A. Cruise summary

1. Cruise information

(1) Cruise designation (research vessel)
MR10-06 (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

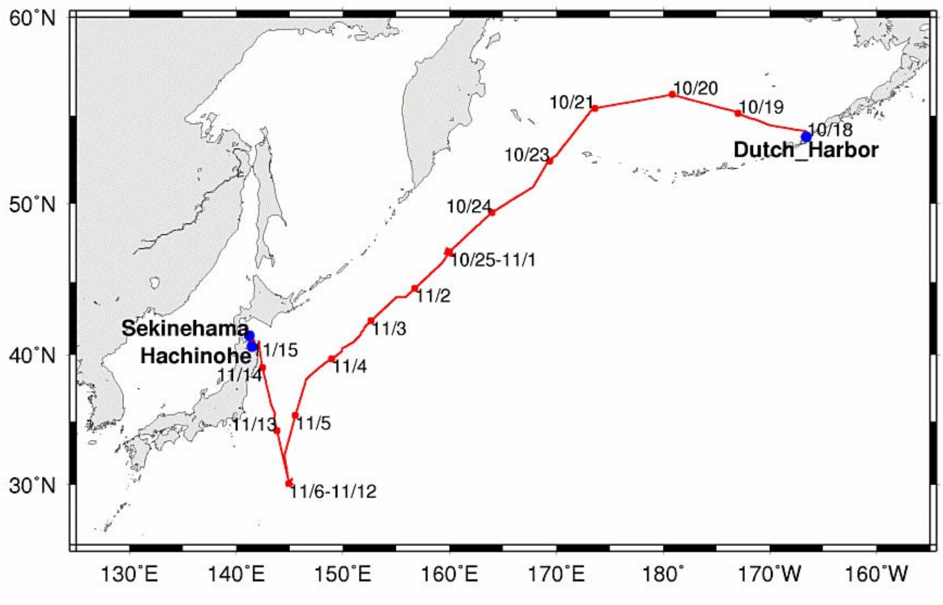
Affiliation	PI	Proposal titles
AORI / The Univ. Tokyo	Koji HAMASAKI	Studies on the microbial-geochemical processes that regulate the operation of the biological pump in the subarctic and subtropical regions of the western North Pacific
Kagoshima Univ.	Toru KOBARI	Effects of meso-zooplankton on food web and vertical flux
Nagoya Univ.	Osamu ABE	An evaluation of past change of primary productivity at the region of NPIW formation using oxygen triple isotopes, O_2, N_2 and noble gases.
Nagoya Univ.	Ippei NAGAO	Measurement of sea-to-air flux of marine biogenic gas (dimethyl sulfide) by eddy covariance method
JAMSTEC	Makio HONDA	Research and development of optical measurement of marine snow
Okayama	Osamu	Onboard continuous air-sea eddy flux measurement

Univ.	TSUKAMOTO	
Nagoya Univ,	Yoshihisa MINO	Settling velocity of particles in the twilight zone
JAMSTEC	Hisanori TAKASHIMA	Tropospheric aerosol and gas profile observations by MAX-DOAS on a research vessel
MRI	Michio AOYAMA	Long-term study on nutrients in global ocean
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	Yoshimi KAWAI	Observational research on air-sea interaction in the Kuroshio-Oyashio Extension region
JAMSTEC	Naoyuki KURITA	Rain and seawater sampling for stable isotopes

(4) Cruise period (port call)
18 October 2010 (Dutch Harbor) – 16 November 2010 (Sekinehama)

(5) Cruise region (geographical boundary)
The western North Pacific (60°N – 30°N, 140°E – 165°W)

(6) Cruise truck and stations



2. Overview of MR10-06

(1) Objective

Objective of this cruise is to collect biogeochemical and physical data in late autumn at our western Pacific time-series stations K2 (subarctic gyre) and S1 (subtropical data).

(2) Overview of MR10-06

Scientific cruises for the time-series observational study of biogeochemical oceanography in the western North Pacific has been conducted since late 1990's. These cruises have been in trouble for bad weather and rough sea condition very often. We expected that we would be also forced to suffer from bad condition and would give up many observations during coming cruise. Actually a fright (Anchorage - Dutch Harbor) for several participants was cancelled and their arrival was delayed. In addition, approach of R/V MIRAI to Dutch Harbor was very tough because of rough sea condition. However unlike we expected, MR10-06 cruise was generally plain sailing. We were sometimes forced to cancel some observations and to wait the good sea condition for observation, and but that was only a tiny part. We were able to conducted comprehensive observations including water sampling, plankton sampling, meteorological observation, recovery and deployment of mooring systems and so on at stations K2 and S1 on schedule. The followings are a part of preliminary results of our observation.

