eddy, flow through Amchitka Pass, and circulation in the Aleutian Basin. The June 1987 map suggests that circulation in the southern Aleutian Basin is more cyclonic with southward flow through the pass. This anomaly

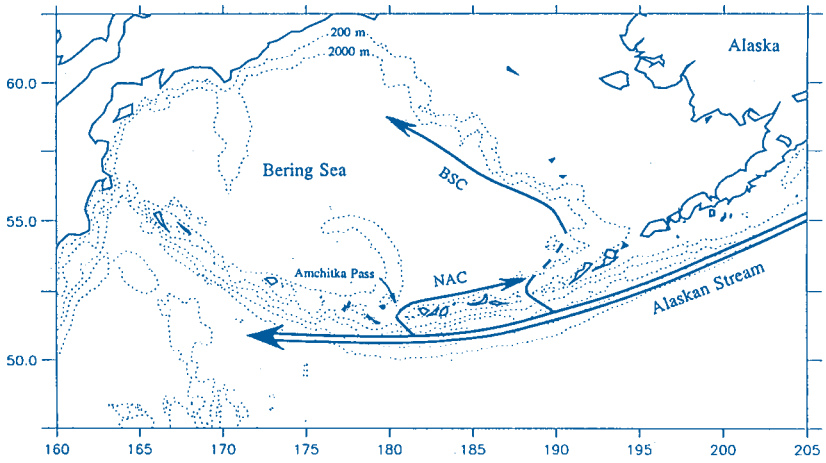


Fig. 1. Circulation schematic of the Bering Sea region; North Aleutian Current (NAC); Bering Slope Current (BSC).

