Japan Geoscience Union Meeting 2015
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AOS23-01 Room:201B Time:May 24 14:15-14:30

Current states and future prospects of modeling studies for lower trophic level marine ecosystem.

HASHIOKA, Taketo[1*]

[1]Japan Agency for Marine-Earth Science and Technology

Historically large scale ecosystem models for lower trophic level have been developed for understanding of global biogeochemical cycles such as global carbon budget. For this purpose, a concept of Plankton Functional Types (PFT), in which plankton are categorized into several types depending on their roles on biogeochemical cycles, have been employed as one of effective representations of marine ecosystem. Even now this approach of PFT modeling is the main force for a large scale modeling represented by earth system model. On the other hand, the demand on ecosystem modeling have been expanding and diversifying. Namely interest in understanding of ecosystem itself being heightened (e.g., future impact of climate change on ecosystem roles and diversity). As a results, modeling approach for explicit representations of plankton physiological response and ecological interaction have been attracting attention in recent years. Large scale ecosystem modeling also being in transition. In this presentation, based on internal activities of CMIP (Coupled Model Inter Comparison Project) and MAREMIP (MARine Ecosystem Model Intercomparison Project), we review the current state of PFT modeling and discuss future prospects of lower trophic level modeling.

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AOS23-02 Room:201B Time:May 24 14:30-14:45

Vector digram analysis of ocean carbon pumps: application to the climatological data and CMIP5 simulations

OKA, Akira[1*]

[1] Atmosphere and Ocean Research Institute, University of Tokyo

The ocean stores 60 times more carbon than the atmosphere and therefore the ocean carbon cycle has a critical role in controlling the atmospheric CO2 concentration. By using the three dimensional distribution of dissolved carbon concentration (DIC), total alkalinity (ALK), phosphate, and salinity, four types of ocean carbon pumps (organic matter, calcium carbonate, gas exchange, and freshwater flux pumps) are defined here and I propose a method with which individual effects of four carbon pumps on atmospheric CO2 concentration can be quantitatively evaluated. By applying this method to the climatology, the contributions of four carbon pump components to atmospheric CO2 are clearly evaluated in one figure (the vector diagram); each carbon pump component is represented by one vector and its contribution to pCO2 can be measured from the difference in the contour values between the beginning and the end of the vector. The same analysis is also applied to the CMIP5 earth system model simulations. Although all models reproduce the same level of the atmospheric CO2 concentration as the climatology, it is shown that contributions from four carbon pumps are not the same among models. This study demonstrates that the vector diagram analysis introduced here is a powerful tool for quantifying the individual contributions of the ocean carbon pumps on atmospheric CO2 concentration and also a useful tool for evaluating the reproducibility of ocean carbon cycle models.

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AOS23-03 Room:201B Time:May 24 14:45-15:00

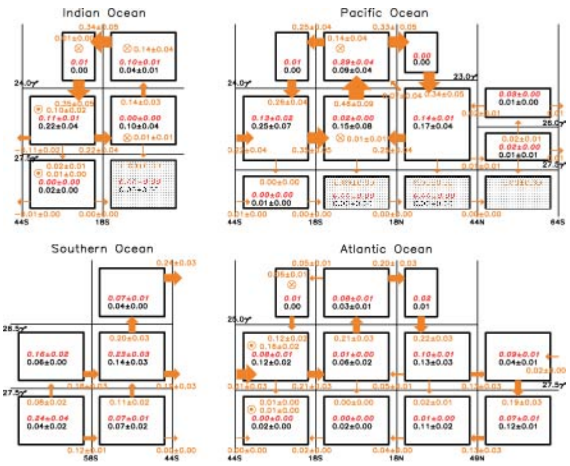
Anthropogenic CO2 uptake, transport, storage, and dynamical controls in the ocean: a modeling study

NAKANO, Hideyuki[1*] ; ISHII, Masao[1] ; RODGERS, Keeth[2] ; TSUJINO, Hiroyuki[1] ; YAMANAKA, Goro[1]

