

World Premier International Research Center Initiative (WPI)

FY2023 WPI Project Progress Report

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Common instructions:

* Unless otherwise specified, prepare this report based on the current (31 March 2024) situation of your WPI center.

* So as to execute this fiscal year's follow-up review on the "last" center project plan, prepare this report based on it.

* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.

☐ Prepare this report within 10-20 pages (excluding the appendices, and including Summary of State of WPI Center Project Progress (within 2 pages)).

Summary of State of WPI Center Project Progress (write within 2 pages)

The WPI-Advanced Institute for Marine Ecosystem Studies of Change (WPI-AIMEC) aims to elucidate the response and adaptive mechanisms of marine ecosystems to Earth system dynamics and to realize systematic projection of marine ecosystem change through an integrated approach of marine physics, ecology and mathematical data sciences. WPI-AIMEC was officially established on January 1st, 2024, with Professor Toshio Suga of Tohoku University appointed as the Director of the Institute. In this section, we describe the major scientific activities in FY2023, followed by measures to promote fusion research. The progress of the research center concept implemented in the first year is also reported.

Promoting world-class research

Five research units were established at Tohoku University, the main location of the center: the Marine Biology Integrative Research Unit conducted two times of overseas visits, invited 10 foreign researchers to participate in various research activities including fieldwork. The Ecological Complexity Research Unit already launched ANEMONE (All Nippon eDNA Monitoring Network), the world's first open environmental DNA monitoring network, which is a collaboration between industry, government, academia and the private sector. In this year as the fourth year of the network, the scope was expanded from fish monitoring to terrestrial organisms such as mammals and birds. A scientific paper (Suzuki, Ohno et al., 2023) and a book (Kondoh et al., 2024) introducing the project were published. The Coastal Ecosystem Services Research Unit will conduct long-term measurements and analysis of Onagawa Bay and develop a foundation for comparison with other bays along the Kuroshio and Oyashio currents. Now, with the introduction of long-lead metagenomics techniques, this unit is actively harnessing the power of genomics. In the Ocean-Solid Earth Dynamics Research Unit, Principal Component Analysis (PCA) was applied to the OBP time series of the Network System for Earthquakes and Tsunamis (DONET), monitoring PC stability to detect non-stationary tectonic components and promoting interdisciplinary research between solid earth science and ocean science. The Marine Environment Integrative Analysis Unit published an integrated estimate of CO₂ uptake and its uncertainty in the Arctic Ocean (Yasunaka et al., 2023), and showed that the Arctic Ocean is a net sink for CO₂, and CO₂ uptake has increased in recent years.

Four research units were established at JAMSTEC: the Marine Microbial Ecology Research Unit provides important insights into material cycling in marine ecosystems, and for a more comprehensive understanding of marine biogeochemical processes, the EPS (extracellular polymeric substances) dynamics. The Marine-Earth System Analytics Unit has emphasized the fundamental need to take into account the high resolution to be inherently important, based on several previous research findings (e.g., doi.org/10.1175/JCLI-D-22-0510.1). The need will give impetus to the ongoing development of a 0.1° resolution ocean model at WPI-AIMEC. The Marine Biogeochemical Dynamics Research Unit is studying the analysis and prediction of non-linear time series based on path signatures (mathematical transformation of paths into matrices). This method is useful for pre-processing AI methods and the method has been applied to the problem of predicting El Niño and La Niña cycles, showing high predictability even using simple deep learning network structures (Derot, et al., 2024). The Marine Ecosystem Modelling Research Unit will develop, test and refine models that capture the dynamic response of complex marine ecosystems, ultimately providing tractable equations for use in large-scale, long-term modelling studies, as well as Earth system climate models.

Interdisciplinary research measures

WPI-AIMEC has a strong interest and awareness of how data from the various disciplines that define marine ecosystems are intertwined with each other. At the first All-Hands meeting on 7 March 2024, the nine research unit leaders presented the activities and directions of their units based on the academic backgrounds of the unit members. While the content of their perspectives and research strategies emphasized the specialization of their units, three elements common to all units applied: ecosystem stability, connectivity and adaptability, and the fundamental question of how to assess complex network systems. The need for fusion research to elucidate the mechanisms of highly complex marine ecosystems was strongly recognized by the PIs actually leading the research, and in FY2024, an in-house fusion start-up was designed.

Global research environment and institutional reform

International research environment

PIs include the Director, who was co-chair of the International Argo Programme, the Deputy Director, who was a key member of the IODP, and Kawamiya and Xie, who made major contributions to the writing of the IPCC assessment report. Professor William McDonough, Section President of AGU, and Professor Keith Rodgers, Co-Chair of CLIVAR in the USA, have also joined as PIs from FY2024, bringing together a number of researchers in leadership positions. The project was also able to attract a large number of researchers in leadership positions. In addition, the GP-EES, which has been mainly led by Tohoku University and the University of Hawaii to grant Joint Degrees, is being expanded to cover a wider range of academic fields covered by AIMEC to create an environment for granting Joint Degrees. The participation of JAMSTEC researchers in this framework will enable them to gain new experiences as part of their postgraduate education that they cannot obtain at universities. In addition, to make it easier for foreign post-doctoral researchers to conduct research in Japan, an annual salary of 5.6 million yen has been offered.

Organizational reform

On the Tohoku University side, AIMEC organizational regulations were developed and became effective as of 1 January 2024, while on the JAMSTEC side, a task force was established and as of 1 April, an organization with the structure as Tohoku University was set up. The operating rules of this organization within JAMSTEC are AIMEC's own operating rules, which differ from JAMSTEC's standard organizational rules and are developed in consultation with the JAMSTEC director in charge and the legal department, as necessary. This approach has enabled the establishment of an integrated decision-making scheme. In the course of the transition to these new structures, a unified personnel system was established in both organizations. In designing these systems, they were made as simple and internationally understandable as possible.

Values for the future

Creating and communicating the social value of basic research

On 8 March, a kick-off symposium, including one for the general public, was held in Sendai. For this purpose, advertisements were placed in both the national and Tohoku editions, including an introduction to AIMEC's research. As a result, the event attracted a crowd that almost filled the venue (total participants 376, on-site participants 158). In this context, several existing activities related to AIMEC and networking time with participants were arranged to promote the combination of basic research. In addition, a website was built and opened to the public at the end of March, and at the same time a brochure (in English) was prepared and distributed at various locations. Furthermore, an article introducing AIMEC was published in the newsletter for members of the Japan Geoscience Union, and on 23 March 2024 (Sat), AIMEC co-organized with the Graduate School of Science a "Burari Science Walk for High School Students" at the Aoba Science Hall, Aobayama Campus.

Human resource development, higher education and career development

We are currently proposing a GP-EES-based strategy to those responsible at the university. The aim is to broaden the scope of postgraduate education in other departments associated with AIMEC, such as the Graduate School of Science, but also the Graduate School of Agricultural Sciences, the Graduate School of Life Sciences, the Graduate School of Information Sciences, and the Graduate School of Engineering. It aims to contribute to a more comprehensive postgraduate education across a range of disciplines and ultimately contribute to AIMEC's goal of integrating marine ecosystem research.

A sustainable center

At Tohoku University, AIMEC has established itself within the Institute of Higher Education. The host institution was briefed on the construction of the building and the relevant departments of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) were also briefed. There is a shared awareness between the host institution (Tohoku University) and AIMEC of the need to secure tenured positions; at JAMSTEC, there is a shared awareness of the issue among the heads of existing departments within JAMSTEC regarding the need for tenure positions with a view to the next ten years.

* Describe clearly and concisely the progress being made by the WPI center project from the following viewpoints.

1. World-Leading Scientific Excellence and Recognition

1-1. Advancing Research of the Highest Global Level

* Among the research results achieved by the center, concretely describe those that are at the world's highest level. In Appendix 1, list the center's research papers published in 2023.

The WPI-Advanced Institute for Marine Ecosystem Change (WPI-AIMEC) was officially launched on 1 January, 2024, with the appointment of Professor Toshio Suga of Tohoku University as Director. WPI-AIMEC will challenge to expound on the response and adaptive mechanisms of marine ecosystems to Earth system dynamics using a fusional approach that integrates marine physics, ecology, and mathematic information science to facilitate systematic forecasting of change. This section describes key research achievements in FY2023, and future direction of the AIMEC research units.

Marine Biology Integrative Research Unit (Unit Leader: Cheryl Ames)

This fiscal year, the WPI-AIMEC Marine Biology Integrative Research Unit was established with Cheryl Ames (Tohoku University Graduate School of Agricultural Science, Faculty of Agriculture), as AIMEC's Marine Biology Integrative Research Unit leader. Additional members include Tohoku University Faculty AIMEC Unit members, Satoshi Katayama (Agriculture), Goh Nishitani (Agriculture), and Gaku Kumano (Asamushi Research Center for Marine Biology, Graduate School of Life Sciences). Tohoku University AIMEC graduate students are Yongstar Chanikarn (D1 Ames Lab), Bryson Torgovitsky (D1 Ames Lab), Tan Kei Chloe (M1 Ames Lab), Muhammad Izatt Nugraha (D2 Nishitani Lab), Naotaka Fukano (M2 Katayama Lab), Yuki Nagai (D2 Collaborator Sato-Okoshi Lab), and Towa Onda (Collaborator Murakami Lab).

UL Cheryl Ames conducted multiple overseas visits and invited 3 international researchers (Dr. Allen Collins, National Oceanography & Atmospheric Administration (NOAA) NSL, "Building Verifiable Voucher-Based Genetic Reference Libraries for Marine Species – Case Studies with Medusozoans and Ctenophores", Dr. Jimena García-Rodríguez, Sao Paulo University, "Comparative analysis of the gonadal structures of Cubozoa in the evolutionary context of Medusozoa (Cnidaria)", Dr. Karen Osborn, Smithsonian NMNH & Monterey Bay Aquarium Research Institute, "Through their eyes: the challenges of seeing in the midwater and of imaging the diverse animals found there") to participate in various research activities, including fieldwork as well as student monitoring and internal exchanges. In this fiscal year, arrangements were made for AIMEC graduate student (Tan Kei Chloe M1) to undertake a 3-month graduate research experience (2024/4/1-2024/7/1) in the labs of collaborators, Dr. Monica Medina, Professor, Pennsylvania State University (PSU) and Dr. Allen Collins, Curator Smithsonian NMNH & Director NOAA National Fisheries Services National Systematics. Additionally, she will conduct fieldwork in the Florida Keys in conjunction with Ames's unit's NSF MUCUS grant conducting research on jellyfishes in the group that causes stinging water syndrome massive outbreaks. This is related to AIMEC's Marine Biology Integrative Research Unit objective (2) Clarifying the underlying mechanisms of regime shifts including the phenomena of mass outbreaks and mortality of marine organisms. This AIMEC graduate student will incorporate these data into her master's thesis and develop a better understanding of the emergence of "stinging water" in these jellyfishes and whether it is perturbed by warming ocean temperatures. Additionally, genomic approaches as well as cellular observations should allow us to address questions related to symbiotic algal and their capacity to adapt to warming oceans.

Ecological Complexity Research Unit (Unit Leader: Michio Kondoh)

It has been four years since the establishment of the world's first open environmental DNA observation network, ANEMONE (All Nippon eDNA Monitoring Network), a collaboration between industry, government, academia, and the public. Starting in 2023, the network expanded its scope from monitoring fish to include terrestrial species such as mammals and birds. All acquired data is made available freely and without usage restrictions through the dedicated database ANEMONE DB. This has not only facilitated research activities by the scientific community but also opened up potential for new business creation by corporations. An academic paper introducing this project (Suzuki-Ohno et al., 2023) and a book (Kondoh et al., 2024) have been published.

A causal inference method applicable to time series data was developed. In ecology, a causal inference method known as Convergent Cross Mapping (CCM, Sugihara et al., 2012) is used to estimate

interspecies interactions from time series data for each species. However, CCM, which was conceived from nonlinear dynamics, lacked a clear statistical foundation and faced known challenges, such as high false positives and difficulty distinguishing between indirect and direct causality. In this study, the CCM causal inference method was redefined from an information-theoretic perspective, establishing a statistical foundation. Consequently, CCM was identified as a specialized estimation method of Transfer Entropy (TE, Schreiber 2000), another causal inference method, with robustness to observational noise on the causal side but a potential for false positives under certain circumstances. Thus, CCM and TE theories were integrated, resulting in the development of a new causal inference method, Unified Information-theoretic Causality (UIC). UIC not only exhibits higher estimation capability than CCM and TE in various scenarios but also enables the statistical distinction between indirect and direct causality. Additionally, based on the clarified statistical foundation, modifications to the CCM calculation algorithm were made (predictive metric bias, manifold data density skew, model averaging, robust estimation). These results have been submitted to a peer-reviewed English scientific journal. The developed method has also been released as the rUIC package, which is available for use in the R programming language.

Based on nonlinear time series prediction techniques, a method was developed to detect changes in the fluctuation patterns of communities. This method was applied to underwater fish observation data in a marine area where fish communities changed significantly due to the shutdown and restart of a nuclear power plant. The method detected shifts in the fluctuation patterns of biodiversity indicators such as species count, Shannon diversity index, and distribution latitude center. The results revealed different types of environmental dependency in the fluctuation patterns of biodiversity indicators: indicators that respond to temperature changes, those that do not respond, and those that respond to variations other than temperature changes. These findings suggest that regime shifts in biological communities vary depending on the dimensions of the communities being considered. This research has been published in a peer-reviewed international journal (Otomo et al., 2023).