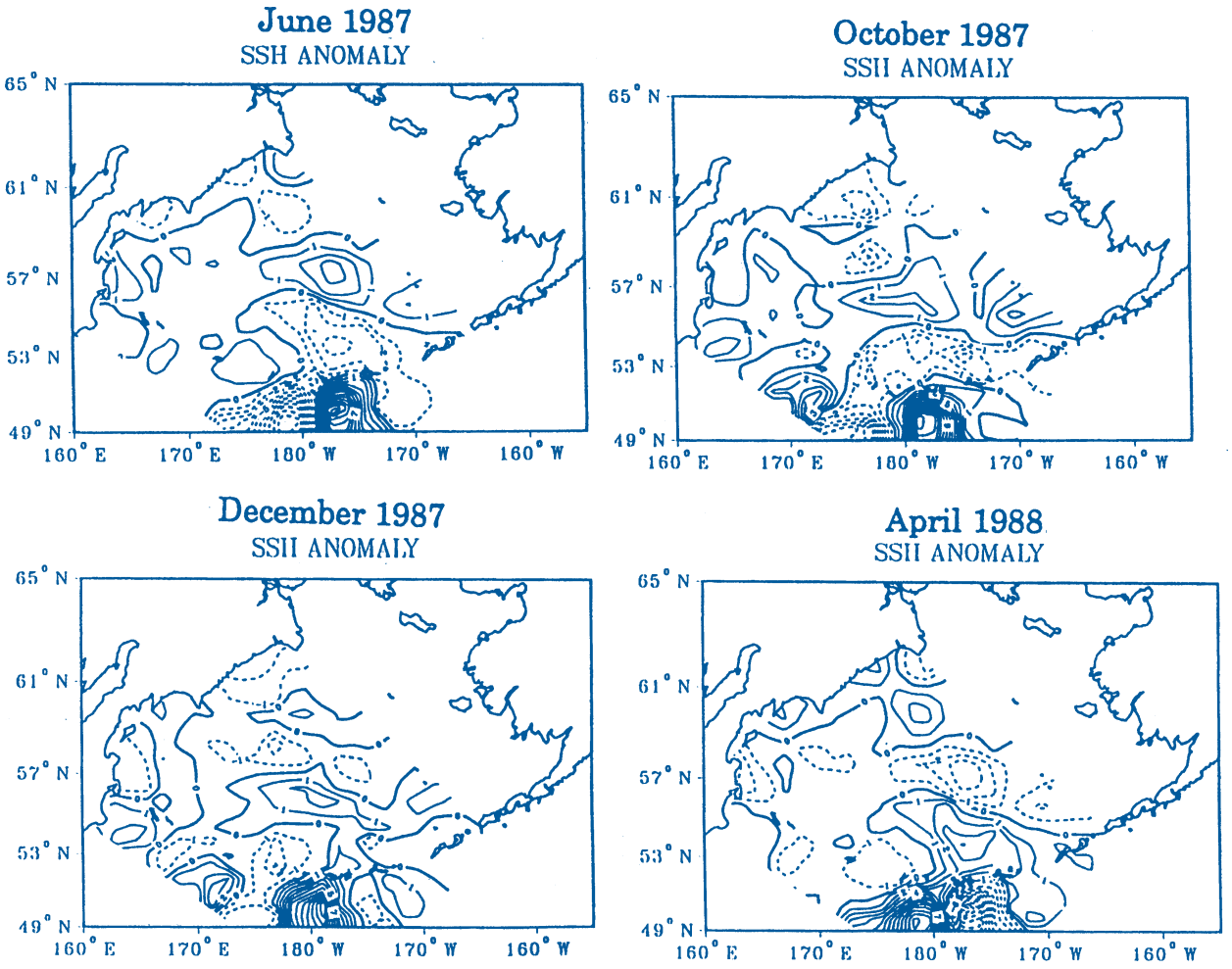


Fig. 2. Sea Surface Height anomaly field. Solid lines are positive anomalies and dashed lines are negative anomalies. The contour interval is 1cm (from Okkonen, 1996).

moved from east to west so that by December 1987 circulation in the Aleutian Basin has become anomalously anticyclonic. Independent current-meter records in Amchitka Pass from June 1987 to June 1988 indicate that there is a northward component of flow through the pass. Southward flow begins in July 1987 and continues until October 1987 when it reverses to flow northward again (Reed, 1990). The comparison of SSHa maps in the Bering Sea region with current meter records indicate that flow through Amchitka Pass responds to the transit of a large eddy in the Alaskan Stream south of the pass

3. Okhotsk Sea

It is generally understood that the subarctic North Pacific region plays an important role in climate change through processes such as the formation of North Pacific Intermediate Water (NPIW) and uptake of CO_2. However, we have little knowledge about the water mass formation and modification mechanisms along the Subarctic Gyre.

There are several ideas about the source region of NPIW with the Okhotsk Sea being the strongest candidate. However, transport and modification processes of NPIW source water formed in the Okhotsk Sea across the Kuril Islands are not well described.

Several hydrographic sections were occupied across the Kruzenshtern Strait and Bussol' (Urup) Strait during the US-Russian expedition in spring of 1995 (Riser, 1996). A CTD section across the Kruzenshtern Strait, which was carried out 3 times over a 2-day period, suggests a strong variability through the strait on time scale as short as a portion of a day. Consequently, the calculated geostrophic transport through strait is highly variable on the three surveys. Riser (1996) claimed that the flow cannot in general be geostrophic! The implication from this result is that the flow through Kruzenshtern Strait must be dominated by strong tidal flows, with the geostrophic flow being of secondary importance.

Recent numerical study including the tidal effects by Awaji (1996) demonstrates that the tide-induced mean transport shows significant net exchange of water between the Okhotsk Sea and the North Pacific via several straits in the Kuril Islands. Tracking of numerous particles in the calculated velocity field clearly demonstrates the Lagrangian movement of the Okhotsk Sea. This suggests the importance of the tide-induced outflow of the Okhotsk Sea water in formation of the Oyashio water and NPIW.

4. Approach and work plan

Our study involves observational and modeling components. The former includes combining data from satellite altimeter and current meters. The modeling efforts are devoted to the construction of a high resolution tidal model which can evaluate the water exchange through the island chains. We have conducted a CTD and hydrographic survey around the central Aleutian Islands aboard the R/V *Alpha Helix* of the University of Alaska since 1995 (*Fig. 3*). We have deployed a mooring consisting of

