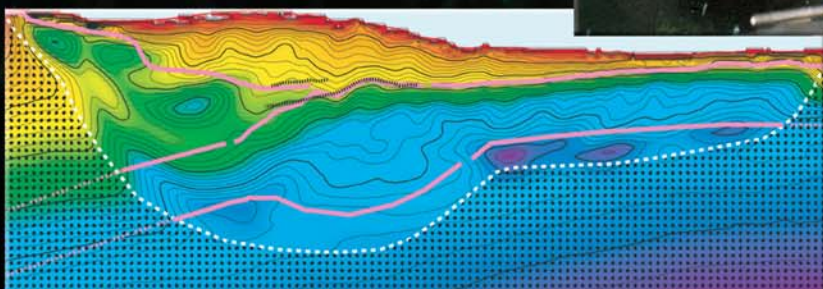




JAMSTEC

2000 Annual Report



JAMSTEC 2000 Annual Report

Japan Marine Science and Technology Center

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Preface

JAMSTEC has greeted its 30th anniversary this year, the 21st century's very first year.

The latter half of the 20th century, when JAMSTEC was born and grew, saw great discoveries made in the field of ocean and earth science. Mankind was able to see the earth from space -- a beautiful, blue planet, full of water. Outstanding discoveries include, for example, the theory of plate tectonics, which has not only been fully substantiated by subsequent research but also enabled it to go farther beyond, and the discovery of extremophiles, with their astonishing energy metabolic rates. All these forced us to experience major paradigm shifts.

With a rapid progress taking place in marine science and technology then, JAMSTEC started with studies on basic underwater engineering, and gradually pushed back its horizon to coastal seas, deep seas, and the great oceans. Nowadays, JAMSTEC is engaged in a wide variety of research in all the world's oceans, ranking with other leading oceanographic institutions of the world. Last year, JAMSTEC discovered another new dipole-mode climate events in the subtropical Indian Ocean. JAMSTEC installed, also last year, a new type of drifting buoy in the Arctic Ocean, to allow continuous observation of the currents in the arctic ocean, which is believed to greatly affect the global climate. All these constitute part of JAMSTEC's effort in global environmental observation. At the Nankai Trough off Shikoku Island, JAMSTEC discovered a large seamount, comparable in size to Mt. Fuji, in the process of subduction beneath the Japanese archipelago. The knowledge obtained through these discoveries will contribute to understanding global climate change and disaster prevention associated with earthquakes in Japan.

It is often said that science and technology advance by a tug of war between the two to bring knowledge and the well-being of mankind. JAMSTEC, therefore, positively promotes development of large-scale technologies that

will assist all researchers, or common infrastructure. Last fiscal year, JAMSTEC continued to work on the CHIKYU (scheduled to be commissioned in 2008), a deep sea scientific drilling vessel with an intent to reach the mantle, and the Earth Simulator (scheduled to be commissioned in 2002), the world's fastest supercomputer that can forecast global environmental change. JAMSTEC was also at work on the URASHIMA, Deep Sea Cruising AUV.

It is mandatory that JAMSTEC maximize the limited research resources of Japan in its research and development activities. In May last year, JAMSTEC underwent a third-party evaluation of its research and development activities and organizational management. JAMSTEC will do its best to improve its research and management based on the recommendations made by the evaluation committee.

This annual report outlines JAMSTEC's activities during fiscal 2000 (ending in march 2001). We at JAMSTEC hope this annual report will help the readers learn more about our research and development activities in marine science and technology. In presenting this report, we humbly request your continued support and cooperation toward JAMSTEC.

December 2001



Takuya HIRANO

President

Japan Marine Science and Technology Center

A handwritten signature in black ink, appearing to read 'T. Hirano', written over a white background.

Outline of Activities

To promote ocean development in our country, Japan Marine Science and Technology Center (JAMSTEC) continued to carry out a variety of activities during FY2000 (ending March 31, 2001) in close cooperation with domestic and foreign organizations concerned. These activities included research & development efforts, education and training services, information services, and construction, improvement and shared use of facilities and equipment. Each of these categories are described below.

Research and development activities

JAMSTEC carries out its R & D activities under categories of Research Project; Category 1, Research Project; Category 2 or Personal Research depending on the objective, content and progress status of these activities. JAMSTEC has established a flexible R & D system under which to conduct research according to the plan drawn up at the beginning of each fiscal year, that enables creative research based on researchers' own initiatives or adjustment to the situation change. In addition, JAMSTEC carries out Commissioned Research and Cooperative Research at the request from, and with the cooperation of, other domestic and foreign organizations. The R & D activities that JAMSTEC carried out for FY2000 are summarized below:

(1) Research Project; Category 1

JAMSTEC carries out important, large-scale or comprehensive R & D projects as Research Project; Category 1 to make contributions to the economic and social development and the improvement of marine science and technology. In FY2000, JAMSTEC carried out Research Project; Category 1 as listed in Table 1.

(2) Research Project; Category 2

As Research Project; Category 2, JAMSTEC carries out R & D projects to further develop the basic results obtained from Personal Research and other researches

that may possibly develop into future Research Project; Category 1. In FY2000, JAMSTEC carried out Research Project; Category 2 as listed in Table 2.

(3) Personal Research

As Personal Research, JAMSTEC carries out research projects based upon individual researchers' free conceptions to maximize their abilities, or those that might develop into Research Project; Category 2 or Researches Project; Category 1 in the future. In FY2000, JAMSTEC carried out Personal Research as listed in Table 3.

(4) Commissioned Research and Cooperative Research

As Commissioned Research, JAMSTEC carries out research projects involving marine science and technology, which are commissioned by other organizations to JAMSTEC and whose implementation JAMSTEC considers will benefit its own interests. In FY2000, JAMSTEC carried out commissioned Research as listed in Table 4.

As Cooperative Research, JAMSTEC carries out research projects in which high-level results are likely to come, while reduction in costs and required time is expected by sharing R & D resources with other organizations. In FY2000, JAMSTEC carried out Cooperative Research as listed in Table 5.

Outline of Activities

Training and Education Activities

JAMSTEC has had training and education programs for diving techniques for researchers, engineers and rescue members, and also had marine science education programs for high school students, university students and schoolteachers. And "Asia-Western Pacific Ocean Research Network program" has been started for establishing an oceanographic observation network in the Asia and Western Equatorial Regions.

Activity Related to Information Technology

JAMSTEC collects literature (books, journals, conference materials, technical reports) necessary for research and development on marine science and technology, and it has published various reports, toward having its research results become extensively known at home and abroad. JAMSTEC has promoted construction of marine information databases and operation of supercomputer systems.

Operation of the JAMSTEC Fleet

To be able to promote the activities mentioned above, JAMSTEC owns a fleet consisting of the following vessels and support facilities. First, JAMSTEC owns a 2,000-meter-class research submersible vessel system, consisting of the SHINKAI 2000 (a manned research submersible) and its support vessel: the NATSUSHIMA, and onshore maintenance facilities. Other members of the fleet are the DOLPHIN-3K, a remotely operated vessel; the KAIKO, a 10,000-meter-class remotely operated vessel; the HYPER DOLPHIN, a 3,000-meter-class remotely operated vessel; the KAIYO, a oceanographic research vessel; the SHINKAI 6500, a 6,500-meter-class manned research submersible system with a support vessel: the YOKOSUKA, and onshore maintenance facilities;

the KAIREI, a deep-sea research vessel, and the MIRAI, a oceanographic research vessel. In fiscal 2000, these vessels and systems conducted the following operations.

1) SHINKAI 2000

The SHINKAI 2000 dove a total of 87 times, at sites near the Nansei Islands, in the Sea of Japan, in the sea areas off Hokkaido and the Sanriku area, in the Izu-Ogasawara sea area, and in Sagami Bay and Suruga Bay.

2) NATSUSHIMA

In addition to support work for the SHINKAI 2000 and the DOLPHIN-3K, the NATSUSHIMA made its own voyages. In fiscal 2000, the NATSUSHIMA was at sea for a total of 300 days.

3) DOLPHIN-3K

The DOLPHIN-3K conducted test and training dives, preliminary surveys of deep-sea areas for the SHINKAI 2000, and exploratory dives off the Nansei Islands, the Sanriku area, Eastern Hokkaido, and in the Izu-Ogasawara sea area. Dives totaled 50.

4) KAIYO

In addition to supporting dives of the HYPER DOLPHIN, the KAIYO conducted various oceanographic observations and towing of deep-sea vehicles. In fiscal 2000, the KAIYO was at sea for 311 days, including the number of days the KAIYO was standing by off the Hawaiian Islands in connection with the sinking of the Ehime Maru, a Japanese fishing training boat.

5) HYPER DOLPHIN

The HYPER DOLPHIN made 34 training dives and 15 dives for recovery of ocean bottom seismographs (OBS).

Outline of Activities

6) SHINKAI 6500

The SHINKAI 6500 made a total of 66 dives in the Japan Trench, the Nankai Trough, the Nansei Islands, and the Izu-Ogasawara sea area.

7) YOKOSUKA

In addition to support work for the SHINKAI 6500, the YOKOSUKA made its own exploratory voyages. In fiscal 2000, the YOKOSUKA was at sea for a total of 278 days.

8) KAIKO

The KAIKO made a total of 33 dives in such sea areas as the Nansei Islands, the Japan Trench near Japan, and the Indian Ocean and the Mariana Central sea area.

9) KAIREI

In addition to support work for dives of the KAIKO, the KAIREI made independent exploratory voyages and conducted research on ocean bottom dynamics. In fiscal 2000, the KAIREI was at sea for 245 days.

10) MIRAI

The MIRAI carried over joint-research-type voyages from fiscal 1999 to fiscal 2000. In fiscal 2000, the MIRAI made seven joint-research-type voyages, which kept the MIRAI at sea for 298 days. The MIRAI was at sea for a total of 311 days.

Table 1 Research Project; Category 1

	Subject	Period	Department
1	Research on ocean bottom dynamics	FY1998-	Deep Sea Research Department
2	Development and deployment of Long-term Deep Sea Floor Observatories	FY1992-	Deep Sea Research Department
3	Research and Development of Advanced Technology	FY1998-	Marine Technology Department
4	Research and Development of Autonomous Underwater Vehicle	FY1998-	Marine Technology Department
5	Research and Development of Ocean Observing Buoy	FY1993-	Marine Technology Department
6	Research and Development of Technology to Utilize Ocean Energy	FY1989-	Marine Technology Department
7	Development of atmospheric sampling and onboard analyzing systems for stratospheric platform. (the former Study of ocean sensor development for stratospheric platform)	FY1998-	Ocean Observation and Research Department
8	Tropical Ocean Climate Study	FY1993-	Ocean Observation and Research Department
9	Development of Ocean Acoustic Tomography System (Large-scale Simultaneous Intensive Observation using Ocean Acoustic Tomography System)	FY1989-	Ocean Observation and Research Department
10	Study on the Kuroshio Extension	FY1986-	Ocean Observation and Research Department
11	Long-term oceanographic and meteorological observation of North Pacific Subtropical area.	FY1987-	Ocean Observation and Research Department
12	Arctic Ocean Observation study	FY1991-	Ocean Observation and Research Department
13	Study of Air - Sea Interaction	FY1997-	Ocean Observation and Research Department

Outline of Activities

Subject		Period	Department
14	Development of Ocean LIDAR System	FY1987-	Ocean Observation and Research Department
15	Biogeochemical study of the northern North Pacific and its adjacent seas	FY1995-	Ocean Observation and Research Department
16	Observational Study on primary production in the Equatorial Pacific	FY1997-	Ocean Observation and Research Department
17	Study on the Coastal Ocean Ecosystem Dynamics (the former Study on dynamics of marine ecosystems)	FY1998-	Marine Ecosystems Research Department
18	Mesopelagic Biology Program	FY2000-	Marine Ecosystems Research Department
19	Studies on Deep-sea Ecosystems.	FY1997-	Marine Ecosystems Research Department
20	Research on the past marine environmental changes (the former Study on the Global warming mechanism)	FY1999-	Mutsu Institute for Oceanography (the former Mutsu Branch)
21	Frontier Research System for Global Change	FY1997-	Frontier Research Promotion Department
22	Development and Operation of Information System for the Global Change Prediction	FY1999-	Frontier Research Promotion Department
23	Frontier Research Program for Deep-sea Extremophiles	FY1990-	Frontier Research Promotion Department
24	Frontier Research Program for Subduction Dynamics	FY1996-	Frontier Research Promotion Department
25	Research and Development of application software for the Earth Simulator (the former Development of Parallel Software for Earth Simulator)	FY1998-	Frontier Research Promotion Department
26	Frontier Observational Research System for Global Change	FY1999-	Frontier Research Promotion Department
27	Promotion of Ocean Drilling in the 21st century (the former Research and Development of a Deep-sea Drilling Vessel)	FY1990-	Office of OD21 Program
28	Research and Development of Coastal Environments and their Utilization	FY1998-	Program Management Division
29	Development and maintenance of TRITON buoy network	FY1993-	Research Support Department and Mutsu Institute for Oceanography (the former Mutsu Branch)
30	Promotion of the Earth Simulator Project	FY1999-	Computer and Information Department

Outline of Activities

Table 2 Research Project; Category 2

	Subject	Period	Department
1	Research into the Mechanism Earthquake and Tsunami Generation in the Sea Area near Papua	FY1998-FY2000	Deep Sea Research Department
2	B02-Paleo and Rock-magnetic studies of deep-sea sediments: Implications for paleo environment changes	FY1999-FY2001	Deep Sea Research Department
3	Integrated solid earth research in Java-Sunda Trenches around Indonesia	FY2000-FY2002	Deep Sea Research Department
4	Study on development of oceanic arc (Izu · Ogasawara · Mariana)	FY2000-FY2002	Deep Sea Research Department
5	Integration of long term monitoring schemes and methodologies to study the Earth's Interior	FY2000-FY2002	Deep Sea Research Department
6	Research on the Autonomous Underwater Vehicle Technology in Ice-covered Sea Area	FY1998-FY2001	Marine Technology Department
7	Studies on isolation and cultivation methods of deep-subsurface microorganisms	FY2000	Frontier Research Program for Deep-sea Extremophiles
8	Research on deep structure and fluctuation of microseismicity around Kozu and Miyake Islands	FY2000-FY2001	Frontier Research Program for Subduction Dynamics and Deep Sea Research Department

Table 3 Personal Research

	Subject	Period	Department
1	Research concerning sample processing for petrochemical analysis of bottom material samples and measurement of rock properties	FY1998-FY2000	Deep Sea Research Department
2	Research concerning the activity and structure of spreading axis magma reservoirs	FY1996-FY2000 ; suspended in FY1997-FY1998	Deep Sea Research Department
3	Study on sea bottom gamma ray measurement by manned and unmanned submersibles	FY1998-FY2002	Deep Sea Research Department
4	Research on Early Detection of Tsunami and Crustal Deformation using Cable-type Observation Equipment	FY1999-FY2001	Deep Sea Research Department
5	Feasibility study on the methane flux monitoring in the area of gas hydrate distribution	FY2000-FY2002	Deep Sea Research Department
6	Detection of submarine volcanic activity by the long-term seafloor cabled observatories	FY2000-FY2001	Deep Sea Research Department
7	A relationships between regional variation of seismic activity and the crustal structure in the Japan Trench region	FY2000-FY2001	Deep Sea Research Department
8	Development of sampling system revealing for activity record of deepwater active fault	FY2000-FY2001	Deep Sea Research Department

Outline of Activities

	Subject	Period	Department
9	Study of crustal generation and deformation in the Mid-Atlantic Ridge	FY2000-FY2002	Deep Sea Research Department
10	Geophysical measurements in drillholes	FY2000-FY2002	Deep Sea Research Department
11	Research on Improvement of the Propulsion Maneuver System of manned submersible "SHINKAI 6500"	FY1998-FY2000	Marine Technology Department
12	Research on Unprovement of the Anti-rolling Device	FY1999-FY2001	Marine Technology Department
13	Research of very high resolution and long range sonar for seafloor surveying	FY1997-FY2001 ; suspended in FY1998-FY1999	Marine Technology Department
14	Evaluation of TRITON buoy sensors and validation of buoy data	FY1996-FY2000	Ocean Observation and Research Department
15	Study on high-frequency measurement of oceanic CO ₂ -system parameters	FY2000-FY2002	Ocean Observation and Research Department
16	Preliminary study on the mass and heat distribution being associated with the ocean general circulation	FY2000-FY2002	Ocean Observation and Research Department
17	A study on the modeling of marine ecosystems by combining multiples sub-models	FY1998-FY2000	Marine Ecosystems Research Department
18	Method of evaluating seawater movement in the vicinity of coral	FY1998-FY2000	Marine Ecosystems Research Department
19	Decompression sickness on scientific divers occurred by hypobaric environment transfer other Dive	FY1998-FY2000	Marine Ecosystems Research Department
20	Fundamental study on quantitative measurement of coral fishes	FY1998-FY2000	Marine Ecosystems Research Department
21	Study on the Influences of the Kuroshio Current on the Fluctuating Hydrographic Properties of the Deep Seawater in Suruga Bay	FY1999-FY2001	Marine Ecosystems Research Department
22	Studies on abundance of plankton community concerned on the regenerated production	FY1999-FY2001	Marine Ecosystems Research Department
23	Study on Autonomic nervous system on adaptation and re-adaptation	FY1999-FY2001	Marine Ecosystems Research Department
24	Research on the evaluation of deep sea water quality	FY2000-FY2002	Marine Ecosystems Research Department
25	Research into Parallel Computing Techniques in Marine Computation	FY1999-FY2001	Computer and Information Department

Outline of Activities

Table 4 Commissioned Research

Subject		Period	Consignor	JAMSTEC Dept.
1	Global Dynamics:Elucidation of Superplume Form from Gravity and Geoid Study, conducted as a part of International Cooperative Research for Elucidation of Variance Theory Applicable to Earth System Leading to the Central Core	FY1996-FY2000	Ministry of Education, Culture, Sports, Science and Technology (the former Science and Technology Agency)	Deep Sea Research Department
2	Mt.Unzen:study of the crustal structure of Shimabara Peninsula based on the reanalysis of airgun seismic data among cooperative research to elucidate the eruption mechanism and magma activity by scientific drilling	FY1999-FY2001	Ministry of Education, Culture, Sports, Science and Technology (the former Science and Technology Agency)	Deep Sea Research Department
3	Study on deep sea radioactivity measurement(V)	FY2000	Japan Atomic Energy Research Institute	Deep Sea Research Department
4	Global Carbon Cycle and Related Mapping Based on satellite Imagery	FY1998-FY2002	Ministry of Education, Culture, Sports, Science and Technology (the former Science and Technology Agency)	Ocean Observation and Research Department
5	Development of parallel software for global climate change	FY1998-FY2000	Research Organization for Information Science and Technology	Ocean Observation and Research Department
6	Comprehensive study on modeling earthquake mechanism and enhancement of observation system for reduction of trench-type great earthquake disaster at Nankai Trough	FY1996-FY2000	Geological Survey of Japan	Frontier Research Program for Subduction Dynamics
7	Fundamental study on the Eco-Float (Offshore type Mega-Float Equipped with Wave Energy Absorbing Device and Utilize Renewable Energy)	FY1999-FY2000	Corporation for Advanced Transport & Technology	Marine Technology Department
8	Subarctic Gyre Experiment	FY1997-FY2001	Ministry of Education, Culture, Sports, Science and Technology (the former Science and Technology Agency)	Ocean Observation and Research Department
9	Urgent Research on Subsurface Structure in the East off Kozushima Island	FY2000	Ministry of Education, Culture, Sports, Science and Technology (the former Science and Technology Agency)	Frontier Research Program for Subduction Dynamics and Deep Sea Research Department

Outline of Activities

Table 5 Cooperative Research

Subject		Period	Partners	JAMSTEC Dept.
1	Long-term Monitoring of Seafloor Hydrothermal Flow Regimes	FY1998-FY2002	Rutgers University and University of Washington	Deep Sea Research Department
2	Study on the origin and depositional environment of cold seep carbonates	FY1995-FY2000 ; suspended in FY1997-FY1998	Hiroshima University	Deep Sea Research Department
3	Comparative Research into Trench Type Earthquakes around Japan and the American Continents and Geological Phenomena Associated with the Earthquakes	FY1997-FY2000	Woods Hole Oceanographic Institution	Deep Sea Research Department
4	Basic research on network observation for seismological and geodetic applications on the ocean floor	FY1999-FY2002	Earthquake Research Institute, the University of Tokyo	Deep Sea Research Department
5	The research of electric field fluctuation measurement by the submarine cable	FY2000-FY2002	National Research Institute for Earth Science and Disaster Prevention (NIED)	Deep Sea Research Department
6	Observation-methodological study on geoelectromagnetic fluctuations acquired in deep sea.	FY2000-FY2002	Earthquake Prediction Research Center, Institute of Oceanic Research and Development Tokai Univ.	Deep Sea Research Department
7	Research on Real Time Estimation for Catenary of ROV Tether Cable	FY1997-FY2000	Mitsui Engineering & Shipbuilding co.,LTD	Marine Technology Department
8	Development of the DPS by R/V "KAIREI" for Deep Sea Research	FY1998-FY2000	Kawasaki Heavy Industries, Ltd.	Marine Technology Department
9	Study on dynamic behavior of marine flexible pipe	FY2000-FY2002	Research Institute for Applied Mechanics of Kyushu University, Ship Research Institute Ministry of Transport, Kawasaki Heavy Industries, Ltd.	Marine Technology Department
10	Research on the monitoring technology for the hydro thermal plume	FY2000-FY2003	Central Research Institute of Electric Power Industry	Marine Technology Department
11	Study on automation of measurement of chemical components in sea water	FY1998-FY2000	National Institute for Resources and Environment, National Research Institute of Aquaculture, Kawasaki Heavy Industries, Ltd., Kimoto Electric Co., Horiba, Ltd.	Ocean Observation and Research Department
12	Study on sensitive and precise analysis of radionuclides in oceanic samples	FY1999-FY2002	National Institute for Environmental Studies	Ocean Observation and Research Department
13	Observational research on variability of intermediate and deep ocean circulation	FY1998-FY2002	Ocean Research Institute, the University of Tokyo	Ocean Observation and Research Department
14	Study on estimation of basin-scale CO2 fluxes in the North Pacific	FY2000-FY2004	Meteorological Research Institute	Ocean Observation and Research Department

Outline of Activities

Subject		Period	Partners	JAMSTEC Dept.
15	Research on effective utilization of thermal energy using deep sea water and hot spring water	FY2000-FY2002	Geological Survey of Hokkaido	Marine Ecosystems Research Department
16	Research on long-term rearing of mid-water animals	FY2000-FY2002	Monterey Bay Aquarium Research Institute	Marine Ecosystems Research Department
17	Research on the spawning characteristics of the Japanese eel (<i>Anguilla japonica</i>)	FY2000-FY2002	Ocean Research Institute, the University of Tokyo	Marine Ecosystems Research Department
18	A study on the property of deep seawater in Toyama Bay	FY2000-FY2002	Toyama Prefectural Fisheries Research Institute, Toyama Institute of Health	Marine Ecosystems Research Department
19	Study of shooting method and video image quality evaluation, performance improvement of the image device in the Underwater Super-HARP High Definition television Camera.	FY1999-FY2001	Science & Technical Research Laboratories, Japan Broadcasting Corporation	Research Support Department

Deep Sea Research Department

Overview

The research activities at Deep Sea Research Department are focused on better understanding of the earth's dynamics operating in deep oceans with emphasis on active processes evident at or through the ocean floor. Significant efforts are put into establishment of seafloor observatories to detect and monitor various active geological processes to scrutinize them and to test physical models that explain these phenomena. Research highlights during FY2000 (April 2000 to March 2001) include the discovery of methane gas bubbles beneath which gas hydrate layer is suspected in southwestern Japan. Diving and sampling at the Atlantis II Bank in SW Indian Ridge revealed the differentiation process of mantle to crustal rocks in a slow spreading environment. We are grateful to many collaborators within and outside Japan who jointly worked to bring about these results. We welcomed our new staff members at DSRD, Eiichiro Araki (seismologist), Tadanori Goto (geo-electromagnetist), and Hidenori Kumagai (geochemist). A brief summary of our seafaring activities is attached at the end of this report. Scientific results are published in outside review journals and JAMSTEC reports. During FY2000, our staff members (19) and fellows (4) were authors of 26 peer reviewed outside journals.

Sea Floor Dynamics

Southwest Indian Ridge: Atlantis II Bank

R/V *Kairei* with ROV *Kaiko* was sent to the Atlantis II Fracture Zone at the ultra-slow spreading Southwest Indian ridge as a joint project between JAMSTEC and WHOI (Woods Hole Oceanographic Inst.) in September, 2000 (Figure 1). This visit was the second and we are scheduled to revisit the site in 2001-2002 for the third time. The main purpose of the survey was to investigate the crust-mantle boundary rocks exposed on the fracture zone. On this cruise, the weather condition allowed us only 3 dives on the transform wall of the fracture zone. However, we could observe and sample both the lower crust and uppermost mantle rocks. How mantle rocks melt and form the crust is still a major geological and petrological problem to be solved. From this cruise, we found; (1) important evidence of gradual change in petrology spanning about 2 km vertical distance; (2) also a detachment fault suspected to be the sliding fault to uplift the Atlantis II Bank was found; (3) SeaBeam mapping in a nearby

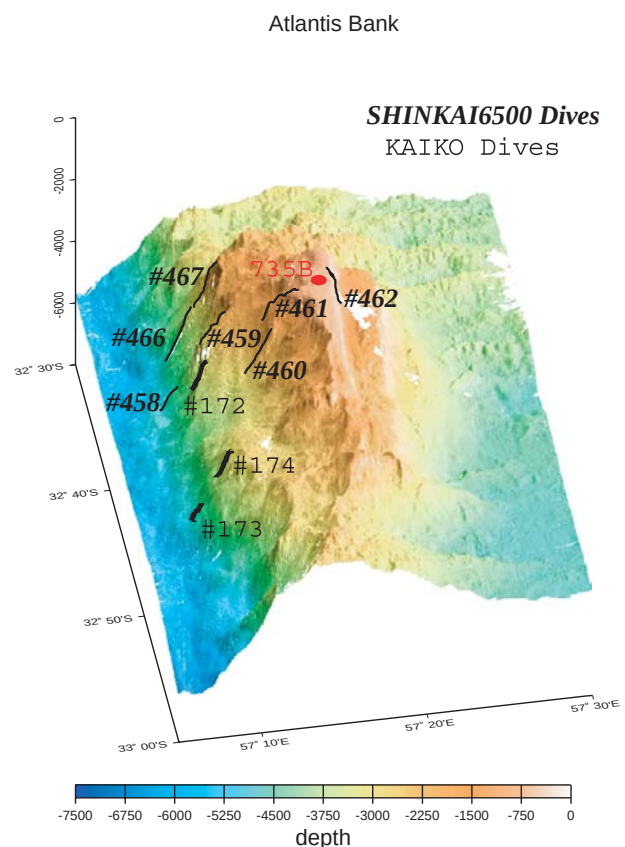


Fig. 1 Location map of Southwest Indian Ridge, Atlantis II Fracture Zone survey area.

Deep Sea Research Department

obliquely spreading ridge area imaged changes in the spreading mode with time.

Shinkai 2000 Dives on the Kuroshima Knoll, off Ishigaki Island

We are continuing our seafloor surveys around the Japanese islands selecting areas such as where hydroge-

ological processes related to sub-seafloor fluid fluxes can be best studied. One such area is the Ryukyu Islands in plate subduction environment. Here we wish to highlight the Kuroshima Knoll, which exists on the forearc, 26 km south of Ishigaki Island. The Ishigaki Island is one of the islands chain called Yaeyama Islands near the western end of the Ryukyu Island Arc (Figure 2).

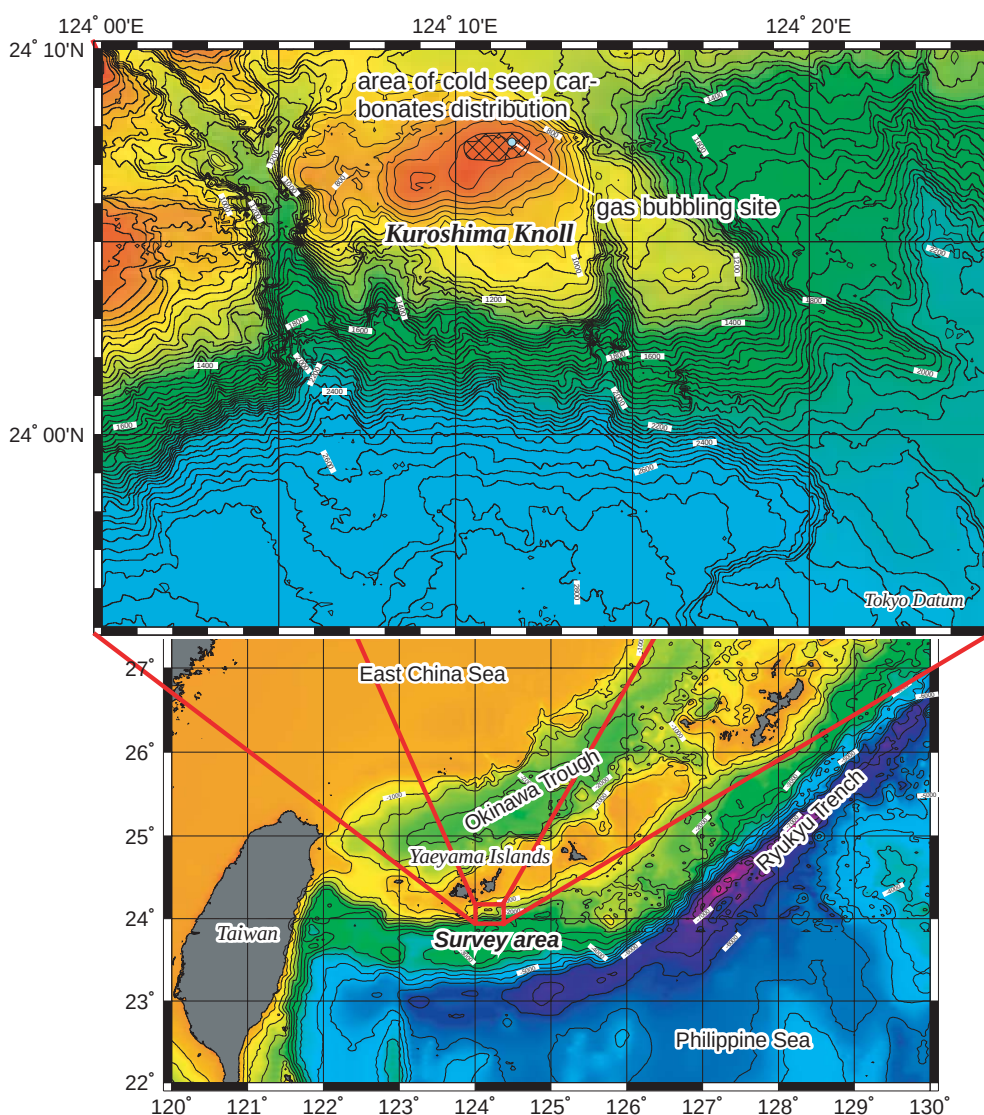


Fig. 2 Location map of Kuroshima Knoll survey area. Cold seep carbonates, chemosynthetic communities, and a gas bubbling site were found on the top of the knoll.

Deep Sea Research Department

On the top of the Kuroshima Knoll, a widespread occurrence of cold seep carbonates such as pavement-, chimney-, nodular/crust-, and massive-type were found. Carbon and oxygen isotopic composition of these carbonates suggest that the carbonates were formed under methane seep condition and the origin of the methane seep to be the fluid from gas hydrate dissociation. These carbonates as well as *Calyptogena* colonies seem to be controlled by the existence of cracks of fault origin and slip planes. Age dating by ^{14}C AMS shows that the age of fossil *Calyptogena* and dolomite chimney and of fossil *Bathymodiolus* in the pavement-type are 1.4-2.6 kyBP and 6.8-9.8 kyBP, respectively. We also found a gas bubbling site, where we measured the chemistry of gas to be of highly concentrated biogenic methane. Thus, beneath this knoll seems to lie a gas hydrate layer. The area is known to have experienced landslides and tsunamis in the past perhaps triggered by the unstable sliding of such layer. We are now trying to understand how fluids, their pathways, and gas hydrates are linked to the tectonic processes operating in the area. In order to further our understanding we will conduct seismic profiling and long-term methane flux monitoring.

Side-Scan Sonar Imaging of Seismically Active Zone near Kozu-shima and Nijima Islands

In June 2000 a volcanic eruption started at Miyakejima Island in the Izu-Ogasawara Island Arc system. This caused the population to evacuate the island, which is still continuing to this date. Numerous earthquake accompanied the volcanic activity and expanded to Nijima and Kozu-shima areas. As part of a comprehensive observations conducted by many institutions to monitor and assess the various crustal activities, we conducted a back-scattering sonar imaging employing a high resolution side-scan sonar owned by the ORI of the University of Tokyo equipped on R/V *Yokosuka*. The survey was conducted in December, 2000 in an area of fast bottom currents.

While the bottom sediments showed wave ripples created by the bottom current, we could observe fissures likely created by the magmatic activity trending EW. This trend is in accordance with the observed GPS crustal deformation and probable magma intrusion.

Investigation of the Sunda Strait Area

We conducted a seafloor survey in the Sunda Trench System in Jan-Feb, 2001 by R/V *Yokosuka* as part of a joint research agreement with the Agency for the Assessment and Application of Technology (BPPT) of Indonesia. Our study follows previous surveys conducted by U.S. and Germany. The Indo-Australia plate subducts obliquely beneath the Sumatra Trench but normally beneath the Java Trench. How this obliquity change takes place and is accommodated tectonically is not well resolved. At the junction area of the two trenches, the Krakatau Volcano exists slightly out of place from the volcanic front. Our swath bathymetry survey clarified that the on-land Sumatra Fault (right-lateral strike slip fault) continues southwards and eventually merges to the Sunda Trench at its SW end (Figure 3). This seems to mark the boundary of the Sumatra Arc block on the northwestern side and the Java Arc bloc on the south-eastern side.

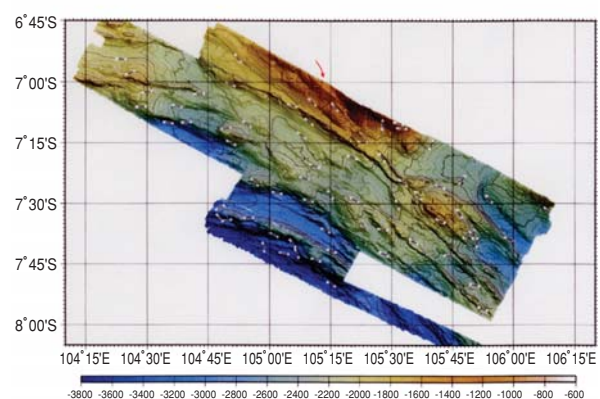


Fig. 3 Location map of Sunda Strait survey area.

Deep Sea Research Department

Observation Networks on Deep Sea Floor

Fiber Optic Cable Systems

The real-time cabled observatory systems have been operating providing critical seismic data for the JMA national seismic network (Figure 4). These submarine ocean bottom seismographs and hydrophones are distributed off the coast of Japan principally for detection of nearby local earthquakes. Here we report that these

sensors are also effective in detecting volcanic sources at great distances. Many swarms of T-phases (acoustic signals through water column) were observed particularly between Sep-Dec, 1999 during Jan 99-Dec 00 period. From multiple station readings the sources of these signals were found to originate in the northern part of the Marianas (19° N 146° E) suggesting submarine volcanic activities. An interesting feature is the half-day period variation in the amplitudes of seismo-

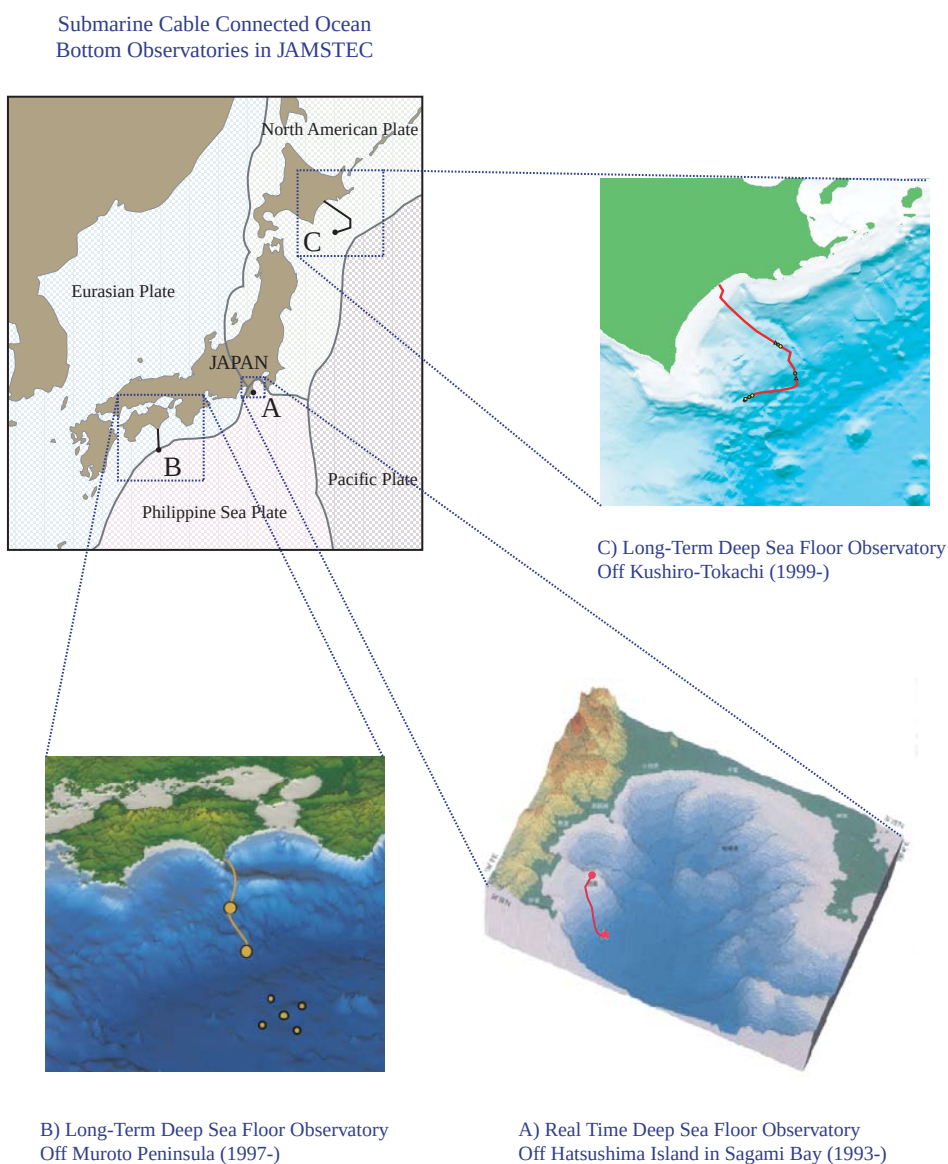


Fig. 4 Real-time cabled observatory system of JAMSTEC.

Deep Sea Research Department

grams corresponding to the tide.

We are also collaborating with National Research Inst for Earth Science and Disaster Prevention (NIED) to measure the electric field fluctuations at the feeder of the submarine cable of off Hatsushima Island seep seafloor observatory to seek their relations to natural causes. In FY200 the signal detection device was attached to the spare feeder for test measurements to detect fluctuations due to operations of active sensors attached to the Hatsushima system.

Another collaboration is made with the Earthquake Prediction Research Center of Tokai University for eventual installation of torsion sensor magnetometer. The magnetometer is compact in size for installation in the pressure case. Long-run test was made on land with fluxgate magnetometer for comparison for a week at Yatsugatake geomagnetic observatory (YMO) in central Japan. The sensor calibration test was made at Kakioka magnetic observatory (KMO). Based on these

tests, we are improving the sensor system for lower power consumption and more accurate measurements.

Seafloor Borehole Observatories

We are participating in the Ocean Hemisphere Network Project with the Earthquake Research Institute of the University of Tokyo in order to establish borehole observatories in the western Pacific oceans. Two stations off the coast of NE Japan equipped with broadband seismographs and strain- and tilt-meters were successfully installed in summer 1999. We have been improving the power source system from the original sea-water battery system to lithium battery system. In 2000, during ODP Leg 192, another borehole observatory, this time broadband seismographs in the solid basement rock, was installed in the Northwest Pacific Basin. Preliminary data from this site proves the superiority of the borehole signal quality, particularly the horizontal sensors at long periods (>10 s).

Deep Sea Research Department

Brief summary of sea bottom surveys conducted /participated by DSRD 2000 Apr-2001 Mar

JAMSTEC Cruises

KR00-01/10K	Apr	Izu-Ogasawara	Kikawa
NT00-05/D3k	Apr-May	Ryukyu Island Arc System	Machiyama, Hattori, Okano, Matsumoto
MR00-K03	May	High latitudes	Kanamatsu
NT00-06/2K	May	Ryukyu Island Arc System	Machiyama
KY00-01/HD	May	Sagami Bay	Iwase
KR00-03/10K	May	Ryukyu/Mariana	Kawaguchi
YK00-04/6K	May	Japan Trench	Mitsuzawa
NT00-07/D3K	Jun	Ryukyu Island Arc System	Mitsuzawa, Hattori, Okano
NT00-08/2K	Jun	Okinawa Trough	Mitsuzawa
KY00-02	Jun	Japan Trench	Mikada, Fujie
YK00-06/6K	Jul-Aug	Nankai Trough/Ryukyu Tr.	Wu, Matsumoto, Iwase, Machiyama
MR00-K05	Jul	N Pacific	Kanamatsu
NT00-09/D3K/2K	Sep	Kurile Trench/Japan Trench	Mikada, Mitsuzawa
YK00-08/6K	Sep	Izu-Ogasawara/Nankai Tr.	Mitsuzawa, Fujiwara
KR00-06/10K	Sep	SW Indian Ridge	Matsumoto, Kumagai
NT00-10/D3K	Sep	Izu-Ogasawara/Nankai Tr.	Hattori, Kaiho
KY00-08	Oct	Miyakejima-Kozujima	Sugioka
KR00-07/10K	Nov	Japan Trench/NW Pac	Kaiho, Kawaguchi, Hirata, Araki, Mitsuzawa
KR00-08	Nov	Miyakejima-Kozujima	Fujie
KY00-09/HD	Nov	Japan Trench	Araki
NT00-12/2K	Nov-Dec	Sagami Bay/Ogasawara	Iwase, Kumagai
YK00-12	Dec	Miyakejima-Kozujima	Soh, Machiyama, Kubo
YK00-13	Dec	Marianas	Soh, Fujiwara
YK01-01	Jan	Marianas	Kido
YK01-02	Jan-Feb	Sunda Java Trenches	Soh
NT01-01	Feb	Papua New Guinea	Matsumoto
KY01-01/HD	Mar	Sagami Bay/Miyakejima	Iwase, Kubo

NT: R/V Natsushima (mother vessel of Shinkai 2000 (2K), ROV Dolphin 3K (D3K))

KY: R/V Kaiyo (mother vessel of ROV Hyper Dolphin (HD))

KR: R/V Kairei (mother vessel of ROV Kaiko (10K))

YK: R/V Yokosuka (mother vessel of Shinkai 6500 (6K))

MR: R/V Mirai

Marine Technology Department

Outline and Research Policy of the Marine Technology Department

The Marine Technology Department has provided means to learn more about the ocean and the earth, through development of important and innovative facilities and technologies needed for oceanographic observation as well as deep-sea research submersible vessels, remotely operated vehicles, and oceanographic observation buoys. These ocean investigation ships, marine equipment, and various technologies are used and highly evaluated by concerned researchers both within and outside JAMSTEC.

The Marine Technology Department aims to contribute to the advancement of ocean and earth science technology through development of basic technologies. Specifically, these technologies include deep sea scientific drilling vessels, to obtain information on the earth's interior under the deep seafloor; offshore floating structures, with facilities for electric power generation, aimed at effective utilization of the huge supply of marine energy and other resources; and underwater acoustic and imaging basic technologies.

Research Project ; Category 1

(1) Research and Development of Innovative Technology

Since fiscal 1998

(a) Research on Imaging Technologies

TV camera images are very important information sources in order to operate remotely operated vehicles (ROVs). This research aims to provide the operators or researchers of submersibles with realistic images, which adopt the advancing virtual reality technologies. This fiscal year, the Marine Technology Department established an algorithm and developed a program for processing multiple TV camera inputs and imaging outputs, which system consists of a number of TV cameras and monitors.

Then, problems with the research were identified through experiments, and the produced images were compared with those obtained underwater TV camera images that used the fish-eye lenses in order to evaluate them.

(b) Research on Power Source

The lithium-ion battery becomes heavier if its capacity is larger. It is too heavy and large to handle

the long cruising range vehicle easily. In order to extend its cruising range, we plan to replace with the fuel cell for power source of URASHIMA. In the research, we will develop pressure hulls for holding the fuel and oxidizer for fuel cell. The fuel and oxidizer is hydrogen gas and oxygen gas. This fiscal year, a study on hydrogen gas storage alloys, and absorption performance tests on them, were done. The arrangement of pressure hulls on URASHIMA were also studied this fiscal year. Results of these studies, we suggest necessity of extracting of discharged hydrogen for electric generation from hydrogen storage alloys, by using exhaust heat from the fuel cell.

(c) Research on Underwater Acoustic Technology

In underwater acoustic communication, the effects of disturbance by multi-path and Doppler are increasing as higher transmission rate. However their mechanisms have not been well understood. The Marine Technology Department is conducting research to understand the underwater acoustic field, aimed at establishing high-speed and reliable data transmission technologies.

In fiscal 2000, transmission tests were carried out in real sea area at a vertical distance of 900 meters, con-

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cerning the quadrature amplitude modulation (QAM) system, which sends information on both the amplitude and phase of acoustic waves. Tests results indicate that a transmission speed of 32 kbits per second is possible with 16 signal points. Figure 1 shows an example of demodulation. A signal-to-noise (S/N) ratio of a received signal is 22.1 dB. Figure 1(c) shows that 16 signal points are well separated by application of adaptive equalization and phase compensating processes.

(d) Research on Measurement and Sensor Technology

Operators for ROVs put a lot of effort to control an attitude of them in oceanographic observation using ROVs. ROVs need a high ability of kinematical control to take autonomous functions with high-accurate sensors and high-performance computers. This research aims to develop sensors that can accurately measure movements in water. In fiscal 1999 and 2000, The Marine Technology Department successfully improved the performance of ring laser gyros, reducing the drift error by half that of previous gyros. In fiscal 2000, these ring laser gyros were incorporated in an inertial navigation system and tested. The tests showed that the error was reduced by half also, in the system.

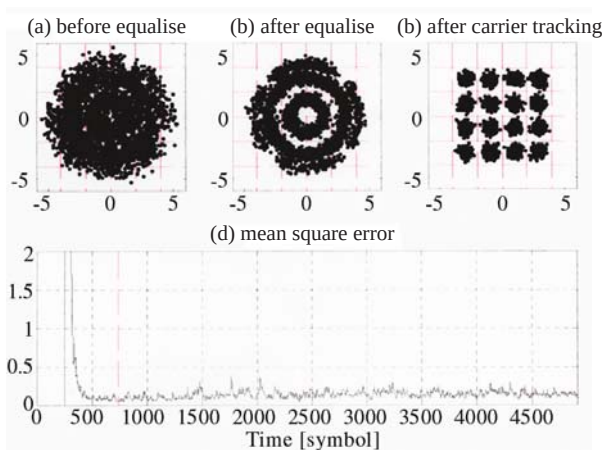


Fig. 1 An example of 16-QAM demodulation (SNR=22.1dB, Error rate 0/4000)

(2) Research and Development of Autonomous Underwater Vehicle

Period: from fiscal 1998

An autonomous underwater vehicle can cruise long distance region in the sea and collect data automatically according to preset schedule program. The key design parameters are listed in Table 1. The vehicle was named URASHIMA after a hero of a Japanese famous old tale. The target maximum cruising distance is 300km. The maximum working depth is 3,500m. The cruising speed is 3knots. URASHIMA has a streamlined shape and an oval cross section for reducing hydrodynamic drag. The vehicle consists of titamium frames with some pressure hulls include electrical devices and buoyancy materials. They are covered with Fiberglass Reinforced plastics cover. High-performance power sources and navigation system are essential technology to realizing long range cruising. URASHIMA can choose his power source from lithium-ion rechargeable battery and solid polymer electrolyte fuel cell. URASHIMA has high accuracy Inertial Navigation System that consists of three sets of ring laser gyro and accelerometers. The hybrid

Table 1 Key design parameters

Dimensions	Length	9.7 [m]
	Width	1.3 [m]
	Height	1.5 [m]
	Weight	7 [ton]
Maximum Range (Plan)	300 [km] (Fuel Cell) 100 [km] (Lithium ion battery)	
Maximum Depth	3,500 [km]	
Cruising Speed	3 kn (Maximum 4 kn)	
Navigation	Inertial Navigation System Doppler Velocity Log Homing Sonar	
Operation Mode	Autonomous Remote (Optical, Acoustic)	
Equipment	Multiple Water Sampler Side Scan Sonar Snap Shot Digital Camera Obstacle Avoidance Sonar CTDO	

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mode provides precise navigation by combining data of Inertial Navigation System and Acoustic Doppler Current Profiler. A variety of observation instruments are installed in the vehicle, such that the color TV camera, the snap shot digital camera, the acoustic image device and side scan sonar. And the vehicle is also equipped the CTDO sensor and automatic water sampler as exploration devices. Photo 1 and Figure 2 show the appearance and general arrangement of the vehicle, respectively.

The development project of URASHIMA has been started since 1997. The construction of the body is completed in March 2000. We took place 4 times sea

trial in 2000. Launch-and recovery tests, including training operations, and diving tests were conducted 27 and 18 times, respectively. As a result, safe operation procedure and operation manual were established. Through these diving tests, data of the responses of the body to depth, and on cruising performance and operation parameters, were obtained. The maximum working depth achieved during the fiscal year was 1,753m recorded in Suruga Bay. The research team will improve the control system based on the data obtained in these tests.

(3) Research and Development of Oceanographic Observation Buoy System

Period: from fiscal 1993

This program aims to develop an oceanographic observation buoy system which can make a long term continuous and accurate observation in a vast 3D ocean space to collect a various kind of oceanographic data. Buoys for low-latitude areas have already been practically operated as TRITON buoys and a buoy for mid and high-latitude areas is under development. In this fiscal year, mooring test in a real sea was carried out using a two-piece sinker which is based on last year's model test and moves when current becomes stronger than estimated in order to avoid sinking of



Photo 1 URASHIMA at sea trial

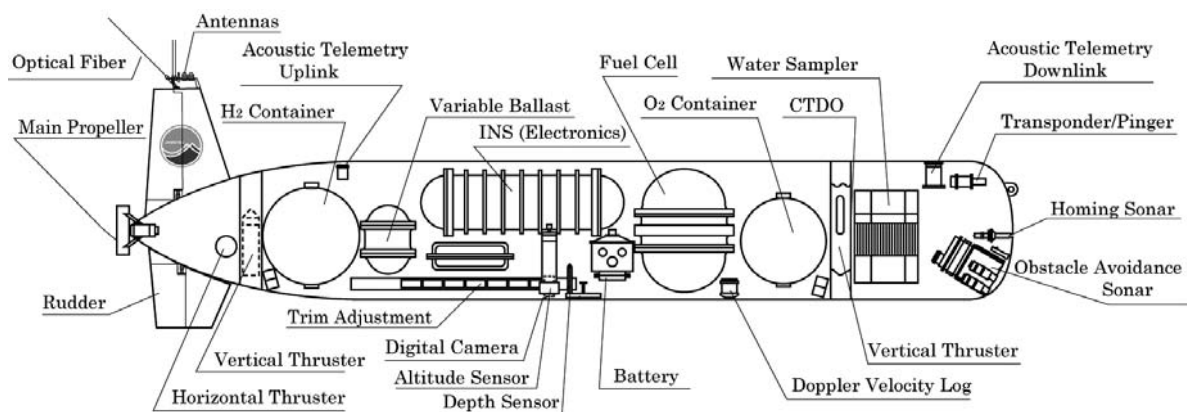


Fig. 2 General arrangement of URASHIMA with Fuel Cell

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buoy. But the test was suspended because current was stronger than we had ever been experienced, the buoy drifted, and there was danger that the sinker might damage submarine cable.

(a) Mooring Test

On July 27, 2000 in the MIRAI MR00-K05 cruise, the prototype buoy was moored at the point of $37^{\circ}46.8'N$ and $152^{\circ}24.0'E$ of which depth is 5,380m, and was scheduled to be recovered June 2001. In the early morning of October 6, the buoy began to drift, dragging the sinker. As it was feared the sinker might damage submarine cables nearby, mooring test was discontinued, and the buoy was recovered, on October 11.

(b) Current Speed

Figure 3 shows the current conditions during the period from the time the pilot buoy was placed on the sea to the time it was recovered. The figure shows that the current speed increased to about 2.5 knots several times until October 6, but such strong current did not last for so long. However, after October 6, the current faster than 2.5 knots continued, and reached 3.5 knots in the maximum.

(c) Cause of Drifting

The two-piece sinker used in this test had been designed to withstand the fastest current speed observed in this area for 450 days in a previous continuous measurement. The buoy drifted because it

encountered current faster than the assumed fastest currents.

(d) Future Measures

The force required to break the vacuum to loosen the sinker was found to be almost the same as that calculated from the result of the model test. Recently, a number of submarine cables have been laid in this area. It has been found, accordingly, that a movable sinker, as a means to prevent a buoy sinking, cannot to be adopted. Further previous observation of current in this area will be done. Also this problem will be studied in a deep-sea moored buoy study committee consisting of experts.

(4) Research and Development of Ocean Energy Utilization Technologies

Period: from fiscal 1989

Utilization of inexhaustible and clean natural energy is drawing increasing attention now, with growing awareness of global environmental problems. Also, utilization of natural energy in a convenient and compact form is expected to increase in isolated islands, remote areas, and developing countries. Wave energy, available in coastal areas, is expected to be effectively utilized as a promising natural energy. JAMSTEC has been conducting research and development work on the MIGHTY WHALE since 1987. The MIGHTY WHALE is an offshore floating type wave power device. The MIGHTY WHALE efficiently absorbs wave energy, which is effectively utilized in the surrounding coastal area, and calms the waves in the sea area behind, thereby making the sea area suitable for effective utilization, such as aquaculture.

JAMSTEC began, in September 1988, the first-phase, the open sea tests by the prototype of MIGHTY WHALE, off the mouth of Gokasho Bay, Nansei-cho, Watarai-gun, Mie Prefecture. The prototype of MIGHTY WHALE is 50 meters long and 30 meters wide. The first-phase experiment ended at the end of

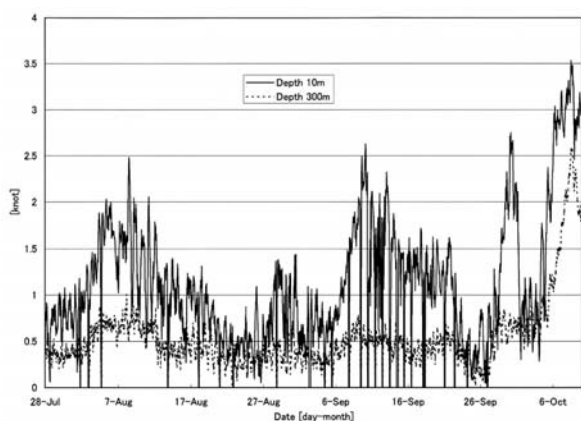


Fig. 3

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fiscal 1999. JAMSTEC is Now conducting detailed data analysis of the open sea tests. Concurrently, JAMSTEC has started the second-phase, the open sea tests using the prototype on research and development of applied technologies for wave power device. The purpose of the second-phase research and development includes practical application of wave power device based on the open sea tests data. The description of the open sea tests in the second-phase are the investigation of technologies for using wave energy to improve marine environmental conditions, and hybrid power generation with such other natural energy as photovoltaic power generation. In fiscal 2000, JAMSTEC conducted experimental pumping up of seawater by an airlift pump using pneumatic air produced by electric power with wave power generation (See Photo 2). Along with it, JAMSTEC installed a 10-kW photovoltaic power generation facility (See Photo 3), and started collecting data on the hybrid power generating system. The experimental pumping up of seawater was done using a flexible polyethylene pipe, 30 meters long and 150 millimeters across in inside diameter, attached to the MIGHTY WHALE. As shown in Figure 4, the experiment confirmed that a maximum of 30 liters per second of seawater was pumped up, at an air rate of 50 Nm³/hour, and that the performance agreed with theoretically calculated values.

Research Project ; Category 2

(1) Research on Technologies for Autonomous Underwater Vehicle working in the Ice-covered Sea Area

Period: from fiscal 1998

The pole region is remarkably affected area by global warming. There are many important data for elucidate the global warming, such that CTD data (Conductivity of seawater, Temperature, Depth), thickness of ice and quantity of dissolved carbon dioxide.



Photo 2 Experiment of seawater drawing by airlift pump



Photo 3 10kw photovoltaic power generation system

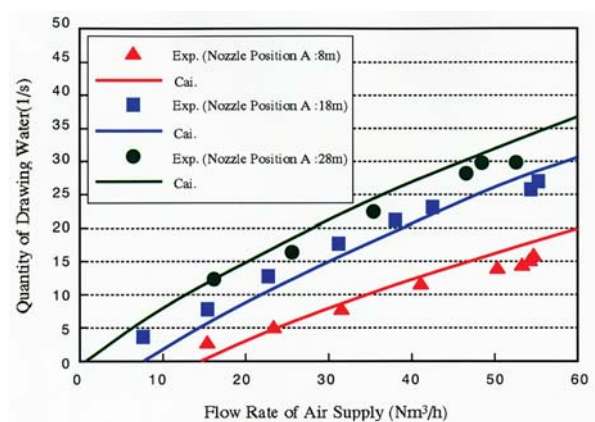


Fig. 4 Characteristic of seawater drawing by airlift pump

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JAMSTEC research and develop essentially technique of measurement to collect these data in the pole region.

This year JAMSTEC developed and mounted Inertial Navigation System (INS), CPU, motor drivers for thrusters and any other electrical devices. The INS is very important navigation system for unmanned underwater vehicle. The CPU is programmed for enable autonomous cruising.

Figure 5 shows the MR-X1 under development.

Personal Research

(1) Research on Improvement of Propulsion and Control System for SHINKAI 6500

Period: from fiscal 1998

This fiscal year JAMSTEC conducted tank tests and real sea area tests of models. In the tank test, model test was executed to research on multi-variable control with five degrees of freedom, except for pitch. In the real sea test, two test using optimal control and Ossman's adaptive control algorithm thrusters are attached tentatively on both sides of the SHINKAI 6500, and moved the vessel forward and backward. The test evaluated the adequacy of thrust-response characteristics of the thrusters, and also measured thruster noise.

(2) Research on Improvement of the Hybrid antirolling System

Period: from fiscal 1999

The hybrid antirolling system on board "MIRAI" is the first system for a large class vessel. It has capability to reduce rolling motion by a moving mass controlled by a computer even at the vessel is drifting or stopping. To investigate the operation of the system, mass motion and oceanic data was obtained for one year. Statistical analysis of the collected data led to the follows. 1) The amplitude of a moving mass is almost proportional to the roll angle of the vessel, and the antirolling system is effective up to 8 degrees of



Fig. 5 MR-X1

significant double roll angle of the vessel. 2) Active force by motors is greater than passive force generated by the arced rail. 3) The operation of the system should not be determined only by significant wave height, to bring out the maximum capability of the system.

(3) Research of very high resolution and long range sonar for seafloor surveying

Period: from fiscal 1997 (suspended in fiscal 1998 and 1999)

This is basic research to develop a high-resolution, long-distance sonar capable of exploring seafloor topography or sunken ships from a long distance, using aperture synthesis technology already used in the field of radar. This fiscal year, JAMSTEC conducted characteristic measurements of the transmitter and receiver, and prepared precision transfer equipment.

Cooperative Research

(1) Research on the real-time catenary estimation technology of tether cables for the remotely operated vehicles

For a remotely operated vehicle such as "Dolphin 3K", any improper operation of its tether cable may

Marine Technology Department

result in an accident such as cable cutoff. In addition, the operation of the cable has largely relied on the operator's experiences, because any information was not provided on the catenary of the cable. This research project has been implemented to develop a technology for estimating the catenary of a tether cable in real time, based upon the cable length data as well as the positioning data of the support ship and the remotely operated vehicle, and displaying the results on a screen. In the 2000 fiscal year, as the last year of this project, linking each module of the system, we carried out the debugs using the data obtained in the ocean last year. As the result, we could confirm the usefulness of this system except the case with the large data flier on the boundary condition.

(2) Research on an Automatic Navigation System for the KAIREI for Deep Seafloor Investigation and Observation

Period: from fiscal 1998

This research aims to develop an automatic navigation system, equipped with a computer and able to effectively keep the vessel in position, and capable of landmark navigation, to replace the joystick-type Kawasaki Integrated Control System (KICS) onboard the KAIREI.

This fiscal year, JAMSTEC improved both hardware and software aspects of the technologies, using data obtained in last fiscal year's demonstration tests. JAMSTEC also conducted a demonstration test on real sea areas, to confirm feed forward compensation to unknown disturbances. This fiscal year being the end of this research, JAMSTEC conducted a test simulating the KAIKOU diving, with a successful good result.

(3) Research on Dynamic Behavior of Flexible Pipe

Period: from fiscal 2000

This research aims to clarify dynamic behaviors of flexible pipe, covering large displacement of flexible pipes under disturbances of tides and waves, as well as

interference to and from a platform (floating structure). The research will then proceed to establish a standard design of a system covering the floating structure and flexible pipes, that will provide safety and satisfactory performance. This being the first fiscal year of this research, JAMSTEC studied methods to theoretically analyze flexible slender structures, including a riser pipe, needed to clarify their dynamic behavior, and studied the present status of the technologies on flexible pipes. JAMSTEC also measured dynamic behaviors of a water-intake pipe for the airlift pump of 30 meters length installed on the MIGHTY WHALE, a floating type wave power device, in the process of open sea tests off the mouth of Gokasho Bay, Mie Prefecture. JAMSTEC conducted first-stage observation, consisting of behavior of the entire flexible pipe, using video cameras. The images obtained by the first-stage observation provided information on the locations at which measuring instruments should be placed to enable effective behavior measurements, and magnitudes of the dynamic behavior of an object.

(4) Research on the monitoring technology for the hydro thermal plume

The observatory of the hydro thermal plume spouting out from the sea bottom is very important to understand the dynamics at the interior of the earth and the global circulation of the chemical materials. This research project aims mainly to develop the chemically observatory method, and to carry out the model test and the in-situ measurement to confirm its usefulness, as the key technologies required for the efficiently survey of the plume source and the grasp of the temporal spatial variation of the hydro thermal plume. In the 2000 fiscal year, we carried out the fundamental experiments using the pH electrode made of Ion Sensitive Field Effect Transistor combined with the solid chloride ion reference electrode to confirm its good stability under the high hydrostatic pressure.

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Commissioned Research

(1) Fundamental Study on the Eco-Float (Offshore type Mega-Float Equipped with Wave Energy Absorbing Device and Utilize Renewable Energy)

Duration of the project: March 1, 2000~ March 31, 2001

Mega-Float is expected to be applied in the near future to various utilization such as Offshore Airport, Hub Port, Dual Port (having airport and seaport functions), etc. then its site should be offshore. So far the Mega-Float is assumed to be installed in a bay or behind the breakwater because the hydroelastic deformation sea condition. And also, for the case of offshore type Mega-Float, it would be difficult to install and maintain to supply electricity, gas, fresh water to the land.

Therefore this study aimed to achieve ① advanced technology for new offshore type Mega-Float which is equipped with wave energy absorbing device and floating breakwater mooring system to reduce the hydroelastic deformation on structure, and ② the concept of self-sufficient Mega-Float ("Eco-Float") which utilizes renewable energy such as wave, solar and

wind power on its wide deck area and has rainwater utilizing system and waste recycling system, waste disposal works etc.

Imagining 24 hours service Dual Port (water depth is 50-100m, significant wave height is 12m (wave period is 14sec, and wind velocity is 50m/sec.), this study has been performed.

The results are hereinafter;

1) It was found that the hydroelastic deformation due to wave can be reduced to about one fourth by providing floating breakwater and wave energy absorbing are chambers around the periphery of pontoon type Mega-Float. It was also shown that the multi-catenary lines mooring system can be applied for floating breakwater and Mega-Float in deep sea region.

As a result, offshore Mega-Float is technically feasible.

2) It was found that the natural energy obtained on the Mega-Float can fill sufficiently the needful electricity for Dual-Port. Also rainwater utilizing system, waste water recycling system and waste disposal works can make Dual-Port independent from shore.

Ocean Observation and Research Department

Overview

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

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

- Group 1: collects and analyzes ocean and atmosphere data by ships and TRITON (TRIangle Trans-Ocean buoy Network) buoys in the western equatorial Pacific and the eastern Indian Ocean for better understanding of El Niño and Asian monsoon;
- Group 2: studies large scale variability in the mid latitudes of the Pacific;
- Group 3: conducts field experiments in both Eastern and Western Arctic Oceans, using surface vessels and automated drifting stations (J-CAD: JAMSTEC Compact Arctic Drifter);
- Group 4: carries out an ocean acoustic tomography experiment in the central equatorial Pacific Ocean and long term observation in Oki-no-torishima;
- 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;

Tropical Ocean Climate Study (TOCS)

The tropical ocean, which serves as a furnace for the rest of the world, has an important role in the heat balance of the earth. Especially, the western equatorial Pacific is characterized by the warmest sea water (warm water pool) in the world, which variation is strongly related with the El Niño / Southern Oscillation (ENSO) phenomena. On the other hand, the tropical Indian Ocean has an oscillation named the Dipole Mode Event, which is closely linked to Asian-Australian Monsoon, affecting the climate system in not only the neighboring countries but also the East Asia, including Japan. Therefore, the western tropical Pacific Ocean and the tropical Indian Ocean are thought to be key areas in the global climate variability.