Coastal Ecosystem Services Research Unit (Unit Leader: Takeshi Obayashi)

The Coastal Ecosystem Services Research Unit aims to comprehensively elucidate the biological dynamics of Onagawa Bay, which is a vital research site for understanding coastal ecosystems due to several factors. Firstly, Onagawa Bay is situated on the Sanriku Coast, where the Kuroshio and Oyashio currents converge, providing a rich fishing area for both open ocean and aquaculture. In addition, the area underwent significant damage due to the tsunami caused by the 2011 East Japan Great Earthquake, and recovery is still in progress. Therefore, long-term and detailed measurements and analyses are particularly crucial for understanding the environmental interactions between the open ocean and the land, influenced by physicochemical, biological, and anthropogenic factors. Obayashi's unit has conducted long-term measurements and analyses of Onagawa Bay and established a basis for comparing it with other key bays along the Kuroshio and Oyashio currents near the Japanese coastal areas. By currently introducing long-read meta-genomics technology, his unit actively harnesses the power of genomics. Long-read sequencing directly provides a reference genome for analyzing metabarcoding. Additionally, this technology offers new opportunities to integrate functional metagenomics predictions into ecological modeling. Using Onagawa Bay as a model case, the unit strives to elucidate the marine dynamics of the Sanriku Coast, ultimately contributing to environmental conservation on a global scale. For this purpose, his unit has developed data-driven genomic platforms that connect genomes and phenotypes in animal, plant, and microalgae species. These platforms provide a foundation for functional metagenomics-based ecological modeling (Obayashi et al., 2023).

Ocean-Solid Earth Dynamics Research Unit (Unit Leader: Yusaku Ohta)

Ocean bottom pressure-gauge (OBP) records play an essential role in seafloor geodesy and oceanography. Oceanographic fluctuations in OBP data, however, pose a significant noise source in seafloor transient crustal deformation observations, including slow slip events (SSEs), making it crucial to evaluate them quantitatively. To extract the significant fluctuation phenomena common to multiple observation networks, including oceanographic fluctuations and tectonic signals, Ohta's unit applied principal component analysis (PCA) to the 3-year Dense Ocean-floor Network System for Earthquakes and Tsunamis (DONET) OBP time series for 40 stations during 2016–2019. The spatial distribution of the first four principal components (PCs) reflected the common component. By subtracting each PC from the time series, they could significantly reduce the sea depth dependence of OBP records (Otsuka et al., 2023). They also confirmed that these extracted PCs are spatiotemporally stable. The results suggest that

monitoring PCs stability can detect non-steady tectonic components. Establishing a method for separating these non-tidal oceanographic fluctuations is an extremely important achievement in promoting research in the multidisciplinary field of solid earth and oceanographic science.

Marine Environment Integrative Analysis Unit (Unit Leader: Sayaka Yasunaka)

To detect and understand ocean environmental and biological changes from coast to world ocean from seasonal to 10,000-year scale, Yasunaka's unit has promoted the observational and modeling projects and conducted the integrative analyses. The project led by Toshio Suga, "Establishment of the Integrated Global Ocean Observing System 'OneArgo' and Promotion of Ocean Interdisciplinary Research", was listed as one of 12 projects in MEXT Roadmap 2023, (https://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu4/toushin/1423056_00026.htm).

As a contribution to an international project to establish the greenhouse gas budgets (RECCAP2; <https://www.globalcarbonproject.org/reccap/>), Yasunaka's unit presented synthesized estimates of Arctic Ocean CO₂ uptake and their uncertainties (Yasunaka et al., 2023). The Arctic Ocean was a net sink of CO₂, and the CO₂ uptake has increased in recent years, especially in regions that have experienced sea ice loss. Regarding the long-timescale changes, Yasunaka's unit investigated the $\delta^{18}\text{O}$ record in the Holocene corals from Kikai Jima (Chuang et al., 2023). The results imply that the relationships of the East Asian winter and summer monsoon to the El Niño/Southern Oscillation and Pacific Decadal Oscillation dominant in the North Pacific might have been modulated by or associated with the Atlantic Multidecadal Oscillation dominant in the North Atlantic during the Late Holocene. This unit also has started quantitative investigations of the taxonomic composition of glacial and interglacial coral assemblages and reconstruction of the variabilities of seawater temperature and carbonic acid system in the Northwest Pacific subsurface to intermediate waters.

For the coastal oceans, Yasunaka's unit established a lab-scale experimental system that includes a device for continuously measuring dissolved oxygen concentration. Additionally, they developed models describing the behavior of particulate organic matter and its oxygen consumption in coastal areas. To understand future changes in the North Pacific subtropical gyre, they have focused on subtropical mode water and the preliminary analysis indicated that the volume of subtropical mode water will decrease by about 50% in a future under global warming.

Marine Microbial Ecology Research Unit (Unit Leader: Tatsuhiko Hoshino)

The extracellular polymeric substances (EPS) present in marine particles, including transparent exopolymer particles (TEP) and Coomassie Brilliant Blue-stained particles (CSP), are an integral part of the marine carbon cycle. TEP's adhesive properties facilitate the aggregation of particles, thereby enhancing the sequestration of carbon (Fig. 1). This process highlights the critical role of TEP in the biological carbon pump. However, the dynamics of TEP in the carbon cycle are complex and not fully understood, in particular due to the conflicting nature of TEP buoyancy in seawater. The buoyancy of TEP-rich aggregates, which would normally counteract their downward transport, introduces a paradox in understanding their role in carbon flux. Hoshino's unit analyzed both suspended and sinking marine particles from the subarctic and subtropical regions to assess the components of EPS, in particular CSP and TEP. The results show a different role for TEP in these environments. In the subarctic zone, influenced by diatom blooms, TEP is thought to form aggregates with organic matter, facilitating the sinking of particles. Conversely, in the oligotrophic ocean of the Kuroshio region, TEP is involved in the aggregation of denser particles such as dust minerals and protistan skeletons, suggesting that TEP enhances the sinking properties of marine particles.

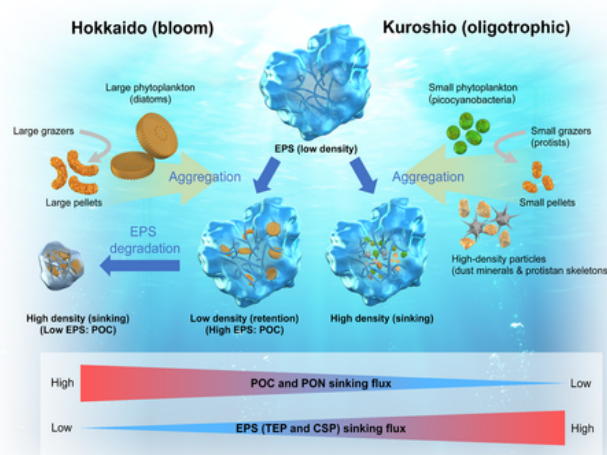


Fig 1. Conceptual Diagram of EPS function particles between sinking and retention in the two ocean regions

This study provides important insights into material cycling in marine ecosystems and highlights the fundamental need to take EPS dynamics into account for a more comprehensive understanding of marine biogeochemical processes.

Marine-Earth System Analytics Unit (Unit Leader: Michio Kawamiya)

Climate models typically have a cold sea surface temperature (SST) bias for the Arabian Sea, which regulates the Indian monsoon system as a water vapor source. Since the SST for the Arabian Sea is critical for the Indian monsoon, a better understanding of the processes that affect the SST is required. UL Kawamiya's unit investigated the effects of mesoscale oceanic variability on simulations of the Arabian Sea SST and Indian summer monsoon precipitation based on a comparison of climate model experiments in which non-eddy and eddy-permitting ocean components are coupled. In the eddy-permitting model, warm water advection driven by mesoscale variability near the Gulf of Aden and the Gulf of Oman increases the SST in the western Arabian Sea. Lateral eddy heat transport enhances warm water outflows to the Arabian Sea and suppresses surface water cooling by coastal upwelling during the southwestern monsoon season. Furthermore, a sensitivity experiment shows the primary importance of resolving oceanic mesoscale eddies and the secondary importance of resolving the Persian Gulf and the Red Sea for the Arabian Sea SST. Also, the summer monsoonal precipitation decreases (increases) over the southeastern Arabian Sea (western and northern India) in the eddy-permitting model due to the enhancement of wind convergence in the lower troposphere. Atmospheric general circulation model experiments indicate that the precipitation difference is partly caused by SST changes over the western Arabian Sea. The findings imply that the ocean resolution of climate models is a key factor in efficiently simulating the Indian monsoon.

The results are published in the *Journal of Climate* (<https://doi.org/10.1175/JCLI-D-22-0510.1>), categorized in the Q1 quantile in the field of climatology with an impact factor being 4.9 for 2022, clearly demonstrating that the study is the world's highest level. The finding that higher resolution is essentially important provides some momentum to the development of the 0.1-degree resolution ocean model that is ongoing in WPI-AIMEC.

Marine Biogeochemical Dynamics Research Unit (Unit Leader: Shinya Koketsu)

UL Koketsu's unit investigates analysis and prediction methods for nonlinear time series based on path signature, which is a mathematical transformation of the path to the matrix. As the functions with the input of path signature can represent nonlinear functions of original path data, the transformation can be useful for preprocessing for AI methods. They apply the methods to the prediction problem of El Nino and La Nina cycles, and show high predictability even with simple deep learning network structures and simple methods for interpretation of the relationship between input time series (Derot, et al., 2024). This method is also applied to the prediction of atmospheric profiles (Fujita et al., 2024).

UL Koketsu's unit also conducts observations and analyzes of ocean observation datasets. Along Indian ocean sections, where the observation cruise was conducted in 2019, they reported ocean turbulent distributions near the Antarctic circumpolar current, where relatively high turbulences contributing to material distribution in the ocean were detected and were strongly influenced by topography and geostrophic currents (Sasaki et al., 2024). Furthermore, along the sections, they also analyze processes to determine spatial distribution of dissolved organic matter (DOM) based on measurements regarding optical properties of DOM and dissolved organic carbon. This unit can successfully identify the main processes as biological production and ocean circulation in the surface layers, photodegradation, and vertical transports, as well as show the spatial distributions of the effect of each process on DOM. The analysis also implies interaction between photodegradation and microbial production in the subtropics, for the first time (Shigemitsu et al., in press).

UL Koketsu's unit contributes to multiple international reviews of recent problems in the ocean environment. The review investigated how present models represent historical observations of oceanic dissolved oxygen inventory and to what extent the future projections of ocean deoxygenation by the models converge (Shigemitsu et al., 2024), and they contribute to assessments of global heat content changes (von Schuckmann et al., 2023) and recent state of Deep Argo networks (Zilberman et al., 2023). In addition, they develop a nitrogen isotope model to make a nitrogen isoscape of phytoplankton, which helps to foster

our understanding of habitat of marine organisms or fish migration (Yoshikawa et al., 2024).

Marine Ecosystem Modeling Research Unit (Unit Leader: Sherwood Lan Smith)

Mathematical and numerical models, by incorporating scientific knowledge and making specific predictions, have proven valuable for generating and testing hypotheses about the structure and function of ecosystems (Chen et al., 2019, Masuda et al., 2021, Masuda et al., 2023, Wirtz et al., 2022). However, much remains unknown about how complex ecosystems respond to environmental change, such as climate change, anthropogenic nutrient inputs, etc. It is a formidable challenge to develop meaningful (i.e. sufficiently realistic and informative) models that are also computationally tractable (Smith et al., 2014, Chen & Smith, 2018). By collaborating with observation-based scientists and theoretical ecologists, this unit aims to build on previous work (Chen et al., 2019, Masuda et al., 2021, Masuda et al., 2023, Wirtz et al., 2022, Chen & Smith, 2018) to develop, test, and refine models that capture the dynamic response of complex marine ecosystems, and ultimately to provide tractable equations for use in large-scale, long-term modeling studies, as with Earth System Climate Models.

During this first partial year, connections were established with several international researchers, with whom the unit leader had not before collaborated, and plans were made jointly with them and others for new research to be conducted as part of this Unit. This included inviting three leading international researchers from abroad (Dr. Suzana G. Leles, University of Southern California, “Reconciling theory to predict microbial responses to ocean warming”, Prof. Aletta Yñiguez, University of the Philippines, “Advancing technologies and tools for ocean resource management in the Philippines: Ongoing developments and challenges”, Dr. Subhendu Chakraborty, ZMT-Bremen, Germany, “A New Horizon in Oceanic Diazotrophic Research”), for brief visits of about one week each. During those visits and other online meetings, they brainstormed and discussed ideas for proposals to be written jointly with them and other international collaborators to request funding for research projects. Specific topics discussed were research into understanding and developing cutting-edge models of: 1) the occurrence of Harmful Algal Blooms (HABs), 2) how the intracellular eco-physiology of plankton impacts large-scale biogeochemical cycles, and 3) the response of marine ecosystems as Complex Adaptive Systems (CAS).

1-2. Generating Fused Disciplines

* Describe the content of measures taken by the center to advance research by fusing disciplines. For example, measures that facilitate doing joint research by researchers in differing fields. If any, describe the interdisciplinary research/fused discipline that have resulted from your efforts to generate fused disciplines. You may refer to the research results described concretely in “1-1. Advancing Research of the Highest Global Level.”

The history of the Earth over the past four billion years has demonstrated that changes in the global environment have a profound effect on changes in marine ecosystems and, conversely, that changes in marine ecosystems have the potential to dramatically alter the global environment, including climate and element cycling. WPI-AIMEC is keenly interested in and aware of how data from the disciplines that define marine ecosystems are intertwined with each other.

At the All-Hands meeting held on March 7th (Photo 1), 2024, before the WPI-AIMEC kick-off meeting, nine research unit leaders presented their units' activities and directions based on the unit members' academic backgrounds. Although the content of each perspective and research strategy emphasized the unit's expertise, three common elements apply to all units: stability, connectivity, and adaptability, as well as fundamental issues such as how to evaluate complex networking systems. Unraveling the mechanisms of spatiotemporal variability of marine ecosystems as fluid and highly complex systems is only possible to achieve through fusion research.



Photo 1 Group photo at the 1st All-Hands meeting

WPI-AIMEC is currently accepting applications for 10 of each Postdoctoral Fellows and AIMEC Researchers, and the following 10 themes have been established to practice fusion research between units:

1. Monitoring the marine physico-chemical environment from the coast to the open sea; developing analytical techniques for marine environmental restoration; and studying marine environment-ecosystem co-variation using environmental indicator organisms.
2. Observations and modeling to understand the state of ecosystems and biodiversity, and conducting theoretical and empirical research to clarify the principles that drive, maintain, and respond to ecosystems and biodiversity.