[1]Meteorological Research Institute, [2]Princeton University

Using an ocean carbon cycle model embedded in an ocean general circulation model, we examine how the budget of anthropogenic CO2 is dynamically controlled. The budget is composed of transport, storage rate, uptake from the atmosphere, and density conversion. We estimate (1) vertically integrated budget, (2) three-layer budget, and (3) eleven-layer budget for the eleven sub-domain of the global ocean. This work is the first attempt to conduct the budget analyses in the density framework. The vertically integrated budget is appropriate for examining the inter-basin transport of the anthropogenic CO2. The estimated budget is largely consistent with the previous studies. The three-layer budget allows us to identify how the meridional overturning circulation related transport determines the thermocline inventories for anthropogenic CO2. It is found that Subtropical Cells and the thermohaline circulation play a fundamental role for the budget in the Pacific and Atlantic Oceans, respectively. Along with a inventory map in each isopycnal layer, the eleven-layer budget is suitable for examining how anthropogenic CO2 is stored and transported in various water masses. For the mode waters, which serve as reservoirs of anthropogenic CO2 accumulated in the ocean interior, it is found that uptake via gas exchange is important but much of the uptake via gas exchange occurs non-locally to the mode water formation regions through the Subtropical Cells

Keywords: anthropogenic carbon, OGCM, transport



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AOS23-04 Room:201B Time:May 24 15:00-15:15

Modeling the global cycle of marine dissolved organic matter and its influence on marine productivity

HASUMI, Hiroyasu[1*] ; NAGATA, Toshi[1]

[1]AORI, UTokyo

A three-dimensional numerical model is developed for studies on the marine biogeochemical cycles by dealing with coupling of planktonic and microbial processes. The coupling is achieved by explicitly representing generation and consumption of dissolved organic matter (DOM). The model is applied to investigate mechanisms by which the global cycle of marine DOM influences marine productivity. Two categories, biodegradable (DOMb) and refractory (DOMr), are considered for DOM. DOMb is generated through phytoplankton exudation, zooplankton excretion, detritus decomposition, and photodissociation of DOMr. Bacteria consume DOMb and generate DOMr. After the long-term adjustment, the observed amount of DOM was reproduced from homogenous conditions of nutrients and plankton. Spatial distribution of bacterial abundance is reasonably validated against recently observed large-scale data. Sensitivity experiments indicated that: i) over a multi-decadal timescale, contribution of DOMr to global biogeochemical cycles is negligible, ii) the existence of DOM significantly reduces the global marine primary productivity, and iii) DOMb originated from phytoplankton exudation is transported to subtropical regions, leading to enhanced primary productivity there as a consequence of nutrient supply associated with remineralization of transported DOMb.

Keywords: marine biogeochemical cycles, dissolved organic matter, microbial loop, marine productivity, numerical modeling

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AOS23-05 Room:201B Time:May 24 15:15-15:30

Stable isotope study using Fe: implication to understand the Fe-biocycles in marine environment

YAMAGATA, Yuko[1*] ; TANAKA, Yuki[1] ; TANABE, Shinsuke[2] ; ITAI, Takaaki[2] ; ISOBE, Tomohiko[3] ; YAMADA K., Tadasu[4] ; TAJIMA, Yuko[4] ; HIRATA, Takafumi[1]

[1]Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University, [2]Center for Marine Environmental Studies, Ehime University, [3]National Institute for Environmental Studies, [4]National Museam of Nature and Science