For better understanding of the role of these areas in the climate variability, we have been observing ocean currents, temperature and salinity distribution and variability in these areas by on-board observations and mooring buoys. We have been also simulating using a high-resolution global circulation numerical model to clarify the ocean dynamics mechanism from comparison with the observation data.

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

Ocean Observation and Research Department

Table 1 Summary of cruises conducted under the TOCS project during FY2000.

Duration	Ship	Ports of call	Buoy work	No. Of CTD/XCTD sites
2000.08.20~2000.10.01	R/V Kaiyo	Yokosuka→Chuuk, Micronesia →Kavieng, PNG→Palau	TRITON buoy: 4 buoys recovery and 6 buoys repair ADCP buoy: 3 buoys deployment and 3 buoys recovery	117
2000.10.18~2000.11.20	R/V Mirai	Sekinehama→Hachinohe→Singapore →Jakarta, Indonesia	TRITON buoy: 3 buoys deployment ADCP buoy: 2 buoys deployment and 1 buoy recovery	107
2001.02.14~2001.03.23	R/V Mirai	Sekinehama→Hachinohe→Guam, USA →Yokosuka	TRITON buoy: 8 buoys deployment and 6 buoys recovery ADCP buoy: 1 buoy deployment and 1 buoy recovery	57

We deployed 11 TRITON buoys at 2°N and 0° along 138°E, at 5°N, 2°N and 0° along 147°E, and 8°N, 5°N, 2°N, 0°, 2°S and 5°S along 156°E during the R/Vs Mirai and Kaiyo cruises. The time series data from these buoys indicated that the largest warm water accumulated in the past 10 years has been formed in the western equatorial Pacific Ocean since March 2000. In late November to early December, the westerly wind became strong in the western equatorial Pacific, and the eastward movement of the warm water associated with the westerly wind was observed.

First Indian Ocean cruise using the R/V Mirai was conducted in the middle of November 2000. One may expect the strong eastward flow in the upper layer near the equator associated with the Wyrtki jet in October/November. The horizontal velocity distribution taken by the shipboard acoustic Doppler current profiler (ADCP), however, showed that weak westward flow on the equator during the cruise (Fig. 2). This was also confirmed by the trajectories of the surface drifting buoys for several days after the deployment. The analysis of wind data indicated that the amplitude of the annual and the semiannual components are similar to the climatological values. It also turned out that the large amplitude intraseasonal variability in the zonal wind is superimposed on the

annual and semi-annual components. In early December, the drifting surface buoys started to move eastward, then drifting to southeastward to the coast of Sumatra. These analyses suggest that the intraseasonal wind variability strongly modulates the amplitude of the equatorial jet and generates the intermittent aspect of the jet.

For understanding the role of the ocean to climate variation especially focused on the equatorial ocean circulation, numerical experiments have been performed by using a high-resolution global circulation model with 1/4-degree grid spacing and 55 vertical levels. The model was forced by the surface data with year to year variation from 1982 to 1998. The model simulates the El Niño events in 1982/83, 1986/87 and 1997/98, and the La Niña events in 1984/85 and 1988 as shown in the surface temperature anomaly in the Nino3 area (Figure 3). Figure 4 shows the model monthly mean velocity distribution in the periods of mature and terminated state of 1997/98 El Niño. In the mature period, the typical flow pattern consisted of the New Guinea Coastal Undercurrent (NGCUC), the Halmahera Eddy (HE), the Mindanao Eddy (ME) and the Equatorial Undercurrent (EUC) can be seen despite shallower thermocline in the western equatorial Pacific Ocean. In November 1998 after El Niño has been ter-

Ocean Observation and Research Department

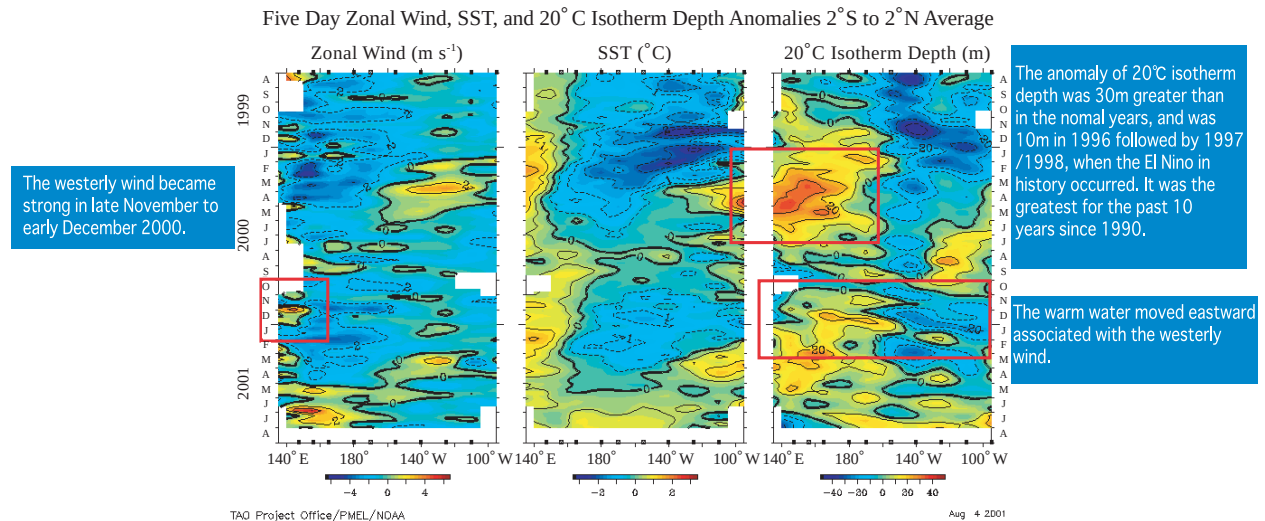


Fig. 1 Longitude-time series plot of 5-day mean anomalies of the zonal wind (left), sea surface temperature (center) and 20 degree isotherm depth (right) between 2N and 2S.

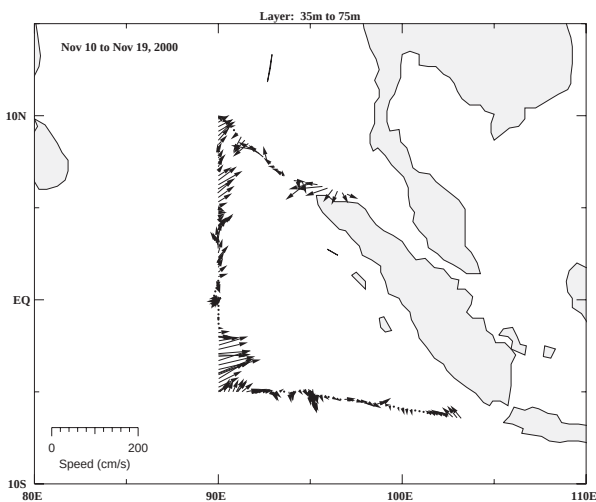


Fig. 2 Horizontal distribution of current velocity averaged at 30m to 75m depth taken by the shipboard ADCP.

minated, there can be seen no remarkable eddies (ME, HE) and meanders. Though the NGCUC and the EUC still exist, the cross equatorial current along the New Guinea coast is not recognized. This no cross equatorial current state is consistent with the velocity observation at 138°E on the equator. These features can be recognized also in 1982/83 El Niño. It is suggested that the restore of the warm water in the northwestern Equatorial Pacific Ocean under the condition of a quickly developed La Niña may prevent the cross equatorial current. Though some improvements are left in mixed layer parameterization and surface heat flux condition, the model simulates the observed oceanic variation, corresponding to El Niño events as stated above. The mechanism of El Niño and the role of the western Pacific Ocean variation will be investigated by quantitative analysis and comparison with observed data.

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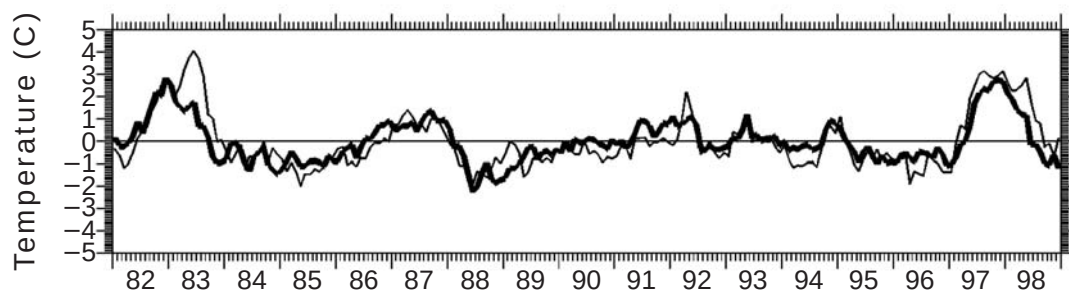


Fig. 3 Time series of sea surface temperature anomaly in Niño-3 area. The observed data (thick line) and the model (thin line).

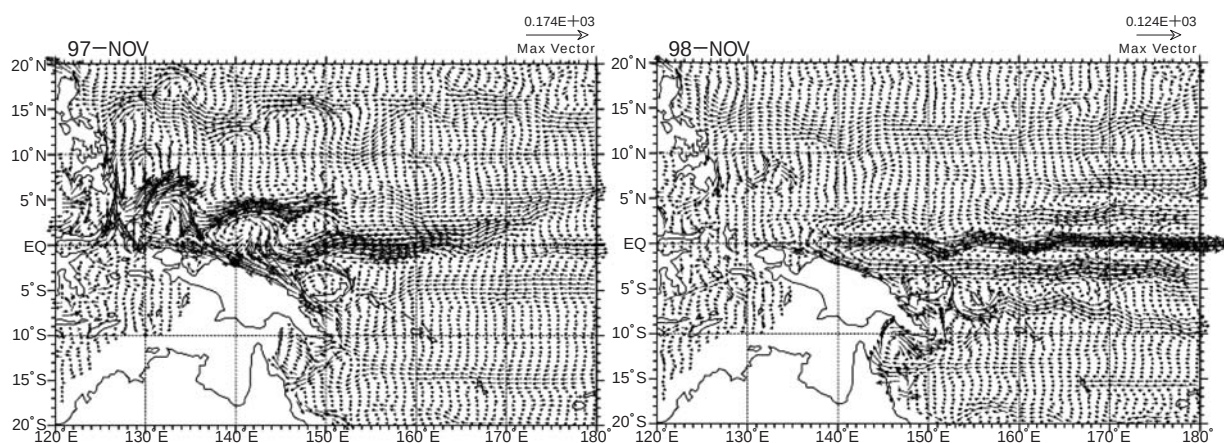


Fig. 4 Model monthly mean velocity at 100m depth in the western Pacific Ocean. Left: November 1997, Right: November 1998.

Study of the Air-Sea interaction in the Tropics

Precipitation is a key element to understand the air-sea interaction, especially over the tropical western Pacific Ocean, where the warmest sea surface temperatures exist and is often called "warm water pool". To study the air-sea interaction focussing on the precipitation mechanism of the deep convections developed over the warm water pool, stationary observation by the R/V MIRAI equipped with many sophisticated instruments such as shipboard Doppler weather radar and radiosonde has been carried out. In the FY 2000, two observational cruises were conducted.

In June 2000, observation was conducted at 7°N,

140°E for two weeks. It was designed to observe the well-organized cloud clusters developed over the intertropical convergence zone (ITCZ), where north-easterly and south-easterly trade winds encounter and produces much precipitation in the range of between 5°N and 10°N. An example of the precipitating system, observed by Doppler radar, is shown in Fig. 5. There were few cases of the observed internal structure of ITCZ. The analyses for the internal structure and environmental condition are proceeding.

Another observational cruise, on the other hand, had been carried out from late November through mid-December at 2°N, 138°E focussing on the convections accompanied with the equatorial intraseasonal oscillation

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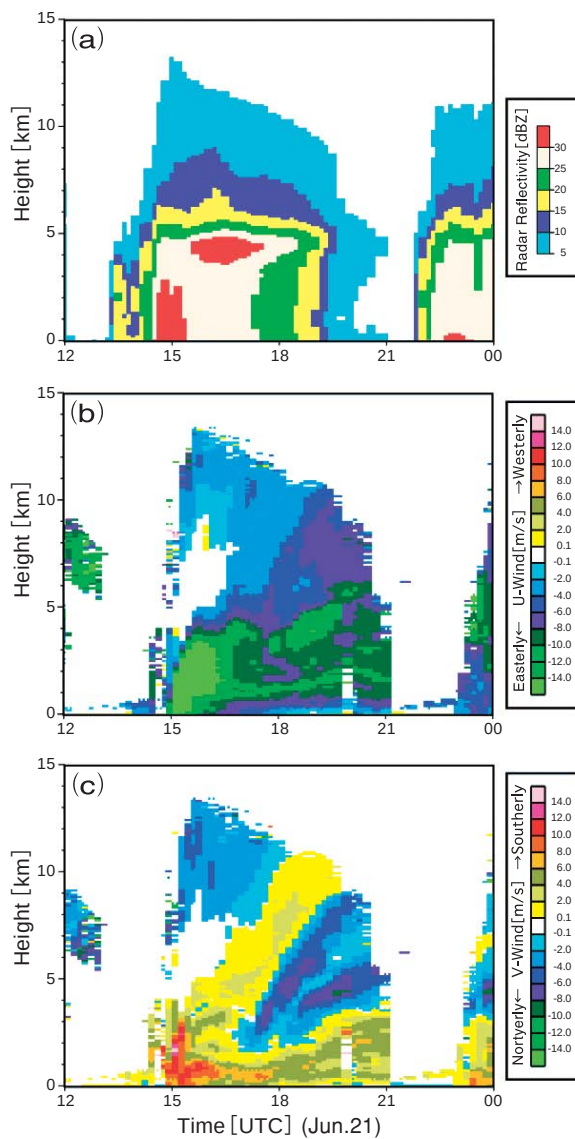


Fig. 5 Time-height cross section of the observed internal structure of a precipitating system. (a) radar reflectivity, (b) east-west component of the wind which derived by velocity azimuth display (VAD) analyses, and (c) north-south component of the wind by VAD analyses.

(or Madden-Julian Oscillation). The most outstanding feature during the cruise was to observe the westerly wind burst (WWB) that has been recently recognized as key element of trigger and/or termination of El Niño event by many researchers. Further analysis is expected to reveal the relation between the WWB and the oceanic response.

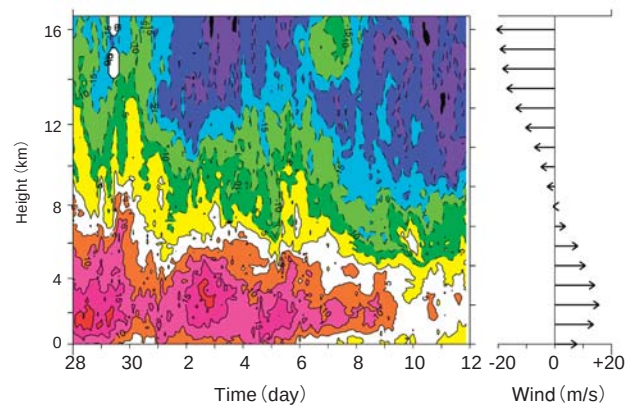


Fig. 6 Time-height cross section of zonal wind component obtained by radiosonde sounding (left panel). Mean profile during November 28 through December 5, 2000 when westerly wind bursts were dominant (right).

Development and maintenance of TRITON buoy network

JAMSTEC maintains a surface moored-buoy network named TRITON (TRIangle Trans-Ocean buoy Network) for observing oceanic and atmospheric variability in the Pacific in cooperation with interested Japanese and foreign agencies and institutions. The principal scientific objective is to understand variations of ocean circulation and heat/salt transports with emphasis on ENSO, the Asian monsoon, and decadal scale variability that influences climate change in the Pacific and its adjacent seas. In its first phase, the buoy network was established mainly in the western tropical Pacific Ocean, and harmonized with TAO-ATLAS array which is maintained by NOAA's Pacific Marine Environmental Laboratory.

The fundamental functions of TRITON are (1) basin scale ENSO monitoring, and (2) measurements of heat, freshwater, momentum fluxes for improving modeling capability. The scientific goals of the TRITON project address the observational requirements of international research program of Climate

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Variability and Predictability (CLIVAR), a major component of the World Climate Research Program sponsored by the World Meteorological Organization, the International Council of Scientific Unions, and the Intergovernmental Oceanographic Commission of UNESCO. TRITON array is one of the major components of CLIVAR observing system, and also Global Ocean Observing System (GOOS) / Global Climate Observing System (GCOS). This is also accepted as an important project to be promoted by US-Japan collaboration in a framework of US-Japan Pacific ocean observation and research initiative (TYKKI) panel of US-Japan conference on development and utilization of natural resources (UJNR). We have also collaboration with Agency for the Assessment and Application of Technology (BPPT), Indonesia and National Institute of Oceanography (NIO), India.

JAMSTEC has started the deployment at four TRITON of 8°N, 5°N, 2°N and 0°, 156°E by R/V Mirai in March 1998. The TRITON buoys were deployed at eleven sites along 156°E, 147°E, and 138°E by the end of March 2000 (Photo. 1, Fig. 7). The TAO-ATLAS buoys along 156°E, 147°E and 137°E had been replaced with TRITON buoys until November 1999 since February 1999. TRITON data has been distributed through GTS (Global Telecommunication

System) and web page the same as TAO data. The web display and distribution software for the combined TAO/TRITON data sets has been developed based upon the TAO software.

One of the major purposes of TRITON array is to monitor ENSO in the entire tropical Pacific Ocean harmonized with TAO array. For that purpose, the data from both buoy arrays should have compatibility with good quality. To validate the data compatibility between the two buoy systems, the TRITON buoys were deployed close to TAO buoys at several sites to enable the intercomparison from a few months to eight months as longest in March 1998-November 1999 when the TRITON buoys replaced the TAO buoys in the western tropical Pacific Ocean. The compared parameters, which are obtained by the standard TAO buoy (standard ATLAS buoy), are wind direction, wind speed, air temperature, relative humidity, and water temperature. The results show generally good agreement between the meteorological data from the two buoy systems, except the wind direction. The wind directions measured by TRITON buoys deviate more significantly, and pre- and post-calibration will be taken to minimize the difference. The water temperature from both systems shows good agreement



Photo 1 TRITON buoy

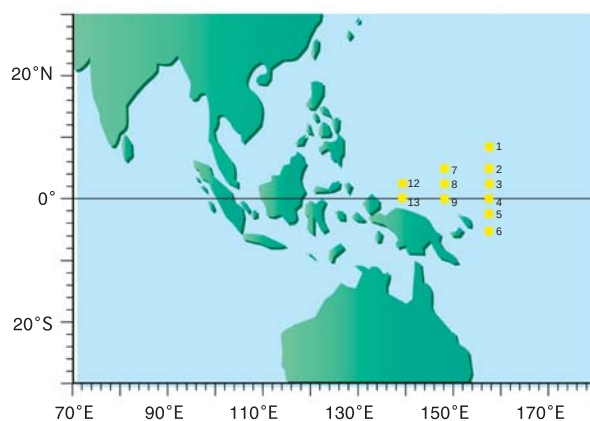


Fig. 7 TRITON/ATLAS buoy array

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Photo 2 Intercomparison

and stability of temperature sensors of TRITON buoy is quite stable during one year measurement.

A land-based intercomparison study among TRITON, ATLAS and Woods Hole Oceanographic Institute (WHOI) buoys was also conducted at WHOI in May-June, 2000. The purpose of this study was to confirm the compatibility of meteorological data from the three systems, and the preliminary result shows good agreement.

Development of atmospheric sampling and onboard analyzing systems for stratospheric platform

(1) Fundamental requirements for air sampling and onboard-measurement systems

In the conceptual design carried out in the first half of 12th fiscal year, it was proposed to aim at developing the systems which satisfy the following specifications, according to the advise from Research Discussion Group for Atmospheric Observation from Stratospheric Platform whose members are mostly a specialist in atmospheric science. It was also recommended to initiate development based upon currently available sampling and onboard-measurement systems for aircraft.

- target gas component is carbon dioxide.

- two types of system are developed, i.e. measurement system for in-situ continuous analysis of carbon dioxide concentration and automatic air sampling system for analysis of upper atmosphere after recovery.
- followings are principal specifications proposed for the continuous analysis of carbon dioxide.
 - altitude range in onboard measurement :
3~15Km
 - dynamic range in measurement:
340~400 μ Mol/Mol
 - minimum sensitivity:
 $\pm 0.2 \mu$ Mol/Mol
- automatic sampler will collect 300cm³ of air, at least in two sites.
- 40Kg will be upper limit of total weight of the continuous carbon analyzer and automatic air sampler, including peripheral instruments like air inlet and communication system (according to weight control with air ship)
- Allotted space is 45cm $\times$ 45cm $\times$ 45cm for each of above two systems (ibid)

(2) Current status in development process.

- Currently available air sampling and in-situ-measurement systems onboard aircraft require only normal moderate condition to work, while these two systems which are exposed to severer condition in the Stratosphere must clear minimum criteria to operate regularly at much lower temperature and pressure in the Stratosphere and under large change in air temperature and pressure in ascending and descending modes. In order to complete detailed design of the systems which satisfy the specifications proposed in the conceptual design, some technical pre-examinations below were carried out on the ground to examine performances of some principal component systems and the results were reflected to the

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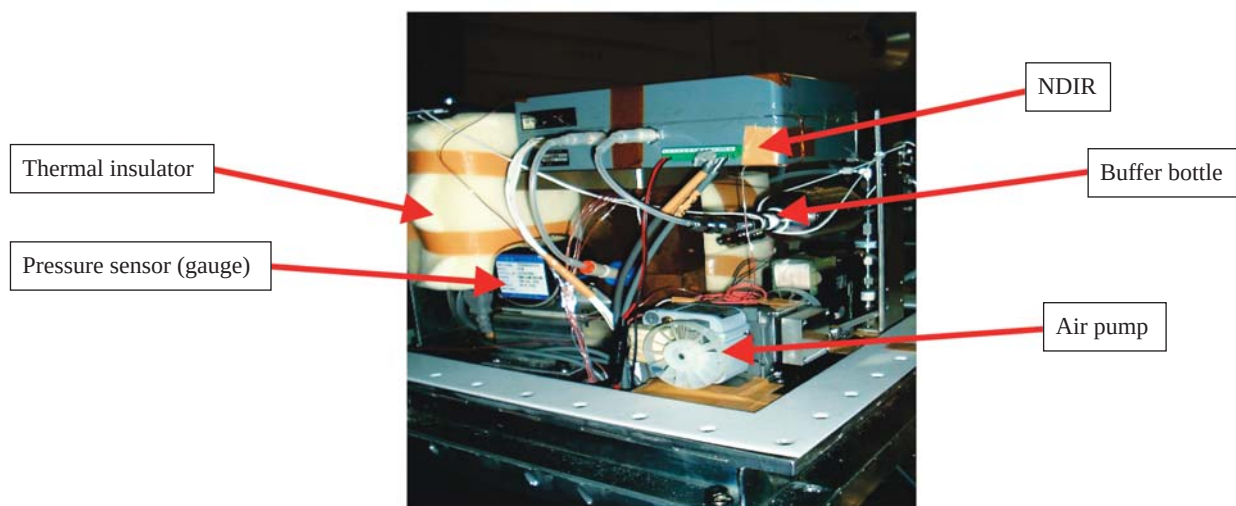


Fig. 8 Instruments for pre-examination(gas systems/detection system)

detailed design.

- air sampling pump
- sub-system for carbon dioxide measurement (NDIR)
- valve-sequencer
- It was concluded according to these examinations that some improvements are still necessary, however, explicabilities of these sub-systems are quite prospecting.

Evaluation of TRITON buoy sensors and validation of buoy data

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

the data from TRITON buoy.

In the FY2000, as the drift of conductivity sensors were recognized in laboratory calibration and from in-situ comparison, we attempted to correct the drift by assuming linear trend of drift with time. The results of correction improve the quality of TRITON salinity data, and we decided to use this method in the operation. The results of evaluations of all meteorological sensors indicate that the calibrations have performed properly in laboratory, and the drifts of each sensor were small compared with uncertainties in laboratory calibration. The comparison with in-situ measurements from ship and buoy indicated that the data from TRITON have the same quality as those.

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

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

In order to understand the intermediate and deep ocean circulation, collaborative research with Ocean Research Institute (ORI) of Tokyo University by onboard observation and moorings has been conducted. JAMSTEC is in charge of the observations of the Antarctic Intermediate Water (AAIW) along the New Guinea coast, and ORI is in charge of the observations of deep flow in the Wake Island Passage and Melanesia Basin. During FY2000, we conducted observation cruises north on New Guinea. We also analyzed the data obtained during past observations at

the Wake Island Passage, Melanesia Basin and north of New Guinea.

Analytical result by ORI shows that the deep flow at the Wake Island Passage is confined below 3000m depth (Fig. 9), but deep flow at the Melanesia Basin is not as strong as that at the Wake Island Passage.

We, JAMSTEC, conducted on-board observations along 142° E line, which is located at the north of New Guinea, since 1994. These cruises' results show that temperature and salinity of the AAIW during boreal summer season is lower than boreal winter season (Fig.10). This is probably due to large volume transport of the New Guinea Coastal Undercurrent, which advects the AAIW to the Northern Hemisphere, during boreal summer season.

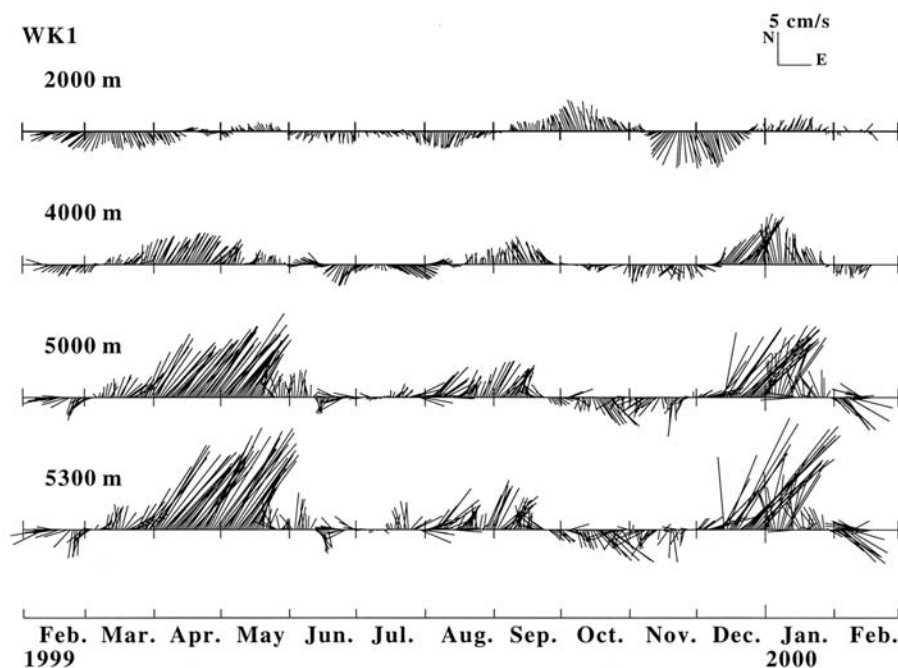


Fig. 9 Time series of current velocity at the Wake Island Passage (18° 20'N, 169° 30'E).

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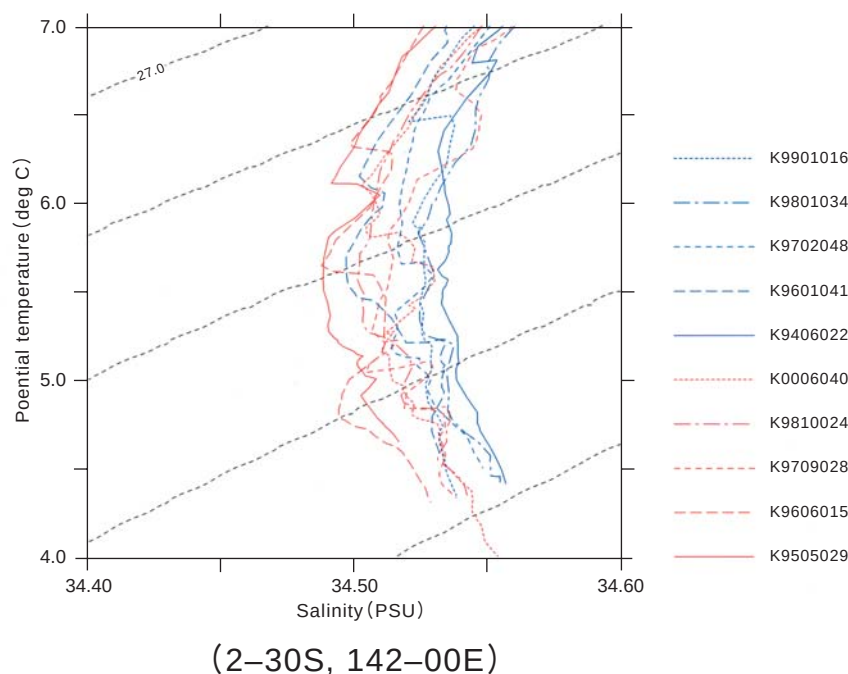


Fig.10 Potential temperature - salinity relations near the New Guinea Coast (2° 30'S, 142° E) from ten cruises conducted from 1994 to 2000. Red lines denote the result during boreal summer season, and blue ones denote that during boreal winter season.

Study on the Kuroshio Extension

The Kuroshio in the western North Pacific is called as the Kuroshio Extension and forms the clear northern boundary of the sub-tropical gyre. The Kuroshio Extension is active and generates cold and warm eddies very frequently. There is a large possibility that these eddies play an important role in the meridional exchange of heat and freshwater across the Kuroshio Extension.

In order to clarify the physical and dynamical structure of eddies along the Kuroshio Extension, spatially dense CTD full section from 30° N to 40° N along 152.5° E with LADCP was made up in July 2000(R/V Mirai, MR00-K05 cruise). Fig.11 shows the cross section of the potential temperature. The Kuroshio Extension existed between 34° N and 35° N. The North

Pacific Subtropical Mode Water was distributed in the sea south of the Kuroshio Extension. North Pacific Intermediate Water was distributed around the Kuroshio Extension as a patch like feature. Intrusion of fresh water patches of the North Pacific Intermediate Water seems to be seen up to 32° N. Especially at 32.5° N thick water layer over 80m existed, and then could contribute freshwater flux to sub-tropical region across the Kuroshio Extension.

Some features of the flow field at Kuroshio Extension region were revealed by direct current measurement of LADCP. Fig.12 is a snapshot of the east-west flow along 152.5° E measured by LADCP. At the time the Kuroshio Extension flowed northeastward. Just below the strong current a weak flow of opposite direction existed, which could be related with fresh water exchange process associated with an eddy

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activity. It appeared a deep flow at the latitude of Kuroshio Extension existed. The deep flow was eastward and stronger near the sea bottom. Its speed was up to 10cm/s, and then contributed to the volume transport at the Kuroshio Extension region. The eastward volume transport between 33°N and 34°N was up to 72Sv, though geostrophic transport refer to 2000m was 46Sv. In the subtropical region narrow countercurrent was appeared. In the mixed water region eastward and westward flow pattern stood in alternately, of which typical spatial scale was 130km.

The flow shows barotropic feature and strong flow of 10cm/s was appeared. It has good agreements with the flow feature obtained by a moored current at 37.5°N in 1998-1999, where mesoscale eddies has almost equivalent barotropic structure, exhibiting occasionally a strong current of about 20 cm/s near the bottom. In order to understand the mesoscale variabilities and its contribution to heat budget in the Kuroshio Extension region we are planning to conduct an intensive observation in FY 2001.

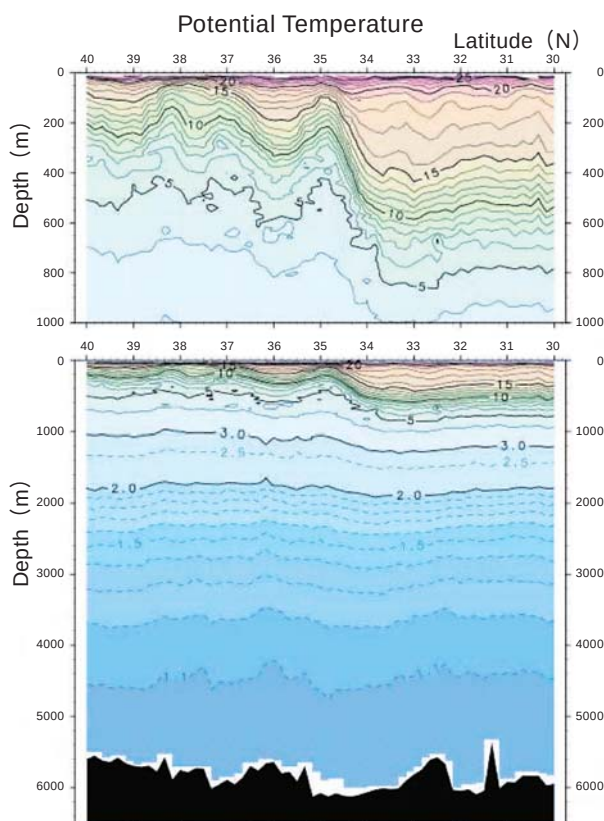


Fig.11 Cross section of potential temperature along 152.5E

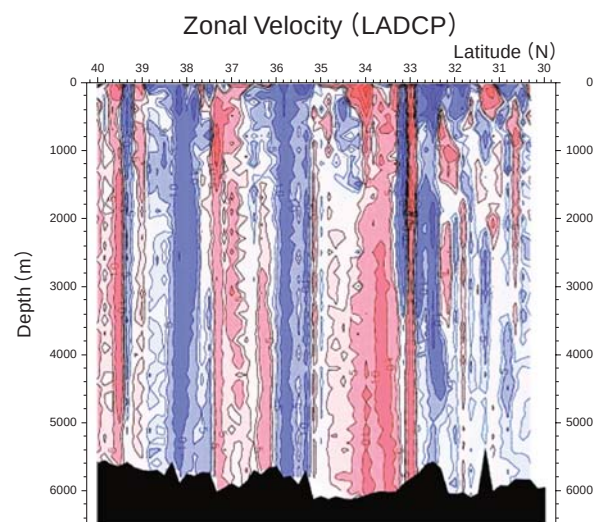


Fig.12 Cross section of east-west flow along 152.5E observed by LADCP. Red (Blue) shows eastward (westward) direction.

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Arctic Ocean Research

Background and objective

It is now our common understanding that the Arctic regions react particularly and sensitively to global climate change. However, recent studies show that the Arctic may be a key player to control the heat balance of the earth. In particular, Japan is located in the mid-latitude in the northern hemisphere; the change of the Japanese climate is controlled not only by unusual phenomena in the tropical region but also by changes

in the Arctic region. Although the prediction of global climate change in future is simulated by various numerical models, we should progress not only virtual predictions but also an understanding of on-going real changes simultaneously. Recent 30 years, sea ice extent has been continuously monitored by satellites. However the satellite system cannot acquire underlying oceanographic changes in either temperature or salinity which controls the long-term climate change and variability. Our research objective is to clarify the role of the Arctic Ocean on the global climate system,

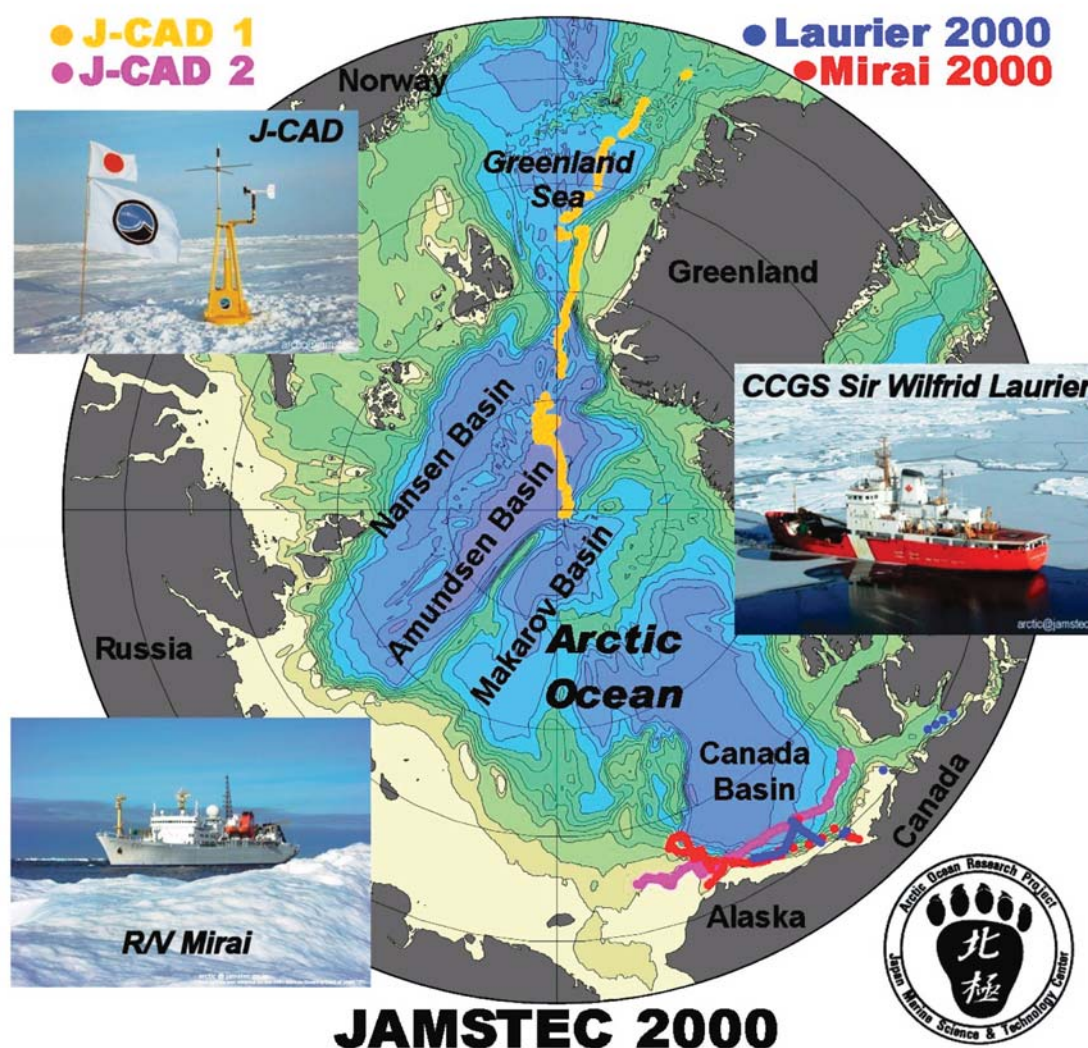


Fig.13 Research activities in FY2000.

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especially focusing on the inflows of both Pacific and Atlantic waters. The inflows influence the heat and freshwater budget, which causes the changes in ice cover. These integrated changes also trigger biogeochemical environment changes. Based on this direction, our field experiments in FY2000 were carried out in both the eastern and western Arctic Oceans (Fig.13). Here we briefly introduce our activity and preliminary results.

1. Eastern Arctic Ocean (Atlantic side of the Arctic Ocean)

We have developed a new type of drifting buoy called J-CAD (JAMSTEC Compact Arctic Drifter) in 1999. The first J-CAD was installed near the North Pole (89.68N, 130.33W) on April 24, 2000, as a part of the North Pole Environmental Observatory (NPEO). *The New York Times* (August 19, 2000)

reported that "The North Pole is melting; an ice free patch of ocean about a mile width has opened at the top of the world". This led to discussions on an evidence of global warming.

Fig.14 shows the typical vertical profiles of temperature and salinity obtained by J-CAD-1 and the EWG (Environmental Working Group) climatological (1948-93) data near the North Pole. The J-CAD data tell us the following evidences:

- (1) The salinity of surface mixed layer in 2000 was much higher than the climatology, which caused a weakening of the Arctic halocline, in other words a weakening of the static stability in the upper ocean.
- (2) The weakening of the static stability provides an unfavorable condition for the sea-ice formation in the Eastern Arctic Ocean, and enhances the upward heat and salt flux of underlying Atlantic Water.

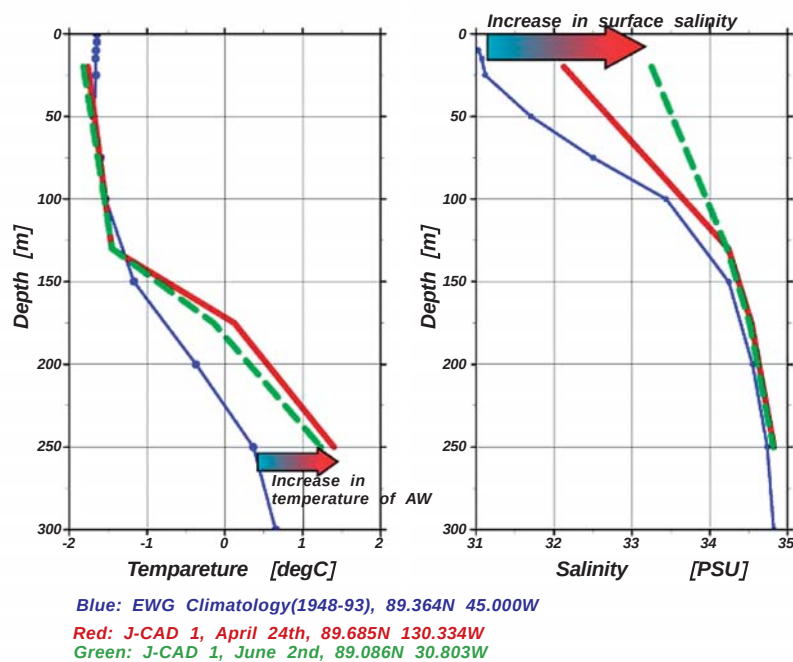


Fig.14 Vertical profiles of temperature (left) and salinity (right) obtained by J-CAD-1.
 Red solid line; April 24, 2000 (89.685N, 130.334W)
 Green broken line; June 2, 2000 (89.086N, 30.803W)
 Blue solid line with solid circle; the EWG climatology (89.364N, 45.000W)

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- (3) The Atlantic Water just beneath the cold halocline layer was much warmer than the climatology.

Since the salinity within the surface mixed layer (<30m) was not lower than the climatology, the thinning and retreat of ice cover was not caused by the ice melt due to oceanic heat flux. An important issue to be noted is that the current oceanic condition is not preferable for the ice production.

2. Western Arctic Ocean (Pacific side of the Arctic Ocean)

We have investigated the surface water circulation and its influence on the ice cover in the western Arctic Ocean since 1996. In FY2000, in addition to the above research theme, we also focused on the circulation and modification of the intermediate water, in particular on the Atlantic Water circulation. The field experiments were conducted by R/V Mirai and CCGS Sir Wilfrid Laurier in cooperation with Canadian Institute of Ocean Sciences (IOS).

2.1. Shelf water spreading (Pacific Water spreading)

Fig.15(a) shows CTD/XCTD casts conducted by R/V Mirai and CCGS Sir Wilfrid Laurier in late summer of 1999 and 2000. The upper ocean temperature and salinity along the southern perimeter of the Canada Basin are depicted in Fig.15(b-c). The warm water with the salinity range of 31.0-32.0 psu is characterized by summer shelf water (ECSW: Eastern Chukchi Summer Water), which is one of major heat sources for ice melt in the western Arctic. Both the horizontal and vertical distribution of the ECSW in 2000 was quite different from that in 1999. In 2000, the stored heat within the ECSW in the basin was much greater than in 1999. The influence of the oceanic heat was also clearly found in the ice retreat pattern. Fig.16 shows the RADARSAT images in the

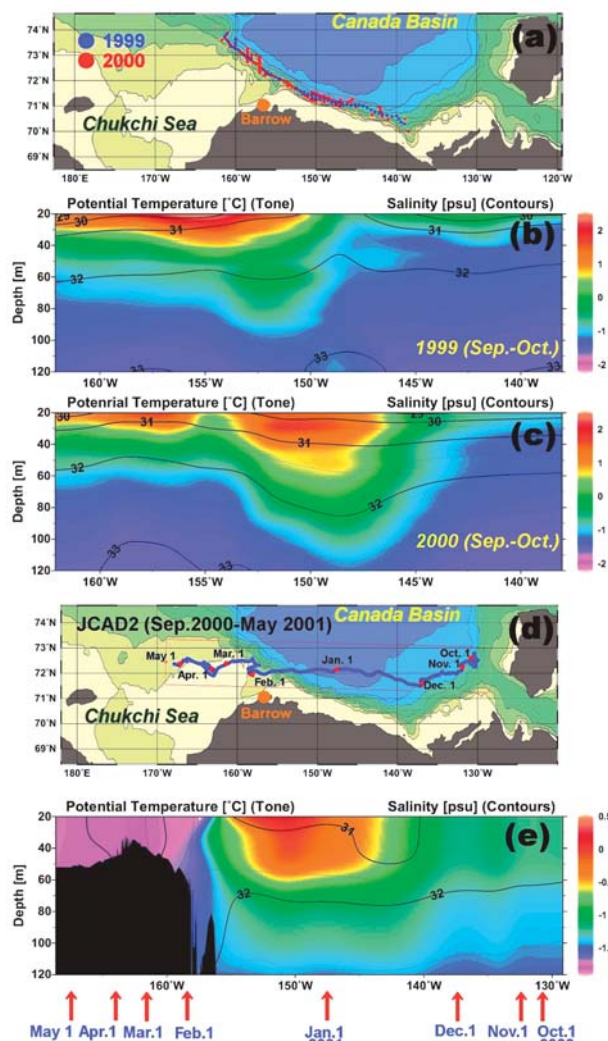


Fig.15 Vertical sections of temperature and salinity in the southern Canada Basin.

- (a) CTD and XCTD casts of 1999 and 2000 from R/V Mirai and CCGS Sir Wilfrid Laurier.
- (b) Vertical section of temperature and salinity in late summer 1999.
- (c) Vertical section of temperature and salinity in late summer 2000.
- (d) Drift track of JCAD-2.
- (e) Vertical section of temperature and salinity from JCAD-2.

area where the warm ECSW was found in 2000. The warm water was not in uniform distribution, but in patch-like distribution associated with vigorous interactions between the mean flow and eddies. These non-

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linear behaviors of ECSW are important processes to evaluate the quantitative heat transport from the shelf region into the basin.

In addition to the field experiment aboard the surface vessels, we have also autonomous observation using a drifting buoy (J-CAD2) which was installed in the southeastern Canada Basin off Banks Island at 72.46N, 130.16W on September 12, 2000. The J-CAD2 drifted across the deep southern Canada Basin (Fig.15(d)) and measured the upper ocean hydrographic condition over the winter period (Fig.15(e)). The maximum temperature along the drift track of the J-CAD2 was observed off Alaska in January 2001. The spatial distribution of warm ESCW suggested that the intermittent offshore transportation of ESCW in the vicinity of Barrow, and the stored heat in the ECSW were not ruined even during winter, since the sea ice played a role of a thermal insulation material which inhibited upward heat flux from the ocean to the atmosphere. The temperature of ECSW observed by J-CAD2 in the basin was higher than usual. The stored heat had a potential of 50cm ice melt, which is equivalent to the potential of ESCW that entered into the

Canada Basin in 1997. The current atmospheric circulation pattern over the Arctic Ocean is different from the period of 1997-1998. The difference between the ice retreat pattern in 1998 and in 2001 will tell us the coupled influences of ocean and atmosphere on the changes in ice cover.

2.2. Atlantic Water circulation

Extra warm Atlantic Water (GWWA: Great Warm Water Anomaly) spreading in the Arctic Ocean is a current fascinating phenomenon among the issue of Arctic changes. In the western Arctic Ocean, the GWWA with the interleaving in temperature and salinity (T and S) was first observed on the flank of the Mendeleyev Ridge in 1993 from CCGS Henry Larsen. After that the GWWA continued to propagate eastward along the perimeters of the Makarov Basin, Chukchi Plateau and Northwind Ridge (Fig.17) during the last decade. Beyond the topographic obstacles of the above major ocean ridges, the GWWA with large amplitude of interleaving structures was first found on the perimeter of the southern Canada Basin east of the Northwind Ridge from R/V Mirai in 2000. The maxi-

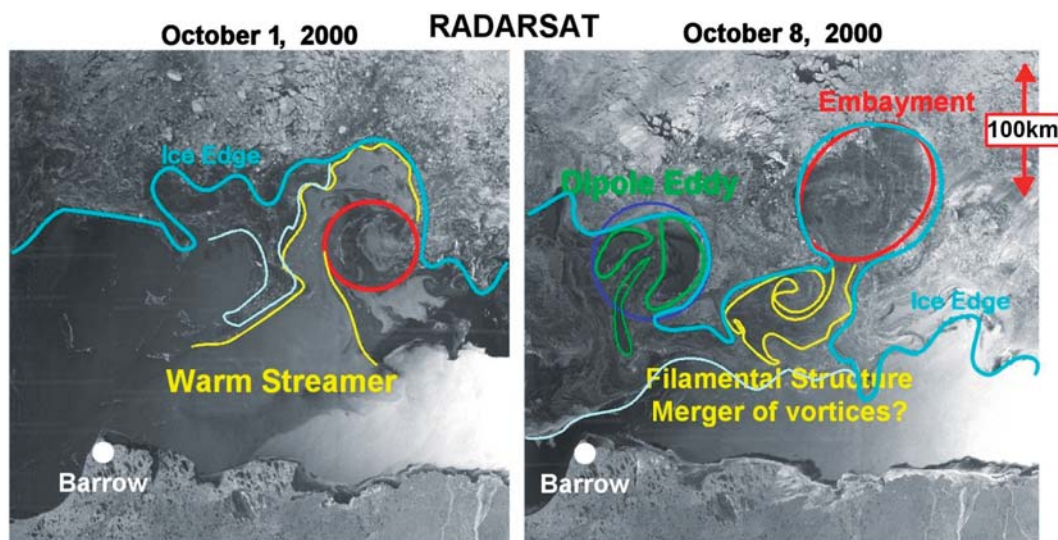


Fig.16 RADARSAT images near Point Barrow in early October in 2000. (2000 Canadian Space Agency)

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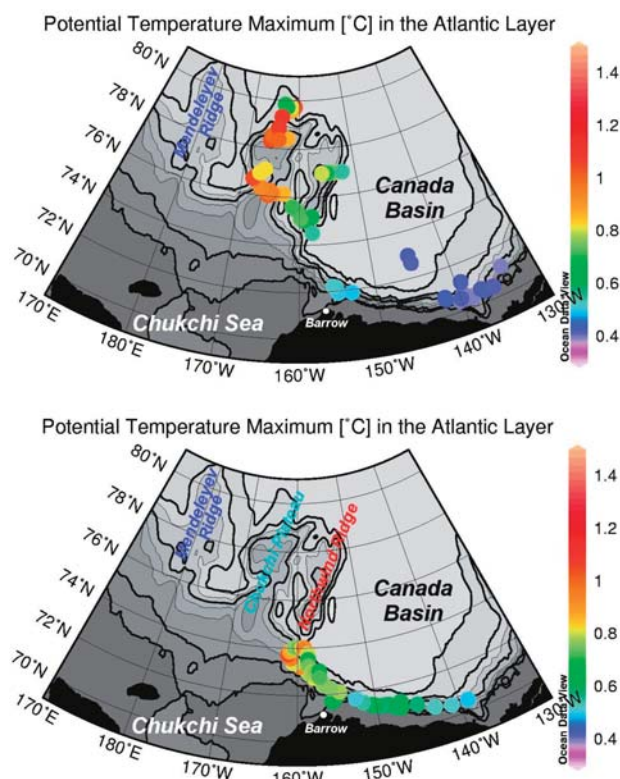


Fig.17 Spatial distribution of temperature maximum in the Atlantic Layer in 1995-1998 (top) and 2000 (bottom).

imum temperature was still higher than 1 degree Celsius in this region. The influence of the western Arctic climate, in particular upward oceanic heat flux, should be examined in forthcoming years.

An Ocean Acoustic Tomography Experiment in the Central Equatorial Pacific Ocean

Introduction

The tropical and subtropical Pacific Ocean is suggested to connect via a shallow meridional circulation cell by Gu and Philander (1997). This subtropical cell (STC) has been hypothesized to the El Niño-Southern Oscillation phenomena in the tropic, which then, in turn, can affect the subtropical ocean via rapid atmospheric forcing. But no direct measurements exist and

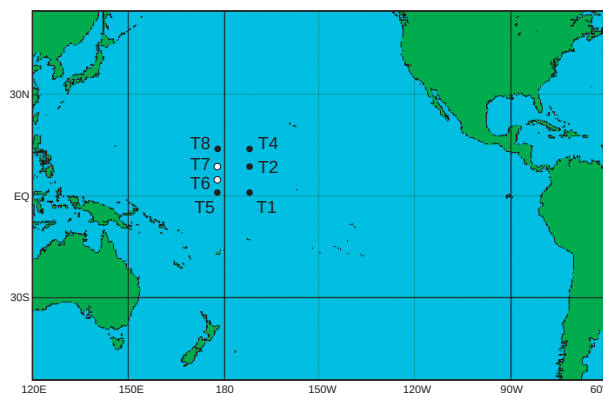


Fig.18 location map

indirect measurements and modeling support the hypothesis.

JAMSTEC conducted a program to directly measure part of the circulation cell using the system acoustic tomography system in the Central Equatorial Pacific Region (0.5°N to 13.6°N , 177.7°E to 172.1°W) from December 1998 to December 2000.

Observation

Seven 200 Hz tomography transceivers were deployed to monitor the rectangular region from 178°E to 172°W and from 0.5°N to 13.5°N . There were 21 acoustic paths connecting the various transceivers. The transmission schedule had a four-day cycle consisting of one sing-around transmission day, one non-transmission day, one simultaneous transmission day, and one non-transmission day. The cycle of transmissions began on January 5, 2000. Each of the transceivers sequentially transmitted the 200 Hz acoustic signals, modulated by a tenth-degree m-sequence every four hours on the sing-around transmission day. The measured data for sing-around transmissions were available via satellite telemetry and analyzed in near-real time; these are the data reported here.

The reference sound speed profile was determined from CTD casts and the NODC database. The sound channel was at a depth of about 1000 m with a steep

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thermocline above. The travel times of eigenrays for each acoustic path were calculated according to the reference profile. The ray identification of multipaths was carried out by comparing calculated values with observed data. There were 232 eigenrays identified for all acoustic paths. The sum and difference travel times for each eigenray were obtained using this identification.

The stochastic inverse method was used for reconstructing the temperature (sound speed) fields. The sound speed anomaly was vertically expanded using the first four empirical orthogonal functions (EOFs) and horizontally by a Fourier series. The three-dimensional temperature fields were reconstructed using the sum travel times. The travel time differences along the acoustic paths from the reciprocal transmissions were averaged over a day and directly converted to barotropic velocity using the simple relation,

$u = (C^2/R) \delta t$, where u is velocity, C is a nominal sound speed, R is range between transceivers, and δt the measured differential travel time.

Temperature Field

The three-dimensional temperature field over the observing area was reconstructed every four days. From these fields, zonal water temperature along 5°N was depth-averaged from 100 m to 400 m (Figure 19).

The left panel of this figure shows that warm and cold waters interchangeably moved westward during La Niña and disappeared during the normal state. The phase velocity of these waters is about 0.5 m s^{-1} , which is the same as that reported by Legeckis for equatorial instability waves. The time-series of 20°C Isotherm depth anomaly at 5°N by Tropical Atmosphere Ocean (TAO) array coincided with the time-series of reconstructed zonal water temperature anomaly. A comparison of both panels of Figure 19 clearly indicates that the Legeckis waves were active during La Niña, but inactive during the normal state.

Barotropic Flows

The barotropic velocity along several of the acoustic paths is shown in Figure 20. The flow along the 172°W meridian from 9°N to 13.5°N changed during La Niña and during the normal state (Figure 20). The flow along the 178°E meridian did not change in the same way during these periods, (Figure 20c). The phase appears to be delayed by about 50 days (the second peak in Figure 20a relative to the first peak in Figure 20c). The flow along the 9°N zonal line from 178°E to 172°W was eastward during La Niña and reversed during the normal state (Figure 20d). The flow along the 13.5°N zonal line from 178°E to 172°W was westward during La Niña and eastward during the normal state (Figure 20b).

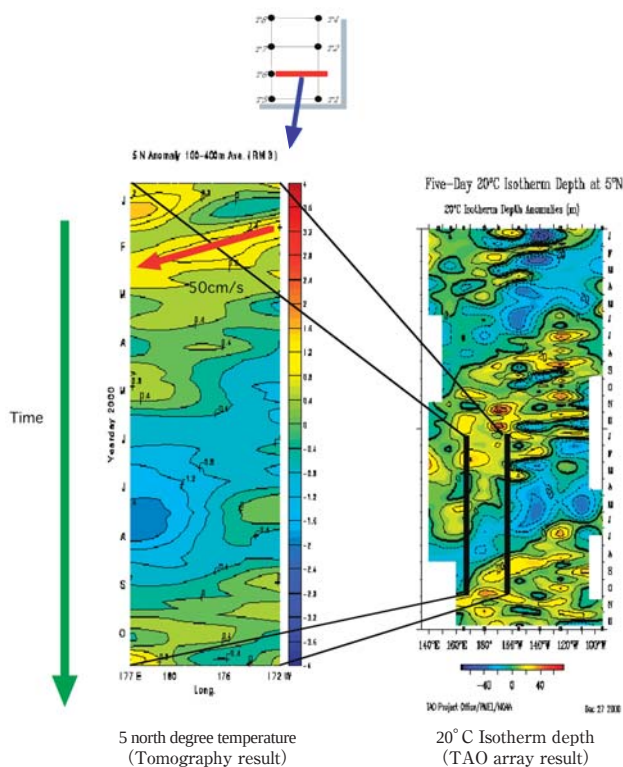


Fig.19

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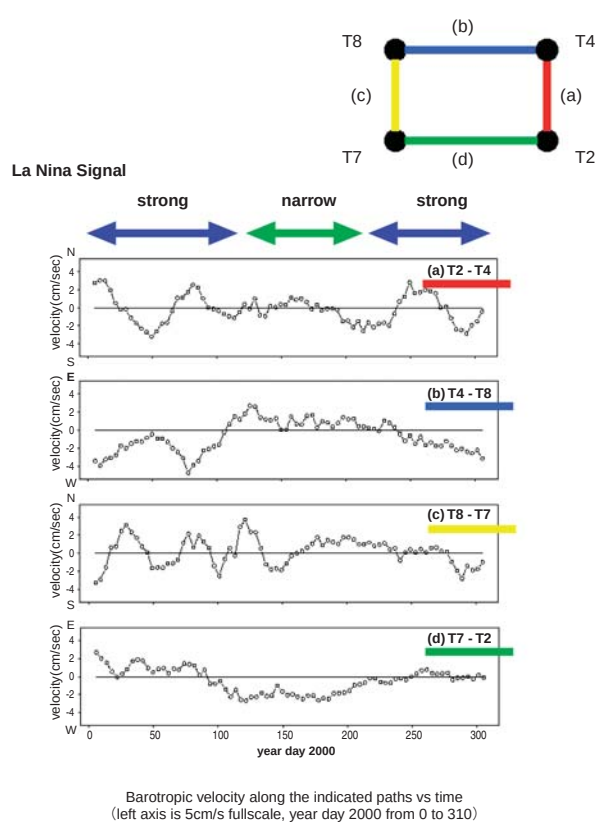


Fig.20

Quasi-normals of meteorological elements at Oki-no-Tori Sima

Oki-no-Tori Sima is a coral reef located at the south-most end of Japan and isolated from other islands as shown in Figure 21. Oki-no-Tori Sima is one of the important points out of the existing meteorological observation network. JAMSTEC has been conducting a marine weather observation at Oki-no-Tori Sima since 1993. All available data obtained from April 1993 to February 2000 at Oki-no-Tori Sima (20.42N, 136.07E), were statistically calculated to make a quasi-normals of meteorological elements at Oki-no-Tori Sima. These data indicate a typical seasonal change around Oki-no-Tori Sima as shown in Figure 22.

The air temperature takes the minimum of 23.2°C in

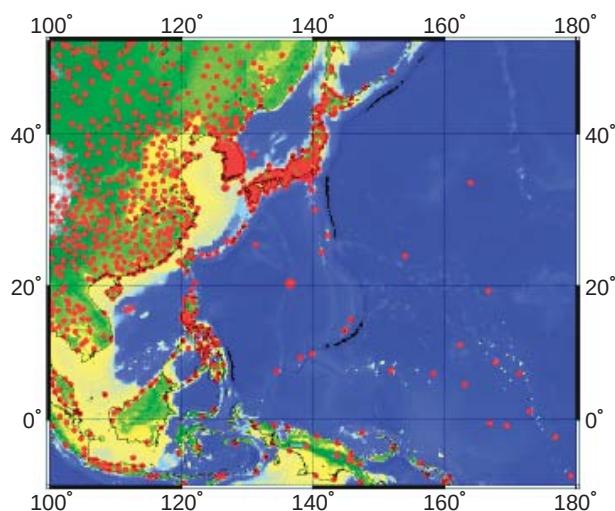


Fig.21 Distribution of meteorological observations in East Asia (Oki-no-Tori Sima is marked by a bigger red circle near the center)

February. It begins to warm in March. And, from April to June, it rises up rapidly to reach the maximum of 28.5°C in June. From July to September, it keeps in a high temperature condition of about 28°C. It falls down gradually from October to January. After all, it takes the minimum in February. The annual mean difference between the minimum and the maximum temperature is 5.4°C.

The change of sea surface temperature synchronizes with that of the air temperature. After the temperature takes the minimum of 24.7°C, it rises up monotonously from April to June. In July, it takes the maximum of 29.5°C. The temperature keeps over 29°C during the summer from June to September. Then, it gradually decreases from October to February. The annual mean difference between the minimum and the maximum sea surface temperature is 4.8°C lower than that of the air temperature. A north-north-east wind is dominant during December to March. The east-north-east trade wind blows constantly from April to October. And, in November, it changes to northeast wind. In the summer times, the strong east-south-east or southeast wind

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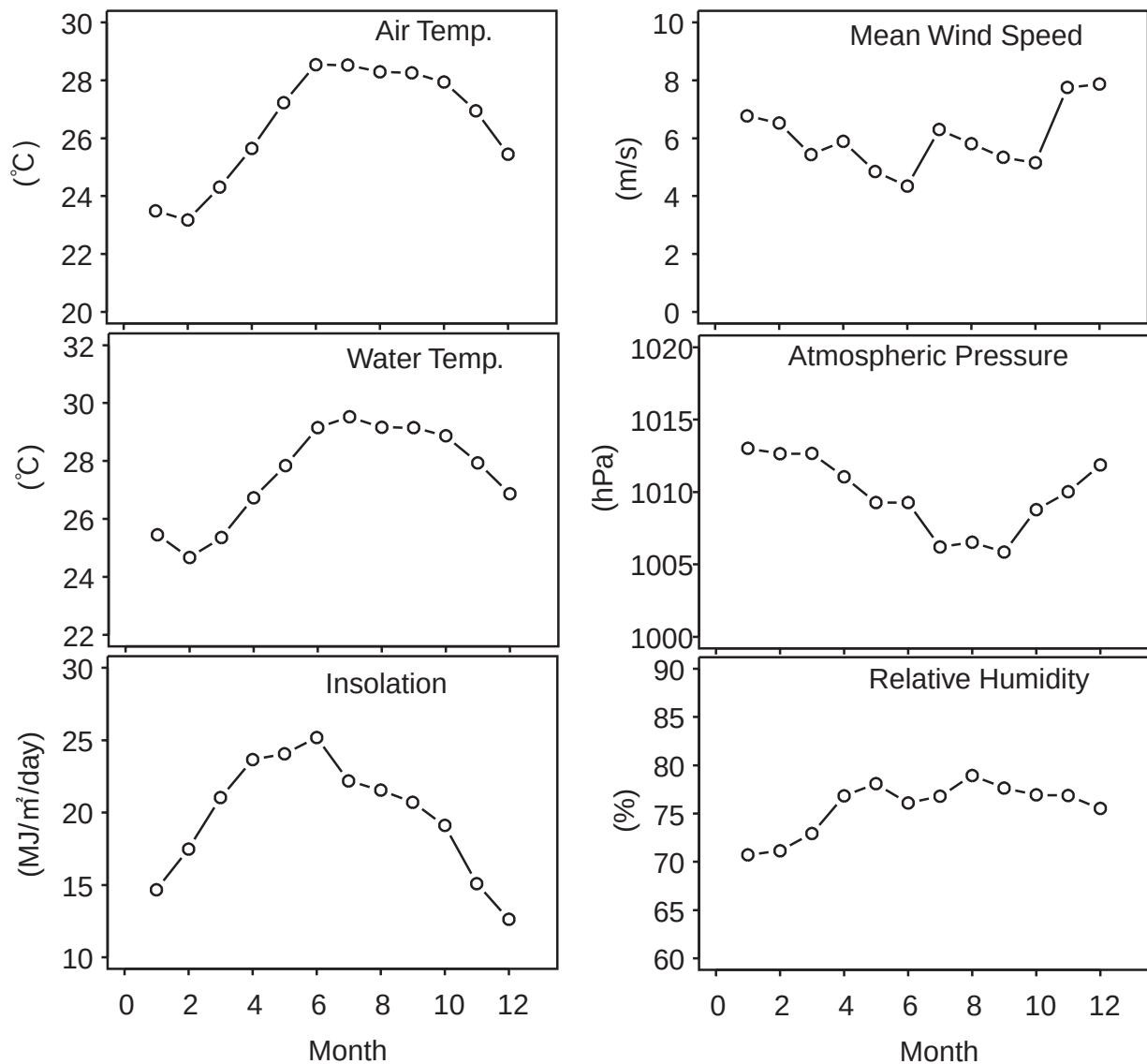


Fig.22 Quasi-normals of major meteorological elements for Oki-no-Tori Sima

blows frequently because typhoon passes by Oki-no-Tori Sima. Oki-no-Tori Sima is usually in the control of the subtropical anticyclone, and shifts in the control of a northeast monsoon in winter when the subtropical anticyclone gets weak.