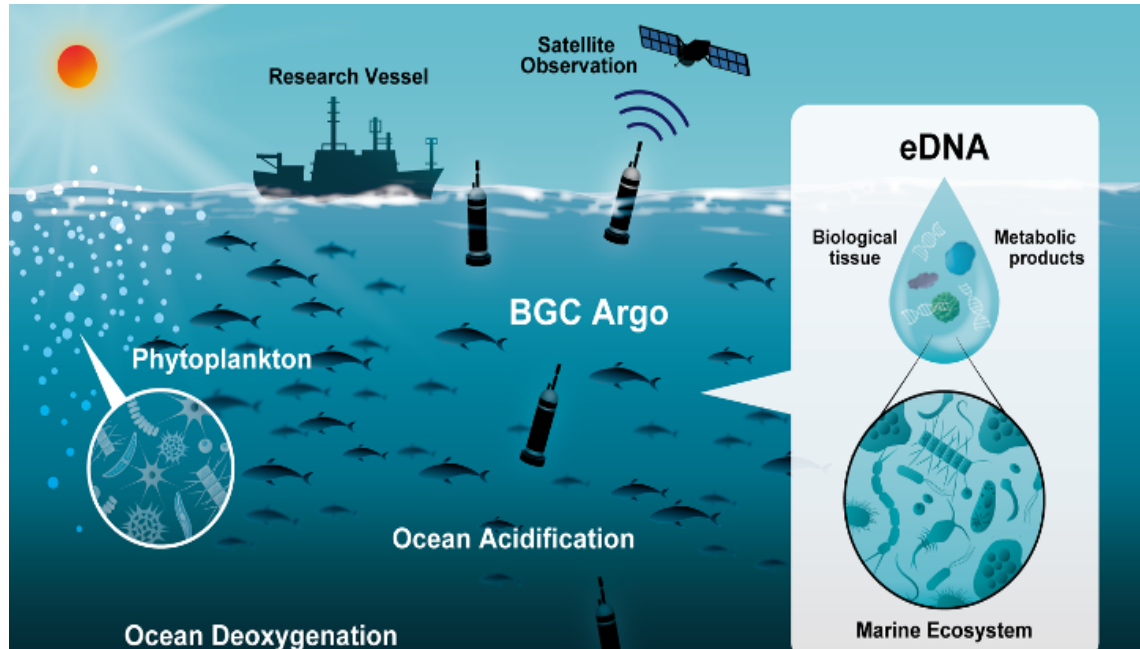


Fig. 2. Elucidating the mechanisms of marine ecosystem change requires matching the quality and spatiotemporal coverage of data corresponding to the physics, biogeochemistry and ecology (Suga, T., Inagaki, F., Ando, K., and Kotani, M. Expanding the functionality of integrated ocean observing systems to address marine ecosystem change. UN STI Forum Science-Policy Briefs, submitted).

3. Developing methods for assessing and analyzing marine ecosystems using functional genomics, etc., and elucidating the responses of coastal ecosystems and its services to human activities in coastal areas.
4. Observing the seabed, including its hydraulic observations, to clarify ocean-solid earth change phenomena, and making observations and models to understand spatiotemporal oceanic changes to enable advances in underwater acoustic ranging.
5. Studying the environmental response and adaptation mechanisms of marine organisms at the individual and community levels and developing evaluation and analysis methods; clarifying the mechanisms of regime shift phenomena, including mass outbreaks and mass mortality of marine organisms.
6. Developing molecular biological techniques for analyzing marine microbial ecosystems; studying the dynamics of marine particles and material circulation and the response and adaptive mechanisms of microbial ecosystems to changes in the marine environment, and developing technology for this.
7. Conducting research and technological development related to observations of the effects of circulation and microbial distribution on the distribution of substances in the ocean, maintaining automated oceanographic observation networks, and integrating the analysis of oceanographic observations and simulations.
8. Conducting modeling research and applying artificial intelligence to marine ecosystems (including the physical and chemical environment of the surrounding ocean and atmosphere), and maintaining and developing the computational infrastructure.
9. Developing equations that describe the structure of marine ecosystems and related biogeochemical cycles and their variability, and developing models of the response of marine ecosystems (including harmful toxic algal blooms) and their capacity to adapt to environmental changes in estuarine, coastal, and open ocean environments.
10. Assessing the impacts and interactions of changes in marine ecosystems on human society and vice

versa, and social and behavioral changes based on such assessments.

The selection review of these members will be in the next year, and WPI-AIMEC will focus on the potential to promote international fusion research as a top criterion for the review. Developing advanced oceanographic physical observations in the Northwest Pacific Ocean, combined with environmental DNA analysis, is one of the most essential items to be accomplished by WPI-AIMEC. We advocated the need for an observation network combining the wide-area deployment of the BGC Argo equipped with biogeochemical sensors and the automated environmental DNA collection system being developed by JAMSTEC. This is the so-called “OneArgo” concept, one of the significant research roadmaps by UNESCO-IOC, in which Director Suga is involved as a steering committee member (**Fig. 2**). We submitted a perspective paper on promoting OneArgo’s technological advancement to the UN STI Forum Science-Policy Briefs for the SDGs 2024 (Track 1: Rapidly emerging frontier technologies and emerging science issues and sustainable development). This need for science and technology is also promoted with the involvement of the private sector in the JST COI-NEXT program led by Kondoh of Tohoku University, which aims to contribute to the “Nature Positive 2030” (adopted by COP15) and TNFD (Taskforce on Nature-related Financial Disclosures) initiatives.

Forecasting marine ecosystem changes in response to Earth system dynamics is vital for creating sustainability. Over the past decades, remarkable advances have been made in general circulation models of oceans and atmosphere-ocean integrative models that reproduce their physical environments. WPI-AIMEC will further advance model predictions by combining innovative observational techniques and data science from coastal areas to the open ocean. One promising solution for new insights is the application of AI in the assimilation and integration of high-resolution spatiotemporal data with other data of lower granularity. We are discussing that constructing predictive models of change in marine ecosystems applicable on a global scale requires the incorporation of transformations that use neural networks (deep learning) in big data assimilation and integrative analyses of physical and ecological data. Given the rapid progress of AI technologies, we may need agile system reforms in the unit and its member organization to accomplish this challenging mission. We also need to maximize computational power and its flexible usability by using Tohoku University’s supercomputer Aoba and JAMSTEC’s supercomputer Earth Simulator and to promote its applications to the various stakeholders. The strengthening of mathematical and data science aspects will be continued in the next fiscal year and beyond, including system reforms of WPI-AIMEC and host institutions.

Currently, PI Kawamiya’s unit is undertaking a project titled “Identifying key processes and sectors in the interaction between climate and socio-economic systems: a review toward integrating Earth–human systems.” This project aims to integrate earth-human systems as fused disciplines, extending beyond the confines of internal collaboration within WPI-AIMEC. His unit is developing an Earth system – socioeconomic coupled model for interdisciplinary research dealing with interactions between the natural environment and human society. To that end, they reviewed existing studies on those processes/sectors through which the climate impacts socio-economic systems, which then, in turn, affect the climate (<https://doi.org/10.1186/s40645-021-00418-7>). For each process/sector, we review the direct physical and ecological impacts and, if available, the impact on the economy and greenhouse gas (GHG) emissions. Based on this review, land sector is identified as the process with the most significant impact on GHG emissions, while labor productivity has the largest impact on the gross domestic product (GDP). On the other hand, the energy sector, due to the increase in the demand for cooling, will have increased GHG emissions. Water resources, sea level rise, natural disasters, ecosystem services, and diseases also show the potential to have a significant influence on GHG emissions and GDP, although for most of these, a large effect was reported only by a limited number of studies. As a result, more studies are required to verify their influence in terms of feedback to the climate. In addition, although the economic damage arising from migration and conflict is uncertain, they should be treated as potentially damaging processes.

2. Global Research Environment and System Reform

2-1. Realizing an International Research Environment

- * Describe what’s been accomplished in the efforts to raise the center’s recognition as a genuine globally visible research institute, along with innovative efforts proactively being taken in accordance with the development stage of the center, including the following points, for example:
- Efforts being developed based on the analysis of number and state of world-leading, frontline researchers (in Appendix 2); exchanges with overseas entities (in Appendix 4); number and state of visiting researchers (in Appendix 5)
 - Proactive efforts to raise the level of the center’s international recognition and to obtain diversity within the center including gender balance.

- Efforts to make the center into one that attracts excellent young researchers from around the world (such as efforts fostering young researchers and contributing to advancing their career paths)

Toshio Suga, the Director of WPI-AIMEC, served as co-chair of the operating committee of the Argo program supported by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, with participation from over 30 countries. Additionally, he is a key member of the Global Ocean Observing System (GOOS), with participation from over 50 countries. These international networks are directly linked to the Intergovernmental Panel on Climate Change (IPCC) and the United Nations' declared "Decade of Ocean Science for Sustainable Development" (2021-2030), supporting efforts to maintain ocean health and bringing together ocean stakeholders worldwide (Stakeholder Forum). Fumio Inagaki, the Vice Director and Division Director of Research, is also one of the leaders of the International Ocean Discovery Program (IODP), organized in over 20 countries including Japan, the United States, and Europe. He played a leading role in the Deep Carbon Observatory of the Alfred P. Sloan Foundation and currently serves as an advisor for the Earth 4D: Subsurface Science & Exploration Program (CIFAR).

In addition, among the 17 Principal Investigators, there are individuals such as UL Michio Kawamiya and PI Shang-Ping Xie who have contributed to the writing of IPCC reports. Their combined total citation counts for papers are over 9,000 and just under 70,000, respectively, and their research on climate change is widely recognized worldwide. Furthermore, prominent figures from Tohoku University such as Michio Kondoh and Takeshi Obayashi, who conduct research on ecosystem dynamics using environmental DNA and genetic information, are also involved. Their research results, totaling over 6,000, have been extensively cited.

As of April 1st, William F. McDonough has assumed the role of PI, focusing on understanding Earth-like planets, particularly the nature, structure, evolution of Earth, as well as the composition of Earth's core, mantle-crust, and atmosphere-hydrosphere systems. He serves as the director of the Plasma Mass Spectrometry Laboratory, Department of Geology, University of Maryland and has published over 245 peer-reviewed papers, providing data for the graduation theses, master's theses, and doctoral dissertations of 6 high school students, 28 undergraduate students, and 53 graduate students. Additionally, he has authored over 205 peer-reviewed papers and book chapters and edited two books. The total citation count of his research exceeds 75,000, leading to his election as a fellow in numerous international academic societies. Similarly, Keith Rodger, also newly appointed as a PI, focuses on applying hierarchical modeling to understand the processes controlling marine ecosystems and evaluating how marine ecosystems will respond to future climate change using this understanding. His research has been cited over 10,000 times, and he also serves as co-chair of the US-CLIVAR Working Group within the United States, contributing to research coordination. The successful recruitment of these highly accomplished researchers as PI highlights the institution's commitment to excellence in research.

Building on the collaborative efforts between Tohoku University and the University of Hawaii/IPRC, as well as the joint research activities between JAMSTEC and the University of Hawaii/IPRC, the University of Hawaii/IPRC has been preparing to become an overseas satellite base. The establishment of IPRC symbolizes a significant aspect of the Japan-US common agenda at the governmental level, based on a cooperation agreement signed between the University of Hawaii and JAMSTEC in 1997. Since then, IPRC has become a leading research institution in the Asia-Pacific region for observational and modeling studies of climate and ocean variability. Tohoku University has also entered into agreements with IPRC and SOEST, and the "Graduate Program in Environmental Earth Science (GP-EES)," led by Director Suga, serves as a core educational framework in collaboration with this base. From the University of Hawaii at Manoa, PIs Niklas Schneider and Angelique White have joined as senior researchers, exploring from the ocean-atmosphere-biosphere system to marine ecosystems in the Asia-Pacific region. Particularly, Schneider has authored numerous papers with researchers from JAMSTEC, with a total citation count exceeding 10,000. Additionally, White is an esteemed researcher in marine biogeochemistry and serves as an observer in charge at a long-term monitoring site near Hawaii, with many cited papers to her credit. In February 2024, Director Suga and Administrative Director Ando visited the University of Hawaii to discuss activities at the AIMEC satellite base centered around IPRC with Schneider and White, leading to the signing of a Collaborative Research Agreement (CRA). The CRA includes considerations such as establishing research units at the University of Hawaii, designating research papers produced by this unit as affiliated with WPI-AIMEC, among other aspects.

PI Sayaka Yasunaka has been actively promoting gender equality mainly through activities centered

around the Japan Oceanographic Society, and has been in charge of summer schools for junior and senior high school girls. Leveraging her experience, AIMEC has appointed her as a unit leader to strive for a diverse research institute. Furthermore, as Tohoku University has been welcoming many international students, the existing Principal Investigator's laboratory already has a significant number of international students conducting research, ensuring diversity among the student body.

In order to attract exceptionally talented young researchers worldwide, JAMSTEC has decided to include the highest salary level, which has not been utilized in the postdoctoral fellowship system of JAMSTEC, in the recruitment guidelines and initiate public recruitment. This salary is set at an annual rate of 5.6 million yen. Additionally, JAMSTEC and Tohoku University are considering the possibility of providing postdoctoral researchers who achieve outstanding results during their service with annual salaries exceeding 6 million yen.

2-2. Making Organizational Reforms

- * Describe the system reforms made to the center's research operation and administrative organization, along with their background and results.
- * If innovated system reforms generated by the center have had a ripple effect on other departments of the host institutions or on other research institutions, clearly describe in what ways.
- * Describe the establishment of an integrated management system for the center, including an effective decision-making scheme and risk management, carried out in cooperation with the host institutions.
- * Describe the center's operation and the host institutions' commitment to the system reforms.

