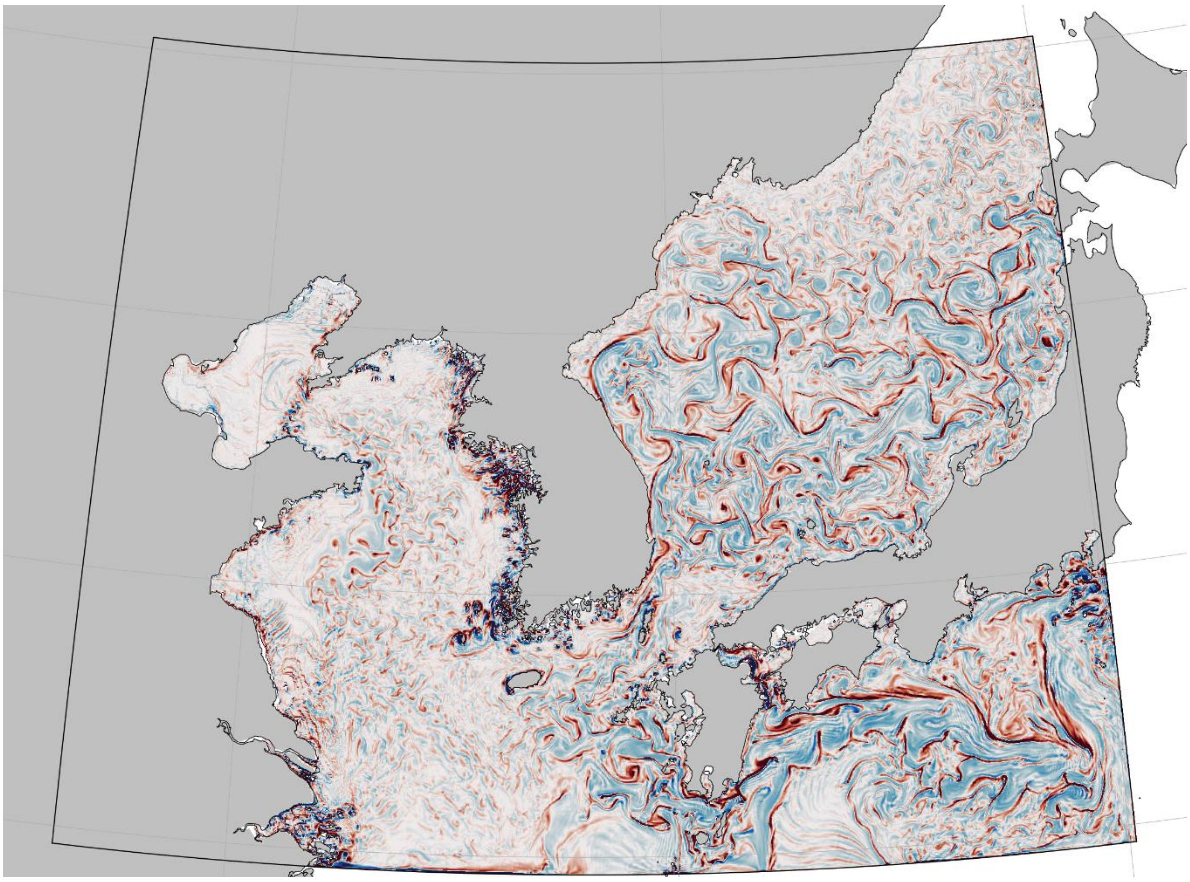
The 17th Korea-Japan Joint Seminar on Ocean Sciences



Date: April 3-4, 2023

Venue: Lah Jeh Kun Hall (B147), the Commons (Baekyangro Underground), Yonsei University

Local Organizing Committee: Hajoon Song, Yign Noh, Yeonju Choi (Yonsei University)

Day 1 (April 3)

09:00 Opening Address (Yign Noh)

Session I (Jae-Hun Park)

9:15 Chanhyung Jeon (Pusan National University) (Invited), S. Boury, K.-H. Cho, E.-J. Lee, J.-H. Park, T. Peacock

Observation of temporal and spatial variability of deep near-inertial waves in the western Arctic Ocean

9:45 Akie Sakai (Kyushu University), T. Senjyu

Generation and intensification of near-inertial internal waves in the Yamato Basin

10:00 Kang-Nyeong Lee (Inha University), C. Jeon, Y. Seung, H.-R. Shin, S.-K. Son, J.-H. Park

Observational evidence of generation and propagation of barotropic Rossby waves induced by tropical instability waves in the Northeastern Pacific

10:15 Ajin Cho (Yonsei University), H. Song, H. Seo

Atmospheric and Oceanic Responses to Surface Current Coupling near the Kuroshio Current

Session II (Tomoharu Senjyu)

10:45 Hidekazu Tsuji (Kyushu University) (Invited), N. Hirose

Numerical Analysis of Internal Tides and the Influence of the Kuroshio at Continental Slope in the East China Sea

11:15 Hajin Song (Inha University), J.-Y. Chae, J.-H. Park, D. G. Kim, H. S. Min, J. H. Lee

Seasonal variability of deep western boundary current in the Philippine Basin from observation and numerical simulation

11:30 Seonghyun Jo (Jeju University), J.-H. Moon, T. Kim, H. Cha, Y. T. Song

Interannual modulation of Kuroshio intensity in the East China Sea over the past three decades

11:45 So-Young Kang (Jeju University), J.-H. Moon, T. Kim, C. Jeon

Impacts of river-discharged freshwater on surface ocean environments revealed by satellite measurements

Session V (Hajoon Song)

2:00 Shinichiro Kida (Kyushu University) (Invited)