A mean wind speed takes the minimum of 4.3m/s in June. Then the speed is suddenly intensified by 2m/s and becomes 6.3m/s. The wind speed gradually decreases until October. But, in November, the wind speed is sud-

denly intensified by 2.6m/s. It takes the maximum of 7.9m/s in December. From January to May, the wind speed gets a gradual decrease, even though in April the wind speed is slightly magnified. The former sudden intensification is due to typhoons. The latter are triggered by the onset of the winter monsoon. The wind gust takes the maximum of over 50m/s in the typhoon season.

The relative humidity records the minimum of 70.7% in January, and it takes the maximum of 78.1%

Ocean Observation and Research Department

and 78.9% in August respectively. The relation humidity of January is 4.8% lower than that of December. The winter monsoon makes Oki-no-Tori Sima dry. There is no rainy and dry season at Oki-no-Tori Sima.

The atmospheric pressure at a height of 26m is low in Summer. It takes the minimum value of about 1006hPa in the typhoon season. During the other seasons, it keeps high because Oki-no-Tori Sima is always affected by the subtropical anticyclone and traveling anticyclones. The pressure records the maximum of 1013hPa in January.

The cumulative insolation records the minimum value of 12.6MJ/day in December (the winter solstice), and the maximum of 25MJ/day in July (the summer solstice). This change is apparently related to the seasonal change due to the earth revolution. Even though the transition periods between the two solstices are the same, the cumulative insolation in the former six months from January to June is stronger than the one in the latter six months from July to September. The strong insolation can effectively heat up the sea area around Oki-no-Tori Sima from March to June.

The climatology of Okino-Tori Sima will be compared with those of the two meteorological stations, Hengchun in Taiwan and Aprri in Philippine whose locations are 22.0N, 120.45E and 18.22N, 121.38E, respectively. Figure 23 shows that the air temperature for Okino-Tori Sima changes as similar as that for Aprri from January to June, but differently from July to December. The figure also shows that the relative humidity for Okino-Tori Sima changes as similar as that for Hengchun except in summer from June to September.

In summary, the climate of Okino-Tori Sima is a kind of tropical rainforest climate characterized by the northeast winter monsoon and subtropical anticyclone and typhoons because it is just located at the boundary of tropical and subtropical regions.

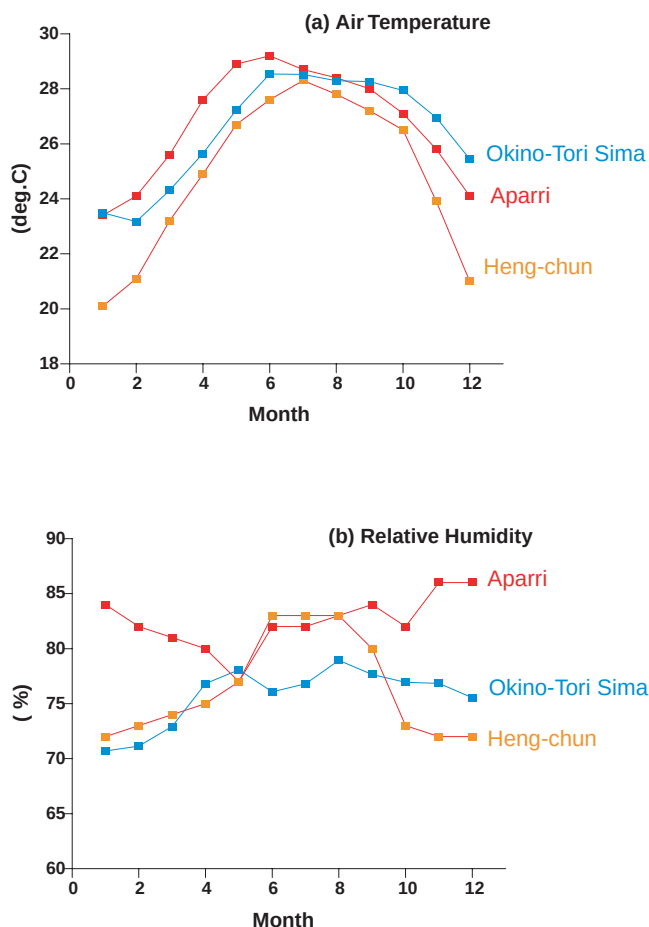


Fig.23 Comparison of quasi-normals of air temperature and relative humidity for Okino-Tori Sima

Development of ocean LIDAR system (FY87 ~FY01)

The ocean Lidar system was installed at the bottom of "MIRAI" in 1999. The observation to evaluate the performance of the system has been made. As the result of the observation, the "laser excited fluorescence" agreed well qualitatively with the measurement by "TURNER" fluorometer. In 2001, we will study the method to analyze the vertical profile of suspended matters from the scattered light by Laser and also try to evaluate the system quantitatively.

Ocean Observation and Research Department

Biogeochemical study of the northern North Pacific and its adjacent seas (FY95~)

In FY2000, we carried out two cruises of R/V Mirai: MR00-K03 cruise (May/00) and MR00-K06 cruise (Sep./00). Following are the outlines of the results.

- (1) During MIRAI cruise MR00-K03, observations were carried out near the Kuril Islands and the Okhotsk Sea where the primary productivity is high. Along an edge of a cold eddy, increasing of phytoplankton and decreasing of concentration of total CO_2 were found (Figure 24). These results show that the biological activity depends on the structure of the eddy in this area.
- (2) During MIRAI cruise MR00-K06, coccolith bloom was observed. In the center of the blooming area, total alkalinity was lower than that in the surrounding area as $80 \mu\text{mol kg}^{-1}$ and pCO_2 was higher than $400 \mu\text{atm}$ (Figure 25). Also concentrations of nitrate and silicate were low, which implies activity of diatom was weak. This situation could cause the observed coccolith bloom.

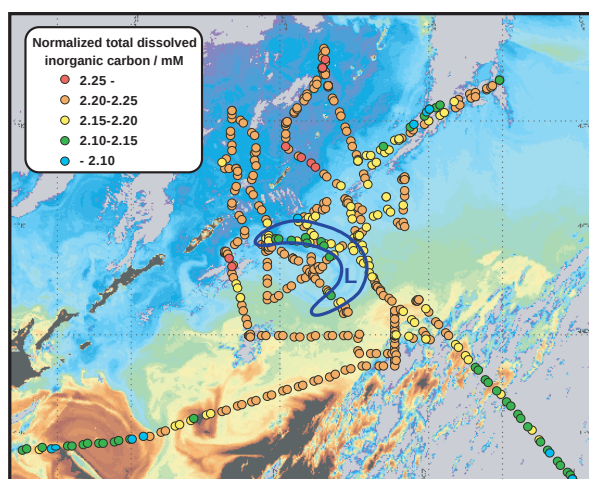


Fig.24 Concentration of total CO_2 (mM) in surface water in the western North Pacific and the Okhotsk Sea (MR00-K03). There was a low concentration patch along an edge of a cold eddy that locates in the center of the figure.

- (3) In order to study the role of biological pump in the uptake of atmospheric CO_2 , sediment trap experiments have been conducted at two stations ($44^\circ\text{N}/155^\circ\text{E}$ and $50^\circ\text{N}/165^\circ\text{E}$) during MIRAI cruise MR00-K03 and MR00-K06. As same as experiments in 1998 and 1999, seasonal variability in opal flux, CaCO_3 flux, and opal/ CaCO_3 ratio (mole) were found.

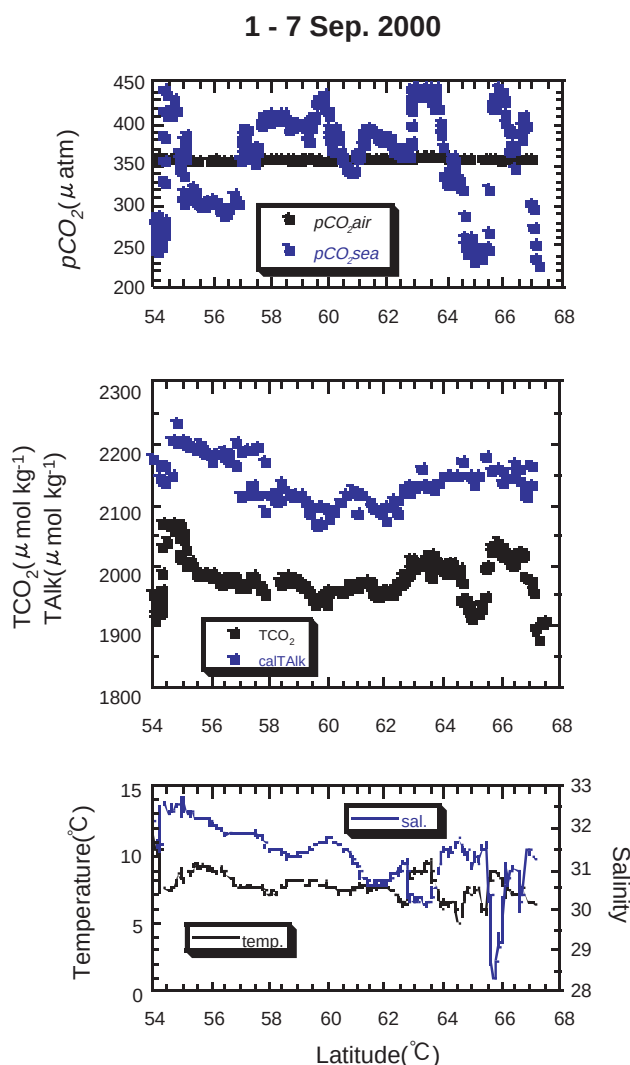


Fig.25 Distributions of Atmospheric pCO_2 , surface water pCO_2 , total CO_2 , total alkalinity, water temperature, and salinity in the Bering Sea (MR00-K06).

Ocean Observation and Research Department

Observational study on primary productivity in the equatorial Pacific (FY97~)

In this study, we have carried out the biogeochemical observation from the warm water region to the upwelling region in the equatorial Pacific to clarify the primary production and the mechanism of variations. In MIRAI cruise MR00-K08 (Dec./00 – Feb./01), there was kept in La Niña condition from 1999 observation. The front of nutrients correspond to the boundary between the warm water region and the upwelling region was appeared around 160° E. Primary productivity were double ranged from 465 to 927 mgC/m²/day between the warm water region and the upwelling region, and increased eastwards from the warm water region. Phytoplankton species in this area were almost dominated by extreme small phytoplankton (<10 μm), which were roughly divided to three groups – *prochlorococcus*, *synechococcus* and eukaryotes. These phytoplankton distributions were showed in Figure 26. We recognized the differences of growth area in each phytoplankton groups. *Prochlorococcus* were increased around the thermocline in the warm water region, *synechococcus* were increased around the boundary between the warm water region and the upwelling region, and eukaryotes were increased in the upwelling region. It is suggested that the differences between phytoplankton species and the distribution were related to the variations of primary production.

Study on high-resolution measurement of carbonate chemistry (FY00~FY02)

In this study, we will develop a system for high-resolution measurement of carbonate chemistry in the western North Pacific where effects of water mixing and biological activity are large. In FY2000, we modified a coulometer for total CO₂ measurement and started experiments for pH and total alkalinity measurements. Additionally we carried out experiments for pCO₂ measurement.

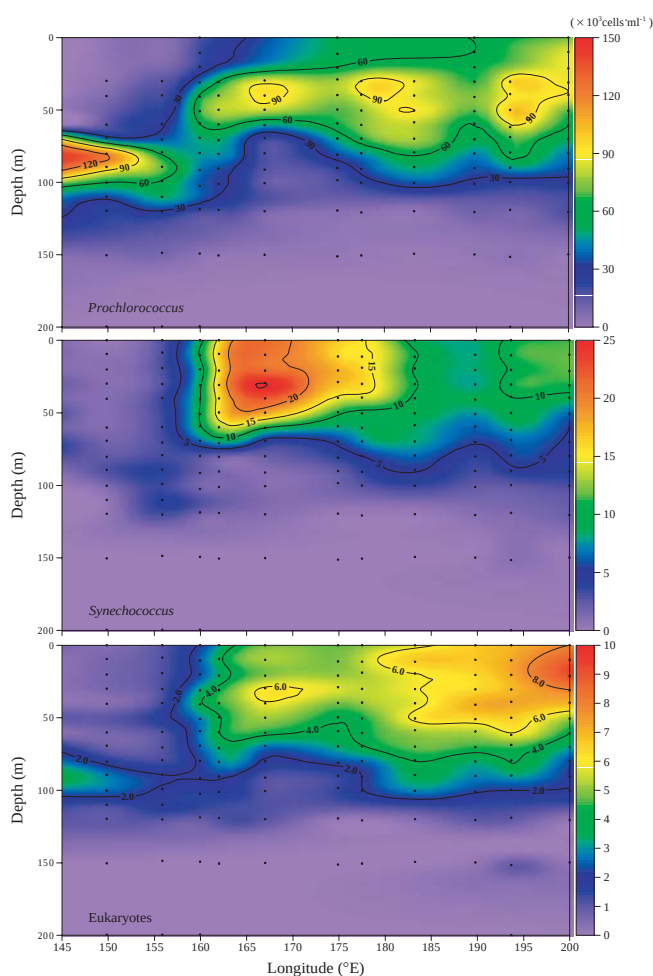


Fig.26 Contour plots along the equator of *prochlorococcus* (top panel), *synechococcus* (middle panel) and eukaryotes (bottom panel).

Study on the application of the ocean color satellite in the western equatorial Pacific (FY98~FY00)

In this study, our objective is to develop the primary production model from the ocean color satellite data to evaluate the primary production quantitatively at the world scale. We have carried out the observation at the same time with the satellite survey in the equatorial Pacific, and then we developed the primary production model. The calculated results of our model were well agreed with the observation results than the past-proposed model.

Ocean Observation and Research Department

Study on automation of measurement of chemical components in sea water (FY98~FY00)

Goals of this study are (I) to develop automated system for measurement of biological and chemical components in sea water and sea water sampling system, (II) to install the systems in the wave energy generator 'Mighty Whale' for the field test. In FY1999, the systems for automated measurement were installed in 'Mighty Whale'. Since then, the systems have been in use. For the mooring system, a computer program was developed.

Study on sensitive and precise analysis of radionuclides in oceanic samples (FY99~FY02)

The purpose of this study is development of preparation methods for sensitive and precise analysis of radionuclides in organic matter in sea floor sediments

by an accelerator mass spectrometry. In FY2000, we developed the preparation system. Using the system radiocarbon in organic matter in a small volume of sediment sample was measured. This result gave a new information of sedimentation in coastal sea.

Study on estimation of CO₂ flux in the North Pacific (FY00~FY04)

The purpose of this study is estimation of CO₂ flux in the North Pacific by an inter-comparison of CO₂ data between JAMSTEC and MRI (Meteorological Research Institute). In FY2000, JAMSTEC and MRI carried out research cruises in the North Pacific including the Bering Sea and the central Equatorial Pacific, respectively. During the cruise in the Bering Sea, coccolith bloom was observed.

Marine Ecosystem Research Department

Introduction

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

Research Project ; Category 1

“Studies on dynamics of coral ecosystem”

Period: 1998-2000.

The coral is widely distributed around the tropical and subtropical area in the world. Coral is an important primary producer of the ocean and complex coral ecosystem is managed by the production. Distribution, coverage and health of corals are highly affected by environmental changes. Therefore, Coral is used as an important bioindicator of environmental changes such as global warming and depletion of ozone layer.

Sekisei lagoon (25 × 25 km), the largest coral sea in Japan was selected as a monitoring area for our study. The objective of this study is to measure total amount and distribution of live coral around the area with environmental conditions. Annual survey has been conducted to detect the changes in corals. Also, several technological development have been completed for measure primary production of coral, coral biomass, coral health and so on. At the same time, safety diving

for scientist was a important research themes as an back ground of underwater research work (figure 1).

(1) Field studies at Sekisei lagoon

Basic coral distribution map of Sekisei lagoon was produced by applying coral cover database obtained between 1996 and 1997. This is the control data for our study, since global coral bleaching in 1998 affected severe coral death at many areas. Since 1998, annual coral monitoring has been conducted at 26 diving survey sites (50 m length line intercept transect at 3, 6 and 9 meters depth) and 10 cruising surveys by tow system. Two patch reefs are selected for precise monitoring. Spawning, settlement and survival process of corals are examined with continuous monitoring of water temperature.

Width of Sekisei lagoon is 270km² and Coral cover width of whole area was 16km² before coral bleaching. Though the whole Sekisei lagoon suffered bleaching event in summer 1998, almost of corals were survived in the southern area. Anyway, northern area suffered big damage, they are around Taketomi-jima and Kohama-jima and between these two Islands.

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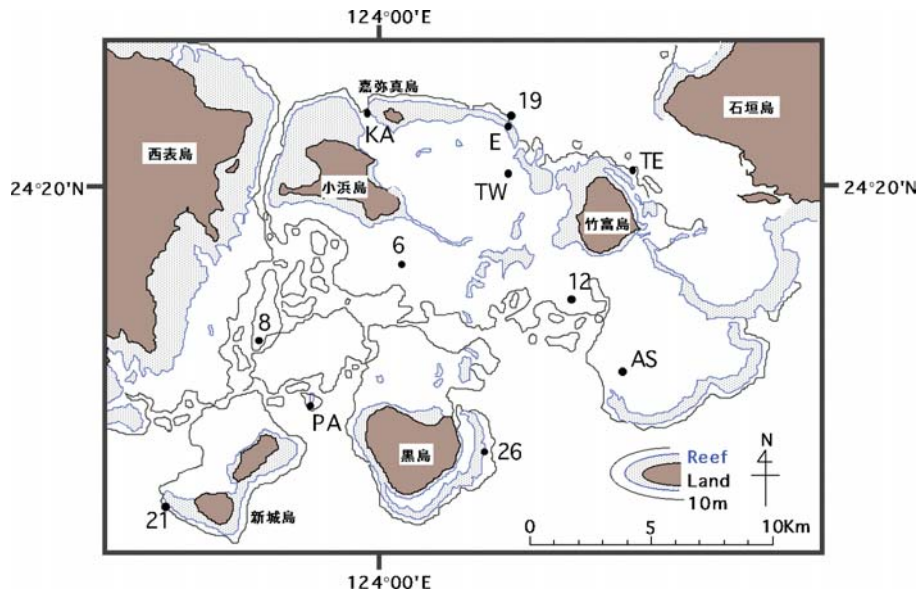


Fig. 1 Sekisei lagoon and 12 core sampling points.

Approximately 50% decrease in coral cover was observed at the outer reef slope.

Recovered *Acropora* corals spawned in May 1999. Also, mass spawning was observed in May 2000. By the plate study for examining recruitment potential of mass spawning corals, number of settled juveniles were less than 1 % in 1999 and 5% in 2000, compared with the data obtained Sesoko at Okinawa island before bleaching. Recruitment number in Sesoko dropped to zero after bleaching.

By the three years field study, annual quantitative coral data was obtained, and fluctuation of corals was identified clearly. The suitable survey procedure to use Sekisei lagoon as a bioindicator of environmental changes is successfully completed. Further annual survey will be continued here. In addition, many important knowledge was obtained on recruitment, survival and growth of the juvenile corals. This will be applied to new project "research and development of coral reconstruction technique" from 2001 (figures 2-4).

(2) Study on history recorded in corals

The small boring machine that got the core of 2 cm diameter and 20 cm length was developed. The meaning of this core size is to collect many samples from small massive corals without killing them. At 12 sites of Sekisei lagoon (figure 1), 80 cores from *Porites lutea* and *Porites lobata* were collected in autumn 2000. Biomass measurement and zooxanthellae number analysis were examined from the coral surface. Then plate of 3-mm thickness was obtained from all the core. They are analyzed by applying soft X-ray technique and elemental analysis using PIXE.

The developed core sampling machine is compact in sizes and easy to handle. Further core sampling along Ryukyu island and Kuroshio current will be useful for the examination of interaction between environmental changes and the response of coral.

(3) Development of technologies supporting underwater research

For safe scientific diving, new nitrox saturation diving table and bounce diving table were developed. The tables were evaluated by on land simulation dives

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Fig. 2 Mass spawning of *Acropora*.



Fig. 3 Young coral obtained by plate technique. Planula attached underside of the plate, grows up to approximately 10 mm during one year. This procedure is applicable for coral recovery.



Fig. 4 The dead coral around Okinawa island. Died out by the bleaching event in 1998.

and modified using the results. For evaluate breaching apparatus, automated respiration simulator and respiratory monitoring system were developed. Also, respiratory monitoring system for SCUBA diving was developed successfully. As a critical technology for future undersea laboratory realization, safety research of the electricity use under high pressure and development of automatic environmental control system was carried out successfully. The medical and physiological research was examined by applying decompression bubble detector. Also, dysbaric osteonecrosis prevention study are carried out to prevent accident and injury by the diving.

“Mesopelagic Biology Program”

Period:2000-

The Japan Marine Science and Technology Center (JAMSTEC) established a federally-funded program beginning in fiscal year 2000 to survey the mesopelagic and benthopelagic communities around Japan. This program combines the unique technology of the submersibles at JAMSTEC with experience gained from similar mesopelagic studies elsewhere. Such submersibles are invaluable for studies of the delicate gelatinous midwater fauna that, although extremely abundant, are unable to be sampled in conventional net tows. Biological sampling equipment such as slurp gun systems have been redesigned and adapted for use on the JAMSTEC submersibles and other forms of biological sampling equipment, such as the gate sampler, have been newly developed in-house in conjunction with overseas colleagues from UCLA and MBARI. Working databases of the midwater fauna of Sagami Bay and the waters above the Japan Trench have been developed.

Limited midwater research has been carried out in-house at JAMSTEC since 1996. Sagami Bay has been the principle target area for midwater studies at JAMSTEC during this period. Dives made during 1996 &

Marine Ecosystem Research Department

1997 in Sagami Bay yielded a working database and taxonomic list. This database resulted in three manuscripts (Hunt & Lindsay, 1998; Hunt & Lindsay, 1999; Lindsay et al., 1999). In 1998, 1999 & 2000 limited dives were also carried out in other areas around Japan and compared to the Sagami Bay database. This allowed basic characterization of the Japanese fauna and has helped target oceanographic areas of scientific interest for future in-depth surveys. Dives in Sagami Bay were also made during 1998-2000 and these yielded greater insights into the species diversity, vertical distributions and overall ecology of the bay. A large amount of effort during these first five years has gone into developing or otherwise acquiring biological (slurp guns, gate samplers, D-sampler hydraulic systems) and physico-chemical (CTD-DO, turbidity and chlorophyll a sensors) sampling gear, facilities for the maintenance of midwater animals (on-board and lab-based planktonkreisels, coolers), lab equipment (night vision scopes, video-recordable microscopes, camera equipment, a DNA-sequencer), and otherwise laying the groundwork for a world-class mesopelagic biology program.

During fiscal year 2000, we continued to expand the Sagami Bay database and developed a database describing the midwater fauna over the Japan Trench. We acquired a non-linear video editing system to link video footage with distributional and physico-chemical data in order to facilitate species-level studies and allow comparisons to be made between different seasons and oceanographic regimes. In fiscal year 2001 we plan to acquire a combined turbidity/chlorophyll a sensor rated at 6500m to investigate the effects of primary productivity and resuspended sediment on meso- and benthopelagic organisms. In the near future we also plan to acquire a multiple-layer opening-closing net to relate the distributions of more robust organisms to those of the gelatinous animals and we also hope to start a new taxonomic program based here at JAMSTEC. This

organization will act as a distribution point for materials and collection point for data on new pelagic species (collected with JAMSTEC submersibles).

The mesopelagic and benthopelagic biological survey program at JAMSTEC serves two purposes. First, JAMSTEC will complement ongoing international research programs such as those by the Monterey Bay Aquarium Research Institute (MBARI). This will provide data from Japanese waters to compare and contrast to other points around the world. Such broadly reaching studies are vital for a global understanding of mesopelagic and benthopelagic community structure and ecology. Second, the JAMSTEC survey will complement work done by scientists throughout Japan also interested in midwater biology and oceanography. Submersible data differs from that which can be collected by traditional techniques. Such data lend themselves well to collaborative efforts as well as comprehensive reviews investigating similar areas of interest or specific fauna. For example, trawls and towed

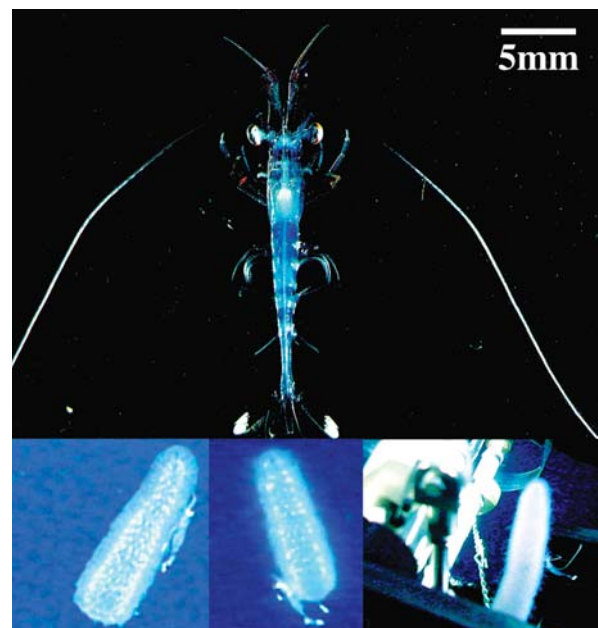


Fig. 5 *Funchalia sagamiensis* was found to associate with pyrosomes during its juvenile phase

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equipment can provide good information on overall abundance, vertical distributions, and taxonomy by collecting quantitative numbers of specimens from a given area. Submersibles can supplement this effort with good information about specific behaviours, feeding, reproduction, vertical migration, and precise morphology for taxonomic keys. These two types of surveys combine well, and will provide a stronger national program for open-ocean biology here in Japan.

“Studies on Deep-sea Ecosystems”

Period : 2000-

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

In August 2000, a research cruise to the Indian Ocean using the Japanese ROV *Kaiko* (Japan Marine Science and Technology Center) was planned in order to search for hydrothermalism and associated biological communities, and was focused on a small volcanic knoll, named the Hakuho Knoll, located approximately 22km north of the Rodriguez Triple Junction (Fig.6.). Active hydrothermal vents and thriving hydrothermal vent communities were discovered on the southwestern flank of the Hakuho Knoll. At least seven active vent sites including black smoker com-

plexes, the largest of which was over 10m in height, covered approximately 40m by 80m of the upper part of a small mound (25° 19.17'S, 70° 02.4'E) between depths of 2420m and 2450m. The maximum temperature measured from an active black smoker was 360° C, and the pH (at 25° C) was 3.4. This vent site was named the “Kairei Field” after the R/V *Kairei*. Numerous shrimp (*Rimicaris* sp.), alvinocaridid shrimps, unidentified actinians, an undescribed mytilid species (*Bathymodiolus* sp.), some species of gastropods (*Alviniconcha* sp., *Phymorhynchus* sp., *Lepetodrilus* sp., Provannidae gen. sp. and limpets), galatheid crabs (*Munidopsis* sp.), *Austinograea* sp. crabs, undescribed cirripeds (*Neolepas* sp.), parasitic polynoids (*Branchipolynoe* sp.) and zoarcid fishes occurred in the hydrothermal vent fields. A typical scene of the vent communities at the Kairei Field is shown in Fig. 7. The hydrothermal vent communities of the Kairei Field are closely similar to those of the Atlantic vent fields in appearance. However, some organisms were known only from the Pacific vent sites. Other vent organisms were reported in the deep-

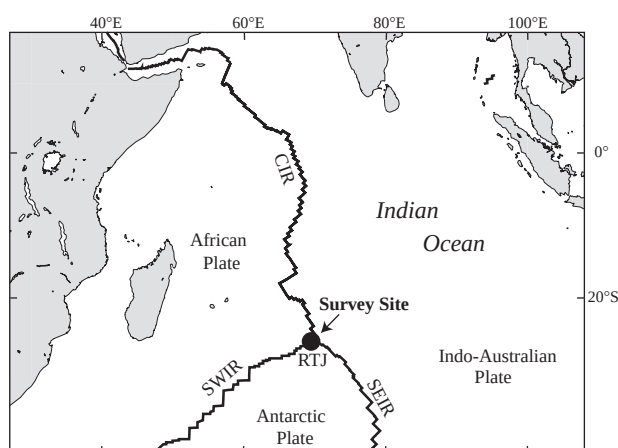


Fig. 6 Location of the survey site, north of the Rodriguez Triple Junction (RTJ) in the Indian Ocean. CIR, SWIR and SEIR refer to the Central Indian Ridge, South West Indian Ridge and South East Indian Ridge, respectively.

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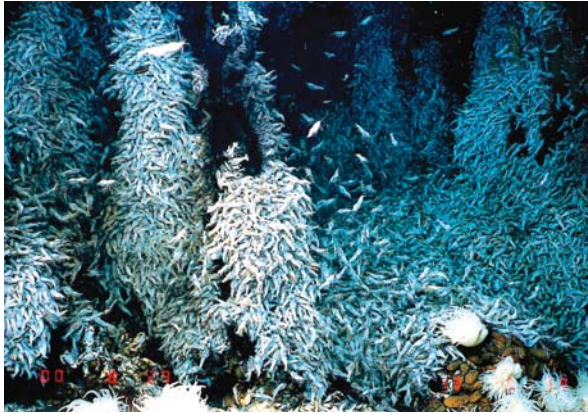


Fig. 7 Dense hydrothermal vent communities at the Kaiei Field. *Rimicaris* swarms and actinians beds were observed around an active black smoker complex. *Alviniconcha* snails, *Austinograea* crabs and small-sized scale worms can be seen at the base of the complex (25° 19.16'S, 70° 02.34'E, 2436m)

sea hydrothermal vent fauna from the Atlantic and Pacific Oceans. This suggests that significant communication exists between the vent fauna in the Indian and Pacific oceans. Similar communication might exist between the Indian and Atlantic oceans.

Deep-sea biological research was conducted at cold seep communities in the Japan Trench by the *Shinkai 6500* and hydrothermal vent communities at the Hatoma Knoll in the Okinawa Trough by the *Shinkai 2000*. During these investigations, we collected data and useful samples for the ecological study of deep-sea chemosynthetic ecosystems.

“Research on the characteristics of the deep seawater in Suruga Bay, and the cascade methods of deep seawater utilization”

Period: FY1998-FY2003

Shizuoka Prefecture drew up the Effective Utilization Project for Suruga Bay Deep Seawater (off Yaizu). Three kind of intake pipes for surface water (at depth of 24m) and deep seawater (at depths of 397m and 687m) were laid on August 2000. On-land facilities have been

under construction and will open on October 2001.

The objectives of this research are to make contributions to implementing the Project by Shizuoka Prefecture and establishing the practical technology for deep seawater utilization. For the purposes, we carry out the preparation of analysis and observation systems; and the scientific explication of deep seawater in the intake sea area and its surroundings, and the research and development on the effective utilization technology for the deep seawater in cooperation with Shizuoka Prefecture.

In FY 2000, the following items were carried out.

(1) Preparation of analysis and observation systems

Being continued since the year before, we prepared equipment of analysis and observation systems which was necessary to study the deep seawater. Especially, we produced experimentally a new water sampler for the bottom boundary layer and carried out practical tests of it.

(2) Scientific explication of deep seawater

We made marine observations using research vessel in the sea areas for the intake of the deep seawater and around there on October 2000 and March 2001. The results indicated as following. We confirmed that the deep seawater had main characteristics of rich nutrient, low temperature, and clean water quality at observation stations (S1, S2) at each intake depths (397m, 687m). But the concentration of suspended solid was slightly higher at the bottom boundary layer. Continuously we need to investigate of the distribution of suspended solid. Then we accumulate knowledge about temperature, salinity and nutrients. Moreover we conducted biological method used phytoplankton with collected deep seawater in large quantities and confirmed that deep seawater had high biological production. To confirm the clean water quality of deep seawater, we investigated about endocrine disrupters and pathogenic bacteria. As a result, the water quality of deep seawater was clean (Fig.8).

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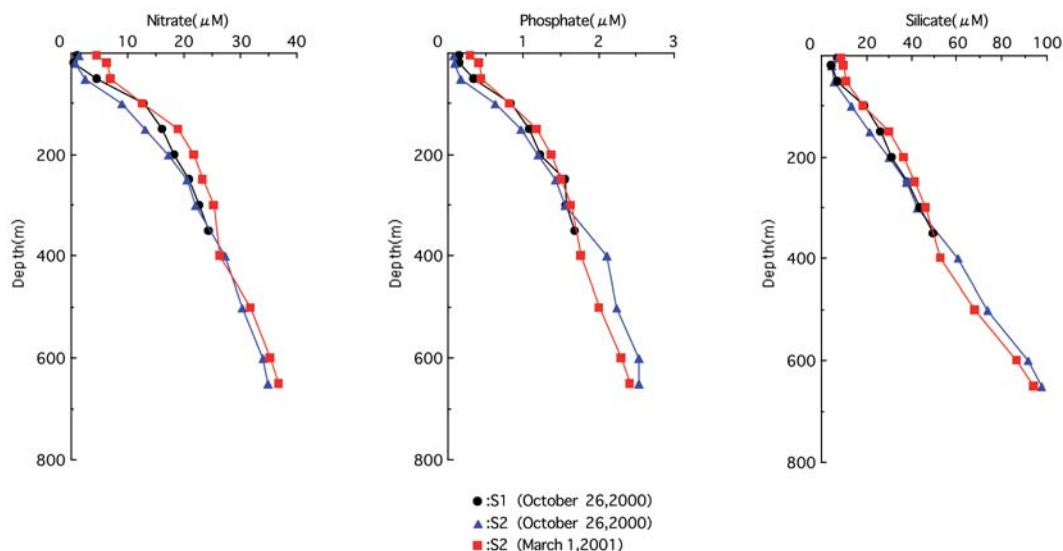


Fig. 8 Vertical profiles of nutrients in the intake sea area of the Suruga deep seawater.

(3) Examination on the cascade methods of deep seawater utilization

According to the cascade methods of deep seawater on last year, we chose giant Japanese spider crab, eels and algae for the research subject of fishery field which Shizuoka Prefecture conduct. And we examined principal study for drainage of deep seawater and the influence of used deep seawater on environment.

“Feasibility study on the bio-remediation for the inland sea”

Period: 2000

This joint research between JAMSTEC and Nagasaki Prefecture aimed to make a feasibility study whether the fundamental and sustainable remediation of the highly closed and eutrophicated bay might be practically realized or not. Consequently, a combined system of no-feeding mariculture (oyster etc.) and aeration from seabed was extracted to remediate the water quality. The aeration was expected to supply oxygen and activate macro-benthos (sea cucumber etc.) at sea bottom surface, therefore, sea bottom soil quality was

also expected being remediated. Such complex system was evaluated to pay by the harvesting of oyster.

The research committee consisted of the specialists was held three times, and following results were related.

1. Efficiency

- (1) Nitrogen and Phosphorus would be removed from the sea up to 60 kg and 5 kg respectively by an experimental unit. The units covering 1/4 of the given bay (Katagami Wan, Nagasaki) would compensate the N, P loading from the rivers. (Experimental unit was designed with 16 oyster rafts and 3 aeration lines in 100 m square.)
- (2) Oxygen enriched sea bottom might enable the sea floor habitats to survive even in the mid summer (Fig. 9). Thus, activated ecosystem contributes to the usual fisheries which means the N, P recycle.
- (3) The N-P circulation model should evaluate the function and the efficiency of above designed system. The numerical simulation model should

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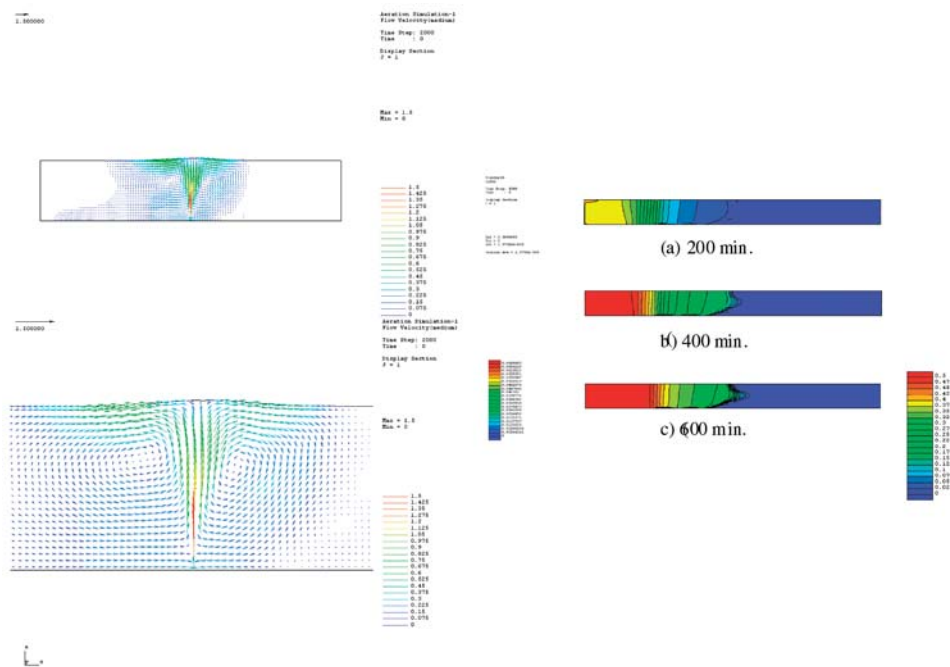


Fig. 9 An numerically simulated example of induced flow (left) and the increased dissolved oxygen (right) by aeration to the shallow sea.

estimate efficiency for the practical use in the wide area with many units. These models will be useful for the general use in the other eutrophicated seas.

2. Economical performance

Around 5.6 and 6.9 million Yen were estimated for a unit, year. Thus, 1.3 million Yen might be expected for profits.

3. Social contribution

- (1) Contribution to realize the recycling society focusing on the nutrient.
- (2) Expects of the sustainable exploitation of the inland sea.
- (3) Promotion of fisheries, conservation of sight seeing and leisure resources, and contribution to the economy.

Personal Research

“A study on the modeling of marine ecosystems by combining multiple sub-models”

Period : FY 1998-FY 2000.

This study is the research and development on the method of combining some models to make the marine ecosystems model with high accuracy. The model is compounded the plankton behavioral model (vertical migration behavior model of the zooplankton) in addition to advection and diffusion model (physical model) and material circulation model (the biochemical model). On the plankton behavioral model, the zooplankton behavioral model is developed for the module of marine ecosystem model. It was able to appear the behavior of vertical migration of zooplankton in the marine ecosystem model.

In the 2000 fiscal year, to use the plankton behavioral model that developed in last year, we considered the factor induced diel vertical migration (Fig.10) and

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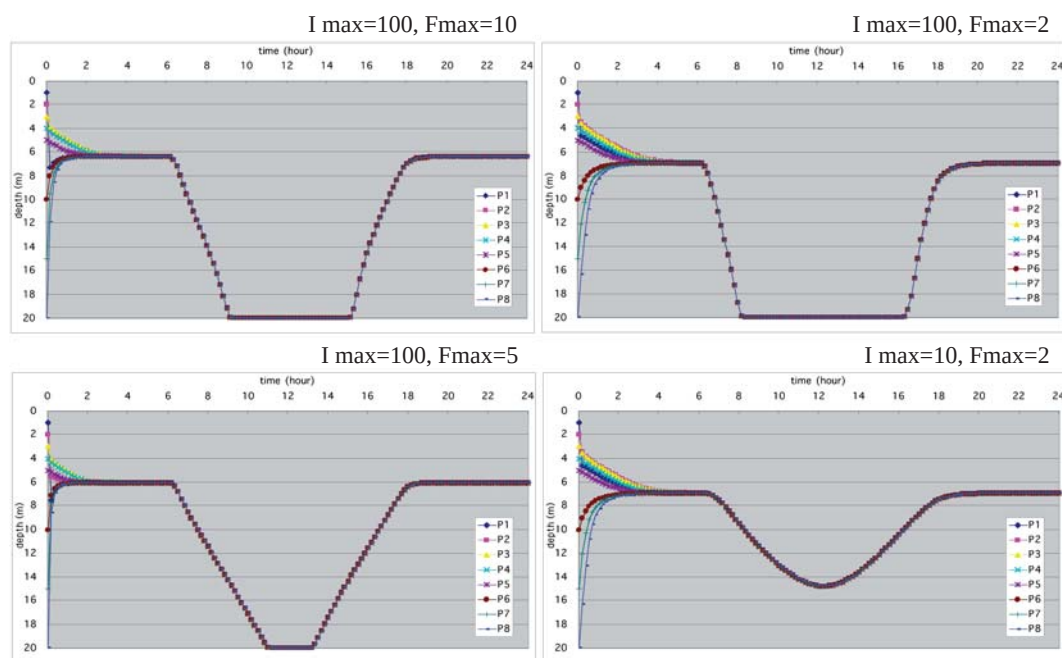


Fig.10 The sample outputs of zooplankton behavioral model. (light intensity: $I_{\max}$, food (Chl-a): $F_{\max}$). Initial depth of plankton particles: 1, 2, 3, 4, 5, 10, 15, 20m (8 layers).

simulated seasonal variation of zooplankton behavior with the seasonal variation of environmental factor. In addition, to combine this model with marine ecosystem model, we discussed about the influence for lower trophic level ecosystem.

In the future, we will try to apply this model for understanding the vertical flux of nitrogen in the marine ecosystem.

“Methods of evaluating seawater movement in the vicinity of coral”

Period : FY 1998-FY 2000.

(1) Purpose of study

In shallow water regions (e. g., coral reefs), where the effect of the flow is important in growing processes and spawning settlement of the planktonic spores and larvae of marine organism inhabiting the area. Generally electromagnetic current meters and ultrasonic current meters, etc., are used to measure rates

of flow. However, in very small-scale areas, such as seaweed beds and coral reefs, it is difficult for this equipment to be used considering the size of these sensors. Also, it is topographically complicated in seaweed beds and coral reefs, so measurements at a large number of are necessary in order to examine the relation between flow and the organisms. It is quite involved and costly to measure a large number of points by using current meters especially due to the work involved in mooring the meters. For sessile organisms such as corals and oysters, the maximum instantaneous current velocity rather than the intensity of the averaged flow is important. To measure currents in shallow waters, a plaster ball technique has already been developed and used. However, the current measurement by plaster ball could only be accomplished for about 2 days (around 50 hours).

In this study, we produced plaster balls of various materials that could measure velocities in the long term

Marine Ecosystem Research Department

in order to evaluate the small-scale water motion in important environment fields such as coral reefs (patch reef). The dissolution experiment was carried out in Sekisei lagoon of the Ishigaki Island in Okinawa Prefecture (Japan) to evaluate the effectiveness of the velocity sensor. Simultaneously, it examined whether normal plaster ball and velocity sensor, which produced another materials, were effective for the measurement of the flow in coral reef region with field experiment.

(2) Result and discussion

In plaster ball, the intensity of the time-mean flow is converted from the change of the wet weight of the sphere in installation and after the installation. And, it is possible to guess the flow direction from the deformation condition of the sphere.

The purpose of this study is to improve the material of plaster balls to make them usable for longer periods. We tested six different types of plaster balls: viz. plasters for dental use types 1, 2, and 3, polymer type, cement type, and paint type. We estimated the resolution rate using each test plaster ball and normal plaster balls in the coral reef region by comparing the measurements with those observed by electromagnetic current meters (Fig.11). Experimental results in a patch

reef in the Sekisei lagoon (Okinawa prefecture, JAPAN) indicated that measurements could be obtained for about seven to ten days when using a ball with cement in the plaster.

In order to understand flow environment near the patch reef, large number of plaster ball was set up and measured intensity of the time averaged flow and flow direction (Fig. 12). Simultaneously, it carried out the current measurement by electromagnetic current meter, comparison with examination between velocity sensor and measured value. The results of our experiment in a patch reef in the Sekisei lagoon clearly showed that the intensity of the flow varied with depth and position, and that a small vortex had been generated around the patch reef. That differential water motion and small vortices will affect the growing processes and spawning settlement of corals is considered. Further, the difference of the flow environment had a close relation to coral distribution.

Finally, it was possible to produce the velocity sensor in which long-term measurement is more possible than normal plaster ball experimentally in this study. And, it was able to grasp that the technology of plaster ball was effective in order to clarify flow environment in the patch reef.

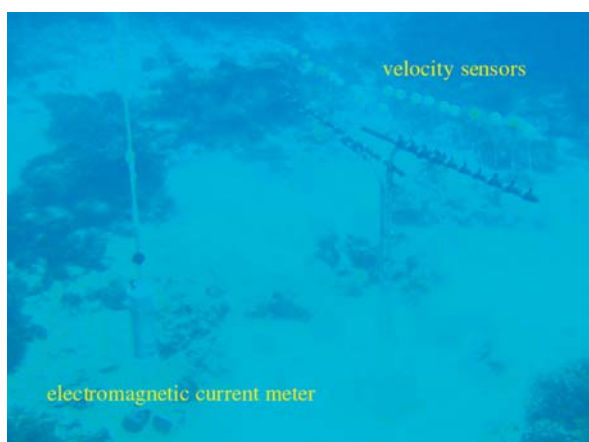


Fig.11 The experiment on the dissolution rate using every kind of velocity sensors in Sekisei lagoon.

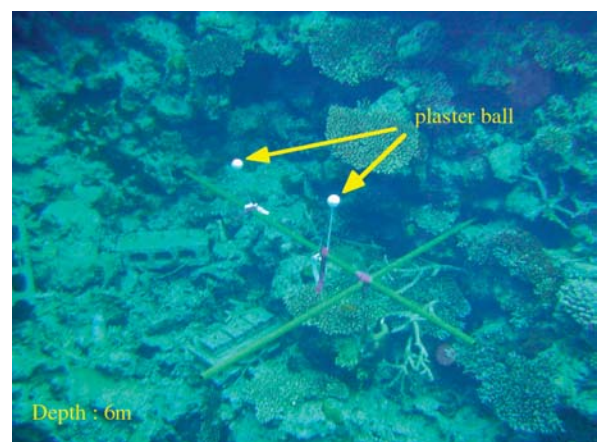


Fig.12 The measurement of the time-averaged flow in the patch reef (South side, Depth: 6m).

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“Studies on the Effect of the Post-diving exposure to High Altitudes on Scientific Research Divers”

Period: 1998-2000

The risk of Decompression Sickness (DCS) concerning with the hypobaric environment exposure by ascending in an automobile and flying after diving was well known. However, this risk is increasing in recent years in Japan by the advance of the diving equipment and transport technology and by the debasement of the air fare. The diving in west coast of Izu Peninsula is very popular for recreational scuba divers, living in the Tokyo area. Many of them return to Tokyo, driving pass the mountainous area in Izu Peninsula. The diving in Nansei Islands also becomes very popular in these several years, and many divers fly back to the mainland. Therefore, we measured the altitude of the expressway that is main route from Izu to Tokyo and the internal pressure of the aircraft cabin (cabin altitude) from the Nansei Islands to Tokyo. In addition, we tried to verify the risk of flying after diving by the animal experiments with rats and rabbits, the effects of hypobaric exposure after the hyperbaric exposure.

The altitudes of the expressway from Izu to Tokyo and the cabin altitudes of flight from Nansei Islands to

Tokyo were measured with the hand held altimeter on the vehicle and on the passengers respectively. On the animal experiments, we used the profile of saturated diving (30 m depth on rats and 40m depth on rabbits) for 2h30, after the decompression from diving. We put the five interval times (1, 5, 10, 20 and 30 min.) before the decompression start to the six hypobaric conditions (equivalent altitudes of 500, 1,000, 1,500, 2,000, 2,500 and 3,000 m), and the pressure was hold for 30 min. in each hypobaric conditions.

The highest point in the expressway from Izu peninsula to Tokyo was only 466m, we arrived there after 20 min. drive from the near entrance of diving spots. Generally the cabin altitude linearly increased to 2,000 m- 2,570 m, during 10-15 min. after take-off for the flights at around 10,000 m altitude. With the animal experiments, we found the high level DCS over 1,500 m altitude for short interval conditions, and the rabbit has high tolerance to decompression compared with rats. We conclude that we can not extrapolate the results of animal directly to human, but we confirmed that the flying after diving is very dangerous.

“Study on the quantitative measurement of fishes around coral reef”

Period : 1998-2000.

Since fish is positioned as high ordered predators in the coral ecosystem, it is important to measure the biomass of it correctly. However, quantitative measurement of fish is very difficult, since many kinds of fishes are distributed in the coral sea and the bottom profile of their is too complicated. Consequently, biomass survey of coral fishes is needed to combine several techniques; they are visual census by scientific diver, echo sounding, experimental catch and so on. Even applying these techniques, fish that is distributed close position to the obstacle like as coral and coral reef are still very difficultly.

In this study, use of the three-dimensional television

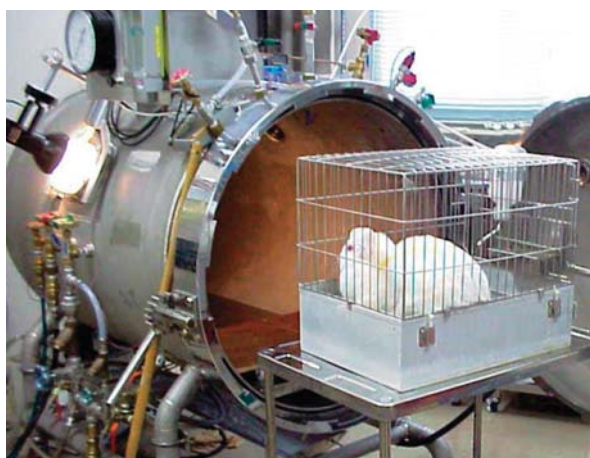


Fig.13 The animal experiment on the risk of decompression sickness caused by flying after diving with rabbits.

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system was examined as to add newly quantifies method of the fish to the conventional measurement technique. Data obtained around the whole patch reef was analyzed to develop measurement procedure and data analysis argolyzm. Size of the patch reef is 60 m in diameters and is standing at 14 m depth area. Video recording was conducted at 31 points for 45 minutes each during daytime. Lists of species-by-species population was made at five second interval for 30 minutes from 45 minutes video record. Fork length measurement of all fish species was carried out, and the body weight of them was obtained using fork length-body weight curves.

As this result, 106 kinds of fishes were confirmed around the whole patch reef. Major fish species as total frequencies of appearance at 31 points were Pomacentridae (70%: *Pomacentrus philippinus*: 21%, *Pomacentrus lepidogenys*: 14%), *Prionurus microlepidotus* (16%) and Labridae (7%). In the total body weight, *Ctenochaetus* sp. (18%), *Acanthurus lineatus* (16%), *Pomacentrus philippinus* (11%) and *Abudefduf sexfasciatus* (7%) were dominated (Fig. 14). Pictured space at 31 points measurement was 58 m³ and aver-

age fish weight in it was 2.0 kg. Average biomass of fishes around the patch reef was calculating 34 g/m³.

Many fishes were distributed within several meters around the coral reef. Conventional fish survey technique was not applicable in the area. The only possible investigation was the line transect method by the scientific diver. By the method, fish fauna and number of each species can be obtained. Anyway, there is a problem in the quantify of fish species which escape from the diver quickly. By the echo sounding, almost area of coral fishes can be measured. Anyway, the ultrasonic wave does irregular reflection by the complicated shape of the coral reef vicinity, and the acquisition of fish data separating from reef is very difficult. The combination of three-dimensional television camera and echo sounder will be the suitable technique for survey biomass of fishes.

“Study on the Influences of the Kuroshio Current on the Fluctuating Hydrographic Properties of the Deep Seawater in Suruga Bay”

Period: FY1999-FY2001

The project to pump up the deep seawater in Suruga Bay has been promoted by Shizuoka Prefecture. In order to utilize the deep seawater effectively, it is important to grasp hydrographic variation properties such as currents in the intake sea area. The objectives of this research are to grasp variation properties and to explicate variation factors that have influences on these properties.

In FY2000, we analyzed the time series data obtained by the mooring observation in previous year and studied characteristics of currents in the intake sea area of the deep seawater. The results indicated that variation at deep depths in the bay might be caused by variation out the bay (see Fig.15). In order to study the influence of variation factors enter the bay, we have proceeded with numerical simulations. From a view point of utilization of the deep seawater, we got

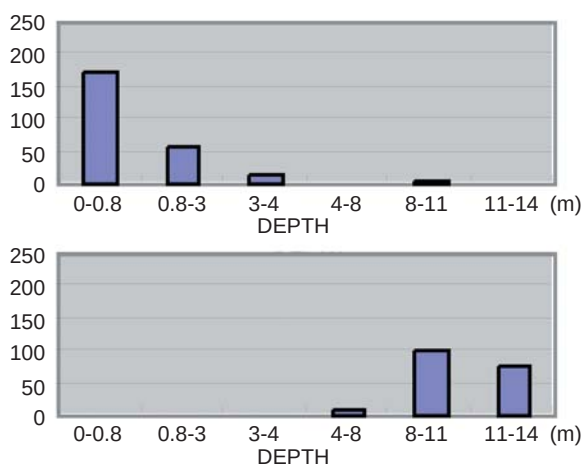


Fig.14 Appearance number of fishes according to the water depth. Above: *Acanthurus lineatus*. Below: *Amblyglyphidodon leucogaster*.

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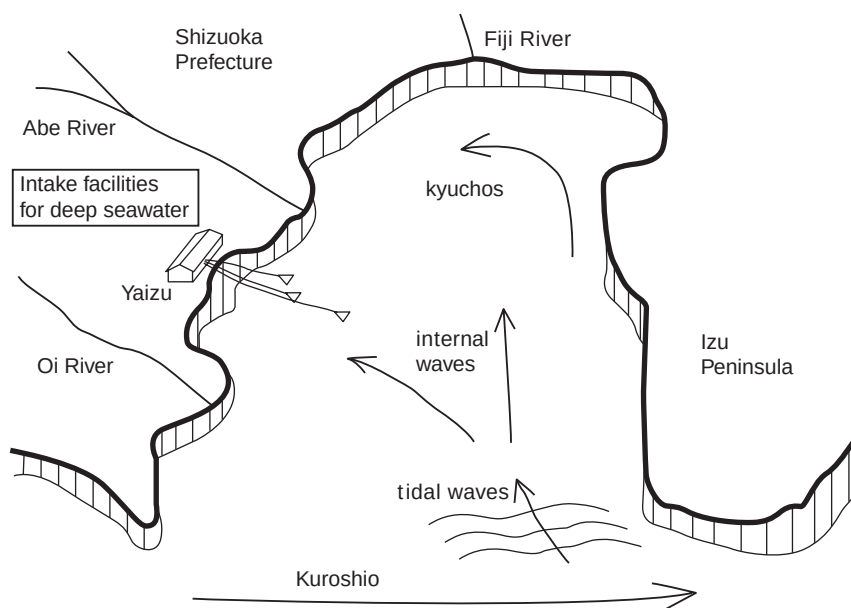


Fig.15 Major variation factors to influence the deep seawater in Suruga Bay.

new knowledge about the relation between turbidity and current variation in bottom boundary layer. These study results were referred for the determination of intake depths of the deep seawater by Shizuoka Prefecture.

“Studies on abundance of plankton community concerned on the regenerated production”

Period : 1999-2001

The circulation (the regeneration production) of materials in the surface layer of the sea has been thought important phenomena since 1980's. The relation between this and classical food chain is indispensable to clarify the ecosystem structure of the ocean. Micro zooplankton that concerning the regeneration production is very fragile, and the sophisticated technology is needed to measure the standing crop of it. This technique called Quantitative protargol stain method (QPS) is one of the major analyzing methods of it. This is to dye the plankton for the measurement

of volume and number of it. Technical development was carried out through the analysis of the sample obtained by night and day survey at coral sea.

“Studies on the Autonomic Nervous System on Re-adaptation to the Normobar after Diving”

Period : 1999-2001

It is well documented in animals and humans that a bradycardia occurs in response to exposure to a hyperbaric environment, but the mechanisms underling this phenomenon are not yet completely understood. In human, bradycardia is induced at diving and tachycardia at ascent. This phenomenon greatly involves the autonomic nervous system. In a deep-sea diving experiment using animals, it was shown that the absence of tachycardia at decompression inhibits the re-adaptation to the atmospheric pressure, thereby leading to death. The purpose of this study was to examine the activities of the autonomic nervous system, especially the circulatory kinetics, mainly at the return from a high-pressure environment to the atmospheric pressure, i.e. re-

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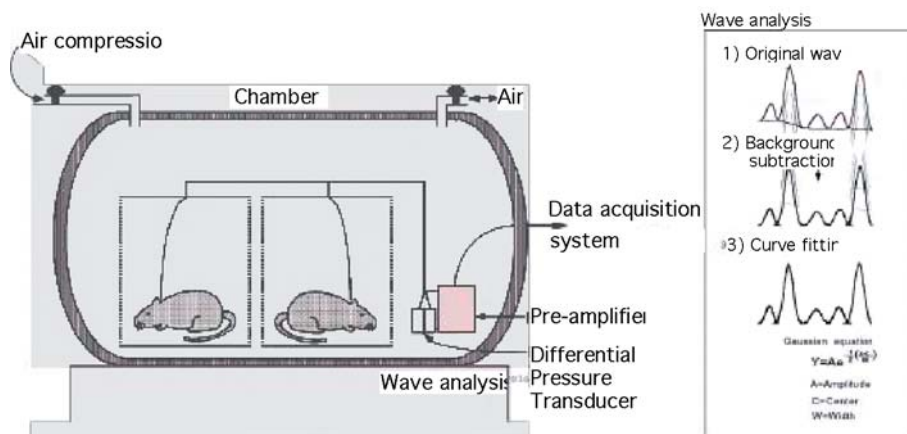


Fig.16 General arrangement and signals of Study on the Autonomic Nervous System on Re-adaptation to the Normobar after Diving (3 and 5 ATA air) on Rats.

adaptation, to understand the development of techniques is promoted for measuring, with a high precision, the autonomic nervous system functions of subjects under high-pressure environment. This year, in a animal experiment, measurements of the activities of digestive tract, etc., were obtained from subjects under a high-pressure environment (3 ATA and 5 ATA) with a considerable precision. From our these results, 5 ATA high pressure environment has no important effect on the activities of digestive tracts, though the rapid decompression inhibited this activities via vagal nerve system. were observed at bradycardia under a high-pressure atmosphere.

“Research on the evaluation of deep sea water quality”

Period: FY2000-FY2002

It is becoming a popular to use deep sea water in fishery and non-fishery (foods, cosmetics, etc.) fields.

There are 4 land-based artificial upwelling system (Muroto city Koch pref., Takaoka Kochi pref. {Aqua farm}, Namerikawa city Toyama pref. and Kume island Okinawa pref.) and 2(Yaizu city Shizuoka pref., and Nyuzen town Toyama pref.) land-based systems

are under constructing in Japan (Fig. 17). Further more, several cities are planning to build the system.

One of the useful features of deep sea water is the biological cleanliness, and the feature is used in the material of foods popularly. But, there are few information of the biological cleanliness, especially harmful microorganisms and endocrine disruptor. Therefore, it is important to certificate the biological cleanliness of deep sea water.

The aim of this research is to investigate the way of deep sea water quality evaluation, particularly, harmful microorganisms and endocrine disruptor. Each prefecture, which have or will have a land based artificial upwelling system, supports this research.

This year, we considered the evaluation techniques of harmful microorganisms and endocrine disruptor. Figure 17 indicates that the point and the depth of pumped deep sea water.

In harmful microorganisms, mainly germ by artificial contamination, we investigated the technique that the measurement of microbe concentration of coiffure bacillus (O-157), salmonella, and vibrio parahemolytica on genetic analysis. Consequently, observed the sea water that sooner as pumped, we could have obtained the superior result.

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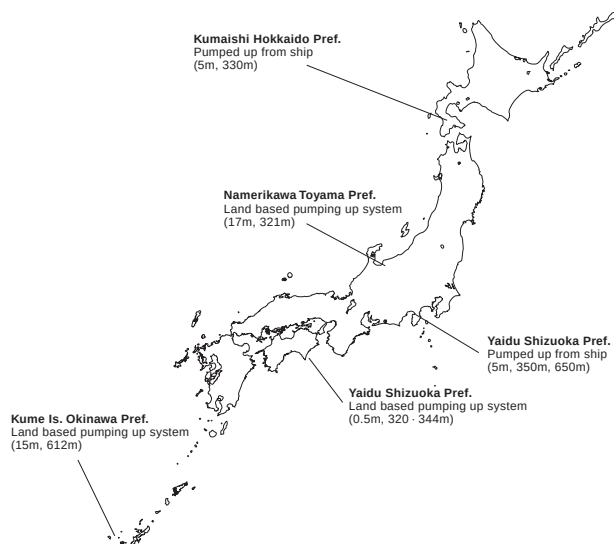


Fig.17 The point and the depth of pumped up deep sea-water

In endocrine disruptor, mainly halogenated environment organic pollutants, after condensing the sea water at each point, we analysed it on a gas chromatography. Consequently, we found this technique is suitable for land based artificial upwelling system. It required more than 2000 litre of deep sea water to analyze the endocrine disruptor, because of few quantity of endocrine disruptor in it. Furthermore, we could not compare with each analyzed endocrine disruptor on different analyzing condition.

Cooperative Research

“Research on effective utilization of thermal energy using deep sea water and hot spring water”

Period: FY2000-FY2002

It is examined to built a land based artificial upwelling system at Kumaishi-cho, Rausu-cho and Iwanai-cho in Hokkaido. In cold district, it becomes important to use hot spring water for saving energy. The aim of this study is examination of possibilities of saving energy using deep sea water and hot spring water in the system.

In 2000, we investigated the water temperature, salinity and distribution of inorganic nutrients off Kumaishi. Consequently, we confirmed that the sea water off Kumaishi had a characteristic of proper water mass in Japan Sea. According to this research and former result, the deep sea water under the 250m depth off Kumaishi was stable cold temperature and nutrient rich in the whole year (Fig.18). We have measured the hot spring water temperature in Kumaishi consequently, was about 60°C. The deep sea water off Kumaishi at 300m depth was about 1°C. The utilizable possibility on the temperature difference of the deep sea water and the hot spring water was about 60°C. And the submarine topographies off Kumaishi and Raus were confirmed by sonic prospecting investigation of Geological Survey of Hokkaido.

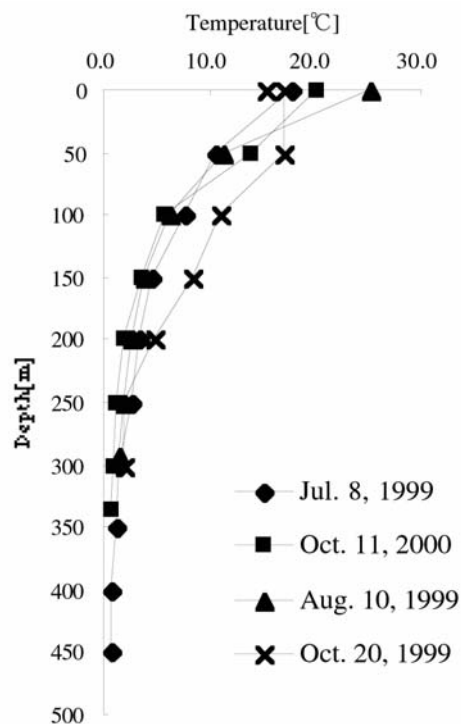


Fig.18 Vertical distribution of temperatures off Kumaishi. The data of Jul. 8, 1999 and Oct. 11, 2000 are the results of investigation of JAMSTEC. The date of Aug. 10, 1999 and Oct. 20, 1999 are the results of Geological Survey of Hokkaido

Marine Ecosystem Research Department

“Research on long-term rearing of mid-water animals”

Gelatinous zooplankton that are at present too fragile to keep in aquaria over the long-term, are very abundant in the midwater zone. So far, physiology, ecology and the life history of midwater animals are poorly understood. In this study, we will develop long-term rearing techniques and contribute to the elucidation of the functional role of midwater ecosystems acting on the ocean ecosystem. Also, the present research project collaborates with the Monterey Bay Aquarium Research Institute (MBARI), under a memorandum of understanding (MOU). This includes the sharing of ROV payload protocols and data comparisons between the midwater ecosystems studied by both parties.

At first, we designed and constructed a plankton kreisel (drum form aquarium tank), and purchased a filter, circulation pump, and sterilizing light in FY2000. We analyzed the relationship between the distribution of midwater animals and environmental

factors, and investigated water quality realized in an aquarium tank. Also, we reared polyps of a hydromedusa collected from the Off Hatsushima site, Sagami Bay, 1150m depth, and observed the polyps release ephyrae. This is the first time this has been achieved for a deep-sea hydromedusa and contributes to the clarification of its life history (Fig. 19).

“Research on the spawning characteristics of the Japanese eel (*Anguilla japonica*)”

Period: FY 2000-FY2002

This joint research between JAMSTEC and Ocean Research Institute, Tokyo University aimed to clarify the spawning characteristics and environmental conditions under spawning, and migration process of the Japanese eel (*Anguilla japonica*) to contribute to the marine biology and fisheries.

In this year, multiple plankton nets being equipped to the deep towed camera system was prepared for the coming field investigation around the Mariana Island.

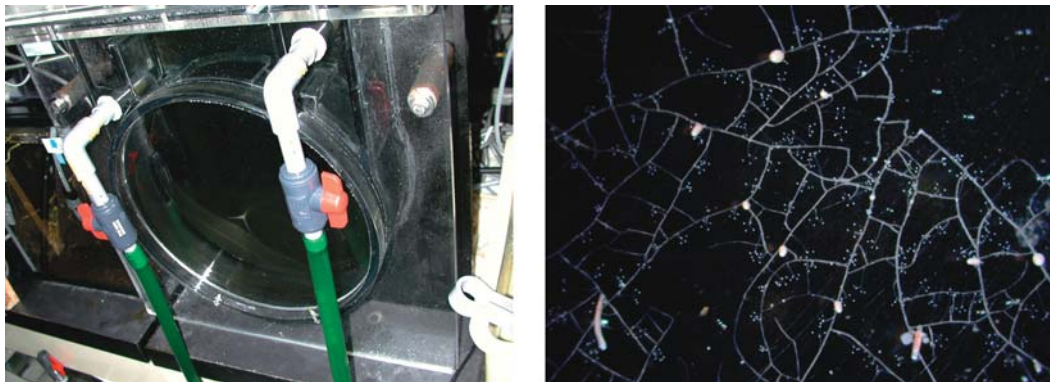


Fig.19 Plankton kreisel (left) and polyps releasing ephyrae of a deep-sea hydromedusa (right).

