A. Cruise summary

1. Cruise information

(1) Cruise designation (research vessel)
MR11-03 (R/V MIRAI)

(2) Cruise title (principal science proposal) and introduction
Change in material cycles and ecosystem by the climate change and its feedback
Introduction

Some disturbing effects are progressively coming to the fore in the ocean by climate change, such as rising water temperature, intensification of upper ocean stratification and ocean acidification. It is supposed that these effects result in serious damage to the ocean ecosystems. Disturbed ocean ecosystems will change a material cycle through the change of biological pump efficiency, and it will be fed back into the climate. We are aimed at clarifying the mechanisms of changes in the ocean structure in ocean ecosystems derived from the climate change,

We arranged the time-series observation stations in the subarctic gyre (K2: 47°N 160°E) and the subtropical gyre (S1: 30°N, 145°E) in the western North Pacific. In general, biological pump is more efficient in the subarctic gyre than the subtropical gyre because large size phytoplankton (diatom) is abundant in the subarctic gyre by its eutrophic oceanic condition. It is suspected that the responses against climate change are different for respective gyres. To elucidate the oceanic structures in ocean ecosystems and material cycles at both gyres is important to understand the relationship between ecosystem, material cycle and climate change in the global ocean.

There are significant seasonal variations in the ocean environments in both gyres. The seasonal variability of oceanic structures will be estimated by the mooring systems and by the seasonally repetitive ship observations scheduled for next several years.

(3) Principal Investigator (PI)
Makio Honda
Research Institute for Global Change (RIGC)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

(4) Science proposals of cruise

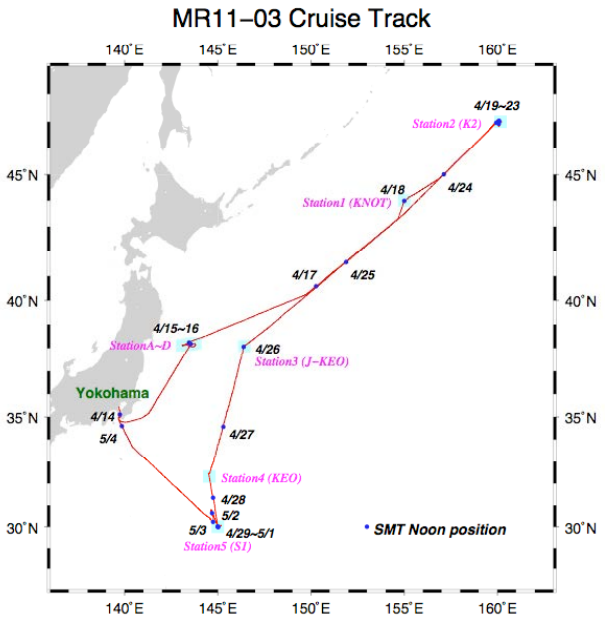
Affiliation	PI	Proposal titles
AORI / The Univ. Tokyo	Koji HAMASAKI	Studies on the microbial-geochemical processes that regulate the operation of the biological pump in the subarctic and subtropical regions of the western North Pacific
JAMSTEC RIGC	Hiroshi UCHIDA	1. Absolute salinity measurements of seawater 2. Temporal changes in water properties of abyssal water in the western North Pacific
JAXA	Hiroshi OHYAMA	Validation of GOSAT products over the sea using a ship-borne high-resolution Fourier transform spectrometer
JAMSTEC RIGC	Yoshimi KAWAI	Observational research on air-sea interaction in the Kuroshio-Oyashio Extension region
JAMSTEC BioGeoss / KCC	Ken TAKAI / Weiren LIN	The Tohoku Earthquake impact on deep-sea environment

not onboard study		
Kagoshima Univ.	Toru KOBARI	Effects of meso-zooplankton on food web and vertical flux
Okayama Univ.	Osamu TSUKAMOTO	Onboard continuous air-sea eddy flux measurement
JAMSTEC	Hisanori TAKASHIMA	Tropospheric aerosol and gas profile observations by MAX-DOAS on a research vessel
Toyama Univ.	Kazuma AOKI	Maritime aerosol optical properties from measurements of Ship-borne sky radiometer
JAMSTEC	Toshio SUGA	Study of ocean circulation and heat and freshwater transport and their variability, and experimental comprehensive study of physical, chemical, and biochemical processes in the western North Pacific by the deployment of Argo floats and using Argo data
NIES	Nobuo SUGIMOTO	Study of distribution and optical characteristics of ice/water clouds and marine aerosols
Chiba Univ.	Masao NAKANISHI	Tectonics of the mid-Cretaceous Pacific Plate
Ryukyu Univ.	Takeshi MATSUMOTO	Standardization of marine geophysical data and its application to the ocean floor geodynamics studies
JAMSTEC	Naoyuki KURITA	Rain and seawater sampling for stable isotopes

