Transport of age-0 jack mackerel (*Trachurus japonicus*) from the East China Sea to coastal areas along the Kuroshio.

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Jack mackerel (*Truchurus japonicus*) inhabiting coastal areas in temperate western North Pacific is an important fisheries resource in East Asian countries. Ichthyoplankton sampling surveys indicate that large spawning grounds are formed in the south of East China Sea from February to March, which is thought to be the main source of the resources in the Pacific coastal waters of Japan. However, transport and recruitment processes from the East China Sea to the coastal waters of Japan have yet to be quantified. In the present study, transport of age-0 jack mackerel by the Kuroshio and the recruitment to the southern coastal areas of Japan were investigated by analyzing fisheries landing records and temperature data from real time monitoring buoy systems. Mean seasonal fluctuation of the landing of age-0 jack mackerel compiled from 10-years records showed multiple peaks in the western part (Miyazaki and Kochi prefectures), first in mid spring and second in mid fall, and single peak in the eastern part (Mie, Shizuoka and Kanagawa prefectures). Time lags of the first peaks are not linearly related to the distance between the fishing grounds, and the eastward propagation of the landing is clearly observed only from Ehime to Kochi. The timing of the peaks in the eastern part in Mie (first peak), Shizuoka (single), Kanagawa (single) prefectures were detected in mid fall, later than the timing expected for those from the East China Sea. These results suggest that larvae and juveniles from the East China Sea are not predominant source and local population reproduced in each area is also important. In the presentation, temperature fluctuations around the landing pulses and their physical characteristics are also discussed.

Keywords: Jack mackerel, Kuroshio, larval transport, recruitment process

Development of a physical-biogeochemical-fish coupled model for the western North Pacific

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Japanese food culture is highly depends on seafood and marine capture fishery is one of the important food supply for Japanese. However, the catch of many fish species in Japan showed multi-decadal fluctuations. Species alternation of sardine, anchovy, and chub mackerel is one of the distinctive phenomena. Until now, the mechanisms of fish stock fluctuations are still unclear, although many studies have been conducted. The authors are focusing on a 18.6-years tidal oscillation. Tides generate strong mixing interacting with bottom topography. Therefore, we focused on the Kuril Islands, Izu Ridge, and Nasei Islands as tidal mixing hotspots. As fish species live in tidal mixing hotspot areas in the western North Pacific, the authors are focusing on Jack mackerel, chub mackerel, and Pacific cod. To investigate the influence of the 18.6-years tidal oscillation on those species, we are planning to apply the Regional Ocean Modeling System (ROMS) coupled with North Pacific Ecosystem Model for Understanding Regional Oceanography For Including Saury and Herring (NEMURO.FISH) for chub mackerel in the western North Pacific (hereafter: this model is referred as the ROMS-NEMURO.FISH). The ROMS-NEMURO.FISH was driven by the atmospheric forcing of Common Ocean Reference Experiment version 2 (CORE2). Also, the Simple Ocean Data Assimilation (SODA) was used as the initial and the boundary conditions for the ROMS-NEMURO.FISH. In this presentation, as a first step, we briefly report the climatology and interannual fluctuation of physical fields and will discuss the model reproducibility to evaluate the model physical field from the point that the model can be applied for the fish stock fluctuations.

Keywords: physical-biogeochemical-fish coupled model, ROMS, NEMURO.FISH, chub mackerel

A challenge to investigate environmental factors which determine spawning migration variability of Pacific saury

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Spawning migration is one of the most difficult behavior to represent by a numerical model. For example, Pacific saury make a wide spawning migration from the subarctic to subtropical regions, while the detailed mechanism of the spawning migration has not been elucidated. Based on the synoptic survey of Pacific saury as realistic initial condition, an Euler-type model of Pacific saury was applied to investigate environmental factors which determine spawning migration variability. As realistic boundary conditions, satellite derived environmental conditions were used as forcing; sea surface temperature (SST), prey density estimated from surface chl-a concentration and surface current velocity fields. Growth of Pacific saury was calculated based on a fish bioenergetics model (NEMURO.FISH). A fitness algorithm was applied for feeding migration in which the fish are assumed to be moving towards a place with optimal growth condition. A larvae fitness algorithm was applied for spawning migration in which the spawning fish moves to a place of the optimal growth of larvae. For spawning migration, westward migration was added to reproduce realistic spawning grounds around Japan Islands. Strength of the westward migration during spawning migration was adjusted to realize observed variability of saury migration to fishing grounds. The adjusted westward migration variability was compared to the environmental factors.

