Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

AOS24-01 Room:311 Time:April 30 15:15-15:30

Modeling of marine biogeochemical and ecosystem in Japan: future perspective and review during the last 20 years

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The first global 3-D marine biogeochemical modeling was developed by Bacastow and Maier-Reimer(1990), and marine ecosystem model was developed by Fasham(1993) as pioneer works, such as Yamanaka and Tajika (1996) and Kawamiya et al.(2000) in Japan. Around 2000, most of marine biogeochemical models have the explicit ecosystem components as well as ecosystem model with focusing short-termed changes in nutrient concentration and pCO2 associated with spring bloom in subarctic regions. And representation of iron cycle was an important issue for both modeling, and trial of coupling between climate and carbon cycles was also started.

Everybody wish to develop the ultimate model explicitly and detailed representing hundreds, thousands, millions of plankton and nekton groups. As the first step, Plankton Functional Types (PFTs) models dealing with relatively small number of plankton and nutrient were introduced (e.g., Le Quere, 2005; Kishi et al., 2007). We have two directions as future model developments for marine biological cycles and marine ecosystem. Former focuses on grouping of phytoplankton having large energy (material) flow, and latter focuses on grouping of zooplankton having the linkage to higher trophic levels such as fish as wood web. If both two directions were covered by the almighty model, we would need unlimited number of prognostic values as plankton number multiplied by elemental components (and grazing-grazed relations proportional to square of plankton numbers). Therefore, model developing along two directions are separated necessarily. We are easily focusing on number of prognostic values as a discussion of model complexity (e.g., Friedrichs et al., 2007). But, we do not forget important improvements leaded by studying individual process and trade-off problem between parameters. For example, recent studies discussed formulation using affinity instead of half saturation constant as classical Michaelis-Menten fomula, unrestricted nutrient uptake optimized by the parameter of restricted nutrient, and different impacts by the global warming between these formulations (Smith and Yamanaka, 2007; Smith et al., 2009). Many people are interesting in another type of models relevant to biodiversity are recently developed (Follows, 2007)

I would like to mention another view such as developing researcher community developing biogeochemical cycles and ecosystem model. Pioneers for marine biogeochemical modeling launched Ocean Carbon cycle Model Intercomparison Project (OCMIP). Studies are leaded by the pioneers at earlier periods but by young researchers relevant to OCMIP around the end of Phase 2. It goes without say that they are the present world-leading scientists in this academic field (such as Le Quere, Follows, Gruber etc.). MARine Ecosystem Model Intercomparison Project (MAREMIP) as going project is designed based on OCMIP experiences, and next generations figure just in this field. I should mention other groups. I think developing NEMURO, a marine ecosystem model, in North Pacific marine Science Organization (PICES) as another good international collaboration. As for formulating specific processes such as trade-off problem, North Germany group are leading. Finally, I would like to express my wish that next generation in Japan friendly and positively get chance to lead international research projects one of world-leading scientists with their beautiful lives. This is based on my cancelled invited talk in the last year.

Keywords: marine biogeochemical cycles, marine ecosystem, modeling, international research project, OCMIP, MAREMIP

AOS24-02 Room:311 Time:April 30 15:30-15:45

Modeling fish production in the ocean: impacts on biogeochemical cycles and ecosystem service evaluation

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Marine organisms play fundamental roles in biogeochemical cycles in the ocean. Ecosystem models formulating chemical and biological processes relevant to these organisms and materials have been developed in the past few decades, enabling quantitative evaluation of biological production, carbon and nutrient cycles, and their impact on the climate system. However, many of these models consider trophic levels up to zooplankton. Although much of storage and flux of carbon and nutrients are observed in the lower trophic levels, which is a good reason to focus on this level, importance of higher trophic levels has been increasingly recognized. Here, we review modeling studies incorporating higher trophic levels than zooplankton, especially focusing on fish production models. There are two major motivations developing the fish production model. The first one is that lower trophic level models with zooplankton as the highest trophic level are sometimes controlled too strongly by parameterized zooplankton mortality terms. Although parameterization of mortality terms is needed unless the model contains the apex predator (trophic closure), inclusion of planktivorous fish components does decrease the arbitrariness of the biogeochemical cycle in the model. The second reason to develop fish production models, the more classical reason than the first one, is based on the fact that fish stocks themselves have been major food resources for human societies. In this context, some recent models do not only include commercially important large piscivorous fishes but also consider fishing fleets. Increasing concern for the conservations of marine mammals and sea birds also enhances the model development. There are two different streams of the fish modeling at present: size-based and species-based approaches. We review their advantages and limitations and discuss future improvements of preferable frameworks of the higher trophic models.