The dynamics of the Tsushima Warm Current

2:30 Tianran Liu (Kyushu University), N. Hirose, K. Takayama

Future Projection of Physical-Biogeochemical Environment in the Deep Japan/East Sea

2:45 Hyojun Seunu (Yonsei University), H. Song

Physical and biogeochemical characteristics of four types of eddies in the Southern Ocean

3:00 Tadanori Yamaguchi (Kyushu University), H.-R. Shin, N. Hirose

Sampling Japanese common squid (Todarodes pacificus) caught in the West Sea of Korea

Session IV (Jae-Hong Moon)

3:30 Jeong-Yeob Chae, Jae-Hun Park (Inha University) (Invited)

Estimation and prediction of sea surface current around the Korean peninsula using artificial neural network

4:00 Daehyuk Kim (Kongju University), H.-R., Shin, C.-H, Kim, J. Kim, N. Hirose

Characteristics of the intrinsic variability in the upper layer circulation of the East Sea (Japan Sea)

4:15 Satoru Tanimura (Kyushu University), T. Senjyu

Bottom water stream to the Yamato Basin from Tsushima Basin in the Japan Sea

4:30 Hiromi Matsuura (Kyushu University), S. Kida

The role of Japan Sea Throughflow on the spatial variability of the SST warming trend in the Japan Sea (East Sea)

4:45 Eun-Joo Lee (Inha University), J.-H. Park

Reconstruction of Long-Term Sea-Level Data Gaps Using Neural Network Operator

6:00 Bangquet (Uri-Idong Galbi, Shinchon)

Day 2 (April 4)

Session V (Naoki Hirose)

9:30 Yong-jin Tak, Hajoon Song (Yonsei University) (Invited), Y. Noh, Y. Choi

Physical and biogeochemical responses in the Southern Ocean to a simple parameterization of Langmuir circulation

10:00 Yujin Kim (Yonsei University), H. Song

Development of a Regional Ocean Model for the Northwest Pacific and Analysis of the Residual Overturning Circulation

10:15 Tahira Irfan (Kyushu University), A. Isobe, H. Matsuura

Numerical Modelling on transport of riverine plastic debris released into Indian Ocean

10:30 Kyunghun Han (Yonsei University), H. Song, Y. Kim

Prediction of future ocean changes in East Asia and overturning circulation changes in the East Sea using regional ocean circulation model

Session VI (Chanhyung Jeon)

11:00 Hajoon Song, Yeonju Choi (Yonsei University), J. Marshall, S. Y. Choi

Responses of Antarctic Sea-Ice and Southern Ocean to the Meridional Wind Forcing

11:15 Miho Yoshitake (Kyushu University), A. Isobe

Formation of 'subsurface plastic maximum' in coastal waters

11:30 Juchan Kim (Pusan National University), W. Son, H. S. La, C. Jeon

Detection of double-diffusive staircase structures from broadband acoustic measurements in the Chukchi and East Siberian Seas

11:45 Hyeonsoo Cha (Jeju University), J.-H. Moon, T. Kim, Y. T. Song

Underlying drivers of decade-long fluctuation in the global mean sea-level rise

12:00 Closing Address (Hajoon Song)

Observation of temporal and spatial variability of deep near-inertial waves in the western Arctic Ocean

Chanhyung Jeon[1,2], Samuel Boury[3], Kyoung-Ho Cho[4], Eun-Joo Lee[5],
Jae-Hun Park[5], Thomas Peacock[2]

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Near-inertial waves are waves propagating in the interior of the ocean. Created by surface storms, they have the potential to influence the ocean environment by inducing vertical mixing. Compared to other oceans, the Arctic Ocean has low near-inertial wave activity, but might be changing. It is a challenge, however, to predict near-inertial wave activity in the Arctic Ocean due to its intricate vertical salinity and temperature stratification. Our in-situ campaign has obtained the first direct deep current measurements revealing notable temporal and spatial variability of deep near-inertial waves in the western Arctic Ocean. These observations are an important step towards a clearer depiction of the evolving energy budget, and concomitant mixing, associated with potentially high impact near-inertial wave activity in an increasingly ice-free Arctic Ocean.

Generation and intensification of near-inertial internal waves in the Yamato Basin

Akie Sakai[1], Tomoharu Senjyu[2]

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[2]Research Institute for Applied Mechanics, Kyushu University, Japan

Current observations at six layers were conducted at Stn. PM5S (37.37° N, 134.41° E) in the Yamato Basin from October 2019 to November 2020. In October 2019 and the period from January to February 2020, near-inertial internal waves (NIWs) with large amplitude were observed at the shallowest depth (916 m) and the near bottom depths (deeper than 2400 m) for a few weeks. These NIWs features suggest the superposition of downward and upward propagating NIWs (Senjyu and Shin, 2021). By contrast, during November through December 2019, significant NIWs were observed only at the shallowest depth. We tried to clarify the differences between these two cases.

The ray-tracing experiments revealed that the ray paths emanated from the north and east of Stn. PM5S were blocked by the shallow topography and cannot reach to the bottom of Stn. PM5S. This suggests that the topography around the Yamato Basin prevents the NIWs from superimposing near the bottom of the Yamato Basin.

Inertial flow induced by the wind in the surface mixed layer was estimated using a slab model. Before the former case, strong inertial flow occurred in the northeastern part of the Yamato Basin, where the rays can propagate into the bottom. These results suggest that the excited region of NIWs determines if NIWs can reach to the bottom of Stn. PM5S or not.

