2nd International Symposium "Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem"

Atmosphere and Ocean Research Institute (AORI),
the University of Tokyo

Ocean Mixing Processes:
Impact on Biogeochemistry, Climate and Ecosystem
Grant-in-Aid for Scientific Research in Innovative Areas
(MEXT)

November 4, 2018

2nd International Symposium "Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem"

Date: November 4 (SUN), 2018
Venue: AORI Auditorium, Atmosphere and Ocean Research Institute, The University of Tokyo (Kashiwa Campus)
Access map: http://www.aori.u-tokyo.ac.jp/english/access/index.html
Campus map: http://www.aori.u-tokyo.ac.jp/english/access/campusmap.html

Background:
Ocean diapycnal mixing is a fundamental physical process that regulates ocean vertical circulations of water, nutrients, carbon and heat; however, its distribution and generation mechanisms have not been known because of the difficulties of observations. In order to tackle this problem, a five-year project "Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem (OMIX)" was launched in Japan on 2015 under the funding framework of MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan) Grant-in-Aid for Scientific Research in Innovative Areas. This research project is developing efficient observing systems of ocean diapycnal mixing and next-generation numerical models, those of which are able to quantify the maintenance mechanism of deep and bio-geochemical circulations and to reproduce observed bi-decadal ocean and climate variability. This new interdisciplinary study on ocean mixing opens the integrated sciences from physical, chemical, biological oceanography to climate and fisheries sciences.

Purpose:
In this international symposium, leading scientists are invited from overseas to present OMIX related research activities especially focusing on the North Pacific and discuss with scientists joining OMIX regarding on their progress under OMIX and future collaborations. Posters are also to be presented by OMIX members on individual research topics. Find more about OMIX at http://omix.aori.u-tokyo.ac.jp/en/

Speakers:
Invited
John Barth, Oregon State University
Annalisa Bracco, Georgia Institute of Technology
Kristen Davis, University of California
Yign Noh, Yonsei University
Bo Qiu, University of Hawaii

OMIX PIs

Ichiro Yasuda, The University of Tokyo
Shuhei Masuda, Japan Agency for Marine-Earth Science and Technology
Jun Nishioka, Hokkaido University
Xinyu Guo, Ehime University
Naomi Harada, Japan Agency for Marine-Earth Science and Technology
Shin-ichi Ito, The University of Tokyo
Toshiyuki Hibiya, The University of Tokyo
Hiroyasu Hasumi, The University of Tokyo

Primary Sponsors:

Atmosphere and Ocean Research Institute (AORI),
the University of Tokyo

Ocean Mixing Processes:
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Accommodation:

For invited speakers, we booked a room for you at Mitsui Garden Hotel Kashiwa-no-ha (check-in 3rd Nov. & check-out 5th Nov.):

https://www.gardenhotels.co.jp/kashiwanoha/eng/

All rooms reserved are single, non-smoking, including breakfast. If you accompany your family and want change the room style or schedule, please contact to secretary Ms. Rie Goda (riegoda0130@aori.u-tokyo.ac.jp).

Mitsui Garden Hotel Kashiwa-no-ha locates nearby the Kashiwanoha Campus Station on TX (Tsukuba Express). The transportation from Yokohama to Kashiwanoha Campus Station is take JR to Akihabara and change to TX to Kashiwanoha Campus Station. It takes about 100 minutes.

On the way back to your country, the distance to Narita and Haneda Airport is almost same. However, there are frequent direct bus connection to Haneda Airport.

Program

November 3 (Sat)

09:30 Meet at Yokohama and go together to Kashiwanoha (for invited speakers)

18:00 Welcome reception at Kashiwanoha (only applicants will participate)

November 4 (Sun)

9:00—9:30 Registration and coffee

9:30—10:00 Opening

Shin-ichi Ito (The University of Tokyo): Welcome and logistics

Ichiro Yasuda (The University of Tokyo): Introduction on the OMIX project

10:00—11:40 Session 1 (Chair: Sachihiko Itoh)

John Barth (Oregon State University): Transport and mixing across the inner shelf: An overview of the 2017 Point Sal, California, Inner Shelf Dynamics Experiment

Ichiro Yasuda (The University of Tokyo), Yasutaka Goto, Maki Nagasawa, Shinya Kouketsu and Toshiya Nakano: Development of CTD-attached fast-thermistor measurements method and preliminary results

Annalisa Bracco (Georgia Institute of Technology): Multiscale impacts of submesoscale flows

Satoshi Osafune (Japan Agency for Marine-Earth Science and Technology), Shuhei Masuda, Nozomi Sugiura, Toshimasa Doi. Tadashi Hemmi: Ocean state estimation by using observed mixing data

11:40—13:00 Group Photo, Lunch

13:00—14:00 Poster (with coffee)

14:00—15:40 Session 2 (Chair: Toshiyuki Hibiya)

Yign Noh (Yonsei University): Parameterization of Langmuir Circulation in the Ocean Mixed Layer Model Using LES and its Application to the OGCM

Toshiyuki Hibiya (The University of Tokyo): Improvement of the parameterization of ocean mixing processes in the surface, deep, and bottom layers

Kristen Davis (University of California): Fate of internal waves on a shallow shelf

Takao Kawasaki (The University of Tokyo): Effect of remote tidal mixing on the Pacific meridional overturning circulation

15:40—16:10 Break and Poster (with coffee)

16:10—17:50 Session 3 (Chair: Hiroyasu Hasumi)

Bo Qiu (University of Hawaii): Dynamical links between the Kuroshio & Oyashio Extensions

Takeshi Matsuno (Kyushu University), Eisuke Tsutsumi, Takahiro Endoh, Yiing-Jang Yang, Sen Jan, Xinyu Guo: Intensified vertical mixing in the Kuroshio downstream of I-lan ridge east of Taiwan

Maki Noguchi Aita (Japan Agency for Marine-Earth Science and Technology): Modelling impacts of atmospheric and riverine nitrogen inputs on marine biogeochemistry

Shin-ichi Ito (The University of Tokyo): Challenges on elucidation of climate variability impacts on living marine resources and new findings

17:50—18:00 Closing Remarks

Ichiro Yasuda (The University of Tokyo)

18:30—20:30 Night Session

Poster

P01 Ichiro Yasuda
Impact of the astronomical lunar 18.6-yr tidal cycle on El-Niño and Southern Oscillation

P02 Toshiya **Nakano**, Daisuke Sasano, Takahiro Kitagawa, Naoki Nagai, Yoshiteru Kitamura, Michio Aoyama, and Masao Ishii
Recent deoxygenation in the Japan Sea Proper Water in the northeastern Japan Basin

P03 Shinya **Kouketsu**, *Satoshi Osafune, and Toshimasa Doi*
Estimation of oxygen utilization rate with vertical diffusivity distributions inferred from salinity budgets

P04 Toshimasa **Doi**, Satoshi Osafune, Shuhei Masuda and Nozomi Sugiura
Representation of multi-decadal changes in dissolved inorganic substances in the Estimated Ocean State for Climate Research (ESTOC) which included the estimation of iron limitation

