

JAMSTEC

1998 Annual Report



JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

J A M S T E C 1 9 9 8 A n n u a l R e p o r t

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Preface



This annual report presents an overview of JAMSTEC's activities during FY1998 (April 1998 - March 1999).

Since the UN-sponsored Kyoto conference to combat global warming (COP3) in December 1997, Japan, including both government and non-government sectors, has been putting forward a concerted effort to follow up the resolutions adopted at the conference. To those of us concerned with geoscience, this meant reconfirmation of the formidable task before us to develop a precise understanding as to the mechanisms of global warming.

We are expected, for example, to acquire accurate knowledge on how carbon dioxide, the major target among all greenhouse gasses, behaves globally. Regrettably, our knowledge at hand is yet very much limited and the search has just begun.

After COP3, JAMSTEC has given global warming the first priority in organizing its observation and research activities. We have, for example, included circulation processes of both inorganic and organic carbons in our material cycle observation effort in addition to the existing hydrothermal circulation studies.

JAMSTEC has submitted budgetary requests to the Japanese government for the development of a new ocean drilling vessel, which, when completed, is expected to go a long way toward advancing man's overall knowledge about the Earth, not only in its present state but also in its past climate and other evolutions, fields that directly relate to the mechanisms of global warming.

Satisfactory results have continued to be witnessed in our deep sea research area using our manned research submersibles Shinkai 2000 and Shinkai 6500, and the unmanned vehicles Dolphin-3K and Kaiko, as well as in deep sea microbiology research using the deep sea baro/thermophiles collecting and cultivating system developed

by JAMSTEC. Also noted was the progress in ocean observation based on the principles of acoustic ocean tomography and in new technologies for ocean energy utilization. Worthy of particular mention also is the achievement of MODE'98 (Mid-Oceanic Ridge Diving Expedition '98), a round-the-world voyage to study ocean floor dynamics in the Atlantic and the Indian Oceans using Shinkai 6500, marking the world's first dive attempt via manned submersible in the Indian Ocean. JAMSTEC's new large Earth observation vessel MIRAI, in the meantime, experienced its first ice sea cruise.

The activity of the Frontier Research System for Global Change (FRSGC), a new comprehensive, 'think-tank' type set-up started last year as a cooperative effort between JAMSTEC and the National Space Development Agency of Japan (NASDA) has also begun showing promising signs of steady growth. In this connection, we have been feeling a strong need for an additional program focusing on "observation" as a response to the ever-growing demand for global-scale data on the Earth.

A new building was completed at the end of FY1998 within the main campus of the University of Alaska at Fairbanks (UAF) to house the International Arctic Research Center (IARC), established jointly between FRSGC and UAF and named for bilateral promotion under the Common Agenda for Cooperation in Global Perspective between the U.S. and Japan (the Common Agenda, for short). IARC was incorporated earlier in FY1997, and research activity had been initiated there as part of the FRSGC program. Full-scale research activity at IARC is expected to begin in FY2000. Further strengthened activity is also expected at the International Pacific Research Center (IPRC), the second U.S.-Japan international cooperative research center also established in FY1997 between FRSGC and the University of Hawaii at Manoa within the UHM campus. IPRC also has been named for promotion under the Common Agenda.

I sincerely hope this booklet will help your understanding of what we do and what types of research we are engaged in at JAMSTEC. Your continued support and cooperation would be greatly appreciated.

November 12, 1999

Takuya HIRANO

President

Japan Marine Science and Technology Center

Outline of Activities

With the aim of promoting ocean development by Japan, the Japan Marine Science and Technology Center continued, in 1998, to conduct research and development operations, training operations, information-related operations, and operations related to the improvement and commissioning of facilities and installations. These operations were conducted in close linkage with various organizations both at home and abroad.

The various operations performed by the Japan Marine Science and Technology Center are summarized below.

1. Research and development operations

Taking into consideration the objectives, details, and progress status of research and development activities, the Center categorizes these activities as project research, special research, and ordinary research activities so that it can conduct its activities according to the plans established at the beginning of each fiscal year. At the same time, the Center adopts a flexible system enabling creative new research and development subjects to be implemented in mid-fiscal year in response to changes in situations or on the basis of expanding concepts. In addition, the Center does consigned research and joint research in response to the requests of or in cooperation with various organizations both at home and abroad.

The research and development operations performed by the Center in fiscal 1998 are:

1) Project research activities

To contribute to the development of the economy and society and to help advance marine science and technology, the Center promotes important, large-scale, or comprehensive research and development subjects as project activities; in fiscal 1998, the following 27 subjects were implemented as project research activities:

- Research into ocean bottom dynamics
- Development and enhancement of a comprehensive submarine earthquake observation system
- Research into long-term observation using sea floor observatories
- Research and development of advanced technologies
- Research into an oceanographic observation sensor intended for use aboard a stratospheric platform
- Development of an oceanographic buoy system
- Research and development of ocean energy utilization technologies
- Research and development of a deep-sea drilling vessel system - Part 1
- Research and development of a deep-sea drilling vessel system - Part 2
- Research into observation in the equatorial regions of the tropical zone
- Research and development of ocean acoustic tomography system technologies
- Research and development of automated ocean observation technologies
- Observation of and research into the circulatory system in the subtropical zone
- Development of technologies for oceanographic observation in the Arctic Ocean, observation of and research into the Arctic Ocean
- Development of technologies for ocean-atmosphere interactions, observation of and research into such interactions
- Research and development of ocean laser observation technologies
- Observation and research for elucidating the material cycle mechanism in the high latitude areas of the seas
- Observation and research for elucidating the primary production mechanism in the tropical and subtropical zones
- Research into the interaction between the heat and material fluxes and the biosphere
- Research for elucidation of the mechanism of changes in the marine ecosystem
- Development and reinforcement of the Triton buoy network
- Frontier research into subbottom deep tectonics
- Frontier research system for deep-sea environment
- Earth frontier research system
- Research and development of coastal environments and their utilization
- Development of a testing unit for an autonomous unmanned underwater vehicle

Outline of Activities

- High-performance three-dimensional crustal structure analysis system

2) Special research activities

The Center promotes special research and development activities that are to be evolved into future project research activities; in fiscal 1998, five subjects were implemented as special research activities:

- Research into technology for a remotely controlled vehicle for ice ocean use
- Experiment using models and analysis of behavior of riser tubes
- Research into an oceanographic observation evaluation method based on a high-resolution global ocean circulation model
- Elucidation of changes in paleoenvironments in Kuroshio extension regions
- Research into the mechanism whereby earthquakes and tsunamis are generated in the sea areas around Papua

3) Ordinary research activities

The Center promotes ordinary research and development activities based on expanding concepts resulting from the research capabilities of individual researchers or which are expected to evolve into special or project research activities in the future; in fiscal 1998, 23 subjects were implemented as ordinary research activities.

4) Consigned research and joint research activities

The Center does research consigned by other organizations which is related to marine science and technology and which the Center considers useful for it to perform; in fiscal 1998, the Center accepted 10 consigned research projects.

In addition, the Center does joint research which will result in reducing expenses and time and which will bring excellent results as a consequence of the mutual utilization of research and development capabilities and sharing of research results with other organizations; in fiscal 1998, the Center participated in 25 joint research projects.

2. Training operations

With the aim of making the results of the research and development activities known widely to the general public and of contributing to training the human resources

necessary to promote ocean development in Japan, the Center performs training operations. In fiscal 1998, the Center held training sessions for diving techniques and opened science camps for senior high school students as well as a marine science school for senior high school students and teachers.

3. Information operations

The Center collected foreign and domestic literature on marine science and technology (including books, magazines, conference materials, technical reports, etc.), necessary to conduct research and development activities; at the same time, the Center published various reports with the aim of making the results of research activities known and available both at home and abroad. In addition, the Center made advances in structuring a marine information database system and in the operation of a super computer system.

4. Operations of vessels

For carrying out the operations described above, the Center owns a variety of equipment, including a 2,000-meter-depth-class research submersible system (consisting of a manned research submersible Shinkai 2000, a support mother ship Natsushima, and a shore maintenance station), an unmanned underwater vehicle Dolphin-3K, a 10,000-meter-depth-class research submarine Kaiko, an ocean investigation ship Kaiyo, a 6,500-meter-depth-class manned research submarine system (consisting of a manned research submersible Shinkai 6500, a support mother ship Yokosuka, and a shore maintenance station), a deep-sea research ship (or vessel) Kairei, and an ocean and earth research vessel Mirai. The track records for these vessels for fiscal 1998 are:

1) Shinkai 2000

Dived a total of 85 times in sea areas around Japan such as Sagami Bay and in the Manus basin areas of the sea.

2) Natsushima

Supported diving of Shinkai 2000 and Dolphin-3K and performed solo investigation; the total number of days underway in fiscal 1998 was 294.

Outline of Activities

3) Dolphin-3K

Dived a total of 39 times for tests, training, and preliminary investigation for Shinkai 2000, including dives off the Nansei Islands and Papua New Guinea and in Sagami Bay.

4) Kaiyo

Performed various experiments, observation, and deep-sea towing in operational areas of the sea; the total number of days underway in fiscal 1998 was 260.

5) Shinkai 6500

Dived a total of 54 times in the Mid-Atlantic Ridge and Southwest Indian Ridge.

6) Yokosuka

Performed solo investigation navigation in addition to supporting Shinkai 6500; the total number of days underway in fiscal 1998 was 277.

7) Kaiko

Dived a total of 39 times in sea areas around Japan including the Nansei Islands and Japan Trench and in the Mariana Trench and sea areas around the Hawaiian Islands.

8) Kairei

Performed solo investigation and investigated subbottom deep tectonics in addition to supporting Kaiko; the total number of days underway in fiscal 1998 was 276.

9) Mirai

Performed familiarization training in fiscal 1998 as in fiscal 1997, deploying Triton buoys at the same time. A shared type full-scale operation was started on October 30, 1998, completing three rounds of navigation. The total number of days underway in fiscal 1998 was 302, including 140 days of shared operations.

Deep Sea Research Department

Overview

Our department's major area of research is the seafloor dynamics, that is to try to understand how oceanic plates form, evolve, deform and subduct; how they interact with continental margins; and how they recycle through mantle of the earth. In order to achieve our goals, we are utilizing JAMSTEC's research facilities that include submersibles, *Shinkai 2000*, *Shinkai 6500*, ROVs, *Dolphin3K*, and *Kaiko*, and research vessels, *Natsushima*, *Yokosuka*, and *Kairei*. While these facilities allow us to circumnavigate the globe to conduct marine geological and geophysical surveys at places of research interests, we are also developing seafloor observatories to continuously monitor active processes that remain largely unknown because *in situ* time series data are almost non-existent. We highlight below our activities in 1998 conducted through national and international cooperation. The first topic is the investigation of the Papua New Guinea Tsunami event, which was obviously not planned, but quick actions could be taken to gather important data for future hazard mitigation. We will then summarize our studies of the seafloor dynamics at Hawaii hotspot area, ridges and subduction zones and then focus on seafloor observatory efforts.

Papua New Guinea Tsunami Event Investigation

On Jul 17, 1998, a large tsunami accompanied the M7.1 Papua New Guinea earthquake and struck the northern coast of New Guinea Island claiming more than 1500 lives. Proposed by SOPAC (South Pacific Applied Geoscience Commission), two JAMSTEC cruises (*Kairei* and *Natsushima/Dolphin3K*) were made in the area in FY98 to conduct precise bathymetry and marine geology and geophysics surveys. A large-scale collapse on the steep slope of a seamount and en echelon fissures, both of which looked fresh, were found and may prove to be the cause of the unexpectedly large tsunami for the size of the earthquake.

Hawaii Hot Spot

Hawaii hot spot volcanoes were surveyed using ROV *Kaiko* and its mother vessel *Kairei* (KR98-09) in order to image and sample (1) the Loihi seamount, which is a volcano in immature stage, (2) the Hilina Slump, south of Kilauea, the most active volcano in the area, and (3) the Nuuanu landslide, northeast of Oahu, the largest landslide in the area. The bathymetry of the entire Nuuanu landslide area as well as its adjacent Wailalu landslide area was mapped extending 200 km from Oahu. Subareally erupted basalt samples originated from north of Oahu were collected from the largest block (Tascalooa seamount: 20 × 30 km²). The landslide caused the steep cliff of

northern Oahu. Fresh basalt samples were collected from the south rift of Loihi (Photo 1).

Plate Boundary Processes

Ridges

A major undertaking of the year 1998 was the MODE'98 Program, for which the entire *Yokosuka/Shinkai 6500* cruise was devoted. The MODE'98 cruise surveyed the Cape Verde Fracture Zone and the TAG hydrothermal mound in the Mid-Atlantic Ridge system, and the Southwest Indian Ridge. Gabbro and mantle peridotite samples were collected from the Cape Verde Fracture Zone (15° 20' N) on both sides of the rift valley of the neovolcanic

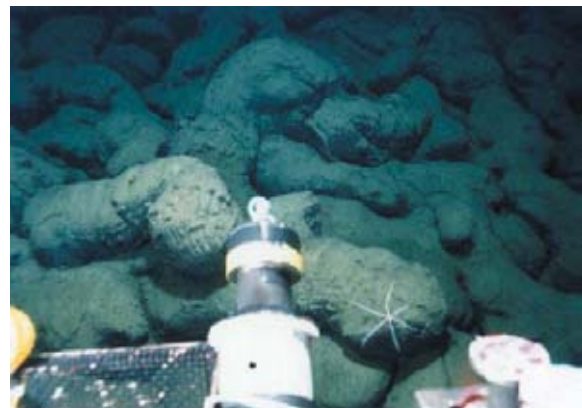


Photo 1 Fresh pillow lava from the summit of Loihi Seamount.

Deep Sea Research Department

ridge (Photo 2). Together with an extraordinarily low gravity and magnetic anomalies for an oceanic ridge, it is suggested that low magmatic activity and tectonic stretching of the rift valley caused to expose the rocks of lower crust and upper mantle.

The surveys around TAG took place at the TAG hydrothermal mound (26° 08' N, 44° 49' W), Dantes Dome megamullion (26° 40' N, 44° 20' W), and Rainbow hydrothermal site (36° 14' N, 33° 54' W). Various findings include a change in the hydrothermal activity since 1994 at TAG, existence of plumes 200-300 m above the two active vent sites, and hydrothermal mounds that are large but now-inactive or active and low-temperature around TAG.

Signs of hydrothermal activity was found at the Rodriguez R-R-R-type triple junction and the nearby Southwest Indian Ridge; i.e. inactive chimneys and dead chemosynthetic organisms. The Atlantis Bank facing the Atlantis-II Fracture Zone was confirmed to be constructed of rocks that form the crust-mantle boundary, from which an unaltered mantle peridotite sample was collected.

Island Arcs

Japan Trench-Nankai Trough

Our multi-channel Seismics (MCS) system and Ocean Bottom Seismographs (OBS) fleet were put into normal operation starting in April, 1998. The 120-ch MCS system was acquired in 1995 and had been tested in the Japan Trench and Nankai Trough areas for 3 years together with the Frontier Research Group for Subduction Dynamics. Three seismic survey cruises were carried out in 1998; off Fukushima of the Japan Trench region (KR98-04),



Photo 2 Mantle peridotite collected on the neovolcanic ridge segment near the Cape Verde Fracture Zone on the Mid-Atlantic Ridge.

Kumano-nada (KR98-06) and off Ashizuri (KR98-10) in the Nankai Trough area. All these profiles were aligned with temporary land stations deployed by the University of Tokyo, Earthquake Research Institute.

The combined use of OBS and MCS is producing much clearer and deeper images of the subduction of the Philippine Sea plate and the Pacific plate both of which cause destructive earthquakes in the vicinity of Japan (see pages ** - **). The variability in the seismogenesis at different areas still remains unexplained, but new results are emerging that may turn out to be important controlling factors of generating earthquakes, such as distribution of thin low velocity materials sandwiched at plate boundaries.

Izu-Ogasawara(Bonin)-Marianas

Huge hydrothermal chimneys, which consist of Au-rich Kuroko-type deposit, were discovered around the southeastern part of Myojin caldera floor at 1200 m water depth during a series of our submersible *Shinkai 2000* dives (NT98-07) in the northern part of Izu-Ogasawara area (Photo 3). Also in the area, a possible hydrothermal activ-



Photo 3 Hydrothermal chimneys observed around the southeast part of Myojin caldera floor.

Deep Sea Research Department

ity was inferred from the γ -ray anomaly around the western part of the caldera of the South-Hachijo knoll located south of Hachijo-island.

Three cruises were made in the Izu-Ogasawara-Mariana arc system in FY97 to characterize in particular the distribution of numerous monogenetic volcanoes in relation to tectonic features. It is found that the distribution is controlled by tectonism, for example, by the West Mariana Ridge or the Sofugan Tectonic Line.

In cooperation with the Japan Atomic Energy Research Institute, developments are under way to monitor radiation in the ocean as well as characterizing the source radionuclides using NaI (T1) scintillation spectrometer and Germanium semiconductor detectors fitted to ROVs and submersibles. Fresh pathways into subseafloor zone such as hydrothermal vents are where anomalies are expected and have been observed.

Long-term Deep Seafloor Observatories to Monitor Active Processes at Plate Boundaries

The real-time cabled observatory system (System #1) deployed in March 1997, off Cape Muroto, Shikoku continued to operate to give much better control than by land network on focal depths of earthquakes that occur beneath the seafloor. The current meter data from the cable end station at a water depth of 3572 m. The second system was put into construction southeast off Kushiro, Hokkaido. This cable is 240-km long and is twice as long as System #1.

The Hatsushima cabled station has been running for more than 5 years since Sep 1993 and is due for renewal in FY 1999. Mud flows with remarkable increase of turbidity and change in current velocity was observed to accompany earthquake swarms. Such mudflows caused distribution change of *Vesicomyid* clam community (Photos 4, and 5) and subbottom temperature increase, which may partly be due to change in the subseafloor fluid flow system. Cold seepage is feeding the clam community and tubeworms such as those found 1.4 km NNW of the station (Photo 6).

The VENUS (Versatile Eco-Monitoring Network by Undersea-Cable System; FY95-99) project in its fourth year successfully carried out the dock test of the whole seafloor observatory system to check its performance in Sep '98 (Photo 7). The first multiple-sensor observatory



Photo 4 Video image by the station camera (April 25, 1998)



Photo 5 Video image by the station camera (May 6, 1998)

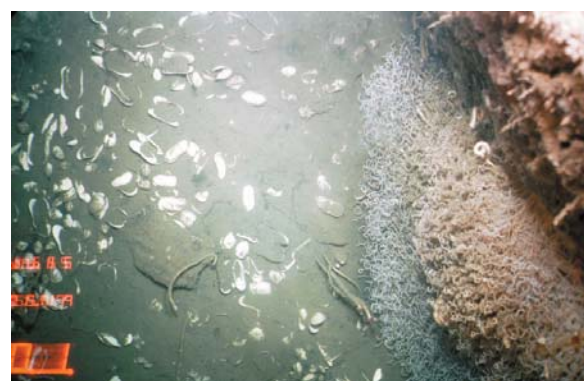


Photo 6 Chemosynthetic biological community found by the deep-tow survey (March 19, 1999)



Photo 7 Multi-sensor package unit and seismogram during the on-land trial test.

Deep Sea Research Department

off Ryukyu to be inserted into the decommissioned co-axial submarine cable between Okinawa and Guam was developed by multi-institutional efforts. In Nov, 98 the first trial to install the Junction Box with Tsunami sensors was problematic and the operation was postponed to FY99 after recovery of the Junction Box.

As part of the International Cooperative Research on the Energy and Mass Flux of Ridge Crests (FY93-98), *Yokosuka/Shinkai6500* cruise was made in Jul-Sep, 97 in southern EPR at low-temperature RM24 (17° 25' S, 113° 12' W) and high-temperature RM28 (18° 26' S, 113° 23' W) active sites. A total of 39 long-term observation instruments were deployed by the submersible to be re-

covered during *Atlantis/Alvin* cruise in Sep, 98. At both sites, fluctuations in currents and water temperature were found to be governed by semi-diurnal and diurnal ocean tides whereas the heat flux seemed to respond to earth tide. At RM24, several active events could be recorded in images (8 mm video), water temperature, turbidity and hydrophone. A hydrothermal plume of buoyant water was observed to form 100 to 400 m above the vent at RM28.

In cooperation with Rutgers University and University of Washington, we are developing long-term hydrothermal plume imaging sonar. JAMSTEC is responsible for constructing a deployment and recovery system of the sonar.

Marine Technology Department

Overview

The Marine Technology Department has provided the means to find out about the oceans and the earth, through the development of many types of ocean research vessels, such as deep-sea submersibles, unmanned vehicles and unmanned observation buoys, together with the development of important, advanced, fundamental technology common to many types of ocean observation, such as underwater acoustics. These ocean research vessels, marine instruments and technologies developed by the Marine Technology Department are widely used and have garnered the acclaim not only of researchers of the Marine Science & Technology Center, but also of external researchers.

The Marine Technology Department will continue to aim to contribute to the advance of ocean and earth science and technology through the development of exploration vessels that probe for information about the earth itself that lies deep beneath the ocean floor; the development of long-distance voyage-type unmanned submersible vehicles that automatically investigate wide areas of ocean; the development of offshore floating wave power devices that attempt to effectively use resources of the vast oceans, including energy; and the development of basic technology such as underwater sound and images.

Chapter 1 Project Research

1. Development research of deep sea drilling vessel

Period: from 1990

A deep-sea drilling vessel system is a system for drilling even below the sea floor and collecting samples of sedimentary rock and igneous rock from the bore hole, as well as conducting various types of physical and chemical measurements within the bore hole. The data thereby obtained also promotes research concerning environmental changes, variations in sea water and other types of global changes; elucidation of diastrophic processes and the mechanism of earthquake occurrence; elucidation of ocean plate movement based on drilling as far as the unexplored mantle; and the search and research of organisms within the earth's crust. These help to promote research on earth sciences. Deep-sea drilling vessel systems assume an important role amidst that. This research has been continuously performed since 1990 with the aim of researching and developing this kind of deep-sea drilling vessel system. Figure 1 shows an general view of a deep-sea drilling system.

In 1998, we conducted investigative analysis concerning deep-sea drilling, manufactured a sea floor drilling system test machine and so forth. An overview of these follows.

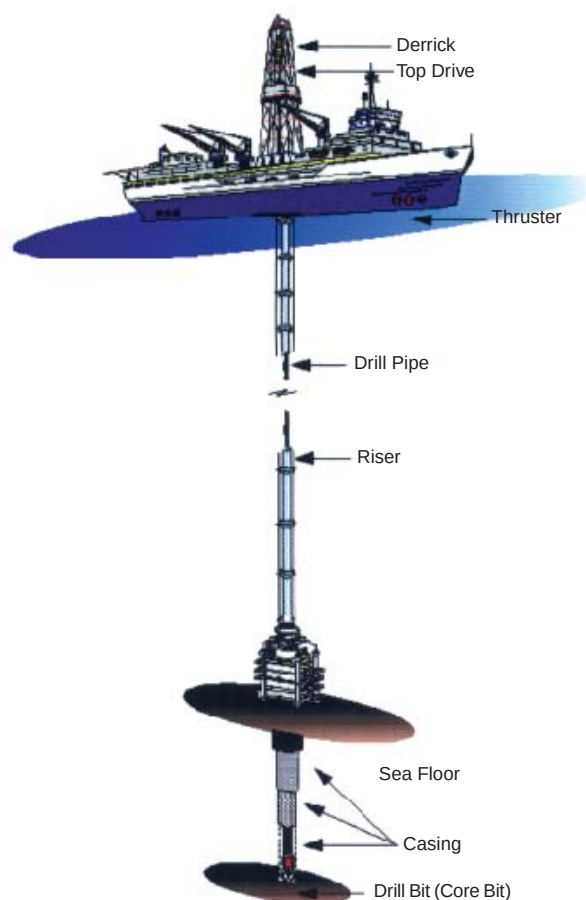


Fig. 1 General view of deep sea drilling vessel system

Marine Technology Department

(1) Investigative analysis

We conducted an analysis on the latest technological trends concerning scientific drilling and the construction status of ocean petroleum drilling rigs. We also carried out an investigation and experiments concerning waste sludge, and investigated and found out points at issue when commercially-available sludge processing equipment was used for this project, and produced experimental materials and equipment for acquiring more detailed data. Furthermore, with regard to core contamination by sludge, we carried out a chemical analysis of test cores, and acquired and analyzed basic data.

(2) Manufacture of a sea floor drilling system test machine

"Sea floor drilling systems" consists of two types: "special sample collection systems," which are used on deep sea drilling vessels, since they collect good quality samples (cores) from layers deep beneath the sea floor, and "bore hole usage systems," which use the hole created after drilling to measure various types of data within the bore hole. The test machine of this system is the product of development, design, production and testing we have carried out for a period of three years from 1998 until 2000, and in 1998, we collected basic design data, as well as creating specs. for each system, and made a start on design.

(3) Examinations for efficient drilling

In carrying out the fundamental design of a deep sea drilling vessel, scheduled to be commenced in 1999, we examined basic required conditions and investigated the latest technical trends, and carried out examinations in order to reflect this in a deep-sea drilling vessel.

2 Development of a prototype autonomous underwater vehicle

Period: from 1998

Autonomous underwater vehicle refers to an unmanned vehicle that can autonomously navigate underwater according to a schedule programmed in advance. In this research, we will develop an AUV (autonomous underwater vehicle). Table 1 shows the principal particulars of a proto type AUV. The vehicle is able to dive to a depth of 3,500m, and has a capability to cruise 300km maximum at a cruising speed of 3kn. To navigate long ranges, a

high-performance power source and a high-performance navigation system are essential. We will make the former a solid high-molecular fuel cell and a lithium ion rechargeable battery. In order to minimize the error that occurs in inertial navigation, the latter combines an optical ring laser gyro. Moreover, one can load an automatic multi-stage water sampler, side scan sonar and other measuring instruments, and collect sea water and investigate the sea floor. The vehicle is a torpedo shape with a total length of 10m and a weight of 7t. Figure 2 is a image of the vehicle.

In 1998, we constructed the vehicle fuselage, whose structure is shown in Figure 3, and a testing device on land. We confirmed the operation of each measuring in-

Table 1 Principal particulars of AUV (plan)

Range	300 km	Length	10 m
Depth	3,500 m	Width	1.5 m
Cruising Speed	3 kn	Height	1.5 m
Top Speed	4 kn	Weight	7 t
Power	Fuel Cell (PEFC) and Liion rechargeable batteries		
Navigation	Ring Laser Gyro and Doppler Sonar INS, Acoustic-Homing, Obstacle Avoidance Sonar Autonomus Cruises. Expendable Optical Fiber Cable Remote Control.		
Sensors	CTDO, Multi Sea Beam, Water Sampler (200 cell)		



Fig. 2 Cruising Image of AUV

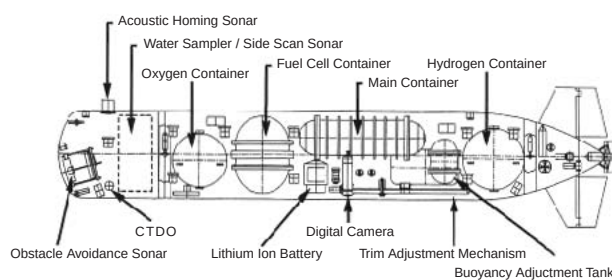


Fig. 3 Structural drawing of AUV

Marine Technology Department

strument and measured the characteristics of the propulsion device. Moreover, so that we can carry out efficient development of autonomous underwater vehicles in future, we carried out investigations concerning development trends at overseas, and the future outlook.

3. R&D of progressive technology

Period: from 1998

We will conduct advanced research on fundamental technology that forms the core of the development of deep sea research submersibles, unmanned underwater vehicles, general-purpose oceanographic observation instruments, etc., that are deemed necessary for the investigative research of wide areas of ocean.

(1) Research on image technology

TV camera images are the most important form of information for unmanned underwater vehicles when finding out conditions underwater. In this research, we will install the latest image technology and conduct research on image systems for providing operators and researchers with surround images. This year, we advanced examination of image output systems, along with designing and manufacturing a spherical curvilinear screen for downward use to shoot images.

(2) Research on power sources

In this research, we develop containers the fuel and oxidizer, because it is necessary to mount fuel cell onboard of AUV. The fuel and oxidizer use hydrogen gas and oxygen gas, respectively. This year, we carried out an inves-



Photo 1 Exterior view of sample container

tigation and examination on hydrogen storage alloys and conducted tests on occlusion performance. Photo 1 shows an exterior view of the container when we placed storage alloy in the container and conducted an experiment. As a result, while there is a possibility of application to an actual machine in the case of occlusion performance, problems concerning the container to contain storage alloy became clear.

(3) Research on underwater acoustic technology

Communications by underwater acoustic signal become more susceptible to external disturbance such as multi-path and Doppler shift as transmission rate increases, and transmission reliability declines. In this research, we will grasp the effect that external disturbance has on a sound field, and establish technology to transmit data at high speed and with high reliability.

In 1998, we produced an acoustic transmitter and a receiver for underwater installation, and carried out acoustic



Photo 2 View of installation in a real sea test

Marine Technology Department

field measurements in 1,200m depth area of the sea. For the measurements, we installed each device at locations separated by a horizontal distance of about 500m and a slant range of 700m, and performed acoustic transmissions, and acquired data that included reflected waves of the sea floor and sea surface. Photo 2 shows the way in which the acoustic transmitter were installed in the real sea trial.

(4) Research on measurements and sensor technology

In oceanographic surveys using remotely operated vehicles, a good deal of effort is being demanded of operators to control the position of remotely controlled vehicles. If remotely operated vehicles become equipped with even more advanced functions, it will be necessary to incorporate various types of automatic functions by high-precision sensors and high-performance computers, and increase the movement control of remotely controlled vehicles. In this research, we will develop a sensor that measures movement underwater with high precision. In 1998, we carried out trial design of an underwater mobile distance computation unit.

4. Development of an oceanographic observation buoy system

Period: from 1993

This R&D is aimed at developing an oceanographic observation buoy system for measuring various types of oceanographic data continuously, in three dimensions and at high precision for long periods in vast ocean spaces.

In response to the suspension of last year's sea test in middle latitude, we carried out various experiments this year to examine countermeasures against the cause thereof, strong currents.

(1) Preparatory mooring test

In last year's sea test, the buoy was on the verge of sinking in response to the large amount of tension directly below. Because the current meter came off, current data could not be obtained, but from the (amount of) tension, it is estimated that there was current that far exceeded design conditions. Moreover, it is assumed that the reason the current meter fell off was because the mounting fixtures broke through fatigue because of vibration caused by karman vortex.

Thereupon, we conducted a preparatory mooring test

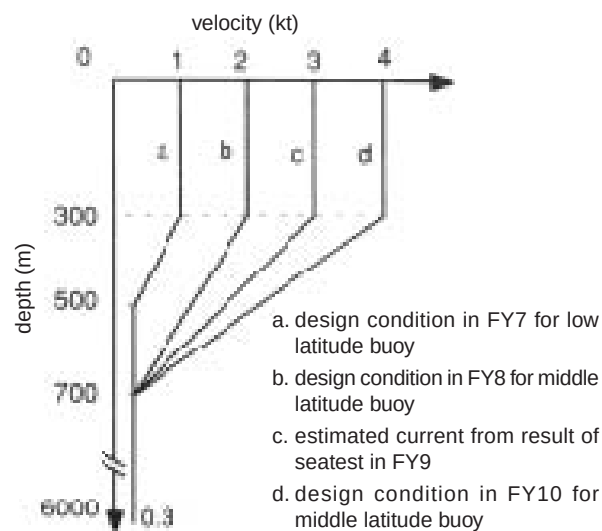


Fig. 4 current velocity profile

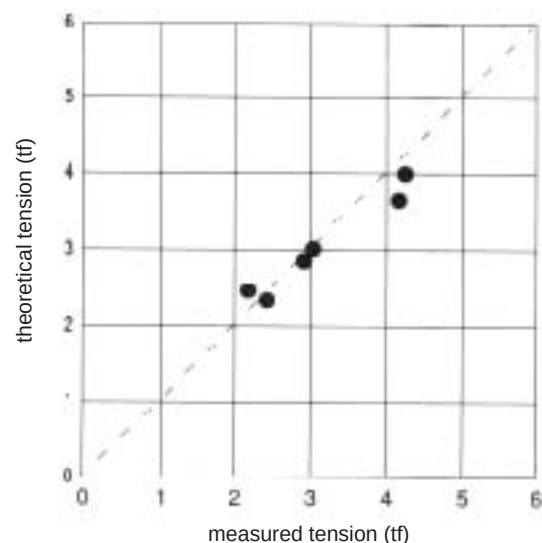


Fig. 5 Theoretical tension based on current velocity profile and actual measured tension

in the Kuroshio current area, and in addition to confirming that the relationship between tension directly beneath the buoy and the current profile was roughly in accordance with calculations, we measured the relationship between current velocity and vibration of the mooring line. Figure 5 shows the relationship between calculated tension and actual measured tension, based on the measured current profile.

Marine Technology Department

(2) Mooring system towing test

Meanwhile, buoys for low latitude use that we produced last year were deployed in the actual sea area. One of them was deployed in stronger current than the design condition and its mounting fixtures of the underwater sensor wore down.

Thereupon we conducted a towing test, and as a measure to counteract strong currents for a low latitude system, we fitted spiral tubes and confirmed the effect of strengthening mounting fixtures. Figure 6 shows the results of measuring vibrations in the system when towing at 2 knots.

(3) Improvement of middle latitude prototype

Since we were unable to accurately set the maximum current velocity at middle and high latitudes, we set a maximum current velocity (4 knots), and made the buoy larger and remodeled the mooring system to include a faring with a wing-shaped cross-section, so the sinker would move at current velocities above the limit, and thus avoid the buoy's sinking.

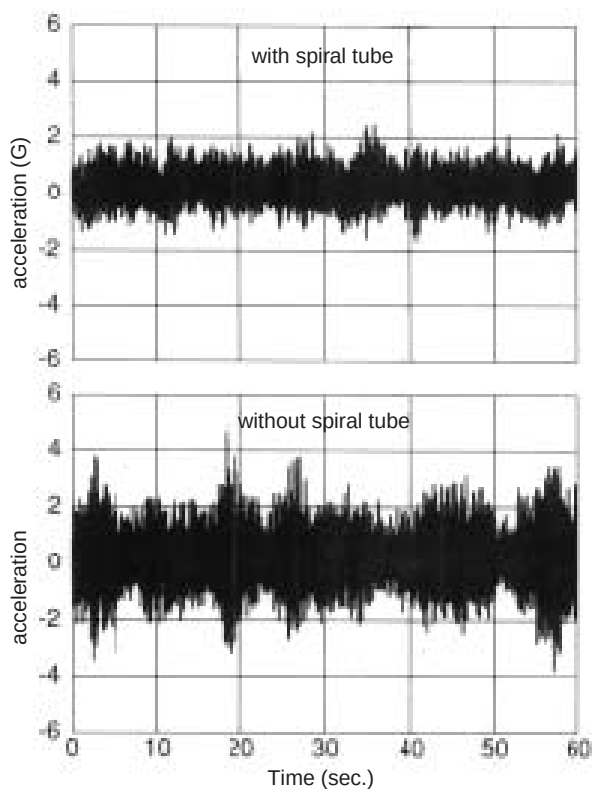


Fig. 6 Cable vibration when towing at 2 knots

5. R&D of technology using the ocean's energy

Period: from 1988

Nowadays when global environmental issues have come to be recognized, the use of clean, inexhaustible natural energy is once again drawing attention, and along with this, the use of natural energy, which is a compact and convenient energy source, is being anticipated in remote islands, outlying regions and developing countries. As one such source, the effective use of wave energy obtained in coastal areas is being anticipated. Since 1989, this center has carried out R&D of the "Mighty Whale," an offshore floating wave power device that is able to efficiently absorb wave energy and put it to effective use in coastal waters, as well as making the waters around the device tranquil and enabling the use of this sea space for fish farming, etc. By this time, we were able to obtain a forecast of the "Mighty Whale"'s basic functions and device safety and economy by theoretical examination and a water tank experiment using a reduced-scale model. Based on this, we completed the detailed design of the prototype (length 50m, width 30m) by 1995, and began construction from 1996. The "Mighty Whale"'s main body was completed by May 1998 and in July it was towed and moored in the test site of Gokasho Bay of Nansei-cho, Watarai-gun, Mie Prefecture (Photograph 3), and after adjusting all the on-board instruments, we commenced experiments from September 10.



Photo 3

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As Table 2 shows, the open-sea test consisted of measuring the main body's position, motion, mooring tension, water level in and outside the air chamber and atmospheric conditions and sea conditions. As Fig. 7 shows, measurement data is basically analyzed and saved on the floating body, and for device safety and to monitor the operating status of on-board instruments, a portion of data is radio-transmitted to Shore-based Measurement and Control Station. Moreover, from Shore-based Measurement and Control Station, we can carry out the following operations by

Table 2 Measurement items

Items	Parameters
(1)Environment	- Incident wave height and direction - Wind speed and direction - Atmospheric temperature pressure - Transmitted wave height
(2)Hull Dynamic Response	- Oscillations - Drift motion
(3)Primary Energy Conversion	Water displacement in and outside air chambers
(4)Secondary Conversion	- Air pressure - Pressure drop, RPM, Torque, safety valve, Machinery generated noise
(5)Generators	Voltage, Current, Power
(6)Air Compressor	- Air flow, Air pressure - Hull absolute position
(7)Mooring System	Mooring tension
(8)On board Electricity Consumption	Voltage, Current

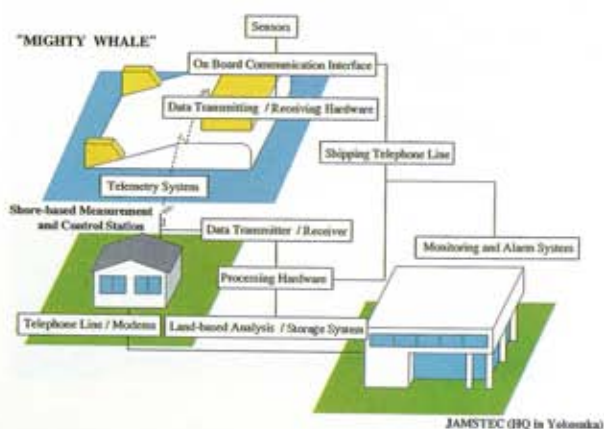


Fig. 7 Measurement and monitoring system

wireless remote control operation: commands to select the capacity of the wave power generator; start & stop of the auxiliary generator; operation of the designated on-board instruments.

After the experiment commenced, typhoons 5, 6, 7 and 8 passed through the test site or nearby consecutively from September 15 to September 23, and as Figure 8 shows, a significant wave height of about 4-10m was measured, and electricity generation by wave force was confirmed (Figure 9).

In future, we will gather and analyze various types of data in the open-sea test, and would like to make efforts so that aiming for the application of this device will be of use in promoting the overall development of coastal waters. Furthermore, in the open-sea test, we plan to examine application technology for using wave energy, as well as the safety and structural resistiveness against wave action of floating offshore structures.

R&D of coastal environment and usage

6. R&D of ocean bottom installation-type breeding systems

Period: from 1995

The high waves due to the winter seasonal winds peculiar to the Japan Sea have drastically restricted industrial activities on the Japan Sea coast. Ensuring a calm seas surface in times of rough weather is technically and economically difficult, particularly in areas that have a level coastline, like Yamagata prefecture. For that reason, we are paying attention to the fact that the sea bottom is calm even during the high waves of the winter season, and with the aim of effectively using the sea bottom that hitherto has been unused, we are carrying out development jointly with Yamagata Prefecture that is aimed at establishing seedling production technology targeted at rock oysters, which live in Japan Sea coastal areas, and the application of a breeding device and use system.

We aim to make this R&D development useful for the promotion of coastal culture fisheries by making improvements towards the application of a breeding system created by regional joint development (1995-1997), as well as shedding further light on the rock oyster's ecology and conducting breeding tests on fingerlings.

This series of R&D will establish the proliferation tech-

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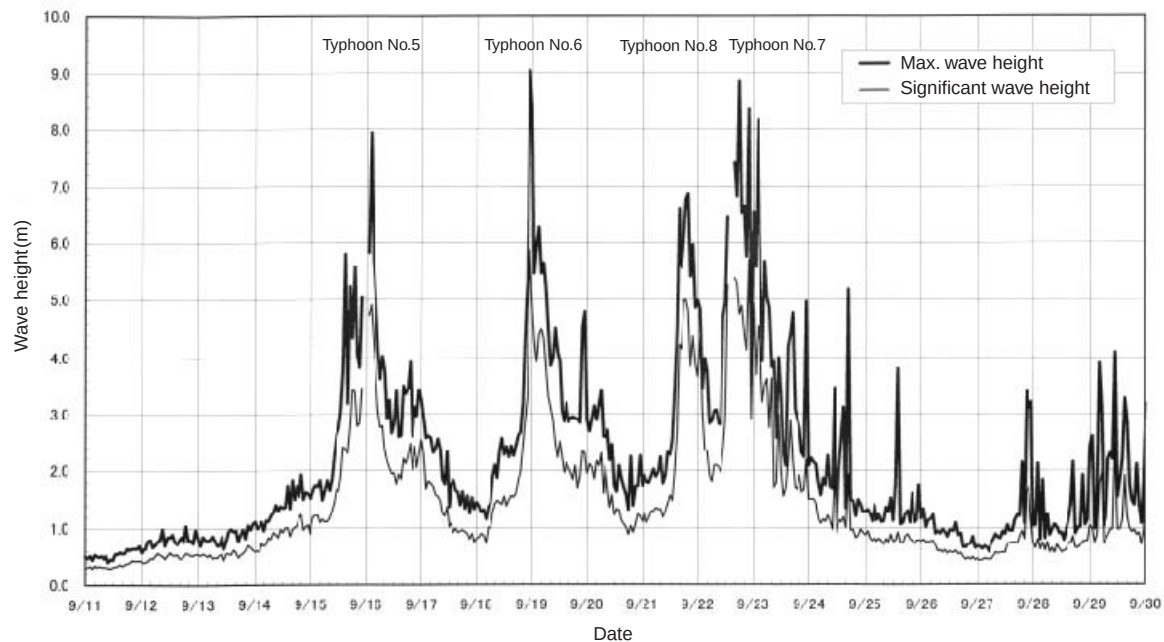


Fig. 8 Diagram showing wave height variation with time (10,Sept.1998 - 30,Sept.)

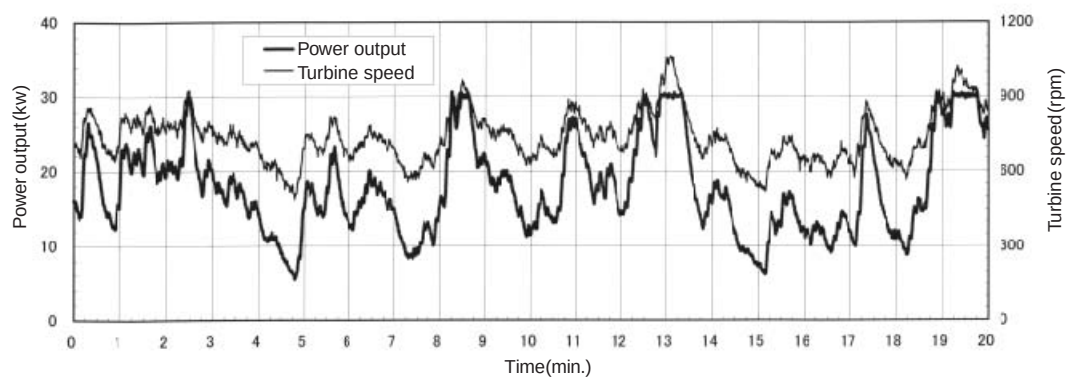


Fig. 9 Number 3 vessel electricity output and turbine revolutions (H10.9.16 02:50 - 03:10)

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nology of rock oysters and other marine creatures that dwell on the sea bottom; boost ocean resources, and contribute to development of the regional economy.

In 1998, we carried out the following R&D.

(1) R&D of sea bottom installation-type breeding device

In order to apply a sea bottom breeding system, we investigated the fluid dynamic characteristics of breeding containers within the device, and researched the scale of the system as a whole. As a result, we found that for the fluid dynamic characteristics of breeding containers, the form factor in uniform flow is in the range 1.0-1.5.

Based on this experimental result, we examined the specifications of a system composed of 20, 30, 50 and 100 breeding containers. Furthermore, we performed detailed design and manufacture of the 30-container prototype shown in Figure 10 through examination of specifications, and commenced an experiment, installing it at a depth of 40m in the experimental sea area.

(2) Rock oyster ecology research and growth test

The amount of growth in rock oysters (1 year-old at time of commitment) over 260 days according to a system whereby the said breeding containers shown in Figure 11 launched in 1997 were arranged on ropes (perpendicularly down) and on the sea bottom was $30.1 \pm 10.4\text{mm}$ in the rope method portion (daily growth rate: $115 \pm 40 \mu\text{m}$), while the growth rate of the conventional sea bottom portion was $26.8 \pm 6.5\text{mm}$ (daily growth rate: $103 \pm 40 \mu\text{m}$). From this it became clear that for devices installed in the same spot, the growth rate is better in middle layer areas than sea bottom areas. Furthermore, the procreation rate in each area was 89-100%, and the effect of improving the breeding containers was recognized.