Observational evidence of generation and propagation of barotropic Rossby waves induced by tropical instability waves in the Northeastern Pacific

Kang-Nyeong Lee[1], Chanhyung Jeon[2], YoungHo Seung[1], Hong-Ryeol Shin[3], Seung-Kyu Son[4], Jae-Hun Park[1]

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Tropical instability waves (TIWs), which are located at the boundary between the Eastern Pacific warm pool and the equatorial cold tongue, propagate westward with 25–40-day periods with seasonal and inter-annual variations. TIWs are stronger during July–December and La Niña periods, when the cold tongue is fully developed. It is known that they are generated by the instability of the equatorial currents which also induce radiation of barotropic Rossby waves (BTRWs). To verify the northward propagation of BTRWs, we used long-term near-bottom current data at 10.5°N and 131.3°W collected during 2004–2013, satellite-measured sea surface height (SSH), and velocity results from data-assimilated ocean model, called GLORYS12V1. The in-situ near-bottom current measurements revealed a spectral peak at 25–40 days, where significant coherences were found with satellite-measured SSH in a wide region of eastern Pacific except along the latitude 10°N. The discontinuity supports a coherent superposition of TIWs with barotropic Rossby waves induced by TIW (BTRWTIW). Simulated deep currents from GLORYS12V1 concur with the observed near-bottom currents, and both currents are consistent with the typically temporal variations of TIW. Further analyses using 25–40-day bandpass-filtered barotropic velocity data from the model revealed that they reasonably satisfied the theoretical dispersion relation of BTRWTIW. In addition, the filtered simulated barotropic velocity results exhibit the inter-annual variations which are related to El Niño-southern oscillation (ENSO). We reconfirmed BTRWTIW propagating northward above 10°N in the northeastern Pacific by in-situ observations firstly.

Atmospheric and Oceanic Responses to Surface Current Coupling near the Kuroshio Current

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The so-called frontal-scale air-sea interaction describing the atmospheric responses to oceanic fronts has been mainly discussed in the context of interactions between sea surface temperature and surface winds. The ocean current also influences the surface winds, which can significantly affect the atmosphere, especially in regions of energetic ocean currents and mesoscale activities as in the western boundary current systems. This study uses an atmosphere-ocean coupled model to analyze how the Kuroshio Current affects the momentum and turbulent heat fluxes and the atmospheric boundary layer and how these responses feed back to the ocean and atmosphere in this region. The ocean current coupling influences the path of Kuroshio extension and the eddy activities by mechanical and thermal current feedbacks. Mechanical current feedback reduces momentum flux and damps eddy kinetic energy (EKE) by reducing wind work as expected. On the other hand, the thermal current feedback associated with turbulent heat fluxes injects EKE by baroclinic energy conversion. Overall, the shift of Kuroshio Current and the change of eddy activities impact the region of strong turbulent heat release to the atmosphere, which can eventually trigger changes in weather systems.

Numerical Analysis of Internal Tides and the Influence of the Kuroshio at Continental Slope in the East China Sea

Hidekazu Tsuji, Naoki Hirose

Research Institute for Applied Mechanics, Kyushu University, Japan

It is recognized that, in the global ocean, the large amount of tidal energy is converted from barotropic to baroclinic internal tide which is then one of the main source of the turbulent energy dissipation. The process of energy transfer is greatly affected by topography, tidal motion, and ocean currents, and is expected to vary from region to region. For the East China sea (ECS) where has the one of the largest tidal energy in the world ocean, Niwa and Hibiya(2004) studied the M2 internal tides using numerical model analysis. We perform high-resolution numerical experiments of the Kuroshio with tidal motion on the continental slope of ECS for two summers in 2016 and 2017, when the Kuroshio axis and strength were significantly different. The distributions of barotropic-baroclinic energy conversion rates on the continental slope are compared to assess sensitivity to initial and boundary conditions. Sensitivity assessment shows that the Kuroshio mean flow plays an important role in determining the distribution of the energy conversion. Frequency analysis of domain-averaged conversion rates showed that the contribution of higher-frequency motions, including the M2 period, to the time-mean conversion rate is comparable to that of lower-frequency. The depth-integrated baroclionic energy fluxes and conversion rates are roughly in balance. They are positve in most areas, but negative in some domains due to the complex topography and tidal flow. These results provide fundamental and important insight into the coupling the Kuroshio including the frontal waves with tidal motion.

Seasonal variability of deep western boundary current in the Philippine Basin from observation and numerical simulation

Hajin Song[1], Jeong-Yeob Chae[1], Jae-Hun Park[1], Dong Guk Kim[2], Hong Sik Min[2], Jae Hak Lee[2]

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Deep western boundary current (DWBC) can play important role on the global climate through its contribution on heat and mass balance in a basin scale. From 2-year-long in-situ near-bottom current measurements, a DWBC which was flowing southeastward with a mean speed of ~4 cm/s was discovered in the Philippine Basin. The observed DWBC was dominated by evident seasonal variability - stronger southward current in winter and vice versa in summer. Further analyses were carried out to explain a reason of the seasonal variability using data-assimilated numerical simulation (GLORYS12V1), which included seasonal variability in DWBC agreeing well with the observation. In the GLORYS12V1, a significant anti-phase relationship was discovered between the seasonal variabilities of both the North Equatorial Current bifurcation latitude (NECBL) and DWBC. Near the DWBC, the seasonal variation of NECBL leaded change of upper pycnocline depth, which becomes ~13.5 m deeper (shallower) in summer (winter), by ~2 months. Due to the layer thickness change, a seasonal variability of bottom trapped deep anticyclonic eddy was induced to satisfy the potential vorticity conservation. In the summer, the enhanced deep anticyclonic eddy blocked the DWBC path and generated a northward current. In the winter, the DWBC was available to flow southward due to the weakened deep anticyclonic eddy. From an estimation using a linear potential vorticity conservation equation, it was revealed that the upper pycnocline depth change (~27 m) can produce a comparable intensity change in the deep anticyclonic eddy.