The establishment of the WPI base this time is multi-hosted, so if we were to operate AIMEC under one roof, inevitably one of the host institutions would need to align with the system of the other host institution, requiring significant system reforms in many aspects. First and foremost, in order to carry out these system reforms, it was necessary to review the comprehensive cooperation agreement between Tohoku University and JAMSTEC, which serves as the premise for both institutions, and to formulate subsidiary agreements for AIMEC and proceed with signing them. This comprehensive cooperation agreement (parent agreement) and the subsidiary agreement detailing AIMEC were signed on December 26, 2023, following approval by the respective boards of directors of each institution.

Based on this agreement, Tohoku University has positioned AIMEC under its Organization for Advanced Studies (OAS), modeling it after Advanced Institute for Materials Research (AIMR) at Tohoku University. AIMEC's organizational regulations, excluding the parts concerning research units, were launched on January 1st, 2024 at Tohoku University. During these discussions, strategies to materialize the "under-one-roof" concept were also considered. Tohoku University aimed to create and provide a shared "roof" as a fundamental principle, aligning the organization with Tohoku University's structure, while JAMSTEC aimed to create a mirror organization that fits the existing JAMSTEC's structure. Consequently, numerous discussions took place within JAMSTEC, resulting in the establishment of unique operational regulations for AIMEC, deviating from JAMSTEC's standard organizational regulations. These regulations would ensure that the operations of AIMEC do not conflict with Tohoku University AIMEC's internal regulations. Operational standards would be established through consultation with responsible executive directors and legal departments within JAMSTEC as needed. This approach enabled the construction of an integrated decision-making scheme. By following this method, by the end of March 2024, minimum necessary internal regulations and operational standards for organizational management were established.

During these institutional reforms, a unified personnel system was established by both institutions. For administrative departments, existing systems were utilized as they were closely related to each institution's main body system. However, in research departments, efforts were made to create a system that could be unified between both institutions, including treatment as much as possible. Tohoku University does not have a system specifically called "postdoctoral researcher," but rather utilizes a system of special researchers, each department employing its own criteria. As there were no departments to refer to, AIMEC designed its postdoctoral researcher system based on JAMSTEC's postdoctoral researcher system to fit the existing Tohoku University's system. As a result, it became a system conforming to international standards. Similarly, AIMEC's researcher system was based on systems from both institutions, aiming to be simple and transparent internationally. Additionally, a retirement age of 70 was set for AIMEC, with provisions allowing researchers over the age of 70 to be employed as advisors. This provision applies not only to researchers who are truly outstanding and admired by overseas researchers but also to high-paid researchers from overseas.

Furthermore, there was a decision to expand the International Joint Degree Graduate Program in

Environmental Earth Science (GP-EES), which Tohoku University has been conducting, to include AIMEC. This decision is related to the evolution of the Earth Environment Science research cluster within Tohoku University following AIMEC's adoption. Specifically, in the past, support for GP-EES included a commitment to support five students, but now the possibility of supporting more than ten students is being considered. This expansion may involve utilizing funds from AIMEC. If this progresses smoothly, it will facilitate visits by Tohoku University graduate students to the University of Hawaii, at the overseas satellite base, making the International Jointly Degree Program even more vibrant.

Regarding offices and research spaces, Tohoku University has set up temporary office spaces in the Katahira campus and secured relatively spacious areas on the Aobayama Campus, where construction for office spaces has been initiated. Similarly, at JAMSTEC, space at the Yokohama Institute for Earth Sciences was secured and construction was carried out. Both actions were made possible through commitments by the host institutions.

3. Values for the Future

3-1. Creating and Disseminating the Societal Value of Basic Research

- * Describe the content of measures taken by the center to widely disseminate the results of its basic research to the general public.
- * Describe what was accomplished in the center's outreach and other activities last year and how they have contributed to creating the Societal Value of Basic Research. In Appendix 6, describe concretely the contents of these outreach activities. In Appendix 7, describe media reports or coverage, if any, of the activities.

On March 8th, 2024, a kick-off symposium titled "Unlocking the Future of the Ocean and its Ecosystems" was held in Sendai with simultaneous interpretation into Japanese. At the venue, there was a comprehensive explanation by Director Suga and Division Director of Research Promotion and Planning Ando about the overall objectives of WPI-AIMEC in elucidating and predicting the response and adaptation mechanisms of marine ecosystems to Earth system changes. Detailed research introductions were also given by PIs. Furthermore, during the panel discussion, lively debates took place on the complexity and stability of marine ecosystems, their interaction with human society, and the prospects for highly accurate predictions of ecosystem fluctuations. The total number of participants, both on-site and online, was 376, with nearly all 120 seats prepared for on-site participation being filled. Advertisements on newspapers were placed in the nationwide edition of the NIKKEI, and the Tohoku edition of the SANKEI SHINBUN, to promote the symposium. In the three days following the newspaper advertisements, the number of registrants increased by an average of about 15 per day compared to usual. Posters of the kick-off symposium were distributed to high schools in Sendai and posted on their premises. During the afternoon session of the symposium, an extended coffee break was provided, during which posters were displayed by individuals involved in AIMEC-related activities such as JAMSTEC's Earth Simulator (www.jamstec.go.jp/es/jp/), Tohoku University's AOBA (www.cc.tohoku.ac.jp/service/supercomputer/), and COI-NEXT activities (www.jst.go.jp/pf/platform/), Tohoku University's Tohoku Forum for Creativity (<https://www.tfc.tohoku.ac.jp/>), and JST's Precursory Research for Embryonic Science and Technology (PRESTO) (<https://www.jst.go.jp/kisoken/presto/en/about/index.html>). This allowed for networking opportunities, with lively discussions taking place in front of each poster. Additionally, novelty items were produced and distributed at the reception desk.

We created the website (<https://wpi-aimec.jp/en/about/>) to be as user-friendly as possible and published it at the end of March. Simultaneously, we prepared a brochure (in English) and distributed it at the kick-off symposium. Additionally, an introduction article about AIMEC was submitted to and accepted by the newsletter of the Japan Geoscience Union (JpGU) for stakeholders, and it was published in the February 2024 issue (https://www.jpгу.org/wp-content/uploads/2024/02/JGL-Vol20-1_ALL_240214-3.pdf).

On March 23rd, 2024 (Saturday), in collaboration with the Graduate School of Science at Tohoku University, we held "Bura-Rigaku (Stroll for Science, tentative translation) for High School Students" at the Aoba Science Hall on the Aobayama Campus. One of the speakers was Michio Kondoh, a Principal Investigator at AIMEC. Additionally, JAMSTEC conducted a media briefing at its Tokyo office on February 27, 2024.

3-2. Human Resource Building: Higher Education and Career Development

- * Describe the content of measures taken by the center to foster young researchers, including doctoral students, through their participation in a research system that creates new interdisciplinary domains within a rich international environment.

We are currently proposing to the university's responsible director a strategy based on the GP-EES, one of the international joint graduate programs that Tohoku University has been engaged in, primarily with the University of Hawaii. This proposal involves not only the Graduate School of Science but also other relevant departments at the university, while considering the use of AIMEC funding. By expanding the GP-EES, we aim to broaden the scope of graduate education beyond the Graduate School of Science to include other departments participating in AIMEC, such as Graduate School of Agricultural Science, Graduate School of Life Sciences, Graduate School of Information Sciences, and Graduate School of Engineering. This expansion would contribute to achieving a more comprehensive graduate education across various fields and ultimately contribute to AIMEC's goal of integrating research in marine ecosystem studies.

In parallel with the aforementioned efforts, we are also in the process of establishing procedures to appoint several JAMSTEC Principal Investigator and others as professors at Tohoku University through a cross-appointment system. This initiative aims to enable their participation in graduate education at Tohoku University. Through this system, we will be able to offer a diverse range of education that cannot be available solely through Tohoku University.

At the aforementioned kick-off symposium, we encouraged the participation of graduate students from Tohoku University. Additionally, we invited graduate students and young researchers from overseas who are associated with AIMEC's overseas Principal Investigators, resulting in the participation of four graduate students and young researchers. Furthermore, we extended invitations to foreign university professors who have contributed to GP-EES in the past. These individuals also attended the All-Hands meeting held the day before the kick-off symposium. Among the young participants, there were expressions of interest in applying for postdoctoral researcher positions within AIMEC. It's worth noting that the All-Hands meeting provided the first opportunity for all Principal Investigators, except for two foreign principal investigators who participated remotely, to meet in person. During this meeting, discussions were held on the activity plans of each research unit and the integration of research among units.

In February 2024, we held discussions in Hawaii to establish a satellite base at the University of Hawaii. The plan is to establish research units within the University of Hawaii by the end of the fiscal year 2024. These research units are intended to facilitate the participation of faculty members and students from the University of Hawaii. Additionally, within the aforementioned international joint graduate program, it is planned that students receiving mentorship in Hawaii will have activities centered around these research units.

As individual initiatives, UL Sherwood Lan Smith, a Principal Investigator at JAMSTEC, invited three young researchers from overseas to conduct a seminar at JAMSTEC as described above. Additionally, a workshop organized by UL Cheryl Ames, from the Graduate School of Agricultural Science at Tohoku University, was held at the end of March.

3-3. Self-sufficient and Sustainable Center Development

* Describe the state of implementation of the Alliance's host institutions' mid-to-long term measures based on robust collaboration among host institutions participating in the Alliance for supporting the center toward becoming self-sufficient and sustainable after the 10-year funding period ends, such as reforming the host institutions' organizations, providing personnel with priority allocation of tenured posts to the center, providing fundamental financial support, and material support including land and buildings.

As mentioned earlier, at Tohoku University, AIMEC has established its position within the Advanced Institute for Higher Education. We have explained to the host institution regarding the construction of buildings, and also provided explanations to the relevant department at the Ministry of Education, Culture, Sports, Science and Technology (MEXT). There is a shared awareness between the host institution (Tohoku University) and AIMEC regarding the necessity of securing tenure positions. For the current operational space, cooperation from the Faculty of Science has enabled the use of the Chemistry Building (with a total space of approximately 592 m², expandable up to 1,384 m²). Furthermore, thanks to the understanding of related departments, each unit's activities can also be conducted within their respective main departments.

At JAMSTEC, we have established a similar system to Tohoku University's organizational regulations through the Cross-Appointment system, and we have formulated operational regulations that allow for

rules to be implemented separately from existing regulations, aligning with Tohoku University's AIMEC organizational regulations. However, to streamline administrative tasks, we have made an exception by implementing a policy where one party covers the full salary for cross-appointments. This enables us to adapt Tohoku University's AIMEC internal regulations to JAMSTEC as well. Regarding the necessity of tenure positions looking ahead ten years, there is a shared awareness of this issue among the heads of existing departments within JAMSTEC. As for the activity space, we will renovate the space on the 1st floor of the Frontier Building at the Yokohama Institute for Earth Sciences and until a new building is constructed at Tohoku University, each unit's activities can be carried out within the respective main departments with the consent of the host institution.

4. Others

* In addition to the above 1-3 points, if there is anything else that deserves mention regarding the center project's progress, please note it.

In the Roadmap 2023 by the Ministry of Education, Culture, Sports, Science and Technology (https://www.mext.go.jp/content/20231222-mxt_gakkikan-000033259_1.pdf), OneArgo proposed by Director Suga was adopted, and the responsibility for its budget request has been assigned to the AIMEC Tohoku University office.

5. Efforts to improve points indicated as requiring improvement in application review and results of such efforts

* Describe the status of responses to items in "Major points that need to be improved" in "The screening result for WPI centers launched in FY 2023."

* If you have already provided this information, please indicate where in the report.

1. *The project focuses on observation, data collection and data processing. In order to predict changes in marine ecosystems, it should have a clear plan for how these data will be incorporated into Earth System Models e.g., which ecosystem/biological models, a strategy and ambition for model development and coupling, how to deal with scale compatibility issues. The roadmap should be clearer about the scientific goals and milestones that they seek to achieve over the 10-year period. What is meant by "Generative AI for Marine Ecosystem Change" should be made clear.*

In light of the WPI-AIMEC kick-off symposium and All-Hands meeting on March 2024, we have engaged in in-depth discussion and debate on how to extract the necessary information and data on the complexity of marine ecosystems and their changes over seasonal to decadal timescales, and how to integrate these data and theories into advanced Earth system models and simulations of marine ecosystem change. While focusing on the North Pacific between Japan and Hawaii, especially in the Japanese coastal environment where both SST data eDNA data (from ANEMONE DB) are already been well accumulated, we will challenge multivariate correlation analysis using these existing data. In terms of eDNA analysis, ecological studies on interspecies interactions have been mainly conducted on fish species, but will be expanded to include other key species as they can be analyzed using the same DB and/or the same original DNA samples. For example, photosynthetic primary producers associated with harmful algal blooms (HABs), zooplankton that prey on phytoplankton, marine and sedimentary eukaryotes such as fungi, and prokaryotic communities such as bacteria, archaea, and CPR domains. To provide quantitative data on these taxonomic variables, we will consider to applying the qSeq method developed by Hoshino & Inagaki, PLoS One, 2017 and newly developing isotope geochemical and epigenomic/proteomic proxies. To address scale compatibility issues, we will focus on inverse extrapolation/prediction based on the results of each variable correlation analysis, and attempt to build theories and models in which data gaps are mathematically filled. In particular, for regime shifts, which are highly nonlinear phenomena, we will conduct detailed data analysis using AI machine learning, including not only the current seawater environment but also molecular and geochemical records of past ecosystems in sediments deposited on the seafloor, utilizing representative observation sites such as Onagawa Bay and Asamushi, where Tohoku University's field center is located. We plan to conduct a workshop on the strategy development on June 17, 2024 in Asamushi, Aomori Prefecture, Japan. As for generative AI, it will be an outcome, and we are not the ones

who actually develop it, but rather the ones who use it with the stakeholders scientifically and publicly. Nevertheless, we will continue to discuss and explore how to use large-scale language models (LLMs) for predicting changes in marine ecosystems and link them more broadly with multiple LLMs and generative AI, including the effective use of available application programming interfaces.