Keywords: marine ecosystem model, fish growth-migration model, Pacific saury, climate variability

Revisiting response of oceanic carbon cycle to global warming

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Climate warming tends to reduce oceanic uptake of CO_2 from the atmosphere thereby accelerating the rate of CO_2 accumulation in the atmosphere and global warming. Most previous studies have shown that the physical effects, decrease in CO_2 solubility and increased stratification, are major contributors to this reduction in oceanic CO_2 uptake [Sarmiento et al., 1998; Plattner et al., 2001]. In those previous studies, changes in the biological pump associated with ocean circulation change were regarded as a second-order process even though biological effects on the natural carbon cycle can be very important. However, the contributions of both physical and biological effects to the reduction in oceanic CO_2 uptake are not evaluated directly in the recent generation of coupled atmosphere–ocean general circulation models (AOGCMs) and ocean biogeochemical models. To address this we reevaluate the individual mechanisms contributing to the reduction in oceanic CO_2 uptake using a series of multi-centennial global warming simulation conducted with AOGCM and an offline ocean biogeochemical model. The uptake reduction of 13% due to global warming at 140 years is consistent with the same simulation using models in the CMIP5 [Arora et al., 2013]. Sensitivity studies show that changes in the biological pump and gas solubility are the dominant processes for this reduction in oceanic carbon uptake, which is opposite to most of the previous studies: changes in ocean circulation and solubility are the dominant processes. Decrease in new production caused by lower nutrient supply and enhanced remineralization from seawater warming increase dissolved inorganic carbon at the surface, thereby substantially preventing oceanic CO_2 uptake. The weaker Atlantic meridional overturning circulation reduces oceanic CO_2 uptake, while weaker equatorial upwelling and increased mixing due to enhanced westerly winds in the Southern Hemisphere enhance CO_2 uptake. As these effects cancel each other out, the effect of circulation change becomes a second–order process. Our results demonstrate that the biological pump plays a significant role in not only natural carbon cycle but also anthropogenic carbon cycle.

Keywords: Global warming, Carbon cycle, Ocean biogeochemical model

Analysis of future changes in ocean primary production using CMIP5 models

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Due to global warming, changing ocean environment such as stratification, acidification, and deoxygenation is expected to affect marine phytoplankton and its primary production. Multiple modeling studies show that global Net Primary Production (NPP) and Export Production (EP) will decrease in the future because stratification reduces supply of nutrient from the deep ocean (Fu et al., 2015). However, though EP decreases in all CMIP5 models, NPP does not change significantly in a few CMIP5 models, exceptionally (Bopp et al., 2013). The purpose of this study is to clarify the reason why responses of NPP to global warming significantly differ among models.

Because it is found that the tropical ocean mainly contributes to changes of global NPP and EP, we focus on this area. By analyzing NPP and EP simulated in 10 CMIP5 models, we found that the inter-model difference in response of NPP to global warming is attributed to combination of stratification and temperature dependence of remineralization. For a model that shows exceptional response of NPP (GFDL-ESM2G), we suggest the possibility that the temperature-dependent parameter of remineralization is overestimated in this model; global warming promotes remineralization, which tends to increase NPP in spite of decreasing EP. As a further analysis, we investigate response of NPP to El Nino by regressing Nino.3 SST index to NPP. We found that the satellite-based estimate and the other CMIP5 models show decrease of NPP during El Nino, whereas GFDL-ESM2G shows increase of NPP. This result implies that evaluation of models by investigating response of NPP against natural variability such as ENSO is useful for improving the future prediction.

As a next study, we plan to perform sensitivity experiment by using the marine ecosystem models in order to evaluate how ocean primary production affect the changes of carbon cycle in global warming climate.

Keywords: Primary Production, Export Production, CMIP5, global warming

Preliminary experiment of ocean acidification in the western North Pacific

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Responses of marine phytoplankton to ocean acidification is reported from an on-board manipulation experiment in the western North Pacific (March 9, 2015; 41.9N, 146E). In this experiment, it is suggested that an increase in nano-/pico-phytoplankton and a decrease in diatoms under high pCO2 conditions (1420 and 2850 μatm; 1420 μatm corresponds to Y2150 of AR5 RCP8.5 scenario), respectively. In this study, we parameterized the responses of phytoplankton to acidification, and conducted a simplified ocean acidification experiment using a 1D ecosystem model, MEM (Shigemitsu et al., 2012) at the Station A04 (42.15N, 145.07E). The results showed a potential of delay in spring bloom with decrease in the magnitude, and an importance of acidification on not only calcifiers but also on general phytoplankton.