P05 Hung Wei **Chou**, Humio Mitsudera, Kaihe Yamazaki, Hatsumi Nishikawa
Dynamic of Barotropic Water Exchange between the Sea of Okhotsk and Pacific through tidal effects

P06 Taiga **Honma**, Toru Kobari, Takeru Kanayama, Fukutaro Karu, Naoki Yoshie, Daisuke Hasegawa, Ayako Nishina, Hirohiko Nakamura
Response of plankton standing stocks and productivity to turbulent nitrate flux in the Kuroshio across the Tokara Strait

P07 Tetsuichi **Fujiki**, Minoru Kitamura, Shigeki Hosoda, Naomi Harada, Masahide Wakita and Yoshihisa Mino
Influence of physical and chemical processes on phytoplankton community in the western subarctic Pacific

P08 Yoshihisa **Mino**, Chiho Sukigara, Makio C. Honda. Hajime Kawakami, Tetsuichi Fujiki, Minoru Kitamura, Naomi Harada and Masahide Wakita
Seasonal and interannual variations in the upper layer nitrogen availability and particles export in the western subtropical North Pacific

P09 Hiroaki **Tatebe**, Yuki Tanaka, Yoshiki Komuro and Hiroyasu Hasumi
Impact of deep ocean mixing on the climatic mean state in the Southern Ocean

P10 Tomihiko **Higuchi**, Toyoho Ishimura, Yasuhiro Kamimura, Kotaro Shirai, Hana Shindo, Kozue Nishida, Kosei Komatsu and Shin-ichi Ito
Otolith oxygen isotope analysis and temperature history in early life stages of the chub mackerel *Scomber japonicas*

P11 Takaaki **Yokoi**, Yoshimasa Matsumura, Shin-ichi Ito, Raphael Dussin and Enrique Curchitser
Application of The Modified ROMS-NEMURO.FISH for understanding growth and migration processes of particular fish species the Western North Pacific

P12 Chenying **Guo** and Shin-ichi Ito
Evaluating the effects of environmental conditions on the growth and migration of Pacific chub mackerel *Scomber japonicus*

P13 Megumi **Enomoto**, Shin-ichi Ito, Motomitsu Takahashi, Chiyuki Sassa, Tomihiko Higuchi and Kotaro Shirai
Habitat layer change timing of Japanese jack mackerel (*Trachurus japonicus*) estimated by stable oxygen isotope ratios in fish otoliths

P14 Akira **Kuwata**, Hiroshi Kuroda, Tsuyoshi Watanabe, Kazuaki Tadokoro and Jun Nishioka.
Mechanism of spring bloom of diatoms in the Oyashio region

P15 Hitomi **Oyaizu**, Shin-ichi Ito and Sachihiko Itoh
Modeling growth and mortality processes of immature Pacific saury (Cololabis saira) using an individual-based, bioenergetics-migration model

P16 Yohei **Onuki** and Toshiyuki Hibiya
Decay rates of internal tides estimated by an improved wave-wave interaction analysis

P17 Michio **Watanabe**, Hiroaki Tatebe, Tatsuo Suzuki, and Kaoru Tachiiri
Impact of deep ocean mixing on transient climate response and steric sea level rise

P18 Hatsumi **Nishikawa**, Humio MITSUDERA, Takuya NAKANOWATARI, Tomohiro NAKAMURA, Keisuke UCHIMOTO, Hiroyasu HASUMI
High-resolution modeling of nutrient transport in the northwestern North Pacific

P19 **E. R. Maúre**, J. Ishizaka, H. Aiki, Y. Mino, N. Yoshie, J. I. Goes, H. R. Gomes, H. Tomita
Triggers of the Spring Bloom Initiation in Mesoscale Eddies Revealed by One-Dimensional Turbulence-Ecosystem Model

P20 Takuya **Hara**, Hirofumi Tazoe, Toshitaka Gamo and Hajime Obata
Study on the circulation process of neodymium in seawater in the North Pacific Ocean, the Bering Sea and the Chukchi Sea

P21 Kazuki **Ogi**, Naoki Yoshie, Anri Kabe, Eisuke Tsutsumi, Toru Kobari, Takeru Kanayama, Fukutaro Karu, and Taiga Honma
Effects of nutrient enrichment on lower-trophic level ecosystem in the Tokara Strait

Local Organization Committee:
Shin-ichi Ito (AORI, the Univ. of Tokyo)
Sachihiko Itoh (AORI, the Univ. of Tokyo)
Ayuko Sakata (AORI, the Univ. of Tokyo)
Rie Goda (AORI, the Univ. of Tokyo)
Naomi Kobayashi (AORI, the Univ. of Tokyo)

Session 1

Transport and mixing across the inner shelf: An overview of the 2017 Point Sal, California, Inner Shelf Dynamics Experiment

John A. Barth[1], James A. Lerczak[1], Jacqueline McSweeney[1] and Stephen D. Pierce[1]

[1] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 104 CEOAS Admin Bldg, Corvallis, OR, 97331-5503,
U.S.A. E-mail: jack.barth@oregonstate.edu

The inner shelf, the region inshore of the 50-m isobath and lying between the wind-forced continental shelf and the breaking-wave surfzone, connects the coast and open ocean. During September to October 2017, an intensive field experiment was conducted from the mid-continental shelf, through the inner shelf and into the surfzone near Point Sal, California, USA (35N). We used satellite, airborne, shore- and ship-based remote sensing, in-water moored and ship-based sampling, and numerical ocean circulation models forced by winds, waves and tides to investigate the exchange of water, momentum and energy across this region. Of interest are the forcing by wind, surface waves and internal gravity waves, and the interactions between these processes. The field study was designed to resolve the propagation, transformation and dissipation of Non-Linear Internal Waves (NLIWs) from the mid-shelf and across the inner shelf, as well as cross-shelf eddy fluxes between the mid and inner shelf created by flow instabilities in both shelf and surfzone alongshore flows. We deployed 80 moorings with high-vertical resolution temperature and velocity over the inner shelf at various horizontal separations and 70 moorings in the surfzone. We used five oceanographic vessels from 30 to 240-feet in length operating at the same time to sample the mid shelf to the surfzone. We present a 3-dimensional look at the transformation of NLIWs during shoaling across the inner shelf and evaluate how they impact inner-shelf stratification and circulation. The low-frequency wind-driven circulation and eddies are examined using both shipboard and mooring data.