Interannual modulation of Kuroshio intensity in the East China Sea over the past three decades

Seonghyun Jo[1], Jae-Hong Moon[1,2], Taekyun Kim[2], Hyeonsoo Cha[1], Y. Tony Song[3]

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Previous studies have suggested that westward-migrating mesoscale eddies are a dominant factor that modulate the interannual Kuroshio intensity in the East China Sea (ECS), indicating a close positive correlation between them. According to the extended record of altimetry-based sea level anomalies (SLAs) until 2020, however, the interannual variation of the Kuroshio intensity no longer has a strong positive correlation with eddy activity in the subtropical countercurrent (STCC) region since the early 2000s. Our observational analyses showed that the Kuroshio intensity in the ECS can be modulated by the combined effect of westward-migrating mesoscale eddies and westward-propagating oceanic planetary waves from the east. Until the early 2000s, the interannual variability of Kuroshio was mainly affected by eddy migration from the STCC region, associated with oceanic instability driven by large-scale wind patterns over the western North Pacific. Since then, oceanic planetary waves propagating westward across the Pacific basin have largely modulated the interannual variability of the ECS-Kuroshio intensity by superimposing the SLAs related to mesoscale eddies that propagated towards the east of Taiwan.

Impacts of river-discharged freshwater on surface ocean environments revealed by satellite measurements

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A Large amount of freshwater discharged from the Changjiang River supplies high concentrations of nutrient and organic matter into the East China Sea (ECS). The river-discharged freshwater plays an important role in physical and biochemical responses of ocean environment, which are also closely related to regional carbon cycle. In this study, we used satellite-derived datasets for sea surface temperature (SST), chlorophyll a (*Chl-a*), and sea surface salinity (SSS) to investigate the impacts of freshwater on surface ocean environments in the northern ECS over 2015–2022. The corrected SSS shows a distinct interannual variation, with a strong seasonal cycle in winter maximum and in summer minimum. By comparing with SST and *Chl-a* anomalies, we found that the river-induced low-salinity water is closely linked to SST warming and high levels of *Chl-a* concentration relative to their long-term means. In addition, relatively low partial pressure of carbon dioxide (pCO_2) estimated appears in the northern ECS in 2016, which corresponds to the regions where in the SST warming and high levels of *Chl-a* concentration are significant. These results suggest that warm and nutrient-rich freshwater at the surface may contribute to a reduction of surface pCO_2 by prompting biological uptake of CO_2.

The dynamics of the Tsushima Warm Current

Shinichiro Kida

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The dynamics of the Tsushima Warm Current (TWC) is reviewed based on Godfrey's Island Rule. The Island Rule assumes a steady, flat ocean with a single island and explains the magnitude of the throughflow transport around the island from vorticity balance. Thus, the impact of bathymetry and the width of the straits need to be incorporated for the theory to be applicable to the Japan Sea. TWC is the inflowing branch of the throughflow, and the Tsugaru Warm Current and Soya Warm Current are the outflowing branches. Island Rule shows that the throughflow transport is determined by the magnitude of the wind stress curl in the open ocean rather than the local winds over the marginal seas, suggesting the importance of remote winds over the Northern Pacific. How the TWC transport partitions into the Tsugaru Warm Current and Soya Warm Current is then determined from mass balance and the frictional integral, the sum of frictional drag around an island. In this talk, I will introduce how the theory successfully explains the dynamics of the TWC from short-term and seasonal variability to long-term mean and trend.

Future Projection of Physical-Biogeochemical Environment in the Deep Japan/East Sea

Tianran Liu, Naoki Hirose, Katsumi Takayama

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Using a physical-biogeochemical coupled model, we predicted the long-term environment in the deep Japan Sea/East Sea (JES) under global warming scenarios. The representation of 4-dimensional model variables was improved by adjusting the initial conditions and parameters based on Green's function method with constraint of WOD18 data. The root-mean-square differences of simulation with optimal parameters decreased by 11.5% for dissolved oxygen (O) and 32.5% for nutrient (N). Then, the prediction experiments extended to 100 more years showed that the O concentration decreases by a rate of 0.8 μmol/kg and N increases by a rate of 0.1 mmol/m3 at most of time. However, the deep convection occurs frequently, which leads to abrupt increasing of O and decreasing of N due to vertical mixing. It is interesting that the deep layer potential density difference between the two scenarios RCP2.6 and RCP8.5 depends on reference pressure. For σθ, RCP8.5 is larger than RCP2.6 at most depths in the JES. On the contrary, for σ2, RCP8.5 becomes lower than RCP2.6. This is because of the higher temperature and salinity for RCP8.5 in deep layers. This study implies that the cabbeling should be examined carefully in the study of future projection of physical environment in deep ocean.

Physical and biogeochemical characteristics of four types of eddies in the Southern Ocean

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Mesoscale eddies in the ocean are important in ocean circulation and the transport of physical and biogeochemical properties. They are also abundant near strong currents, such as Antarctic Circumpolar Current in the Southern Ocean, where meanders near multiple fronts can be transformed into well-formed vortices. Here, we categorize mesoscale eddies into four groups; anticyclone, cyclone, mode-water eddy and thinny. Mode-water eddies and thinnies have the same sign of sea level anomaly to anticyclones and cyclones, respectively, but are characterized by reversed isopycnals in the upper layer, creating the opposite sign of surface density anomaly to anticyclones and cyclones, respectively. Mode-water eddy and thinny account for about 40% of total eddies in observation and even higher in the model data. Mode-water eddies have positive anomalies in vertical diffusivity. These anomalies are particularly larger in winter. Due to this feature, there is a strong supply of iron in mode-water eddies in winter. A higher concentration of iron can stay near the surface at the eddy center in the mode-water eddy and enhance biological when sunlight is supplied. In the previous study, anticyclones were listed to have strong biological activities, but our research confirmed that this was actually a feature of mode-water eddies.