Iron is one of the most important inorganic nutrients for almost all plants and animals. For marine organisms, because of very low concentration range of Fe ($<10^{-7}$ wt%) in the seawater, intake efficiency of Fe could become very high to avoid possible loss of many biochemical functions associated with Fe. This is well demonstrated by the small changes in the Fe isotope ratios ($^{56}Fe/^{54}Fe$ and $^{57}Fe/^{54}Fe$) among the marine organisms of various trophic levels (TL) (e.g., plankton, shrimp, tuna : Jong et al., 2007; Bergquist and Boyle, 2006). This lack in the changes in the Fe isotope ratios can be explained by the high-intake efficiency of Fe from the dietary foods. This is contrasting with those for the land organisms. For land organisms, the $^{56}Fe/^{54}Fe$ and $^{57}Fe/^{54}Fe$ ratios vary significantly with the increase of the trophic level (Walczyk and Blankenburg, 2002, 2005). This could be explained as reflecting the large isotope effects on Fe isotopes, mainly due to the low intake-efficiency of Fe. In fact, availability of Fe for land organisms would be much higher than that for marine organisms, because Fe concentrations in the most rocks, minerals or soils would be much greater than that in the seawater. However, the intake efficiency would not be a major source of the changes in the Fe isotope ratios. Chemical form or oxidation status of Fe would also affect be magnitude of isotope effect on Fe. Moreover, it should be noted that the Fe bio-cycle can not be evaluated only by the traditional trophic level, defined by the $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios, which should reflect the food chain of the organic substances, such as amino acids or proteins. This suggests that the conventional trophic level did not reflect the food chain of Fe. To investigate this, we have measured the $^{56}Fe/^{54}Fe$ and $^{57}Fe/^{54}Fe$ for series of marine organisms, especially for higher trophic level animals.

In this presentation, *Peponocephala electra* (n=23; TL=4.3), *Thunnus alalunga* (n=7; TL=4.0), *Thunnus obesus* (n=1; TL=4.0), *Kajikia audax* (n=1; TL=4.0), *Berryteuthis magister* (n=5; TL=3.4), and *Octopus longispadiceus* (n=2; TL=3.3) were subsidized to the Fe isotope ratio analysis. After the chemical decomposition and chemical separation procedures, the $^{56}Fe/^{54}Fe$ and $^{57}Fe/^{54}Fe$ ratios were measured by the multiple collector-ICP-mass spectrometer (MC-ICP-MS). The measured $^{56}Fe/^{54}Fe$ and $^{57}Fe/^{54}Fe$ ratios varied significantly from those for lower trophic level organisms. Several important features of the Fe isotopes for marine organisms could be derived from the present results. The changes in the $^{56}Fe/^{54}Fe$ isotopes could be explained either by the poor intake efficiency of Fe from the dietary foods, or by the changing chemical form of Fe in the dietary foods for the marine organisms of higher trophic levels. If in the case that the Fe was adsorbed as a heme-Fe (Fe(II)) from the dietary foods, the magnitude of the isotope fractionation would be smaller than that found in adsorption of non-heme Fe (e.g., Fe (III)). This suggests that the major source of Fe for higher trophic animals would be non-heme Fe. Another possible cause of changes in the $^{56}Fe/^{54}Fe$ ratio would be originating from the definition of the trophic level of the marine organisms. This suggests that the food-chain for the inorganic nutrients should be defined by the separate definitions. The details of the mechanism in the variation of the $^{56}Fe/^{54}Fe$ ratios for the marine organisms will be discussed in this presentation.

Keywords: stable isotope of iron, iron biocycle, marine organisms, multiple collector-ICP-mass spectrometry, trophic level

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AOS23-06 Room:201B Time:May 24 15:30-15:45

New Models of the Flexible Response of Plankton Ecosystems: from Theory to Practical Implementation

SMITH, S. lan[1*] ; YOSHIKAWA, Chisato[2] ; SASAI, Yoshikazu[3] ; CHEN, Bingzhang[3] ; GARCIA-COMAS, Carmen[3]

[1]Marine Ecosystem Dynamics Research Group, RCGC, JAMSTEC & CREST, JST, [2]Institute of Biogeosciences, JAMSTEC, [3]Marine Ecosystem Dynamics Research Group, RCGC, JAMSTEC

For over two decades, detailed models have been developed to reproduce the flexible response of phytoplankton, and to a lesser extent of zooplankton, as well known from laboratory experiments. This research has yielded scientific insights, and some of those detailed models have been applied in coupled physical-biological ocean models. However, such detailed models are in general too complex for practical applications in large-scale and long-term ocean modeling studies. Therefore, most current marine ecosystem models do not account for the flexible physiological response of plankton. Nevertheless, large-scale and long-term ocean modeling studies are necessary in order to test the theoretical ideas embodied in these detailed models against oceanic observations and to explore the impact of flexibility on the response of plankton ecosystems to environmental change. In order to advance scientific understanding of plankton ecosystems in the ocean, we aim to reconcile the results of laboratory experiments, theoretical modeling, and oceanic observations. For this purpose, we are developing new, relatively simple models of the flexible response of interacting phytoplankton and zooplankton communities, which can be applied in practical ocean modeling. Recent results will be presented from one-dimensional (vertical) coupled physical-biological models of the ocean compared to oceanic observations. These results include: 1) the impact of the process of photo-acclimation on the vertical distributions of phytoplankton biomass, particulate organic nitrogen, and chlorophyll, and 2) the potential role of the hypothesised *Kill-the-Winner* grazing effect for sustaining plankton biodiversity.