1) Ocean structure

Surface seawater temperature (SST) at station K2 was approximately 8°C (Fig. 1a). Intermediate cold water (dichothermal layer) of 1°C was observed at around 100 m. SST at station S1 was 26°C. These temperatures were approximately 5°C warmer than those in winter (January and February) observed during previous cruise (MR10-01). Surface mixed layer depth (MLD: 0.125 criteria) at station K2 and S1 was approximately 42 m and 35 m, respectively (Fig. 1b). These MLD were approximately 50 m shallower than winter MLD.

Euphotic layer (depth with 0.5% of surface photosynthetic available radiation (PAR)) at station K2 was approximately 50 m (no data shown). On the other hand, euphotic layer at station S1 was approximately 100 m. It is easily suspected that this is attributed to the difference in abundance of particulate materials in the water column.

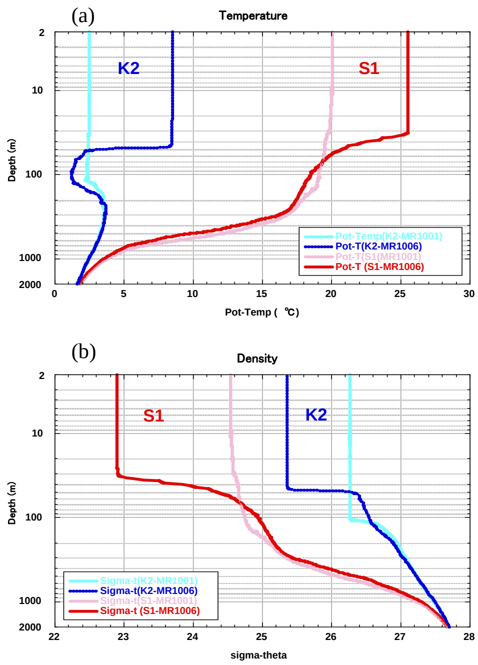


Fig.1 SST (a) and density in sigma-theta (b)

2) pCO_2

During cruise, underway pCO_2 observation was conducted. Surface pCO_2 (xCO_2) at station K2 (47°N) was approximately 340 ppm against approximately 390 ppm of atmospheric pCO_2 (Fig. 2 a). It is indicative of that station K2 during this cruise was potentially the sink of atmospheric CO_2 unlike winter (source of CO_2). Surface pCO_2 at station S1 (30°N) was 375 ppm and slightly smaller than atmospheric pCO_2. Station S1 was also the sink of atmospheric CO_2 during

MR10-06. Compared to winter pCO_2 (Fig. 2 b) observed previous cruise (MR10-06), surface pCO_2 at station K2 in autumn decreased by approximately 80 ppm (from 420 to 340 ppm). This is attributed to uptake of CO_2 by biological activity. On the other hand, pCO_2 at station S1 increased by approximately 50 pm (from 325 to 375 ppm). This is attributed to increase of SST.

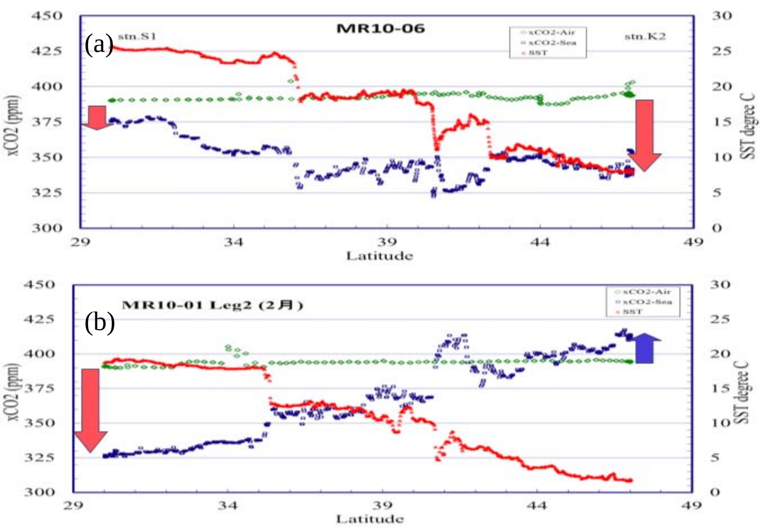


Fig.2 Surface pCO_2 (blue), atmospheric pCO_2 (green) and SST (red) during this MR10-06 cruise (a) and previous MR10-01 cruise (b).