Sampling Japanese common squid (Todarodes pacificus) caught in the West Sea of Korea

Tadanori Yamaguchi[1], Hong-Ryeol Shin[2], Naoki Hirose[1]

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[2]*Atmospheric Sciences, Kongju National University, South Korea*

To estimate the migration of the Japanese common squid to the West Sea of Korea (the Yellow Sea), we examined small (ca. 16cm in mantle length) and large (ca. 21cm) frozen squid obtained at a fish store in Taean County. These squid were caught off Taean in South Korea on July 22 and September 27, 2022, respectively. Statoliths were picked from each squid to analyze Sr/Ca ratios from the nucleus to the edge by an election probe micro-analyzer. Judging from the Sr/Ca ratios that have a negative correlation to water temperatures the squid experienced, the small squid experienced monotonic rising water temperatures until July 22 and the large squid seemed to experience increasing temperatures for several months, too. However, the Sr/Ca ratios of the large squid indicate the squid temperature decreased in one or two months before they were caught. The water temperatures at a depth of 22 m off Taean (DREAMS_M) increased from 3 ℃ in March to almost 24 ℃ in August and decreased to 21 ℃ in October. The temporal variation in the water temperatures was consistent with the estimated squid temperatures after June, as the squid were supposed to enter into the Yellow Sea. On the other hand, squid water temperatures were stable around 15 or 16 ℃ until June, which suggests the squid hatched in the Tsushima/Korea Strait or around the shelf edge of the East China Sea and was transported to the Yellow Sea because the squid probably belonged to the winter hatching cohort.

Estimation and prediction of sea surface current around the Korean peninsula using artificial neural network

Jeong-Yeob Chae, Jae-Hun Park

Department of Ocean Sciences, Inha University, Incheon, South Korea.

The prediction of sea surface current through the well-made hindcast data can help various marine activities. The recent improvements of numerical models make it possible to estimate a more realistic ocean with the help of data-assimilation and fine spatial resolution. It looks reasonable to adopt the state-of-the-art numerical model for practical purposes. However, the numerical ocean model requires high computational power and time which typically create a barrier to be practically utilized. To compensate the high computational costs, there is a need to develop novel approaches with efficient computational costs, combined with the numerical model outputs. In that way, artificial neural networks could be one of the solutions. They need low computational power and time for the practical use, since it uses pretrained parameters. Here, we present a current prediction framework applicable to the seas around the Korean peninsula using three-dimensional convolutional neural networks (3D-CNN). The network is based on the U-shaped neural network structure and modified to predict ocean currents from the few days of oceanic and atmospheric data. It is optimized to minimize the error of the next day’s ocean current field, and its recursively predicting structure allows more days to be predicted. The network's performance is evaluated by changing input days and variables to find the optimal surface-current-prediction artificial neural network model, which demonstrates its strong potential for practical uses near future.

Characteristics of the intrinsic variability in the upper layer circulation of the East Sea (Japan Sea)

Daehyuk Kim[1], Hong-Ryeol Shin[1], Cheol-Ho Kim[2], Joowan Kim[1], Naoki Hirose[3]

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[3]*Research Institute for Applied Mechanics, Kyushu University, Japan*

The ocean circulation variabilities are represented in numerical experiments with steady external forcings without interannual variability. These variabilities are known as "Ocean Intrinsic Variability". The intrinsic variability is mainly concentrated on the mid-latitude western boundary currents such as the Kuroshio, Gulf Stream, and Agulhas Current, their extensions, and eddy-rich regions.

As in other mid-latitude boundary current regions, the East/Japan Sea (hereafter the East Sea) has various ocean current patterns and eddies, and these upper layer circulations are driven by interactions with various external forcings. The East Sea also shows the intrinsic variability in numerical experiments without interannual variation in external forcings. However, previous studies are insufficient on the physical mechanism of intrinsic variability in the East Sea.

In this study, the physical mechanisms of intrinsic variability are analyzed using numerical experiments. The experiments are conducted with constant forcings and seasonal variation in the external forcings, which are defined as intrinsic process experiments. The intrinsic variabilities in the East Sea mainly appear in the southern part, especially the meandering or eddy-rich activity regions. In the southern part, the sea surface height anomalies propagate westward to the western boundary due to the baroclinic Rossby waves. The Rossby waves can change the strength of the eastward jet or the north-south movement of the jet axis. Among the external forcings, the volume transport through the Korea/Tsushima Strait is an important factor for driving intrinsic variability, and wind stress plays a role in expanding and strengthening variabilities.

Bottom water stream to the Yamato Basin from Tsushima Basin in the Japan Sea

Satoru Tanimura[1], Tomoharu Senjyu[2]

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[2]*Research Institute for Applied Mechanics, Kyushu University, Japan*

The Japan Sea Proper Water is a homogeneous seawater that exists in the Japan Sea below about 300 m. As the deep layer of the Japan Sea is isolated from other seas, the Japan Sea Proper Water have unique characteristics. The Japan Sea Proper Water is formed in the northwestern part of the sea near the coast of Vladivostok due to strong winter cooling at the sea surface, and then it circulates in the Japan Sea.