Keywords: plankton, ecosystem modelling, ocean, observation, validation, trade-off

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AOS23-07 Room:201B Time:May 24 15:45-16:00

Phytoplankton coexistence based on niche differentiation studied by an OGCM

MASUDA, Yoshio[1*] ; YAMANAKA, Yasuhiro[1]

[1]Hokkaido Univ.

Oceanic phytoplankton have high diversity. Observational studies estimate that there are over 70,000 phytoplankton species. In mechanisms which enable the high diversity, we focused on niche differentiation, and inspected it by using an oceanic general circulation model (OGCM). We also explored effects of advection and diffusion on the phytoplankton diversity.

Based on NEMUEO and MEM, we developed a marine ecosystem model which can express a few hundred phytoplankton species and combined it to a physical oceanic model, MRI.com. The physical field represents idealized subpolar and subtropical gyres in a rectangular model domain of 30 by 30 degrees. To explore effects of advection and diffusion, an offline model (hereafter 0D model) is also developed, in which only concentration of phytoplankton and zooplankton are prognostic variables, and advection and diffusion of the two variables are set to be zero.

We seeded 240 phytoplankton species which have different trait for temperature, light and nutrient, and 31 species survive. In the 0D model, the same experiment results in 85 surviving species, in which only one species survives in one grid box. Therefore advection and diffusion increase alpha diversity but decrease gamma diversity.

We divided a surviving species into 8 species, in which optimum temperature is slightly different. As a result of competition of 248 ($31*8$) species, 125 species survive. This is not considered to be the upper limit of niche differentiation, and further differentiation would be possible. We found coexistence of two species which differ only 0.1 degrees in optimum temperature. The fact that slight difference of niche enables coexistence is considered to be significant to explain the high diversity of oceanic phytoplankton.

Keywords: Phytoplankton diversity, marine ecosystem model, OGCM

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AOS23-08 Room:201B Time:May 24 16:15-16:30

Arctic sea ice algae modeling: Response to shelf-basin water transport

WATANABE, Eiji[1*]

[1]JAMSTEC

Seasonal and interannual variability in biogenic particle flux was captured by the multi-year bottom-tethered sediment trap moorings in the Northwind Abyssal Plain (Station NAP: 75N, 162W, 1975 m water depth) of Chukchi Borderland. The trapped sinking flux of biogenic particles had an obvious peak and the major component of diatom valve flux was sea ice-related species Fossula arctica in August 2011. On the other hand, the observed summer particle flux was considerably smaller in 2012 than those in 2011. The suppression of sinking materials would attribute to the extension of oligotrophic Beaufort Gyre water toward the Station NAP. In this study, to address an impact of water mass condition on biogenic particle flux during the summer season, sea ice algae component was newly incorporated into the lower-trophic marine ecosystem model NEMURO. The original NEMURO coupled to the pan-Arctic sea ice-ocean physical model COCO represented pelagic plankton species (i.e., diatom, flagellate, and copepod) and reproduced the early-winter peak of sinking flux of Particulate Organic Nitrogen (PON) [Watanabe et al., 2014]∗. Whereas the mesoscale shelf-break eddies played a great role in the early-winter peak, the simulated summertime peak was significantly delayed behind the trap data partly owing to lack of sea ice algae component in the previous experiment.