Keywords: fish production model, trophic closure, fisheries resources

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The iron budget in ocean surface waters in the 20th and 21st centuries: projections by the Community Earth System Model

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We investigated the simulated iron budget in ocean surface waters in the 1990s and 2090s using the Community Earth System Model version 1 and the Representative Concentration Pathway 8.5 future CO_2 emission scenario. We assumed that exogenous iron inputs did not change during the whole simulation period; thus, iron budget changes were attributed solely to changes in ocean circulation and mixing in response to projected global warming, and the resulting impacts on marine biogeochemistry. The model simulated the major features of ocean circulation and dissolved iron distribution for the present climate. Detailed iron budget analysis revealed that roughly 70 % of the iron supplied to surface waters in high-nutrient, low-chlorophyll (HNLC) regions is contributed by ocean circulation and mixing processes, but the dominant supply mechanism differed by region: upwelling in the eastern equatorial Pacific and vertical mixing in the Southern Ocean. For the 2090s, our model projected an increased iron supply to HNLC waters, even though enhanced stratification was predicted to reduce iron entrainment from deeper waters. This unexpected result is attributed largely to changes in gyre-scale circulations that intensified the advective supply of iron to HNLC waters. The simulated primary and export production in the 2090s decreased globally by 6 and 13 %, respectively, whereas in the HNLC regions, they increased by 11 and 6 %, respectively. Roughly half of the elevated production could be attributed to the intensified iron supply. The projected ocean circulation and mixing changes are consistent with recent observations of responses to the warming climate and with other Coupled Model Intercomparison Project model projections. We conclude that future ocean circulation has the potential to increase iron supply to HNLC waters and will potentially buffer future reductions in ocean productivity.

AOS24-04 Room:311 Time:April 30 16:15-16:30

Response of phytoplankton community structure to global warming

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In recent studies using high-performance liquid chromatography (HPLC) pigment data, empirical relationships between total chl-a concentration and a phytoplankton size/PFT fraction on a global scale are shown. For example, a fraction of diatoms increases with total chl-a concentration. The same tendencies can be seen in the most of the hindcast experiments by current PFT models of MARine Ecosystem Model Intercomparison Project (MAREMIP) and Coupled Model Intercomparison Project Phase5 (CMIP5) although the reproduced absolute values of a phytoplankton fraction still has large uncertainties. Then, two different mechanisms can be expected as potential responses of phytoplankton community to global warming. One is a possibility that the phytoplankton community structure (i.e., relationships between a phytoplankton fraction and total chl-a concentration) can be significantly changed by changes in ecosystem dynamics under global warming condition (e.g., changes in grazing pass/strength, decomposition/mortality/respiration rate and phytoplankton stoichiometry). Another possibility is that the plankton community shifts to the other stable states associated with changes in total chl-a concentration (e.g., by decrease/increase in nutrient supply to the surface ocean by changes in stratification) while maintaining the current relationship between a phytoplankton fraction and total chl-a concentration. To clarify impacts of both effects, we analyzed model results of future simulation, which was conducted by CMIP5 and MAREMIP under the RCP8.5 emission scenario. PFT model more than half showed that relationships between phytoplankton composition and total chl-a concentration are stable against environmental changes associated with global warming. In these model results, changes in phytoplankton composition are mainly caused by plankton community shifts associated with changes in total chl-a concentration. This result suggests the possibility that current empirical relationships obtained by HPLC would be maintained in a future environment. Based on this hypothesis, we project a potential future community structure of phytoplankton using a multi-model ensemble mean of future changes in total chl-a concentration with the empirical relationship of HPLC. Some other models projected large changes in the community structure in specific regions and seasons. These results also suggest potentially important mechanisms, regions and seasons.