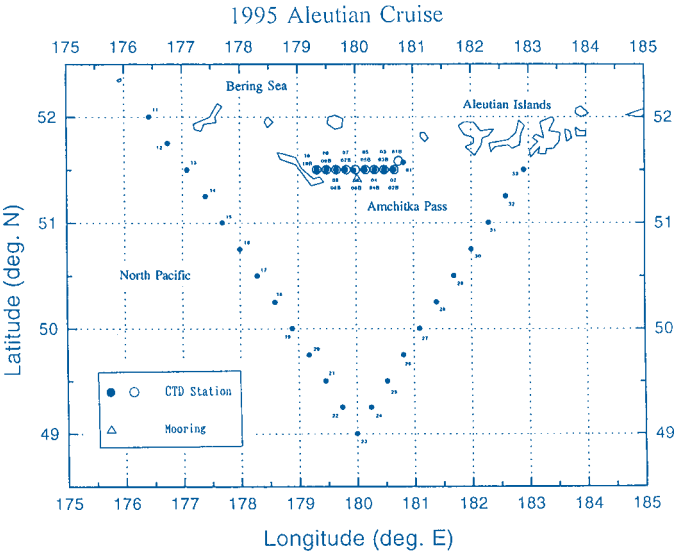
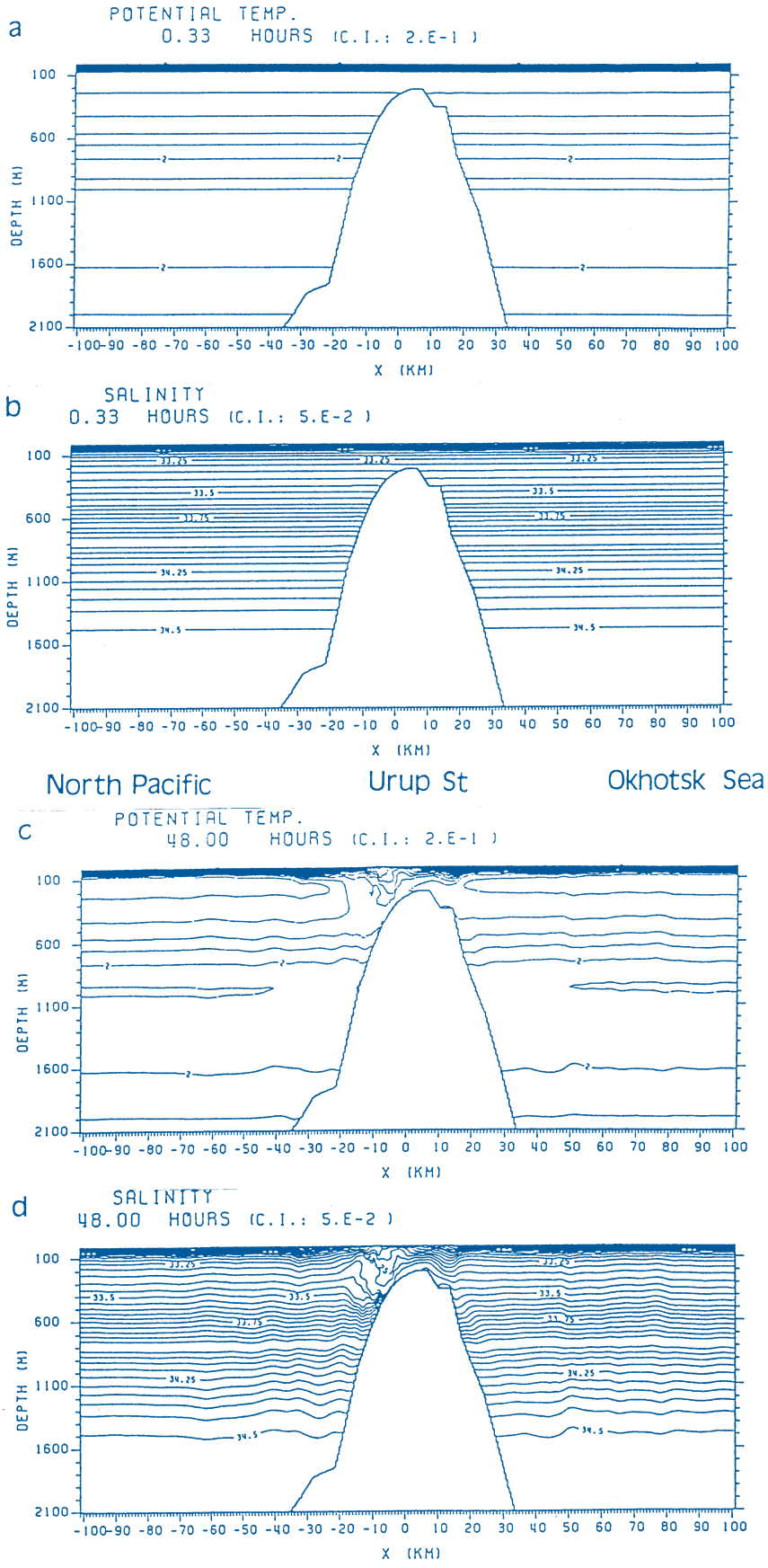