2. Since changes in marine ecosystems have deep societal implications, the project needs to create a deeper and attractive plan to engage the broader public and policy makers beyond simply relying on the existing channels to the UN or holding biannual public roundtables.

AIMEC's UL/PI Kondoh and his colleagues have already established an observation network of coastal ecosystems with regular eDNA sampling with over 200 private sector collaborators. PI Kondoh is also leading the JST COI-NEXT program, which is collaborating with a private shipping company to establish an eDNA sampling network on ships that regularly sail from Japan to Southeast Asia, Australia, and the Indian Ocean. Similarly, WPI-AIMEC has "Citizen Science" collaborations with the general fishing industry, including turtle, jellyfish, and oyster farming. They are strongly linked to the valuation of ecosystem services from multiple perspectives, such as food security, human health, and economy. They have the potential to become a pipeline for engaging knowledge co-sharing and co-production with the broader public and policy makers. On the other hand, WPI-AIMEC is not yet fully committed to working with international frameworks, especially those relevant to science-policy interactions. Therefore, we believe that there is still much room to expand collaboration and increase its presence through activities over the next decade. In particular, we consider the collaborative partnerships with the UN Decade of Ocean Science for Sustainable Development (2021-2030) and the UNESCO IOC to be extremely important in relation to policy agreements such as SDG 14 and Nature Positive. These partnerships with the UN and government-related organizations will be established through the Joint Management Meeting between our host institutes Tohoku University and JAMSTEC and will be established in cooperation with MEXT and other relevant ministries and government agencies. Although these efforts have just begun, the WPI-AIMEC kick-off symposium held on March 8th, 2024 in Sendai, Japan was accredited as an "Activity" of the UN Decade of Ocean Science.

3. The WPI-AIMEC International Graduate Degree Program is important for nurturing the next generation of researchers in the interdisciplinary field of Ocean-climate-marine ecosystem dynamics and changes. The details of the program, including the interdisciplinary curriculum, admissions from abroad, and schedule should be clarified.

WPI-AIMEC places the utmost importance on fostering the next generation of Early Career Researchers (ECRs: graduate students and postdoctoral researchers) and international higher education in the ocean sciences. It is essential for the future leadership in planetary stewardship with a transdisciplinary bird's-eye view. With the establishment of WPI-AIMEC in January 2024, Tohoku University has positioned WPI-AIMEC as one of the Advanced Research Institutes. Accordingly, the existing Earth and Environment International Joint Graduate Program (GP-EES) will be upgraded to a "Core Research Cluster" after the fall of 2024, and the number of departments at Tohoku University accepting the program for graduate students will be greatly expanded. In addition, seven of JAMSTEC's AIMEC Unit Leaders and PIs received official professor status from Tohoku University. This allowed JAMSTEC researchers to be directly involved in higher education at WPI-AIMEC. The educational context will be more interdisciplinary, and curricula are being developed. In addition, we submitted a proposal to the JST "ASPIRE for Top Scientists" program (FY2024-2029) to establish an "International Brain Circulation Platform" centered at the Tohoku University, JAMSTEC, and the University of Hawaii at Manoa, and to support ECRs under WPI-AIMEC's higher education initiative.

4. Marine ecosystem change is a high priority area studied intensively at leading institutions in the U.S., Europe and elsewhere. A clear strategy for win-win international engagement and collaboration should be established.

The mechanisms of marine ecosystem change in response to Earth system dynamics, as a global phenomenon, will be difficult to fully understand by any one institution or country alone. Therefore, research is often conducted in the framework of international collaborations that define the ocean areas and roles in research cruises and observations. At WPI-AIMEC, for example, the “OneArgo” initiative within the UN Decade of Ocean Science will strengthen initiatives within international projects, while increasing win-win international engagements. In this context, we aim to test new instruments and observing technologies, and develop unique research focusing on climate-ocean-ecosystem interactions unique to coastal areas and the North Pacific. AIMEC Director Suga submitted a proposal to MEXT last year to implement “OneArgo” and promote integrative marine science, which was selected as one of the twelve projects for the “Roadmap 2023” to promote large-scale projects in academic research. In March 2024, we have also submitted a white paper to the UN STI Forum Science & Policy Briefs entitled "Expanding the functionality of integrated ocean observing systems to address marine ecosystem change" (under review).

Appendix 1 FY 2023 List of Center's Research Results and Main Awards

1. Refereed Papers

- List only the Center's papers published in 2023. (Note: The list should be for the calendar year, not the fiscal year.)

- (1) Divide the papers into two categories, A and B.
 - A. WPI papers
List papers whose author(s) can be identified as affiliated with the WPI program (e.g., that state "WPI" and the name of the WPI center (WPI-center name)). (Not including papers in which the names of persons affiliated with the WPI program are contained only in acknowledgements.)
 - B. WPI-related papers
List papers related to the WPI program but whose authors are not noted in the institutional affiliations as WPI affiliated. (Including papers whose acknowledgements contain the names of researchers affiliated with the WPI program.)

Note: On 14 December 2011, the Basic Research Promotion Division (the Basic and Generic Research Division at present) in MEXT's Research Promotion Bureau circulated an instruction requiring paper authors to include the name or abbreviation of their WPI center among their institutional affiliations. From 2012, the authors' affiliations must be clearly noted.

- (2) Method of listing paper
 - List only refereed papers. Divide them into categories (e.g., original articles, reviews, proceedings).
 - For each, write the author name(s); year of publication; journal name, volume, page(s) (or DOI number), and article title. Any listing order may be used as long as format is consistent. (The names of the center researchers do not need to be underlined.)
 - If a paper has many authors (say, more than 10), all of their names do not need to be listed.
 - Assign a serial number to each paper to be used to identify it throughout the report.
 - If the papers are written in languages other than English, underline their serial numbers.
 - Order of Listing

A. WPI papers

1. Original articles N/A

(1) Jitsuno, K; Hoshino T; Nishikawa Y; Kogawa, M; Mineta, K; Strasser, M; Ikehara, K; Everst, J; Maeda, L; Inagaki, F; Takeyama, H; IODP Expedition 386 Scientists, 2024, mSphere, 9, 1, e00337-23, Comparative single-cell genomics of Atribacterota JS1 in the Japan Trench hadal sedimentary biosphere.

2. Review articles N/A

3. Proceedings N/A

4. Other English articles N/A

B. WPI-related papers

1. Original articles

- (1) Iskandar, MR; Jia, YL; Sasaki, H; Furue, R; Kida, S; Suga, T; Richards, KJ, 2023, J. Geophys. Res.-Oceans, 128, 5, e2022JC019610, Effects of High-Frequency Flow Variability on the Pathways of the Indonesian Throughflow.
- (2) Adiwira, H; Suga, T, 2023, Front. Mar. Sci., 10, 1205292, The interannual variability of the Indian Ocean subtropical mode water based on the Argo data.
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- (3) Submission of electronic data
- In addition to the above, provide a .csv file output from the Web of Science (e.g.) or other database giving the paper's raw data including Document ID. (Note: the Document ID is assigned by paper database.)
 - The papers should be divided into A or B categories on separate sheets, not divided by paper categories.
- (4) Use in assessments
- The lists of papers will be used in assessing the state of WPI project's progress.
 - They will be used as reference in analyzing the trends and whole states of research in the said WPI center, not to evaluate individual researcher performance.
 - The special characteristics of each research domain will be considered when conducting assessments.
- (5) Additional documents
- After all documents, including these paper listings, showing the state of research progress have been submitted, additional documents may be requested.

2. Invited Lectures, Plenary Addresses (etc.) at International Conferences and International Research Meetings

- List up to 10 main presentations during FY 2023 in order from most recent.
- For each, write the date(s), lecturer/presenter's name, presentation title, and conference name.

Date(s)	Lecturer/Presenter's name	Presentation title	Conference name
2024.03.25	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change: WPI-AIMEC Marine Biology Integrative Analysis Unit	WPI-AIMEC Mini Symposium for the Marine Biology Integrative Analysis Unit, Tohoku University
2024.03.18	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change: WPI-AIMEC Marine Biology Integrative Analysis Unit	WPI-AIMEC Retreat Symposium for the Marine Biology Integrative Analysis Unit, Tohoku University
2024.03.12	Michio Kawamiya	Introduction of Advanced Institute for Marine Ecosystem Change (AIMEC)	General assembly for "Optimal high-resolution Earth System Models for exploring future climate change" (OptimESM, an EU funded project)
2024.03.08	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change	WPI-AIMEC All-Hands Sendai Japan
2024.03.07	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change	WPI-AIMEC Kickoff Sendai Japan
2024.03.01	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change	Molecular Marine Ecology Lecture Series Wageningen, Netherlands
2024.02.26	Cheryl Ames	Changing Approaches to Monitoring Marine Biodiversity Change: WPI-AIMEC	Department of Oceanography Lecture Series Halifax Canada
2023.10.19	Shinya Koketsu	Autonomous oceanic observations for detections of interior ocean variability - Developing Argo float and future technologies-	International Symposium: Past, Present, and Future of the Marine Environment and Ecosystems
2023.10.18	Sherwood Lan Smith	Challenges for Modeling Marine Ecosystems: Acclimation, Adaptation, and Complexity	Tohoku Forum for Creativity International Symposium: Past, Present and Future of the Marine Environment and Ecosystems
2023.07.15	Yusaku Ohta	A review of the contribution of real-time GNSS to disaster	28th IUGG General Assembly 2023, Jul 15, 2023

		prevention and mitigation in Japan	
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3. Major Awards

- List up to 10 main awards received during FY 2023 in order from the most recent.
- For each, write the date issued, the recipient's name, and the name of award.
- In case of multiple recipients, underline those affiliated with the center.

Date	Recipient's name	Name of award
2024.02.25	Yusaku Ohta	2022 Research Paper Award of the Seismological Society of Japan
2024.02.25	Fumiaki Tomita	2022 Research Paper Award of the Seismological Society of Japan
2024.02.25	Fumiaki Tomita	2023 EPS (Earth, Planets and Space), Excellent reviewer award
2024.02.07	Tomoe Nasuno	Advances in Atmospheric Sciences Editor's Award for Reviewers 2024
2023.09.27	Sayaka Yasunaka	The JOS Environmental Science Prize
2023.08.29	Kentaro Ando	The 16th Prime Minister's Commendation for the Promotion of Maritime Nation (tentative translation)
2023.08.01	Kaoru Tachiiri	Progress in Earth and Planetary Science The Most Downloaded Paper Award2023
2023.08.01	<u>Michio Kawamiya, Kaoru Tachiiri</u>	Progress in Earth and Planetary Science The Most Downloaded Paper Award2023
2023.06.29	Fumio Inagaki	The 2023 Philipp Franz von Siebold Award

Appendix 2 FY 2023 List of Principal Investigators

NOTE:

*Underline names of principal investigators who belong to an overseas research institution.

*In the case of researcher(s) not listed in the proposal for newly selected centers in FY2023, attach a "Biographical Sketch of a New Principal Investigator"(Appendix 2a).

*Enter the host institution name and the center name in the footer.

		<Results at the end of FY2023>						Principal Investigators Total:22
Name	Age	Affiliation (Position title, department, organization)	Academic degree, specialty	Effort (%)*	Starting date of project participation	Status of project participation (Describe in concrete terms)	Contributions by PIs from overseas research institutions	
Toshio Suga		Department of Geophysics / Graduate School of Science / Tohoku University • Professor	Physical Oceanography	90	Ocrober 3rd, 2023	usually stays at the center		
Fumio Inagaki		Department of Earth Sciences / Graduate School of Science / Tohoku University • Professor	Geomicrobiology, Earth Life Engineering	80	Ocrober 3rd, 2023	usually stays at the center		
<u>Benjamin Horton</u>		Earth Observatory of Singapore / Nanyang Technological University • Director	Oceanography	10	Ocrober 3rd, 2023	joins a video conference from another institution one time per two weeks.	planned to accept young scientists from the WPI center	
<u>Sabine Kasten</u>		Section Marine Geochemistry / Alfred Wegener Institute • Head	Sediment geochemistry, Biogeochemistry	15	Ocrober 3rd, 2023	joins a video conference from another institution one time per two weeks.	planned to accept young scientists from the WPI center	
Michio Kawamiya		Research Center for Environmental Modeling and Application / JAMSTEC • Director	Oceanography, Meteorology, Earth System Modeling	80	Ocrober 3rd, 2023	usually stays at the center		
Michio Kondoh		Department of Ecological Developmental Adaptability / Graduate School of Life Sciences / Tohoku University • Professor	Theoretical Ecology	80	Ocrober 3rd, 2023	usually stays at the center		
Takeshi Obayashi		Department of System Information Sciences / Graduate School of Information Sciences / Tohoku University • Professor	Systems Genomics	80	Ocrober 3rd, 2023	usually stays at the center		
Yusaku Ohta		Research Center for Prediction of Earthquakes and Volcanic Eruptions / Graduate School of Science / Tohoku University • Associate Professor	Solid State Geophysics	80	Ocrober 3rd, 2023	usually stays at the center		
Riko Oki		Earth Observation Research Center / Space Technology Directorate I / Japan Aerospace Exploration Agency • Director	Atmospheric and Hydrospheric Science	30	Ocrober 3rd, 2023	joins a video conference from another institution one time per two weeks.		
<u>Shuhei Ono</u>		Department of Earth / Atmospheric and Planetary Sciences / Massachusetts Institute of Technology • Professor	Isotope Geochemistry	25	Ocrober 3rd, 2023	joins a video conference from another institution one time per two weeks.	planned to accept young scientists from the WPI center	

<u>Niklas Schneider</u>		International Pacific Research Center / Department of Oceanography / University of Hawaii at Manoa • Director, Professor	Oceanography	40	October 3rd, 2023	usually stays at the satellite, joins a video conference from the satellite one time per two weeks.	planned to accept young scientists from the WPI center
<u>Angelicque White</u>		Department of Oceanography / University of Hawaii at Manoa • Professor	Biological and Chemical Oceanography	30	October 3rd, 2023	usually stays at the satellite, joins a video conference from the satellite one time per two weeks.	planned to accept young scientists from the WPI center
<u>Shang-Ping Xie</u>		Scripps Institution of Oceanography / University of California, San Diego • Professor	Climatology, Physical Oceanography	30	October 3rd, 2023	joins a video conference from another institution one time per two weeks.	planned to accept young scientists from the WPI center
Cheryl Lynn Ames		International Integrative Research & Instruction / Graduate School of Agricultural Science / Tohoku University • Professor	Molecular Biology	80	October 3rd, 2023	usually stays at the center	
Shinya Koketsu		Global Ocean Observation Research Center / JAMSTEC • Director	Atmospheric and Hydrospheric Science	80	October 3rd, 2023	usually stays at the center	
Sherwood Lan Smith		Research Institute for Global Change / JAMSTEC • Senior Researcher	Marine Ecology	80	October 3rd, 2023	usually stays at the center	
Sayaka Yasunaka		Center for Atmospheric and Oceanic Studies / Graduate School of Science / Tohoku University • Professor	Marine Environmental Sciences	80	October 3rd, 2023	usually stays at the center	
Keith Rodgers		Advanced Institute for Marine Ecosystem Change (WPI-AIMEC) / Tohoku University • Professor	Oceanography	100	April 1st, 2024	usually stays at the center	
William F. McDonough		Advanced Institute for Marine Ecosystem Change (WPI-AIMEC) / Tohoku University • Professor	Geomicrobiology	67	April 1st, 2024	usually stays at the center	
Shingo Watanabe		Research Center for Environmental Modeling and Application / JAMSTEC • Deputy Director	Meteorology, Earth System Modeling	10	April 1st, 2024	usually stays at the center	
Youichi Ishikawa		VAIG / JAMSTEC • Director	Oceanography, modelling, AI development	10	April 1st, 2024	usually stays at the center	
Tatsuhiko Hoshino		Kochi Institute for Core Sample Research / JAMSTEC • Senior Researcher	Chemical Engineering, Applied Chemistry	80	April 1st, 2024	usually stays at the center	

*Percentage of time that the principal investigator devotes to working for the center vis-à-vis his/her total working hours.