In the developed model, the major habitat of sea ice algae was assumed to be a 2 cm-thick skeletal layer at sea ice-ocean boundary. Since sea ice bottom temperature was always kept at the freezing point of underlying sea water, the growth rate of sea ice algae was calculated following light availability and nutrient uptake terms. Light transmission through snow and sea ice column was given using empirical extinction rates. Sea ice-ocean nutrient exchange was formulated in the different manner for sea ice freezing and melting periods. We assume that sea ice algae can utilize nutrients (nitrate, ammonium, and silicate) both in the skeletal layer and in the ocean surface layer, according to nutrient availability in each layer. This hybrid-type nutrient uptake formulation is considered to represent more realistic characteristics of sea ice algae biology. In addition, the modeled PON was divided into two components with different sinking speeds so that sea ice assemblage could sink faster than other particles derived from pelagic plankton. The one-year experiment from October 2010 to September 2011 demonstrated reasonable spatial distribution and seasonal transition in sea ice algae biomass and the related sinking particle flux during the summer season. The interannual variability and possible background mechanisms (e.g., influence of Beaufort Gyre variation) will also be discussed.

∗Watanabe, E., J. Onodera, N. Harada, M. C. Honda, K. Kimoto, T. Kikuchi,
S. Nishino, K. Matsuno, A. Yamaguchi, A. Ishida, and M. J. Kishi (2014)
Enhanced role of eddies in the Arctic marine biological pump
Nature Communications, 5:3950, doi:10.1038/ncomms4950.

Keywords: Arctic marine ecosystem model, ice algae, Beaufort Gyre, particle flux

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AOS23-09 Room:201B Time:May 24 16:30-16:45

Mesoscale eddies, 3D turbulence, internal waves and associated nutrient flux in the Kuroshio Front

NAGAI, Takeyoshi[1*]

[1]Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology

The Kuroshio, one of western boundary currents in the North Pacific, plays very important roles in transporting heat, organic and inorganic constituents. Because it also carries many pelagic fish larvae along with its strong current from their spawning grounds toward feeding grounds, the Kuroshio-Oyashio confluent regions, primary and associated secondary production in the Kuroshio are considered to be critical for their recruitments. In this study, we attempt to quantify the nutrient fluxes to the Kuroshio, which sustain the biological production there, through variety of physical processes, including along isopycnal fluxes: (1) mesoscale eddy flux, (2) subduction and obduction near the front, and diapycnal fluxes: (3) turbulent mixing and (4) double-diffusive mixing.

We conducted field campaigns to measure three-dimensional density structures and microscale turbulent kinetic energy dissipation rates in the Kuroshio Extension Front in Oct., 2009. Results from the Oct. 2009 cruise suggest that low salinity water is subducted from the surface to over 300 m depth, forming low salinity tongue on the north side of the front. The simultaneous nitrate measurements show that within this tongue, nitrate concentration is high, suggesting that subduction of the low sanity water could also contribute to the nutrient flux to the Kuroshio. Using an Omega-equation, we estimate that O(10 m/day) vertical velocity could lead large nitrate flux of O(100 mMol/m^{-2}day^{-1}) at 60 m depth. However, because of the alternating meanders of the front, how much net nitrate flux to the Kuroshio euphotic zone occurs is still unclear. The series of microstructure measurements taken near the Kuroshio Front suggest that turbulence is enhanced under the Kuroshio main stream in the thermocline, where bands of ageostrophic shear is frequently accompanied. The shear bandings could be due to wind-induced near-inertial internal waves. However, our hypothesis is that the meandering Kuroshio Front can spontaneously radiate near-inertial internal waves. The 1-km horizontal resolution numerical simulation shows that near inertial waves are generated from the meandering front with no external forcing. Because near inertial waves can be trapped and dissipated near the front (Kunze 1985, Whitt and Thomas 2013), this spontaneous near inertial waves with wind-induced inertial waves could be source of turbulent nutrient flux right under the Kuroshio main stream. Our measurements using a microstructure profiling float and EM-APEX floats, support the hypothesis. In this talk, the results from eddy-resolving simulation to evaluate the eddy nutrient flux to the Kuroshio will also be presented.