(5) Cruise period (port call)
14 April 2011 (Yokohama) – 5 May 2011 (Yokohama)

(6) Cruise region (geographical boundary)
The western North Pacific (50°N – 30°N, 140°E – 160°W)

(7) Cruise truck and stations



2. Overview of MR11-03

(1) Objective

Objective of this cruise is to collect biological, biogeochemical and physical data in winter at our western Pacific time-series stations K2 (sub-arctic gyre) and S1 (sub-tropical data).

(2) Overview of MR11-03

1) Urgent research relating the great East Japan Earthquake

On 11 March 2011, the great earthquake of magnitude 9 occurred off Miyagi prefecture, Japan. This earthquake and the relevant tsunami with its height of more than 10 m attacked mainly the Pacific coastline of Tohoku district and approximately thirty thousand people were killed, missing or injured. What is worse is that Fukushima No.1 nuclear power plant was seriously damaged by this earthquake and the tsunami, resulting that a gigantic radiation has been leaking to the atmosphere, land and ocean. After this record crisis, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) requested JAMSTEC to send JAMSTEC fleets to 30 km off Fukushima in order to monitor level of radiation of seawater, air and aerosol. R/V Mirai also participated this monitoring activity for approximately two weeks. After this contribution, it was decided that R/V Mirai starts original scientific cruise (MR11-03) in the western North Pacific with additional mission. This is water sampling near seafloor of earthquake and the tsunami source (Fig.1). This is based on the hypothesis that gasses and bacteria might be emitted from seafloor after the earthquake. We conducted four hydrocasts there. As a result, low beam transmittance layer was discovered near seafloor (Fig.2). It is suspected that this is attributed to re-suspension of seafloor sediment by the earthquake. In future, results of chemical and biological analysis of collected seawater will supply new insights, and more precise geological / geophysical / biological / geochemical researches will be conducted by JAMSTEC research vessels, deep-tow, ROV and Shinkai submersible.