Computer and Information Department

Research and Development Policy

The Computer and Information Department promotes various research and development programs aimed at advancing computer science and technologies applicable to marine affairs. The programs include development of databases of various observed data, research support for development of numerical models for supercomputers, visualization technologies of the results of numerical simulations, development of innovating computation methods, and surveys on computer utilization environments.

The department conducted “Research on Parallel Computing in Marine Science and Technology (General Basic Research)” in fiscal 2000, aimed at developing an effective parallelization. Further, the department initiated new Joint Researches as new research themes.

Outline of Research and Development

(1) Research on Parallel Computing in Marine Science and Technology (Personal Research)

With the recent remarkable advancement of computer technologies, numerical analysis by computer is becoming technologically established as a third approach in various research fields. Clearly, JAMSTEC will have to address an increasing number of problems by computer application, and for that, JAMSTEC must become equipped with such hardware as supercomputers and a parallel computer system capable of rapid computations, and software technologies to both speed up calculation and make effective use of computer resources. One such measure is tuning by parallelization of source programs.

This research program will study parallel processing of the computation methods used in ocean models, and also methods to improve computation efficiency through improvement of source programs. In addition, this research program will search for the hardware best suited to running such software.

JAMSTEC has designed and developed a 4-node MPP-type PC cluster, and a 2-node 4-CPU SMP-type PC cluster. JAMSTEC conducted a benchmark test on the effect of parallel processing, using a large comput-

er (NEC SX-4 and IBM SP) and PC cluster systems. First, JAMSTEC selected an ocean model used to compare performances of the parallel computing systems, to evaluate the effects of parallel tuning of computation. Second, JAMSTEC identified problems with programs to be encountered in the realization of parallel processing of ocean models on the parallel computer systems JAMSTEC has introduced.

(2) Research on Marine-Related Computation Models Suited to a Scalar-Type Parallel Computer System (Cooperative Research)

The Earth Simulator Project, capable of rapid vector operations, is the core of Japan's Earth System Model studies. On the other hand, distributed-memory-type parallel computer systems were introduced into the ASCI White Project of the United States and the European Union, and scalar-type computations have become the mainstream with improved general-purpose software. Given that the world's trend for computer technologies is broadly divided into vector-type computation and scalar-type computation, JAMSTEC considers it very important to study recent trends of scalar-type computation, in addition to vector-type computation. JAMSTEC will prepare itself, from now, to be ready to cope with advancement of next-

Computer and Information Department

generation computer science, by studying and evaluating scalar-type marine-related computation models.

This research conducted a comparative analysis of scalar-type computation and vector-type computation, by putting a test marine computation model to a scalar-type parallel-type computer system. This research also comprehensively evaluated the scalar-type computer system and the vector-type computer system that could run the test marine computation model, with due consideration given to environments

in which the computer systems were placed. In fiscal 2000, a test marine model that can be run by the scalar-type computer system was selected. That model was input into the scalar-type parallel computer system owned by JAMSTEC, IBM RS6000/SP, and the marine model was tuned to parallel processing, and the computation results were compared with a single processor, to identify problems with parallel processing.

Frontier Research Program for Deep-Sea Extremophiles

Microbial Genome Analysis

We have determined the complete genomic sequence of alkaliphilic *Bacillus halodurans* C-125 and compared its genome with that of *Bacillus subtilis*. Alkaliphilic *B. halodurans* is the second *Bacillus* species for which the entire genomic sequence has been completely defined.

1. Analysis of the *B. halodurans* genome

(a) Prediction of the gene set required for alkaliphilia

Sigma factors belonging to the σ^{70} family (σ^A , σ^B , σ^D , σ^E , σ^F , σ^G , σ^H , and σ^K) are required for sporulation, and σ^L is well conserved between *B. halodurans* and *B. subtilis*. Of 11 sigma factors identified in *B. halodurans* belonging to the extracytoplasmic function (ECF) family, σ^W is also found in *B. subtilis*, but the other 10 (BH640, BH672, BH1615, BH2026, BH3117, BH3216, BH3223, BH3380, BH3632, and BH3882) are unique to *B. halodurans*. These unique sigma factors may have a role in the special physiological mechanisms by which *B. halodurans* is able to live in an alkaline environment, because it is well known that ECF sigma factors are present in a wide variety of bacteria and they control the uptake or secretion of specific molecules or ions and control responses to a variety of extracellular stress signals.

A teichuronopeptide (TUP) is present as a major structural component of the cell wall of C-125 and is a copolymer of polyglutamic acid and polyglucuronic acid. Thus, the negative charges on acidic nonpeptidoglycan components may enable the cell surface to absorb sodium and hydronium ions and to repel hydroxide ions, and as a consequence may allow the cells to grow in alkaline environments. A mutant defective in TUP synthesis grows slowly at alkaline pH. The upper limit of pH for growth of the mutant is 10.4, whereas that of the parental strain C-125 is 10.8. The *tupA* gene encoding TUP has been cloned from

C-125 chromosomal DNA. In the course of our studies, it has become clear that *B. halodurans* C-125 has no paralogue of *tupA* in the genome and that the orthologue of *tupA* cannot be found in the *B. subtilis* genome.

Members of the superfamily of adenosine triphosphate (ATP)-binding-cassette (ABC) transport systems couple the hydrolysis of ATP to the translocation of solutes across a biological membrane. ABC transporter genes are the most frequent class of protein-coding genes found in the *B. halodurans* genome, as in the case of *B. subtilis*. They are extremely important in Gram-positive bacteria such as *Bacillus* species, because these bacteria have an envelope consisting of a single membrane. ABC transporters allow such bacteria to escape the toxic action of many compounds. Through the series of analyses described above, 75 genes coding for ABC transporter/ATP-binding proteins were identified in the *B. halodurans* genome. In this analysis, 67 CDSs (CDS: protein coding DNA sequence) were grouped in the category of ATP-binding protein genes, although 71 ATP-binding protein genes have been identified in the *B. subtilis* genome. We found that *B. halodurans* has eight more oligopeptide ATP-binding proteins, but four fewer amino acid ATP-binding proteins compared with *B. subtilis*. We did not find any other significant difference between *B. halodurans* and *B. subtilis* in terms of the other ATP-binding proteins, although it should be noted that the specificity of some of these proteins is unknown. The genes for oligopeptide ATP-binding proteins (BH27, BH28, BH570, BH571, BH1799, BH1800, BH2077, BH2078, BH3639, BH3640, BH3645, BH3646, AppD, and AppF) are distributed throughout the C-125 genome. We speculate that these may contribute to survival under highly alkaline conditions, although there is no direct evidence to support this.

B. halodurans C-125 has a respiratory electron transport chain and the basic gene set for it is conserved as

Frontier Research Program for Deep-Sea Extremophiles

compared with *B. subtilis*, but the gene for cytochrome *bd* oxidase (BH3974 and BH3975) is duplicated in the C-125 genome. It is also clear that two genes for *bo3*-type cytochrome *c* oxidase (BH739 and BH740) not seen in *B. subtilis* are present in the C-125 genome. Thus, we also speculated that these extra oxidases may contribute to produce energy under alkaline conditions.

(b) Identification and distribution of new insertion sequences in the genome of alkaliphilic *B. halodurans* C-125

Fifteen types of new insertion sequences (ISs), IS641–IS643, IS650–658, IS660, IS662, and IS663 and a group II intron (Bh.Int), were identified in the 4,202,352-bp genome of alkaliphilic *Bacillus halodurans* C-125 (Table 1). Of 120 ISs identified in the C-125 genome, 29 were truncated, indicating the occurrence of internal rearrangements of the genome (Fig. 1). The ISs

other than IS650, IS653, IS660, IS663, and Bh.Int generate a 2-bp to 9-bp duplication of the target site sequence, and ISs other than IS650, IS653, and IS657 carry 14-bp to 64-bp inverted repeats. Sequence analysis revealed that six ISs (IS642, IS643, IS654, IS655, IS657, and IS658) belong to a separate IS family (IS630, IS21, IS256, IS3, IS200/IS605, and IS30, respectively) as new members. In addition, IS651 and IS652 were characterized as new members of the ISL3 family. Significant similarity was found between the transposase (Tpase) sequences in IS650 and IS653 (78.2%), IS651 and IS652 (56.3%), IS656 and IS662 (71.0%), and IS660 and IS663 (44.5%), but the others showed no similarity to one another. Tpsases in 28 copies of IS651 elements in the C-125 genome were found to have become diversified. Most of the IS elements widely distributed throughout the genome were inserted in noncoding regions, although some genes,

Table 1 New IS elements and group II intron identified in the *B. halodurans* genome

IS	Size (bp)	TSD ^a (bp)	IR (bp)	No. of IS elements			Family ^c
				Total IS	IS with ends ^b	Truncated IS	
IS641	1405	9	18	3	2 (0)	1	IS4
IS642	1142	2 [TA]	26	1	1 (0)	0	IS630
IS643	2485	5	64	2	1 (0)	1	IS21
IS650	1929	0	—	2	1	1	IS650/IS653 *
IS651	1384	8	23	28	22 (5)	6	ISL3
IS652	1461	8	27	19	19 (6)	0	ISL3
IS653	1805	0	—	7	7	0	IS650/IS653 *
IS654	1384	8	31	9	9 (1)	0	IS256
IS655	1221	3	38	5	5 (0)	0	IS3
IS656	1558	4	15	4	4 (1)	0	IS656/IS662 *
IS657	734	2 [TT]	—	9	8 (0)	1	IS200/IS605
IS658	1058	4	27	4	3 (0)	1	IS30
IS660	1963	0	16	23	6	17	IS1272*
IS662	1566	4	15	2	2 (0)	0	IS656/IS662 *
IS663	1980	0	14	2	1	1	IS1272*
Bh.Int	1883	0	—	7	5	2	Group II intron

^a The target site sequence is shown in brackets.

^b IS elements with two intact ends. Numbers in parentheses show the IS elements without a target site duplication.

^c New IS families proposed are shown by asterisks.

Frontier Research Program for Deep-Sea Extremophiles

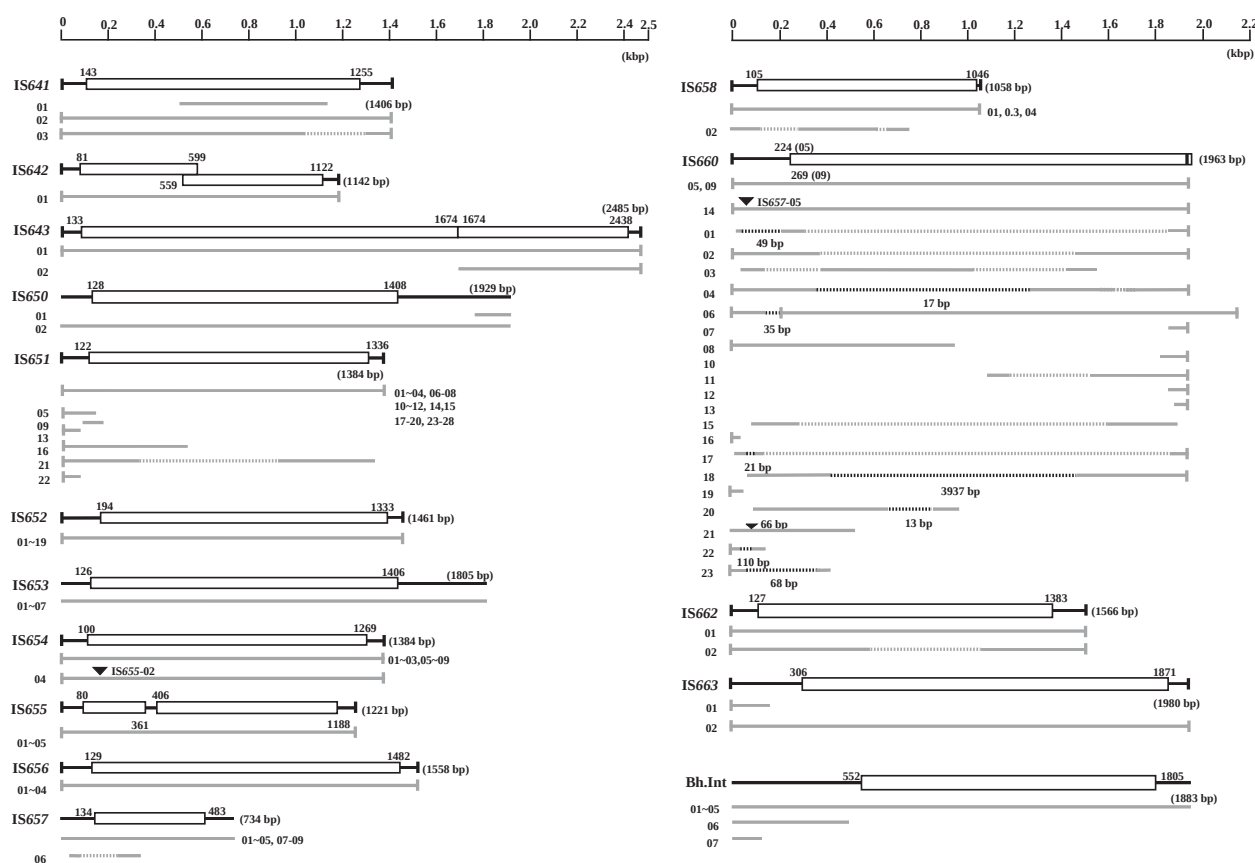


Fig. 1 Structure of each IS element and group II intron identified in the *B. halodurans* genome. The box shows the Tase of each element, and the numbers beside each box indicate the position of Tase in the element. The grayish lateral bar indicates the elements identified in the genome. The grayish and black dashed lines indicate deleted and inserted parts, respectively, in the element. The small vertical bar at the end of the element denotes IRs. The black upside-down triangle denotes insertion of another element. Partial IS elements without a terminal sequence shorter than 100 bp are omitted from this figure.

such as those coding for an ABC transporter/permease, a response regulator, and L-indole 2-dehydrogenase, have mutated through the insertion of IS elements. It is evident, however, that not all IS elements have transposed and caused rearrangements of the genome in the past 17 years during which strain C-125 was subcultured under neutral and alkaline conditions.

(c) Characterization and comparative study of *rrn* operons of alkaliphilic *B. halodurans* C-125

The ribosomal RNA operons (*rrn*) of alkaliphilic *B. halodurans* C-125 were characterized and com-

pared with those of *B. subtilis*. We isolated clones containing *rrn* operons from a lambda-phage library of the C-125 chromosome and the complete nucleotide sequence of each was determined. Eight *rrn* operons were identified by pulsed-field gel electrophoresis (PFGE) analysis of the C-125 chromosome digested with *I-CeuI* (Fig. 2). The transcriptional orientation of the *rrn* operons mapped on the chromosome by Southern blot hybridization analysis was the same as the direction of replication of the chromosome. These operons were designated as *rrnA-H*, starting from the *oriC* locus in clockwise rotation.

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Sequence and structural analyses of these operons suggested that six of the *rrn* operons in the C-125 chromosome, *rrnA*, *rrnB*, *rrnC*, *rrnD*, *rrnE*, and *rrnH* correspond to *rrnO*, *rrnA*, *rrnJ-rrnW*, *rrnI*, and *rrnD* in *B. subtilis*, whereas the other *rrn* operons (*rrnF* and *rrnG*) were specifically observed in *B. halodurans* C-125 (Fig. 2). The *rrn* loci were positioned from 0° to 90° on the physical map, with the *oriC* locus assigned the position 0°.

Two open reading frames (ORFs) annotated as *tnpA* and *ykfC*, of which the gene products are likely to act as transposases, were found downstream from these six operons. Comparative analysis of the 16S-23S and 23S-5S internally transcribed sequence (ITS) regions of *B. halodurans* C-125 and those of *B. subtilis* revealed that the ITS regions in C-125 were much longer than those in *B. subtilis*. There was no significant difference in the length of potential promoter sequences in *B. halodurans* and *B. subtilis*.

The intragenomic heterogeneity of ITS regions in

the *rrn* operons of *B. halodurans* C-125 was analyzed and compared with those in *B. subtilis*. The 16S-23S ITS (ITS1) and 23S-5S ITS (ITS2) regions in the *B. halodurans* *rrn* operons were found to be much longer than those in *B. subtilis* *rrn* operons. There were several unique sequence blocks in the ITS regions of *B. halodurans* and commonly conserved sequences in both species. These conserved sequence blocks of ITS regions in the *B. halodurans* genome were very diversified in contrast to those in *B. subtilis*.

(d) Construction of the "ExtremoBase" genome database for *B. halodurans* C-125

A new database specifically established for the *B. halodurans* sequence called the "ExtremoBase" will be accessible on the World-Wide Web at <http://www.jamstec.go.jp/jamstec-e/bio/DEEPSTAR/FResearch.html> (Fig. 3). The sequence has been deposited in EMBL/GenBank/DBJ under accession numbers AP001507 to AP001520.

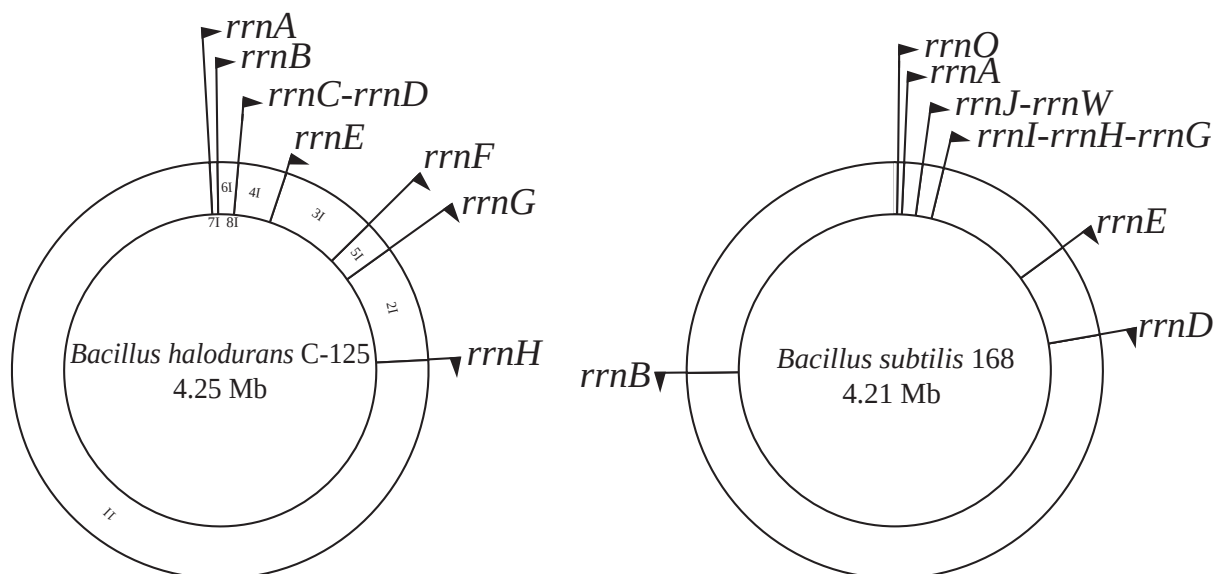


Fig. 2 Location of eight *rrn* operons in the *B. halodurans* chromosome and comparison with that of 10 *rrn* operons in the *B. subtilis* chromosome. The transcriptional orientation of the *rrn* operons is symbolized by a black flag.

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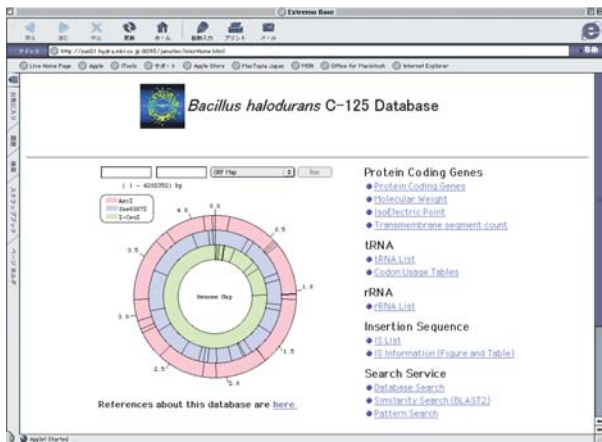


Fig. 3 Home page of ExtremoBase (<http://sun01.hydra.mki.co.jp:8093/jamstec/micrHome.html>).

2. Genome sequencing project of *Marinobacillus iheyensis* gen. nov. sp. nov., strain HTE831, a deep-sea extremely halotolerant and alkaliphilic species

Restriction endonucleases that recognize an 8-bp sequence were tested for their ability to digest the chromosome of *Marinobacillus iheyensis* strain HTE831 isolated from a depth of 1,050 m on the Iheya Ridge. *Apa* I (5'-GGGCC/C-3') and *Sse*8387I (5'-CCTGCA/GG-3') generated 37 and 25 resolvable fragments, respectively (Fig. 4). The sizes of these fragments were determined by comparison with size standards on a series of PFGE gels. The mean total size of the genome of *M. iheyensis* HTE831, estimated by totaling the *Apa* I or *Sse*8387I fragments, was 3.6 Mb (Fig. 4).

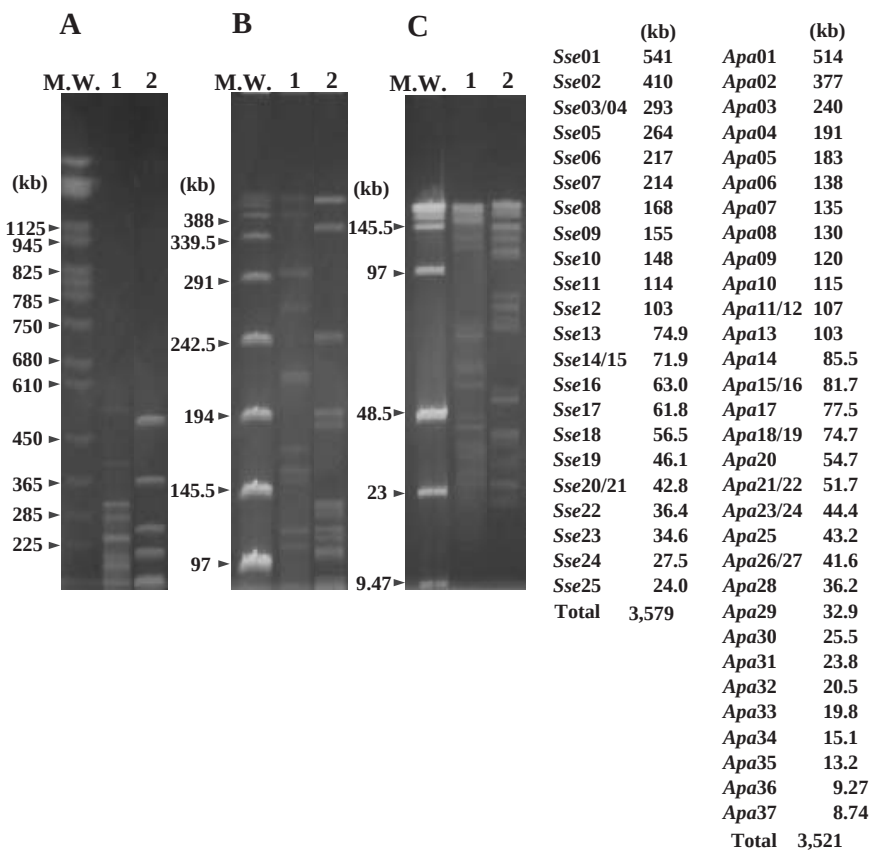


Fig. 4 Digestion patterns of the chromosomal DNA of strain HTE831 obtained with *Sse*8387I and *Apa*I. A, Separation of fragments ranging in size from 200–1000 kb. B, Separation of fragments ranging in size from 100–400 kb. C, Separation of fragments ranging in size from 5–75 kb. Lanes: 1, complete *Apa*I digestion; 2, complete *Sse*8387I digestion. M.W., molecular size marker.

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Chromosomal DNA from *M. iheyensis* HTE831 was fragmented by shearing force. One hundred microliters of DNA solution (20 ng/ μ l) was treated with HydoShear (Genemachine, Co. Ltd.) 20 times at speed code number 6. The treated DNA fragments were blunt-ended using a DNA blunting kit (Takara Shuzo Co., Japan) and loaded on a Spum column filled with Sepharose CL-4B to remove small fragments. DNA fragments 1–2 kb in length were ligated to the *Sma*I site of pUC18 which had been previously treated with BAP (bacterial alkaline phosphatase) and introduced into competent DH5 α cells by the standard method. We usually obtained transformants with a frequency of $5 - 6 \times 10^5/\mu$ g DNA, and they were used for amplification of insertion in the colony polymerase chain reaction (PCR) method.

The DNA fragments inserted into pUC18 were amplified by PCR using M13-20 and reverse primers. PCR fragments treated with exonuclease I and shrimp alkaline phosphatase to eliminate excess primers in the PCR reaction mixture were used for sequencing analysis as template DNA. Sequencing was performed with the DNA sequencer MegaBACE1000 (Amersham-Pharmacia Biotech. Inc.). We have already sequenced 35,000 shotgun clones and will continue random sequencing up to 45,000 clones. Statistical coverage of the sequenced region reached 5.8-fold at the stage of 35,000 clones, and those clones sequenced appeared to be nearly saturated (Fig. 5). At a statistical coverage of 5.8-fold, the assembly using Phrap yields 490 contigs and the total length of each contig was 3.56 Mb, corresponding to 98.9% of the entire genome of *M. iheyensis* HTE831 (Fig. 5). To complete the sequencing of the entire genome, we are trying to fill the gaps that have occurred using the sequences of both ends of large insert libraries such as lambda-phage and cosmid clone and by PCR with the primers designed based on the internal sequence in each contig.

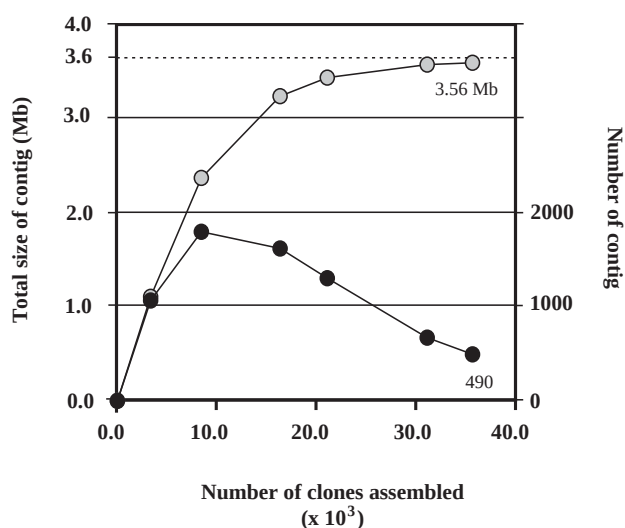


Fig. 5 Assembly summary of shotgun clones from the entire genome of *M. iheyensis* C-125. Open circles: total size of constructed contig; closed circles: number of constructed contigs.

Studies on Metabolism and Adaptation Mechanisms

1. Taxonomy and preservation of newly isolated deep-sea microorganisms

We isolated and identified new genera of piezophilic bacteria. In bacterial flora under continual high-pressure cultivation using the DEEPBATH system, novel species of piezophilic *Moritella*, *Colwellia*, and *Psychromonas* were observed. Novel species of the *Proteobacteria* ϵ -subgroup were also cultivated, and these *Proteobacteria* were anaerobic, psychrophilic, and piezophilic. This was the first identification of culturable ϵ -*Proteobacteria* that are piezophilic, and therefore we attempted to determine better conditions for the cultivation and isolation of this bacterium. A new genus of piezophilic bacteria has been identified which can now be described for publication in the *International Journal of Systematic and Evolutional Microbiology* and deposited in the Japan Collection of Microorganisms as a novel piezophilic

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bacteria called *Psychromonas kaikoi*.

We began the process of identifying the taxonomic positions of 30 alkaliphilic *Bacillus* strains that produce several useful enzymes. DNA–DNA hybridization data between these alkaliphiles and type strains suggest that more than 10 new species should exist, and therefore we are now conducting tests to identify these phenotypic characterizations.

Eleven strains from the Iheya Ridge and one strain from the Japan Trench were newly isolated as yeast species. Ten of these strains have already been identified. Sixty-eight strains of yeast previously isolated from deep-sea environments were sequenced in the D1/D2 region of 26S rDNA. Phylogenetic analysis of these sequences suggests that new species are among the 68 isolates examined. Furthermore, many of the yeast strains isolated from the tubeworm *Lamellibrachia* sp. clearly occupy phylogenetic placements corresponding to new species.

In 2000, four deep-sea sediment samples obtained by the SHINKAI 2000 research vessel from the Okinawa Trough, 10 samples obtained by the SHINKAI 6500 research vessel from the Japan Trench, and six samples obtained by the KAICO research vessel from the Japan Trench were preserved in liquid nitrogen. In total, we now have 265 types of deep-sea sediment samples in the liquid nitrogen storage tank. Thirteen microbial type strains that were obtained from the International Type Culture Collection Organization were stored in liquid nitrogen, and a total of 94 type strains are maintained under the same conditions in our laboratory. We have newly isolated four deep-sea strains (four piezophiles), and these are also stored in liquid nitrogen.

2. Microbial diversity in deep-sea environments

(a) Microbial diversity in deep-sea hydrothermal vent environments

Archaeal community structures in microhabitats in

a deep-sea hydrothermal vent chimney structure were evaluated through the combined use of culture-independent molecular analyses and enrichment culture methods. A black smoker chimney was obtained from the PACMANUS site in the Manus Basin near Papua New Guinea, and subsamples were obtained from vertical and horizontal sections. The elemental composition of the chimney was analyzed in different subsamples by SEM-EDS (Scanning Electron Microscopy-Electron Diffusion Spectroscopy), indicating that zinc and sulfur were major components, while elevated levels of elemental oxygen in exterior materials reflected the presence of oxidized materials on the outer surface of the chimney. Terminal-restriction fragment length polymorphism (T-RFLP) analysis revealed that a shift in archaeal ribotype structure occurred in the chimney structure. By sequencing rDNA clones from archaeal rDNA clone libraries, it was demonstrated that the archaeal communities in the chimney structure consisted for the most part of hyperthermophilic members and extreme halophiles and that the distribution of such extremophiles in different microhabitats of the chimney varied. The results of the culture-dependent analysis partially supported the view that changes in archaeal community structures in these microhabitats are associated with the geochemical and physical dynamics in the black smoker chimney. The archaeal population found in the chimney structure may represent the possible existence of an indigenous subvent biosphere beneath the active deep-sea hydrothermal seafloor.

(b) Studies on the frequency of halophilic or halotolerant microorganisms in the deep-sea environment

The results of a previous study suggested that there is a correlation between the depth of the seafloor and the population density of halophilic or halotolerant bacteria in the sediment, i.e., as the depth of seafloor increases, the population density of halophilic or halo-

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tolerant bacteria in the sediment decreases. In our recent study, we found that this general rule regarding the distribution of deep-sea microorganisms with respect to the depth of their habitats holds true and that the population density of halophilic or halotolerant microorganisms in the seafloor sediment decreases as the depth of the sea increases. This trend is due to a decrease in the intracellular concentration of potassium ions, which are a major compatible solute for osmotic stress in microorganisms. Furthermore, *Escherichia coli*, a nonextremophile, was also found to be sensitive to high osmotic pressure under high hydrostatic pressure conditions. This shows that microorganisms are averse to salinity under high hydrostatic pressure and that if the sea were less salty, the deep-sea environment might have broader microbial diversity.

3. Analysis of high-pressure adaptation mechanisms in microorganisms

(a) Significance of tryptophan availability in high-pressure growth in yeast

Hydrostatic pressures of more than 15 MPa significantly inhibit cell growth in the yeast *Saccharomyces cerevisiae*. The addition of a 50-fold concentration of tryptophan enabled the cells to grow under high-pressure conditions (Fig. 6). The remaining 19 amino acids had no effect on cell growth at high pressures. Tryptophan is a rare amino acid in nutrients and is essential for all animals. It possesses a bulky residue, and organisms may have developed unique systems for the import of this amino acid. The complex tryptophan import system is sometimes called the Achilles' heel of a cell and is thought to be the most pressure-sensitive process in living yeast. Overexpression of the tryptophan permease gene *TAT2* in *S.*

cerevisiae dramatically induced cell growth under high-pressure conditions.

(b) Studies of pressure-responsive transcription mechanisms in piezophilic bacteria

Deep-sea bacteria have unique systems for gene and protein expression controlled by hydrostatic pressure. One of the sigma factors, σ^{54} , was found to play an important role in pressure-regulated transcription in the deep-sea piezophilic bacterium *Shewanella violacea*. A glutamine synthetase gene (*glnA*) has been targeted as a model for the pressure-regulated promoter to investigate transcriptional regulation by the σ^{54} factor. Recognition sites for σ^{54} and σ^{70} factors were observed in an upstream region of the *glnA*, and NtrC-binding sites were also identified in this same region. Primer extension analyses determined the transcription initiation sites of both promoters and showed that transcription from the σ^{54} site was regulated by elevated pressure. The σ^{54} promoter is known to be activated

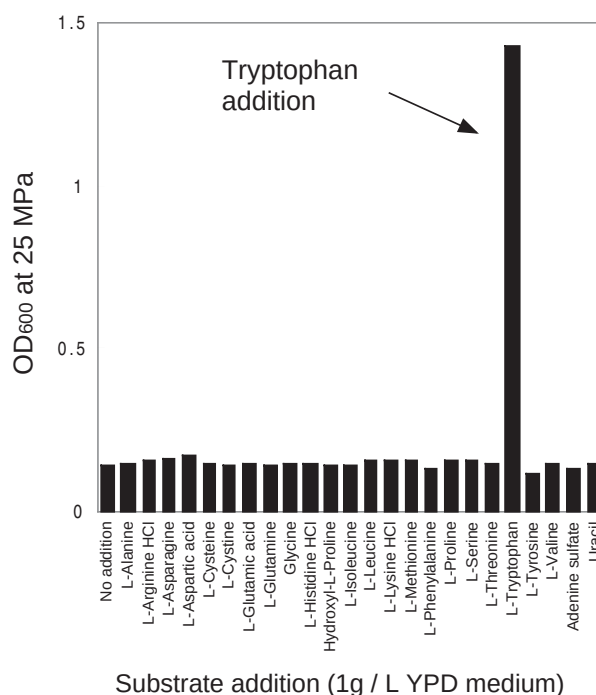


Fig. 6 Effect of the addition of various amino acids (1g/L) on yeast cell growth at 25 MPa.

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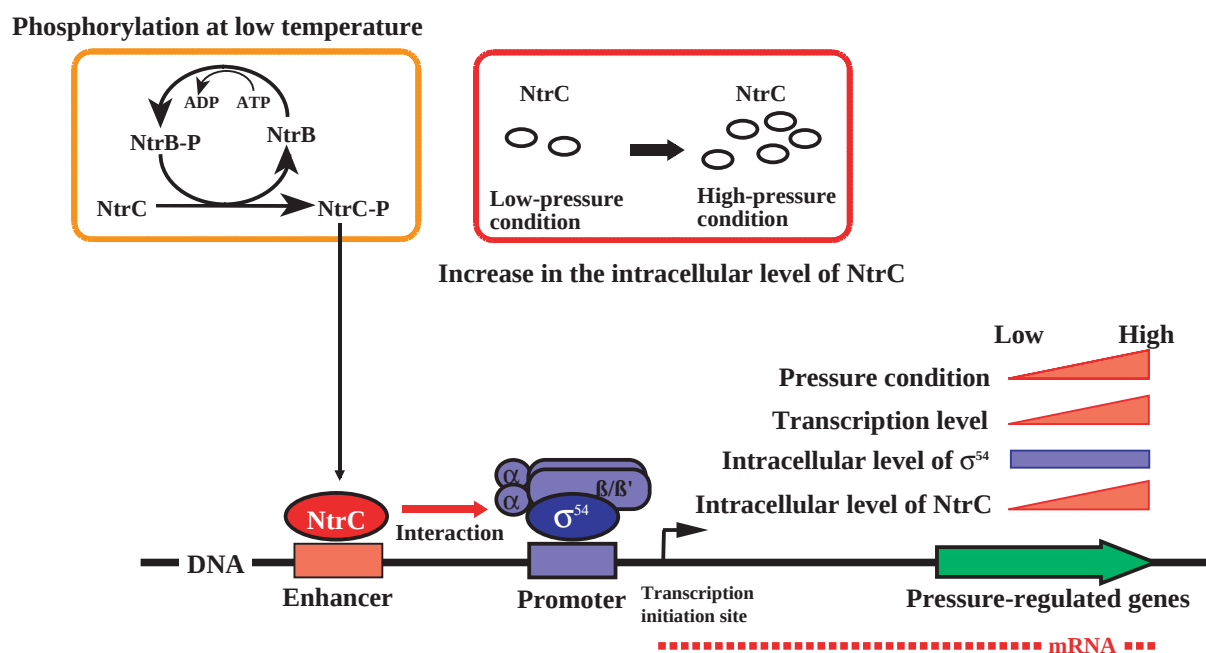


Fig. 7 Diagrammatic representation of the pressure-regulated transcription mechanisms in piezophilic *S. violacea*.

by a two-component signal transduction system, NtrB-NtrC-phosphorylated relay. Our results suggest that this system may be regulated by deep-sea conditions and that gene expression controlled by the σ^{54} promoter was actually regulated by pressure. We proposed a possible model of the molecular mechanisms for pressure-regulated transcription (Fig. 7).

(c) Analysis of cell division in microorganisms under high-pressure conditions

We have already reported that *E. coli* is closely related to deep-sea piezophilic and piezotolerant bacteria, which can grow well under high pressure, based on the phylogenetic analyses of 16S rDNA sequences. To study the adaptive mechanism of gene expression to high pressure, *E. coli* can be used as the piezosensitive standard bacterium for comparison with *S. violacea* DSS12, which is a moderate piezophile. It is well known that *E. coli* grown under high pressure is elongated, although the piezosensitive mecha-

nisms of this cell resulting in such elongation are not known. Since elongation is usually related to the inhibition of cell division, the formation of cell division (FtsZ) rings in elongated *E. coli* cells were examined using immunofluorescence microscopy (IFM), and the chromosomal DNA condensation was observed with DAPI(4'-6-Diamidino-2-phenylindole Dihydrochloride *n*-Hydrate) staining. In the case of cell fixation approximately 5 min after pressure release in an ice bath, many FtsZ rings were observed in the elongated cells (Fig. 8B). Surprisingly, when cells were fixed inside the pressure vessel during high-pressure cultivation using a cell-fixation apparatus (Fig. 9), almost no rings were observed (Fig. 8A).

We also examined chromosomal DNA segregation by DAPI staining at the same time. A condensed nucleoid structure was observed in the filamentous cells when the cells were fixed after releasing the pressure. In contrast, the chromosomal DNA was segregated, but not condensed in whole filamentous cells when

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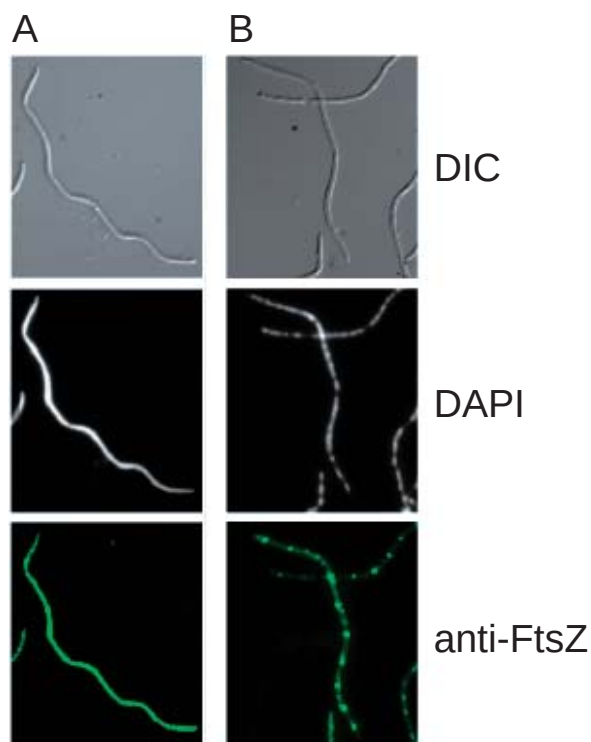


Fig. 8 Localization of chromosomal DNA and FtsZ by DAPI staining and IFM using FtsZ antibody in *E. coli* cells grown at 48 MPa. A, Cells were fixed before pressure release. B, Cells were fixed after pressure release.

the cells were fixed before pressure release (Fig. 8). These results suggest that *E. coli* may grow continuously without septum formation and be "frozen" at an early stage in the cell cycle before FtsZ ring formation and DNA condensation under high hydrostatic pressure. These inhibitions seem to be transient, because FtsZ ring formation and DNA condensation were restored within a few minutes (Fig. 8B), and cell division occurred immediately in many parts of the elongated cells and was nearly completed within 20 min after pressure release (Fig. 10). Therefore, the inhibition of FtsZ ring formation may be caused by physical change in the FtsZ protein, since the restoration of the ring after pressure release was such a rapid reaction. In contrast, the deep-sea piezophile *S. violacea* DSS12 can grow well and cells divide even at pressure of 50

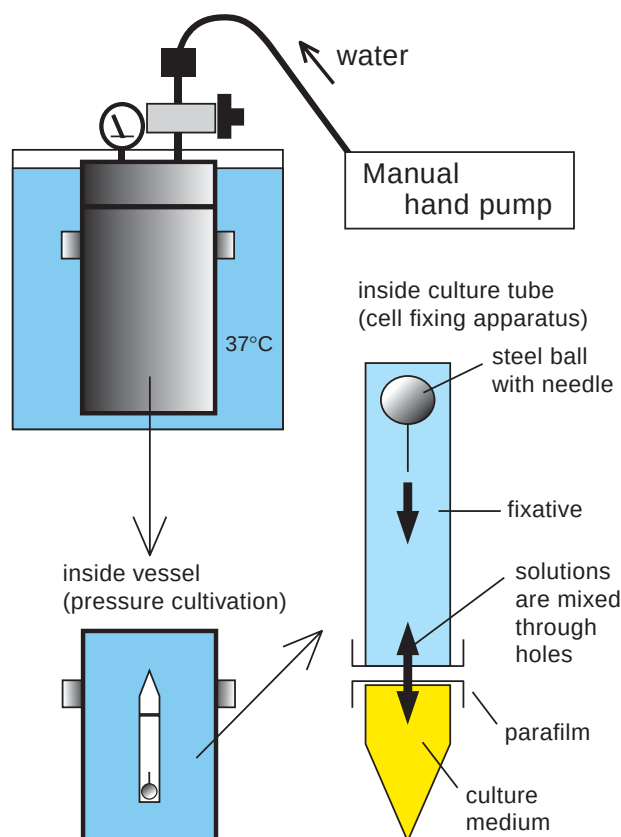


Fig. 9 Pressure apparatus for bacterial cultivation and fixation under high pressure. The cell culture chamber in a sterilized tube was sealed with parafilm and connected with the cell fixative chamber including a steel ball with a needle and incubated at 37°C inside a pressure vessel. After cell growth, the pressure vessel was inverted so that the needle broke the parafilm between the two chambers and shaken until the culture and fixative were mixed completely to fix cells under high pressure.

MPa, at which *E. coli* cells cannot divide. The formation of FtsZ rings in DSS12 under high pressure was also examined by IFM and it was found that FtsZ rings were formed at 50 MPa (Fig. 11).

The *dcw* operon including the *ftsZ* gene from DSS12 was cloned and analyzed. The sequence of the *ftsZ* gene was similar to that of *E. coli*, and reduced amino acid sequences of both FtsZ proteins had 72.2% homology. The expression of the *ftsZ* gene under high

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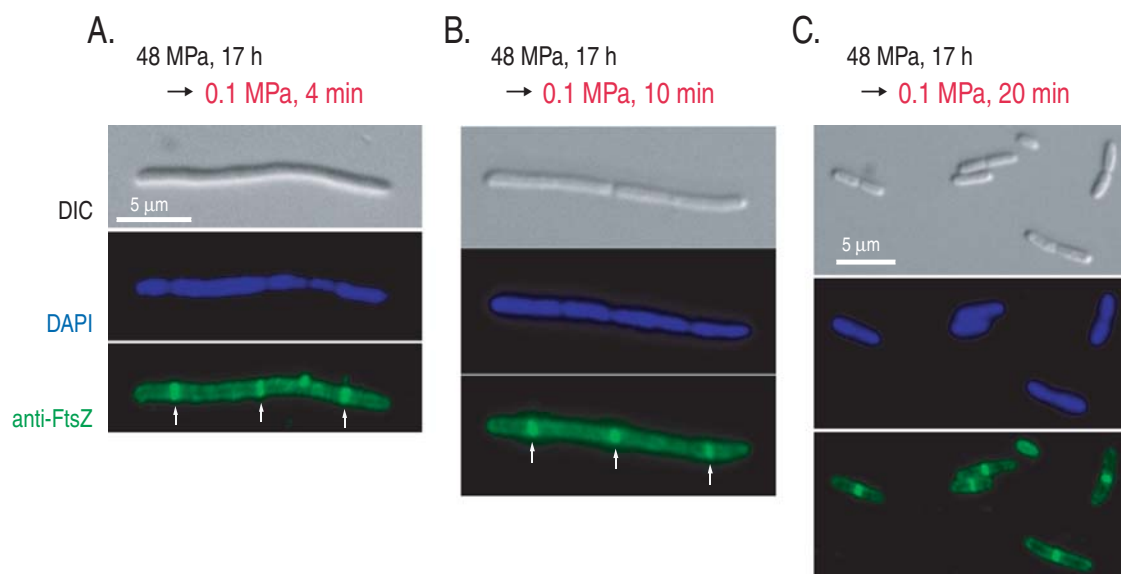


Fig.10 FtsZ localization in filamentous cells grown at pressure of 48 MPa and fixed at 4, 10, and 20 min (A, B, and C, respectively) after release of pressure. Arrows indicate ftsZ rings at division sites.

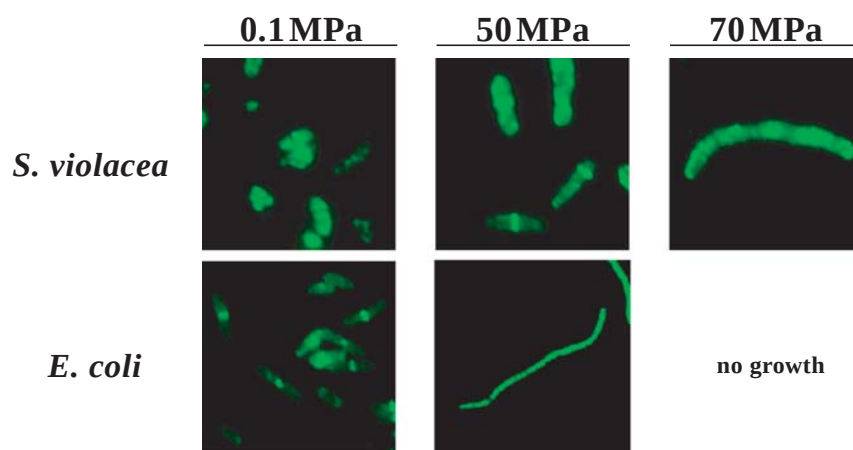


Fig.11 Effect of pressure on FtsZ-ring formation in *S. violacea* DSS12 and *E. coli*.

pressure was slightly enhanced compared with that at atmospheric pressure, as shown by the results of both Northern and Western blotting analyses. Therefore, the difference in FtsZ-ring formation in *E. coli* and DSS12 at 50 MPa may be due to the difference in FtsZ structure that is more tolerant to high pressure, or an

increased in the amount of FtsZ protein under high pressure in deep-sea strains. Further study of the relationship between the FtsZ protein and high-pressure growth of bacteria is now in progress.

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4. Mechanisms of tolerance to organic solvents of microorganisms

Pseudomonas putida IH-2000 was studied to elucidate the mechanisms of organic solvent (especially toluene) tolerance of this strain. *P. putida* IH-2000 produced membrane vesicles from the outer membrane in medium containing toluene. It was suggested that the production of membrane vesicles was one mechanism of toluene tolerance of IH-2000. The membrane vesicles were composed of phospholipid, lipopolysaccharide, a small amount of proteins and toluene molecules. Strain IH-2000 thus has a novel system conferring toluene tolerance which removes organic solvent molecules from the cell membrane by producing membrane vesicles (Fig.12).

IH-2000 exhibited various physiological and biochemical responses with the acclimatization of the cells to organic solvents. As reported in 1999, increased levels of toluene tolerance were induced by the acclimatization of the cells to more toxic solvents with lower log P_{OW} values. The induction of toluene

tolerance was accompanied by an increase in both lipopolysaccharide of the outer membrane and in cell surface negative charges. These biochemical changes could explain the decrease in cell surface hydrophobicity of the cells. The ability to mount a log P_{OW} response in strain IH-2000 was strongly suggested by these results. Moreover, in contrast with other toluene-tolerant bacteria, the mechanism of toluene tolerance in *P. putida* strain IH-2000 was elucidated to be independent of the energy generation system, including the efflux-pump system.

Biological Response Research

1. Research on response mechanisms of deep-sea multicellular organisms

(a) Development of deep-sea organism collection and cultivation equipment with pressure maintenance

We attempted to culture cell lines of deep-sea organisms to elucidate their adaptation and response mechanisms, for which equipment that maintains the

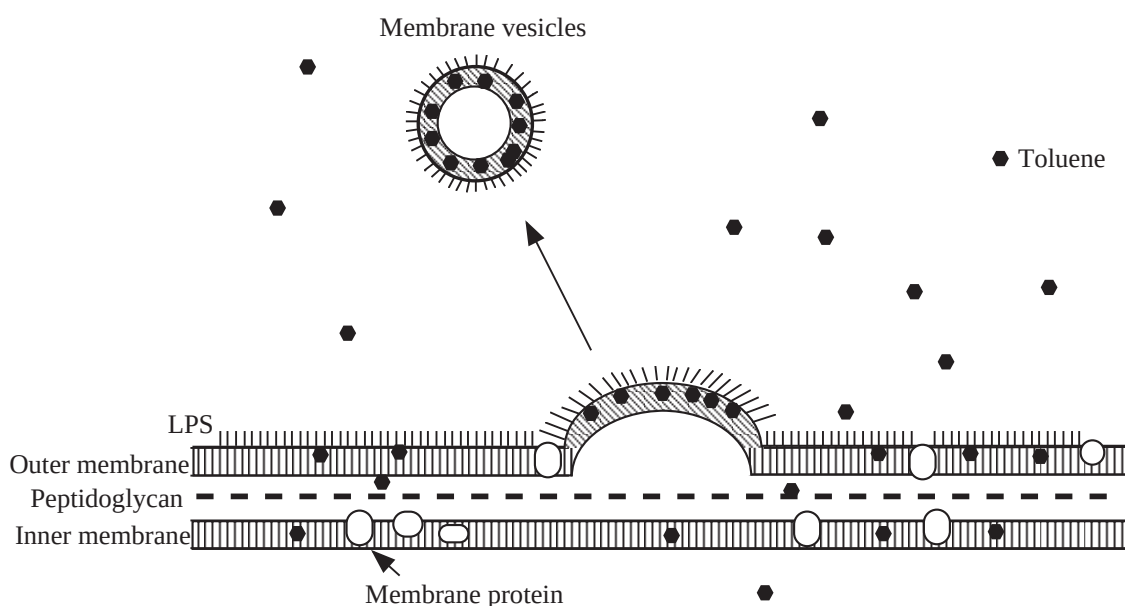


Fig.12 A novel mechanism of toluene tolerance for removing organic solvent molecules from the cell membrane involving the production of membrane vesicles in strain IH-2000. LPS, lipopolysaccharide.

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Fig.13 Pressure maintenance-type fish breeding aquarium and *Ebinaia brephocephala* under pressurization.

deep-sea environment during collection and culture was developed. The newly developed collection and cultivation tank can be installed on research submersible vessels and allows rapid transportation of living deep-sea organisms. A photograph of apparatus is shown in Fig.13. The samples were collected using the manned research submersible SHINKAI 2000 and trawl fishers in Suruga Bay. The design and performance of the equipment were tested in 2000, and field sampling will be carried out in 2001.

(b) Tissue culture of deep-sea fish cells

Cell tissue culture technology at the organizational and cellular levels is a basic requirement. However, the procurement of deep-sea organisms is difficult, and there have been few reports of tissue culture. We attempted primary culture of deep-sea fish cells to carry out continuous research in normal experimental facilities using the fin of the groundfish (*Conger myriaster*), of which some subspecies mainly exist in the deep-sea environment. Using L-15 culture medium supplemented with 0.9% sodium and 20% fetal bovine serum (FBS) with incubation at 25°C, fibroblast cells from the *C. myriaster* fin were successfully cultured. In pressure experiments, cell proliferation at 30 MPa

was confirmed. In direct observation of cultured cells at high pressure, pressure tolerance of about five-fold was seen compared with HeLa Cell.

We also succeeded in cultivating cells from a pectoral fin of *Gephyroberyx japonicus*, which lives at depths of 300–1500 m. Live cells were obtained from *G. japonicus* pectoral fins after 2-h treatment with collagenase and dispase. The *G. japonicus* fin organization was cultured in L-15 medium supplemented with 10% FBS and NaCl 4 g, and it was confirmed that the epiphytic ratio was adequate. The cells proliferated immediately and continued for 82.6 h.

(c) Pressure response of human skin fibroblasts

Pressure stimulation applied to human skin fibroblasts resulted in the activation of protein kinase C (PKC), as evidenced by the increase in the intracellular fluorescence intensity with Rim-1 staining. Direct observation showed that one type of fibroblast migrated to the plasma membrane and another type was activated around the nuclear membrane on activated PKC.

2. Research on Supercritical Water

At high temperatures and pressures above the critical point (374°C, 22.1 MPa, Fig. 14), water becomes a supercritical fluid and exhibits properties that differ remarkably from those of the more familiar ambient water. Supercritical water (SCW) may exist in nature in the Earth's crust or in hydrothermal vents. Understanding water under these conditions is indispensable to study the microorganisms that thrive in such environments. Our research interests include the behavior of biomaterials, colloidal dispersions, and chemical reactions in SCW. We have developed experimental apparatus such as an optical microscope, dynamic light scattering photometer, UV-VIS absorption spectrophotometer, and a reactor that can function at temperatures and pressures above the critical point of water up to 400°C and 40 MPa.

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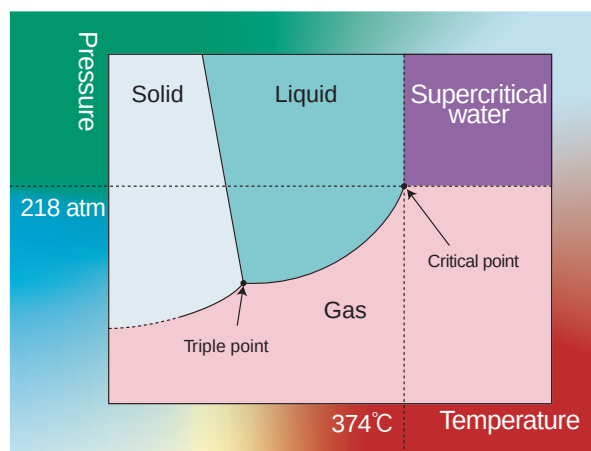


Fig.14 Phase diagram of water.

(a) Microscopic observations of biological substances in near-critical and supercritical water

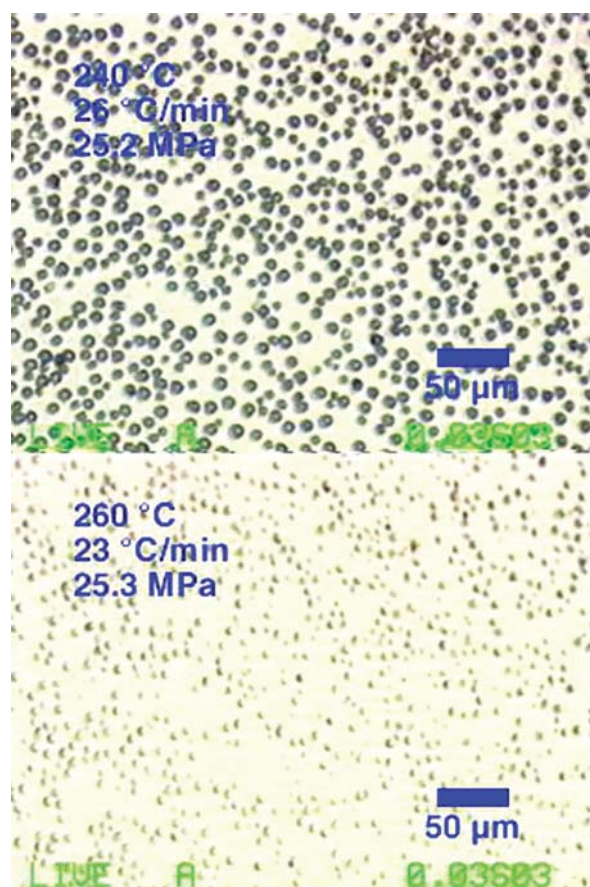
SCW dissolves substances that are insoluble in ambient water. We have studied the behavior of various, mainly biological, substances in near-critical water and SCW using an optical microscope equipped with a high-temperature and high-pressure cell. Cellulose is insoluble in water due to strong intermolecular hydrogen binding. When heated in water at 25 MPa, however, crystalline cellulose dissolved in water at 320–350°C. Observations under cross-polarizers suggested that the dissolution occurs after the melting of the crystalline structure. Chitin, on the other hand, was more stable than cellulose, and dissolved slowly at 390°C. Human hair is a biomaterial composed of the protein keratin and does not decompose easily. When heated in water at 25 MPa, supercontraction was observed at 190°C, followed by dissolution at 250°C. A comparison of the dissolution temperature of human hair and polysaccharides revealed that polysaccharides, which were expected to be more prone to hydrolysis, dissolve in water at higher temperature. This could be ascribed to the strong hydrogen bonds between the polysaccharide chains.

Microorganisms were also studied. The cell struc-

ture of the deep-sea yeast *Cryptococcus* sp. N6 was destroyed at 250°C and 25 MPa, yielding a residue that remained at temperatures of up to 300°C (Fig. 15). Other substances studied include spores of *Flammulina velutipes*, and *E. coli*, C₆₀, amorphous silica, glass, and quartz.

(b) Colloidal phenomena in SCW

A dynamic light-scattering photometer with a high-temperature and high-pressure cell has been developed to study colloidal dispersions in SCW. The performance of the apparatus was tested using an aqueous dispersion of monodisperse polystyrene latex. Measurements have been performed at high tempera-

Fig.15 Optical micrographs showing dissolution of the deep-sea yeast *Cryptococcus* sp. N6, at 250°C and 25 MPa.

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tures and pressures in the range of 24–325°C and 0.1–28 MPa. The measured diffusion coefficient of the latex increases significantly at higher temperatures due to a decrease in the viscosity of the medium, but its dependence is well described by the theoretical predictions for the diffusion coefficients of particles with constant size at up to 275°C. The result clearly shows that the apparatus performs well at high temperatures and pressures. The measured size increased at temperatures above 300°C, which could be related to the coagulation of the latex at these temperatures. The main problem that we have been confronted with in studying colloidal dispersions in SCW is finding a colloidal particle that is chemically stable in SCW. We are planning to study inorganic particles such as gold, silica, and diamond. Stable dispersion of fullerenes is another candidate research topic.

(c) Chemical reactions in SCW

The remarkably different solvent properties of SCW compared with those of ambient water affect chemical reactions. We have focused on reactions that are assumed to occur in hydrothermal vents and are thus relevant to the origin of life.

When an aqueous solution of the amino acid glycine was injected into near-critical water or SCW, the formation of oligoglycines was observed. This result shows that dehydration, which is unlikely to proceed in water, occurs in near-critical water or SCW. At fixed pressure of 22 MPa, the major product was glycine at 300°C, while the major product was diketopiperazine at 350°, 374°, and 400°C. The yield of diglycine was highest at 350°C. At all temperatures investigated, a trace amount of triglycine was formed.

(d) Search for SCW in the deep-sea environment

Many hydrothermal vents have been discovered in the deep sea, but water that exceeds the critical temperature (374°C) has not been reported. We are devel-

oping an apparatus to discover SCW spectroscopically in the deep-sea environment. The apparatus will be mounted on a research submersible, sunk into the deep sea, and used to seek SCW in hydrothermal vents.

Fisibility Study (FS): Methodology for Isolation and Cultivation of Deep-subsurface Microorganisms

FS has started for dealing with subsurface microorganisms from samples obtained from subsurface environments. This FS was supported by the JAMSTEC Special Fund for Fiscal Year 2000. This FS is recognized as a preliminary study for the future study of the seafloor biophere, which is one of the most important research areas in ocean drilling in the 21st century.

1. Methodology for obtaining contamination-free core drilling samples

Suspected microbial contamination during drilling with forced external water necessitates the evaluation of the microbiology of the deep subsurface biosphere. Several tests for microbial contamination are now performed in terrestrial and oceanic drilling. However, a combination of these contamination tests may be preferable, and contamination-free or -reduced retrieval techniques are used in microbial surveys of the deep subsurface biosphere. We sought to develop a contamination-reduced core retrieval system using antimicrobial polymer gels. In fiscal year 2000, we succeeded in synthesizing several antimicrobial polymer gels that inhibit microbial growth on solid media, including the gels.

2. Development of a rapid, quantitative method for analysis of subsurface microbial communities and case studies

To establish a rapid and quantitative system for the analysis of subsurface microbial community struc-

Frontier Research Program for Deep-Sea Extremophiles

tures, we developed a new method using quantitative fluorescence PCR. It was applied to the analysis of subsurface microbial communities in several deep-sea subseafloor environments in combination with other newly developed molecular techniques. The combined use of these molecular techniques will be appropriate for mass analysis of numerous samples obtained during ODP (Ocean Drilling Project) and OD21 drilling cruises. We applied the new approach to several typical subsurface microbial ecosystems: a deep subsurface geothermal water pool; a Japanese gold mine environment; a Cretaceous black shale formation in southern France; deep-sea pelagic sediments in the Philippine Sea; a deep-sea sedimentary rock in the Japan Trench; and a subseafloor core sample including methane hydrate from the Nankai Trough.

3. Case studies

(a) Deep subsurface geothermal water pool

Based on molecular phylogenetic analysis of a naturally occurring microbial community in a deep subsurface geothermal environment, the phylogenetic diversity of the microbial population was extremely limited, and only hyperthermophilic archaeal members closely related to *Pyrobaculum* were present. All archaeal rDNA sequences contained intron-like sequences, some of which had an ORF with repeated homing-endonuclease motifs. Sequence similarity analysis and phylogenetic analysis of these homing endonucleases suggested possible phylogenetic relationships among archaeal rRNA-encoded homing endonucleases.

(b) Subsurface gold mine environment in Japan

Culture-independent molecular analysis of microbial communities in groundwater and rocks collected from a Japanese gold mine was performed using a combination of culture-dependent and -independent techniques. Samples included various water samples

obtained from different depths of origin and sedimentary or igneous rocks from the Cretaceous and Pleistocene periods, respectively. The microbial communities in shallower environments revealed an active, thermophilic community structure; most members appeared to be most closely related to hydrogen-oxidizing, methane-oxidizing, and ammonia-oxidizing thermophilic bacteria. Some archaeal rDNA clones obtained from hot groundwater of deep origin were most closely related to the environmental rDNA clones from marine environments (marine group I; MGI). The water samples also yielded genetic signatures of marine bacteria. These results suggest that Japanese gold mines harbor novel indigenous subsurface microbial communities closely associated with the geologic and stratigraphic setting and with the past and present geochemical processes of the mine.

(c) Cretaceous black shale formation in southern France

Microbial habitats at ocean anoxic events (OAEs) are significant in comprehending paleoenvironmental dynamism, although their diversity remains poorly demonstrated. Indigenous bacterial rDNA recovered from the OAE level is dominated by oceanic sulfur-reducing bacteria closely related to the δ subclass of *Proteobacteria*, which is phylogenetically similar to microbial communities at euxinic seeping environments. This genetic evidence corresponds with the lower shift of organic-sulfur and carbon isotopic records resulting from bacterial metabolism. Our findings suggest that the global OAE sedimentation process may be attributed to an effect of euxinic water expelled from subsurface environments associated with "superplume" episodes.

(d) Deep-sea pelagic sediments in the Philippine Sea

We discovered vertically shifted community structures of Archaea in a typical oceanic subseafloor core

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sample (1410 cm) recovered from the West Philippine Basin at a depth of 5719 m. Beneath a surface community of ubiquitous deep-sea Archaea (marine crenarchaeotic group I; MGI), an unusual community consisting of extremophilic Archaea, such as extreme halophiles and hyperthermophiles, was present. These organisms could not be cultivated, and may be microbial relics more than 2 million years old. Our discovery of archaeal rDNA in this core sample, probably associated with past terrestrial volcanic and submarine hydrothermal activities surrounding the West

Philippine Basin, serves as potential geomicrobiological evidence reflecting novel records of geothermal events in the Pleistocene period concealed in the deep-sea seafloor (Fig. 16).

