

JAMSTEC

1997 Annual Report



JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

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CONTENTS

Preface	1
Outline of Activities	3
Research Activities	
Deep Sea Research Department	7
Deep Sea Technology Department	18
Ocean Research Department	28
Coastal Research Department	50
Deep-sea Environment Exploration Program	62
Frontier Research Program for Subduction Dynamics	67
Frontier Research System for Global Change	73
Project Team	
Ocean Acoustic Tomography	79
Marine Observation Satellite Research	83
Oceanographic Research Vessel	86
Support Activities	
Technical Information Services	89
Scientific Computing Division	93
Ship Operations Department	100
Training and Education Division	107
Mutsu Branch	109
Appendix	
Appendix A:Publications	113
Appendix B:Organization Chart	125
Appendix C:Scientific & Technical Staff	126
Appendix D:Support Staff	130
Appendix E:Budget	132

Preface



This year is the United Nation's International Year of the Ocean. As symbolized by the international exposition on the ocean held in Lisbon, Portugal, the recognition of our relationship with the ocean is expected to be deepened while our understanding of the research into, development of, and utilization of the ocean is being promoted.

In Japan, recognition has grown of the importance of science and technology in the renovation of the industrial structure. At the same time, the Kyoto Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3), held in Kyoto last December, has made us feel how the impact of global environmental problems are closely related to the socioeconomic activities of humankind. Particularly in the field of marine science and technology, recognition has broadened of the ocean as playing crucial roles in climate change, and research is being done from the viewpoint of regarding the ocean as an integrated part of the earth. In addition, the development and utilization of the ocean is one of the fields expected to be a powerful means of promoting science and technology, and it is predicted that more interest will be directed to the ocean in the future.

Under these circumstances, Japan Marine Science and Technology Center (JAMSTEC) is confident that

it has steadily achieved important successes by promoting research and development work which includes: deep sea exploration and research using the deep sea research submersibles "Shinkai 2000" and "Shinkai 6500", and the remotely operated vehicle "Dolphin-3K" and "Kaiko"; research into deep sea microbes in special environments in deep-sea areas through the use of deep sea microorganisms collecting and cultivating system; oceanographic observation that uses acoustic tomography technology; and ocean energy utilization technology that uses "Mighty Whale". Furthermore, the deep sea research vessel "Kairei" and oceanographic research vessel "Mirai" were commissioned into activities in 1997, dramatically improving JAMSTEC's exploration and observation capabilities.

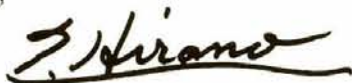
With this background, it can be said that the world's top class infrastructure and the basis for a center of excellence (COE) are being enhanced and updated in JAMSTEC, with the roles that it plays in interdisciplinary research activities as an integrated test and research organization becoming increasingly important. In particular, JAMSTEC's high technological capabilities for exploring deep seas, represented by remotely operated vehicle "Dolphin-3K" System, has received great attention around the world. Last year, the system demonstrated its capability in exploring the Russian tanker, Nakhodka, which caused an oil-spill accident in the Sea of Japan and sank, and by discovering the Tsushima Maru, a vessel carrying evacuated school children which sank in the vicinity of Akuseki Island, Kagoshima Prefecture during World War II.

With the aim of realizing predictions of global change, JAMSTEC started the Frontier Research System for Global Change as a joint project with the National Space Development Agency of Japan (NASDA) in October 1997, initiating full-scale research to solve global environmental problems.

This annual report briefly summarizes the activities of JAMSTEC in 1997. It will be our pleasure if this report helps our readers gain an understanding of the activities and research and development work in which JAMSTEC is engaged. We hope that fur-

ther support and cooperation from the general public
will be given to JAMSTEC.

December, 1998

A handwritten signature in black ink, appearing to read 'T. Hirano', written in a cursive style.

Takuya HIRANO

President

Japan Marine Science and Technology Center

Outline of Activities

In FY 1997, JAMSTEC engaged in a variety of activities including research and development, training and information services, as well as the provision and joint use of facilities and equipment based on close cooperation with relevant domestic and overseas organizations—all in order to promote Japan's ocean research and development.

An overview of each area of operations follows below.

1. Research and development Activities

JAMSTEC classifies research into project research, special research and research based on working expenses, depending on the goal, content and state of progress of research and development. While we conduct research and development in accordance with the plan that we establish at the beginning of the fiscal year, we also have a flexible structure that always allows for changes in circumstances and creative research based on new insights midway through the year. In addition, we carry out commissioned research and joint research based on the requests and cooperation of other related organizations in Japan and overseas.

The research and development that we have carried out in FY1997 is as follows.

1) Project Research

JAMSTEC classifies important, large scale or integrated research and development which aims to contribute to economic development and to improving ocean science technology as project research. In FY1997, we engaged in the following 29 areas of project research.

- Deep-sea survey research
- Long-term observation using a deep sea floor observatory
- Research of the interrelationship between heat and material cycles and the biosphere
- Development and installation of a seafloor earthquake comprehensive monitoring system
- Frontier research of ocean crust dynamics
- Research and development of a deepsea research submersible system
- Research and development of a remotely operated vehicle
- Research and development of a deep sea drilling system
- Outfitting of the oceanographic research vessel "Mirai"
- Development of an oceanographic observation buoy system
- Development of an acoustic data transmission system
- Research and development of an ocean acoustic tomography system monitor
- Research and development of the deep-sea environment
- Explanation of the mechanism of change in the ecosystem of coastal regions
- Research for technology which uses ocean energy
- Research and development of technology for underwater work
- Regional cooperative research and development
- Observation of the tropical equatorial region
- Observation of mid and high latitude sea regions (sub-tropical)
- Observation of mid and high latitude sea regions (sub-polar)
- Research and development of an ocean acoustic tomography system
- Research and development of automated marine observation technology
- Observation of the Arctic Ocean region
- Observation of the interaction between the oceans and the atmosphere
- Observation of the material cycle in high latitude waters
- Research and development of marine laser observation technology
- Research of explaining the basic productive mechanism
- Promotion of the Frontier Research System for Global Change
- Improvement of the system for using the oceanographic research vessel "Mirai"

2) Special Research

JAMSTEC classified research and development that rests on the merits of research based on working expenses and is to be developed into future project research as special research. In FY 1997, we carried out special research on the following four topics.

- Research into observation methods using a marine observation satellite
- Research into methods of evaluating marine observation
- Explanation of past environmental change and verification of models
- Research to promote the development of creative technology

3) Research Based on Working Expenses

JAMSTEC classified research topics that are based on the ideas of individual researchers exercising their research capacities or research topics that will later develop into special research or project research as research based on working expenses. In FY 1997, research based on working expenses covered a total of 19 topics.

4) Entrusted Research and Joint Research

JAMSTEC carried out research under commission as requested by other organizations, when it is beneficial to JAMSTEC because it involves ocean science technology. In FY 1997, we carried out commissioned research into nine areas.

In addition, we undertake joint research into those areas where we can reduce expenditure, shorten the time needed for the research and obtain superior research results by pooling research and development capabilities and results with other organizations. In FY 1997, we carried out joint research in 23 areas.

2. Training and Education Activities

JAMSTEC took part in training and education activities in order to publicize the results of research and development as widely as possible and to foster the human resources needed for the promotion of

ocean development in Japan. In FY 1997, we carried out training in areas such as diving technology, ran science camps for high school students and marine science schools for high school teachers.

3. Technical Information Activities

In addition to collecting documents from Japan and overseas on marine science technology which are needed for research and development (including books, journals, conference data and technical reports), we publish many kinds of reports in order to publicize our research results both in Japan and overseas. In addition, we are promoting the construction of a marine information database and the operation of a super computer system.

4. Operation of Vessels

In order to carry out the activities described above, JAMSTEC operates a 2,000m-class research submersible vessel system (“Shinkai 2000”, “Natsushima” and land facilities), remotely operated vehicles “Dolphin-3K” and “Kaiko”, the research vessel “Kaiyo”, the 6,500m-class research submersible vessel system (research submersible vessel “Shinkai 6500”, support vessel “Yokosuka” and land facilities), the deep sea research vessel “Kairei” and the oceanographic research vessel “Mirai”. The FY 1997 operations of these vessels are reported below.

1) “Shinkai 2000”

The vessel carried out a total of 69 submersions in Japanese waters, such as Sagami Bay, and around the Mariana Islands.

2) “Natsushima”

In addition to supporting the underwater missions of “Shinkai 2000” and “Dolphin-3K”, the vessel carried out solo surveys and was at sea for a total of 281 days in FY 1997.

3) “Dolphin-3K”

In addition to carrying out test and training sub-

mursions and advance surveys for "Shinkai 2000", the vessel performed underwater surveys in areas such as Sagami Bay. Further, the vessel carried out surveys on the Tsushima-maru, which sank during World War II while evacuating children from Japan's war-torn industrial cities, and the submerged section of the Nakhodka, following last year's survey, and made a total 47 underwater voyages.

4) "Kaiyo"

The vessel carried out various experiments in real ocean areas, observation and deep-sea tug surveys, with a total of 264 days at sea in FY 1997.

5) "Shinkai 6500"

The vessel carried out a total of 51 underwater voyages in Japanese waters in the Nansei Islands and the Japan Trench in addition to the East Pacific Rise.

6) "Yokosuka"

In addition to supporting the underwater missions of "Shinkai" 6500, the Yokosuka carried out solo surveys and spent a total of 268 days at sea in FY 1997.

7) "Kaiko"

"Kaiko" was completed in March 1997, has carried out a total of 39 voyages including test and training submersions and survey submersions. In addition, the vessel carried out a survey of the Tsushima-maru, the evacuee ship for school children, using a launcher.

8) "Kairei"

"Kairei" was completed in March 1997. In FY 1997, it carried out practice exercises using its various on-board observation instruments, surveys, and supported the underwater missions of "Kaiko", with a total 260 days at sea.

9) "Mirai"

"Mirai" was completed in September 1997 and spent a total 164 days at sea in FY 1997 carrying out practice exercises using its various on-board observation instruments.

5. Survey of the Wreck Site of the Tsushima-maru

In December 1997, after 53 years, using the unmanned surveyor "Dolphin-3K" and the support vessel "Natsushima", JAMSTEC located the hull of the Tsushima-maru, an evacuee ship for school children which sank during World War II, 10 km northwest of Akuseki Island in Kagoshima Prefecture, lying on the seabed at a depth of 870m. In August 1944, the Tsushima-maru was on its way from Naha to Nagasaki, evacuating school children from Okinawa, when it was attacked and sunk by an American submarine, costing the lives of 1,484 people, including 738 school children.

The survey of the wreck site was carried out on the request of the Okinawa Development Agency to the Director of the Science and Technology Agency with the cooperation of the Ministry of Health and Welfare.

The survey, which took place December 3-6, used the Rov "Kaiko" (towed vehicle) and the deep sea research vessel "Kairei" to carry out an acoustic survey which discovered an object which appeared to be a ship's hull.

A video camera survey carried out by "Dolphin-3K" and "Natsushima" on December 11 and 12 confirmed the ship's name Tsushima-maru on the right side of the ship's bow.

6. Resurvey of Submerged Section of the Nakhodka

From January 2, 1997, using a Deep Tow and the Rov "Dolphin-3K", JAMSTEC carried out a two month survey of the submerged stern of the Nakhodka, the Russian registered tanker which sank in 2,500m of water 140km northeast of the Oki Islands, Shimane Prefecture on January 2, 1997. We checked the hull and determined the state of the heavy oil leakage and the rupture in the ship's bow. Approximately one year later, while the quantity of heavy oil leakage from the submerged portion of the hull had decreased, it was continuing to appear on the surface of the sea. Therefore, we carried out two underwater surveys on March 6 in order to ascertain the oil leakage from

the submerged section of hull and the condition of the hull using “Dolphin-3K” and the support vessel “Natsushima”.

The results of this survey are as below.

- ① It was confirmed that the overall volume of leaking heavy oil had decreased compared to the previous survey.
- ② No particular changes in the position and condition of the ship’s hull were observed.
- ③ At sites that were surveyed individually, areas where new adhesion of oil could no longer be observed and areas of oil adhesion probably caused by the leakage of a considerable volume of oil from the ship’s own tank, which were not confirmed in the previous survey, were established. In addition, as in the previous survey, a white substance, thought to be an anti-corrosive zinc compound, was observed adhering to a number of areas on the ship’s hull.

Deep Sea Research Department

1. Outline of the research plan

Deep sea research of the Japan Marine Science and Technology Center, JAMSTEC, aims to have a comprehensive understanding of the deep sea, that is, the dynamic phenomena of deep sea from past to future and mutual relation among physical, chemical, biological and geological phenomena. Manned submersibles "Shinkai 2000" and "Shinkai 6500", ROV "Dolphin-3K" and "Kaiko" and JAMSTEC deep tow systems were used for the above purpose. The training cruises of the deep sea research vessels "Kairei" and "Mirai" have been performed from this FY 1997 for the scientific use.

Since 1983, various unknown phenomena had been found from the deep sea and it had been clarified that the deep sea was diverse world. These phenomena have close relationship to the minerals, biology, circumstances and prevention against disasters. Therefore, research relating these phenomena and interrelations to these problems are also important targets. The long-term observations have played an important role to understand the unpredictable phenomena a short-term observations. In order to predict and to make less the disasters, we also put a lot of emphases on the elucidation of the deep crustal structure in trench area where the large earthquakes occur.

In FY 1997 we performed the following five major researches; 1) Comprehensive study of the Japanese seas using "Shinkai 2000" and "Dolphin-3K", 2) Researches around the Japanese Islands and the East Pacific Rise using "Shinkai 6500", 3) Long-term monitoring of the Sagami Bay off Hatsushima Island and off Cape Muroto by the use of the Seismic and Environmental Seafloor Monitoring System, 4) Geological and geophysical research of the Philippine Sea by

piston corings and dredges,5) Research of the deep crustal structure of the eastern and western Nankai Trough and Japan Trench off Sanriku.

1) Research by "Shinkai 2000" and "Dolphin-3K"

In 1997, "Shinkai 2000" made its second expedition outside Japan with an exploratory survey in the northern Mariana Trough. This survey was undertaken primarily to gather information on the geology of submarine volcanoes and the island arc system, concurrently investigating the biogeography of the fauna of hydrothermal vent communities. An inactive chimney was discovered on the western face of the northern portion of the Mariana Trough. In addition, a hydrothermal vent community on the Daini-Kasuga Seamount, first discovered by the *Alvin* in 1987, was revisited and several undescribed species were collected.

Further surveys were conducted at the annual survey sites in Sagami and Suruga Bays, the Japan Sea, the Nansei Islands, the Nankai Trough and the Izu-Ogasawara Islands. In the Nansei Islands, a study was carried out on the geology, chemistry, micro- and macrobiology of the hydrothermal vent community which was discovered in the northern portion of the Iheya Ridge in 1995. In addition, a new hydrothermal vent community was discovered near Amami Island in the Nansei Islands during the survey on the effects of an ocean bottom earthquake. In the Japan Sea, the survey on the effect of crude oil spillages was carried out, and the geology and biology around the plate boundary was investigated. Surveys at the Myojin Knoll chemosynthetic community, discovered in 1996 in the Izu-Ogasawara Islands area, and on gas hydrates in the Nankai Trough area were carried out. Biogeochemical and biological studies on the chemosynthetic communities in Suruga and Sagami

Bays were continued.

Survey areas investigated by ROV "Dolphin-3K" are the Japan Sea, the Nankai Trough, Sagami Bay, the Nansei Islands and the Mariana region. Geological research was carried out in the western Kanasu-nose Bank, Nankai Trough, under the KAIKO-TOKAI project. In Sagami Bay, research efforts were directed at the cold seep chemosynthetic communities, as with the "Shinkai 2000" surveys. In the Nansei Islands, the reproductive ecology of *Lamellibrachia satsuma* in Kagoshima Bay was investigated.

2) Research by "Shinkai 6500"

Fy 1997 exploration using "Shinkai 6500" consisted of four cruises. The first cruise was executed in the Izu-Bonin Trench and the Japan Trench, the second and third were in the East Pacific Rise, and the fourth was in the Nankai Trough. The purpose of each cruise is as follows:

The first cruise

- Investigation of basement and volcanic rocks in the Sofugan Tectonic Line, the Palace Vela Rift, and Nishi-Jokyo Seamount
- Investigation of protists in the chemosynthetic community on a whale carcass, eastern Torishima Island
- Investigation of microbes on the seaward slopes and of *Calyptogena* colonies on the landward slope of the Japan Trench, off Sanriku

Second and third cruises

- Long-term observation of magma and hydrothermal activities and the spreading phenomenon in the East Pacific Rise (financed by Special Coordination Funds for Ridge Flux Project, promoted by Science and Technology Agency)

Fourth cruise

- Investigation of the microtopography of accretionary prism and cold seep in the Nankai Trough (Japan-France KAIKO-TOKAI Project)
- Installation and deployment of the long-term deep seafloor observatories with a cable (financed by Special Coordination Funds for "Investigation Concerning the Development of a Multi-purpose Global Environment Monitor Network Using a

Submarine Cable System", promoted by Science and Technology Agency)

These investigation and research activities were conducted not only by the researchers of the JAMSTEC but also in cooperation with researchers from various universities and public research institutions. The detailed results are presented in section (2) Details of Major Research and Development Activities.

3) Research by Deep Tow

In April 17 to 20, 1997, "Kaiyo" was used for deep sea exploration by Deep Tow (KY97-05-SGM/MRT) off the Hatsushima Island in the Sagami Bay. The aim of this exploration was to investigate the conditions of the seafloor in the vicinity of hypocenter, in which the remarkable turbidity current and changes in topography were observed by the Off-Hatsushima Long-term Observation Station, after the swarm earthquakes occurred in the eastern side of off Izu Peninsula during one week from September 3, 1997. The investigation made it clear that the remarkable turbidity current observed at the station was due to the collapse of surface sediment layer induced by the earthquakes rather than to its instability.

In February 2 to 9, 1998, "Yokosuka" was used to carry out deep sea exploration by Deep Tow (YK98-02): The purpose of the exploration was to conduct a preliminary investigation for installing observation equipments and checking the conditions of the former TPC-2 submarine cables on the Okinawa-Miyako Flat in the landward of the Ryukyu Trench, which is a part of the VENUS Project (financed by Special Coordination Funds for "Investigation Concerning the Development of a Multi-purpose Global Environment Monitor Network Using a Submarine Cable System", promoted by Science and Technology Agency). A deep tow camera system consisting of nine lateral lines was towed mainly along the cable route between repeaters 138° and 139° of the former TPC-2 submarine cable, to which the long-term observation equipment for the VENUS Project will be connected. As a result, the submarine cable was observed visually at a total of 36 points. This observation enabled us to deter-

mine the position of the cable between the two repeaters. It was made clear that the cable was shifted about 1,500 m to the northeast in the vicinity of the repeater located on the north side and about 600 m to the northeast in the vicinity of the other repeater located on the south side. When viewed section by section, the cable meanders here and there; however, it is laid almost straight when viewed on the entire route. Most of the seafloor near the cable consists of flat mud or sand, without outcrops at all.

In March 26 to 28, 1998, "Kaiyo" was used to carry out deep sea exploration by Deep Tow with the aim of determining whether the former TPC-2 submarine cable was bound by other submarine cables or not, because binding by another cable was suspected as one of the possible causes of the dropping of the former TPC-2 submarine cable during the lifting operation after it was cut. The investigation showed the absence of any objects that could have bound the former TPC-2 submarine cable, though a rope with a diameter of less than 10 mm, used as fishing gear, was found.

4) Long-term deep seafloor observation

The observation by the Real Time Deep Seafloor Observatory off Hatsushima Island in Sagami Bay was continued for more than 4 years since the deployment. In order to investigate the causes of generation of the mudflow associated with swarm earthquake east off Izu Peninsula, the seafloor survey by deep-tow camera and submersible "Shinkai 2000" was carried out in April and May, 1997.

The observation by Long-term Deep Seafloor Observatory off Cape Muroto in Kochi Prefecture which was deployed in March, 1997 was started. In August, the installation conditions of tsunami pressure gages, seismometers and the Cable End Station was observed by ROV "Kaiko" and the geothermometer of the station was installed in the seafloor. The transfer of seismometer and tsunami sensor data to JMA (Japan Meteorological Agency) was started in December 1997.

In the VENUS (Versatile Ecomonitoring Network by Undersea-cable System) project which was per-

formed through Special Coordination Funds for Promoting Science and technology of the Science and Technology Agency of the Japanese Government, although two cruises in the area off Okinawa Islands were carried out in November 1997 and March 1998 for the purpose of installing the observation equipment which was developed since the 1995 fiscal year, the installation was unsuccessful. The installation was postponed by the 1999 fiscal year.

5) Research by use of seismic exploration system

Seismic surveys have been carried out at the Zenisu Ridge (2/May - 9/May), the Nankai Trough off Muroto (25/June - 22/July) and the Japan Trench off Sanriku (30/September - 16/October) using a seismic exploration system on board of R/V "Kairei". Those surveys have been done as a part of a test/training cruise of "Kairei". During the Zenisu Ridge survey, a system performance test was carried out. In the meantime, integrated deep seismic studies, which mainly consists of a seismic reflection and refraction surveys, were performed in cooperation with "Frontier Research Program for Subduction Dynamics", during the cruises in the Nankai Trough and the Japan Trench. The survey area in the Nankai Trough is in/near rupture area of the 1944 Tonankai (M=8.2) and 1946 Nankaido earthquakes (M=8.2). Historic records since 7th shows that Magnitude 8 class earthquakes have been occurred in the Nankai Trough repeatedly with their recurrence interval about 100 - 200 years. It is believed that understanding of the earthquake mechanism of this area is an urgent issue, because it has been passed more than 50 years since the last large earthquake occurred in this area. Off Sanriku area is also important for understanding a mechanism of large thrust earthquake, since several large earthquakes hit this area (e.g. 1994 off Sanriku earthquake).

2. Main Results

1) Deep sea research

① Geophysics

Investigation into the East Pacific Rise

To implement the research project titled Deep Sea Exploration and the Joint International Research for Elucidation of Energy and Material Flux at Ridges (Ridge Flux Project), "Shinkai 6500" was put to diving expedition in the East Pacific Rise (Y97-05, 06) from July to September 1997.

The Southern East Pacific Rise (ridge), which was the subject of the diving expedition this time, is known as the fastest seafloor spreading axis with the seafloor spreading eastward and westward at a speed of 15 cm per year. Based on the results obtained through past exploration, the diving this time aimed at conducting long-term observation of magma and hydrothermal activities and spreading phenomena in the Southern East Pacific Rise and thereby clarifying the heat budget of ridges, geochemical material budget, and energy and material flux associated with biological activities. Our purpose on Leg 1 was to install various observation equipments on the seafloor by using "Yokosuka/Shinkai 6500" to start long-term observation that was to last for about one year. Our purpose on Leg 2 was to conduct geophysical observation to obtain geological and chemical data which were to be used to acquire basic data for structuring models and at the same time, to install a long-term observation system on the seafloor.

The major geophysical results obtained on both legs are as follows:

(a) To observe short-term changes, the self-recording long-term observation station Manatee was installed in the hydrothermal community for about nine days. As a result, 12-hour period changes in water temperature and other factors were observed together with irregular spike-shaped changes. After this observation, one of the same systems was installed in the high temperature hydrothermal activity area and the other in the low temperature hydrothermal activity area to capture one-year long-term changes. In addition, various long-term observation systems pre-

pared by other research organizations were installed on the seafloor.

(b) Basic data, to be used to create ridge development models based on new classification of segments, topography classification, and topography measurement, were obtained from the results of the investigation made thus far.

(c) New information on the formation of grabens (asymmetric and seven-step escarpments, terraces, and taluses) was obtained.

(d) Distribution of new lava was determined accurately and the amount of ejecta was estimated (Time and spatial distribution of magma was determined).

(e) High precision mapping of hydrothermal fluid sites was conducted (RM28 and RM24 oasis sites; the site designation notation in the form of "RM**" was decided on during the cruises in 1993).

(f) R/V "Yokosuka" was used to observe topography, gravity, and geomagnetism; in particular, the Brunne/Matsuyama boundary was determined by using the Proton and a three-component magnetometer, with the magnetic structure estimated by using a site-use three-component magnetometer.

In addition, investigation into gravity and magnetism was conducted in the Ryukyus during the diving expedition of "Shinkai 6500" and in the northern Mariana Islands and the western Philippine Basin during the learning navigation of R/V "Kairei."

② Topography and geology

Investigation was conducted in the arc-trench system in the oceanic island arc area running in a line from the Izu-Bonin Islands to the Mariana Islands; the investigation covered an extensive range including submarine volcanoes on the volcanic front, volcanoes in the back arc area, and the back arc basin west of it, the Shikoku Basin.

The Myojin Knoll is a submarine volcano on a volcanic front running southward from the Izu Peninsula, with the Myojin-sho located northwest of the knoll. At the center of the submarine volcano, a caldera with a diameter of about 5 km exists; on the western side of the volcano, the FY 1996 investigation confirmed the existence of submarine hydrother-

mal activities accompanied by sulfide deposit. The investigation done in this fiscal year confirmed hydrothermal activities on the northwestern part of the caldera wall.

The Sofugan Tectonic Line divides the Izu-Bonin Arc into the northern and the southern part. In this fiscal year, diving expedition using "Shinkai 6500" and topography investigation using the mother ship, "Yokosuka", were conducted in the vicinity of the Sofugan Tectonic Line in the southern part of the Izu-Bonin Arc. In the vicinity of the Sofugan Tectonic Line, four dives were made to observe and collect samples of that upper crust of the Izu-Bonin Island Arc which is distributed along the tectonic line. As a result, it was made clear that the tectonic line is structurally oriented from NE to SW and that escarpments with a maximum drop reaching 1,500 m are ranged along a distance of 200 km (Photo 1). The observation also made it clear that repeated alternation of strata consisting of lava flows and pyroclastic rock is distributed along the tectonic line and that clastic volcanic rock tends to occur more frequently in an upward direction. In addition, fresh dolerite, peridotite, basalt, and other rocks were collected.

"Yokosuka" took cruise in the Izu-Bonin area. This cruise covered three areas: (a) the area extending from



Photo 1 Photograph of outcrop of jointed lava on a cliff along the Sofugan Tectonic Line

the Seven Week Day Seamounts to the eastern edge of the Sofugan Tectonic Line; (b) the sea area between Hachijo Island and Aogashima Island; and (c) the Manji Seamount area. The main subjects of investigation during this cruise were topography, gravity, and geomagnetism. This investigation revealed the flattening of the graben structure developing in the Seven Week Day Seamounts in the area (a), the caldera-shaped topography with a diameter of 5 km in the sea area (b), and the summits in the area (c).

In the south of Iwojima Island in the northern Mariana, "Shinkai 2000" performed diving expedition and R/V "Kairei" performed topographical and geological structure investigation during their training cruise. The diving expedition by "Shinkai 2000" revealed the existence of inactive chimneys consisting of manganese oxides, on the western trough walls at the northern tip of the Mariana Trough (Photo 2). R/V "Kairei" was used to investigate the seafloor topography, geological structure, and geophysical aspects in the Mariana Trough between latitude 24 and 22 degrees 30 minutes north and the nearby area. The investigation made it clear that many small-scale volcanoes exist west of the trough and that fault topographies running from north to south and from north-northwest to south-southeast exist extensively in the



Photo 2 Photograph of inactive chimney in the northern Mariana Trough area

trough and its neighborhood.

The topographic and geological research was done in the East Pacific Rise as a Ridge Flux project (Funded by Science and Technology Agency). Precise topographic survey and sampling of lavas were conducted by the use of "Shinkai 6500". As the results three different ages of lavas were identified and the distribution and volume of the lavas were estimated. The detailed structure of the rifts were also surveyed and seven fault cliffs and terraces were recognized and traced areally.

In the Philippine sea, rock sampling by dredge haul and piston coring were carried out at the Parece Vela Basin and the southern Mariana Trench. It was clear that the hard sediments within the sedimentary hiatus distribute widely in the West Philippine Basin. The detailed topographic survey was done in the Mariana Trench and the Central Basin Fault. Fresh ultramafic rocks were collected from the Parece Vela Rift and less altered basalts were collected from the Central Basin Fault.

With the aim of observing changes in the flow mode at the tip and in the middle of lava flows, investigation into seafloor lava flows was conducted off Atagawa in the Sagami Bay, clarifying that the flow mode at the tip of a lava flow consisting mainly of pillow lava and clast is different from that in the middle of a lava flow consisting of sheet lava.

Geophysical and geological study on the large-scale earthquake tsunami was conducted in the western Ryukyu region.

The landward slope of the westernmost part of the Nanseishoto (Ryukyu) Trench was surveyed in order to detect the tectonic features, mainly surface ruptures and origin of large-scale tsunamis. Relationship between the chemosynthetic communities discovered in this region and possible surface ruptures was also studied through the diving programme by "Shinkai 2000", "Dolphin-3K" and "Kaiko". The background of the programme is a hazardous tsunami named "the 1771 Yaeyama Earthquake Tsunami" ("Great Meiwa Tsunami") which occurred in 1771 around 24.0N, 124.3E in the landward slope of the Ryukyu Trench, off Miyako and Yaeyama Islands. The origin of the

tsunami is considered to be a large-scale underwater landslide occurred on the southern slope of the Kuroshima Knoll, on the landward slope of the trench, and 30 km south of the Yaeyama Islands, according to the result of seismic reflection surveys and a numerical simulation.

During the survey cruise by JAMSTEC/Deep Tow in the study area in 1996, *Calyptogenia* community corresponding to cold seepage was discovered on the summit plain of the knoll. So, a detailed survey for mapping and sampling of the community was carried out by use of ROV "Dolphin-3K" and submersible "Shinkai2000" in October 1997. *Calyptogenia* community was found to be widespread towards west of the knoll. The distribution of dead clams is extremely dense in the central part of the knoll. The distribution of living clams is sparse and is limited to the eastern edge of the knoll. Surface rupture, breccias and mounds derived from local stress of the surface of the knoll are located beside the community. A number of chimneys or sand pipes made up of layered limestone were also observed near the community. These findings suggest a spout of mud from the subsurface due to a local stress. The study area is characterised by a rupture zone accompanied by faulting and the consequent cold seepage which occurred repeatedly in the past and is still taking place along the hidden faults and/or the surface ruptures on the knoll.

In the Nankai Trough, a submersible survey was



Photo 3 Photograph of pillow lavas and its surface in the Eastern Pacific Rise area

performed to investigate, as part of the KAIKO-TOKAI Project, microtopography on the seafloor surface and upwelling from below the seafloor on the Nankai Trough accretionary prism.

In the Oshima-Oshima Island sea area, "Shinkai 2000" was used to collect sediment originating from mountain collapse to study the formation process of slip cliffs. In the Okushiri Basin, seafloor observation and collection of sediment were conducted to obtain information on the seafloor collapse and sedimentation process by earthquakes caused by the Hokkaido Nansei Oki Earthquake.

③ Biology

In order to understand oceanic environment on a global scale, it is necessary to determine both the effect of environmental parameters on marine organisms and the effect of these organisms on their environment (ecosystem studies). As over 90% of the ocean biome is based in the deep sea, the study of deep sea organisms is paramount in gaining an understanding of the total oceanic ecosystem. Furthermore, these organisms are adapted to the dark, low temperature, high pressure environments in which they live and, due to these adaptations, it can be expected that useful compounds may be characterized and extracted from their tissues.

Japan Marine Science and Technology Center (JAMSTEC) maintains both manned and unmanned research submersibles and, as such, has greater access to the ocean depths than any other organization in Japan.

Research undertaken on deep sea organisms at JAMSTEC during the 1997 fiscal year include the following:

○Research on chemosynthetic biological communities

- Analysis of the structure and composition of biological communities
- Studies on the dispersal mechanisms of chemosynthetic species
- Research on the relationship between environmental parameters and community ecology
- Searching for commercially valuable biogenic



Photo 4 Dense aggregation of sole fish at a vent site in the Daini Kasuga Seamount

materials

○Research on mid to deep water pelagic communities

- Investigations on the ecology of meso-/bathypelagic species
- Analysis of the structure, composition and biomass of meso-/bathypelagic communities

Under the auspices of the "Structure and composition of biological communities" and "Dispersal mechanisms of chemosynthetic species" projects we were able to continue surveys of the chemosynthetic communities in the Sagami Bay, the Okinawa Trough, and the Ogasawara area, among others. Furthermore, we were able to survey the hydrothermal vent community at the Daini-Kasuga Seamount in the

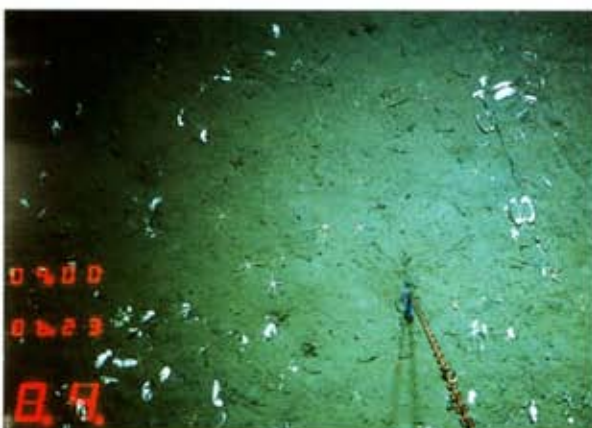


Photo 5 Cold seep community (dominated by *Calyptogenia sp.*) at 1,200m off Kushiro, Hokkaido

Marianas Trough region, an extremely important area for the investigation of the biogeography of chemosynthetic communities in the western Pacific. A chemosynthetic hydrothermal vent community was discovered at 400 m-depth on the peak of this seamount (Photo 4). The composition of this community was similar to that found at the Kaikata Seamount in the Ogasawara area. In addition, a cold seep chemosynthetic community dominated by clams was discovered by a deep tow camera survey at 1,200 m off Kushiro, Hokkaido (Photo 5). The discovery of this colony is expected to greatly advance our understanding of the speciation and biogeography of vesicomylid clams in the North Pacific subduction zone.

Under the "Relationships between environmental parameters and community ecology" project, *in situ* studies were carried out in the Sagami Bay on the reproductive ecology of the vesicomylid clam *Calyptogena soyoeae* and on the growth rate of the deep-sea mussel *Bathymodiolus platifrons*. Furthermore, research on the development of the vestimentiferan tube-worm *Lamellibrachia satsuma* from the Kagoshima Bay was carried out.

Under the "Searching for commercially valuable biogenic materials" project, vesicomylid clams and vestimentiferan tube worms were probed and a compound that inhibits the side effects of anti-cancer drugs was extracted from an organic solvent preparation of *Calyptogena soyoeae*.

Under the "Investigations on the ecology of meso-bathypelagic species" and "Analysis of the structure, composition and biomass of meso-/bathypelagic communities" projects, surveys were undertaken in the Sagami Bay, the Ogasawara Islands and the Japan Trench. As a result of these surveys, several new species were identified (Photo 6), and behavioral observations were also carried out.

2) Long-term deep seafloor observation

① The Real Time Deep Seafloor Observatory off the Hatsushima Island in the Sagami Bay

The observation by the Real Time Deep Seafloor Observatory off the Hatsushima Island in the Sagami



Photo 6 Unidentified swimming polychaete worm at 6,000m, Japan Trench

Bay was continued for more than 4 years since the deployment. The seafloor survey by a deep tow camera was carried out in April 1997 (KY97-05 cruise) and the survey by submersible "Shinkai 2000" was carried out in May 1997 (NT97-08 cruise) in order to investigate the causes of generation of the mudflow associated with earthquake swarm east off the Izu Peninsula occurred in March 1997. In both surveys seafloor were found to be covered with the considerably unstable sediment (Photo 7). The mudflow seems to be caused in the way that the sediment of the unstable surface layer on the slope in the west of the station slipped off the slope like surface avalanche, which was triggered by the earthquake.

In the survey by ROV "Dolphin-3K" which was carried out in June 1997, a TV camera which had been turned over by the earthquake (Photo 8) was placed to the adequate position and underground tempera-



Photo 7 Photograph of disturbed Sediment by the Deep Tow



Photo 8 Photograph of the tilted camera

ture at several sites around the station was measured.

The geo-thermometer and one of 2 TV cameras of the observatory were broken in September 1997 and March 1998, respectively. In order to continue observation, recovery and improvement of the station are required.

② Long-term Deep Seafloor Observatory off Cape Muroto in Kochi Prefecture

To establish the observation system for submarine earthquake or tsunami and the seafloor environment near the Nankai Trough where giant earthquakes occurred repeatedly, the Long-term Deep Seafloor Observatory off Cape Muroto in Kochi Prefecture was developed in 1996 and 1997. The system consists of the observatory with a cable (the following "the cable type observatory") and the buoy-satellite observatory. The cable type observatory which consists of submarine optical cable of about 120km overall length, cable-end station which was mounted on several sensors such as a video camera, two ocean bottom seismometers (accelerometers) and two tsunami pressure gages were deployed in March 1997 and the observation was started. In August, the installation conditions of tsunami pressure gages, seismometers and the station at the cable terminal were observed by ROV "Kaiko" and the geo-thermometer was installed in the seafloor. The transfer of seismometer and tsunami sensor data to JMA (Japan Meteorological Agency) was started in December 1997.

The ecdysis of galatheidæ was observed by the video camera of the observatory in February 1998.

The buoy-satellite observatory is composed of "the mother station" and "satellite stations". A seismometer, a tsunami pressure gauge, a geo-thermometer, a hydrophone, a digital still camera, an electromagnetic current meter, CTD are installed on "the mother station", and data that are compressed to 1MB are transferred to an automatic pop-up buoy every 1 month and data are transmitted to the land station via the Argos satellite. "Satellite station" is the pop-up type ocean bottom seismometer with a hydrophone. In water depth 30m sea area near the Hatsushima Island in the Sagami Bay, first total operation confirmation test of the observatory was carried out in shallow water depths for about 10 days in April and the second test was carried out for about 1 month from December 1997 to January 1998. In March 1998, the observatory was deployed at the depth of about 1,000m east off the Cape Muroto in Kochi Prefecture, and test observation for about 3 months was started.

③ VENUS project

VENUS (Versatile Ecomonitoring Network by Undersea-cable System) project was performed through special coordination funds of the science and technology of the science and Technology Agency of the Japanese Government since FY 1995. Although two cruises in the area off Okinawa Islands were carried out in November 1997 and March 1998 for the purpose of installing the observation equipment which had been developed since FY 1995, the installation was unsuccessful. In the latter cruise, the cable was cut by the cable cutter (Photo 9) and the cable gripper with a lift rope was attached to the cable successfully at the depth of 2,200m by the submersible "Shinkai 6500". But the cable was fell out of the gripper while lifting it to the surface by the cable ship. The final installation of the observatory was postponed by FY 1999.

3) Seismic survey for imaging deep crustal structure

Integrated crustal study, consisting of a multichannel reflection and ocean-bottom seismographic survey, have been carried out in 1998 during a test cruise of a new deep sea research vessel "Kairei". The seis-

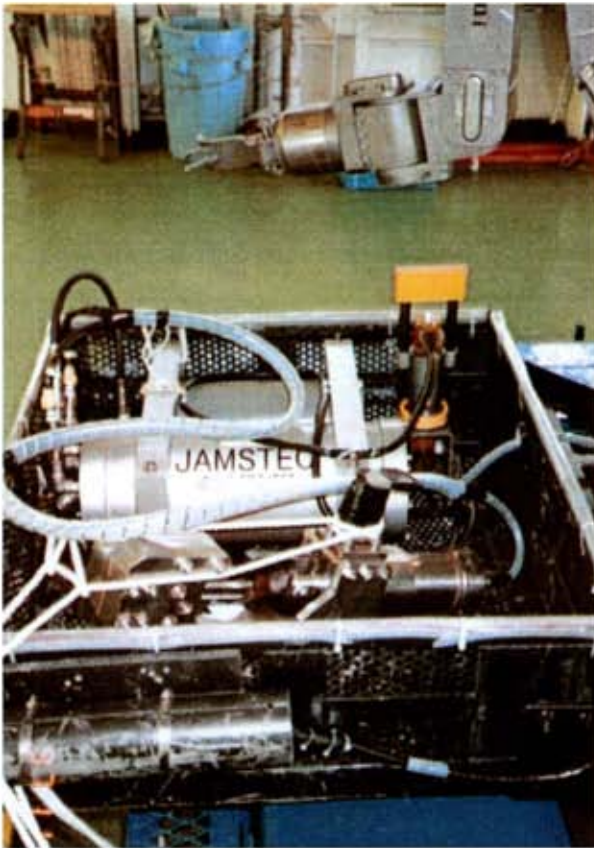


Photo 9 Photograph of the cable cutter and its hydraulic unit

mic data were acquired in cooperation with the "Frontier Research Program for Subduction Dynamics".

①Off Muroto Nankai Trough

The first integrated seismic survey using the seismic exploration system aboard the R/V "Kairei" has been performed in the off Muroto Nankai Trough from 25/June - 22/July 1998 (Fig. 1). Large earthquakes with magnitude 8 have been occurred every 100 - 200 years in the off Shikoku Nankai Trough. It has been already passed more than 50 years since the last Tonankai and Nankaido earthquakes.

The seismic data were acquired along five profile across the Nankai Trough (50 - 250 km long) and five

profile parallel to the trough (20 - 100 km long). A seismic source used was an air gun array consisting of four 1,000 cu. inch air guns and shot with 2,000 psi. The seismic signal from the air gun array were recorded by a 120 ch hydrophone streamer equipped on "Kairei" and ocean-bottom seismographs deployed along the profiles. Temporal land seismic stations were also deployed in order to obtained a deeper crustal structure. Several important results have been found already, even if the data processing and analysis have not completed yet due to large volume of acquired data. For example, large thrust fault extending from subducting oceanic crust to seafloor was found on the seismic reflection data. The ocean-bottom seismograph data have revealed the structure of the subducting oceanic crust down to 30 km below the Shikoku. This structure implies that a rupture plane of the 1946 Nankaido earthquake might extend below an accretionary sediment near the trough beyond the oceanic/island arc upper crust contact plane.

②Japan Trench off Sanriku

Following the survey off Muroto, another integrated seismic study has been carried out in the Japan Trench off Sanriku. The seismic survey has been done as a part of test cruises of "Kairei" as the same as the survey in the Nankai trough, however the seismic data have been acquired in cooperation with other research institutions, which have performed seismic surveys on land and at the Japan Sea off Tohoku region. Consequently those surveys enable to image a deep structure from the Pacific Plate to the Eurasian Plate across the northern Honshu Arc. The results of the surveys are expected to provide fundamental and important data in order to investigate a mechanism of earthquakes in the Japan Trench and at the presumed newborn plate boundary in the Japan Sea, and seismic and volcanic activity at Honshu Arc.