Chapter 2 Special Research

1. Model test and response analysis of the riser

Period: from 1998

Riser drilling technology is an important technology in deepwater drillships. A riser is a large-bore (400-500mm) steel pipe that links a vessel with a blowout preventer device installed on the sea floor. A drill pipe for drilling is passed through this pipe to drill.

Riser drilling at great depths is extremely rigorous from the viewpoint of riser strength. The target riser drilling depth is 2,500m, but riser drilling at this kind of depth is seldom carried out even in global ocean oil drilling. Moreover, computers are being used to evaluate riser strength, and numerical analysis is being performed, but almost no comparison is being made with experimental data. The purpose of this research is to conduct an experiment using a model riser of one-one-hundredth scale, and verify the results of numerical analysis using experimental data, and establish a riser design method.

This year, we designed and produced a model riser. We produced an experimental system that acquires the behaviour of the model riser in water. Figure 12 shows an overall view of the experimental system we produced. A TV camera mounted on the aluminum frame for measurement observes the model riser behaviour. We carried out test operation of the experimental system in a water tank, and were able to confirm the model riser's behaviour. We also created a program for numerical analysis.

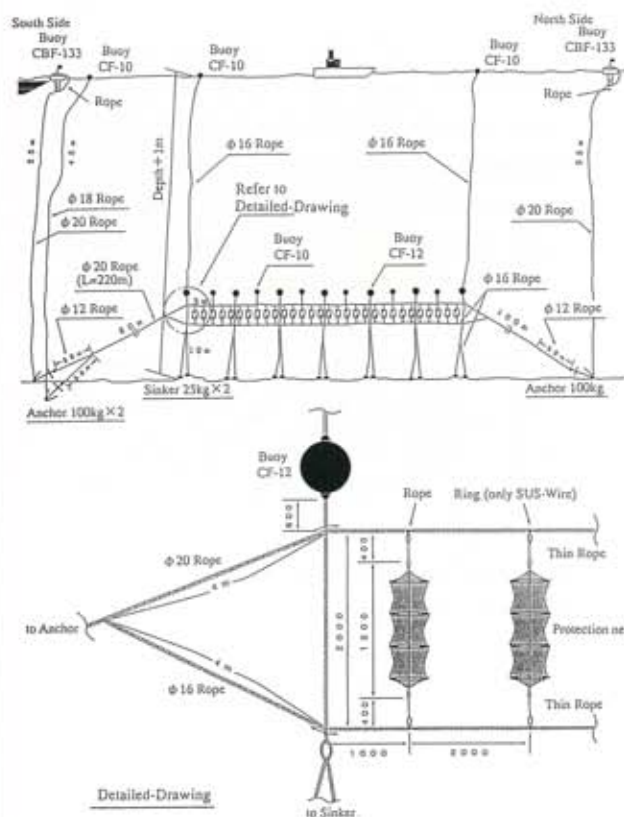


Fig.10 Sea bottom breeding device for practical use (30-container prototype)

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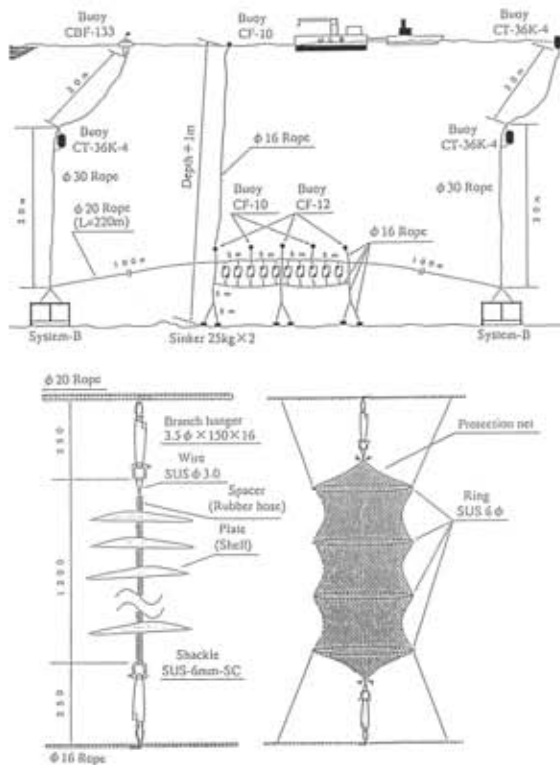


Fig.11 1997 breeding device (for water depth of 40m)

2. Research on technology of remotely operated vehicles in ice zone

Period: from 1998

In this research, we will study the measurement technology necessary when gathering ice zone CTD data, ice thickness and information on carbon dioxide data, etc., using remotely operated vehicles in the Arctic region, where the effect of global warming is considered to be conspicuous.

Based on experiments up until the previous year, we prepared this center's remotely operated vehicle, "Phantom," (photo 4), loaded it into Canada's Louis Saint Lauren (photo 5), and put the remotely operated vehicle to use in the Arctic Ocean from September to October in 1998. Photo 6 shows the state of Louis Saint Lauren's propeller, using the Phantom in ice ocean. As a result, it was apparent that the propeller had been damaged. Moreover, problems became clear in terms of using the remotely operated vehicle below freezing point.

Chapter 6 Joint research

1. Research on long length small diameter optical communications for unmanned remotely operated vehicles (UROV)

Period: from 1996

To use a small diameter optical fiber cable for unmanned remotely operated vehicle at great depths, long-length optical fiber is essential. In this study, we will

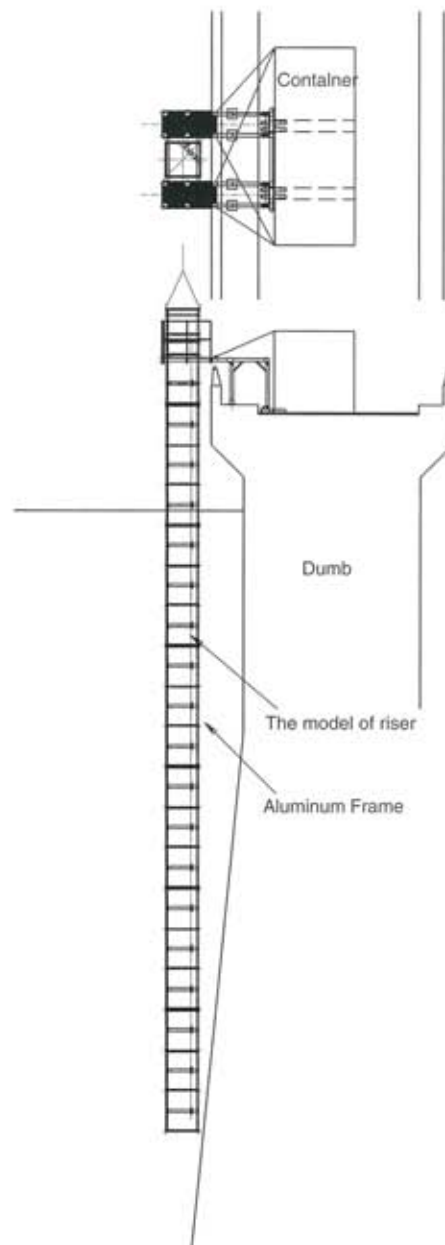


Fig.12 General view of rise experimental system

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research and develop an optical fiber container and high-speed communications in long-length optical communications for UROV. This year, we carried out the following, based on results up until last year. We applied winding slack prevention countermeasures to the optical fiber spooler that houses the long-length optical fiber. We carried out a performance test of a connection device, which becomes necessary when using multiple optical fiber spoolers, and achieved favorable results. We conducted a spooler descent trial at sea, (depth of 6,000m or more), and confirmed that it was repeated without breaking. Photo 7 shows an exterior view of the optical fiber spooler used in the descent test. In order to carry out large-capacity communications, we also began an examination on increasing speed (1Gbps).

2. Research of automatic water collection unit

Period: from 1996

To inquire into the causes of global warming, measurement of carbon dioxide gas in water is considered to



Photo 4 Exterior view of Phantom remotely operated vehicle



Photo 5 Louis Saint Lauren, which used a remotely operated vehicle in the Arctic Ocean



Photo 6 Louis Saint Lauren's damaged propeller

be important. In this study, we collected a number of sea water samples by an autonomous unmanned remotely operated vehicle, and researched a water collection unit that can efficiently analyze samples on land that have been obtained. The 1998 supplementary budget determined the construction of an "autonomous unmanned vehicle (AUV) test machine," which would include an automatic water collection unit, and the design and manufacture of an actual machine began from this year. For this reason, the meaning disappeared of manufacturing by way of trial a mock-up incorporating a single cell, and conducting test operations, which we were planning this year; we therefore called a halt to the research.

3. Research on real time catenary estimation technology of tether cables for unmanned underwater vehicles

Period: from 1997

In the case of cable-operated unmanned research vehicles like "Dolphin 3K," neglecting correct cable operation is liable to cause cable breakage. However, since information concerning cable catenary can not be obtained, operation is largely dependent upon the experience of operators. In this study, we estimate cable catenary in real time, based on the positioning information of support vessels, and develop technology that displays the results visually. This year, we amended functions for outputting and displaying estimation results, and proceeded with the development of a program to calculate the 3-dimensional unsteady flow around the cable.

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Photo 7 Exterior view of optical fiber spooler used in descent test

4. Research on technology for the efficient use of unmanned underwater vehicles that considers cable twist characteristics

Period: from 1997

Since we have become able to grasp to a certain extent the twist behaviour of tether cables of late, "cable kink" hardly occurs at all now. In this study, we are making an even more detailed investigation of tether cable twist characteristics, and in consideration of cable twist characteristics, are conducting research in order to minimize the build up of cable twist.

This year, we produced a small model based on results from the previous year, and carried out an experiment concerning prevention of twist build-up. As a result, new information was obtained concerning the twist build-up mechanism.

5. Research on an automatic navigation system in "Kairei" for deep sea floor investigation and observation

Period: from 1998

In this study we will develop an automatic navigation system that will enable the holding of an effective fix necessary for operation, and lateral line navigation, even in rough waves and other such environments. Based on actual results up to the previous year, we provisionally installed the "Kairei" automatic navigation system this year, and conducted tests to verify the operation of each automatic navigation function. As a result, the system's usefulness was demonstrated even under choppy conditions. Photo 8 shows how the automatic navigation system is provisionally installed on "Kairei."

6. R&D of sea water drawing technology using compressed air

Period: from 1998

In this study, we develop technology for efficiently and simply collecting bottom level water, using compressed air from wave power. Based on the results of examining basic theory up until the previous year, we conducted the following this year. We experimented with a bottom layer water draw up system using compressed air in a large tank, and extracted points at issue upon conducting an experiment in a real sea area. Based on the results of this experiment we examined the basic theory concerning the mixed flow of air and water, and developed numerical calculation technology of real sea-scale systems.

Chapter 4 Current research

1. Development of a launching system for deep sea TV observation equipment

Period: from 1996

In this study, we load into a manned submarine the "small TV observation equipment for deep sea use" developed in the current research, and develop a launching system comprised of a cable reel and housing necessary for use in the real sea. This year, we confirmed the operation of the launching system's compositional elements we manufactured by the previous year. Moreover, we manufactured a safety device to be used in manned submersible vehicles, and performed overall adjustments of the combined system and confirmation and testing of functions.

2. Research concerning LED-based non-contact data communications

Period: from 1997

With this study, we examined non-contact data communications for use at sea using LEDs, and developed a device to enable their loading on research submersible vehicles. Based on the investigation of various types of LED characteristics up until last year, we carried out the following this year. First, we examined the system and conducted an experiment of physical characteristics; then we examined a non-contact communications unit using the near infrared. Next, we commenced design and manufacture of a non-contact communications device using the near-infrared.

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Photo 8 View of temporary installation of "Kairei"'s automatic navigation system

3. Research on obstacle avoidance forward looking sonar

Period: from 1997

In this study, we recognize objects that form obstacles to autonomous remotely operated vehicles, and develop techniques to avoid them. Based on results up until the previous year, we carried out the following this year. We designed by way of trial an interface to connect a sonar with a control unit, and made adjustments to the electronic circuit. We carried out design of software to fetch signals to the control unit, and confirmed operating status in a pool.

4. Research concerning improvement to the performance of the "Shinkai 6500" thruster and steering unit

Period: from 1998

In this research, we conducted a study on a thruster and steering device that enables nimble movement and advanced position and attitude control. This year, we carried out the following. We carried out a water tank experiment of a thruster (DC brushless motor-driven duct propeller) that we manufactured in project research in

1997, and grasped its steady characteristics. We also manufactured a sensor unit to measure submersible movement, and experimentally fitted this sensor unit and the thruster on the "Shinkai 6500" and carried out a real sea experiment, and obtained data for use in examinations of control techniques. Photo 9 shows the thruster mounted onto the upper part of "Shinkai 6500."



Photo 9 Thruster mounting onto the top of "Shinkai 6500"

5. Research on operation technology for UROV7K at great depth

Period: from 1998

In order to use the UROV7K in areas of deep sea, this research establishes operation technology suited to thin diameter cable systems. Repairing the chassis that was damaged the previous year, we mounted a TV camera and other observation equipment, control instruments and thruster, etc., onto the chassis. After an operation experiment in a water tank, we used the "Yokosuka" to carry out test dives at depths of 100m, 1000m and 2000m. Photo 10 shows the UROV7K hoisted up by an A-frame crane in a real sea area. As a result of the dive tests, the problems in use in real sea areas became clear; therefore, we will examine countermeasures and make improvements from next year onwards.

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6. R&D of a calm sea development system based on optimum arrangement of floating structures

Period: from 1997

In this research, we optimally arrange multiple floating structures on the sea surface, and construct calm sea development technology that can make that area of sea calm. Moreover, we also grasp the effect of floating structures on the physical environment. Based on results up until last year, we carried out the following this year. We

conducted a theoretical examination of techniques for analyzing the degree of calmness when multiple floating structures are arranged, and carried out a mock experiment. We made a quantitative examination of energy balance and degree of permeability in front of and behind the group of floating structures, and through variation of floating structure arrangement, found there to be an arrangement where permeability becomes one-half or less.



Photo 10 Scene of UROV7K hoisted up by an A-frame crane

Policy

It is essential for clear understanding and prediction of the global environmental changes to elucidate the real state of the oceans which occupy about 70% of the earth's surface. For this purpose, several international research programs are in progress, such as WCRP (World Climate Research Program), CLIVAR (CLimate VARIability and predictability study), ACSYS (Arctic Climate SYstem study) and GOOS (Global Ocean Observing System).

The Ocean Research Department at Japan Marine Science and Technology Center (JAMSTEC) has conducted researches in the North Pacific and Arctic Ocean, and developed ocean observing technology in conjunction with the international programs. Five groups in the Department are actively engaged in the following researches:

- Group 1: collects ocean data by ships and by TRITON buoys in the western equatorial Pacific for a better understanding of El Niño and Asian monsoon;
- Group 2: studies large scale variability in the mid latitudes of the Pacific and develops ocean acoustic tomography system;
- Group 3: conducts observational research using vessels and fully automated drifting ice stations to ascertain the role of the Arctic in the global climate system;
- Group 4: conducts atmospheric observations for a better understanding of air-sea interaction, focusing on precipitation mechanisms in the tropical western Pacific;
- Group 5: develops the ocean lidar system which can detect vertical and lateral distributions of phytoplankton, and conducts biogeochemical study of carbon and its related materials in the ocean.

As for observations of the vast oceans in order to elucidate the mechanism of the climate and ocean changes, which are necessary for the prediction of the global warming, ENSO (El Niño / Southern Oscillation), Asian monsoons, etc., it is essential to make observations systematically and to accumulate the data over a long period of time. Consequently, the observation should be planned and carried out, in cooperation with other research institutes aiming at each unique research target.

Tropical Ocean Climate Study (TOCS)

The tropical Pacific Ocean has an important role in the heat balance of the earth because the large radiant energy from the sun enters into the tropical ocean. Especially, the western equatorial Pacific is characterized by the warmest sea water in the world, (warm water pool), which variation is strongly related with the El Niño / Southern Oscillation (ENSO) phenomena. Therefore, the western tropical Pacific is thought to be one of the key area in the global climate variability.

In order to understand the role of the western tropical Pacific in the climate variability, we have been observing ocean currents, temperature and salinity distribution and variability in this area by on-board observations and mooring buoys.

In this fiscal year, We conducted three ocean observation cruises using R/Vs Kaiyo and Mirai collaborating with NOAA /PMEL (National Ocean Atmospheric Administration / Pacific Marine Environmental Laboratory, USA) and BPPT (Badan Pengkajian Dan Penerapan Teknologi, Indonesia). They are summarized in Table 1.

Table 1. Summary of cruises conducted under TOCS project during FY1999.

Duration	Ship	Ports	Buoy work	No. of CTD/XCTD site
August 15 - September 11, 1998	R/V Kaiyo	Guam - Chuuk - Palau	ATLAS buoys: 6 buoys deployment, 7 buoys recovery and 2 buoys repair ADCP buoys: 3 buoys deployment and 4 buoys recovery	36
January 26 - March 2, 1999	R/V Kaiyo	Majuro - Palau - Palau	ATLAS buoys: 2 buoys deployment and 2 buoys recovery ADCP buoys: 1 buoy deployment and 2 buoys recovery Current meter buoy: 1 buoy deployment	122
February 8 - March 31, 1999	R/V Mirai	Hachinohe - Guam - Honiara - Chuuk - Shimonoseki	TRITON buoys: 9 buoys deployment ATLAS buoys: 4 buoys deployment, 4 buoys recovery and 1 buoy repair ADCP buoys: 1 buoy deployment and 1 buoy recovery	42

Stations of CTD and XCTD casts, ADCP, ATLAS and TRITON (Triangle Trans-Ocean Buoy Network) buoys during these cruises are shown in Figure 1. In particular, nine TRITON buoys were deployed at 5 °N, 2 °N and 0 °N along 147 °E line, and 8 °N, 5 °N, 2 °N, 0 °N, 2 °S and 5 °S along 156 °E line during the R/V Mirai cruises. Data from the TRITON buoys will be available at the web page of JAMSTEC (<http://www.jamstec.go.jp/jamstec/TRITON>) from next fiscal year (after April 1999).

Some interesting results are derived from these observations. Time series of zonal component of current measured by the moored ADCP at 0 °N, 156 °E is shown in Figure 2. Strong eastward current exceeding 50cm/s, the Equatorial Undercurrent, is seen between 150m and 200m depth. After spring 1998, this current became further strong with monthly mean velocity exceeding 1m/s, and its current axis shoaled around 100m depth. We think this is a unique phenomenon because we have never observed the

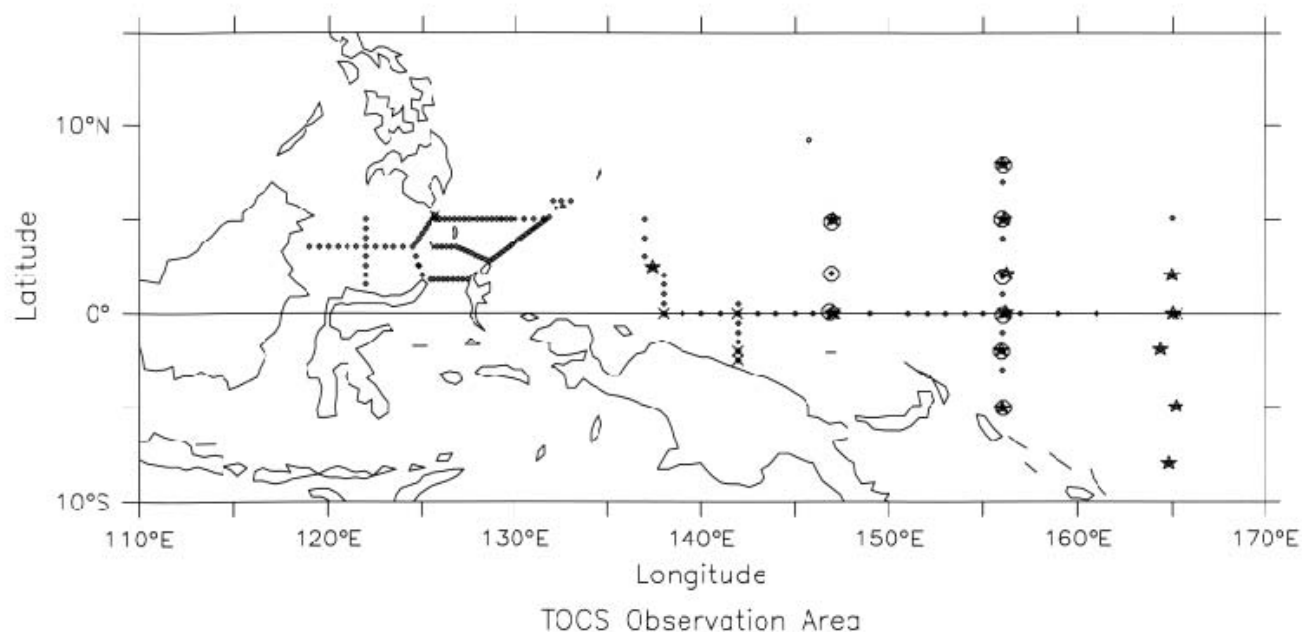


Fig. 1 CTD/XCTD and mooring sites during TOCS cruises conducted in this fiscal year. Dots, circles, stars and crosses denote the locations of the CTD/XCTD cast, TRITON, ATLAS and ADCP buoys, respectively.

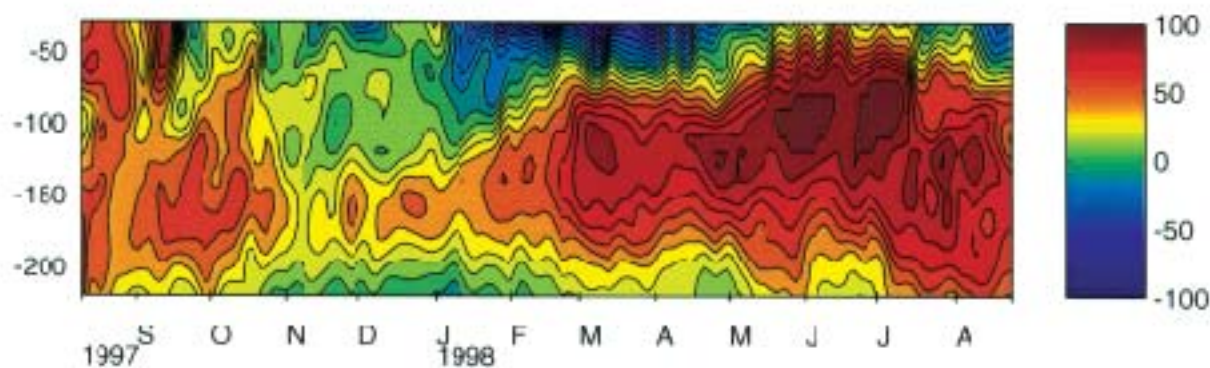


Fig. 2 Depth-time series plot of the zonal velocity measured by the acoustic Doppler current profiler at 0 °N, 156 °E. Positive value means eastward flow.

strong Equatorial Undercurrent with monthly mean velocity exceeding 1m/s since 1994.

We also obtained interesting results from observation in and around the Celebes Sea on R/V Kaiyo in February 1999. Complicated structure of the Mindanao Current, which flows southward along the Mindanao (Philippines) coast, is given by the shipboard ADCP (Figure 3). It splits into three branches south of the Mindanao, and the westernmost one entered the Celebes Sea. Part of last one retroflected around a cyclonic eddy in the western Celebes Sea and returned to the Pacific.

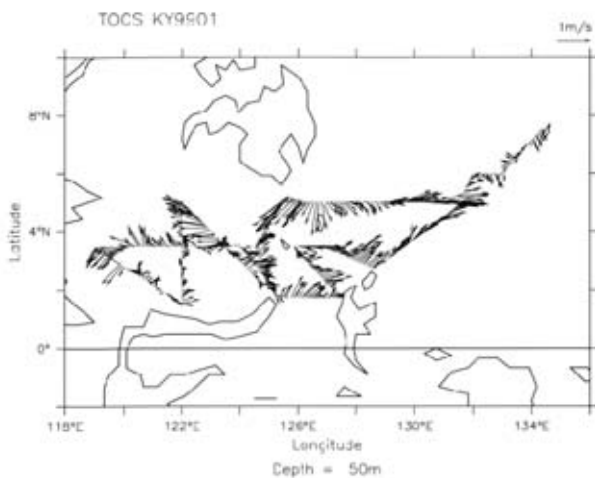


Fig. 3 Currents measured by the shipboard ADCP on R/V Kaiyo in February 1999.

Evaluation of TRITON buoy data and performance of TRITON sensors

The operation of TRITON buoy has began since 1997, and the data from the buoys are expected to be useful not only for the scientific purposes but also for world wide weather forecast. To contribute to such purposes, we need to produce quality controlled data for scientific and operational community. However, calibration methods of rainfall sensor, shortwave radiation sensor and conductivity sensor, for example, are not established enough. The purpose of this study is to evaluate especially performance of such sensors and also to evaluate the quality of the data from TRITON buoy.

In the FY1998, we compare the data from TRITON buoys sensors with the data from R/V Mirai sensors. These sensors are the same type, so that the comparison

was focused on the differences in platforms. The results shows the differences were very small, and the data from TRITON buoys showed the similar quality to the data from research vessel.

The results from the analysis of CT (Conductivity and Temperature) sensor drift before deployment and after recovery show that the averaged drift of temperature sensor is small and 2mK per year, and the averaged drift of conductivity sensor is larger than we expected and 0.02-0.03 psu per year. The same analysis is performing to the meteorological sensors.

We believe that the results from this study will be valuable to control the quality of the data, and also to check the daily transmitting data.

Development and Maintenance of TRITON Buoy Network

Japan Marine Science and Technology Center (JAMSTEC) is developing a surface moored buoy network named TRITON (TRIangle Trans-Ocean Buoy Network) for observing oceanic and atmospheric variability in the Pacific Ocean and its adjacent seas in cooperation interested Japanese and foreign agencies and institutions.

The principal scientific objective is to understand variations of ocean circulation and heat/salt transports with emphasis on ENSO, the Asian monsoon, and decadal scale variability that influences world wide climate change. In its first phase, the TRITON array will be established mainly in the western tropical pacific Ocean, and harmonized with TAO array which are presently maintained by Pacific Marine Environmental Laboratory (PMEL), NOAA. The fundamental functions of TRITON are (1) basin scale ENSO monitoring, and (2) measurements of heat, fresh-water, momentum fluxes for improving modeling capability.

After two demonstrative experiments in North Pacific Ocean near Japan, 4 actual TRITON Buoy systems were deployed in the western tropical Pacific Ocean in March 1998, for the observation of 1 year. (see photo.1)

In June 1998 communication troubles were occurred at the one of 4 Buoys and we lost the information of the Buoy position.

When the Buoy was recovered by R/V "Mirai" for the repair of the Buoy 's troubles, the remarkable erosion was found at the chains between the Buoy body and the wire rope. Because this phenomenon was found in the rest



Photo 1 TRITON Buoy body

Buoys, the rest 3 Buoys were also recovered.

To investigate the causes and establish quickly measures against erosions, special team called for "inquiry group against erosions " was started under the TRITON Project team and, also, the fact -finding technical committee was held to evaluate the investigation's reports and the effectiveness of the measures against erosion.

As the main cause of erosion was cleared that an electronic erosion occurred by the contact of different kind metal which had different electric potential, and the one is stainless steel of Buoy structures and the other is the carbon steel chains.

The acceleration factors to the erosion are also to be clear as follows. The first factor is the coming off of the paintwork of the Buoy structures. The second factor is the existence of lead ballast exposed to the Buoy structures. The third factor is an increase of sea water temperature in the western tropical Pacific Ocean for about 10 degrees C compared with the temperature in North Pacific Ocean near Japan which cause the increase up to 150% of an electronic erosion.

According to these investigations, several measures against erosion were considered, tested by dockside, and applied to actual Buoy structures and mooring system as

follows.

The first one was isolation between different kind metals. The second one was, for failsafe, installation anti-erosion of anodes to Buoy structures and the chains. The forth one was improvement of foundation treatment for paintwork to Buoy structures. (see Fig.4)

And also it became clear that unexpected increase of current speeds at the moored area caused mooring wire vibration and some damages to the installation equipment of underwater sensors. For this countermeasure against vibration damage, spiral tube was installed to a strong current part of the mooring wire for reduction of vibration forces, and the installation equipment of underwater sensors was

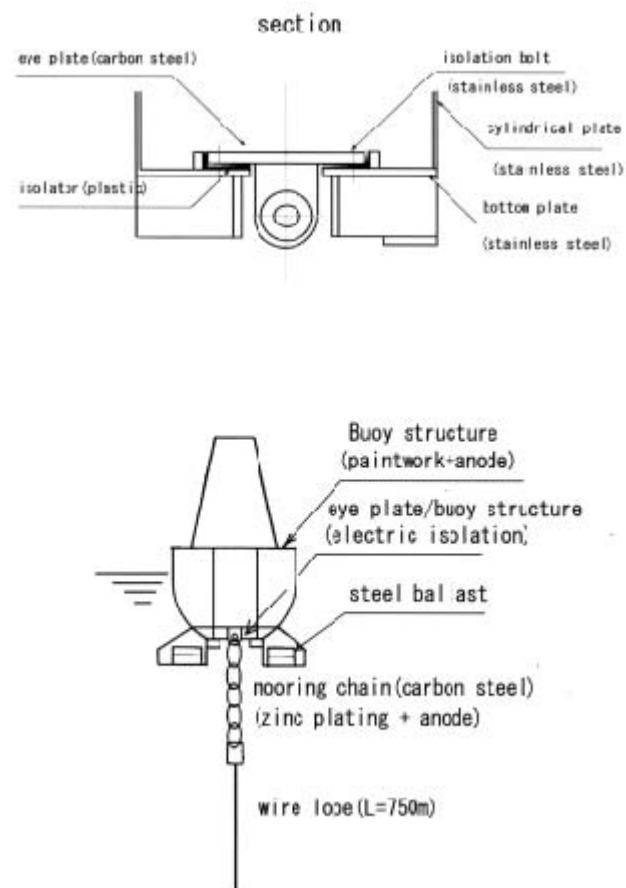


Fig. 4 Measures against erosion for TRITON Buoy system

reinforced according to tank test results. (see Fig.5)

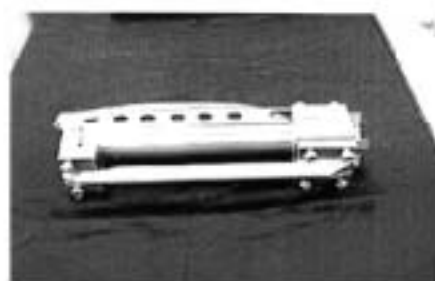
In this fiscal year, 1998 14 Buoy systems were manufactured and 9 Buoy systems were deployed in the western tropical Pacific Ocean in from February to March for a year observation. (see Photo 2)

The Buoy data (every 10-minute surface meteorology

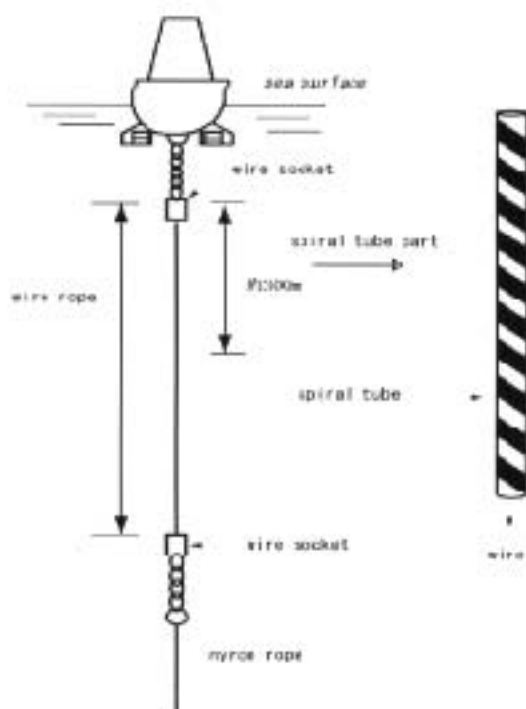
and underwater data) are averaged for 1 hour and transmitted to land from TRITON buoys via ARGOS satellite data collection system. The real time data will be distributed on GTS (Global Telecommunication System) via French ARGOS global processing center. The meteorological agencies and institutions will use the data for ENSO



installation equipment for CTD
(old type)



installation equipment for CTD
(new type)



installation equipment
for current meter (old type)



installation equipment
for current meter (new)

Fig. 5 Spiral tube and underwater sensor units



Photo 2 TRITON Buoy and R/V MIRAI

monitoring, daily weather forecasts, so on. While the data come into JAMSTEC Mutsu Branch, data quality is checked daily and the checked data are sent to Pacific Marine Environmental Laboratory (PMEL). After receiving the TRITON data, PMEL integrates the TRITON data with TAO data, and creates a same format grid data. Therefore, JAMSTEC and PMEL will distribute the data from both homepages in January 2000.

Study of intermediate and deep ocean circulation structure and its variability in the tropical Pacific Ocean

In order to understand the intermediate and deep ocean circulation, we started the collaboration study with Ocean Research Institute (ORI) of Tokyo University by onboard observation and moorings from this fiscal year. We, JAMSTEC, are in charge of the observation of the Antarctic Intermediate Water along the New Guinea coast, and ORI conducted observation of deep flow in the

Melanesia Basin.

During FY1998, we deployed four current meters with the acoustic Doppler current profiler (ADCP) moorings at 2.5S, 142E at 500, 700, 850, and 1000m depths to observe the New Guinea Coastal Undercurrent advecting the Antarctic Intermediate Water. A current meter also was deployed at 0N, 138E and 0N, 147E at 700m depth.

Only one current meter at 0N, 138E was recovered during this FY. Eastward current exceeding 30cm/s and variability with a period of about one month were observed at this location (Fig.6). This result is new and interesting although the relation between this current and Antarctic Intermediate Water is not still clear until all moorings are recovered.

Preliminary Results from a 1000-km Scale Three-Dimensional Tomography Experiment in the Kuroshio Extension Region

Our first 1000-km scale four-dimensional ocean acoustic tomography experiment are conducted in the Kuroshio Extension region from July to September 1997 in order to demonstrate the capability of the tomographic techniques in monitoring the variability of the 1000km-scale three-dimensional ocean structures (both the temperature and current fields) in the Kuroshio Extension region. After separating from the east coast of Japan at (35°N, 142°E), warm high salinity Kuroshio water meets cold low salinity southward flowing Oyashio water, and turns eastward forming the Kuroshio-Oyashio frontal zone (the Kuroshio Extension) in the region 30-40°N, 140-180°E (Fig.7)

The Kuroshio Extension is characterized as an eastward flowing inertial jet accompanied by large amplitude meanders and vigorous pinched-off eddies or rings. we report here the preliminary results of this experiment.

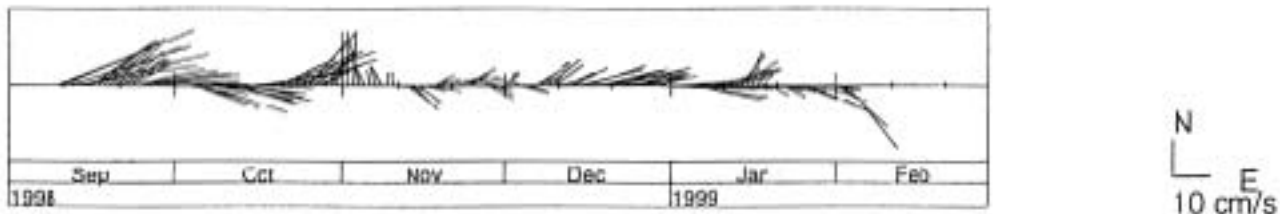


Fig. 6 Time series of current velocity measured by a current meter at the depth of 700m at 0N, 138E

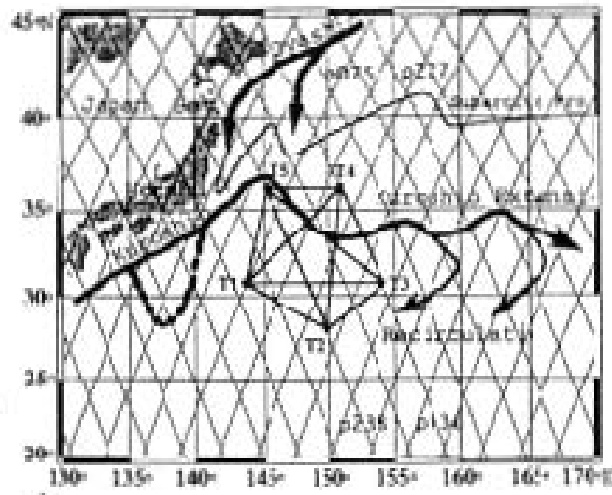


Fig. 7 Location map of Kuroshio Extension tomography experiment with the path of major currents and the frontal position. Thick solid lines connecting transceiver stations T1-T5 show the acoustic ray paths projected on the horizontal section. Thin crossing solid lines show the ground tracks of the TOPEX/POSEIDON satellite.

Observation Methods and Data

Five 200-Hz transceiver moorings, each equipped with a sound source and a 5-element vertical hydrophone array were deployed at 1100m depth over a 1000km-scale do-

main centered at 33° N, 149° E. the five-mooring array produced 10 horizontal connecting paths.

All of the transceivers (T1-T5) were placed on TOPEX/POSEIDON (T/P) satellite altimeter ground tracks to simplify the comparison of the acoustic tomographic data and the T/P altimeter data. Sound was transmitted every 3 hours in August and every 6 hours in July and September; transmissions were singarround and taking 2 hours to complete. After beamforming at the vertical arrival angles of -10° and $+10^\circ$, the received acoustic data were recorded on internal hard disk and correlated in situ with a replica of the transmitted pseudo-random M-sequence signal to select travel times for the largest 150 peaks which were sent to a land-station in real-time from the surface buoys using the INMARSAT-C satellite communications system. The mooring motion was precisely tracked using local long baseline acoustic navigation net with a precision of 2 meters. The measured arrival patterns for $+10^\circ$ arrival angle from T5 to T2 (1000.4 km range) contain approximately ten early, discrete arrivals followed by an extended cluster of arrivals (Fig.8); these early arrivals are very stable and persistent and can be followed from day to day.

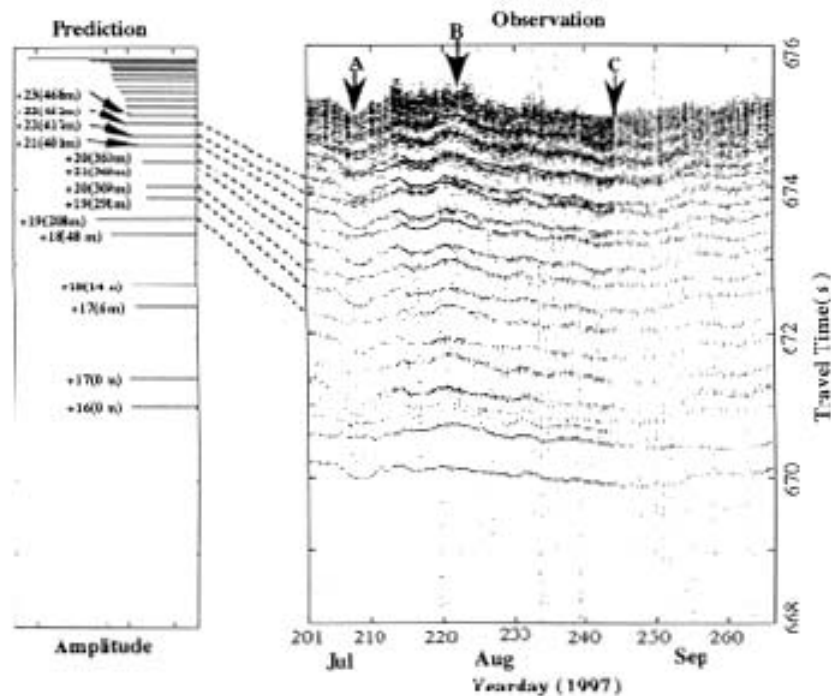


Fig. 8 The time series of the travel times with positive arrival angle($+10^\circ$) for transmissions from mooring T5 to T2(1000.4 km range, along the T/P track p238, seeing Figure 7). The largest 50peaks are plotted;transmissions occurred every 3 hours in August and every 6 hours in July and September. The predicted arrival pattern derived from an area-averaged reference constructed from NODC hydrographic data is shown at the left of figure; the dashed lines indicate the rays that were used in the inversion.

Inversion

The tomographic inversion for sound speed (temperature) discussed here used only the average of the travel times in reciprocal directions along individual ray paths to remove the uncertainty caused by oceanic currents. A 2-day running mean is applied to the time series of travel times to remove higher-frequency fluctuations such as tides, inertial oscillations and internal waves. A total of 141 ray paths are used for the inversion.

The linear stochastic inversion is used to reconstruct the sound speed anomaly fields from the travel time data. A time averaged reference sound speed profile and a priori variance were determined from historical hydrographic data to be used as the reference state in the inversion collected in the experiment region from 1968 to 1986 during June to August [NODC,1991]. Sound speed was calculated using the Del Grosso formula [De Grosso, 1974]. speed profile is used Sound speed anomalies (δC) in the horizontal and vertical are represented by truncated Fourier series with the high wavenumber cut off (1 cycle/240km) and the first 4 empirical orthogonal functions (EOF'S), respectively [Howe et al., 1987; Gaillard, 1992]. The spatial covariance function of C is assumed to have a Gaussian distribution with a 150 km correlation length. The root mean square (rms) travel time uncertainty is set at 20 ms to take into account errors in travel time measurements as well as inadequacies in the parametrized model.

Three-dimensional sound speed fields reconstructed by the inversion are converted into temperature fields using a simple sound speed formula [Mackenzie 1981]. The expected rms uncertainty of the inversion for temperature takes a maximum value of 0.3°C near the thermocline between 250 m and 350m depths (compared to the a priori expected variation of 4.1°C), and about 0.1°C at depths greater than 700 m (compared to the a priori expected variation of 1.7°C);

Results

The three months of data for the path T5-T2 (1000.4 km range) running along the T/P track p238 (see Fig.7) are plotted. The sound speed anomaly shows the drastic changes to have a maximum on July 27 (marked A), minimum on August 10 (marked B) and maximum on August 31 (marked C), indicating a temporal variability of about a one month period. The warming event occurring from

the end of August to the beginning of September is especially pronounced. A prominent feature for a vertical temperature section between stations T2 and T5 obtained by the XCTD/CTD hydro casts from July 20 to July 22, 1997 is that there are large temperature gradients of isotherms from 200 m to 1000 m near station T5; this is the Kuroshio front (Fig.9(b), dashed lines). The range-averaged temperature difference (ΔT) between the XCTD and tomography data in the vertical section is less than 0.5°C over the entire depth. A cold water mass with temperatures less than 4°C and a depth range of 100 m intrudes into the 400 m layer around station T5. Three-dimensional fields of temperature anomaly (δT) calculated by the inverse analysis are shown with the contour plots on various horizontal sections in Figure 10 to emphasize the complicated evolution of the temperature field in both time and space of the tomographic site. The first, second, third and fourth

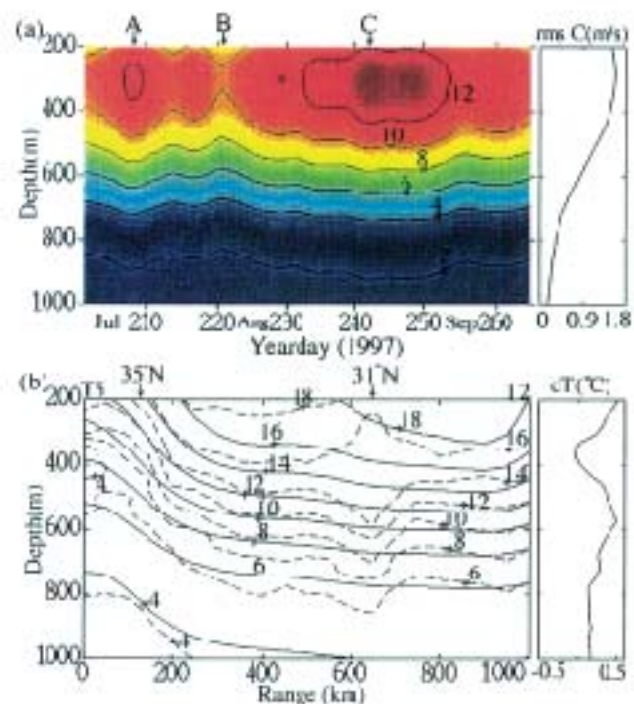


Fig.9 (a) Time evolution of the range-averaged sound speed anomaly along the path T2-T5 (1000.4 km range, along the T/P track p238) determined by the inversion analysis of the travel time data. The contour interval is 2 m/s. The rms uncertainty for these profiles is shown on the right panel. (b) Temperature distributions in the vertical section between stations T2 and T5. Solid lines are constructed from the tomography measurement at 00:00 July 20, 1997 (UTC) and dashed lines from the XCTD/CTD hydrocasts done every 50-km during July 20-22, 1997. The contour interval is 2°C . The range-averaged difference ΔT between the two temperature fields is presented at the right edge of the figure.