Keywords: Phytoplankton, Community structure, Global warming

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Introduction to our on-going development of an adaptive model for plankton communities in the North Pacific

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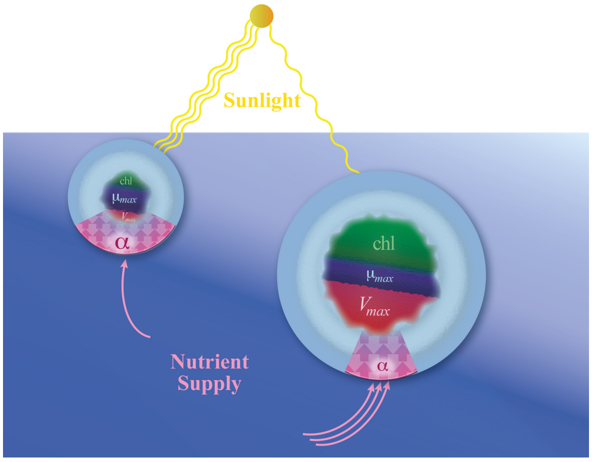
This presentation will introduce our on-going efforts, as part of a CREST project funded by JST, to develop a new prototype model to represent the biodiversity and adaptive capacity of lower-trophic ecosystems in the North Pacific. The ultimate goal is to develop a computationally efficient representation of the community-level interactions of the producers (phytoplankton) and consumers (zooplankton) with each other and with the marine environment. This of course includes the adaptive response of plankton communities to changing environmental conditions, and later potential feedbacks, including for example the impact of plankton communities on controlling nutrient concentrations. We will present the size-based model of phytoplankton communities that is already under development and one scientific result already obtained, regarding the size-scaling of growth parameters, as commonly applied in large-scale models, in terms of the more commonly measured parameters for nutrient uptake kinetics. This scaling relationship provides a basis for consistently incorporating observed allometries into models based on Monod growth kinetics. This new simplified model of phytoplankton communities accounts for biodiversity via size-scaling of phytoplankton traits and for flexibility of the C:N ratio of biomass.

Fig. 1. Traits, which define how organisms respond to environmental conditions, have evolved subject to inescapable biophysical constraints. Thus have arisen trade-offs in competitive ability under different conditions, here illustrated for typical small phytoplankton adapted to low-nutrient, high-light conditions, which have high affinity (α), low maximum uptake rates (V_{max}) and relatively less allocation to chlorophyll/light harvesting ability, vs. large phytoplankton adapted to high-nutrient, low-light conditions, which have low α, high V_{max}, and relatively more allocation to chlorophyll/light harvesting ability. Maximum growth rate (μ_{max}) is constrained by the opportunity cost of allocating resources to the various processes necessary to support growth.

Keywords: plankton, ecosystem, model, traits, trade-offs, adaptive



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AOS24-06 Room:311 Time:April 30 16:45-17:00

Exploring mechanisms of phytoplankton coexistence using a marine ecosystem model with eddy-resolving resolution

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Observational studies estimate that there are over 70,000 phytoplankton species. Various mechanisms which enable phytoplankton coexistence are proposed. Niche segregation are inspected under pelagic environment, using a numerical model. Since we considered that variation of pelagic environment resulted in mesoscale eddies plays an important role on phytoplankton diversity, an eddy-resolving model is employed. 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 niche segregation, we seeded 240 phytoplankton species which have different trait for temperature, light and nutrient. After 10 years integration, 31 species are survived. In the subpolar (subtropical) region, species favorable high (low) nutrient condition are survived. Segregation with temperature is also confirmed.