(e) Deep-sea sedimentary rock

Microbial community structures in a deep-sea rock (siltstone) collected from the Sanriku Escarpment in the Japan Trench at a depth of 6337 m were analyzed using enrichment culture methods and culture-independent molecular phylogenetic techniques. The silt-

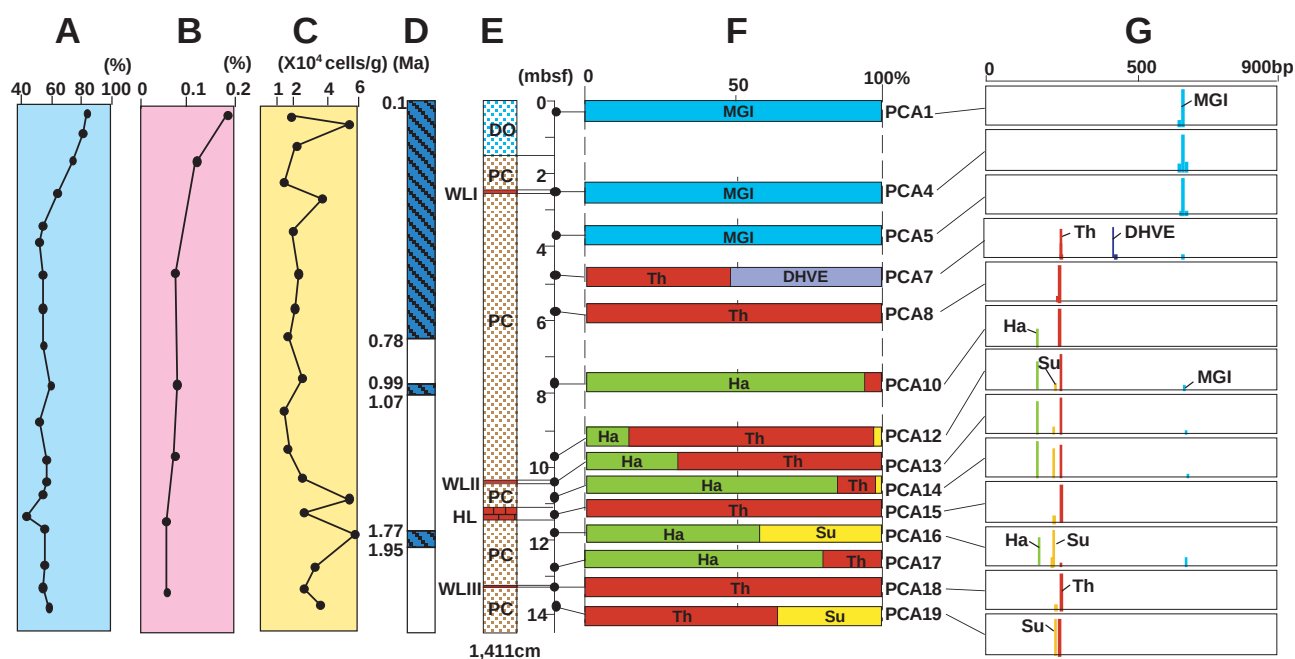


Fig.16 Vertical characterization of the PC-4 core. A, Water content of the sediments. B, Concentration of total organic carbon (TOC). C, Direct cell counts by epifluorescence microscopic observation after DAPI staining. Total cell densities were calculated from an average of 50 microscopic fields. D, Magnetostatic shift and putative stratigraphic ages of the sediments. E, Lithology and depth from the surface of the seafloor. Abbreviations for lithology are as follows: DO, diatom ooze; PC, pelagic clay; WL, white layer; HL, hard layer. F, Archaeal ribotype structure. Single-strand sequences 300 bp in length determined by means of the Arch21F primer (48 clones from each section) were used in similarity analysis by the FASTA3 and gapped-BLAST systems. Abbreviations for phylotype of clones from PC-4 core sediments are as follows: MGI, marine crenarchaeotic group I; Th, genus *Thermococcus* members; DHVE, deep-sea hydrothermal vent euryarchaeotic groups; Ha, genus *Haloarcula* members; Su, genera *Sulfolobus* and *Sulfurisphaera* members. G, Ribotype-fingerprint patterns of the archaeal rDNA community based on T-RFLP analysis. The archaeal PCR product was amplified using Arch21F and Arch958R-FAM primers and digested with *Hha* I at 37°C for 8 h. The positions of each peak correspond to the terminal length of *Hha* I-digested rDNA from the Arch958R-FAM primer end. Abbreviations indicate putative phylotypes based on the *Hha* I-site of rDNA sequences of representative clones. The color of the peak and abbreviation corresponds to that of the clone type shown in F.

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stone was subsampled into four sections (S1 to S4, from the surface to the inside), and carbon concentrations and colony-forming units were determined under several culture conditions. T-RFLP analysis of PCR-amplified 16S rRNA gene (rDNA) sequences indicated that a shift in bacterial and archaeal ribotype structures occurred in the sections at different depths from the surface. rDNA clone analysis revealed a significant change in microbial rDNA community structures. Bacterial rDNA community structures in sections S1 to S3 were comprised of typical marine bacteria, mainly members of the α and γ subclasses of *Proteobacteria*, while rDNA signatures for the β subclass of *Proteobacteria* and the high G+C Gram-positive group were obtained from the innermost structure. Major archaeal rDNA clones were shifted from those of MGI (S1) to those of *Thermococcales* (S2–S4). The transition of bacterial and archaeal rDNA community structure revealed the possible infiltration of seawater and microorganisms into the rock and strongly suggested the existence of unusual endolithic microbial communities in isolation during the geological time scale of the history of the rock.

(f) Subseafloor methane hydrate in the Nankai Trough

We detected the abundant occurrence of the extremophilic Archaea *Thermococcus* and *Haloarcula*, which may be derived from hydrothermal vent fields, in the microbial community structures occurring in subseafloor sediments containing methane hydrate layers in the Nankai Trough. However, no apparent genetic signature of methanogenic Archaea or methanotrophic bacteria was obtained. These results were inconsistent with the results of the carbon isotopic analysis of the methane in the methane hydrate strata. Although carbon isotopic and chemical analyses indicate the possible biogenic origin of methane, they do

not necessarily provide insight into the process of formation of methane hydrate. Our findings suggest that the methane in the methane hydrate strata may derived from microbial activities occurring outside the present microbial community in the methane hydrate.

2. Preservation of deep-sea microorganisms

In 2000, sediment samples were collected from the Japan Trench landward slope at depths of 6,400–7,500 m, which contain typical deep-sea cold-seep environments with chemosynthesis-based animal communities. These sediment samples were transferred to the DEEPBATH system and cultivated continually at 68 MPa and 5°C in two types of media (marine broth medium and sulfate-reducing bacterial medium) separately. The new genus of piezophilic bacteria identified in those sediment samples was described and deposited in the Japan Collection of Microorganisms as the novel piezophilic bacteria *P. kaikoi*, as described above. In addition, yeast strains isolated from the tubeworm *Lamellibrachia* sp. from Sagami Bay clearly occupied phylogenetic placements corresponding to new species, and the novel strain *Rhodotorula lamellibrachii* was described. Sixty-six strains of ascospore yeast previously isolated from deep-sea environments were sequenced in the D1/D2 region of 26S rDNA. Phylogenetic analysis of these sequences suggested some new species in these isolates. Newly isolated microorganisms preserved in our facility included 17 bacteria strains (four piezophiles and 13 others) and 12 yeast strains (11 from the Iheya Ridge and one from the Japan Trench), and these strains are being stored in liquid nitrogen conditions. Twenty deep-sea sediment samples obtained by the SHINKAI 2000, SHINKAI 6500, and KAIKO research vessels in 2000 were also preserved in liquid nitrogen conditions, as outlined above.

Frontier Research Program for Subduction Dynamics

Research Overview

The objective of this research program is to utilize the research facilities of the Japan Marine Science and Technology Center to elucidate the seismogenic mechanism of great subduction zone earthquakes. The program was first established in the latter half of the 1996 fiscal year, with research beginning in earnest in fiscal year 1997. This Frontier research program encompasses the following 3 research themes:

- 1) Ocean Lithospheric Structure Research
- 2) Long-term Monitoring Research
- 3) Seafloor Deformation Modeling Research

By integrating these three research themes, as indicated in Figure 1, the numerical implementation of high-precision computer simulations of lithospheric deformation will be achieved, which will help explain the seismogenic mechanism of great subduction zone earthquakes.

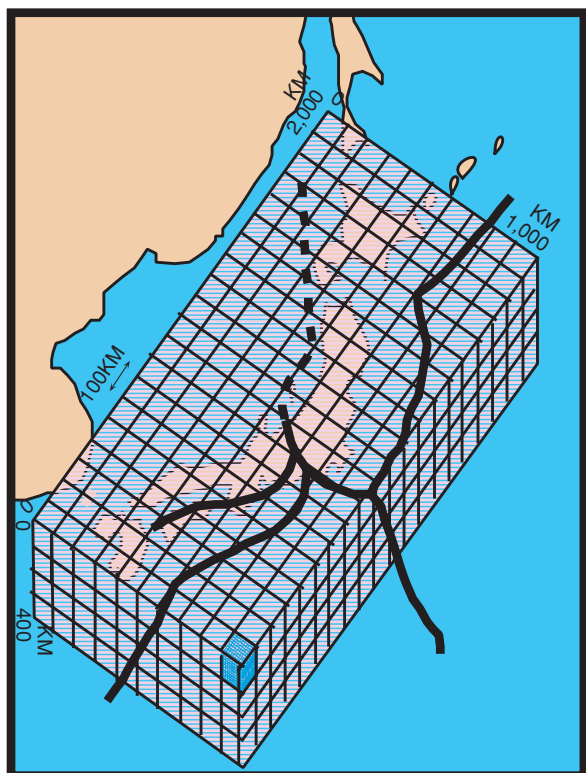


Fig. 1 Numerical model for simulation of crustal deformation

Summary of Research Results for Fiscal Year 2000

1. Ocean Lithospheric Structure Research

This research utilizes multichannel seismic reflection (MCS) and self-floating ocean bottom seismometers (OBS) to ascertain both large-scale and detailed lithospheric structure. It is also aimed at elucidating the earthquake rupture process through the study of seismicity along with structural irregularities of the subducting ocean lithosphere such as subducting seamounts which may play a role in seismogenesis. The survey work has focused on the Nankai Trough and the Kuril Trench as the main research targets (Fig. 2).

During the 2000 fiscal year surveys have been conducted in the northern part of the Japan Trench and the southern Kuril Trench (Fig. 3) using the research vessels "Kaiyo" and "Kairei".

A detailed MCS survey conducted in the vicinity of the Erimo seamount at the junction of the Japan and Kuril Trenches survey detected structural irregularities subducting there. Imaging of these structural irregularities was also attempted using data from high-precision magnetome-

Frontier Research Program for Subduction Dynamics

ter survey conducted at the same time as the MCS survey. An OBS survey was also conducted which stretched from Hokkaido to the Okhotsk Sea to study structure of the lithosphere at the continent-ocean boundary there, with the aim of ascertaining the overall structure of the subduction zones around Japan. According to the surveys conducted thus far in the Japan Trench, the thickness of sediments and eroded continental material incorporated near the plate boundary due to the irregular structure of the oceanic

crust's upper boundary varies along strike (Fig. 4). The relationship between the thickness of this material near the plate boundary and earthquake activity is still being investigated.

During the course of MCS and OBS surveys conduct-

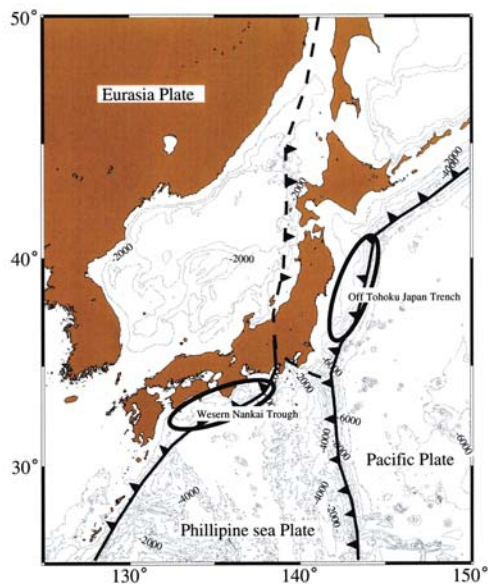


Fig. 2 Sites for marine seismic survey (MCS, OBS seismic survey)

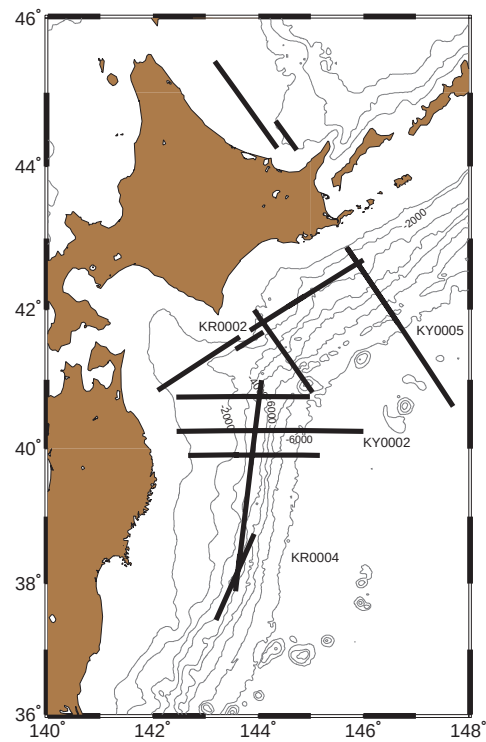


Fig. 3 Seismic survey lines conducted by the Frontier Research Program for Subduction Dynamics in 2000.

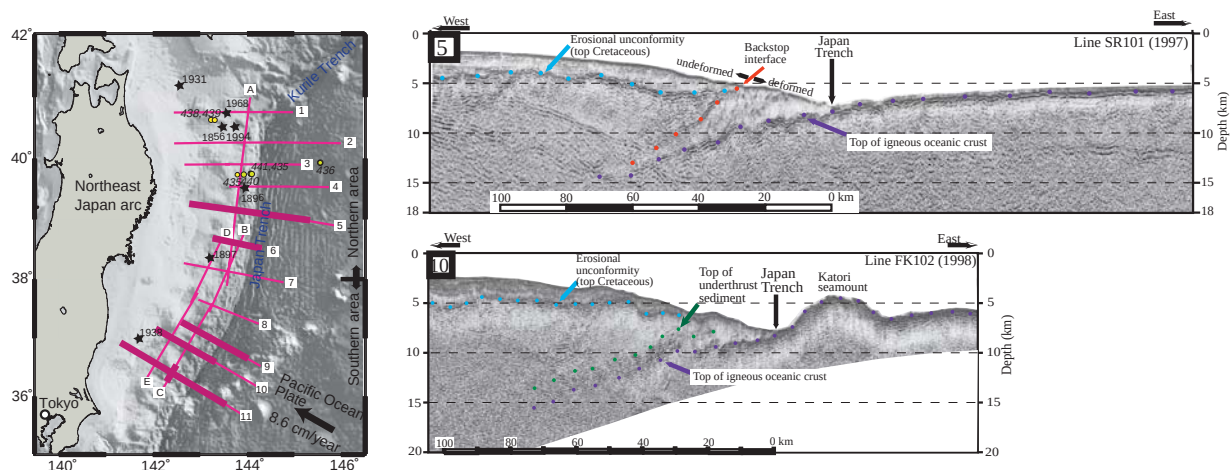


Fig. 4 Seismic lines and MCS profiles in the Japan Trench

Frontier Research Program for Subduction Dynamics

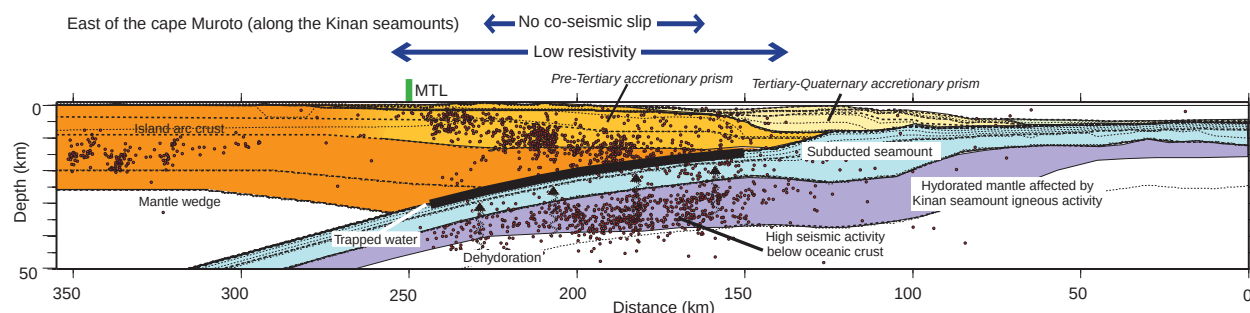


Fig. 5 Structure near the continent-ocean boundary in the Nankai Trough near cape Muroto.

ed in the Nankai Trough since fiscal year 1997, irregular structure which may represent a subducting seamount has been discovered off Cape Muroto (Fig. 5), which is thought to be related to the rupture and aftershock area of the 1946 Nankai earthquake. This subducting seamount may have acted as a barrier to along-strike rupture propagation after the earthquake rupture initiated off the Kii Peninsula; westward of this barrier rupture only occurred on the deep part of the seismogenic zone. Further research is being conducted to compare lithospheric structure in the Nankai Trough at Kumano Nada, off Cape Muroto, and offshore Ashizuri, to study how structural differences may affect the character of great earthquake rupture (Fig. 6).

Along with conducting surveys to study lithospheric structure, research will continue to study its relationship to the seismogenic mechanism.

2. Long-term Monitoring Research

This research aims to assess earthquake activity and specify the up-dip and down-dip limits to the seismogenic zone based on earthquake focal mechanism determinations which utilize data from concentrated seismicity surveys and the Real-time Seafloor Seismic Observatory deployed off Kushiro and Cape Muroto. Also, this research group facilitates the efficient utilization of past and present research results by incorporating them in a database from which the numerical implementation of lithospheric structure models can be achieved.

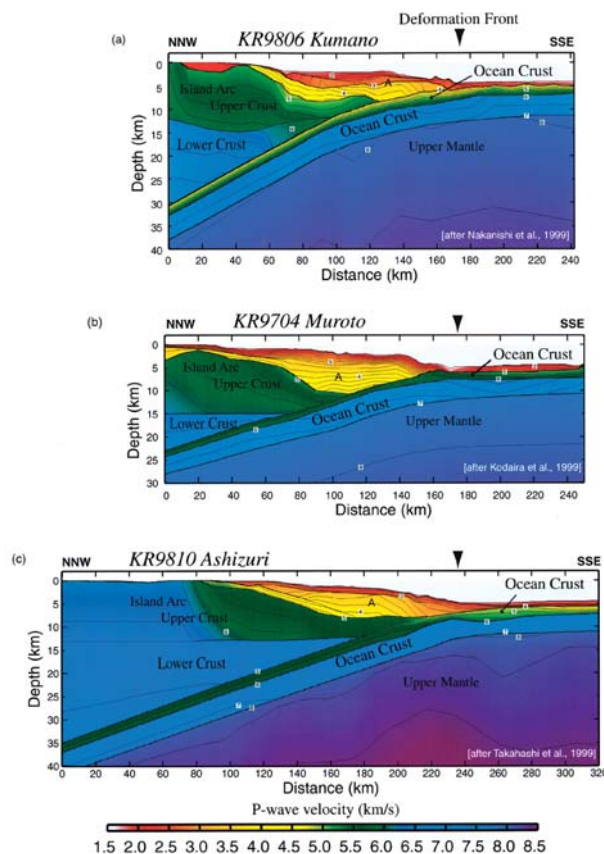


Fig. 6 Velocity structure models in the Nankai Trough (top: off Kumano, middle: off Muroto, bottom: off Ashizuri)

Since fiscal year 1998 a dense network of self-floating ocean bottom seismometers has been deployed in the Nankai Trough off Cape Muroto in a temporary seismicity survey conducted in collaboration with institutes such as University of Tokyo's Earthquake Research Institute

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and Ocean Research Institute (Fig. 7, 8). This study has established that earthquakes tend to cluster within the seaward flank of the subducting seamount discovered off Cape Muroto (Fig. 9). This earthquake activity is

thought to reflect the deformation of the seamount itself associated with its subduction, a hypothesis which is being tested through numerical modeling.

In the future it is planned to continue this kind of

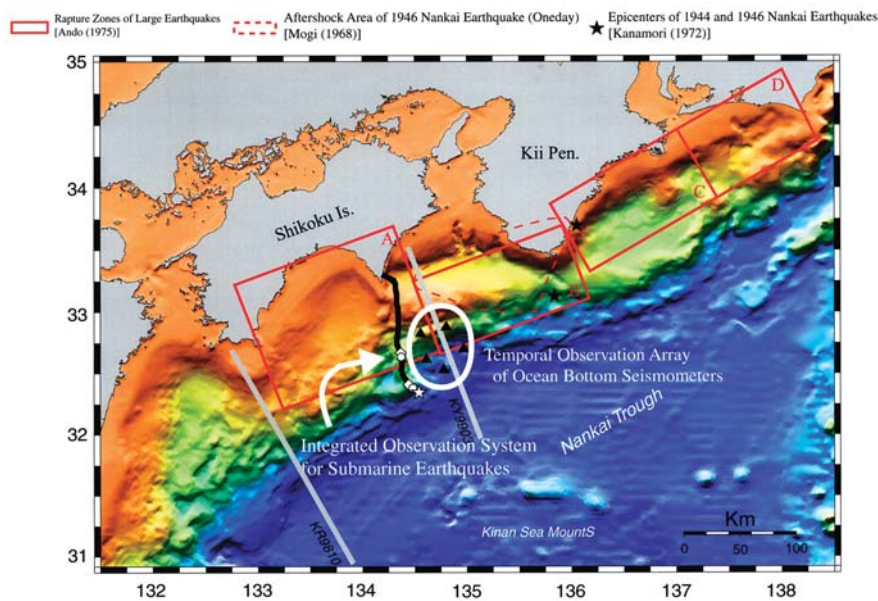


Fig. 7 Real-time Seafloor Seismic Observatory and temporal OBS observation array off Muroto.

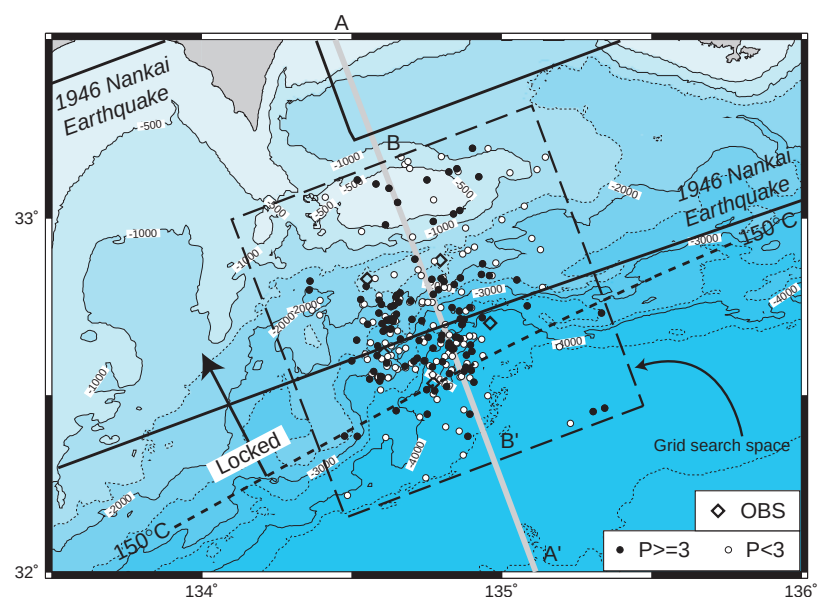


Fig. 8 Epicenter distribution off Muroto observed by temporal OBS observation array.

Frontier Research Program for Subduction Dynamics

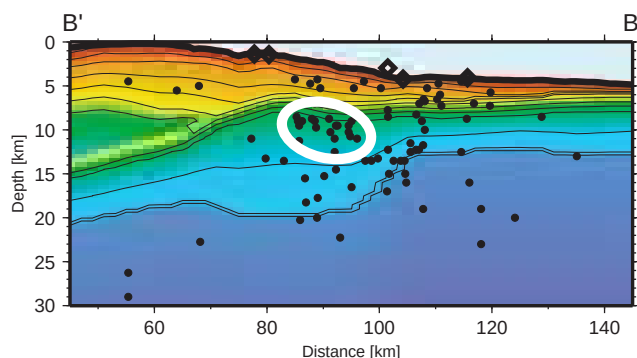


Fig. 9 Subducting seamount and hypocenters off Muroto.

observational study, in order to increase the precision of focal mechanism determinations which will support further research into the relationship between lithospheric structure and seismicity. Also, numerical implementation of models for lithospheric structure will be facilitated by further development of the earth sciences database.

3. Seafloor Lithospheric Deformation Modeling Research

Seafloor lithospheric deformation modeling research utilizes results from ocean lithospheric structure and long-term monitoring research in the analysis of crustal deformation accompanying stress accumulation and release processes in subduction zones, as well as in the study of the rupture processes of past great earthquakes. Also, basic numerical modeling studies are conducted into the role of heat in the seismogenic process. By "feeding back" information from the results of this research to the work in lithospheric structure and long-term monitoring, it is anticipated that an integrated understanding of the seismogenic mechanism will be attained that will facilitate the construction of a long-term earthquake forecasting model.

Utilizing existing data from seismic surveys and microseismicity studies, the shape of the Philippine Sea Plate subducting beneath southwestern Japan has been estimated. This has made possible the analysis of crustal deformation and earthquake rupture processes

using a more realistic representation of plate boundary shape particularly near the trough axis. This model has been used to estimate the crustal deformation that occurred at the time of the 1946 Nankai earthquake through analysis of tsunami waveform data. Combining this with the result of an analysis of seismic waves conducted at the same time results in an image of the rupture process that is closely correlated with features of the plate boundary shape, in particular a subducting seamount and a contortion in the plate (Fig.10).

Based on the discovery of at least two seamounts subducting offshore Shikoku, a numerical model of a subducting seamount was constructed (Fig.11) and the deformation, earthquake rupture, and stress field change near the plate boundary associated with its subduction were estimated. This established that the

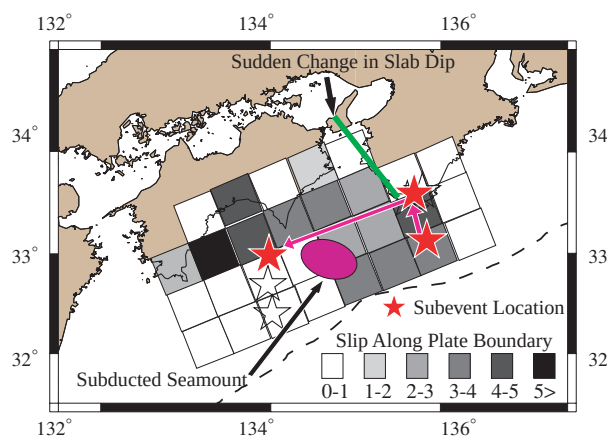


Fig.10 Source process of the 1946 Nankai earthquake estimated from seismic and tsunami wave.

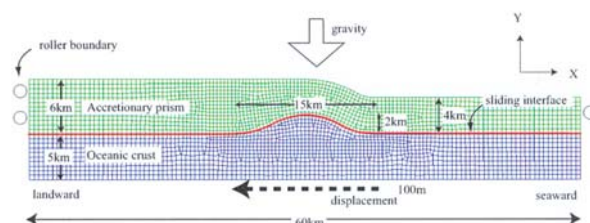


Fig.11 Two dimensional finite element model of a subducting seamount based on the results of seismic surveys along the Nankai trough.

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observed deformation and rupture characteristics of such seamounts can be explained by the deformation and stress change accompanying their subduction, and also that this process tends to promote rupture on splay faults within the upper plate.

Furthermore, in order to consider the role of heat in the seismogenic process, numerical modeling was performed to study the effects of a fault constitutive relation based on the interaction between heat and deformation. This showed that the dependence of slip stability could be expressed as a function of temperature and slip rate (Fig.12). Finally, in order to study the relation between subduction zone thermal structure and the depths of the upper and lower limits of the seismogenic zone, programs are being developed to simulate thermal structure on a large scale encompassing the entire subduction zone including the mantle wedge, as well as to compute thermal structure of the accretionary prism taking into account the effects of fluid flow.

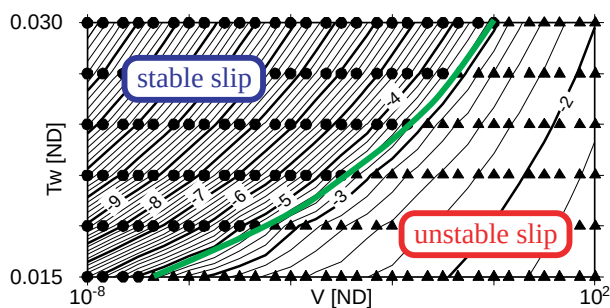


Fig.12 Domain diagram for the stability of steady-state slip for the various values of ambient temperature (T_w) and slip rate (V). Solid circles indicate that the steady state is stable, while solid triangles indicate that the steady state is unstable to an infinitesimal perturbation. The thin solid contours indicate the logarithm of the rate of frictional heating $\log_{10} \Phi = \log_{10}(\sigma_{ss} V)$. The thick green solid line indicates the approximate location at the boundary of the stable and unstable domains.

Future Research

In order to elucidate the relationship between plate geometry and the earthquake rupture process, further seismic survey and numerical modeling will be conducting which will lead to an understanding of how structure may control the seismogenic process. Also, results from deep sea drilling and rock deformation and fracture experiments, as well as material properties research will be incorporated in order to explain plate boundary fault dynamics in subduction zones. As for numerical modeling work, along with further research into elemental processes and consideration of other geographical regions, advancements in technology for large-scale numerical simulation realized in the Earth Simulator will be effectively utilized to conduct numerical simulations on the scale of the entire Japanese archipelago or the entire Philippine Sea Plate. Finally, the numerical modeling of the separate elemental process will be brought together in the realization of a model for plate dynamics model which integrates the various phenomena associated with the dynamics of the earth's surface.

This research program has now become a part of the Institute for Frontier Research on Earth Evolution, which was established in fiscal year 2001.

Frontier Research System for Global Change

Total Activity

The Ecosystem Change Research Program was established in October 1999. Then researchers were recruited, and all the programs for global change became ready for their research activities in fiscal 2000.

As global environmental problems become socially important issues, many countries have established their own research systems for global change, an area that requires cooperation of experts in various fields. Regarding this aspect Frontier Research System for Global Change (FRSGC) is unique in that the system uniformly covers all major areas of global change, and in that all researchers stay at one place and concentrate on one Joint Research Project. This has been made possible by focusing methods of study on one approach, or modeling. A possible drawback to this approach is that researchers in one particular field may not well coordinate or balance model studies with observations of real phenomena. This drawback can be overcome by various efforts, including cooperation with the Frontier Observation Research System for Global Change.

The Frontier Research System for Global Change was established in response to a report submitted by the Council for Aeronautics, Electronics, and Other Advanced Technologies, in 1996, and it has been expanding its fields of research to cover six objectives mentioned in the Council's report. The report, while focusing on global changes, recommended research on interactions between the environment of the earth's surface, including the atmosphere and oceans, and the state of the solid earth, and also modeling of the earth's interior, common to the surface and interior, as a sixth objective. In response to this recommendation, the Earth's Interior Research Program was established in FY 2000, following the Ecosystem Change Research Program established in the preceding fiscal year. Meanwhile the establishment of a new Frontier Research System covering the entire solid earth was planned in response to the construction of a deep sea scientific drilling vessel as a core of the Integrated Ocean Drilling Program (IODP) an international program in which JAMSTEC has been participating. It was then decided that the Earth's Interior Research Program should be integrated into the new Frontier Research System for the Solid Earth, to be established in FY 2001. Since establishment of the new frontier research system was confirmed by the end of FY 2000, the Earth's Interior Research Program was separated from the Frontier Research System for Global Change in April 2001.

The Frontier Research System for Global Change, which was established on October 1, 1997, will have completed its first five years at the end of September 2002, marking entry into the second five years. As prescribed by a rule set at the start of the system, an interim evaluation report, reviewing the performances of the first five years and re-examining the plan for the latter five years' plans, must be prepared before JAMSTEC can formulate the FY 2002 plan. Thus FRSGC prepared for evaluation by outside experts, to be executed in May 2001. Since October 2000, FRSGC has selected candidates to conduct the evaluation: five experts from abroad and four Japanese ones, and asked them to conduct the evaluation. All candidates except one from Japan accepted to work as members of the evaluation committee -- more than had been expected, much to the FRSGC's delight. The experts included such leading scientists in various areas covered by the Frontier Research System for Global Change as Dr. B. Moore III, Chairman of IGBP, and Dr. G. Brasseur, the successor to Dr. Moore. This may be taken to indicate that the Frontier Research System for Global Change is attracting much attention internationally. The preliminary meeting, on March 23, 2001, decided to hold the

Frontier Research System for Global Change

evaluation meetings from May 23 to May 25. The meetings finished, and the draft final report had already been prepared by the time this annual report was prepared. The oral presentation at the time of the evaluation meeting highly evaluated past activities of the Frontier Research System for Global Change, and recommended that its various programs covering different areas can be well coordinated to formulate a research strategy covering all areas, and can be promoted to develop an integrated model. As mentioned at first, an organization, with various programs to cover the entirety of global change, has just been formulated, so that we FRSGC scientists will promote research in a manner to make the best of our capacity.

Major Research Activities of the FRSGC's Programs

(1) Climate Variations Research Program

This program area consists of three groups: the Model Group, the Climate Diagnostics Group, and the Predictability Research Group. In actual research activities, the first two groups work cooperatively and complementarily, on the same phenomena of their research themes. Presently, the major research themes are variations of the coupled atmosphere-ocean system in the Indian Ocean, variations of the atmosphere and ocean in the high- and middle-latitude Pacific Ocean, and the ocean circulation in the sea areas near the Japanese Archipelago.

Regarding variations of the coupled atmosphere-ocean system in the Indian Ocean, these groups discovered a phenomenon now known as Indian Ocean dipole (IOD), in the equator sea area, similar to El Niño. Further, these groups discovered, last year in the subtropical sea area, a mode of annual movement in which sea surface temperature varies in the east and west in opposite directions. Their analysis indicates that, in the atmosphere side, this phenomenon is associated with the east-west movement of the subtropical high pressure system of the Southern Hemisphere Indian Ocean. In fiscal 2000, an experiment was con-

ducted by the coupled atmosphere-ocean model developed by the National Research Institute for Earth Sciences and Disaster Prevention (NIED), by combining a spectral AGCM developed at the Meteorological Research Institute and MOM. The experiment successfully reproduced variations corresponding to the subtropical dipole (Figure 1). The FrAM, developed through modification of the physical processes of the above-mentioned AGCM, has already been used to study SST's impacts on the atmosphere, and it is further being improved.

Research on the atmosphere-ocean variation in the high- and middle-latitude Regions, has indicated, since the year, a phenomenon in which strengths of the Aleutian low and the Icelandic low, which are predominantly influential on the climate of the Northern Hemisphere's winter, alternate in opposite way in their intensity. It has been discovered, from further study, that such variations are not frequently seen in the first half of the winter, from November to January, but they are more often seen in the latter half, from February to April. Recently, it has been suggested that the North Atlantic oscillation, a seesaw between the Icelandic low and the high pressure system south of it, should be regarded as a phenomenon of the oscillation covering the entire area of the Arctic Region (arctic oscillation). Thus this research theme, in this respect, is to study

Frontier Research System for Global Change

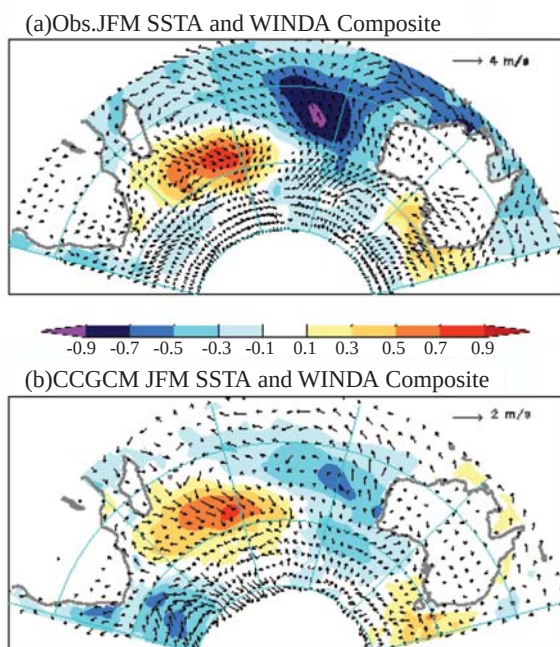


Fig. 1 Indian Ocean subtropical dipole pattern as observed (a) and simulated by a coupled model (b). Both show sea surface temperature anomaly and wind anomaly composites.

the seesaw between the Aleutian-Icelandic lows, and to study similarities and dissimilarities among these known oscillations (AO and NAO) and their interactions.

The Japan Coastal Ocean Predictability Experiment (J-COPE) Group developed an ultra-high-resolution model (mesh interval 1/18 degrees), and nested it in a model of medium resolution but covering the entire North Pacific Ocean. The group conducted a simulation study on currents driven by wind stress, using the nested model. It was found that the rise and fall of the sea level associated with variation of the Kuroshio and its extension, are reproduced in the simulation to about the same degrees observed by altimeters on board artificial satellites.

Apart from the above-mentioned, the Climatic Variations Research Program is developing a high-resolution (1/16 degree) ocean circulation model, with

cooperation by the National Aerospace Laboratory (Japan) (NAL), to realize a detailed simulation of the currents and their variations for the global ocean, caused by winds. The simulator will use NAL's super-computer called numerical wind tunnel (NWT). The Program intends to upgrade the resolution, and conduct various experimental work, after the Earth Simulator begins to work. In the Predictability Research Group, each researcher studies from the principles of physics, basic features of atmospheric and ocean circulations from various angles, and their constraints, and how the findings in these aspects can be applied to simulations and understanding of real circulations.

(2) Hydrological Cycle Research Program

This Program consists of the Wide Area Hydrological Cycle Process Group, the Hydrological Cycle Process on Land Group, and the Clouds and Precipitation Process Group. The Wide Area Hydrological Cycle Process Group studies water balances from the entire earth to regional scale, their variations, and phenomena and mechanisms governing these variations, by means of data analysis and models. One outstanding achievement of FY 2000 was the discovery of the precipitation memory effect by the combined effects of the permafrost and taigas of East Siberia. Figure 2 shows the interannual variation in amount of water evaporated from the basin of the Lena River (E), and precipitation (P). The precipitation is shown two years behind. The parallelism of these lines suggests that the amount of evaporation is determined by the amount of precipitation in the summer two years before. This result also supports the recent finding that trees of the taiga absorb water melted from the permafrost and evapotranspire to the atmosphere.

The Hydrological Cycle Process on Land Group has started development of a new regional climate model,

Frontier Research System for Global Change

to analyze mechanisms of hydrological cycles and energy circulation in a more detailed and correct manner, as one of its objectives. The group is developing a new and advanced convective cloud scheme, first, to modify the RAMS, a regional atmospheric model developed by Colorado State University, for making more suited to long-range integration. The group is doing so, second, by incorporating MATSIRO, a parameterization scheme of land hydrological processes developed by a Japanese research group into the model. Simultaneously, the group integrated MATSIRO into the CCSR/NIES climate model, and applied two different methods to estimate albedo of snow, to check the degree of the difference between the results of the two methods, and how the difference emerged. The group will use such results to study the effects of albedo of snow on the climate. The group also developed a parameterization scheme for exchange of water and energy between ground surface covered with vegetation and the atmosphere. The group then proceeded to simulation tests on exchange of CO_2 , sensible heat, and latent heat of evergreen broad-leaved forests, using a vegetation model based on physiological phe-

nomena of each leaf. Through such processes, the group demonstrated that seasonal physiological fluctuations of leaves will affect amounts of exchange of such substance and energy between the ground and the atmosphere on a plant community level.

The Clouds and Precipitation Process Research Group continues work to clarify the role of the meso-precipitation system in the hydrological cycle of East Asia, using GAME/HUBEX data obtained in 1998, and development of a cloud resolving model. The Cloud Microphysical Process Research Group has been studying the size distribution of cloud droplets, and how solar light is reflected and penetrates through them for a given set of size distributions of aerosols, and upward velocity, aerosols being the nuclei of cloud droplets. This study is very important in clarifying the basics of one of the most important problems in the global warming prediction: the feedback of clouds. It has become clear, from research done in FY 2000, that the number (or concentration) of cloud droplets varies with the upward velocity of the air containing aerosols that form cloud condensation nuclei, when a sufficiently large amount of aerosols exist, as shown in Figure 3. (The faster the upward flow is, the smaller and the more the cloud droplets are.) However, the hygroscopic property of aerosol materials virtually does not affect the formation of cloud droplets. This is an important finding casting doubt on the classical study of Twomey (1959).

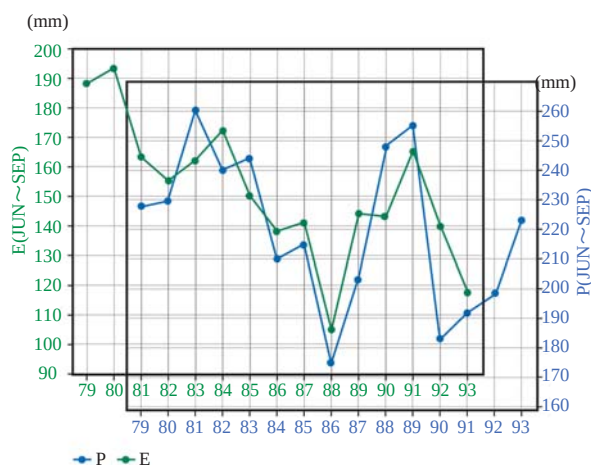


Fig. 2 Interannual variations of evaporation (E) and precipitation amounts for June-September in the Lena river basin in the period 1979-1993. The curve for P is plotted with a lag of 2 years relative to the one for E.

(3) Global Warming Research Program

This program consists of three research groups: the Global Warming Experiment Group, the Ocean Carbon Cycle Research Group, and the Paleoenvironment Research Group.

The Global Warming Experiment Group is conducting a detailed experiment on changes of atmospheric phenomena under conditions of global warming. Specifically, the group uses the sea surface tempera-

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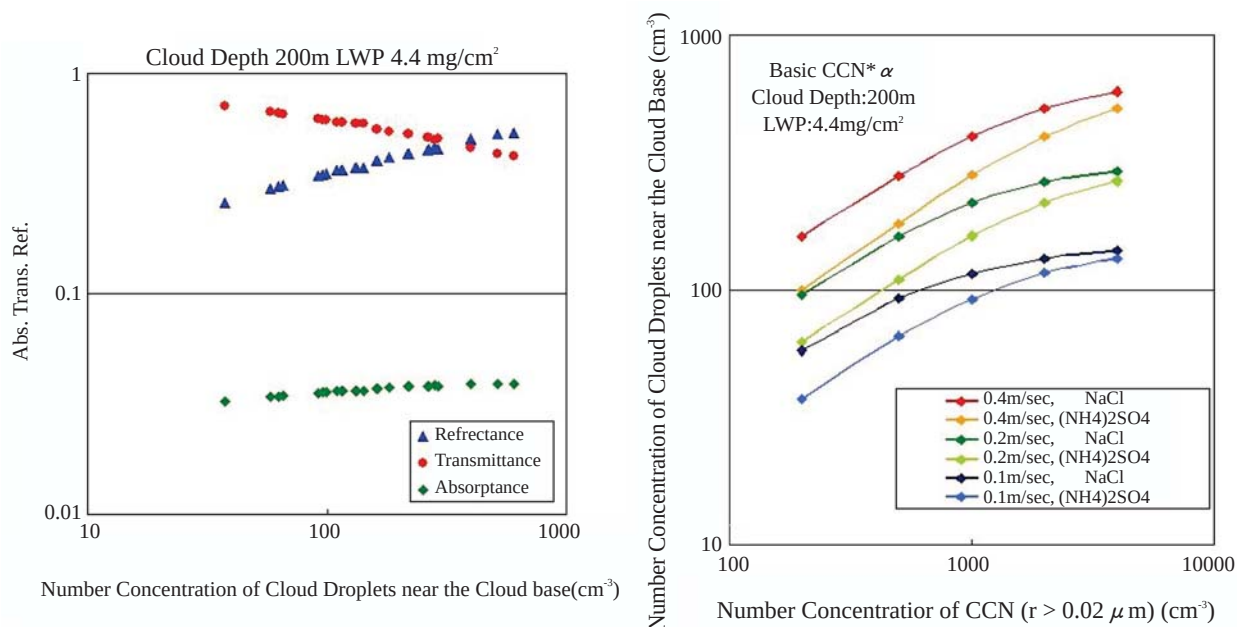


Fig. 3 Results of numerical simulation of cloud formation and cloud's optical properties. The right panel shows number concentrations of cloud droplets (ordinate) as functions of the number concentration of cloud condensation nuclei (CCN). Different curves represent different conditions in upward velocity and chemical composition of CCN. The left panel shows reflectance, transmittance and absorptance of cloud layer of 200m thickness corresponding to different number concentrations of cloud droplets.

ture when the CO_2 concentration is twice the present value, previously obtained by the low-resolution model of the Meteorological Research Institute. The group gives this sea surface temperature to a high-resolution (T106) MRI atmospheric model, as the lower boundary conditions, and studies, in detail, changes in atmospheric phenomena under conditions of global warming. The group has so far concentrated on an experiment on typhoons (tropical low pressure system), and found that the number of typhoons will be reduced by 20 percent under global warming conditions. The group conducted a series of experiments on the following cases, to deepen understanding of this result: variation of sea surface temperature uniformly to plus and minus 2°C with no change in the CO_2 concentration; and, variation of sea surface temperature to plus 2°C with the CO_2 concentration increased 2 times, and 4 times, respectively. The results of these

experiment indicate that the number of tropical low pressure systems is affected more by CO_2 concentration than by sea surface temperature. It is no less important to know the number, intensity, and variation of locations of temperate zone low pressure systems than those of the tropical low pressure systems, from the standpoint of the effects of climate and weather changes on human living and industry. Accordingly, this fiscal year, the group will study the change of extratropical low pressure systems using the T106 atmospheric model, applying the same method used for the tropical low pressure systems. The experimental results, with CO_2 concentration doubled, are now being analyzed, and the preliminary results indicate that low pressure systems tend to occur less frequently for both Northern and Southern Hemispheres, but intense low pressure systems will occur more frequently near Antarctica. Dr. Manabe, Director of the

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Program, used to work for the Geophysical Fluid Dynamics Laboratory of the National Oceanic and Atmospheric Administration (GFDL/NOAA) of the United States, and he continues a Joint Research on experiments on global warming. The most serious of all global warming effects on human society is said to be the change of water resources. Dr. Manabe announced a shocking forecast, about 20 years ago, when he was at GFDL, to the effect that the North American Continent would become drier in the summer as a result of global warming. The model used for this study did not have enough horizontal resolution. Other researchers came up with opposite conclusions. Discussions on this issue are still active. Figure 4 shows results of an experiment conducted by the latest coupled atmosphere ocean model of GFDL. The difference in soil moisture content relative to the natural condition (the condition before the Industrial Revolution), in percentage terms, is shown for the four seasons. It may be noted that, during the summertime, most of the land area will become drier (though some presently dry areas will become wetter, in relative terms, because of a small increase in precipitation).

The Paleoenvironment Research Group is conducting a simulation of the climatic conditions of the Last Glacial Maximum, using the high-resolution (T106) CCSR/NIES atmospheric model. The study indicates the possibility of the ice sheet being stably maintained, from the distribution of precipitation and evaporation. The group promotes this study also to find the equilibrium state of the ice sheet, by giving the results of the climate model to an ice-sheet model that incorporates water balance and ice flow. When the ice-sheet model becomes established, it will be possible to forecast changes of the ice sheet associated with global warming.

The Ocean Carbon Cycle Research Group intends to develop an ultra-high-resolution (1/4 degree) ocean circulation model, for use in simulating the transport of CFCs and other tracers, including transport by eddies.

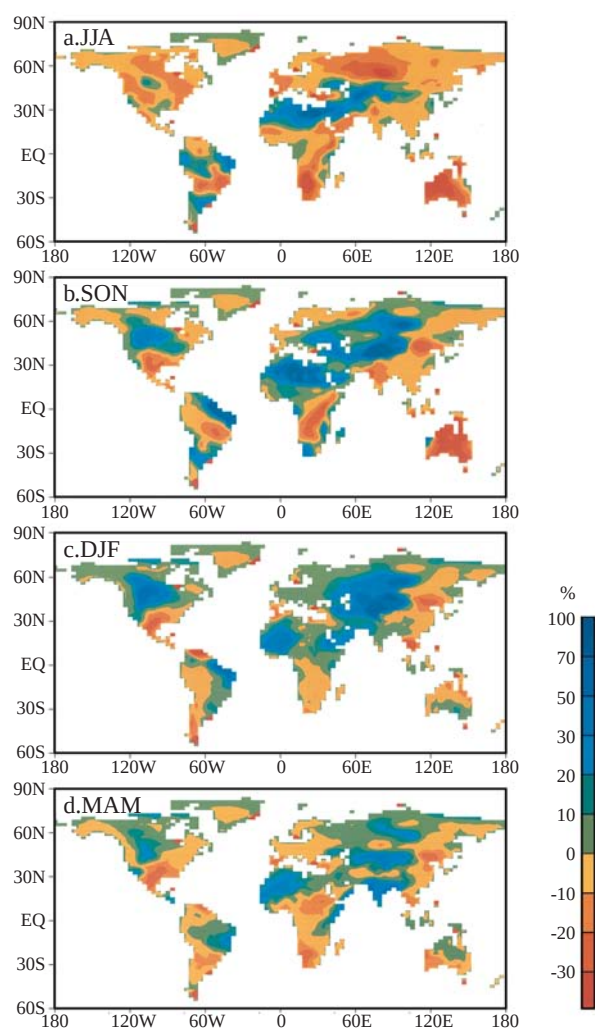


Fig. 4 Results of global warming experiments conducted by Dr. Manabe and GFDL/NOAA. Figures show percentage changes of soil wetness in the middle of the 21st century under the present increase rate of CO₂. a, b, c and d show changes in four seasons.

(4) Atmospheric Composition Research Program

This fiscal year is the second year of practical operation of this program. The three groups of the program: the Global Chemical-Transport Modeling Group, the Regional-Scale Chemical-Transport Modeling Group, and the Greenhouse Gases Modeling Group, are in full swing and have produced some achievements. The “chemical weather map”, a major objective of this program from the outset, has been

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developed sooner than was anticipated, through cooperative work by two groups. Now it is possible to draw, in real time, the chemical weather map not only by a regional scale model but also by a global model.

The chemical weather map, as a research objective of this program, is a chart that displays, in real time, the temporal and spatial distribution of concentrations of trace components in the atmosphere, like an ordinary weather chart. Such a model has been in use for relatively small areas for forecasting photochemical smog, for forecasting the route of a radioactive air mass, in a case of radioactive leakage, and recently for forecasting the route of volcanic gas associated with the eruption of Miyakejima Island. The program expanded such a chemical weather map to the regional scale, and further to global-scale dimensions, and to incorporate NO_x , SO_2 , VOCs, and other substances emitted from the ground surface, and a large number of such trace substances as ozone, and aerosols produced as a result of atmospheric photochemical reactions of these substances. Figure 5 shows the distribution of the monthly average concentration distribution of ozone in the East Asian Area. The chemical weather map developed by this program is effectively utilized in the International Global Atmospheric Chemistry Programme, IGAC/ACE-ASIA on outflows from the Asian Continent to East Asia from March to April 2001, and NASA/TRACE-P Campaign. In the future, this technology will be used to forecast trans-boundary air pollution.

In addition to long-lived greenhouse gases as CO_2 and CH_4 , NO_x and CO contribute indirectly to global warming. Although NO_x and CO do not have a greenhouse effect, they produce ozone, a greenhouse gas, and extend the life time of the atmospheric CH_4 by changing the concentration of OH radical. Like these NO_x and CO, there are reactive substances that indirectly change life time and hence the concentration of greenhouse gases, thereby affecting radiative forcing.

Monthly averaged Ozone concentration(surface)1997 Jan.

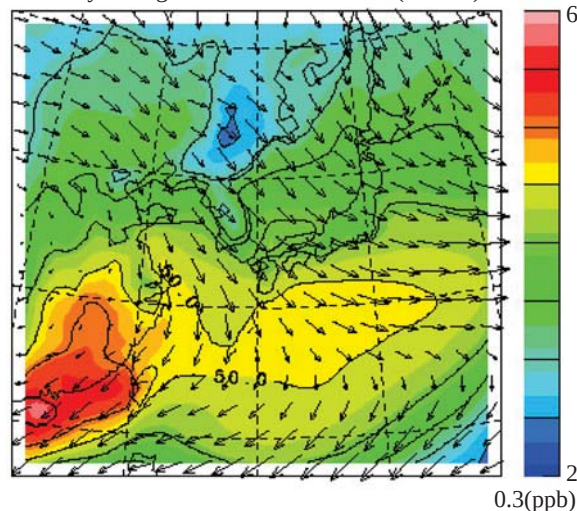


Fig. 5 Result of chemical-transport model calculation of the monthly mean surface ozone concentration in East Asia under the conditions of January 1997.

However, it is difficult to quantitatively evaluate radiative forcing of these reactive substances; therefore, IPCC has scarcely discussed this issue. Regarding this theme, the Global Chemical-Transport Modeling Group used the GISS • GCM to analyze natural mode of the atmospheric chemical reaction system. Through such efforts, the group divided the effect of NO_x and CO into (1) a short-life mode, regarding regional tropospheric ozone generation, and (2) a long-life mode, coupled with global perturbation of CH_4 -CO- O_3 , and successfully proposed a method to quantitatively evaluate indirect greenhouse effects of these reactive gases, for the first time. As a typical example of such evaluation, an increase of 0.5g TgN of global emission of NO associated with combustion of fossil fuels will result in a short-time increase of tropospheric ozone, and hence will give a positive effect on radiative forcing. But in the long run, the radiative forcing of NO will become negative through reduction of the CH_4 concentration by an increase in OH concentration (See Figure 6).

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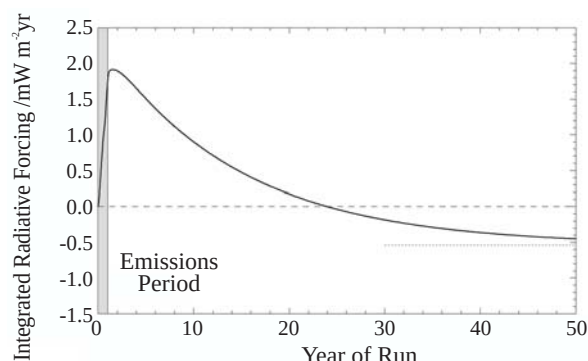


Fig. 6 Integrated radiative forcing as a function of the lapse of time after the release of 0.5TG NO_x at the initial time. At first positive radiative forcing appears due to the formation of O_3 but with the lapse of time depletion of CH_4 due to an increase of OH results in negative cumulative values of the radiative forcing.

The Greenhouse Gases Modeling Group is conducting research on inverse modeling, which estimates emission and absorption of CO_2 on the earth's surface from known three-dimensional distributions of atmospheric CO_2 concentration and wind velocity. The group also calculated seasonal and annual changes of CO_2 concentrations, through combining the existing three global terrestrial ecosystem models and a three-dimensional atmospheric transport model, and compared the calculated results with observed CO_2 concentrations, for estimating the effect of the terrestrial ecosystem on the carbon cycle. Any of the models used gave good approximations of the global average of seasonal variations, but there are some differences in output among different models, and there is disagreement between the calculated and observed results in the central region of continents. The calculated interannual variations agreed rather well with the observed data, although only the ecosystem was taken into account. This result suggests that the exchange between the ecosystem and the atmosphere is more pronounced than in the case of oceans, in interannual fluctuation. Further, the most important factor affecting the exchange with the ecosystem was found to be

temperature change. The group has started preparing emission inventories of such gases as NO_x , SO_2 , CO , CH_4 , and VOCs, as common data base for all groups, by cooperation with organizations in the world.

(5) Ecosystem Change Research Program

The Ecosystem Change Research Program was inaugurated in October 1999, with the following ultimate objectives.

- To study the effects of the functions of the ecosystem on global environmental and climate changes such as global warming, and
- To clarify the effects of such global environmental and climate changes on the ecosystem, and clarify the mechanisms of these effects, and to develop a model simulating such mechanisms

However, the ecosystem, the terrestrial ecosystem in particular, is not uniform regionally or locally, with different vegetation, soils, water, or elements constituting the ecosystem. Moreover, these elements interact with each other, making the structure of the ecosystem difficult to understand, and to simulate. For this reason, observation and simulation by modeling the terrestrial environment is still premature compared with the atmospheric or oceanographic environments.

This program set the following four themes as its research objectives.

- a. Research on ecosystem-atmosphere interaction
- b. Research on ecosystem architecture
- c. Research on ecosystem geographical distribution
- d. Research on marine biological processes

In the following, pages explain the group's achievement in FY 2000 will be explained.

(a) Ecosystem-Atmosphere Interaction Model Group

This group's research objective is to build a model terrestrial ecosystem, and to develop high-resolution

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mapping for the exchange of CO_2 between the global atmosphere and the total ecosystem, and to predict the response of the ecosystem to global environmental changes. In FY 2000, the group made global simulation of the CO_2 exchange between the atmosphere and the terrestrial ecosystem by using an existing carbon cycle model (Sim-CYCLE) incorporating vegetation distribution, and classification between C_3 plants and C_4 plants, with different photosynthesis abilities and carbon isotope discrimination values ($\delta^{13}\text{C}$), into Sim-CYCLE. The annual photosynthesis production by the terrestrial ecosystem is estimated to be 124 PgC, of which contribution by the C_4 plants is about 18 percent. The net primary production of the ecosystem, or the total photosynthetic production minus respiration, was estimated at 60.5 PgC per year. The C_3 plants and C_4 plants differ in carbon isotope discrimination value associated with photosynthesis (at 20.2 and 2.5 percent, respectively), and the C_4 plants grow mainly in tropical grasslands. Accordingly, there was a clear regional difference in $\delta^{13}\text{C}$ distribution. The accuracy of estimation would be validated by a comparison with observed results.

Regarding the interannual fluctuation in carbon balance of the terrestrial ecosystem, it has been made possible to input observed climatic data to the Sim-CYCLE model, for analysis. It has been pointed out that input data affect the result. Therefore, it became necessary to examine the degree of dependency of the model analysis on data. The group computed interannual fluctuations of the terrestrial carbon balance for the period from 1979 to 1993, on three different re-analyses climatic data, and compared the results (Figure 7). The overall features of the annual climatic fluctuation are similar for different reanalysis data. The estimated carbon balances of the terrestrial system show some qualitative similarity among different input reanalysis data, but quantitatively the estimated values differ significantly.

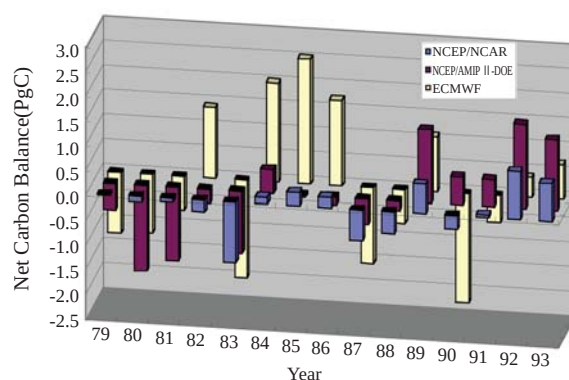


Fig. 7 Interannual variations of net carbon balance of the terrestrial ecosystem, calculated by the same model but with different meteorological data sets.

(b) Ecosystem Architecture Model Group

This research group aims to build a group of process models capable of long-range prediction, on the order of 100 years, of changes of the terrestrial ecosystem in response to changes of climate and the environment. The group is developing models based on observation of forests, the greatest -- to the extent of 90 percent -- organic carbon stock of the terrestrial ecosystem.

To describe the response of organic production by the ecosystem to environmental changes, a model that relates plant physiological processes of the shoot, or a branch with leaves, a unit constituting an architecture of a leaf group, with branching behaviors. This group has developed such a model, named PipeTree (Figure 8). The model is being modified to reproduce a tree group's various responsive behaviors.

(c) Ecosystem Geographical Distribution Model Group

This research group is conducting a study that measures, in particular, the spatial distribution of ecological parameters, and converts their variation into a geographical distribution model. The group places particular emphasis on studies using remote sensing from artificial satellites.

To clarify the effect of land cover changes on the

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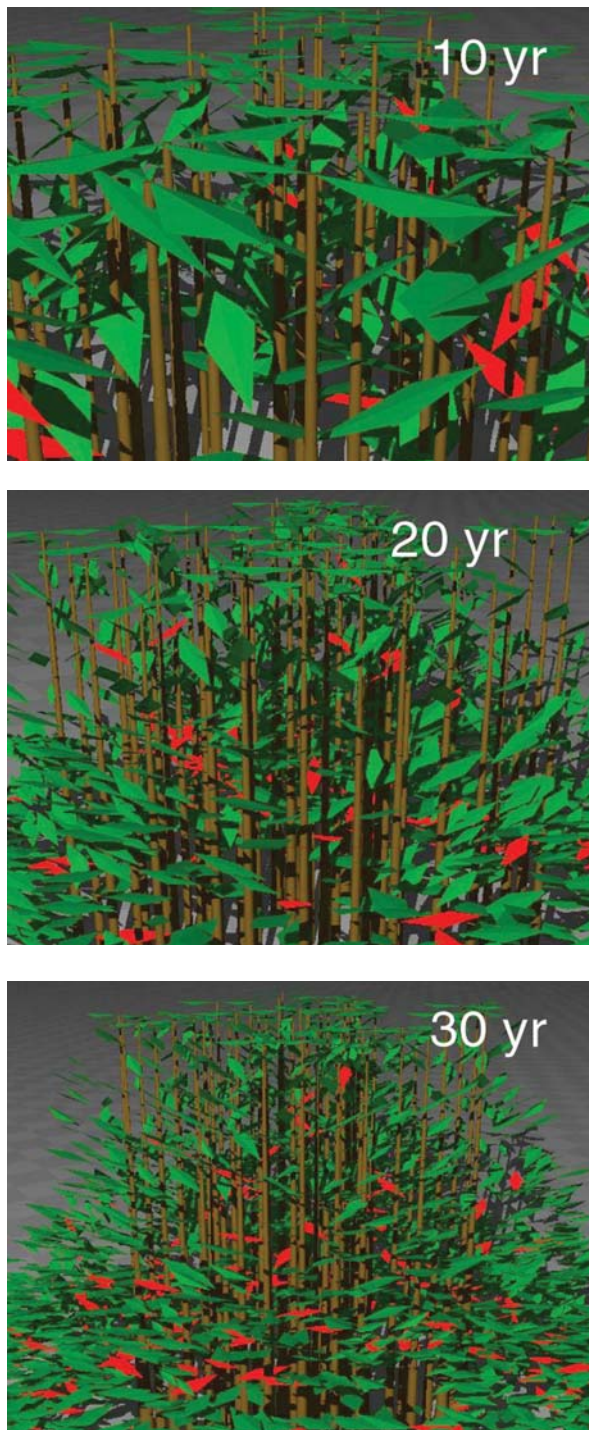


Fig. 8 Evolution of a model forest at 10, 20, 30 years as simulated by the Pipe Tree model.

carbon cycle of the terrestrial ecosystem, the group studied the impacts of changes in land utilization on the net primary production, NPP, and ecological carbon stock of the ecosystem in the Zhi Jian delta area of China, from 1988 to 1996. The changes in land utilization over a period of nine years reduced annual carbon fixation by vegetation by 1.6Mt C, or minus 7.5 percent. This reduction was brought about by a change in land utilization, in which an area of high biological production was converted into an urban area. The magnitude of the carbon pool in the terrestrial system was reduced by 12 Mt C, or minus 6.1 percent. A reduction of this magnitude corresponds to the estimated reduction resulting from destruction of a boreal forest of an equal area. The group also studied the secular change in distribution of the no-snow-cover period in the Northern Hemisphere. This study was done because the snow cover greatly affects the terrestrial ecosystem through temperature of soil and atmosphere, water supply to soil, and suppression of photosynthetically active radiation (PAR) to the surface layer vegetation. This analysis used time-series data on the areas of snow cover obtained by satellite observations. The no-snow-cover period in the high-latitude areas of the Northern Hemisphere increased from the first half of the 1970s to the latter half of the 1990s. Disappearing (melting) of snow in the spring became earlier, at a rate of 5 days per 10 years; the snow-cover period in autumn was starting later, at a rate of 4 days per 10 years. The annual no-snow-cover period increased, at a rate of 9 days per 10 years. The above observed trends agree with earlier intake of atmospheric carbon dioxide by the northern hemisphere ecosystem, and earlier greening of vegetation observed by artificial satellites.

(d) Marine Biological Process Model Group

It is becoming increasingly clear that the marine environment and biological production affect the long-term climatic change. However, in the sea areas close

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to the Japanese Archipelago, signs indicating such effects have been scarcely seen. This group studied secular variations of phytoplankton population in the Sea of Japan and in the Oyashio Current versus the marine environment indicated by the existing data. The data used are mainly obtained from time series analyses of such data as from the PM line (central part of the Sea of Japan) and the PH line (Oyashio region), both being areas for fixed line observation by the Japan Meteorological Agency. The Chl-a concentration, in the spring, has declined since the later half of the 1970s, both in the Sea of Japan and the Oyashio region. The seawater temperature of the intermediate depth layer of the Sea of Japan has declined since the later half of the 1970s. The surface seawater temperature remained almost unchanged during this period; therefore, stratification conceivably became more pronounced. A decline of nutrient was noticed; therefore, it is conceivable that the supply of nutrient to the deeper layer declined, which resulted in the decline of the Chl-a content.

In contrast, the surface temperature of the Oyashio region has declined since the later half of the 1970s, and therefore stratification has become less pronounced. In the Oyashio region, a seasonal thermocline in the spring promotes proliferation of phytoplankton. This seems to be why a decline of stratification leads to a reduction of Chl-a content. Since the later half of the 1970s, the Aleutian low has become stronger, which intensified the subarctic circulation, which in turn increased the supply of cold water from the north to the Oyashio Current, flowing in the west side of the Pacific Ocean, and lowered its temperature. The concentration of nutrient in the mixed layer of the Oyashio region in winter and summer, has been linearly declining since the later half of the 1960s. It may be possible, therefore, that the amount of nutrient had already declined before the bloom started.

(6) Integrated Modeling Research Program

(a) Mission of the Program

The mission of the program include, first, development of next-generation models, to be run on the Earth Simulator, scheduled to be completed March 2002, one year from now, with a theoretical maximum vector performance of 40 TFLOPS, or 300 times faster than the presently used NEC SX-5. The mission of the Program also include development of an integrated global environment model, by combining achievements by all programs of the Frontier Research System for Global Change, as the name of the program implies. In addition to developing these models, the program will develop a data assimilation system, a method to use a model to obtain more reasonable and detailed information on the atmosphere and oceans, from incomplete observation data.