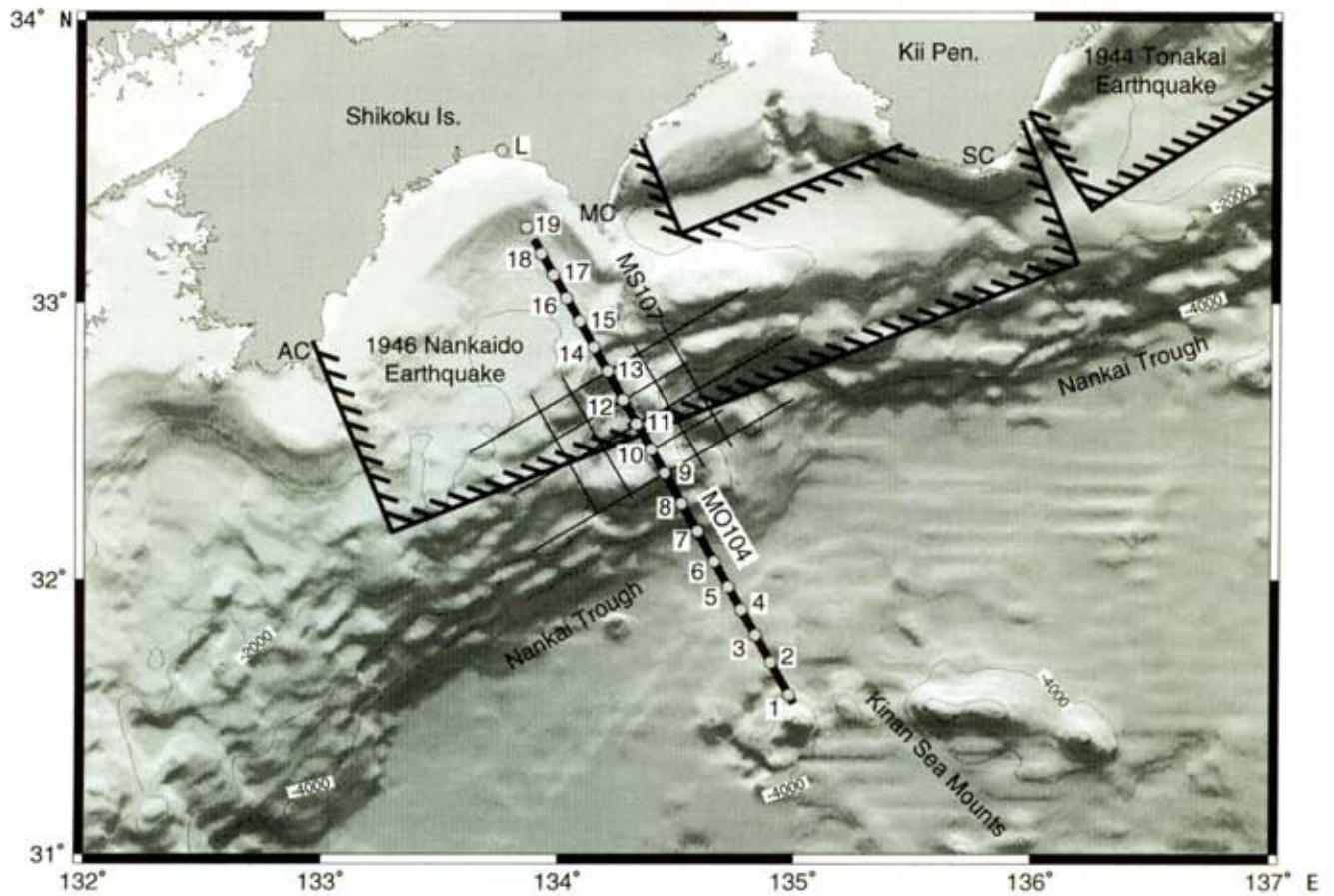


Fig. 1 Profile of seismic survey in the Nankai Trough off Muroto. Multichannel and ocean-bottom seismic data were acquired along black and bold lines. Circles indicate ocean-bottom seismograph and another six ocean-bottom seismographs were deployed in the survey area. The deep structure obtained along the bold line shows in the section of "Frontier Research Program for Subduction Dynamics". The rectangular areas indicate presumed rupture zone of the 1944 Tonankai and the 1946 Nankaido earthquakes. The profiles were designed to cross the presumed rupture zone of the Nankaido earthquake. The ocean-bottom seismographic data have been acquired in cooperation with the Ocean Research Institute, University of Tokyo and Chiba University

Deep Sea Technology Department

1. The policy of research and development

1) The Deep Sea Technology Department is developing large equipment for exploration of deep sea : for example, research submersible vessel, remotely operated vehicle (ROV), ocean investigation ship, and so on. Until now, the Deep Sea Technology Department has succeeded in developing manned research submersible "Shikai 2000" and support vessel "Natsushima", 3,000m class ROV "Dolphin-3K", manned research submersible "Shinkai 6500" and support vessel "Yokosuka", 10,000m class ROV "Kaiko" and deep sea research vessel "Kaimei". In September 1997, the Deep Sea Technology Department finished making over nuclear powered ship "Mutsu" into oceanographic research vessel "Mirai".

2) The development research of deep-sea drilling vessel system is carried out in order to promote search and research of organismal research and crustal movement process and elucidation of the earthquake occurrence mechanism and elucidation of the oceanic plate motion by the excavation without still reached thing to the mantle, in the crust on the earth fluctuation, etc.. It becomes possible that various physics and chemistry measurements, etc. are carried out in the hole, while that samples such as sedimentary rock and igneous rock are collected by this system from drilling hole becomes possible.

2. The outline of research and development

1) Research & Development of deep sea scientific drilling vessel system

Deep sea scientific drilling vessel system is a system intended for drilling deep into the sea floor to collect core samples such as sedimentary rock and

igneous rock from the bore hole and to carry out various physical and chemical measurements in the hole. Based on the data obtained through these scientific operation, the following research are promoted:

- Precise reconstruction of the earth's environment changes
- Establishment of new whole-earth tectonics theory
- Understanding plate-subduction dynamics and developing natural disaster prediction capability
- Research the evolution of the life in the crust

This will help promote studies regarding earth science and, eventually, establishment of a unified image of the earth system. The deep sea drilling vessel system is to play a very important role in such researches. This study has been in progress, since 1990, for the purpose of development and construction of such deep sea drilling vessel system.

In FY 1997, "Conference on Cooperative Ocean Riser Drilling" (CONCORD) was held in cooperation with ORI (Ocean Research Institute, the University of Tokyo), and JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling). Over 150 leading earth scientists and drilling engineers from the world attended this conference, and the science plan (OD21; Ocean Drilling in the 21st Century) using this drilling vessel was welcomed by the participants. In addition, general survey and study of the entire system were carried out.

2) The development of the ocean observation buoy system

In JAMSTEC the development of the ocean observation buoy system is going on that can acquire meteorological data and oceanographic data precisely and continually for long term and covers extensive area. This program started at FY1992 in the feasibility study. And basic designing in FY1994, buiding

of the prototype buoy for the tropical ocean in FY1995 and open sea experiment in FY1996 were carried out. In FY1997 four practical buoys were built and deployed in tropical ocean. And the prototype buoy for middle latitude area was built and deployed for experiment. But it was failed because current was much faster than that we had supposed.

3) Development and research of the unmanned exploration vessel

Recently, the cause for the global scale with global warming becomes the urgency problem. It is increasing a necessity of using observation equipment in severe environment whose temperatures such as polar region become under freezing point.

By these backgrounds, "environmental tests of water connectors under freezing point" was carried out by using molded connectors and oil filled connectors as a trial product in FY 1997.

As the result, the molded connectors had been caused fractures under dry or wet environment -45 to 55°C. Those fractures were not at each connector's joint part but at middle of the cable part. However, the oil filled connectors had not been caused any problems such as a crack on it during 0°C to -65°C, but lubrication in the tube (insulation oil) had been become viscosity by cold temperature.

4) The development of the acoustic data transmission system

The half-duplex data transmission system using acoustic signal is developed for the purpose of transmitting observation data and command between buoy or ship and observation equipment deployed in the ocean. The data transmission system was produced experimentally in the 1995 fiscal year, and the horizontal transmission test was carried out. And the practical system was manufactured in the 1996 fiscal year.

In FY 1997, we carried out transmission test of the oblique direction using these transmission system, and it was confirmed that the communication was possible at 1,250bps transmission rate. And, high data rate transmission test equipment was manufac-

tured in order to improve transmission reliability and transmission rate.

5) "UROV7K"

"UROV7K" is the 7,000m class expendable fiber optics ROV. The purposes of "UROV7K" are to watch mooring systems installed in deep sea and to investigate seabed.

For a power source, a lithium-ion rechargeable battery with high-efficient is mounted on the vehicle, and only one fiber optics cable which is 1 mm in diameter connects the onboard unit and vehicle. The spoolers, which are wound with the fiber optics cables, are mounted on the support vessel and vehicle respectively. The vehicle cruises, spooling out the fiber optics cable from each spooler. Then the vehicle surfaces after cutting the fiber optics cable at the end of the cruising.

This year, the land test, tank test and shallow water test were carried out. The test results were good, but there are some problems, for example the launching-recovering system etc, which need improvement.

6) Research & development of fuel cell for underwater equipment

A polymer electrolyte fuel cell (PEFC) for available for use in the water was developed in 1993, then, we have been conducting various kinds of performance tests for utilizing this fuel cell as the main power source for the long-range autonomous underwater vehicle (AUV). The operation temperature of PEFC is about 80°C. But, when PEFC is equipped on AUV for a power source, PEFC may be operated in low temperature. Because AUV need electric power from right after starting when PEFC doesn't rise to the sufficient temperature (about 20-30°C), or temperature around PEFC is low (about 5°C). Therefore, this year, low temperature test of PEFC was carried out. As the result, when the operating temperature becomes lower, the voltage dropped in the high current area and the output power of PEFC decreased.

7) The fundamental study on the chemical sensor effective under high hydrostatic pressure

On the purpose of the application mainly to the deep sea hydrothermal study, we are developing the stand-alone type pH sensor for deep sea use with using Ion Sensitive Field Effect Transistor (ISFET). In FY1997, we carried out *in situ* measurement at the deep sea bottom using this ISFET pH sensor installed to the research submersible, mainly for the selection of the reference electrode, the understand of the characteristics change against the long term continuous measurement, and the application to the observation of the hydrothermal activity. In the results of the pH measurement in the hydrothermal area of Izu-Bonin site, we succeeded to detect the pH anomalies caused by the hydrothermal activities, and we verified that it is sufficiently effective to observe the hydrothermal activity using this pH sensor. Also, we could extract the problems on the reference electrode. Moreover, in the research dive at the southern East Pacific Rise(EPR), we deployed the long term observation station equipped with this pH sensor on the sea bottom. We'll recover this in September, FY1998, and after its recovery, we'll analyze the data to estimate the change of the characteristics against long term continuous use.

8) The deep-sea research vehicle system

The purpose of this research is to improve "Shinkai 2000" and "Shinkai6500" system for more good performance and more safety. This research has been carried out since FY 1977. The research on performance improvement of thrust controlling system was started from last year, and propulsion unit (thruster) was manufactured in this fiscal year.

3. Contents of main studies

1) Research & Development of deep sea scientific drilling vessel system

Deep sea scientific drilling vessel system is a system intended for drilling deep into the sea floor to collect core samples such as sedimentary rock and igneous rock from the bore hole and to carry out vari-

ous physical and chemical measurements in the hole. Based on the data obtained through these scientific operation, the following research are promoted:

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① General Survey

A survey was conducted on the current situation and trend of scientific boring projects currently under execution or planning both in the ocean and on the land. The objects of investigation mainly included JOIDES-TEDCOM (Technology and Development Committee). Further more, An outline of drillships under construction was surveyed.

② Study of the entire system

Assuming supply of fuel and drilling related materials using a supply boat, the valuable load of the deep sea drilling vessel system were reviewed. And on-board drilling related equipment were studied to make use of stand pipe, which is the pipe string connected by 3 single pipes, handling system to shorten the handling time of drill string. In addition, the evaluation of experiments of riser connector was car-

ried out and the specification of riser was confirmed. In the study, we divided the vessel system into the three sub-systems which are hull related system, on-deck drilling related system, and subsea related system, while maintaining consistency to arrange the entire system.

Through this study, the preparation for starting the basic design was almost finished while the general image of the deep sea drilling vessel system was grasped.

(a) Integrated study of the hull related system

It was assumed as following:

- Supply of fuel and drilling related materials would be carried out using a supply boat for every 2 weeks.
- Drilling equipment and other materials for drilling operation of 4 weeks stored on board.
- Fixed pitch propeller would be installed in the vessel for the main propulsion unit. Under these assumptions, principal particulars of the hull, power system and variable load were reviewed.

Concerning to the dynamic positioning system (DPS), the study on dynamic positioning of vessel adopting the riser angle as control parameters was carried out, and the control logic was evaluated through the numerical simulation. The consideration on the acoustic measurement system for DPS which was suitable for the drilling procedure was also carried out, and requirement for the acoustic system was grasped. In addition, DPS damage mode and the effect of damage were studied, while surveys were carried out on actual accidents of DP ships, and the requirement for the reliability assurance was arranged.

(b) Integrated study of on-deck drilling-related system

The study on stand pipe handling system of the drill pipe and on requirement and arrangement of related drilling equipment such as dynamic derrick, was carried out. Concerning to drilling related system, the study of riser hang off system, guide horn, handling equipment of subsea system and mud circulation equipment was also carried out. In addition, the comparison between AC drawworks system and pneumatic system was conducted concerning to the active compensator for drill string.

(c) Integrated study of the subsea related system

Concerning to the riser quick disconnection system, items mainly studied were requirements for telescopic joint, dimensions of the moon pool and load on the blow out preventor (BOP).

On the riser unit element experiment conducted in FY 1996, function evaluation of riser connector and performance evaluation of welded zone of the riser made of X80 and X90 against H₂S were carried out. As a result, good performance of riser connector was confirmed.

Considering the parameter of the riser component variously, critical water depth under riser hang-off condition was studied in detail, and various kinds of specifications of riser which could be adopted over 2,500m water depth was obtained.

Concerning to the deepwater drilling technology, the requirement of choke line which was auxiliary line of the riser was grasped through the well control simulation. Also, the detailed load analysis of BOP, downhole equipment was carried out, and those requirements were grasped. In addition, investigations of requirements for drilling fluid were carried out.



fig.1 Deep-sea drilling vessel system

The detail specification on core barrel, core bit and drill string was studied as a downhole system.

Further more, the study on reentry system of BOP and other equipment into the hole, and on ROV for the BOP control was carried out.

2) The development of the ocean observation buoy system

In order to cope with the global environmental change, the necessity of the oceanographic observation at all global scale had been recognized worldwide, and the TOGA (Tropical Ocean Global Atmosphere) plan was carried out in the international framework in 1994 since 1985, and the substance of the El Niño event was clarified by the development of ATLAS buoy. And, the CLIVAR (Climate Variability and Predictability) plan is promoted by handing over this. Also, in JAMSTEC the Triangle programme is carried out, and the development of the TRITON (Triangle Trans-Ocean Buoy Network) buoy is going on. And this plan was agreed in the conference of CLIVAR held in Sapporo in June. This program started at FY1992 in the feasibility study. And basic designing in FY1994, buiding of the prototype buoy for the tropical ocean in FY1995 and open sea experiment in FY1996 were carried out.

In FY1997 four practical buoys were built and deployed in tropical ocean. And the prototype buoy for middle latitude area was built and deployed for experiment. But it was failed because current was much faster than that we had supposed.

- The experiment result of the prototype for tropical ocean

The prototype was recovered in May 1997 after six month deployment in Ogasawara. Followings were found.

- ① The buoy has been stabilized enough to acquire meteorological data.
- ② The elongation characteristic of the nylon rope for long term is almost as expected.
- ③ Within the current of 1 knot (design condition), mounting gear of the water sensor is all right.
- ④ The molding of temperature sensor and pressure sensor and the endcap of CTD should be improved.
- ⑤ The antifouling paint, the foot and the anticorrosive anode of float should be redesigned.
- ⑥ The small abrasion of shackle isn't a problem considering that tropical area is calmer than Ogasawara.
- ⑦ The strength of the wire rope and its termination didn't deteriorated.
- ⑧ The strength of the nylon rope deteriorated about 10%.

The practical buoy was redesigned based on above and four buoys built and deployed in tropical ocean. The middle latitude experiment.

The prototype buoy for tropical area was converted into that for middle latitude. The displacement was increased from 6ton to 8.5ton, the diameter of wire rope from 16mm to 19mm, the diameter of nylon rope from 24mm to 28mm and the weight of sinker from 4ton to 7ton.

Its sea experiment was conducted at 37°N, 152°30'E in October. But it was not successful because current was much faster than supposed. It was about 3knot.

3) Development and research of the remotely operated vehicle

Until now, we had been carried out various performance tests of molded connectors which have been used at many different parts of 10,000m class ROV "Kaiko" system. The 1995 fiscal year's tests were proven that the connectors received the effect of the water pressure, though the difference of results such as a change of contact resistance had been shown by different size, number of pins or shape of molded connectors. Also, the 1996 fiscal year's tests were proven that if the receptacle connector of the molded connectors made of a plastic had been handled without torque management exactly, it might be cracked at the end of the screw parts and that of reliability might be become lower. Then, we have been carried out the same various performance tests, as the molded connectors had been done, against small oil filled connector, which is replaceable with these types of molded connectors. That result was everything good, and it had been shown the high reliability of the oil

filled connector.

Recently, the cause for the global scale with global warming becomes the urgency problem. It is increasing a necessity of using observation equipment in the environment whose temperatures such as polar region become under freezing point. Examples of accident of molded connectors were also reported in winter season at north Japan sea area. By these backgrounds, "environmental tests of water connectors under freezing point" was carried out by using molded connectors and oil filled connectors as a trial product in the 1997 fiscal year. Water connectors used for the test at this time are molded connectors of Brantner and impulse and small oil filled connector as a trial manufacture.

The performance tests were carried out under the environment such become under freezing point of using the water connectors, which was stored in the condition that was made to put receptacle and plug connectors in the refrigerator (0°C). We tested flexibility of the cable in freezing point (0°C~-65°C) and electrical stability under a high water presser environment such as a deep sea. Then, we also had tested them in the following different environment ; condition with snow or water droplet adhered to the cable and dried condition, etc. using the cable in the freezing point area(Fig.2).

As the result, the molded connectors had been caused fractures under dry or wet environment about -45 to 55°C. Those fractures were not at each



fig.2 180° bending test

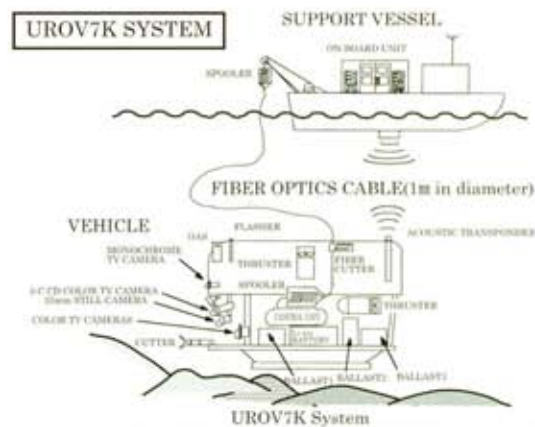
connector's joint part but at middle of the cable part. However, the oil filled connectors had not been caused any problems such as a crack on it during 0 to -65°C, but lubrication in the tube (insulation oil) had been become viscosity by cold temperature.

4) The development of the acoustic data transmission system

As a system for transmitting observation data between buoy or ship and observation equipment deployed in the ocean, the data transmission system using acoustic signal is developed. To reduce the power consumption, the FSK (Frequency Shift Keying) was adapted to the modulation method. Half duplex digital bi-directional communication was realized using HDLC(High-level DataLink Control) in the communication protocol. It is constituted as the result which the hardware of each equipment is all same, and it is able to select the master or slave station by shorted switch. The communication flow is controlled by the master station. In April 1997, the data transmission test of the oblique direction in the sea was carried out using the data transmission equipment produced by the 1996 fiscal year. As the result, communication was possible within 1,250 bit per second transmission rate, about 3,000m~4,000m propagated distances, about 85~55 degree from horizontal and, the communication was possible. However, there is a case in which the part communication is not possible in the place of about 60 degree in the depression angle, and this seems to be the effect of the multi-path of sea surface. And, high data rate transmission test equipment was manufactured in the 1997 fiscal year in order to carry out the research with the aim of improvement of the transmission reliability and the transmission rate. On this equipment, modulation and demodulation would be processed by the software. It would be done easily to test various modulation and demodulation method, only with the change of the software. And, to improve of the communication performance, on the case in which especially, the effect of multi-path, tank tests and sea trials are repeated using this test equipment after 1998 fiscal year.



fig.3 Acoustic data transmission system



Weight	About 2700kg
Dimensions	About 2.8(L) × 1.8(W) × 2.0(H)m
Max.operating depth	About 7,000m
Power	Lithium-Ion Rechargeable Battery 108V60Ah (Oilfilled and Pressure-compensated)
Propulsion	2 horizontal thrusters, 2 vertical thrusters DC brushless motors 800W (Oilfilled and Pressure-compensated)
Equipment	<ul style="list-style-type: none"> • Wide color TV camera(×2) • Monochrome TV camera • Altitude sonar • Ring laser gyro • Obstacle avoidance sonar • 3-C CD color TV camera • Still camera & strobe light • Depth meter • Flasher • Acoustic transponder

Specification of UROV7K

fig.4 "UROV7K" system

5) "UROV7K"

The figure 4 is "UROV7K" system. The lithium-ion rechargeable battery with high-efficient for a power source and optical communication system are most important equipment in "UROV7K" system.

The tests in this year was carried out to certain that these equipment worked good and the operation, especially launching-recovering method, at sea trial do smoothly .

In the land test, all equipment worked normally.

In the tank test, buoyancy adjust and equipment running test were carried out. The results of the test, ballast tank was bigger and the ground circuit was improved for noise of TV signal.

The sea trial near Sagami Bay was carried out and "UROV7K" was equipped on the mother ship "Yokosuka". "UROV7K" landed seabed of 50m depth. Then main equipment on "UROV7K" worked good and clear picture was transmitted from "UROV7K". But there are some problems, for example the launching-recovering system etc., which need improvement.

6) Research & development of fuel cell for underwater equipment

A polymer electrolyte fuel cell (PEFC) for power



fig.5 "UROV7K"

source of underwater equipment, for example, the long-range autonomous underwater vehicle (AUV) and long-term monitoring system, was developed in 1993, then, various kinds of performance tests have been carried out. PEFC is possible to operate about 80°C of under 100°C. Especially, when PEFC is equipped on AUV for a power source, PEFC may be operated in low temperature. Because AUV need elec-

tric power from right after starting when PEFC doesn't rise to the sufficient temperature (about 20-30°C), or temperature around PEFC is low (about 5°C). Therefore, we investigate the characteristic of PEFC at low temperature, and then it is need to investigate the temperature condition around PEFC.

The figure 7 is the test result. As the result, when the operating temperature becomes lower, the voltage dropped in the high current area and the output power of PEFC decreased. Therefore, when AUV equips PEFC and operating temperature is low, PEFC system need heaters to heat up PEFC and to get rated output.



fig.6 Under real sea area test Fuel cell

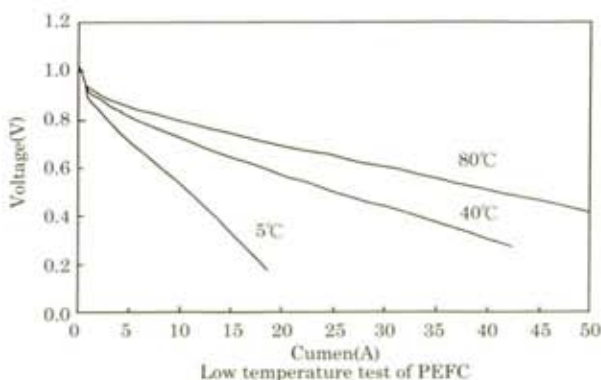


fig.7 For the underwater vehicle vessel Low temperature operation test result

7) The fundamental study on the chemical sensor effective under high hydrostatic pressure

As the research method of the hydrothermal chemistry, it is popular to analyze the sample water recovered on board or on land, however, it would be better to measure in the environmental condition in view of the chemical property change while the recovery of the sample. So it is desired to develop the chemical sensor which can work under high hydrostatic pressure, since this kind of sensor is not existing. Also, if these sensor would be available, it could be expected the great contribution to not only the deep sea chemical study, but also the biological study.

The purposes of this study are firstly the research of the existing and future technology about the chemical sensor effective under high hydrostatic pressure, secondly the selection of the chemical sensors applicable to the deep sea use, and finally the investigation of the fundamental characteristics of these sensors under high hydrostatic pressure.

Through the feasibility study, we aimed the pH sensor using Ion Sensitive Field Effect Transistor (ISFET) as the sensor capable for the application to the deep sea use. ISFET is the semiconductor which can be used in the water, and one of the devices in the micro machine system which was developed for the measurement of H⁺ concentration in the solution. Recently, ISFET becomes to be manufactured from the major sensor company as the pH sensor for the field use. As ISFET is solid module, it is easier to handle and stronger against the shock than glass electrode, and additionally, it has a good responsibility and accuracy. Moreover, ISFET itself is sensitive against H⁺, however, by coating the insulating film on the gate of the ISFET electrode with other ion sensitive membrane, it could respond to various ion, e.g., PCO₂, Ca, and it has a great potential to be widely applied to the ocean observatory in the future.

In the results of the FY 1996, we certified that ISFET could work well under high hydrostatic pressure, and obtained the vertical profile of the sea water pH correspond to the submersible's descend and ascend. Also, we had good results on the responsibility under high hydrostatic pressure. We could con-

firm the primitive and qualitative characteristics of ISFET pH sensor under high hydrostatic pressure, however, we also had some problems on the investigation of the calibration method, the selection of more stable reference electrode, and the quantitative understanding about the drift characteristics and the durability of the electrode against the long term continuous use.

In FY 1997, we built the prototype of the digital pH logger for simplifying the calibration method. We carried out the pH measurement near the hydrothermal vents in the Izu-Bonin site, and succeeded to detect the pH anomalies correspond to the hydrothermal activities.

One of the sea test results is shown in Figure 8, where the left ordinate denotes pH, the right ordinate the water temperature, the abscissa the time. Figure 1 includes two results of different reference electrodes, both of which consist of Ag/AgCl rod, however, one use the saturated NaCl inner solution as the electrolytic solution, whose result is shown by the thin solid line(No.5) in the figure, and the other use the ambient sea water, whose result is shown by the thick solid line(No.10). The dotted line (T in the figure) denotes the water temperature measured by STD of "Shinkai 2000". In the time with the event mark "◇", "Shinkai 2000" positioned near the hydrothermal vents to carry out some operations like sampling, observation and so on.

From the figure, we can confirm the spike changes of pH correspond to the "◇" mark in both results of No.5 and No.10 which indicate pH anomalies, and each quantity of the change are almost same except the result at 13:26. From the view of the absolute value, the curve of No.5 is shifted upwards about pH0.14 higher than No.10. We can confirm the temperature anomalies caused by the hydrothermal activities from the data of the sea water temperature in some of the "◇" mark, however, for example around 15:29, we can see the pH change, but nothing of the temperature change.

We consider that the reason of the pH variation like drift or hysteresis is concerned with the effect of the other ion on the reference electrode. Therefore,

we improved its electrochemical stability by covering the Ag/AgCl rod of the reference electrode with the ion exchange tube. We tested this improved pH sensor with equipped to "Shinkai6500" to measure pH near hydrothermal vents at EPR, however, its stability was not improved sufficiently, and now we still continue to investigate the improvement of the reference electrode.

Also, in the research cruise of EPR using "Shinkai 6500", we deployed the long term observatory station include this pH sensor. Its recovery will be scheduled in September, FY1998, and after its recovery, we'll analyze the data to estimate the characteristics change of this pH sensor against the long term continuous use.

We presented the results of FY1997 to the American geophysics union, the Society of oceanography in Japan, SHINKAI symposium, and the Society of ocean science and engineering in Japan.

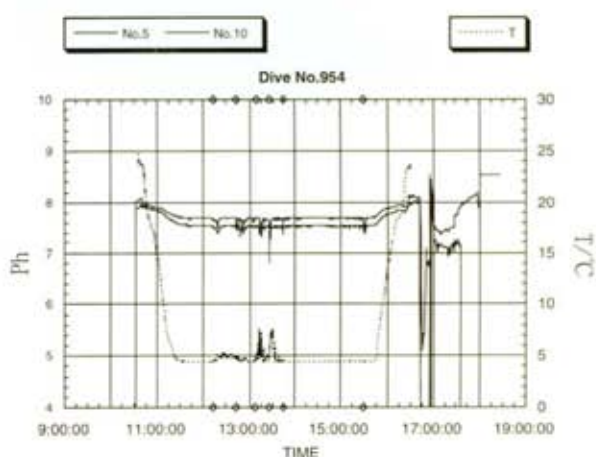


fig.8 Real sea area test result ("Shinkai 2000" 954th underwater navigation)

8) The deep sea research vehicle system

The purpose of this research is to improve "Shinkai 2000" and "Shinkai6500" system for more good performance and more safety. This research has been carried out since the 1977 fiscal year. The research on performance improvement of propulsion control system was started from last year.

In present, "Shinkai 6500" has a neck-swing-style main propeller of large diameter, perpendicular thrusters and bow side thrusters. But the response of the main propeller is slow, because it was designed mainly to make the efficiency of straight sailing high and not to make a noise. So it is difficult to deal with the advanced operation required recently.

Then, using multiple thrusters and motion sensor, the basic research on the propulsion control system will be performed to reduce operator's load and also to enable quick motion and advanced control of the

position and attitude.

The two thrusters which are composed of the oil-filled DC brushless motor of 5.7 HP and the high-efficient ducted propeller were manufactured in this fiscal year. Performance test of these thrusters and real sea test in which they are experimentally equipped with "Shinkai 6500" are carried out in the next fiscal year, and measurements of kinetic characteristics of the vehicle and examination of the control algorithm, etc. are carried out.

Ocean Research Department

1. R & D Policy

It is essential for clearer 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, 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.

1) Tropical Ocean Climate Study

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 water in the world (warm water pool), which variation is strongly related with the El Niño / Southern Oscillation (ENSO) phenomena. Therefore, the tropical Pacific is thought to be one of the key area in the global climate variability.

In order to understand the role of the tropical Pacific in the climate variability, we will continue to observe ocean current, temperature and salinity distribution and variability in this area by on-board observations and mooring systems. Simultaneously, numerical studies is also conducted for this purpose.

2) Subtropical and Subarctic ocean study

The Kuroshio, the western boundary current of the North Pacific Subtropical gyre, transports an 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 and so on. In addition, it is pointed out that fluctuation of the volume transport and/or current velocity could be connected with the variation of the Kuroshio path south

of Japan. In order to understand the Kuroshio recirculation system, we are studying the hydrographic structure and its variations over the Izu-Ogasawara Ridge in the Kuroshio recirculation region. We intend to observe the mesoscale eddies along the Kuroshio counter-current, which are likely to play an important role in the Kuroshio recirculation system.

The North Pacific Subarctic area which includes the Bering Sea plays a crucial role in global climate change. It is not only one of heat sinks of the global circulation but a sensitive indicator of global climate change. Recently, the North Pacific Subarctic area is also recognized as the formation area of the North Pacific Intermediate Water, whose area is related to an important sink of atmospheric CO₂. In spite of the importance climate of, our knowledge is not enough to understand the circulation and water mass formation of the North Pacific Subarctic area because of the lack of oceanographic observation. The purpose of this study is to clarify the hydrographic structure and circulation of North Pacific Subarctic area. For this purpose, we intend to observe ocean current and heat transfer in the North Pacific Subarctic area.

Combination of conventional and new observations which covers various time- and space- scale are required for our studies. We develop a long-term mooring buoy, ocean acoustic tomography and the autonomous marine observing system. We also develop the analytical procedures for the data obtained by such new technology.

Ocean acoustic tomography is an innovative observation technology making it possible to observe the fluctuations of ocean currents and water temperature three dimensionally and its early practical application is desired internationally. We are developing an ocean acoustic tomography system which will be capable of observing 1,000km × 1,000km square of the ocean on a real-time basis. We are also developing analytical procedures indispensable for the ocean structure analysis. This R & D has been carried out by the Ocean Acoustic Tomography Project Team.

We are developing the autonomous marine observing system that can make a long-term oceanographic and meteorological observation at Okino-tori-shima

Island maintained by power suppliers using natural energy resources. In addition, obtained data by using this system, shall be intensively analyzed and utilized as one of important long-term data in mid-ocean south of the North Pacific Subtropical area.

Observation of the ocean by using satellites sensors plays an important role in elucidating various aspects of oceanic phenomena in global environmental variations. This R & D has been carried out by the Marine Observation Satellite Research Project Team. In this project, technology of satellite data processing and analysis is to be established. Further, data assimilation techniques are to be developed.

3) Comprehensive observation research in the Arctic Ocean

The Arctic region, which is the largest heat sink in the global climate system, affects the global environmental changes through the interaction and feedback processes among the atmosphere, the ocean, snow and ice, and land. Besides, the sea ice, glaciers, the tundra and the permafrost, etc. are highly sensitive sensors for environmental changes, and they respond sensitively to any slight change in the air temperature, the solar radiation, air pollution and so on. Thus, it is believed signs of any environmental change appear in the Arctic region earliest on the earth. We intend to capture as early as possible changes in the Arctic region where the environmental changes may be the most predominate, and to clarify what role the Arctic region play in the global climate system.

4) Study of air-sea interaction

Air-sea interaction is an important factor for a better understanding of the El Niño/Southern Oscillation (ENSO) event. In particular, precipitation plays an important role in affecting the sea surface temperature and salinity. JAMSTEC will initiate the air-sea interaction study using meteorological measurement systems such as shipboard C-band Doppler radar and radiosonde mounted on the new research vessel "Mirai" in the tropical western Pacific region.

MR98-02 Cruise Track

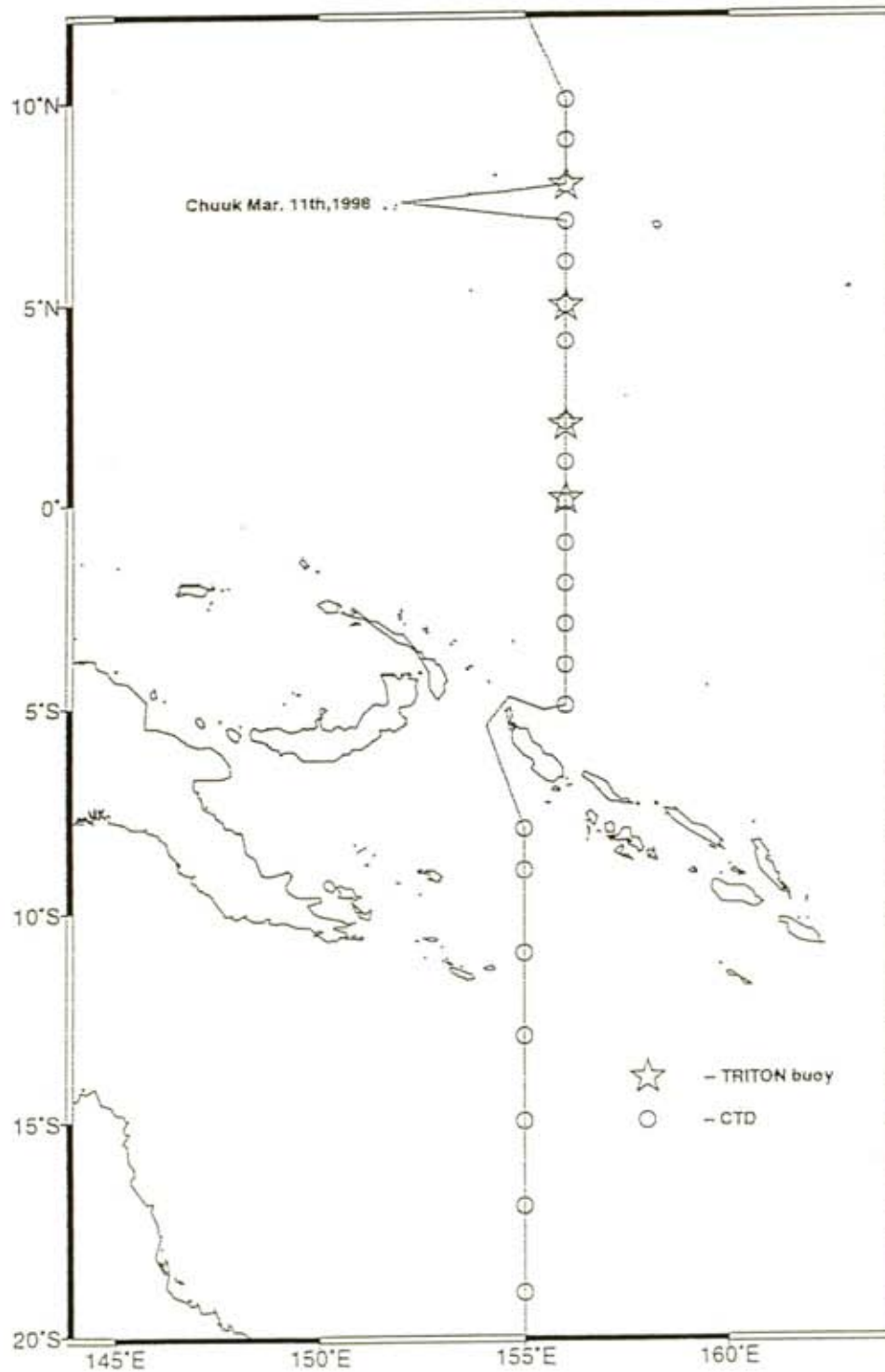


Fig. 1 Track of the R/V "Mirai" cruise during March 1998. Asterisks and circles denote the location of the TRITON buoys and CTD casts

5) Biogeochemical study of the ocean and development of observation system

Recently, due to increase of greenhouse gases such as CO₂ and CH₄ in the atmosphere, the global warming has been of great concern. Since the ocean, which makes up about 70% of total surface of the earth, contains carbon over 50 times of that in the air, a minute change of carbon in sea water results in a significant change of CO₂ concentration in the atmosphere. In addition, mechanisms of transport and transformation processes of carbon and its related elements in the ocean are yet to be understood fully. Therefore, it is very important for the future of the earth to clarify the mechanisms.

2. Major R & D Projects

1) Tropical Ocean Climate Study

We have been investigating the processes of accumulating and dissipating warm water and air-sea interaction in the western equatorial Pacific. For these purposes, three ocean observation cruises in FY 1997 using R/Vs "Kaiyo" and "Mirai" were conducted collaborating with NOAA / PMEL (National Ocean At-

mospheric Administration / Pacific Marine Environmental Laboratory, USA) and BPPT (Badan Pengkajian Dan Penerapan Teknologi, Indonesia); two cruises by R/V "Kaiyo" on August 1997 and January 1998 in the western equatorial Pacific and one cruise by R/V "Mirai" on March 1998 between Sekinehama and Sydney, Australia.

In FY 1997, The TRITON (Triangle Trans-Ocean Buoy Network) buoys, were first deployed at 8°N, 5°N, 2°N and 0°N, 156°E during this R/V "Mirai" cruise (Fig. 1). These TRITON buoys have been operated by the TRITON buoys operation project team, working for data quality control, data publishing, check of the sensors' performance, improvement of the buoys, and emergency cases such as their lost, and so on.

The biggest El Niño in this century occurred in 1997. We succeeded in observing the strong eastward flow (~1.5m/s) on the equator, which would be the presage phenomenon of this El Niño, by moored acoustic Doppler current profilers (Fig. 2).

This flow was found from the middle of December 1996 to the beginning of January 1997 from the sea surface to the 150m depth. Strong westerly wind

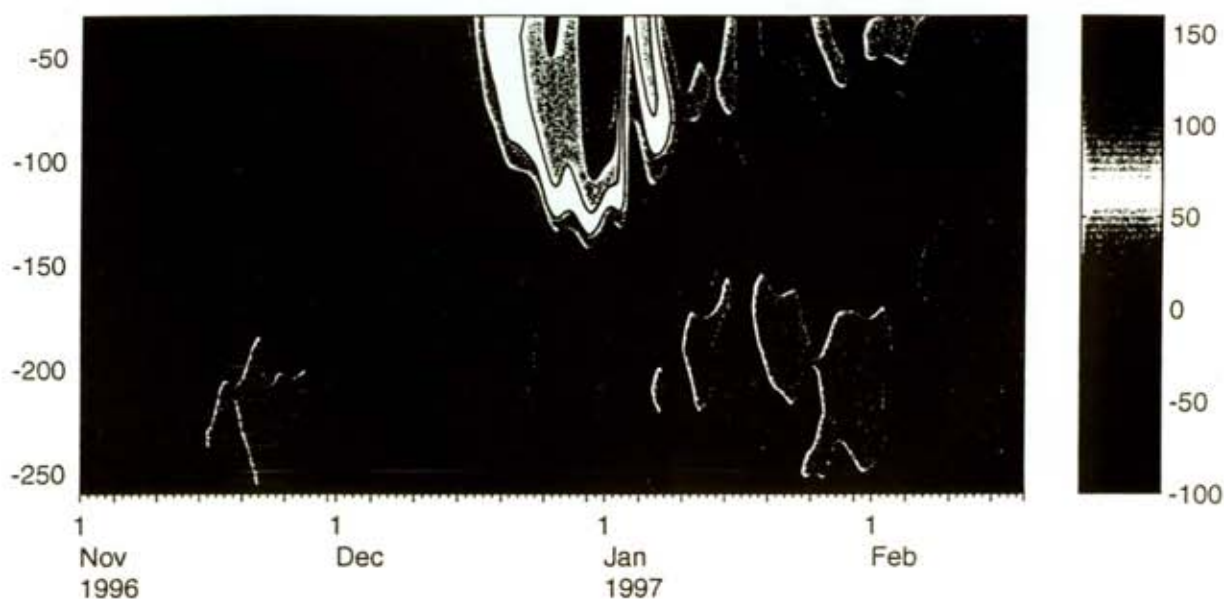


Fig. 2 Depth-time series plot of the zonal velocity measured by the acoustic Doppler current profiler at 0°N, 147°E. Positive value means eastward flow. The very strong eastward currents developed from mid of December 1996 to mid of January 1997. The biggest El Niño occurred after this event.

(Westerly Burst), which is thought to be closely related with the beginning of the El Niño, was also observed over this region by the earth observation satellite "Midori", just before the occurrence of this strong eastward current. The 1997/98 El Niño appears to occur associated with the eastward shift of the warm water in the western tropical Pacific due to the Westerly Bursts occurred in December 1996 and March 1997.

We have also investigated the Indonesian Throughflow (ITF) and low latitude western boundary currents in the Pacific; the former is the interocean exchange flow between the Pacific and Indian Ocean, and the latter seems to play an important role in the ocean circulation in the western tropical Pacific. Some new scientific results regarding them were obtained from the observation data. With

regard to the ITF, we found the 50-days oscillations in the western boundary region of the Philippine Sea (Fig. 3), suggesting that the variability of volume transport of the ITF has the signal with this frequency.

The results from the moorings deployed at the New Guinea coast shows that New Guinea Coastal Current (NGCC) flows reversely during boreal winter, and variation with a frequency of 20 to 30 days is seen in the NGCC and New Guinea Coastal Undercurrent (Fig. 4).