Development of CTD-attached fast-thermistor measurements method and preliminary results

Ichiro Yasuda[1)], Yasutaka Goto[1)*], Maki Nagasawa[1)], Shinya Kouketsu[2)] and Toshiya Nakano[3)]

1) Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8564, Japan

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2) Japan Agency of Marine-Earth Science and Technology, Natsushima 2-15, Yokosuka, Kanagawa 237-0061, Japan

3) Japan Meteorological Agency, Otemachi 1-3-4, Chiyoda-ku, Tokyo 100-8122, Japan

Turbulent vertical mixing in the ocean is crucial in controlling meridional overturning circulation (MOC) which affects climate as well as marine ecosystem through the transports of heat and materials as nutrient and carbon. However, turbulence observations measuring micro-structures have been difficult and scarce. We here develop a new turbulence estimate method which enables to efficiently obtain data by attaching fast-response thermistors to common ship-based observational platforms, and succeed in revealing micro-structure-based surface-bottom cross-Pacific turbulence distributions for the first time. Turbulent energy dissipation rate ε_{obs} is found to depend on local squared buoyancy frequency N^2 (density stratification) and internal tide energy. This finding contributes to revising three-dimensional distribution ε_{model} which was used in an ocean model.

Multiscale impacts of submesoscale flows

Annalisa **Bracco**[1], Guangpeng Liu[1], Santiago Herrera[2], Matthew Galaska[2], Andrea Quattrini[3]

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[2] Lehigh University, Bethlehem, PA 18015, USA
[3] Harvey Mudd College, 1250 N. Dartmouth Ave., Claremont, CA, USA

At the ocean boundary layers, near the surface and at the bottom, ageostrophic, coherent flow structures with typical scales of hundreds of meters to few kilometers and a lifespan of few days often appear in the form of vorticity filaments, density fronts or coherent vortices. These so-called submesoscale circulations provide a pathway for energy transfer towards smaller scales, contribute to the global overturning budget, and impact substantially lateral and diapycnal mixing. They develop in presence of density gradients, and therefore in and around mesoscale structures, are characterized by a seasonal cycle and their statistics are not yet constrained in a global sense.
This talk will present an overview of recent studies illustrating physical and biogeochemical interactions across mesoscale and submesoscale flows focusing on the Gulf of Mexico, where much modelling and observational work has been taking place since the 2010 Deepwater Horizon blow-out. The physical interpretation of several biogeochemical data-sets will illustrate how mesoscale and submesoscale circulations impact the dispersion of biologically and climatically relevant tracers, from coral larvae to carbon.

Ocean state estimation by using observed mixing data

Satoshi **Osafune**, Shuhei Masuda, Nozomi Sugiura, Tadashi Hemmi, and Toshimasa Doi,

Research and Development Center for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan.E-mail: osafune@jamstec.go.jp

Recent data synthesis experiments showed that adjusting mixing coefficients through data assimilation approach is a promising way to reduce a global misfit between a model simulation and ocean observations, and to improve an ocean state estimation. However, those experiments do not impose any constraints on mixing coefficients, although they are closely related to the energy budget. Aiming for a data synthesis experiment that is energetically consistent with the known constraint on the ocean energy budget, and can assimilate observed turbulent mixing data, we are developing a new quasi-global four-dimensional variational data assimilation system, based on our system of the Estimated STate of the global Ocean for Climate research (ESTOC). We will introduce the new system, and present some preliminary results of long-term data synthesis experiments using this system.

Session 2

Parameterization of Langmuir Circulation in the Ocean Mixed Layer Model Using LES and its Application to the OGCM

Yign **Noh**[1], Hyejin Ok[1], Eunjeong Lee[1], Takahiro Toyoda[2], and Naoki Hirose[3]

[1]Yonsei University, Seoul, Korea. noh@yonsei.ac.kr
[2]Meteorological Research Institute, Tsukuba, Japan
[3]Kyushu University, Kasuga, Japan

The effect of Langmuir circulation (LC) on vertical mixing is parameterized in the ocean mixed layer model (OMLM), based on the analysis of large eddy simulation (LES) results. Parameterization of LC effects is carried out in terms of the modifications of the mixing length scale as well as the inclusion of the contribution from the Stokes force in momentum and TKE equations. The performance of the new OMLM is examined by comparing with LES results, together with sensitivity tests for empirical constants used in the parameterization. The new OMLM is then applied to the ocean general circulation model (OGCM) MRI.COM and its effect is investigated. The new OMLM helps to correct too shallow MLDs in the high-latitude ocean, which has been a common error in most OGCMs, without making the thermocline in the tropical ocean more diffused. The parameterization of LC effects is found to affect mainly the high-latitude ocean, in which MLD is shallow in summer and stratification is weak in winter.

Improvement of the parameterization of ocean mixing processes in the surface, deep, and bottom layers

Toshiyuki Hibiya

Department of Earth and Planetary Science, Graduate School of Science,
The University of Tokyo, Tokyo, Japan. Email: hibiya@eps.s.u-tokyo.ac.jp

Although an accurate representation of turbulent mixing processes in ocean global circulation models is essential for climate predictions, the existing fine-scale parameterizations of turbulent dissipation caused by internal wave breaking in the deep ocean still have much room for improvement.

For turbulent dissipation rates in the ocean interior, the Gregg-Henyey-Polzin (GHP) parameterization is most widely used since it takes into account distortions from the Garrett-Munk (GM) spectrum in the frequency domain using the shear/strain ratio ($R\omega$). The GHP parameterization, however, tends to overestimate the turbulent dissipation rates when the internal wave spectrum is biased to lower frequency and hence the internal wave field is dominated by near-inertial waves ($R\omega >> 3$).

For turbulent dissipation rates over rough ocean bottom, the St. Laurent (SL) parameterization is the most popular one. Nevertheless, the SL parameterization neglects the trade-off relationship between the turbulent dissipation rate at the ocean bottom and the vertical extent of the enhanced dissipation region off the ocean bottom as well as the transformation of linear internal waves into quasi-steady internal lee waves as tide-topography interactions strengthen.

In this study, we first point out the flaws in the formulation of the GHP parameterization and then correct them to obtain the Ijichi-Hibiya (IH) parameterization which yields turbulent dissipation rates much more consistent with the observed microstructure data for all the values of $R\omega$. Toward the improvement of the SL parameterization, on the other hand, we perform a series of eikonal calculations to clarify the dependence of the vertical structure of bottom-enhanced mixing on the tidal flow amplitude and the horizontal wavenumber of the bottom topography.

Fate of internal waves on a shallow shelf

Kristen A. Davis[1], Robert S. Arthur[2], Justin Rogers[3], Oliver Fringer[3], Emma C. Reid[1], Thomas M. DeCarlo[4], and Anne L. Cohen[5]

[1]Department of Civil & Environmental Engineering, University of California, Irvine
[2]Department of Civil & Environmental Engineering, University of California, Berkeley
[3]Department of Civil & Environmental Engineering, Stanford University
[4]University of Western Australia
[5]Department of Geology and Geophysics, Woods Hole Oceanographic Institution

Internal waves strongly influence the physical and chemical environment of coastal ecosystems worldwide. We report novel observations from a distributed temperature sensing (DTS) system that tracked the transformation of internal waves from the shelf break to the surf zone over a shelf-slope region in the South China Sea. The spatially-continuous view of temperature fields provides a perspective of physical processes previously available only in laboratory settings or numerical models, including internal wave reflection off a natural slope, shoreward transport of dense fluid within trapped cores, internal "tide pools" (dense water left behind after the retreat of an internal wave), and the transport of internal wave upwelled water on to a shallow reef. Analysis shows that the fate of internal waves on this shelf – whether transmitted into shallow waters or reflected back offshore –is mediated by local water column density and shear structure, with important implications for the distribution of energy, heat, and nutrients on the shelf.