Keywords: Ocean Acidification, Ecosystem Model, western north Pacific

Modelling the impact of riverine and atmospheric nitrogen inputs on the marine biogeochemistry

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Nitrogen in the ocean plays a key role in primary production, and biological activities, such as assimilation of phytoplankton and decomposition of organic matter are well studied. However, nitrogen cycle of the basin scale is still unclear because of the quite long time scale of the processes such as denitrification, sediment processes, and advection caused by meridional overturning circulation. Furthermore, the impact of the atmospheric and riverine nitrogen input has not been clarified. Human activities will change the nitrogen cycle in the ocean shifting riverrine and atmospheric nitrogen inputs, so that it is required to study the nitrogen balance in the whole ocean. To evaluate the nitrogen cycle in the ocean, we created a marine biogeochemical model including processes such as nitrogen fixation, denitrification, atmospheric and riverine nitrogen input, then embedded it into an Earth System Model: MIROC-ESM 5.9 developed by Program for Risk Information on Climate Change, JAMSTEC. We spun up MIROC-ESM for 800 years and analyzed the results of the last 10 simulated years. The model results showed that riverine nitrogen and atmospheric nitrogen inputs changes the production of phytoplankton about 20% and 10%, respectively, especially in the subtropical region of the eastern North Pacific and equatorial region of the western Atlantic Ocean. Riverine nitrogen input changed nitrate concentration up to ±2.5 umol L^{-1} in the high latitudes such as the subarctic and polar regions (excluding the coastal regions). Our results showed the importance of riverine and atmospheric nitrogen inputs to the basin-scale nitrogen cycle.

Keywords: Nitrogen cycle, riverine nitrogen input, atmospheric nitrogen deposition, marine biogeochemistry, Earth System Model

Biophysical Controls on Vertical Fluxes of Dissolved and Particulate Carbon, Nitrogen and Phosphorus in the Northern South China Sea

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Vertical fluxes of particulate organic matter and diffusion flux of dissolved organic matters (DOM) are the major part of biological pump in the ocean. In this study, we employed shipboard observations and sediment-trap deployments to collect water samples and sinking materials for hydrographic and chemical analyses in the northern South China Sea (NSCS). In addition to seasonal variability, effects of eddy and internal waves on vertical fluxes of carbon (C), nitrogen (N) and phosphorus (P) are also explored. Vertical fluxes of C, N and P in the NSCS were respectively estimated to be 66.8±1.29 mg C m^{-2} d^{-1}, 12.8±0.38 mg N m^{-2} d^{-1} and 0.99±0.07 mg P m^{-2} d^{-1} in the spring season, about 64.3±1.47 mg C m^{-2} d^{-1}, 12.1±0.47 mg N m^{-2} d^{-1} and 0.93±0.04 mg P m^{-2} d^{-1} in the summer season, and about 155±15.9 mg C m^{-2} d^{-1}, 21.2±1.68 mg N m^{-2} d^{-1} and 1.79±0.19 mg P m^{-2} d^{-1} in an internal-waves induced event. Meanwhile, the organic carbon flux derived from the modified Vertical Generalized Production Model (VGPM) was 183±17 mg C m^{-2} d^{-1} in a winter anticyclonic eddy in NSCS. Positive correlations were significant between the chlorophyll inventory and DIN inventory, and also significant between vertical fluxes of CNP and DIN inventory in the euphotic zone. Thus, vertical fluxes of CNP were apparently driven by primary production that was determined by the availability of DIN. The diffusion flux of DOM increased generally with depth and was enhanced obviously in the internal-waves condition. The proportions of CNP vertical fluxes to the biological pump in NSCS are 66.5%, 74.3% and 71.3%, respectively, in regular spring, about 63.8±9.18%, 76.6±0.58% and 75.1±2.02%, respectively, in regular summer, and about 62.1%, 73.5% and 64.7%, respectively, in an internal-waves induced event. The vertical flux accounts for the highest proportion of the biological pump. However, the proportion of DOM flux is insignificant in the biological pump.