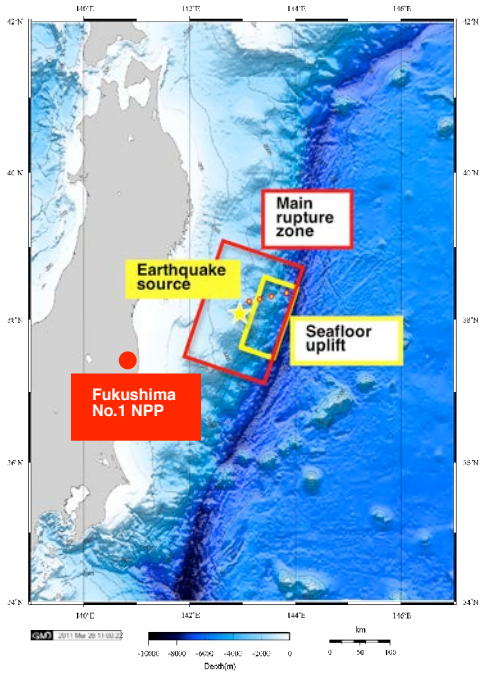


Fig. 1 Urgent research area near the earthquake / tsunami source

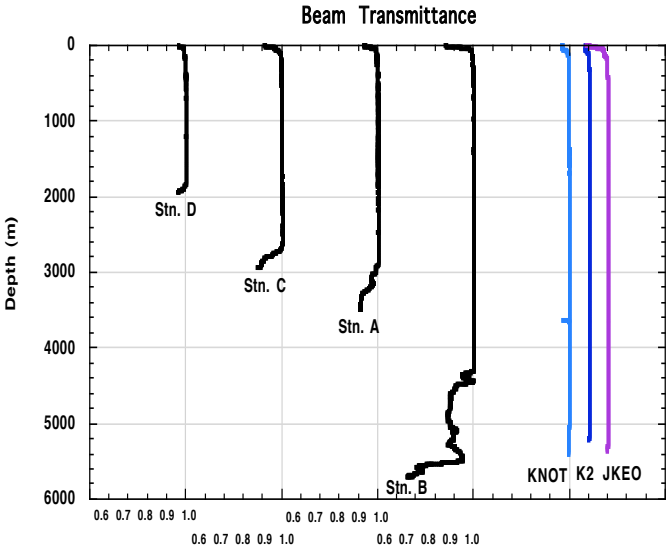


Fig. 2 Vertical profile of beam transmittance at urgent investigation area: stations A, B, C, D. For comparison, vertical profiles at our time-series stations are also shown

2) Outline of time-series observation at station K2 and S1

In order to certify seasonal and annual variability in ecosystem and biogeochemistry in the western North Pacific, biological and biogeochemical observation were conducted at time-series stations: K2 and S1 succeeding cruises of MR10-06 (September-October 2010) and MR11-02 (January-February 2011). Followings are main features during this cruise.

2-1) Station K2

Surface seawater temperature was approximately 1.7°C and less than that during last winter cruise: MR11-02 (approximately 2°C) (Fig. 3a). However temperature minimum layer with 1°C was observed at around 100 m and, thus, the maximum winter condition was likely over. Concentration of $Si(OH)_4$ in the surface seawater was approximately 42 μmol kg^{-1} and constant upper 100 m (Fig. 3b). Based on previous reports, this concentration was almost the annual maximum at station K2. Concentration of chlorophyll-*a* was slightly higher than or comparable to that during the last winter cruise (MR11-02) (Fig. 3c). Integrated primary productivity was approximately 200 mg-C m^{-2} day^{-1} and higher than that during MR11-02 (Fig. 3d).