3) Phytoplankton and Primary productivity

Concentration of Chlorophyll *a* (Chl-*a*) in the upper 40 m was approximately 0.6 mg m^{-3} at station K2 (Fig. 3 a). Below 40m, Chl-*a* decreased largely. Based on measurement of accesary pigments by HPLC, it was suspected that a half of phytoplankton was *haptophytes*, and *diatom*, that is representative phytoplankton of Western Pacific subarctic gyre, was small fraction during this cruise. At station S1, concentration of Chl-a was smaller than that at station K2. Subsurface Chl-*a* maximum was observed at around 90 m (Fig. 3 b). Subsurface Chl-*a* maximum is generally observed in the area where surface light intensity is too strong for phytoplankton growth and nutrient is depleted near surface. Oceanographic condition of Station

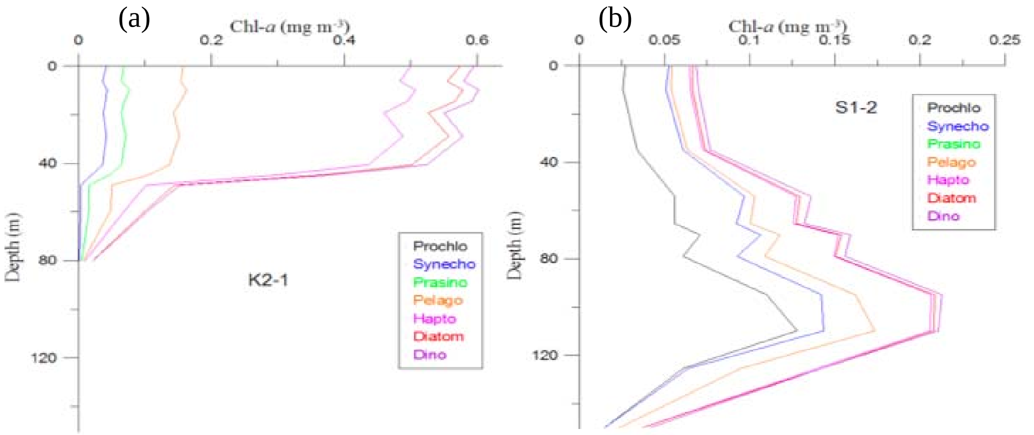


Fig. 3 Chl-*a* concentration at station K2 (a) and S1 (b). Composition of phytoplankton is also shown.

S1 might correspond to this condition. *Prochlorococcus* was pre-dominant and it is noted that diatom was very little.

Primary productivity (PP) was measured twice by simulated in situ incubation (SIS) at station K2 (Fig. 4). PP decreased with depth and nearly zero at the bottom of euphotic layer (~ 50 m). Integrated PP were 284 and 401 mg-C m^{-2} day^{-1}. Compared to winter PP (~ 100 mg-C m^{-2} day^{-1}), PP was high. PP at station S1 also decrease with depth. PP was observed to the deeper depth because euphotic layer was approximately 100 m. Integrated PP at station S1 was 131 mg m^{-2} day^{-1} and one fourth of PP observed during MR10-01 cruise (~ 500 mg-C m^{-2} day^{-1}). It is noted that weather during the above incubation was cloudy or rainy and surface PAR was very low (~ 7 mol quanta m^{-2} day^{-1}).

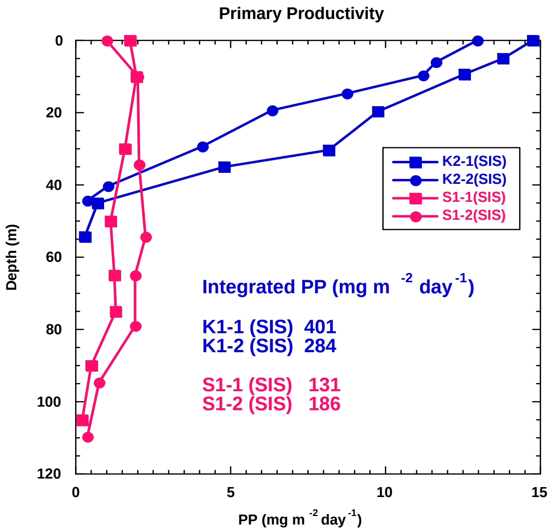


Fig.4 Primary productivity

4) Sinking particles collected by sediment traps

Seasonal sinking particle fluxes were collected at approximately 200 m, 500 m and 5000 m at stations K2 and S1 between February and October 2010. In order to know seasonal variability of sinking particle flux qualitatively onboard, heights of collected particles in collecting cups were measured with a scale. Particles collected at 200 m mainly consist of creature larger than 1 mm such as small fish, shrimp and large zooplankton. Thus these materials might not be sinking particles, but “swimmer”.

(Station K2)

Sinking particle flux at 200 m started to increase from 22 February (start date of sample collection) and peaked at around middle May (Fig. 5a). Sinking particle flux at 200 m also increased in autumn centering early September. Sinking particle flux at 500 m show similar seasonal variability to that at 200 m with some differences: period of flux peak was delayed by one cup period (12 days), and peak in autumn was smaller than that observed at 200 m (Fig. 5b). The first peak also appeared at 5000 m with time lag (12 days) from 500 m flux peak (Fig. 5c). If sinking particle flux at 500 m arrived at 5000 m after 12 days, sinking velocity can be estimated to be approximately 375 m day^{-1}. After high flux was observed, little sinking particles were collected by 5000 m sediment trap. It is likely attributed not to that sinking particle fluxes were very small, but to “the clogging” of 5000 m sediment trap after high flux.