Some numerical experiments were also conducted using the isopycnal coordinate global ocean model to investigate the ITF. They show the flow from the Indian Ocean to the Pacific in the deep layer; it is inconsistent with the other observation and numerical results. We will conduct the numerical experi-

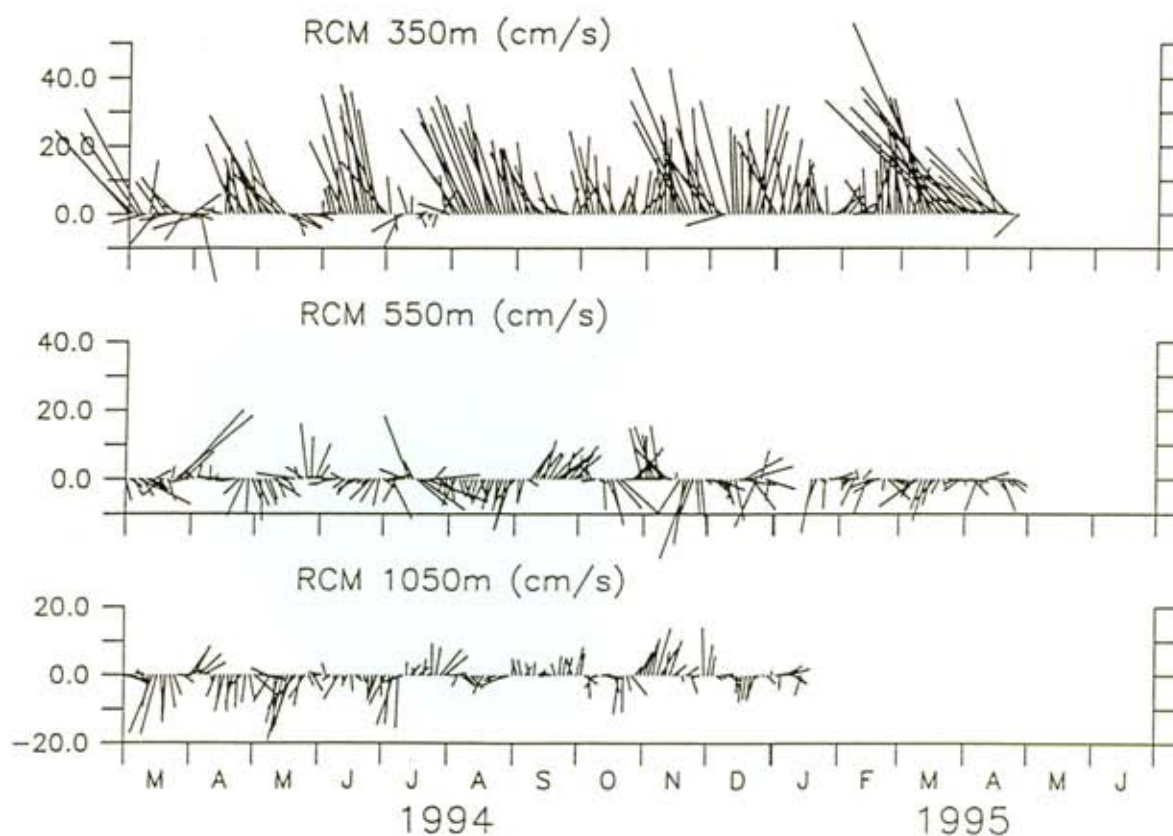


Fig. 3 Time series of velocity measured by current meters at $4^{\circ}1'N$, $127^{\circ}31'E$ (in the Indonesian exclusive economical zone)

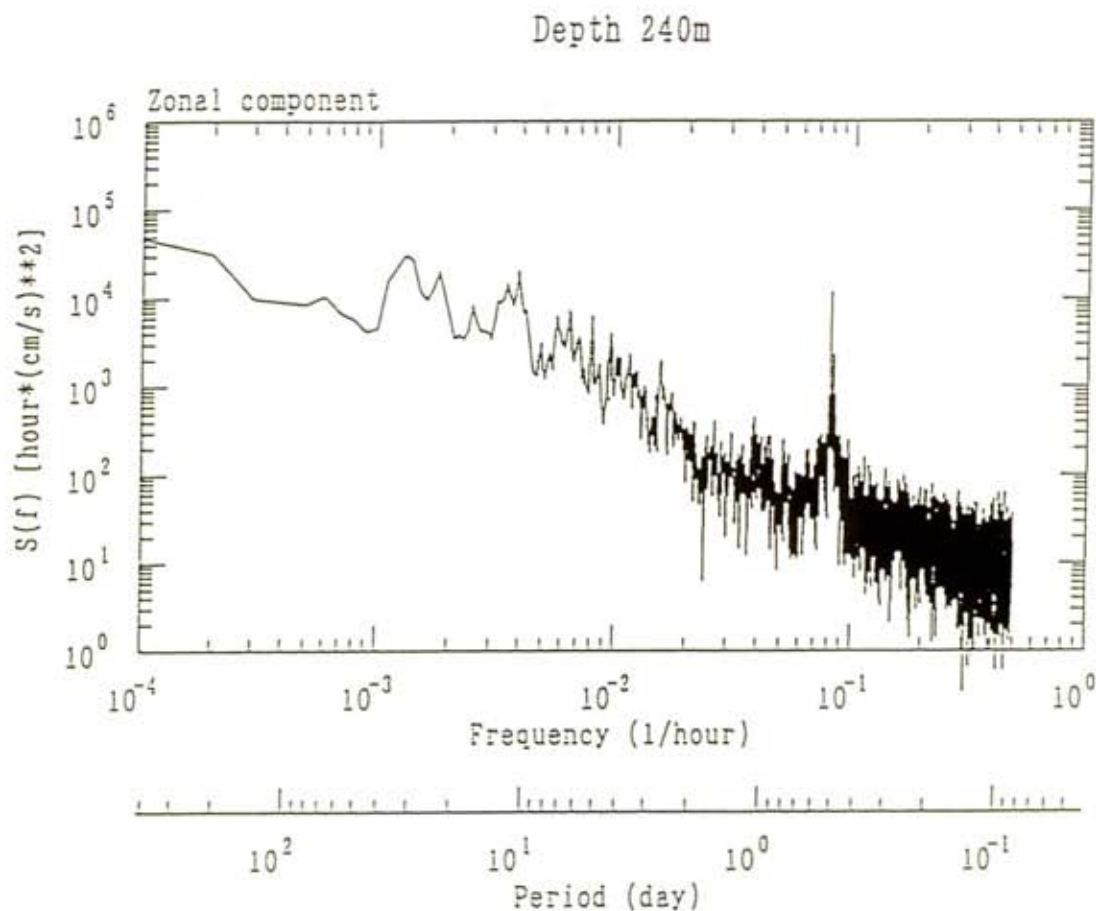


Fig. 4 Power spectrum of the zonal velocity at the 240m depth near the New Guinea coast (2.5°N, 142°E)

ment using another model to clarify its reason.

2) Research and Development of the Subtropical and Subarctic ocean study

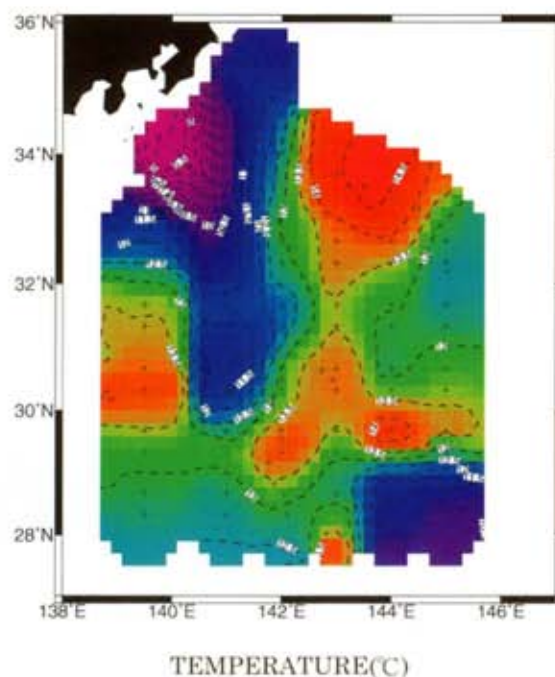
① Subtropical ocean

Since 1996 we investigate the Kuroshio return flow variation and westward propagation of mesoscale eddies over the Izu-Ogasawara Ridge. In 1997 there were cruises by R/V "Mirai" and "Kaiyo". In these cruises CTD observations were carried and mooring buoy of current meters was recovered and another buoy was deployed for the long term monitoring.

A map of temperature at 500m deep observed from 24 December 1997 to 14 January 1998 is shown in Fig. 5. At that time the Kuroshio flowed south of the Hachijo-jima Island (33°N, 140°E) and then it curved

northward. There existed cold eddy south of the Kuroshio. The North Pacific Intermediate Water (NPIMW) were also observed, as dotted pattern, north of 32°N east of the Izu-Ogasawara Ridge.

We deployed 5 sets of acoustic tomography system (400Hz type) in order to observe the seasonal change of ocean structure east of the Izu-Ogasawara Ridge. We also monitored the Kuroshio and its recirculation over the Izu-Ogasawara Ridge by using the ferry shuttling between Tokyo and Chichi-jima Island in the Ogasawara Islands. In January 1997 the ADCP system installed on the ferry was improved to get more accompany data, such as every GPS data and ship's tilting data. These instruments must help the ADCP system more accurately. Thus the intensive observation system in order to monitor the mesoscale phe-



TEMPERATURE(°C)

MR9704-DEPTH-500.0 1997/12/24 1998/01/14

Fig. 5 Temperature at 500m depth (24 December 1997 - 14 January 1998)

nomena south of the Kuroshio was constructed. The array of the instruments are shown in Fig. 6. These buoys will be recovered in summer 1998. And then we will analyzed the features of mesoscale phenomena.

Working in cooperation with the Marine Observation Satellite Research Project Team, we analyzed the sea surface height data observed by satellite sensor and then succeeded to detect a mesoscale eddy that propagated westward over the Izu-Ogasawara Ridge and interacted the Kuroshio south of Kyushu. Furthermore, working in cooperation with the Ocean Acoustic Tomography Project Team, we had done one of tomography (200Hz type). And then we succeed to detect the variation of the Kuroshio path.

② Observational research of Subarctic Gyre

The Amchitka Pass is one of the major passes through the Aleutian Islands Arc allowing exchange between the North Pacific and the Bering Sea. Hydrographic observations have been carried out since 1995 in this region. Zonal sections in the Amchitka Pass show the existence of colder and fresher subsurface water with higher dissolved oxygen in the

western side of the pass (Fig. 7). The layer of the subsurface water is about 200 m thick beneath the surface mixed layer and its characteristics are very similar to that of the temperature minimum layer in the Bering Sea. Geostrophic transports in the Amchitka Pass toward the Bering Sea are between -1.56 and 6.39 Sv referenced to near bottom from the present data. Zonal profiles of the geostrophic velocity are much complicated. Mooring observations were also carried out at two locations in the Amchitka Pass. Fig. 8 shows a stick diagram of daily mean current at the eastern Amchitka pass mooring during November 1996 and February 1997. Steady inflow toward the Bering Sea was observed from the mooring data from August 1996 to April 1997 in the eastern Amchitka Pass. The mean speed is 31 cm s^{-1} with right-bounded direction along the isobath. The data of temperature and salinity shows that strong vertical mixing occurs at the spring tide in the central Amchitka Pass. Four current meters are useful to show the current structure in the central Amchitka Pass from August to October 1996. Southward mean current was observed from upper three current

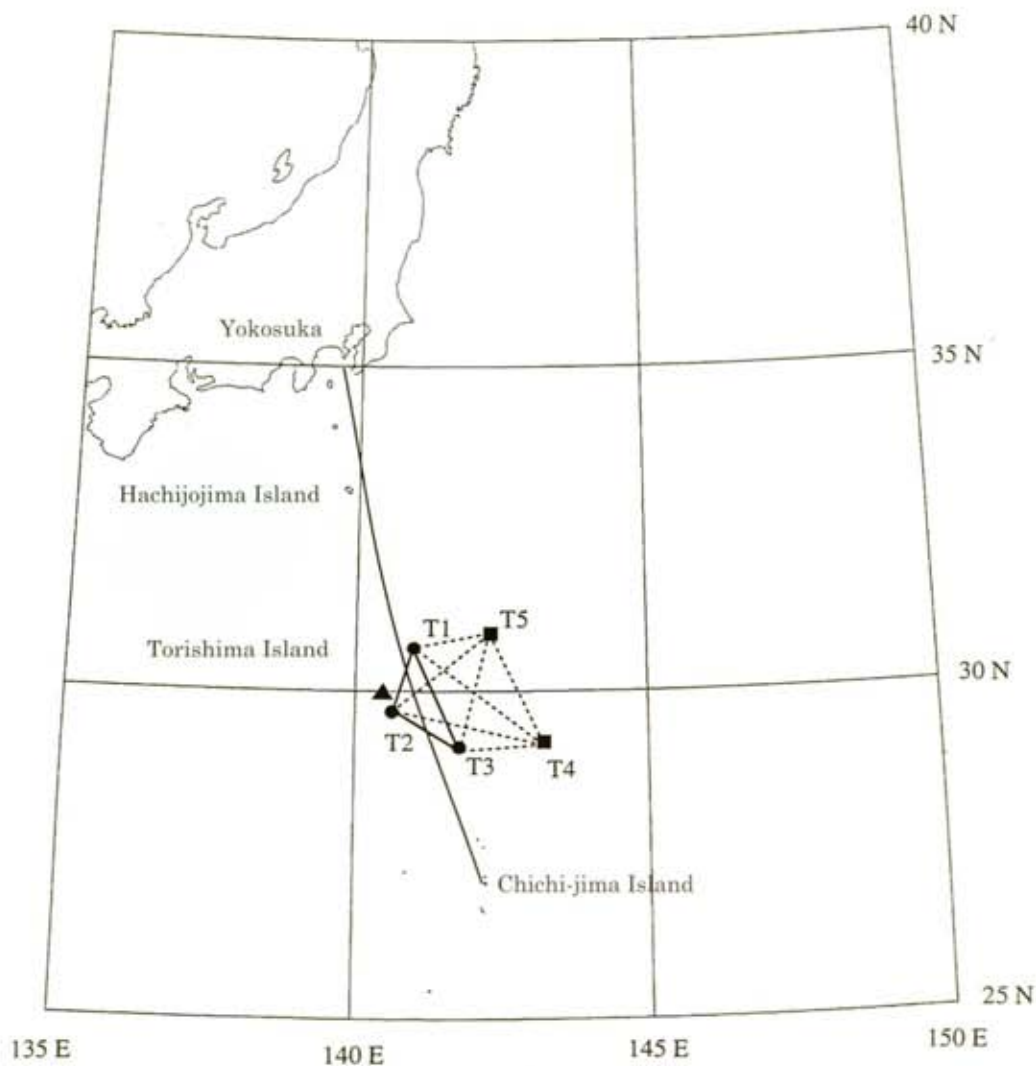


Fig. 6 The array of the instruments deployed east of Izu-Ogasawara Ridge. ■ are the mooring buoys of the ocean acoustic tomography, and ▲ is the mooring buoy of current meters

meters, while inverse flow was found at the lowest current meter when upper southward current is strong.

③ Autonomous marine observing system

A long-term oceanographic and meteorological monitoring at the Okino-tori-shima Island south of the Shikoku Basin are carried by using the autonomous marine observing system developed from 1988 to 1996. The monitoring system is maintained by using the power suppliers using natural energy resources. Furthermore we developed and succeeded

the data transmission system using the ARGOS system in 1997.

In October 1997, when the Typhoon 10th moved just above the Okino-tori-shima Island, we had a chance to get *in-situ* sea surface meteorological and ocean data. We found the closely correlation among the variation of the wind, the air-temperature and that of the sea surface temperature.

In February 1998 we had been to maintain the monitoring system at the Okino-tori-shima Island using the R/V "Natsushima". And then another set of me-

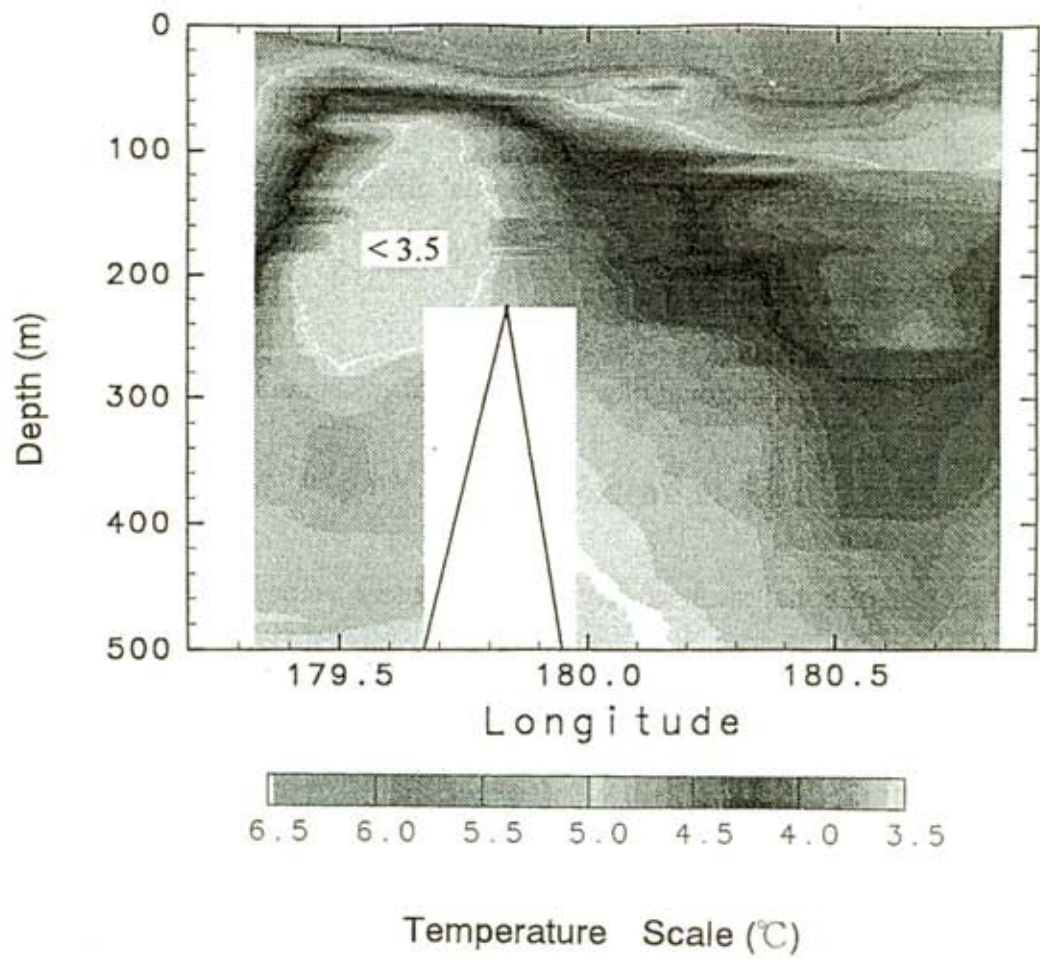


Fig. 7 Temperature section along Lat. 51.5°N at the Amchitka Pass (August 1995)

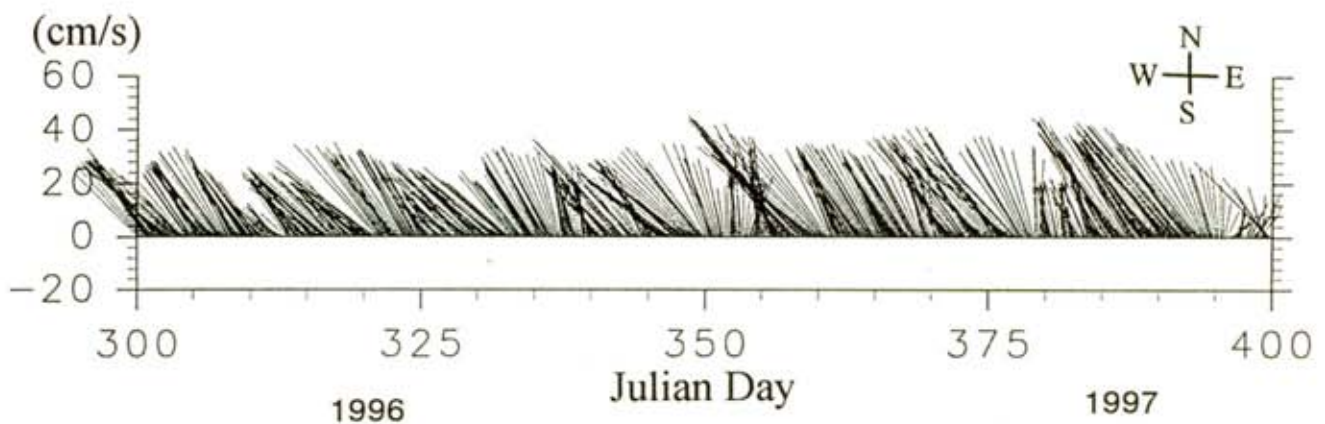


Fig. 8 Stick diagram of daily mean current of the eastern Amchitka Pass mooring (51°35' N, 179°15' W) at the depth of 230m during November 1996 and February 1997

teological sensors was deployed and then dual observation was started, those would prevent losing the data.

3) Arctic Ocean research program

① SHEBA (Surface Heat Budget of the Arctic Ocean)

The Surface Heat Budget of the Arctic Ocean (SHEBA) is an international, interdisciplinary, inter-agency research project designed to enhance understanding of the thermodynamic coupling among the atmosphere, the sea ice, and the ocean. The goals of the program are to use this increased understanding to improve the treatment of the arctic climate in global models and to enhance the observation and analysis of arctic climate by developing more accurate remote sensing techniques. To achieve these objectives, the SHEBA field experiment was started in the autumn of 1997 in the pack ice of the Arctic Ocean off Alaska.

The Arctic Research group of JAMSTEC participates in the SHEBA project. In the SHEBA field experiments, JAMSTEC focuses on the ocean dynamics, especially on the ocean circulation and the oceanic response to variabilities of sea-ice and atmosphere. The followings are their scientific background.

(a) Mooring observation on the eastern slope of the Northwind Ridge

An ADCP data of the IOEB-1 deployed in the Beaufort Sea in 1992 indicated a significant rectification of the ocean current flowing along seafloor topography (Fig. 9). The rectification was mainly observed on steep slopes of sea mounts or shelf breaks where the intrusion of the warm and salty Atlantic Water was often observed. Since the warm Atlantic Water with positive temperature is one of major heat source in the Arctic Ocean, understandings of its circulation will progress our knowledge on both the present climatic condition of the Arctic Ocean and the future climate change. To examine the rectification processes of the ocean current by the seafloor topography, JAMSTEC deployed a mooring constituting CTDs and current meters on the eastern slope of the Northwind Ridge (Fig. 10). The background why the Northwind Ridge was elected as location of the deployment is summarized as follows.

- According to the nonlinear theory of the geophysical fluid dynamics, the rectification would be possible both via an interaction between tidal or inertial current and seafloor topography, and via an interaction between mesoscale eddies and seafloor

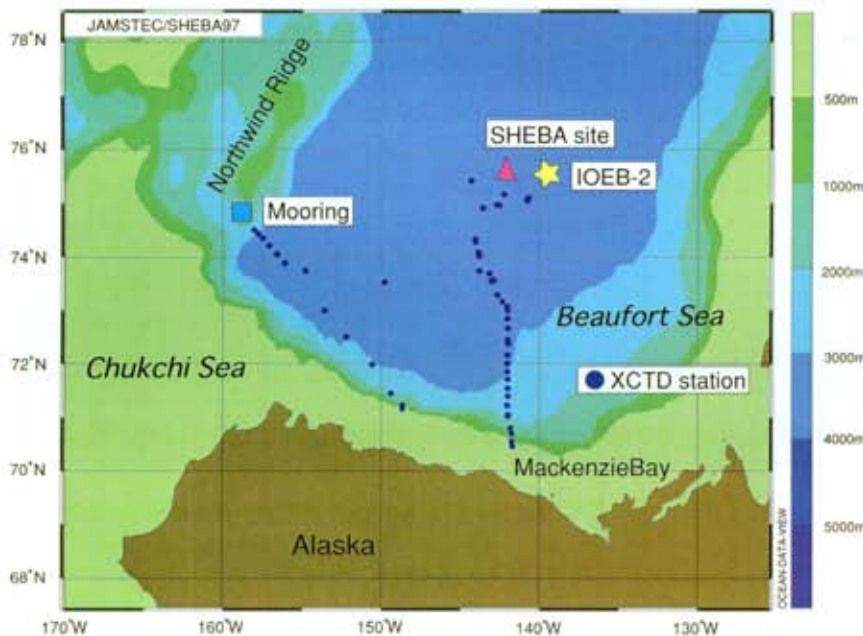


Fig. 9 Seafloor topography and horizontal velocity at 250m deep along the drift track of the IOEB-1

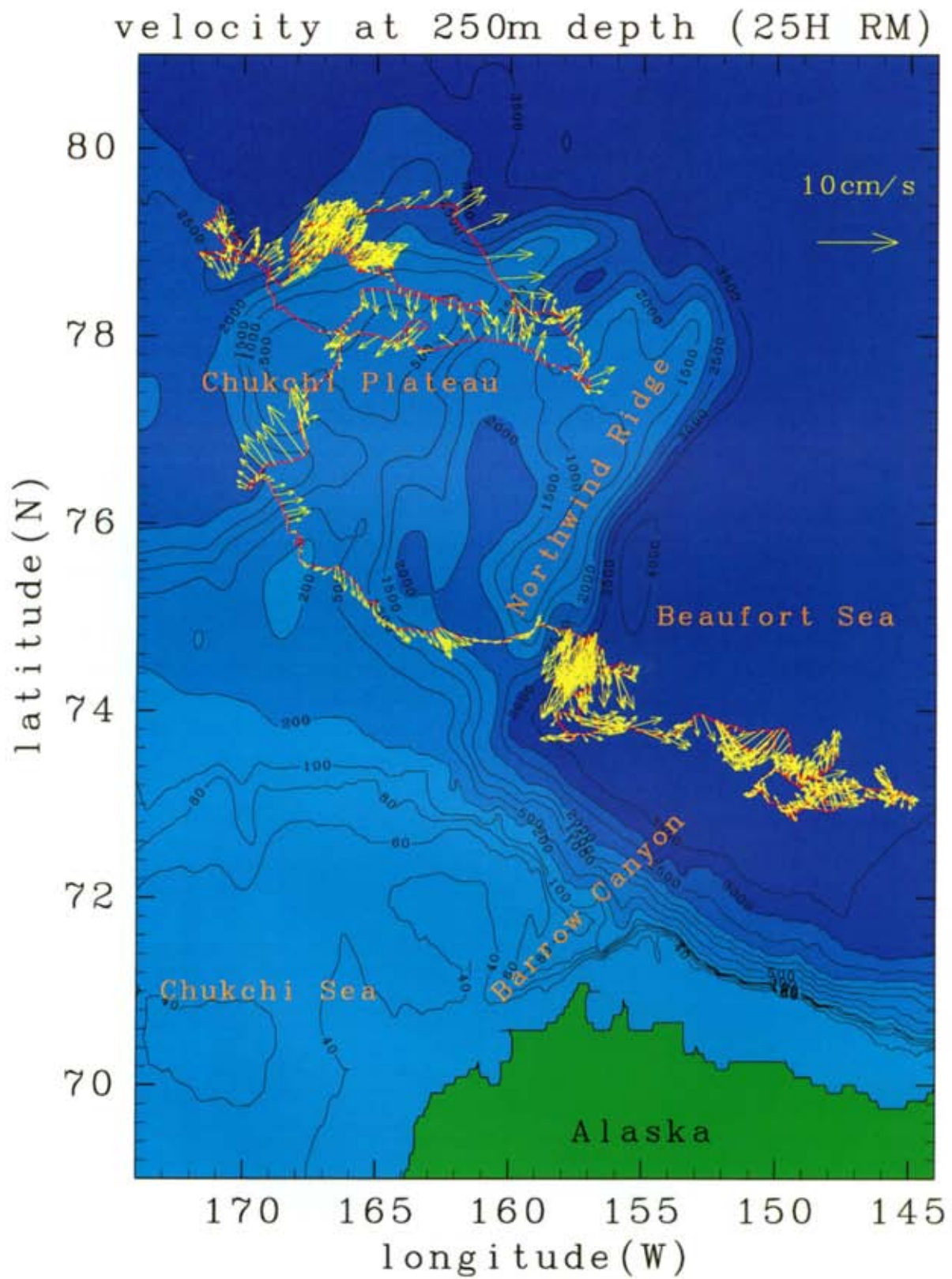


Fig.10 Position of the Northwind Ridge mooring, deployment position of the initial SHEBA site and IOEB-2 in the autumn 1997

UT AND GRADIENT OF BOTTOM TOPOGRAPHY (R=50KM)

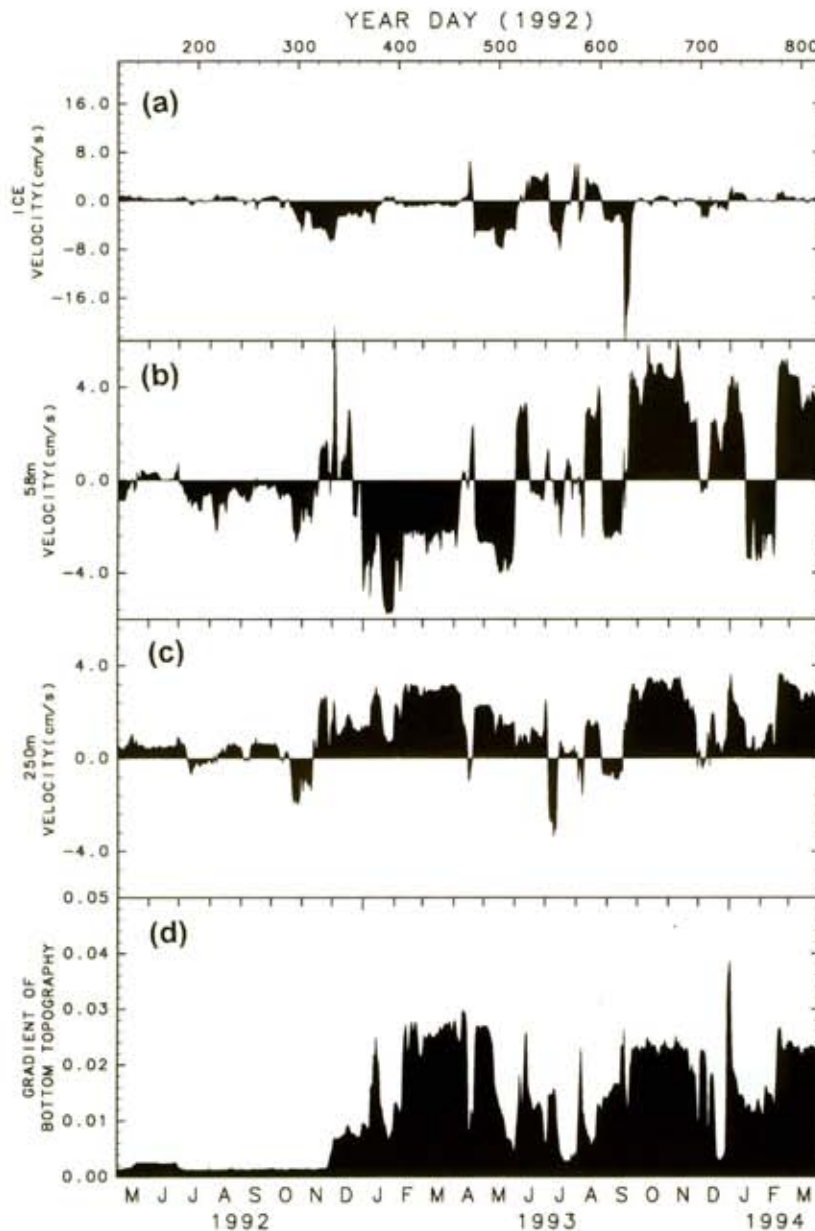


Fig.11 Time series of the velocity component tangential to the seafloor topography and maximum gradient of the seafloor topography along the drift track

(a) sea ice (b) 58m (c) 250m (d) maximum gradient of the seafloor topography

topography. Since the IOEB drifted according to the sea-ice motion, long-term Euler observation was not possible. The mooring observation measurement on the Northwind Ridge will improve our understanding of which has more important role on the rectification, the tidal effect or mesoscale

eddies.

- Intensification of both barotropic and baroclinic current component was observed by the ADCP data of the IOEB (Fig. 11bc). The drift speed of the sea ice was too weak to drive directly such strong ocean current (Fig. 11a). Thus a large-scale

wave dynamics in the presence of the finite amplitude elevation of the seafloor topography would govern the intensification. On the flat deep basin east of the Northwind Ridge, Rossby wave has westward propagation. The wave, however, could not have continuous westward propagation over the ridge. The ridge would be able to be considered as a western boundary for the barotropic mode. As the results, a kind of barotropic western boundary intensification could occur. In the Arctic Ocean, internal Rossby deformation is much smaller than that in the mid-latitude ocean. Then nonlinear long baroclinic Rossby wave dynamics would be applied to the baroclinic current intensification. According to the nonlinear theory, characteristics of the long wave are possible to be intersected in the presence of finite amplitude of seafloor topography. The intersection forms a large amplitude elevation of the main pycnocline around ridges or troughs. As the results, a strong baroclinic current would be established around the ridges or troughs (Rhines, 1989). If the above hypothesis were valid, the variability of the current on the ridges would be related to the variability of the sea-ice and atmosphere in the remote region east of the ridge. During the same period of the mooring observation, the year-round SHEBA field experiment is conducted. The comparison between the mooring data and comprehensive data obtained around SHEBA site, will progress our understandings of the mechanism of the current intensification.

(b) Ice-Ocean Environmental Buoy (IOEB-2)

Two IOEBs were developed by the collaboration between JAMSTEC and WHOI. The scientific objective of the IOEB research program is to clarify both global role of the variability of the sea ice, and regional processes of the sea ice, ocean, and atmosphere. In addition to the physical climate processes, biochemical processes are also examined by a sediment trap system and several bio-chemical sensors mounted on the line of the IOEB. These comprehensive informations will improve our understandings

of both the regional processes controlling the Arctic climate system and the role of the Arctic region in the global climate system.

Based upon the results of the IOEB-1 observation in the Beaufort Sea since 1992, the importance of the seafloor topography on the ocean circulation in the Arctic Ocean. In order to progress our understandings of the ocean circulation in the presence of the finite amplitude of the seafloor topography, the other IOEB-2 was deployed south of the initial SHEBA site in September 1997. The data comparison between the mooring data at Northwind Ridge and the IOEB-2 data will provide a key information on the effects of the seafloor topography on the ocean circulation with the scale from Rossby deformation radius (inertial period or tidal period) to the basin width. In addition to the above objective on the ocean circulation in the presence of seafloor topography, the IOEB-2 was deployed as a one of buoys constituting the SHEBA outer buoy array. The SHEBA outer buoy array was designed to clarify the upper ocean effects on the local surface heat/momentum budget of the Arctic Ocean, estimating the state of the mixed layer and the flux of heat, salt, and momentum at the ice-ocean interface. The SHEBA buoy array will improve the parameterization for the heat and momentum flux condition at the interface in the current Arctic climate model.

(c) XCTD observation focusing on the mesoscale circulation in the Arctic Ocean

The third mission of JAMSTEC in the SHEBA field experiment is the XCTD observation focusing on the mesoscale structure of the Beaufort Sea. In the Arctic Ocean, the cold halocline layer characterized by nearly homogenous temperature of freeze point and increase of salinity with depth were found. It shields positive heat flux from the underlying warm Atlantic Water and prevents from deep convection arising from surface cooling. Thus the cold halocline layer offers a suitable condition for the sea ice formation and maintenance (Aagaard and Carmack, 1989). Since the cold halocline layer is characterized by a maximum value of dissolved oxygen and silicate, the origin of its water mass has been considered to be traced back

to the shelf region (Jones and Anderson, 1994). Currently the formation and transportation process of the cold halocline water is one of important theme of the Arctic Oceanography. The significance of the mesoscale eddies about the transportation process of the shelf water has been pointed out (Aagaard and Carmack, 1994). In order to measure the mesoscale feature, an eddy resolving XCTD observation was performed on the line between the Mackenzie Bay and the initial SHEBA site (Fig. 12). The result showed that the cold halocline water trapped by the mesoscale eddies was characterized by not only nearly homogenous temperature of freeze point and increase of salinity with depth, but also low potential vorticity water mass (Fig. 13). When the density is chosen as the ordinate (Fig.14), the mesoscale eddies are not clearly identified by the distribution of both temperature and salinity, but are identified by the low value of the potential vorticity. This implied that the water mass constituting the eddies should be formed through mixing processes such as shallow vertical convection at coastal polynya, tidal mixing on the shelf break. In addition to the study on the characteristics of the water mass, an international mooring observation among US, Canada, and Japan is now ongoing to estimate the mass transportation and the instability of the topographically trapped

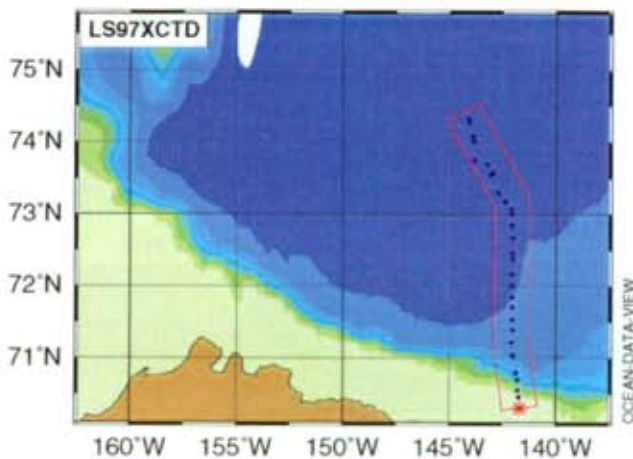


Fig.12 Station map for the eddy resolving XCTD observation between the Mackenzie Bay and the initial SHEBA site (MS-line)

current along the shelf break, and to clarify the dynamics of the formation processes of mesoscale eddies related to the instability.

② Baroclinic Instability observed by Transpolar IOEB-2

The transpolar IOEB-2 observation was conducted in 1994 to measure environment along the transpolar

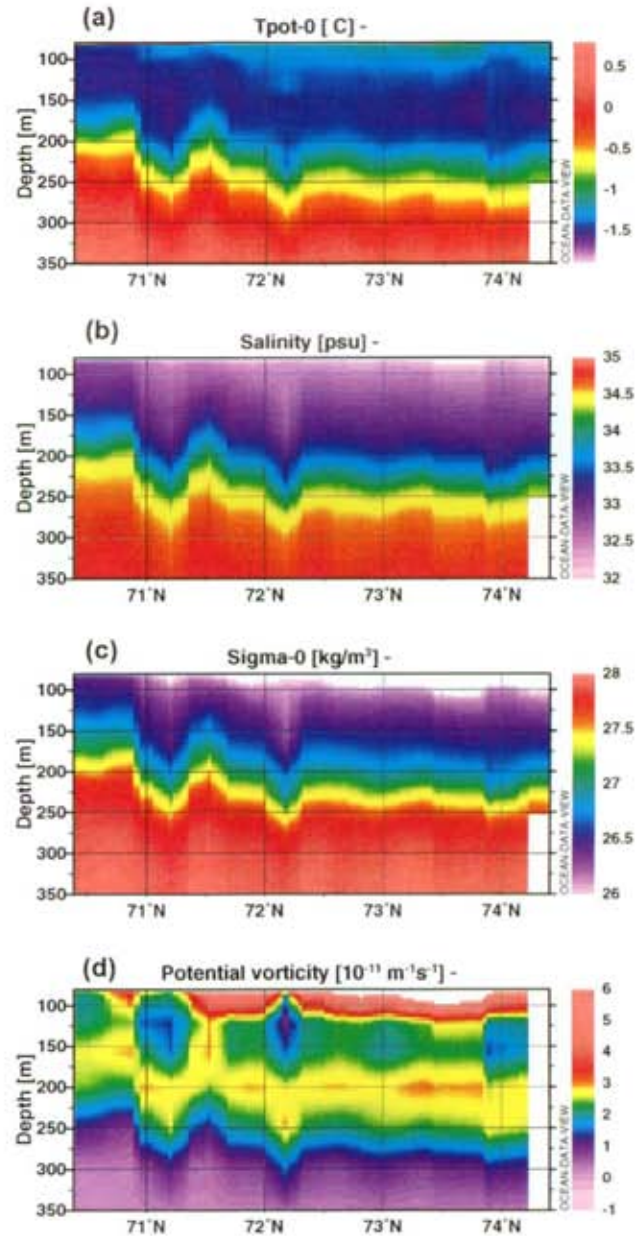


Fig.13 Vertical section along the MS-line with depth as the ordinate

(a) potential temperature, (b) salinity, (c) density, and (d) potential vorticity

drift with its origin in Laptev Sea and extending to the Denmark strait through the Fram Strait. The analysis of the transpolar IOEB-2 data was conducted with attention to the mesoscale phenomena. A lot of salinity events were found in the records of the CTD data of the IOEB-2. These events were found north of Fram Strait where the fresh/cold East Greenland currents originating from Arctic surface water encountered the saline/warm West Spitzbergen current originating from the Atlantic water. The two different water masses formed a strong frontal structure, then the current near the front was considered to be easily evolved into street of mesoscale eddies via baroclinic instability. Fig. 15 shows the anomaly of

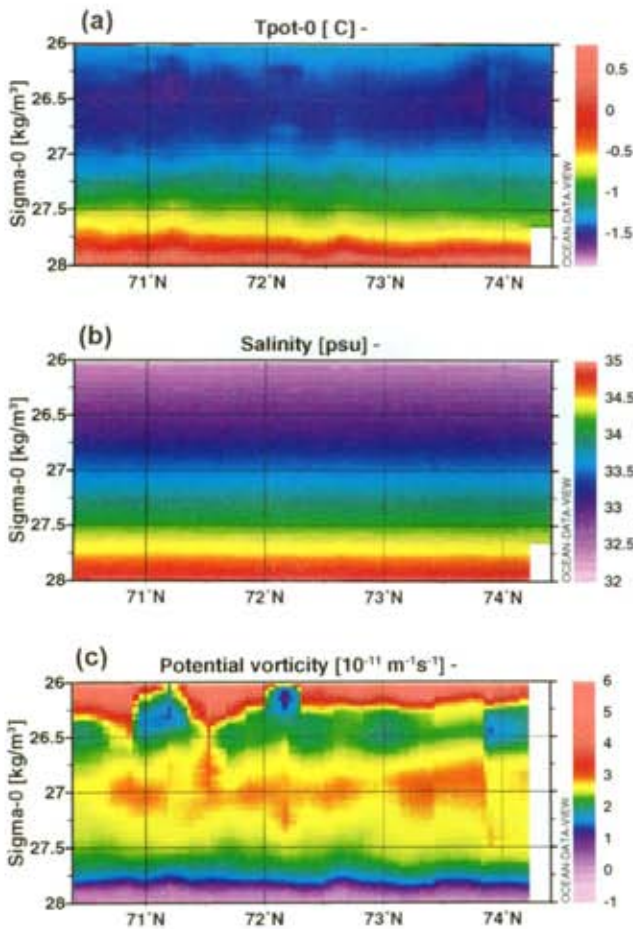


Fig.14 Vertical section along the MS-line with density as the ordinate
(a) potential temperature, (b) salinity, and (c) potential vorticity

the density, and potential vorticity in meridional section. Their patterns of the disturbances were inclined north to south with depth and they are identical to the vertical structure of unstable baroclinic waves.

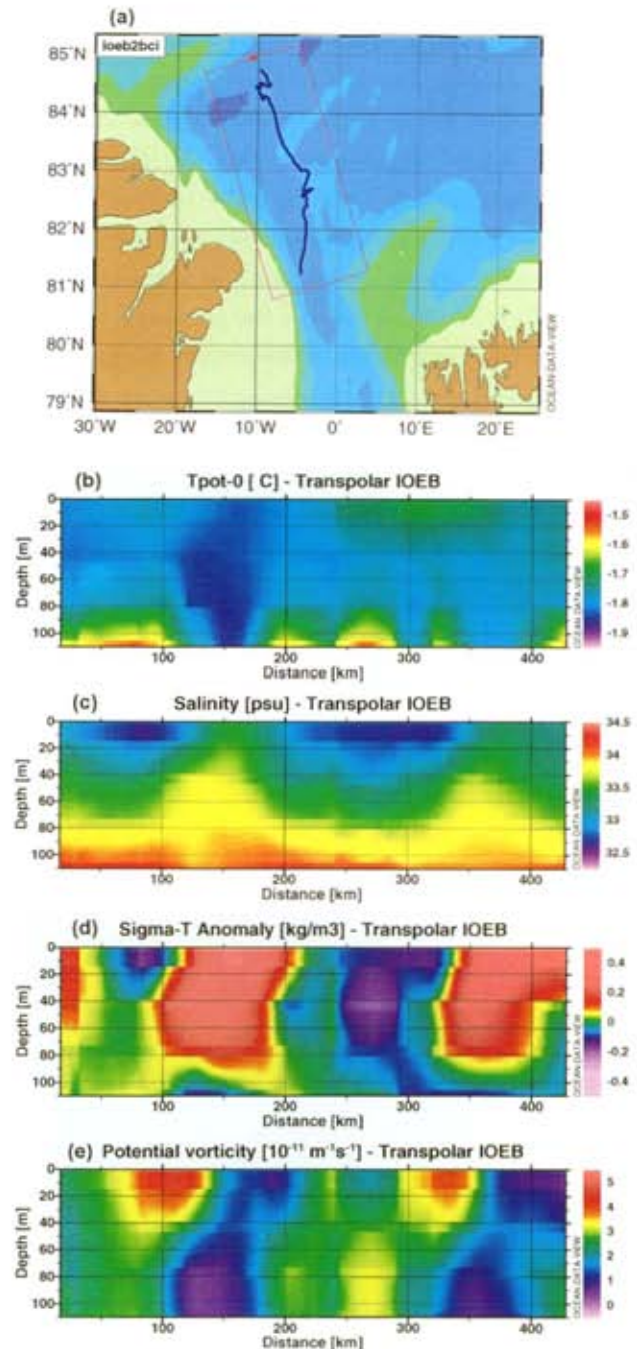


Fig.15 (a) Drift track of the transpolar IOEB-2 and the vertical distribution of (b) potential temperature, (c) salinity, (d) density anomaly, and (e) potential vorticity

In addition, the scale of the disturbance was identical to the scale of the fastest growing wave of the baroclinic instability based on the background density field.

4) Study of air-sea interaction

For the better understanding of the mechanism and behavior of warm water pool and ocean-atmosphere interaction in the tropical western Pacific ocean, JAMSTEC has been conducting TOCS (Tropical Ocean Climate Study) cruise twice a year (summer/winter). In the cruise, CTD, shipboard ADCP and radiosonde observations are carried out in addition to the maintenance of JAMSTEC sub-surface ADCP moorings and NOAA/PMEL ATLAS buoys.