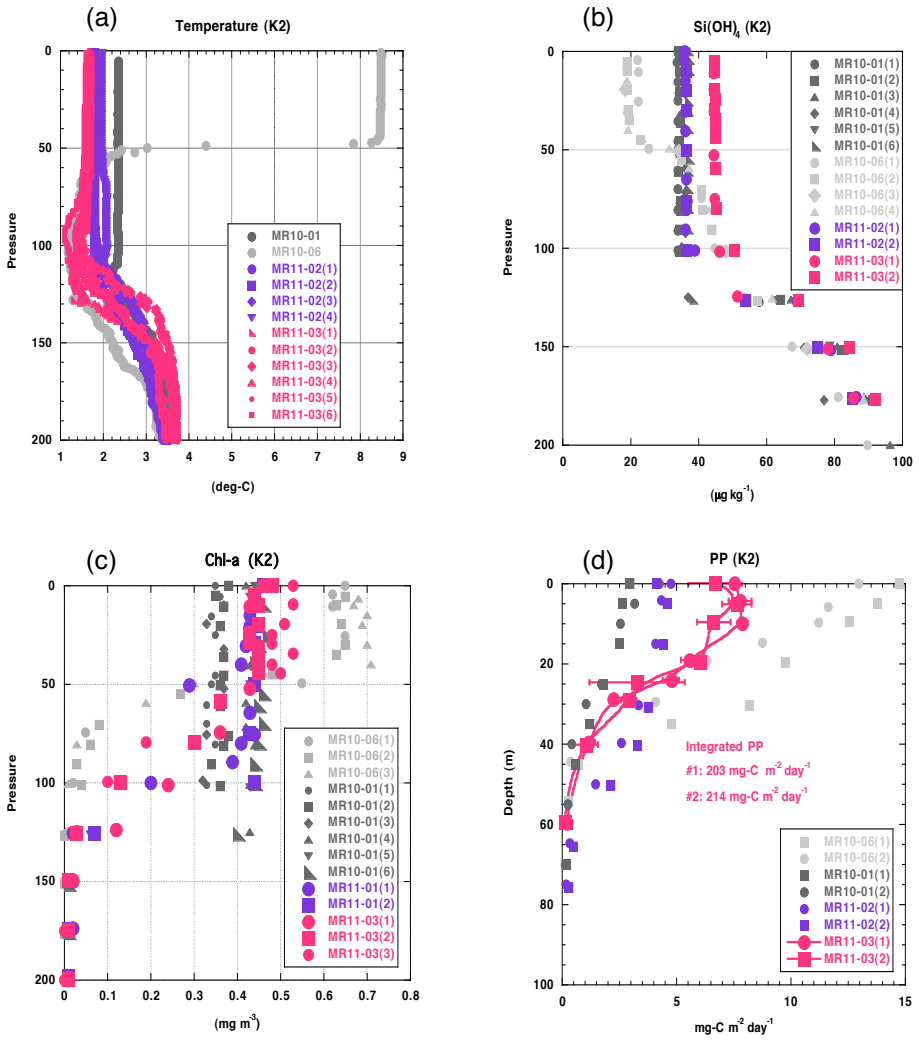


Fig. 3 Vertical profiles of (a) water temperature, (b) $Si(OH)_4$, (c) chlorophyll-*a* and (d) primary productivity at station K2

It was notable that standing stocs of planktonic foraminifera was quite high at station K2 (Kimoto, personal communication). Maximum of standing stock was approximately 3,000 individuals m^{-3} above 100 m water depths. Most dominant species was *Globigerina bulloides* and occupied more than 60 % of total individuals. *G. bulloides* is well known as carnivorous species and an upwelling indicator, therefore production of this species should be related with increasing of small zooplankton and nutrient supply by vertical mixing in this area. This remarkable foraminiferal production had never recorded from other season's observations (i.e. February ~ March 2010 and October ~November 2010), and their higher production should contribute to transportation of carbon to the intermediate/deep water and ocean carbonate chemistry in the north Pacific. This is supported by large foraminifera flux in spring observed by time-series sediment trap at station K2 previously.

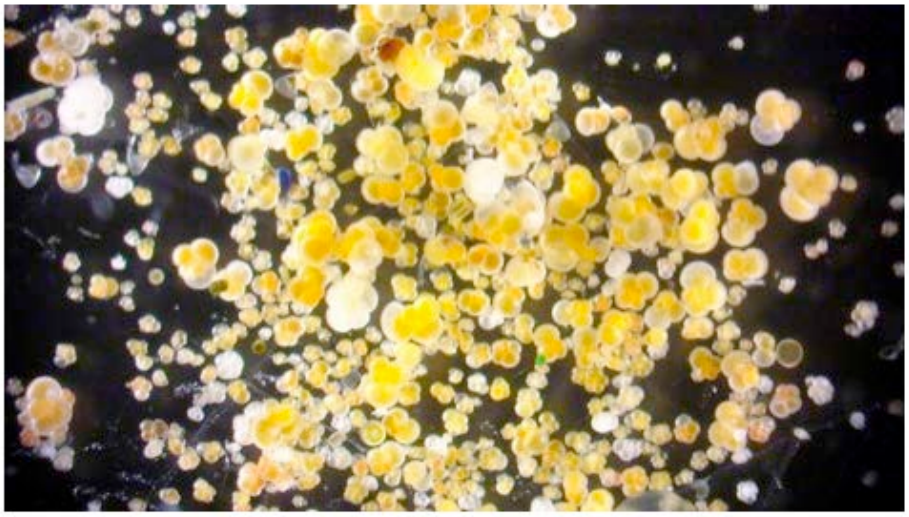


Fig. 4 Planktonic fotraminifera recovered by vertical plankton tow

Moreover, adult copepodite *Neocalanus cristatus* (stage c5) was observed upper 50m by IONESS sampling (Kitamura, personal communication) (Fig. 5). During the last winter cruise (MR11-02), adult copepodite was observed between 200 m and 300 m for resting or hibernation. It is reported that adult copepodite dies between 200 m and 500 m after egg laying. After hatching, larva ascends to upper layer and grow up gradually toward autumn. Thus exist of adult copepodite in April is indicative of that *Neocalanus cristatus* quickly grew up during last few months or adult copepodite does not die below 200 m. If the former is true, grazing pressure might be higher in April than previous report. If the latter is true, carbon flux by zooplankton ontogenetic migration might be smaller than we expected. Future biological analysis of collected sample and additional onboard experiment will reveal role of zooplankton in carbon cycle at

Fig.5 Copepodite *Neocalanus cristatus* collected by IONESS

station K2.