Keywords: Vertical fluxes, Biological pump, Carbon, Nitrogen and Phosphorus, Northern South China Sea

Impact of mesoscale eddies on spring bloom initiation in the Japan Sea

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Mesoscale eddies play an important role in the ocean primary production and biogeochemical processes and induce large spatial and temporal variability of near surface chlorophyll-a concentration (CHL). In particular, they are known to impact on the temporal variation of mixed layer depth (MLD), which is important for biological processes such as phytoplankton spring bloom phenomenon, a recurring phenomenon observed in temperate seas that results in large increase in phytoplankton abundance in springtime. In this study we investigated the influence of mesoscale eddies on timing of spring bloom initiation in the Yamato Basin region (133-139º E and 35-39.5º N), Japan Sea, in a period spanning 2002-2011. We identified mesoscale eddies based on geometric characteristic of satellite estimated geostrophic velocity around eddies (Nencioli et al., 2010). Eddy region was defined based sea level anomaly (SLA) data as the outmost closed contour of SLA enclosing identified centre (Chelton et al., 2011). CHL from winter (January) to early summer (June) was used to capture the spring bloom event. We also used in-situ profiles of temperature-salinity data within eddy region to estimate the MLD on individual profiles as the density change of 0.03 kg m^{-3} from surface reference level (10 m). Results showed that bloom was initiated early in cyclonic eddies (CEs) with shallow MLD (mostly < 100 m) compared to anticyclonic eddies (AEs) in which it was initiated despite the deeper MLD (> 100 m). From the examination of net heat flux (Q_0) within eddies we found that the onset of spring bloom in CEs occurred while large heat loss to the atmosphere was being observed, whereas in AEs it was observed close to the commencement of positive Q_0. This suggested that in AEs relaxation of turbulent mixing was important for bloom to start, whereas in CEs, because of shallower MLD, improved light condition for phytoplankton growth within the turbulent layer was reached earlier, thus triggering the bloom.

Keywords: Mesoscale eddies, mixed layer depth, phytoplankton, spring bloom

Global size distribution of phytoplankton communities from space

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We developed a remote sensing methodology to estimate size distribution of various pigment-based phytoplankton groups such as diatoms, peridinin-containing dinoflagellates, haptophytes, cyanobacteria etc. Our estimation was compared with a local in situ observation to show an agreement between them. According to our state-of-the-art remote sensing methodology, global size structure of the entire phytoplankton community could be divided into three classes to the first approximation, agreeing well with a conventional classification based on historical in situ observations. However, in contrast to historical size classifications (Sieburth et al, 1978), i.e. pico-phytoplankton (< 2 μm), nano-phytoplankton 2-20 μm, micro-phytoplankton (> 20 μm), we propose new size boundaries for these classes based on global satellite observation: pico-phytoplankton (< 1 μm), nano-phytoplankton 1-10 μm, micro-phytoplankton (> 10 μm). Size-diversity index of a given phytoplankton group, defined by a difference between logarithmic maximum and minimum sizes of the group, was largest for haptophytes than diatoms. The maximum size-diversity of a given phytoplankton group was not necessarily correlated to its dominance in chlorophyll abundance either. Our results are expected to cast light upon global marine biodiversity and marine ecosystem analysis.

Keywords: phytoplankton, biodiversity, size, ocean color, ecosystem, ocean

Converting electron transfer rates of phytoplankton into daily carbon fixation rates in coastal waters of Ariake Bay and the East China Sea

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In the last 20 years, introduction of the active fluorescence technique, fast repetition rate fluorometer (FRRf), has opened up capability to measure instantaneous electron flow rate through phytoplankton photosystem II (electron transfer rate, ETR). However, in most of the early studies, the conversion factor (K_C) from ETR to primary production was assumed to be constant. Recent studies have shown that *Kc* can vary over a large range in nature and that understanding of the variability of K_C in relation to other physical and biogeochemical parameters is the crucial for accurately estimating primary production with FRRf. In this study, K_C was determined from parallel measurements of ETR and daily net primary production (NPP) and modeled as a function of key environments and phytoplankton community structure for the first time in Ariake bay and the East China Sea. In Ariake Bay study, we firstly confirmed that K_C varied considerably in nature and then demonstrated the strong correlation ($R^2 = 0.94$) between daily photosynthetically active radiation (PAR) and K_C; the novel and simple PAR-dependent relationship used for deriving K_C opens the possibility for directly FRRf based NPP estimating. In the East China Sea study, we confirmed that PAR was still the main controlling factor of K_C ($R^2 = 0.72$); moreover, this factor appeared secondarily influenced by dominant phytoplankton taxa present. Results showed that the correlation between K_C and PAR was improved ($R^2 = 0.78$-0.86) by considering two clusters of taxonomical groups, large phytoplankton (>20 μm) and small phytoplankton (<20 μm). Overall, we have developed a novel algorithm for estimating K_C from PAR and phytoplankton community composition and this algorithm can be applied to future FRRf-based high resolution studies of primary production.

Keywords: ETR, Primary productivity, Quantum requirement for carbon fixation, Phytoplankton composition, Fast repetitive rate fluorometer