Effect of remote tidal mixing on the Pacific meridional overturning circulation

Takao **Kawasaki**[1] and Hiroyasu Hasumi[1, 2]

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[2]Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

Tidal mixing is important process for maintenance of the Pacific meridional overturning circulation. Three-dimensional structure of PMOC induced by ocean mixing and its biogeochemical impact are investigated in our research group (A04-8). We develop ocean and climate models by using the mapping of tidal energy dissipation rate based on a tide model improved in the group A04-7. In our presentation, we focus on the effect of tidal mixing on the deep PMOC in the ocean model.

Although many previous modeling studies employed distributions of the tidal mixing enhanced near the ocean bottom (local mixing), a previous study suggested that tidally-induced mixing far from the ocean bottom (remote mixing) significantly influences the strength and structure of PMOC. A recent observational study (in group A01-1) suggested the mixing energy depends on the ocean stratification by microscale vertical temperature profiles. Here, we try to reproduce the PMOC by using the distribution of remote mixing based on the recent observation.

The model employed in this study is an ocean general circulation model (COCO). Its horizontal grid size is 1 degree. The distributions of local and remote tidal mixing energies are estimated by a tide model. An empirical one-dimensional vertical profile (horizontally constant) of vertical diffusivity is also employed for comparison.

The strength of PMOC is underestimated by using the stratification-dependent tidal energy of the remote mixing. The small tidal energy at the upper deep layer causes the underestimate of the PMOC by comparison with the empirical one. The lateral boundary mixing induced by the remote tidal energy, which is propagated from the open ocean regions, has a potential to resolve the discrepancy. The effect of the boundary mixing on the PMOC will be discussed in our presentation.

Session 3

Dynamical links between the Kuroshio & Oyashio Extensions

Bo **Qiu**, Shuiming Chen and Niklas Schneider

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Rather than a single and continuous boundary current outflow, long-term satellite observations reveal that the Oyashio Extension (OE) in the North Pacific subarctic gyre is comprised of two independent, northeast-southwest slanted, front systems. With a mean latitude along 40°N, the western OE front exists primarily west of 153°E and is a continuation of the subarctic gyre western boundary current. The eastern OE front, also appearing along 40°N, is located between 153°E and 170°E, whose entity is disconnected from its western counterpart. During 1982-2016, both of the OE fronts exhibit prominent decadal fluctuations, although their signals show little contemporaneous correlation. An upper ocean temperature budget analysis based on the ECCO2 state estimate reveals that the advective temperature flux convergence plays a critical role in determining the low-frequency temperature changes relating to the OE fronts. Specifically, the western OE front variability is controlled by the decadal mesoscale eddy modulations in the upstream Kuroshio Extension (KE). An enhanced eddy activity increases the poleward heat transport and works to strengthen the western OE front. The eastern OE front variability, on the other hand, is dictated by both the meridional shift of the KE position and the circulation intensity change immediately north of the eastern OE. Different baroclinic adjustment speeds for the KE and OE are found to cause the in-phase changes between these latter two processes. Lack of contemporaneous correlation between the decadal western and eastern OE variability is found to be related to the interaction of meridionally migrating KE jet with the Shatsky Rise near 159°E.

Intensified vertical mixing in the Kuroshio downstream of I-lan Ridge east of Taiwan

Takeshi **Matsuno**[1], Eisuke Tsutsumi[1], Takahiro Endoh[1], Yiing-Jang Yang[2], Sen Jan[2], and Xinyu Guo[3]

[1] Kyushu University, Kasuga, Fukuoka, Japan. E-mail: matsuno@riam.kyushu-u.ac.jp
[2] National Taiwan University, Taipei, Taiwan
[3] Ehime University, Matsuyama, Ehime, Japan

Our group focuses on the mixing within and around the Kuroshio, particularly enhanced turbulence associated with bottom topography, such as straits with sea mounts or ocean ridge. East of Taiwan is one of our target fields, because it is located in the main stream of the Kuroshio. We had carried out field observations around I-lan Ridge east of Taiwan in May 2018 under collaboration with colleague of National Taiwan University. During the observations, strong turbulence larger than $\varepsilon>10^{-5}$ (W/kg) was observed accompanied with the Kuroshio passing through the I-lan Ridge, where well mixed layer thicker than 50 m was found around the pycnocline. Energy dissipation estimated with observed ε was relatively smaller than buoyancy flux calculated from density difference between neighboring stations, compared with the mixing efficiency assumed in the dissipation method. This means the locally enhanced mixing intensity when the strong current passes through the significant bottom topography could not be estimated with the magnitude of ε. We did not find increase in chlorophyll in the surface layer associated with strong vertical mixing around the I-lan Ridge. This is a different way from the Luzon Strait, where significant increase in chlorophyll was found in the surface layer accompanied with strong turbulence above the ocean ridge. In the Luzon Strait the intensified turbulence was generated with tidal motions, while that east of Taiwan is generated by the Kuroshio passing through the ridge.

Modelling impacts of atmospheric and riverine nitrogen inputs on marine biogeochemistry

Maki Noguchi **Aita**[1], Fumikazu Taketani[1], Takashi Sekiya[1], Kazuyo Yamaji[2], Taketo Hashioka[1], Michio Watanabe[1], Tomohiro Hajima[1] and Naomi Harada[1]

[1]Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan E-mail: macky@jamstec.go.jp
[2]Graduate School of Maritime Sciences, Kobe University, Kobe, Japan.

To estimate the influence of the atmospheric deposition of inorganic nitrogen compounds produced in East Asia on marine ecosystems, we developed a three-dimensional marine ecosystem model (COCO4.9-NEMURO) combined with an atmospheric chemical transportation model (WRF-CMAQ). We were focusing on the atmospheric input and applied it in simulations with and without atmospheric nitrate and ammonium (in gas and aerosol phases) deposition. Comparison of the two cases shows that in the subtropical western North Pacific, nitrate concentration increased by 0.5 umol L^{-1} in winter time. This suggests that nitrogen inputs from the atmosphere enhance near-surface chlorophyll-a concentrations by 0.05 - 0.2 mg m^{-3}. In order to evaluate the nitrogen cycle in the ocean, we have also constructed an ocean biogeochemical model including processes such as nitrogen fixation, denitrification, atmospheric and riverine -N input, then embedded it into an Earth System Model (MIROC-ES2L). Preliminary simulation results by the ESM showed that riverine and atmospheric nitrogen inputs contribute about 20% and 10%, respectively, to primary production. These contributions were greatest in the subtropical eastern North Pacific and equatorial western Atlantic Ocean. Riverine nitrogen input changed nitrate concentration by as much as ±2.5 umol L^{-1} in the high latitude subarctic and polar regions.