Principal investigators unable to participate in project in FY 2023

Name	Affiliation (Position title, department, organization)	Starting date of project participation	Reasons	Measures taken
N/A				

Appendix 2a **Biographical Sketch of a New Principal Investigator**

(within 3 pages per person)

Name (Age)

Tatsuhiko Hoshino

Affiliation and position (Position title, department, organization, etc.)

Geomaterials Science Research Group, Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology (JAMSTEC); Senior Researcher

Academic degree and specialty

2005 Ph.D., Chemical Engineering, Waseda University, Tokyo, Japan

2002. M.S., Chemical Engineering, Waseda University, Tokyo, Japan

2000 B.S, Applied Chemistry, Waseda University, Tokyo, Japan

Effort

80 %

* Percentage of time that the principal investigator devote to working for the center vis-à-vis his/her total working hours.

Research and education history

2023–present Guest Professor, Kochi University

2016–present Guest Associate Professor, Hiroshima University, Graduate School of Advanced Science and Engineering

2014-present Senior Researcher, Kochi Institute for Core Sample Research, JAMSTEC

2009-2013 Researcher, Kochi Institute for Core Sample Research, JAMSTEC

2008-2009 Postdoctoral researcher, Research Fellow, Department of Microbiology, Institute of Oceanography, University of Tokyo

2008-2009 Postdoctoral researcher, Department of Ecology, Aarhus University, Denmark

2008-2009 Research Fellowship SPD, JSPS

2006-2008 Postdoctoral researcher, Department of Microbial Ecology, University of Vienna, Austria

2006-2008 Overseas Postdoctoral Fellowship for Research, JSPS

2004-2006 Assistant Professor, School of Science and Engineering, Waseda University

Achievements and highlights of past research activities

Tatsuhiko Hoshino's research interests lie in microbial ecology in elemental cycles in both engineered and natural environments. Early in his career, he studied microorganisms involved in nitrogen metabolism in wastewater treatment. In nitrogen removal by biological wastewater treatment processes, denitrifying bacteria are responsible for converting dissolved nitrogen to gaseous nitrogen for release to the atmosphere, but it was unclear what type of bacteria were responsible for this reaction. He developed the world's first technique to amplify the functional genes responsible for denitrification in individual cells by in situ rolling circle amplification and visualize them together with the 16S rRNA gene under fluorescence microscopy to simultaneously visualize bacterial function and phylogeny.

He then shifted his research focus to the microbial ecology of subseafloor sediments. He set up the

Global Subseafloor Microbiome Project to address the lack of a comprehensive global view of the microbiome in subseafloor sediments, which had been studied using different methods on different research expeditions, introducing methodological biases. At first, a protocol for DNA extraction, gene quantification and sequencing was established, and then he analyzed the microbial community in subseafloor sediments from around the world using the consistent protocol. Focusing on digital PCR, which allows absolute quantification of genes without the influence of foreign substances, he accurately quantified bacteria and archaea in sediments and showed that the archaea/bacteria ratio in sediments is comparable to that in oceans on a global scale. The further fundamental question of microbial diversity in subseafloor sediments was also addressed by combining microbial diversity derived from comprehensive 16S rRNA gene sequencing with classical ecological models to estimate the number of microbial species in global sediments. The results indicated that the number of microbial species present in sediments is comparable to that found in the total ocean and surface soils, despite the extremely low-energy environment below the seafloor (published in PNAS, top1% paper).

Achievements

(1) International influence * Describe the kind of attributes listed below.

a) Recipient of international awards

- 2021 Deep Life Paper Award, International Center for Deep Life Investigation (IC-DLI)
- 2017 The PNAS Cozzarelli Prize 2017, National Academy of Science of the USA (Trembath-Reichert et al., PNAS, 2017: Category IV)

b) Member of a scholarly academy in a major country

c) Guest speaker or chair of related international conference and/or director or honorary member of a major international academic society in the subject field

- Hoshino T., Microfluidic digital PCR for less-biased quantification of microbial communities in marine subsurface environments, 15th International Symposium on Microbial Ecology, Seoul, 2014, 25-29 August
- Hoshino T., Linking function with identity inside bacterial cells by in situ Rolling Circle Amplification – FISH. 13th International Symposium on Microbial Ecology, Seattle, 2010, 22-27, August

d) Editor of an international academic journal

2022-present Associate Editor, Frontiers in Microbiology

(2) Receipt of major large-scale competitive funds (over the past 5 years)

- 2022-2026 JSPS Grants-in-Aid for Scientific Research (B), Microbial adaptation and evolution in subseafloor sediment (PI), ¥17,290,000
- 2021-2024 JSPS Grant-in-Aid for Scientific Research (Exploratory), Understanding past ecosystems using environmental DNA in marine sediment (PI), ¥6,240,000
- 2022-2025 JSPS Grants-in-Aid for Scientific Research (A), - Japan Trench turbidite material supply systems and spatio-temporal correlations with ultra-deepwater and sub-

seafloor microbial ecosystems. (Co-I), ¥42,640,000

(3) Major publications (Titles of major publications, year of publication, journal name, number of citations)

Hoshino, T., Doi, H., Uramoto, G.-I., Wörmer, L., Adhikari, R. R., Xiao, N., Morono, Y., D'Hondt, S., Hinrichs, K.-U., & Inagaki, F. (2020). Global diversity of microbial communities in marine sediment. *Proceedings of the National Academy of Sciences*, 117(44), 27587–27597. (Cited by 204, top1%)

Morono, Y., Ito, M., **Hoshino, T.**, Terada, T., Hori, T., Ikehara, M., D'Hondt, S., & Inagaki, F. (2020). Aerobic microbial life persists in oxic marine sediment as old as 101.5 million years. *Nature Communications*, 11(1), 3626. (Cited by 88)

Heuer, V. B. et al (incl **Hoshino, T.** and 40+ Authors) (2020). Temperature limits to deep subseafloor life in the Nankai Trough subduction zone. *Science*, 370(6521), 1230–1234. (Cited by 66)

Hoshino, T., & Inagaki, F. (2019). Abundance and distribution of Archaea in the subseafloor sedimentary biosphere. *The ISME Journal*, 13(1), (Cited by 65)

Wörmer, L., **Hoshino, T.**, Bowles, M. W., Viehweger, B., Adhikari, R. R., Xiao, N., Uramoto, G., Könneke, M., Lazar, C. S., Morono, Y., Inagaki, F., & Hinrichs, K.-U. (2019). Microbial dormancy in the marine subsurface: Global endospore abundance and response to burial. *Science Advances*, 5(2), eaav1024. (Cited by 74)

Ijiri, A., Inagaki, F., Kubo, Y., Adhikari, R. R., Hattori, S., **Hoshino, T.**, Imachi, H., Kawagucci, S., Morono, Y., & Ohtomo, Y. (2018). Deep-biosphere methane production stimulated by geofluids in the Nankai accretionary complex. *Science Advances*, 4(6), eaao4631. (Cited by 79)

Hoshino, T., Toki, T., Ijiri, A., Morono, Y., Machiyama, H., Ashi, J., Okamura, K., & Inagaki, F. (2017). Atribacteria from the Subseafloor Sedimentary Biosphere Disperse to the Hydrosphere through Submarine Mud Volcanoes. *Frontiers in Microbiology*, 8, 1135. (Cited by 51)

Inagaki, F., et al (incl **Hoshino, T.** and 44 authors) (2015). Exploring deep microbial life in coal-bearing sediment down to ~2.5 km below the ocean floor. *Science*, 349(6246), 420–424. (Cited by 413, top1%)

Hoshino, T., & Inagaki, F. (2012). Molecular quantification of environmental DNA using microfluidics and digital PCR. *Systematic and Applied Microbiology*, 35(6), 390–395. (Cited by 142)

Hoshino, T., Yilmaz, L. S., Noguera, D. R., Daims, H., & Wagner, M. (2008). Quantification of target molecules needed to detect microorganisms by fluorescence in situ hybridization (FISH) and catalyzed reporter deposition-FISH. *Applied and Environmental Microbiology*, 74(16), 5068–5077. (Cited by 148)

Appendix 2a Biographical Sketch of a New Principal Investigator

(within 3 pages per person)

Name (Age)

Yoichi Ishikawa

Affiliation and position (Position title, department, organization, etc.)

Research Institute for Value-Added Information Generation (VAiG), Center for Earth Information
Science and Technology (CEIST), Director

Academic degree and specialty

Ph.D., Graduate School of Science, Kyoto University, Japan

M.S., Graduate School of Science, Kyoto University, Japan

B.S., Faculty of Science, Graduate School of Science, Kyoto University, Japan

Effort **10 %**

* Percentage of time that the principal investigator devote to working for the center vis-à-vis his/her total working hours.

Research and education history

April 1996 JSPS Research Fellowship for Young Scientists (DC1) 1996

April 1999 JSPS Research Fellowship for Young Scientists (PD) 1999

May 2001 Research Associate, Graduate School of Science, Kyoto University

April 2007 Assistant Professor, Graduate School of Science, Kyoto University

October 2010 Visiting Senior Technical Scientist (II) (concurrent), Japan Agency for Marine-
Earth Science and Technology (JAMSTEC)

April 2011 Visiting Senior Technical Scientist (concurrent), Japan Agency for Marine-Earth

Science and Technology (JAMSTEC)

April 2012 Group Leader, (Senior Technical Scientist), Data Research Center for Marine-Earth

Sciences (DrC), Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

2019 Director, Information Engineering Programme, (Principal Researcher), Research Institute for Value-Added-Information Generation (VAiG), Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

2022 – Director, Center for Earth Information Science and Technology (CEIST), (Principal Researcher), Research Institute for Value-Added Information Generation (VAiG) , Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Achievements and highlights of past research activities

Yoichi Ishikawa has developed a data assimilation system that combines realistic simulation models of ocean circulation fields with observation data and numerical simulations. He led the

creation of datasets for past reconstructions and future predictions using these systems. The datasets created, particularly in the northwest Pacific region, lead globally in terms of resolution and duration and are widely utilized by many users. Furthermore, based on these datasets, he has advanced research on the impact of climate change in the fisheries sector. He has also served as a lead author for the IPCC Sixth Assessment Report and contributed to efforts on climate change adaptation both domestically and internationally.

Achievements

(1) International influence * Describe the kind of attributes listed below.

- a) Recipient of international awards
- b) Member of a scholarly academy in a major country
- c) Guest speaker or chair of related international conference and/or director or honorary member of a major international academic society in the subject field
- d) Editor of an international academic journal

Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)

Working Group II (WG2) Impacts, Adaptation, and Vulnerability Chapter 10: Asia, Lead

Author

(2) Receipt of major large-scale competitive funds (over the past 5 years)

- 2021 - 2030 Data Integration and Analysis System [PI]
- 2023 – 2028 Environment Research and Technology Development Fund (ERTDF) 【S-21-1】 Development of an integrated assessment model on the socio-ecological system [co-I]
- 2022 – 2026 SENTAN/Advanced Studies of Climate Change Projection [co-I]

(3) Major publications (Titles of major publications, year of publication, journal name, number of citations)

- Kawakami et al.: Future changes in marine heatwaves based on high-resolution ensemble projections for the northwestern Pacific Ocean. J. Oceanogr. 2024. doi: 10.1007/s10872-024-00714-y
- Shaw, R., et al.: Asia. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2022, p. 1457-1579, doi: 10.1017/9781009325844.012.
- Nishikawa et al.: Development of high-resolution future ocean regional projection datasets for coastal applications in Japan. Prog. Earth Planet. Sci, 2021, doi: 10.1186/s40645-020-00399-z. [cited by 19]

- Igarashi et al.: Identifying potential habitat distribution of the neon flying squid (*Ommastrephes bartramii*) off the eastern coast of Japan in winter. *Fish. Oceanogr.* 2018, doi: 10.1111/fog.12230. [cited by 14]
- Toyoda et al. Intercomparison and validation of the mixed layer depth fields of global ocean syntheses. *Clim. Dyn.*, 2017. Doi: 10.1007/s00382-015-2637-7 [cited by 54]
- Usui et al. Four-dimensional variational ocean reanalysis: a 30-year high-resolution dataset in the western North Pacific (FORA-WNP30). *J. Oceanogr.*, 2017. Doi: 10.1007/s10872-016-0398-5 [cited by 83]
- Ishikawa et al.: Variational data assimilation system with nesting model for high resolution ocean circulation. *Fulid Dyn. Res.*, 2015, doi: 10.1088/0169-5983/47/5/051401 [cited by 17]
- Barmaseda et al., The Ocean Reanalyses Intercomparison Project (ORA-IP), *J. Oper. Oceanogr.*, 2015, doi: 10.1080/1755876X.2015.1022329. [cited by 191]
- Nishikawa et al.: Impact of paralarvae and juveniles feeding environment on the neon flying squid (*Ommastrephes bartramii*) winter-spring cohort stock. *Fish. Oceanogr.* 2014. Doi: 10.1111/fog.12064 [cited by 37]
- Kawamura et al.: Preliminary Numerical Experiments on Oceanic Dispersion of ¹³¹I and ¹³⁷Cs Discharged into the Ocean because of the Fukushima Daiichi Nuclear Power Plant Disaster. *J. Nucl. Sci. Tech.*, 2011. Doi: 10.3327/jnst.48.1349[cited by 182]
- De May et al.: APPLICATIONS IN COASTAL MODELING AND FORECASTING, *Oceangr.* 2009. Doi: 10.5670/oceanog.2009.79 [cited by 13]

(4) Others (Other achievements indicative of the PI's qualification as a top-world researcher, if any.)