Fig. 3. Hydrographic stations of 1995 Aleutian cruise.

current meters and CTDs at Amchitka Pass. In August of 1996, the revisit of hydrographic stations and re-deploy of moorings were carried out.

As for the Okhotsk Sea, we hope to start an oceanographic observation program in 1997. Furthermore, we are developing a tidal model of the Okhotsk Sea in cooperation with the Kyoto University. Our 2-dimensional non-hydrostatic model across the Kuril Islands shows an interesting tidal mixing process around the sill (*Fig. 4*).



JAMSTEC is going to launch a new research vessel *Mirai* (8,600 gross ton) in the fall of 1997. She is capable of undertaking observation missions to high-latitude regions exposed to severe weather and sea conditions. We expect that her cruise will contribute to the acquisition of observational data necessary to understand the role of the subarctic North Pacific in climate change.

References

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Reed, R.K., 1990. A year-long observation of water exchange between the North Pacific and the Bering Sea. Limnol. Oceanogr., 35:1604-1609.

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Fig. 4. A preliminary result of 2-D non-hydrostatic tidal model (Nakamura et al, 1996. Private communication). Contours of the potential temperature and salinity at 0.33 hours (a), (b) and at 48 hours (c), (d)

Appendix

Japan Marine Science and Technology Center

Japan Marine Science and Technology Center (JAMSTEC) was incorporated in October 1971 by investments of the government and industry. The government contribution of funds remained near 90% in recent years and the balance is supplied by the sponsors' group, which consists of some private enterprise and business organizations involved in such fields as shipbuilding, electricity, steel, and machinery.

JAMSTEC has four principal functions as follows:

Research & development

To promote R&D of advanced technologies on the ocean floor, surveying, data acquisition, ocean energy, and manned undersea work systems.

Training

To develop human resources by holding training courses on diving techniques and marine engineering seminars for researchers and technicians.

Technical information services

To collect and disseminate information on marine science and technology.

Operation & maintenance of facilities for public use

JAMSTEC establishes and maintains various types of large-scale testing facilities for public use. They include an undersea simulation and training facility, a high pressure test facility, and an underwater anechoic (free from echoes, designed for acoustic measurements) tank and deep sea micro organisms collecting and cultivating system, etc.

The research and development activity is divided into three categories: (1) *research of deep-sea environment,* (2) *research of ocean zones* and (3) *development and utilization of coastal zones* including development and construction of manned and unmanned deep research submersibles, studies of optical fibers for deep sea cables, optical-elector-mechanical cables for remotely-operated vehicles, remote sensing by passive microwave, oceanic applications of laser, and new data acquisition buoys.

The progress of activities in recent years are as follows:

1. Deep Sea Research

It aims at comprehensive understanding of deep-sea area by investigating the variational phenomena at the deep seafloors from the past to the present and the interactions among the accompanying physical, chemical, biological and geological phenomena. For this purpose, our research is advanced by making good use of the manned submersible systems, "Shinkai 2000" and "Shinkai 6500", unmanned vehicles, "Dolphin-3k" and "Kaiko", a deep towed survey system, "JAMSTEC/Deep Tow".

By means of long-term observations of the deep-sea area, we expect to determine precisely long-term variations on the deep seafloors undetectable by short term surveys, or to catch accurately unpredictable phenomena. Moreover, we intend to explicate the processes of materials circulation in the ocean as a whole by the investigation of the migration and diffusion processes of both terrigenous and biomassive materials into the deep sea area, and of the material fluxes supplied from the seafloor into the deep sea such as hydrothermal fluid and cold seepage. Furthermore the detailed elucidation of deep structures under the seafloor is very useful for the prediction of the crustal movement or for the reduction of disasters and so we intend to clarify the underground structures in the trench area which have a high probability of a gigantic earthquake occurrence.