The Tsushima Basin and Yamato Basin in the southern Japan Sea are separated by the Oki Spur, which extends from the Oki Islands to the Yamato Rise. However, there are two gaps of 1000 and 1500 m in the Oki Spur. A previous study based on the ARGO float datasets have revealed that there is a direct flow from the Tsushima Basin to the Yamato Basin through the two gaps in the Oki Spur. In this study, CTD data obtained in the gaps were analyzed to clarify the structure of the flow through the gaps. Our results showed that a cold water was distributed along the eastern slope of the Oki Spur suggesting a density flow from the Tsushima Basin to the Yamato Basin through the gaps in the Oki Spur.

The role of Japan Sea Throughflow on the spatial variability of the SST warming trend in the Japan Sea (East Sea)

Hiromi Matsuura[1], Shinichiro Kida[2]

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Sea surface temperature (SST) is an important physical parameter that can influence the atmosphere and ocean productivity. The state of the SST in the Japan Sea affects the amount of snowfall and rain along the coast of Honshu, Japan where it faces the Japan Sea (Takahashi et al. 2013, Takahashi and Idenaga 2013). The Japan Sea shows a larger SST warming trend than the surrounding oceans (Japan Meteorological Agency 2020). However, the SST trend in the Japan Sea does not occur uniformly in space. Weak trends are observed near the Tsushima Strait and strong trends are observed in the interior of the Japan Sea. The direct heat input from the atmosphere and Tsushima Current cannot explain this spatial distribution.

A numerical model was used to understand the mechanism that generates the spatial variability in the SST warming trend. The Japan Sea has two steady oceanic current pathways known as the Japan Sea Throughflow; a zonal flow along the coast of Honshu and 39N in the interior of the Japan Sea. This throughflow is responsible for exchanging the water mass of the Japan Sea with the external oceans. The existence of this current may shorten the residence time scale and reduce the amount of heat received from the atmosphere. The observed SST trend shows a weak trend along the pathway. We developed an idealized model reproducing the basic character of the ocean circulation field and the SST trend in the Japan Sea. We find weak trends along the oceanic current pathways and a strong trend in the interior. The heat budget analysis supports the role of the oceanic currents cooling the SST along its pathway while the interior is heated due to atmospheric forcing and long residence time. Model results suggest that the Japan Sea Throughflow is the primary mechanism that controls the spatial distribution of the SST warming trend in the Japan Sea.

Reconstruction of Long-Term Sea-Level Data Gaps Using Neural Network Operator

Eun-Joo Lee, Jae-Hun Park

Department of Ocean Sciences, Inha University, Incheon, South Korea

Sporadic misses in coastal sea level observations occur frequently, which hinders understanding of ocean physics in coastal areas. In other words, general-purpose time-series analysis and prediction methods are vulnerable to missing data. For this reason, scientists have been working hard to fill the gaps, but the existing reconstruction techniques have the disadvantage of producing low-accuracy values for long-term missing values. Artificial neural network, a state-of-the-art technique, is also being used to reconstruct missing data, but this method has a chronic problem that the shape of the target is fixed. To overcome this obstacle, we suggest a model that predicts the sea level after an hour (one-step prediction operator) by utilizing an artificial neural network that creates multivariate and nonlinear regression equations. The repeatability of this model makes it possible to reconstruct missing data even longer than 72 hours successfully, which was almost impossible by using traditional gap-filling methods. A data assimilation technique is also applied to merge smoothly the model-predicted sea level with observations.

Physical and biogeochemical responses in the Southern Ocean to a simple parameterization of Langmuir circulation

Yong-jin Tak[1], Hajoon Song[2], Yign Noh[2], Yeonju Choi[2]

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Langmuir circulation (LC) is a phenomenon that deepens the mixed layer of the ocean, especially in weakly stratified areas. The use of LC parameterization has been shown to improve the accuracy of various oceanic variables in the Southern Ocean, but the effects of LC mixing on ocean dynamics and biogeochemical processes have been largely unexplored. This study implemented LC parameterization in a physical-biogeochemical model and found that it enhances the turbulent mixing length scale and turbulent kinetic energy, resulting in the deepening of the mixed layer, particularly in the subantarctic region. The deepening of the mixed layer brings deeper warm and saline water to the surface layer and weakens the surface meridional velocity by transferring momentum deeper. The LC effect also drives the retreat of sea-ice south of 60°S, leading to cooler and fresher water in the southern region of 60°S. These changes in the sea-ice distribution, mixed-layer depth, and dissolved inorganic carbon distribution alter the air-sea CO2 exchange, indicating that the LC parameterization in the model can improve the air-sea CO2 exchange by 10%. LC effects on biogeochemical tracers, such as iron and dissolved inorganic carbon, are mainly determined by changes in ocean circulation. The altered meridional circulation caused by LC effects spreads the impacts to a deeper layer and improves the overall representation of physical, biogeochemical tracers, and air-sea CO2 exchange in the Southern Ocean, suggesting that a simple LC parameterization can improve the ocean model.

Development of a Regional Ocean Model for the Northwest Pacific and Analysis of the Residual Overturning Circulation

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The East/Japan Sea (EJS) is a marginal sea bordered by Korea, Japan, and Russia. While most Pacific Ocean is not well-ventilated, the EJS is deeply ventilated. This means that there is an overturning circulation. Heat, salinity, freshwater, and nutrients are transported along the residual circulation, which is the sum of the wind-driven and turbulent-driven circulation. However, in the EJS, residual circulation was not calculated yet. Therefore, a regional ocean model in Northwest Pacific was constructed, and residual circulation in the EJS was analyzed. Using the MIT General Circulation Model (MITgcm), the meridional overturning circulation for 20 years (1996-2015) was calculated. In the annual average circulation, the clockwise circulation at 36-41°N, which appears in the eulerian circulation, was also in the residual circulation. The latitudes at which subsidence occurred in summer and winter were different. Eddy-driven circulation, the difference between residual and Eulerian circulation, intensified or weakened the circulation at 700m depth. In order to improve the simulation performance of the EJS current and circulation, continuous modeling studies and observations will be required.