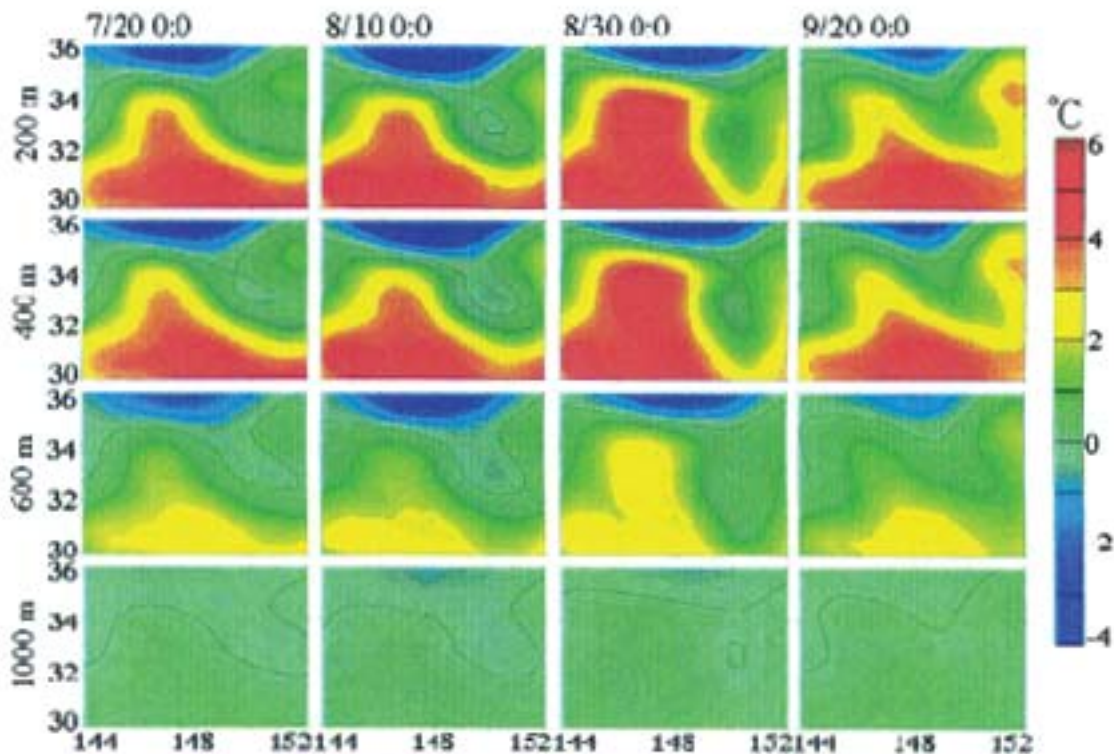


Fig.10 Temperature anomaly (δT) distributions in the horizontal sections of 200, 400, 600, 1000m depths. The results of inversion are shown about every 20 days between July 20 and September 20. Color codes of temperature are presented at the right edge of the figure.

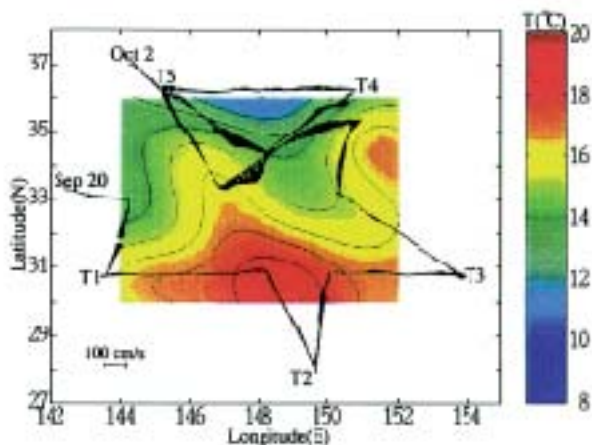


Fig.11 Velocity vectors at 190m depth derived from the in situ shipboard from ADCP measurements during the recovery cruise (from September 20 through October 2), superimposed on horizontal temperature field at 200m determined from the tomography measurement. Both of these show the meander of the Kuroshio Extension.

rows correspond to 200, 400, 600 and 1000 m depth sections, respectively. The meandering Kuroshio Extension front is seen along the 2 and 3 °C isotherms at both 200 and 400 m depths and makes little change of position with increasing depth. The Kuroshio meander grows gradually from July 20 (first column) to August 10 (second column), inducing a cold eddy on the right-hand flank of the meander crest. A warm eddy is seen at 30.5 °N, 148 °E, and moves westward with a speed of 5.8 cm/s during the period. The meridional amplitude of the meander reaches a maximum on August 30 (third column). At this time, a new, intense, warm eddy newly appears in the meander crest, forming a pair with the pre-existed cold eddy. The meander decays rapidly with the diminishing of the warm and cold eddies on September 20 (fourth column). A warm eddy reappears in almost the same place as that of the July 20 warm eddy. Temperature anomalies due to the meander and eddies are nearly constant in the upper 400 m and decrease at depths greater than 400 m. The contour map of sea surface dynamic heights (SSDH) constructed by JMA (Japan Meteorological Agency) from the T1 al-

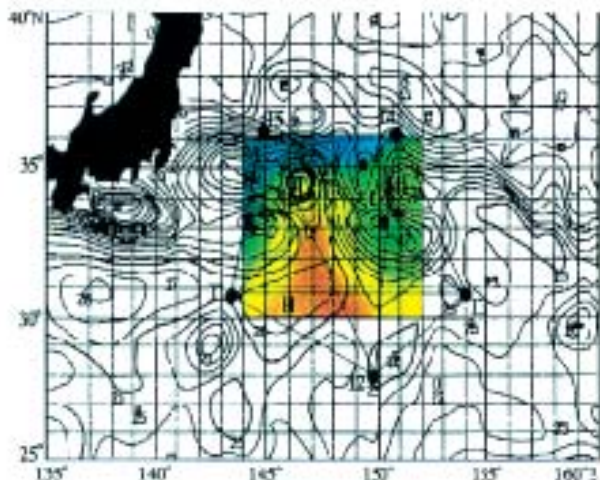


Fig.12 Contour map of sea surface dynamic height(SSDH) derived from the T/P altimeter data around the tomography site on July 28, 1997(Modified from [Yoshioka at JMA, personal communication, 1998] superimposed on horizontal temperature field at 200m determined from the tomography measurement of July 30, 1999. The 1500 db surface is assumed to be the level of no motion. The thick solid lines connecting stations T1-T5 show the ray paths. H and L indicate the position of anticyclonic(warm) and cyclonic(cold) eddies, respectively. The contour interval is 10cm.

timeter data around the tomography site on July 28, 1997 indicates an array of warm and cold eddies associated with the Kuroshio Extension meander Figure 12 [JMA, 1997 Yoshioka at JMA, personal communication 1998]. The positions of the warm and cold eddies (marked H and L, respectively) in the SSDH map are excellently coincident with those in the superimposed tomography map. The well developed warm eddy southeast of station T5 makes a remarkable warming of the water lying in the upper 400 m between stations T2 and T5, as indicated with mark C in Figure 9(a). Finally, it is concluded the Variable 1000km-scale three-dimensional temperature fields in the Kuroshio Extension region are well detected by the present tomography experiment.

Study on Kuroshio Extension

The Kuroshio, western boundary current of the North Pacific Subtropical gyre, transports enormous amount of thermal energy from the tropical to the subarctic region. The long-term variations in the heat transport interact with the climate changes, such as ENSO phenomena, the Asian monsoons etc. One of the key areas is the Kuroshio Extension, where heat and momentum are exchanged be-

tween subtropical and subarctic gyre, and where enormous heat is exchanged between ocean and atmosphere. In order to understand the effect of the Kuroshio recirculation system on climate changes, we have been studying variability and its mechanism of Kuroshio recirculation system by using in site observation and numerical model since FY1997.

In spring FY1998 we observed the Kuroshio extension region for the first time by using R/V MIRAI. We carried out three cross sectional observations of CTD measurements across the Kuroshio at 145.0E, 147.5E and 152.5E (Fig.13). The Kuroshio was meandering south and north in the Kuroshio extension region. The North Pacific Intermediate Water (NPIW) distributed as a patch-like under the Kuroshio and mesoscale eddies. Some were seen as if they are associated with water exchange between the subtropical region and the mixed water region. The salinity of the core of NPIW, that is characterized as a

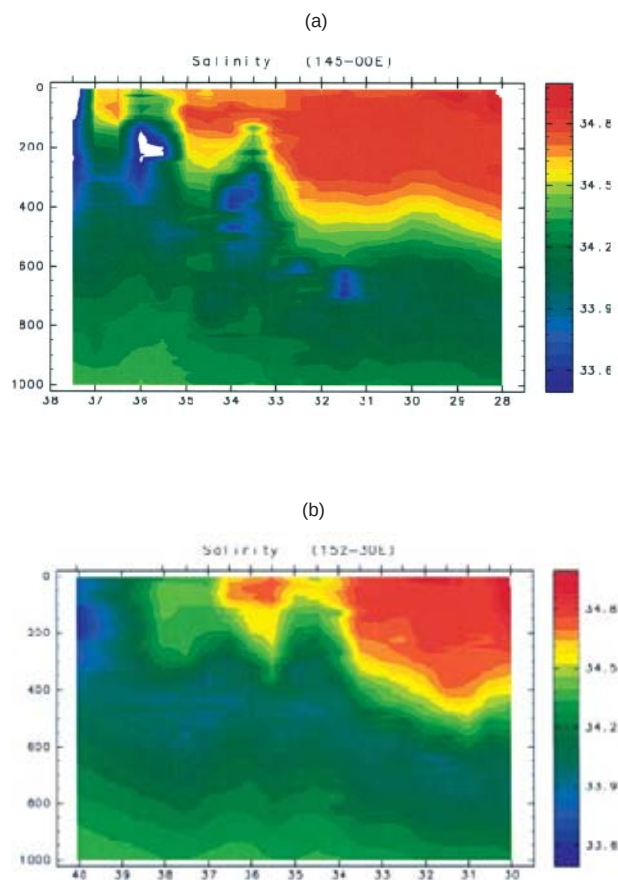


Fig.13 Meridional salinity sections. (a) along 145.0E, (b) along 152.5E.

salinity minimum on 26.8 sigma theta surface, was gradually increasing along downstream, and then the water character is not obvious at 152.5E.

We deployed a subsurface mooring buoy of current meters at 37.5N, 152.5E, where the Mid-latitude TRITON buoy is planned to deploy. Current meters will be recovered in FY1999 and then mesoscale variability of current field in the mixed water region should be analyzed.

The variability of the Kuroshio extension and the mixed water region have been studied by using a numerical model, which is based on the Princeton Ocean Model and modified to represent the Kuroshio recirculation system.

In FY1998 some boundary condition were modified to include effects of the water property of the Sea of Okhotsk. And then the Oyashio and mixed water region has been well represented. The Sea of Okhotsk is likely to be important factor to the mixed water region as well as formation of NIPW.

The model ocean has significant variations in the Kuroshio extension. The CEOF analyses show there are some independent modes in the sea surface height variabilities: The 1st mode (Fig.14) has large variance off Japan coast (around 35N, 144E) and west of Shatsky-Rise (around 35N, 155E). The phase cycle of this mode is one year. Real ocean observed by the T/P altimeter also shows

such variabilities. This mode should be linked with and/or driven by annual cycle forcing such as wind stress, local cooling, Oyashio, etc. The 2nd mode, not shown here, has large variance at the trough of Kuroshio meander around 34N, 148E, and the anomaly propagates to the subtropical region from the mixed water region. The mechanism of such variabilities should be examined in FY1999.

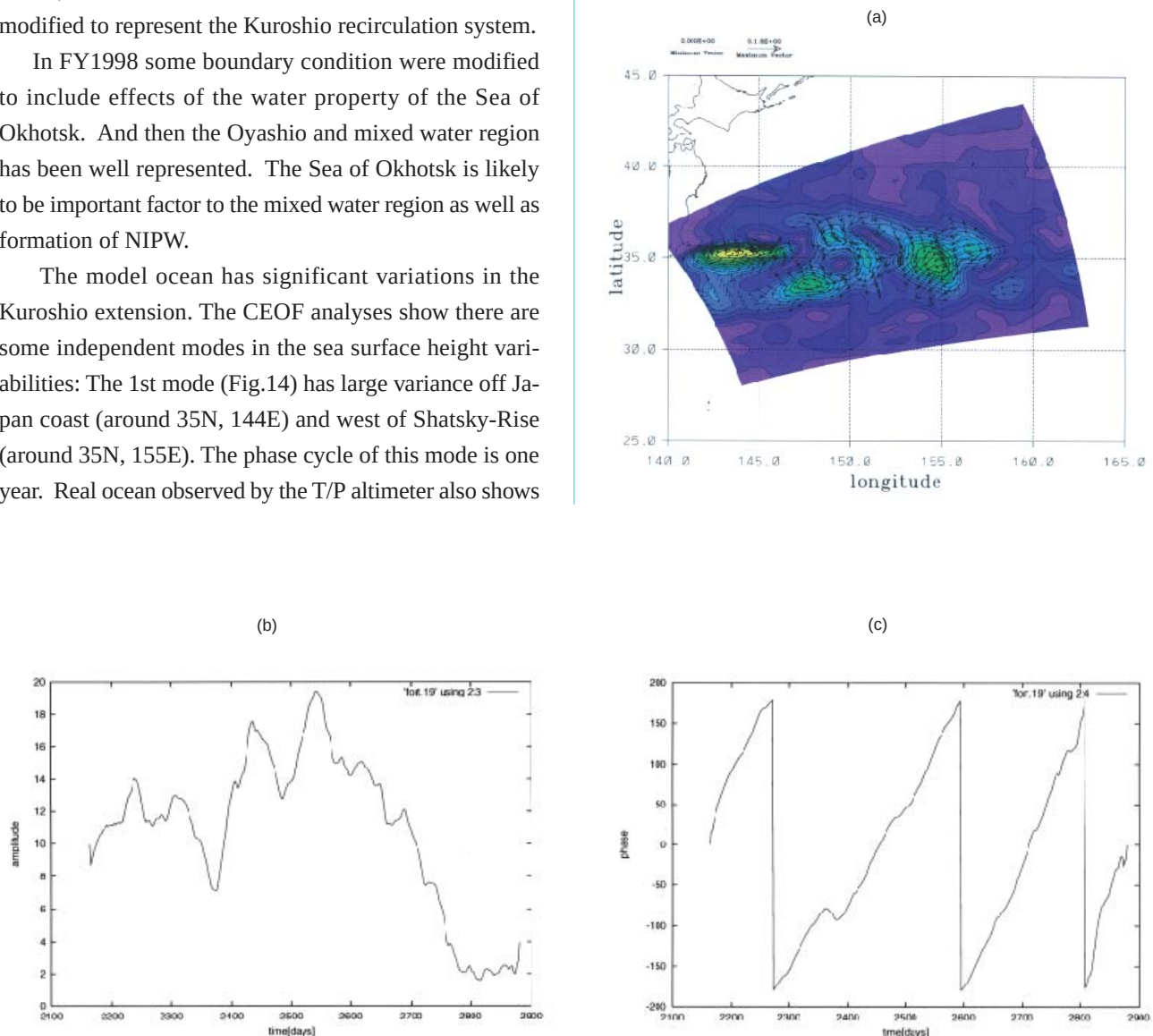


Fig.14 1st CEOF mode of model sea surface height anomaly. (a) spatial amplitude and horizontal gradient of spatial phase. (b) time series of temporal phase. (c) time series of temporal amplitude.

Ocean data analysis by using a high-resolution GCM.

Comprehensive analysis of oceanic phenomena by using Ocean General Circulation Model (GCM) is useful for accurate ocean state estimate and for understanding the role of the ocean to climate variation. Especially high-resolution GCM can provide realistic ocean structure including meso-scale eddies, which play a role in the global circulation. The objectives of this study are to simulate ocean circulation with a high-resolution GCM, and to investigate the mechanism of oceanic variation by comparing the simulated state with observed one. The surface and subsurface circulation is focused to investigate seasonal to interannual variability. The model has the resolution with 1/4 degrees in both latitude and longitude and 55 vertical levels. In the fiscal year 1998, we have proceeded the analysis of the results of the climatological experiment in which the model ocean is forced by climatological wind and heat/freshwater flux. We have also started the year to year variation experiment.

The model in the climatological experiment simulates quite well the observed features, e.g., the Kuroshio and its separation from western boundary, and the equatorial currents system comprising the Equatorial Currents and Undercurrent and the Subsurface Countercurrents (SCCs). Especially the SCCs were first simulated successfully in an GCM in this study. This suggests that the vertical resolution should be high in the equatorial region, where the high vertical mode motion dominates. The model also shows the fluctuations on the basis of observation, such as active meso-scale eddy activity in the western boundary regions, latitudinal dependence of the westward phase speed of the Rossby wave, and fluctuations of the Indonesian throughflow. The snapshot of velocity vectors at 100m depth in the western Equatorial Pacific Ocean is shown in Fig.15 as an example. The Mindanao Eddy (anti-clockwise) southeast of Mindanao Island of Philippines and the Halmahera Eddy (clockwise) southeast of it are well simulated. The model shows that a part of the Mindanao Eddy is detached and then propagates westward into the Sulawesi Sea with a period of about 40 days. Low salinity water from the North Pacific Ocean is transported into the Indonesian Seas according to this eddy shedding. Some observational data show similar fluctuation, which is suggested to be related to the variations of equatorial currents, i.e., the New Guinea Coastal Undercurrent and the

Equatorial Undercurrent. Detailed analysis is planned to investigate the mechanism of the driving and maintenance mechanism of ocean circulation and the variability.

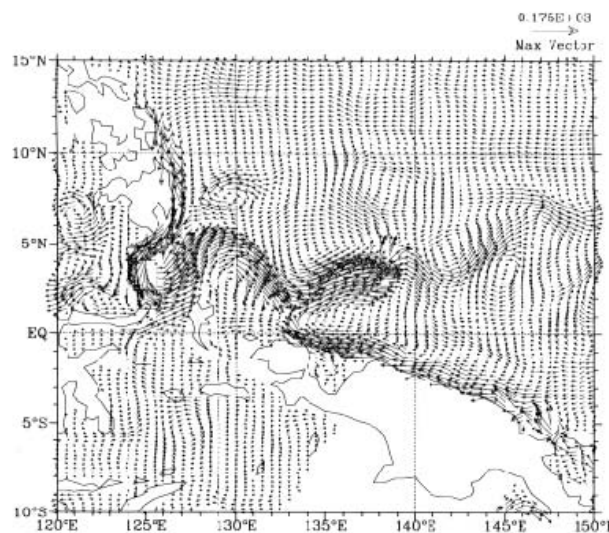


Fig.15 Simulated horizontal velocity at 100m depth in the western Equatorial Pacific Ocean.

Fy 9~11 Elucidate the Paleoceanography a change of Kuroshio Extention

It is closely related to subtropical circulation (Kuroshio current) and subarctic circulation (Oyashio current) on the Northwest Pacific Ocean. These currents exchange the vast of heat, and moreover, It is remarkably heat, vapor and momentum exchanges both of the atmosphere and ocean in this area. It is also have close to do long term ocean circulation at the north Pacific the middle layer. It has an impact on large-scale changes from several years to several hundred years. It suggest that this front move the north-south for several thousand years scale during the glacial and interglacial. We do not know the how to the changes front of movement more higher resolution over estimate of future. It forms low salinity and low temperature of the intermediate water at the northern subtropical area. This area is also important part. The parts are storage and transport of global warming materials from atmosphere. The living productivity is also very high area. This area is very important over consideration mass flux. The history of seawater circulation changes and mass flux record in the sea floor sediments. The records are very important infor-

mation of the present ocean and the future. The study of Kuroshio path changes need to the model verification.

We talk about our themes. We sample the sea floor sediments by closely space at the north-western Pacific Ocean. We research the boundary area (the north and south movements) of Kuroshio and Oyashio over the past 1.8 thousand years. The accuracy of high resolution is several hundred years.

We estimate the past ocean water temperature by using the class of microfossil changes (radiolaria, foraminifera, etc.) and called a organic compound. Moreover, this study makes the changes of glacial and interglacial on the mass flux system and the basic productivity.

It talks about the contents of study next. We collected five piston cores off the east coast of Japan during the training cruise of R/V Mirai (MR97-04). Except one core which include large amounts of volcanic ashes, four cores were retrieved from 1270m to 2300m water depth with different submarine topography (i. e. relatively flat plane, basin, and hill) off the east coast of Japan. We describe two piston cores (Fig.16: St.1, St.3) of them. These cores were retrieved from 1520m to 2308m water depths off the

east-coast of Japan and submarine hill off Kuji and Choshi city. We studied the warm current species of plankton foraminefera, calcareous nannoplankton and diatom population during past 20 thousand years in marine sediments. We estimated the changes of the warm current and the cold current during the past 20 thousand years.

It talks about the result of plankton foraminifera. There is nothing warm species of plankton foraminifera off Kuji (St.1). There are possibility of transition by Kuroshio warm current at the individual 15.6ka(15600 years ago) and 12ka. and transition by Tsugaru warm current(origin Tsushima current)at the Holocene individual. This site cannot imagine direct influence Kuroshio current. It was increased the warm species off Choshi by 16ka. The individuals were the number of 310. The time of 11ka decreased the number of 215 at chill time of younger dryas stage. The time of 6ka "Jomon" transgression increase the number of 500. The time of 1.8ka decrease the number of 120. The time of 1ka was 290 and 0.1ka decrease the number of 93. The off Kuji(St.1) and Choshi(St.2) core show the rise and fall of warm species of plankton foraminifera

The result of calcareous nannoplankton shows Fig.17, Fig.18. The time of 18ka shows the lowest temperature the lower photic zone at the last maximum glacial off Kuji(St.1). The 15ka once warmer and the12ka occurred cold trend at one time. After the 10ka, it was warm trend because decrease Oyashio current influence. From the 22ka to 17ka was strong vertical mixing at photic zone. This time was stronger influence Oyashio current. From 18ka to 17ka, Oyashio current was strong. It was rapid warmer the after. After the 9ka, it was nothing influence Oyashio current. It was not remarkable cold trend of younger dryas stage off Choshi.

It talks about the result of diatom shows. It was beginning to warm from the 3ka at St.3. It was beginning to warm from the 11ka at St.1. St.1 was beginning to warm the late 2 thousand years than St.3. The warm peak was at the 8ka. It was increase the fresh water, the coast species and the endangered species at last maximum glacial stage.

We analyzed microfossil association. We selected the association were warm species inhabit Kuroshio system and cold species inhabit Oyashio system. We study paleoceanography from 20 thousand years ago to present. The result of this study, microfossil (plankton foraminifera, calcareous nannoplankton and diatom) shows ocean

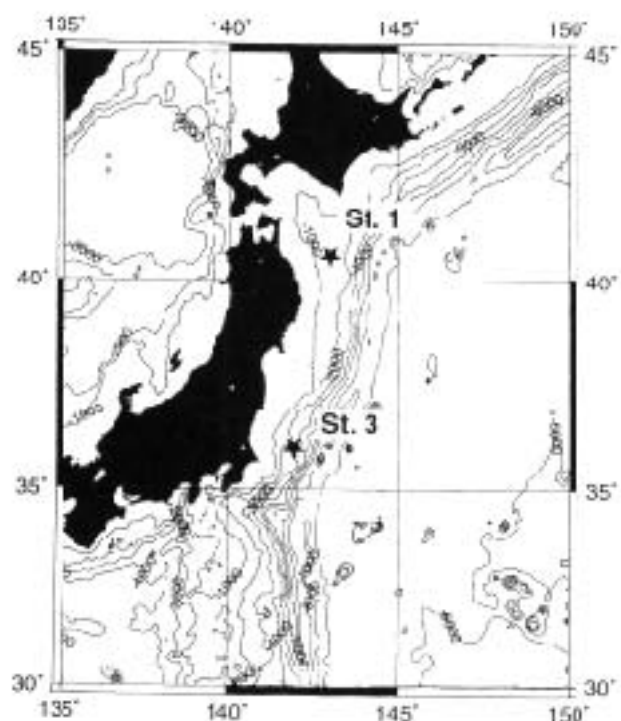


Fig.16 Location of two piston cores collecting during "Mirai" MR97-04 cruise

environment in those days. Especially, We can verify the younger dryas stage (from 13ka to 11.5ka). We can investigate more closely the ocean changes by combine these data.

We do higher meaty analyze in the future. We analyze the radioralia. And we will estimate the sea surface temperature from these fossil. We have an addition 14C measurement and geomagnetism. We go ahead with this plan from the point to the plane.

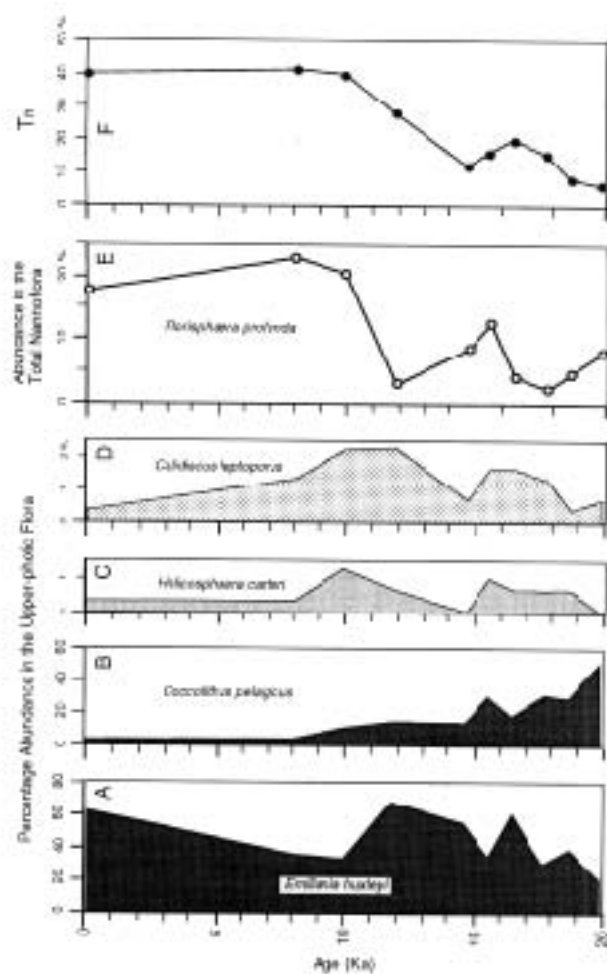


Fig.17 Percentage abundance in the upper-photonic flora(A ~ D) at St.1
Abundance in the total Nannoflora(E)
 T_n = cold species / (cold species + warm species)

Ocean data assimilation using a high-resolution GCM

Data Assimilation is the process of ingesting observational data into a numerical model. The result is a comprehensive and dynamically consistent dataset which represents the best estimate of the state of the ocean at that time. The objectives in this research are to develop and to optimize an ocean data assimilation system in parallel supercomputing environment using a global general circulation model resolving mesoscale eddies of spatial scale

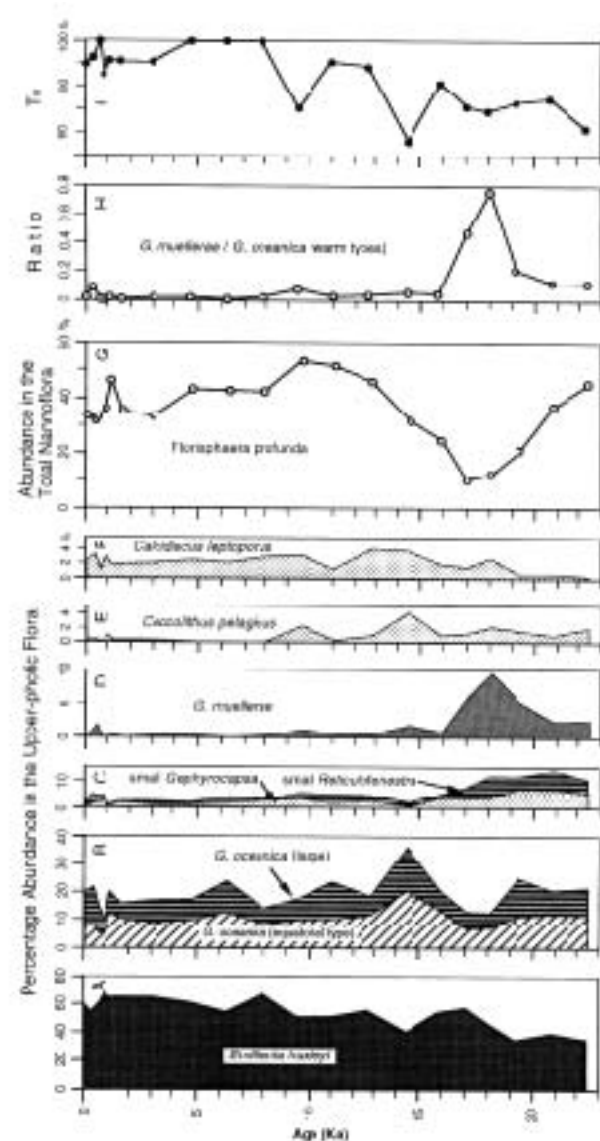


Fig.18 Percentage abundance in the upper-photonic flora(A ~ F) at St.3
Abundance in the total Nannoflora(G)
Ratio cold species and warm species of Gephyrocapsa genus
 T_n = cold species / (cold species + warm species)

of tens to several hundreds kilometers. In the first research fiscal year 1998, we have started investigating to reduce computational time and memory size for data assimilation system. We have also reviewed the assimilation method appropriate for global high-resolution data assimilation. Fortran direct access method for model variables (temperature, salinity, velocities) to disk not to memory has been investigated to suppress the increase of memory size, which is expected in global data assimilation. It is found that only about 2 times of computational time is necessary to complete the same simulation as with memory access method. Nudging scheme using satellite sea surface height anomaly data is found to be efficient and useful for a high-resolution model because too high computational resources will be required to conduct more sophisticated assimilation methods such as the Kalman filter or the adjoint method. Prototype model of ocean data assimilation will be developed and tested in the next fiscal year.

Arctic Ocean Research

1. Background and Purposes

Global climate models indicate that there will be a "polar amplified" warming response to increasing greenhouse gas concentrations. One conceivable consequence of this is a change in the present-day sea-ice cover followed by alterations in the thermohaline circulation and/or global albedo levels. Changes in productivity patterns may occur because of the opening up of more shelf areas to biogeochemical processes that now occur seasonally in marginal ice zones like the Bering/Chukchi Seas.

The shelf processes influence a number of important global physical/geochemical/biological cycles. For example, outflows produced through physical processes effectively transfer biogeochemical products from the shelves into the subsurface layers of the Arctic Ocean. In the western Arctic, the Pacific Ocean is an important source of nutrient-rich, low-salinity water that flows northward through the Bering Strait into the Arctic Ocean, ultimately influencing the nutrient maximum in the upper halocline. The large continental shelves are important for transporting atmospheric CO₂ to deeper regions of the ocean. Arctic waters can be a significant source of dimethylsulfide (DMS), a gas that affects the radiative properties of the Arctic atmosphere.

On the other hands, in the central Arctic basin, the recent workshop report on "The Study of the Arctic Change" held at University of Washington in November 1997 summarizes observational results of recent changes in the Arctic. The observations reveal that the Arctic is in the midst of change extending from the top of atmosphere to below 1,000m in the ocean. The time sequence of observations suggests the change in the ocean began in the late 1980s or early 1990s.

The overarching objective of our Arctic Ocean Research is to tackle the Arctic change issues in terms of both the comprehensive process studies concerning on the shelf basin exchange and the basin scale Arctic change including the change of the cold halocline/Atlantic Water circulation.

The former subject is approached using mooring and hydrographic observations by ice capable vessels or ice breakers. The latter subject is approached using Arctic Drifting Buoys consisting of oceanographic, sea-ice, atmospheric sensors.

2. First cruise of R/V Mirai to the Arctic (MR98-06)

"Mirai", with its large and ice-strengthened sturdy hull, was launched in 1997 (Dimension; LxBxD=130m x 19m x 13.2m; 8,600 Gross tons) (Fig.19).

The ship is equipped with many state-of-the art oceanographic and marine meteorological instruments and is expected to act as a floating platform for sophisticated interdisciplinary researches. The ship, in particular, with its large size and its anti-rolling device of special design, is capable of undertaking missions to high-latitude and polar regions exposed to the extremely harsh weather and sea conditions.



Fig.19 R/V Mirai in the Arctic Ocean

The cruise MR98-06 for July - September 1998 was a trial cruise of R/V Mirai in the Arctic Ocean. The purposes of this cruise were; (1) to test the capability of the oceanographic equipment onboard, (2) preliminary studies of the physical/chemical/biological oceanography at the marginal ice zone on the shelves of the Chukchi/Beaufort Seas. The cruise track is shown in Fig.20. "Mirai" passed the Bering Strait on 18 August, 1998 and stayed in the Chukchi/Beaufort Seas for 11 days. The CTD stations and the ice edge position during 20-26 August, 1998 are indicated in Fig.21. The about half of our projected observation lines was located within the pack ice field, so that we canceled about half of projected CTD stations.

The marginal ice zone in the Arctic Ocean is characterized by low temperature at the sea surface, which oper-

ates to increase solubility of CO_2 . At the same time, the harsh weather conditions cool the surface water to result in increased surface density. This means that the Arctic surface water can absorb much CO_2 and be subducted into the deeper layers.

Atmospheric and surface seawater pCO_2 (partial pressure of CO_2) were measured continuously by the automated system with a non-dispersive infrared (IR) analyzer. Figure 22 shows a variation of the atmospheric and surface seawater pCO_2 as a function of sea surface temperature in the Chukchi/Beaufort Seas. It is found that the differences of pCO_2 (ΔpCO_2) between the sea water and the atmosphere reached $-130\mu\text{-atm}$ at the sea surface temperatures below 2.25°C . This suggests that this area is a potential sink for atmospheric CO_2 during summer.

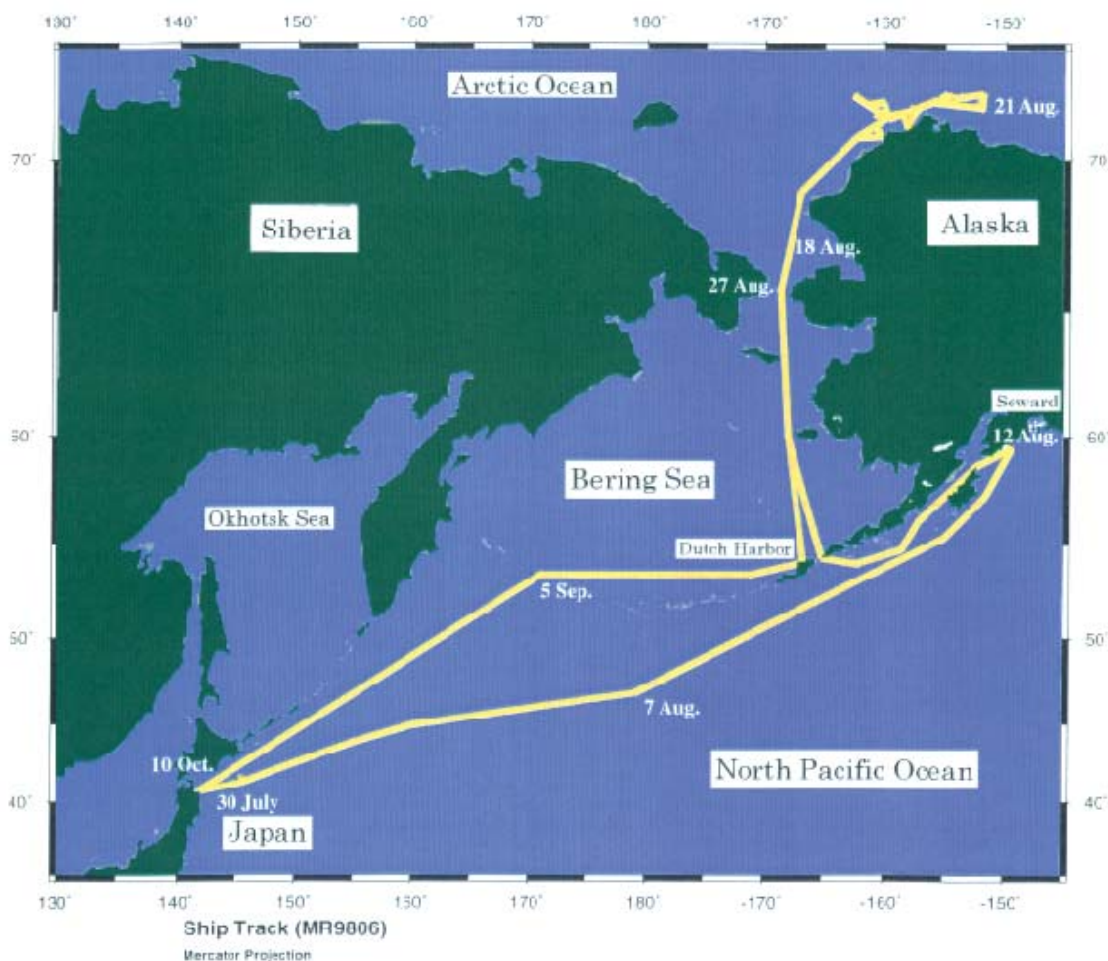


Fig.20 Cruise track of MR98-06

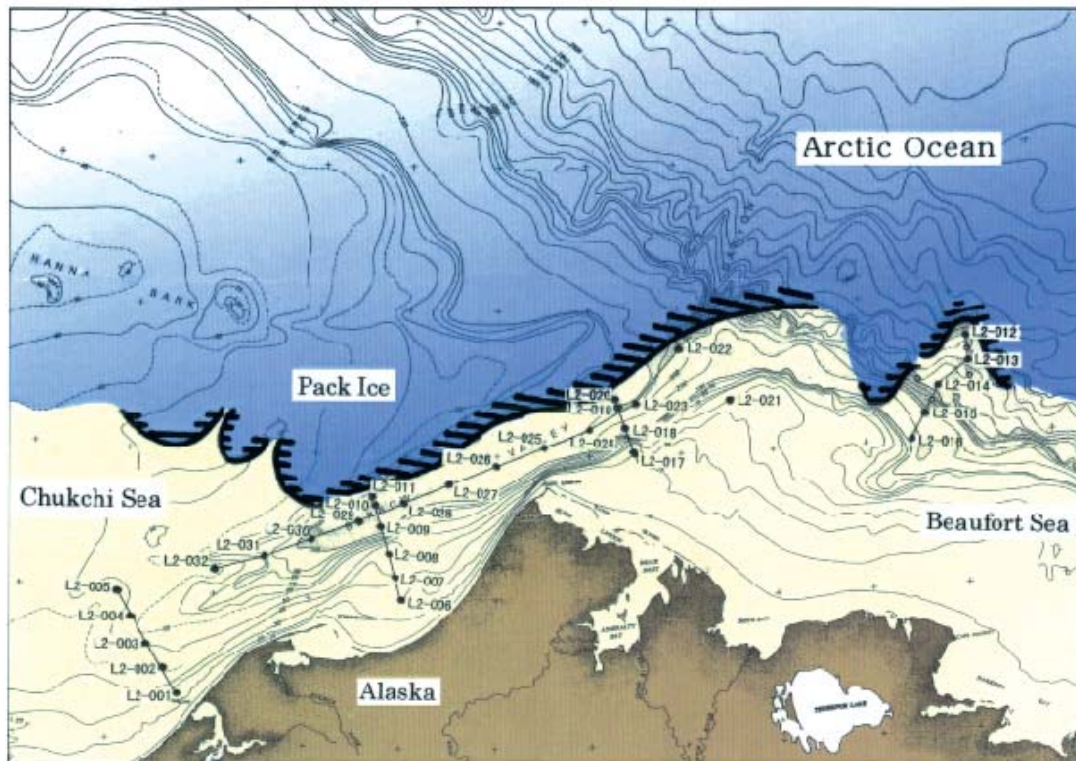


Fig.21 CTD stations and ice-edge position during 20-26 August ,1998

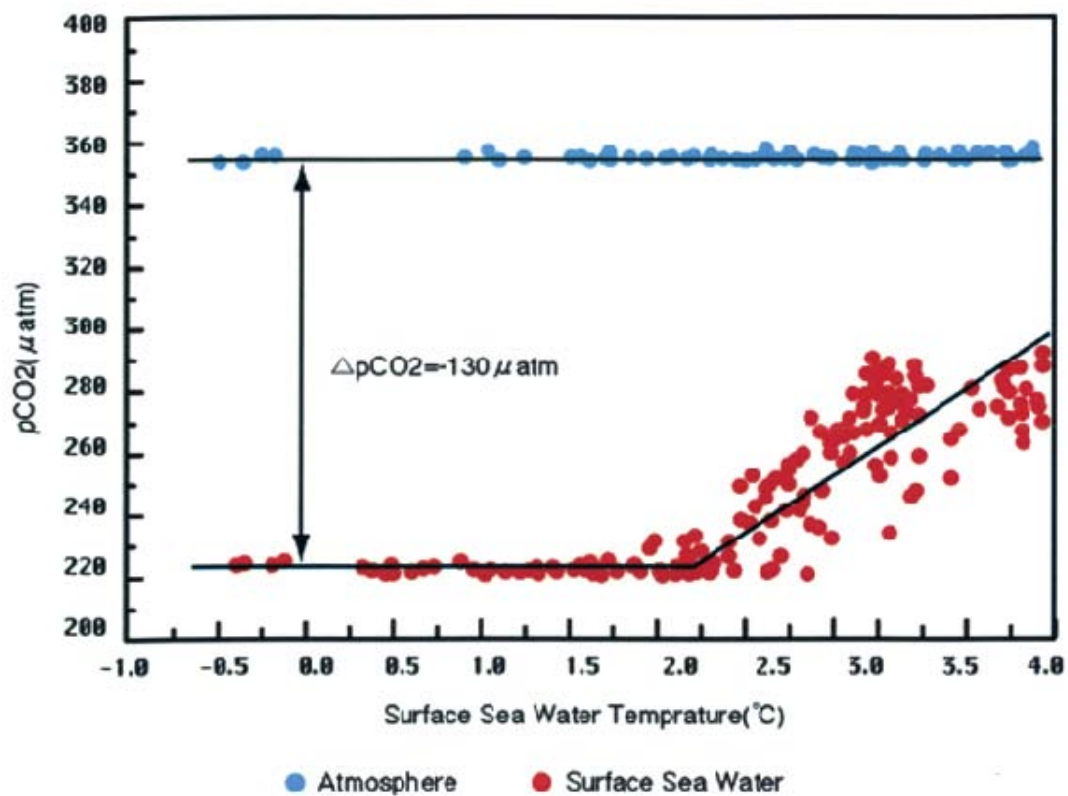


Fig.22 Variation of pCO_2 of the Atmosphere and the surface sea water

3. Inflow of Pacific water during SHEBA field experiment in 1997-98

As a part of the international project of SHEBA (Surface Heat Budget in the Arctic Ocean), we recovered two moorings in 1998; one (CBE96) was deployed off Barrow, AK in 1996 and the other (NWR97) at the eastern slope of the Northwind Ridge in 1997. At the same time, recovery of the SHEBA-IOEB(IOEB-2) which was deployed near the SHEBA ice camp in 1997 and XCTD(Expendable Conductivity Temperature Depth Sensor) observations from off Barrow to the eastern slope of the Northwind Ridge were conducted. Furthermore, two moorings (BFK98, BFS98) were deployed in collaboration with Applied Physics Laboratory (APL) of University of Washington and Institute of Marine Science (IMS) of University of Alaska to observe directly the transport along the shelf slope of the Beaufort Sea. Figure 23 shows the drift track of IOEB, positions of moorings and XCTD stations.

Our mooring data suggest that the Alaskan Coastal Water (ACW), which originates in a summer Pacific water and is characterized by relatively high temperature, advects from off the coast of Barrow (CBE96, 78m) to the

Northwind Ridge (NWR97, 104m). It takes about 2-3 months between two mooring points. In addition, a cross-section of temperature along the track of IOEB (Fig.24) indicates that the ACW was trapped along steep slopes of sea mount/plateau. Consequently, an advection path of the ACW is depicted schematically as shown in Fig.25.

Moreover, the mooring off the coast of Barrow (CBE96, 78m) observed that the seasonal maximum temperature in 1997, reaching 4 °C in October to November, is much higher than in 1996 (-0.5 °C). This high temperature anomaly might be advected by the ACW and arrived at the Northwind Ridge in January to February, 1998 (Fig. 25). It was at this very moment that the SHEBA camp arrived at the Northwind Ridge and the break-up of ice floe around the camp occurred. In addition, around the Northwind Ridge, the ice edge in late summer to autumn of 1998 located at the latitude of 77 °N, where is usually covered by sea ice in that season, and therefore, the ice edge was retreated northward in 1998 in comparison with the usual year. We can probably conclude that the ACW largely influences the variation of sea ice in the Arctic Ocean.