Especially, the first collaborative work among NCAR, BNL, and JAMSTEC was made in the February 1997 cruise (hereafter, KY9702 cruise) focusing on diurnal cycle in this region. In KY9702 cruise, meteorological measurements using Wind Profiler with RASS, Sounding Aerosol Backscatter Lidar, Portable Radiation Package by BNL and so on were also conducted in addition to conventional JAMSTEC

TOCS cruise above mentioned. JAMSTEC's R/V "Kaiyo" left Majuro (7°06'N, 171°22'E) on Jan. 26, 1997 for the equatorial western Pacific and arrived at Palau (7°20'N, 134°28'E) on Feb. 28, 1997 via Chuuk (7°28'N, 151°51'E) (Fig. 16).

One of the most notable feature during KY9702 cruise was the occurrence of westerly wind burst (WWB) whose strongest wind speed (>20m/s) was observed at 850hPa after Feb.19 (Fig. 17). Mean humidity during WWB period shows more moist conditions than during anti-WWB period. The feature is corresponding to the past works. Although the westerly wind was also observed in the past TOCS boreal winter cruises and showed moist feature, KY9702 showed the most moist condition among past three years. Besides, from the comparison with the data of TAO buoys and ADCP moorings, only WWB observed in KY9702 was accompanied with the eastward propagation of warm water. Since recent TOCS cruise (August 1997) also shows WWB, it is expected that the eastward shift of warm water region is reinforced. In the present study, the feature of WWB in KY9702 will be discussed further based on the com-

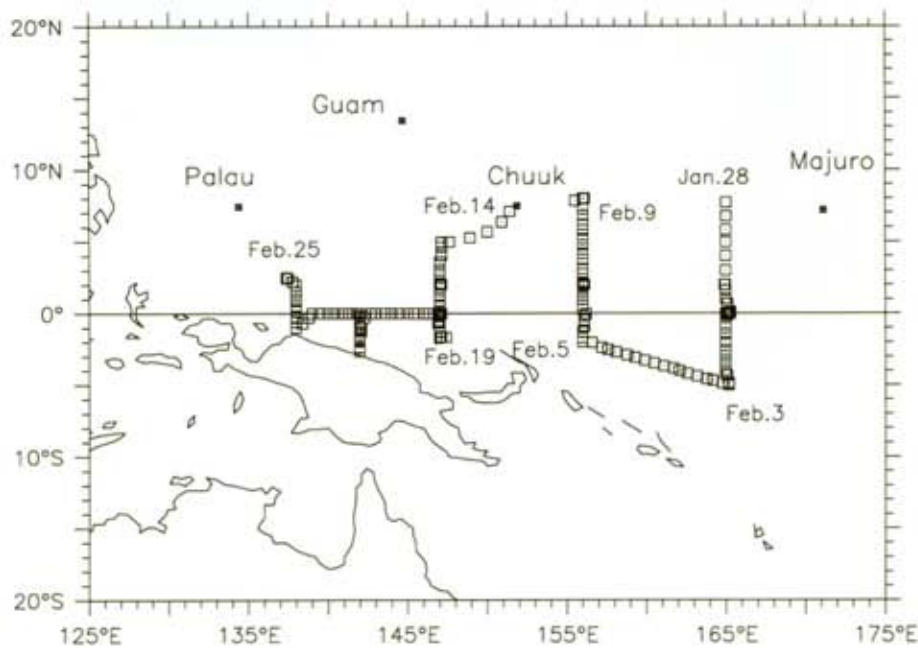


Fig.16 KY9702 cruise track of R/V "Kaiyo"

parison with past other WWB and anti-WWB period features.

5) Biogeochemical study of the ocean and development of observation system

① Development of ocean LIDAR system

We demonstrated usefulness of the shipboard ocean LIDAR system as a result of the phytoplankton observation by the prototype of the ocean LIDAR system until 1996. Based on the previous experiments, we have started developing a new shipboard ocean LIDAR system for practical use to carry on the bottom of R/V "Mirai" from 1997. This year, we designed the detail of the system and we also made the optical bench for the system.

② Biogeochemical study of the Equatorial Pacific

Through the biogeochemical observation such as chemical analysis of seawater, primary productivity

and optical measurements, we will study the mechanism of high-nutrient-low chlorophyll condition in the equatorial upwelling region, deep chlorophyll maximum layer in the warm water pool region in the western equatorial Pacific and primary productivity in the Indian Ocean related to Indonesian through-flow. We also receive the satellite remote sensing data such as sea-surface temperature and ocean color to observe temporal variation of standing crop of the phytoplankton. By combining this data with the oceanic primary production data, we will estimate the primary productivity in the wide area of the ocean.

We conducted biogeochemical cruise by R/V "Kaiyo" in December 1997 at the warm water pool region in the western equatorial Pacific and also made by R/V "Mirai" in January 1998 as a part of training cruise in the equatorial upwelling region. Fig. 18-19s show cruise tracks of R/V "Kaiyo" and "Mirai", respectively.

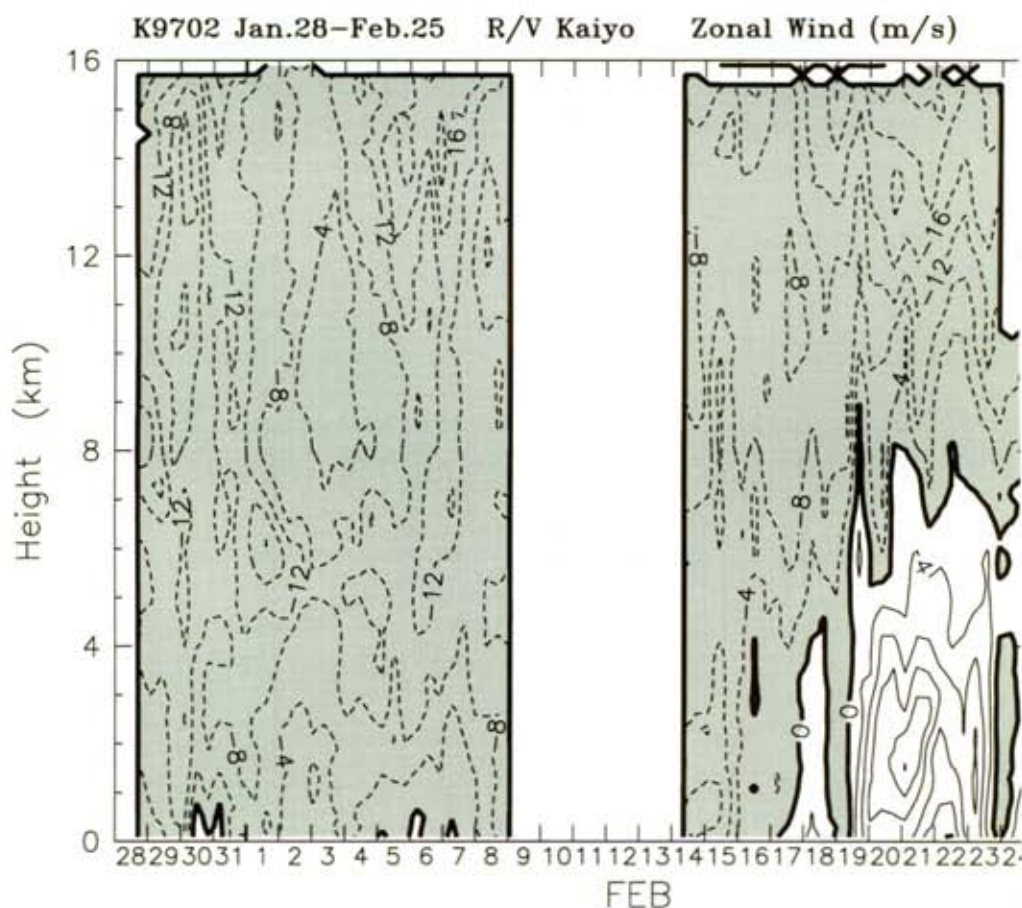


Fig.17 Time-height cross section of zonal wind

Sea water temperature of the surface was high and nutrients were depleted with El Niño that was said as the biggest one in this century. In the "Mirai" cruise, we received remote sensing data from the ocean color sensor (SeaWiFS) carried on Orbview-II as well. We also conducted *in-situ* incubation to measure primary production using ^{13}C and ^{15}N as a tracer. We deployed two incubation bottles for 13 layers including chlorophyll maximum, for 3 hours.

The distribution of the chlorophyll-a which is indicative of the standing crop of the phytoplankton is shown in Fig. 20. Usually, nutrients are supplied to the surface layer by the effect of equatorial upwelling on the east of the date line and consequently chlorophyll maximum layer becomes shallower to the east. However warm water pool was spreading out even on the east side during the cruise by El Niño, and chlorophyll maximum existed 70m in the whole area of the observation.

This cruise was conducted as joint researches with

Dalhousie University for "Research and monitoring of primary production and environmental parameters on the equatorial upwelling", and with Meteorological Research Institute of Japan for "observation research of primary production and flux of green house gasses in the equatorial Pacific".

③ Biogeochemical study of the northern North Pacific and its adjacent seas

Goals of this projects 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, 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 variation.

During a shakedown cruise of newly built R/V "Mirai" from 10 Nov. to 5 Dec., 1997, 13 stations were occupied in the northwestern North Pacific (Fig.21).

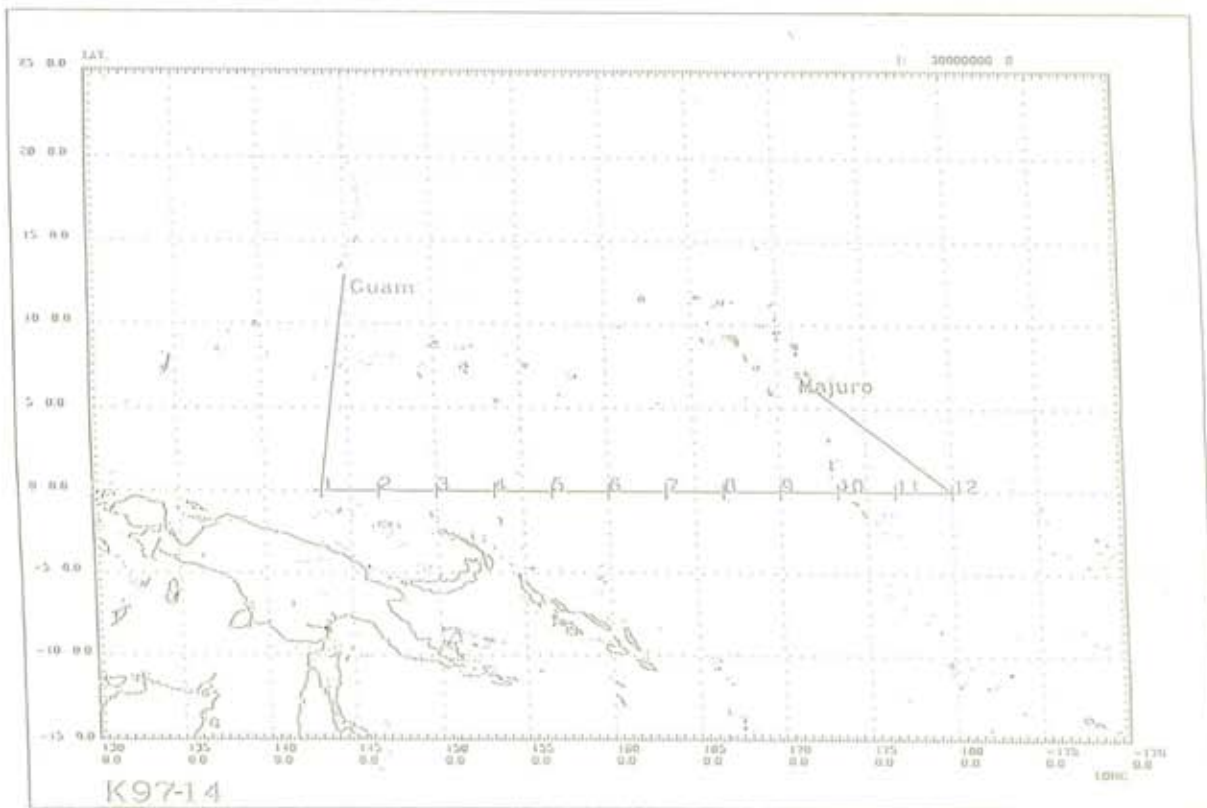


Fig.18 KY9714 cruise track of R/V "Kaiyo"

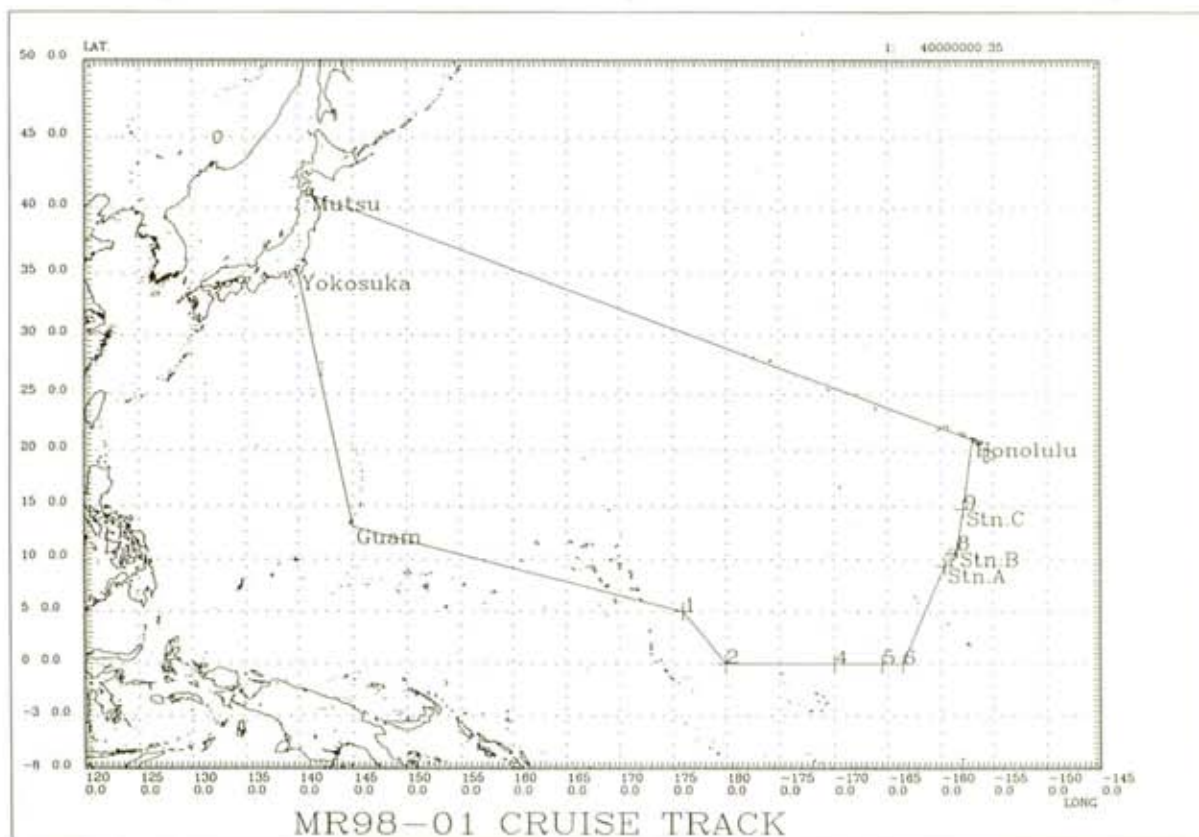


Fig.19 MR9801 cruise track of R/V "Mirai"

Analysis of the samples are still in progress. Results obtained are shown below.

(a) Distributions of nutrients

Vertical distributions of nutrients in the northwestern North Pacific have been determined. In general, distribution patterns can be categorized into three groups; (1) subarctic water, which shows high density and high nutrient concentration in surface layer, (2) transition zone, (3) subtropical water, which is low density and lack of surface nutrients. Possible intrusion of the Bering Sea Water with low density and high nutrient concentration was observed at 2,000-3,000 m depth of a station close to the Emperor Sea Mount. The data with other data such as salinity and temperature will be further analyzed for the structure of the water and biogeochemical cycle in the northern North Pacific. In addition, comparison of the data with historical data will reveal the abundance of nutrients and its temporal change in the

northwestern North Pacific.

(b) Vertical profiles of pH, normalized total dissolved inorganic carbon (NTCO₂), and normalized total alkalinity (NTALK)

Vertical profiles of pH, NTCO₂, and NTALK in the northwestern North Pacific show that values for these parameters are constant within measurement errors in the abyssal water deeper than 2,000 m. On the other hand, these values shallower than 1,500 m depth for each stations are different each other significantly as follows. 1) Values of pH decrease with decreasing depth in the north of 44° N (hereinafter northern area) with a minimum around 200 to 400 m depth, and increase drastically toward the surface. In the south of 44° N (hereinafter southern area), on the other hand, values of pH begin to increase moderately around 800 m toward the sea surface, and pH values in the surface water is larger than those in the northern area. 2) Vertical profiles for NTCO₂ have

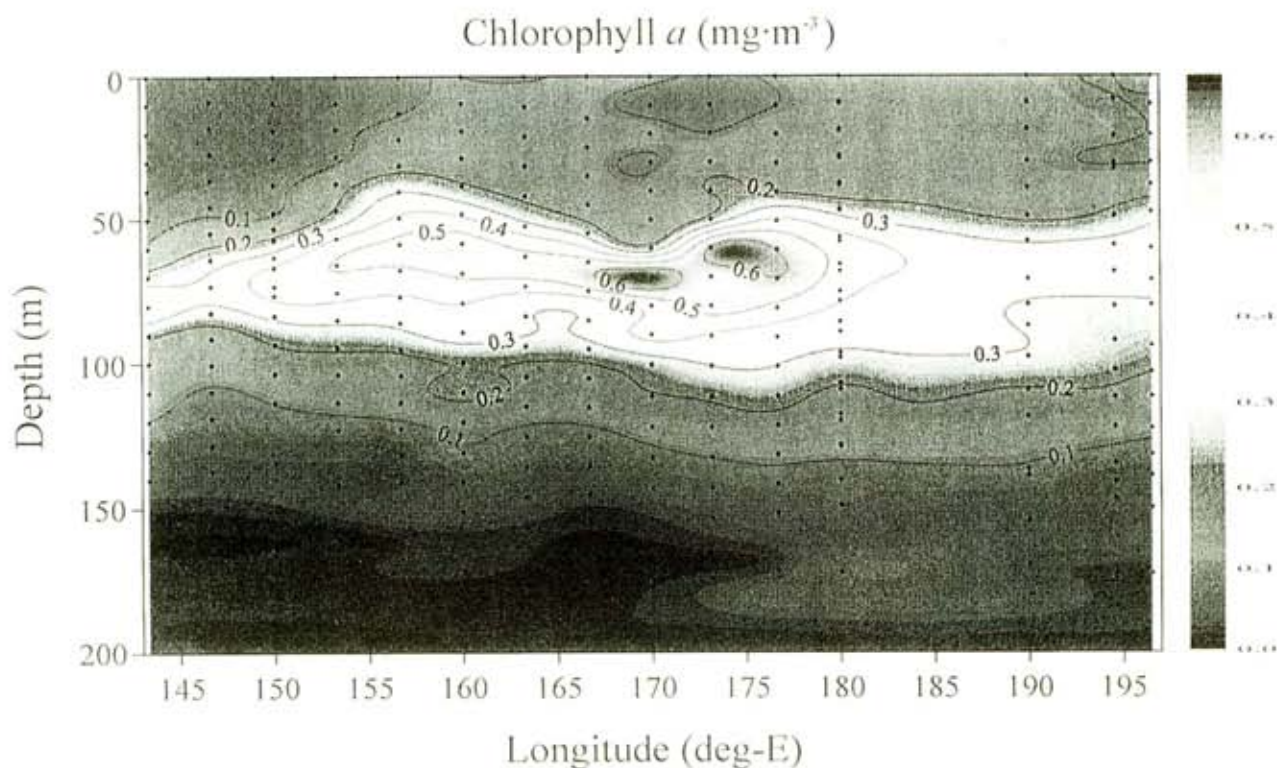


Fig.20 Distribution of chlorophyll-a

the maximum value around 1,400 m depth. In the southern area, values of NTCO_2 between 1,400 m and around 300 m depth do not show significant change, while values of NTCO_2 decrease with decreasing depth moderately in the northern area. Values of NTCO_2 in the surface water are larger in the northern area than in the southern area. 3) Comparing with values of pH and NTCO_2 for each stations, difference in NTALK values for each stations is small. However, it can be seen that values of NTALK shallower than 1,000 m are slightly larger in the northern area than the southern area.

(c) Accumulation of anthropogenic carbon dioxide (CO_2) in the northwestern North Pacific

In order to estimate how much anthropogenic carbon dioxide (CO_2) has accumulated in the northwestern North Pacific recently, NTCO_2 values observed in 1997 were compared with those obtained during "GEOSECS Pacific Expedition" in 1973. As a result, it can be concluded that accumulation rate of anthropogenic CO_2 at 40°N is similar to or slightly larger

than the average rate of the whole ocean estimated by mathematical simulation, while that at 50°N is approximately 4 times larger than the average.

(d) Distribution of total dissolved inorganic carbon in surface water

Fig. 21 shows horizontal distribution of total dissolved inorganic carbon (normalized by salinity 35 psu; NTCO_2). The lowest (ca. $1975 \mu\text{mol/kg}$) and highest (ca. $2225 \mu\text{mol/kg}$) concentration of NTCO_2 were observed at the lowest and highest latitude in our research area, respectively. As the latitude is lower, the NTCO_2 concentration is lower while longitudinal variation is relatively small. This is almost corresponded with horizontal distribution of water temperature and salinity which were measured continuously. Takahashi *et al.* (1991), who measured NTCO_2 in surface seawater using container ships, reported similar results in winter season. It is suggested that the distribution of NTCO_2 in winter in the North Pacific is controlled by physical factors (water mixing).

(e) CO_2 concentration in the atmosphere and surface

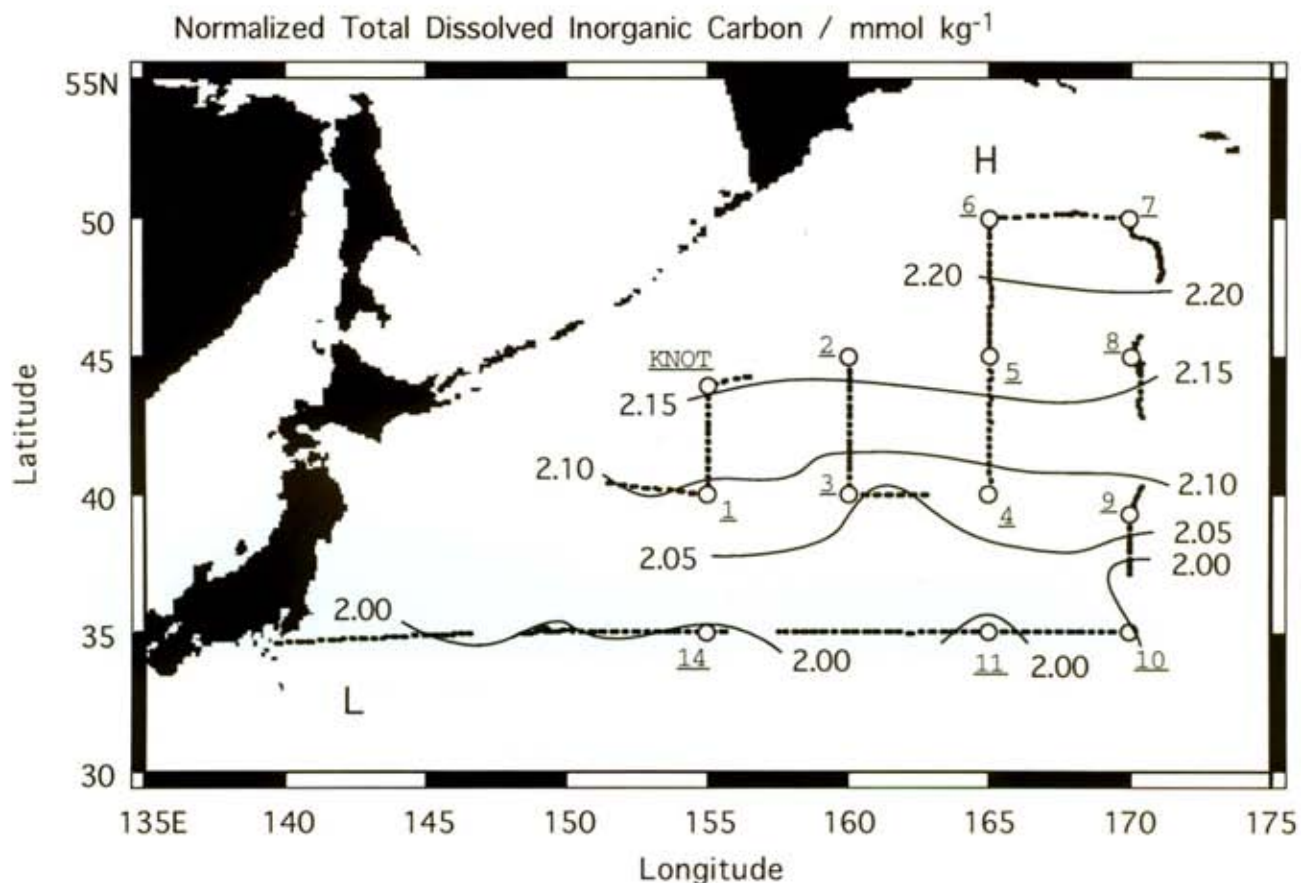


Fig.21 Horizontal distribution of total dissolved inorganic carbon (normalized by salinity 35 psu; NTCO₂).
Open circles and underlined numbers represent sampling and stations and station numbers, respectively

water

Concentrations of CO₂ in the atmosphere and surface water were measured along the 170°E meridian from 35°N to 50°N. Its atmospheric concentration were 365 ppmv (parts per million by volume) and 370 ppmv in the lower and higher latitudes, respectively, showing a gradual northward increase. Concentrations of CO₂ in the surface remained constant at 320 ppmv. However, the concentrations increased gradually (about 50 ppmv) from 43°N to 45°N and reached about 370 ppmv in the northernmost latitudes. The calculated $\Delta p\text{CO}_2$ which indicates the driving force of air-sea exchange of CO₂ was -50 ppmv and 0 ppmv in the lower and higher latitudes, respectively.

The north to south variations in concentrations of CO₂ in the study area of MR97-02 cruise showed almost the same tendency, except for the seas close to

Japan. From the observations, it is found that in the early winter, the lower latitudes of the study area acted as a sink for atmospheric CO₂, while the higher latitudes was almost equilibrated with atmospheric CO₂.

(f) Distributions of Fe in sea water

Behavior of iron in the northwestern North Pacific was studied. Water samples were collected vertically using 12L Teflon-coated Niskin 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 1nM.

(g) Distributions of ²³⁴Th in the surface water

Concentrations of dissolved and particulate ²³⁴Th in the upper 200 m water columns were measured at 7 stations. Analysis is still in progress.

(h) Sediment trap deployment

In order to collect settling particles and study biological pump associating with uptake of atmospheric CO₂ in the northwestern North Pacific, sediment trap mooring systems were deployed at stn. KNOT (Japanese biogeochemical time-series station), stn. 4 (subarctic front), and stn. 6 (western subarctic gyre) on MR97-02 R/V "Mirai" cruise. Each mooring system consists of three sediment traps with 21 collecting cups (McLane mark 7G-21 or Mark 78-21), acoustic current meters (and turbid meter), glass floatations, wire / nylon ropes, and an acoustic releaser (Benthos 865A). Before deployment, collecting cups were filled with sea water based 5 % buffered formalin to preserve collected settling particles for one year. Each cup was programmed to rotate every 17.375 days and start at 1 December, 1997. Sediment traps on each mooring system were deployed at approximately 1,000 m, 3,000 m, and 5,000 m. These mooring systems are planned to be recovered next year by R/V "Mirai".

④ Chronology of ice core with amino acid racemization (Joint Study with Nagoya University)

In order to estimate age of ice core, it is useful to

count its lamina which formed seasonally. However, this method is not suitable for the ice cores which had post-depositional redistribution of waters due to its evaporation like those in the Antarctica, or of which the lamina is unclear. Therefore, we tried to apply amino acid racemization chronology to estimate the age of ice core. At first, amino acid concentration was measured for three ice cores collected at Konron in China, Antarctic iceberg and Asuka Station in the Antarctica.

The particulate amino acid concentration was higher than dissolved ones in the ice core in China. Asp, Glu, and Thr were the dominant amino acids. Since a racemization rate of Asp is highest among the amino acids, Asp can be used to estimate the age of ice core in China for the time scale of decade to millennium.

For the ice cores in Antarctica, the amino acid concentration in particulate matter was also higher than dissolved amino acids, but it was almost same level as the detection limit (pg) of HPLC. Therefore, amino acid chronology is not suitable for Antarctic ice core due to quite low concentration of amino acids.

Coastal Research Department

1. The Principles of Research and Development

1) The Human Theme

The UN Law of the Sea was established in 1982 to build a common understanding of the oceans as the collective asset of humanity and a source of life.

This common understanding includes the fostering and preservation of living resources and the protection and preservation of the marine environment.

Meanwhile, as the global population rapidly approaches ten billion, we need to solve problems caused by human activity such as global warming, the hole in the ozone layer, environmental pollution and the lower productivity of living resources. Accordingly, we believe that one of our responsibilities is to promote research based on international cooperation in order to clarify the mechanisms of change in the coastal environments that are due to the interaction of the ocean and the atmosphere, including those caused by human activity, as it is vital to preserve the environment of the ecosystem.

2) Coastal Research

The Coastal Research Department carries out research which mainly focuses on coastal areas. Coastal regions are areas with a high primary productivity, as they are spawning grounds for fish and nurseries for fingerlings, and also used for aquaculture and recreation. In addition, they have also been subject to intensive human activity. As these coastal regions have such great efficiency, they have been over-exploited by human beings, and there are already many actual examples of such overuse.

Taking this situation into account, the Coastal Research Department established a research system that recognizes the importance of the coastal ecosystem in FY 1994 and established projects that address

“Research for changing mechanisms of the coastal ecosystem” from FY 1995.

There are three main areas of research at the department. These include ocean energy and scientific diving (research into underwater operations technology) in addition to the coastal ecosystem research. While we concentrate on the ecosystem research, we have conducted research which complements the coastal ecosystem research in both these areas, with results in ocean energy research and research into scientific diving that enables scientists themselves to safely carry out ecosystem research by diving.

We believe that it is our responsibility to engage in research and development that only our department, out of the various public marine-related research organizations, can carry out. In other words, it is important for us to fully utilize our proficiency in the development of equipment, our multi-disciplinary research function and our diving survey capabilities. In addition to researchers in such fields as marine engineering, naval architecture, marine biology, marine chemistry and diving medicine, the department possesses pre-eminent diving technology. We believe that the department is needed because we conduct research on the development and usage of coastal regions combining our multi-disciplinary research areas and technology.

2. Overview of Research and Development

As we have already explained, the wide range of research at the department running from ocean engineering to ecology and diving medicine is carried out in four groups. We will introduce an overview of the main research themes in later chapters, so here we will introduce the research carried out in each group.

1) Research on Deep Seawater Utilization

As for deep seawater resources, joint study entitled "A study on the property and distribution of deep seawater in the Sea of Japan" was conducted with Toyama Prefecture Fisheries Research Institute to promote the utilization of the deep seawater of the Sea of Japan. Vertical distribution of temperature, salinity, nutrients, were investigated and their algal growth potentials were estimated on the samples collected in autumn. And a joint study entitled "A feasibility study on fertility of the sea using deep seawater" was conducted with Kochi prefecture, Shimizu corporation, and Kansai Environmental Engineering Center co. to make concept of the drainage technology of deep seawater, which must be necessary when deep seawater utilization technology will be done in the utility scale. Possibility to fertilizing the sea using deep seawater and the process of the development were examined.

2) Research on the Coastal Physical Environment

The second research group aims to clarify the physical role of the sea in the mechanisms of change in the coastal regions and carries out monitoring of the physical environment and modeling, and develops research aimed at simulation. In research for changing mechanisms of the coastal ecosystem, we surveyed and researched sea water flows, the sea water environment, the changing nature of the seabed and the development of transplanted coral in different environments in order to relate the health of the coral reef to the physical environment and to produce the parameters for an ecosystem model. In the Project for Research and Development of a Monitoring System for Massive Amounts of Water Flow, which is a joint project with Miyagi Prefecture, we carried out monitoring and observation aimed at making practical use of the underwater elevator system which was developed in order to enable continuous measurements of the vertical structure of the marine environmental factors. In the Research and Development of Technology to Control the Generation of Oxygen-deficient Water Mass in Ohmura Bay, which began

FY 1997 as a joint project with Nagasaki Prefecture, we carried out fixed point and wide area surveys of Ohmura Bay in August and November in order to clarify the generation of oxygen-deficient water mass. In addition, we planned and manufactured a prototype seawater flow mixing and carried out basic performance tests. In the ongoing project "Research into the Interrelationship between Coastal Water Flow and the Open Sea", we carried out a wide area numerical simulation, including Sendai Bay, using a three dimensional water flow model of an open type bay area and investigated the interrelationship between flow within the bay and sea flow in the open sea, in addition to comparing the results of the simulation with actual data recorded in Ishinomaki Bay.

3) Study on the mechanism of low trophic stage

As for the study on low trophic stage, in the project entitled "the elucidation of the change mechanism of the coastal sea ecosystem", distributions of nutrients, phytoplanktons, zooplanktons and benthos were investigated in coral reef and development of underwater microscope for *in situ* observation of coral and algae living in the coral was conducted.

Investigation was conducted at coral reef of the east coast of Ishigaki Island in September and October of 1997.

On nutrients distribution, nitrate, nitrite, ammonium, dissolved organic nitrogen and phosphate were measured. Concentrations of nitrate, nitrite and phosphate were extremely low, and distributed relatively uniform both inside and outside the reef. Ammonium were relatively low and have a tendency of being lower in the concentration outside the reef than that inside the reef. Dissolved organic nitrogen distributed in low concentration and relatively uniform, and occupied most of dissolved total nitrogen.

On plankton distribution, chlorophyll was measured as indicator of phytoplankton. Remarkable difference was observed between in and out of the reef. Chlorophyll concentrations of surface in the reef were 1/5 - 1/3 compared with outer reef. Consequently, it was suggested that phytoplankton biomass of the inner reef was extremely lower than the outer reef. As

for zooplankton distribution, their abundance in the reef surface was low similar to phytoplankton distribution. While high zooplankton abundance was observed around bottom layer in the reef, especially on broken coral area. Accordingly, it was guessed that predator-prey activity of plankton was high around the bottom layer in the reef.

The main purpose of benthos investigation was cover rate and coral formation. The research was conducted from the upper stream to the lower reaches in the reef. As a result, acroporidae was abundant on the upper stream. While, a lot of other corals were observed on the lower reaches.

This difference was suggested the effect of quick water exchange in this area.

An underwater microscope has been developed for *in situ* observation of corals. The underwater microscope was improved the digital microscope to use in hydrospace. The microscope is covered with acrylic cylinder case. The magnification of the microscope varies from 150 to 800 times. Images by the underwater microscope can be recorded as digital still pictures and animation using the controller on a boat. During the test with the underwater microscope, it was possible to conduct observations of corallities, septas, the tentacles of polyp and symbiosis alga in polyp.

3. Main Research and Development

1) Research for the Coastal Ecosystem Dynamics

This research project aims to contribute to the preservation of the ecosystem, which is in danger of breaking down due to human activity, and to continued utilization, by clarifying the mechanisms which are involved in changes in the coastal ecosystem.

There are a variety of coastal ecosystem types, but this research will focus on the coral reef ecosystem first. In recent years, the coral reef has been the ecosystem that is in most danger of breaking down. In order to clarify the mechanisms of change in the coral reef ecosystem, we selected the coral reef located on the central eastern coast of Ishigaki Island in

Okinawa as our survey area. The first phase of the research ran from FY 1995 to FY 1997, and we planned to collect actual measurements through field surveys, conduct modeling using the accumulated data and predict changes.

Although the coral reef ecosystem exists in a marine environment that is low in nutrients, it has high productivity and supports biodiversity. We carried out a preliminary study of the material cycle in order to find the response of the coral reef to problems in the coastal region and environmental change by drawing a relationship between the health of the coral reef ecosystem and the environment.

Between the end of September and October of 1997, we conducted surveys in the moat, on the reef slopes and outside the reef in which researchers from a variety of fields including biology, chemistry and physics participated. In addition to understanding the standing stock of biomass and dissolved material, we carried out a survey of environmental factors by studying water flow from outside the reef to the moat. A summary of the findings follows.

In the survey area, concentrations of nitrates, nitrites and phosphates were extremely low, and there was a relatively even distribution with no significant difference in concentration between the moat and outside the reef. There was also a relatively low level of ammonium salts, but levels outside the reef were clearly lower than those within the moat. There was a low level of dissolved nitrogen for seawater, and it was also relatively evenly distributed representing the majority of dissolved nitrogen.

There was a clear difference between the moat and outside the reef in terms of phytoplankton, zooplankton and benthos. The results of the phytoplankton survey showed that the concentration of chlorophyll on the surface of the reef slopes was three to five times that on the surface of the moat. There were also low concentrations of zooplankton and phytoplankton on the surface of the lagoon, but it was confirmed that communities of zooplankton were distributed at high concentrations at lower levels (particularly immediately above dead coral).

The benthos survey mainly looked at the forma-

tion of the coral from the up stream to down stream of the moat. The results clearly showed that while *Acropora* was dominant in the up stream, other types of coral were prevalent in the southern area.

In order to understand the system of water flow in the coral reef, we set up a current meter within the moat, on the reef crest and on the reef slopes and while taking point measurement during the observation period, we also carried out a Lagrangian current measurement using a floater. In the reef, a flow pattern predominates over tidal currents and winds. The flow enters from the north side of the reef crest and flows southwards through the moat, exiting through a water channel on the south side. We reproduced this flow pattern using numerical modeling and discovered that changes in the flow pattern are influenced by two water channels on either side of Tamatorizaki cape, adding further complexity to the flow pattern.

In the future, we will carry out an ongoing integrated study in order to understand the material cycle within the survey area at the same time as researching and developing an ecosystem model that clarifies its mechanism.

2) R&D on Wave Power Device "Mighty Whale"

Ocean wave energy is a natural, renewable, and clean energy source well suited for utilization in coastal areas.

Since 1987, JAMSTEC has carried out research and development on an offshore, floating wave power device named "Mighty Whale". This device not only will enable efficient conversion of wave energy, but also generate a relatively calm water surface behind it. Therefore, the space behind the device could readily be used for fish cultivation and other similar purposes.

Earlier work on this project provided a basic understanding of device operation, enabled design of es-



Fig. 1 Launching of completed prototype (98/03/24)

sential safety features, and clarified the device's economic performance. This was achieved by theoretical studies and analysis, followed by experiments on scale models in laboratory wave tanks. Based on this research, a detailed design for the "Mighty Whale" open sea prototype was completed in December 1996. Construction began in January 1997. The completed steel hull was launched on March 24, 1998 (Fig. 1). The next stage is installation of the Measurement and Control system with the prototype floating in the Outfit dock. Following that, the prototype will be towed to Gokasho Bay, Nansei Town, Watarai District, Mie Prefecture. Open sea tests will be carried out from mid-July, 1998 through March 2000.

The main features of the prototype are as follows:

① Hull Construction

- Dimensions : Length 50 m, Breadth 30 m, Depth 12 m, Draft 8m
- Air Chambers : 3 chambers each 8 m wide and 10 m deep
- Displacement : 4,400 tons
- Light weight : 1,260 tons

② Air turbines, Generators, and Compressor (Fig. 2)



Fig. 2 Air turbine + generator system

- Air turbines : Wells tandem rotor type, 3 units
Diameter : 1.7 m
Material : Aluminum alloy
Blade section : NACA 0021
- Generators: Induction generators, 3 units
Rated output : (50 kW + 10 kW) × 1 (with electri

cal change-over) 30 kW × 2

Cooling : Force air cooled

RPM : 500 - 1800 RPM

Output voltage : 200 V AC, 3 phase

- Air compressor : 3 phase AC 200 V

Type : Air cooled oil-less

Rated output : 7.5 kW

Rated pressure : 7 kgf/m²

③ Mooring System

The mooring system consists of 6 slack lines with intermediate weights and sinkers (Fig. 3 and 4).

Mooring chain safety factor: 2.0

Sinker safety factor: 1.2



Fig. 3 Mooring chain link

4. Research and Development on Underwater Technology

1) Research of diving and hyperbaric medicine

Two simulated saturation diversions using nitrogen and oxygen mixed gas (Nitrox) were conducted in July-August and November with eight divers. The maximum pressure was 30 meter of sea-water equivalent depth (4 ATA N₂-O₂). The purpose of this research was to confirm of the safety shallow saturation diving for scientist and researchers. The measurements of these experimental diving were as followed, the autonomic nervous functions, confirmation of the safety of new liner decompression technique which does not use pure oxygen breathing, decompression

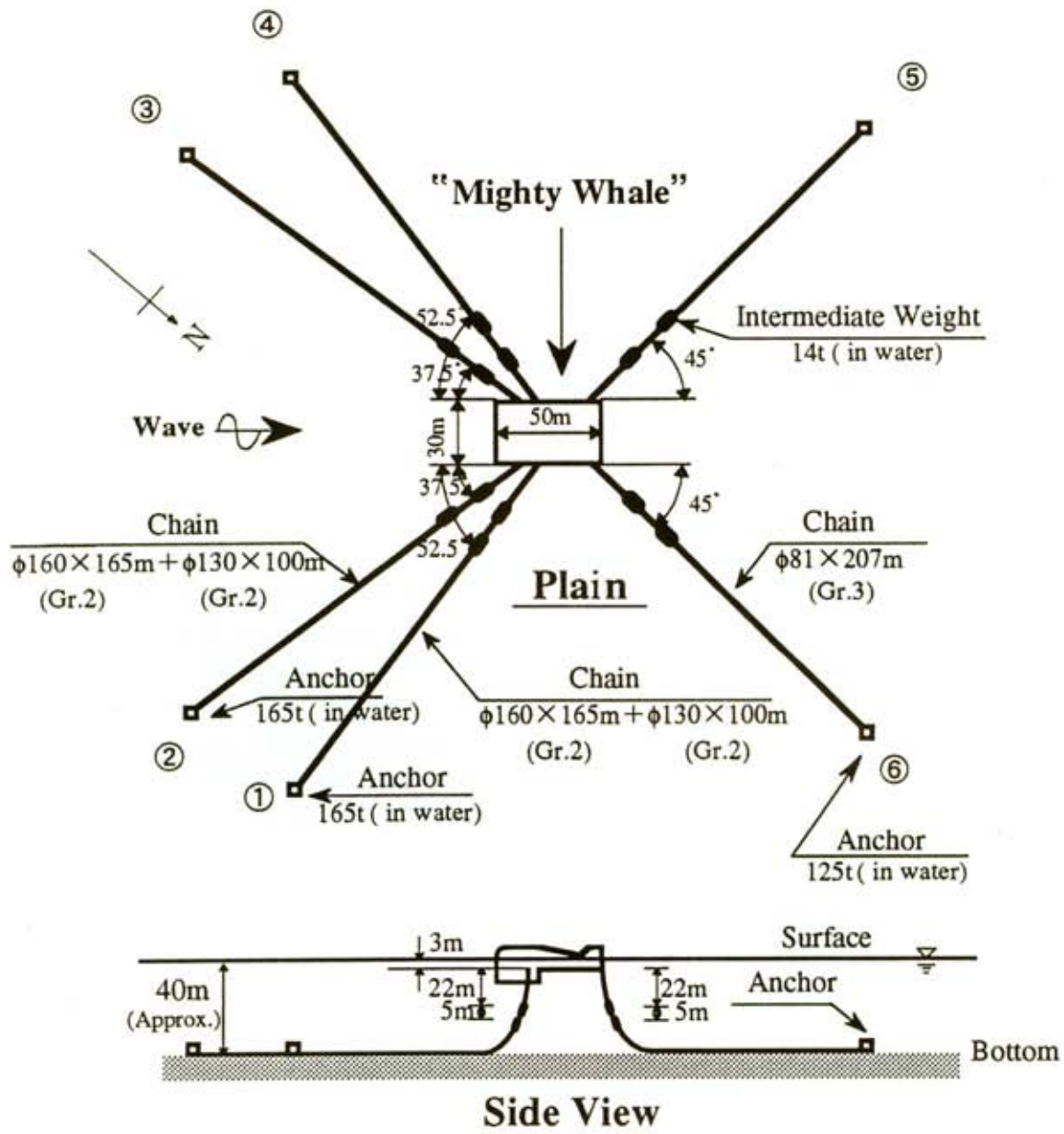


Fig.4 Scheme of the Mooring System

fatigue and hyperbaric diuresis phenomenon, work capacity and stress investigation on physical and psychological functions, communication problem of voice under hyperbaric and high density gas environments, monitoring system of electric research apparatus in hyperbaric living chamber for their safety utilization.