Numerical Modelling on transport of riverine plastic debris released into Indian Ocean

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Large amounts of mismanaged plastic wastes enter the world`s oceans every year. Indian Ocean is particularly important in this regard because of the high amount of waste released from the countries bordering it coastlines. Despite this, little is known about the transport of plastic debris in the Indian Ocean. Therefore, this research aims to understand the transport of plastic debris and various factors influencing the plastic debris transport in Indian Ocean using a Particle Tracking Model (PTM). In PTM the modelled particles were carried by ocean surface currents from HYCOM, horizontal diffusivity, Stokes drift and satellite derived winds (windage). The model incorporated an exchange process between ocean and beaches such that the modeled particles washed ashore on beaches were re-drifted on a timescale of 200 days in accordance with the field experiment of Kataoka et al., (2013).

Plastic input from South Asian countries was incorporated into the model based on Lebreton et al. (2017) `s estimate. The modeling starts in the ocean free of plastics and continued for 10 years under the monthly-averaged currents and winds repeatedly used in the computation. The PTM experiments indicated higher beaching in Indian Ocean in the Summer (south-westerly monsoon). The model showed a higher seasonality in number of beached particles in the Bay of Bengal which is consistent with the observation. The seasonality was influenced by wind and Stokes drift. Further, the tracking experiments indicated the role of wind and Stokes drift in trapping macroplastic particles in the northern hemisphere Indian Ocean.

Prediction of future ocean changes in East Asia and overturning circulation changes in the East Sea using regional ocean circulation model

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The East Sea is referred to as a small version of the global ocean that experiences various phenomena.

It is unique in that warm and salty currents from the south (Kuroshio) flow through the Korean Strait and a cold current from the north (North Korean) descends. Depending on the season, thermalohaline circulation can occur, similar to the AMOC in the Atlantic Ocean.

This type of circulation is critical in transporting temperature, salinity, and freshwater in both the East Sea and other oceans. Thus, it is crucial to understand this circulation to predict future marine environments.

Previous studies have been conducted on the East Sea's overturning circulation, with more recent studies focusing on residual circulation. However, most are analysis of current conditions, not predictions of the future.

On the other hand, global climate models used in ocean modeling often have low resolution due to the need to integrate results over a long period. This is not a significant problem for larger scale phenomena, but for smaller scale ocean circulation, such as medium-scale eddies, it can result in inaccuracies. Medium-scale eddies are important for ocean circulation and affect material transport and ecosystems, but the nonlinear characteristics of these eddies cannot be fully expressed in models with low resolution.

Therefore, we built an East Asian regional ocean circulation model based on the MIT General Circulation Model (MITgcm) using cmpi6 data(KACE, MPI-esm-LR, and Canesm etc.). Our goal is to examine changes in ocean elements (SST, SSS, MLD, EKE, etc.) in the near future (2021-2040) and mid-future (2041-2060) compared to the present (1996-2014). Finally, we will analyze the changes in future overturning circulation

Responses of Antarctic Sea-Ice and Southern Ocean to the Meridional Wind Forcing

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The meridional wind, which can modulate the sea-ice extent with its stress, has been changed over the Antarctic sea-ice region and partially contributed to the Antarctic sea-ice extent variability. In this study, using observations and an eddy-resolving numerical model, we investigate the influence of meridional wind variability on sea-ice distribution, as well as ocean states and circulation in the Southern Ocean. The results show that southerly wind anomalies in austral winter lead to an increased sea-ice extent with equatorward sea-ice drift, resulting in more ice production and buoyancy loss in the coastal region and freshening near the Antarctic Circumpolar Current. In contrast, southerly wind anomalies in austral summer reduce the sea-ice extent owing to a positive temperature anomaly near the sea-ice edge. This positive anomaly results from the enhanced meridional overturning circulation under the southerly wind anomalies, which brings relatively warm water-mass toward the summertime sea-ice edge. The water-mass transformation analysis suggests that the enhancement of the meridional overturning circulation stems from the increased deep water formation caused by brine rejection and heat loss at the polynyas. The sea-ice extent, ocean states and the meridional overturning circulation behave the opposite way under the northerly wind anomalies. These results suggest that the meridional wind changes can modify not only the sea-ice distribution but also the ocean's meridional overturning circulation through the buoyancy fluxes at the polynyas.

Formation of 'subsurface plastic maximum' in coastal waters

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Less dense microplastics (MPs) are considered to float around sea surface. In fact, previous studies such as Reisser et al. (2015) observed the concentrations of these buoyant MPs in the different depths and found highest concentration at the sea surface regardless of size and wind conditions. However, we here present a quite different result from previous understanding especially for very small MPs (< 300 μm) using observations in Korean coastal waters in summer (partly presented in Song et al., [2018], Yoshitake et al., [JGR -Oceans, in revision]). By analyzing surface, middle and bottom seawater samples, we found a lot of very small MPs not only around the sea surface but also in the middle and bottom water. In particular, these 'subsurface plastic maximum' was clearly formed under the condition with the wind speed higher than around 3.0 m/s. As the wind speed becomes higher, although relatively large MPs (> 300 μm) existed still around the sea surface, very small MPs especially around 100-μm size formed a subsurface maximum around 20-m depth. Moreover, this subsurface plastic maximum was coincided with the bottom of the surface mixed layer (just above the pycnocline) suggested from the vertical profile of water temperature. Phytoplankton are also often found below the sea surface, which is referred to as a subsurface chlorophyll maximum (SCM). Then we assumed that phytoplankton is related to the subsurface MPs maximum.