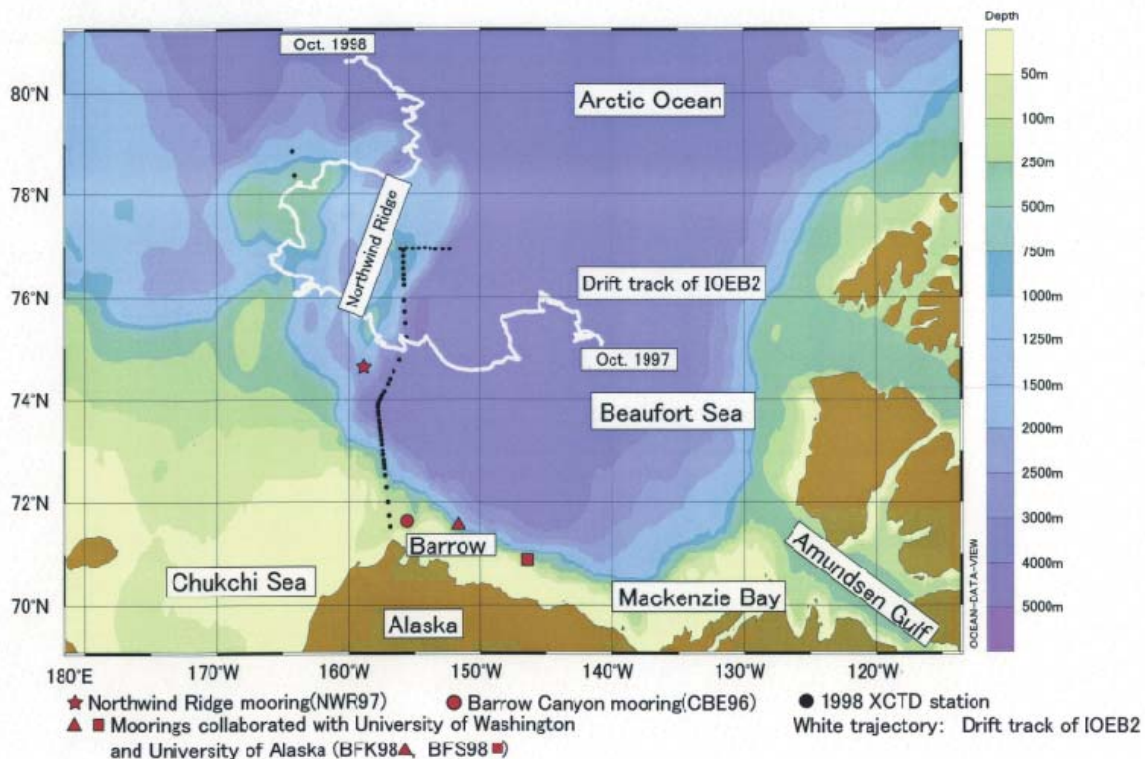


Fig.23 Positions of moorings, XCTD stations and a track of IOEB-2. The Northwind Ridge mooring(☆, NWR97) and the Barrow Canyon mooring (○, CBE96) were recovered in 1998. Two moorings were deployed at the Beaufort shelf slope (△, BFK98; □, BFS98). The solid circle ● denotes XCTD stations.

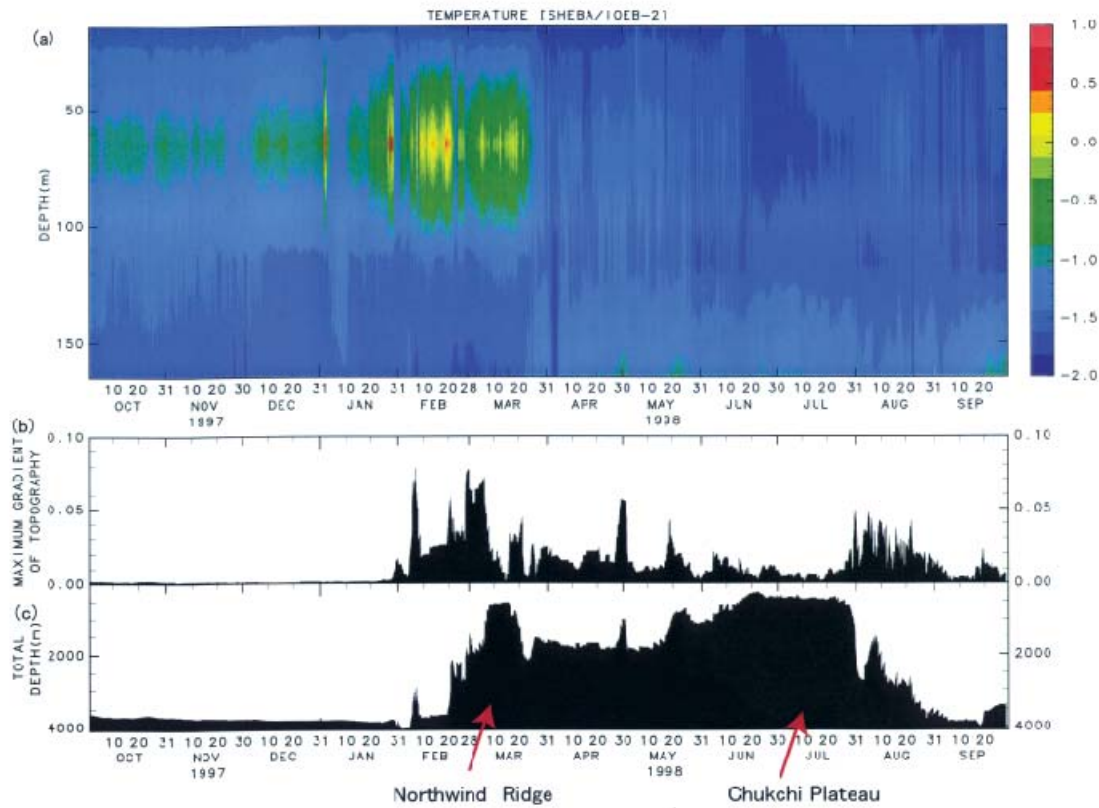


Fig.24 Cross-sections of (a) temperature, (b) gradient of bottom topography and (c) bottom topography along the drift track of IOEB-2.

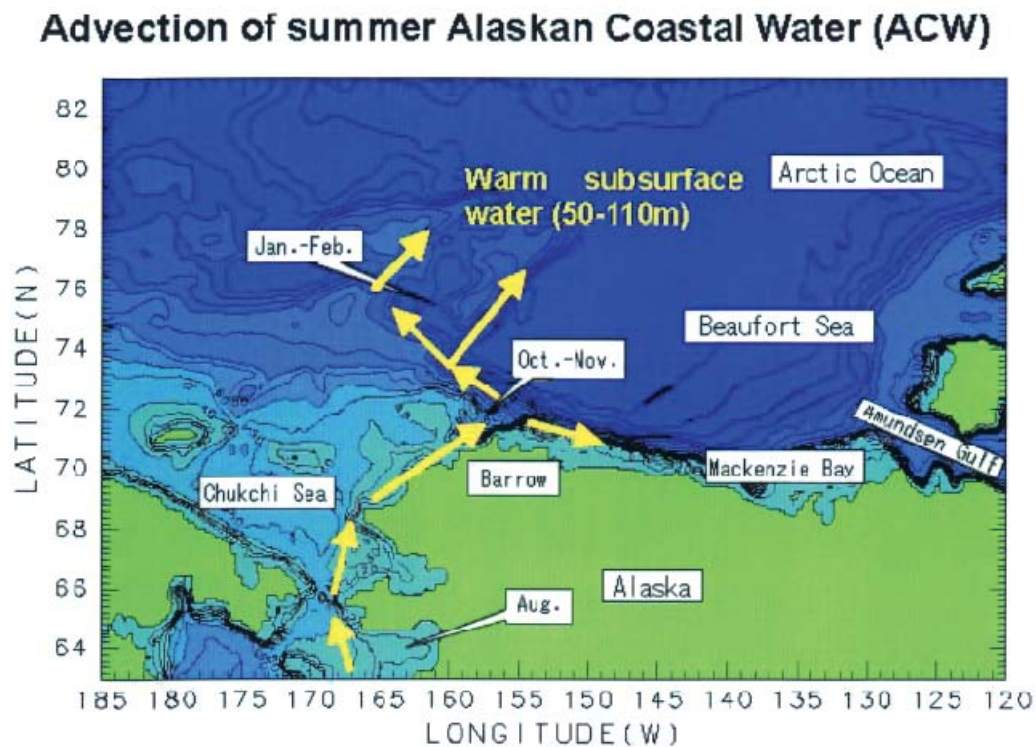


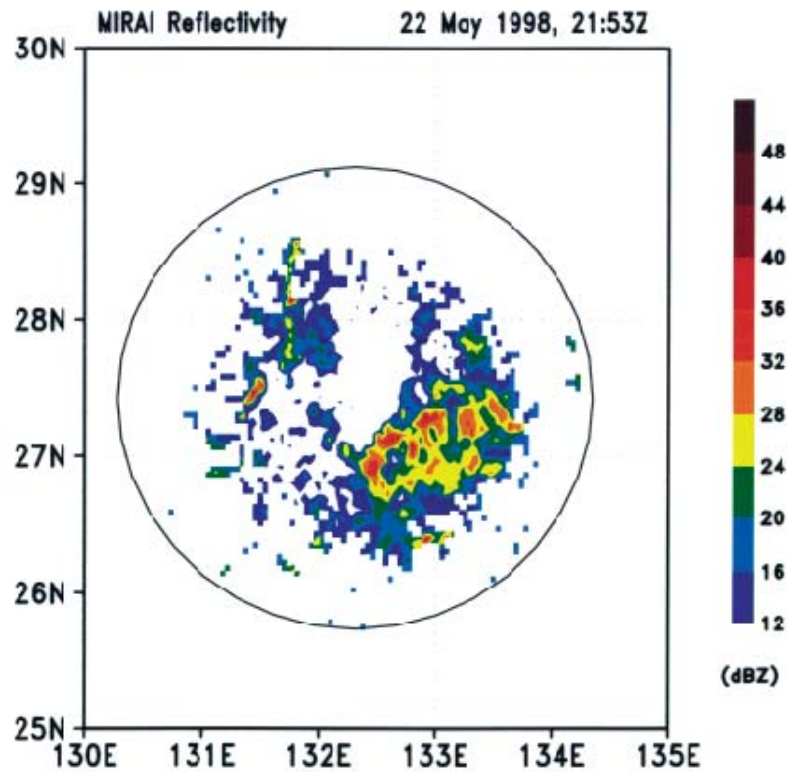
Fig.25 Schematic figure of the ACW advection suggested from the mooring and IOEB observations.

Research Project for the Study of the Air-Sea Interaction

Air-sea interaction is one of the inevitable factor to be studied for the better understanding of the various atmospheric/oceanic phenomena such as the ENSO(El Nino/Southern Oscillation) and the Monsoon. Since the "precipitation" is playing an important role for both atmosphere and ocean structures, we mainly study the precipitation mechanism in the point of view of air-sea interaction using powerful observation tools on board the R/V MIRAI such as Doppler radar.

In the JFY1998, we conducted the observational cruise at off Miyako Island, south of Japan from May 21 through June 4 (Leg-1), and in the Tropical Western Pacific along 156E line from June 6 through June 27 (Leg-2). Especially, the main mission of the Leg-1 was to provide the precipitation data obtained by the MIRAI Doppler radar for the validation of the data obtained by the satellite

TRMM(Tropical Rainfall Measuring Mission). We could collect seven simultaneous data when the TRMM passed over the MIRAI Doppler radar observation area. Although we had a few precipitation systems during Leg-1, they showed good correspondence between the data obtained by MIRAI and TRMM. An example of simultaneous observation is shown in the Figures.26 and 27. Open circle and parallel lines in each figure represent MIRAI Doppler radar observation range and TRMM radar swath, respectively. It is evident that not only the precipitation area coverage but also the intensity is corresponding well each other. Their difference of reflectivity is about 3dBZ(MIRAI's value is lower). In the Leg-2, we observed various precipitation systems, though the observation time was limited due to the urgent mission to recover the TRI-TON buoys. Based on the accumulation of these kinds of data sets, it is expected to contribute to evaluate the impact of this area as heat engine to the rest of the globe.



GrADS: COLA/IGES

1999-08

Fig.26

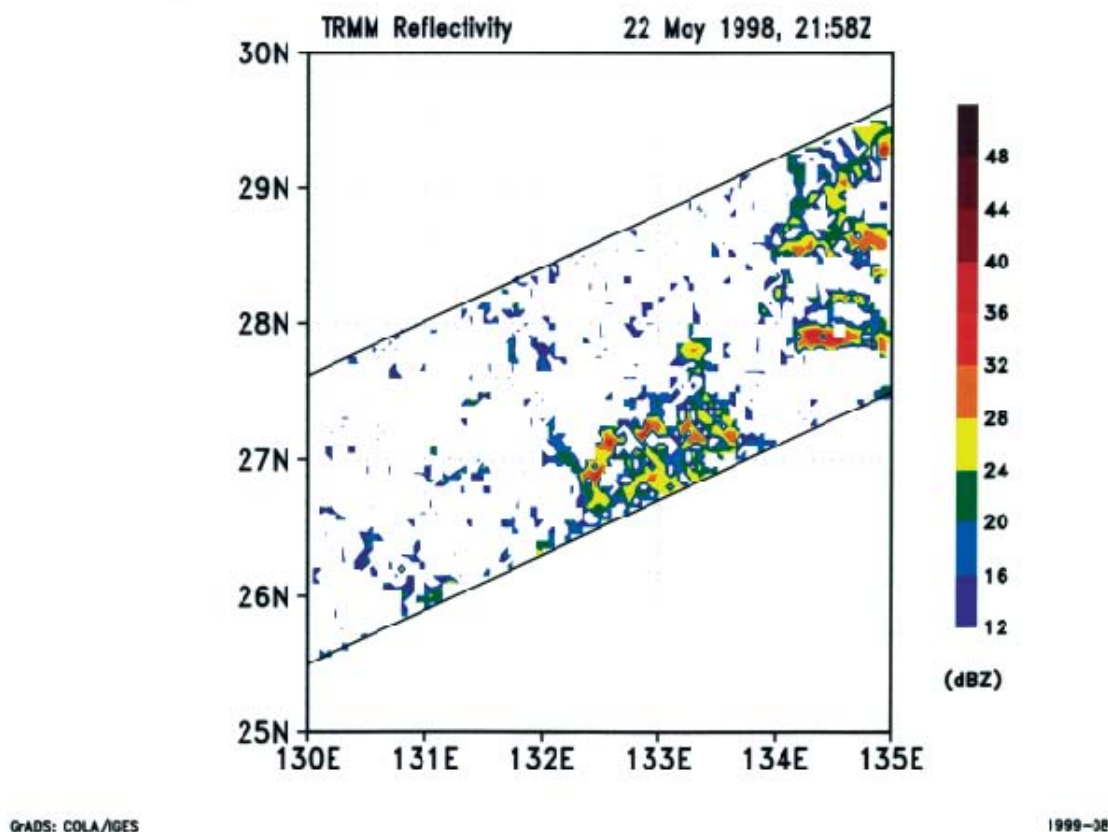


Fig.27

Stratospheric platform sensors for ocean observations

This program started in 1998, aiming to develop a stratospheric platform for communications, broadcastings, and earth observations by interministerial project between the Science and Technology Agency and the Ministry of Posts and Telecommunications.

In this project JAMSTEC has been engaged in the development of earth observation sensors to be onboard the platform in collaboration with NASDA. We have studied the following two items in 1998.

1. Technology surveys of earth observation systems onboard the stratospheric platform.

We have surveyed current status of arts of fuel cell technology, which is the most likely candidate, for power supply systems. Other issues such as a frequency matching, on-board measurement systems and data transmission technologies were also investigated as well as atmospheric sampling systems.

2. Surveys of potential, observation of global environment from the platform.

We have surveyed the potential application of the plat-

form with sensors, such as ocean, land, space, disaster and traffic monitoring, and coastal managements.

Biogeochemical study of the ocean and development of observation system

① Development of ocean LIDAR system

An Optical window for discharging laser beam was installed at the bottom of R/V "Mirai" in 1998. The main body is combined with optics bench made in 1997, and it will be mounted in "Mirai" in the 1999 fiscal year.

② Biogeochemical study of the northern North Pacific and its adjacent seas

Goals of this project are; a) to assess the spatial and temporal variation of flux of CO_2 , b) to clarify the mechanisms to control the biological pump and its role in the carbon cycle, c) to clarify transportation processes of dissolved materials in conjunction with the formation of intermediate water, and d) 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 variations.

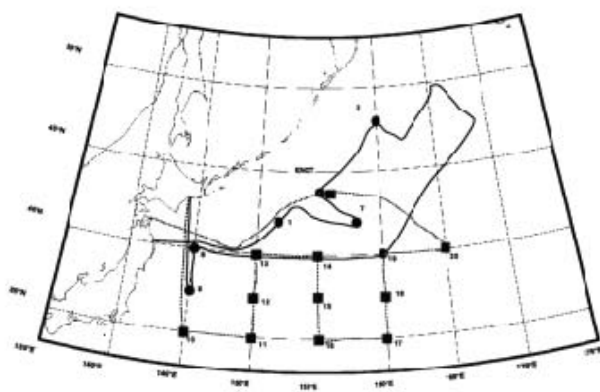


Fig.28 Sampling stations of MR98-K01 cruise.

●: Leg. 1, ■: Leg. 2

In FY1998, we joined three cruises of R/V Mirai: (I) MR98-05 cruise (July); recovery and re-deployment of sediment traps and sampling of bottom sediments. (II) MR98-06 cruise (Aug. -Sept.); mainly CO_2 measurements, and (III) MR98-K01 cruise (Nov.-Dec.); systematic observations for the biogeochemical study of the northwestern North Pacific were carried out at stations shown in Fig. 28. The following are the outlines of the results.

(a) During the MR98-K01 cruise, total dissolved inorganic carbon (TDIC) was measured in seawaters at several stations from surface to bottom and in surface seawater continuously. The results show that distribution of TDIC is controlled only by water mixing of subtropic and subarctic water in winter. We also collected more than 700 of seawater samples for AMS radiocarbon measurement during the MR98-K01, MR98-05, and MR98-06 cruises. In 1998, seawater samples collected during the MR97-02 cruise (winter, 1997) in the western North Pacific were analyzed for ^{14}C . Comparing our results (1997) and GEOSECS ones (1973) at 40°N , 160°E , there is no significant increase of ^{14}C in a past decade (Fig.29), which contrasts with radiocarbon change in the South Pacific.

(c) In the MR98-06 cruise, it was observed that surface seawater $p\text{CO}_2$ reached 420 ppmv in the area centered at 165°E , 45°N . In summer, surface seawater $p\text{CO}_2$ usually remains at 330 ppmv or less due to biological activity. Thus surface seawater $p\text{CO}_2$ observed in MR98-06 was higher by about 90 ppmv than usual. During the MR98-K01 cruise, we performed measure-

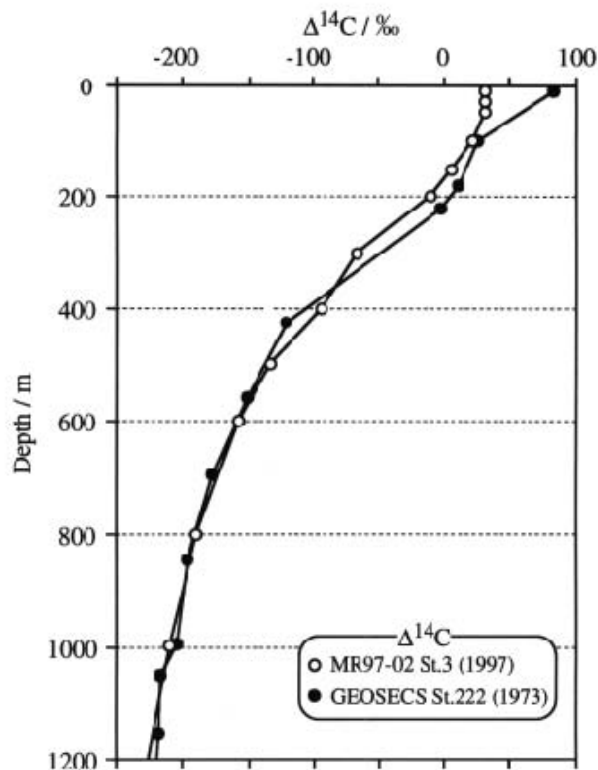


Fig.29 Vertical distributions of ^{14}C at 40°N , 165°E . Open circle: MR97-02, 1997. Solid circle: GEOSECS, 1973

ment of concentrations of atmospheric and surface seawater $p\text{CO}_2$ in the Kuroshio Extension. Concentrations of surface seawater $p\text{CO}_2$ was 320 ± 10 ppmv, and those of atmospheric $p\text{CO}_2$ was about 368 ppmv. The calculated $\Delta p\text{CO}_2$, which indicates the driving force of air-sea exchange of CO_2 , was about -50 ppmv, accordingly.

(d) Behavior of iron in the northwestern North Pacific was studied. Water samples were collected vertically using 12 L Teflon-coated Niskin-X bottles mounted on a CTD/rosette system. Atmospheric dust samples were also collected using a high volume air sampler while the ship was steaming or at the stations. Concentrations of dissolved iron were lower than 1 nM.

(e) During the MR98-K01 cruise, vertical profiles of ^{234}Th , ^{210}Po and POC were determined at the 9 sampling stations. Measurements are still in progress. The available data at the present stage show that the flux of particulate organic carbon from the euphotic zone to deep sea gradually increases eastward in the observed area.

(f) In order to study the role of "the biological pump" in the uptake of atmospheric CO_2 , we deployed sediment trap mooring systems at three stations (Stn. KNOT: 44°N, 155°E, Stn. 50N: 50°N, 165°E, Stn. 40N: 40°N, 165°E) and began to collect settling particles at 1000, 3000 and 5000 m in December, 1997. Sediment trap mooring systems were successfully recovered and re-deployed in July, 1998 and May, 1999. At laboratory, concentrations of organic carbon and inorganic carbon for settling particles were measured.

Fig.30 shows seasonal variability in organic carbon flux, inorganic carbon flux and the ratio of the organic carbon to inorganic carbon flux (Co/Ci ratio) from a 3000-m deep sediment trap at Stn. KNOT. Carbon fluxes increased from March and reached to the highest in summer. Carbon flux was also higher in October, 1998 and in winter. The Co/Ci ratio was high in summer when carbon flux was high, and low in winter. Compared with the results of previous sediment trap experiment, annual average of carbon fluxes and Co/Ci ratios at Stn. KNOT and Stn. 50N were lower.

In future, the seasonal and annual variability in the biological pump for the carbon cycle in the northwestern North Pacific will be discussed with using satellite data and dissolved carbonate species.

(g) Sediment core samples were collected by using a multiple corer and piston corer at six sites in the northwestern North Pacific during the MR98-05 cruise from July 7 to July 24 in 1998. Analyses of the cores are still in progress. But, carbonate content, organic carbon content and total nitrogen content in a piston core collected at the Emperor Seamount (40°N, 170°E) were measured. Other substances such as alkenone, stable isotopes, and radioisotopes, that are indicators of the past climate condition, will be measured.

③ Observational study on primary productivity in the Equatorial Pacific

We carry out the bio-optical observation including chemical composition analysis of sea water, measurement of the primary production, underwater light and so on. Then, we study the mechanism in relation of High Nutrient Low Chlorophyll condition in the equatorial upwelling

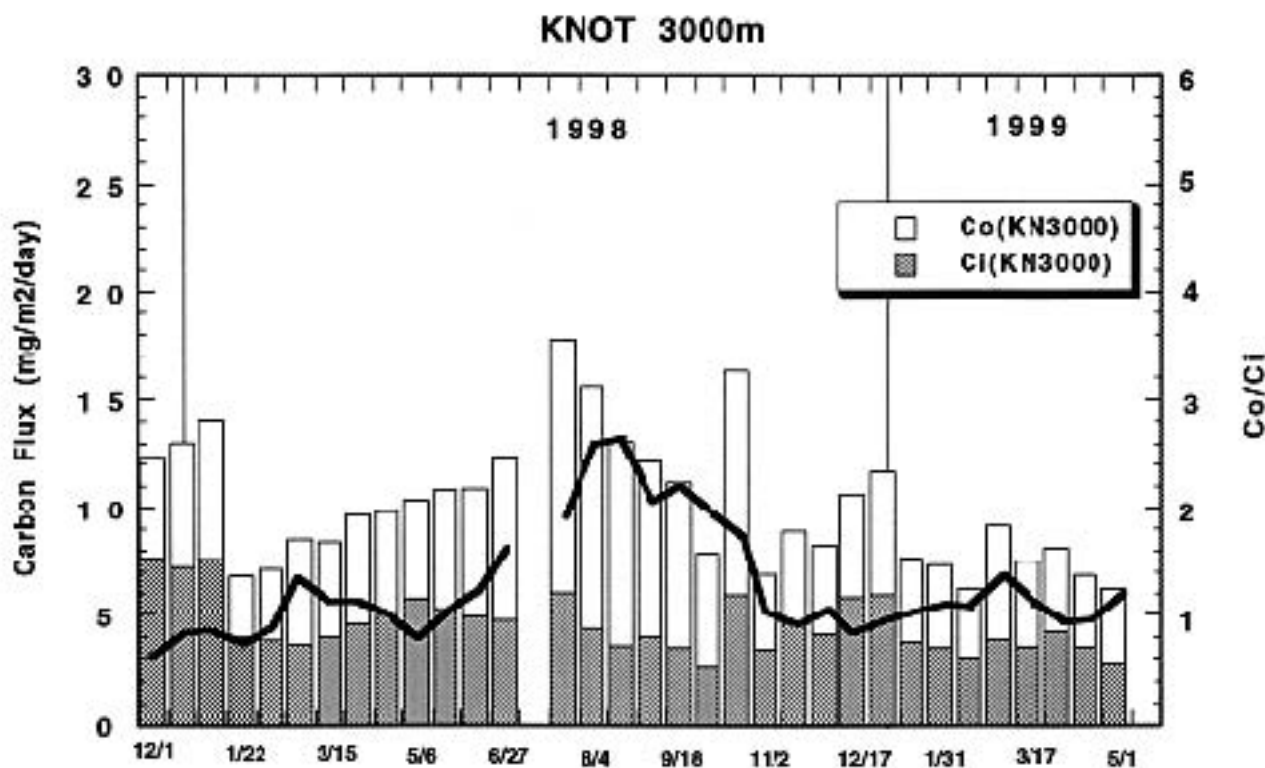


Fig.30 Seasonal change of fluxes of organic carbon, inorganic carbon, and their ratios (Co/Ci) of settling particles collected at 3000m depth of Stn. KNOT (44°N, 155°E)

region and the deep chlorophyll maximum in the warm water pool. The bio-optical observation was carried out by R/V Mirai in the western Equatorial Pacific (Fig.31) from Dec. 1998 to Jan. 1999. The vertical distribution of temperature is shown in Fig.32. It was so-called "La Nina" condition during the observation. The warm water mass was being pushed in the west and the effect of the equatorial upwelling exceeded the date line, and it reached near 160°E. Fig.33 shows the vertical distribution of the chlorophyll-a concentration. In the east of 160°E chlorophyll-a was widely distributed from the surface to 100m depth, and the remarkable chlorophyll maximum could not be seen. In the west of 160°E, the upwelling weakened, and the thermocline formed near the 90m depth by the warm water pool. In the layer shallower than the thermocline, nutrient supply from deeper layer was cut off by the warm water mass with the temperature of more than 30°C

(Fig.34). Consequently, the chlorophyll a concentration is low (0.1mg/m³ or less) in the surface layer, and the chlorophyll maximum of over 0.3mg/m³ existed at near the thermocline. During the El Niño in the previous year, the warm water pool proceeded to the east, and the thickness of the warm water pool thinned, since the warm water region extends. As the result, the chlorophyll maximum layer also shallowed. However, in the observation in La Nina this year, because the upwelling region westward expands, the thickness of the warm water pool increased, and the chlorophyll maximum also deepened. Since it deviates from the Equator, the observation point around the Palau of 135°E did not receive the effect of the warm water pool. Therefore, the chlorophyll maximum exists at 70m depth, shallower than that in the warm water pool.

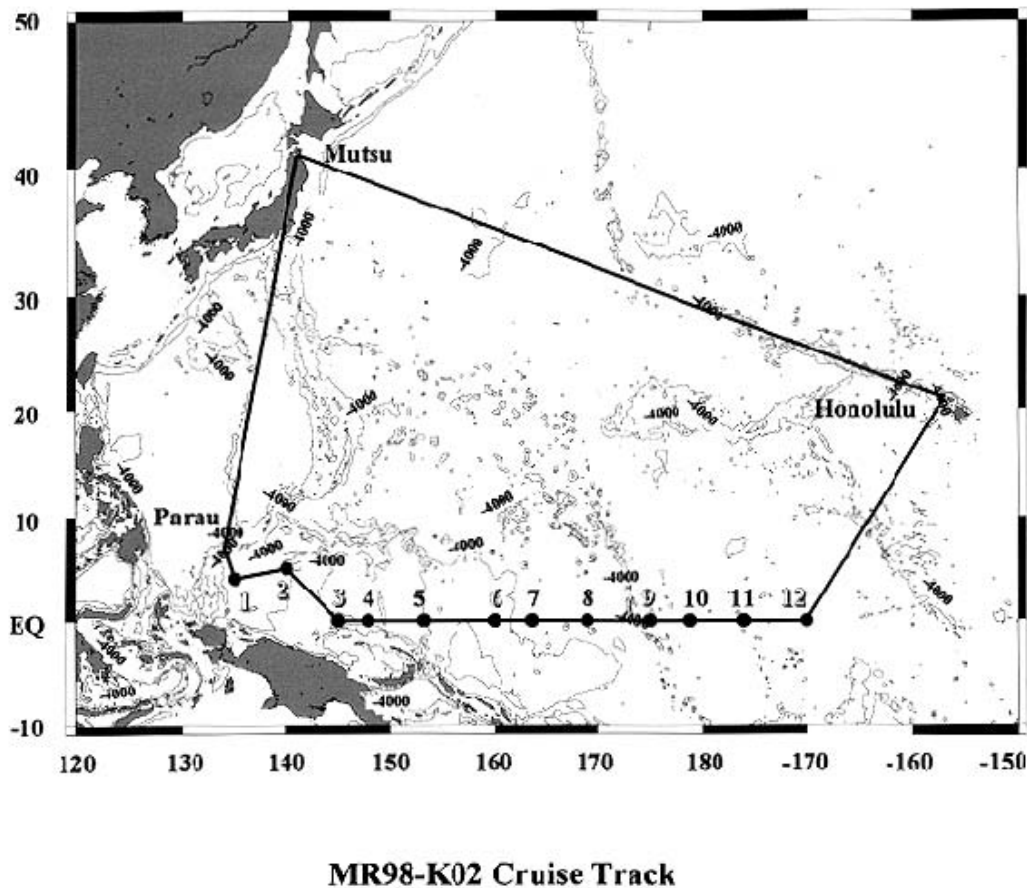


Fig.31 Sampling locations in the Equatorial Pacific

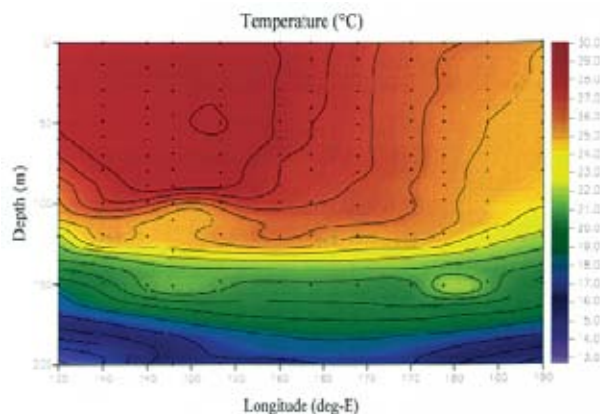


Fig.32 Vertical distribution of temperature

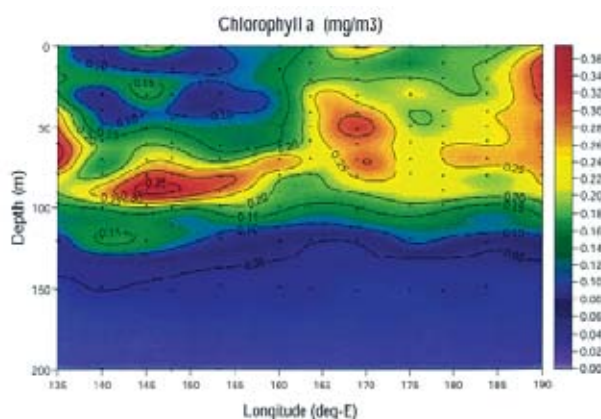


Fig.33 Vertical distribution of chlorophyll-a

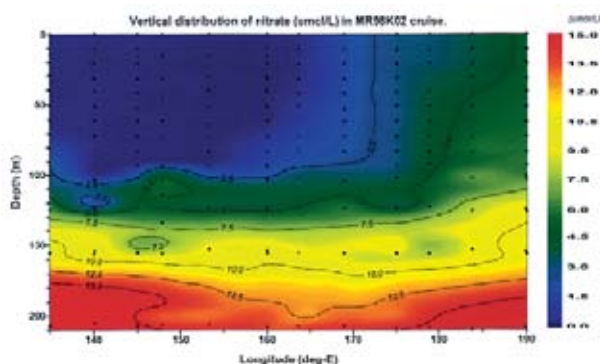


Fig.34 Vertical distribution of nitrate

④ The construction of preparation system for measurement of ^{14}C in dissolved organic carbon (DO^{14}C).

The purpose of this study is to construct a preparation system of DO^{14}C by UV oxidation method to measure the DO^{14}C activity in sea water.

A prototype preparation line of DO^{14}C was constructed in 1998. This is a system which produces graphite carbon from the DOC in sea water sample under the vacuum condition. Analytical procedure consists of three steps, as follows: (1) UV oxidation of DOC to carbon dioxide, (2) purification of produced carbon dioxide, (3) reduction of carbon dioxide to graphite carbon. Optimum analytical condition has been determined using a commercial reagent (glucose). The recovery of carbon dioxide was not satisfactory (ca. 50%) so that further improvement of the system, especially change the wave length of UV lamp is necessary. This preparation line is not only for DO^{14}C but also useful to prepare solid materials such as sediment and sediment trap samples. ^{14}C data on carbonate fossils in sediment samples have been published.

⑤ Study on standard material for nutrient measurement

In order to clarify the temporal and spatial variations of oceanic biogeochemical processes, it is essential to have reliable standard material for nutrient measurement. Goal of this study is to establish the method for the standard preparation. In 1998, various conditions for preparation of standard were tested. And a manual for the preparation was made.

⑥ Study on technical improvement of measurements of CO_2 system parameters in the ocean.

To examine high frequency measurement of surface seawater pCO_2 by a membrane equilibrator, comparison with shower-head equilibrator installed in the R/V Mirai was made. Values obtained from the two equilibrator agreed each other within 1 ppmv.

We joined an international calibration of TDIC measurement. Values presented by JAMSTEC differed by 2-3 $\mu\text{mol/kg}$ from the internationally certified value.

⑦ Study on the behavior of the trace metals (dissolved iron) in the ocean

Iron has been known as an essential micro-nutrient for the phytoplankton growth in the ocean. Due to its extremely low solubility, however, the concentration becomes

so low that plankton growth is subdued where its supply is limited. Thus, the fate of iron in seawater is closely related to the biological activity. It is very important to know the behavior of iron in the ocean for the study of the global biogeochemical cycles of carbon and its related elements. In order to clarify the role of iron in the biogeochemical process, the behavior of iron in the northern North Pacific have been studied.

In order to avoid contamination, sampling bottles were improved and procedures of samples were established. Water samples were collected vertically at 17 stations using 12 L Teflon-coated Niskin-X bottles mounted on a CTD/rosette system during MR98-K01 cruise. The measurement of samples has been continued; concentrations of dissolved iron in most samples were lower than 1 nM. These low concentrations of dissolved iron indicate that the samples were not contaminated during the sampling and the measurement.

⑧ Study on the application of the ocean color satellite in the western Equatorial Pacific

Primary production is one of the major subjects in global carbon cycle study because its flux plays an important role in biological pump. The horizontal and vertical distribution of phytoplankton and their primary production has seasonal and interannual change in each water mass. The purpose of this study is to develop the algorithm to

estimate the primary productivity using the satellite data such as ocean color, sea surface temperature and so on. Satellite data (SeaWiFS and AVHRR) were directly received by the shipboard receiving system on R/V Mirai in the Western Equatorial Pacific during the bio-optical observation cruise in Dec. 1998 to Jan. 1999. Fig.35 shows composite of chlorophyll-a distribution during the cruise observed by SeaWiFS. In the area from 175°E to 165°W, which corresponds to the westernmost part of the equatorial upwelling region, the relatively high chlorophyll-a concentration from 0.3 to 0.5mg/m³ was observed. In the west of this region, which corresponds to warm water pool, low chlorophyll-a concentration of 0.1mg/m³ or less was observed.

⑨ Inter-annual variability in heat, carbon, nitrogen fluxes in the Equatorial Pacific

We carry out the cooperative research to study the fluctuation of primary production and environmental factors caused by the impact of El Niño and La Nina, mainly in the equatorial upwelling region with Dalhousie University, Canada.

The co-operative observation was carried out from Dec. 1998 to Jan. 1999 in the Equatorial Pacific. The fluctuation of water-column primary production for the past of 2 years is shown in the Fig.36. It was El Niño in1997-98. This fluctuation of the primary production was not caused

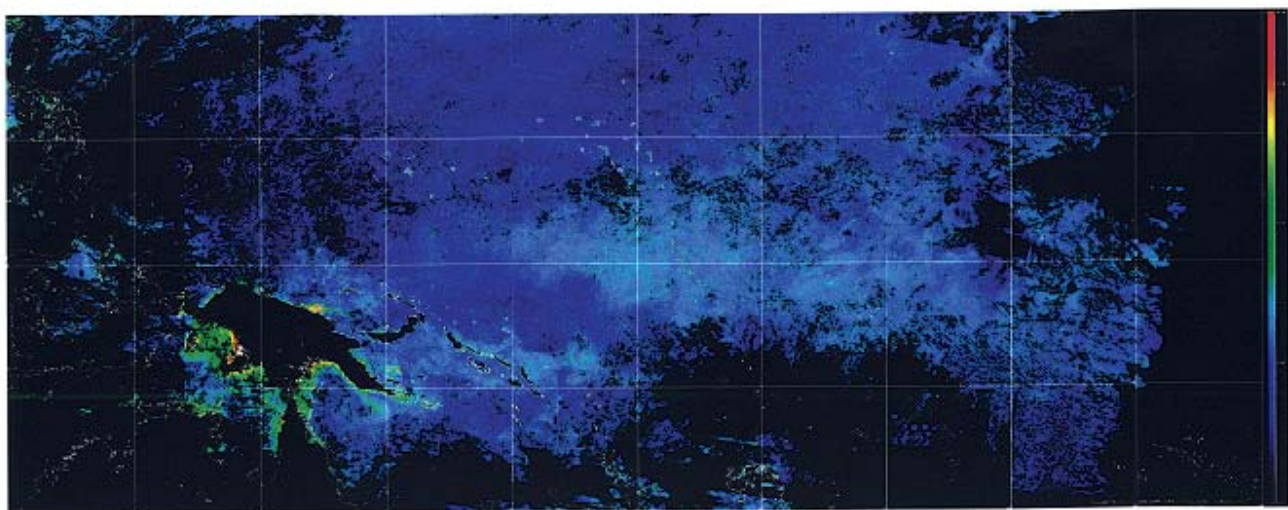


Fig.35 Distribution of chlorophyll-a observed by SeaWiFS during the cruise

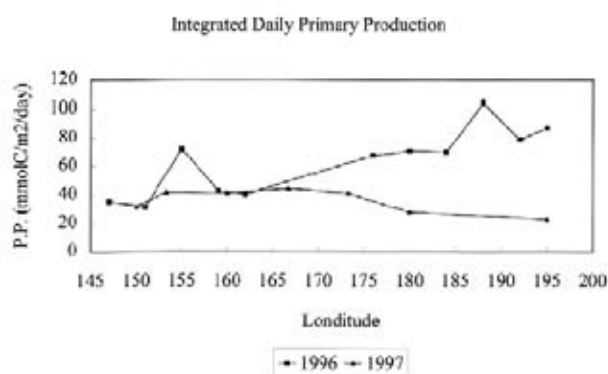


Fig.36 Fluctuation of water-column primary production for the past 2 years

only by the change of biomass but also by environmental factors such as nutrient, trace metal and so on.

⑩ Study on automation of measurement of chemical components in sea water

Goals of this study are : (I) to develop automated system for measurement of biological and chemical components in sea water and sea water sampling system, (II) to install the systems in the wave energy generator 'Mighty Whale' for the field test. In 1998, prototypes of the systems were built. In addition, a scale model of the autonomous biogeochemical monitoring platform was made, and tested in a pool for its movement under simulated rough condition.

⑪ Study on substances that cause global warming.

In the Meteorological Research Institute, calibration of CO₂ working standard gases used in the R/V *Mirai* was made based on the gases traceable to the WMO standard gases. Before and after individual cruises (MR97-02 and MR98-06), differences of concentrations of the working standard gases were less than 0.1 ppmv.

Weather Observation at Oki-no-Tori Sima

Introduction

Oki-no-Tori Sima is the southernmost place in Japan at the location of 20°25'N, 136°05'E near the boundary of Tropics in the central part of the Philippine Sea and far from Tokyo at a distance of 1700km as shown in Figure 37. It is a coral reef with no significant land mass. This natural condition makes it possible to observe the pure oceanic weather. The weather is very important to study on the pure change of atmosphere and ocean without human con-

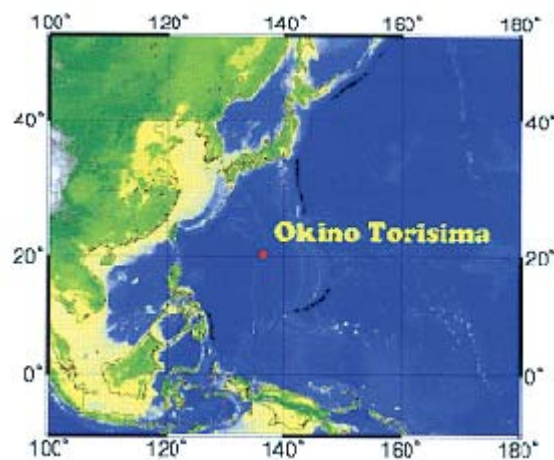


Fig.37 Geographical Location of Oki-no-Tori Sima

tamination. The climatology of the Western North Pacific showed that SST and Air temperature at Oki-no-Tori Sima is heated up by the Tropical sunshine and cooled down by the Winter Monsoon. Oki-no-Tori Sima is just located at the south lim of the Winter Monsoon. The weather at Oki-no-Tori Sima is sensitive to the conditions of Winter Monsoon and Tropical SST.

Weather Observation

The weather station which JAMSTEC used at Oki-no-Tori Sima is an Andderra weather station in combined with an Argos Transmitter as shown in Figure 38. The tide gauge was an Andderra water level meter to measure both pressure and water temperature. JAMSTEC has started to observe the long term weather and oceanic conditions since April 1993. The weather station and tide gauge were maintained once a year in February or March. All of the sensors were replaced by new ones at that time.

Characteristic of Weather Condition

In winter, the air temperature changed up and down at a temperature range of about 4°C according to a change of two phases which are a cooling and warming ones as shown in Figure 39. In the cooling phase that the dry and



Fig.38 Weather Sensors

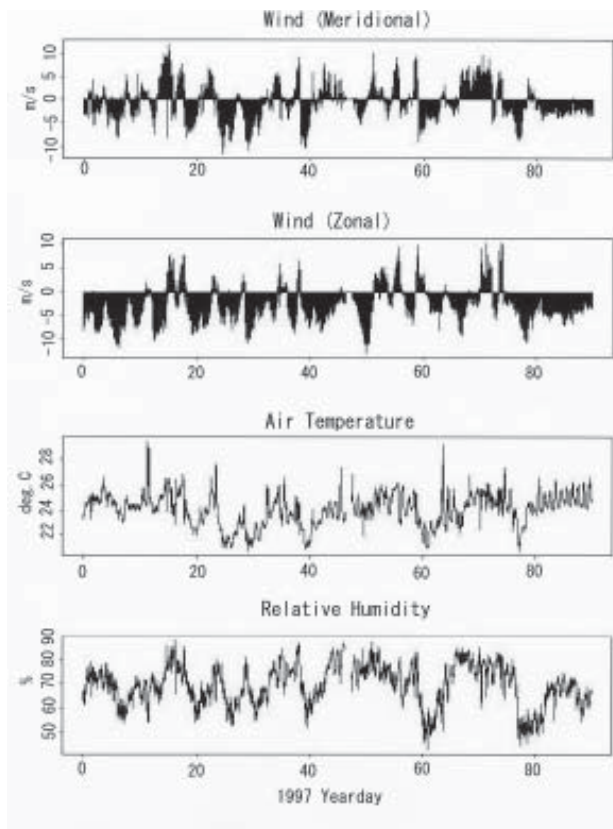


Fig.39 Weather Condition at Oki-no-Tori Sima
(From January to June in 1998)

cold northerly wind blow over Oki-no-Tori Sima, the air temperature was effectively cooled down. In the warming phase that the wet and warm South wind blows, the air temperature was warmed up. Both phases appeared and disappeared interchangeably in a short period. This rapid

change of air temperature was due to the cooling of Winter Monsoon and the heating of South warm wind and Solar heating.

The main feature of the weather condition from the winter to spring is a drastic phase shift. At Oki-no-Tori Sima, the winter suddenly ceased and the spring begins promptly.

The onset of warming period (spring) which was related to the onset of warm SST northward movement occurred just after the last cooling phase ceased in winter. The number of cooling phases was very important to affect the mean temperature of Winter. On the other hand, the air temperature got warm steadily to the maximum in summer during the warming period. These change should be interpreted as a subprocess of Asian Monsoon because the onset of warming period seemed to have a close relation with the end of Australian Summer Monsoon.