Keywords: Kuroshio, Turbulence, Mesoscale eddies, Internal waves, Double diffusion, Nutrients

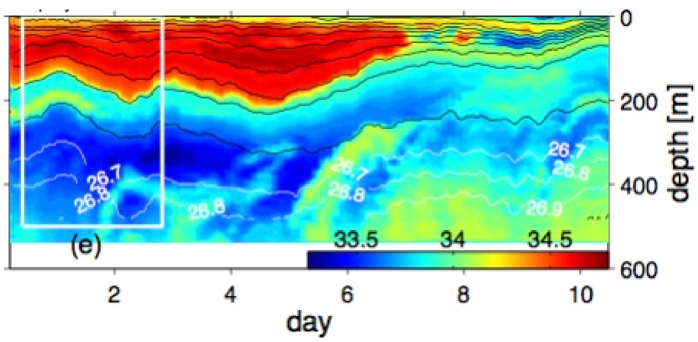

Fig. 1: Salinity measured along the Kuroshio main stream using an EM-APEX Float. White box is measurement range of the microstructure profiling float.

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AOS23-10 Room:201B Time:May 24 16:45-17:00

Ecosystem modeling using Ecopath with Ecosim and fishery related data for practical application

KIYOTA, Masashi[1]*

[1]National Research Institute of Far Seas Fisheries, Fisheries Resarch Agency

Concepts and methods of ecosystem-based fisheries management have not been fully discussed in Japan, and thus data collection, assessment and conservation planning of marine ecosystems have not yet been established. However, fishery-related surveys and oceanographic monitoring have long been conducted around Japan and the resultant data are accumulated. It will be helpful to evaluate the current status of marine ecosystems and assess fisheries interactions using these existing data. In this respect, Fisheries Research Agency have examined feasibility of ecosystem modeling using fishery-related data and Ecopath with Ecosym (EwE).

EwE is an end-to-end model that expresses an ecosystem as flows of biomass. A simple relationship between consumption (Q_i), production (P_i), respiration (R_i) and unassimilated excretion (U_i) of a functional group i is represented as,

$Q_i = P_i + R_i + U_i \cdots (1)$.

A mass balance equation is presumed which means input and output of a functional group is balanced as,

$P_i - Y_i - M2_i - Pi\,(1 - EE_i) - EX_i - BA_i = 0 \cdots (2)$

where Yi is fishery catch, M2 is predation mortality, $P_i(1 - EE_i)$ is other mortality (EE_i is a ratio called ecotrophic efficiency), EX_i is export, and BAi is biological assimilation. The predation mortality is divided into consumption of prey i by predator j,

$M2_i = \sum Q_j\ DC_{ji} \cdots (3)$

which leads to linear simultaneous equations of predator-prey relationships (DCji is the ratio of prey i in the diet of predator j). By solving the equations, Ecopath estimates the flows of biomass and estimates trophic levels, trophic interactions and network properties. However, comparison of network properties between different models is not effective because these values vary depending on the model structure. Ecopath is more suited to summarize flows and biomasses into trophic levels and calculate system productivity or transfer efficiency.

Mean trophic level of catch (MTLc, Pauly et al. 1998), primary production required (PPR) to support catch (Pauly & Christensen 1995), loss of food for higher trophic levels caused by fishery removals (L index, Libralato et al. 2008) and other indices of fishery impacts can be calculated using the outputs. Comparison of Ecopath models of several waters around Japan with world models published in literature revealed that the Japanese commercial fisheries harvested over relatively wide range of trophic levels and had moderate impacts on marine ecosystems.

Ecosim uses the left part of formula (2) as the differential equation of biomass and simulates the temporal dynamics after the mass balance is broken. Dynamic behavior of Ecosim is largely dependent on the vulnerability parameter, which determines the functional response of a predators to prey density change. The vulnerability parameters can be tuned if time series data on relative abundance of functional groups are available.

Many expanded functions are added to recent versions of EwE such as age-structure, spatial heterogeneity (Ecospace), economic evaluation (Value chain) and management strategy evaluation (MSE). Ecospace simulates spatio-temporal dynamics and is used for predicting the effect of spatial management but it also stands on the balanced homogeneous state of Ecopath.

EwE appears to be a good starter of marine ecosystem modeling for understanding foodweb structure and fishery impacts because Ecopath is tailored to take fishery related information as input data in the form of ratios to biomass (P/B, Q/B) or diet composition (DC). The assumption of mass balance does not necessarily mean that the system is in steady balanced state but is rather understood as that the biomass budget is balanced at an average condition over a certain space and period. Preparation of relevant data by appropriate spatio-temporal scale and comparison and/or coupling with other models while exploring data and modeling gaps will be effective steps for the development and practical application of ecosystem modeling to management.