Detection of double-diffusive staircase structures from broadband acoustic measurements in the Chukchi and East Siberian Seas

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Double-diffusive stratification characterized by staircase structures, related to vertical flux of heat, composes mixed layers of temperature and salinity. They are often observed in the Arctic Ocean at the upper boundary of Atlantic water layer which is warm and salty. These mixed layers were investigated using hydrocasts that can have enough vertical resolutions to see the O(0.1–10) m of the staircase structure, while herein we tried using broadband acoustic measurements. We used CTD and EK60 (broadband acoustic measurement) datasets collected from Research Vessel Araon in 9–21 August 2015 over the Chukchi and East Siberian Seas of the Arctic. This provides an opportunity to examine how accurate and useful the acoustic way is to detect the double-diffusive staircase structures.

Underlying drivers of decade-long fluctuation in the global mean sea-level rise

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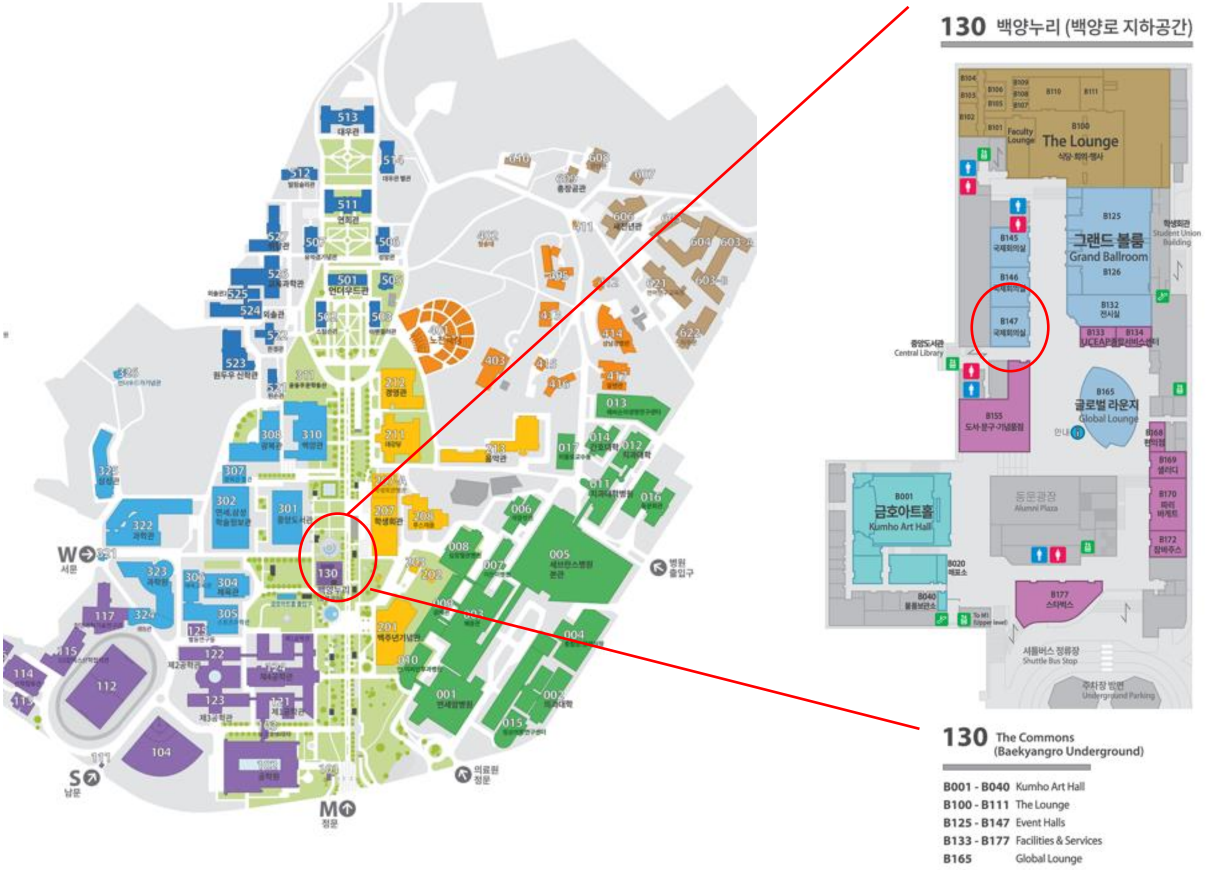
Natural climate variability can mask the background trend of global mean sea-level (GMSL) caused by global warming. Recent advances in satellite measurements and ocean heat-content estimates have enabled the monitoring of GMSL budget components and provide insights into ocean effects on the Earth's energy imbalance and hydrology. We observed a decadal fluctuation in GMSL rise, which coincides with an increasing trend in the 2010s after the warming "hiatus" during the 2000s, and demonstrated that this can be attributed to climate-related decadal fluctuations in ocean heat storage and hydrology. Since ~2011, the climate-driven decadal changes have resulted in additional ocean mass gain (271±89 Gt yr^{-1}) from glacier-free land water storage and increased ocean heat uptake (0.28±0.17 W m^{-2}), accelerating the GMSL rise rate by 1.4±0.4 mm yr^{-1}. The suggested estimates of sea-level and Earth's energy budgets highlight the importance of natural variability in understanding the impacts of the ongoing sea-level rise.



Venue: Lah Jeh Kun Hall (B147), the Commons(Baekyangro Underground), Yonsei University

Bangquet (Uri-Idong Galbi, Shinchon)