Weather condition of 1998 at Oki-no-Tori Sima was unusually calm. Few Typhoons attacked Oki-no-Tori Sima. The largest El Nino in the 20th century decayed and disappeared until June 1998. Generally Speaking, the weather condition of 1998 seemed to be a typical one.

JAMSTEC will keep this kind of observation at Oki-no-Tori Sima to study on the relation of climate change between Japan main land and Oki-no-Tori Sima. Hopefully, we would find a precursor for the extremely cool summer to the summer of 1993.

Global environmental problems are the most serious issues facing humankind today, and are also issues that should be dealt with as soon as possible. In order to discover ways to resolve global environmental problems, it is important to evaluate the kind of impact that variations in species diversity caused by environmental changes will have on the future of the global environment. At the same time, it is also necessary to clarify the mechanism of environmental change, looking hard from a global perspective at the material cycle as it relates to ecological systems. The oceans occupy 70% of the earth's surface, and one can not clarify global-scale phenomena relating to environmental change without understanding the oceanic ecosystem. Therefore, we will proceed with a multifarious study of biology, physical oceanography, chemical oceanography and ocean engineering focusing on coastal areas, where primary productivity is high and which is susceptible to environmental changes, and deep sea areas from the mesopelagic zone through to the ocean floor and abyssal trenches.

Project research

"Study to elucidate the mechanism of ocean ecosystem changes"

Period: from 1998-1999

Coral is widely dispersed in the seas from tropical to subtropical regions, and is a biological indicator that grows and declines in response to global warming and destruction of the ozone layer. The coral reef ecosystem, the primary production of which is based on coral, is important in terms of basic production in the ocean, and is also a nursery for the young of oceanic organisms. This study is aimed at elucidating the mechanism of coral reef ecosystem changes.

From 1995 to 1997, Tamatori Point at Ishigaki Island was the target of our study, but from 1998, we changed the target to this country's largest coral reef area, "Sekisei Reef" (25x25km), and commenced full-scale investigative research.

Our aim during the two-year period of 1998 and 1999 was to develop techniques for finding the biomass of live coral, phyte plankton and so forth in regard to the coral reef ecosystem of this sea area as a whole, and moreover to develop technology for measuring various physical and chemical factors that contribute to its growth and decline.

We conducted the first full-area investigation in October 1998, and subsequently carried out timely investigations on each issue.

Investigative research by "the lower-order production and water quality investigation team" is divided broadly into the two items below.

(1) Observation of upwelling plume formation along the channel.

In order to investigate factors for the development of coral reef on the reef slope, we measured distributions of water temperature, salinity, chlorophyll-a and nutrient mainly near the inflow channel of Sekisei Lagoon, and confirmed the possibility of upwelling which was thought to be contributing to the mechanism for supply of nutrient from outside the reef. We also made the survey to investigate environmental changes attendant to the passing of the typhoon, and considered its relevance to the coral bleaching phenomenon.

(2) Investigation of coral activity level on the reef slope.

Using exclusive types of coral taken from the reef slope, we observed the coral's ecology with an underwater microscope in a water tank on land, and also tested the underwater microscope's operation in the sea on-site. We also investigated the priority type and covering of an exclusive type of coral taken from the reef slope surface of the upwelling area, and studied the condition of activity and bleaching of the coral.

Investigative research by the "organism measurement team" is broadly divided into the following three items.

(1) Issues concerning basic data set development for making Sekisei Reef a biological indicator

We investigated the biomass of coral and plankton of the Sekisei Reef as a whole, and various environmental factors such as water quality and flow that related to it (Photo 1). For use in the coral investigation, we set 26 diving locations, and 10 line transect investigation routes.

With regard to plankton and water quality, we set up 9 lateral lines and 20 observation points.

(2) Themes concerning coral reef ecological system research and development of measurement techniques in patch reefs

We selected three patch reefs where coral activity differed, and made clear the structure of the coral reef ecological system, as well as investigating the relationship between coral's microstructure and various environmental factors, schooling behavior of fish and the day and nighttime distribution structure.

(3) Leading themes concerning the functions of coral reef ecological systems and predicted changes

We examined phenomena that have a possibility of affecting the coral reef ecosystem and new measurement technology. This includes attempting to measure coral health and measuring the photosynthesis of collected coral based on element analysis, as well as attempting to measure the health of coral using fluorescence or color.

The physical environment group investigated the following research in the Sekisei lagoon in October, 1998.

(1) Vertical profile measurement at reef slope by underwater elevator

We installed an underwater elevator system and an acoustic current meter at a depth of 32m in Kayamabishi reef which develops on the north side of Sekisei lagoon and faces the East China Sea, and measured the vertical distribution of water temperature, salinity and current. By the runoff of seawater from the reef, it was observed that the surface water temperature was 0.8 degrees Celsius higher than the lower waters.

(2) Exchange of reef waters

We set up current meters at four stations on the reef ridge and in the lagoon, and investigated the correlation between tides and currents. At low tide waters were closed up in the lagoon, and during the up-tide waters flow in over the reef, but outflows from inside to outside of lagoon were formed at the channel. Within the reef, northerly currents did not develop so large by south winds, but by north winds, southerly flow developed rather strong. Waters may flows into the reef during the winter season with northeast winds.

(3) Development of artificial plankton-larva tracking system

We carried out a test of an automatic tracking performance of the system that tracks the artificial plankton larva drifting underwater along the current at the depth. We obtained basic data concerning acoustic positioning performance and tracker propulsion performance and steering performance in order to design an actual system.

We are the first in the world to study the coral reef ecological system with a vast sea area like Sekisei coral reef as the target, and with the cooperation of many researchers that belong to the Ocean Ecological System Committee and the Scientific Diving Society, we were able to proceed with research to shed light on its mechanism of change.



Photo 1 Measurement of photosynthetic activity using fluorescence meter

"Research concerning the dynamics of the heat and materials fluxes, and their relationship to the marine biosphere"

Period: from 1997-

Apart from photosynthesis-based ecosystems, ocean ecosystems include chemosynthesis-based ecosystems, which are formed on the ocean floor through the ejection of hydrothermal fluid and cold seeps. Of particularly large scale are the hydrothermal vent populations and cold seep zone populations in deep sea areas. These directly and indirectly incorporate substances that are ejected from the sea floor and maintain a huge biomass of organisms, also being thought to contribute significantly to the circulation and reattrition of ejected materials. Making use of deep sea investigative systems such as submersibles and ROVs, this research aims to clarify the interrelationship between

substances ejected from within the earth and deep sea chemosynthetic ecosystems, and the basic physiological and ecological characteristics of deep sea chemosynthetic populations.

Through field investigations using research submersible vessels and laboratory investigations, we carried out physiological and ecological research on west Pacific Ocean chemosynthetic populations from around Japan and on those from the Manus Basin. As a result, data was obtained concerning the community structure of constituent organisms in each population, their detailed distribution patterns, growth and the systematics of symbiotic bacteria and so forth. Moreover at a point at 7326m depth in the Japan trench, we discovered the world's deepest chemosynthetic community. Furthermore, in the Mariana Trench, we carried out a biological investigation at the deepest point on earth, and collected geological and biological samples such as gammarid amphipods (Photo 2). In this fiscal year we designed and ordered a suction-based deep sea organism sampler that can efficiently collect biological samples, acquired environmental measurement devices, and organism rearing equipment, a DNA sequencer, and other laboratory equipment.



Photo 2 A Gammarid amphipod (*Hirondellea gigas*) collected from the Challenger Deep (depth of approx. 10,900m), Mariana Trench

"Development of technology for using and enlarging offshore underwater space, based on ocean-type artificial sea floor"

Period: from 1994-1998

This research was begun from 1994 as an area joint R&D project with Iwate Prefecture. It was aimed at developing and using an artificial sea floor that descends

and rises, and using underwater space offshore up to a depth of 100m. To that end, we manufactured by way of trial the "Ochan Marine No.1" ocean-type artificial sea floor in 1995, and installed it in waters of depth 40m in Funakoshi Bay, and carried out real sea general tests, and acquired many types of experimental data for designing an application machine. In the final year of 1998, we performed the following experimental research.

① Abalone mariculture test

We continued breeding the abalone whose mariculture we commenced in 1997, and obtained data on growth, rate of procreation and amount collected when we performed year-round breeding. As a result, it was judged that abalone mariculture is possible even in seas that are affected by ocean waves.

② Non-destructive inspection

We periodically confirmed safety and durability, and in order to acquire accurate data on deterioration status, we performed anti-erosion potential measurements of the equipment main body as well as mooring chains; volume consumption measurements of the aluminum positive electrode; measurement of the mooring chain diameter wear; visual inspection of the exterior; sea water ballast system open inspection; and measurement of the weight of fouling. As a result, it was confirmed that adequate anti-corrosion potential is ensured for the equipment main body and mooring system (within about 8m from the facility); that the amount of volume consumption of the positive electrode is not irregular; and that the amount of wear of the chain diameter is roughly in accord with the design value.

③ On-land inspection

After completion of the real sea test, we collected the facility, and conducted a visual inspection of its exterior on-site, and at the factory carried out an investigation of the exterior view of chain links, as well as an investigation of cross-section form and remaining strength (tension). Consequently, we confirmed that while blue mussels were clinging to the facility under the water surface, the surface showed no paint peeling, rust or other corrosion after they were removed; that while there were differences in the amounts of fouling of the mooring chains, there was no damage, corrosion or abnormal diameter wear (Photo 3). Apart from that, valuable data was obtained in terms of producing an actual machine.

④ Report compilation

We compiled a report summarizing research results for the five-year period.



Photo 3 Mooring system collected for on-land inspection

"Development of monitoring system for coastal fisheries environments"

Period: 1994-1998

Sendai Bay is open to the Pacific Ocean. River waters, Oyashio cold waters, and Kuroshio warm waters flow together in this bay, resulting in a complex water circulation system within the bay. Moreover, for this reason the primary productivity is high, and the coastal waters of Sendai Bay are utilized to a high degree mainly for the fishing industry and the aquaculture, especially oyster industry, including natural oyster-larva collection and monitoring of the thick distribution area of oyster planktonic larva. Observing the sea water environment of these waters, and in particular by monitoring the movement of water mass is hoped to lead to elucidation of the actual conditions of biological production environments.

In this joint research with Miyagi Prefecture (Phase II), we conducted research for the application of a system to monitor the movement of water mass, based on an underwater elevator system which we developed in Phase I (1994-1996). Furthermore, using this system, we continuously monitored the vertical distribution of the sea water environment (Fig.1), and attempted to use the data of fisheries people, along with conducting an investigation of oyster planktonic larva and other biology, and shed light on the mechanism of dispersion, piling up and accumulation of planktonic larva in Sendai Bay, and made it useful in promoting coastal aquaculture.

In 1998, we made improvements to the underwater elevator system and mini-underwater elevator system, and monitored the fisheries environments of Ishinomaki Bay from June until August. In late July, early August and early September, we made experiments on the dynamics of the vertical distribution of oyster larvae using an enclosure system. We also compiled a comprehensive manual for the underwater elevator system.

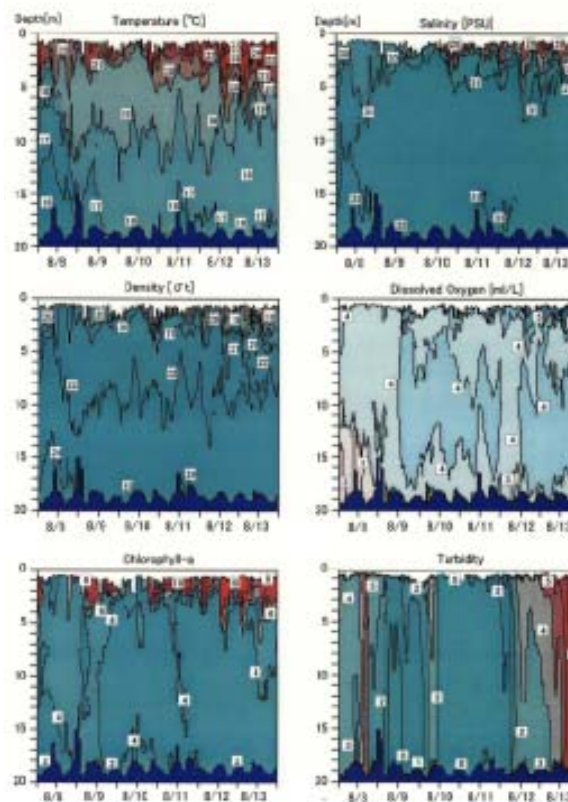


Fig. 1 Change of vertical distributions of environmental parameters measured by the underwater elevator (8/8 - 8/13, 1998).

"R&D on the technology controlling the oxygen-deficient water mass in Omura Bay"

Period: from 1997-1999

Omura Bay is located in central Nagasaki Prefecture, and at the bottom of the inland bay, sediments have accumulated thick. Because of the urbanization around Omura Bay in recent years, the water quality has degraded under the environmental target, and oxygen-deficient water mass develops regularly in every summer. In oxygen-deficient water mass, benthic animals can't survive, and it also accelerates the nutrient dissolution from sediments, which results in red tides after the fast mixing of waters as the

Typhoon. Nagasaki Prefecture has regulated the total amount of COD load, but a comprehensive strategy for maintaining the environments of the bay is now an urgent issue. Along with understanding on the mechanism of developing oxygen-deficient water mass in Omura Bay, we will develop a water circulation technology to control its incidence. This joint research program between JAMSTEC and Nagasaki Prefecture aims to propose some water circulation technology for helping to plan that strategy. This system pumps oligotrophic surface waters to the bottom, mix them with the eutrophic bottom waters, disperse horizontally them in mid-depth, and promote a primary production which we expect a healthy ecosystem to follow in the bay.

In 1998, we investigated the current status for oxygen-deficiency mechanism, eutrophication, and modeling. We carried out environmental monitoring at the station where the water circulation system will be installed,

and investigated its performance evaluation procedures. Moreover, we developed a floating platform for power supply to and controlling of the circulator and monitoring weathers and sea conditions (Fig.2). Since the Omura bay has non-uniform wind distribution, we developed a sea water flow model that could take account of this.

"Development of a simple collection system and breeding techniques for vestimentiferan tube worms"

Period: from 1997-1999

The vestimentiferan tube worm is a peculiar organism that does not have a digestive tract, and instead uses energy produced by chemosynthetic bacteria that coexist within its body. Large colonies have been found in waters of 82-110m within Kagoshima Bay. At present, large-scale systems such as the Marine Science & Technology Center's research submersible vessel or remotely operated vehicle are necessary in order to collect these

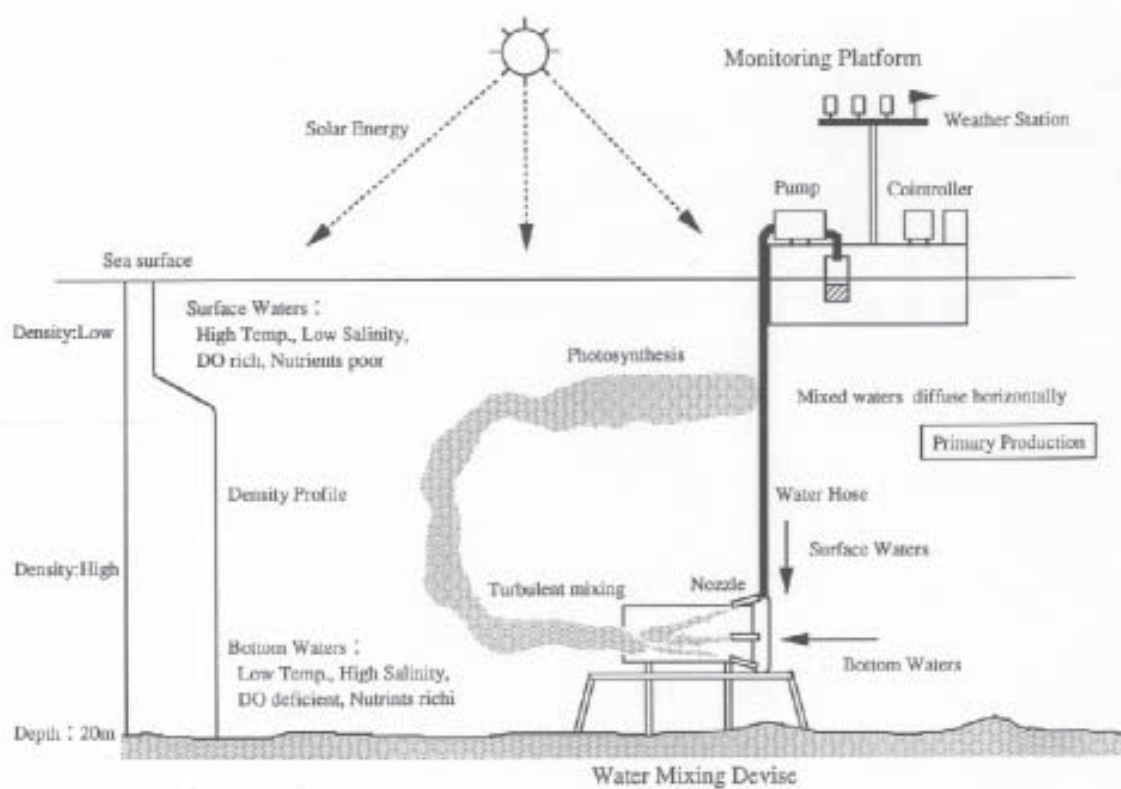


Fig. 2 Scenario of Water-quality Improvement in Omura Bay. Water mixing device mixes turbulently surface waters with bottom water, and the resultant mixed waters diffuse horizontally and in a wide range at the mid-depth, and increase the primary production. The DO-deficient bottom environments are expected to be improved. Maintaining the diversity and abundance of phytoplankton may prevent red tides generating after density stratification and increase the higher production web. Finally fisheries may take the nutrients out of the Bay and restore it.

vestimentiferan tube worms, and therefore the samples that can be gathered for research are limited. We developed a simple collection system (grabber system with camera), that can be loaded onto a small boat and can be used to gather samples easily (Fig.3). Moreover, in partnership with Kagoshima City Aquarium, we developed technology for rearing vestimentiferan tube worms in a satisfactory state, and aim to popularize and educate on marine science and technology through this cooperation.

In 1998, we acquired a power source and control unit for the on-board system, and acquired the underwater camera lens section and camera control unit. We conducted an underwater transmission test, and confirmed that the camera and power source control unit operation were satisfactory. We also manufactured a CD-ROM for the general public that deals with deep sea chemosynthetic organisms including vestimentiferan tube worms.

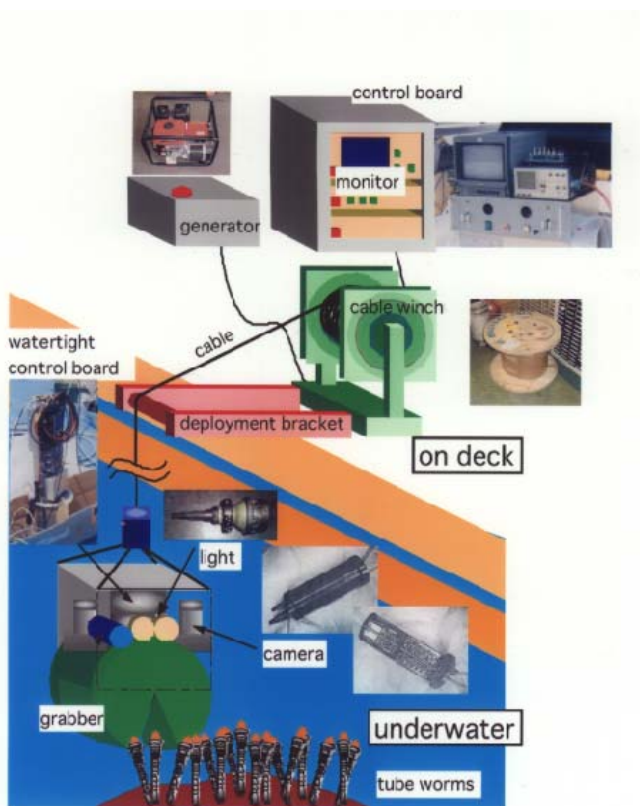


Fig. 3 Concept drawing of vestimentiferan tube worm simple collection system

"Research for scientific characteristics of deep seawater in Suruga Bay and for the multistage use system"

Period: from 1998-2000

We conduct this research with the aim of effectively promoting projects for effective use of Suruga Bay deep seawater, and contribute to the establishment of practical deep seawater usage technology (Fig.4). This year is the first year of research, and in order to attempt to effectively promote research, we formulated a research execution plan and examined a research structure (project team organization, visiting researchers, etc.), as well as making a start on basic and advanced analysis and preparation of observation equipment. Types of instruments that we prepared include a microscopic component analysis device targeted at microscopic metals; a device to analyze components in large amounts, targeted at types of nutrients; a organism examination and analysis device that assesses water quality by organisms; ship-loaded ocean research instruments, and moored ocean research instruments.

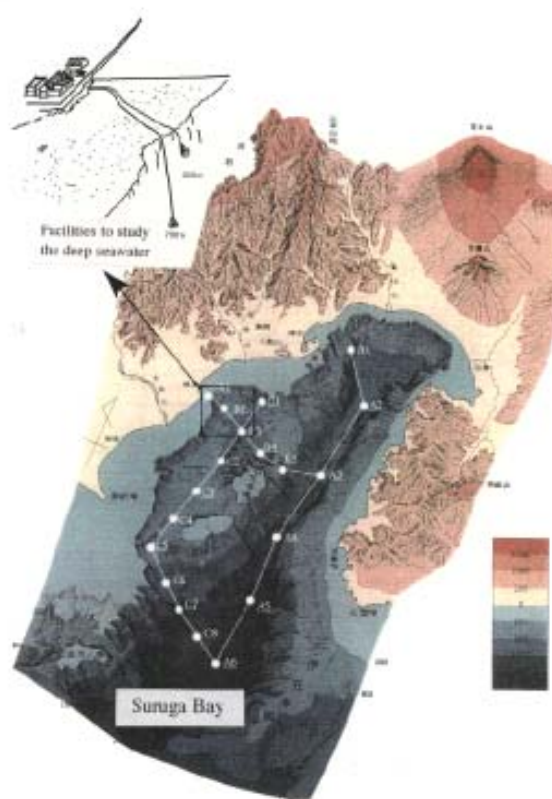


Fig. 4 Observation points in Suruga Bay

Current research

"A study on the modeling of marine ecosystems by combining multiple submodels."

Period: from 1998-2000

This study involves creating models for each individual phenomenon of marine ecosystems as simply as possible, and by combining those models, we will research and develop a marine ecosystem model of higher precision. We are aiming for the combination of models such as the flow dispersion model (physical model), material flux model (biochemical model), organism behaviour model (vertical migration of plankton, etc.), and will develop a parallel calculation program of calculation efficiency, and carry out calculations using a parallel computer.

In 1998, we grasped that the vertical migration of plankton was an important key in marine ecosystem models, and an addition performed an investigation of documentation concerning plankton behaviour models. Moreover, in regard to model parallelization, we examined the parallelizing of not only ecosystem models, but also physical models (Fig.5).

As a future plan, we will develop a behaviour model that models the vertical behaviour of plankton. We will also perform parallel processing of the physical model. Furthermore, we plan to perform parallel processing of each compartment for a regular ecosystem model, as well as combine the physical model and plankton behaviour model, and investigate the technique that is most efficient and offers computational safety.

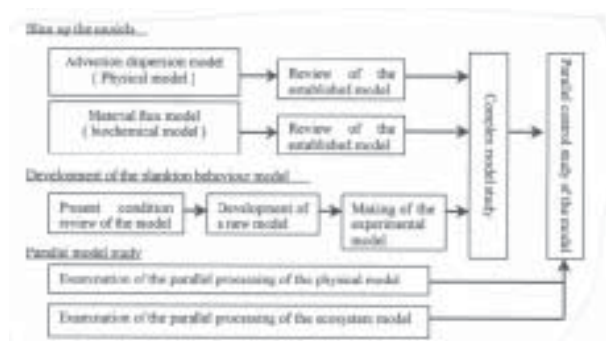


Fig. 5 Research flow of combined modeling of marine ecosystems

"Methods of evaluating seawater movement in the vicinity of coral"

Period: from 1998-2000

In order to clarify the mechanism of change in coral reef ecosystems, it is important to appreciate not only at biological changes in that habitat, but also the physical environment. In particular, grasping minute flows in the vicinity of coral reefs (patch reefs), is important in terms of finding out the coral growth process, spawning, and the living environment of zooplankton, etc. In general, mooring-type observation is carried out using a current meter to grasp flow region, but in small-scale sea areas such as patch reefs, the use of measuring instruments itself is difficult in consideration of size. Therefore, in this kind of location, plaster balls technology, used to ascertain flow environments in small-scale sea areas such as seaweed bed and aquaculture field. However, flow measurement by plaster balls has the disadvantage that it can only be carried for 2-3 days. In this study, we will develop a long-term installation-type integral flow velocity sensor based upon the plaster balls technology, which can evaluate integral current velocities from one week to around ten days, to one month. Furthermore, using the developed sensor, we will carry out a experiment of study field, and examine the coral growth process, spawning, the habitat of zooplankton, etc., and the relationship with minute flow.

This year, we manufactured by way of trial sensors that can be installed long-term (improved raw materials), and furthermore, conducted experiments with each type of trial-manufactured sensor in the Sekisei lagoon (Ishigaki Island, Okinawa Prefecture) (Photo 4). As a result, it was

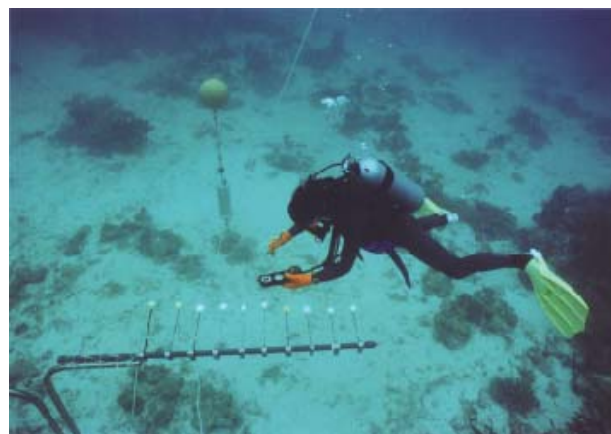


Photo 4 Experiment of long-term installation-type flow velocity sensors in Sekisei lagoon (Ishigaki Island, Okinawa Prefecture).

found that by combining fine grains of cement in the gypsum, we could make a sensor that was capable of taking measurements for about a week.

As a future study, we are considering a dissolution experiment of trial-manufactured sensors based on differences in water temperature, salinity and current velocity (in Sekisei lagoon and laboratory). And we hope to extract a high-precision sensor that can be installed long-term, and use it to think about the above points.

"Decompression Sickness :DCS caused by low ambient pressure exposure after diving."

Period: from 1998-2000

The normal decompression table was calculated for returning to the sea level. If the diver were exposed to the low ambient pressure by crossing a mountain or by travel in the plane immediately after their dive, they would be suffering from DCS. The important factors of DCS during dive were dive depth, dive time and breathing gas volume, and the after dive factors are the altitude in the mountain or the cabin pressure of the plane. We measured the altitude of Tokyo-Nagoya freeway crossing the foot of Mt. Fuji where many divers in Tokyo pass along after their dives in the west Izu peninsula. And also we measure the cabin pressure of Japanese domestic air lines. The cabin pressure decreased to 2,000-2,700m equivalent altitude after 15 minutes from the take-off. Then we concluded that the air travel immediately after dive is most dangerous case. And we started making the animal model with rats for this type of DCS.

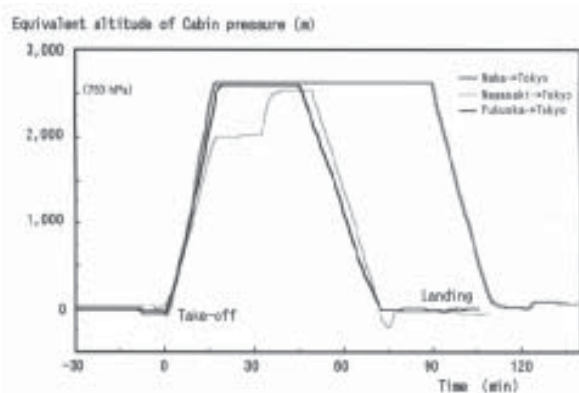


Fig. 6 Equivalent altitude of cabin pressure of Japanese domestic flights. Maximum flight altitudes were between 10,000 m and 11,500 m.

"Research on techniques to measure biomass of coral reef fish"

Period: 1998-2000

Within the coral reef ecosystem, fish are positioned as high order predators. Therefore, it is important to ascertain the biomass thereof, but since many types of fish are distributed in a coral reef sea area, moreover the sea floor topography is complex, it is difficult to grasp quantitatively. What is more, coral reef fisheries are also thinning out from the ecosystem, and it is necessary to accurately ascertain its mass.

With regard to biomass measurement, we used a 3-D TV camera to attempt to measure the types and the dimensions of fish distributed there. The installation, measurement and collection of a cable-type TV camera was difficult, but we obtained the forecast that sound results could be obtained by observing in identical locations in units of 30 minutes. We planned to compile fish types of similar body shape, and find the weight from the length. With regard to coral reef fisheries, we grasped the general situation by an examination of documentation and by an aural investigation.



Photo 5 3-D TV camera installed in the coral reef

"Studies on hydrothermal vents and their relationship to the concerning mutual action of life phenomena"

Period: 1996-1998

It is suggested that the global environment of about 4 billion years ago when life came into being on earth was hot and an anaerobic. It is thought that bacteria-like organisms emerged as the first life under this kind of environment. Deep-sea hydrothermal vents in the ocean and hot springs on land are thought to be representative of the hot and near anaerobic or reducing environments presented at that time. The JAMSTEC has long since engaged in research targeted at deep-sea hydrothermal vent populations. In order to clarify the structure of deep-sea hydrothermal vent communities, approaches from various directions are necessary. Therefore, information on hot spring ecosystems, which exhibit a simpler population structure, informative, and by doing a comparative study of both, we aim to probe into the structure of hydrothermal vent populations, and explore the form of primitive communities.

As a result of estimating a food chain from sulfur isotope ratios, it became clear that snails and shrimps present in hydrothermal vent areas were feeding on vent-associated bacteria. In the case of deep-sea hydrothermal vent areas and hot springs on land, we found that members of the same genus of cyano-bacteria were primary producers both deep-sea and land-based hydrothermal systems. On the other hand, in the case of hot spring bacteria mats (Photo 6) and the mats of deep-sea hydrothermal vent areas, we were able to show that the dominant species were almost completely different. According to a rough estimate, the amount of bacteria produced in hydrothermal vent areas was estimated at 1×10^4 cells/cm²/day.

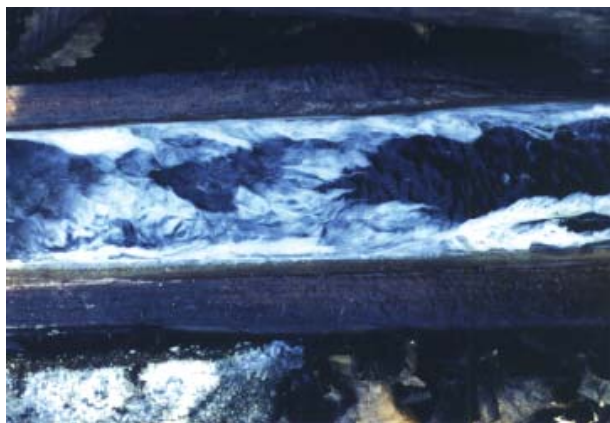


Photo 6 Mat of microorganisms formed by spring source of Lake Tazawa hot spring, Akita Prefecture. Called sulfur turf.

"Development of Tools for the Sampling and Maintenance of Midwater Organisms."

Period: from 1998-2000

Although our understanding of marine ecosystems has advanced considerably over the last hundred years or so, research has concentrated mainly on near-shore, benthic, or upper oceanic ecosystems. However, over 90% of the oceanic biome is comprised of the midwater zone, that area of the ocean below 200m depth but above the ocean floor, and the organisms inhabiting this zone remain little studied. The majority of work that has been done on midwater animals and the physical environment they inhabit has used nets or water samplers lowered from boats. However, recent research using crewed submersibles and remotely operated vehicles (ROVs) has shown that gelatinous zooplankton are a major and hitherto almost ignored component of the midwater fauna. Gelatinous zooplankton (jellyfish, siphonophores, ctenophores, larvaceans etc.) are extremely fragile and are impossible to collect in pristine or even reasonable condition using nets, making laboratory experiments on captured animals almost impossible. As a result there is a real lack of information on the taxonomy, physiology, ecology and behaviour of a large portion of the midwater fauna.

The present 3-year project was instigated in 1998 with a view to remedy this situation by developing tools for the sampling and maintenance of midwater organisms. During the 1998 fiscal year, a 6-cannister suction sampler capable of operation at depths below 6500m was developed for the ROV Kaiko (Photo 7). Furthermore, in order to obtain the most samples possible per dive survey, a multiple cannister suction sampler for the ROV Dolphin-3K

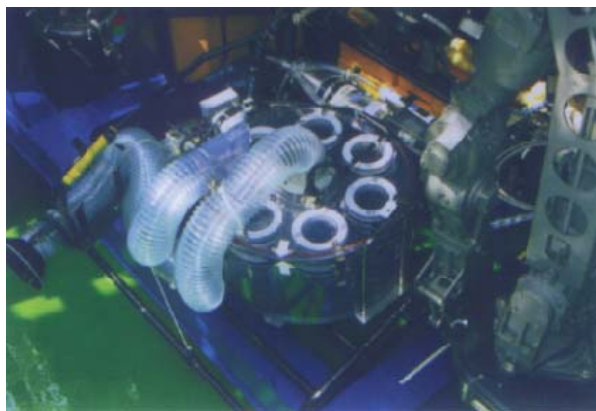


Photo 7 Six-cannister suction sampler attached to the ROV Kaiko.

was designed and is now under construction. A cooling unit to enable maintenance of midwater organisms aboard ship and in the laboratory was also acquired.

Joint research

"Feasibility study concerning the technology to fertilize the sea by using deep seawater"

Period: 1997-1998

We conducted this research with the aim of establishing design principles for deep water release technology in harmony with the environment, when returning drawn up deep water to the sea after using it. This year is the final year, and we have examined basic ideas of deep water release technology and ways of utilizing released deep water; studied release technology hardware and software; examined the contents of real sea empirical experiments; and compiled the results. As a result of investigating cases of releasing deep water in the past, it was confirmed that algae flourishes along with the release of deep water. Based on this fact, it was confirmed that if conditions can be set that impede the dispersal of deep water after release, the preparation of algae beds in sea areas will become possible. In this study, we carried out concept design of struc-

tures and water release methods in order to realize this, but there is a need to perform an empirical study in an actual sea area in future.

"Research concerning properties, and distribution and fluctuation characteristics of the proper water mass in Japan Sea"

Period: 1997-1999

This study is aimed at elucidating the properties and characteristics of distribution and change of water peculiar to the Japan Sea, in order to use it efficiently and to contribute to development of industrial uses. This year, we carried out an ocean investigation at Namerikawa offshore within Toyama Bay in September, and revealed the water temperature, salinity, distribution characteristics of inorganic nutrients and the vertical characteristics of potential algae production capability. Among the inorganic nutrients, nitrate in particular increased with depth after 100m, and stabilized at high concentrations at depths of 250m or more. Moreover, potential algae production capability showed high values at depths of 250m or more, and a high correlation between the two was recognized (Fig.7).

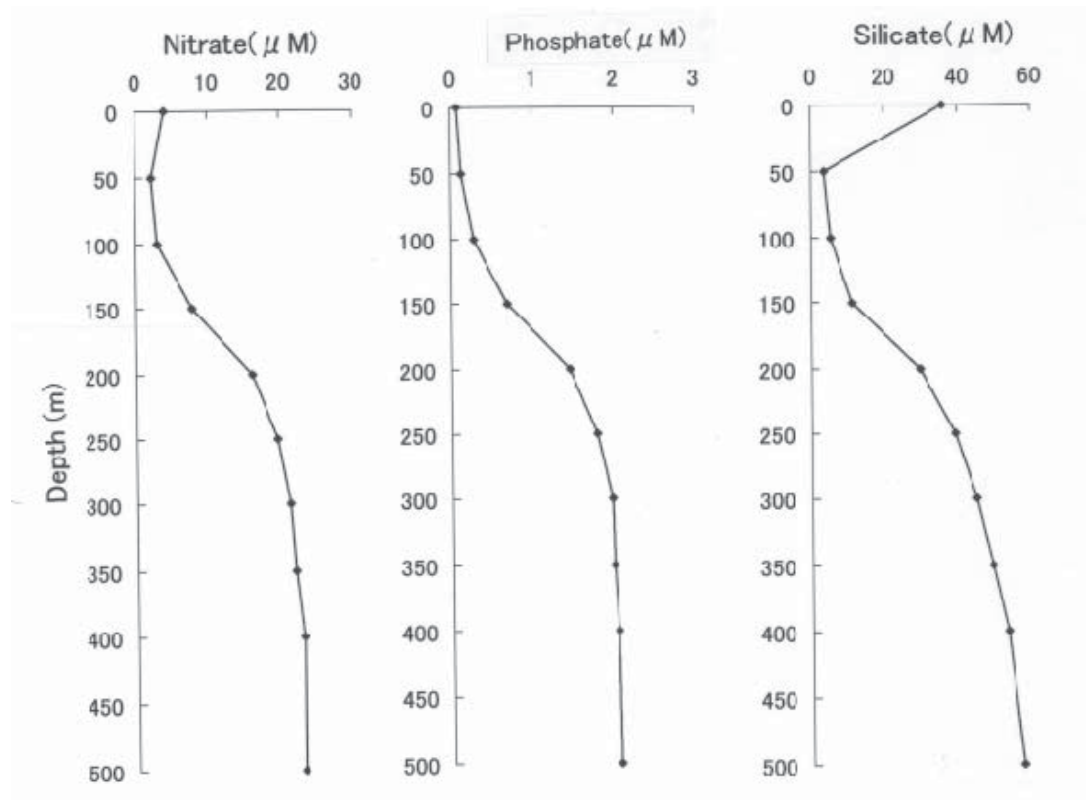


Fig. 7 Vertical characteristics of nitrate, phosphate and silicate in Toyama Bay

"The basic study for marine ecological research by using automatic zooplankton counters"

Period: from 1997-1999

With purposes to get characteristics of automatic zooplankton counters and promote to use these devices, we conducted ocean studies with the National Research Institute of Fisheries Science in and around the subtropical Kuroshio area. The Optical Plankton Counter (OPC, Photo8) and Electronic Plankton Counting and Sizing System (EPCS) were used, and zooplankton samples were obtained by an open-closing net in this study. Measurement results of OPC and EPCS were compared with manual counted results of net samples under a microscope. Positive correlations were obtained between OPC and EPCS for zooplankton abundance. While correlations between OPC and manual counts were lower than that of OPC and EPCS. For biomass, correlations were also obtained between OPC and EPCS, however correlation coefficients were lower than abundance results. These relationships were subtly different from the subarctic Oyashio area. This difference shows that abundant population in the ocean is influent on the OPC and EPCS measurement. We will analyze the details of these data and establish methods of measurement, and further improve these systems.



Photo 8 Optical plankton counter (OPC) mounted on the tow body.

"Basic research concerning the usefulness of high partial pressure oxygen"

Period: 1997-1999

In high-pressure physiological medicine and submarine medicine research, the usefulness of oxygen and its toxicity are problems. As for the effectiveness of oxygen, this high partial-pressure oxygen or the combined use of high partial-pressure oxygen and anti-cancer drugs dis-

play the effect of working on tumor cells to control tumors; as for oxygen's toxicity, it is known that the effect on the lungs continues. In this study, we aim to grasp the changes in production performance of red blood cells due to long-term exposure by high partial-pressure oxygen, and make this basic material that examines the possibility of application to leukemia and other blood diseases, as well as looking into the toxicity of oxygen from morphological changes in the lungs and lung functions, and use it in ensuring diver safety and in health management aspects.

In a manned experiment, we tested lung functions before and after the experiment and up to the 30th day after completing the experiment, but no significant changes were recognized. The production performance of red blood cells was held in check under high pressure. Leukemia cells (L1211) were administered to DBM/II mouse in the abdominal cavity, and on the second day, 2mg/1mg/kg of the anti-cancer drug DNR (Daunomycine) was administered, and exposed under high pressure for one hour per day for seven days; in the 3-day period from the seventh day to the ninth day, we administered G-CSF. Under oxygen partial pressure of 1.6ATA, the exposure time was from the third day to the ninth day, and as a result, it was suggested that by adding high-pressure exposure, the anti-cancer drug administration amount was reduced by half.

"Midwater Research using ROVs"

Period: from 1997-1999

The largest black box in our understanding of ocean ecology and processes is the ecology of midwater organisms and the physical parameters that determine their distribution and behaviour. It is becoming clear through research carried out by the Monterey Bay Aquarium Research Institute (MBARI) based in California, USA, that ROVs can be invaluable tools for studies on midwater ecology.

JAMSTEC has worked under a memorandum of understanding (MOU) with MBARI since 1994 on a comparison of the chemosynthetic communities of the Sagami and Monterey Bays. During this period it became evident that similarities and important differences existed between the midwater fauna of the two bays and a three year collaborative project was set up in 1997 to compare the midwater faunas of the Monterey and Sagami Bays using Remotely Operated Vehicles. In 1998, hydraulically-

powered actuator systems for Detritus-samplers (D-samplers) usable on the ROV Dolphin-3K and the ROV Kaiko as well as the MBARI ROV Ventana were developed. Furthermore, midwater surveys were carried out in both the Monterey and Sagami Bays. A database for the midwater fauna of Sagami Bay, similar to that which exists for the Monterey Bay, was constructed and preliminary information on the horizontal and vertical distributions of key organisms as well as information on the feeding ecology and life histories of several species was gained (Photo 9).

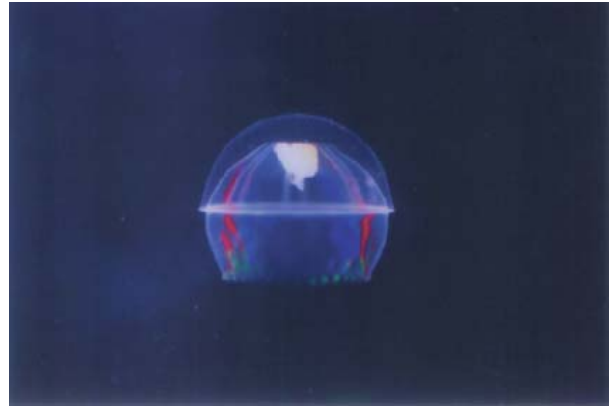


Photo 9 A medusa collected from the benthopelagic layer of Sagami Bay. This species is one of the dominant components of the benthopelagic fauna of the bay but has remained undescribed because until recently no specimens were available in even reasonable condition.

1. Course of action for developmental studies

Frontier Research Program for Deep-sea Extremophiles, a 15-year program launched by JAMSTEC in 1990, aims at unveiling new phenomena discovered in deep-seas. This project, conducted by the Deep-sea microorganisms research group (the DEEPSTAR group), places particular attention on microorganisms growing in certain specialized environments in the deep sea. Many microorganisms in the deep sea are true extremophiles, because they can thrive under extreme conditions of low temperatures, high temperatures, high pressures, or in high concentrations of inorganic compounds. They have never experienced solar energy, and they have to metabolize compounds not derived from sunlight. It is distinctly possible that very ancient life-forms might be hibernating in the world's largest refrigerator. Conversely, they might have some special functions to biodegrade xenobiotic, because the deep sea bottom is usually clean. Microorganisms isolated from the deep sea will give us new information on the origins of life, its evolution, and some useful applications for environmental protection.

Our Group has conducted research mainly on the following topics.

2. Major Research and Development

1) Genome analysis studies

① Analysis of the genome of a facultatively alkaliphilic *Bacillus* strain

An alkaliphilic bacterium, strain C-125 (JCM 9153), isolated in 1977, was identified as a member of the genus *Bacillus* and reported as a β -galactosidase and xylanase producer. It is the most thoroughly characterized strain, physiologically, biochemically, and genetically, among those in our collection of alkaliphilic *Bacillus* isolates. Last year, we initiated analysis of the C-125 genome, which has a size of 4.25 Mb, and systematic sequencing of the entire genome is in progress. Thus, it is clear that alkaliphilic *Bacillus* sp. C-125 is interesting and quite important for further advancement of basic and applied alkaline microbiology. The taxonomic placement of *Bacillus* sp. C-125 is still unclear, although taxonomic studies have been carried out in an effort to classify alkaliphilic *Bacillus* strains at the species level and some new species have been proposed. Therefore, we attempted to identify strain C-125 not only based on conventional physiological and biochemical characteristics but also through phylogenetic analysis based on comparison of 16S rDNA sequences and through comparison of DNA-DNA hybridization patterns. Through a series of experiments we have correctly identified strain C-125 as *B. halodurans* in this study, and we will refer to this strain as *B. halodurans* C-125 in future reports.

Systematic sequencing of the whole genome of *Bacil-*

lus halodurans C-125 has been routinized since the beginning of May in 1998 and more than 95% of the whole genome has been sequenced so far.