(b) Targets of Model Development

The program has identified the following targets for model development, in view of the present status of climate research, social needs, and feasibility of computational method.

- (i) Development of a spectral atmosphere model with a horizontal resolution of T213 (about 60km), and an ocean model with a horizontal resolution of about 0.1° (10km), and a coupled model of the two

The atmosphere model will have a resolution about one-step finer than the typical resolutions of the present representative atmosphere models 100km to 250km, and therefore it will be able to simulate relatively small phenomena, like typhoons or the Baiu front, which are important in predicting global warming. The ocean model, with its horizontal resolution of 0.1° , will be able to simulate meso-scale ocean eddies of several tens of km, which will enable the model to represent the transport effect of heat and salt in global-scale circulation (parameterization by Gent-

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Mc Williams). The ocean model will also be able to express currents under the influence of delicate topography, and this will improve the reliability of global warming prediction.

- (ii) Research and development aiming at an atmosphere model able to directly handle meso-scale convective phenomena, with a horizontal resolution of 5km or smaller, covering the entire earth

Presently, with the mesh size of 60km or larger of the present models, medium-scale (mesoscale) convective effects can only be incorporated in the models after being parameterized according to empirical rules. Direct expression of a convective system by mesh is desired. At the Integrated Modeling Research Program we have decided to pursue this entirely new direction, in view of the ability of the Earth Simulator by which we can simulate a large area comparable to the entire earth with a horizontal resolution of 5km or finer. Treating the meso-scale convection processes of typhoon generation or convective heavy rains in the Baiu season or summer will be simulated in a better manner. This “closer to the first principle” approach is considered to be scientifically sound and in its application it will contribute to improving the reliability of forecast of disasters and changes in water resources.

- (iii) Research and development of integrated models which enable us to handle such global environmental changes as changes of atmospheric composition and ecosystem, in addition to physical climate change

The Integrated Modeling Research Program will develop an integrated model that can predict total global environmental changes, associated with global warming, for example, on the basis of the achievements of the Atmospheric Composition Research Program and the Ecosystem Change Research Program. The Frontier Research System for Global Change is the best place for this kind of research for it has a number of researchers of different disciplines.

Implementation of the research is scheduled for the later five years of the entire schedule.

(c) Present Status of Model Development

(i) Coupled model

The CCSR/NIES model, a medium-resolution spectral atmosphere model, with the horizontal resolution of T42, or equivalent to about 280km and with 20-vertical layers, developed at the Center for Climate System Research of Tokyo University and the National Institute for Environmental Studies, was transplanted. The Research Program is improving this model into one with T213 (about 60km) and 50 vertical layers, in cooperation with the above two research groups and the Global Warming Research Program. As the ocean model we adopted MOM3, developed and disclosed to the public by the Geophysical Fluid Dynamics Laboratory of the National Oceanic and Atmospheric Administration (GFDL/NOAA) of the United States. The necessary preparatory research work is being done. As the resolution becomes finer, the longitudinal grid interval becomes extremely short near the North Pole. This is avoided by turning the polar axis of the spherical coordinates so that both poles may fall on land. It was confirmed that computation can be done correctly despite this axis turning, and that no problem arose for integration over 1,000 years with a horizontal resolution of $2.8^\circ \times 2.8^\circ$. Further, the Integrated Modeling Research Program is examining resolution of $1/6^\circ \times 1/6^\circ$, with the polar axis turned. The program is conducting a numerical experiment to see if Gent-Mc Williams' effect for “equalization of thickness of isopycnal layers” is really right, as a nonlinear effect of meso-scale eddies.

In addition to the above, in order to realize higher resolutions of coupled atmosphere and ocean models, we are gradually increasing the resolution of low-resolution coupled atmosphere-ocean models (Figure 9), in cooperation with the Center for Climate System

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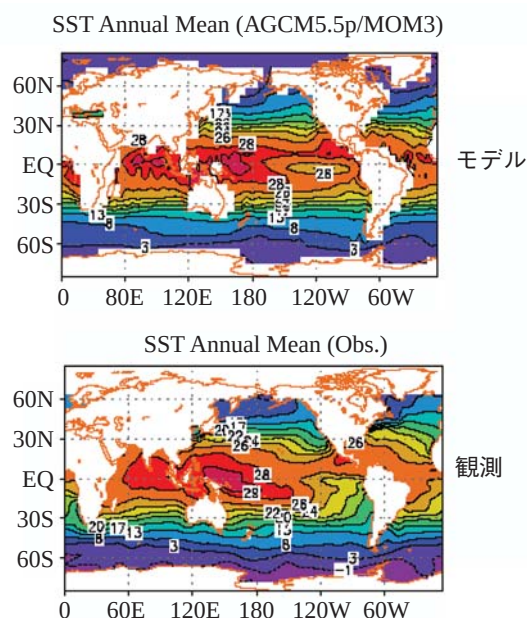


Fig. 9 Annual mean sea surface temperature calculated by the low-resolution coupled atmosphere-ocean model (top panel) and the observational counterpart (bottom panel).

Research of Tokyo University. The Program is also making necessary improvements of physical processes. At the Program a coupled model is now being developed, by combining the T42 atmosphere model and an ocean model with a resolution of a $2.8^\circ \times 2.8^\circ$. It is intended that a coupled model of the T42 atmosphere model and an ocean model of $1.4^\circ \times 1.4^\circ$ resolution will be completed by the end of FY 2001. Models of higher resolutions will be developed using the Earth Simulator.

(ii) Development of next-generation atmosphere model

The spectral method becomes inefficient in terms of computation amount as horizontal resolution is increased. In the mesh method, if we adopt the latitude-longitude coordinate system longitudinal lines become too close near the poles so that it is practically impossible to use it. At the program, therefore, we are studying different grid systems which cover a sphere

nearly uniformly. One is a regular icosahedron, with each face being a regular triangle, with each side divided into 1/2, 1/4 segments, and even finer segments, to be projected on the surface of a sphere placed in the center of the icosahedron. The other is a regular hexahedron (cube) treated similar to the regular icosahedron, but it could have other features. Research and development on methods of numerical solution of hydrodynamic equations (dynamic core) using such meshes are being conducted. This Program has succeeded in developing superior methods through improvement of mesh generation methods and finite difference schemes. Figure 10 shows the results of tests of the new methods applied to shallow water equation.

(d) Development of an Assimilation System for Oceanographic Data

Large-area oceanographic observation, hitherto impossible, is now becoming possible, as in the case of atmospheric observation with new technologies. The new technologies to be employed are observation by artificial satellites, a stationary buoy observation network (TRITON BUOY), and the ARGO international cooperative project, led by the United States and Japan, which deploys 3,000 intermediate depth layer buoys throughout the world's oceans, beginning in 2001. An analysis method using a model, known as four-dimensional data assimilation, is best suited to grasp the oceanographic conditions (currents, seawater temperature, salinity) using the data obtained by such means of observation, to the extent possible in time and space. Throughout the world, research is under way on the method of data assimilation. The Frontier Research System for Global Change is no exception, and it is keen on research and development of data assimilation. The Frontier Research System has developed an adjoint model which is able to treat past data for computation by integrating backward in time, and feeding observa-

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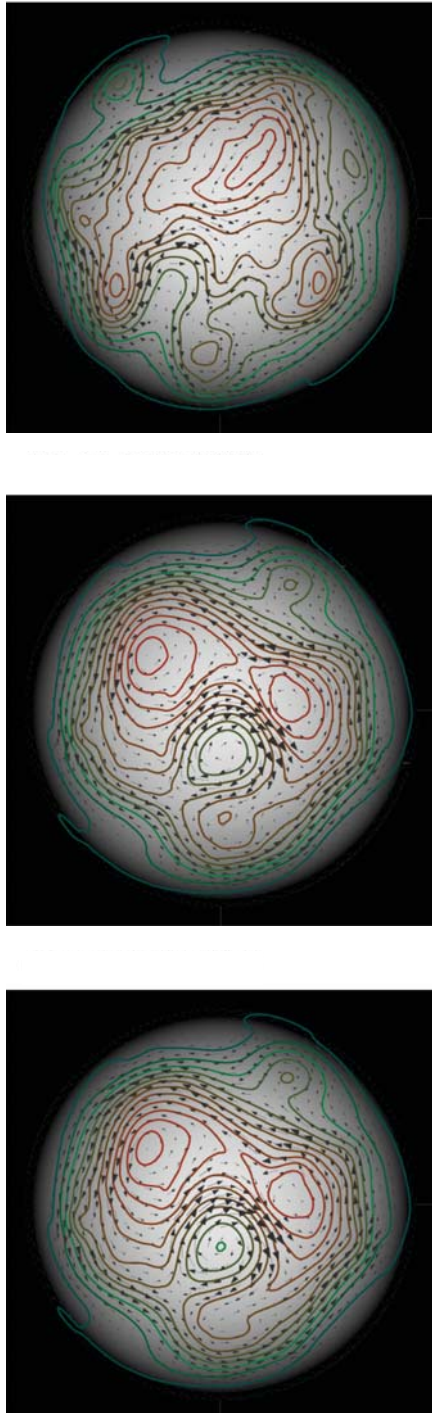


Fig.10 Results of numerical integrations of the shallow water equation obtained by using T213 spectral method (middle) and icosahedral grid with a comparable resolution (bottom). The top panel shows the initial pattern.

tion data at different times without contradiction with the dynamics equations. This model produced a three-dimensional distribution of currents, water temperatures, and salinity, consistent with respect to their seasonal cycle (time-wise changes), with a resolution of $3^\circ \times 3^\circ$ for latitude and longitude, by means of dynamic equations using Levitus' data on temperature and salinity. Simultaneously, the most probable distributions of heat and freshwater flux on the sea surface were obtained, as unknown variables.

(7) Research by the International Pacific Research Center, IPRC

(a) Outline

The International Pacific Research Center, IPRC, was established in 1997, within the framework of the U.S.-Japan Common Agenda. No issue of global climate change is ever limited to one country, and international cooperation is needed to resolve such issues. The researchers of IPRC are from a number of countries: the U.S., Japan, China, ROK, Russia, Germany, India, Denmark, Australia, etc. Now, 28 researchers are affiliated with IPRC and promote research in the following four fields.

- Ocean climate of the Indian-Pacific Ocean Area
- Effects of the monsoon sea area
- Asia-Australia monsoon
- Effects of global warming

Research on the first three themes is already under way, promoting the researches as explained below. Regarding global warming, the research staff in charge has just joined IPRC in 2000.

(b) Ocean Climate of the Indian-Pacific Ocean Area

The ocean is considered to have a decisive effect on long-range climatic phenomena lasting for several to several tens of years. Therefore, the research subjects are such variation phenomena as El Niño Southern Oscillation (ENSO), and North Pacific Decadal

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Variation both in atmosphere and ocean, and bases for their modeling, namely, parameterization of the ocean mixed layers and processes for atmosphere-ocean interactions.

One achievement deserving particular notice is the great advance in research on the shallow meridional circulation, or Subtropical Cell (STC), occurring between the tropical and subtropical regions of the Pacific Ocean and Indian Ocean. By conducting an experiment by use of an ocean general circulation model, to separate the effects of tropical circulation and those of STC, it was found that fluctuations of STC are more than 50 percent responsible for decade variation of seawater temperature in the equatorial region. As a result of these studies, it was also found that the STC in the Indian Ocean is in the opposite direction in the summer and in the winter, because of the effect of monsoon variations, and that transport in the north-south direction by the Ekman layer is great even in the equatorial areas. These are unique characteristics of the Indian Ocean not seen in the Pacific Ocean.

It was also learned, from analysis of high-resolution distributions of sea surface temperature and wind velocity in the tropical region of the Eastern and Central Pacific Ocean, obtained by artificial satellites, that such small phenomena as the tropical unstable waves show strong coupling with the atmosphere (Figure 11).

(c) Effects of the Monsoon Sea Area

In the Asia-Australia monsoon area, the western coastal area of the Pacific Ocean is important in the transport of heat, salt, and other substances, because of its topography being very complicated and the presence of the Kuroshio, a narrow and strong western boundary current. There is a social need to study the possibility of predicting strong and complicated currents. From such standpoints, IPRC promotes research on a high-resolution ocean general circulation

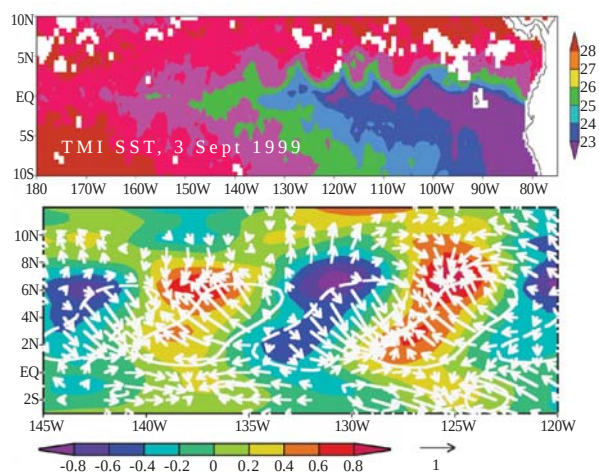


Fig.11 Unstable ocean waves generated in the equatorial Eastern Pacific Ocean as observed by SST distribution (top panel). This SST field affects the atmosphere to cause sea surface winds and humidity as shown in the bottom panel. The wind and humidity were obtained by the satellite observation.

model, and on data assimilation technology.

IPRC has studied the Kuroshio meander, to make a breakthrough in the predictability of boundary currents. An anticyclonic eddy appearing in the south of the Kuroshio extension, moves westward, as far as off Shikoku Island, and it interacts with the Kuroshio to cause the Kuroshio meander. The above process was also seen from altimeter data from artificial satellites. A model simulating the above mechanism, was developed and succeeded in reproducing the meander by the model. It has been shown that such variations are predictable for a period of several months ahead.

(d) Asia-Australia Monsoon

At the IPRC studies on monsoons are conducted from various angles. Specifically, IPRC research themes include long-term variation of intraseasonal fluctuations, the relationship between the radiation-cloud SST feedback and ENSO, teleconnection between monsoons and the North American climate, the relationship between SST regulation in the warm

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water pools and the tropospheric two-year oscillation, thermal energy balance of the Indian Ocean, and modeling of intra-seasonal oscillations.

(e) Data Research Center

One function of IPRC is to establish a data center for climate studies of the Asia Monsoon Region, with cooperation by the National Ocean and Atmosphere Administration (NOAA) of the United States. IPRC has been doing the preparatory work for it. IPRC intends to establish a data center easy to access through the Internet, by using recent network technologies. It must be connected with research activities, and also useful for reanalysis and storage of valuable data. This fiscal year, IPRC developed and tuned the data server for the Internet, and conducted communication tests with research institutes, in cooperation with Pacific Marine Environmental Laboratory, PMEL, of the United States, and the Frontier Research System for Global Change.

(8) Research at the International Arctic Research Center, IARC

The IARC's research objective is to clarify the contributions of the Arctic region to the global environmental change, and conversely to clarify effects of the climatic and environmental change on the Arctic region, and to make possible predictions of these effects.

The IARC was established in October 1997. Initially, projects were almost all proposed by the Japanese side, with very few by the American side. In August 2000, Dr. Akasoku, who had served in the tentative post of the founding director of IARC, was officially appointed to the Director. At the same time, funding by the National Science Foundation (NSF) of the United States, was granted to the IARC. Using the fund from NSF, the IARC planned to initi-

ate two projects: development of a community model targeted for the Arctic region (CAMP), an observation program to investigate the structure of water mass in the Arctic Ocean (NABOS). With this arrangement, U.S.-side projects are expected to be promoted, together with the Arctic Climate Impact Assessment (ACIA) now under way jointly with NOAA. Now it is very important to make the IARC really powerful by making the frontier research funded by Japan, and new research, mutually supplementary, cooperative, and sharable.

The research by the Frontier Research System at the IARC may be broadly broken down into two themes: (1) clarification of the coupled system of the oceans, sea ice, and atmosphere, and (2) multi-disciplinary research. Below are, briefly, present research activities and recent achievements on both themes. The IARC promotes research on the Arctic region through both observation and model studies; therefore, the Frontier Research System conducts observation in the multi-disciplinary part of the IARC program.

(a) Coupled System of the Ocean, Sea Ice, and Atmosphere

It was a common view, from the studies of global warming in the past 20 years, that global warming would have the most noticeable effects in the Arctic region. Despite that the global average temperature has risen by 0.7°C, no noticeable rise in temperature corresponding to this temperature rise has been seen in the Arctic region. On the other hand, the area and thickness of sea ice have been significantly reduced in the past 20 years. Recently, a phenomenon known as arctic oscillation (AO) has drawn much attention. Arctic oscillation represents various variations of the high-altitude atmosphere on various time scales with the same spatial pattern.

The arctic climate and environmental changes pres-

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ent complicated challenges. The root of the difficulty in these challenges apparently lies in strong mutual interactions among the atmosphere, including clouds, the ocean, and sea ice in the Arctic region. The climate models so far developed are far from complete to adequately deal with any components of their interactions and to produce correct results. The Frontier Research System intends to tackle, this complicated system from various angles, specifically, promoting the following activities.

- Development of a coupled model for sea ice and the ocean.
- Detailed study of the mechanism of the down-slope flow of the cold and low-salinity water formed on the continental slope of the Arctic Ocean.
- Analysis of data obtained in cooperation with Russian research institutes, and discovery of a trend for a decreasing amount of stratus in the winter, for the past 30 years (Figure 12).

(b) Multidisciplinary Research

A great difference between Antarctica and the Arctic region is that the former is the only area not inhabited by people, and the latter is surrounded by a continent inhabited by people and is increasingly contaminated by the development for seeking resources as oil, gas, and forests. The contamination means not merely environmental deterioration limited to the Arctic region but also affects the energy cycle and climate in the Arctic region, through changes in the ecological system and atmospheric composition. This could eventually contribute to the global climate change. Similar to the coupled ocean, sea ice, atmosphere system mentioned above, the Frontier scientists promote multi-angle approaches to these even less-understood themes.

- Observation of the Arctic Ocean using the MIRAI, and collecting oceanographic biochemical samples, carbon, which nitrogen compounds, and indicate that there are active biochemical activities on the continental slopes.

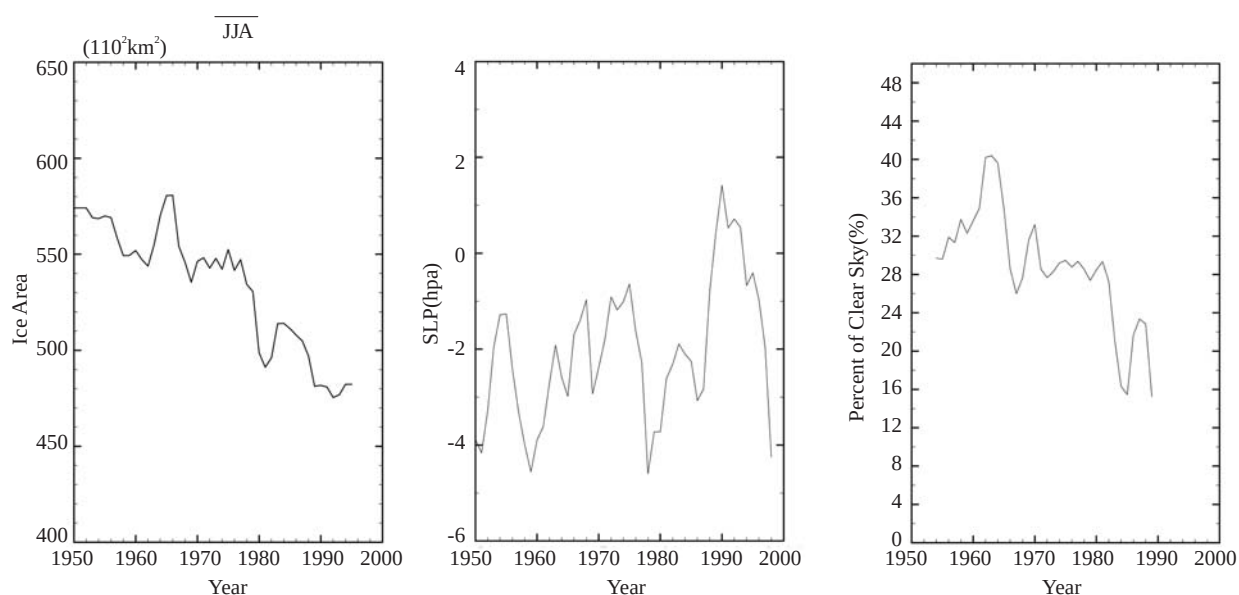


Fig.12 The time series of the sea-ice area in summer (left), the annual mean pressure difference between 60°N and 80°N (middle) and the percentage of clear sky days in the autumn to spring period (right). Decreasing trends are seen both in the sea-ice area and clear sky rate.

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- Analysis of seafloor deposit samples collected by Russian researchers from continental slopes.
- Clarification of the transport of gases and particles using satellite data and atmosphere models, to confirm the results by comparing these data with field observation data.
- Collection of samples of biogenic substances on the surfaces of glaciers. Their effects on the albedo of glaciers, which may accelerate global warming, must be examined.

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Outline of the Research Activities

The Frontier Observational Research System for Global Change, the Earth Simulator in charge of super-computer operation, and the Frontier Research System for Global Change (FRSGC) in charge of model research, work together integrally. Through cooperative work, the three organizations intend to positively contribute to forecasting of global change, thereby helping to prevent global warming. In the development of a next-generation high-resolution integrated global model for forecasting global environmental changes by simulation, the need for highly precise observation data covering wide areas for an extended period, is strongly emphasized. Currently such data are not sufficiently available. To resolve this lack of data, it is necessary to mobilize various measures to collect necessary data. Such measures will include cooperation with ongoing observation projects, cooperation with research organizations both at home and abroad, effective utilization of existing observation facilities, and a new framework whereby dynamic and concentrated observation research can be done. The Frontier Observational Research System for Global Change is staffed with capable research leaders. With their leadership, the Frontier Observational Research System for Global Change will utilize a flexible assignment system, a system of cooperation that transcends boundaries among ministries and agencies, national research institutes, universities, and private organizations; and appropriate assignment of observation engineers and research promotion staff to tackle huge observation research of global dimension. The observation research will be very wide and will cover a variety of areas. Major objectives are clarification of the phenomena of climate change on a great scale, spatially and temporally; acquisition of global observation data necessary for analysis of phenomena of climate change, and the establishment of a global observation system for data assimilation. Through these activities, the Frontier Observational Research System for Global Change will contribute to the advancement of observation research.

Description of Major Research Activities

(1) Climate Variations Observational Research Program

The objective of the Climate Variation Observational Research Program is to analyze and clarify climate change and associated variational phenomena of the atmosphere and ocean, over a period of several tens of years, mainly in the Western Pacific Ocean and Indian Ocean. Through such a step, the Program intends, ultimately, to realize the establishment of an integrated model and an observation system able to forecast future

climate change and various associated variational phenomena.

● Air-Sea Interaction Group

The objective of the Air-Sea Interaction Group is to clarify the interaction between the atmosphere and ocean in the Western Tropical Pacific Ocean and the Indian Ocean. This objective consists mainly of clarifying the mechanism of the atmosphere-ocean variation in subject sea areas, roles of intraseasonal oscillation, the relationship between El Niño and the Asia monsoon, and the mutual interaction between

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the atmosphere and ocean in the tropics, including mesoscale cloud groups.

The Air-Sea Interaction Group started, in November 2000, the PALAU (Pacific Area Long-Term Atmospheric Observation to Understand Climate Change) Project. The PALAU's purpose for fiscal 2000 was to clarify the air-sea interactions and the cloud and precipitation processes in the Western Tropical Pacific Ocean (or the sea area surrounding Palau Island). Intensive observation (PALAU2000) for fiscal 2000, conducted from November 14 to December 17, coincided with the voyage (MR00-K07) of the MIRAI, an ocean earth research vessel, to a stationary observation point, at latitude 2 degrees north, longitude 138 degrees east, close to the Palau Islands. This expedition conducted continuous observation on such various ground climatic elements as temperature, humidity, wind direction, wind velocity, precipitation, barometric pressure and precipitable water (Figures 1 and 2), in Peliryu Island of the Republic of Palau. Also, on Guam Island, the team flew unmanned climate observation equipment (aerosondes), and observed the three-dimensional high-altitude climate (Figure 3).

The intensive observation observe large-scale west wind bursts associated with tropical cyclones, and

noticeable increases in precipitation, as a part of intraseasonal variation. These phenomena were also observed by the MIRAI. The observation in the West Tropical Pacific Ocean was conducted jointly with the Hydrological Cycle Observational Research Program.

In the warm sea area of the East Indian Ocean, observations were aimed at clarifying the intraseasonal disturbances and oceanographic changes over several years. In November 2000, the Program moored an intermediate-depth-layer acoustic Doppler current profiler (ADCP for short), at longitude 90 degrees east on the equator, to study the currents on the equator. This moored system will be recovered in October 2001 and



Fig. 2

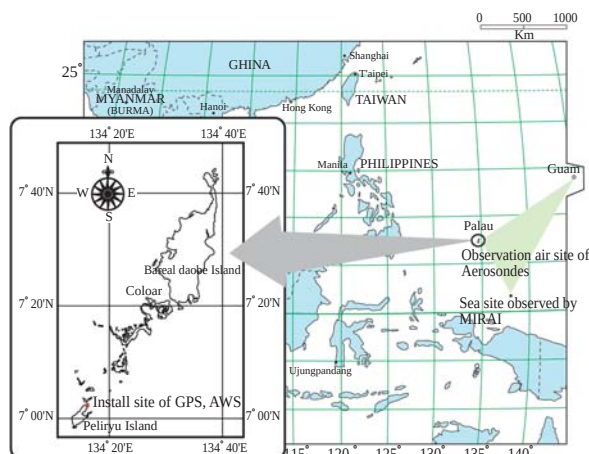


Fig. 1



Fig. 3

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will be reinstalled. Further, the MIRAI's MR00-K07 voyage observed short-interval oscillation of the Wyrski jet, which occurs twice a year in the tropical region, by using an shipboard ADCP and drifting buoys.

The Program has started the XBT/XCTD observation, as a Joint Research with the Meteorological Agency and the Fishery Agency, on two observation lines in the Indian Ocean, and on one observation line in the Pacific Ocean by a volunteer boat. In addition, the Program is conducting a wide-area XBT/XCTD observation in the Indian Ocean, with the cooperation of fishing training boats of fishery vocational high schools and fishing boats (Figure 4).

● Ocean Variation in the Subsurface Layer and the Middle Layer Group/ARGO Project

The objective of the Ocean Variation in the Subsurface Layer and the Middle Layer Group is to understand water mass distribution, circulation and their variations in the subsurface and middle layers in the western North Pacific. They must be major contributors to the climate change, of which time scale is ten to a few tens of years. Another objective of the group is to contribute the ARGO project, in cooperation with the Ocean Observation and Research Department (OORD). Activities of the group in fiscal 2000 are summarized below.

In May 2000, members of the group and OORD visited University of Washington to learn the technology to adjust buoyancy of the ARGO float. The group purchased the instruments to calibrate temperature-conductivity-pressure (CTP) sensor of the float. Then the joint study team of the group and OORD has developed the technology to adjust buoyancy of the float and calibrate the CTP sensor by itself. The joint group also conducted a series of field test in the tropical Pacific in February 2001 to compare performance of the CTP sensors of different types, including that

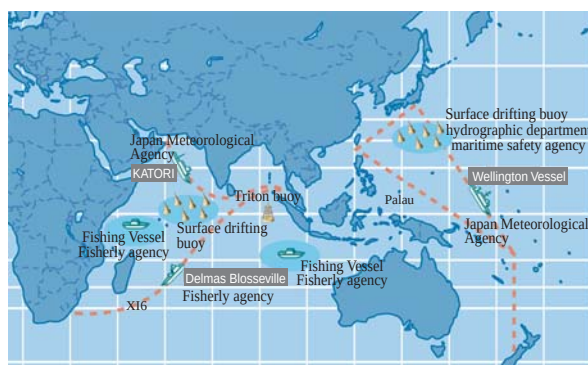


Fig. 4

used in the ARGO float.

The group developed a data processing and distribution system of the data obtained from the ARGO floats. The system was soon ready for operational use for processing raw data, quality control, distribution of the data to other contributors to the ARGO project, and public relation. In order for quality control of the float data, high quality, historical hydrographic data such as WOCE data sets were archived. A method was developed, based upon Hydro Base, to judge whether or not each temperature and salinity profiles reported by the ARGO floats were climatically acceptable in each region. The high quality historical data were used in the judgment.

The group developed a method to simulate float trajectories by using output of a general circulation model of the world ocean. The method is used to infer float positions, rate of crash into the seafloor, and rate of stranding, for four years after the deployment. Deployment positions and thus the cruises for the deployment of the floats are determined based on the simulation.

Two floats were released into the sea south of Kuroshio Extension in October 2000 during a R/V Mirai cruise. Thirteen were deployed in the regions north, middle and south of Kuroshio Extension during the other R/V Mirai cruise in February 2001. Together

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with two floats deployed in March 2000, 17 floats had been deployed as of the end of fiscal 2000. 15 of them worked well but 2 floats that were deployed in October and one in February got some trouble a few months after their deployments.

A case study of water mass distribution and a cyclonic eddy in the region south of Kuroshio Extension was conducted by using the data obtained from the floats that deployed in fiscal 1999. Vertical structure of the eddy was revealed. Meanwhile, the



Fig. 5

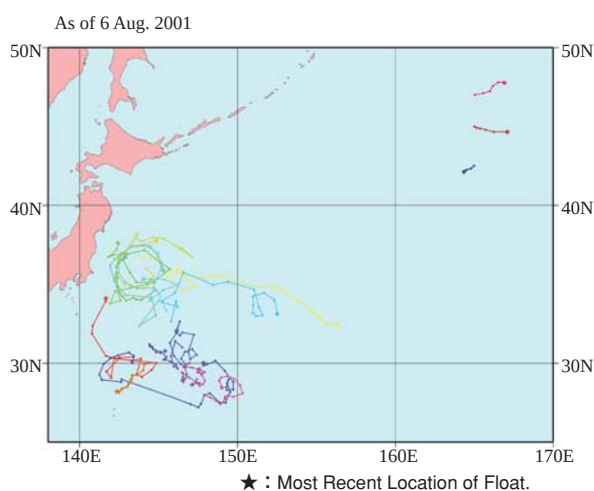


Fig. 6

two floats failed in surfacing from August through November because sea surface temperature in the region was so high that the buoyancy of the floats was not sufficient enough to come up to the sea surface. They resumed observation by December 2000. The 15 floats deployed in fiscal 2000 were improved to overcome the shortcoming.

● Japan Coastal Ocean Predictability Experiment Group

The objectives of the Japan Coastal Ocean Predictability Experiment Group are, first, to conduct observational research on various physics concerning variations of volume transport and meander of the Kuroshio Current flowing along the southern coast of Honshu, and second, to improve observational accuracy to verify the reliability of numerical models, for climate change prediction of the ocean and atmosphere, over periods from several years to several tens of years, using observational data. To understand variation mechanisms of the Kuroshio Current south of Honshu, it is necessary, beforehand, to clarify the variation mechanisms of the Kuroshio Current in the East China Sea, the Kuroshio upstream region, and the northward current in the east of the Ryukyu Islands, or the Ryukyu Current System. However, the Ryukyu Current System is not well understood until now. This group tentatively aims to clarify seasonal to interannual variations of the current system in the southeast of Okinawa Island, using moored instruments with an inverted echo sounder equipped with a pressure gauge (PIES) (Figure 7) as a central component (Figure 8). This fiscal year, this group performed a preliminary evaluation of PIES observational system, using the past CTD data obtained in the Kuroshio recirculation region south of Honshu including the east of Okinawa Island. The group studied a relationship between the time required for sound to travel from PIES to the surface in two ways, and the dynamic height of sea sur-

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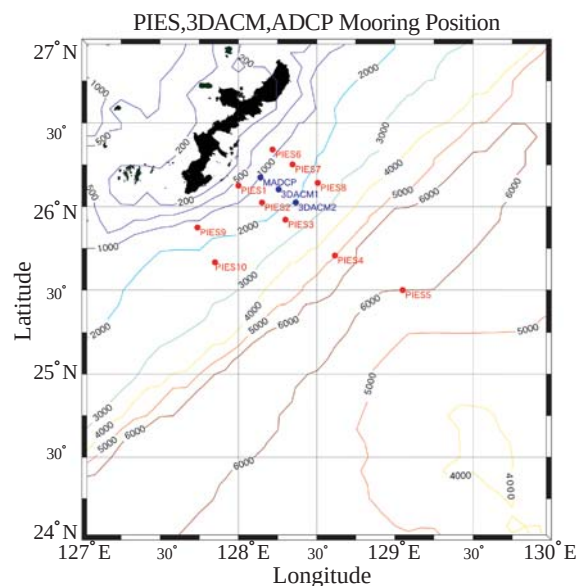
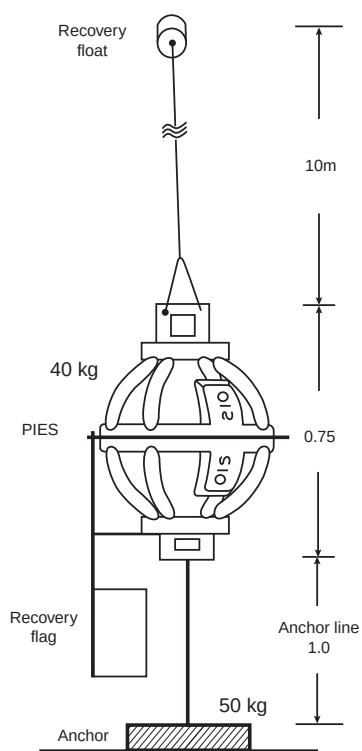


Fig. 8

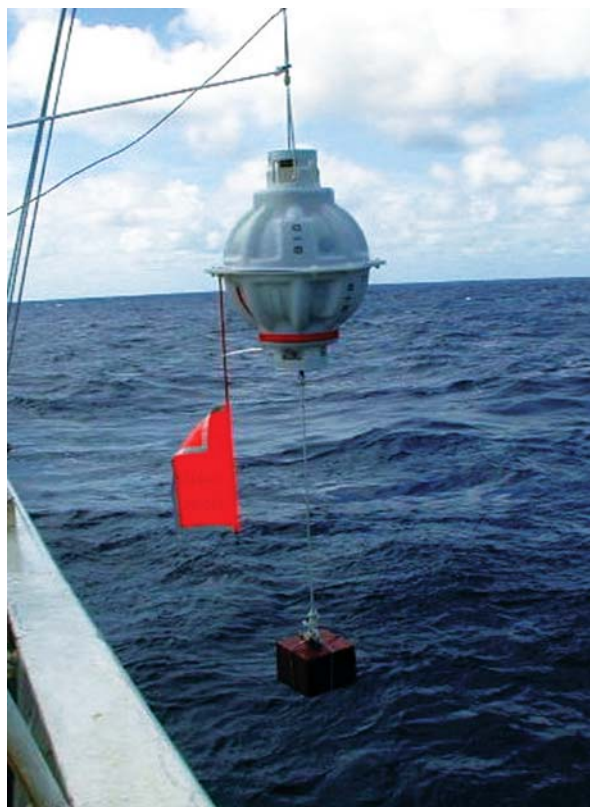


Fig.7 Schematic drawing (upper panel) and photo (lower panel) of PIES

face, and confirmed that the region east of Okinawa Island was a suitable one for the deployment of PIES. In addition, the group placed three PIESs, and one, three-dimensional acoustic current meter (3D-ACM) on July 4, 2000 in a region about 1,000 m deep, on the westside of the Amami-Oshima Island. This operation is a preliminary one, to experience the safety deployment and recovery of PIES and moored instruments and to evaluate the performance of the whole system. The group recovered safely these instruments on August 24, 2000. The group estimated vertical distributions of water temperature and density by means of the Gravest Empirical Method (GEM method), in which time required for sound waves to travel in two ways, obtained by PIES, and a large number of previous CTD data for this region, were combined. Further, the group reconstructed, using the dynamic calculation, the vertical section distribution of geostrophic current relative to the observed current 100 meters above the seafloor, obtained by the 3D-ACM (Figure 9). The root-mean-square values of differences between the

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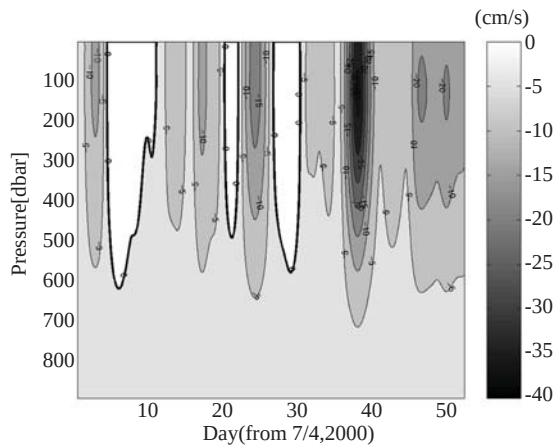


Fig. 9 Time-depth diagram of absolute geostrophic flow obtained by the GEM method. A contour interval is 5 cm/s, and a positive and a negative value show the northward and southward currents, respectively.

water temperature measured by the CTD casts during the mooring period, and the estimated water temperature by the GEM method, are distributed from 0.17°C to 0.46°C , in the depth range of 300 to 900 db. It was discovered, by application of the GEM method, that a gentle southward flow of 5 to 10 cm s^{-1} usually prevailed in the observation region, but a relatively strong southward flow, exceeding 20 cm s^{-1} , occurred at depths less than 400 m around August 8, when Typhoon 0009 (Typhoon No. 9 of 2000) came close to the area. It is likely that this caused the shoreward shift of the Kuroshio stream axis.

Apart from the preliminary experiment, the group launched seven sea level drifting buoys in a joint research with the Hydrographic Department of the Japan Maritime Safety Agency. The purpose was to study the variability of the Kuroshio recirculation region, including the east of Okinawa from 24°N to 30°N near the Izu-Ogasawara Ridge (Figure 10). By the drifting buoy data accompanied by the satellite derived altimetric data, the group found oceanic variability of the surface layer, by drifting buoys, that was

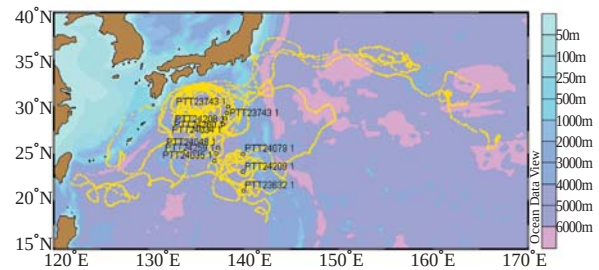


Fig.10 Trajectories of seven drifting buoys.

likely to be caused by warm-and-cold eddies in the east of the Ryukyu Islands and a warm eddy south of Shikoku.

Note: GEM method

The GEM method is a technique to reconstruct the vertical profile of water temperature or density from acoustic travel time data. For this purpose, a linear relationship between the above variables and travel times has to be established from the past CTD data.

(2) Hydrological Cycle Observational Research Program

The purposes of the Hydrological Cycle Observational Research Program are, first, to clarify physical processes of Asian monsoon variations -- both annual and long-range variations, the latter being associated with global warming -- and of water resources variation; and second, to build an integrated model to forecast the processes of the Asian monsoon variation and water resource variation, and to establish an observational system for them. The annual and long-range variations of the Asian monsoon strongly influence climate changes, mainly of the Asia monsoon area, the Eurasia Continent, and Japan.

● Large-Scale Hydrological Cycle and Processes Group

The Large-Scale Hydrological Cycle and Processes Group intended to complete preparation for full-scale

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observation to start from fiscal 2001. The purpose of the observation is to clarify the processes of variations of the large-scale atmosphere and hydrological cycle in the Asian monsoon area. With this schedule in mind, the group completed a series of work, from drafting of agreements, sealing of agreements, fields surveys of the planned observation sites, and acquisition of materials, for preliminary analyses for the subject countries; namely, Indonesia, Thailand, and Nepal. The preliminary analyses produced the following outcomes, which have been reported to academic societies at home and abroad. Presently, the group is presenting some essays. The group's activities are being conducted in various areas, of which outlines are presented below.

(a) Observation of secular changes of cloud activities of the ocean and terrestrial system of Indonesia

The group conducted preparatory surveys, mainly in Bukittinggi, the central part of Sumatra, for the observational research of next fiscal year. The group also collected past records of ground and aerological data covering all of Indonesia. Even in the preparatory surveys, the group was able to get hold of various climatic phenomena. These climatic phenomena were regional classification of the entire Indonesia based on seasonal changes of precipitation and the wind system, changes of interval in year of the Hadley circulation, semi-annual variations of easterlies jet streams, secular changes of precipitation and the wind system associated with the El Niño southern oscillation, and the collapse on the west coast of Sumatra of wind groups originating in the Indian Ocean.

(b) Observational research and preliminary survey for daily variations of water and heat circulation in Tibet and Thailand

The group placed a GPS receiver at Nagu and

Gaize, cities respectively located in the east and west of the Tibet highland, and began observation of soil moisture content. The group conducted a preliminary survey in Thailand, for a similar observation planned for fiscal 2001. In the preliminary survey in Chiang Mai, Thailand, it was discovered that there are seasonal fluctuations of the convective cloud activity, that is a major process of water transport between the ground surface and the atmosphere (Figure 11). Specifically, a daily cycle, with its peak at around 6:00 p.m., predominates in April, and a semidiurnal cycle, with its peak appearing twice a day at around noon and in the middle of the night, predominates in August in Chiang Mai.

(c) Surveys for sources of precipitation in Nepal, Tibet, and Siberia

The group established a sampling network for precipitated water and river water in the Tibet and Nepal area. The group also conducted an intensive sampling of snowcover water, river water, and lake water. The group also executed preparatory work in Indonesia and Thailand, for observational research to be done in fiscal 2001. The number of samples so far collected amounts to 1,600, which are being analyzed now. The group intends to identify sources of precipitation in various areas of East Asia, and the roles of snowcover water in the interaction between the atmosphere and vegetation (Figure 12). The above (a) and (c) are being conducted as Joint Researches with Kyoto University.

● Land-Surface Hydrological Cycle and Processes Group

The purpose of the Land-Surface Hydrological Cycle and Processes Group's observational research is to clarify the terrestrial system processes of the cold regions of continents, and the interaction between the atmosphere and ground surface, to thereby understand

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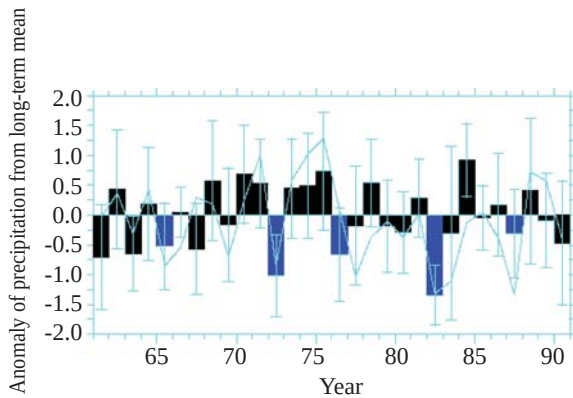


Fig 11

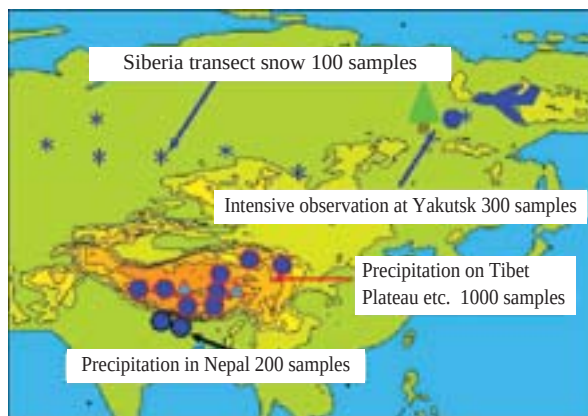


Fig 12

the roles of the terrestrial system in the regional and global hydrological cycles. The research themes so far accomplished are given below.

(a) To clarify the effects of snow and ice in snow-cover and frozen soil, and those of vegetation, on the processes of water and heat circulation of the terrestrial system, in such semi-arid areas as East Siberia, Tibet, and Mongolia, on the Eurasian Continent; (b) To build a data set that should enhance understanding of water and heat circulation; and (c) To develop a terrestrial scheme for understanding the physical processes of water and heat circulation, and to use this scheme for verification of schemes already developed for regional and global models.

Regarding these objectives, the group conducted the following observational research in fiscal 2000.

- i) Observation of three-dimensional water and heat circulation in an area near Yakutsk, East Siberia, where the taiga forest predominates (Photos 1 and 2)
- ii) A year-round observation of the water and heat exchange in river basins in areas south of the Taiga Area (Photo 3)
- iii) A year-round observation of water and heat circulation in the western region of the Tibet Highland (Photo 4)
- iv) Analysis of hydrological and land surface processes by using meteorological and hydrological data taken at operational stations
- v) Observation aimed at developing a method to correct solid water precipitation in the Arctic strong wind zone, and observation of water and heat transport processes in drifting snow

In fiscal 2000, observational research was done with particular emphasis on i) of the above observations. In particular, seasonal variations and spatial distribution of transport of heat and moisture from heterogeneous ground surface to the atmosphere, were intensively surveyed. The group installed four forest-and-grassland



Photo 1

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Photo 2



Photo 3

towers in this area, and conducted observations of major meteorological elements at 15 locations. In close coordination with the ground observational operations, aircraft observations were done for altitudes between 100 meters



Photo 4

and 4,000 meters, on fine days, from April 24 to June 20, in cooperation with the Moscow Central Aerological Observatory. This observational research discovered that the water and heat circulation is under strong influences of distortions of spatial distribution, and of localized circulation caused by the Lena River. These results will be useful in analyzing ground-level heat and water fluxes.

The group was able to promote observational research smoothly in other areas. Some of these observational researches are still under way, and good-quality data are being acquired.

● Cloud and Precipitation Processes Group

The purpose of the Cloud and Precipitation Processes Group is to conduct accurate and high-resolution observational researches that will contribute to the development of a cloud resolution model, thereby clarifying seasonal variations and yearly variations of the East Asia Baiu front and cumulus convections.

In fiscal 2000, the group made preparations for preliminary observations of the structure and development process of the precipitation system at the Yangtze River downstream area during the Baiu period with process of clouds and precipitation in the West Pacific sea area near the Palau Islands.

Regarding observation in the downstream area of the Yangtze River, the group concluded, first, an observation

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agreement with the Chinese Academy of Meteorological Sciences. The group surveyed planned areas for placing a wind profiler, three Doppler radars, two bistatic radars, and three automatic weather systems (AWS), near Suzhou city, Jiangsu Province, and studied practical candidate sites and methods of installation. After being tuned, these instruments were transported to the sites and properly installed, in March 2001 (Figure 13). Some experts of the group participated in an international conference on cloud and precipitation, held in August 2000 in the United States. The experts took this opportunity to visit concerned organizations, and they obtained information to improve observation by the wind profiler and by the Doppler radar, and to improve the method of analysis.

In the observational research in the Western Tropical Pacific Ocean sea area (the Palau Islands), the group executed a series of works with the Air-Sea Interaction Group of FORSGC. These works are a site survey in June 2000, negotiations with the concerned organization of the Republic of Palau in September, and preparatory work for installing ground meteorological observatory instruments in October. Finally, the group conducted an intensive observation from November 14 to December 17, 2000. In April 2000, some experts tested meteorological observatory instruments on board the MIRAI, an ocean and earth research vessel, and also prepared programs to analyze observed data.

(3) Observational Research of the International Arctic Research Center, IARC

The International Arctic Research Center (IARC), intends to clarify climate change by natural causes and artificial environmental changes by greenhouse-effect gases in the Arctic Region, and to develop technologies to forecast these changes. For this purpose, the IARC conducts observational research focussed on mutual interactions of various global changes and their effects on the Arctic Region, in particular. The IARC executed observational research on the following two themes in fiscal 2000.

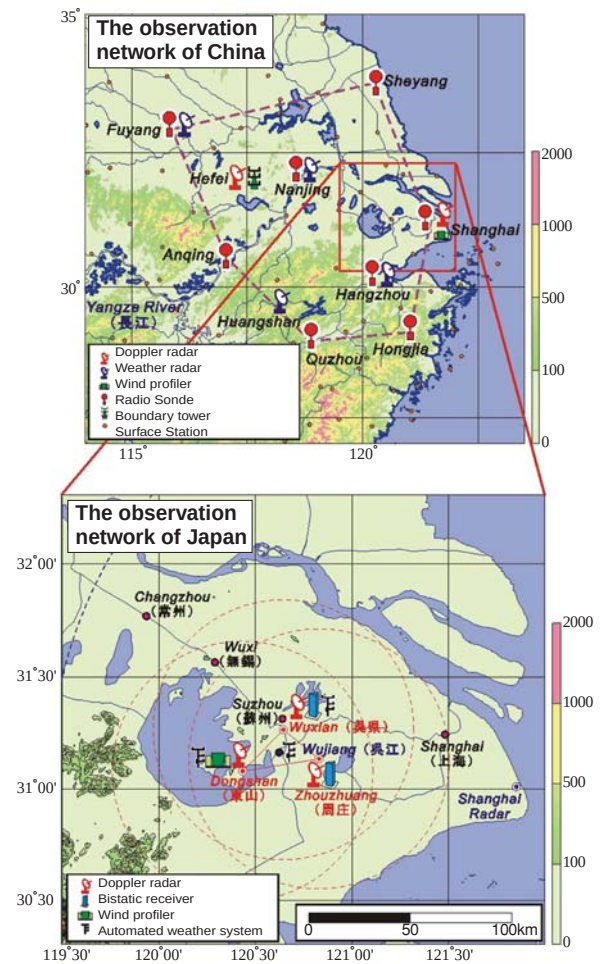


Fig.13

● Coupled System of the Ocean, Sea Ice, and the Atmosphere

To be able to clarify the complicated arctic climatic system, observational research on the ocean sea ice and atmosphere system, and on the mutual interactions of ocean, sea ice, and the atmosphere in the Arctic Ocean, in particular, are necessary. Observational research in fiscal 2000 was concentrated on the sea areas of the Arctic Ocean that have close interactions with the Pacific Ocean. The IARC traced the transport of freshwater in seawater, using a stable oxygen isotope. The result of this observation indicates that the water mass observed in the Beaufort Sea deviates from a straight line connecting the freshwater with the North Atlantic

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seawater, and therefore the water mass has been generated from melting of sea ice or independent formation.

To observe and understand the processes of formation and melting of ice, the IARC conducted detailed measurement of mixing processes below the sea ice, by instruments, to measure turbulent flows. As may be noted from Figure 14, stepwise vertical distributions of density were observed. Since the seawater density is expressed by a non-linear function of the seawater temperature, once vertical mixing occurs, that portion of the seawater becomes heavier, which, in turn, further promotes vertical mixing.

The IARC reviewed satellite data obtained by the National Space Development Agency of Japan, NASDA, and a number of other organizations, and analyzed the

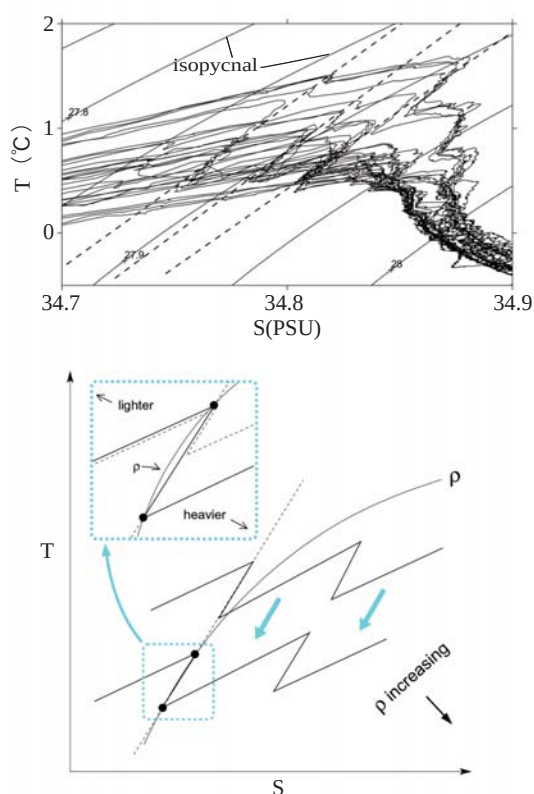


Fig.14 Structure of Water Mass Observed by a Vertical Profiler (If a low-temperature, low-salt-content water mass exists below a high-temperature, high-salt-content water mass, mixing of these two masses makes the density of the mixture even greater, which, in turn, increases the density of the mixture, and hence promotes vertical mixing.)

data useful for the clarification of climate change. Using the data on sea ice types, observed by a microwave radiometer mounted on an artificial satellite, the IARC improved the method of analysis, referring to past data obtained by airplane and boat, from the Sea of Okhotsk and sea areas to the east of Hokkaido Island. As a result of such efforts, the improved method can estimate thickness of sea ice to the order of several tens of centimeters.

● Multi-Disciplinary Research

Multi-disciplinary researches are concentrated mainly on observational research in the areas where bio-earth science processes have great bearing on climate change. In fiscal 2000, the IARC collected samples of seawater, sea ice, and sediments on the seafloor, in the sea area from the Bering Sea, to the Arctic Ocean, to north of the Bering Sea, and started biochemical analyses of these samples. The samples were taken by the MIRAI, an ocean and earth research vessel. The items for analysis are Chl.a, nutrient salts, suspended and dissolved carbon and nitrogen, their stable isotope ratios, lipid bio-markers, etc. The analyses are now under way. The results so far obtained indicate the following (Figure 15).

- Water effluent from the Yukon River and the Mackenzie River may be traced in the Arctic Ocean by using dissolved organic carbon and its isotope ratio.
- The cold halocline formed on the continental shelf of the Chukchi Sea supplies a large amount of organic carbon to the middle layer, deep

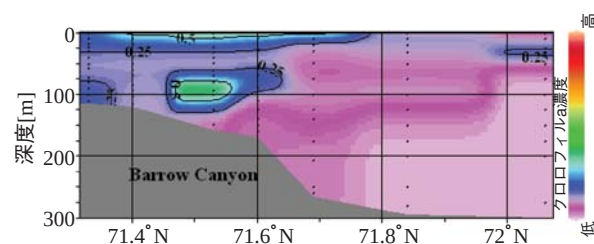


Fig.15 Vertical Cross Section of Distribution of Chlorophyll Concentration in a Seafloor Canyon off Barrow

Frontier Observational Research System for Global Change

ocean water, and seafloor sediments of the Arctic Ocean. Organic carbon was transported by the continental shelf flow in Barrow Canyon.

The vertical distribution data obtained by the MIRAI indicate that DMS and DMSP exist at high concentrations only in the surface layer, to depths of several tens of meters. Since phytoplankton contain DMSP at relatively high concentrations, but they contain DMS only at low concentrations, the low concentrations in the deeper layers indicate that microbial decomposition of DMSP and DMS is very active in the summer. The MIRAI also observed large-scale blooms of coccolithophorids, lasting for several months, in the Bering Sea. DMS and DMSP were detected at extraordinarily high concentrations in seawater around the blooms.

A preliminary observation was conducted in May 2000, at Point Barrow, Alaska State, to clarify the relationship between ice algae and DMSP production. Secular changes of the sulfur compound concentration in sea ice and seawater around the observation point were

obtained. Data on temperature, salt contents, nutrient salt contents, total organic carbon contents, chlorophyll a contents, and accessory pigments of phytoplankton in sea ice and seawater, were obtained at the same time.

Seemingly black cryophilic microorganisms reduce their albedo and increase absorption of solar radiation, thereby promoting melting of glaciers. The IARC conducted a preliminary survey of glaciers in the central part of Alaska, in August 2000. The preliminary survey confirmed that various kinds of cryophilic microorganisms thrive on the Alaskan glaciers, which demonstrated the possibility of a biological effect to reduce albedo. The IARC also participated in the survey of burned-out forest sites in central Alaska, from November 1999, to study the effects of aerosols and trace gas components on the atmosphere of the Arctic Circle. The IARC measured emission of greenhouse-effect gases from soils, in this survey.

Figure 16 represents the spots of these research activities.

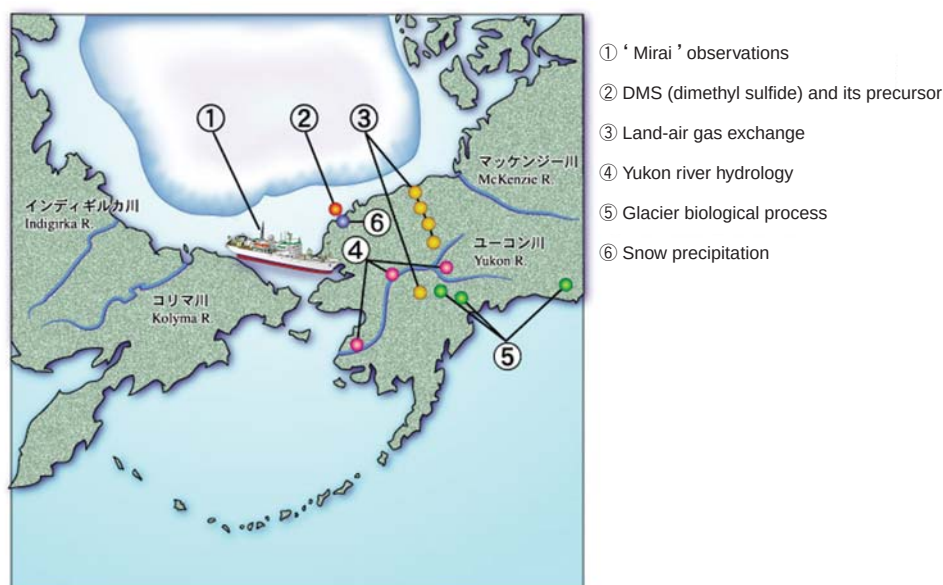


Fig.16

OD21

Outline of Ocean Drilling in the 21st Century (OD21)

Ocean Drilling in the 21st Century (OD21) intends to build the Deep-sea Drilling Vessel incorporating the most advanced scientific drilling capacity, and to operate the vessel, to clarify the mechanisms of climate change and global change, including the mechanism of earthquakes. OD21 further intends to explore unknown deep biospheres and deposits of gas and gas hydrates, and thus to establish a new area in earth science and life science, and to promote comprehensive understanding of this new scientific area.

Presently, 21 countries are jointly promoting the Ocean Drilling Program (ODP), using the JOIDES Resolution (JR), a scientific deep-sea drilling vessel of the United States. In Ocean Drilling in the 21st Century (OD21), Japan will develop the Deep-sea Drilling Vessel, exceeding the technological limits of JR. The new vessel, and a conventional deep-sea drilling vessel of the United States, will be operated internationally, in a manner to mutually supplement each other, to obtain core samples under the seafloor. Ocean Drilling in the 21st Century (OD21) will promote earth science and life science by using the core samples and drilled boreholes. The present ODP will terminate at the end of September 2003; thereafter, the Integrated Ocean Drilling Program (IODP) will start, in which the two vessels mentioned above will be operated. Now, preparation of the IODP is under way internationally. The task force for Ocean Drilling in the 21st Century (OD21) is busy working on construction of the Deep-sea Drilling Vessel, development of associated technologies, study of the system to operate the vessel, and establishment of a domestic and international cooperation system.

Development of Technologies for Exploration of the Earth's Deep Interior

(1) Construction of the Deep-sea Drilling Vessel

The Deep-sea Drilling Vessel system, as shown in Figure 1, aims to drill formations under the seafloor, to obtain continuous core samples, including sedimentary rocks and igneous rocks, and to conduct analyses and research on the core samples aboard the vessel. The system conducts measurements of physical and chemical data and seismic waves, to obtain information on the state of the earth's interior. The system addresses such themes shared by all of mankind as global warming, earthquakes, and the origin of life. The various data to be obtained by this system will promote studies on a variety of themes. The themes



Fig. 1 Outline of the Deep-sea Drilling Vessel System

OD21

will include such global changes as environmental changes and seawater changes, clarification of the mechanism of destruction in earthquake zones, studies on mantle substances, to be obtained for the first time in human history, and pursuit for living organisms in the earth's crust. These studies promise marked advancements in earth science and life science.

To accomplish such research, a number of difficult hurdles, which conventional riserless drilling technology cannot adequately cope with, must be overcome. Acquisition of good core samples from unstable hydrocarbon-containing formations, deep drilling through earthquake faults, very deep drilling to the upper mantle layer, and stable and long-range observations in boreholes, are some of such difficulties. The existing riserless deep-sea drilling vessel cannot drill gas- or petroleum-bearing formations, and it is constrained in drilling depth and core sample recovery rate because of the drilling method.

Research and development of this system started as early as fiscal 1990. Technologies concerning riser drilling, and those on the Dynamic Positioning System (DPS) for the Deep-sea Drilling Vessel, both being key technologies of the system, were intensively studied, to make the entire system really reliable (Refer to Figure 2). The specifications of the system

have been determined for the system to drill the deep seafloor, 2,500 meters deep (4,000 meters deep in the future), to 7,000 meters below the seafloor, under rough oceanographic conditions, with a maximum significant wave height of 4.5 meters. Effective use of various data to be obtained by this system will contribute to clarifying global environmental changes, understanding the mechanisms of earthquakes, acquiring of the mantle substance, discovering of earth crust living organisms, and advancing of earth science and life science.

The basic design for the Deep-sea Drilling Vessel was started in fiscal 1999, and it was finished on February 28, 2000. The contract for construction was awarded to Mitsubishi Heavy Industries, on March 27, 2000. Detailed design of the vessel was carried out in fiscal 2000, and manufacture of various facilities started. The main engines, main generators, and other facilities, constructed under funding by the second fiscal 1999 supplementary budget, were completed in March 2001 (Refer to Figure 3). The construction cost for the second portion of the three-phase construction contracts was budgeted from fiscal 2000, as acts incurring liabilities on the treasury. Reflecting this, JAMSTEC amended the contract with Mitsubishi Heavy Industries on September 1, 2000.



Fig. 2 Test on the Dynamic Positioning System, Control of Riser Inclination



Fig. 3 Main Engine

OD21

Major specifications and features of the Deep-sea Drilling Vessel are given below (Refer to Table 1).

Table 1 Major Specifications of Deep-sea Drilling Vessel

Length	210 m
Width	38 m
Depth	16.2 m
Draft	9.2 m
Variable load	25,500 ton
Speed	10 knots
Cruising range	14,800 km
Accommodation	150 personnel

(Major features)

- The vessel is designed to be compartmentalized, to afford living comfort to the crew and researchers, in view of long-term stays for drilling and research activities.
- The Global Positioning System (GPS) is adopted, to determine the location of the vessel for DPS. The vessel is equipped with a riser inclination controlling function, to estimate optimum location from the angle of the line connecting the upper and lower end of the riser.
- Considering the possibility of increasing depth of water and deep-drilling operations, the vessel is designed to have an ample variable load.
- The vessel is designed to hold, instead of dumping to the sea, such drilling wastes as cuttings and waste mud that are generated with drilling operations, as a measure to prevent marine environmental pollution. The vessel also has space for a drilling waste disposal facility, now under development.
- To enable the vessel to operate in all sea areas of

the world, except for icebound seas, oceanographic design conditions for the riser hangoff (a means of tiding over during stormy weather with the riser hanging from the vessel) comply with the World Wide Sea State (worldwide oceanographic conditions), after study of the Guidance Note of Det Norske Veritas (DNV), or the relationship between the wave period and the wave height using worldwide wave statistics. The rise system is designed to withstand the wave height obtained from all wave period conceivable from the World Wide Sea State.

- Automatic operation is extensively adopted for drilling operations, to secure safety of operation and to improve efficiency.

(2) Development of Test Seafloor Drilling System

Period: from fiscal 1998 to fiscal 2000

The manufacture of a test seafloor drilling system consists of manufacturing a special core sampling system and development of a borehole utilization system.

(a) Manufacture of the Test Borehole Utilization System

The boreholes of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Program (ODP) are not just unnecessary holes left after core samples are taken; rather, they represent opportunities for scientific research. It is desired to install seismometers in the rock formation of the earth's crust, to measure seismic waves at high S/N ratios. Also, information available only below the seafloor must be obtained, to clarify material circulation in the earth's crust and mysteries of deep biospheres. Long-term observations by instruments placed deep in these boreholes represent very effective means for such scientific purposes. As a means to place measuring instruments in the boreholes, the Deep-sea Drilling Vessel can be used. The Deep-sea Drilling Vessel can easily handle heavy

OD21

objects for installation and reentry operation. Frequent use of the Deep-sea Drilling Vessel to place and recover measuring instruments in and from these boreholes, however, would significantly restrict the vessel's operation for drilling and core sampling -- the intended purposes of the Deep-sea Drilling Vessel -- and hence such use is not practical. Accordingly, a system of technologies to use boreholes for measurements without relying on the Deep-sea Drilling Vessel, is needed.

JAMSTEC has developed a borehole utilization system: BENKEI, in a three-year project that started in 1998. BENKEI is brought to a borehole site aboard the KAIREI, the support vessel for 10,000-meter class Remotely Operated Vehicle KAIKO. BENKEI places measuring instruments and permits real time measurements on board the support vessel, lasting for about two days. BENKEI consists of a system aboard the support vessel, an active launcher, an observation station, and borehole sensors. Certain facilities for the KAIKO are used for BENKEI. These facilities include a winch, a heave compensator, a primary cable (kevlar-sheathed fiber/copper composite cable), a recovery facility, rail and a bogie on the support vessel. Figure 4 shows the appearance of BENKEI.

Development of this system met the following challenges. The system should have the following performances.

- Ability to quickly locate a re-entry cone
- Ability to steadily hover on a re-entry cone
- Correction of heaving of underwater facilities
- Minimization of impact on the re-entry cone when coupling with the observation station
- High reliability of data transmission
- Light weight and compactness of the system
- Reliability of recovery operation of the observation station

Fiscal 2000 being the final year for development, a series of onshore testing, tank testing, and sea trial was



Fig. 4 Appearance of BENKEI

done, and the system's performances for satisfactory operation were confirmed (Refer to Figure 5).