The results in two saturation diving experiments indicated that 30 meter equivalent depth hyperbaric environment had no important effects on the physiological and psychological functions, the equilibrium function slightly decreased. Also the new decompression procedure was safe and comfortable for the



Photo 1 Measurement of the autonomic nervous function during simulated saturation dive (Electrocardiogram, Forearm blood flow and Blood pressure)

divers. Also the insensible water loss from the skin was depressed at hyperbaric environment, and this would be an important factor of hyperbaric diuresis, the pronunciation of diver became ambiguous at 30 m depth, we could confirm the useful monitoring system for safe use of electric apparatus in underwater laboratory.

In the research on tolerance and decompression sickness, osteonecrosis research which would become continuously a problem as a chronic decompression sickness in last year was studied with beagles. We established the cultivation method of bone cells for researching the hyperbaric effects on bone cell activity. And we investigated the relation between physical work level and the decompression, the possibility of hyperbaric oxygen treatment for cancer cells.

In the research on the health care of divers, the physiological and medical examination on 10 divers who participated to the saturation dive experiments was carried out. The image data of the MRI and X-ray were input into the new database that would be connected to the Net.

In the research of prediction and prevention of decompression sickness, not only conventional doppler method that be able to count the number of decompression bubble, but also it will be necessary to develop the new bubble volume detector with visual

sensor utilizable under hyperbaric conditions.

2) Research and development of fundamental diving technology

This research has the purpose of efficiency improvement and safety improvement for the research diving, and was divided roughly into following 3 items.

In the research on the safety of the research diving, undersea breathing and decompression was focused and carried out in order to make the research diving manual. As for the undersea breathing, it succeeded in the development of the equipment that can measure and can record actual undersea breathing condition of the research divers, which was uncertain until now. It is expected that the data obtained here greatly contributes to the safety of the undersea respiration. As regard to the decompression, new decompression table for the research diving was developed. The new table was confirmed both to be safe and convenient for use through the demonstrated experiment using the diving simulator. According to this new decompression table, it is also verified that the conventional decompression time can be approximately halved. It is greatly expected that this result may contribute to the efficiency and safety improvement of the research diving. In the meantime, the scientific diving workshops were held twice, and international standardization of the manual, etc. was examined, when the essential constitution of the scientific diving manual was discussed.

The research of the environmental control technology has the purpose to develop the full-automatic carbon dioxide eliminator for hyperbaric use. This system was assumed to be introduced into the saturation diving for the research diving (nitrox saturation diving). This fiscal year, the diving simulator was equipped with this equipment developed over FY 1994 - 1996, and the preparation of the service test was arranged. If long-time running is verified, the safer, cheaper, and easier operation of the saturation diving will be realized.

The research of the undersea and hyperbaric respiration monitoring technique is aimed to clarify the features of the human respiration at hyperbaric and

underwater environment, and is expected to contribute to the improvement of the environmental control technology, and evaluation of the underwater breathing apparatus. In FY 1997, the experiment to grasp the quantitative change of gas supply ability accompanied with the change of operating depth and the respiratory pattern was started for 4 kinds of underwater breathing apparatus. By this test, the basic data for the comparative evaluation between the underwater breathing apparatuses was obtained. Treating the present result with the actual respiration data obtained in safety study of the research diving, the contribution to safer and easier underwater respiration is expected.



Photo 2 The equipment that measures and records the actual respiratory condition of the research diver (It can be seen on the air cylinder on the diver's back.)

5. Development of the offshore undersea space utilization expansion technology by applying a submersible platform

This study was started as region cooperative research with Iwate Prefecture from FY 1994. The last goal of this study is to develop submersible platform that can be deployed in the sea area to the 100 m water depth that receives the ocean wave. The experimental platform "Ohchan Marine No.1" was installed at 40 m depth area of Funakoshi Bay in Feb-

ruary, 1996, in order to acquire various actual data for designing the practical facility.

The following experiments and researches were carried out in FY 1996.

1) Abalone cultivation test

Possibility of abalone cultivation at offshore which receive the ocean wave in two sizes of one, cultivation of juvenile abalone and adult one.

2) Underwater non-destructive inspection

Platform, cathodic protection system, mooring line and water ballasting systems were inspected annually by applying precise inspection from scientific point of view to obtain the accurate data on degradation. Especially at the sea bottom attachment part of chains where engineering data was most insufficient within the mooring line, the aging degradation was measured in detail using vernier caliper.

3) Development inspection ROV of mooring chain

Purpose built compact inspection ROV was developed for survey mooring chains and anchors. The ROV equipped with two cleaning brushes, color TV for access and TV camera for close up inspection.

4) Examination of underwater repair procedure

To verify the field repair operation procedure of the platform, underwater welding and chain repair procedure were demonstrated successfully.

6. Using the Coastal Fisheries Monitoring System

This research uses the underwater elevator system developed during Phase I (from FY 1994 to FY 1996) of a joint research project with Miyagi Prefecture to carry out continuous monitoring of the vertical distribution of the coastal fisheries environment, in addition to performing a survey of biomass such as oyster larvae with the aim of clarifying the distribution, settlement and concentration mechanism of larvae in Sendai Bay as Phase II of the joint research project with Miyagi Prefecture (from FY 1997 to FY

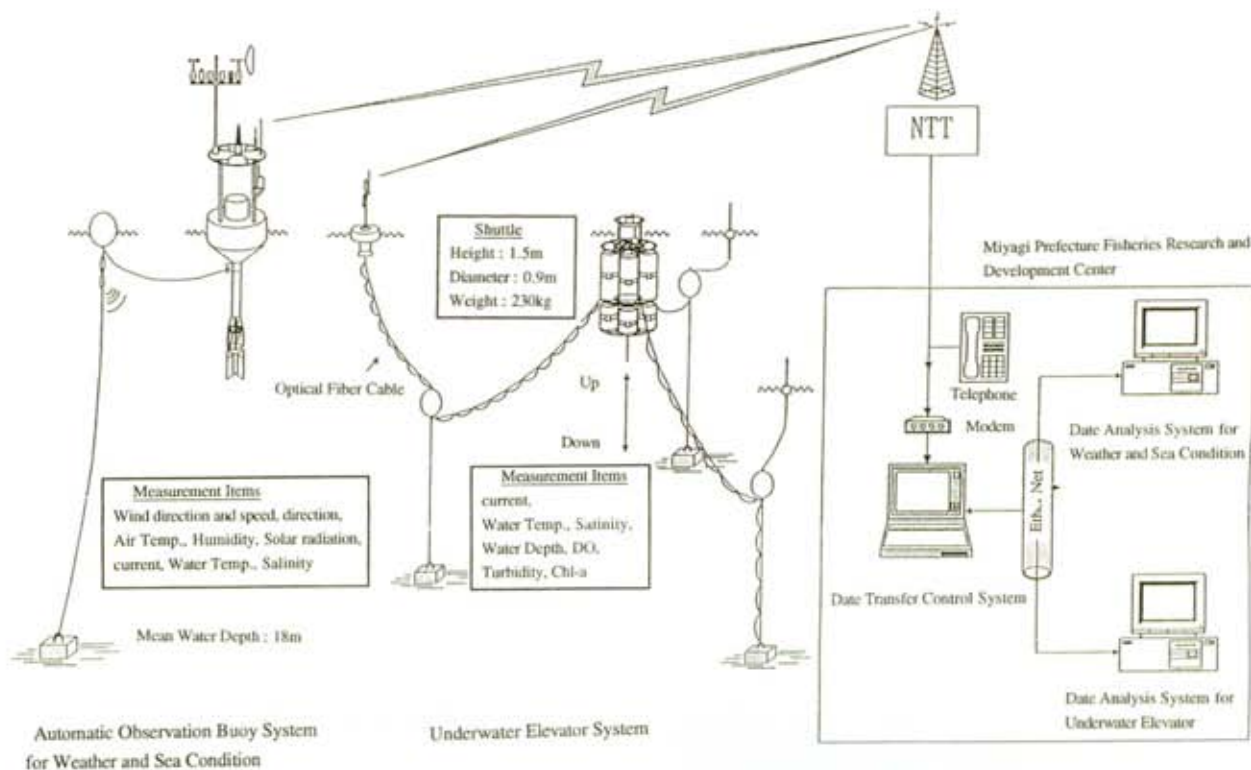


Fig. 5 Coastal monitoring used underwater elevator system

1998).

The implementation of the project for FY 1997 is as follows.

1) The Vertical Distribution of the Marine Environment (refer to Fig.5)

We carried out a survey of the vertical distribution of the marine environment using the underwater elevator system from the completion of the system until September 9, 1997. We measured of current direction and speed, water temperature, salinity, dissolved oxygen, turbidity and chlorophyll at hourly intervals.

2) Observation of Weather and Sea Conditions (refer to Fig. 5)

We carried out continuous measurements of wind direction and speed, buoy direction, air temperature, humidity and sunlight as well as current direction and speed, water temperature and salinity at a depth

of two meters below the surface using the automatic observation buoy for weather and sea conditions.

3) CTD Measurements Using the Mini-Underwater Elevator

We set up the mini-underwater elevator in an area of sea established as a survey point for floating oyster larvae and measured the vertical distribution of water temperature and salinity.

4) Survey of Water Flow Distribution Using ADCP

In order to clarify the mechanism of floating seed oyster larvae concentration in the eastern part of Ishinomaki Bay, we carried out a observation of water flow distribution once every two weeks using ADCP. The survey was carried out using the Miyagi Prefecture Fisheries Research and Development Center's survey vessel "Kaiyo".

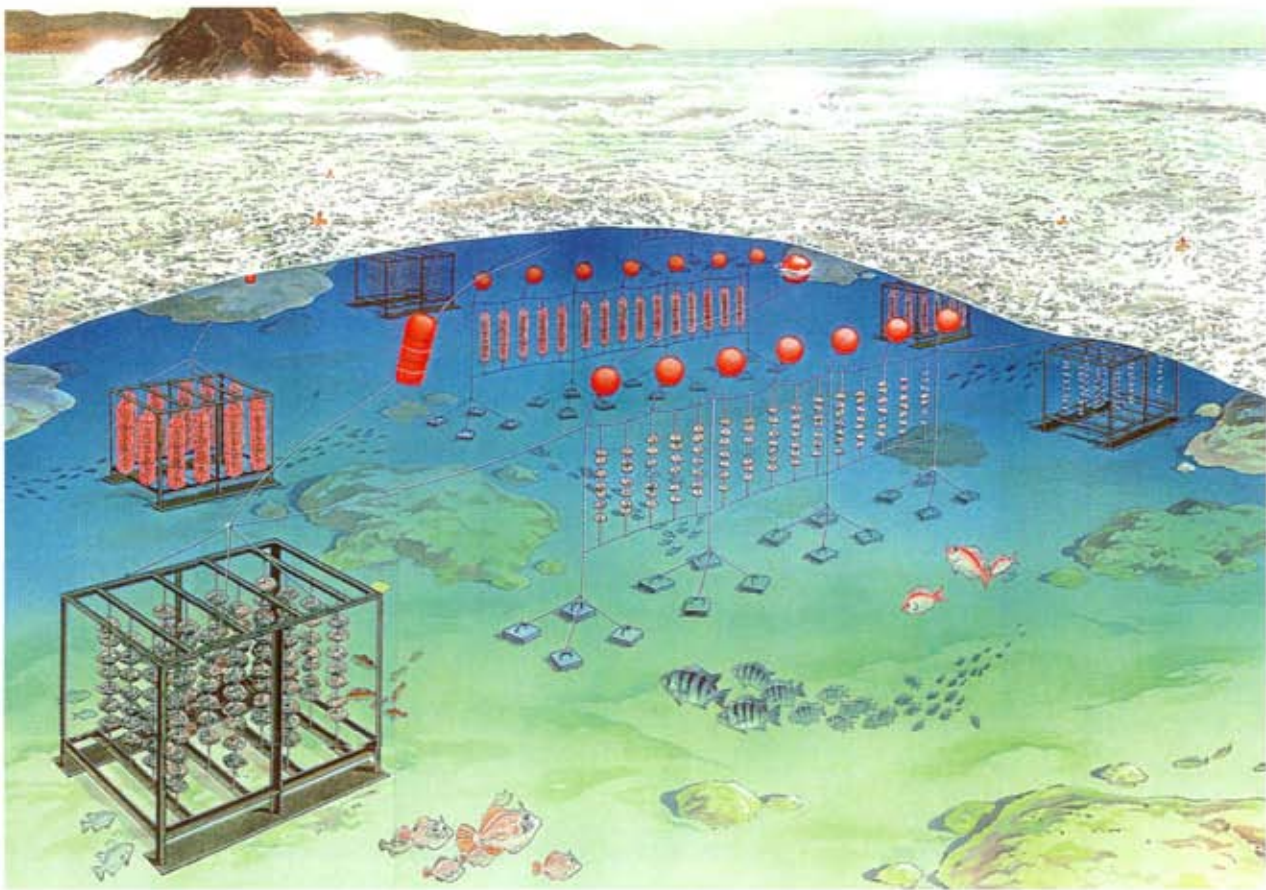


Fig. 6 Mariculture system

5) Survey of Floating Oyster Larvae Distribution

In order to understand the distribution of seed oysters in Ishinomaki bay, the Miyagi Prefecture Fisheries Research and Development Center carried out a survey of horizontal distribution at 11 points in Ishinomaki Bay once a week while also surveying the distribution of floating larvae by depth at the site of the underwater elevator.

6) Survey of Floating Oyster Larvae Behavior

In order to clarify the distribution and concentrations of floating oyster larvae and to relate it to the environment of the coastal fisheries, we analyzed water taken at three meter intervals from the surface to the seabed from sunrise until after sunset at three sites focusing on the site of the underwater elevator. We took water a total of five times at two week intervals.

7. Research and Development on a Mariculture System Set Up on the Sea Bottom

JAMSTEC carried out this research in cooperation with Yamagata Prefecture as a three-year regional joint project from FY 1995 to FY 1997. Due to stormy weather in the winter, fishermen cannot take advantage of coastal regions on the Japan Sea side (e.g. Yamagata Prefecture). Our aim was to enable use of the sea bottom, where it is relatively calm even during stormy weather. Therefore, we developed a new mariculture system that is installed on the sea bottom. As our prototype target, we chose a special kind of oyster known as Iwagaki, which is a highly valued product of the Japan Sea coastal area and is also available in summer. We developed devices to enable cultivation of Iwagaki on the sea bottom and investigated ways to operate these devices safely and eco-

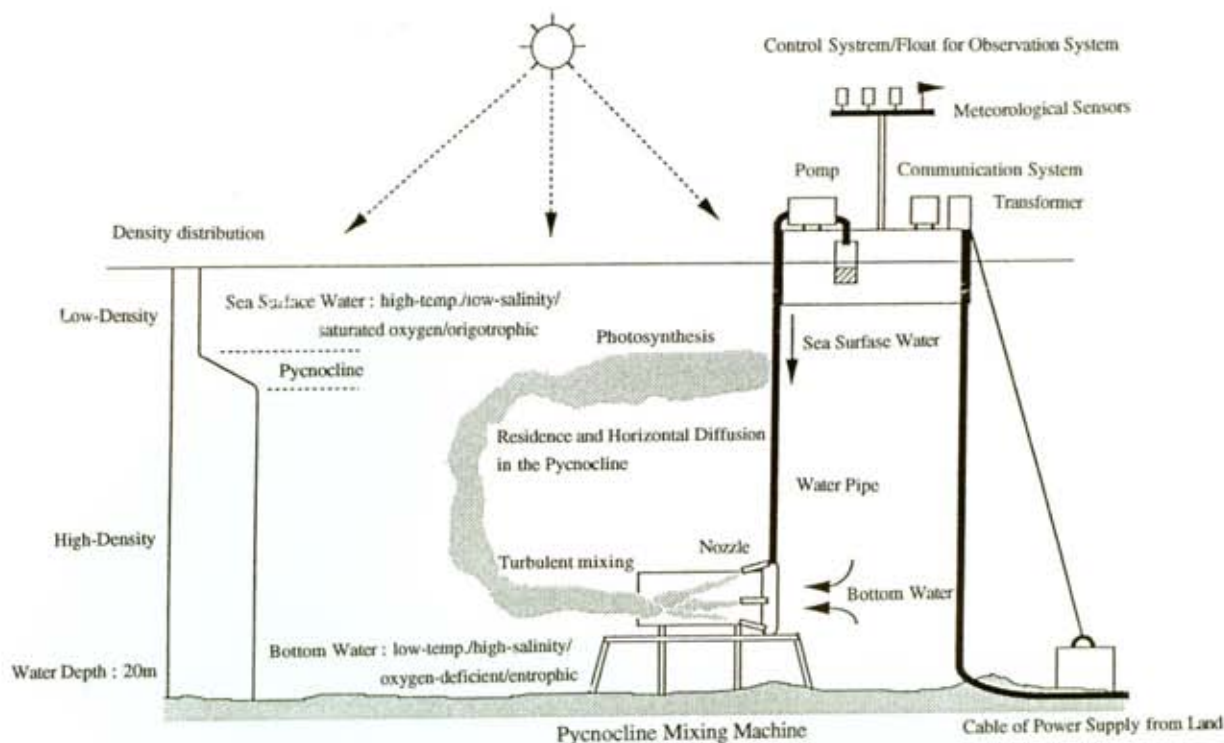


Fig. 7 Scenario of the purification of water quality for Ohmura Bay

nominally.

In FY 1997 we carried out the following research and development.

1) Design and construction of bottom-mounted mariculture devices

We studied device designs which could cultivate oysters reliably even in turbulent conditions of the stormy winter weather. Then we developed a network of marking buoys and rope lines, with the lines connected with the mariculture devices (Fig. 6). We used the lines to fix device positions on the sea bottom and to retrieve the devices. We tested the system offshore off Yura in Yamagata Prefecture at locations where the water depth was 40, 30, and 20 m.

We researched the effect of sea environmental conditions on oyster growth. We measured water temperature, salinity, and chlorophyll distribution with bottle sampling of sea water.

2) R & D on the technology for oyster breeding

We investigated the relation between the initial density of larvae and their survival rate, which would affect the results of oyster seed production.

We studied the conditions needed for promoting the maturity of oysters as broodstock, which would help artificial seed production.

3) Open Sea Tests

We measured the physical (wave height, current velocity) and biological (water temperature, salinity, chlorophyll distribution, dissolved oxygen) parameters on the sea bottom. Based on this information, we investigated the growth rate for oyster larvae on the sea bottom.

4) Conclusion

We compiled and analyzed three years worth of experimental observations and data, and drew conclusions regarding the developed system.

8. Research and Development of Technology to Control the Generation of Oxygen-deficient Water Mass in Ohmura Bay

This research is part of a joint project with Nagasaki Prefecture, which began in FY 1997, and aims to clarify the mechanism by which oxygen-deficient water masses occur in Ohmura Bay, as well as researching and developing technology to control these, and laying the foundations of a clean up strategy for Ohmura Bay. It is expected that technology that forces water immediately above the seabed to rise to the middle to prevent the settling of anoxic water immediately above the seabed, and that mixes it with the well oxygenated surrounding water by means of a revolving current, will be beneficial (refer to Fig. 7).

FY 1997 is the first year of a three year plan, and in addition to carrying out a survey into the current environmental condition of Ohmura Bay and preliminary fixed point surveys, we designed a flow/mixing system. The details follow below.

1) Survey of the Current Environmental Condition of Ohmura Bay

① Research of fertilization

- We surveyed the existing data for the cities and towns in the basin such as national surveys and agricultural statistics and investigated the possibility of using it for an inflow load assessment.
- We framed a plan for carrying out the survey, including the classification of pollution sources, determining the method of making a load assessment and dividing the basin.
- We carried out actual surveys including collection and organization of existing data, a primary unit survey and a survey of major sources of pollution.

② Research into oxygen-deficient water occurrence

- In order to clarify the oxygen consumption mechanism of accumulated sediment on the seabed, we carried out a preliminary survey of the nature of the seabed and floating sediment.

- We surveyed the behavior of the oxygen-deficient water masses in Ohmura Bay.
- Using a sediment trap, we surveyed the volume of sediment in each season.
- We commissioned the Department of Fisheries at Nagasaki University to carry out research into the oxygen consumption mechanism of the accumulated sediment on the seabed.

③ Fixed point monitoring

- We carried out a preliminary survey to select a site to set up the flow/mixing system device.
- We produced a monitoring instrument to measure the vertical distribution of environmental conditions.
- We developed a systematic water-sampling device that can automatically sample water at regular intervals.

2) Research and Development of a Flow/Mixing System

- We performed a water tank experiment using a model of a flow/mixing system device and planned an experimental instrument for use in the sea in addition to investigating the optimum combination for the levels of flow and mixing.
- We commissioned the Nagasaki Institute of Applied Science to carry out the model water tank experiment under the proviso that the device should contain a system which does not cause excessive disturbance to the sediment on the seabed.

3) Water Pollution Modeling

- We worked on the research and development of a three-dimensional physical ecosystem model.
- We created a model of liquid volume from sea water exchange at the bay mouth, sediment volume and the nature of the seabed.
- We commissioned the Department of Fisheries at Nagasaki University to carry out research into modeling the process of the resolution of organic matter.

Deep-sea Environment Exploration Program

1. Course of Action for Developmental Studies

Deep-sea Environment Exploration Program (DEEP), a 15-year program JAMSTEC has launched in 1990, aims at unveiling new phenomena discovered in the deep sea. This project, being carried out 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 survive under extreme conditions such as low temperature, high temperature, high pressure, or in high concentration of inorganic compounds. They have never experienced solar energy, and they have to metabolize compounds not coming from sunlight. It is distinctly possible that truly ancient life-forms might be hibernating in the world's largest refrigerator. On the other hand, 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 been conducting research mainly on the following topics.

2. Major Research and Development

1) Study on culture and morphology

① Taxonomic studies of deep-sea barophilic bacteria that have been isolated in our laboratory

Numerous barophilic and barotolerant bacteria have since been isolated and characterized by this DEEPSTAR group, from deep sea sediments at depths ranging from 2,500 - 11,000m obtained by the sterilized mud samplers from the submersibles "Shinkai

6500" and "Kaiko". Most of the isolated strains are not only barophilic or barotolerant, but also are psychrophilic and cannot be cultured at temperatures above 20°C. These isolates were closely related to the genus *Shewanella* and *Moritella* based on 16S ribosomal RNA gene sequence comparisons, as shown in Fig. 1. From the results of taxonomic analyses, we have identified several novel species from our barophiles collection, 1 novel species was identified from the genus *Shewanella*, and two novel species were identified from the genus *Moritella*. We have been now preparing reports about these new species.

② Taxonomic studies of deep sea yeast

We had isolated 134 deep sea yeast strains including the 35 newly isolated forms of yeast from sediments collected in Suruga Bay, and preserved all isolates in liquid nitrogen after purification. Relatedness among depths, localities and rates of the basidiomycetous yeasts (or the ascomycetous yeasts) was observed about the deep-sea yeast isolates. 92 strains in 134 strains were identified as each species from the morphological, biophysical and biochemical characteristics. Among these strains, 11 strains were considered as new species of the genus *Kluyveromyces* characterized having evanescent asci and Q-6 as major ubiquinone. The tree based on small subunit (18S) rRNA gene sequences placed the isolates into a cluster of *Kluyveromyces*. The sequences of 18S, 5.8S and ITS region of rRNA determined in the *Kluyveromyces* isolates were completely identical. DNA complementarity among the isolates and five related species of *Kluyveromyces* confirmed eleven isolates to be a new species of *Kluyveromyces*. We will describe the isolates as *Kluyveromyces nonfermentati* sp. nov., which lacks the fermentation ability as an important criterion for the genus *Kluyveromyces*.

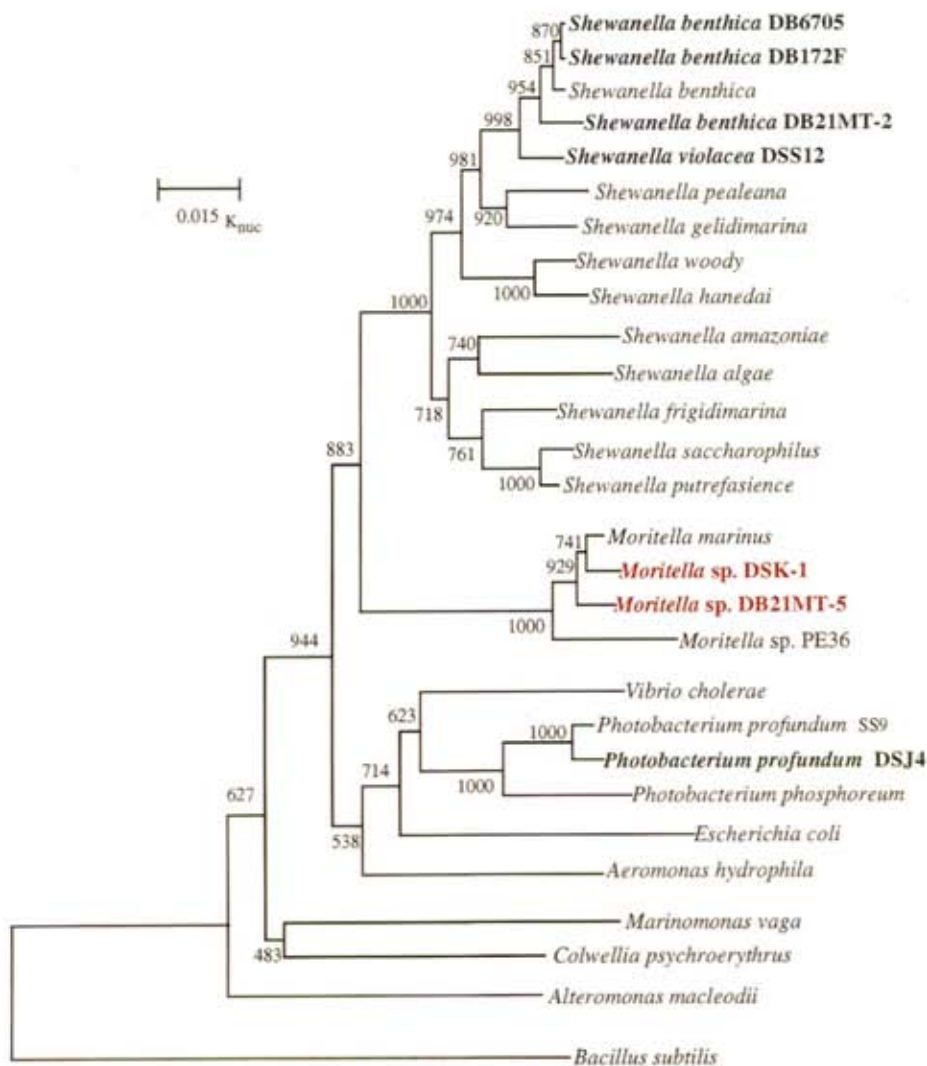


Fig. 1 Phylogenetic tree showing the bacterial relationships based on 16S rDNA sequences. The scale represents the average number of nucleotide substitutions per site

③ Preservation of deep sea microorganisms and samples

About 3,000 isolated deep-sea microorganisms have been stored in liquid nitrogen tanks. Deep sea sediment samples and animal samples have been also stored in the liquid nitrogen tanks, and newly 28 sediments and 4 animal samples were added in this year. We have opened this information on-line in the JAMSTEC computer network.

2) Study on genes and proteins

① Isolation of novel barophilic bacteria and studies

on microbiological diversity in deep-sea environment

(a) Analysis of changing microbial communities under pressure using DEEP-BATH system

A sample of deep sea sediment was obtained from the Japan Trench at a depth of 6,292 m using a pressure-retaining sediment sampler. Microorganisms in the sediment sample were cultivated in marine broth 2216 at ambient pressure (65 MPa) without decompression, and at atmospheric pressure (0.1 MPa) as a control experiment. 16S ribosomal RNA genes (rDNA) were amplified by PCR from DNA extracted

from the original sediment sample and the mixed cultures, and the nucleotide sequences were determined. The results of phylogenetic analysis based on 16S rDNA sequences indicated that: I) microbial diversity in the original sediment samples showed a wide distribution of types in the domain bacteria, whereas II) in the mixed cultures incubated at 65 MPa without decompression, bacterial strains belonging to the *Shewanella* barophiles branch and the genus *Moritella* existed together at the beginning of cultivation, and *Moritella* strains became dominant towards the end of the cultivation period, and III) in the mixed cultures incubated at atmospheric pressure, strains belonging to the genus *Pseudomonas* were dominant at all times. Analysis of fatty acids extracted from the cultures supported the phylogenetic results. In fact, we could isolate bacteria belonging to the genus *Shewanella* and *Moritella* under high pressure condition and the genus *Pseudomonas* at atmospheric pressure condition.

(b) Relations between host species and endosymbiotic bacteria in deep-sea clams

We extracted DNA from homogenized gill tissues from *Calyptogena* specimens collected from deep sea cold seeps (Sagami Bay, Nankai Trough, and Japan Trench land side slope) and hydrothermal vents (Okinawa Trough). Extracted DNA was amplified by PCR using specific primers for small-subunit ribosomal RNA genes (*ssr*). The libraries were constructed in *Escherichia coli*, and several different clones were selected by RFLP-PAGE analysis. Cloned *ssr* sequences were determined, and a phylogenetic analysis was carried out. The results suggested that bacterial symbiont species from hydrothermal vent *Calyptogena* were similar, however the species from cold seep host were distributed at least to two branches. Our results also suggested that the host species determined by their mitochondrial DNA sequence may not concern the bacterial symbiont species, and they may be more related to environmental conditions.

② Studies of high-pressure adaptation mechanisms in deep-sea bacteria

(a) Analysis of the respiratory proteins in barophilic

bacteria

We have analyzed the pressure-regulated operon from the deep sea barophilic isolates, and found the terminal oxidases of the bacterial respiratory system would have very important role for pressure adaptation. So as to characterize the function of the respiratory proteins, we have purified such proteins as shown in Table 1. This table showing the results of specific induction of respiratory chain components in response to the high pressure conditions. In case of an obligately barophile, strain DB 172F, a terminal quinol oxidase enzyme was found to be specifically synthesized under a high pressure condition, and consists of 2 heme *c* and 1 heme *b*. Moreover, two *c*-type cytochromes were also analyzed. Cytochrome *C₅₅₁* was expressed at high levels at high pressure, whereas, cytochrome *C₅₅₂* was synthesized only at atmospheric pressure. Although, the subunit structure and isoelectric values were quite similar. In case of a moderately barophilic strain DSS12, cytochrome *C₅* was found to be overexpressed under high pressure conditions. Generally, these data suggest that, barophilic bacteria has ability to regulate its respiratory chain components in response to the external growth pressure.

Table 1 Properties of respiratory proteins purified from barophilic strains (ND; not determined)

Strain	Protein	Expression		M.W. pI		sub-units	Heme/mol
		0.1 MPa	High pressure	(kDa)			
DB172F	Quinol oxidase	-	+	197.5	5.0	4	2 heme <i>c</i> 1 heme <i>b</i>
	Cytochrome <i>c₅₅₁</i>	+	++	43.8	4.8	2	2 heme <i>c</i>
	Cytochrome <i>c₅₅₂</i>	+	-	31.6	4.3	2	1 heme <i>c</i>
DSS12	Cytochrome <i>c₅</i>	+	+	8.3	ND	-	1 heme <i>c</i>
	Cytochrome <i>c₅</i>	+	±	23.0	ND	-	2 heme <i>c</i>

(b) Analysis of cold-shock protein in barophilic bacterium

We have cloned and sequenced a cold-shock-inducible gene from the psychrophilic and moderately barophilic bacterium, *Shewanella* sp. strain DSS12 by a PCR-based approach using a pair of degenerate prim-

ers with sequences corresponding to a highly conserved region within CspA-related proteins. The cloned gene, designated *cspA*, encodes a 70-residue amino acids which possesses 62% sequence identity with *Escherichia coli* CspA. Following a temperature downshift, the level of the *cspA* mRNA transcript increased, as shown by Northern analysis. It indicates that *cspA* gene expression is regulated by temperature on transcription level. Since CspA functions as a RNA chaperone in *E. coli*, we will characterize DSS12 CspA as a RNA chaperone under the deep-sea environment, that is low temperature and high hydrostatic pressure condition.

(c) Genomic analysis of barophilic bacteria

A new class of sequence-specific endonucleases was recently discovered. These "homing endonucleases" are classified as enzymes whose catalytic activities result in self-propagation. Homing endonucleases have potential in their analysis of large genomes, because their unique recognition sequences are usually composed of 12-40 nucleotides far more than those recognized by type II restriction enzymes. The I-CeuI homing endonuclease is encoded by the fifth intron in the chloroplast large subunit rRNA gene of the green alga *Clamydomonas eugametos*, introduces a double strand break in a 26 base pair sequence present near the insertion site of the intron in cognate intronless allele. The genomes of enteric bacteria like *Escherichia coli* K12 and *Salmonella typhimurium* are cut by I-CeuI at seven sites corresponding to all *rrn* operons. No other sites have been cut. Since rRNA-determining genes are very highly conserved, I-CeuI would be expected to cleave the DNA of a wide range of bacteria in the rRNA genes. We used the I-CeuI homing endonuclease for genome analysis of several deep-sea adapted bacteria ranging from obligatory barophilic to barotolerant strains isolated in our laboratory. Preliminary results show that deep sea isolates are cut by I-CeuI in at least 10-12 sites, which may correspond to 10-12 *rrn* operons.

③ Study of the microorganisms living at hydrothermal vents

We have isolated a novel hyperthermophilic archaeon from the hot water sample of hydrothermal

vent obtained at Okinawa Trough, and submitted a name, *Thermococcus siculi* sp. nov. *T. siculi* is able to grow optimally at 85°C, and produce several thermophilic enzymes.

3) Study on the metabolism and physiological properties

① Genomic analysis of alkaliphilic *Bacillus* sp. strain C-125

The most concentrated and widespread occurrences of organisms are generally in so-called "moderate" environments with approximately neutral pH, temperatures around 20-37°C, pressures near 0.1 MPa, and adequate concentrations of nutrients and saline. In contrast, the deep sea is an extreme environment with especially high hydrostatic pressure and low temperature. Microorganisms living there presumably have developed particular characteristics that allow them to thrive in such an environment. How these organisms are adapted to living in extreme environments is one of the most interesting and challenging questions facing microbiologists today. Our group has a specific interest in especially alkaliphilic bacteria which have been isolated even from Mariana Trench and has been using a genome analysis approach to elucidate how these organisms are adapted to living at high pH. Recently a physical map of the chromosome of alkaliphilic *Bacillus* sp. strain C-125 was constructed to facilitate further genome analysis and the genome size was revised from 3.7Mb to 4.25Mb. However, the nucleotide sequences of three independent fragments (designated as No. 3, 4, and 9; each 15 - 20 kb in size) of the genome of alkaliphilic *Bacillus* sp. C-125 cloned in a λ phage vector have been determined. All identified ORFs in three clones were analyzed and it was found that the organization of ORFs in the genome of strain C-125 was found to differ from the order of genes in the chromosome of *B. subtilis*, although some gene clusters were conserved as operon units the same as in *B. subtilis*. We are proceeding with genome sequencing of the strain C-125 to complete whole genome analysis. We are simultaneously attempting to make best sequencing method to accelerate the analysis of small size bacte-

rial genome.

② Studies on the adaptation mechanisms to extreme-environment in microorganisms

(a) Physiological analysis of the effect of hydrostatic pressure in microorganisms

–A study in Baro-(Piezo-) physiology–

In the yeast *Saccharomyces cerevisiae*, the vacuole is a large acidic organelle involved in the degradation of cellular proteins or storage of ions and various metabolites. Vacuolar pH, as determined using the pH-sensitive fluorescent dye 6-carboxyfluorescein, was analyzed in a hydrostatic chamber with transparent windows under elevated hydrostatic pressure conditions. A pressure of 40-60 MPa transiently reduced the vacuolar pH by about 0.33. The vacuolar acidification was observed only in the presence of fermentable sugars, and never observed in the presence of ethanol, glycerol or 3-*o*-methyl-glucose as the carbon source. Analysis of a glycolysis-defective mutant suggested that glycolysis or CO₂ production is involved in the pressure-induced acidification. Hydration and ionization of CO₂ is facilitated by elevated hydrostatic pressure because a negative volume change accompanies the chemical reaction (CO₂ + H₂O → H⁺ + HCO₃⁻, ΔV < 0). Moreover, the glucose-induced cytoplasmic alkalization is inhibited by elevated hydrostatic pressure probably due to inhibition of the plasma membrane H⁺-ATPase. Therefore, the cytoplasm tends to become acidic under elevated hydrostatic pressure conditions, and this could be crucial for cell survival. To maintain a favorable cytoplasmic pH, the yeast vacuoles may serve as proton sequestrants under hydrostatic pressure. We are investigating the physiological effects of hydrostatic pressure in the course of research in a new experimental field, Baro- (Piezo-) physiology.

(b) Physiological response to organic solvent in microorganisms

Organic solvents (OSs)-tolerant microorganisms have been proved to be obviously a characteristic group in deep-sea environment. OSs-tolerant micro-

organisms can grow in the presence of OSs which usually show broad-cytotoxicity. The mechanisms for OSs-tolerance will have interesting potentials to contribute both for cell microbiology and its application. To elucidate OSs-mechanisms we used toluene-tolerant bacteria, toluene-sensitive derivatives and toluene-tolerant mutants from toluene-sensitive bacteria, and several genes possibly responsible for toluene-tolerance were cloned.

(c) Elucidation of protective function for deep-sea multicellular organisms

All of organisms have protective function against micro- and macro-environmental alteration. The deep sea multicellular organisms might have the specific protective function because of the deep sea environment is high pressure and differ from land. However, study of the protective function for deep-sea multicellular organisms has been hampered by the lack of established tissue culture method. At the present stage, we examine a novel tissue culture method for the deep sea multicellular organisms.

(d) Study on the utilization of deep-sea microorganisms

We have succeeded in isolation of G4-amylase producing strain MS300 from Challenger Deep of Mariana Trench. MS300's G4-amylase was purified and investigated its property. This G4-amylase has higher metal resistance than the G4-amylase produced by microorganisms isolated from ground and its optimum pH for reaction was also different from those. Production of enzyme by MS300 was the most under 20 MPa and detected even under 100 MPa. This data suggested that strain MS300 would be active at the bottom of the Challenger Deep of Mariana Trench (depth: about 11,000 m). We are suppose to study the enzymatic reaction of this enzyme under high hydrostatic pressure after the completion of the systems for high hydrostatic pressure reactor. Now, we are searching novel enzyme producer from deep-sea soil.

Frontier Research Program for Subduction Dynamics

1. Introduction

1) Research development policy

Research has been carried out since October 1996 under the auspices of the Frontier Research Program on Earthquakes, which comprises the following members:

- a) Japan Marine Science and Technology Center
Frontier Research Program for Subduction Dynamics
- b) Power Reactor and Nuclear Fuel Development Corporation
Earthquake Frontier Research for Terrestrial Subsurface
- c) Institute of Physical and Chemical Research
International Frontier Project on Earthquake Research
Earthquake Disaster Mitigation Research Frontier
- d) National Space Development Agency of Japan
Earthquake Remote Sensing Frontier Research
- e) Japan Atomic Energy Research Institute
Seismic Safety and Disaster Mitigation Frontier Research

Impetus was given to research directed at understanding and mitigating the effects of earthquakes following the 1995 southern Hyogo-ken ("Kobe") earthquake. One point of this research has been 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 research is to utilize JAMSTEC's expertise so as to understand by way of long-term modeling the seismogenic mechanism 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, measure, prove, interpret and model quantitatively the subsurface structure and physical conditions of the seismogenic environment. A database containing the results of geologic investigations and research results is helping with this process.

Frontier is carrying out marine geophysical surveys in tandem with JAMSTEC's Deep Sea Research Section 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 used 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 earthquake activity are being monitored.

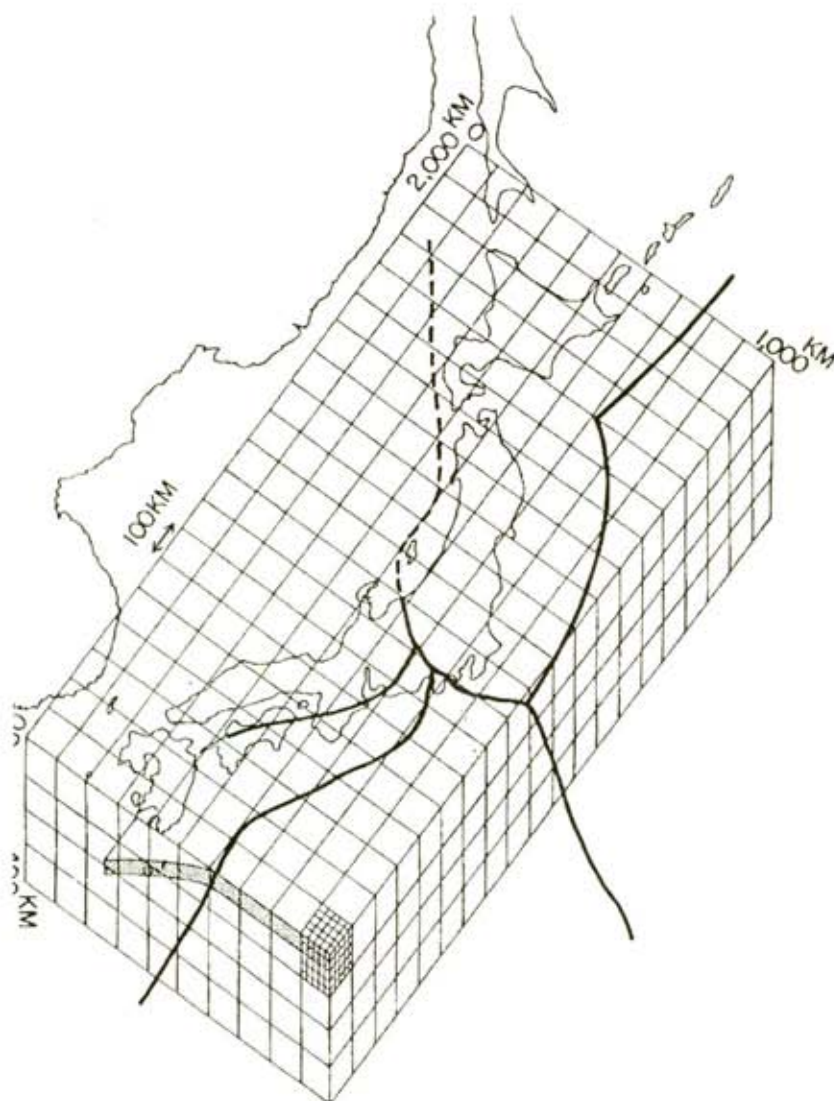


Fig. 1 Numerical model for a crustal deformation analysis

3) Numerical simulation of oceanic lithosphere deformation

Numerical modeling incorporates the results of the foregoing to quantify crustal deformation, verify and assess previous models' 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.

3. Main research progress

To clarify seismogenic mechanisms, numerical deformation modeling of the region depicted in Fig.1 and continuous improvements of the resultant models are considered necessary.