(Station S1)

Sinking particle flux at 200 m increased in late April 2010 (Fig. 5d). Small flux peak was also observed in late February and early March. Small flux peak was observed in March at 500 m (Fig. 5e). On the other hand, clear flux increase at 5000 m was not observed (Fig. 5f). Compared to fluxes at station K2, seasonal variability and flux of sinking particles was very small at station S1.

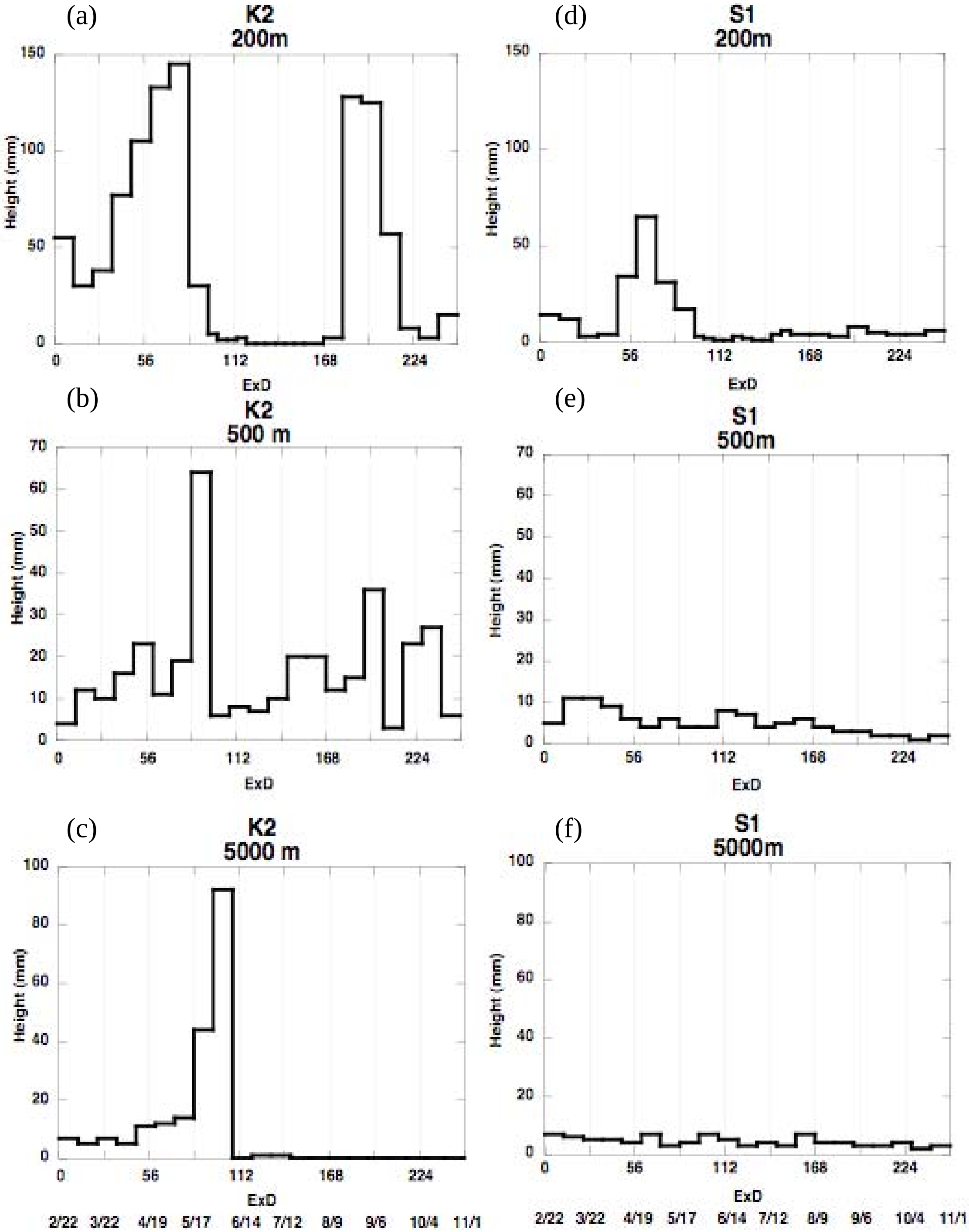


Fig. 5 Visual estimation of total mass flux at respective depths at station K2 (left side figures) and S1 (right side figures)