(a) Preparation of a shotgun library of the whole genome

Chromosomal DNA was isolated from *Bacillus halodurans* C-125, described above. A 20 μ g aliquot of chromosomal DNA was sonicated for 5 to 25 sec with a Bioruptor UCD-200TM. The sonicated DNA fragments were blunt-ended using a DNA blunting kit and fractionated by electrophoresis on a 1% agarose gel. DNA fragments 1-2 kb in length were excised from the gel and eluted by the freeze-squeeze method. The DNA recovered was ligated to the *Sma*I site of pUC18, which had been previously treated with BAP, and the ligation product was introduced into competent XL1-Blue cells by the standard method. We usually were able to obtain transformants at a frequency of 5 - 6 $\times 10^5$ per μ g of DNA. The DNA inserts in the plasmids harbored by these transformants were amplified by the colony PCR method.

(b) Determination of the sequences of both ends of λ phage clones

We constructed a λ phage library of the *Bacillus halodurans* C-125 chromosome and sequenced both ends of each lambda clone in order to fill the gaps encountered in assembly of the sequence data obtained in analysis of the whole genome shotgun clones. The efficiency of insertion of DNA fragments into the λ phage vector was more than 70% and the insert DNA was successfully se-

quenced with greater than 90% probability.

(c) Development of a total genome analysis system

We have been developing a total system for whole genome analysis, the so-called GAMBLER (Genome AsSEMBly and gEnome information Research) system, in collaboration with the Graduate School of Nara Institute of Science and Technology, Kyushu University, and Mitsui Knowledge Company. A series of processes for genome analysis, assembly of sequence data, assignment of open reading frames (ORFs), homology searches, and also submission of whole genome data with annotation to DNA data banks such as DDBJ, EMBL and GeneBank are accomplished automatically using the GAMBLER system.

(d) Construction of an I-CeuI physical map and analysis of the *rrn* operon

We have already constructed an *AscI*/*Sse8384I* physical map as one of the milestones in analysis of the genome of *Bacillus halodurans* C-125, and it was completed last year. For further analysis of the genome with another rare-cutting endonuclease (*I-CeuI*) which specifically recognizes an internal sequence of 23S rDNA, we attempted to construct an *I-CeuI* physical map and to characterize the *rrn* operon in the chromosome. The *I-CeuI* physical map has been completed and this work revealed that there are eight *rrn* operons in the C-125 chromosome (Fig. 1).



Fig. 1 Physical and genetic map of the chromosome of *Bacillus halodurans* C-125.

2) Studies on metabolism and adaptation mechanisms

① Taxonomic studies of deep-sea microorganisms

(a) Taxonomy of deep-sea piezo(baro)philic and piezo(baro)tolerant bacteria

Taxonomic analyses of the deep-sea piezophilic bacteria that we have isolated in the DEEPSTAR project have been performed. The results indicated that most of the piezophilic isolates which belonged into the genus *Shewanella* were members of the species *Shewanella benthica*, except for strain DSS12. Strain DSS12 was a novel species, and we named this species "*Shewanella violacea*". These strains were submitted to the Japan Collection of Microorganisms (JCM, Wako-shi, Saitama, Japan); the JCM numbers assigned to the seven *S. benthica* strains were JCM10173 - 10178, JCM10262 and that assigned to *S. violacea* was JCM10179. Other taxonomic results indicated that the piezophilic strains DSK1 and DB21MT-5 belonged to the genus *Moritella* and were members of two new species which we named *Moritella japonica* and *Moritella yayanosii*, respectively. These strains also were submitted to the JCM, and the numbers assigned to *M. japonica* and *M. yayanosii* were JCM10249 and JCM10263, respectively.

(b) Taxonomy of deep-sea yeast

We have isolated 202 strains of deep-sea yeast this year (6 strains from Suruga-Bay; 176 strains from the Mariana Trench; 6 strains from tube-worms in Sagami-Bay and the Iheiya-Ridge; 14 strains from the Manus Basin), and in total 336 strains have been preserved at JAMSTEC. Basidiomycetous red yeasts have been frequently isolated from various deep-sea environments. Because the assimilation tests of carbon and nitrogen compounds were not so useful to identify the basidiomycetous yeasts, we determined internal transcribed spacer (ITS) regions and 5.8S rDNA sequences of 92 type species belonging to the genus *Rhodotorula*, *Sporobolomyces* and *Bensingtonia*, and constructed the database for the identification. Using the database, adequacy of identification in the morphological and physiological characteristics were estimated. Some of isolates identified morphologically and physiologically as *Rhodotorula glutinis* were appeared to recognize phylogenetically as *R. mucilaginosa* group. Tendency to occur the some *Rhodotorula* species was clearly different between animal and mud. An experimentation about isolates which be expected to be new species is in progress.

(c) Preservation of deep-sea microorganisms and sediment samples

Thirty-one microbial type strains were obtained from the International Type Culture Collection Organization were stored in liquid nitrogen, and in total seventy type strains are being kept under the same conditions in our laboratory. This year, we have newly isolated eleven deep-sea strains (6 piezophiles, 2 psychrophiles, 3 thermophiles), and these are being stored in liquid nitrogen. Fourteen deep-sea sediment samples obtained by means of the SHINKAI 2000 system from Sagami-Bay, the Okinawa Trough, and the Izu-Bonin Trough, five samples obtained by means of the SHINKAI 6500 system from the Mid Atlantic Ridge and the South West Indian Ocean, and sixteen samples obtained by means of the KAIKO system from the Mariana Trench and the Japan Trench, were preserved in liquid nitrogen. In total, we have 205 kinds of deep-sea sediment samples in the storage tank.

② Studies on microbial diversity in deep-sea environments

(a) Microbial diversity in deep-sea hydrothermal vent environments and investigation of genetic origin

Molecular phylogenetic analysis of members of naturally occurring archaeal communities in deep-sea hydrothermal vent environments was carried out by PCR-mediated small subunit rRNA gene sequencing. As determined through partial sequencing of rDNA clones amplified using Archaea-specific primers, the archaeal populations in deep-sea hydrothermal vent environments showed great genetic diversity, and most members of these populations appeared to be uncultivated and as-yet-unidentified organisms. In the phylogenetic analysis, a number of rDNA sequences obtained from deep-sea hydrothermal vents were placed in deep lineages of the crenarchaeotic phylum prior to the divergence of cultivated thermophilic members of the crenarchaeota, or between thermophilic members of the euryarchaeota and members of the methanogen-halophile clade. These findings expand our view of the genetic diversity of archaea in deep-sea hydrothermal vent environments and of the phylogenetic organization of archaea.

A novel baro(piezo)philic, hyperthermophilic archaeon was isolated from a deep-sea hydrothermal vent chimney at the Myojin Knoll, the Ogasawara-Bonin Arc, Japan. The cells were found to be irregular cocci and motile with po-

lar flagella. Growth was observed between 60 and 88°C (opt.: 83°C; 30 min doubling time), pH 4.0 and 8.0 (opt.: pH 6.0), 20 and 73 g/l sea salts (opt.: 47 g/l), and 0.1 and 60 MPa (opt.: 30 MPa). The isolate was a strictly anaerobic, chemoorganotroph capable of utilizing proteinaceous substrates such as yeast extract, peptone, tryptone and casein in the presence of elemental sulfur or iron (II). The G+C content of the genomic DNA was 53.5 mol%. Phylogenetic analysis based on 16S rDNA sequences indicated that the isolate was a member of an ancient lineage of Thermococcales, that diverged prior to the formation of two genera *Thermococcus* and *Pyrococcus*. On the basis of the physiological and molecular properties of the new isolate, we proposed the name *Palaeococcus ferrophilus* gen. nov., sp. nov (type strain: DMJ; JCM 10246).

(b) Analyses of microbial diversity in the sediment of the Japan Trench and high pressure cultivation

We successfully obtained a deep-sea sediment sample from the deepest site on the sea bottom in the Japan Trench (a depth of 7,326 m) using the unmanned submersible, "KAIKO" system, without microbial contamination. DNA was extracted directly from the sediment sample and 16S ribosomal RNA gene sequences were amplified, cloned and sequenced. The results indicated that 14 different sequences were present and most of them belonged to the gamma-Proteobacteria branch. This sediment sample was transferred to the DEEPBATH system and cultivated continually at 68 MPa and at 5°C in two kinds of media (Marine Broth: MB, Sulfate Reducing Bacterial medium: SRB), separately. In the SRB culture, *Shewanella benthica* and related piezophilic bacteria were observed, however, in the MB culture, a member of a novel piezophilic genus was detected by 16S rDNA analysis. This novel bacterium was found to produce a substantial amount of docosaheptaenoic acid (DHA) among its cellular fatty acids, and this organism was not detected by analysis of DNA in the sediment. This suggested that the members of this genus may exist as a minor component of the microbial population in the sediment, and the DEEPBATH system was proven to be useful to recover such difficult-to-culture piezophiles.

(c) Analysis of microbial diversity in cold deep-sea environments

The Japan Trench land slope at a depth of 6,400 m is the deepest cold-seep environment with *Calymptogenia* com-

communities. Sediment samples from the *Calypptogena* communities were collected and the microbial diversity in the sediment samples was studied by molecular phylogenetic techniques. 16S rDNAs were amplified by the polymerase chain reaction (PCR) method from DNA extracted directly from the sediment samples. The sequences of the amplified 16S rDNAs selected by RFLP analysis were determined and compared with sequences in DNA databases. The results showed that 33 different bacterial 16S rDNA sequences from the two samples analyzed fell into similar phylogenetic categories, the α -, γ -, δ -, and ϵ -subdivisions of Proteobacteria, Cytophaga and Gram-positive bacteria; some of the 16S rDNA sequences were common to both samples. δ - and ϵ -Proteobacteria related sequences were abundant in both sediments. These sequences are mostly related to sulfate-reducing or sulfur-reducing bacteria and epibionts, respectively. Eight different archaeal 16S rDNA sequences were cloned from the sediments. The majority of the archaeal 16S rDNA sequences clustered in Crenarchaeota and showed high similarities to marine group I archaeal rDNA. A *Methanococcoides burtonii*-related sequence obtained

from the sediment was placed in the Euryarchaeota indicating that *M. burtonii*-related strains in the area of *Calypptogena* communities may contribute to production of methane in this environment. Based on these results, we have proposed a possible model of sulfur circulation within the microbial community and that of *Calypptogena* clams in the cold-seep environment (Fig. 2).

Seven sediment samples taken from different depths of the deep-sea in the range of 1,159 m to 6,482 m were examined. A total of 75 different 16S rDNA sequences (149 clones) analyzed clustered into the Proteobacteria, Gram-positive bacteria, Cytophaga, Planctomyces, and Actinomycetes and many sequences were from microorganisms that showed no phylogenetic affiliation with known bacteria. Clones identical to 16S rDNA sequences of members of the genus *Pseudomonas* were observed in all of the sediments examined. The second group of common sequences cloned from six sediment samples was related to the 16S rDNA sequence of a chemoautotrophic bacterium, a *Solemya velum* symbiont. Five 16S rDNA sequences from three sediments were related to those of an *Alvinella pompejana* epibiont which is a member of the ϵ -Proteobacteria. Only one sequence was obtained that was closely related to the 16S rDNA of the barophilic bacterium *Shewanella benthica* and this might represent a minor population in the deeper sediments. δ -Proteobacteria-related sequences were cloned from sediments obtained from sites near man-made garbage deposits and a *Calypptogena* community. These environments obviously would be richer in nutrients than other sites, and might be expected to show more types of bacteria than other deep-sea sediments. A large number of cloned sequences in this study showed very low identity to known sequences. These sequences may represent communities of as-yet-uncultivated microorganisms in the sediments.

③ Analysis of pressure-adaptation mechanisms in microorganisms

(a) Baro-(Piezo-) physiology

In order to analyze the physiological effects of elevated hydrostatic pressure, we are proposing the establishment of a new research field, "baro-(piezo-) physiology" which can be achieved using recent advanced biological techniques. "What is required for understanding piezo-tolerant, piezophilic or piezo-sensitive phenotypes of microorganisms?" "Regarding environmental sensing, could

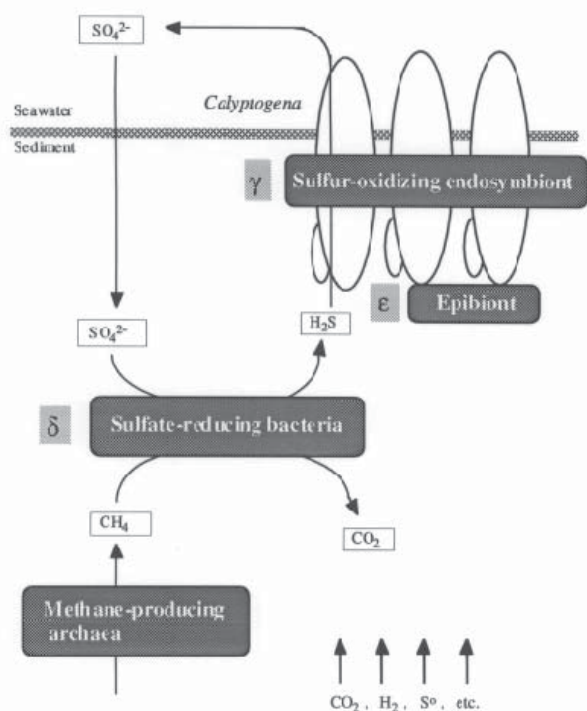


Fig. 2 A model of sulfur circulation within the microbial community and the community of *Calypptogena* clams in a cold-seep environment.

growth inhibition be explained as growth arrest which may be regulated by a certain cellular mechanism?" It might be enough to consider only a few genes to understand the properties of cells under high pressure. At the beginning, we tried to isolate mutants of the yeast *Saccharomyces cerevisiae* capable of growth at higher pressures.

Approximately 400 high pressure growth mutants were obtained. Among them, 34 mutants were classified into four independent groups. These were named HPG (High Pressure Growth) 1, HPG2, HPG3 and HPG4. In a further study, we are going to characterize these mutants and analyze the sensory mechanism by which the cells respond to changes in hydrostatic pressure.

(b) Analysis of the respiratory system in piezophilic bacteria

Two *c*-type cytochromes from the soluble fraction of a deep-sea moderately piezophilic bacterium, *Shewanella violacea*, were purified and characterized, and the genes coding for these cytochromes were cloned and sequenced. One cytochrome with a molecular mass of 8 kDa, designated as cytochrome c_A , was found to contain one molecule of heme *c* per molecule, and the other cytochrome with a molecular mass of 23 kDa, designated as cytochrome c_B , was found to contain two molecules of heme *c* per molecule. The level of expression of cytochrome c_B was lower in cells grown under high hydrostatic pressure conditions (50 MPa) than that in cells grown at atmospheric pressure, however, cytochrome c_A was constitutively expressed and the level of expression was the same under any pressure conditions. These results suggested that the components of the respiratory chain of moderately piezophilic *S. violacea* can be exchanged depending on the growth pressure conditions, and a model of pressure regulation of the respiratory system will be proposed.

We cloned and sequenced the genes for all of the subunits of quinol oxidase from the deep-sea bacterium *S. violacea*, and subsequently the intact enzyme complex, from cells grown at 50 MPa pressure, was partially purified and characterized. Based on the deduced amino acid sequences, the quinol oxidase seems to consist of five kinds of subunits with molecular masses of 74, 43.2, 36.6, 23.2 and 12.4 kDa. The enzyme was found to contain 0.88 mol of protoheme or heme *o* and 0.92 mol of covalently bound heme *c* per mol of enzyme. The protoheme in the enzyme seems to react with carbon-monoxide or cyanide,

and its catalytic activity was found to be 50 % inhibited by 5 μ M cyanide. Two oligonucleotides designed based on amino acid sequences conserved in subunit I of the ubiquinol oxidase of *E. coli*, *Acetobacter acetii* and *Paracoccus denitrificans* were used to amplify a fragment by PCR for use as a probe. A λ -phage library of *S. violacea* chromosomal DNA was constructed and screened with the above probe and a 1.9 kb fragment containing a putative open reading frame for the whole subunit I gene (*cyoB*) of quinol oxidase was thereby obtained. Nucleotide sequence analysis of the region neighboring the subunit I gene revealed that the genes (*cyoA*, *cyoC*, *cyoD* and *cyoE*) coding for the other four subunits (II, III, IV and V) were clustered upstream and downstream of the *cyoB* gene in the order *cyoA*, *cyoB*, *cyoC*, *cyoD* and *cyoE*. Analysis of the deduced amino acid sequences of the *cyo* subunits showed that this oxidase is structurally related to and has high sequence similarity to the *Escherichia coli* *bo*-type quinol oxidase. Northern-blotting analysis of the RNAs from *S. violacea* cells grown under several pressure conditions showed that this enzyme is expressed at a high level when the bacterium is grown under elevated pressure conditions.

(c) Studies on transcription mechanisms in deep-sea piezophilic bacteria

We have performed studies focusing on the RNA polymerase of the deep-sea bacterium *Shewanella violacea* strain DSS12, with the aim of purification of the transcriptional apparatus and with the aim of isolation of the genes encoding its components. In this study, we isolated the genes encoding the subunits of the RNA polymerase core enzyme, α (*rpoA*), β (*rpoB*) and β' (*rpoC*) from this bacterium. Sequence analysis showed that the gene organization was as follows: β - *str* - S10 - *spc* - α , in this order. This deep-sea isolate is Gram-negative, but the gene organization differed from that of *E. coli*. It was similar to that of *B. subtilis*. The physiological significance of this difference in gene organization is uncertain. In addition, we showed that the *rpoA* gene isolated from strain DSS12 complemented the defect in an *E. coli* *rpoA112* mutant.

We are also now examining the molecular mechanisms of gene regulation under high pressure conditions. A pressure-regulated operon was discovered in piezophilic *S. violacea* strain DSS12, and the expression of genes in this

operon was shown to be controlled by elevated pressure at the level of transcription. The σ^{54} -consensus sequence was also found in this operon. Subsequently, the *rpoN* gene encoding this sigma factor (σ^{54}) in strain DSS12 was cloned and its nucleotide sequence was determined. Amino acid sequence analysis showed that the σ^{54} of this strain has 62.8% amino acid identity with the σ^{54} of *E. coli*. The DNA-binding (promoter recognition) domain at the carboxyl-terminus of the σ^{54} of *S. violacea* is well conserved and contains two motifs, the helix-turn-helix motif and the RpoN box. Transcription by the σ^{54} -containing RNA polymerase requires the bacterial signal-transducing protein NtrB and the enhancer-binding activator protein NtrC. The *ntrBC* genes encoding NtrB and NtrC were cloned and the nucleotide sequences were determined. The amino acid sequences of the *ntrBC* products of *S. violacea* are homologous to those of NtrB (48.5% identity) and NtrC (70.2% identity) of *E. coli*.

(d) Effects of hydrostatic pressure and temperature on membrane composition in a piezo(baro)tolerant bacterium

A piezo(baro)tolerant member of the genus *Pseudomonas* was isolated from deep-sea sediment collected from the Japan Trench, at a depth of 4,418 m. The growth temperature was found to affect the hydrostatic pressure range in which the bacterium could grow; the optimum hydrostatic pressure for growth shifted to a higher pressure with increasing temperature. We examined the lipid composition of the inner membrane of cells grown at various hydrostatic pressures and temperatures. The fatty acid components of the inner membrane lipids were C16:0, C16:1, C18:0 and C18:1. Under all growth conditions employed, the relative concentrations of total C16 (C16:0 + C16:1) and total C18 (C18:0 + C18:1) were approximately 60 % and 40 %, respectively. The change in ratio of C18:1 to C18:0 with changing temperature was larger than that of C16:1 to C16:0. The ratio of total unsaturated fatty acids to total saturated fatty acids changed with varied temperature and hydrostatic pressure. The phospholipid components of the inner membrane were phosphatidylethanolamine (PE), cardiolipin (CL), phosphatidylglycerol (PG) and phosphatidylserine (PS). The relative proportion of CL increased with increasing temperature at pressures in the range of 0.1 to 30 MPa, and decreased with increasing hydrostatic pressure at 30 and 37°C; it is worthy of note

that the effect of elevated hydrostatic pressure is comparable to the effect of low temperature.

④ Mechanisms responsible for organic solvent tolerance in bacteria

The *CyoABCDE* operon coding for a homolog of cytochrome o ubiquinol oxidase, which is a terminal oxidase in the respiratory chain, was found to be involved in toluene tolerance in *Pseudomonas putida* IH-2000. Cell surface hydrophobicity is reported to be important for organic solvent tolerance. In strain IH-2000, decreased hydrophobicity (increased hydrophilicity) was observed in cells grown in the presence of an organic solvent with a low log *P* value. Moreover, preculture of cells of strain IH-2000 with organic solvents with a log *P* value higher than that of toluene was found to prevent loss of viability upon abrupt exposure to toluene. These results indicate that lowered hydrophobicity of the cell surface is one of the factors involved in bacterial acclimation when exposed to organic solvents and that strain IH-2000 can adapt to altered environmental conditions through changes in cell surface hydrophobicity.

3) Biological response research

① Elucidation of mechanisms of physiological accommodation to extreme environments in multicellular organisms.

Chemical signals trigger cells to discharge intercellular signaling molecules (cytokines) which function to activate intracellular information networks. We were interested to examine the possibility of cytokine secretion under elevated hydrostatic pressure conditions. In cultures of human skin fibroblasts, secretion of interleukin-6 (IL-6) and -8 (IL-8), which are signaling molecules known to affect interactions between cells in the immune response, was found to be promoted by pressure stress. Furthermore, we monitored the expression of these genes. Under optimal pressure conditions for production of IL-6 and IL-8 (20-30 MPa at 20-30 min), the productivity was found to be twenty-fold greater than that under atmospheric conditions. We also examined the pathways of production of IL-6 and IL-8 in the cells. Consequently, it was found that protein kinase C activated IL-6 production under conditions of pressure stress.

② Physicochemical studies on colloidal dispersions and solutions of biopolymers in supercritical water

The physicochemical properties of water under high

pressure and high temperature conditions such as those surrounding microorganisms in the deep sea will be studied to elucidate the mechanisms of microbial adaptation to extreme conditions. These studies will focus mainly on supercritical water as an example of an extreme state

of water. Three instruments (a dynamic light scattering instrument, an UV-vis absorption spectrophotometer, and an optical microscope) for studying corrosive supercritical water have been developed and set up.

Frontier Research Program for Subduction Dynamics

1. Introduction

Research has been carried out since October 1996 under the auspices of the Frontier Research Program on Earthquakes.

Impetus was given to research directed at understanding and mitigating the effects of earthquakes following the 1995 southern Hyogo-ken ("Kobe") earthquake. This resulted in the creation of the Frontier Research Program on Earthquakes, and specifically the Japan Marine Science and Technology Center's (JAMSTEC) Frontier Research Program for Subduction Dynamics (henceforth "Frontier"). This program's aim is to utilize JAMSTEC's expertise in marine science to understand the seismogenic mechanics of giant earthquakes occurring in marine trenches.

Establishment of Frontier took place in FY 1996, and research has been carried out since 1997 under the following three themes :

- (1) Studies of oceanic lithosphere structure
- (2) Long-term monitoring of seafloor changes
- (3) Numerical simulation of lithosphere deformation

2. Research Outline

1) Studies of oceanic lithosphere structure

To clarify seismogenic mechanisms, it will be necessary to first survey, reliably interpret and model quantitatively the subsurface structure and physical conditions of the seismogenic environment.

Frontier is carrying out marine geophysical surveys in tandem with JAMSTEC's Deep Sea Research Department using a multi-channel seismic (MCS) profiler system and self-floating ocean-bottom seismometers (OBS), deployed from the Research Vessel (R/V) "Kairei". The results of these surveys are being combined with gravity, magnetic, heat flow and bathymetric data in the evolving geophysical database.

The process of updating and developing the database will continue with the cooperation of researchers within JAMSTEC and those from outside organizations.

2) Long-term monitoring of seafloor changes

Observations made by the long-term seafloor observatory located off Cape Muroto are being used both to improve the accuracy of structural models and to corroborate the obtained results. Additionally, precursory and postseismic changes in heat flow related to activity are being monitored.

A database containing the results of geologic investigations and research results is helping with this process.

3) Numerical simulation of oceanic lithosphere deformation

Numerical modeling incorporates the results of the

foregoing to quantify crustal deformation, verify and assess previous model's results, and construct long-term models of deformation. Existing finite element modeling software is being utilized at the same time as new modeling techniques aimed at problems specific to earthquake-related research are developed.

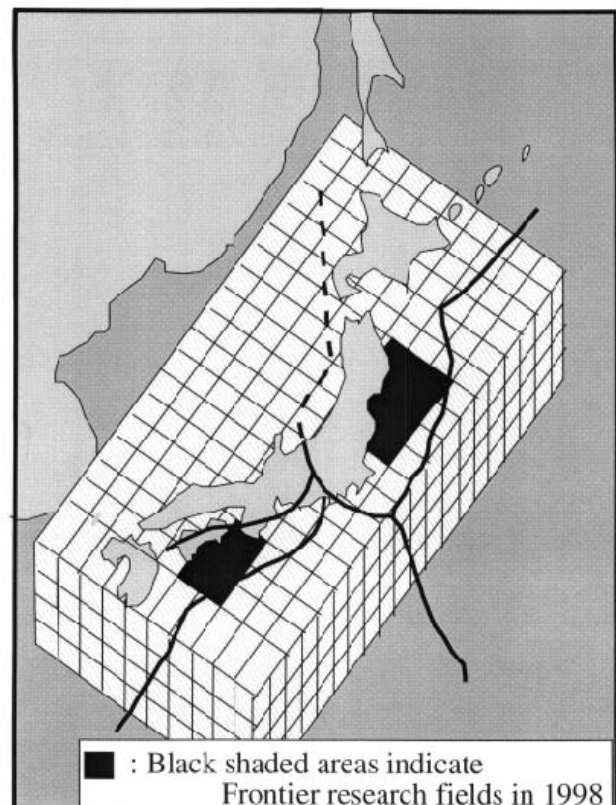


Fig. 1 Numerical Model for Crustal Deformation

Frontier Research Program for Subduction Dynamics

3. Main research progress

To clarify seismogenic mechanisms, numerical modeling of regional deformation as depicted in Fig.1, along with continuous improvements of the models are considered necessary.

1) Studies of oceanic lithosphere structure

Investigations are being carried out in the vicinity of the Nankai Trough and Japan Trench according to the research plan given in Fig.2. During FY 1997 and 1998, the R/V "kairei" completed successful research cruises in the

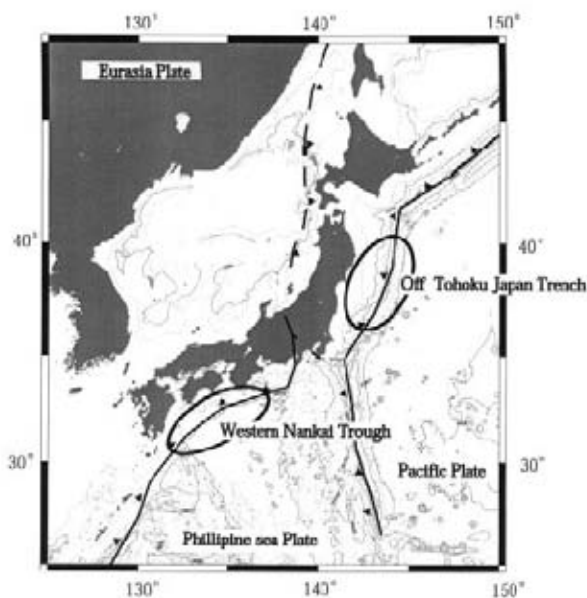


Fig. 2 Sites for Marine Seismic Survey (MCS, OBS Seismic Survey)

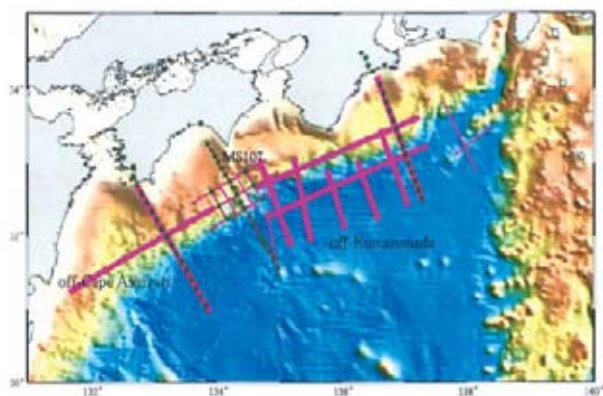


Fig. 3 1998 Seismic Survey Lines Made by Frontier Research Program for Subduction Dynamics

Nankai Trough off Muroto (1997), off Kumanonada (1998) and off Ashizuri (1998) as shown in Fig.3, and in the Japan Trench off Sanriku (1997) and off Fukushima (1998) as shown in Fig.4. During the former, the structure of a seismic thrust off Muroto was determined (Fig.5). As a result of the survey in the Japan Trench off Sanriku carried out in 1997, a horst and graben structure was clearly delineated and its relationship to seismogenesis will be addressed henceforth. The Sanriku investigation revealed subduction geometry in the Japan Trench, which will be jointly interpreted in detail with results of the concurrent and collaborative Northeast Japan Crustal Structure experiment.

2) Long-term monitoring of seafloor changes

During FY1997 and FY1998, procedures for analyzing data acquired by the Muroto long-term seafloor observatory were developed. Earthquake hypocenter location was performed in collaboration with Kochi University. Fig.6 illustrates the epicenters of marine and onland earthquakes. Subsequent research will address the relationships between subsurface structure revealed during ongoing investigations and earthquake locations, and incorporate deformation modeling.

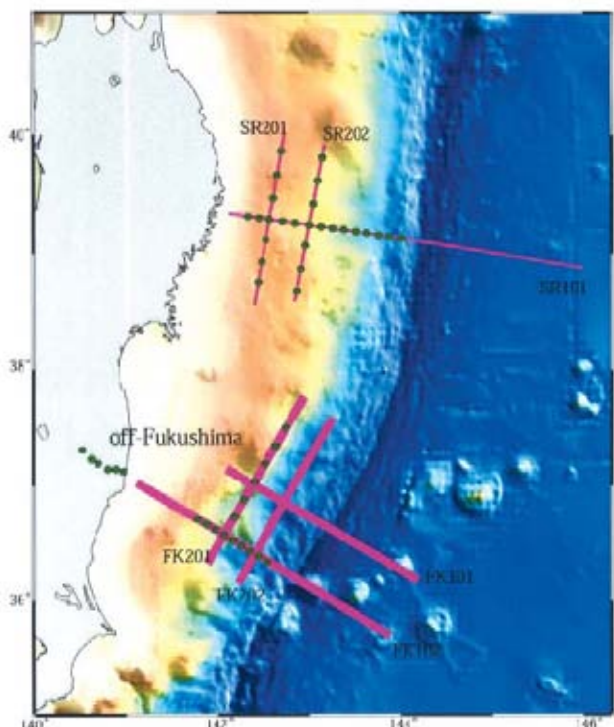


Fig. 4 1998 Seismic Survey Lines Made by Frontier Research Program for Subduction Dynamics

Frontier Research Program for Subduction Dynamics

Additionally, system software necessary for development of a database was acquired, and case studies are being made.

3) Numerical simulation of lithosphere deformation

Lithosphere deformation modeling with time scales of tens to tens of thousands of years is necessary for interpreting the seismogenic mechanisms of giant, ocean trench earthquakes. In particular, ongoing testing and refinement

using real observations of such models and their predictions are of paramount importance.

In FY1998, elastic and viscoelastic simulations have been made, and the effects of each physical property and the model's boundary conditions are being analyzed. As a result of this analysis, the quality and accuracy of the model will be improved.

Fig.7 illustrates the cross-sectional model for subsur-

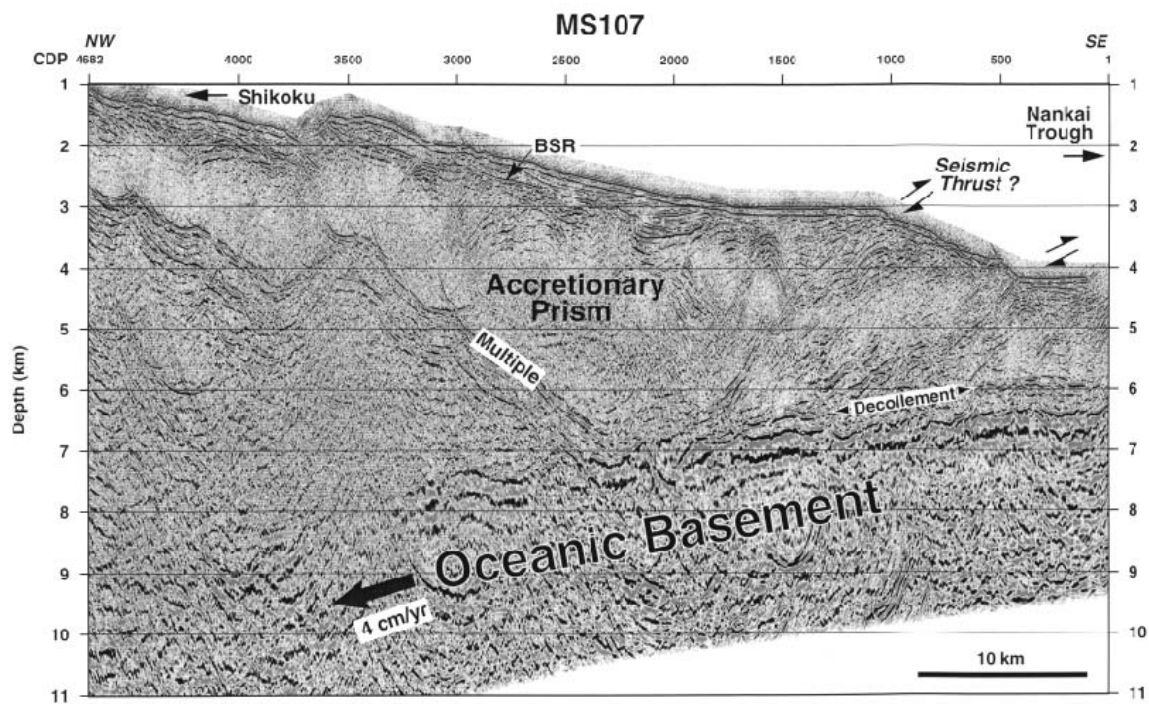


Fig. 5 Depth Migrated Section by Reflection Survey in Line MS107

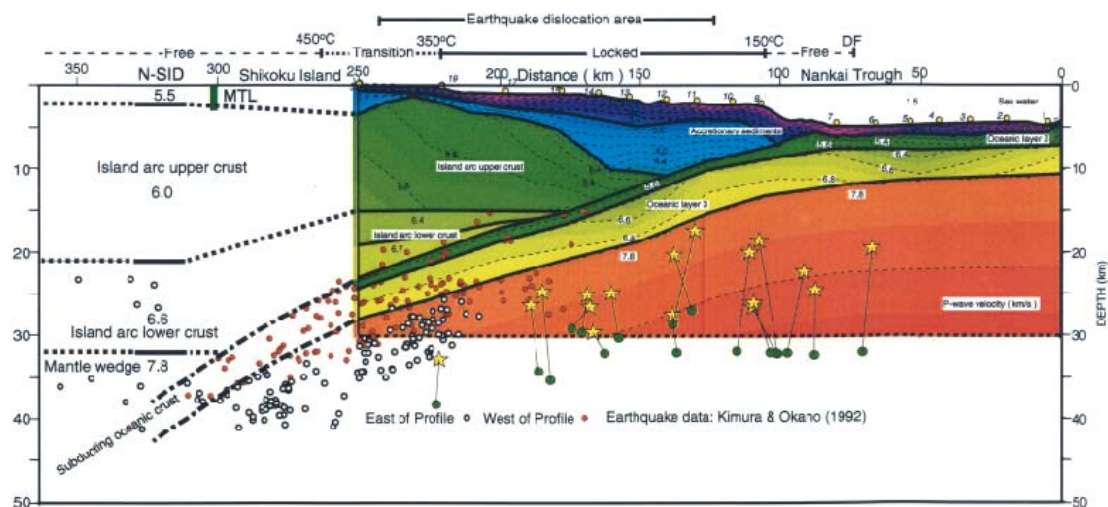


Fig. 6 Deep Structure by OBS & Hypocenter in Western Nankai

Frontier Research Program for Subduction Dynamics

face structure off Muroto in the western Nankai Trough. Fig.8 and Fig.9 show finite element grids used for the calculations of coseismic displacement and results of calculations for the 1946 Nankai earthquake.

Calculations constraining rupture to the plate boundary are compared with the inferred seafloor deformation in Figure 9a. However, the sharp peak in the calculated result is too narrow, and results in an unreasonably strong

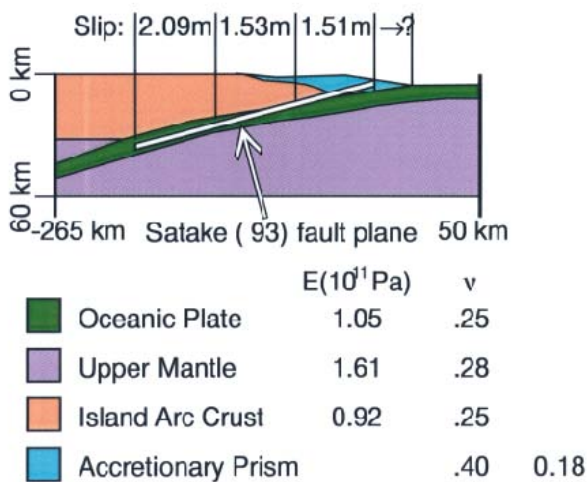


Fig. 7 Nankai EQ Slip Model and Material Properties

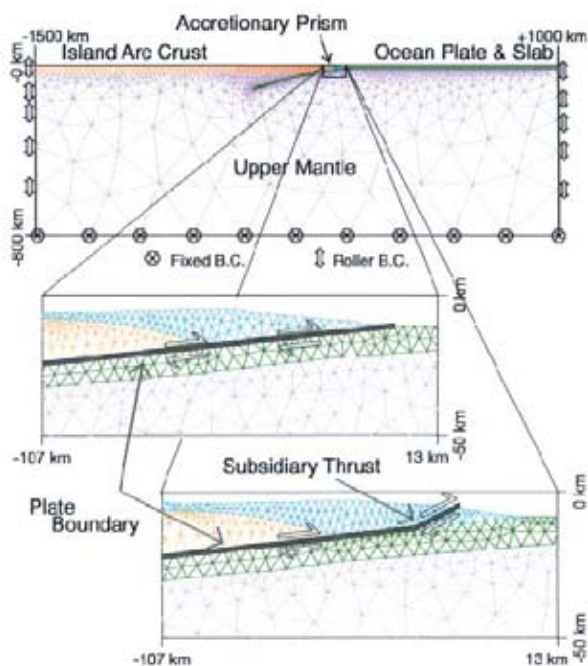


Fig. 8 Finite Element Grids Used for the Calculations Displacement

stress concentration in the weak material of the accretionary prism. This stress concentration can be relaxed by allowing the rupture to propagate all the way to the seafloor deformation.

On the other hand, if rupture proceeds along the plate boundary only to the base of the subsidiary thrust imaged by the MCS profile, and from there ruptures upward, the seafloor deformation is fit relatively well (Figure 9b). Thus, This latter model for the updip limit of rupture is best because it fits the seafloor deformation and is also consistent with the weakness of the material comprising the accretionary prism.

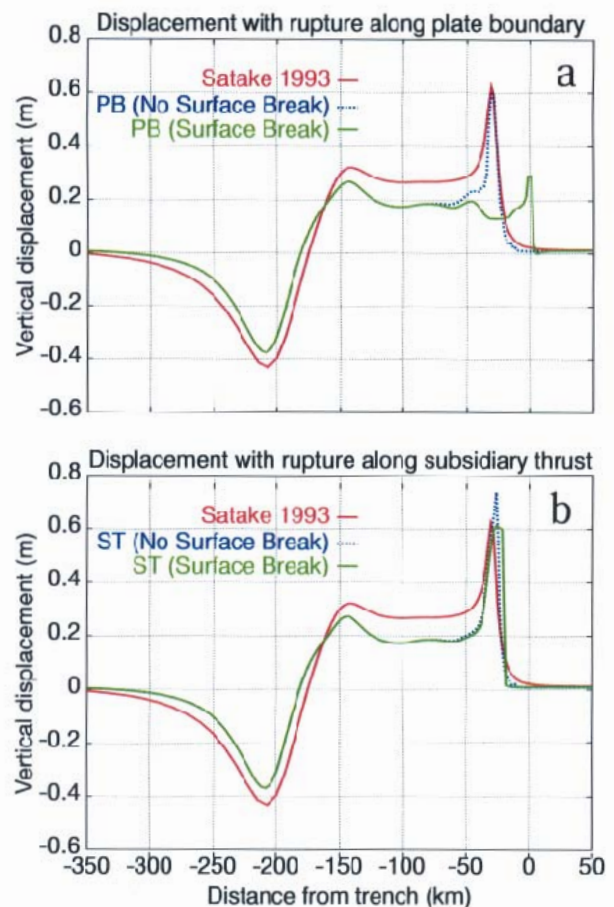


Fig. 9 Calculations of Coseismic Displacement for the 1946 Nankaido Earthquake

Frontier Research Program for Subduction Dynamics

Conclusion

Resolving the effects on numerical models of different physical properties, interplate coupling and other conditions is difficult with incomplete or sparse geophysical datasets. Notwithstanding this, structural models of the lithosphere compiled from data in the steadily evolving geophysical database are being constructed, and at the

same time increasingly sophisticated deformation modeling software is being developed. On the basis of this research, and the verification of model results with crustal monitoring data, long-term crustal deformation can be investigated with the aim of producing predictive seismogenic models.

Frontier Research System for Global Change

(1) Overview or research activities

The Frontier Research System for Global Change regards the planet as one system, and is aimed at elucidating the complex interaction between the atmosphere, oceans and land masses, using numerical models. These simulations contribute towards the realization of high accuracy forecasts of many global phenomena. Our research activities are being developed as a joint project with the Space Development Project Group.

The special feature of this system is that, as a new research project suited to the 21st century, it brings together from far and wide, researchers from within and outside the country to work under outstanding research supervisors. Frontier employs a mobile research worker system, where employment contracts are on a single-year basis and renewed according to research progress. We have introduced a well-defined wage system whereby outstanding researchers are rewarded commensurate with ability, regardless of age. This mobile research worker system has made it possible for this flexible research organization to achieve the goal of predicting global change.

To implement this research, a strong computer network is essential to carry out experiment calculations. We are successfully preparing a computer environment that does not impede the progress of research in terms of computational ability and calculation time. In particular, the introduction of a "Global Variation Prediction Research Information System" based on a large super computer was agreed by the 1998 third revised budget, and is scheduled to go into operation from this October. Furthermore, to create an environment where researchers can devote themselves to research, we have set up a research promotion staff system, which provides out clerical and technical support.

Currently, in addition to the domestic Global Variation Research Institute (Tokyo headquarters and Tsukuba Satellite, IGCR), we are carrying out research activities with a total of more than 130 researchers (as of the end of March, 1999). This includes researchers from the International Pacific Research Center (IPRC) in Hawaii, established as part of joint research for predicting global variations based on a U.S.-Japan common agenda, and from the International Arctic Research Center in Alaska. In March we also sponsored workshops and symposiums with the EU, and this system is performing a pivotal role of international cooperation in Japan's global variation research and forecasting field.

(2) Content of main research activities

1. Climate Variations Research Program

We are advancing research in a three-group configuration consisting of the Variability Model Group, Data Analysis Group and Predictability Research Group. From an early date we made a start on ocean circulation modeling, and with high resolution models aimed at forecasting ocean circulation variations in the western Pacific rim area, such as Kuroshio variations, we are now able to reproduce detailed structure of the oceans and perform stable computations. Moreover, with sub-group models, which place emphasis on low latitudes, we have obtained results showing for instance that independent seasonal variations are occurring in the Indian Ocean and Bay of Bengal that rival El Nino. This result appeared in the September 1999 issue of the science magazine, "Nature", and is being hailed as a revolutionary result. The mid-latitude ocean circulation research subgroup is constructing a planetary ocean circulation model with a horizontal resolution that will be of world class standard, and under joint research with the Aeronautics and Space Technology Research Institute of the Science and Technology Center, is in the midst of continuing seasonal variation experiments of this model, and is at the stage of having completed calculations of 12 years.

Medium- and high-latitude ocean circulation is in the process of adjusting initial disturbances, but for circulation in low latitude regions, it is thought that a state of approximate dynamic equilibrium has been realized. The group introduced the results of this model at this year's HPC Asia 98, and it is even gaining a certain amount of acclaim in the field of high performance computer science. [Figure 1.1 shows an example of calculation results based on the planetary circulation model with a mesh with a horizontal resolution of 1/6 degrees (about 18km on the equator). Surface ocean currents and medium-scale vortex activity are simulated.]

Furthermore, we are in the midst of developing a compound model with the aim of simulating variations of the combined atmospheric-ocean system for the Pacific Ocean in the near future. Meanwhile, the group that studies the actual state of atmospheric and oceanic interannual variations (DICE), is performing data analysis from a unique perspective with regards to atmospheric and oceanic variations in the northern Pacific Ocean. This is a very active field of research worldwide, and is continuing to yield results, for example, that variations in the tropical regions and variations in high latitude regions are different.