1) Studies of oceanic lithosphere structure

Investigations are being carried out in the vicinity of the Nankai Trough, Japan Trench and eastern Japan Sea margin according to the research plan given in Fig.2. During FY 1997, the R/V "Kairei" completed

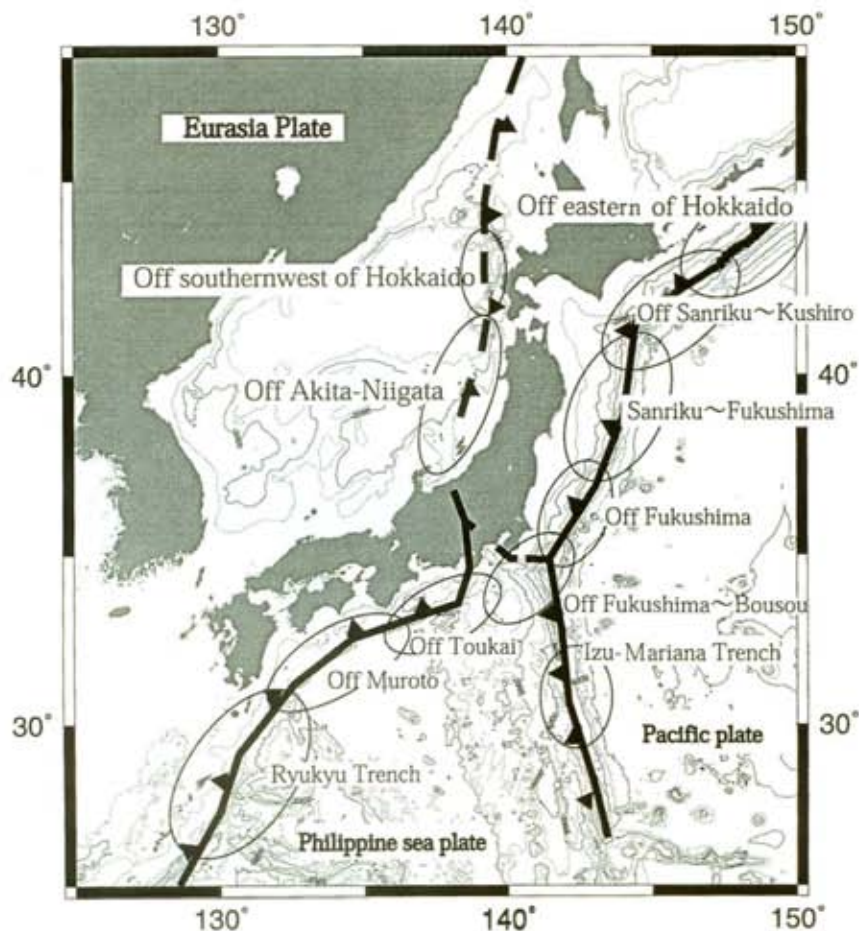


Fig. 2 Planned sites for a marine seismic survey

successful research cruises in the Nankai Trough off Muroto, and in the Japan Trench off Sanriku. During the former, the crustal velocity structure to the depth of the seismogenic zone and the structure of seamounts and the subduction zone were determined (Fig. 3 and 4), and their relationships 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. Additionally, system software necessary for development of a database was acquired, and case studies are being made at present.

2) Long-term monitoring of seafloor changes

During FY 1997, 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.5 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.

3) Numerical simulation of lithosphere deformation

Lithosphere deformation modeling with timescales of tens to tens of thousands of year is necessary for interpreting the seismogenic mechanisms of giant, ocean trench earthquakes. In particular, ongoing testing and refinement using real observations of such

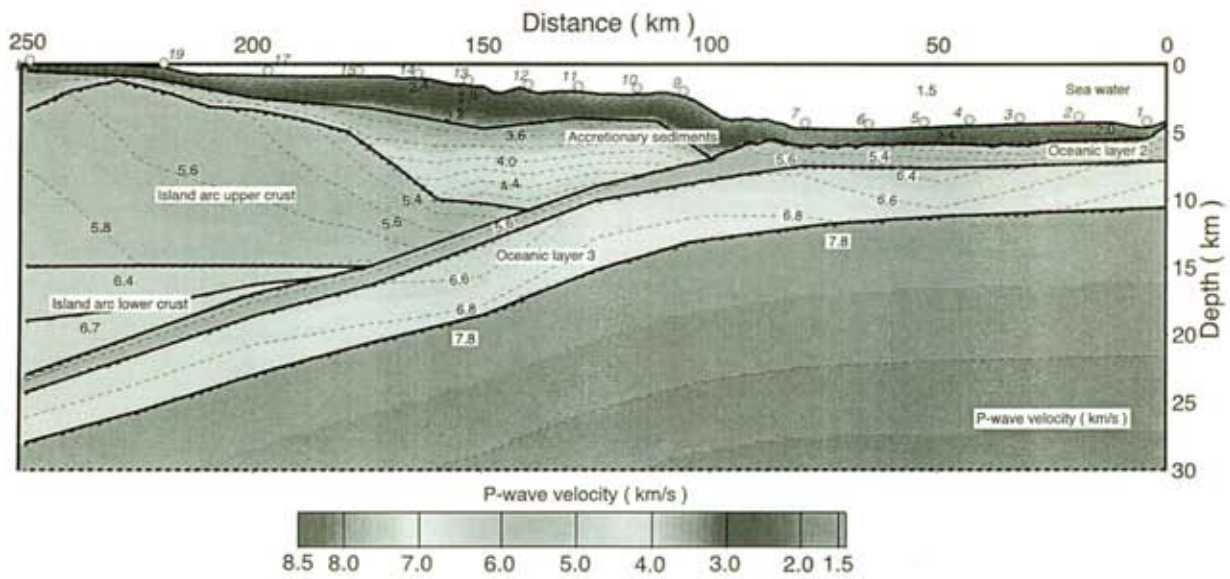


Fig.3 Deep structure in the Western Nankai Trough obtained from an OBS survey

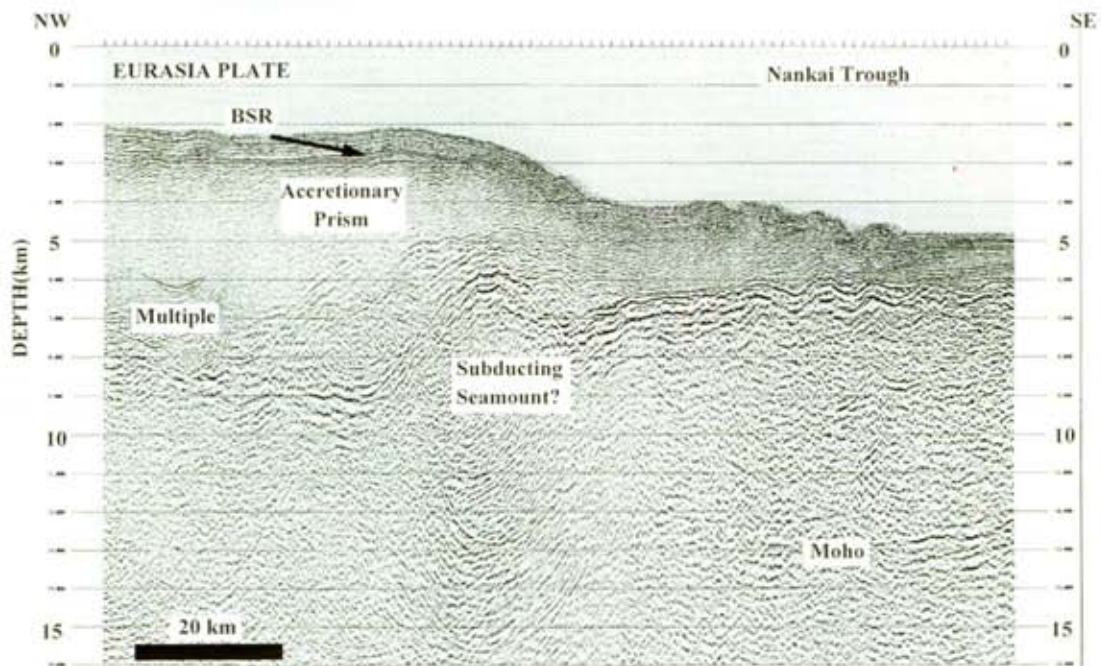


Fig.4 Depth section in the Western Nankai Trough obtained by a MCS survey

Earthquake 05:23, April 23rd, 1997
Magnitude: 2.6

Results of hypocenter determination	
Using only land stations	Using OBS data
Lat. : 32.6470°	Lat. : 32.6885°
Long. : 134.4985°	Long. : 134.4790°
Depth : 23.98 km	Depth : 26.49 km

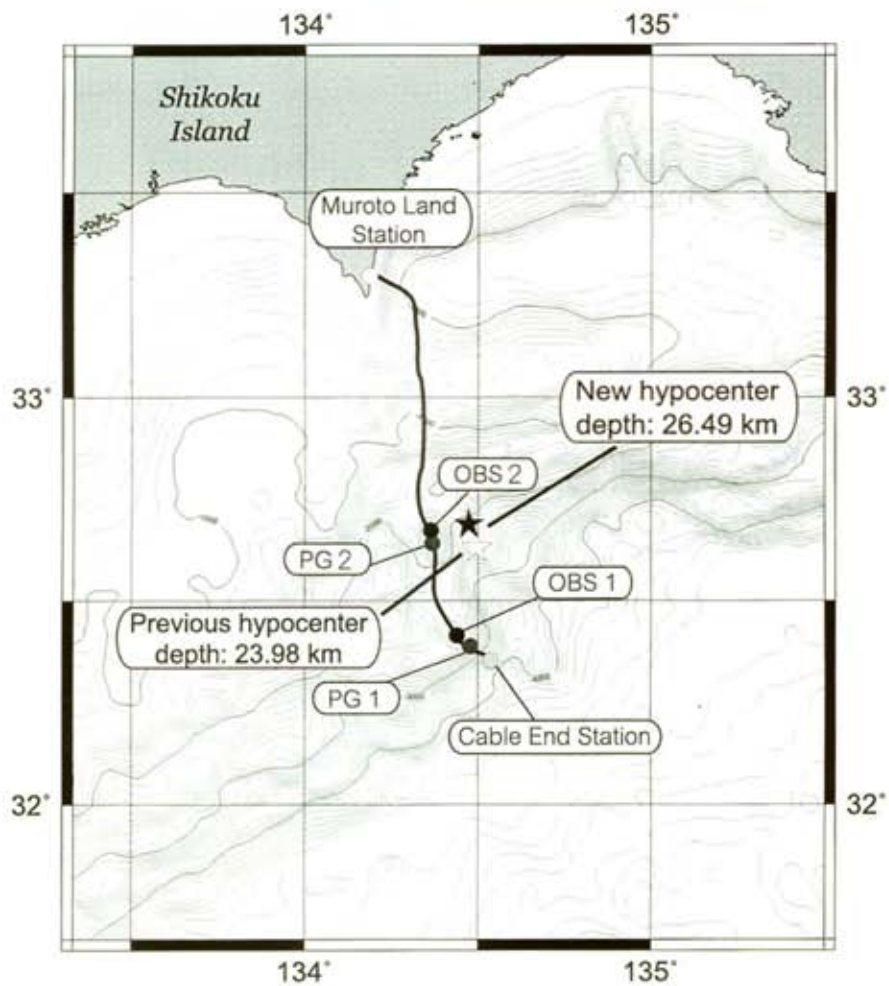


Fig.5 An example of re-determination of an earthquake hypocenter using ocean bottom seismometer data

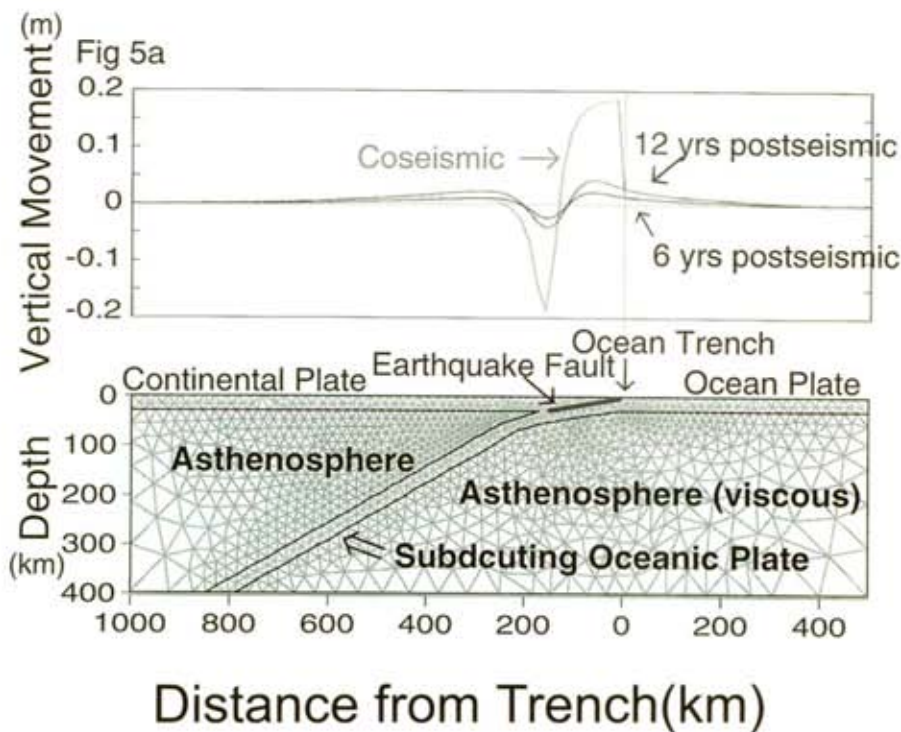


Fig.6 Co- and Postseismic Deformation for a Great Subduction Zone Earthquake

models and their predictions are of paramount importance. Finite element modeling (FEM) techniques previously developed to deal with static and dynamic problems during FY 1997. In particular, while gravitational effects have been largely neglected detailed structure for reasons of computational efficiency, it has been realized that such effects may be important in the subduction of oceanic lithosphere. Software incorporating gravitational effects has also been developed.

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

Fig.6 illustrates the deformation accompanying an ocean trench earthquake, and the results of analysis showing subsequent deformation. It is clear that deformation at the time of an earthquake is mitigated by subsequent (postseismic) deformation. Future

models will incorporate real structural data and realistic earthquake focal mechanisms and be directly comparable/verifiable with global positioning satellite (GPS) data.

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. Frontier Research System for Global Change

The Frontier Research System for Global Change (FRSGC) was established on October 1, 1997, based on the recommendation stated in the report "Towards the Realization of Global Change Prediction" which was presented by the Subcommittee on Earth Science and Technology, Council for Aeronautics, Electronics and Other Advanced Technologies, Science and Technology Agency on July 9, 1996. FRSGC, the system for conducting a joint research project of the National Space Development Agency of Japan (NASDA) and JAMSTEC, consists of the three institutes: the Institute for Global Change Research (IGCR) in Tokyo; the International Pacific Research Center (IPRC) of University of Hawaii, Honolulu; and the International Arctic Research Center (IARC) of University of Alaska, Fairbanks. The latter two were established for undertaking international cooperative research of global change under the Japan-US Common Agenda.

2. Events to Mark the Inauguration

After the system was formally inaugurated on October 24 1997, the first meeting of the Advisory Committee was held where the research plan of the FRSGC was presented to the committee members from the various related research organizations and the academic advisors to be reviewed and endorsed. In the afternoon, we marked the inauguration by holding the First Frontier Symposium on Global Change Research at the Mita Meeting Hall. Over three hundred people from the academic world and related organizations participated in the symposium. After presentations by the four Program Directors, a panel discussion was held, where there were lively

questions and answers.

The evening reception after the symposium was attended by Dr.Gibbons, Assistant to the President for Science and Technology, Dr.Lane, the Secretary of the NSF, Mr.Tanigaki, then Minister of State for Science and Technology and many guests from related organizations and private industries.

Prior to this event, the opening ceremony of the IPRC was held, hosted by Dr.Mortimer, the President of the University of Hawaii, at the university's Manoa Campus on October 20, 1997. Attendees included Dr.Gibbons; Ms.Hirono, the Vice-Governor of the State of Hawaii; Dr.Raleigh, the Dean of the School of Ocean and Earth Science and Technology; Mr.Kato, the Parliamentary Vice-Minister of the Science and Technology Agency; Mr. Hirano, the President of JAMSTEC and Prof. Kaifu, the Director of the National Astronomical Observatory, Hawaii Observatory, where a telescope had been under construction on the summit of Mt.Mauna Kea. The ceremony was a simple but impressive event symbolizing the dawn of the Japan-US cooperation in the field of global change research. The symposium celebrating the inauguration of the IARC was held in October, 1998.

3. The Structure of the FRSGC

The report from the Subcommittee on Earth Science and Technology, "Towards the Realization of Global Change Prediction," designated the following six goals with consideration of major research fields needed to be explored and their socioeconomic implication.

- ① Prediction of climate variations in the Asia-Pacific region
- ② Prediction of variations and changes of the hydrological cycle in the Asian region

-
- ③ Prediction of global warming
 - ④ Prediction of atmospheric composition change in the Asia-Pacific region
 - ⑤ Prediction of ecosystem change in the Asian region
 - ⑥ Elucidation of the mechanism of the earth's interior change

In order to achieve these goals, the FRSGC will create six fields of research programs and carry out them with a systematic strategy, under the leadership of the Program Directors. In FY1997, the Frontier's first year, we formed programs for ① ② and ③.

Although not included in the six goals, we also initiated "Integrated Modeling (next generation climate modeling) Research Program" to efficiently carry out numerical modeling, which is a common research tool covering many areas. Each research area consists of several research groups each of which works as a unit. The structure of the system as of the end of FY 1997 is shown in Fig.1

4. Composition of Personnel

Similar to other "Frontier" research initiatives taken by Science and Technology Agency, the research activities at the FRSGC are conducted by "mobile researchers" ,i.e. researchers who originally are affiliated with universities, national research institutes, or private companies and take a leave of absence from their home institutes to participate in the FRSGC or work at the FRSGC as a part-time researcher, while maintaining their affiliation with home institutes. Nation-wide top researchers from other institutes join FRSGC to lead the program or the research group. Some of the Program Directors and the group leaders are participating in the FRSGC on full-time basis. Under their leadership, younger researchers including post-doctoral researchers (full-time employees) are working to tackle respective problems. The Frontier staffing as of April 1, 1998 is shown in Table 1.

5. Progress of Research Activities

At the time of the initiation of research projects in October 1997, objectives and plans of respective research programs were defined under the leadership of the director of each program and started the research. Since it has been only six months since the start of the projects, reporting research results here is not meaningful. Therefore, we will report outline of the research plan for each area and the progress of activities taking place along the plan.

1) Climate Variations Research Program

This research program will focus in particular on the interaction between the atmosphere and the oceans. By examining climate variations on various time scales from the viewpoint of variations of coupled atmosphere-ocean system, we will clarify the physical mechanism of the variations and discuss their predictability. It is also attempted to reproduce ocean circulations by numerical models of the ocean under prescribed forcing from the atmosphere.

This research program will be conducted by three groups: modeling research group, analysis research group and predictability research group.

The modeling research group is developing an atmospheric model to investigate the response of the atmospheric circulation to variations of the sea-surface temperature over a decadal time scale. As the first step of the ocean modeling, an experiment to reproduce the circulation of the northern Pacific Ocean is conducted, by using a high-resolution ocean circulation model developed by the University of Tokyo. During the process, special focus is placed on the seasonal and interannual changes of the Kuroshio, and the complex circulation systems in the seas around Indonesia. The analysis research group analyzes changes of the sea-surface temperature (SST) of the northern Pacific using long term observation data from a viewpoint somewhat different from previous researches. Some new facts, such as SST variations over a ten-year period are mainly found in the areas of sub-polar and sub-tropical fronts and they are linked to the changes of the Aleutian low pres-

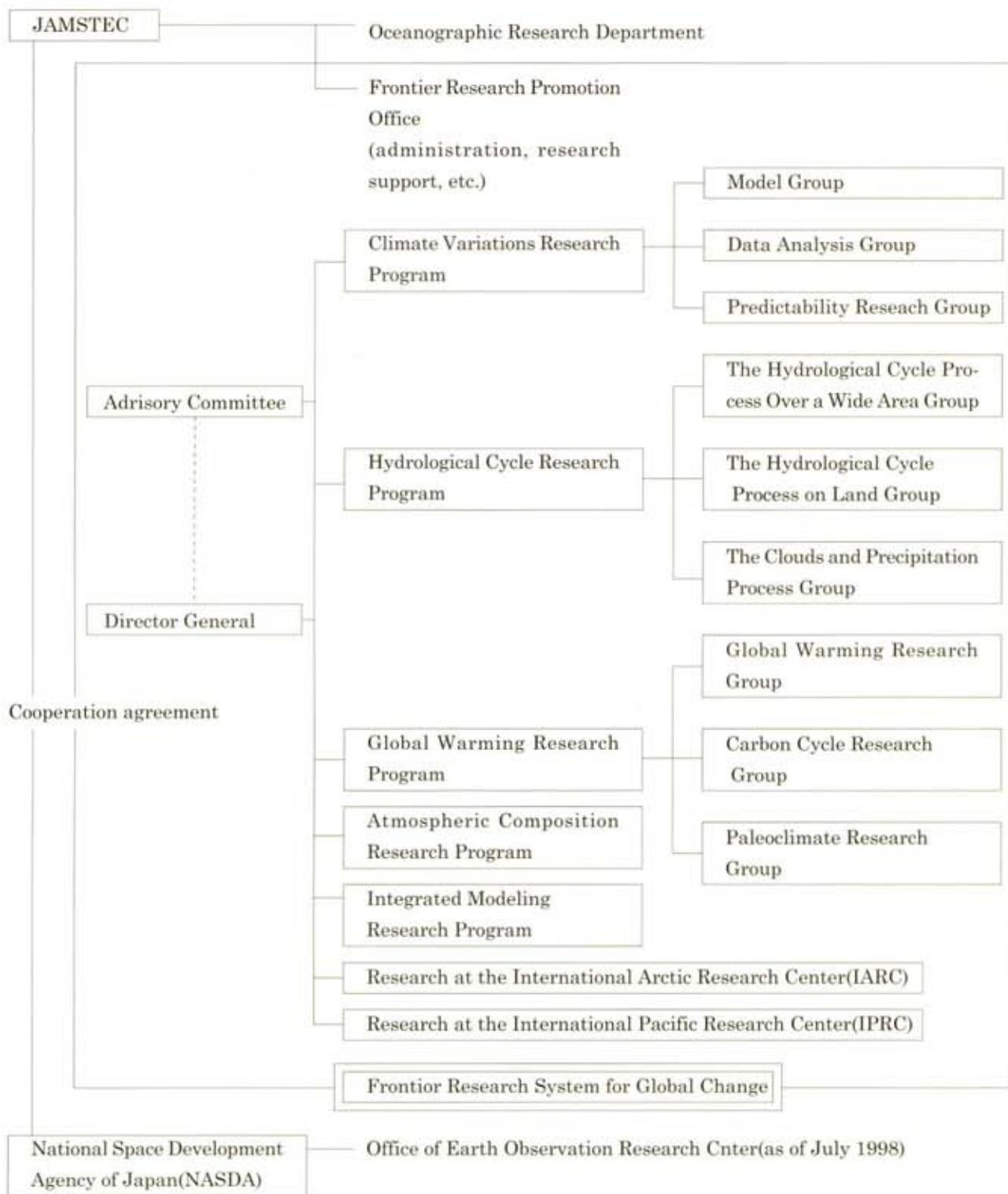


Fig.1

Table 1

		IGCR			IPRC · IARC	
		PD	GL&SL	Researchers	GL	Researchers
Full-time appointment (non-Japanese)		1 (1)	1 (0)	24 (5)	1 (0)	10 (6)
Part-time appointment with double affiliations	Home institutes					
	University	3	5	9	0	5
	National Research Laboratories	0	0	2	0	0
	Other	0	0	1	0	0

PD: Program Director

GL: Group Leader

SL: Sub-leader

sure and the subtropical high pressure respectively. The predictability research group is engaged in basic studies including theoretical research into the average state of the atmosphere, governed by radiation and convection.

2) Hydrological Cycle Research Program

This research program analyzes the elementary hydrological processes on the Asian (Eurasian) continent and the interaction between the atmosphere and the land surface (including vegetation, snow and ice) using observational data. Based on the results obtained from the analysis, attempts will be made to construct a continental-scale model of the hydrological cycle; to reveal the actual variations and changes in the hydrological cycle of Asia and the western Pacific region, including variations of the Indian monsoon; and to understand their mechanisms. The ultimate goal of this program is to predict variations and changes in the hydrological cycle.

The program consists of three groups: Hydrological Cycle over a Wide Area Research Group, Hydrological Processes on Land Research Group and Clouds and Precipitation Process Research Group.

The Hydrological Cycle Over a Wide Area Research Group investigates variations of the Asian and Australian monsoons and the interaction between El Niño-Southern Oscillation and monsoon. This group also analyzes the interaction between these variations

and land conditions such as snowfall, using past observational data as well as those obtained from GAME, the international cooperation project which was carried out in the summer of 1998.

The Hydrological Cycle Process on Land Group collects the observational data of elementary processes in cooperation with GAME, to carry out modeling of the mechanisms of energy, water and material exchange between the atmosphere and the land surface, which differ in forests and plains.

Using GAME's special observation data on Huahi River basin in China as well as analyzing data obtained from the Baiu precipitation observation project, the Clouds and Precipitation Process Group will understand the large-scale mechanism of rainy season (Baiu-front) and conduct numerical modeling of the meso-scale precipitation system. Further, the group will attempt to develop a detailed physical model of clouds in order to predict possible change of cloud properties under global warming conditions: factors which have hindered reliable global warming predictions.

3) Global Warming Research Program

This program carries out research to obtain practically useful and important information on global warming such as detailed assessment of climate changes and prediction of the occurrence of typhoons after warming has taken place. Most of the research

in this program will be conducted by using the numerical modeling method. Since the Meteorological Agency's Meteorological Research Institute and the Center for Climate System Research of the University of Tokyo also conduct research on global warming prediction, FRSGC will cooperate with these institutes where appropriate and conduct complementary research. The program has three research groups: Global Warming Research Group, Carbon Cycle Research Group and Paleoclimate Research Group.

The Global Warming Research Group will cooperate with the Meteorological Research Institute to develop a high-resolution climate model with emphasis on improvement of physical processes. By using the model, the group will attempt to predict possible changes in important regional phenomena, such as the rainy season (Baiu), the number and intensity of typhoons. In addition, the group will seek to model the mechanism of deep-ocean circulation more accurately, which plays an important role in slowing the progress of warming.

The Carbon Cycle Research Group will reproduce the natural carbon cycle of the atmosphere and oceans using a three-dimensional ocean circulation model incorporating the biogeochemical process. This model, developed by the Center for Climate System Research, the University of Tokyo, is one of the few such models currently existing in the world. The group will then conduct experiments to find how the oceans absorb carbon, including anthropogenic CO₂ emissions.

The Paleoclimate Research Group will investigate the mechanisms of the natural climate changes in the Ice Ages, including glacial and interglacial periods. The group will also study the warm climate of the Mesozoic era, which is comparable to or even larger than possible global warming or our era, using modeling experiments, to deeply understand the climate change mechanisms. In addition, the group will develop a three dimensional ice sheet model to find out how the ice sheets of Greenland and the Antarctic change in response to major changes in climatic conditions including the possible anthropogenic warming.

4) Integrated Modeling Research Program (Next-Generation Climate Model Research)

In this research program, next generation climate models will be developed to be run on the earth simulator (effective operation speed: 5TFLOPS), a super parallel computer in the early 2002, by integrating the results obtained from individual process study in other research programs. It also carries out basic research on processes that the other groups do not cover.

Two types of development will be made for the next generation climate models. One is to develop a model which is basically the same as existing models but with increased horizontal resolution (horizontal grid intervals of around 30-50 km) and with improved physical processes. The other includes development of an atmosphere model that will calculate directly (without parameterizing) convection clouds (meso-scale convection cloud clusters) with horizontal grid intervals of less than 10 km.

The Earth Simulator Research and Development Center will provide technical support, such as parallel computer technology which is necessary for the earth simulator.

5) Research Plan for the IPRC (Japan Core Group)

The International Pacific Research Center (IPRC) was established jointly by Japan and the US to increase understanding of the global environment changes which appear in the Asia-Pacific region and to contribute to the science to predict such changes. The research at the IPRC is conducted under the separate IPRC overall science plan which envisages cooperation with other researches at the FRSGC. Therefore, here, the provisional research topics will be described:

- ① Research on predicting climate variations and change in the Asia-Pacific
- ② Research on the hydrological cycle in the region
- ③ Analysis of the relationship between the global warming phenomenon and regional climate change

Both data analyses and numerical model experiments will be conducted concerning the above sub-

jects.

The Japanese group is currently planning to emphasize the topic ① and cover ② and ③ in the future.

(a) Research on the atmospheric and oceanic processes which link the Asian Monsoon and El Niño/Southern Oscillation

The research will clarify the relationship between the variability of the Asian monsoon and east-west movement of the tropical tropospheric heat source region on time scale of one season to ten years, which might be the link between the monsoon variation and El Niño/Southern Oscillation. It will also investigate the role of the interaction between the low and middle latitude ocean circulations in heat transport and fresh water transport.

(b) Understanding of atmospheric and ocean processes that cause long-term change in the North Pacific climate system

Research will be carried out to identify changes in the north Pacific climate system on scales ranging from ten years to several decades and to understand the mechanism of changes and the possibility of predicting them. In addition, the formation of North Pacific Intermediate Water masses and their role in the carbon cycle will be investigated.

(c) The role of the marginal seas in Asia and India and archipelagoes in the climate system of Asia and the North Pacific

In Asia, which is densely populated with intensive activities in coastal regions, there is a pressing social need for predictions of regional climate change. In addition, each sea area has its own characteristic interactions among the atmosphere, ocean and land. Understanding of them, using analysis of atmospheric and ocean data and high-resolution regional models, will propel improvement in the overall physical processes of climate models.

6) Research Plan for IARC (Japan Core Group)

The research at the IARC is conducted under the separate IARC overall science plan, which envisages cooperation with other researches at the FRSGC. Therefore, here we report only the goals of the research.

The climate system of the Arctic region changes on various time scales ranging from a seasonal cycle to ten years or more, and the magnitude of the changes often exceeds that of the climate change taking place on the global scale. In addition, it is thought that global warming is actually taking place, and warming of the Arctic region is particularly apparent in predictive models. The characteristics of the Arctic region, where there is snow ice, is that it clearly plays an important role in global changes, and it seems that changes at the Arctic region feed back into global changes. Meanwhile, the ecosystem is responding to climate change by altering and adapting, and this, in turn, also has an impact on human activity. Change in the ecosystem feeds back into climate change, as seen in the example of the carbon cycle.

IARC will clarify the role of the Arctic region in global climate change at the same time as predicting the significant impacts of the processes of global climate change, such as warming, on the Arctic region. It is essential to understand the physical and chemical processes of the system which link the oceans, sea ice and the atmosphere in order to achieve the above mentioned main goals. In addition, IARC aims to predict the response of the land ecosystem to climate changes and also investigate the possibility that the ecosystem give an impact on climate change. IARC will contribute to a variety of international Arctic researches.

Ocean Acoustic Tomography

JAMSTEC completed the substantial 200 Hz ocean acoustic tomography system that consists of five sets of the 200 Hz tomography transceiver mooring in March 1997. Three new sets of the transceiver mooring were made up in 1997 while the two existing sets were completed in 1994. This system has a potential capability to observe 1,000 km scale three-dimensional distribution of water temperature in quasi-real time. In order to evaluate this capability, we started an open sea experiment for about three months and deployed the five sets of the 200 Hz tomography transceiver system at each vertex of a pentagon in the Kuroshio Extension region over 1,000 km by 1,000 km.

We also have another observation program to study the behavior and property of the meso-scale eddies crossing the Izu-Ogasawara Ridge through the passage off the Torishima Island. The preliminary observation was conducted at the passage by using three sets of 400 Hz tomography transceivers from November 1996 to July 1997. The observation was started in November by Woods Hole Oceanographic Institution and JAMSTEC as an international joint observation program composing five sets of 400 Hz tomography transceiver consisting of three sets from JAMSTEC and two sets from Woods Hole Oceanographic Institution. This observation would be terminated in July 1998. The analysis of obtained data is in progress.

The detailed result of the open sea test of the 200 Hz ocean acoustic tomography system is shown below:

1) Observation area

In the observation area, the warm water from Tropic and the cold water of the Kurile current makes a clear front and the Kuroshio Extension flows along

this front. The generation and distinction of cold eddies and warm eddies are active in this region. The test field was selected in considering the sea area where the topography was comparatively flat near the Japan Trench and Izu-Ogasawara Trench in the North Pacific Basin. The geography of the test field is shown in Figure 1. It is one of the ideal field for the performance test of a 200 Hz ocean acoustic tomography system.

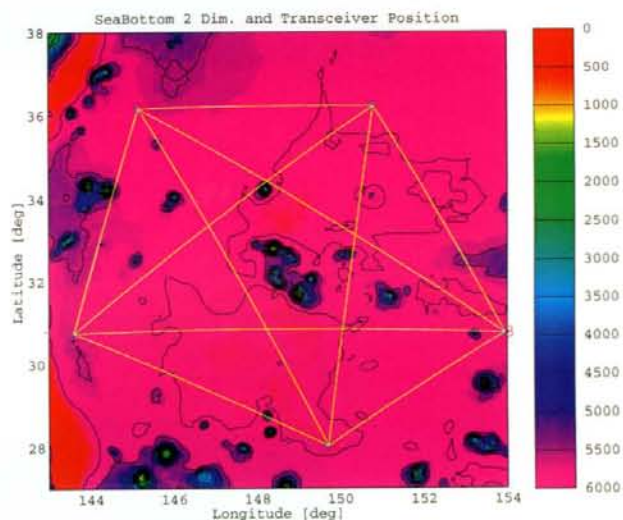


Fig.1 The geography of the test field

2) Character of the test field

After the deployment of all of the tomography transceivers, CTD and XCTD casts were conducted to gather the reference hydrographic data. Points T1, T2, T3, T4 and T5 in Figure 2 stand for transceiver No.1, No.2, No.3, No.4 and No.5, respectively. The water temperature distribution obtained by the CTD and XCTD casts showed that Point T1, T2 and T3 were located in the warm water area, but Point T4 and T5 were in the cold water area. The line T2-T5 and the line T3-T4 coincided with the ground track

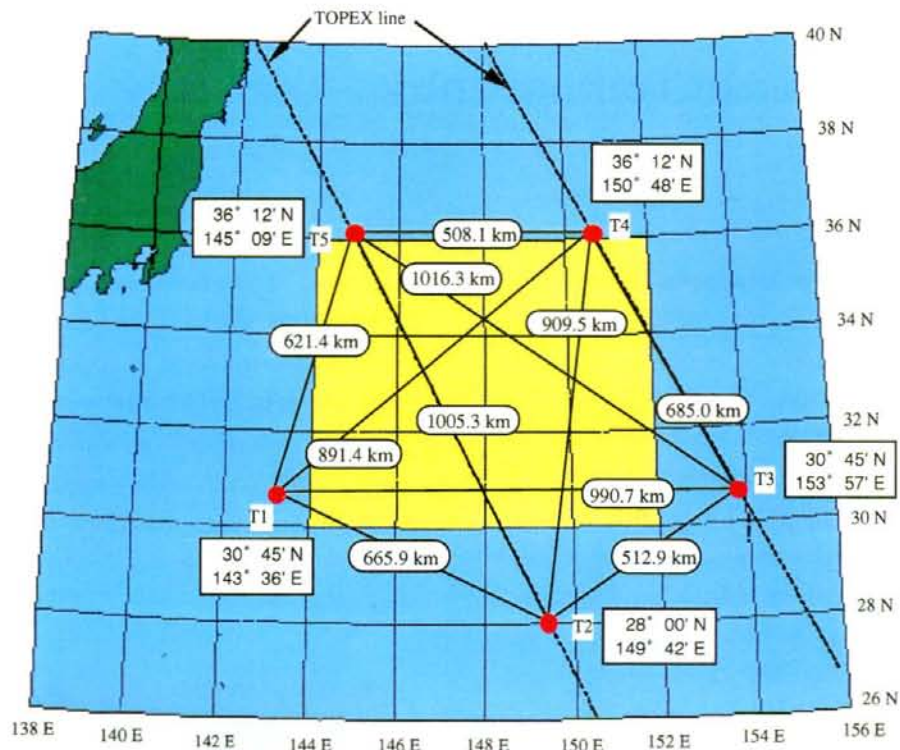


Fig.2 The location map

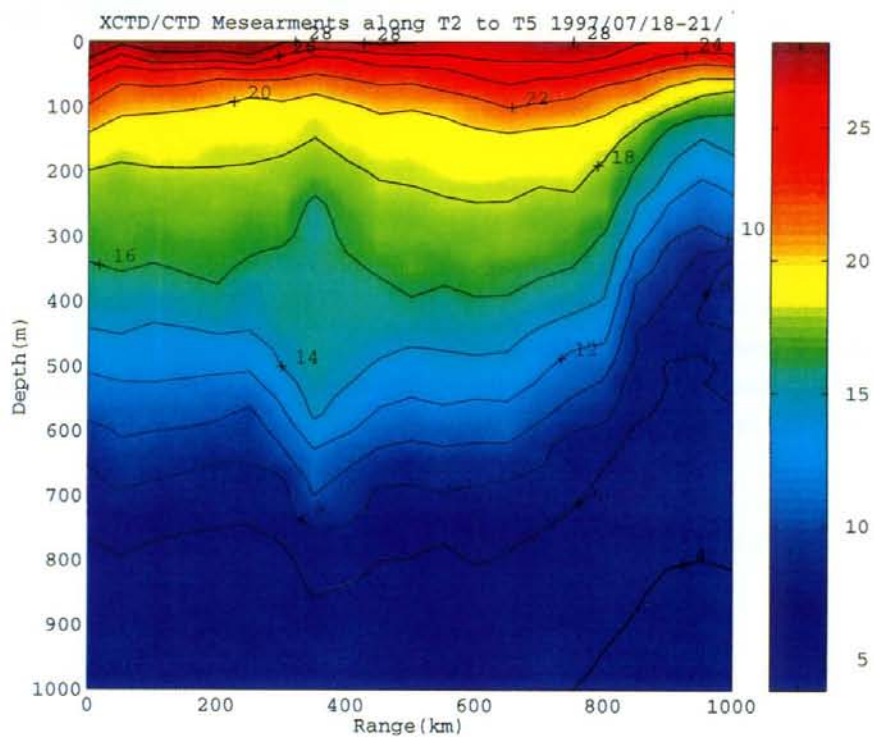


Fig. 3 The water temperature distribution of the line T2-T5

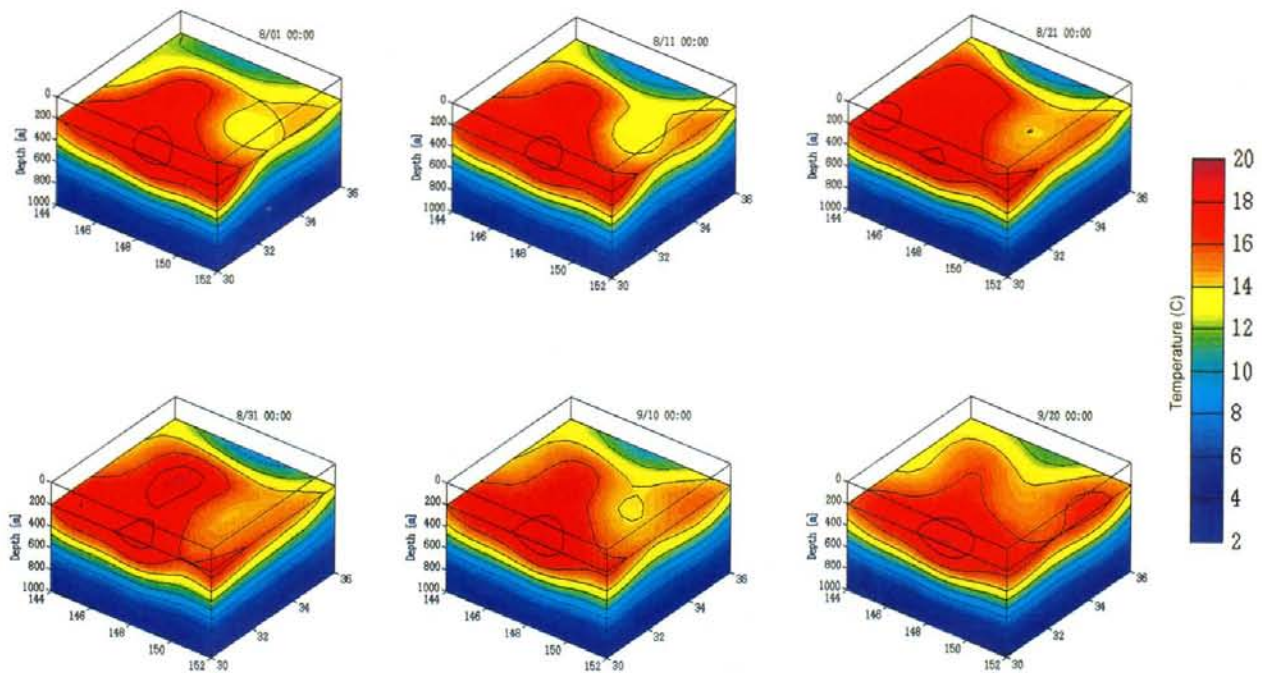


Fig.4 Time series of 3D temperature field

of the TOPEX/POSEIDON Satellite. Especially the line T2-T5 was intensively observed in detail as the reference line. The water temperature distribution of the cross section of line T2-T5 shown in Figure 3 pointed out that the disklike water mass which was about 100 km in diameter and 15°C in temperature existed around the intersection between lines T2-T5 and T1-T3. Also, it was confirmed that there was a fairly warm water around T2 and a cold water around T5.

3) Tomography observation

The five sets of the 200 Hz transceiver system were deployed every two days from July 1 to July 9, 1997. However, the transceiver No.1 was inspected after it was recovered on July 11 because some errors were detected in the data of the transceiver No.1 transmitted to the land station. The surface buoy, E/M cable, electric circuits of the No.1 were replaced by the spares, on deck. Also, the hydrophone array was replaced by the spare one because the array was damaged and the silicon oil filled in the array was leaked. The transceiver No.1 was redeployed on July 13.

After the redeployment, the exact position was determined as shown in Figure 2. The performance test was resumed on July 20 and terminated on September 20. The sound transmission was repeatedly in the typical SOFAR channel which naturally formed at the mid-latitude. So the separation of acoustic rays is fairly clear. At this time we developed the automatic ray tracking program that is a preliminary one for the purpose of the ultimate automatic ray identification because the data volume to be processed increased to 10 times compared with the case for the two sets. This program was much useful and reduced the analysis time to a great extent.

Accidentally the No.5 stopped the data telemetry at the early stage of the test. It was the reason why the Kuroshio Extension goes south unexpectedly, and this swift flow enclosed the transceiver No.5, and pulled down the surface buoy into the deep water. At the recovery of transceiver No.5 it became clear that, the internal antenna contained inside the antenna dome was damaged due to hydrostatic bending. The water pressure gauge attached to the aluminum hall of the surface buoy showed that the sur-

face buoy sank down to the depth of more than 400m. Therefore, it was only possible to analyze the incomplete data of four transceivers in realtime after August 2. The complete data analysis was done after the transceiver No. 5 was recovered.

4) Recovery of the system

The terminal end of E/M cable connecting to the sub-surface buoy was cut off in recovering transceiver No.1 and No.4. The E/M cable of transceiver No.4 was stabbed by a fishing needle of tuna long-line. And in this case, the inner steel tension member was exposed. After the experiment, the E/M cable was tested to examine the breaking strength.

It was realized that the breaking strength of the cables has decreased remarkably in the terminal. The record of the water pressure to the transceivers showed the significant change of depth for the No.1 and also No.4 at the early stage after the system deployment. It almost agrees with the time when a group of the tuna ships was seen. However, the strength of the E/M cable that got worse at the time of recovery work the cable suffered an unexpected strong force and moment as a result of the interaction between the pulling force by ship and the movement of the sub-surface buoy. Therefore, the E/M cables were broken out by waves.

5) Land reception system

The land reception system, was redesigned and reconstructed substantially in accordance with the application of five transceiver systems rather than the application of two transceiver systems. A new communication terminal was added to the existing land station to increase the reliability. In this way, the new land station worked well and the lost of the data by the failure of a communication terminal became

few. The software to monitor the system was greatly improved and modified. It was easy to find which transceiver was in trouble and to display the record of sensors.

6) Three-dimensional maps of water temperature field

The data obtained in the tomography observation from June 20 to September 20 was analyzed by using the 3D tomography inversion program. As a result, time series of 3D temperature field was obtained as shown in Figure 4. This figure broaches the sea area where was surrounded with the zonal lines of the north latitude 30° - 36° , and the meridian lines of the east longitude 144° - 152° in the test field. The top face at the front left aspect is the water temperature distribution of the level section at the depth of 200 m and the east and west section which goes along to the parallel of zonal line of the north latitude 30° .

The front right aspect is the north and south section which goes along to the meridian lines of the east longitude 152° and the water temperature distribution of the depth of 200m to 1,000m are shown.

The warm water of the Kuroshio Extension and the cold water of Kurile current joined between the north latitude 32° and 36° . Centering around the meridional line of the east longitude 147° , the Kuroshio Extension was weak on August 11, and strong on August 31 and weakened after that. Also, the temperature field fluctuates dynamically every day and the cold eddy and warm eddy of the scale at about 200 km in diameter change the shapes center around points (33°N , 151°E) and (33°N , 147°E). Figure 4 clearly shows the dynamical fluctuation of this meander of Kuroshio Extension.