Appendix 2a Biographical Sketch of a New Principal Investigator

(within 3 pages per person)

Name (Age)

William F. McDonough

Affiliation and position (Position title, department, organization, etc.)

Department of Earth Sciences, Graduate School of Science, Tohoku University, Japan; Specially Appointed Professor

Department of Geology, University of Maryland, College Park, MD, 20742, U.S.A.; Professor

Academic degree and specialty

1988 Ph.D., Geochemistry, Research School of Earth Science, Australian National University, Australia

1983 M.S., Geochemistry, Sul Ross State University, Alpine, TX, U.S.A.

1979 B.S., Anthropology, University of Massachusetts, Boston, MA, U.S.A.

Effort**67%**

* Percentage of time that the principal investigator devote to working for the center vis-à-vis his/her total working hours.

Research and education history

2017-present Specially Appointed Professor, Graduate School of Science, Tohoku University

2011 Guest Professor, China University of Geosciences (Wuhan), China

2010-present Affiliate Professor, Department of Chemistry and Biochemistry, University of Maryland

2005-present Professor, Department of Geology, University of Maryland

2001-present Director, Plasma Mass Spectrometry Laboratory, Department of Geology, University of Maryland

2000-2005 Associate Professor, Department of Geology, University of Maryland

1994-2000 Research Associate, Department of Earth & Planetary Science, Harvard University

1995 Lecturer, Department of Earth Sciences, Boston University

1989-1994 Research Fellow, Australian National Univ, Research School of Earth Science

1987-1989 Alexander Von Humboldt Fellow, Max-Planck-Inst. für Chemie, Mainz, Germany

1978-1980 Consultant Geologist, Private practice, Oregon

Achievements and highlights of past research activities

William McDonough's research interests includes understanding the nature, structure and evolution of the terrestrial planets, particularly for the Earth, and the composition of the Earth's core, mantle-crust, and atmosphere-hydrosphere systems. By providing chemical and isotopic analysis of a wide range of materials (metals, minerals, tissues), he delivers new constraints on the nature, timing, and dynamics of processes occurring in the Earth's biosphere and geosphere, as well as the habitability of Mars and exoplanets. His research in neutrino geoscience focuses on quantifying the amount of radioactive energy inside the planet and thus defines the planetary-scale, energy budget left to drive the Earth's engine, powering plate tectonics, mantle convection, and the geodynamo, with the latter generating the magnetosphere, a protective planetary boundary that shields us from cosmic rays. He has designed and built laser ablation systems and plasma mass spectrometers for chemical and isotopic analyses. These analyses have provided critical data for transdisciplinary research in geology, biology, medicine, chemistry, physics, forensic science, nuclear industry, archaeology, and environment studies. Since 2001 he has been the director of the Plasma Mass Spectrometry Laboratory, a \$1.5M research facility that has produced more than 245 peer-reviewed papers, and provided data for senior thesis, MS thesis, and dissertations of 6 high school students, 28 undergraduates, and 53 graduate students. He has published more than 205 peer-reviewed articles and book chapters, edited 2 books, and given some 31 media interviews, demonstrating the qualification to be the international and transdisciplinary WPI Administrative director.

Achievements**(1) International influence** * Describe the kind of attributes listed below.

a) Recipient of international awards

Robert Wilhelm Bunsen Medal, the European Geosciences Union

b) Member of a scholarly academy in a major country

President (2017-19), VGP-section (~9000 members and affiliates), the American Geophysical Union; Advisory Board member, COMPRES (Consortium for Materials Properties Research in Earth Sciences); Executive Board Member, *Geochemistry, Geophysics and Geosystems* (G3); Co-chair, Program committee, JpGU-AGU Joint Meeting 2020 in Makuhari, Japan; Co-organizer International Workshop: Continental Margin in South China: multidisciplinary frontiers in neutrino geoscience, Chinese Academy of Science, Beijing, China; Chair, Science committee: Co-Convener – International Workshop: Neutrino Research and Thermal Evolution of the Earth, workshop, Tohoku University, Sendai, Japan; Co-Chair – Scientific Committee, International Summer Institute, Using Particle physics to understand and image

the Earth: geoneutrinos, monography, cosmogenic nuclides, L'Aquila, Italy; Advisory committee member of CIDER (Co-operative Institute for Dynamic Earth Research); Member - Robert Wilhelm Bunsen Medal Committee, European Geosciences Union; Member - Advisory Committee, Institute for Study of the Earth's Interior, Okayama University, Misasa, Japan; Associate Chair - Policy Committee, IEDA (Integrated Earth Data Applications), NSF-funded data facility; Scientific Committee, Neutrino Geosciences, seven different international workshop; International Advisory Committee, Applied Anti-neutrino Physics 2013, Seoul, South Korea; Member – Independent Laboratory Review, Laser Ablation for Chemical Analysis, at the Lawrence Berkeley National Laboratory; Scientific Organizing Committee - 8th International Sector Field Inductively Coupled Plasma; Committee Member - National Screening Committee for the U.S. State Department; Vice President, Geological Society of Washington.

c) Guest speaker or chair of related international conference and/or director or honorary member of a major international academic society in the subject field

233 (in 23 countries) invited lectures and keynote presentations

d) Editor of an international academic journal

Treatise on Geochemistry, vol. 15: *Treatise on Geochemistry*, vol. 15: *Analytical Geochemistry/Inorganic Instrumental Analysis*; and Editor-in-Chief, *Geostandards and Geoanalytical Research* (Wylie Journal); Founding member, *Geochemistry, Geophysics and Geosystems*; Guest Editor, *Chemical Geology*, special issue: Chemical Evolution of the Mantle; Associate Guest Editor, *Journal of Geophysical Research*; Editorial Board, *Geology*; Editorial Board, *GERM* (Geochemical Earth Reference Model); Editor 1991, Annual Report: Research School of Earth Sciences, Australian National University.

(2) Receipt of major large-scale competitive funds (over the past 5 years)

NSF EAR 2234566 (\$336,623) UPGRADE of existing Element2 (ICPMS) and ACQUISITION of a replacement laser ablation system at the University of Maryland, Geology (PI), U of MD College Park, 07/01/2022 - 06/31/2023

NASA, ROSES DALI (\$3,200,000) PLASMA: Pulsed Laser Ablation Sampling and Mass Analysis (PI.), U of MD College Park, 2022 - 2025

NSF EAR 2050374 (\$340,500) Neutrino Geoscience: Geoneutrinos and heat production in the Earth (PI), U of MD College Park, 05/01/2021 - 04/31/2024

NASA, ROSES PICASSO (\$1,230,951) Miniaturized Inductively Coupled Plasma Mass Spectrometer (ICPMS) for Trace Element Analysis (Co-I.), U of MD College Park, 2018 - 2021

NSF EAR1659023 (\$480,000) Acquisition of a State-of-the-Art Multi-Collector Inductively-Coupled Plasma Mass Spectrometer (Co-I), U of MD College Park, 08/01/2017 - 07/31/2019

(3) Major publications (Titles of major publications, year of publication, journal name, number of citations)

Sun, S.S., and **McDonough, W.F.** (1989) Chemical and Isotopic Systematics of oceanic basalts: implications for Mantle Composition and Processes. *In*: A.D. Saunders and M.J. Norry (eds.) *Magmatism in the Ocean Basins, Spec. Publ. Vol. Geol. Soc. Lond.*, No. 42, pp. 313-345. (Cited by 34,886)

McDonough, W.F., and Sun, S.S. (1995) The composition of the Earth. *Chemical Geology*, **120**, 223-254 (Cited by 15,864)

An, F., et al (incl. **McDonough, W.F.**, and 200+ authors) (2016) Neutrino physics with JUNO. *Journal of Physics G: Nuclear and Particle Physics*, **43**, 030401. (Cited by 1397)

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Rudnick, R.L., **McDonough, W.F.**, and Chappell, B.W. (1993) Carbonatite metasomatism in the Northern Tanzanian mantle: petrographic and geochemical characteristics. *Earth and Planetary Science Letters*, **114**, 463-475. (Cited by 914)

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- McDonough, W.F.**, Sun, S.-S., Ringwood, A.E., Jagoutz, E., and Hofmann, A.W. (1992) Potassium, rubidium, and cesium in the Earth and Moon and the evolution of the Earth's mantle. *Geochimica et Cosmochimica Acta*, **56**, 1001-1012. (Cited by 750)
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- Dasgupta, R., Hirschmann, M. M., **McDonough, W. F.**, Spiegelman, M. and Withers, A. C., (2009) Role of Carbonatitic Melt in Mantle Geochemistry Based on New Mineral-Melt Trace Element Partitioning Experiments. *Chemical Geology*, **262**: 57-77. (Cited by 303)

(4) Others (Other achievements indicative of the PI's qualification as a top-world researcher, if any.)

Fellow, American Geophysical Union, 2011, Copernicus Visiting Scientist, University of Ferrara, Italy, 2010, Fellow, Geochemical Society and the European Association for Geochemistry, 2010, Fellow, Mineralogical Society of America, 2009, Fellow, Geological Society of America, 2003, Fellow, Alexander von Humboldt Society, 1987 (Alexander von Humboldt Foundation, Federal Republic of Germany), ISI Highly Cited Paper (<http://www.in-cites.com/papers/WilliamMcDonough.html>) (>26,200 cites); ISI Highly Cited Paper (April 2005), The Composition of the Earth (*Chemical Geology*, **120**: 223-253); >205 published papers, 75,600 citations; h-index: 79; i10-index: 182; Wikipedia page geoneutrino; >\$10.8M in research funding (\$5.9M since 2019); 11 undergrad senior thesis, 7 MS thesis students, and 20 PhD students completed, 1 in progress; Editor of 2 books: *Analytical Geochemistry / Inorganic Instrument Analysis*, volume 15, in *Treatise on Geochemistry* (eds. H.D. Holland and K.K. Turekian), (2014) Elsevier-Pergamon 453 pp; Co-editor, *Composition, Deep Structure and Evolution of Continents* (1999) Elsevier, 300 pp.

Appendix 2a Biographical Sketch of a New Principal Investigator

(within 3 pages per person)

Name (Age)

Keith Rodgers

Affiliation and position (Position title, department, organization, etc.)

WPI-Advanced Institute for Marine Ecosystem Change, Tohoku University, Sendai, Japan,
Faculty/Professor

Academic degree and specialty

1998 Ph.D., Oceanography, Columbia University, New York, U.S.A.
1992 M.S., Engineering Mechanics, Columbia University, New York, U.S.A.
1988 B.A., Physics, Reed College, Portland, U.S.A.

Effort **100%**

* Percentage of time that the principal investigator devote to working for the center vis-à-vis his/her total working hours.

Research and education history

2024-present	Faculty/Professor, WPI-Advanced institute for Marine Ecosystem Change, Tohoku University, Sendai, Japan
2023-2024	Visiting Researcher, Dept. Geophysics, Graduate School of Science, Tohoku University, Sendai, Japan
2018-2023	Senior Research Scientist, ICCP, Busan, South Korea
2005-2018	Research Scientist, AOS Program, Princeton University, Princeton, U.S.A.
2000-2005	Post-doctoral fellow, jointly at LODYC and LSCE, France
1998-1999	Post-doctoral fellow, Max-Planck-Institut für Meteorologie, Hamburg, Germany
1992-1998	Graduate Research Assistant, Columbia University, New York, U.S.A.

Achievements and highlights of past research activities

Keith Rodgers' primary research interest lies in applying hierarchies of modeling to understand processes that regulate marine ecosystems, and to use that understanding to evaluate how marine ecosystems will respond to future climate change. His most recent work has focused on understanding the relationship between remineralization of organic matter in the ocean's twilight or mesopelagic zone spanning 100m-1000m and primary production in near-surface waters over the low latitude oceans. This work called into question a long-standing paradigm that maintains that low-latitude primary production is largely fueled by an ocean overturning structure linking Southern Ocean surface waters to low latitude upwelling regions. The main finding was that it is rather the combined effects of low-latitude processes, namely relatively shallow remineralization within thermocline waters and thermocline overturning processes, that are primarily responsible for low latitude primary production, and thereby sustaining higher trophic level ecosystems. In parallel efforts over the last decade, he was the scientific lead on the CESM2 Large Ensemble (CESM2-LE) project, a scientific collaboration between the ICCP in Busan, South Korea, and NCAR in Boulder, USA. The project itself involved developing a 100-member large ensemble with CESM2, a CMIP6-class Earth system model, and running 100 ensemble members over 1850-2100 under a relatively strong concentration pathway forcing (SSP3-7.0). For the CESM2-LE presentation paper (Rodgers et al., 2022), the focus was on evaluating how climate change projects onto changes in the variance or natural variability of the climate system. The fact that lower trophic level ecosystems are projected to experience marked changes in their degree of natural variability over the coming century underscores the importance of understanding the mechanistic drivers of variability, as this will

have important implications for impacts and sustainable development.