2. Hydrological Cycle Research Program

This is composed of three groups : the Hydrological Cycle Process Over a Wide Area Group, the Hydrological Cycle Process on Land Group and the Clouds and Precipitation Process Group. Associated with GAME (GEWAX Asian Monsoon Experiment) of the international cooperative research program, it is aimed as a whole at producing sounder models of the precipitation process and humidity process on land based on data obtained from outdoor observations, which will contribute to the improvement of the hydrological cycle process in next-generation climate models. We gathered special observation data in Thailand (Tropical zone), Tibet, Duihe Basin (subtropical region) and Siberia (frigid zone) that goes hand-in-hand with GAME intensive observations, and have made a start on preliminary analysis. Moreover, we are also attempting models of atmosphere-land surface water exchange through hydrological cycles and vegetation in areas of perpetually frozen soil. The Clouds and Precipitation Process Group is developing a cloud resolution model, and is participating in the international comparative experiment on the simulation of convection clouds observed above the tropical zone of the Pacific Ocean (part of GCSS).

3. Global Warming Research Program

This is composed of three groups : the Global Warming Research Group, Carbon Cycle Research Group and Paleoclimate Research Group. In order to investigate the effect of global warming on typhoons, they carried out an experiment to see how results change according to differing convection schemes and differing sea surface temperature distribution. In all cases, results showed that typhoons decrease in number with warming. With regards to carbon cycle modeling, they took part in the Ocean Carbon-Cycle Model Intercomparison Project (OCMIP), and performed an experiment on atmosphere-ocean material interchange in line with that. They have also begun preparations for constructing a model that also incorporates changes in ocean ecological systems. In order to collaborate global warming predictions, the Paleoclimate Research Group, which investigates the mechanism of past climate variations and studies whether or not they can be generated in models, made a start on a simulation based on a high resolution climate model under conditions of the last Ice Age (about 20,000 years ago) and the Period of Climate Warming (about 6,000 years ago).

4. Atmospheric Composition Research Program

This group focuses on climate variations and the physical and chemical processes of transportation, degeneration and settling of microscopic atmospheric components involved in environmental pollution of the atmosphere mainly in the Asia-Pacific region (including the central Eurasian continent and Arctic region). It aims to produce a chemical weather map of this area, together with constructing a model that forecasts future atmo-

spheric composition fluctuations including feed-back to climate variations, and making advanced future predictions.

5. Integrated Modeling Research Program

The development of a "next-generation climate model" for conducting research utilizing the planetary simulator (a joint project of Japan Atomic Energy Research Institute, Space Development Foundation and this center) is underway. The simulator possesses 1,000 times the computational ability of current super computers and in particular, it is designed to investigate points concerning the handling of convection clouds, and advance development in the following two directions.

- (A) To carry out conventional parametrization (using the physical volume of a lattice to estimate the effect that phenomena, on a smaller scale than nucleons, have on the physical volume of a lattice) at a horizontal resolution of about 30-50 km, and add improvements according to resolution. With the planetary simulator, 10-20-year integration will probably be possible in 2-3 days.
- (B) A wide-area cloud resolution model with horizontal resolution of about 1km, and a planetary atmospheric model with horizontal resolution of about 5km, which is aimed at directly handling tropical zone cloud clusters (a state where a cumulonimbus clouds form one group and are structured into one large cloud mass). As resolution increases, it will be necessary to directly handle processes other than that as well, so we will commence basic research for that purpose.

With regards to ocean models and sea ice models also, we will advance research on processes that form the basis of models.

6. International Arctic Research Center (IARC)

Research is focused on revealing the role of the Arctic region in planetary climate variations, and at the same time detecting and forecasting the impact that appears conspicuously in the Arctic region due to process in which global warming and other such global variations occur. There are two initial research themes, as follows :

- (A) Elucidation of the combined ocean-sea ice-atmospheric system
- (B) Elucidation of biochemical processes and ecological systems in the Arctic region. Further dividing these themes into several issues, we prepared a research structure, for example advertising for the necessary research workers.

7. International Pacific Research Center

The IPRC concentrates on shedding light on natural climate variations in the Asia Pacific region and revealing the possibly of predicting them, as well as revealing the regional characteristics of environmental changes on a global scale, such as warming.

Through cooperation between the U.S. and Japan, we are supporting the following four research themes, and are advancing the formation of groups.

Frontier Research System for Global Change

- (A) Climate of the Asia Pacific (region)
- (B) Possibility of forecasting oceanic variations of the Pacific region
- (C) Asia-Australian monsoon and hydrological cycle
- (D) Effect of global changes on the climate of the Asia Pacific region

We have already made a start on each of the themes, and are continuing to yield results in the following : high-resolution

modeling of ocean compound layers and investigations based on ocean models of cycles on equal-density surfaces within main temperature layers, thought to be related to variations with a timescale of years to decades analysis of atmospheric overheating caused by monsoon rainfall in the Asia Pacific region; and accurate modeling of the transmission of equatorial waves based on a special numerical computation law.

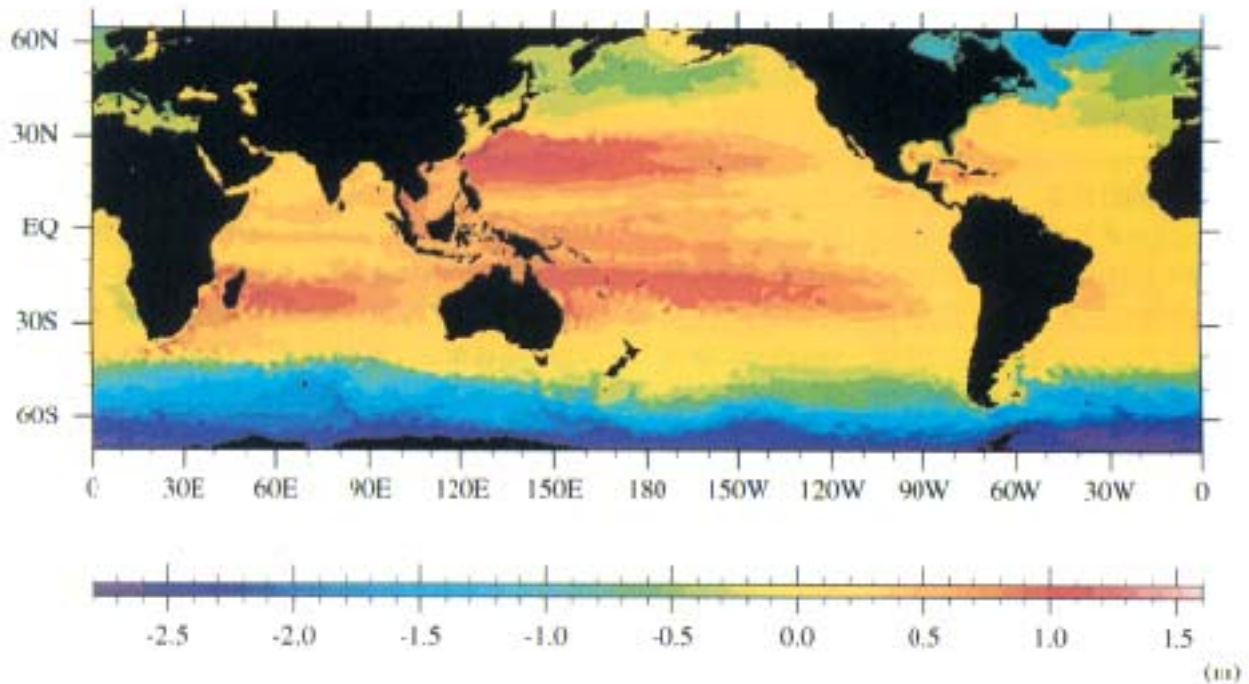


Fig. 1.1 Advanced distribution figure of average sea surface dynamics for January, obtained from a world ocean cycle model of resolution 1/6 degrees. Numerical calculations were performed in a numerical wind tunnel at the Aeronautical and Space Technology Research Institute of the Science and Technology Agency.

Computer and Information Office

(1) Overview of duties

The Computer and Information Office(CIO) is a system that was reorganized as such by integrating Technical Information Services(TIS) and the Scientific Computing Division(SCD). This was designed as a division to introduce activities through publications and the Web in order to effectively diffuse JAMSTEC's research results, and to efficiently manage and provide observation data, etc, without being particular about the medium. Moreover, in order to realize the publication of observation data obtained through ship-based investigation and observation activities in addition to this, it became necessary to position as a new duty of the CIO, a "data quality control structure" that regularly performs revision of observation data, accuracy improvement and so forth.

Cited as features of the system are its function as a research support section and management section, in addition to involving research organizations that realize the development of information dispatch technology using the Internet, and research support technology concerning data processing technology and frontier computer science technology.

The contents of main duties are as follows.

- Matters concerning the collection, classification, organization, processing, provision and storage of information concerning marine science and technology
- Matters concerning technical consultation concerning marine science and technology
- Matters concerning the numerical analysis treatment, processing and visualization of many types of data concerning marine science and technology
- Matters concerning the development and operation of database for many types of observation data concerning marine science and technology
- Matters concerning many types of data analysis processing using electronic computer
- Matters concerning the management and operation of electronic computer systems and network systems
- Matters concerning investigation of frontier computer technology
- Matters concerning the investigative research of data quality control technology

Apart from this, in the U.S.-Japan Global Observation Information Network (GOIN) we participated in a joint U.S.-Japan demonstration in 1995, followed by participation in GOIN workshops in 1996, 1997 and 1998; we are also introducing JAMSTEC databases, etc. Moreover, through actively promoting joint research, current research and other research activities, and accurately and promptly providing information relating to marine science and technology, we aim to assume a role in support activities in the Center and as a body dedicated to various types of marine science and technology information in this country.

(2) Collection, management and provision of books and series publications

As an important information duty, we store a wide range of marine-related books, magazines and technical reports, etc., after collecting, classifying and organizing them. In 1998, we renewed the information management and provision system (ILIS/X-EL) we constructed to manage and search library material so that it would correspond to the Web, and as a "JAMSTEC Book Search" database, we made it easier to use than before. Furthermore, through holding library administration consultations, we are striv-

Table 1 Books

Type	Number in stock	Newly purchased
Japanese books	6,658	876
Foreign books	2,947	285
Donated books	5,804	220
Total	15,409	1,381

Table 2 Journals

Type	Number in stock	Newly purchased
Japanese journals	524 titles	23 titles
Foreign journals	262 titles	14 titles
Total	786 titles	37 titles

Computer and Information Office

Table 3 JAMSTEC related publications

Type	New publication
Periodic publications	12
Consigned research reports	4
Commissioned research report	0
Others	11
Total	27

ing to create an environment that facilitates the use of library materials by users.

1) Status of owned library materials

Tables 1-3 show library materials owned at the end of 1998.

2) Holding of library administration consultations

In the CIO's collecting and managing of library materials based on library material management rules, it held library administration consultations on three occasions based on the main points of library management duties and administration, in order to reflect the opinions of book users and strive to effectively use library materials.

(3) Collection of domestic and foreign information, etc.

The oceans occupy a vast area on the planet, but it is still virtually unknown, and it is obvious that research and development concerning the oceans can not be accomplished by one organization or one country alone. The cooperation of relevant domestic and foreign organs as well as the government-level cooperation of concerned countries, are essential. Moreover, the information requirements concerning JAMSTEC R&D and business are also becoming complex and multi-faceted, and the amount of information on marine science and technology is also increasing. And at present, as R&D activities in particular are becoming integrated, interdisciplinary and international, maintaining cooperative relationships with domestic and overseas information-related organizations, and collecting marine-related information, are necessary.

1) Domestic activities

- ① We participated in the "Domestic Group Exchange of Oceanographic Data" (Secretariat: Hydrographic Department, Maritime Safety Agency), a liaison group concerning marine data in this country, and grasped information on the current state of publication of marine

material in this country and the status of publication in international institutions.

- ② We took part in the Kanagawa Prefecture Information Department's Workshop (Shinshiken), an exchange group of the reference rooms of companies and public organizations located within Kanagawa Prefecture, and grasped the latest information concerning improvement of the administration of computer and information offices.
- ③ We took part in the "Technical Library Managers and Administrators Seminar" and general meeting held through sponsorship by the Technical Libraries Council, a group of technical libraries, and grasped the latest information concerning improvement of the administration of computer and information offices.

2) International activities

For the time being, dealing with the increase of global environmental issues and other needs, and grasping through cooperation with other countries the real situation of the oceans, which cover 70% of the earth's surface and are difficult to access by humankind, is a worldwide trend, and the Center's R&D is also turning international. Therefore, taking into account this kind of situation, the Computer and Information Office is developing information collection activities based on the idea that it is necessary to constantly ascertain the trends of the key countries and major research institutions of Europe and North America, which are advanced countries in marine science, as well as international organizations and international research programs.

① Management and provision of IOC publications

The Intergovernmental Oceanographic Commission (IOC) is an institution that was established with the aim of furthering knowledge concerning natural phenomena of the oceans and ocean resources, and from 1993, this Center became the second within the country to receive IOC publications.

The latest information of IOC publications we have obtained is always carried in JAMSTEC News (Natsushima).

② IAMS LIC

IAMS LIC was established in 1975 with the aim of exchanging marine science information, and 38 countries and about 200 institutions throughout the world are members. This Center is this country's only member institu-

Computer and Information Office

tion, and has participated since 1993. We attended the 24th annual general meeting held in Reykjavik, Iceland, in September 1998, and exchanged information with all participating countries.

③ ASFA

ASFA is a public database that four organizations of the United Nations are promoting, with all-round marine science and technology as the subject. The Computer and Information Office has installed input equipment and is cooperating in the construction of the ASFA database. This Center is cooperating in the form of providing English-language abstracts of "JAMSTEC Deep-Sea Research" and "Japan Marine Science & Technology Center-Testing and Research Report".

④ Information concerning international institutions and international research programs

We believe that the trends of international institutions and international research programs is important information that will decide the major framework of future marine science research, and have made efforts to continue to obtain information.

(4) Editing and publication of many types of publications

In order to widely diffuse research results in the Center, and in order to provide enlightenment relating to the oceans, we edited and published the publications shown in Table-4 during 1998.

(5) Surveys and information activities

We provide many types of information to users within and without the Center, and ensure that users can effectively utilize materials or information.

1) Books and magazines

- ① A guide to new arrival books is carried in the "Natsushima" Center news.
- ② We have changed the contents service of newly-arrived magazines from provision on paper to electronic information, and are ensuring that contents can be viewed online.

Table 4 JAMSTEC publications

Name of publication	Contents	PY 1998 Publication
Report of Japan Marine Science and Technology Center	Collection of scientific papers of research results	Rrport NO.38 and 39
Collected Abstracts No.36 to 39 of Japan Marine Science and Technology Center	Collection of summaries of above (English, Japanese)	No.9
JAMSTEC Journal of Deep Sea Research	Collection of scientific papers on marine survey research results	No.14
Collected Abstracts No.3 for JAMSTEC Journal of Deep Sea Research No.112 to 13	Collection of summaries of above (English, Japanese)	No.3
JAMSTEC	Educational document on marine information	39th to 42th edition
Japan Marine Science and Technology Center Annual Report	Report on the activities of JAMSTEC	FY 1997
JAMSTEC 1997 Annual Report	Report on the activities of JAMSTEC (Annual Report in English)	FY1997

Table 5 Externa database usable at present

	Name of database	Outline
①	JOIS	Science & tecnology and medical focument information (Japanese/English)
②	STN International	About 200 types of database can be used (English)
③	G-SEARCH	Domestic and foreign database window (Japanese-English)
④	DIALOG	About 450 dataase are usable (English)
⑤	JOIDES	Database provided by Hydrographic Department Maritime Safety Agency (Japanese)
⑥	KIS-NET	Database relative to chemical substances (Japanese)
⑦	COPERNICS	No.3 sector network of Kanagawa prefecture (Japanese)
⑧	NACISIS	Database for support of Scientific research activities (Japanese/English)

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2) Internal and external databases

- ① Implementation of a book search service through the “JAMSTEC Book Search” database
- ② Implementation of agency search by the use of external databases concerning location guides to documentation that is not owned (Table-5)
- ③ Twice-monthly provision of information concerning specific themes using Japan Information Center of Science and Technology (JICST)’s SDI service
- ④ Number of cases of usage of external databases by users: 293

3) Current information

- ① Provision of newspaper article information on the oceans as a daily “Newsletter”
- ② Providing an index of ocean-related newspaper articles as “Newspaper Information on the Sea” on our home page
- ③ Provision of conference and exhibition information on our home page whenever necessary
- ④ Printing of publication information on IOC publications in the “Natsushima” Center news and printing of the Oceanographical Society of Japan bulletin “Sea Research” whenever necessary

4) Reference service, etc.

- ① Implementation of a reference service of owned books, magazines and material
- ② Providing consultation and introduction in respect to external inquiries as a liaison service concerning marine science and technology

(6) Operation of information system

1) Improvement of the functions of the information management and provision system

This is a system for managing books and magazines, etc., owned by the Japan Marine Science and Technology Center; this year, we improved the system so that it can be accessed from Web browsers, and renewed it as the “JAMSTEC Book Search” database.

2) Operation of JAMSTEC home page

In order to make full-scale information transmission activities using the JAMSTEC home page in the said year, we planned and executed renewal of the English-language version Center home page, and continuing on from renewal of the Japanese language page in the previous year, worked hard to create an appealing home page that would

be of interest to the general public. Moreover, as a second installment of the Enlightenment Page for Young People, we followed up the previous year’s “Deep Sea 6500” page by creating a page whose subject matter is the “activities of oceanographic observation vessels”.

(7) Equipment status of computer system

1) Super computer system

In order to scientifically elucidate environmental issues of a global scale, it is important to explain the role played by the vast oceans, and not only precise observations by observation instruments, but also the explanation of various ocean phenomena by mathematical analysis methods and predictions of fluctuations by numerical models, are essential. To efficiently promote this research, an ultra-high-speed computational device equipped with a large-capacity storage unit is essential. The installation of a super-computer for this Center was authorized in the 1995 approval budget, and operation commenced from March 1 1996.

With the super-computer system, an integrated magneto-optical disk unit, high-speed display unit, front-end server and so forth centered around SX-4/20 are connected by HIPPI line of transmission speed 800Mbps, and it is also connected to existing internal networks through an FDDI cross-bar switch (GIGAswitch), as Figure-1 shows.

Moreover, in order to graphically display results elucidated by the super-computer system, the ONYX system manufactured by Silicon Graphics Corporation is installed as an image analysis and processing system. With simulations of the ocean’s general circulation, there are many cases where display by animation facilitates the grasping of phenomena, and an image editing device for that purpose has also been prepared, which enables digital recording and editing of output from ONYX.

2) Common computer system

A large number of softwares that run on VMS as OS have long since existed at this Center, and at the end of September 1998, we updated the DEC7620 (Open VMS Alpha) VMS cluster environment to Alpha Server 4100. Furthermore, Alpha Server 8400 that runs on Digital UNIX is in operation as a UNIX arithmetic server, and apart from this, an 8-node configuration IBM SP was installed as a distributed memory parallel computer. We have commenced parallelizing research in order to execute ocean

Computer and Information Office

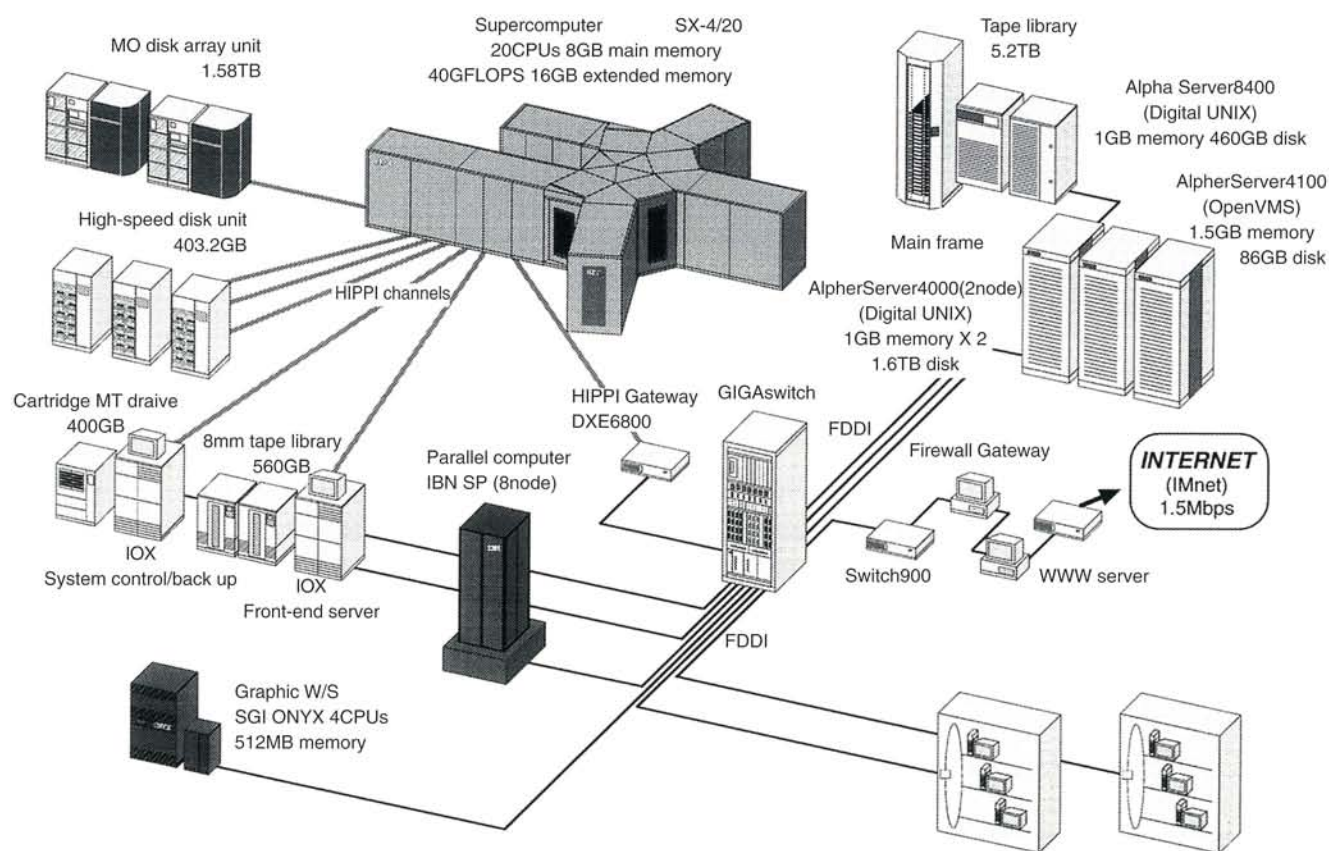


Fig. 1 General outline of the computer system in JAMSTEC

general circulation models at higher speed and on larger scales, and are using it to verify the application results thereof and analyze performance.

These common computer systems are used throughout the entire Center, and user registration for electronic mail usage totaled about 560 users at the end of 1998.

(8) Status of network preparation

1) JAMSTEC network

① Yokosuka internal network

A full-scale internal network was prepared for this Center in 1993, and in 1998 we reinforced branch line LAN. This network consists of 100Mbps FDDI (optical cable) trunk line that links each building and in-house Ethernet (10base-T/100base-TX) branch line LAN, and is centered around the FDDI cross-bar switch (GIGAswitch) installed for common computer systems within the Scientific Computing Division building. It is possible for users to access internal networks and the

Internet from terminals in each private room, and connection to the Internet is executed via a firewall to ensure security.

Furthermore, workstations and terminals connected to internal networks continue to increase, and as of the end of 1998, there were about 110 servers and workstations, about 580 personal computers (Macintosh), 210 PCs (Windows and other) and about 80 X terminals.

② Networks outside Yokosuka

Figure-2 shows a current network connection diagram. The Tokyo Liaison office was connected to the Yokosuka internal network by ISDN line from 1994, and currently, it is connected along with the Frontier Research Promotion Office by a 128kbps private line, attendant to the move to Hamamatsucho. Furthermore, Mutsu Branch was connected by a 64kbps private line in March 1996, and by October 1998, the speed was increased to 128kbps in order to cope with increased traffic.

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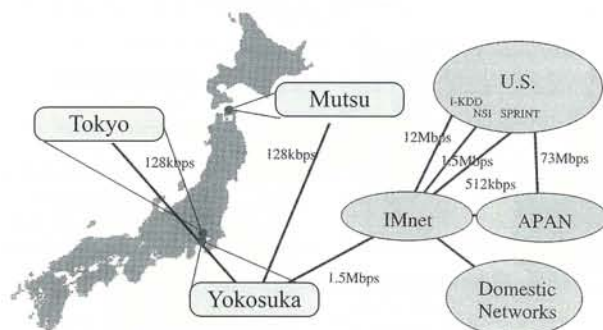


Fig. 2 Network Topology

③ Ship mail system

We have been carrying out tests for a ship mail system since 1995, and have advanced its successive preparation on ships; in January 1998, a mail system was introduced for the final "Natsushima", and an e-mail system using communicate satellite (Inmarsat and N-star) went into operation on all ships owned by this Center. This development marked the preparation of an environment that

enabled not only communication between ships and this Center, but also direct sending and receiving of e-mail to the Internet.

It is now possible to transmit images using this system in the event of Nahotoka investigations and Taima Maru investigations, and view survey images on land in semi-real time.

2) Internet

① IMnet connection

Internet connection at this Center began with the TISN (Todai International Science Network) in January 1993, and from October 1994, the Center was connected by a 768kbps private line to STAnet, which networks research institutions under the Science and Technology Agency umbrella. Thereafter, we expanded the line to 1.5Mbps in July 1996, and in May 1998, we switched over connection to IMnet attendant to the termination of STAnet. We are now able to effectively use this high-speed line for transmission of image data and moving images, which require a large transmission band width.

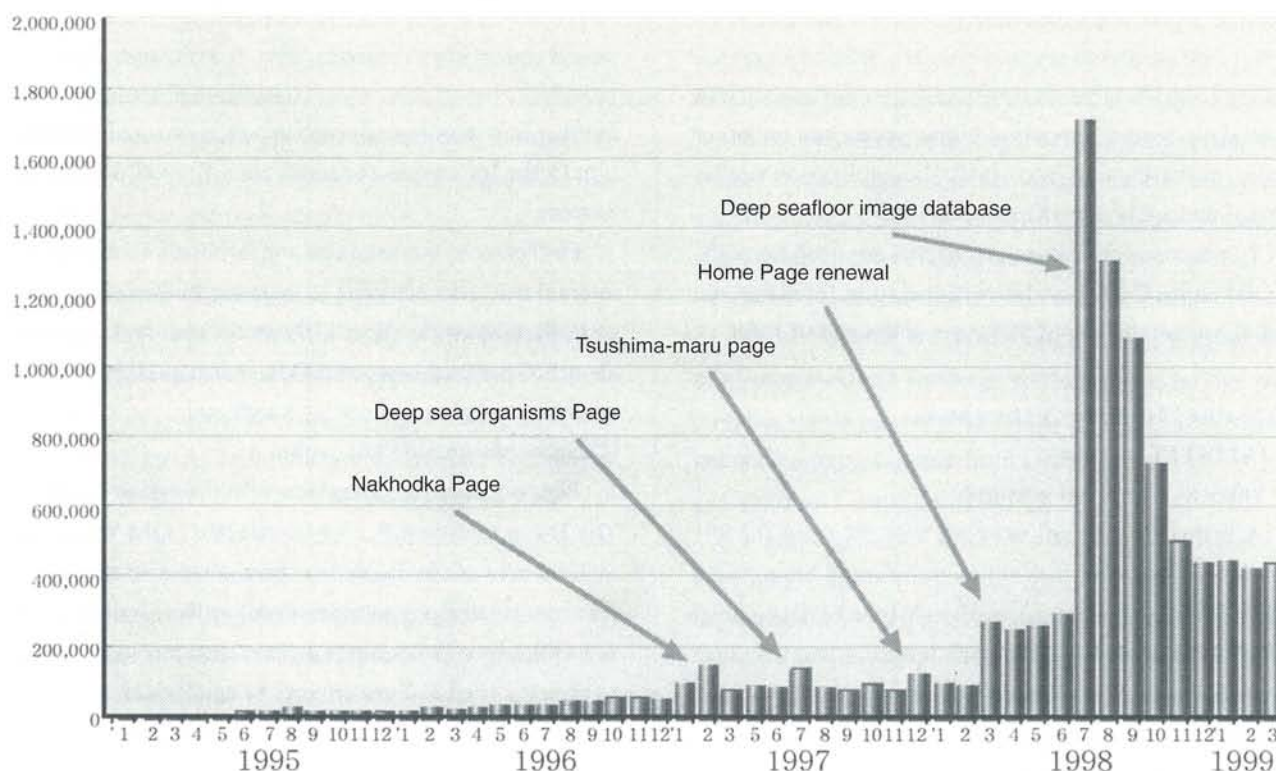


Fig. 3 Monthly access figures for the JAMSTEC Web server

Computer and Information Office

② WWW server

This Center started up a WWW server in September 1994, and has established a JAMSTEC home page. The URL is <http://www.jamstec.go.jp/>.

The number of hits has increased dramatically since we opened a deep sea image database on the Internet in July 1998. Figure-3 shows a graph of month-by-month totals of WWW server hits.

(9) Database development

Along with developing the various types of databases shown below, we are successively carrying out Web development, and advancing preparations so that they can be released through the Internet according to their necessity. In 1998, we commenced release of the deep-sea image database.

1) Operation information database

A database of the operation information of the ships, research submersible vessels, unmanned exploration vehicles and so forth retained by this Center. We have been developing a Web version since 1996.

2) Deep seafloor image database

A database of images (slides) obtained by research submersible vessels and unmanned exploration vehicles, etc. At the end of 1998, 150,000 data items were registered.

3) Oceanographic observation database

A database (prototype) for managing and providing oceanographic observation data obtained by each ship. Also carried as an on-board database of “Mirai” and “Kairei”; we are also carrying Web development in part.

4) Database for book management

We updated the database for book management that was previously being operated on VAX to a distributed database that is managed on dedicated workstations. In 1998 we developed a Web-correspondent system.

5) Integrated database for release

A database that enables access through a common interface to the various databases possessed by this Center. In 1998 we developed a prototype system corresponding to the Web.

Ship Operation Department

The Center owns the Shinkai 2000 system consisting of a manned research submersible Shinkai 2000, a support vessel Natsushima, and a ROV Dolphin-3K. The Shinkai 6500 system consists of a manned research submersible Shinkai 6500, a support vessel Yokosuka, and a 10,000-meter-depth-class ROV Kaiko, a research vessel Kaiyo, a deep-sea research vessel Kairei, and an oceanographic research vessel Mirai. The Center has used these vessels for various tests and research activities regarding marine science and technology including deep-sea research and oceanographic observation.

Regarding the operations and maintenance of these vessels, the Center itself takes care mainly of the operations and daily maintenance of research submersibles and ROV, while a ship operation company is entrusted with operations of support vessels and various research vessels and general maintenance.

Navigational operations in fiscal 1998 can be summarized as follows:

Shinkai 2000 performed underwater survey in sea areas around Japan including Suruga Bay, Sagami Bay, the Sea of Enshu, Nankai Trough, Nansei Islands, the offings of Akita and eastern Hokkaido, and around Izu and Ogasawara. Shinkai 2000's foreign activities were an underwater survey in the Manus basin of Papua New Guinea.

Dolphin - 3K performed preliminary investigation to confirm safety of the underwater navigation route for Shinkai 2000. In addition, it performed survey activities in Kagoshima Bay, Sagami Bay, the Sea of Enshu, Nankai Trough, offings of Akita and eastern Hokkaido. Furthermore, it surveyed the seabed in the earthquake and tsunami areas off the northern coast of New Guinea.

Kaiyo participated in the observation phase of the "observation of and research into the equatorial regions in the tropical zone (TOCS)" and "tomographic observation of the equatorial regions in the Pacific Ocean." In addition, it participated in research into the interaction between the heat and material fluxes and the biosphere and in the exploration of subbottom deep tec-

tonics.

Shinkai 6500 participated in the survey of the Mid-Ocean-ridge Diving Expedition MODE '98 and performed the world's first underwater survey of the Southwest Indian Ridge by a manned submersible.

Yokosuka made a 204-days, round-the-world voyage to support Shinkai 6500 that dived under the MODE '98 project; in addition, Yokosuka participated in the research into ocean bottom dynamics conducted in the Izu and Ogasawara sea areas and in maintenance and reinforcement of the Okinotorishima observation system.

Kaiko performed survey diving in Mariana Trench, around the Hawaiian Islands, off Fukushima, in Japan Trench, and off the Nansei Islands.

Kairei assisted Kaiko in the latter's diving operations. In addition, using its onboard multichannel reflection probe unit, it investigated the Japan Trench off the Sanriku region and the Nankai Trough off Shikoku Island. Furthermore, using its multi narrow beam acoustic depth finder and other equipment, it investigated the Philippine Sea areas and the earthquake and tsunami areas north of New Guinea Island.

Mirai participated in activities for the observation of and research into changes in the subpolar zone-subtropical zone gyre system in the northern Pacific Ocean (from the offing of the Sanriku region to the Ogasawara area of sea), observation of and research into ocean-atmosphere interactions (in the Nansei Islands area of sea), observation of and research into the material fluxes in high latitude regions (in the northwestern part of the Pacific Ocean), observation of and research into the Arctic Ocean (in the Chukchi and Bering Sea areas), observation of and research into the primary production capabilities in the equatorial regions (in the equatorial sea areas in the tropical Pacific), and observation of and research into the western tropical Pacific (in the equatorial areas of sea in the western Pacific).

The vessels owned by the Center were periodically inspected and maintained as usual, with various improvements added to enhance their functions.

Ship Operation Department

Operations Schedule of SV "NATSUSHIMA" in 1998 Fiscal year

JAMSTEC

SHIP NAME	Apr. 98	May	Jun.
NATSUSHIMA	NT98-06 SHINKAI 2000 Support operation Sagami bay Nansei islands 27 30	NT98-07 SHINKAI 2000 Support operation Izu-Ogasawara islands 31	NT98-08 DOLPHIN-3K Support operation Kagoshima bay 7 22
SHIP NAME	Jul.	Aug.	Sep.
NATSUSHIMA	NT98-09 SHINKAI 2000 Support operation Nansei islands 30	NT98-10 SHINKAI 2000 Support operation Japan sea Toyama bay Hokkaido east bay Izu-Ogasawara islands 3 18 19	NT98-11 DOLPHIN-3K Support operation Nantai trough Sagami bay 8 18 19
SHIP NAME	Oct.	Nov.	Dec.
NATSUSHIMA	NT98-12 SHINKAI 2000 Support operation Nankai trough 12 16	NT98-13 SHINKAI 2000 Support operation Narus basin 7	14
SHIP NAME	Jan.	Feb.	Mar.
NATSUSHIMA	Annual inspection 26 31	NT99-01 DOLPHIN-3K Support Operation Sagami bay Suruga bay Nankai trough 5 7	NT99-02 DOLPHIN-3K Support operation Papua newguinea 12
			NT99-03 SHINKAI 2000 Support operation Sagami bay Suruga bay 22 30

DOLPHIN-3K : Unmanned Remotely operated vehicle

SHINKAI 2000 : Deep sea research submersible (Manned)

Operations Schedule of SV "YOKOSUKA" in 1998 Fiscal year

JAMSTEC

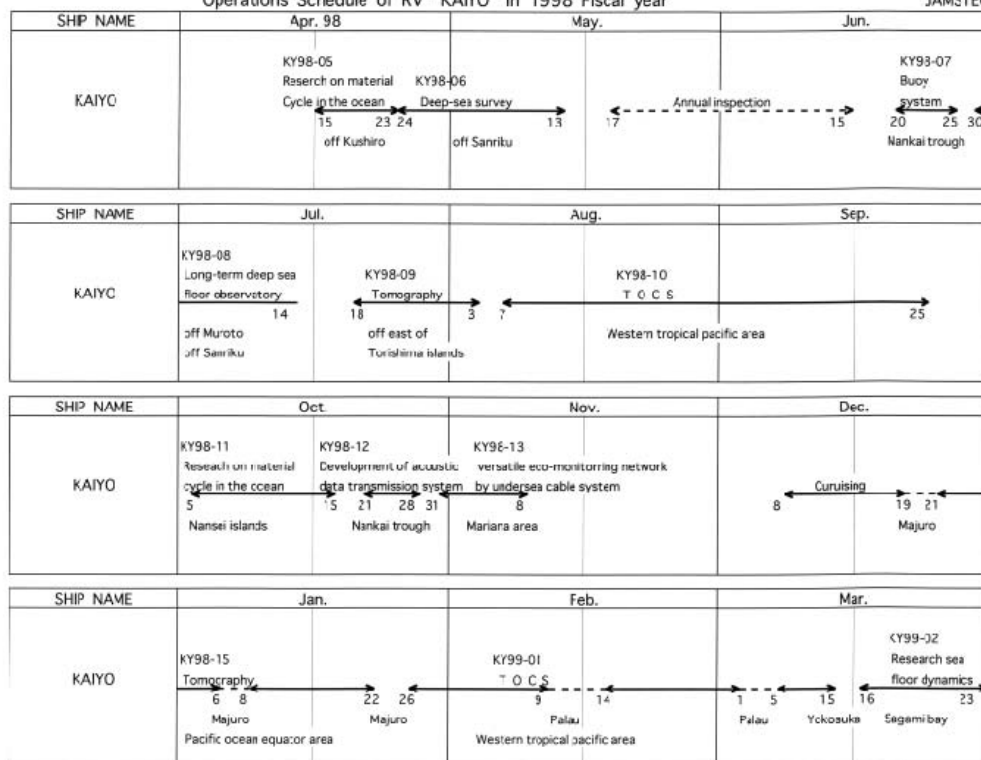
SHIP NAME	Apr. 98	May	Jun.
YOKOSUKA	Annual inspection 2 15	Cruising Yokosuka 21	10 14 17 Panama San Juan West Mid-
SHIP NAME	Jul.	Aug.	Sep.
YOKOSUKA	MODE'98 (Mid Ocean ridge Diving Expedition) YK98-05,06 SHINKAI 6500 Support operation Atlantic Ridge-Kane Fracture Zone 17 23	Trans Atlantic Geotraverse Lisbon 24	Cruising Suez Port Louis 1 7 18 21
SHIP NAME	Oct.	Nov.	Dec.
YOKOSUKA	YK98-07,08 SHINKAI 6500 Support operation Port Louis South West Indian Ridge 17 23	Cruising Port Louis 18 21	YK98-09 UROV-7K Support operation Sagami bay Suruga bay 11 25
SHIP NAME	Jan.	Feb.	Mar.
YOKOSUKA	YK99-01 Research sea floor dynamics Izu Ogasawara islands Mariana trench 14 7	YK99-02 Research of marine automatic observation technique Ckinotcrishima 18 3	YK99-03,04 SHINKAI 6500 Support operation Nansei islands 12 29

SHINKAI 6500 : Deep sea research submersible (Manned)

Ship Operation Department

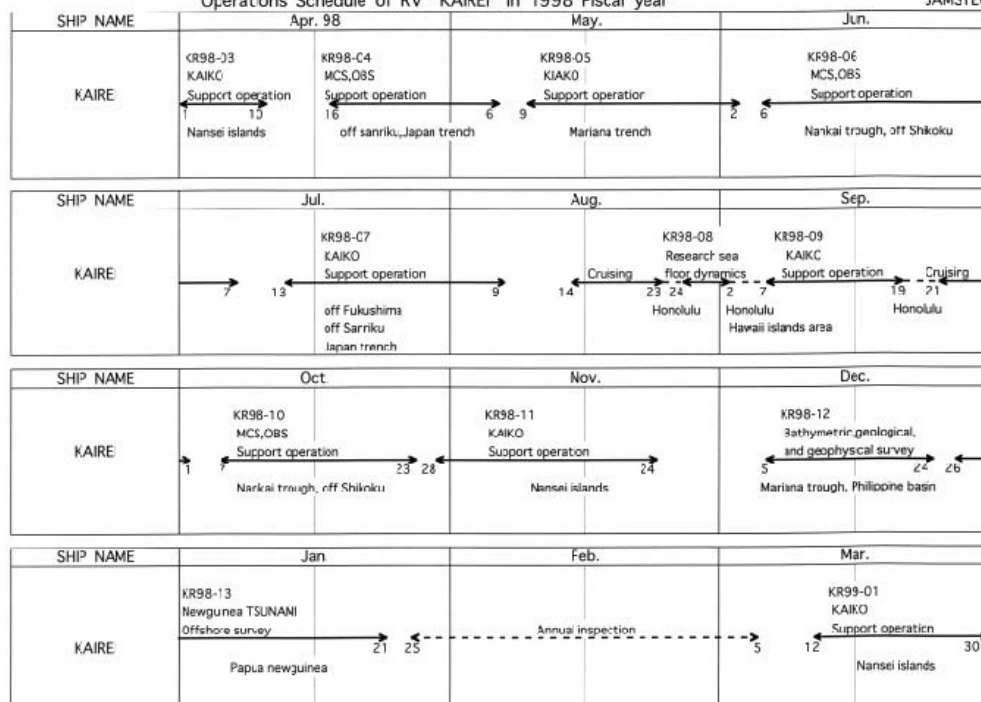
Operations Schedule of RV "KAIYO" in 1998 Fiscal year

JAMSTEC



Operations Schedule of RV "KAIREI" in 1998 Fiscal year

JAMSTEC



KAIKO : Unmanned Remotely operated vehicle

MCS : Multichannel Seismic Profiler

OBS : Ocean Bottom Seismograph

Ship Operation Department

Operations Schedule of RV "MIRAI" in 1998 Fiscal year				JAMSTEC
SHIP NAME	Apr. 98		May.	Jun.
MIRAI	Cruising 15	MR98-03 Research sub arctic north pacific ocean flux off Sanriku~Ogasawara 17	MR98-04 Research air and ocean interaction mechanism 19	off Nanse islands 21
SHIP NAME	Jul.		Aug.	Sep.
MIRAI	MR98-05 Research material flux in high latitude 4	6 Pacific ocean NE area 27 30	MR98-06 Arctic ocean research Chukuchi sea, Bering sea	MR98-07 Development of buoy system 10 11 off Sanriku 17
SHIP NAME	Oct		Nov.	Dec.
MIRAI	Annual inspection 28	30	MR98-K0 Research material flux in high latitude Pacific ocean NE area	16 22
SHIP NAME	Jan.		Feb.	Mar.
MIRAI	MR98-K02 Research primary production at equator-area Pacific ocean tropical and equator zone	1	MR99-K01 Research western tropical pacific Western pacific equator zone	31

Ship Operation Department

Research vessels, submersibles and ROVs of JAMSTEC



Support vessel "Natsushima"

Length : 67.4 m
Gross tonnage : 1,533 T
Speed : 12 knots
Complement : 55 persons



Manned research submersible
"Shinkai 2000"

Length : 9.3 m
Max. depth capability : 2,000 m
Speed : 3 knots
Complement : 3 persons



ROV "Dolphin 3K"

Length : 2.9 m
Max. depth capability : 3,000 m
Speed : 3 knots



Support vessel "Yokosuka"

Length : 105.2 m
Gross tonnage : 4,439 T
Speed : 16 knots
Complement : 60 persons



Manned research submersible
"Shinkai 6500"

Length : 9.3 m
Max. depth capability : 6,500 m
Speed : 2.5 knots
Complement : 3 persons



Research vessel "Kaiyo"

Length : 61.6 m
Gross tonnage : 2,000 T
Speed : 13 knots
Complement : 69 persons



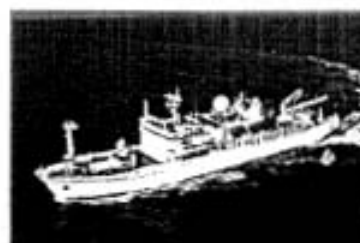
ROV "Kaiko"

Length : 3.1 m (Vehicle)
Max. depth capability : 11,000 m
Speed : 2 knots



Deep sea research vessel
"Kairei"

Length : 105.2 m
Gross tonnage : 4,628 T
Speed : 16 knots
Complement : 60 persons



Oceanographic research vessel
"Mirai"

Length : 126.6 m
Gross tonnage : 8,672 T
Speed : 16 knots
Complement : 80 persons

Training and Education Service

1. Overview of activities and training and education results

The Public Relations, Training and Education Division carries out diving-related training and education targeted at technicians and researchers involved with diving work and ocean research, and strives to cultivate talented individuals in the said field. Moreover, in parallel with this, it carries out safety and hygiene education to supervisors of diving work sites, and practical diving to persons engaged in diving work and beginners. At the same time, from 1995 it has conducted enlightenment and popularization activities concerning “marine science & technology” targeted at senior high school students and senior high school teachers.

As for diving-related training and education, in the same way as last year the Division carried out two types of special training: “diving technology training and education” and “experience (practical) diving”, along with “diving work management training and education”. Apart from this, “Science Camp '98” targeted at high school students, and “Marine Science School '98” targeted at senior high school students and senior high school teachers.

(1) Special training and education

① Diving training and education

This training and education is carried out according to a 5-day schedule as a rule (10 days in some cases), and is aimed at imparting knowledge concerning scuba diving and basic techniques. This year, it was carried out with the participation of 215 persons from 27 institutions including the National Police Agency.

② Experience (practical) diving

This training and education is a course for beginners to experience diving in a pool, and this year, practical scuba diving was carried out over two days, with participation by 21 subscribers to the Science and Technology Health Insurance Union.