Challenges on elucidation of climate variability impacts on living marine resources and new findings

Shin-ichi **Ito**[1], Tetsuichiro Funamoto[2], Osamu Shida[3], Yasuhiro Kamimura[4], Motomitsu Takahashi[5], Kotaro Shirai[1], Tomihiko Higuchi[1], Kosei Komatsu[1], Takaaki Yokoi[1], Tatsuya Sakamoto[1], Chenying Guo[1], Toyoho Ishimura[6], Michio Yoneda[7], and Megumi Enomoto[1]

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Various studies have been conducted to elucidate the climate variability impacts on living marine resources. Larval and juvenile stages are critical periods for the recruitment of living marine resources. However, limitations of observation methods for directly investigating the environments that larvae and juveniles experienced have been obstacles to our understanding. We reviewed the previous studies on climate variability impacts on living marine resources and discussed how reconstruction of environmental histories of larvae and juveniles is important for our understanding of climate variability impacts on living marine resources. We proposed a new, integrated method to reconstruct environmental histories of larvae and juveniles using otolith oxygen stable isotope analyses and fish growth-migration models. Together with the growth estimated from otolith daily increments, it is possible to elucidate climate impacts on larval and juvenile growth through environmental histories of larvae and juveniles using their realistic migration routes. This study was published on “Oceanography in Japan” in 2018.

Posters

P01

Impact of the astronomical lunar 18.6-yr tidal cycle on El-Niño and Southern Oscillation

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Even though El-Niño and Southern Oscillation (ENSO) has a tremendous impact on global climate and society, its long-term forecast remains difficult. In this study, we discovered a statistically significant relationship between ENSO timing and the 18.6-year period lunar tidal cycle in the mature-phase (December – February) ENSO time-series during 1867–2015 and extending back to 1706 with proxy data. It was found that El-Niño tended to occur in the 1st, 10th, and 13th years after the maximum diurnal tide in the 18.6-yr cycle, and La-Niña tended to occur in the 3rd, 12th, and 16th years. These tendencies were also confirmed by corresponding sea-surface temperature (SST) and sea-level pressure (SLP) distributions; particularly Pacific SST and SLP spatial patterns in the third La-Niña and the tenth El-Niño year well resemble those of Pacific Decadal Oscillation (PDO). These findings contribute to understanding and forecasting long-term ENSO variability.

P02

Recent deoxygenation in the Japan Sea Proper Water in the northeastern Japan Basin

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We investigated the temporal variability in the properties of the Japan Sea Proper Water (JSPW) in the northeastern Japan Basin of the Japan Sea where the water depth exceeds 3500 m, using high-quality data of ship-based measurements being conducted each year since 2010 by the Japan Meteorological Agency. From the vertical profiles of potential temperature (θ) and dissolved oxygen (O_2) and their temporal variabilities, the JSPW is classified into three distinctive layers such as the Upper JSPW, the Deep Water and the Bottom Water. The largest O_2 decreases (11 to 18 μmol/kg for 2010–2017) was observed in the Upper JSPW between 500 m and 1000 m. Consequently, an O_2 minimum layer emerged at around 1000 m in 2013 and is being developed to date. The decrease of O_2 in the Upper JSPW accompanied the increase of nitrate. The decrease of O_2 and warming (4 μmol/kg and 0.01°C, respectively, for the same period) were also observed on σ_0=27.349 kg/m^3 in the deeper Bottom Water below 2500 m where the water is vertically uniform. The results of this study are helpful in understanding the difference of circulation structure in the Japan Basin, the formation of JSPW, and mixing and biological process. Further examination is also necessary to reveal the variability and its mechanism of warming and deoxygenation in the JSPW by analysis of a comparable high-quality data in the Japan Sea.

P03

Estimation of oxygen utilization rate with vertical diffusivity distributions inferred from salinity budgets

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Argo float array provides relatively uniform observations of temperature and salinity during the recent decade. Based on the salinity budgets in the isopycnal layers, which were captured by the float array, we estimated 3 dimensional velocity and mixing strength fields averaged over 15 years after 2000 in the North Pacific. With the 3 dimensional velocity field, we could assess reginal roles of water mass modifications (mixings of salinity) in the subsurface layers. In this study, we tried to estimate distributions of oxygen utilization rate under the assumption that in situ concentration changes were sufficiently small, which were obtained as residuals of oxygen and nutrient budgets with the velocity fields and long-term mean concentration distributions. While the obtained oxygen changes after 2000 in deep layers (> 400 m) the subarctic gyre were similar order of long-term trends reported in previous studies, uncertainties of the trends due to spatio-temporal sparse observations and estimation errors in this study might not be neglectable. As the long-term monitoring with BGC-Argo array can improve both the budget estimations and representativity on in-situ concentration changes, we will be able to obtain better estimations of remineralisations and their temporal changes, which could reflect biological activity changes at sea surface.

P04

Representation of multi-decadal changes in dissolved inorganic substances in the Estimated Ocean State for Climate Research (ESTOC) which included the estimation of iron limitation

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A 4-dimensional variational data synthesis system was newly constructed with a pelagic lower trophic level ecosystem model and oceanic general circulation model. The system is capable of estimating physical and biogeochemical variables for the global ocean and is used to integrate available ocean observations obtained from a wide range of observation tools. A set of optimized model parameters in the ecosystem model was obtained based on a Green's function approach with available in situ biogeochemical observations and satellite images including BGC Argo. The climatological iron distribution was applied to represent the iron limitation for the phytoplankton activity in the recent system. The used iron distribution is newly constructed in the similar way of a Green's function approach. We carried out data synthesis experiment for the period of 1957-2011 to estimate a global ocean state on the basis of available ocean observations. We show multi-decadal changes in dissolved inorganic carbon (DIC) and in dissolved oxygen (DO) in this state estimation. The estimated DIC and DO are by and large consistent with previous reports. We try validating the basin scale changes in DIC along the World Ocean Circulation Experiment (WOCE) Hydrographic Program sections to identify the multi-decadal changes in DIC under the diffusion and accumulation of absorbed anthropogenic CO_2.

P05

Dynamic of Barotropic Water Exchange between the Sea of Okhotsk and Pacific through tidal effects

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The exchange flow pattern between the sea of Okhotsk and North Pacific is constituted by an inflow in northern strait and an outflow in southern strait, which are separated by Kuril island Chain in between. According to East Kamchatka Current(EKC) driven mechanism, the approach of EKC to Kuril Chain is determining this exchange flow pattern. By setting K1 tides as experimental run in ocean general circulation model COCO, primary model results present not only wind stress, but also tidal effect is an important factor in controlling the direction of western boundary current (WBC). Further, the barotropic components suggest a Lagrange eddy above a seamount formed by topographic trapped wave is
contributing to modifying the flow direction of EKC to Kuril island
chain.