Keywords: Phytoplankton diversity, Marine ecosystem model, Mesoscale eddy

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Numerical analysis of the influences of the meso-zooplankton mortality

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In recent years, marine lower-trophic level ecosystem consisting of phytoplankton and zooplankton has been seriously affected by the various environmental changes due to the climate changes and the human activities. The quantitative assessment of the lower-trophic level ecosystem changes with the environmental changes is important for the human beings in the world. This is because the lower-trophic level ecosystem changes closely links to the fisheries resources and the global carbon cycles. For example, copepod which is one of the meso-zooplankton in the lower-trophic level ecosystem is main food for the fishes of good-catch such as Japanese saury and anchovy. Copepod also exports a huge amount of organic carbon from the surface water to the deep water in the ocean by the seasonal vertical migration to around 1000m depth and the rapid sinking fecal pellet. We have been developing a plankton functional types (PFTs) model which explicitly calculates each functional group of organisms such as copepod above. In particular, we developed a PFTs model eNEMURO (4-Nutrient, 4-Phytoplankton, 4-Zooplankton, 4-Detritous), which was an extend version of NEMURO [a standard lower-trophic-level marine ecosystem model of PICES (The North Pacific Science Organization)] by introducing the microbial food web and the phosphorous cycles and dividing diatoms to two compartments according to temperature dependency. eNEMURO successfully reproduced the spatio-temporal variations in the lower-trophic level ecosystem around Japan. In this study, we investigated the influences of the meso-zooplankton mortality which was little known from the filed observations and the laboratory experiments on the lower-trophic level ecosystem. We conducted the sensitivity analysis of two parameters of the meso-zooplankton mortality in eNEMURO in five regions with different types of the lower-trophic level ecosystem around Japan. Model result shows that the increase of the meso-zooplankton mortality associated with water temperature rising has large impacts on the nutrients concentrations, the biomasses of phytoplankton and zooplankton, especially in the regions with the high temperature. We also introduce results from the biological parameters optimization of eNEMURO using the genetic algorithm method.

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AOS24-08 Room:311 Time:April 30 17:15-17:30

A benthic-pelagic coupled ecosystem model to clarify nutrient cycles in coastal areas

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In many enclosed coastal seas in japan, coastal environment have changed due to increase of nutrient loading and land development after 1960s. This caused loss of material cycles balance, generation of red tides, anoxic conditions and hydrogen sulfide.Water quality has been gradually improved because of some policies such as water quality standard and water pollution control law, but the loss of balance remains in many areas. It is because various factor such as benthic system, fishery industry and the open sea of the areas affect it.

We developed a benthic-pelagic coupled ecosystem model to clarify the role and the contribution of them. The model also included important factors for the coastal environment as dissolved oxygen, oyster and eelgrass.

It was developed for Mitsu Bay area in the western part of Seto Inland Sea. In this area, oyster culture distribute widely. Model results indicated the most important factor for the material cycles was advection from out of the area. Nutrient load had lower impact than advection and oyster. Anoxic water did not appear but the oyster culture caused accumulation of organic matter on the sediment under oyster rafts and hydrogen sulfide production. It was suggested that control of it is important for improve the material circulation and keep it in balance.

Keywords: Marine Ecosystem Model, Marine Material Cycles

AOS24-09 Room:311 Time:April 30 17:30-17:45

A challenge to investigate environmental factors which determine spawning migration variability of small pelagic.

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In recent years, lower trophic ecosystem models, which represent phyto and zoo-plankton, have been coupled to fish growth-migration models. These coupled models enable to elucidate fish response to climate variability. However, mechanisms of fish migration has not been well clarified. Especially the mechanisms of spawning migration, by which spawner fish can home on to their spawning grounds, are one of the most difficult behavior to represent by a numerical model. Using realistic initial and boundary condition, an Euler-type model of Pacific saury was applied to investigate environmental factors which determine spawning migration variability. The initial distribution of Pacific saury was defined by synoptic surface trawl surveys and satellite derived environmental conditions were used as forcing; sea surface temperature (SST), prey density estimated from surface chl-a concentration and surface current speed. Growth of Pacific saury was calculated by 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 was adjusted to realize observed variability of saury migration to fishing grounds. The adjusted westward migration variability showed high correlation with basin wide SST in the North Pacific. This result suggested a strong influence of climate to fish spawning migration.

Keywords: ecosystem model, fish growth-migration model, Pacific saury, ocean environment