Keywords: ecosystem-based fisheries management, fishery impacts, marine food web, mass balance model, monitoring data

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AOS23-11 Room:201B Time:May 24 17:00-17:15

Numerical analysis of controlling factors of the interannual variations of Japanese common squid around Japan

YOSHIE, Naoki[1*] ; GUO, Xinyu[1] ; WANG, Yucheng[1] ; KUBOTA, Taishi[1]

[1]Center for Marine Environmental Studies, Ehime University

Japanese common squid (*Todarodes pacificus*) is one of the most important fish resources to Japan, Korea and China. It has a clear life cycle: spawns from the shelf slope of East China Sea to southwestern area of the Japan Sea; makes a feeding migration from its spawning area to Japan Sea or Pacific side of Japan; makes a spawning migration back to the East China Sea after growing up in the Japan Sea and Pacific side of Japan. In past several decades, its resources in the Japan Sea and Pacific side of Japan have large interannual variations. Although some studies paid attention on influences of environmental conditions (mainly sea surface temperature) on its spawning area, there is still no quantitative argument on what is the most important factor controlling interannual variation of Japanese common squid resources. In this study, we use a particle tracking model to simulate feeding migration of Japanese common squid larvae to the Japan Sea and South of Japan from 1992 to 2012. In our model, we consider the transport of larvae by ocean current and random walk, the survival condition of larvae by water temperature, and the influence of parent stock on larvae number. Our model results show that the parent stock is likely the most important factor controlling the interannual variation of Japanese common squid resources.

Keywords: Japanese common squid, particle tracking model, interannual variation

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AOS23-12 Room:201B Time:May 24 17:15-17:30

Impacts of global warming on fish resources in North Pacific

SHIBANO, Ryota[1*] ; YAMANAKA, Yasuhiro[1] ; SHIGEMITSU, Masahito[1]

[1]Faculty of Environmental Earth Science, Hokkaido University

Some recent researches reported global warming impact to marine ecosystem. Cheung et al. (2013) estimated the impacts in global ocean using a habitat model. The model provided the future distributions of fishes due to preferred environments and logistic function. However, they deal no components for ecosystem as predation (e.g. primary production) and a few scenario. We develop a habitat model referred from Cheung et al. (2008; 2013) and estimate the impacts to fishes resources using the results of climate model. We deal primary productions for preferred environment to ecosystem component and some RCP scenarios. In this presentation, we show the results calculated by a climates model: MIROC-ESM.

Keywords: fishery resources, global warming, climate model, habitat model

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AOS23-13 Room:201B Time:May 24 17:30-17:45

Modeling large-amplitude recruitment variability of marine fish

ITOH, Sachihiko[1*] ; HASUMI, Hiroyasu[1]

[1]Atmosphere and Ocean Research Institute, The University of Tokyo

Marine ecosystem modeling has advanced considerably in the past few decades, enabling quantitative evaluation of biogeochemical cycles in the ocean. Some models are incorporated into the earth system model and applied for projecting future climate change. However, many of these models consider trophic levels up to zooplankton and do not include fish and other nekton. Although abundances of some marine fish species show large interannual fluctuations synchronous to environmental variations, few model frameworks had capability of explicit analyses on their linkage. A recently developed approach for fish modeling takes both biomass and number of individuals into consideration, which is one of necessary factors of fish community structure; however, even with this approach, present fish models do not usually reproduce drastic variation in the abundances of some small pelagic fishes such as sardine and anchovy. In the present study, we step into recruitment processes of marine fish, which has been suggested by field studies to be determinants of the population size. A food-web model for planktivorous and piscivorous fishes was developed, which will be coupled with a lower trophic ecosystem model and a hydrodynamic model. We focus on the environmental variability in the western North Pacific and the accompanied responses of sardine and anchovy, and test several growth and survival models during early life stages of these fishes. In the presentation, possible amplification processes from plankton to fish will also be discussed.