For confirming the function of seamount trapped eddy in two-straits-exchange system, a simple idealized model with two straits, a closed basin and a seamount located in northern strait is designed in MITgcm. The results show only the case with seamount and tidal forcing can lead the flow pattern as close to real state. It suggests the seamount is determining the exchange flow through the tidal formed topographic trapped wave, caused by the stretch of water column height in seamount area. For keeping the constant of potential vorticity, the crest and the trough of topographic trapped wave tend to have different path way around the seamount area, and it induce the high sea surface height signal accumulated in norther part in northern strait and forms the inflow in northern part geostrophic ally. Meanwhile, the estimation of frictions around the middle island also proves the inflow in northern part leads EKC approaching middle island, the exchange flow pattern does not begin with EKC approaches.

P06

Response of plankton standing stocks and productivity to turbulent nitrate flux in the Kuroshio across the Tokara Strait

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Despite spawning and nursery grounds for many migratory fishes, biological productivity has been thought to be low in the Kuroshio due to oligotrophic conditions by strong thermal stratification and low standing stocks of plankton community. In recent years, some researchers propose large nutrients supplies by micro- to mesoscale physics like turbulence, frontal eddy and meandering, in particular the narrow and shallow Tokara Strait. Here, we evaluate response of standing stocks and productivity of phytoplankton and microzooplankton to turbulent nitrate flux based on enriched bottle incubations. Apparent growth rates of all size-fractionated phytoplankton demonstrated a logarithmical increase with nutrients enriched and were positive at the upper ranges of the turbulent nitrate flux measured in the Tokara Strait. Growth rates of pico- and nanophytoplankton were lower for those of microphytoplankton, indicating microzooplankton feeding on smaller autotrophs. These results suggest that phytoplankton productivity is stimulated by turbulent nitrate flux at the Tokara Strait even in the oligotrophic Kuroshio. We will discuss the responses of plankton community to turbulent nitrate flux including microzooplankton standing stocks and growth.

P07

Influence of physical and chemical processes on phytoplankton community in the western subarctic Pacific

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The western subarctic Pacific Ocean is a cyclonic upwelling gyre (western subarctic gyre; WSG) and plays a role as a sink for carbon dioxide (CO_2) from the atmosphere. In the WSG, phytoplankton blooms have been observed in early summer and autumn and likely contribute to the efficient uptake of atmospheric CO_2. However, the mechanisms for occurrence and termination of the phytoplankton blooms in the WSG are not well understood. The ship-based studies make it difficult to observe continuously non-predictable phytoplankton blooms in the ocean. In addition, the satellite data in the WSG have been limited due to persistent cloud cover, and the loss of the satellite data is worst in early summer. Here, we investigated the seasonal variability of the phytoplankton community as well as the physical and chemical characteristics of the environment in the WSG, using the profiling buoy and float systems. We anticipate that our time-series observations will provide a better understanding of the physical and chemical processes that regulate phytoplankton blooms in the WSG.

P08

Seasonal and interannual variations in the upper layer nitrogen availability and particles export in the western subtropical North Pacific

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The magnitude and frequency of nutrients supply into the upper oligotrophic layer control organic matter production and the subsequent particulate flux in the North Pacific subtropical gyre (NPSG). We examined variations in nitrate availability in and particles export from the upper layer of the western NPSG, by using repeated hydrographic cruises data and the time-series sediment trap data with nitrogen isotopic composition of settling particles collected at 200 m during 2010–2014. Reduced $\delta^{15}N$ (<4 ‰) was seen every winter, which corresponded to the convective nitrate supply that triggered phytoplankton bloom. As a result, relative large particulate fluxes occurred with higher $CaCO_3$ concentrations (>50 wt.%), implying new nitrogen enrichment would stimulate coccolithophore growth preferentially and downward transport of their coccoliths. Total inputs of nitrate ultimately sustained >80 % of annual new production in this region. The trapped particles also showed that winter $\delta^{15}N$ drop appeared earlier and thereby low $\delta^{15}N$ remained for ca. a month longer in bloom periods in 2011–2012 than those in 2013–2014, coincidently with higher $CaCO_3$ concentrations and relatively 40% lower export rain ratio of POC:PIC. This reflected stronger convective mixing and hence larger nutrients supply occurred in 2011–2012, likely caused by larger ocean heat loss related with winter monsoon intensity. If a winter convection is reduced associated with global warming, the POC export to deep sea will decline due to less nutrient availability and less $CaCO_3$ ballast whereas its effect on the oceanic CO_2 uptake is counteracted partly by elevated POC:PIC export ratio.

P09

Impact of deep ocean mixing on the climatic mean state in the Southern Ocean

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The Southern Ocean is of great importance for the global stratification and biological carbon storage because it is connected to the global ocean conveyor by which atmospheric information absorbed in the Southern Ocean is redistributed globally and buffered over centuries. Therefore, understanding what controls the Southern Ocean climate, the global ocean conveyor, and links between them is a key to quantifying uncertainties in future climate projections. Based on a set of climate model experiments, here we show that the tide-induced micro-scale mixing in the Pacific deep ocean has significant impacts on the wintertime Southern Ocean climate through basin-scale reorganization of ocean stratification and resultant response of the global ocean conveyor. Specifically, Pacific deep water, which is modified by the deep ocean mixing while travelling south, reinforces the subsurface stratification and suppresses deep convection in the Southern Ocean. Resultant increase of the Ross Sea sea-ice leads to decrease of incoming shortwave radiation and strengthening of the westerly and storms. Because the Southern Ocean could regulate the global warming progress through its role as heat and carbon sink, our study implies that better representation of deep ocean mixing in climate models contributes to reliability improvement in regional-to-global climate projections.

P10

Otolith oxygen isotope analysis and temperature history in early life stages of the chub mackerel *Scomber japonicus*

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In order to determine the temperature history of early life stages of chub mackerel (*Scomber japonicus*), otolith oxygen stable isotope ratios ($\delta^{18}O_{otolith}$) of larval and juvenile fish collected in the western North Pacific during 2004–2015 were analyzed and experienced temperatures estimated accordingly. The $\delta^{18}O_{otolith}$ values decreased with otolith growth during the larval stage (R=-0.54, n=31), whereas those for juveniles were positively correlated with the otolith radius (R=0.73, n=130), increasing with increasing otolith size. Combinations of $\delta^{18}O_{otolith}$ values, average otolith daily increment width and daily age were representative of the difference between better and poorer recruitment years; the former being characterized by earlier spawning and faster growth (resulting from cooler temperatures experienced) and the latter, slower growth. Analyzed fish were sorted into larval and early juvenile growth stages by cluster analysis, the high growth cluster having higher $\delta^{18}O_{otolith}$ values than the low growth cluster. Conversion of the $\delta^{18}O_{otolith}$ values to water temperature indicated that the higher growth cluster experienced a cooler water temperature by ca. 2.0 °C during the later juvenile stage. Therefore, it is suggested that a growth positive spiral exists, wherein individuals with high initial growth proactively enter cooler water temperature areas and access a highly nutritious diet resulting in further rapid growth.