(b) Development of the Special Core Sampling System

The special core sampling system will be mounted on the Deep-sea Drilling Vessel now under construction. The system will be used to drill the formations beneath the deep seafloor and collect samples there. The design work was done in fiscal 1998 and 1999, and the construction, testing, and evaluation were done in fiscal 2000. The system is now stored in a container to be used on board the Deep-sea Drilling Vessel.

OD21

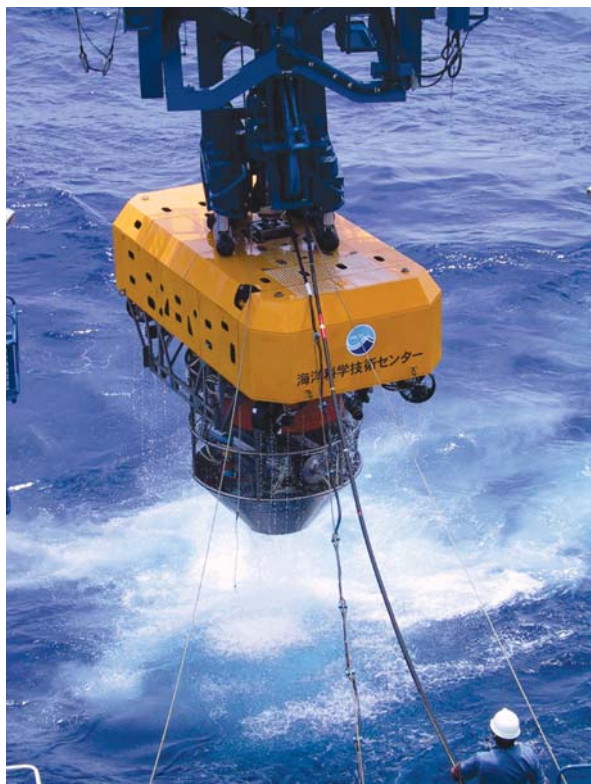


Fig. 5 Comprehensive testing of BENKEI in a Sea trial

i) Core Barrel and Core Bit

JAMSTEC developed four types of core barrels: HPCS, ESCS, RCB, and SD-RCB. JAMSTEC also designed and manufactured eight types of core bits. Testing machines of TeraTech Inc., of Salt Lake City, were used to conduct various tests on these products, under the atmospheric pressure and working pressures for drilling rate, quality of core sample, and contamination of core samples. Although some of the products failed to score satisfactory results, the other results were generally good.

ii) Borehole Tool

JAMSTEC developed four types of borehole tools: jar coupling, bumper sub, overshoot, and shock absorber. These tools have been subjected to various tests and demonstrated their intended performances.

iii) High-Tensile Drill Pipe

The development of high-tensile drill pipe started from a basic material test. To secure corrosion resistance against sulfide stress cracking (SSC) and carbon dioxide, the variation of corrosion resistance had to be reduced to less than half that of the normal high-strength drill pipe material. For this reason, materials comparable to S140 and S150 were selected. (These materials will be patent-applied.) Thereafter, the high-tensile drilling pipe was designed, manufactured, and tested for various performances, to prove the pipe satisfied various target quality levels of OD21.

iv) Drill Collar and Heavy Wall Drill Pipe

JAMSTEC developed a small-diameter drill collar for SD-RCB, and conducted make-break and make-up tests. Also, JAMSTEC developed a heavy wall drill pipe to be set upon the drill string. JAMSTEC confirmed that these products satisfied specified performance requirements, from various test results.



Fig. 6 Core Bit

OD21

(3) Operation of the Deep-sea Drilling Vessel**(a) Pre-survey for Riser Drilling**

The purpose of the Deep-sea Drilling Vessel is to execute deep drilling through formations containing hydrocarbons or otherwise complicated formations, which were impossible in the present ODP to drill. To ensure safety and efficiency of drilling operation under such difficult conditions, a pre-survey, to obtain data on such environmental conditions as oceanographic phenomena, seafloor topography, and underground structure, is essential. Of particular importance is to foresee potential hazards to the extent possible that could emerge during seafloor drilling, and that could make accomplishment of the drilling operation difficult, and to incorporate preventive measures to forestall such potential hazards in the drilling operation. Without such precautionary measures, safe and efficient drilling would be impossible. In fiscal 1999, JAMSTEC prepared a draft for the standard required item list for the pre-survey for OD21 riser drilling. In fiscal 2000, JAMSTEC determined candidate sea areas for the pre-survey, and drafted implementing plans, with due consideration given to the conditions of the candidate sea areas. Consecutively, JAMSTEC conducted a study for preparation of implementation, adjustment of the sea area, and security measures, to be specific, and decided on the shake down courses and selected sea areas most suited for the shake down operation.

(b) Establishment of Deep Sea Scientific Drilling Vessel Management System

The planning for safe and efficient operation of the Deep-sea Drilling Vessel included a study on preparation of the management system, consisting of the management standard, the drilling planning standard, and the drilling operation standard. The results of this study indicated need for a management and maintenance system, a drilling operation management sys-

tem, and a network system connecting the Deep-sea Drilling Vessel, the onshore supporting base, and the headquarters. JAMSTEC estimated that establishment of these kinds of system would take four years, from fiscal 2000 to fiscal 2003, just before planned shake down operations begin. In fiscal 2000, JAMSTEC studied items for crisis management of scientific drilling; namely, oceanographic phenomena, underground structures, and human factors. JAMSTEC also promoted studies on the safety management standard, the drilling planning standard, and the drilling operation standard, while extensively studying such standards of other organizations at home and abroad.

(4) Promotion of Ocean Drilling in the 21st Century (OD21)**(a) Preparation of a Domestic Organization for Promotion**

The task force for Ocean Drilling in the 21st Century (OD21) is assigned to promote Ocean Drilling in the 21st Century (OD21), with the deep sea scientific drilling vessel playing the central role. For this assignment purpose the task force has been promoting establishment of organizations for development and operation management of the Deep-sea Drilling Vessel, and for research therewith, in close cooperation with the concerned ministries and agencies, universities, and research institutes. In fiscal 2000, it is now necessary to reorganize the domestic science advisory structure to effectively study research proposals and research management. The OD21 Advisory Committee was dissolved, to be integrated into the OD21 Science Advisory Committee (OD21 SAC), with Dr. Hajimu Kinoshita as chairman, to study Japan's research strategy, selection of important research themes, and international strategy, with the latter committee established in January 2001. The OD21 Program Department of JAMSTEC conducts various PR activities to promote, in Japan, Ocean Drilling in the 21st Century (OD21).

OD21

The OD21 Program Department issued OD21 Newsletter Nos. 4 to 7, to enhance awareness of Ocean Drilling in the 21st Century (OD21). Also, the OD21 Program Department held OD21 promotion campaigns at 12 universities across the country, to outline the OD21 project and invite submission of research proposals. Further, OD21 held exhibitions on OD21, at various events for science and technology, to enhance public understanding of it. The OD21 SAC publicly begins receiving scientific proposals for IODP in July 2001. As a prelude to this, the OD21 Program Department held, in March, at the Ocean Research Institute, University of Tokyo, an IODP Science Symposium, to give guidance for preparation of scientific proposals, and to establish a common understanding between JAMSTEC and researchers.

(b) Preparation of an International Organization for Promotion

Ocean Drilling in the 21st Century (OD21) promoted by using the Deep-sea Drilling Vessel and the Ocean Drilling Program (ODP), led mainly by the United States, will be into a new Integrated Ocean Drilling Program (IODP). The IODP will be led mainly by Japan and the United States, and will start in October 2003, with a Japanese riser drilling vessel and a U.S. riserless deep-sea drilling vessel.

JAMSTEC is building a system for international cooperation, coordination, and implementation, through its participation in the International Working Group (IWG), the IODP Planning Sub-Committee (IPSC), and various other activities. As of the end of fiscal 2000, countries and international organizations expressing interest in participating in the IODP are Japan, the United States, the United Kingdom, Germany, France, the European Union, Canada, China, the European Consortium (Belgium, Denmark, Finland, Iceland, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Finland, Italy), and Australia.

The IWG is a committee consisting of representatives from member countries' organizations in charge of science and technology policies, to realize the IODP. The IWG is drafting a management scheme for IODP, and discussing themes on technology, organization, and funding, for project implementation. In November 1999, the United States and Japan jointly established the IWG Support Office (IWGSO), in Washington, D.C. JAMSTEC has dispatched its staff to the IWGSO, to support its activities.

The IPSC is an international committee of scientists and experts, to contribute their comprehensive views on study to scientific, technological, and operational aspects of IODP. The task force for Ocean Drilling in the 21st Century (OD21) works to have its opinion reflected in IODP, by stationing its staff. IPSC formulated the final draft for the Initial Scientific Plan (ISP) of IODP, or objectives for the first 10 years from fiscal 2003, announced in May 2001. IPSC held promotion campaigns in Indonesia, the Philippines, Malaysia, and China, to solicit international support for IODP and to invite research proposals.

(c) International Continental Scientific Drilling Program (ICDP)

The International Continental Scientific Drilling Program (ICDP) is an international joint research program, initiated in 1996, with participation by Germany, the United States, and China. In fiscal 2000, JAMSTEC was named the representative organization of Japan to ICDP. In October 2000, JAMSTEC sealed a memorandum regarding JAMSTEC's participation in ICDP with GeoForschungsZentrum (GFZ) in Potsdam, the representative office of ICDP. The OD21 Program Department serves as a secretariat office for the executive committee in Japan of ICDP, executing such work as invitation and coordination of proposals in Japan.

Mutsu Institute for Oceanography

Outline of the Activities of the Mutsu Institute for Oceanography

Outline of the Mutsu Institute for Oceanography

JAMSTEC established, in October 1995, its first local office in Sekinehama, Aomori Prefecture, facing the Tsugaru Strait, to continually use Sekinehama Port, the home port of the Mutsu, a nuclear-powered vessel now modified and renamed the MIRAI, an ocean and earth research vessel. The local office's jobs were management of the MIRAI and support work for such research activities as analyses and studies of samples and data collected by the MIRAI. In view of the contribution of this local office and the need to strengthen research activities for global warming problems, the Mutsu Institute for Oceanography was established, out of the local office, in October 2000. First, the Mutsu Institute for Oceanography serves the required functions as the MIRAI's mother port. For this purpose, the Mutsu Institute for Oceanography has an administrative office, a observation equipment and machinery maintenance shop, and a sample analysis facility, to manage operation of the MIRAI. There is also the Mutsu Guest House, with researchers' rooms, large conference halls, seminar rooms, and accommodations to facilitate communications among researchers at home and abroad, as well as for lectures or training in the Mutsu area. The Mutsu Institute of Oceanography has executed such work as maintenance of observation instruments of the MIRAI and Triton buoys (ocean observatory buoys); collection, processing, and management of observed data, and pretreatment of samples to measure the age of seawater by radioactive C14. The Mutsu Institute of Oceanography is strengthening its research base for marine science, while intensifying its lineup of analytical instruments.

Outline of Research Activities

In fiscal 2000, the Ocean Observation Research Group was moved to the Mutsu Office, and the office was upgraded to the Mutsu Institute of Oceanography, together with strengthening of administration, support, and research systems. The Mutsu Institute of Oceanography intends to become a core facility for research in earth science, mainly in such northern sea areas as the Arctic Ocean and the Sea of Okhotsk. The Mutsu Institute of Oceanography will clarify the mechanism of the cycle of organic substances, considered to be the main sink of carbon dioxide in the Northwest Pacific Ocean, to conduct chemical analysis of seafloor sediments and analysis of micro-fossils assemblages contained in seafloor sediments. For this purpose, the Mutsu Institute of Oceanography will

effectively use its facilities, including the MIRAI. Accordingly, the Mutsu Institute of Oceanography intends to reproduce the global environmental changes that occurred over the past some hundreds of thousands of years, with high accuracy, to clarify the mechanisms of those environmental changes. Ultimately, the Institute aims to understand the environmental changes stemming from human activities taking place in a short time frame of less than 100 years, as a results of such efforts.

PR Activities

For smooth and effective operation of the MIRAI, an ocean and earth research vessel, understanding and cooperation of the people of Mutsu-city, where the mother port is located, are essential. One very impor-

Mutsu Institute for Oceanography

Outline of the Activities of the Mutsu Institute for Oceanography

tant objective of the PR and extension activities of the Mutsu Institute for Oceanography is to impress the achievements and possibilities of marine science and technologies on citizens, including young boys and girls, who will bear the future, in particular.

According to this policy, the Mutsu Institute of Oceanography held five public lectures and two memorial lectures in fiscal 2000.

On April 29, or the Greenery Day holiday, the Mutsu Institute of Oceanography participated in events for National Science and Technology Week, for the first time. The Mutsu Institute of Oceanography opened, to the general public, the KAIREI, an ocean investigation ship, in the Sekinehama Port of Mutsu-city, as well as other facilities of the Institute.

Mutsu Institute for Oceanography

Study on the past marine environmental changes

"Study on the past marine environmental changes" is a paleoceanography project started in FY1999. We focused on reconstructing the natural variability of global and regional climate recorded in the deep-sea sediment during the late Quaternary. We are challenging to the following themes:

- a) Changes in sea surface temperature and surface current systems
- b) Changes in biogeochemical cycles in the ocean (Carbon Cycle)
- c) Changes in global thermohaline circulation

Since FY2000, this project has been carried out as one of the themes of Mutsu Institute for Oceanography (MIO).

In FY2000, we set up the facilities (Carbonate device, HR-ICP-MS) in MIO and performed preliminary examination for sediment analysis. The sediment coring was carried out at the Kuroshio extension area in the NW Pacific, the Okhotsk Sea, and its adjacent area on the cruises MR00-K03 and MR00-K05 of R/V Mirai, respectively (Table 1). Chemical and micropaleontological analysis for these cores are now in progress.

In this year, we investigated the following three themes for cores which were recovered from the NW Pacific on the previous R/V Mirai Cruises: 1) Alkenone paleothermometer, 2) Oxygen and Carbon

isotopes, and 3) Trace metals in calcareous microfossil. Followings are our preliminary results.

1) The Alkenone (long chain, unsaturated alkyl ketones which are produced by marine coccolithophorids) was analyzed during the last 20 kyrs for five cores in the western North Pacific. In the Last Glacial Maximum (LGM), paleo-sea surface temperature (Paleo-SST) calculated from the alkenone decreased approximately 5°C compared with the present (Figure 1). These results are largely different from previous studies which suggested a decreasing of c.a. 2°C (e.g. CLIMAP, 1976; 1981). This is extremely important for the recon-

Table 1 Piston core samples collected in FY2000 on the R/V Mirai cruises.

Cruise	Core	Latitude	Longitude	water depth (m)	core length (m)
Okhotsk Sea					
MR00-K03	PC1	46°18.6'N	152°32.2'E	2793	8.6
MR00-K03	PC2	48°15.0'N	151°59.9'E	3244	20.0
MR00-K03	PC3	48°15.0'N	151°59.9'E	3244	20.0
MR00-K03	PC4	49°22.0'N	153°00.6'E	1821	20.6
Kuroshio extension area					
MR00-K05	PC1	34°30.0'N	147°30.0'E	5911	19.5
MR00-K05	PC2	40°00.0'N	146°00.0'E	5177	20.0

Mutsu Institute for Oceanography
Study on the past marine environmental changes

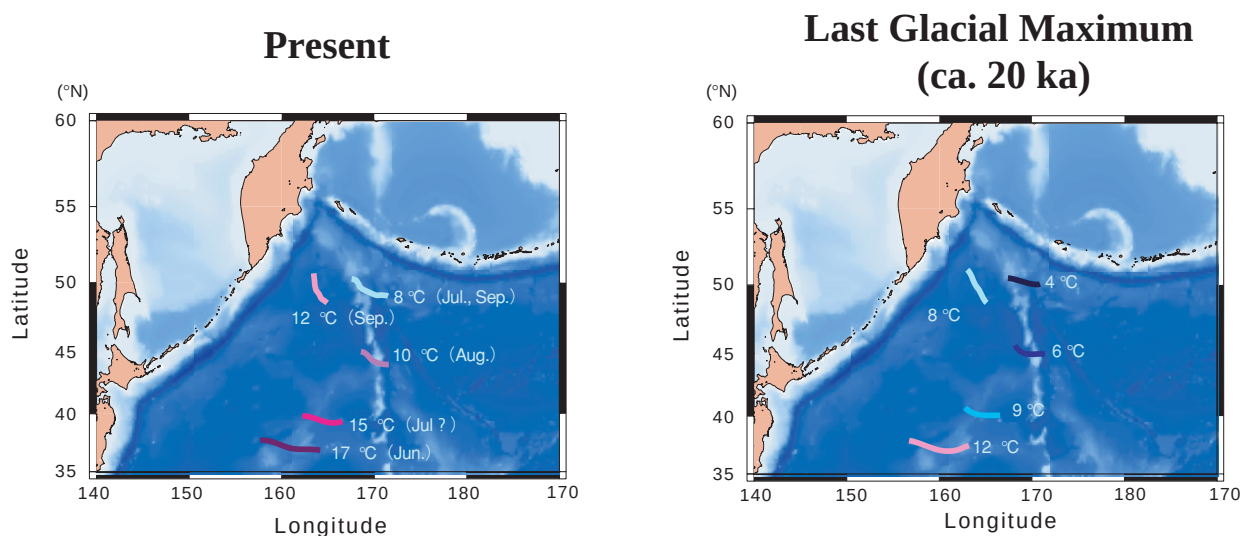


Fig. 1 The observed present sea surface temperature (SST) in each months at 10 m water depth (left) and paleo-SST in the last glacial maximum (LGM) which was reconstructed from alkenone (right).

struction of the earth surface condition and CO_2 inventory during the LGM.

- 2) The oxygen and carbon isotopes of planktonic foraminifera were applied to the core MR97-02 St. 8s, the Emperor Seamounts (44°47.2N, 170°09.6E, water depth: 1,784m). The oxygen and carbon isotopes were measured by Finnigan MAT252 in MIO. The oxygen isotope record showed that this core contained continuous marine environmental record for the last 400 kyrs.
- 3) Cd/Ca ratio of benthic foraminifera which relates to the oceanic PO_4 concentration of deepwater was measured for core MR97-02 St.8s by Thermo Finnigan ELEMENT 2 in MIO to reconstruct deepwater circulation in the western North Pacific. Cd/Ca (mole) ratio during the LGM was 20~30% lower than the Holocene (Figure 2). This data indicated that nutrient concentration in the Pacific deepwater (PDW) was reduced in the LGM and deepwater circulation pattern was different from today.

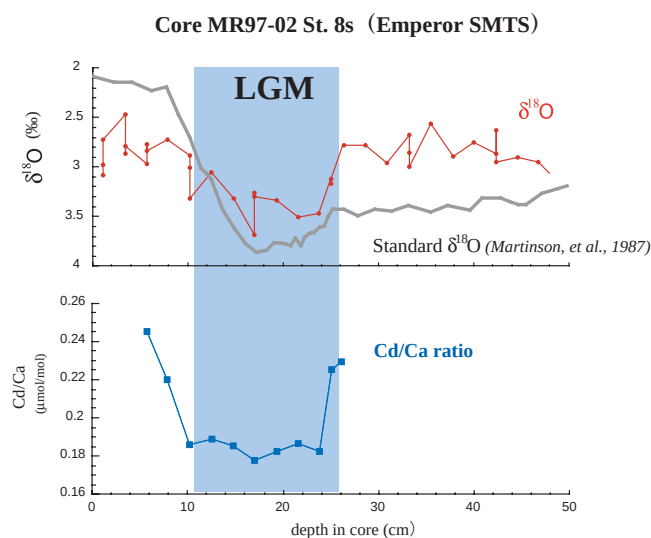


Fig. 2 Oxygen isotope record of planktonic foraminifera (top) and Cd/Ca ratio of benthic foraminifera (bottom) during the last 40 ka in core MR97-02 St. 8s which was recovered from the Emperor Seamounts.

Mutsu Institute for Oceanography

Facilities of the Mutsu Institute for Oceanography

Building

The Observation Equipment and Machinery Maintenance Shop maintains Triton buoys. The maintenance work involves use of paints and solvents. A dangerous object storehouse, for these paints and solvents, was installed next to the shop, as specified by the Fire Service Law. The Triton buoys are deployed for oceanographic observation in the Western Pacific Tropical sea area, an area of great influence on global climate changes.

Additionally, a garage was installed, to house three special-purpose business cars, in the parking lot in front of the Administration Office.

Facilities

The Mutsu Institute of Oceanography has purchased four containers, to store facilities of the Institute, and one container for temporary storage of waste liquid from the Sample Analysis Facility. The container for storage of waste liquid, and one of three for general facilities, are thermally insulated and equipped with ventilating fans and lighting.

The container for storage of waste liquid was placed on a vacant lot by the road beside the Sample Analysis Facility, and the four containers for storage of general facilities were placed in the container yard.

Table 1 shows the present status of the facilities of the Mutsu Institute for Oceanography.

Building name	Specifications	Total space (m ²)	Year of preparation	Remarks
Observation Equipment and Machinery Maintenance Shop	3-storey steel frame construction, partially ventilated	3,046.26	1995-1996	
Administration building	2-storey ferro-concrete building	521.90	1996	2-storey ferro-concrete building
Sample Analysis Facility	2-storey ferro-concrete building	1,942.59	1996-1997	
Mutsu Guest House	3-storey steel frame construction, 1-storey tower	1,547.42	1998	
Dangerous Object Storehouse	1-storey concrete block construction	21.00	2000	paints and solvents

Research Support Activities

Computer and Information Department**Activity overview**

The Computer and Information Department (CID) was established in FY 1998 through an integration and restructuring of the Technical Information Services and the Scientific Computing Division. The move was intended to establish an organizational unit that publicizes the activities of JAMSTEC through paper-based publications and web presence and manages and provides observation data efficiently regardless of the medium as an effective research results dissemination vehicle. CID engages in three types of activities. The first is information activities, which consist of the collection, management and publishing of publications and provision of technical advice. The second is data management activities, which consist of the processing of ocean observation data, its quality control and the development and management of databases. The third is scientific computing activities, which consist of the management of computers ranging from PCs to super-computers, provision of technical support to researchers and administration and designing of computer networks.

In addition to being equipped to fulfill the functions of research support and administration units, the CID contains a whole research organization for the development of information dissemination techniques based on the Internet and other media, their associated data processing technology and research support technologies relating to cutting-edge computational science.

The main aspects of the activities of the CID are summarized below.

(a) Information activities

- Collection, management, supply and storage of information relating to marine science and technology
- Technical consultation concerning marine science and technology
- Editing and publishing of publications

(b) Data management activities

- Enhancement of the quality of ocean observation data through calibration, accuracy improvement and other techniques
- Development and management of databases for various ocean observation data
- Numerical analysis, processing and storage of observed data

(c) Scientific computing activities

- Administration and management of computer systems and networks
- Computer-based data analysis and processing
- Investigation into cutting-edge computer technology

Information activities**(1) Collection, management and supply of books, periodicals and other publications**

The CID collects, sorts/classifies and stores a wide

range of oceanographic publications, including books, journals and technical reports. Continuing from the previous fiscal year, these publications were cataloged via a library information management and supply system (ILIS/X-EL) to make the Internet-based

Research Support Activities Computer and Information Department

"JAMSTEC Reference Collection Search Service" available.

The CID also strives to foster an environment that makes it easy for users to utilize books and other reference materials by, among other things, holding library material management consultation meetings.

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

The oceans, which dominate the Earth's surface, largely remain a mystery, and it is clear that no single organization or country can single-handedly take on ocean-related research and development. For this reason, the domestic and international cooperation of the organizations concerned and government-level cooperation of the countries concerned are essential. On the other hand, JAMSTEC's information needs concerning research and development and other activities are growing more com-

plex and diverse, while the amount of information relating to marine science and technology is increasing. Against this background, particularly in light of the current research and development trend towards more comprehensive, interdisciplinary and international activities, it is necessary to constantly update oceanographic information by maintaining cooperative relationships with relevant domestic and overseas organizations.

1) Domestic activities

a. The CID took part in the National Convention of the Japan Library Association and collected information on the libraries of other organizations.

b. The CID took an active part in the meetings of the Kanagawa Prefecture Data Research Society (KPDRS), an information exchange organization of the reference libraries of companies, public organizations, etc. based in Kanagawa Prefecture, and collected the latest information relevant to the improvement of the administration of the CID.

c. The CID took part in a seminar for technical library managers and administrators organized by the Technical Library Council, an association of technical libraries, as well as its general meeting, and collected the latest information on the management of library holdings.

2) International activities

Amid growing social demands over global environmental problems and other issues, it has become a worldwide trend to attempt to unveil the secrets of the oceans, which account for 70% of the Earth's surface area but have remained relatively inaccessible to humans, through international cooperation, and JAMSTEC's research and development efforts have been taking on a more and more global dimension. Against this background, the CID engages in information gathering activities geared towards keeping track of the activities of major countries and research institutes in Europe and North America, which lead the world in marine sci-

Table 1 Books

Type	Number in stock	Newly purchased
Japanese books	10,523	1,020
Foreign books	4,472	434
Donated books	488	84
Total	15,483	1,538

Table 2 Journals

Type	Number in stock	Newly subscribed
Japanese journals	559	35
Foreign journals	273	11
Total	832	46

Table 3 JAMSTEC related publications

Type	Newly published
Periodical	19 kinds
Consigned research report	2 kinds
Commissioned research report	0
Others	15 kinds
Total	36 kinds

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ence, and those of international organizations, as well as the progress of international research programs.

a. Management and supply of IOC publications

The Intergovernmental Oceanographic Commission (IOC) is an organization set up to advance human knowledge of natural phenomena involving the oceans and marine resources, and JAMSTEC began receiving IOC publications in FY 1993 as the second Japanese organization to do so. The latest information on IOC publication arrivals is posted in the JAMSTEC newsletter "Natsushima" as required.

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

IAMSLIC was established in 1975 to, among other things, facilitate the exchange of marine science information. Joining IAMSLIC in 1993, JAMSTEC is the only Japanese member organization. It took part in the 26th IAMSLIC annual conference, which was held in September 2000 in Victoria, Canada, and gave presentations titled the "Digitization of JAMSTEC Publications" and "JAMSTEC Databases".

c. Aquatic Sciences and Fisheries Abstracts (ASFA)

ASFA is an integrated official marine science and technology database run by four UN organizations, with FAO serving as the secretariat. JAMSTEC contributes to the database by submitting ASFA with English language abstracts for "JAMSTEC Deep Sea Research" and "JAMSTEC research reports".

d. Information on international organizations and international research programs

The CID continues to strive to gather information relating to international organization and research trends in light of their importance in determining the overall framework for future marine science research.

(3) Editing and publishing of publications

To widely disseminate its research results and raise awareness of the oceans, JAMSTEC edits and

publishes a variety of publications, with its FY 2000 publications listed in Table 4. In FY 1999, electronic publishing based on DTP software (QuarkXpress, PageMaker, Photoshop, Illustrator, etc.) was introduced by allocating the necessary resources, consisting of specialized staff and equipment (Apple PowerMac G4s, etc.), to the CID, thereby establishing a publishing system capable of turning out quality publications more quickly.

(4) Investigation and information services

JAMSTEC supplies both internal and external users with a variety of information/data to ensure their effective utilization.

1) Books and journals

- a. Inclusion of a guide to newly arrived publications in the JAMSTEC newsletter "Natsushima" as required
- b. Online contents viewing for newly arrived journals, made possible by a change in the format of the contents supply service from paper to electronic

2) Internal and external databases

- a. Publication search based on the JAMSTEC Reference Collection Search Service. For the locations of publications and other reference materials not held by JAMSTEC, outside databases are to be used. (Table 5)
- b. Supply of information on specific topics via the SDI service of the Japan Science and Technology Corporation (JST). External databases were used a total of 293 times.

3) Current information

- a. Supply of newspaper article information relating to the oceans via a daily e-mail newsletter??
- b. Supply of an index of newspaper articles relating to the oceans via the home page under the title "Headlines"

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- c. Supply of conference and exhibition information via the home page as required
 - d. Posting of IOC publication release information in the JAMSTEC newsletter "Natsushima" as required
- 4) Reference service, etc.
- a. Provision of a reference service for books, journals and other reference materials held by JAMSTEC
 - b. Provision of an advice and referral service on marine science and technology by serving as the point of contact for consultation requests from outside parties

(5) Operation of JAMSTEC web page

During the reporting fiscal year, the CID planned and implemented a renewal of both Japanese and English pages to help users obtain the desired information more easily and strove to develop an attractive web page that is more interesting for the general public, thereby stepping up the JAMSTEC information dissemination activity based on its web page. In addition, pages containing sea-related frequently asked questions were incorporated, while movies recording the activities at sea of JAMSTEC-owned research vessels and submersibles were produced and published.

Table 4 Publications by JAMSTEC

Title of publication	Content	Issue in fiscal 2000
Report of Japan Marine Science and Technology Center	Journal of academic theses on research achievements	Volumes 42 and 43
JAMSTEC Journal of Deep Sea Research	Journal of academic theses on achievements of deep ocean research	Volumes 17 and 18
Blue Earth	Educational journal on oceanic information	Volumes 47, 48, 49, 50, 51 and 52
JAMSTEC 1999 Annual Report (Japanese version)	Business report (Japanese)	Fiscal 1999 version
JAMSTEC 1999 Annual Report (English version)	Business report (English)	Fiscal 1999 version

Table 5 External Databases Currently Available

Database title	Outline
JOIS	Information on literature and research themes on science and technologies (Japanese and English)
STN International	More than 200 international databases are available (English)
G – SEARCH	Contact for Japanese/overseas databases (Japanese and English)
DIALOG	Approx. 450 databases are available (English)
NACSIS	Database for supporting academic research activities (Japanese and English)
AIREX	System for operating space literature by Japanese organizations and NASA (Japanese and English)
ASFA	International literature search system for fisheries (English)

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Data management activities

(1) Oceanographic data management activities

To achieve the efficient management and supply of observed data obtained from oceanographic surveys and deep-sea surveys involving the R/V Mirai and other JAMSTEC-owned vessels and submersibles based on the Guidelines on the Release of Observed Data at JAMSTEC, a data management system geared towards regularly implementing data quality control, accuracy improvement, etc. has been developed since FY 1998.

Continuing from the previous fiscal year, observation data obtained from Mirai joint-utilization voyages was managed in FY 2000, with such data published via the R/V MIRAI Data Web (Figure 1) based on the policy for handling data/samples and results obtained using the "Mirai".

In December 2000, data posted on the R/V MIRAI Data Web recorded 36,000 hits a month. While the bulk of the hits came from government bodies, universities, research institutes, etc., data was also accessed by private enterprises. The results of observation and research results using the R/V MIRAI have been submitted with a "results announcement notice", with 74 submissions received and released on the web as they were received in FY 2000. Detailed information is provided on the

R/V MIRAI Data web with regular updates.

In addition, quality control for public release data, the integrated management of the calibration of CTD sensors used on the R/V MIRAI, an investigation into the volume calibration of dissolved oxygen bottles, and the like were undertaken as part of Mirai joint-utilization observation data quality control efforts.

The integrated management of submarine topography survey data based on multi narrow beam echo sounders mounted on research vessels such as the R/V KAIREI, gravity and magnetism data, and other data was pursued, and submarine topography data sets to be registered with the submarine topography database were developed. To support the voyage plans and fisheries coordination by JAMSTEC, those data sets were visualized and displayed on web pages or plotted/supplied as charts (submarine topography map plotting and supply service), with the supply of electronic charts also launched (Figure 2).

(2) Database development

To properly manage and supply data collected by JAMSTEC, the CID has been developing databases. JAMSTEC plans to release the available data in the web. Regarding databases that have been developed individually, the development of an integrated public-

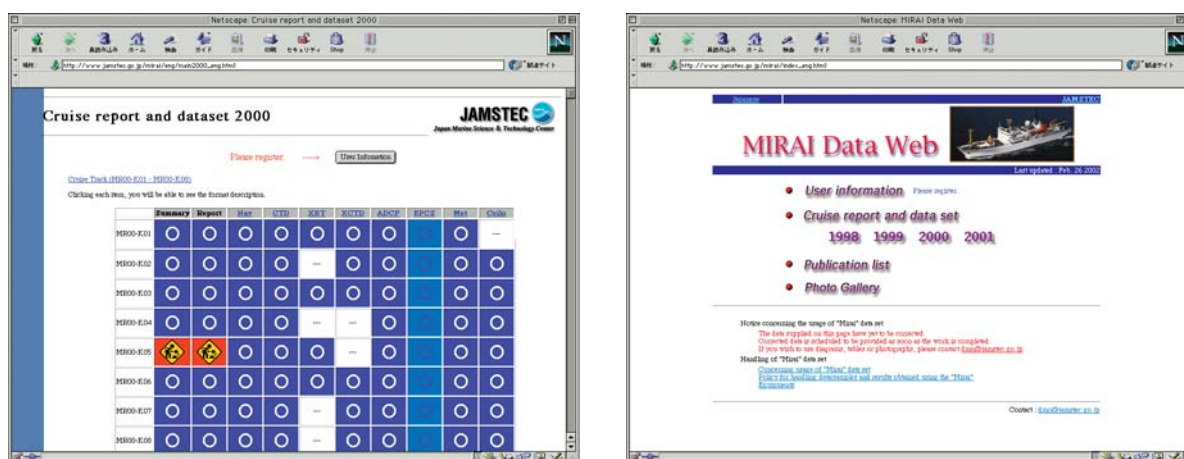


Fig. 1 Example of "R/V MIRAI Data Web" page

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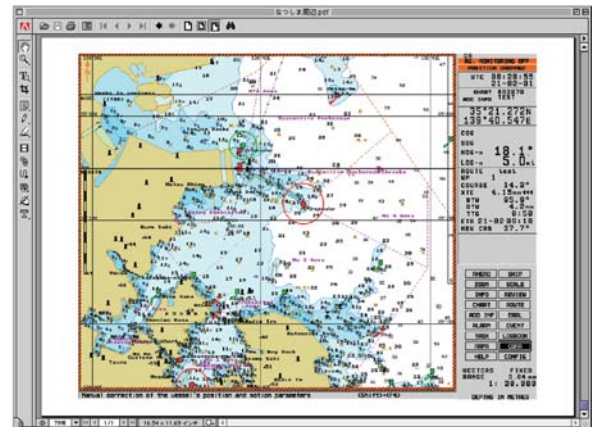
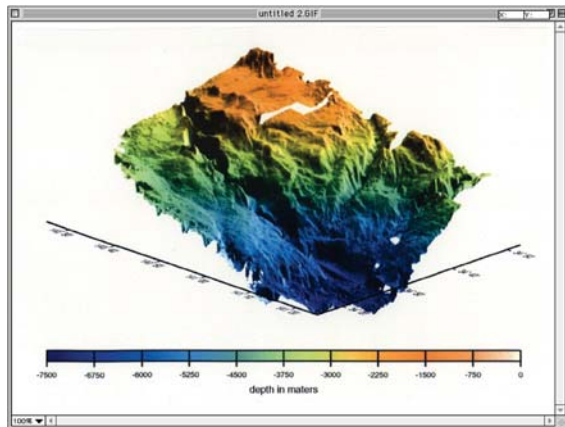


Fig. 2

access database aimed to make crosscutting searches and data supply has been under way with a view to making them available to the public. At present, final adjustments, centering on display features, are being made.

Databases that are currently operational or being developed include a research vessel operational information database, oceanographic survey database, deep sea image database, integrated public-access database, library holding management database and submarine topography database. An overview of databases developed or improved during the reporting fiscal year is given below.

1) Integrated public-access database

A database designed to enable cross-cutting search and retrieval of JAMSTEC-held data. Currently undergoing prototype development, the integrated public-access database will enable users to make diverse searches without worrying about the workings or attributes of individual databases. Figure 3 shows the database interface page.

2) Submarine topography database

A database designed to process bathymetry data obtained with SeaBEAMs, multi-narrow beam echo sounders (MNBES), mounted on the R/V Mirai,

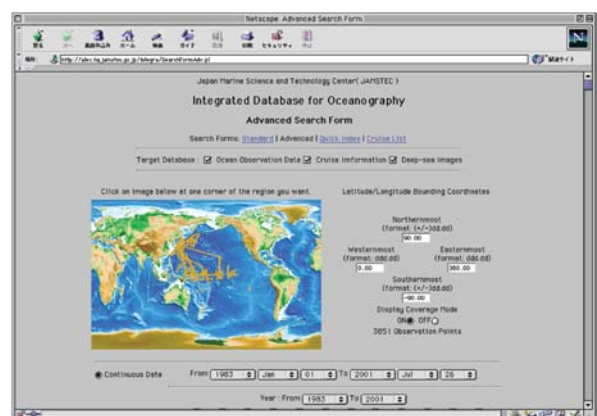


Fig. 3

Kairei, Yokosuka and Kaiyo and manage/supply the produced submarine topography maps and whale's eye view diagrams. It allows data search and on-screen viewing via a web interface. The interface was developed using JAVA and VRML. Figure 4 shows the database interface screen.

3) Research vessel operational information database

This database provides an operational information for research marine vehicles, including ships, submarines and unmanned explorers. Following the development of a Web-enabled version in FY 1996, the operability of the Web interface was improved in

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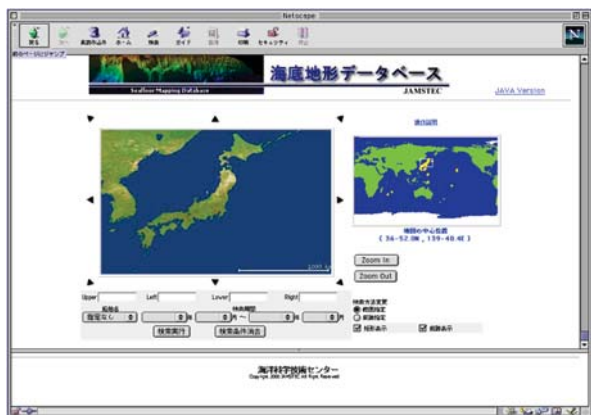


Fig. 4 Seafloor mapping database screen

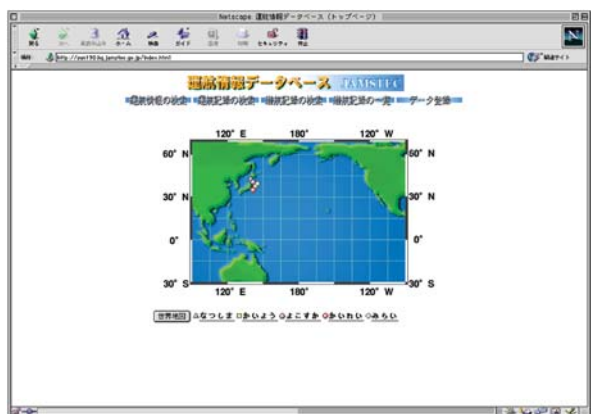


Fig. 5 Ship operations database screen

the previous fiscal year, with a trial run undertaken in the reporting fiscal year. Figure 5 shows the database interface screen.

Scientific Computing activities

(1) Earth simulator

In recent years, public awareness of global warming and other environmental problems of a global scale has been growing, and the resolution of these problems requires the elucidation of complex phenomena. To minimize the damage of natural disasters, including local meteorological disasters resulting from global phenomena and earthquakes caused by crustal

movements, it is important to understand their mechanisms and predict changes in the global environment. Towards this end, the Council for Aeronautics, Electronics and Other Advanced Technologies of the former Science and Technology Agency in July 1996 prepared a report that set six research goals, including global warming forecasting and climate change forecasting, and stressed the importance of a balanced and integrated research approach which would place equal emphasis on "process (basic) research", "observation research" and "simulation research" in achieving these goals. Against this background, the Earth Simulator Project was launched in FY 1997 to put in place an essential infrastructure for simulation research.

The Earth Simulator is a super-fast parallel computing system being jointly developed by the National Space Development Agency of Japan (NASDA), the Japan Atomic Energy Research Institute (JAERI) and the Japan Marine Science and Technology Center (JAMSTEC), with NASDA and JAERI (Power Reactor and Nuclear Fuel Development Corporation (PRNFDC) in FY 1997) undertaking the conceptual design, basic design and production/testing of experimental component technologies. JAMSTEC joined the project in March 2000, when it entered the system manufacturing phase. In December 2000, JAMSTEC completed an Earth Simulator building, simulator research building and cooling facility building on the former site of the Kanagawa Prefectural Industrial Research Institute in Showa-cho, Kanazawa-ku, Yokohama, following a decision made in March 1999 for it to take on the development of Earth Simulator-related facilities and other infrastructure.

Regarding the manufacture of the Earth Simulator system, the trial production of a 0.15-micron process multi-layer single-chip vector processor capable of 8 GFLOPS, high-speed memory with a full pipeline (FPLRAM) and other system components was undertaken in accordance with the detailed design in the

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reporting fiscal year, with various evaluation tests conducted on a single node unit, consisting of eight processors and 16 GB of shared memory. To connect 320 processor node cabinets and 65 interconnection network cabinets, about 83,000 pieces of network cable (2,800 km in total length) were laid on the free access floor of the computer room over four months starting in February.

In the future, it is planned to gradually bring in, install and adjust system components, such as the node and interconnection network cabinets, hard disk arrays and cartridge tape library system, starting in the summer of 2001. The Earth Simulator is scheduled to be ready for use in March 2002 after running a global atmospheric general circulation model on it to demonstrate an effective performance level of 5 TFLOPS. As the operational management of the Earth Simulator is the sole responsibility of JAMSTEC, the establishment of an Earth Simulator center in FY 2001 is planned.

(2) Computer systems

1) Supercomputer system

To gain a good scientific grasp of global environmental problems, it is important to understand the role played by the vast oceans, and this makes it essential to elucidate oceanographic phenomena through scientific computing analysis and predict changes using numerical models, not to mention performing instrumental precision observations. In recognition of the essential need for a super computer with a massive memory capacity to efficiently carry out research in these areas, the introduction of a supercomputer at JAMSTEC was approved under the FY 1995 budget. The computer became operational on March 1, 1996.

As shown in Figure 9, the supercomputer system is built around an NEC SX-4/20, with magneto-optic disk arrays, high-speed disk arrays, a front-end server, etc. connected to it via 800 Mbps HIPPI channels. It is



Fig. 6 Simulator Building



Fig. 7 Computer Room

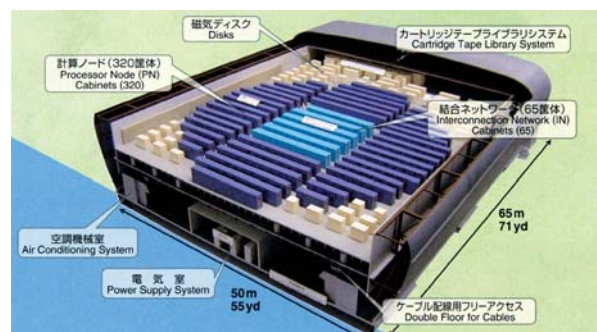


Fig. 8 Image of Earth Simulator

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connected to the JAMSTEC LAN via an FDDI cross-bar switch (GIGAswitch).

At Supercomputing 2000 (SC2000), an international conference and exhibition on supercomputing held in Dallas, Texas in November 2000, JAMSTEC exhibited the results of its supercomputer-based research and other materials. Dating back to 1988, the annual supercomputing conference series, of which SC2000 is one, provide a forum for the presentation and exhibition of the latest computing technologies and supercomputer-based computational results, and are attended by computer manufacturers, research institutes and other supercomputer users from all over the world. Exhibiting for the second time at these conferences - the first being SC99 in 1999 - JAMSTEC explained the use of a supercomputer in the marine science and technology area with panel exhibits, pamphlets and

movies in its booth.

2) Common computer systems

As JAMSTEC has accumulated application software developed for the VMS operating system over the years, the DEC 7620 (OpenVMS Alpha) VMS cluster system was upgraded to the AlphaServer 4100- at the end of September 1998. The AlphaServer 8400 is being used as a UNIX server running under Digital UNIX IBM SP 8-node, a distributed-memory parallel computer, also installed in FY 1996.

These common computer systems cover JAMSTEC organization, with about 800 users registered as of the end of FY 2000 according to e-mail accounts.

(3) Networks

1) JAMSTEC network

JAMSTEC established a the local area network at

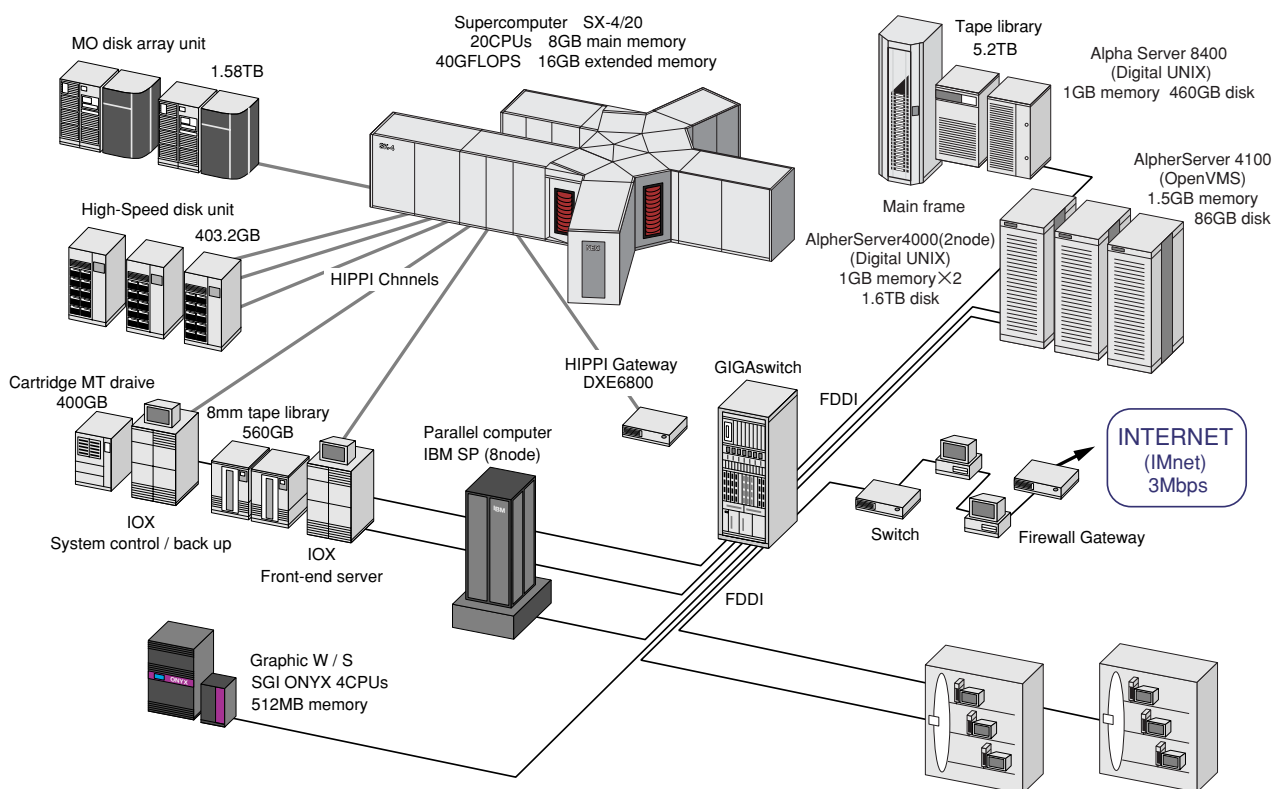


Fig. 9 JAMSTEC's computer system

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its Yokosuka headquarters in FY 1993, with branch LANs speeded up in FY 1998. In FY 2000, new buildings network were connected into the JAMSTEC LAN, with a total of 14 buildings networked by the end of the fiscal year. This network consists of a 100 Mbps FDDI (fiber-optic cable) backbone interconnecting individual buildings via an FDDI crossbar switch (GIGAswitch) located in the computer and scientific building and Ethernet (10base-T/100base-TX) branch LANs covering individual buildings.

Figure 10 shows the WAN topology for the Yokosuka headquarters and other sites. The Tokyo Blunch was connected to the Yokosuka LAN in 1994, and the link speed has since been upgraded to a 128 kbps leased line, along with the Frontier Research Promotion Office. The Mutsu Institute was connected to the Yokosuka headquarters in March 1996, with the link upgraded to a 128 kbps line in October 1988 and again to a 512 leased line in March 2001. The Yokohama campus, which is scheduled to become fully operational in FY 2001, was connected to the Yokosuka headquarters in March 2001 via ATM 100 Mbps.

In view of the recent increase in the number of network users and terminals as well as the expected jump in the network load upon the commencement of fully fledged operation at the Yokohama campus in FY

2001, the domain "jamstec.go.jp" was divided into individual site-based subdomains in March 2001 to balance the network load and streamline network operation and management.

2) Internet

JAMSTEC was connected to the Internet via the Todai International Science Network (TISN) in January 1993. In October 1994, JAMSTEC was connected to STAnet, a network designed to interconnect research institutes affiliated with the former Science and Technology Agency, via a 768 kbps leased line, with the link upgraded to a 1.5 Mbps line in July 1996. In May 1998, the connection was switched to IMnet, with the link upgraded from a 1.5 Mbps leased line to a 3 Mbps ATM in March 2001. The introduction of this high-speed link has made it possible to handle image data and movies that require a large bandwidth more effectively.

To disseminate information via the Internet, JAMSTEC set up a WWW server and launched a web page in September 1994. The URL is "http://www.jamstec.go.jp/". The number of hits increased dramatically in July 1998, when the Deep Seafloor Image Database was made available for public access. Figure 11 shows the monthly trend of the number of accesses made to the WWW server.

(4) Security

JAMSTEC introduced a firewall at the interface between its LAN and the Internet in June 1996 to ensure computer security. In March 1997, the firewall was upgraded to a dual firewall to enhance system resistance to disturbances. The system has been constantly reviewed and upgraded to maintain a balance between the level of service and security, and this has resulted in a very solid firewall.

The introduction of an the intrusion detection system, regular network security checks, the application of security patches and upgrading of network

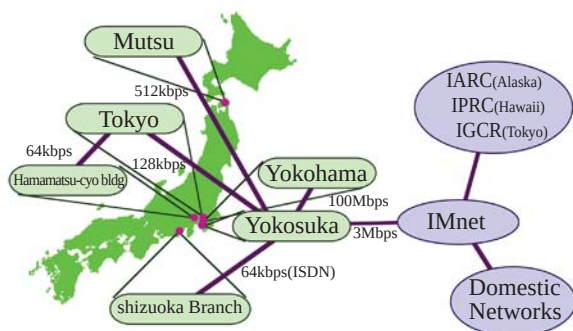


Fig.10 Network topology

Web server access count

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

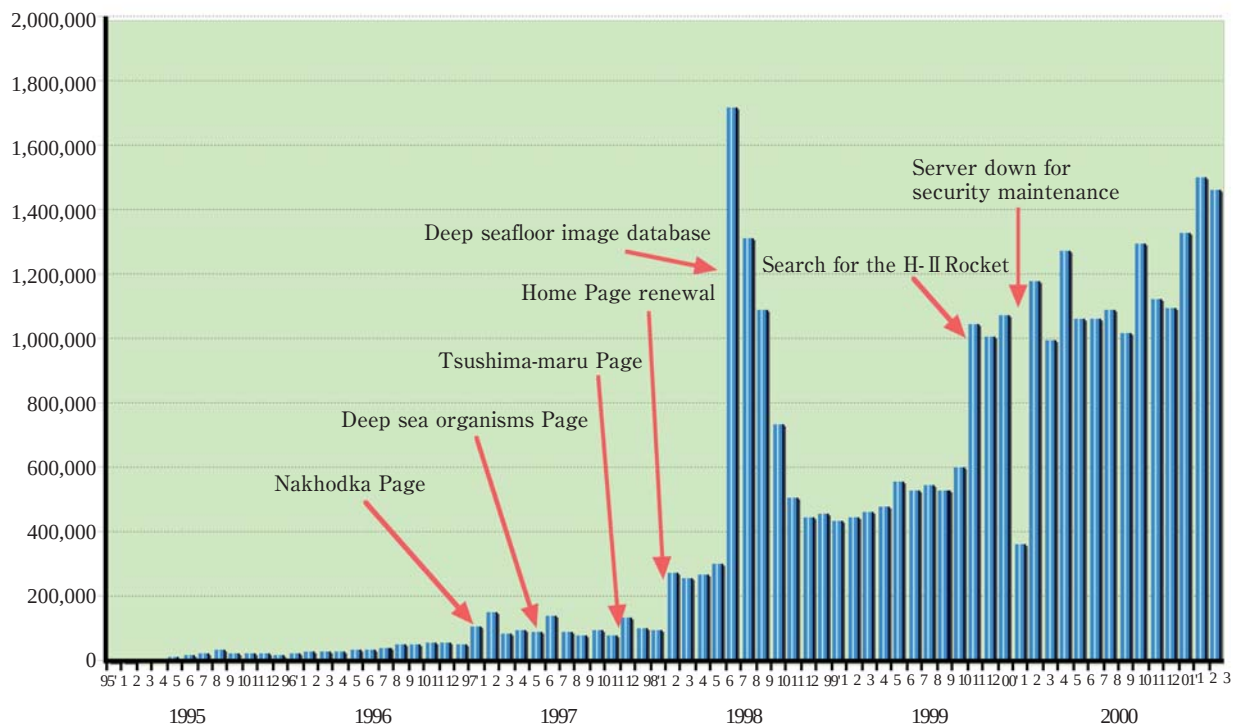


Fig.11 Access count of JAMSTEC WWW Server

service applications ensure the maintenance of a high level of security.

With regard to virus protection, a virus scanning function was incorporated into the server in March

2000 to detect viruses in the incoming data at the server level and prevent them from spreading over the network.

Research Support Activities

Training and Education Activities

Outline

In order to conduct underwater work safely, it is important to have as many competent talents as possible because of special skills and knowledge required. For this purpose JAMSTEC has had training courses for diving techniques for researchers, engineers and rescue members.

In recent years, students in Japan especially high school students have lost interest in pursuing science. It should not be ignored matter in the marine science field ensuring the enough future talents. JAMSTEC also has had education course for marine science and technology for students and schoolteachers.

In addition to these training and education courses, JAMSTEC has started "Asia-Western Pacific Ocean Research Network program", a new training program for ocean observation technology and data processing.

1. Diving training courses

Diving operation in underwater involve many dangers and many lives have been lost in diving accidents. To prevent these accidents, these must be training and education. While we have a license system for professional divers administered by the Japanese Ministry of Labor, but the license examination consists of writing examinations only and no examination on skills is required. For recreational divers, many training courses are held at commercial diving shops. For professional divers, there are but a few training courses in Japan.

Under such circumstances JAMSTEC has had training and education courses for diving techniques since

the establishment of in 1972 and over 4,000 people participated as of the end of 2000. There have been changes in their programs to meet the demand of the time. The Mixed Gas Diving course for deep-sea divers was held once a year from the beginning until 1985. And the SCUBA (Self-Contained Underwater Breathing Apparatus) Diving course has been in operation since 1986 and more than 200 persons attend the course annually for the last every 3 years. Another course for diving supervisors, that is, the Diving Management course have been operated regularly, once or twice a year, since 1987.

(1) SCUBA diving training course

This course is held by request of organizations related to diving work, 336 trainees including rescue members of the police and the fire fighting service, fisheries high school students and those employed by companies attended the courses in fiscal 2000.

(2) Diving Management course

The course was held from November 13 to 17 in 2000, 12 persons from seven organizations attended.



Photo 1 Lecture on the diving training course.

2. Marine science education programs

(1) Science Camp

Science Camp was held by 21 national experiment and research institutions, and five organizations under

Research Support Activities Training and Education Activities

direct supervision of the Science and Technology Agency. JAMSTEC accepted 28 high school students from all parts of Japan for three day during the summer vacation (from August 7 to 9, 2000) at headquarters campus in Yokosuka.

(2) Marine Science School programs

The Marine Science School programs have been operated every year since 1996 with the financial assistance of the Nippon Foundation. 25 teachers attended the course for teachers from July 31 to August 2, 2000. And 46 students attended the course for high school students from August 16 to 18.

Another education course for university students



Photo 2 Earnest looks at "Tube-worm" of high school students in Marine Science School.



Photo 3 University students of Marine Science School in front of the research vessel "Mirai".

and postgraduate students has been operated from 1999 at the Mutsu branch. The first seminar of this year was held from August 1 to 4, and the second from October 9 to 12; a total of 15 students attended.

(3) Training Program for Asia-Western Pacific Ocean Research Network

JAMSTEC has started training program for establishing an oceanographic observation network in the Asia and Western Equatorial Regions with the financial assistance of the Nippon Foundation. This program would be an initiative to share the knowledge on the past and current ENSO events as well as data on the ocean and atmosphere among participating countries, and enable them in predicting such events and making measures in future.

The first training workshop was held from January 15 to March 9, 2001 (8 weeks) at headquarters campus in Yokosuka and at the Mutsu branch. 6 scientists and engineers attended from Papua New Guinea, Indonesia, Philippines, Micronesia, Kiribati, and Fiji.

The training workshop focused on the technologies for oceanic and atmospheric observations, especially on maintaining TRITON buoy system (an oceanographic observation buoy that has been deployed in the tropical regions by JAMSTEC) and equipment on-board the research vessel Mirai.



Photo 4 Data processing training of "Asia-Western Pacific Ocean Research Network program".

Research Support Activities
Training and Education Activities



Photo 5 Trainees and TRITIN bouy will be deploy in the ocean aroud there country.



Photo 6 Theirs first experience of "snowstorm"

Research Support Activities

Ship Operation Department

JAMSTEC's SHINKAI 2000 System consists of the SHINKAI 2000, a research submersible vessel; its support vessel: the NATSUSHIMA, and the DOLPHIN-3K, a remotely operated vehicle. The SHINKAI 6500 System consists of the SHINKAI 6500, a research submersible vessel; its support vessel, the YOKOSUKA; a 10,000-meter-class remotely operated vehicle: the KAIKO, and a 3,000-meter-class remotely operated vehicle: the HYPER DOLPHIN. JAMSTEC also has the KAIYO, an ocean investigation ship; the KAIREI, a deep-sea research vessel, and the MIRAI, an ocean and earth research vessel. Equipped with all these facilities, JAMSTEC has executed various testing and research activities in marine science and technology, notably in deep sea explorations and oceanographic observations.

Regarding management and operation of these vessels and facilities, JAMSTEC directly operates and maintains research submersible vessels and remotely operated vehicles. JAMSTEC consigns operation and general maintenance of support vessels and various research vessels to ship operation companies.

The operation plan for fiscal 2000 was as follows. The SHINKAI 2000 conducted research dives in the sea area of the Nansei Islands, sea areas off Shikoku Island, Suruga Bay, Sagami Bay, the Sea of Enshu, the Nankai Trough, sea areas off the east and west coasts of Hokkaido Island, and Izu-Ogasawara sea areas near the Japanese Archipelago.

The DOLPHIN-3K conducted preliminary surveys of the planned diving routes of the SHINKAI 2000, to confirm safety of the routes. Also, the DOLPHIN-3K conducted research dives in sea areas of the Nansei Islands, off the Sanriku coast, in Izu-Ogasawara sea areas, and in the Nankai Trough.

The HYPER DOLPHIN conducted diving training and recovery of ocean bottom seismographs.

The KAIYO made voyages to support diving operation of the HYPER DOLPHIN. Also, the KAIYO conducted research observations and examination of the earth's crust below the seafloor, in sea areas in the tropical Pacific Ocean, and sea trials of the R-1 robot. In addition, associated with the eruption on Miyakejima Island, the KAIYO conducted an emergency seismological survey, from October 26 to November 5, in the sea areas around the island.

The SHINKAI 6500 conducted research dives to the Japan Trench, the Nankai Trough, in sea areas of the Nansei Islands, and in the Izu-Ogasawara sea area.

In addition to voyages to support diving operations of the SHINKAI 6500, the YOKOSUKA supported sea trials of the URASHIMA, a deep sea cruising AUV, which started this fiscal year. The YOKOSUKA also conducted research observation in a study of seafloor dynamics, in the sea area surrounding the Mariana Islands and the Sunda-Java submarine trench. During the research in the latter sea area, the YOKOSUKA called at the Port of Jakarta, for the first time. The YOKOSUKA participated in emergency seismological observation around Miyakejima Island, from December 7 to December 13, following the KAIYO and the KAIREI.

The KAIKO conducted exploratory dives in the sea areas of the Rodriguez Triple Junction and the Southwest Indian Ridge in the Indian Ocean, and in the central part of the Mariana sea area, the Northwest Pacific Ocean, the sea area off Kushiro, Hokkaido; the Japan Trench, and the sea area of the Nansei Islands (VENUS sea area).

In addition to voyages supporting the KAIKO, the KAIREI conducted observational research by means of

Research Support Activities Ship Operation Department

a multichannel seismic profiler (MCS profiling) aboard the KAIREI, in the Japan Trench, submarine trenches from off the coast of Miyagi Prefecture to off the coast of Aomori Prefecture, and off the southeastern coast of Hokkaido Island. Additionally, the KAIKO conducted emergency MCS profiling in the sea areas around Miyakejima Island and Kozushima Island, where eruptions had occurred. The KAIREI also surveyed the Indian Ocean, using the DEEP TOW and a multi-narrow-beam echo sounder and other instruments, and conducted a confirmation test of BENKEI, a borehole utilization system.

The MIRAI was used for a number of studies. These are “Observational Studies on the Material Cycle in the High Latitude Sea” (northwestern part of the North Pacific Ocean), “Observational Studies on Air Sea Interaction” (tropical western sea area of the Pacific Ocean), “The Subtropical Gyre and the Subpolar Gyre in the North Pacific Ocean” (sea area of the east of Honshu Island), “Observational Studies in the Arctic Ocean” (the Beaufort Sea, Chukchi Sea, Bering Sea), “Observational Studies in the Western Tropical Pacific Ocean and Observational Studies on Air Sea Interaction” (western tropical sea areas of the Pacific Ocean and tropical sea area of the Indian Ocean), “Observational Studies on Primary Productivity in the Equatorial Pacific Ocean” (western tropical sea area of the Pacific Ocean), and “Observational Studies in the Western Tropical Pacific Ocean.” JAMSTEC carried out scheduled maintenance and repair work on all vessel as usual, and various modifications to improve their functions.

Operation of the SHINKAI 2000/NATSUSHIMA

The NATSUSHIMA executed 12 operations in fiscal 2000. Table 1 and Figure 1 show performances and sea areas of operation, respectively.

These are seven operations of the SHINKAI 2000, and six of the DOLPHIN-3K.

The plans for diving research were first formulated by the Deep-Sea Research Implementation Program Coordination Sub-Committee, followed by discussion within the Deep-Sea Research Promotion Committee, and then the plans were finalized by the Board of Directors of JAMSTEC. The diving research was done according to the fiscal year plans thus determined.

The fiscal 2000 plan called for seven operations, including 90 dives (including test and training dives). Actually, the SHINKAI executed 71 exploratory dives,

and 16 tests and training dives, for a total of 87 dives, in the sea areas of the Nansei Islands, the Sea of Japan, sea areas off the east and west coasts of Hokkaido Island, the sea area off the Sanriku Coast, the Izu-Ogasawara sea area, Sagami Bay, and Suruga Bay.

The DOLPHIN-3K conducted two diving tests, and pre-dive surveys to confirm the safety of the diving routes for SHINKAI 2000. Also, the DOLPHIN-3K executed 46 exploratory dives in the sea area of the Nansei Islands, off the coast of Sanriku, off the east coast of Hokkaido Island, and in the sea areas of Izu-Ogasawara. The DOLPHIN-3K made a total of 50 dives in fiscal 2000 plans.

In its independent operation, the NATSUSHIMA executed “Earth's Crust Heat Flow Observational Studies” (Nankai Trough), the “Single-Channel Seismic Profiler (SCS) Operation” (off Aitape, Papua New Guinea), and “Inspection and Maintenance

Research Support Activities Ship Operation Department

Works of the Observation System of Okinotorishima Island” (Okinotorishima Island).

The NATSUSHIMA was opened for public visitation on July 20, at Tagonoura Port, and on August 19 and 20, at Kashiwazaki Port, when the NATSUSHIMA called at these ports during operation.

Operation of the SHINKAI 6500/YOKOSUKA

The YOKOSUKA executed 13 operation as fiscal 2000 plans. Table 2 and Figure 2 show performances and sea areas for operation, respectively.

These are five diving operations of the SHINKAI 6500, and the YOKOSUKA's eight independent operations.

The plans for diving research were first formulated by Deep-Sea Research Implementation Program Coordination Sub-Committee, followed by discussion within the Deep-Sea Research Promotion Committee, and then the plans were finalized by the Board of Directors of JAMSTEC. The diving research was done according to the fiscal year plans thus determined.

The fiscal 2000 plan called for five operations, including 71 dives (including test and training dives). Actually, the SHINKAI 6500 executed 56 observation dives and 10 tests and training dives, for a total of 66 dives, in the Japan Trench, the Nankai Trough, sea areas of the Nansei Islands, and Izu-Ogasawara sea areas. In the tests and training dives, the YOKOSUKA took the UROV7K, a remotely operated vehicle, and conducted performance tests on the vehicle.

In its independent operation, the YOKOSUKA executed sea trials of the URASHIMA, a deep sea cruising AUV, four times (Suruga Bay and Sagami Bay), and three operations in a study of seafloor dynamics, in the sea area surrounding the Mariana Islands, the sea area to the east of the Mariana Islands, and the Sunda-Java submarine trench. The YOKOSUKA executed one operation of emergency seismological

observation around Miyakejima Island, from December 7 to December 13, following the KAIYO and the KAIREI.

On March 28, the Emperor and Empress visited JAMSTEC, with Norway's King and Queen Harald V, in a tour to Kanagawa Prefecture. The Emperor and Empress and their Majesties boarded the YOKOSUKA and observed the SHINKAI 6500. The YOKOSUKA and the SHINKAI 6500 were opened for public visitation, on July 20, at Shimizu Port, and on August 19, at Karatsu Port, when the YOKOSUKA called at these ports during operation.

Operation of the KAIREI/KAIKO

In fiscal 2000, the KAIREI executed 12 operations. Table 3 and Figure 3 show performances and sea areas for operation, respectively.

These are two tests and training operations of the KAIKO, the KAIKO's exploratory dive, and four independent observatory operations of the KAIREI; three MCS observational researches, and three confirmation tests on BENKEI, the borehole utilization system.