2-2) Station S1

Water temperature near surface was approximately 19°C (Fig. 6a) and higher than that during the last cruise (MR11-02). The surface mixed layer was approximately 40 m and shallower than that during MR11-02 (~ 120 m). Concentration of nitrate (NO_3) near surface was nearly zero (Fig. 6b). Chlorophyll-a was variable and its average was comparable to that observed in January-February 2010 (Fig. 6c). Integrated chlorophyll-a was estimated to be 43 mg m^{-2}. Primary productivity at surface was 13 mg-C m^{-3} day^{-1} and decreased with depth (Fig. 6d). Integrated primary productivity was approximately 350 mg-C m^{-2} day^{-1}. During the last cruise, high primary productivity higher than 1,000 mg-C m^{-2} day^{-1} was observed (see MR11-02 preliminary cruise report) and, thus, nutrients were almost consumed within the last two months. However standing stock of phytoplankton was not small and primary productivity still continues. It is one of scientific interests how to maintain primary productivity in the subtropical area, that is, how macro- and micro-nutrients (e.g. Fe) are supplied to sun-lit layer: horizontal transport from the land? via atmosphere? or from subsurface by diffusion?

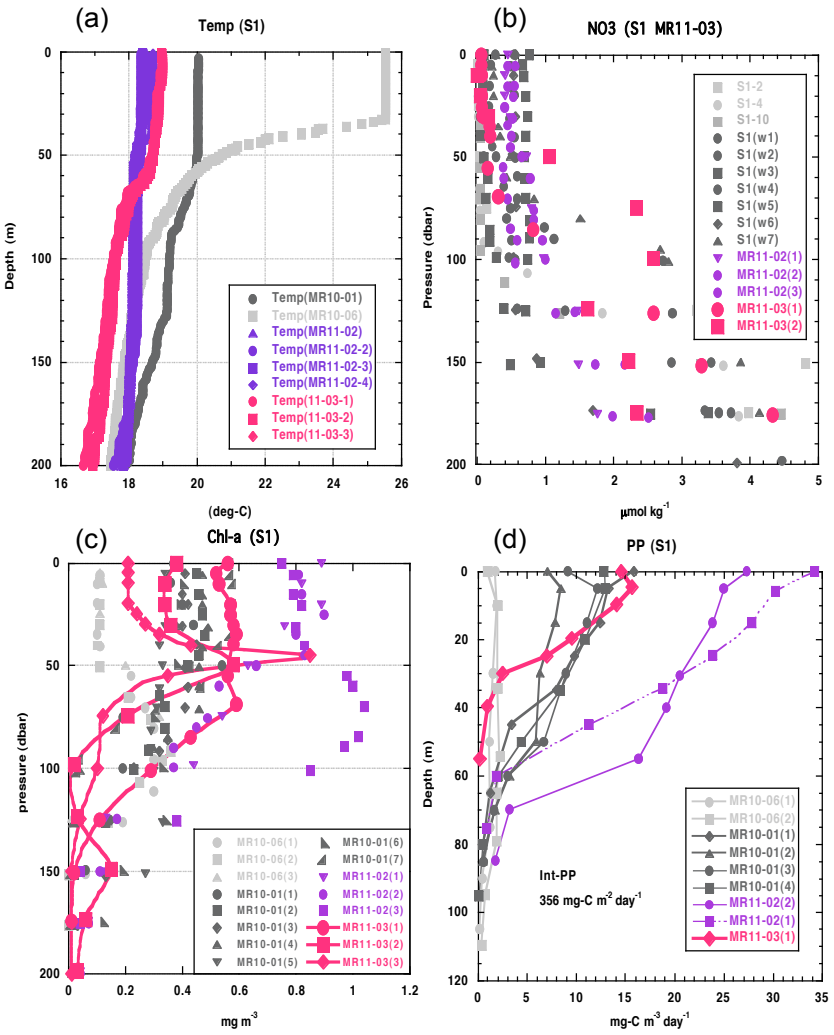


Fig. 6 Vertical profiles of (a) water temperature, (b) NO3, (c) chlorophyll-a, and (d) primary productivity at S1