P11

Application of The Modified ROMS-NEMURO.FISH for understanding growth and migration processes of particular fish species the Western North Pacific

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Japanese food culture is highly dependant on seafood with marine capture providing an important food source. However, the catch of many fish species exhibits multi-decadal fluctuations. Species alternation of sardine, anchovy and chub mackerel is one such distinctive phenomena. Although many studies have been conducted, until now the mechanisms of fish stock fluctuations remain unclear. In this work, the target species are Jack mackerel, chub mackerel, and Pacific cod in the Western North Pacific. In order to simulate growth and migrate processes of these fish species, we use 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 is forced by the atmospheric forcing of Common Ocean Reference Experiment version 2 (CORE2) and Japanese Reanalysis Project (JRA55), and the Simple Ocean Data Assimilation (SODA) is applied as the initial and the boundary conditions. In this presentation, we present early results of the integration focusing on the model climatology and interannual fluctuation of the physical fields.

P12

Evaluating the effects of environmental conditions on the growth and migration of Pacific chub mackerel *Scomber japonicus*

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Pacific chub mackerel (*Scomber japonicus*) is a small pelagic and important commercial fish species widely distributed throughout the coastal areas of the Indo-Pacific. In previous decades, chub mackerel around Japan showed large inter-annual variations of recruitment and total biomass, which was considered to affected by the changing ocean environments through climate, nutrient and prey conditions. Thus, we developed a growth-migration model for chub mackerel to track the environment fish experienced and evaluate the effects on the growth and migration from environmental conditions. The early life history of 2010-year class individuals was simulated in the Northwest Pacific under satellite derived environments. The growth was evaluated by a bioenergetics model which developed by reviewing and analyzing data from previous studies and new respiration experiment. The migration, which was decided by ocean current and predicted swimming behavior after metamorphosis, was calculated by Lagrangian transport model. The model results showed significant difference of growth characteristic among the larval and juvenile groups characterized by different transport routes, indicating the importance of sea surface current on the distribution and fitness of chub mackerel in the early stage. The group initially located around Izu Islands, which is the main spawning ground of Chub mackerel, experienced the stable environment both in temperature and prey environment, and had moderate growth. This fact may be a hint that the reason of chub mackerel spawning around the Izu Islands is because this area may provide stable habitat condition for larvae and juvenile of chub mackerel.

P13

Habitat layer change timing of Japanese jack mackerel (*Trachurus japonicus*) estimated by stable oxygen isotope ratios in fish otoliths

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Japanese jack mackerel, *Trachurus japonicus*, is one of the most important commercial target species. The main spawning ground is located in the East China Sea (ECS) and their eggs and larvae are transported along the Kuroshio and its bifurcation currents in the ECS. This species tends to change habitat layers from surface layer, 10 to 30 meters depth, to semidemersal layer, 70 to 120 meters depth when fish length becomes about 50 mm. The habitat layer change timing possibly influences its recruitment, because migration can allow them avoid predation, and hence decrease its natural mortality rate. In this research, the timing will be elucidated by otolith stable oxygen isotope ratio ($\delta^{18}O_{oto}$). $\delta^{18}O_{oto}$ tends to increase when individual experiences lower water temperature and/or higher salinity. In the ECS, the shallower depth tends to show higher water temperature and lower salinity and the deeper depth shows the opposite tendency. This means $\delta^{18}O_{oto}$ possibly increases by the habitat layer change. The otolith samples were selected from 3 years with different relative abundance of juveniles in near bottom layer; the mean abundance levels were low in 2005, intermediate in 2008 and high in 2009, respectively. In addition, latitudinal dependency of the habitat migration timing within the ECS will be tested. Ten samples were selected from each 3 subareas within the ECS (northern, central and southern areas) for each year. These analyses are ongoing, and the result will be shown in the poster.

P14

Mechanism of spring bloom of diatoms in the Oyashio region

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Diatoms, well-adapted to turbulent and nutrient-rich condition, are making blooms in coastal and upwelling waters. In the pelagic Oyashio region, western North Pacific, massive diatom blooms, such as observed in coastal regions, occur extensively every spring. These blooms could support high biological productivity in this region, one of the world's richest fishing ground. For spring blooming of diatoms in this region, both processes; supply of sufficient nutrients (including N, P, Si and Fe) and seeding of active diatom cells have been recognized to be essential.
The aim of this study is to elucidate mechanism of the spring diatom blooms in the Oyashio region by autoecological approach, focusing on seeding and growth processes. Conditions of spring diatom blooms and population dynamics of key diatom species in this area were examined by analysis of long-term monitoring data of physico-chemical parmaters and diatom communities along a transect known as the "A-line" in the Oyashio off the southeast coast of Hokkaido, Japan.

P15

Modeling growth and mortality processes of immature Pacific saury (*Cololabis saira*) using an individual-based, bioenergetics-migration model

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Pacific saury (*Cololabis saira*) is a commercially and ecologically important pelagic fish in the North Pacific. Total catch by countries along the western North Pacific is recently increasing. However, the stock variability is not solely explained by fisheries catch. The recruitment rate shows marked interannual fluctuations and many studies indicated influence of environmental variability in the spawning and feeding areas to the stock fluctuation. In this study, we examine the recruitment variability of Pacific saury using an individual-based model combining a bioenergetics, migration and mortality model. We parameterize the mortality rate of seasonal spawning cohort (autumn-, winter- and spring-spawned cohort) with the weight, instantaneous growth rate and temperature, and test the performance of each parameterization by comparing the model and observational results. The interannual variability of the growth-rate frequency distribution in the model is generally consistent with those estimated from the observations. The annual survival rates (recruitment per spawning biomass: RPS) in the model (mRPS) are calculated from the number of survived fish at age-1, and compared with RPS derived from the stock assessment for 2003–2012. The interannual variability in RPS is well reproduced in the model, especially in cases parameterizing the mortality using the weight and temperature with higher weighting on the spring- spawned cohort. The importance of the spring–spawned cohort regarding on the annual RPS is consistent with the hypothesis derived from observations during 1990–1998.

P16

Decay rates of internal tides estimated by an improved wave-wave interaction analysis

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Recent numerical and observational studies have reported that resonant wave-wave interaction may be a crucial process for the energy loss of internal tides and the associated vertical water mixing in the mid-latitude deep ocean. Special attention has been directed to the remarkable latitudinal dependence of the resonant interaction intensity; semi-diurnal internal tides promptly lose their energy to near-inertial motions through parametric subharmonic instability equatorward of the *critical latitudes* 29°N/S, where half the tidal frequency coincides with the local inertial frequency. This feature contradicts the classical theoretical prediction that resonant wave-wave interaction does not play a major role in the tidal energy loss in the open ocean. By reformulating the kinetic equation for long internal waves and developing its calculation method, we estimate the energy decay rates of the low-vertical-mode semi-diurnal internal tides interacting with the "ubiquitous" oceanic internal wave field. The result shows rapid energy decay of the internal tides, typically within O(10) days for the lowest-mode component, near their critical latitudes. This decay time is several-fold shorter than those in the classical studies and, additionally, varies by a factor of two depending on the local depth and density structure. We suggest from this study that the numerical integration of the kinetic equation is a more effective approach than recognized to determine the decay parameter of wave energy, which is indispensable for the global ocean models.