(2) Diving management courses

This training and education is carried out for diving workers and employees of diving-related companies, and in addition to safety and hygiene education concerning diving work, we provide a broad range of information on diving work in general, including an overview of saturation diving and the actual status of diving work being carried out overseas. This year, it was carried out on two occasions, with the participation of 14 persons from 12 institutions.

(3) Science Camp '98

We have been conducting this since 1996 at five corporations and five research institutions under the Science and technology Agency umbrella, through sponsorship of

the Science and Technology Agency, Japan Science and Technology Corporation and the Japan Science Corporation. This year, it was held with a schedule of two nights and three days, from August 10-12. This time, we provided an introduction to the various research being conducted at this Center to 23 (8 males, 15 females) senior high school students and vocational high school students selected by essay composition from among 85 applicants, as well as giving them hands-on experience at research sites, and were able to increase interest and concern towards marine science and technology.

(4) Marine Science School '98

This school is aimed at heightening interest and deepening understanding of the oceans by senior high school students and senior high school teachers who instruct them, and is an event that this Center holds with a Japan Foundation subsidy. The features of this school are that it restricts participant regions, and is targeted not only at senior high school students, but also teachers. This year, the school was held on three occasions during the summer and spring breaks with a schedule of three nights and four days, targeting fourteen senior high school teachers and fifty senior high school students from the following prefectures: Fukuoka, Saga, Nagasaki, Kumamoto, Aomori, Akita, Iwate and Yamagata. As for the school's contents, we were able to further increase the concern of participants by incorporating many research results and stories of personal experiences by this Center's researchers, and were able to bring it to a successful conclusion.

Training and Education Service



Photo 1 Marine Science School '98 Scene showing the Mighty Wheel being explained

Mutsu Branch

1. Overview of Mutsu Branch Activities

Due to the fact that Port Sekinehama, Mutsu City, was made the home port of the oceanographic research vessel "Mirai", which commenced operations in October 1997, Mutsu Branch was opened October 1, 1998, as the first regional branch in the Japan Marine Science and Technology Center, in order to operate this smoothly.

The duties of this branch for the time being are as follows.

- Operation of facilities and equipment necessary for research conducted by the oceanographic research vessel "Mirai"
- Popularization and public relations activities in order to enable smooth operation of the oceanographic research vessel "Mirai"
- Other duties necessary for Mutsu Branch administration

(1) Application of facilities and equipment

In order to elucidate mechanisms of global climate change, the oceanographic research vessel "Mirai" carries out observations throughout the entire Pacific ocean and over wide stretches of the Indian Ocean and collects data and samples. The main mission of the oceanographic research vessel "Mirai" is installation and collection in observation sea areas, of oceanographic observation buoys "TRITON buoy", which are scheduled for development in the western equatorial and mid-latitude Pacific Ocean waters. The "TRITON buoy" is expected to demonstrate strength in explaining the real situation of the warm core ring, which is known to have a significant bearing on the El Nino phenomenon.

The Observation Equipment and Machinery Maintenance Shop carries out maintenance, storage and sensor calibration, etc., of these oceanographic observation buoys, along with processing and managing incoming buoy data.

The Sample Analysis Facility processes oceanographic observation data obtained by the "TRITON buoy" and the oceanographic research vessel "Mirai", and analyzes and stores collected samples, and in addition, the sea water pre-processing system installed within the building (a device that performs preprocessing of sea water necessary in order to measure the content of radioactive carbon ^{14}C within sea water by accelerator mass spectrometer), commenced full-scale operation after training and trial operation.

Moreover, as a structure that executes business, Mutsu Branch management section leases a building owned by the Japan Atomic Energy Research Institute, and uses it business as a administration building. (Figure 1).

(2) Public relations activities

For smooth operation of the oceanographic research vessel "Mirai", the understanding and cooperation are essential of the local people of Mutsu City, in which the

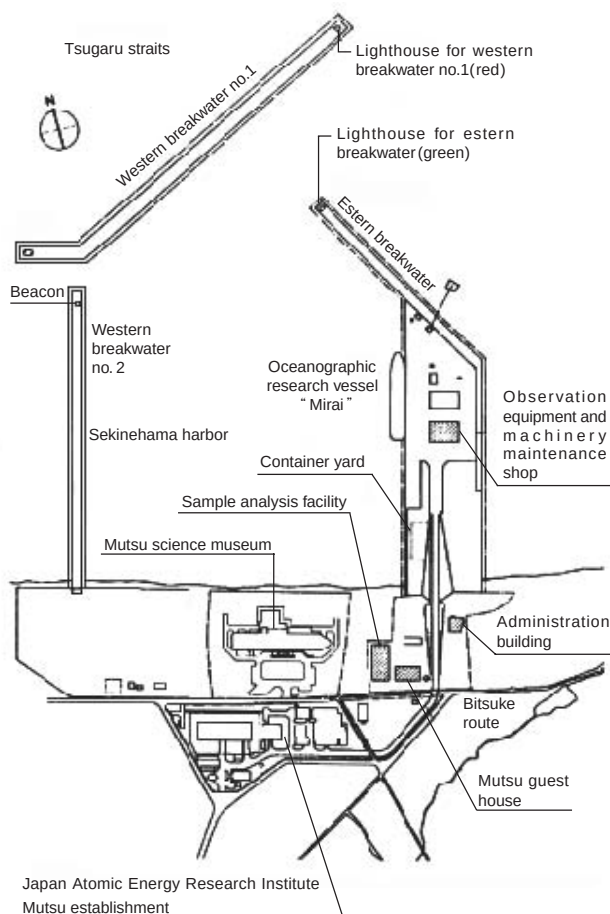


Fig. 1 Layout of Research Facilities at Mutsu Branch

Mutsu Branch

home port is located. The popularization and public relations activities that Mutsu Branch performs involve targeting not only the general public, but also the young who represent the next generation, to propagate the fruits and dreams of marine science and technology. To this end, we conducted a port entry welcoming ceremony and general unveiling of the oceanographic research vessel "Mirai" at Port Aomori, Aomori City, on July 25 and 26, 1998, at which there were 5,265 visitors. And on the 27th, we conducted a classroom at sea from Port Aomori to Port Sekinehama for 38 junior high school students within Aomori Prefecture.

Moreover, on October 31, 1998, we conducted a classroom at sea at Port Hachinohe, for about 50 children of the Hachinohe Sea Scouts and students. On November 1, we held a port entry welcoming ceremony and general unveiling, at which 2,970 attended.

Furthermore, we attempted to encourage understanding of oceanographic research by exhibiting a deep-sea georama display and sea floor station images at the Mutsu Science Museum as research results of the Japan Marine Science and Technology Center.

2. Construction and improvement of facilities and equipment

(1) Buildings

Mutsu Branch constructed the Mutsu Guest House within the branch precinct, with the aim of providing a satisfactory environment to researchers who visit this

branch for the purposes of research voyages of the oceanographic research vessel "Mirai", joint research, and in-service training. (Table-1, Photo-1)

This building is a 3-story building of steel frame construction, consisting of researcher's rooms (8 rooms), conference room (accommodating 80 persons), seminar room, lounge, cafeteria, and etc. It has a total space of 1,547m² and was completed in 1999.

(2) Equipment

To prepare for Mirai cruises and to analysis and process samples and data, we transferred a nutrient automatic analyser from headquarters to the chemical laboratory on the first floor of the Sample Analysis Facility, in addition to preparing an ultra-pure water production system. On the second floor, we also prepared an HRPT satellite data receiving system in the data processing room. This system tracks the NOAA meteorological satellite and the OrbView-2 oceanographic observation satellite, and receives HRPT (high resolution picture transmission format) signals with a 1.2m diameter parabolic antenna, and constructs sea surface temperature distribution dataset from advanced very high resolution infrared radiation (AVHRR) carried on NOAA, and chlorophyll-a concentration distribution dataset from SeaWiFS (sea wide field of view scanner) carried on OrbView-2. Furthermore, we set up refrigeration equipment (internal temperature: +4 degrees C, effective dimensions: 2.9m x 4.5m x 2.2m) in the second floor core sample storage room, and attempted to reinforce the system of receiving and storing core samples

Table 1 Status of Research Facilities and Equipment at Mutsu Branch

Building name	Specifications	Total space	Year of preparation	Remarks
Observation Equipmnt and Machinery and Maintenance Shop	3-storey steel frame construction, partially ventilated	3,046.26	1995-1996	
Administration building	2-storey ferro-concrete building	521.90	1996	2-storey ferro-concrete building
Sample Analysis Facility	2-storey ferro-concrete building	1,942.59	1996-1997	
Mutsu Guest House	3-storey steel frame construction, 1-storey tower	1,547.42	1998	

Mutsu Branch

collected by the oceanographic research vessel "Mirai".

And with the aim of environmental improvement as research rooms for installing and handling precision in-

struments, we installed air-conditioning equipment in the two, second-floor research laboratories in the Observation Equipment and Machinery Maintenance Shop.



Photo 1

Publications

Appendix A

Deep Sea Research Department

- 1) **FUJIWARA Noriyuki, MOMMA Hiroyasu, KAWAGUCHI Katsuyoshi, IWASE Ryouichi, KINOSHITA Hajimu**
[Comprehensive Deep Seafloor Monitoring System in JAMSTEC]UT 98(Underwater Technology '98)
- 2) **OKUTANI Takashi, KOJIMA Shigeaki, FUJIKURA Katsunori**
[Diversity,distribution and phylogeny of chemosynthetic bivalve calyptogena (s.l) in the Northwest Pacific]
World Malacological Congress
- 3) **MOMMA Hiroyasu, KAWAGUCHI Katsuyoshi, IWASE Ryouichi, SHIRASAKI Yuichi, KASAHARA Junzo**
[The VENUS Project -Instrumentation and Underwater Work System-]UT 98(Underwater Technology '98)
- 4) **MITSUZAWA Kyohiko**
[Characteristics of Deep Sea Currents along the Trench in Northwest Pacific.]Journal of Geophysical Research-
Oceans, AGU
- 5) **IWASE Ryouichi, MOMMA Hiroyasu, KAWAGUCHI Katsuyoshi, SUZUKI Shinichiro**
[The relation between sediment and underground temperature variation in deep seafloor in Sagami Bay]
1998 Japan Earth and Planetary Science Joint Meeting
- 6) **KAWAGUCHI Katsuyoshi, MOMMA Yamato, IWASE Ryouichi, SHIROSAKI Yuichi**
[Submarine Cable Handling System for Deep Underwater Vehicles]OCEANS '98
- 7) **MITSUZAWA Kyohiko, FUJIOKA Kantaro, URABE Tetsuro, NAKAMURA Kouichi, SUGAWARA Toshikatsu**
[A week-long observation period on a low-temperature hydrothermal field at the Southern East Pacific Rise]
1998 Japan Earth and Planetary Science Joint Meeting
- 8) **HIRATA Kenji, MORIYA Takeo**
[Initial rupture process of the 1993 Kushiro-Oki earthquake]"Chikyu" Monthly
- 9) **KODAIRA Syuichi, Jin-oh PARK, TAKAHASHI Narumi, KANEDA Yoshiyuki, TSURU Tetsuro**
[DEEP SEISMIC IMAGING OF THE NANKAI TROUGH SEISMOGENIC ZONE FROM MULTICHANNEL AND OCEAN-BOTTOM SEISMIC DATA] International Symposium on Deep Seismic Profiling of the Continents and their Margins
- 10) **KANAMATSU Toshiya, FUJIOKA Kantaro, OKINO Kyoko, OHARA Yasuhiko, HONZA Eiichi, MATSUOKA Hiromi, HISADA Kimikazu, ISHII Teruaki, IKEHARA Ken, KR98-01Shipboard scientists**
[Tomography and Tectonics of the Central Basin Fault,West Philippine Basin and the Mariana Trench-KR98-01-]
The 105th Annual Meeting of the Geological Society of Japan
- 11) **SAKAMOTO Izumi, FUJIOKA Kantaro**
[Geology and Petrographical characteristics of Sofugan Tectonic Line,Izu-Ogasawara Arc]The 105th Annual Meeting of the Geological Society of Japan
- 12) **FUJIOKA Kantaro, SAKAMOTO Izumi**
[Geological crustal structure of Middle part of Izu-Ogasawara Arc Report of the submersible observation and mapping around the Sofugan Tectonic Line]The 105th Annual Meeting of the Geological Society of Japan

Publications

Appendix A

- 13) **SAKAMOTO Izumi**
[Morphological features between hyaloclastite to peperite followed to the rhyolitic lava observed around the Senryoike-inlet, Kozushima Is.] The Volcanological Society of Japan
- 14) **SAKAMOTO Izumi**
[Geological and petrographical characteristics of submarine caldera located between Hachijoshima Is. and Aogashima Is.] The Volcanological Society of Japan
- 15) **IWASE Ryouichi, HIRATA Kenji, MOMMA Hiroyasu, AOKI Misumi**
[Deployment and recovery of pop-up OBS by using deep-tow camera system.] Seismological Society of Japan, Fall meeting
- 16) **MATSUMOTO Takeshi, Peter Kelemen, MODE'98 Onboard Scientific Party**
[Preliminary result of the precise geological mapping of the Mid Atlantic Ridge 14-16N-tectonic extension along the magma-poor ridge axis.] American Geophysical Union Fall Meeting
- 17) **TAKAHASHI Narumi, KODAIRA Syuichi, ABE Shintaro, NISHINO Minoru, HINO Ryouta**
[P-wave structure beneath the forearc of the Northeast Japan arc (off Sanriku) deduced by airgun-OBS data.] JAMSTEC Journal of Deep Sea Research
- 18) **TAKAHASHI Narumi, KODAIRA Syuichi, TSURU Tetsuro, Jin-oh PARK, KANEDA Yoshiyuki, KINOSHITA Hajimu, ABE Shintaro, NISHINO Minoru, HINO Ryouta**
[Heterogeneous Velocity Structure of off Sanriku, the Northeastern Japan Forearc using Airgun-Ocean Bottom Seismograph data.] Seismological Society of Japan, Fall Meeting
- 19) **TAKAHASHI Narumi, KODAIRA Syuichi, TSURU Tetsuro, Jin-oh PARK, KANEDA Yoshiyuki, KINOSHITA Hajimu, ABE Shintaro, NISHINO Minoru, HINO Ryouta**
[Crustal structure of off Sanriku, the Northeastern Japan Forearc.] The 15th Deep Sea Symposium
- 20) **TAKAHASHI Narumi, KODAIRA Syuichi, TSURU Tetsuro, Jin-oh PARK, KANEDA Yoshiyuki, KINOSHITA Hajimu, ABE Shintaro, NISHINO Minoru, HINO Ryouta**
[The heterogeneous velocity structure of off Sanriku, the Northeastern Japan forearc using airgun-OBS data.] 1998 Fall Meeting, American Geophysical Union
- 21) **FUKUMA Koji**
[Plio-Pleistocene magnetostratigraphy of sedimentary sequences from the Irminger Basin.] Proceedings of the ODP Scientific Results
- 22) **FUKUMA Koji**
[Grain size dependence of two-dimensional micromagnetic structures for pseudo-single-domain magnetite (0.2-2.5 μ m).] European Geophysical Society
- 23) **FUKUMA Koji**
[Origin and applications of whole-core magnetic susceptibility of sediments and volcanic rocks from Leg 152.] Proceedings of the ODP Scientific Results
- 24) **FUKUMA Koji, SHINJOE H, HAMANO Y**
[Origin of the absence of magnetic lineations in the Yamato Basin of the Japan Sea: Magnetic properties of mafic rocks from Ocean Drilling Program Hole 794D.] Proceedings of the ODP Scientific Results
- 25) **FUKUMA Koji, TORII M**
[Variable Shape of magnetic hysteresis loops in the loess-paleosol sequence.] Earth Planets and Space

Publications

Appendix A

- 26) **FUKUMA Koji, TORII M**
[Initial magnetic susceptibility of the Chinese Loess: A review]Quaternary Research
- 27) **TAKAHASHI Narumi, KODAIRA Syuichi, TSURU Tetsuro, Jin-oh OARK, ABE Shintaro, NISHINO Minoru, HINO Ryouta**
[Velocity structure of the Northeastern Japan forearc using Airgun-O Bottom Seismograph data]Seismological Society of Japan, Fall Meeting
- 28) **TAKAHASHI Narumi, ABE Shintaro, F.MURAKAMI, NISHIZAWA Azusa**
[The seismic experiments at northern end of the Havre Trough]European Geophysical Society
- 29) **TAKAHASHI Narumi, SUEHIRO Kiyoshi, SHINOHARA Masanao**
[Implications from the seismic crustal structure of the northern Izu-Bonin arc]Island Arc
- 30) **TAKAHASHI Narumi, KODAIRA Syuichi, TSURU Tetsuro, Jin-oh PARK, KINOSHITA Hajimu, HINO Ryouta, NISHINO Minoru, ABE Shintaro**
[The velocity structure of the Northeastern Japan forearc using airgun-OBS data]Western Pacific Geophysical Meeting, AUG
- 31) **Jiren XU, KONO Yoshiteru**
[Geometry and stress field of Philippine Sea plate in and around Nankai trough based seismic data]Seismological Society of Japan, Fall Meeting
- 32) **KODAIRA Syuichi, TAKAHASHI Narumi, KINOSHITA Hajimu, MOCHIZUKI Kimihiro, SHINOHARA Masanao**
[THE NANKAI TROUGH SEISMOGENIC ZONE EXPERIMENT:RESULTS OF WIDE-ANGLE OBS DATA]European Geophysical Society
- 33) **KODAIRA Syuichi, AMANO Hiroshi, TAKAHASHI Narumi, Jin-oh PARK, KINOSHITA Hajimu, MOCHIZUKI Kimihiro, SUEHIRO Kiyoshi, SHINOHARA Masanao**
[Imaging the Western Nankai Trough seismogenic zone by MCS-OBS data]Western Pacific Geophysical Meeting
- 34) **KODAIRA Syuichi, TAKAHASHI Narumi, KINOSHITA Hajimu, MOCHIZUKI Kimihiro, SHINOHARA Masanao**
[1997 THE NANKAI TROUGH SEIMOGENIC ZONE EXPERIMENT:RESULTS OF WIDE-ANGLE OBS DATA]1998 Japan Earth and Planetary Science Joint Meeting
- 35) **SAKAMOTO Izumi**
[Morphological features and petrographical changes between hyaloclastite to peperite of Membo rhyolitic lava, observed around Senryoike inlet, Kozu-shima Is.,Japan]IAVCEI (International Association Volcanology & Chemistry of Earth's Interior)
- 36) **KINOSHITA Hajimu**
[Studies on Seismogenic Zone-Nankai and Zenisu-]American Geophysical Union
- 37) **NAKA Jiro**
[Preliminary result of the KAIREI KR-98-08,09 cruises around the Hawaiian Islands]American Geophysical Union
- 38) **KIKAWA Eiichi**
[Paleomagnetism of Deep Ocean Crust and Upper Mantle:New Data from Oman Ophiolite]American Geophysical Union

- 39) **FUJIWARA Toshiya, SHIMA Nobukazu, YAMAMOTO Michiko, ISEZAKI Nobuhiro · KINOSHITA Hajimu**
「Geomagnetic survey of the off-Kamogawa, Boso Peninsula, Japan」Society of Geomagnetism and Earth, Planetary and Space Science
- 40) **FUJIWARA Toshiya, Shima Nobukazu, YAMAMOTO Michiko, ISEZAKI Nobuhiro · KINOSHITA Hajimu**
「Geomagnetic survey of the off-Kamogawa, Boso Peninsula, Japan」Seismological Society of Japan, Fall Meeting
- 41) **SAKAMOTO Izumi, FUJIOKA Kantaro**
「Geological and petrographical characteristics of the Sofugan Tectonic Line,Izu-Ogasawara Arc」American Geophysical Union
- 42) **KANAMATSU Toshiya, Gary M. McMurtry, Emilio Herrero-Barvera**
「Stratigraphy and Sedimentology of the Nuuanu and Molokai Giant submarine Landslides, Hawaii」American Geophysical Union
- 43) **KAIHO Yuka, L. N. Kennett**
「Three-dimensional seismic structure beneath the Australian region from refracted P and S wave 」America Geophysical Union
- 44) **KODAIRA Syuichi, TAKAHASHI Narumi, Jin-oh PARK, KINOSHITA Hajimu, K. MOCHIZUKI, M. SHINOHARA**
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- 45) **OKANO Masaharu, FUJIOKA Kantaro, MATSUMOTO Takeshi, KATO Kazuhiro, KINOSHITA Hajimu, HATTORI Mutsuo**
「Deep sea gamma ray measurement by "Shinkai 6500", during MODE'98」The 15th Deep Sea Symposium
- 46) **OKANO Masaharu, MATSUMOTO Takeshi, HATTORI Mutsuo, YAMAMOTO Tadatoshi, ITO S**
「Sea bottom gamma ray measurement by deep ROV"DOLPHIN-3K」The 15th Deep Sea Symposium
- 47) **Jiren XU, KONO Yoshiteru**
「Geometry and Stress Field of Nankai Subduction Zone,Japan deduced from hypocentral data and focal mechanism solutions」American Geophysical Union, Fall Meeting
- 48) **HIRATA Kenji, KAWAGUCHI Katsuyoshi, OYAIZU Masahisa, MITANI Hidefumi, TANAKA Norio, TOGASHI Naotaka, SHINAGAWA Michio, MIYOSHI Hiroshi, AOYAGI Emiko**
「Deep-tow camera survey of continental margin off Fukushima, Japan - results of KY98-08-FKS cruise -」
15th SHINKAI symposium 1998

Ocean Research Department

- 1) **KASHINO Yuji, WATANABE Hidetoshi, YAMAGUCHI Hatsuyo, Bambang Herunadi, Djoko Hartoyo, AOYAMA Michio**
「Moored Observation of the Indonesian Throughflow」JAMSTECR
- 2) **HONDA Makio, KUMAMOTO Yuichiro, HARADA Naomi, KUSAKABE Masashi, KATAGIRI Masanobu, NAKAO Kiyotaka, HAYASHI Kazuhiro, KISEN Noriyuki**
「Semi-automated sample preparation system for 14C measurement on seawater sample」JAMSTECR

- 3) **HONDA Makio**
[Paleoproductivity in the last glacial: Change in carbonate chemistry in the ocean.]Journal of Geography
- 4) **KUSAKABE Masashi, HONDA Makio, NAKABAYASHI Shigeto**
[Hydrographic feature of the East China Sea.]Bulletin on Coastal Oceanography
- 5) **HONDA Makio, MURATA Akihiko, KUMAMOTO Yuishiro, KUSAKABE Masashi**
[Measurement of PH, TCO₂, TALK in the northwestern North Pacific.]Advanced Marine Science and Technology Society
- 6) **HONDA Makio, MURATA Akihiko, KUMAMOTO Yuichiro, KUSAKABE Masashi, YAMAMOTO Hideki**
[Biological carbon pump and dissolved carbonate chemistry in the Northwestern North Pacific.]International symposium of CO₂ in the ocean
- 7) **KAKUTA Shinya**
[memory on University of Chicago.]Journal of the Japanese Society of snow and Ice
- 8) **KAKUTA Shinya**
[Development of Arctic Ocean-Ice coupled model at JAMSTEC.]JAMSTECR
- 9) **KAKUTA Shinya**
[The second meeting of TYKKI.]JAMSTECR
- 10) **SHIMADA Koji, HATAKEYAMA Kiyoshi, KIKUCHI Takashi, TAKIZAWA Takatoshi, Greg Holloway(IOS)**
[Analysis of IOEB (Ice-Ocean Environmental Buoy) data (A) Interaction between eddies and seafloor topography (neptune effect) (B) Baroclinic instabilities.]1998 Spring meeting of Japan Oceanographic Society of Japan
- 11) **NISHINO Shigeto, MINOBE Shoshiro (Division of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University)**
[Thermohaline- and Wind-Driven Circulation in an Extended Model of Potential Vorticity Homogenization.]
The 1998 Conference of The World Ocean Circulation Experiment, Ocean Circulation and Climate (poster session)
- 12) **KIKUCHI Takashi, HATAKEYAMA Kiyoshi, TAKIZAWA Takatoshi, YORITAKA Hiroyuki (Japanese Marine Safety Agency)**
[Variations of the hydrographic structure of Amchitka Pass, Aleutian Islands.]1998 Spring meeting, The oceanographic society of Japan
- 13) **KIKUCHI Takashi, HATAKEYAMA Kiyoshi, TAKIZAWA Takatoshi, and YORITAKA Hiroyuki (Hydrographic Department, Japan Maritime Safety Agency), HATAKEYAMA Kiyoshi, TAKIZAWA Takatoshi, and YORITAKA Hiroyuki(Hydrographic Department, Japan Maritime Safety Agency)**
[HYDROGRAPHIC AND MOORING OBSERVATIONS IN THE AMCHITKA PASS.]49th Arctic Science Conference(postersession)
- 14) **MURAKI Hiroaki(Hokkaido Tokai Univ.), KUSAKABE Masashi, HARADA Naomi, NAKAMURA Toshio(Nagoya Univ.)**
[Particulate flux for last 40000 years in the northwestern North Pacific.]Summaries of Researchs Using AMS at Nagoya University
- 15) **NAKATSUKA Takeshi, HANDA Nobuhiko (Aichi Pref. Univ.), HARADANAomi, SUGIMOTO Tatsuhiro (Toyota Motor Company), IMAIZUMI Shigemi (Office of Gifu Prefecture)**
[Origin and decomposition of sinking particulate organic matter in the deep water column inferred from the vertical distributions of its d15N, d13C and d14C.]Deep-Sea Research

- 16) **NAKABAYASHI Shigeto**
[Distribution and source of dissolved iron in the East China Sea]INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (of UNESCO), IOC/WESTPAC-Sida/SAREC Workshop on Atmospheric Inputs of Pollutants to the Marine Environment - An Approach to GPA/LBA, Qingdao, China
- 17) **NAKABAYASHI Shigeto**
[Atmospheric input of iron to the Ocean]1998 Fall Meeting of Oceanographic Society of Japan
- 18) **ISHIDA Akio, KASHINO Yuji, MITSUDERA Humio(IPRC), KADOKURA Teruaki(FRIC)**
[Mean circulation and variability in the global high-resolution GCM - the Equatorial Currents System in the Pacific Ocean -]The international symposium TRIANGLE'98
- 19) **ISHIDA Akio, KASHINO Yuji, MITSUDERA Humio, KADOKURA Teruaki**
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- 21) **WASHIO Yukihiisa**
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- 4) **NAKASONE Kaoru, Ikegami Akihiko, KATO Chiaki, USAMI Ron, HORIKOSHI Koki**
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- 5) **KATO Chiaki**
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- 6) **WADA Tadashi, NAKASONE Kaoru**
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Appendix A

- 21) **M.Smorawska, KATO Chiaki, HORIKOSHI Koki**
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- 22) **KATO Chiaki, LI Lina, HORIKOSHI Koki**
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- 23) **LI Lina, KATO Chiaki, HORIKOSHI Koki**
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- 24) **TAKAMI Hideto, NAKASONE KAoru, OGASAWARA Naoki, HIRAMA Chie, NAKAMURA Yuka, MASUI Nobuaki, FUJI Fumie, TAKAGI Yoshihiro, INOUE Akira, HORIKOSHI Koki**
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- 39) **Francesco Canganella**
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- 45) **TAKAMI Hideto, HIRAYAMA Hisako, INOUE Akira, HORIKOSHI Koki**
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- 46) **TAKAGI Yoshihiro, NAKASONE Kaoru, FUJI Fumie, TAKAMI Hideto, INOUE Akira, HORIKOSHI Koki**
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- 2) **NAKANISHI Ayako, SHIOBARA Hajime, HINO Ryota, MOCHIZUKI Kimihiro, SATO Toshinori, KASAHARA Junzo, TAKAHASHI Narumi, SUEHIRO Kiyoshi, TOKUYAMA Eiichi, SEGAWA Jiro, SHIMAMURA Hideki**
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- 10) **KANEDA Yoshiyuki, KODAIRA Shuichi, TSURU Tetsuro, PARK Jin-Oh, TAKAHASHI Narumi, KINOSHITA Hajimu, KONO Yoshiteru**
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Appendix A

- 23) **HIRANO Satoshi, HATTORI Mutsuo, CUMMINS Phil R., OKANO Masaharu, CHIBA Junichi**
 [Preliminary results of dive surveys of the "Dolphin 3K" and "Shinkai 2000" off Oga Peninsula, Eastern Japan Sea margin.]15th Deep Sea Symposium
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- 28) **KIDO Yukari**
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- 29) **TSURU Tetsuro, PARK Jin-Oh, TAKAHASHI Narumi, KODAIRA Shuichi, KIDO Yukari, KANEDA Yoshiyuki, KONO Yoshiteru**
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 [Evidence of seamount subduction at the western Nankai Trough by seismic reflection data.]The society of exploration geophysics of Japan
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- 36) **NAKANISHI Ayako, MIURA Seiichi, TAKAHASHI Narumi, PARK Jin-Oh, HIGASHIKATA Toshihiko, KANEDA Yoshiyuki, KINOSHITA Hajimu, KONO Yoshiteru,HIRATA Naoshi, IWASAKI Takaya, NAKAMURA Masao**
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- 49) **CUMMINS Phil R., KANEDA Yoshiyuki, HIRANO Satoshi, 1999.** Subduction zone earthquakes and slip along thrusts in the accretionary prism. Workshop on Seismic Coupling at Subduction Zones, (Geological Survey of Japan, Tsukuba, January 26, 1999).

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- 1) **IKEDA Motoyoshi, UKITA Motonobu**
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- 2) **TANIMOTO Yoichi**
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- 3) **Vinayachandran P.N**
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- 4) **Alexander S.Kazmin**
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- 5) **OZAWA Hisashi**
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- 6) **OZAWA Hisashi, OHMURA Atsumu**
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- 7) **YAMAGATA Toshio, KAGIMOTO Takashi, MASUMOTO Yukio, P.N.Vinayachandran**
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- 19) **OKUZONO Aya**
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- 21) **NAKAMURA Hisashi**
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- 22) **TANIMOTO Youichi, Shang-Ping Xie**
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- 23) **TANIMOTO Youichi**
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- 24) **TANIMOTO Yoichi, Shang-Ping Xie**
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- 25) **NAKAMURA Hisashi**
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- 26) **Vinayachandran P.N, YAMAGATA Toshio**
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Publications

Appendix A

- 28) **NAKAMURA Hisashi, YAMAGATA Toshio**
 「Observed Association between SST and Atmospheric Anomalies in the North Pacific Decadal Climate Variability」
 7th Annual Meeting of PICES
- 29) **YAMANE Syouzou, YODEN Sigeo**
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- 31) **KAKU Shinu, Hisashi Hukuda, Yasumasa Miyazawa, Shinya Minato, YAMAGATA Toshio**
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- 32) **KAKU Shinu, Hisashi Hukuda, Yasumasa Miyazawa**
 「A one-way nested model for Japan Coastal Ocean Predictability Experiment」1998 Fall Meeting of Japan
 Oceanographic Society, Kyoto University
- 33) **S.K.Behera, YAMAGATA Toshio**
 「Variability in the Indian Ocean」World Ocean Circulation Experiment (WOCE)
- 34) **NAKAMURA Hisashi**
 「Characteristics of Decadal/Interdecadal climate Events Variability Resents observed in the North Pacific」
 CCSR Library Vol.3
- 35) **NAKAMURA Hisashi, YAMAGATA Toshio**
 「Observed Association between SST and Atmospheric Anomalies in the North Pacific Decadal Climate Variability」
 7th Annual MEETING of PICES
- 36) **NAKAMURA Hisashi, YAMAGATA Toshio**
 「Spatial Structure and Time Evolution of Decadal/Interdecadal Climate Events Observed in the North Pacific」
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- 39) **TANAKA Noriyuki, KAWAMURA Toshiyuki, UKITA Motonobu, KIYOMIYA Mariko**
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- 40) **HONDA Meiji, NAKAMURA Hisashi**
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 to the decadal climate variability」North Pacific Marine Science Organization (PICES) 7th Annual Meeting
- 41) **YAMAZAKI Koji, OHHASHI Yasuaki**
 「Variability of the Eurasian pattern and its interpretation by wave activity flux」North Pacific Marine Science
 Organization (PICES) 7th Annual Meeting

- 42) **TANIMOTO Yoichi, Shang-Ping Xie**
「Decadal variation of air-sea complex fields in the Atlantic Ocean」Meteorological Society of Japan
- 43) **SAKUMA Hirofumi**
「On the nonlinear stability analysis for two-dimensional stratified shear flow」Meteorological Society of Japan
- 44) **MINOBE Syojiro**
「Bidecadal and pentadecadal climate oscillation over the north Pacific」North Pacific Marine Science Organization (PICES) Workshop
- 45) **TANIMOTO Yoichi**
「Ocean-Atmospheric Variability in the Pan-Atlantic basin」TRIANGLE'98
- 46) **Vinayachandran P.N, MASUMOTO Yukio, YAMAGATA Toshio**
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- 49) **YASUDA Ichiro, Masayuki Noto**
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「Simulation of International SST variability in Indian Ocean」TRIANGLE'98
- 51) **S.K.Behera, P.S.Salvekar (Indian Institute of Tropical Meteorology), YAMAGATA Toshio**
「International SST variability in Indian Ocean」TRIANGLE'98
- 52) **TANIMOTO Yoichi, Shang Ping XIE**
「Ocean-Atmosphere Variability over the Pan-Atlantic Basin」American Geophysical Union, 1998 Fall Meeting
- 53) **TANIMOTO Yoichi**
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- 54) **HONDA Meiji, YAMAZAKI Koji, NAKAMURA Hisashi, TAKEUCHI Kensuke**
「Dynamic and Thermodynamic Characteristics of Atmospheric Response to Okhotsk Sea-Ice extent Anomalies」
Journal of Climate (American Meteorological Society)
- 55) **HONDA Meiji, YAMAZAKI Koji, NAKAMURA Hisashi, TAKEUCHI Kensuke**
「Dynamic and Thermodynamic Characteristics of Atmospheric Response to Okhotsk Sea-Ice extent Anomalies」
Journal of Climate (American Meteorological Society)
- 56) **NAKAMURA Hisashi**
「Characteristics of Decadal/Interdecadal Climate Events Recently Observed over the North Pacific」
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- 57) **YAMANAKA Yasuhiro**
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Appendix A

Computer and Information Office

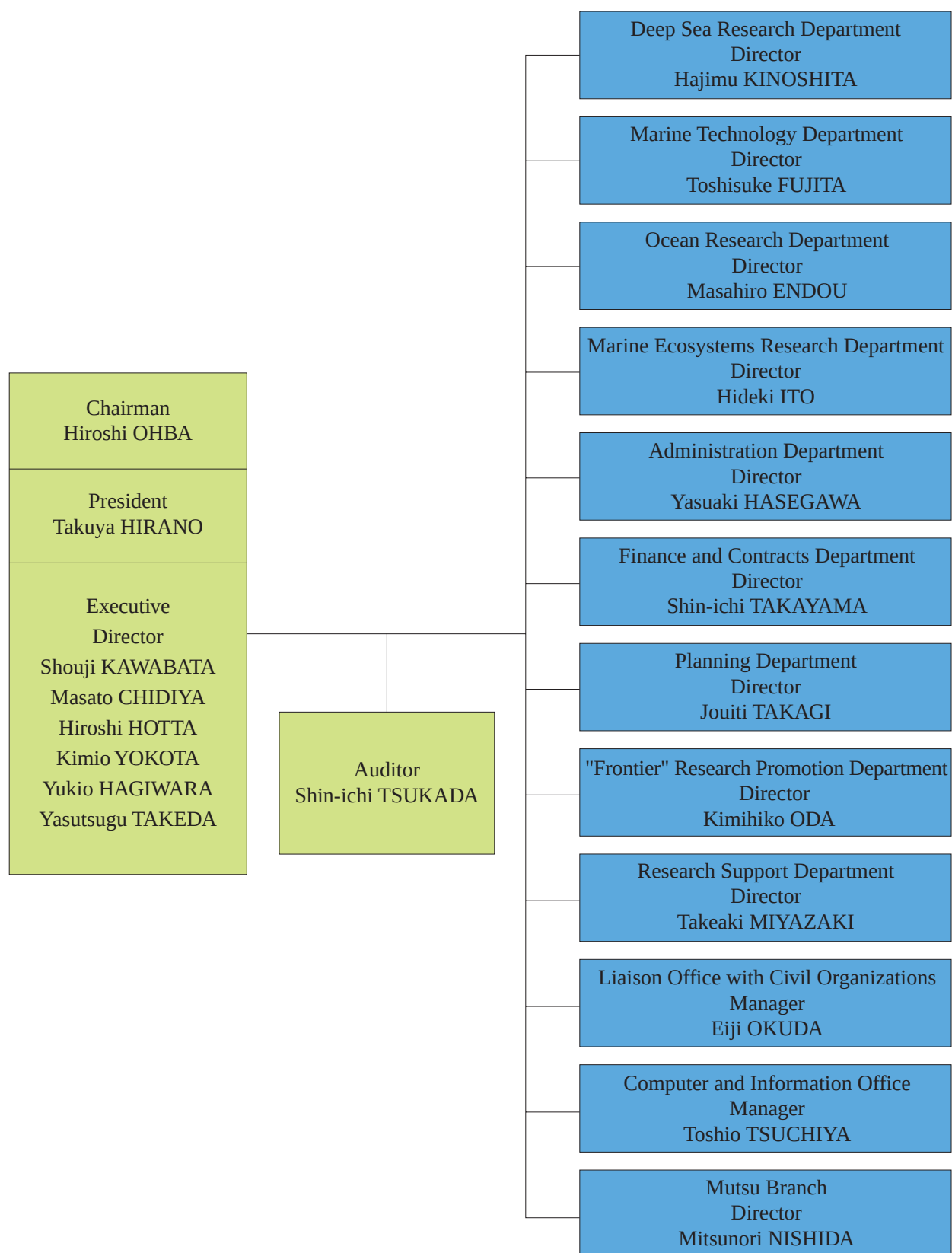
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- 2) **TSUCHIYA Toshio**
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- 3) **FUTA Koji, KIKUCHI Toshiaki, TSUCHIYA Toshio**
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- 4) **TSUCHIYA Toshio, OCHI Hiroshi, NAOI Jun**
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- 5) **TSUCHIYA Toshio , The searching project team of the "TSUSHIMA-MARU"**
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- 6) **T.TSUCHIYA, T.KIKUCHI, T.NAKANISHI**
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Planning Department

- 1) **HOTTA Hitoshi**
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 Technology-」Japan Iron Association, Shiraishi Memorial Seminar

Organization Chart

Appendix B



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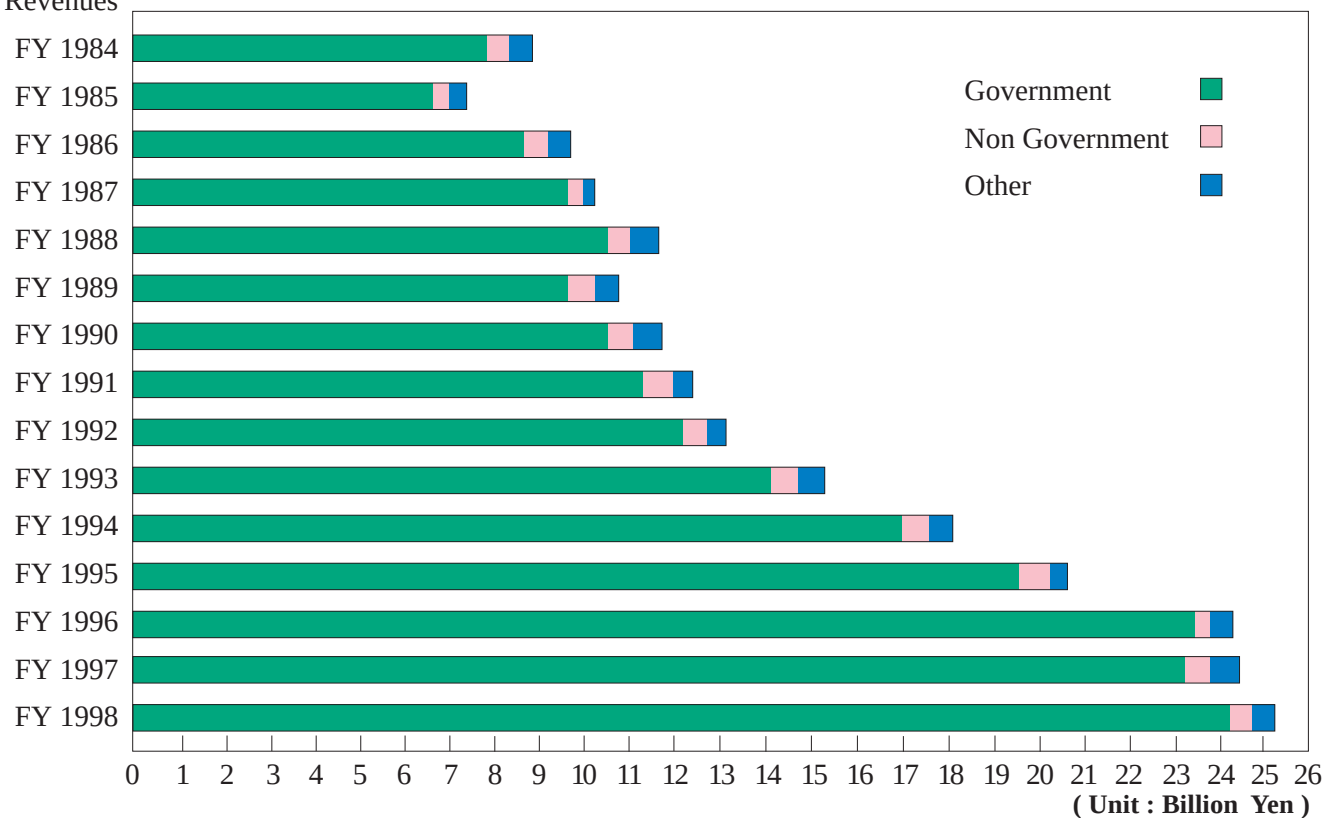
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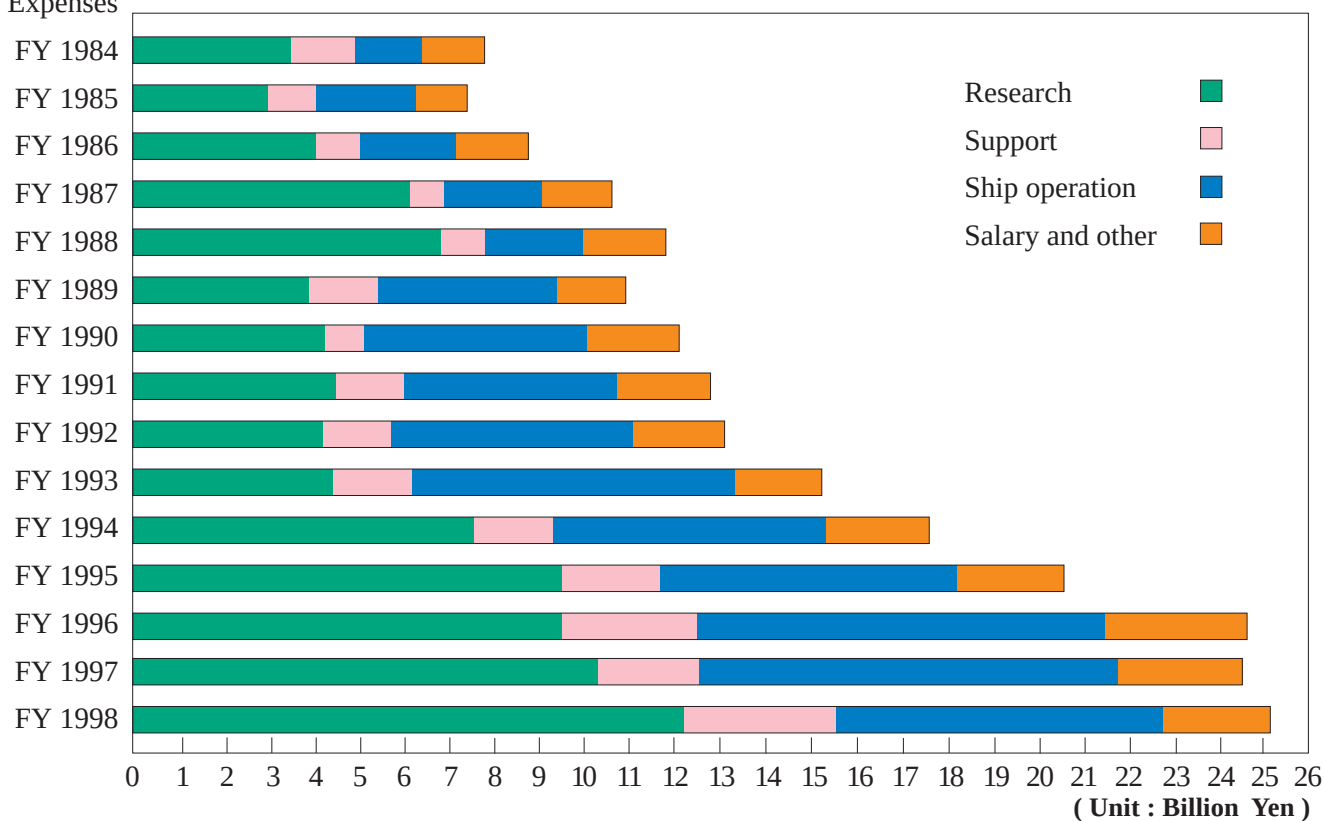
Budget

Appendix E

Revenues



Expenses





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