In this test, the horizontal resolution is about 300km. The temperature accuracy is about 0.3°C .

Marine Observation Satellite Research

1. Summary

Observation of the ocean by using satellites sensors plays an important role in elucidating various aspects of oceanic phenomena in global environmental variations. In this project, methods of satellite data processing and analysis are to be established. Further, the data assimilation techniques, those are useful for establishing the observation system, are to be developed.

In 1997 we processed the AVHRR data of NOAA, those we received, and then established the system which shows the daily sea surface temperature map. Those processed SST maps will be opened to the public through the Internet. We also established the data management device which deals with the sea surface height data and the sea surface wind data. We applied the sea surface height data obtained to the oceanographic work, that is, we detected the Kuroshio and mesoscale eddies and their time evolution by using the sea surface height data. These features are mentioned as follows.

2. Mesoscale eddies and the Kuroshio recirculation south of Japan using satellite data

Mesoscale eddies are often formed near the Kuroshio Extension region. These eddies and/or strong flow of the Kuroshio interact each other and the interactions are important factor for the gyre variability. The eddies pinched off the Kuroshio often propagate westward and then enter the Shikoku Basin south of Japan. These mesoscale eddies carry energy, momentum and some water mass effectively.

In September 1992 an anticyclonic warm eddy with a diameter of 300 km was observed by XBT and ADCP measurement over the Izu-Ogasawara Ridge (Y.

Yoshikawa et al., 1996, K. Hanawa et al., 1996). We detected the westward propagation of this large eddy, that reached south of the Kyushu at last, by using TOPEX/POSEIDON (T/P) altimetric data.

The T/P sea surface height (SSH) anomaly data used and calculated are distributed by AVISO. The satellite is taking exact repeat orbits of 9.91 days period. The ground track spacing is 315km at the equator at about 200km at mid latitude. We analyze

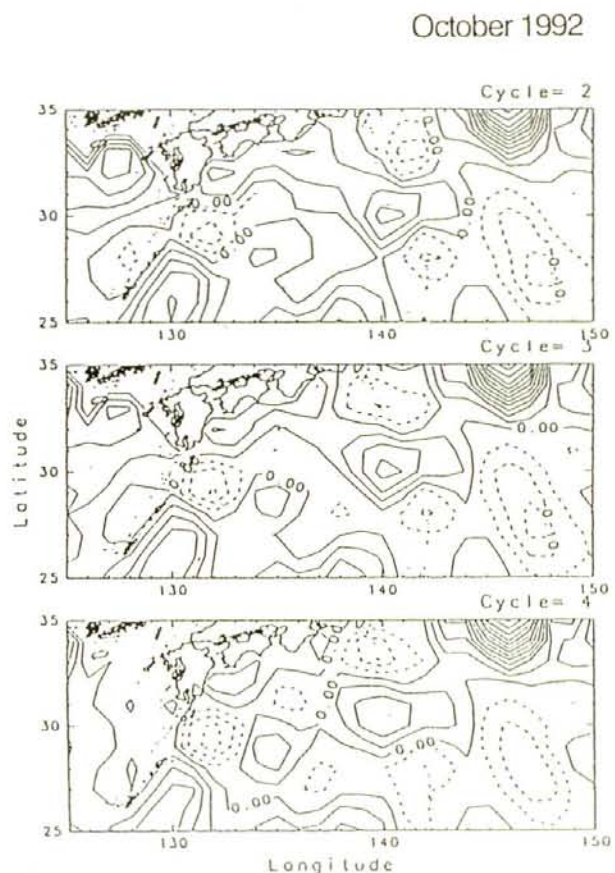


Fig. 1 SSH anomaly fields in October 1992. Contour interval is 0.1m. Solid (broken) line is positive (negative) anomaly

the T/P SSH anomaly data for a period of the first 72 cycles, from 25 September 1992. After smoothing the SSH anomaly data using a box car filter we made data set of 1×1 degree in space and 1 cycle using a Gaussian weighting function.

As observed from the XBT and ADCP measurements, the T/P shows that, the eddy occurred over the Izu-Ogasawara Ridge, about 30° N, 140° E, in early October 1992 (Fig. 1), that is, the positive anomaly region corresponds to a warm eddy. Warm eddy's region, defined by the contours of +20cm, was

a circle with the radius of about 250km. The center of the eddy looks gradually shift westward. The speed of propagation was about 6cm/s, the shift from 140° E to 139° E at the period between cycle 3 to cycle 5.

The warm eddy then gradually propagated westward, and it reached to south of Enshu Nada, 33° N, 136° E in early December (Fig. 2). The positive anomaly region changed its form from a circle to an ellipse and then it divided into two sections looks like. After that the eddy divided into two sections; one was advected northeastward by the Kuroshio and the

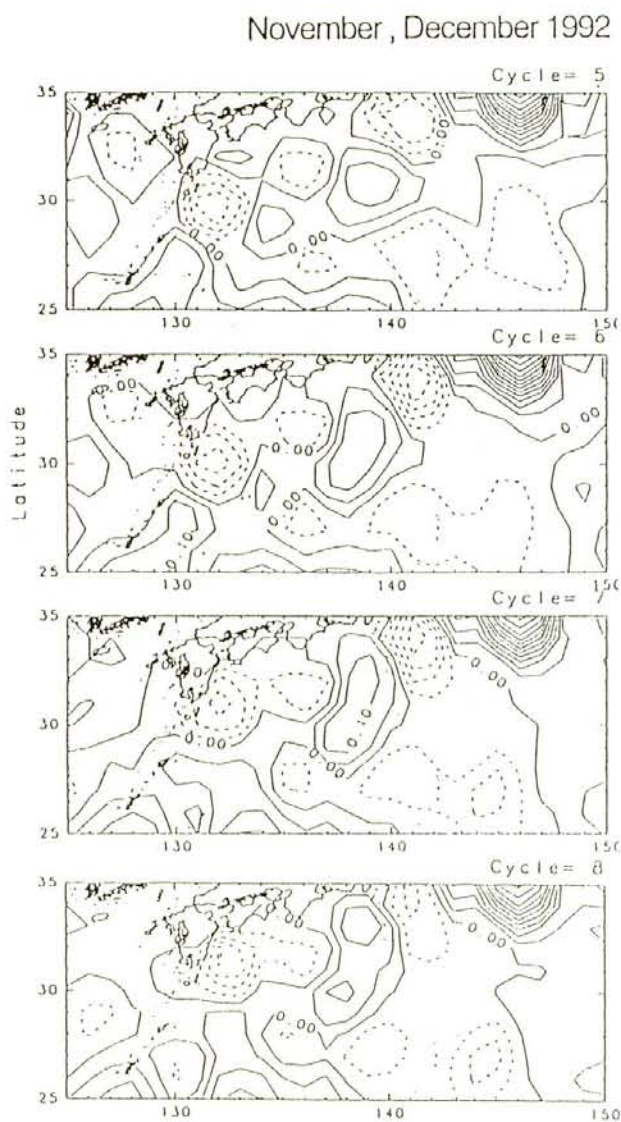


Fig. 2 SSH anomaly fields in November and December 1992

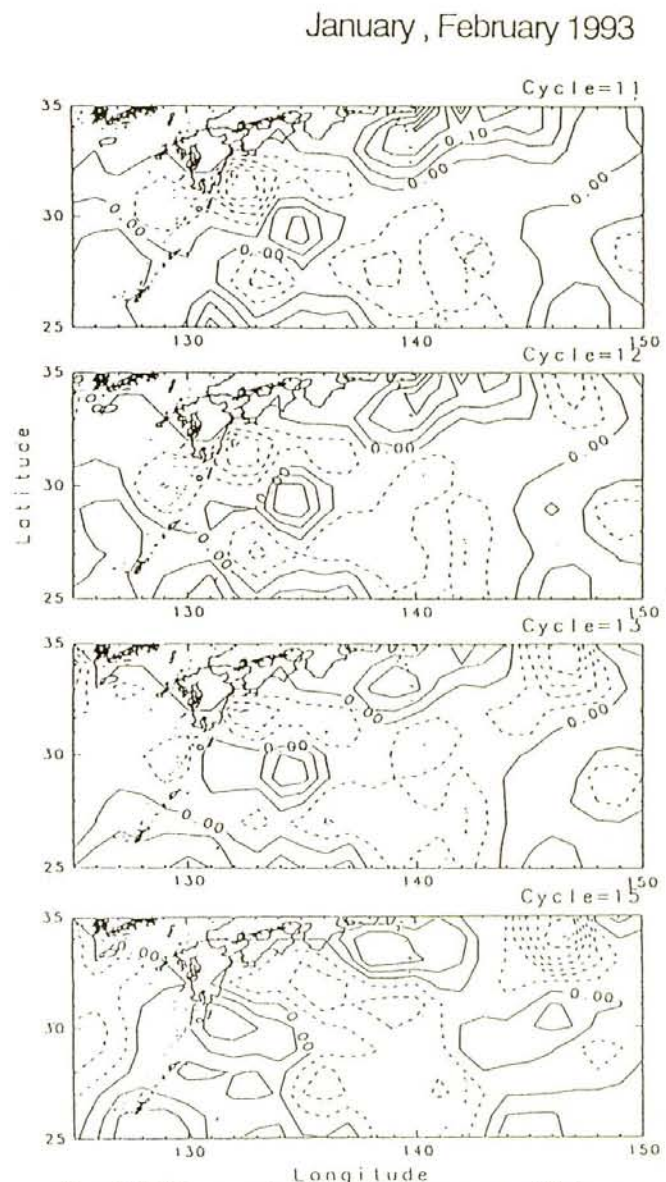


Fig. 3 SSH anomaly fields in January and February 1993

other continued to propagate westward.

In January, the latter propagating section reached south of Kyushu Island, about 30°N, 134°E (Fig. 3). From October 1992 a cyclonic eddy, the so-called the Tanegashima Cold Eddy, existed south of Kyushu Island, that is, the Small Meander of the Kuroshio. The cold eddy remained there more than two months. In December the cold eddy moved north-eastward, that is downstream of the Kuroshio. After that the cold eddy stayed in the region at the south-east coast of Kyushu Island from January to February 1993.

In late February 1993 the warm eddy continued to propagate westward and then reached the western boundary where the Tanegashima Cold Eddy existed in previous autumn. At the same time the cold eddy had trapped south-east coast of Kyushu Island was released and advected fast northeastward direction

along the Kuroshio.

The release process of the cyclonic eddy was explained by the eddy-eddy interaction. That is, the two eddies made and behaved the vortex pair. They rotated in an anticyclonic direction. After that the cold eddy was released and advected by the Kuroshio, on the other hand, the warm eddy remained south of Kyushu Island. The interaction between eddies is likely to be one of important mechanism for triggering the eastward advection of the Small Meander of the Kuroshio south of Kyushu.

The process that cold eddy advected from south to south-east of Kyushu Island could be related to the variation of the flow strength of the Kuroshio. We will study the relationship using the current meter's data. The interaction between flow and eddy are also next work.

The Oceanographic Research Vessel

1. Outline

In recent years, there has been an emphasis on the importance of investigating the various mechanisms of the oceans, which cover 70% of the earth's surface, on a world-wide scale in order to understand global environmental changes such as global warming and the El Niño effect, which are global issues. Therefore, the construction of a vessel that can carry out ocean research and observation in important and fundamental fields such as the role of the oceans in the world's heat cycles and mass transfers, the oceanic ecosystem and the dynamics of the ocean bed in order to explain global changes has been anticipated.

After the Japan Atomic Energy Research Institute donated the hull of the former nuclear powered vessel "Mutsu" to the department at the end of June 1995 following the removal of its nuclear reactor, the oceanographic vessel "Mirai" was delivered to the department on the completion of its refit at the end of September 1997. In FY 1997, the year in which the refit was completed, saw the ship enter the dock for the last time in April, experiments to assess the completed center of gravity, and six sea trials between April and August to check the vessel's functions and performance.

"Mirai" is a large-scale ocean observation and research vessel that aims to carry out long-term ocean observation and research and observation and research of weather conditions safely and efficiently with high levels of precision over wide areas. In particular, the aim is to collect a variety of ocean data at high levels of accuracy from ocean areas about which there is inadequate data due to stormy weather, as well as from the polar regions and equatorial areas, and the vessel began a one year training voyage from October 1997.

Here we will introduce an outline of "Mirai" and those features that deserve special mention.

2. Main Functions and Features of "Mirai"

1) Features of "Mirai"

① Wide-area, long-term observation voyages

The ship's cruising range at 16 kts is about 12,000 nautical miles with a voyage of 60 days, including observation days.

② Superior handling in stormy conditions and ice resistance

The ship is among the world's largest class of observation vessels and uses a newly developed roll reduction device to try to reduce rolling. Envisaging voyages to the North Pole in summer, the hull near the waterline is of an ice resistant construction.

③ Carrying of large-scale observation equipment and machinery and set up and recovery in observation areas

The vessel can carry, set up and recover many large-scale observation buoys (TRITON Buoys), which have been newly developed by the department. In addition, it is also possible to carry and transport equipment such as large scale CTD water samplers, 20m piston core samplers and 6,000m towed vehicle.

④ Construction, inspection and repair of observation instruments in the sea

In order to carry out efficient and meaningful long-term observation voyages, the vessel features the space and facilities needed to construct, inspect and repair observation instruments at sea. In addition, the research support staff needed for this work are regular staff always on board.

⑤ Function and space to allow rapid processing and analysis of collected experimental data at sea

The vessel is equipped with a large variety of the

latest experimental data processing and analysis equipment and has laboratories with the most up to date information processing system.

⑥ Superior handling during observation

Using a diesel electric composite propulsion system with a 2-axle, 2-rudder controllable pitch propeller, the vessel has thrust at the bow and stern. In addition, it uses a joy stick control system and can easily and accurately maintain course and position.

⑦ Joint use research vessel

The operation of the vessel is shared among researchers from related ministries and agencies, universities and government-related bodies in order to carry out ocean research which requires the cooperation of a variety of departments. Therefore, it is equipped with multi-purpose laboratories that can be adapted to new topics and observation activities. In addition, loading of research containers is also possible.

2) Main Functions

① Large-scale buoy handling

The department developed a large-scale ocean observation buoy in order to observe sea conditions and the upper layer of the ocean, and plans to use them in the Pacific Ocean at low through to medium and high latitudes and in the Indian Ocean. In order to house the large scale buoys and to construct them, adjust the observation instruments, lay them and recover them at sea, the housing for the No. 1 and No. 2 mooring buoys, the rope housing and the moored buoy equipment adjustment room are located next to the observation deck. In addition, the vessel is provided with various equipment such as an A-frame crane, mooring cable winding gear, a large scale buoy transport truck, an overhead travelling crane, a lifter and a multi-connection crane so that installing, recovering and moving the buoys can be safely carried out even at high latitudes during stormy weather conditions throughout the year.

② CTD water sampling device handling

CTD is a device that measures the vertical distribution of salinity and water temperature in the sea, which is the most basic ocean observation. We have

installed a rosette sampler (water sampler) on the CTD mounting which can take water samples at the desired depth and carry out various analyses of the collected sea water in the on-board laboratory. The two large-scale CTD water sampling devices and one small-scale water sampling device on "Mirai" can be housed in the sea water processing room and the CTD room respectively. In addition, the vessel is equipped with an A-frame crane, a gallows, a large scale CTD winch, a CTD winch, a lifter and a transport truck so that the devices can be moved, installed and recovered even in stormy weather conditions.

③ Doppler Radar System

This is a device which measures the intensity of rainfall and the speed and direction of rain clouds by emitting radio waves to find out the precipitation mechanism of clouds that form at sea and assess the influence of rainfall on the ocean. Even on board a pitching vessel, it is controlled by a highly accurate inertial navigation device in order to keep the antenna, which is three meters in diameter, in a fixed direction.

④ Laboratories and Observation and Research Facilities

"Mirai" is well equipped with various laboratories designed for the purpose of the research and multi-purpose laboratories that can be used by all researchers. The communal use laboratories include the survey control room, a data processing room and a network control room, the marine research laboratories include a biology/chemistry analysis room, a biological/chemical sample processing room, an analytical darkroom, an auto sal room, a clean room, a CTD room, a surface sea water analysis room, an ocean laser signal processing room, a low temperature experiment laboratory, the weather-related laboratories include the Doppler radar room, a weather observation room, a satellite reception room, an atmospheric gas observation room and a sphere container, the sediment laboratories include wet lab 1, wet lab 2, an X-ray room, a dark room, a sediment sample storage room, a dry lab, a semi-dry lab and a gravity room.

In addition, "Mirai" carries a variety of sound in-

struments. A multi-narrow beam measuring device and a sub-bottom profiler receive sound waves which are regularly emitted from the bottom of the vessel on a multi-channel receiver and in addition to assisting in navigation, can produce a continuous topographical map of the seabed in real time to a depth of 11,000 meters. In addition, through continuous recording of radio waves reflected from beneath the seabed onto a diagram, it is possible to investigate the geological formations up to a depth of several tens of meters beneath the seabed. The sound navigation equipment plots the relative position of the vessel to a transformer attached to the seabed. During regular voyages a transmitter and receptor housed on board the vessel take measurements to a depth of two meters below the bottom of the ship. An acoustic flow meter and tachometer emits sound waves from the bottom of the ship, and, by measuring the Doppler shift of the echo reflected from plankton in the sea, they can measure the direction and speed of the flow to a depth of about 500 meters.

⑤ On board data management system

The vessel is equipped with the world's largest on-board LAN (main network: 100 Mbps, support network: 10 Mbps) on an observation vessel and an on-board CATV, and can create a database from observation data on the on-board data server in real time using a common format and use it for various kinds of analysis. In addition, using the INMARSAT and the N-STAR satellite, it can communicate with laboratories worldwide and with other observation vessels that have the same facilities, over the Internet.

3. Conclusion

"Mirai" will operate out of Sekinehama Harbor in Aomori Prefecture following its one-year training voyage, which came after its transfer. At Sekinehama Harbor work is in progress on shore facilities such as a maintenance shop for observation equipment used on the buoys for marine observation, which is the major mission of the vessel, and a sample analysis building. Performance of "Mirai" and functions, such as the scale of the ship and its performance and the observation equipment it carries, put it in the top class of observation vessels both in Japan and overseas, and, together with the improvements to the shore support facilities and system, it is expected to make a significant contribution to improving Japan's marine observation capacity.

Table 1 Principal Particulars of "Mirai"

Overall Length	128.58m
Length Between Perpendiculars	116.00m
Molded Breadth	19.00m
Molded Draft	10.50m (second deck)
Designed Draft	6.50m
Gross Tonnage	8,672tons
Service Speed	About 16 knots
Endurance	About 12,000 nautical miles
Complement	80 (34 crew, 28 researchers, 18 research support staff)

Technical Information Services

1. Outline of activities

The objective of the activities of Technical Information Services (TIS) is to support the various activities of JAMSTEC and to play the role of a specialist organization for marine science and technology in Japan by providing accurate information promptly on marine science and technology.

The basic tasks of TIS are as follows.

- ① The collection, management and provision of books and publications
- ② Popularization and enlightenment about research results
- ③ Information service activities and cooperation with other organizations
- ④ Transmission of information using the Internet

2. Collection and Management of Books and Publications

TIS holds a wide range of books, journals and technical reports relating to oceanography that have been collected, classified and organized.

We use an information management and supply system (ILIS/X-EL) which has been constructed by TIS to manage and retrieve documents. In addition, we are trying to create an environment in which it is easy to use the library materials by means such as holding library operation meetings.

1) Library material

The library materials as of the end FY 1997 are shown in Tables 1-3.

2) Library operation meetings

TIS has held three library operation meetings based on library material management regulations

Table 1 Books

Type	Number in stock	Newly purchased
Japanese books	6,497	715
Foreign books	2,992	330
Donated books	6,028	444
Total	15,517	1,489

Table 2 Journals

Type	Number in stock	Newly purchased
Japanese journals	501 titles	1 title
Foreign journals	248 titles	5 title
Total	749 titles	6 title

Table 3 JAMSTEC related publications

Type	New publication
Periodic publications	65
Consigned research reports	13
Commissioned research report	0
Total	78

with the aims of reflecting the opinions of users in the management of library material and realizing effective usage of the library's material as specified in the library material management regulations.

3. Collection of Domestic and Overseas Information

The oceans, which cover a wide area of the earth's surface, are still largely an unknown field, and it is clear that ocean related research and development can not be accomplished through the efforts of one organization or one country as in the past. Cooperation of domestic and overseas organizations and cooperation of the related countries at the government level is indispensable. Further, as JAMSTEC's research and development and information needs related to its work become more complex and diverse,

the quantity of information related to marine science and technology is also increasing. In particular, at the present time when research and development activities are becoming integrated, multi-disciplinary and international, it is important to maintain a cooperative relationship with domestic and overseas information-oriented organizations and collect marine related information for the future.

1) Domestic Activities

- ① We took part in the “Domestic Group Exchange of Oceanographic Data” (Secretariat : Hydrographic Department, Maritime Safety Agency) which is a liaison group for oceanographic data in Japan and have obtained information on the existing publications on oceanographic data in Japan and overseas.
- ② We took an active part in the “Kanagawa Prefecture Information Department’s Workshop” (Shinshiken); an organization to exchange data which is composed of companies and public organizations in Kanagawa Prefecture, and we have obtained the latest information about improving the operations of TIS.
- ③ We participated in the “Seminar for Managers and Workers of Special Libraries” sponsored by the Japan Special Libraries Association, a specialist library organization, and in the general assembly, and have obtained the latest information about improving the operations of TIS.

2) International Activities

At present, in response to increasing social impact, such as global environmental problems, there is a worldwide trend toward obtaining information on the condition of the oceans, which cover 70% of the earth’s surface, and facing the problem of human encroachment through cooperation with other countries, and our research and development at JAMSTEC is also undergoing internationalization. Therefore, TIS is developing its information gathering activities based on the view that it is important to obtain information on the leading nations and research organizations of Europe and America, which are the leading countries

in the field of ocean research, along with information on international organizations and trends in international programs.

① Management and Provision of IOC Publications

The Intergovernmental Oceanographic Committee (IOC) is an organization that was established with the aim of furthering knowledge about natural ocean phenomena and marine resources. From FY 1993, JAMSTEC was the second organization to receive IOC publications in Japan.

We published the latest information from the IOC publications we received in the JAMSTEC News “Natsushima”.

② IAMSLIC (International Association of Aquatic and Marine Science Libraries and Information Centers)

IAMSLIC was established in 1975 to promote the exchange of information about marine science and has a membership of about 200 organizations from 38 countries. JAMSTEC is the only Japanese organization and has joined in 1993.

③ ASFA (Aquatic Science and Fisheries Abstracts: a database for marine science and technology)

ASFA is an official database, with the aim of an integrated marine science and technology, promoted by 4 UN organizations (FAO is the Secretariat). TIS cooperates in the construction of the ASFA database by introducing input devices.

④ Information about international organizations and international research programs

We will continue to make efforts to collect information on international organizations and trends in international research projects, as we believe that such information will be important in forming the overall framework for future marine science research.

4. Popularization and Enlightenment about Research results

In FY 1997, we edited and published the publications shown in Table 4 in order to widely disseminate the results of research at JAMSTEC and to increase knowledge about the oceans.

Table 4 JAMSTEC publications

Name of publication	Contents	PY 1997 Publications
Report of Japan Marine Science and Technology Center	Collection of scientific papers of research results	Report No.36 and 37
Collected Abstracts No.8 for Reports No.32 to 35 of Japan Marine Science and Technology Center	Collection of summaries of above (English, Japanese)	No.8
JAMSTEC Journal of Deep Sea Research	Collection of scientific papers on marine survey research results	No.13
Collected Abstracts No.3 for JAMSTEC Journal of Deep Sea Research No.12 to 13	Collection of summaries of above (English, Japanese)	No.3
JAMSTEC	Educational document on marine information	35th to 38th edition
Japan Marine Science and Technology Center Annual Report	Report on the activities of JAMSTEC	FY 1996
JAMSTEC 1996 Annual Report	Report on the activities of JAMSTEC (Annual Report in English)	FY 1996
JAMSTEC Publication List	Collection of research results	FY 1996
JAMSTEC Contributions	Collection of research results bound in book form	FY 1996

5. Research and Information Service

We supply various types of information to people within and outside of JAMSTEC and endeavor to prepare data and information that clients can use effectively.

1) Books and journals

- ① As a general rule, a guide to new publications is published each month in the JAMSTEC News "Natsushima".
- ② The contents service for new journals will be changed from the previous paper notifications to electronic information so that the contents can be viewed on line.

2) Internal-External Database

- ① Implementation of a publication reference service using the information management and supply system (ILIS/X-EL).
- ② Implementation of a substitute reference service using an external database to locate publications not held by JAMSTEC (Table 5).
- ③ Implementation of twice monthly provision of information on special topics, using the SDI service of the Japan Science and Technology Corporation (JICST).
- ④ Frequency of external database usage: 293 times.

3) Current Information

- ① We provide newspaper articles about the oceans daily by "Newsletter".

Table 5 External database usable at present

	Name of database	Outline
①	JOIS	Science & technology and medical document 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 database 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	NACSIS	Database for support of scientific research activities (Japanese/English)

-
- ② We provide an index of newspaper articles once a week as “Newspaper information of the sea”.
 - ③ We regularly supply information on conferences and exhibitions.
 - ④ Information on IOC publications is regularly published in the JAMSTEC News “Natsushima”.

4) Reference Service

- ① Implementation of a reference service for holdings of books, journals and other materials.
- ② Implementation of a consultation and introduction service for external inquiries on marine science and technology.

6. Operation of Information System

1) Improvement of information management and supply system

We made the following improvements to the system that manages the books, journals and other pub-

lications held by JAMSTEC.

- New arrivals information

2) Operation and Maintenance of the Multimedia Information Management and Supply System

We made preparations for the operation of a system which will construct a multimedia database that can input and output photographs, slides and videos.

3) Operation of Internet Web page

We set up a Web Page Editorial Committee in May to create a system which will enable an exchange of views with each department to create an attractive homepage so that transmission of information using the Internet Web page can begin in earnest. While we have completed the renewal of the Japanese page as part of the renewal of the Homepage, we have also established an enlightenment page for young people with the aim of preventing a loss of interest in science and technology among the young.

Scientific Computing Division (S.C.D.)

1. Overview

The former computer center was reorganized on 1 October 1995 as the Scientific Computing Division. The function of this division is to use a supercomputer in conjunction with a mainframe, a workstation, and other computers to analyze oceanographic data, visualization numerical results, and provide data management and database access. The Scientific Computing Division also manages and operates the JAMSTEC computer system and network, researches new computer technology, and engages in other efforts aimed at improving the contribution of computers to oceanographic science.

The principal activities of the Scientific Computing Division are as follows.

- Construction of an oceanographic database
- Support for data processing activities carried out on computers work by the Scientific Computing Division but used as a common resource by all JAMSTEC divisions (oceanographic data, ocean bottom mapping data, etc.)
- Maintenance, management, and operation of computer system and networks
- Management and operation of JAMSTEC's Internet (STAnet) operations, and maintenance of Internet security
- Support for supercomputer users to modeling calculation for big oceanographic model and seismic analysis
- Supercomputer management and operation
- Training for computer Software and Hardware
- Research and development for a management system of, and provision of access to, online oceanographic data (performed on contract)
- Research on how to display the ocean bottom profile using (ocean bottom mapping data) (joint re-

search project)

- Use of the mode theory for research on acoustic propagation analysis in the ocean (research based on working expenses.)

Computer networks in the past were used only for numerical calculation, but they have recently become a tool for file transfer, e-mail, and other forms of communication between researchers throughout the world. As such, they are an indispensable part of any research effort. To meet the need for network access, the Scientific Computing Division maintains and operates servers, an extranet, and JAMSTEC's Internet connections to ensure that the organization can enjoy consistent and reliable networking capabilities.

In addition, Japan and the United States are currently engaged in a joint project called the Global Observation Information Network (GOIN). In 1995, JAMSTEC participated in a joint demonstration which was attended by high-ranking officials from both countries. JAMSTEC has since taken part in GOIN workshops in 1996 and 1997, at which our organization made presentations on, among other things, the deep sea image database.

2. Computer usage and maintenance

1) Supercomputer system

① Supercomputer

In order to achieve a scientific understanding of global warming and other global environment problems, it is important that we understand the role played by the oceans in the global environment. So not only must we be able to measure oceanographic data with precision, but we must also be capable of using mathematical analysis to understand marine phenomena. Furthermore, we must be able to use numerical modeling to accurately describe a wide variety of physical phe-

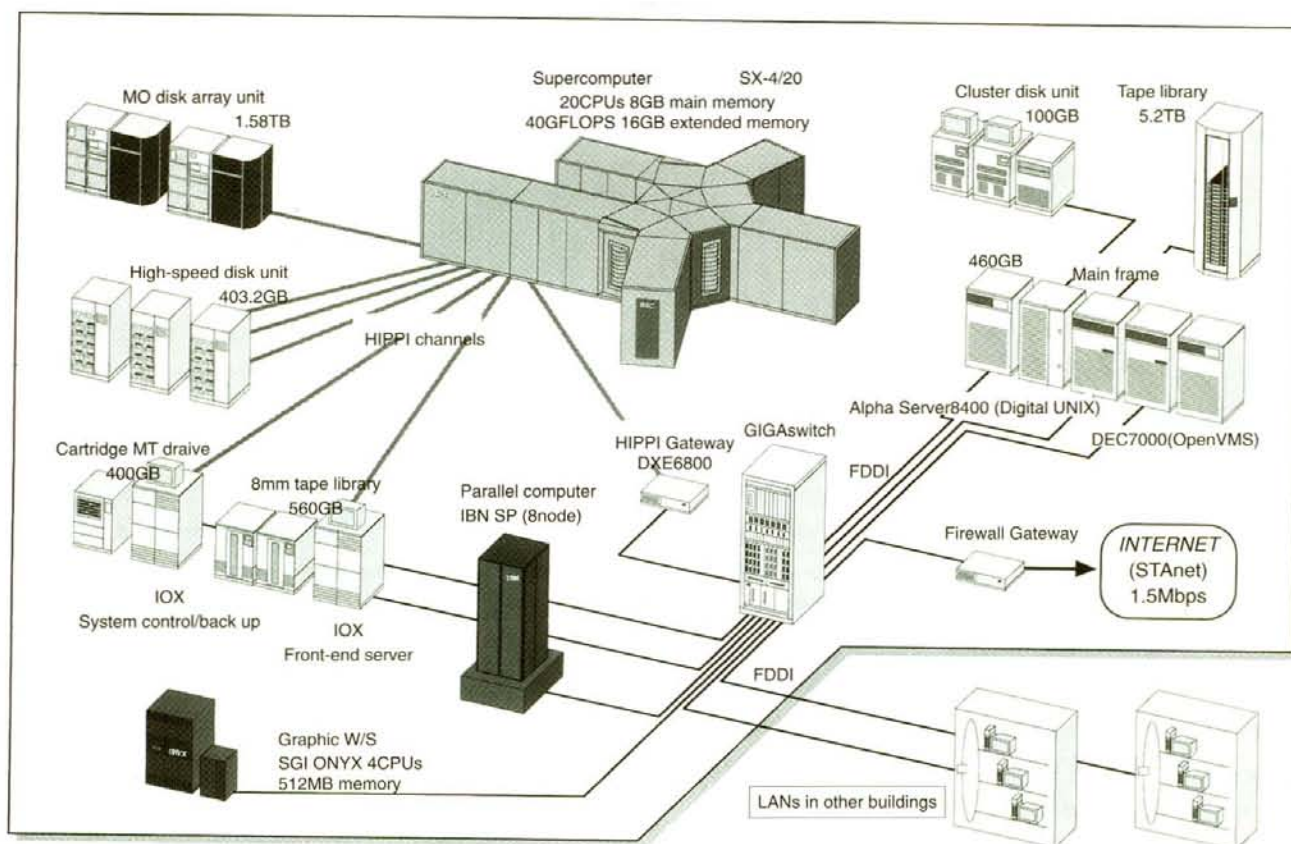


Fig.1 General outline of the computer system in JAMSTEC

nomena, and to forecast changes in these phenomena. Since a supercomputer with a large memory capacity is needed to carry out such modeling efficiently, purchase of a supercomputer by JAMSTEC was approved in the FY 1995 budget, and the computer commenced operation on 1 March 1996.

As shown in Fig. 1, the supercomputer system comprises a an SX-4/20 supercomputer, a 1.58 TB magento-optical disk array unit, and a 400 GB high-speed harddisk array unit. Its front-end access is connected by an 800 Mbps HIPPI channel, and the supercomputer is also connected to the existing local network by an FDDI cross bar switch (GIGAswitch). The principal specifications of the supercomputer are listed in Table. 1.

② Image analysis and visualization unit

An ONYX visualization unit (R4400×4 CPUs) from Silicon Graphics is used to display in graphic format the results of supercomputer analysis. This unit is connected via FDDI to the local network.

Table 1 Specifications of SX-4/20

CPU		
Number of CPUs	20	
Peak vector performance	40GFLOPS	
Peak scalar performance	5GFLOPS	
Main memory		
Capacity	8GB	
Data transfer speed	320GB/sec	
Extended memory		
Capacity	16GB	
Data transfer speed	8GB/sec	
I/O channels		
HIPPI channels	8pairs	
Data transfer speed	1.6GB/sec	

Four Indy workstations and one Indigo2 workstation, all from Silicon Graphics, are connected to the ONYX system, and are available for use by research-

ers. In addition, the Image Analysis Division is equipped with a Picrography 3000 color printer, a Professional Color Point2 PSFJ color printer, and a QMS 1060 printer. This equipment makes is easy to produce high-quality output.

③ Image editing unit

There are many times when oceanographic data are most easily understood when they are displayed in animated format. The simulation of ocean currents is one such example. For this purpose, S.C.D. has digital betacams and other image editing equipment on hand to convert the results of ONYX visualization unit into image frames. Digital image data can be taken straight from the ONYX system, and recorded and edited on this equipment without any image deterioration. In addition to having the ability to cut our digital betacam data, JAMSTEC's other image editing equipment includes the betacam SP, S-VHS, Hi8, CDs, cassette tapes, and MDs.

2) Common use computer system

Table 2 shows list of the common use computers for JAMSTEC researchers. JAMSTEC has always used VMS as its operating system of choice for a wide variety of applications. Accordingly, the Scientific Computing Division is equipped with two DEC7620

units running on Open VMS Alpha, and another such unit running on Open VMSVAX. The three of these units together thus provide a VMS cluster environment. In response to growing demand for a UNIX server, the S.C.D. has also installed an Alpha Server 8400 running on Digital UNIX. In addition, the S.C.D. also acquired an eight-node IBM SP distributed-memory parallel computer in 1996. JAMSTEC is currently studying how to use parallel computing to support modeling of ocean currents on a larger scale and at higher speeds, and the IBM SP system is being used to test the effectiveness of various approaches to this problem. The S.C.D. is also equipped with a backup power supply system to ensure that the common use computer system, including the network devices, is never hit by power outages.

This computer system is used by the entire JAMSTEC organization. As of the end of FY 1997, the system supported 480 registered e-mail users.

3) JAMSTEC networks

① Yokosuka intranet

The first heavy-duty intranet at JAMSTEC was established in 1993. Anchored by an FDDI cross bar switch (GIGAswitch) located in the S.C.D. building where the host computer is installed, the network

Table 2 JAMSTEC Computer System

	msthal	mstkid	msteps	mstgrt	mstunx	mailgate	mstsx4	watatumi	mstsp
Model	DEC7620	DEC7620	VAX4100	AlphaServer8400	AlphaStation200	AlphaStation200	NEC/SX4	ONYX	RS/6000SP
OS	OpenVMSAlpha	OpenVMSAlpha	OpenVMSVAX	DigitalUNIX	DigitalUNIX	DigitalUNIX	SUPER-UX	IRIX	AIX
No. of CPUs	2	2	1	2	1	1	20	4	8nodes
Memory	1GB	512Mb	64MB	512MB	192MB	64MB	8GB	512MB	128MB×8
Disk	52GB	-	4.2GB	464GB	8GB	4GB	403GB	20GB	4.5GB×9
	48GB cluster disk								90GB
Peak performance	364MFLOPS	364MFLOPS		1.2GFLOPS	94MFLOPS		40GFLOPS		480MFLOPS×8
Back up	Back up tape unit(TZ867)		DAT	Backup tape unit(TL820)			8mmTape	(TL820)	8mmTape
Purpose	Server for computing operations	Backup server	EPIC processing unit	File server	Network server	Mail server	Vector computing	Image analysis, computing	Parallel computing
	Computing on the Alpha VMS		Computing on VAX/AMS	Computing on UNIX		POP mail server	Enables high-speed vector computing	Used principally for processing graphics	For researching the use of distributed-memory parallel computing

employs a 100 Mbps FDDI trunk line (optical cable) to link different buildings together, while an Ethernet branch line (10base-T) links up to a LAN within each building. By plugging into modem jacks located in their offices, users can use the JAMSTEC network to access the Internet. Internet access takes place via a firewall to ensure security.

The number of the workstations and other types of computers connected to the intranet has been rising steadily. As of the end of FY 1997, connected devices included approximately 100 servers and workstations, 580 Macintosh computers, 170 Windows machines, and 110 X-terminals.

② Outside network of Yokosuka

Fig. 2 shows the current configuration of the Outside network of Yokosuka. The Outside network of Yokosuka at first consisted only of an ISDN line established in 1994 to connect the Tokyo Office to the Yokosuka intranet. Later, after the Tokyo Office moved to Hamamatsu-cho, both that office and the "Frontier" Research Promotion Department were connected to the Yokosuka intranet via a 128 kbps

line. Mutsu Branch was connected to our intranet via a 64 kbps line in March 1996. All JAMSTEC networks are now able to exchange files with the Yokosuka head office, and to access the Internet.

③ Ship mail system

Four research vessels in the JAMSTEC fleet ("Yokosuka", "Kairei", "Mirai", and "Natsushima") use an e-mail system based on satellite communications (Inmarsat and N-star). This system enables personnel aboard these ships not only to communicate with the JAMSTEC head office, but also to send and receive e-mail via the Internet.

We used this system to transfer images of survey operations involving the Nakhodka and the Tsushima-maru. These images enable JAMSTEC personnel on land to watch the progress of the surveys in quasi-real times.

4) Internet

① STAnet

JAMSTEC began using the Internet in January 1993 when we established a 64 kbps connection to

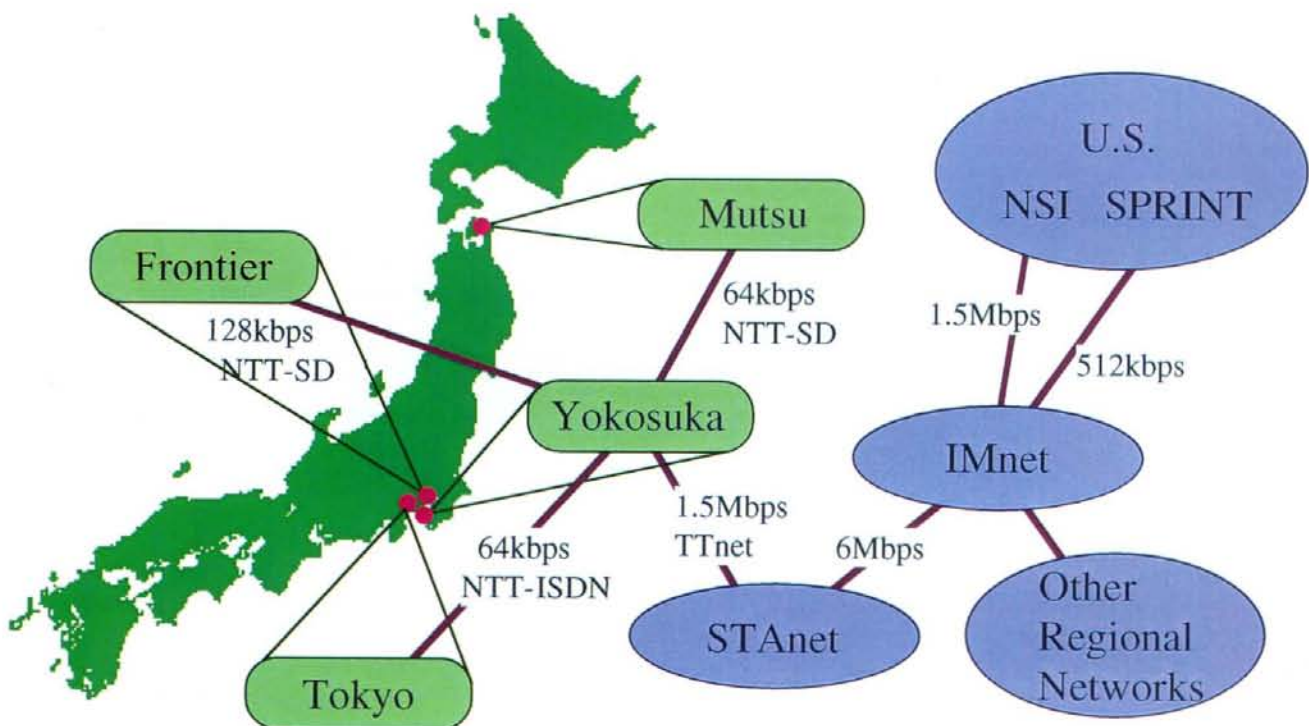


Fig. 2 Network Topology

the Tokyo University International Science Network (TISN), which is run by the Faculty of Science at Tokyo University. This connection enabled our organization to communicate via computer network with other research institutions throughout the world, and we continued to use it until TISN was closed down in March 1996. In the meantime, however, we had already begun in October 1994 to use STAnet, a network set up under the auspices of the Science and Technology Agency for use by research organizations. We joined a 768 kbps connection the STAnet, which was improved in July 1996 to 1.5 Mbps. This high-speed connection has enabled JAMSTEC to make effective use of the Internet for the transmission of high-bandwidth items such as graphics data and moving images.

② World Wide Web (WWW) server

JAMSTEC installed a Web server and established an English-language homepage (shown in Fig. 3) in September 1994. We then established a Japanese version of our homepage in 1995, which has brought greater numbers of log-ons from within Japan. Monthly access figures for the JAMSTEC Web server are shown in a graph in Fig. 4.

The number of log-ons has varied dramatically in connection with Web site additions (such as pages focusing on the sinking of the Nakhodka, research on deep sea life, the sinking of the Tsushima-maru) and revisions. The pages on the Nakhodka and the Tsushima-maru provide quasi-real time access to images of ongoing seuever operations.

To visit the JAMSTEC homepage, point your browser to <<http://www.jamstec.go.jp/>>.

5) Database development

In addition to developing the databases listed below, the S.C.D. is also working to convert the information in these databases to a format that is accessible via the Web browsers.

① Ship operations database

This database contains information on the operations of the ships, research submersible vessel, and remotely operated vehicle in the JAMSTEC fleet. This database originally ran on a VAX system, but a Web version was introduced in 1996.