[†]This study is published in *Journal of Physical Oceanography*, currently in early online release.

P17

Impact of deep ocean mixing on transient climate response and steric sea level rise

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Employing each of two diapycnal diffusivity distributions in the ocean, a traditional one-dimensional one (CTRL) and a three-dimensional one considering tidal energy dissipation (TED), we ran an atmosphere-ocean coupled general circulation model of which value of CO_2 concentration is increased by 1% yr^{-1} for 150 years. Diapycnal diffusion is a key process to determine the strength and pattern of the global ocean overturning circulation. During the first ten years, our results show large upward heat flux in the Southern Ocean with CTRL. With TED, on the other hand, the sea ice in the Southern Ocean prevents the transfer of heat from the ocean to the atmosphere, leading to weaker bottom water formation and lower air temperature. Due to weak convective overturning with TED, the increase in water temperature in the upper layers in the Southern Ocean during the simulation period is much larger than with CTRL. Our results indicate that the transient climate response (TCR) with TED is larger than that with CTRL by about 0.15°C. We also analyzed the steric sea level rise (SLR) associated with the density change. The different distribution of ocean heat content change between CTRL and TED cause significant discrepancy in SLR by ~0.4 m in the Southern Ocean at the end of the simulation period. Our study indicates the no negligible role of ocean mixing on climate response, and it is necessary to clarify the global distribution of diapycnal diffusivity in the real ocean for reliable TCR estimation and future SLR projection.

P18

High-resolution modeling of nutrient transport in the northwestern North Pacific

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It is now well known that the subarctic North Pacific is one of high-nitrate low-chlorophyll (HNLC) regions, caused by a growth-limiting scarcity of the micronutrient iron. On the other hand, in the Oyashio region most of nitrate is consumed during spring and the primary production is high. Recent observations revealed that iron supply from sediment on the northwest continental shelf the Okhotsk Sea, adjacent to the Amur River estuary, plays an important role (e.g. Nishioka et al., 2013). Dense shelf water (DSW), takes up iron from sediment, thereby transporting iron into the Okhotsk Sea intermediate water. Iron in the intermediate water is then raised to the sea surface by tidal mixing around the Kuril Islands, making it available for primary production. Here we aim to clarify the iron cycle not only in the Okhotsk Sea but also in the subarctic North Pacific using a high-resolution iron circulation model. We used an ice-ocean coupled model COCO version 4.2 (Hasumi, 2006). The simulation reproduces HNLC in the subarctic North Pacific where iron concentration is less than 0.1 nM in August. In the subtropical-subarctic transitional region eastward of Hokkaido, however, iron concentration is higher. Meridional cross section across the Okhotsk Sea shows intermediate-layer high concentration of iron around the depth of 300 m originating in the northern continental shelf, suggesting that DSW takes up iron from sediment on the continental shelf. The intermediate-layer iron may support relatively high surface iron concentration in the transitional region.

P19

Triggers of the Spring Bloom Initiation in Mesoscale Eddies Revealed by One-Dimensional Turbulence-Ecosystem Model

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This presentation addresses the impact of mesoscale anticyclonic eddies (AEs) and cyclonic eddies (CEs) on phytoplankton dynamics and spring bloom initiation based on a lower trophic ecosystem model coupled with a one-dimensional physical-turbulence closure model. The lower trophic nutrient-phytoplankton-zooplankton-detritus model simulated the ecosystem dynamics, while the turbulence closure model provided the seasonal cycle of convective turbulent mixing in AEs and CEs. Model results revealed that in AEs convective mixing causes light limitation for phytoplankton growth during the deep winter mixing period and the bloom initiation is delayed until the relaxation of turbulent convective mixing. Conversely, in the shallow mixing CEs, blooms initiate before the end of convection due to early improvement in light conditions following the increase in solar radiation. These results supported previous satellite and ship data-based observations in which the spring bloom initiation was earlier in CEs with shallow mixed-layer depths than in AEs with deeper mixed-layer depths. Furthermore, the model also showed that the relaxation in zooplankton grazing for the deep mixing contributed to weak winter phytoplankton accumulation in AE, while winter phytoplankton accumulation was faster in the shallow mixed-layer CE. Overall, the initiation mechanism and the dynamics of the spring phytoplankton blooms are different between AEs and CEs. These findings are pertinent to understanding physical-biological interactions and their consequent role in ecosystem dynamics and the biological carbon pump in the ocean under climate change.

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Study on the circulation process of neodymium in seawater in the North Pacific Ocean, the Bering Sea and the Chukchi Sea

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Neodymium isotopic composition (ε_{Nd}) in seawater is used as a chemical tracer to investigate water masses and their palaeoceanographic circulation. The Nd data has been obtained in various oceanic areas, but there were not enough data in the North Pacific Ocean and its marginal seas. Comprehensive discussion has recently begun during the GEOTRACES project. In this study, we aimed to investigate the understanding of circulation process of Nd in seawater in the North Pacific Ocean, the Bering Sea and the Chukchi Sea. Seawater samples were collected from the equatorial Pacific to the subarctic regions (0^{o}-55^{o}N, 170^{o}W), the Bering Sea and the Chukchi Sea during R/V Hakuho-Maru KH-09-4 and KH-14-3 cruises. Dissolved Nd concentrations in surface seawater increased (3.3 - 9.8 pM) toward the high latitude, but characteristic ε_{Nd} values were found in surface water masses. In the surface seawater of the Bering Sea, the concentration of Nd increased, and ε_{Nd} become lower at low-salinity areas. On the Bering Sea shelf, the concentration of Nd and ε_{Nd} value were high in the bottom layer. These results suggest that there are two supply processes of Nd from the river water and shelf sediment. Concentrations of Nd and ε_{Nd} in the Bering Sea were explained by mixing of Nd from these two sources and the North Pacific subarctic seawater.

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Effects of nutrient enrichment on lower-trophic level ecosystem in the Tokara Strait

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In recent years, effects of strong turbulent mixing on lower-trophic level ecosystem have received a lot of attention in the Tokara strait, where many seamounts and small islands exit within the route of the Kuroshio in the East China Sea. To investigate these effects, we observed the spatiotemporal distributions of the nutrient concentrations and size structure of the phytoplankton assemblage around the Tokara Strait in the autumn of 2015. From these results, we found that the size structure of the phytoplankton assemblage in the Kuroshio region is significantly affected by the strong turbulent mixing around the Tokara strait. However, we only observed instantaneous values of standing stock of phytoplankton at that time. In order to investigate the response of phytoplankton to the nutrient supply around Tokara Strait, we have conducted nutrient enrichment experiment in the autumn of 2016 and 2017. Results of the experiments showed that phytoplankton significantly increase after 36 hours under the condition with nutrient enrichment much lower than estimated nutrient supply around the Tokara strait. The responsibilities of phytoplankton to the nutrient enrichment before the passing of the Tokara Strait were higher than those after the passing of the strait. These results suggest that phytoplankton sufficiently increase by the nutrient supply around the Tokara Strait.