The KAIKO made five tests and training dives, and 28 dives in the Indian Ocean (the Rodriguez Triple Junction to the Southwest Indian Ridge), the Central Mariana sea area, the Northwestern Pacific Ocean, the sea area off Kushiro on Hokkaido Island, the Japan Trench, and the Nansei Islands (VENUS Sea Area).

To examine the earth's crust below the seafloor, the KAIKO conducted multichannel seismic profiling in the Japan Trench, sea areas off the coasts, from Miyagi Prefecture to Aomori Prefecture, as well as in the Chishima Trench and sea areas off the southeastern coast of Hokkaido. Also, the KAIKO conducted emergency multichannel seismic profiling, from November 21 to November 27, in the sea areas near Miyakejima Island and Kozushima Island.

Research Support Activities Ship Operation Department

The KAIREI conducted some operations apart from the KAIKO. The KAIREI conducted observational research in the Indian Ocean (the Rodriguez Triple Junction to the Southwest Indian Ridge), using the DEEP TOW and multi-narrow-beam echo sounders aboard the KAIREI. The KAIREI also executed confirmation tests of BENKEI, a borehole utilization system.

The KAIREI and the KAIKO were opened for public visitation, on April 29, at the Mutsu Institute for Oceanography, and on May 13, at the JAMSTEC Yokosuka Headquarters.

Operation of the KAIYO/HYPER DOLPHIN

In fiscal 2000, the KAIYO executed 13 operations. Table 4 and Figure 4 show performances and sea areas for operation, respectively.

These were four operations for operation training on the HYPER DOLPHIN, and two other operations: the “Ocean Acoustic Tomography” (tropical sea areas of the Pacific Ocean); and the “Tropical Pacific Ocean Climate Studies” (TOCS) (western sea area of the Pacific Ocean).

Regarding development and testing of observation instruments, the KAIYO executed three projects: the “Development of Acoustic data transmission system” (Suruga Bay and the Nankai Trough), “Development and Preparation of the Ocean Floor Earthquakes Integrated Observation System” (Suruga Bay), and the “R-1 Robot Sea Trial.”

Regarding marine ecological research, the KAIYO conducted one operation with the DEEP TOW system, in Sagami Bay.

The KAIYO executed two examinations of the earth's crust below the seafloor, in the sea areas off the coasts, from Aomori to Iwate Prefectures, and in the sea area off the east coast of Hokkaido Island, by means of the multichannel seismic profiler and the

ocean bottom seismograph (OBS). After the eruption on Miyakejima Island, the KAIYO conducted seismological exploratory research, using the OBS, in the sea areas near Miyakejima Island and Kozushima Island.

The KAIYO stood by in Yokosuka Port from February 15 to March 12, with the HYPER DOLPHIN fully fitted, ready to go search the Ehime Maru, a shipping training boat of Uwajima Fisheries High School in Ehime Prefecture. The Ehime Maru sank in February after a collision with a U.S. submarine off Oahu of the Hawaiian Islands.

The KAIYO was opened to visitors on July 24, at Monbetsu Port, and on November 10 and 11, at Kobe Port, which the KAIYOU called at during operations.

Operation of the MIRAI

The MIRAI executed seven operations in fiscal 2000. Table 5 and Figure 5 show performances and sea areas for operation, respectively.

These seven operations were all joint-utilization-type oceanographic observation research. These are the “Observational Studies on the Material Cycle in the High Latitude Sea,” “Observational Studies on Air Sea Interaction,” “The Subtropical Gyre and the Subpolar Gyre in the North Pacific Ocean,” “Observational Studies in the Arctic Ocean,” “Observational Studies in the Western Tropical Ocean and the Eastern Indian Ocean, and Air Sea Interaction,” “Observational Studies on Primary Productivity in the Equatorial Pacific Ocean,” and “Observational Studies in the Western Tropical Pacific Ocean.”

The MIRAI was opened to visitors, on August 23, at Seattle Port in the United States, and on August 26, at Victoria Port in Canada. A special public exhibition of the MIRAI was held on November 21, in Jakarta.

Research Support Activities

Ship Operation Department

Table 1

Operations Schedule of SV "NATSUSHIMA" in 2000 Fiscal year

SHIP NAME	Apr. 00		May.		Jun.	
NATSUSHIMA	NT00-04 SHINKAI2000 Support operation		NT00-05 DOLPHIN-3K Support operation	NT00-06 SHINKAI2000 Support operation	NT00-07 DOLPHIN-3K Support operation	NT00-08 SHINKAI2000 Support operation
	Suruga bay Sagami bay	Enshu Nada Nankai Trough	19 22 Nansei Islands	6 8 Nansei Islands	31 11 Nansei Islands	15 16 Nansei Islands
SHIP NAME	Jul.		Aug.		Sep.	
NATSUSHIMA			NT00-09 DOLPHIN-3K	SHINKAI2000 Support operation	DOLPHIN-3K SHINKAI2000	NT00-10 DOLPHIN-3K Support ope.
	13 off shikoku Suruga bay Sagami bay	Enshu Nada Nankai Trough	21 off Hokkaido Japan sea	5 8 Japan sea	25 29 off east Hokkaido off Sanriku	9 11 21 23 Izu ogasawara
SHIP NAME	Oct.		Nov.		Dec.	
NATSUSHIMA	NT00-11 SHINKAI2000 Support operation		NT00-12 DOLPHIN-3K SHINKAI2000 Support operation	DOLPHIN-3K SHINKAI2000		
	2 Izu ogasawara	26 29	3 4 Izu ogasawara	16 17 Sagami bay Suruga bay	25 26	8 17
SHIP NAME	Jan. 01		Feb.		Mar.	
NATSUSHIMA	Annual Inspection		NT01-01 Single-channel Seismic Profiler(SCS)operation		NT01-02 DOLPHIN-3K Support ope.	NT01-03 SHINKAI2000 Support ope.
	22 24	cruising	5 6 Papua New Guinea	23 24	6 Suruga bay Sagami bay	11 17 24 Suruga bay Sagami bay

DOLPHIN-3K: Unmanned Remotely Operated Vehicle
SHINKAI 2000: Deep sea research submersible (Manned)

Table 2

Operations Schedule of SV "YOKOSUKA" in 2000 Fiscal year

SHIP NAME	Apr. 00		May.		Jun.	
YOKOSUKA		Annual Inspection	Sea Trial		YK00-04 SHINKAI6500 Support operation	
	5	10	17 Enshu Nada	23	Japan trench	23 27
SHIP NAME	Jul.		Aug.		Sep.	
YOKOSUKA	YK00-05 AUV Support ope.	YK00-06 SHINKAI6500 Support operation	YK00-07 AUV Support ope.		YK00-08 SHINKAI6500 Support operation	
	6 10 Sagami bay	Nankai trough Nansei Islands	22 29 Sagami bay	1	Izu ogasawara Nankai Trough	
SHIP NAME	Oct.		Nov.		Dec.	
YOKOSUKA	YK00-09 AUV Support ope.	YK00-10 SHINKAI6500 Support operation	YK00-11 AUV Support ope.	YK00-12 Research sea floor dynamics		
	6 7 Suruga bay	16 19 Nankai trough	21 25 Suruga bay	4 Izu ogasawara Mariana area	6 26	
SHIP NAME	Jan. 01		Feb.		Mar.	
YOKOSUKA		YK01-01 Research for sea floor dynamics			YK00-02,03 SHINKAI6500 Support operation	
	4 Mariana area	16 17 Guam 25 27 Jakarta Sunda-Jawa trench	9 11 Jakarta	19	1 Nansei Islands	31

SHINKAI 6500: Deep sea research submersible (Manned) AUV: Autonomous Underwater Vehicle

Research Support Activities

Ship Operation Department

Table 3

Operations Schedule of RV "KAIREI" in 2000 Fiscal year

SHIP NAME	Apr. 00		May		Jun.	
KAIREI	KR00-01 KAICO Support ope. 5 off east Ogasawara	KR00-02 MCS operation 21 off southeast Hokkaido	10	KR00-03 KAICO Support operation 15	11	KR00-04 MCS operation 15 off Sanriku Japan Trough
				Nansei Islands Mid Mariana area of the Pacific Ocean		
SHIP NAME	Jul.		Aug.		Sep.	
KAIREI				KR00-05 KAICO Support operation	Port Louis	
	15	cruising Port Hedland 20 30 1 3		Indian Ocean Rodriguez Triple Junction	2 5	29 Indian Ocean South West Indian Ridge
SHIP NAME	Oct.		Nov.		Dec.	
KAIREI	Port Louis 2	cruising	KR00-07 KAICO Support operation	17	Reconstruction	
		21 25	Japan Trough off far Sanriku off Kushiro off Miyagi	22		
SHIP NAME	Jan. 01		Feb.		Mar.	
KAIREI	KR01-01 New ROV Trial	4 5 14	Annual Inspection	KR01-02 New ROV Trial	KR01-03 Cable freefall & KAICO Support operation	KR01-04 New ROV Trial
		15		23 24	5 6 11 off east Ogasawara	16 22 24 31

KAICO: Unmanned Remotely operated vehicle MCS: Multichannel Seismic Profiler Deep tow: Towing type deep sea bottom exploration

Table 4

Operations Schedule of RV "KAIYO" in 2000 Fiscal year

SHIP NAME	Apr. 00		May		Jun.	
KAIYO	Annual Inspection		Sea Trial 3 10 Nankai Trough	KY00-01 HYPER DOLPHIN Support operation 14 23 Sagami bay Suruga bay Nankai Trough	KY00-02 Multichannel Seismic Profiler(MCS) operation 29 off iwate	23 29
SHIP NAME	Jul.		Aug.		Sep.	
KAIYO	KY00-03 HYPER DOLPHIN Support ope. 5 8 Sagami bay Suruga bay Izu Ogasawara	KR00-04 Research for Deep-sea ecosystem operation 12 16 Sagami bay off south Hokkaido	KY00-05 MCS operation 14	KY00-06 Tropical Pacific Ocean climate studies(TOCS) Chuuk 20 2931	Kavieng 11 13 western tropical area of the Pacific Ocean	
SHIP NAME	Oct.		Nov.		Dec.	
KAIYO	Palau 2 4 12	cruising	KY00-07 R-1 robot Sea Trial 14 Myojin-sho volcano	KY00-08 HYPER DOLPHIN Support ope. Kobe 1 4 9 12 Suruga bay Nankai trough	KY00-10 Long-Term deep sea floor observation 3 off Sanriku Miyagi	cruising 22
				Sagami bay off east Hokkaido		
SHIP NAME	Jan. 01		Feb.		Mar.	
KAIYO	KY00-11 Ocean Acoustic Tomography Majuro 2 4	Majuro 17 19 Mid tropical area of the Pacific Ocean	Majuro 1 3	cruising 15	KY01-01 Research for sea floor dynamics Guam 1 15 17 29	cruising
					Mariana area of the Pacific Ocean	

HYPER (HYPER DOLPHIN) : Unmanned Remotely Operated Vehicle

Research Support Activities
Ship Operation Department

Table 5
Operations Schedule of RV "MIRAI" in 2000 Fiscal year

SHIP NAME	Apr. 00	May.	Jun.
MIRAI	Annual Inspection 1 28	Sea Trial 6 9 MR00-K03 Observational Studies on the Material Cycle in the High Latitude Sea Northwestern North Pacific Southern Okhotskoe	MR00-K04 Observational Studies on Air Sea Interaction 10 13 Waters South of Japan
SHIP NAME	Jul.	Aug.	Sep.
MIRAI	MR00-K05 The Subtropical Gyre and the Subpolar Gyre in the North Pacific Ocean 6 10 Waters East of Honshu Japan	Seattle Victoria 1 4 21 24 27	MR00-K06 Observational Studies in the Arctic Ocean Beaufort Sea
SHIP NAME	Oct.	Nov.	Dec.
MIRAI	Dutch Harbor 3 4 12	MR00-07 Observational Studies in the Western Tropical Pacific Ocean and Observational Studies on Air Sea Interaction Singapore 7 8 Western Tropical Pacific Ocean and Eastern Indian Ocean	Jakarta 20 22 Palau 13 14 23 28
SHIP NAME	Jan. 01	Feb.	Mar.
MIRAI	MR00-K08 Observational Studies on Primary Productivity in the Equatorial Pacific Ocean Honolulu 7 8 Western Tropical Pacific Ocean	Guam 1 2 8 14	MR01-K01 Observational Studies in the Western Tropical Pacific Ocean Guam 17 18 23 Western Tropical Pacific Ocean Waters

Research Support Activities
Ship Operation Department

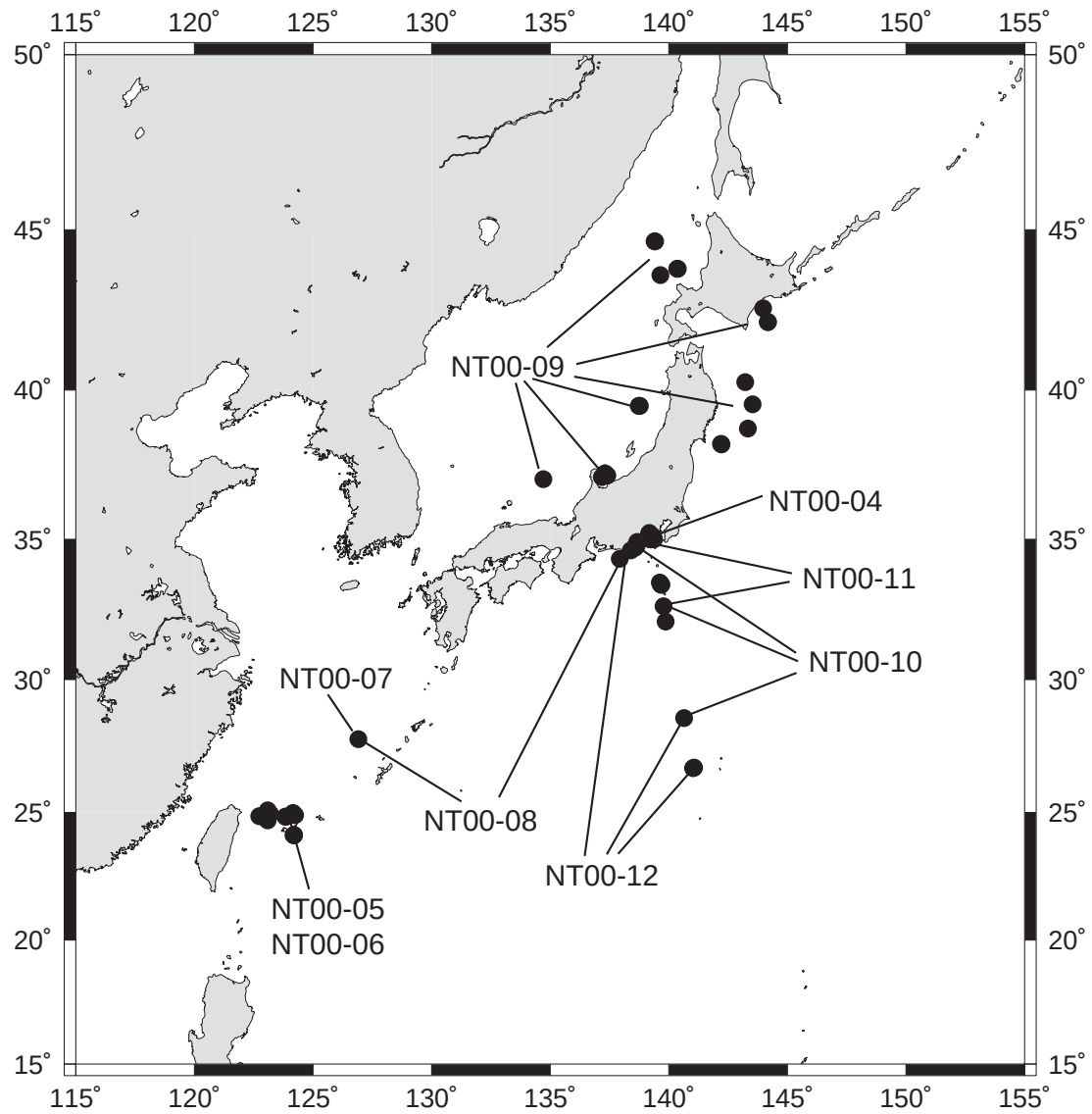


Fig. 1 Research Area of "NATSUSHIMA" in 2000 Fiscal year

Research Support Activities
Ship Operation Department

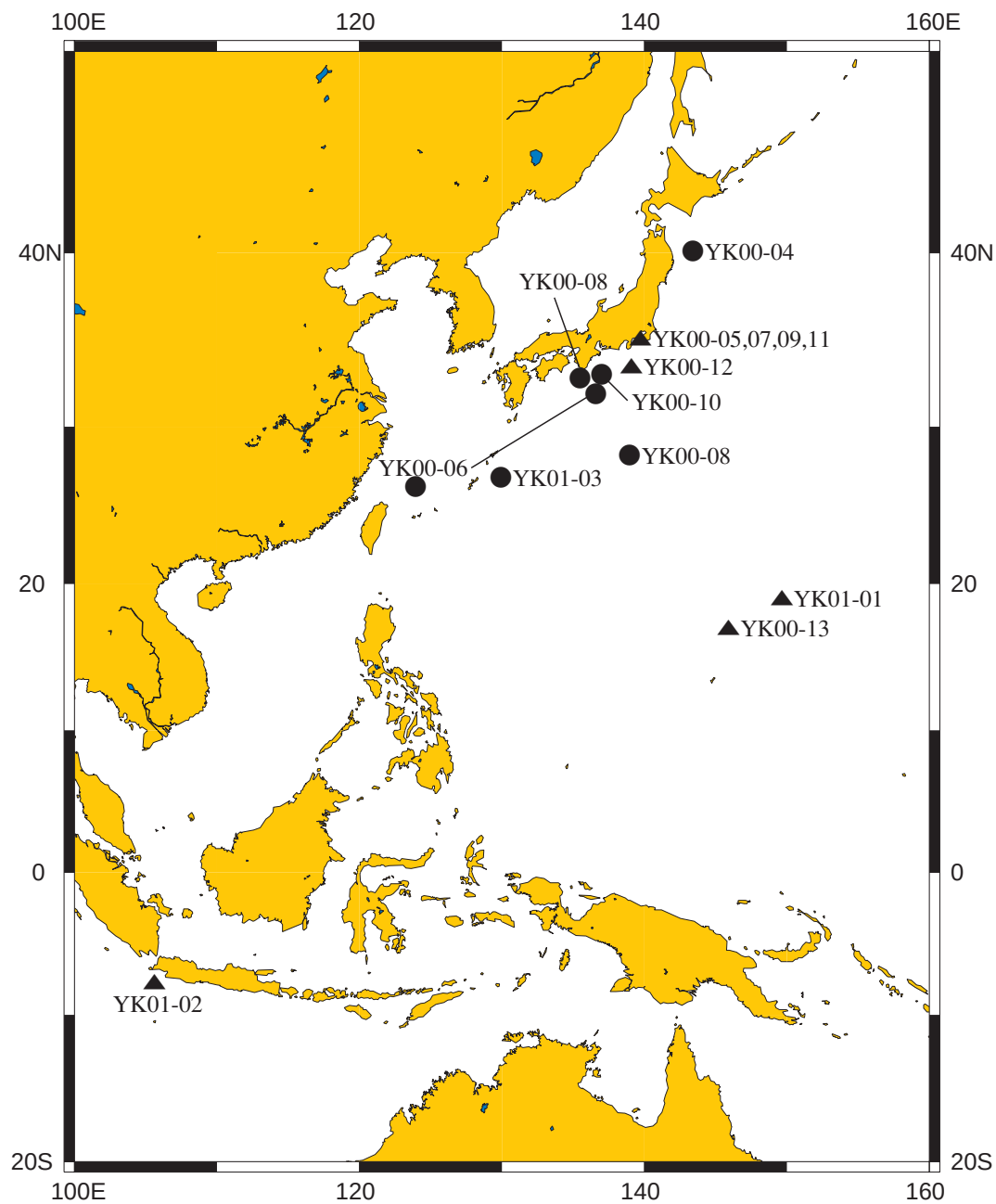


Fig. 2 Research Area of "YOKOSUKA" in 2000 Fiscal year

●: "SHINKAI6500" Research dive

▲: "YOKOSUKA" Research

Research Support Activities
Ship Operation Department

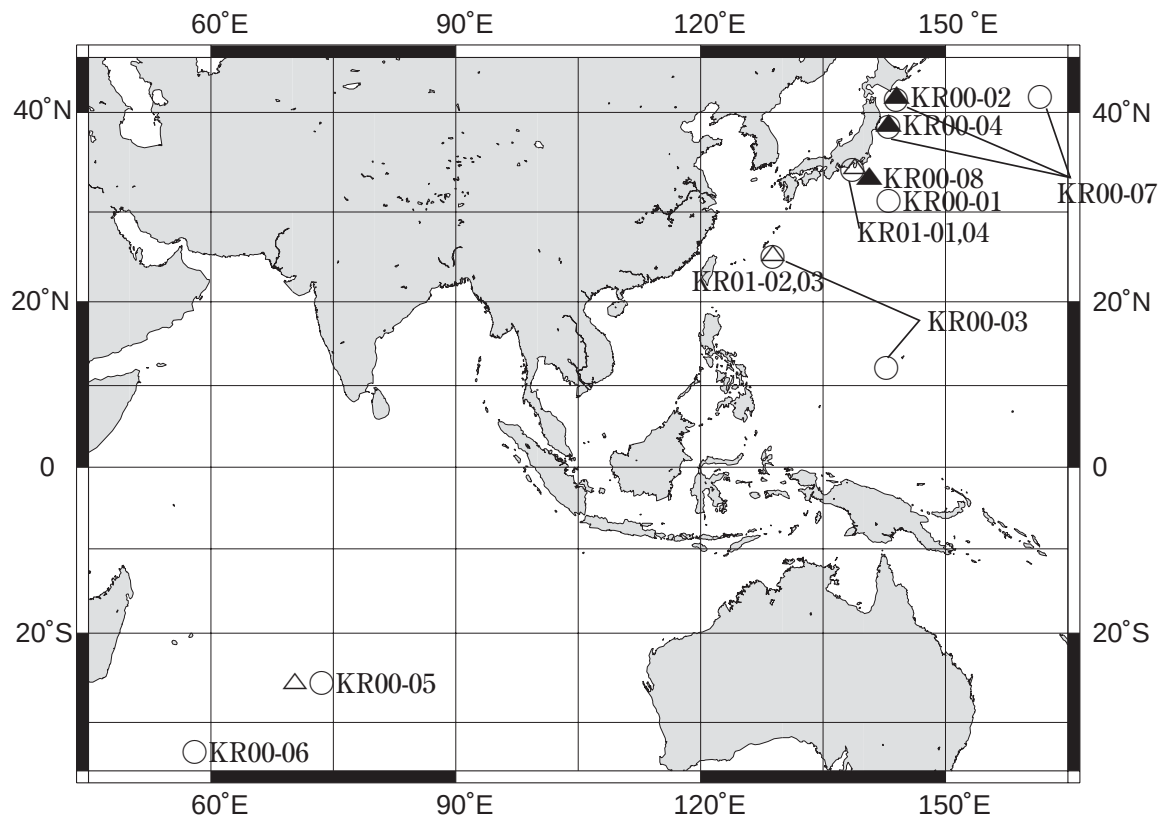


Fig. 3 Research Area of "KAIREI" in 2000 Fiscal year

- : "KAIKO" Research dive
- △: "KAIREI" Research
- ▲: Research by MCS

Research Support Activities
Ship Operation Department

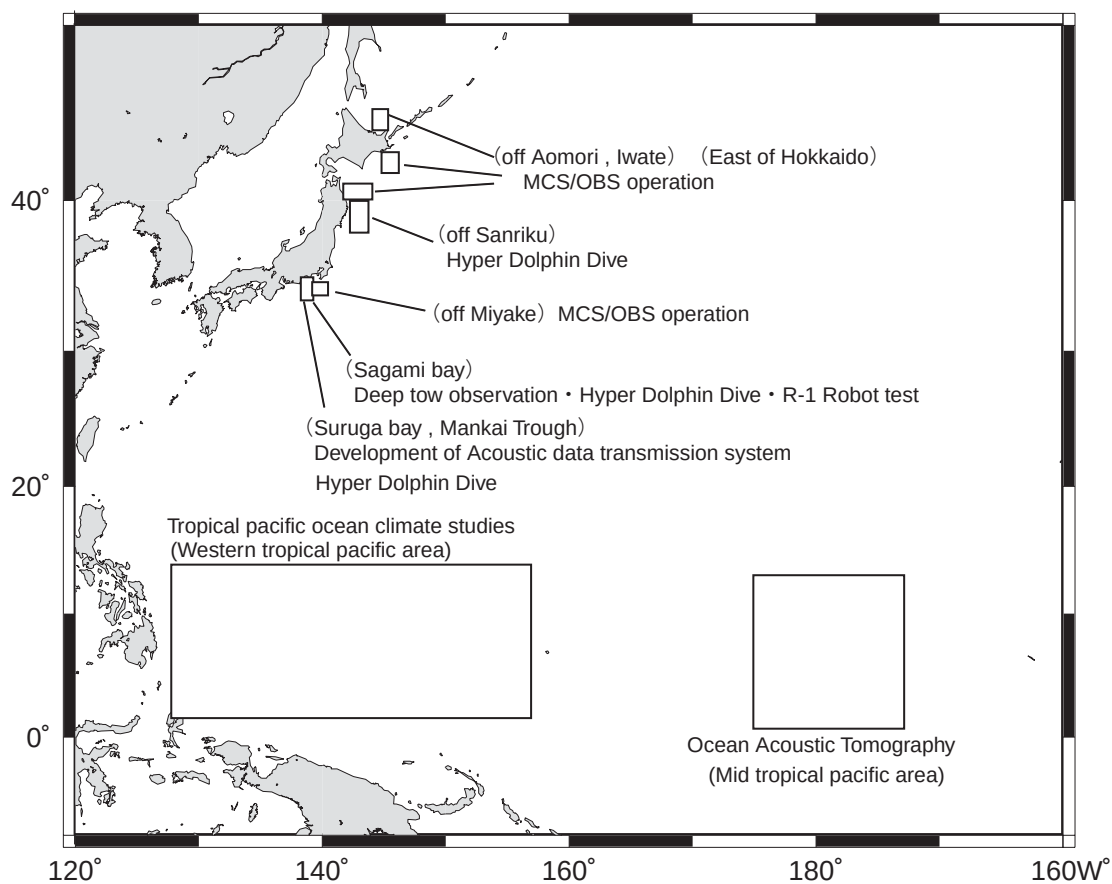


Fig. 4 research Area of "KAIYO" in 2000 Fiscal year

Research Support Activities
Ship Operation Department

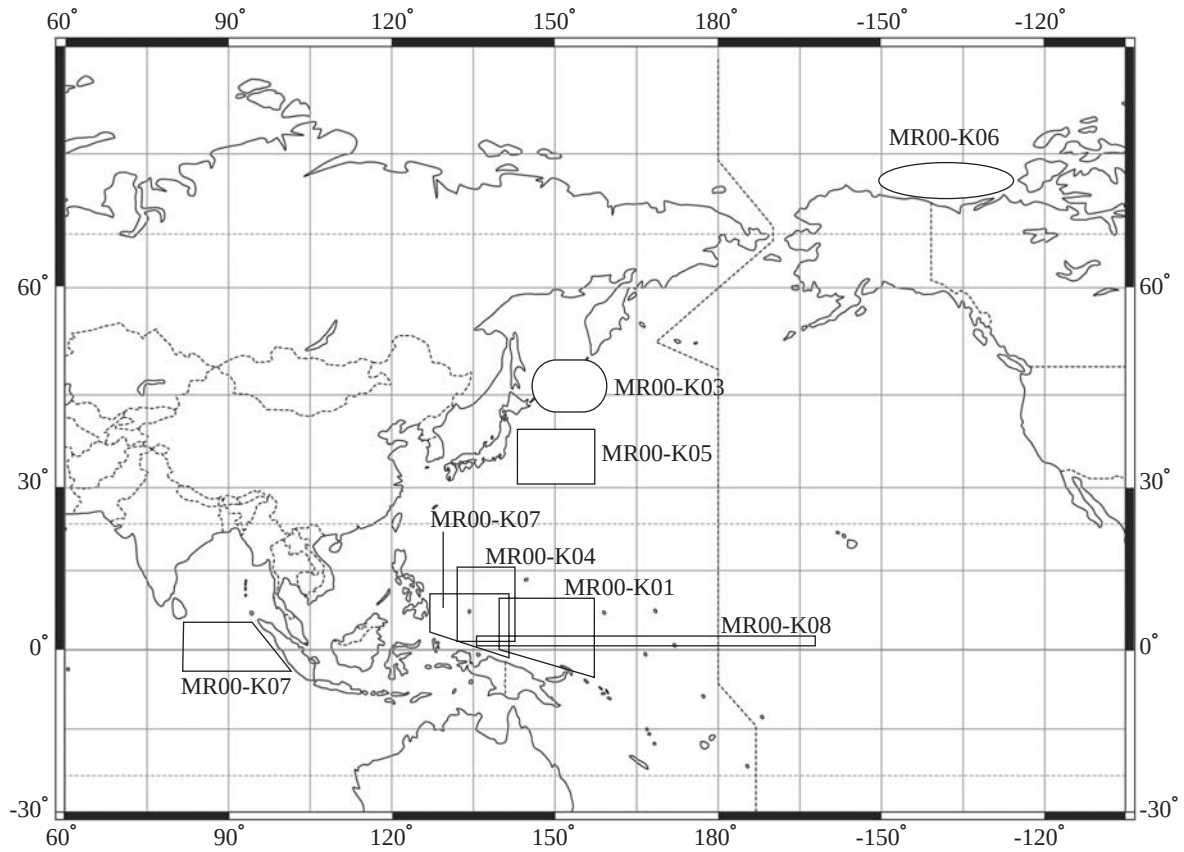


Fig. 5 FY2000 Research Area of R/V Mirai

- MR00-K03 Observational Studies on the Material Cycle in the High Latitude Sea
- MR00-K04 Observational Studies on Air Sea Interaction
- MR00-K05 The Subtropical Gyre and the Subpolar Gyre in the North Pacific Ocean
- MR00-K06 Observational Studies in the Arctic Ocean
- MR00-K07 Observational Studies in the Western Tropical Pacific Ocean and Observational Studies on Air Sea Interaction
- MR00-K08 Observational Studies on Primary Productivity in the Equatorial Pacific Ocean
- MR01-K01 Observational Studies in the Western Tropical Pacific Ocean

Research Evaluation

In August 1997, the Prime Minister decided on "National Guideline on the Method of Evaluation for Government R&D". In response to that, JAMSTEC formulated, in October 1997, "Outline of Steps Taken to Evaluate Research at the Japan Marine Science and Technology Center", to contribute to effective and productive allocation of human and economic resources. "Outline of Steps Taken to Evaluate Research at the Japan Marine Science and Technology Center" called for evaluation of JAMSTEC's projects by the R&D Theme Evaluation Committee, consisting of third-party experts and knowledgeable persons. The R&D Theme Evaluation Committee should conduct an in-advance evaluation, an interim evaluation, and a result evaluation of the themes of Research Projects; Category 1 on the priority fund, and a result evaluation of the themes of the Research Projects; Category 2, the Personal Researches and Cooperative Researches on the basic fund, according to the items and methods for evaluation determined by the R&D Theme Evaluation Committee.

In fiscal 2000, JAMSTEC executed, according to "Outline of Steps Taken to Evaluate Research at the Japan Marine Science and Technology Center", in-advance evaluations of R&D themes, on July 28, 2000, and interim and result-evaluations, from October 2000 to February 2001. The results of evaluations pointed out needs for improvement, but generally the results were affirmative. JAMSTEC will work to promote research and development, while seriously considering the results of evaluations.

1. In-advance Evaluation

(1) Theme for Evaluation (attached Table 1)

JAMSTEC executed in-advance evaluation for the Research Project; Category 1 considered for the budget request for fiscal 2001, to be initiated in fiscal 2001.

(2) Organization for Evaluation

The R&D Theme Evaluation Committee, consisting of third-party experts in marine science and technology and knowledgeable persons in science and technology (attached Table 2), conducted evaluations.

(3) Method for Evaluation

Meetings were held between the researchers in charge of R&D themes in question, and committee members. Each researcher presented his or her research themes, a question-and-answer session between the researcher and the committee followed. The committee evaluated each items below, while discussing among themselves the results of researchers' presentations and the question-and-answer sessions, and referring to the self-evaluation sheet of each researcher.

cussing among themselves the results of researchers' presentations and the question-and-answer sessions, and referring to the self-evaluation sheet of each researcher.

(4) Items for Evaluation

The following items were evaluated.

- Adequacy of purposes, targets, and directions of the research and development
- Adequacy of contents and methods of the research and development
- Adequacy of funds and organizations for research and development
- Expected results and ripple effects of the research and development

2. Interim and Result Evaluation

(1) Theme for Evaluation (attached Table 3)

JAMSTEC executed interim and result evaluation

Research Evaluation

falling into the following categories. These are Research Projects; Category 1 that have passed five years or more after commencement or that have finished, and Research Projects; Category 2, Personal Researches and Cooperative Researches completed in fiscal 1999.

(2) Organization for Evaluation

The R&D Theme Evaluation Committee (attached Table 4-1) and, four special committees, conducted evaluations. Special Committees were the Subcommittee for Ocean and Solid Earth Science, the Subcommittee for Ocean Observation and Research, the Subcommittee for Marine Biology and Ecology, and the Subcommittee for Marine Technology (attached Table 4-2). These Subcommittees evaluated individual research fields.

(3) Method for Evaluation

The R&D Theme Evaluation (in-advance evaluation) Committee deliberated first, on the themes to be evaluated (interim and result evaluations), items for evaluation, and methods for evaluation. Based on the results of deliberation, subcommittees were held in a manner to publicly disclose the evaluation results.

Each subcommittee heard a presentation by each researcher, and held a question-and-answer session between the researcher and the subcommittee. The subcommittees evaluated the research based on the results of presentation and the question-and-answer session, while referring to the self-evaluation sheet of the researcher, and summaries of the researcher's essays. Each item below was evaluated.

The R&D Theme Evaluation Committee finalized the fiscal 2000 evaluation, referring to the evaluation results of subcommittees.

(4) Items for Evaluation

Depending on the degree of progress of each R&D theme, the themes were subjected either to interim evaluation or result evaluation, on the following items.

(a) Interim Evaluation (ongoing themes but five or more years after commencement)

- Adequacy of purposes, targets, and direction of research and development
- Adequacy of the outline, plan, and method of research and development
- Adequacy of research and development expenses, implementing organizations
- Progress of research and development
- Future schedule (plan)

(b) Result Evaluation (themes completed by the preceding fiscal year)

- Adequacy of purposes and targets of research and development
- Adequacy of the outline, plan, and method of research and development
- Adequacy of research and development expenses, implementing organizations
- Degree of achievements of research and development
- Ripple effects of the achievements, extensions, reflection of the achievement on new themes
- Reflection on causes for successes and failures

Research Evaluation

Table 1 Subject of Evaluation of R&D Themes (in-advance evaluation) in FY2000

Subject	Department
Development of Long-term Deep Sea Floor Network for Geoscientific Observations	Deep Sea Research Department
Development of Coral Recovery Technology	Marine Ecosystems Research Department
A. Observation investigation concern to Kuroshio Extension Region B. An extensive three-dimensional realtime observation using Ocean Acoustic Tomography System in Kuroshio Extension Region (Parts of "Study on the Kuroshio Extension")	Ocean Observation and Research Department
Research on Extreme Environment Maintaining Technology for Deep Biosphere	Marine Technology Department
Global Warming Observational Research Program (A part of "Frontier Observational Research System for Global Change")	Frontier Research Promotion Department
Institute for Frontier Research on Earth Evolution	Frontier Research Promotion Department
Frontier Research System for Extremophiles	Frontier Research Promotion Department

Table 2 Member List of the R&D Theme Evaluation Committee for In-advance Evaluation in FY2000

Chairman	Tomio ASAI	Emeritus Professor, Univ. of Tokyo
Member	Tsuneo ASAI	Secretary General, Japanese Association of Science & Technology Journalists
Member	Isao KOIKE	Professor, Ocean Research Institute, Univ. of Tokyo
Member	Kensaku TAMAKI	Professor, Ocean Research Institute, Univ. of Tokyo
Member	Hisaaki MAEDA	Professor, Institute of Industrial Science, Univ. of Tokyo
Member	Yoshitaka NITTA	Director in charge of R&D Review, Planning Div., Central Research Institute of Electric Power Industry
Member *1	Suguru OTA	Professor, Ocean Research Institute, Univ. of Tokyo
Extraordinary Member *2	Tairo OSHIMA	Professor, Department of Molecular Biology, Tokyo Univ. of Pharmacy and Life Science

*1: Deputy for Dr. Akira TANIGUCHI (Professor, Faculty of Agriculture, Tohoku Univ.)

*2: Expert of microorganisms to evaluate the subject "Frontier Research System for Extremophiles"

Research Evaluation

Table 3 Subject of Evaluation of R&D Themes (interim and result evaluation) in FY2000

1. R&D based on priority funding (Research Project; Category 1) 6 Themes

Subject	Department	Category of Evaluation
Long-term oceanographic and meteorological observation of North Pacific Subtropical area	Ocean Observation and Research Department	interim
Study of Air - Sea Interaction	Ocean Observation and Research Department	interim
R&D on the Technology Controlling the Oxygen-deficient Water Mass in Omura Bay	Marine Ecosystems Research Department	result
Development of a Simple Sampling System and Breeding Techniques of Vestimentiferan Tube Worms	Marine Ecosystems Research Department	result
Research on the Characteristics of the Deep Seawater in the Bay of Suruga, and the Cascade Methods of Deep Seawater Utilization	Marine Ecosystems Research Department	interim
Research and Development of Sea Bottom Mariculture System	Marine Technology Department	result

2. R&D based on basic funding (Research Project; Category 2, Personal Research, Cooperative Research) 22 Themes (All Themes are targets of Result Evaluation)

Subject	Category of R&D	Department
Research on the Geology of Izu-Bonin Arc and its Related Area	Cooperative	Deep Sea Research Department
Study on the Behavior of Trace Metal in the Ocean	Personal	Ocean Observation and Research Department
Ocean Data Analysis by Using a High-resolution GCM	Research Project; Category 2	Ocean Observation and Research Department
Inter-annual Variability in Heat, Carbon, and Nitrogen Fluxes in the Equatorial Pacific	Cooperative	Ocean Observation and Research Department
Study on Greenhouse Gasses and Primary Productivity in the Equatorial Pacific	Cooperative	Ocean Observation and Research Department
Study on Improvement of Oceanic CO ₂ Measurement	Personal	Ocean Observation and Research Department
Study on Data Analysis Method of Acoustic Tomography	Cooperative	Ocean Observation and Research Department
Studies on the Utility of Oxygen High Partial-Pressure	Cooperative	Marine Ecosystems Research Department
Research on Characteristics, Distribution and Variation of Proper Water Mass in Japan Sea	Cooperative	Marine Ecosystems Research Department
Development of Tools for the Sampling and Maintenance for Midwater Organisms.	Personal	Marine Ecosystems Research Department

Research Evaluation

Subject	Category of R&D	Department
Midwater Research Using ROVs.	Cooperative	Marine Ecosystems Research Department
Basic Study for Marine Ecosystem Investigation by Using the Automatic Plankton Counting Devices	Cooperative	Marine Ecosystems Research Department
Model Experiment and Motion Analysis of Marine Riser Pipe	Research Project; Category 2	Marine Technology Department
Development of Launching System for Deep-sea TV Observing Equipment	Personal	Marine Technology Department
Research on Non-Contact Data Communication System Using LEDs	Personal	Marine Technology Department
Research on the Image Detection by Using a Forward Looking Sonar	Personal	Marine Technology Department
Research and Development of a Calm-sea Conditions Using an Array of Floating Bodies	Personal	Marine Technology Department
Research and Development of Seawater Drawing Technology Using Compressed Air	Cooperative	Marine Technology Department
Research on the Characterization of Giant Magnetostrictive Materials for 20Hz Sound Source	Cooperative	Marine Technology Department
Research and Development on Autonomous Underwater Vehicle Operation Technology	Cooperative	Research Support Department
Research on the Design and Management Methods of JAMSTEC High-speed Network	Personal	Computer and Information Department
Research on Functional Improvement of Sub-bottom Profiler	Cooperative	Computer and Information Department

Research Evaluation

Table 4-1 Member List of the R&D Theme Evaluation Committee for Interim and Result Evaluation in FY2000

Chairman	Tomio ASAI	Emeritus Professor, Univ. of Tokyo
Member	Tsuneo ASAI	Secretary General, Japanese Association of Science & Technology Journalists
Member (Chief of Subcommittee for Ocean Observation and Research)	Isao KOIKE	Professor, Ocean Research Institute, Univ. of Tokyo
Member (Chief of Subcommittee for Ocean and Solid Earth Science)	Kensaku TAMAKI	Professor, Ocean Research Institute, Univ. of Tokyo
Member (Chief of Subcommittee for Marine Biology and Ecology)	Akira TANIGUCHI	Professor, Faculty of Agriculture, Tohoku Univ.
Member (Chief of Subcommittee for Marine Technology)	Hisaaki MAEDA	Professor, Institute of Industrial Science, Univ. of Tokyo
Member	Yoshitaka NITTA	Director in charge of R&D Review, Planning Div., Central Research Institute of Electric Power Industry

Table 4-2 Member Lists of the R&D Theme Evaluation Subcommittees for Interim and Result Evaluation in FY2000

• Subcommittee for Ocean and Solid Earth Science

Chief	Kensaku TAMAKI	Professor, Ocean Research Institute, Univ. of Tokyo
Member	Kenji NOTSU	Professor, Laboratory for Earthquake Chemistry Graduate School of Science, Univ. of Tokyo
Member	Hajime SHIOBARA	Assistant Professor, Ocean Heimsphere Research Center, Earthquake Research Institute, Univ. of Tokyo
Member	Masato YUASA	Director, Liaison Office for Technology Transfer, Geological Survey of Japan

• Subcommittee for Ocean Observation and Research

Chief	Isao KOIKE	Professor, Ocean Research Institute, Univ. of Tokyo
Member	Shiro IMAWAKI	Professor, Research Institute for Applied Mechanics Kyushu Univ.
Member	Tatsushi TOKIOKA	Counsellor, Administration Dep., Japan Meteorological Agency
Member	Masaaki WAKATSUCHI	Professor, Institute of Low Temperature Science, Hokkaido Univ.

• Subcommittee for Marine Biology and Ecology

Chief	Akira TANIGUCHI	Professor, Faculty of Agriculture, Tohoku Univ.
Member	Mitsuaki AKAHANE	Director, Aomori Prefectural Fisheries Experiment Station
Member	Suguru OTA	Professor, Ocean Research Institute, Univ. of Tokyo
Member	Keizo SHIRAKI	Professor, Dep. of Physiology, School of Medicine, Univ. of Occupatio

Research Evaluation

• Subcommittee for Marine Technology

Chief	Hisaaki MAEDA	Professor, Institute of Industrial Science, Univ. of Tokyo
Member	Nakaji HONDA	Professor, Dep. of Systems Engineering, The Univ. of Electro-Communications
Member	Toshiaki KIKUCHI	Professor, Dep. of Applied Physics, The National Defense Academy
Member	Hisaji SHIMIZU	Professor, Faculty of Engineering, Yokohama National Univ.

Institution Evaluation

JAMSTEC has compiled "Outline of Steps Taken to Evaluate Research at the Japan Marine Science and Technology Center" in October 1997 based on the "National Guideline on the Methods of Evaluation for Government R&D", which was provided by the Prime Minister in August 1997 so that the results of assessment can be used extensively to bring about efficiency and vitality in R&D activities and thus obtain more outstanding results. The Outline specifies that JAMSTEC's management as a whole is subject to be evaluated during its institutional operation. Namely, the evaluation is to cover all JAMSTEC activities, with a view to identifying issues regarding such points as whether operations are in accordance with its original mission, the state of research resources, research efficiency, and future plans, and recommend any improvements that can be made. As a rule, Institution Evaluation of JAMSTEC shall be conducted periodically once five years.

On 25 and 26 May 2000, JAMSTEC has conducted its first institutional evaluation based on "Outline of Steps Taken to Evaluate Research at the Japan Marine Science and Technology Center". JAMSTEC Evaluation Committee recognized that "JAMSTEC engages in comprehensive research and experiments on science and technology relating to ocean development, and possesses a world-class research infrastructure ... [and] also that JAMSTEC is in the process of developing its research systems to be a Center of Excellence (COE) in the field of ocean science and technology." It also put forward a broad range of recommendations with a view to the further development of JAMSTEC. JAMSTEC compiled an action program in December and has been implementing it to consolidate its position as one of the world's leading research institutions based on these recommendations.

1. Evaluation Procedures

Institution Evaluation was carried out by JAMSTEC Evaluation Committee (Annex 1) comprised of members who were selected from the outside for having ample evaluation capabilities. The evaluation focused on the following aspects.

(1) Overall JAMSTEC management

- 1) Consistency of JAMSTEC's stated statutory mission with present situation
- 2) Reason for existing of JAMSTEC as a general comprehensive organization for oceanographic research and development
- 3) Response to the needs of the people's lives, the society, and the economy
- 4) International standing of JAMSTEC as a research institute

(2) Organizational management

- 1) Policy regarding recruitment of researchers
- 2) Policy regarding distribution of research resources
- 3) Cooperation within JAMSTEC
- 4) Research support

(3) Efficiency of research activities

- 1) Strategic consideration in research planning
- 2) Appropriateness of research implementation
- 3) Flexibility in research planning
- 4) Cooperation and relationship with other institutes

In order to understand better the situation, we also evaluated research activities in each field which is essential for understanding the overall condition of a research institution.

Institution Evaluation

2. Evaluation Outcomes

In August 2000, JAMSTEC Evaluation Committee has compiled Report of Evaluation Committee for Japan Marine Science and Technology Center. The following is Recommendations in the Report.

(1) Recommendations

The Committee makes the following recommendations concerning the future direction of JAMSTEC based on the knowledge gained in the course of this evaluation. While some of these recommendations are beyond the scope of JAMSTEC's efforts alone, we hope they can be effective in future examinations into reform of the institution.

1) Revision of JAMSTEC's mission

- Change to a mission that is in line with the current situation of expanding operations into earth science and technology.

2) Realization of strategic research management

- Prioritize research fields, area and themes.
- Establish a science council to provide scientific advice to management.
- Determine to promote technological development contributed to the public directly or not.

3) Improving research efficiency

- Foster a competitive atmosphere in scientific research.
- Strengthen internal cooperation, especially that

between research departments and frontier programs.

- Strengthen the liaison and cooperative structure with universities etc.

4) Achievements and their dissemination

- Promote the publication of reviewed papers.
- Promote technology transfer of patents and other research achievements.
- Take account of scale merit in the collection of observation data.
- Make research data available through the Internet.
- Enhance the library function.
- Expand public relations activities.
- Promote science education for young people.

3. Action Program

Accepting the findings of the Evaluation Committee with sincerity, JAMSTEC must strive to improve the management and operations of the organization. The findings cover all JAMSTEC operations, including the frontier systems, and contain many recommendations that will have a far-reaching effect on how it will operate in the future, so after full and detailed discussion among the entire organization, JAMSTEC needed to formulate policies in response to these recommendations. In this light, JAMSTEC has established the Action Program Examination Committee to examine an action program for improving the operation and management of JAMSTEC and has compiled the Action Program in December 2000.

Institution Evaluation

Annex 1 : Members of the JAMSTEC Evaluation Committee

Yoichi KAYA (Chairperson)

Director General, Research Institute Innovative Technology for the Earth, Japan

Eddie BERNARD

Director, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, U.S.A.

Pierre DAVID

Conseiller maitre en service extraordinaire, Cour des Comptes (former Président Directeur Général of Institut Français de Recherche pour L'exploitation de la Mer), France

Yoshio FUKAO

Professor, Head of Center, Ocean Hemisphere Research Center, Earthquake Research Institute, The University of Tokyo, Japan

Robert GAGOSIAN

Director, Woods Hole Oceanographic Institution, U.S.A.

Takashi HAMADA

Professor, The University of the Air, Japan

Yukiko HORI

President & Director, Enoshima Aquarium Co., Ltd., Japan

Shiro IMAWAKI

Professor, Research Institute for Applied Mechanics, Kyusyu University, Japan

Masanobu KATO

Vice President, Director of Abiko Research Laboratory, Central Research Institute of Electric Power Industry, Japan

Kenichi MATSUBARA

Professor, Graduate School of Biological Science, Nara Institute of Science and Technology

Vice-Director, International Institute for Advanced Studies, Japan

Masami NAKAMURA

Senior Staff Writer, Nihon Keizai Shimbun, Inc., Japan

Koichiro YOSHIDA

Professor, School of Marine Science and Technology, Tokai University, Japan

Appendix A

Research Achievements

(1) Executive Director

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- 25) Hideaki Machiyama, Rika Takeuchi (Univ. Tokyo), Mutsuo Hattori, Takeshi Matsumoto, Mamoru Nakamura, Masaaki Kimura (Univ. Ryukyu), Ryo Matsumoto (Univ. Tokyo), Cold seep carbonates from the Kuroshima Knoll, off Yaeyama Islands: their isotopic composition and depositional environment., 107th Annual Meeting of the Geological Society of Japan
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Appendix A

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(4) Ocean Observation and Research Department

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- 3) Kay I. Ohshima (Hokkaido Univ.), Toshiyuki Kawamura (Hokkaido Univ.), Takatoshi Takizawa, Shuki Ushio (NIRS), Takuya Miyakawa (Meteorological Agency), Current variabilities under landfast sea ice in Lutzow–Holm Bay, Antarctica, J. Geophy. Res, Vol.105, No.C7, 17121-17132
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- 262) T. Yasunari, Transitivity of ENSO/Monsoon System in the Seasonal Cycle and Possible Role of Land-Surface Processes in Triggering Anomalous States of the System, US-Japan Workshop on Monsoon Systems, November 28-30, 2000
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- 2) Alexander G. Ostrovskii, Kaneko, A., Yamagata, T., The Kuroshio Observation Project, Seminar at P.P. Shirshov Inst. of Oceanology
- 3) Eitarou Oka, Naoto Iwasaka, Toshio Suga, Akio Ishida, Keisuke Mizuno, Kensuke Takeuchi, Observation south of the Kuroshio Extension using profiling floats (3), FY 2001 Oceanographic Society of Japan, Spring meeting
- 4) Eitarou Oka, Masaki Kawabe, Dynamic structure in Kuroshio at Tokara strait with relation between variations flow in Japan south course, FY 2000 Oceanographic Society of Japan Autumn meeting
- 5) Naoto Iwasaka, Kensuke Takeuchi, Toshio Suga, Taiyo Kobayashi, Eitarou Oka, Hiroshi Matsuura, Motoki Miyazaki, Yasuko Ichikawa, Masahiro Endoh, Keisuke Mizuno, Kentaro Ando, Yasushi Takatsuki, Akio Ishida, Kenji Izawa, Observation south of the Kuroshio Extension using profiling floats (II), Oceanographic Society of Japan, Spring meeting
- 6) Hisayuki Kubota, "Moring Monday is cold" One week cycle

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- 7) Hisayuki Kubota, Atsusi Numaguti, Seita Emori, Diurnal variation of cumulus convection over tropical ocean- The importance of low-level clouds for developing the nocturnal convection -, AGU 2000 Western Pacific Geophysics Meeting
 - 8) Hisayuki Kubota, Cumulus convection activity observed in West tropical pacific, Meteorological society of Japan summer special seminar
 - 9) Motoki Miyazaki, Yasushi Takatsuki, Asako Inoue, Kentaro Ando, Kenji Izawa, Keisuke Mizuno, Kensuke Takeuchi, Assessment of CTD sensor sensitivity for profiling floats (I), Oceanographic Society of Japan, Spring meeting
 - 10) Yasushi Takatsuki, Yasuko Ichikawa, Taiyo Kobayashi, Toshio Suga, Keisuke Mizuno, Kensuke Takeuchi, Data manegement of ARGO data, Oceanographic Society of Japan, Spring meeting
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 - 13) Taiyo Kobayashi, Estimation of the fresh water transport and the water exchange through the Kuril Straits, Oceanographic Society of Japan, Autumn meeting
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 - 15) Taiyo Kobayashi, Yasuko Ichikawa, Yasushi Takatsuki, Toshio Suga, Naoto Iwasaka, Kentaro Ando, Keisuke Mizuno, Kensuke Takeuchi, Quality control of ARGO data by HydroBase, FY 2001 Oceanographic Society of Japan Spring meeting
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 - 24) Nozomu Takeuchi, Surface albedo reduction of snow and ice by cryo-microbial activity: biological impact on Arctic cryosphere, Oceanographic Society of Japan/Spring meeting Symposium
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 - 28) Nozomu Takeuchi, Kohshima, S., Shiraiwa, T., Kubota, K., Biological investigation of Tyndall Glacier in the Southern Patagonia Ice Field - Biotic albedo reduction of the glacier surface and biological analysis of ice cores, in Patagonia Ice Field, Annual conference of Japanese Society of snow and ice
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 - 31) Tomoyuki Tanaka, Toshiro Saino, Takeshi Kawano, Effect of El-Niño Southern Oscillation Events on the Distribution of

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- Isotopic Composition of Nitrate Nitrogen and Suspended Particulate Nitrogen in the Western and Central Equatorial Pacific, WPGM (2000 Western Pacific Geophysical Meeting)
- 32) Nozomu Takeuchi, Shiro Kohshima, Katsumoto Seko, Structure, formation, and darkening process of albedo-reducing material (cryoconite) on a Himalayan glacier: a granular algal mat growing on the glacier., Arctic, Antarctic, and Alpine Research
 - 33) Tomoki USHIYAMA, Heating distribution by cloud systems derived from Doppler radar observation in TOGA-COARE IOP, International Conference on Clouds and Precipitation
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 - 40) Atsushi Sato, Konosuke Sugiura, Hiroshi Kubota, Heat balance at Taiga far area in Finland, Snow ice society of Japan in Tohoku branch meeting
 - 41) Hiroyuki Yamada, Hiroshi Ueda, Masayuki Maki, Koyuru Iwanami, The factor causes difference of growth convection cell which compose snowfall and crowdfall, Meteorological society of Japan (Poster session)
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 - 48) Konosuke Sugiura, Norikazu Maeno, Particle size dependence of horizontal snow mass flux in drifting snow, The International Snow Science Workshop 2000
 - 49) Konosuke Sugiura, Atsushi Sato, Hiroshi Kubota, Heat budgets in a taiga forest, the Finnish Arctic, Ice and life in Tohoku
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 - 51) Hironori Yabuki, The development of the model which estimates the precipitation from snow depth, Snow and ice society of Japan whole meeting (poster session)
 - 52) Hironori Yabuki, Yuji Kodama, Tetsuo Ohata, A meteorological observation in the Siberia Tiksi 2, Snow and ice society of Japan whole meeting
 - 53) Kazuyoshi Suzuki, Development of snowmelt model under forest canopy and sensitivity study on albedo and air temperature, Year 2000 research press meeting of hydrological and water resource society
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 - 58) Jun-Ichi HAMADA, Manabu D. Yamanaka, Tien Sribimawati,

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- 63) Hiroaki Hatsushika, Yongwon KIM, Long-term Transport of Gaseous and Particulate Materials by Forest Fire, FROSTFIRE Synthesis Workshop: The Role of Fire in the Boreal Forest and its Impacts on Climate Processes
- 64) Kyuug-Hoon Shin, T. Hama, N. Yoshie, S. Noriki, S. Tsunogai, Dynamics of fatty acids in newly biosynthesized phytoplankton cells and seston during a spring bloom off the west coast of Hokkaido Island, Japan, Marine Chemistry 1750 (2000)
- 65) Yongwon KIM, Noriyuki TANAKA, Effect of forest fire on the fluxes of CO_2 , CH_4 and N_2O in Alaskan boreal forest, 2000 AGU Fall Meeting
- 66) Yongwon KIM, Noriyuki TANAKA, Temporal Variation of Fluxes of CO_2 , CH_4 and N_2O in Boreal Forest, Alaska, 2nd International Workshop on Global Change: Connection to the Arctic
- 67) Yongwon KIM, Noriyuki TANAKA, Effect of Forest Fire on the Fluxes of CO_2 , CH_4 and N_2O in Boreal Forest, Interior Alaska, Japanese Oceanographic Society: Symposium Arctic Biogeochemistry
- 68) Kim Yongwon, Noriyuki TANAKA, Variation of N_2O and CH_4 Fluxes through two Winter Seasons in sub-Boreal Forests, Japan, Non- CO_2 Greenhouse Gases: Scientific Understanding, Control and Implementation
- 69) Yongwon KIM, Noriyuki TANAKA, Effect of Forest Fire on the Fluxes of CO_2 , CH_4 and N_2O in Boreal Forest Soils, Interior Alaska, Journal of Geophysical Research/ 2000 Fall AGU Meeting
- 70) Yongwon KIM, Noriyuki TANAKA, Temporal Variation of Fluxes of CO_2 , CH_4 and N_2O in Boreal Forest, Alaska, Bulletin

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(10) Planning Department International Affairs Division

- 1) Tashiro, Shozo., Recently American Research Vessel, Japan Deep Sea Technology Association

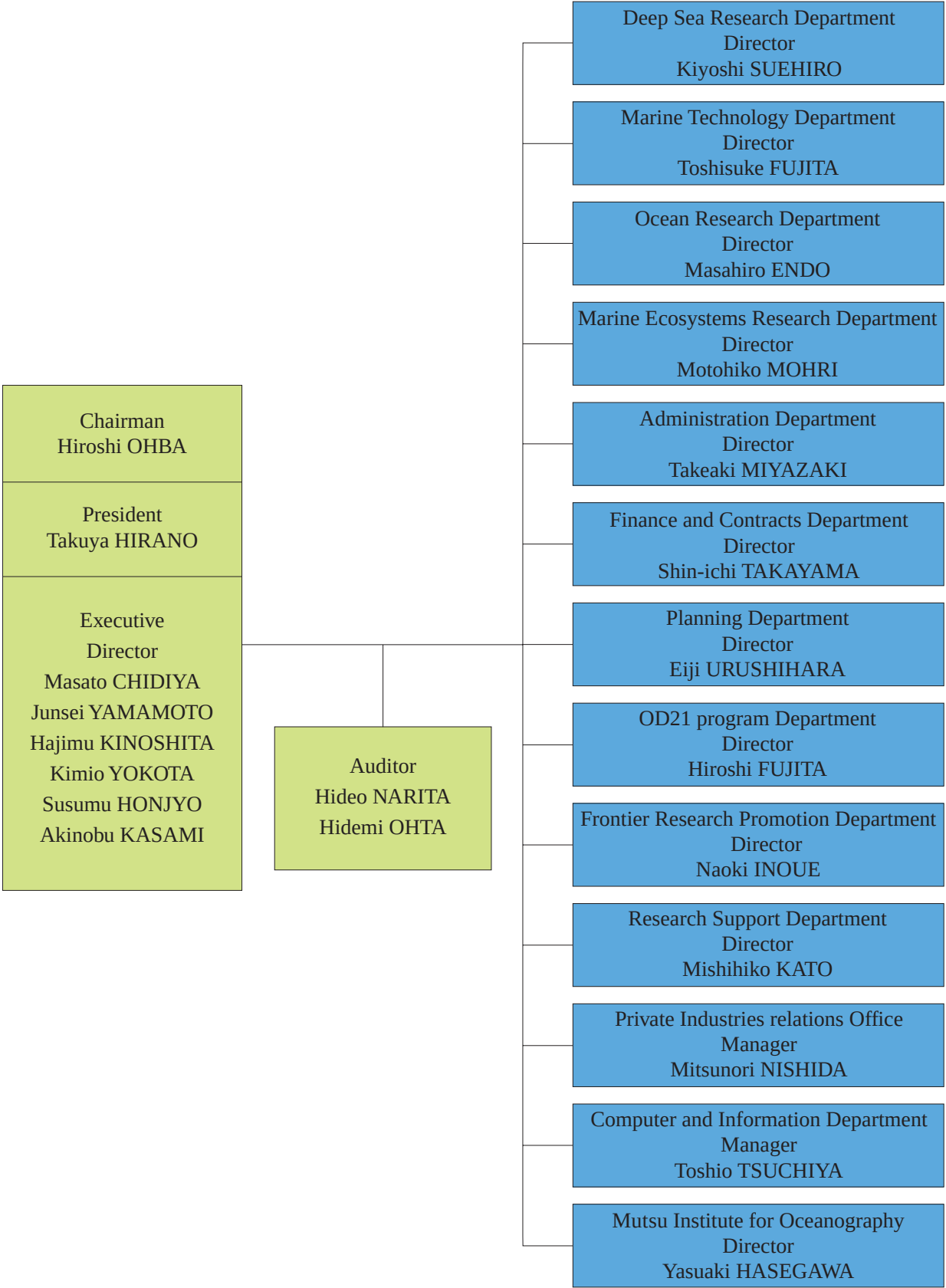
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- 1) WATANABE MASAYUKI, MOMMA HIROYASU, Search for the H-II Rocket Flight No.8 and Recovery of the Engine, Society of Naval Architects of Japan
- 2) Masayuki Watanabe, Hiroyasu Momma, Search & Recovery of The H-II rocket flight No.8 engine, TECHNO OCEAN 2000 International Symposium
- 3) Toshinobu Mikagawa, Tutomu Fukui, Kazuyoshi Hirata (NME), 10,000m class deep sea ROV KAICO and result of underwater operation, TECHNO-OCEAN 2000 International Symposium

(12) Computer and Information Office

- 1) Hideki Yamamoto (MWJ), Jun Naoi, Akira Sonoda, Jun Imai, Kentaro Ohyama (MWJ), JAMSTEC Data Management Activity -CTD data-, Japan Society for Marine Surveys and Technology (poster session)
- 2) Toru Kodera (NME), Jun Naoi, Akira Sonoda, JAMSTEC Data Management Activity -SeaBeam data-, Japan Society for Marine Surveys and Technology (poster session)
- 3) Jun Naoi, Ocean observation data exchange at JAMSTEC, Internet Workshop 2000-APAN Earth Monitoring WG
- 4) Jun Naoi, Akira Sonoda, Toru Kodera (NME), Hideki Yamamoto (MWJ), Yozo Motegi (GODI), Hiroe Suzuki (ESTO), Outline of JAMSTEC Data Management, Japan Society for Marine Surveys and Technology
- 5) Jun Naoi, Hiroshi OCHI, Hideaki SAITO, Yasutaka AMITANI, Toshio TSUCHIYA, Toshio OHYAGI (Toyo Corporation), Sea Trial Results of a Cross Fan Beam Type Sub-Bottom Profiler, Japanese Journal of Applied Physics, Vol.39, pp.3209-3211 Part 1, No.58
- 6) Youzo Motegi (GODI), Jun Naoi, Akira Sonoda, JAMSTEC Data Management Activity -Air temperature data-, Japan Society for Marine Surveys and Technology (poster session)

Appendix B
Organization Chart



Appendix C

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Katsura SHIBATA

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Submersible Operations Team of SHINKAI 6500

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Toshiaki SAKURAI

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Shin-ichi SUZUKI

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Yoshitaka SASAKI

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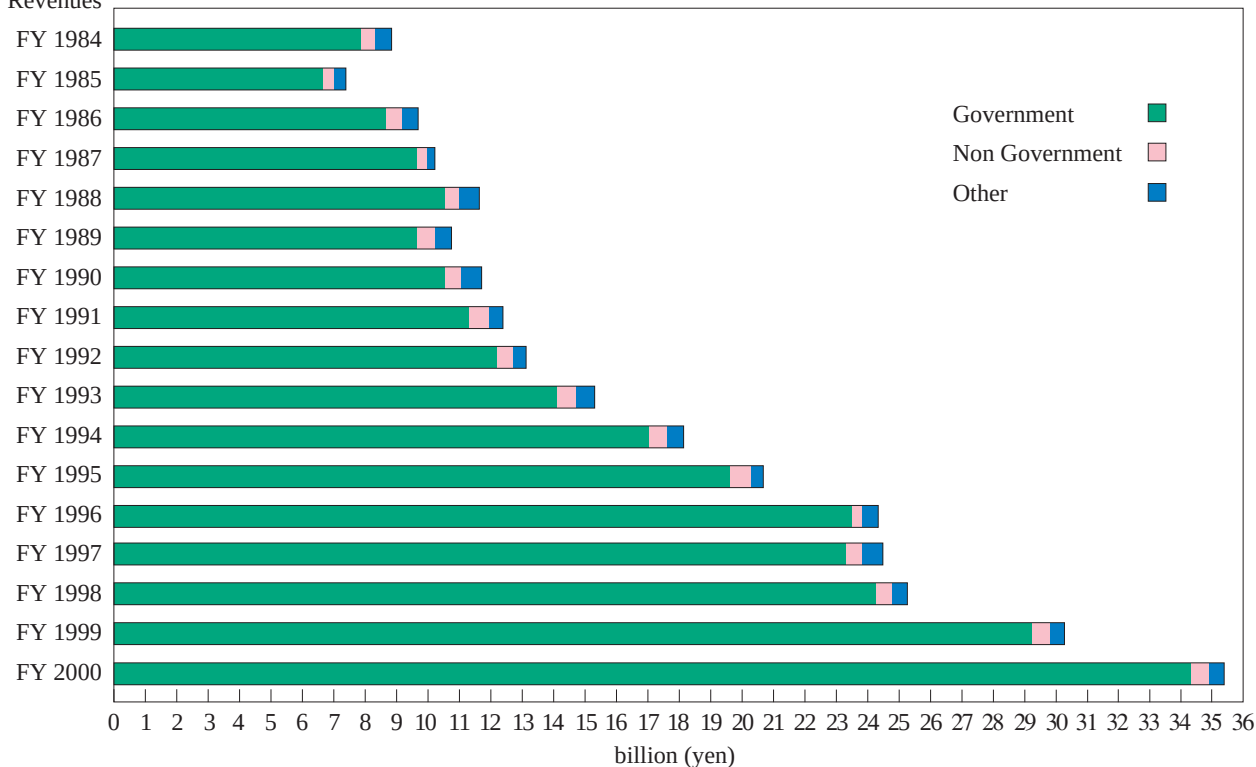
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Appendix E

Budget

Revenues



Expenses





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