2. Ocean Research

We are carrying out the following activities: the ocean observation research in the North Pacific Ocean and the Arctic, the purpose of which is to get a better understanding of the variability and the mechanism of ocean current, heat transport, air-sea interaction etc. and to clarify the primary production of the ocean as well; the development of the global ocean circulation model and the development of ocean observation technology.

‘ Tropical Region

The tropical region is the region that absorbs and accumulates most of the radiant energy of the sun, forms large ocean currents, and is characterized by heat transport by these currents, ocean atmosphere interactions and equatorial upwelling. It also brings about the oceanic change represented by ENSO

phenomena, and thus it is the driving source of the global climate change. We intend to observe ocean current changes in the Western Tropical Pacific, so as to elucidate the mechanism of changes in the Western Tropical Pacific, so as to clarify the mechanism of changes in ocean structures relating to the generation and dissipation of heat.

- Subtropical Region

The Kuroshio current transports an enormous amount of thermal energy from the equatorial region to the subarctic region. The long-term variations in this heat transport affect the climate greatly, i.e. ENSO, Asian monsoon, etc. We have set mooring buoys at the Tokara Strait and monitored the Kuroshio current passing through the strait. In addition, we have set mooring systems in Izu and Ogasawara area to investigate the Kuroshio counter-current and the structure of medium-sized eddies moving westwards along the Kuroshio counter-current.

- Subarctic Region

See pages 7-10.

- Arctic Ocean

For the purpose of clarifying the role of the Arctic region in the global climate changes, we have been conducting an air-sea interaction study in the multiyear ice area in the mid-Arctic Ocean with fully automated Ice-Ocean Environmental Buoys (IOEBs) since 1992. In addition, we have been studying shelf/shelfbreak processes in the Chukchi-Beaufort Seas. The study consists of in-situ observations with a ship in summer, deployment of moorings in the Barrow Canyon area and numerical experiments using a local ocean model.

- Research and Development of Observation Technology

u *Ocean lidar observation technology*

Ocean lidar is innovative equipment which enables us to observe the time- and the space-distribution of phytoplankton over a vast area in a short time. Phytoplankton serves as a direct indication of marine biota production. A new estimation procedure combining of ocean lidar with a satellite borne color sensor is promising. We intend to observe and estimate phytoplankton by the ocean lidar and to develop the correction technique for the satellite borne color sensor data.

u *Ocean Acoustic Tomography Technology*

The ocean acoustic tomography is a computerized tomography system by which the oceanic structure can be observed instantaneously by means of an acoustic wave. We are developing an ocean acoustic tomography system which consists of eight 200 Hz tomography transceiver systems. The system is capable of observing 1,000 km square of ocean.

3. Research and development for the utilization of coastal seas

- Development of a wave energy utilization system

To make use of coastal sea, the “MIGHTY WHALE” project is now in progress. “MIGHTY WHALE” is a floating wave power device, which can convert wave power to compressed air power effectively, and create a calm sea area behind the device.

- Cooperative programs with local governments

In order to develop and utilize the coastal sea effectively, it is necessary to consider specific local requirements and to conduct joint technology development with appropriate local users. Since 1988, we have developed a number of new technologies for the utilization of coastal seas in close cooperation with local governments. The deep sea water utilization technology is designed to effectively utilize this water for marine biological production, energy production and environmental protection. We have developed a new artificial sea bed with submerging and surfacing functions for cultivating fish and shellfish at optimum depths.

4. Ship Operation

In order to perform the aforementioned activities, JAMSTEC has a 2,000 m class research submersible vessel system (“Shinkai 2000” and support vessel “Natsushima”), a 6,500 m class research submersible vessel system (“Shinkai 6500” and support vessel “Yokosuka”), remotely operated vehicles “Dolphin 3K” (3,300 m depth capability) and “Kaiko” (11,000 m depth capability), and the ocean research vessel “Kaiyo”.