② Deep sea image database

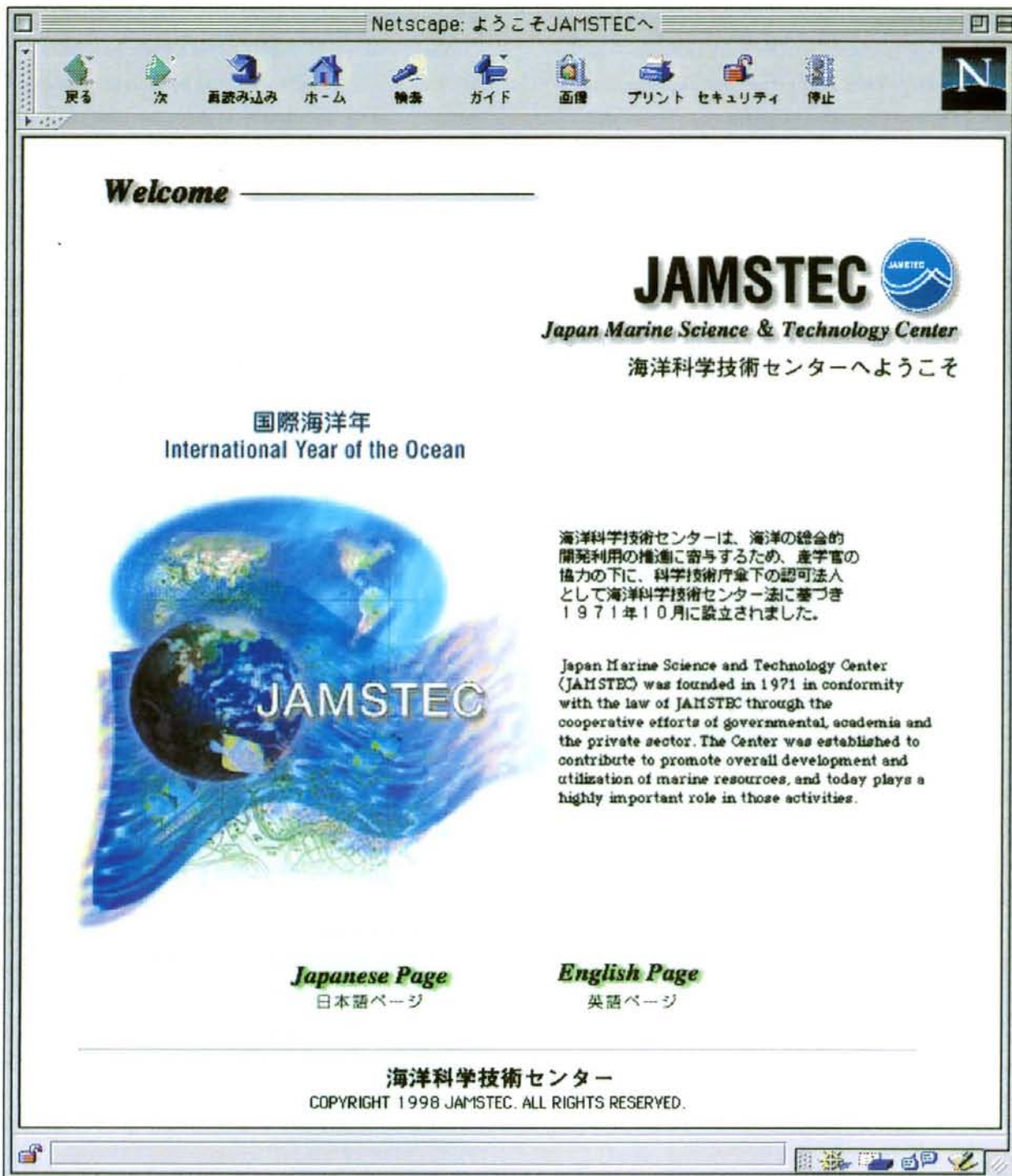
This database contains images (photo slides) obtained by our research submersible vessel and remotely operated vehicle. These images have always been made available to the public in Macintosh format thus far, but we are now developing a Web version of these images, and are adding the JAMSTEC logo through the Internet.

③ Marine observation database

This database (prototype) is used to manage and provide access to the various data obtained by our various ships during marine observation operations. This database is also installed on the our research vessels ("Mirai" vehicle and "Kairei") and part of it has been converted to Web format.

④ Document database

This database was formerly kept on a computer running on a VAX operating system, but we have since switched to a distributed database system running on dedicated work stations. As before, any computer connected to the Yokosuka network can access this database.



<http://www.jamstec.go.jp/>

Fig. 3 JAMSTEC Home Page

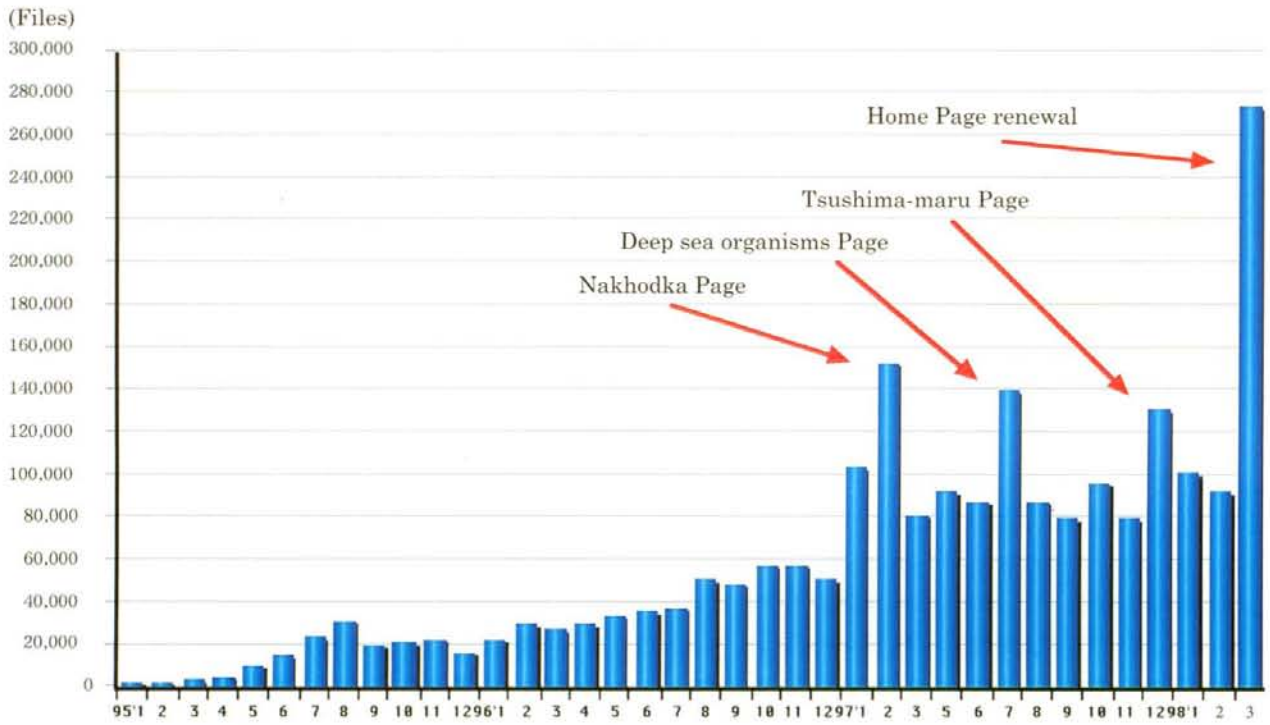


Fig. 4 Monthly access figures for the JAMSTEC Web server

Ship Operations Department

JAMSTEC "Shinkai 2000" system comprises "Shinkai 2000" (research submersible), "Natsushima" (a support vessel), and "Dolphin-3K" (ROV). "Shinkai 6500" system comprises "Shinkai 6500" (research submersible) and "Yokosuka" (a support vessel). JAMSTEC fleet also includes "Kaiko" (ROV), "Kaiyo" (an ocean research vessel), "Kairei" (a deep sea research vessel completed in March 1997), and "Mirai" (an oceanographic research vessel completed in September 1997). The fleet is used to carry out a wide range of deep sea surveys, tests, and research connected with marine science and technology.

JAMSTEC is in direct charge of the operation as well as daily maintenance and repair of the research submersibles and ROVs, while it contracts out to a ship operating company the operation and general maintenance of its support vessels and oceanographic research vessels.

Fleet operations in FY 1997 are described here below. "Shinkai 2000" operated both in Japanese and international waters. Operations off the Japanese coast were carried out in Suruga Bay, Sagami Bay, Enshu Nada, Nankai Trough, Nansei Islands, the Japan Sea, and in Izu - Ogasawara Islands. Internationally, the ship conducted diving surveys in and around the Mariana Islands.

"Dolphin-3K" was used to carry out preparatory dives to ensure the safety of diving routes selected for "Shinkai 2000". It was also used for surveys in Kagoshima Bay, Sagami Bay, Enshu Nada, and Nankai Trough. Surveying of the submerged section of "Nakhodka" continued in FY 1997, and "Dolphin-3K" was used for this survey, as well as for a survey of "Tsushima-maru", which sank during World War II while evacuating children from Okinawa.

"Natsushima" served as a support vessel for dives conducted by the aforementioned "Shinkai 2000" and

"Dolphin-3K". In addition, "Natsushima" was also used to carry out maintenance and inspection of the Okinotorishima Islands Observation System.

"Kaiyo" was used for a wide range of observation tasks, including ongoing tropical observation, tomography observation techniques, and TOCS and subtropical observation. "Kaiyo" also used Deep Tow and the multi-narrow beam echo sounder to carry out deep tow operations in Nansei Islands and off Shikoku.

"Shinkai 6500" was used to conduct diving surveys in Izu - Ogasawara Islands, off Sanriku, Japan Trench, Nankai Trough, Nansei Islands, and East Pacific Rise.

In addition to supporting dives by "Shinkai 6500", R/V "Yokosuka" was used to conduct surveys in Izu - Ogasawara Islands, and was also used to carry out tests involving an ocean floor observation station run by JAMSTEC.

"Kaiko" was placed on board "Kairei" at the beginning of FY 1997. After tests in Suruga Bay and Nansei Islands to prove its seaworthiness, "Kaiko" was used off Shikoku, in Nankai Trough, in Nansei Islands, and in Japan Trench off Sanriku region, to train personnel in diving survey techniques. "Kaiko" was also used in Nansei Islands in conjunction with a launcher tow to survey the sunken remains of "Tsushima-maru".

After construction of "Kairei" was completed in March 1997, the ship used to support dives made by "Kaiko". In addition, training was also carried out to acquaint personnel with the operation of various equipment on board "Kairei", such as the multi-channel seismic profiler and the piston core sampler. To instruct personnel how to use a multi narrow beam echo sounder, gravimeter, and magnetometer, training was also carried out in Izu Islands, Ogasawara Islands, Mariana Islands, and western Pacific Ocean.

Construction of "Mirai" was completed in September 1997, then the ship's equipment was put through comprehensive tests in the waters off Japan's Kanto region. After completion of the tests, personnel were trained how to use the ship's observation equipment in a number of different locations, including the north-

ern Pacific Ocean, off Sanriku, Ogasawara Islands, sub tropical, and tropical equator area.

Maintenance of the vessels was carried out, as in previous years, according to a regular maintenance schedule, and modifications were made to improve performance.

“Shinkai 2000” “Dolphin-3K” & S/V “Natsushima”

Voyage	Cruise Period	Cruise Objective (Area of Operation)	Port of call	Chief Scientist
NT97-06	1 Apr. - 17 Apr.	[Sinkai 2000] Training dives (Suruga Bay, Nankai Trough)	Shimizu Toyohashi	
NT97-07	21 Apr. - 28 Apr.	[Dolphin-3K] Training dives (Nankai Trough, Enshunada)		
NT97-08	12 May. - 22 May.	[Shinkai 2000] Research dives (Suruga Bay, Sagami Bay)		M.Hattori (JAMSTEC)
NT97-09	26 May. - 30 May.	[Dolphin-3K] Research dives (Suruga Bay)		J.Hashimoto (JAMSTEC)
NT97-10	2 Jun. - 26 Jun.	[Shinkai 2000] Research dives (Izu, Ogasawara)		A.Inoue J.Hashimoto (JAMSTEC)
NT97-11	27 Jun. - 6 July.	[Dolphin-3K] Research dives (Sagami Bay, Nankai Trough)		K.Fujikura M.Hattori (JAMSTEC)
NT97-12	10 July. - 24 Aug.	[Shinkai 2000] Research dives (Sagami Bay, Nankai Trough, Off kyoto, Off Hokkaido)	Shimizu Maizuru Hakodate	S.Kuramoto*1 A.Takeuthi*2 others.
NT97-13	31 Aug. - 4 Sep.	[Dolphin-3K] Research dives (Kagoshima Bay)		M.Hattori (JAMSTEC)
NT97-14	7 Sep. - 14 Oct.	[Shinkai 2000] Research dives (Amami Islands)	Nase Kagoshima Ishigaki	H.Tiba*3 T.Miura*4 others.
NT97-15	22 Oct. - 5 Dec.	[Shinkai 2000] Research dives (Mariana Islands)	Futami Guam	J.Naka (JAMSTEC)
NT97-16	8 Dec. - 19 Dec.	[Dolphin-3K] Research dives (Nansei Islands)	Naha	
NT98-01	12 Feb. - 23 Feb.	[Natsushima] Research of marine automatic observation technique (Okinotorishima Islands)		I.Nakano (JAMSTEC)
NT98-02	26 Feb. - 1 Mar.	[Dolphin-3K] Test dives (Sagami. Bay)	Shimizu	
NT98-03	5 Mar. - 8 Mar.	[Dolphin-3K] Research dives (North-Northeast off Oki Island)	Maizuru	
NT98-04	12 Mar. - 21 Mar.	[Natsushima] Research of zooplankton (Off Sanriku)	Hakodate	S.Katou (JAMSTEC)
NT98-05	25 Mar. - 30 Mar.	[Shinkai 2000] Test dives (Sagami Bay)		

*1 : Geological Survey of Japan *2 : Toyama Univ. *3 : Kyushu Univ. *4 : Kagoshima Univ.

R/V “Kaiyo”

Voyage	Cruise Period	Cruise Objective (Area of Operation)	Port of call	Chief Scientist
KY97-04	4 Apr. - 9 Apr.	Development of acoustic data transmission system (Sagami Bay)		T.Tsuchiya (JAMSTEC)
KY97-05	15 Apr. - 28 Apr.	Deep-sea survey (Off Shikoku, Sagami Bay)		T.Momma (JAMSTEC)
KY97-06	9 May. - 14 May.	Development of buoy system (Ogasawara Islands)		T.Tsuchiya (JAMSTEC)
KY97-07	26 Jun. - 15 July.	Tomography (Izu-Ogasawara Islands)		I.Nakano (JAMSTEC)
KY97-08	18 July. - 24 July.	Tomography (Izu-Ogasawara Islands)		I.Nakano (JAMSTEC)
KY97-09	24 July. - 8 Sep.	TOCS (Western Tropical Pacific)	Guam Truk Palau	N.Yoneyama K.Andou (JAMSTEC)
KY97-10	20 Sep. - 4 Oct.	Tomography (Izu-Ogasawara Islands)		N.Nakano (JAMSTEC)
KY97-11	13 Oct. - 30 Oct.	Deep-sea survey (Off Kushiro, Off Sanriku)		J.Hashimoto S.Kodaira (JAMSTEC)
KY97-12	7 Nov. - 23 Nov.	Tomography (Izu-Ogasawara Islands)		I.Nakano (JAMSTEC)
KY97-13	7 Dec. - 26 Dec.	Bio-optical observation in the equatorial Pacific (Equator of Tropical zone)		T.Kawano (JAMSTEC)
KY98-01	3 Jan. - 14 Feb.	TOCS (Western Tropical Pacific)	Majuro	K.Andou T.Yano (JAMSTEC)
KY98-02	1 Mar. - 10 Mar.	Sub Tropical circulation study (Izu-Ogasawara Islands)		Y.Yoshikawa (JAMSTEC)
KY98-03	16 Mar. - 20 Mar.	Versatile eco-monitoring network by undersea cable system (VENUS Project) (Nansei Islands)		H.Momma (JAMSTEC)
KY98-04	26 Mar. - 6 Apr.	Deep-sea survey (Nansei Islands, Off Muroto)		H.Momma (JAMSTEC)

TOCS : Tropical Ocean Climate Studies

“Shinkai 6500” & S/V “Yokosuka”

Voyage	Cruise Period	Cruise Objective (Area of Operation)	Port of call	Chief Scientist
YK97-04	13 May. - 12 Jun.	[Shinkai 6500] Research dives (Izu-Ogasawara Islands, Japan Trough)	Futami Shiogama	I.Sakamoto (JAMSTEC) J.Segawa*1 K.Tamaki*2
YK97-05	10 July. - 13 Aug.	[Shinkai 6500] Research dives (East Pacific Rise)		T.Urabe*3
YK97-06	17 Aug. - 19 Sep.	[Shinkai 6500] Research dives (East Pacific Rise)		K.Fujioka (JAMSTEC)
YK97-07	14 Oct. - 26 Oct.	[Shinkai 6500] Research dives (Nankai Trough)	Shimizu	E.Tokuyama*2 (JAMSTEC)
	27 Oct. - 14 Nov.	[Yokosuka] Versatile eco-monitoring network by undersea cable system (Nansei Islands)	Naha	T.Matsumoto (JAMSTEC)
YK97-08	22 Nov. - 24 Nov.	[Yokosuka] UROV-7K Test dive (Sagami Bay)		T.Aoki (JAMSTEC)
YK97-09	4 Dec. - 7 Dec.	[Yokosuka] Buoy-Satellite Observatory set up (Sagami Bay)		H.Momma (JAMSTEC)
YK97-10	8 Dec. - 25 Dec.	[Yokosuka] Geophysical surveys of the bottom topography (Izu-Ogasawara Islands)	Hachijyojima	I.Sakamoto (JAMSTEC)
YK98-01	9 Jan. - 11 Jan.	[Yokosuka] Buoy-Satellite Observatory recovery (Izu-Ogasawara Islands)		H.Momma (JAMSTEC)
YK98-02	16 Jan. - 15 Feb.	[Yokosuka] Versatile eco-monitoring network by undersea cable system (Off Sanriku, Japan Trench, Off Boso)	Onahama Shiogama Naha	H.Momma (JAMSTEC)
YK98-03	27 Feb - 10 Mar.	[Shinkai 6500] Test dives (Nansei Islands)		
YK98-04	12 Mar. - 29 Mar.	[Shinkai 6500] Test dives (Nansei Islands)	Naha	

*1 : Tokai University

*2 : Ocean Research Institute, University of Tokyo

*3 : Geological Survey of Japan

“Kaiko” & R/V “Kairei”

Voyage	Cruise Period	Cruise Objective (Area of Operation)	Port of call	Chief Scientist
KR97-01	1 Apr. - 3 Apr.	Cruising	JAMSTEC	
KR97-02	13 Apr. - 13 May.	[Kairei] Acoustic navigation, Multi narrow beam echo soubbotom profiler, MCS test and training (Nankai Trough, Zenisu Ridge)	Shimizu	
KR97-03	20 May. - 23 Jun.	[Kaiko] performance test Acoustic navigation performance test (Izu-Ogasawara Islands, JAMSTEC wharf, Suruga Bay)	Shimizu Naha	
KR97-04	25 Jun. - 22 July.	[Kairei] OBS set up, MCS training (Off Sikoku)	Kochi Komatujima	H.Amano (JAMSTEC)
KR97-05	29 July. - 25 Aug.	[Kaiko] Training dives (Off Muroto, Nankai Trough)	Owase	
KR97-06	28 Aug. - 27 Sep.	[Kaiko] Training dives (Nansei Islands, Nankai Trough)	Naha Shimizu	
KR97-07	30 Sep. - 18 Oct.	[Kairei] OBS set up and recovery MCS pre-survey (Off Sanriku, Japan Trough)	Miyako	S.Kodaira (JAMSTEC)
KR97-08	28 Oct. - 10 Nov.	[Kairei] Opening ceremony preparing (Tokyo, JAMSTEC, Mutsu citiy)	Harumi JAMSTEC Sekinehama	
KR97-09	10 Nov. - 28 Nov.	[Kaiko] Research dives (Off Sanriku, Japan Trough)	Miyako	M.Hattori (JAMSTEC)
KR97-10	1 Dec. - 7 Dec.	[Kairei] [Kaiko] Deep-sea survey (Nansei Islands)		
KR97-11	10 Dec. - 28 Dec.	[Kairei] Deep-sea survey training (Izu-Ogasawara Islands)		J.Naka (JAMSTEC)
KR98-01	6 Jan. - 27 Jan.	[Kairei] Deep-sea survey training (Mariana trench, Western pacific ocean)		K.Fujioka (JAMSTEC)
KR98-02	6 Mar. - 9 Mar.	[Kairei] Bouy-Satellite Observatory (Off Muroto)		H.Momma (JAMSTEC)
KR98-03	11 Mar. - 30 Mar.	[Kaiko] Training dives (Nansei Islands)	Naha	

MCS : Multichannel seismic profiler

OBS : Ocean bottom seismogrph

R/V “Mirai”

Voyage	Cruise Period	Cruise Objective (Area of Operation)	Port of call	Chief Scientist
MR97-00	1 Oct. - 19 Oct.	[Mirai] All machine apparatus operation test (Vicinity Area off Kanto)		
MR97-01	28 Oct. - 10 Nov.	[Mirai] Opening ceremony preparing (Tokyo, JAMSTEC, Mutsu city)	Harumi JAMSTEC Sekinehama	
MR97-02	10 Nov. - 6 Dec.	Ocean observation instruments (Water sampler) training (North Pacific Ocean)	Shimizu Naha	M.Kusakabe (JAMSTEC)
MR97-03	6 Dec. - 18 Dec.	[Mirai] Opening ceremony preparing (Kobe, Sasebo)	Kobe Sasebo	
MR97-04	22 Dec. - 16 Jan.	Ocean observation instruments (Piston corer sampler) training (Ogasawara Islands)	Simizu	H.Yamamoto (JAMSTEC)
MR98-01	23 Jan. - 27 Feb.	Training research primary production and sample processing (Sub Tropical Equator Area)	Majuro Honolulu	T.Kawano (JAMSTEC)
MR98-02	1 Mar. - 27 Mar.	TRITON Buoy set up and training (Tropical and Equator Area)	Chhuk	Y.Kuroda (JAMSTEC)

TRITON : Triangle Trans-Ocean Buoy Network

Training and Education Division

1. Overview

The Training and Education Division of JAMSTEC currently provides education and training for technicians, researchers, and others whose work involves diving and oceanographic research. At the same time, safety and health education are provided for diving site supervisors, and experience diving is provided for divers and beginner-level diving students. We also began in 1995 to carry out Marine Science and Technology education campaigns and training programs for high school students and teachers in order to raise the level of public understanding concerning oceanography.

As last year, we offered two types of special diving training (Driving technology courses and experience diving) together with Diving Management Courses. We also carried out Science Camp '97 for high school students, while for high school students and high school teachers we offered Marine Science School '97. These activities were supported by the Nippon Foundation.

1) Special training

① Diving technology courses

These are basically five-day courses, though they sometimes run for ten days. The objective is to provide trainees with basic scuba diving knowledge and skills. A total of 191 trainees from the National Police Agency and 21 other organizations took the courses this year.

② Experience diving

This course gives persons with no diving experience a chance to dive in a pool. This year's course lasted two days, and was attended by 21 persons from the Science and Technology Health Association.

2) Diving management courses

These courses are open to the employees of diving companies and other companies with a connection to diving operations. Course content focuses on the entire range of diving management issues, including diving-related safety and health questions, the basics of saturation diving, and the current state of diving work overseas. The course was held twice this year, and was attended by 25 persons from 16 different organizations.

3) Science Camp '97

Under the joint sponsorship of the Science and Technology Agency (STA), the Japan Science and Technology Corporation, and the Japan Science Foundation, the Science Camp has been held every year since 1995 by five STA-affiliated corporations and five research institutes. A two-night, three-day camp was held this year on 23-25 July. The camp's 25 participants (8 male and 17 female high school and vocational school students) were selected from among 74 applicants on the basis of essays submitted by the applicants. In addition to learning about various research projects being carried out by JAMSTEC, the participants also carried out actual experiments at our research facilities. The purpose of these activities was to encourage greater interest among the participants in marine science and technology.

4) Marine Science School '97

In an effort to spur greater interest in, and understanding of, the ocean among high school students and teachers, JAMSTEC holds the Marine Science School every year with the help of financial support from the Nippon Foundation. The most distinctive aspect of this school is the fact that all participants come from the restricted region of Japan, and not only

students but also teachers can take part. Three-night, four-day sessions were held three times this year during the spring and summer breaks. They were attended by 39 high school teachers and 24 high school students from eight of Japan's southern prefectures (Oita, Miyazaki, Kagoshima, Okinawa, Kochi, Ehime,

Nagasaki, and Kumamoto). Participants heard JAMSTEC researchers speak about their research, and they also had many chances to try their hand at laboratory work. Each session was very successful, and served to heighten the interest of participants in what we do at the JAMSTEC.



Photo 1 Getting hands-on experience of ROV “Kaiko” operation in the control room of R/V “Kairei”

Mutsu Branch

1. Outline of the Activities of Mutsu Branch

Mutsu Branch was established on October 1, 1995 as the first regional branch of JAMSTEC to support the operation of the oceanographic research vessel "Mirai", which was commissioned in October 1997 using Sekinehama Harbor in Mutsu city as her home port.

The current activities of Mutsu Branch are as follows.

- Construction and operation of facilities for the "Mirai"'s research.
- Public relations about the "Mirai"'s smooth operations.
- Management of Mutsu Branch.

1) Construction and operation of facilities

In order to clarify the mechanisms of global climate change, "Mirai" undertakes observation cruises covering the Pacific Ocean and the Indian Ocean, collects data and samples, and engages in research. The primary mission of "Mirai" is to install and recover TRITON buoys, observation buoys to be used in western equatorial and mid-latitude Pacific Ocean waters. The TRITON buoy will be a powerful tool, yielding a clear picture of the warm water masses that have a significant relationship to El Niño phenomenon.

Maintenance and storage of the observation buoys is in the observation equipment maintenance shop (a three storied steel structure with a partial well; total area: 3,046 m²) which was completed in fiscal year 1996. In addition, they carry out sensor calibration for the observation buoys using an observation equipment and machinery maintenance and control system.

Further, reception, processing and management of data from the observation buoys has been ongoing

since March 1998.

The sample analysis building (a two-storied reinforced concrete structure, total area: 1,943 m²) on which work began in the previous fiscal year will be used for the processing of data from the TRITON buoys and from the "Mirai", and to analyze and store samples. Work on the main structure was completed in February 1997 while the sea water pre-processing system set up inside the building was completed at the end of March 1998.

Additionally, the management of Mutsu Branch has leased a former data building from the Japan Atomic Energy Research Institute(JAERI) to use as an administration building.

2) Public Relations

It is indispensable to have the full understanding and cooperation of the citizens of Mutsu city, "Mirai"'s home port, so that its mission can go ahead smoothly. The PR work of Mutsu branch publicizes the results of and hopes for marine science and technology, targeting all the citizens of Mutsu city, and especially the young people, who hold the key to the future.

Accordingly, in November 1997, we opened the research vessel "Mirai" and the deep-sea research vessel "Kairei" to the public in Sekinehama Harbor, and about 8,000 people visited them.

In addition, as in the previous fiscal year, we held the third "Hagaki ni Kakou Kaiyou no Yume" (Ocean Dream Postcard) competition for elementary and junior high school students in Mutsu city and received many entries.

Further, we have been aiming to promote understanding of marine research by displaying the results of JAMSTEC's research, such as a deep-sea georama and a seabed station, at the neighboring JAERI's Mutsu Science Museum.

2. Provision of Facilities and Equipment at Mutsu Branch

1) Buildings

In preparation for the beginning of “Mirai”’s research and observation cruises, Mutsu Branch has leased part of the grounds of JAERI and has built a sample analysis building.

The sample analysis building was constructed with contract authorization in FY 1996 and 1997, and work on the main structure was completed in December 1997. The sea water pre-processing system, an important piece of equipment in the sample analysis building, was completed in March 1998 (Table 1, Pho-

tograph 1).

Meanwhile, as in the previous fiscal year, Mutsu Branch has continued to use the former data building leased from JAERI as an administration building (Table 1, Photograph 1 and Figure 1).

2) Equipment

In addition to the construction of the sea water pre-processing system, which is an important piece of equipment in the sample analysis building, we have implemented a data processing and management system and a LAN system (Table 2).

Table 1 The Provision of Research Facilities at Mutsu Branch

(Unit : m)

Classification of building	Specification	Architectual area	Fiscal Year for improvement	Remarks
Observation machine and material maintenance shop	Three-storied steel structure with partial a well	3,046.26	FY of 1995 and 1996	The old archives owned by JAERI was borrowed and remodeled
Administration building	Two-storied reinforced concrete structure	521.90	FY of 1996	
Sample analysis building	Two-storied reinforced concrete structure	1,942.59	FY of 1996 and 1997	



Photo 1 Sample analysis building

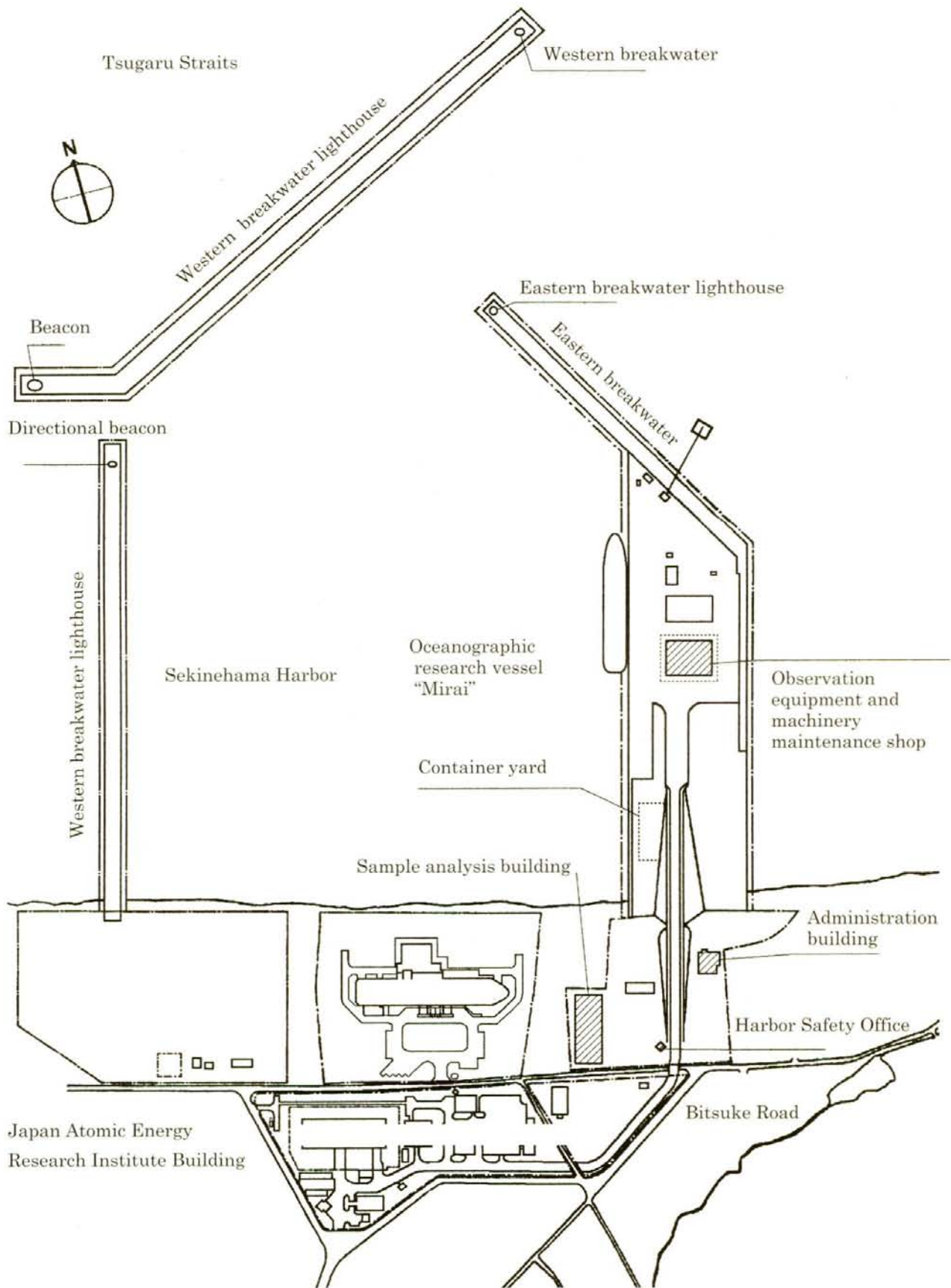


Fig. 1 Layout of Research Facilities at Mutsu Branch

Table 2 Main Equipment in Mutsu Branch Research Facilities

Classification of building	Installation name	Purpose/function
Observation machine and material maintenance shop	<ol style="list-style-type: none"> 1. Buoy data processing and management system 2. Buoy instrument management system 3. Sensor calibration system 	Reception, processing and management of oceanographic data from the research vessel "Mirai", instrument management and calibration of water sensors on observation buoys.
Sample analysis building	<ol style="list-style-type: none"> 1. Observation data processor 2. LAN system 3. Sea water pre-processing system 	<p>Processing and management of voyage data from "Mirai"</p> <p>Connects the sample analysis building, the observation equipment and machinery maintenance shop and the administration building by optical fiber cables, connects the computers in each building through a LAN and transmits data between computers.</p> <p>A piece of equipment which performs the necessary pre-processing of the sea water collected by "Mirai" in order for it to be measured by an accelerator mass spectrometer with radiocarbon (^{14}C). The main device is composed of the following three sub-systems:</p> <ul style="list-style-type: none"> -a system which extracts and refines the mineral carbon in the sea water as carbon dioxide -a system which turns carbon dioxide into graphite -a system which produces a graphite target from graphite

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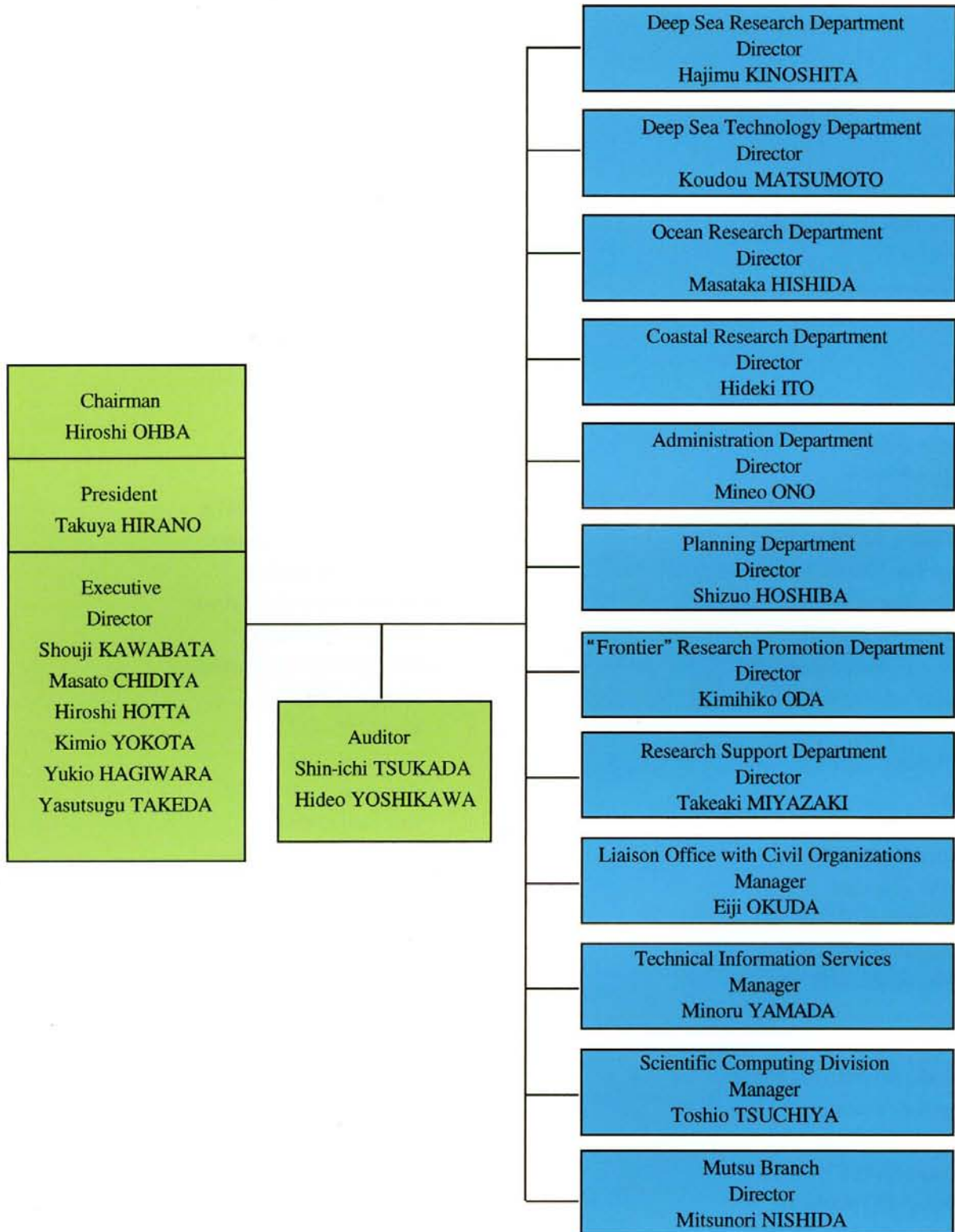
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Appendix B

Organization Chart



Appendix C

Scientific & Technical Staff

Kazuo KOBAYASHI

Scientific Adviser to the President

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Director

Hiroyasu MOMMA

Research Supervisor

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Senior Scientist

Jiro NAKA

Associate Scientist

Takeo TANAKA

Associate Scientist

Shigehito UETAKE

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Yuka SATOU

Ryouichi IWASE

Narumi TAKAHASHI

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Kiyoshige ISHINISHI

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Hiroshi OCHI

Takuya SHIMURA

Hiroshi INOUE

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Hisashi NAKAMURA

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Yukio MASUMOTO
Sub Leader
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Aiko FUJIMURA
Hisashi OZAWA
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Fumio MITSUDERA

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L. M. JAMESON

Appendix D

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Mineo ONO

Director

Mishihiko KATO

Administration Division Manager

Koji KITAGAWA

*Public Relations, Training and Education Office
Manager*

Masayoshi SAKAI

Personal Division Manager

Sadao SAYAMA

Finance and Accounting Division Manager

Masaru TAKANO

Contracts Division Manager

Fumiro SHIDARA

Safety Control Division Manager

Planning Department

Shizuo HOSHIBA

Director

Takao KATO

Planning Division Manager

Nobutaka KIMURA

International Affairs Division Manager

Hitoshi HOTTA

Program Management Division Manager

“Frontier” Research Promotion Department

Kimihiko ODA

Director

Chu ISHIDA

Research Program Planning Division Manager

Yasuaki HASEGAWA

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Research Support Department

Takeaki MIYAZAKI

Director

Takayuki NAGOSHI

Facilities and Equipment Division Manager

Kunioki DANNO

Ship Operations Division Manager

Akitoshi SHIMURA

Ship Maintenance and Repairs Division Manager

Submarine Operations Team of SHINKAI6500

Masahiko IDA

Commander SHINKAI6500

Yoshiji IMAI

Deputy Commander SHINKAI6500

Katsufumi AKAZAWA

Shin-ichi SUZUKI

Haruhiko HIGUCHI

Kikuo HASHIMOTO

Yoshitaka SASAKI

Satoshi OGURA

Kazuki IJIMA

Itaru KAWAMA

Tsuyoshi YOSHIUME

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Tetsuya KOMUKU

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Tsutomu FUKUI

Commander ROV

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Technical Specialist

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Hitoshi NAKAI

Hikari NOMURA

Toshinobu MIKAGAWA

Manabu TATSUTA

Liaison Office with Civil Organizations

Eiji OKUDA

Manager

Technical Information Services

Minoru YAMADA

Manager

Miyoko KUROSAWA

Hisatsugu SAKUMA

Scientific Computing Division

Toshio TSUCHIYA

Manager

Yoshihito ARAI

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Satoshi KAGEYAMA

MUTSU BRANCH

Mitsunori Nishida

Director

Hiromasa TACHIBANA

General Affairs Division Manager

Toshiharu SONODA

Facilities and Maintenance Division Manager

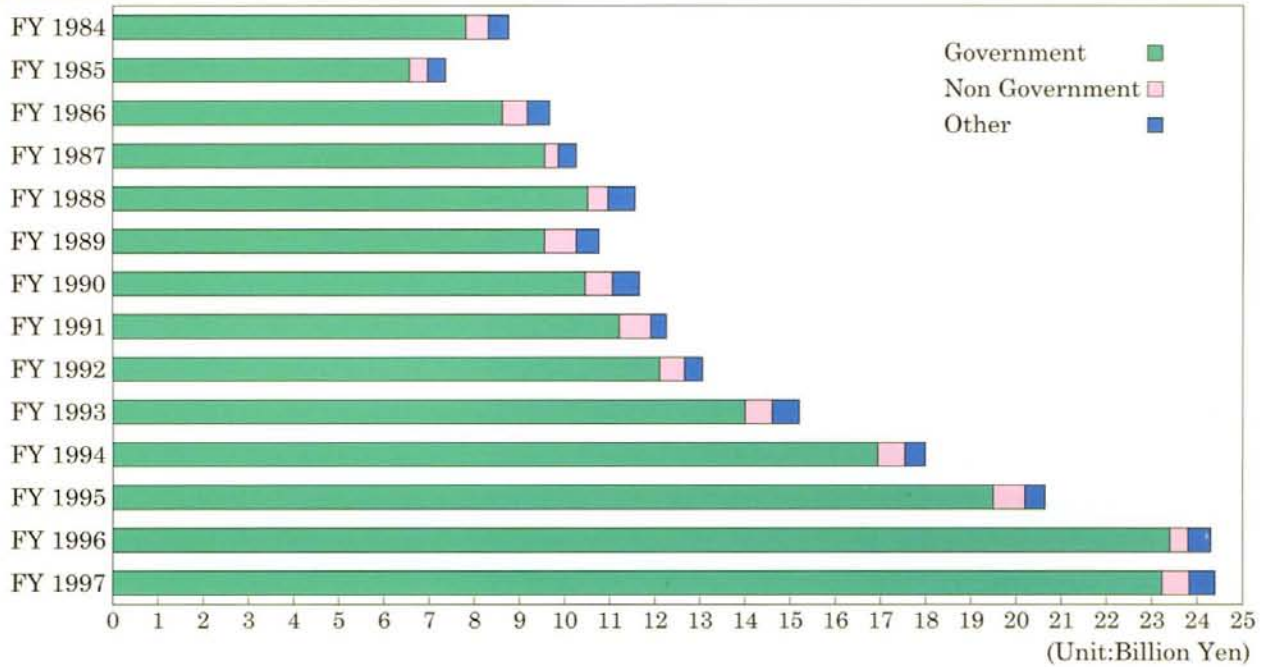
Ichio ASANUMA

Research Specialist

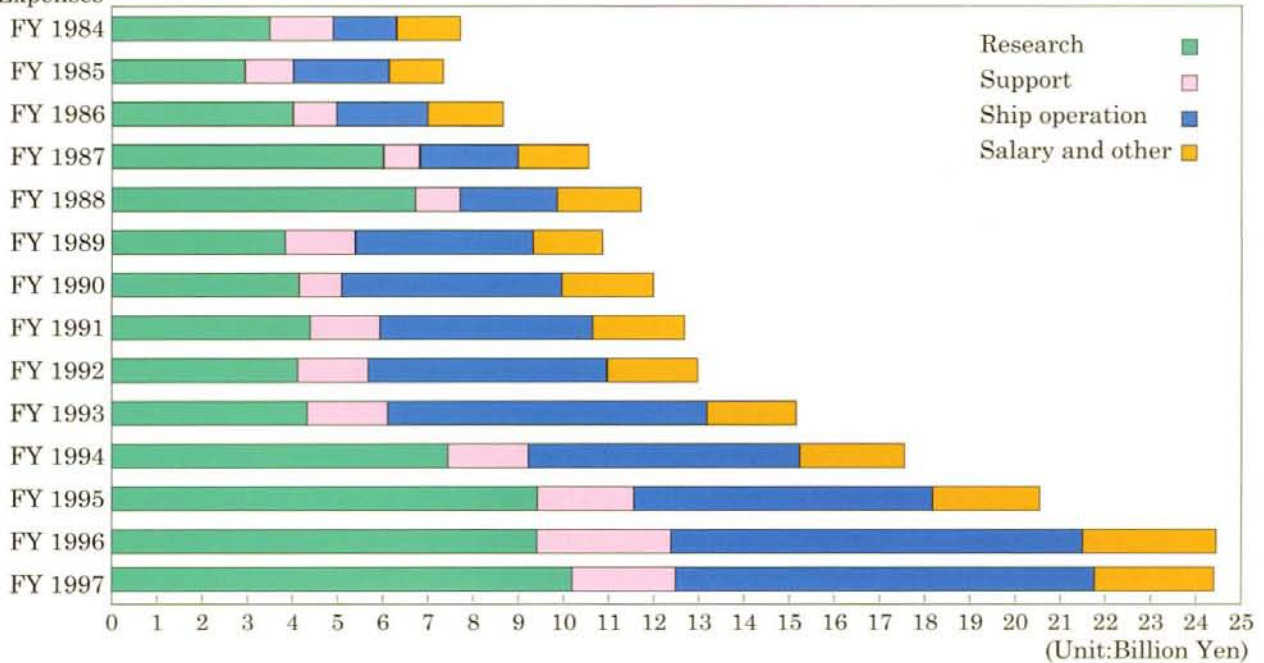
Appendix E

Budget

Revenues



Expenses





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