Achievements

(1) International influence * Describe the kind of attributes listed below.

Co-Chair, US CLIVAR Working Group on Large “Initial-Condition” Earth System Model Ensembles (LEs), 2018-2021 (with co-chair Clara Deser)

Co-PI of CESM2 Large Ensemble Community Project, 2019-2022, a partnership between the ICCP in Busan South Korea and the National Center for Atmospheric Research in Boulder, CO, U.S.A. (with co-PIs Axel Timmermann, Gokhan Danabasoglu, and Clara Deser)

Co-Organizer of two-part international Workshop on CESM2 Large Ensemble, November 2020 and February 2021

(2) Receipt of major large-scale competitive funds (over the past 5 years)

The ICCP in South Korea (workplace 2018-2023) was block-funded, so senior researchers were not able to write independent research proposals. Keith Rodgers' funded proposals through work at Princeton University included:

NASA (\$572,987), Evaluating spatiotemporal scales and underlying mechanisms for emergence of anthropogenic trends in the solubility and biological ocean carbon pumps (PI), Princeton University, 2017-2020.

NASA (\$697,306), Synthesis of new sea surface $p\text{CO}_2$ data products: Evaluation, comparison, and implications for the global carbon cycle (PI), Princeton University, 2014-2018.

NOAA/CICS (\$342,684), Using Models to Improve our Ability to Monitor Oceanic Uptake of Anthropogenic Carbon (PI), Princeton University, 2008-2018.

(3) Major publications (Titles of major publications, year of publication, journal name, number of citations)

Orr, J.C. et al. (incl. Rodgers, K.B., and 20+ co-authors) (2005), Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, *Nature*, 437, 681-686 (cited by 5612).

Rodgers, K.B., O. Aumont, K. Toyama, et al. (2024), Low-latitude mesopelagic nutrient recycling controls on productivity and export, accepted at *Nature*.

Rodgers, K.B., J. Lin, and T.L. Frölicher (2015), Emergence of multiple ocean ecosystem drivers in a large ensemble suite with an Earth system model, *Biogeosciences*, 12, 3301-3320 (cited 181 times).

Yamaguchi, R., K.B. Rodgers, A. Timmermann, et al. (2022), Trophic level decoupling drives future changes in phytoplankton bloom phenology, *Nature Climate Change*, 12, 469-476 (cited 25 times).

Rodgers, K.B., S.-S. Lee, N. Rosenbloom, A. Timmermann, G. Danabasoglu, C. Deser, et al. (2022), Ubiquity of human-induced changes in climate variability, *Earth System Dynamics*, 12, 1393-1411 (cited 198 times).

Deser, C., F. Lehner, K.B. Rodgers, et al. (2020), Insights from Earth system model initial-condition large ensembles and future prospects, *Nature Climate Change*, 10, 277-286 (cited 555 times).

Rodgers, K.B., P. Friederichs, and M. Latif (2004), Tropical Pacific decadal variability and its relation to decadal modulations of ENSO, *Journal of Climate*, 17, 3761-3774 (cited 274 times).

Frölicher, T.L., K.B. Rodgers, et al. (2016), Sources of uncertainties in 21st century projections of potential ocean ecosystem stressors, *Global Biogeochemical Cycles*, 30, 1224-1243 (cited 171 times).

Cheung, W.W.L., (et al., incl. K.B. Rodgers) (2016), Building confidence in projections of the responses of living marine resources to climate change, *ICES Journal of Marine Science*, 73, 1283-1296 (cited 129 times)

(4) Others (Other achievements indicative of the PI's qualification as a top-world researcher, if any.)

Appendix 2a **Biographical Sketch of a New Principal Investigator**

(within 3 pages per person)

Name (Age)

Shingo Watanabe

Affiliation and position (Position title, department, organization, etc.)

Deputy director, Research Center for Environmental Modeling and Application (CEMA),
Research Institute for Global Change (RIGC), Japan Agency for Marine-Earth Science and
Technology (JAMSTEC)
WPI-Advanced Institute for Marine Ecosystem Change, Tohoku University, Sendai, Japan,
Faculty/Professor

Academic degree and specialty

2002 Ph.D., Earth and Planetary Science, Kyushu University, Fukuoka, Japan
1999 M.Sc., Earth and Planetary Science, Kyushu University, Fukuoka, Japan
1997 B.S., Earth and Planetary Science, Kyushu University, Fukuoka, Japan

Effort

10%

* Percentage of time that the principal investigator devote to working for the center vis-à-vis his/her total working hours.

Research and education history

2018-present present position.
2014-2018 Director, Department of Seamless Environmental Prediction, RIGC, JAMSTEC.
2009-2014 Senior Researcher, RIGC, JAMSTEC.
2007-2009 Researcher, RIGC, JAMSTEC.
2002-2007 Post-doctoral fellow, JAMSTEC.

Achievements and highlights of past research activities

Shingo Watanabe is interested in exploring the interaction mechanisms of the various components of the Earth system through numerical modeling and numerical simulation. He is one of the main developers of the Earth system model MIROC-ESM. He has worked on many numerical models, data assimilation systems and machine learning modeling and has played a central role in the assembly of Earth system models, including marine and terrestrial ecosystem components (e.g., Watanabe et al., 2010; Watanabe et al., 2011; Tatebe et al., 2019). Another of his research interests is the study of the dynamics of the middle atmosphere using high-resolution atmospheric general circulation models (Watanabe et al., 2008; Alexander et al., 2010). He was the first in the world to successfully simulate the collapse of the stratospheric equatorial quasi-biennial oscillation in 2015/2016 (Watanabe et al., 2018) and the Lamb and

Pekelis waves caused by the 2022 eruption of the Hunga-Tonga-Hunga-Haapai volcano (Watanabe et al. 2022). The latter, in particular, contributed greatly to the clarification of the mechanism that brought about the meteorological tsunami that hit Japan. Thus, he is also interested in the impact of atmospheric dynamics on the oceans and marine ecosystems.

Achievements

(1) International influence * Describe the kind of attributes listed below.

a) Recipient of international awards **na**

b) Member of a scholarly academy in a major country

Steering Committee member – GeoMIP, APARC DynVAR, ICMA/IAMAS

c) Guest speaker or chair of related international conference and/or director or honorary member of a major international academic society in the subject field

Watanabe, S., D. Koshin, K. Sato, K. Miyazaki, M. Kohma, and S. Noguchi, Gravity wave simulations based on a novel data assimilation system for the middle atmosphere, IUGG2019, 11 July 2019, Montreal.

Watanabe, S., H. Shiogama, Y. Kamae, M. Watanabe, T. Ogura, K. Tachiiri, T. Hajima, and M. Kawamiya, Effects of Interactive Ozone Chemistry on the Climate Sensitivity of an Earth System Model, AOGS2015, 8 August 2015, Singapore.

Watanabe, S., Outcomes from MIROC-ESM on the middle atmosphere general circulation, 6th EU-Japan Workshop on Climate Change Research, 10 October 2011, Brussels, Belgium. (invited)

Watanabe, S., and K. Hamilton, Brief History of Ultra-High Resolution Global Model Studies and Future Plans, AGU Chapman conference on atmospheric gravity waves and their effects on general circulation and climate, 3 March 2011, Honolulu, USA.

Watanabe, S., Constraints on gravity wave drag parameterizations: Implications from gravity wave resolving GCM simulations, SPARC Gravity Wave Momentum Budget Planning Workshop, 26 March 2008, Toronto, 2008.

Watanabe, S., K. Sato, and M. Takahashi, A GCM study of the orographic gravity waves over Antarctica excited by katabatic winds, The 36th COSPAR Scientific Assembly, 16-23 July 2006, Beijing, China.

d) Editor of an international academic journal **na**

e) Peer reviewer for an overseas competitive research program (etc.) **na**

(2) Receipt of major large-scale competitive funds (over the past 5 years)

2016-2022 JST CREST, Study of atmospheric hierarchical structure by fusion of observation data from a global radar network and high-resolution general circulation models, co-PI, 500,000,000 JPY

(3) Major publications (Titles of major publications, year of publication, journal)

name, number of citations)

Watanabe, S., K. Hamilton, T. Sakazaki, and M. Nakano (2022), First detection of the Pekeris internal global atmospheric resonance: Evidence from the 2022 Tonga eruption and from global reanalysis data, *J. Atmos. Sci.*, 79, 3027-3043, doi:10.1175/JAS-D-22-0078.1 [cited by 18]

Watanabe, S., K. Hamilton, S. Osprey, Y. Kawatani, and E. Nishimoto (2018), First successful hindcasts of the 2016 disruption of the stratospheric quasi-biennial oscillation, *Geophys. Res. Lett.*, 44, 1602-1610, doi:10.1002/2017GL076406 [cited by 20]

Tatebe, H., Ogura, T., Nitta, T., Komuro, Y., Ogochi, K., Takemura, T., Sudo, K., Sekiguchi, M., Abe, M., Saito, F., Chikira, M., **Watanabe, S.**, Mori, M., Hirota, N., Kawatani, Y., Mochizuki, T., Yoshimura, K., Takata, K., O'ishi, R., Yamazaki, D., Suzuki, T., Kurogi, M., Kataoka, T., Watanabe, M., and Kimoto, M. (2019), Description and basic evaluation of simulated mean state, internal variability, and climate sensitivity in MIROC6, *Geosci. Model Dev.*, 12, 2727–2765, <https://doi.org/10.5194/gmd-12-2727-2019> [cited by 417]

Watanabe, S., T. Hajima, K. Sudo, T. Nagashima, T. Takemura, H. Okajima, T. Nozawa, H. Kawase, M. Abe, T. Yokohata, T. Ise, H. Sato, E. Kato, K. Takata, S. Emori, and M. Kawamiya (2011), MIROC-ESM 2010: model description and basic results of CMIP5-20c3m experiments, *Geosci. Model Dev.*, 4, 845-872, doi:10.5194/gmd-4-845-2011 [cited by 990]

Watanabe, M., T. Suzuki, R. Oishi, Y. Komuro, **S. Watanabe**, S. Emori, T. Takemura, M. Chikara, T. Ogura, M. Sekiguchi, K. Takata, D. Yamazaki, T. Yokohata, T. Nozawa, H. Hasumi, H. Tatebe, and M. Kimoto (2010), Improved climate simulation by MIROC5: Mean states, variability and climate sensitivity, *J. Climate*, 23, 6312-6335, doi:10.1175/2010JCLI3679.1 [cited by 966]

Alexander, M. J., M. Geller, C. McLandress, S. Polavarapu, P. Preusse, F. Sassi, K. Sato, S. Eckermann, M. Ern, A. Hertzog, Y. Kawatani, M. Pulido, T. Shaw, M. Sigmond, R. Vincent, and **S. Watanabe** (2010), Recent developments in gravity wave effects in climate models, and the global distribution of gravity wave momentum flux from observations and models, *Q. J. Roy. Meteorol. Soc.*, 136, 1103-1124, doi:10.1002/qj.637 [cited by 377]

Watanabe, S., Y. Kawatani, Y. Tomikawa, K. Miyazaki, M. Takahashi, and K. Sato (2008), General aspects of a T213L256 middle atmosphere general circulation model, *J. Geophys. Res.*, 113, D12110, doi:10.1029/2008JD010026 [cited by 136]

(4) Others (Other achievements indicative of the PI's qualification as a top-world researcher, if any.)

Meteorological Society of Japan Award, 2017.

Nishida Prize of Japan Geoscience Union, 2017.

Appendix 3-1 FY 2023 Records of Center Activities

1. Researchers and center staff, satellites, partner institutions

1-1. Number of researchers in the "core" established within the host institution

- Regarding the number of researchers at the Center, fill in the table in Appendix 3-1a.

Special mention

- Enter matters warranting special mention, such as concrete plans for achieving the Center's goals, established schedules for employing main researchers, particularly principal investigators.
- As background to how the Center is working on the global circulation of world's best brains, give good examples, if any, of how career paths are being established for the Center's researchers; that is, from which top-world research institutions do researchers come to the Center and to which research institutions do the Center's researchers go, and how long are their stays at those institutions.

Although there are no specific staffing plans for the final goal yet, we are very excited about William McDonough, who had served as Section President of the American Geophysical Union and had been awarded many Fellows of relevant international science societies. Despite his advanced age, he is an excellent researcher who attracts many researchers and we are pleased to have him as a new PI. As for Keith Rodgers, he co-chaired a panel of CLIVAR in the USA and has since been active in research at the IBS Center for Climate Physics (ICCP), hosted by Pusan National University in South Korea. We are pleased to welcome him to AIMEC after his transfer from ICCP.

1-2. Satellites and partner institutions

- List the satellite and partner institutions in the table below.
- Indicate newly added and deleted institutions in the "Notes" column.
- If satellite institutions have been established overseas, describe by satellite the Center's achievements in coauthored papers and researcher exchanges in Appendix 4.

<Satellite institutions>

Institution name	Principal Investigator(s), if any	Notes
University of Hawaii at Manoa	Prof. Niklas Schneider	Underdevelopment of Collaborative Research Agreement
University of Hawaii at Manoa	Prof. Angelique White	Underdevelopment of Collaborative Research Agreement

< Partner institutions>

Institution name	Principal Investigator(s), if any	Notes
Scripps Institute of Oceanography, University of California San Diego	Shang-Ping Xie	Discussed at the 1st All-Hands meeting
Massachusetts Institute of Technology	Shuhei Ono	Discussed at the 1st All-Hands meeting
Nanyang Technology University	Benjamin Horton	Introductory talk at the 1st All-Hands meeting
Alfred Wegener Institute	Sabine Kasten	Introductory talk at the 1st All-Hands meeting

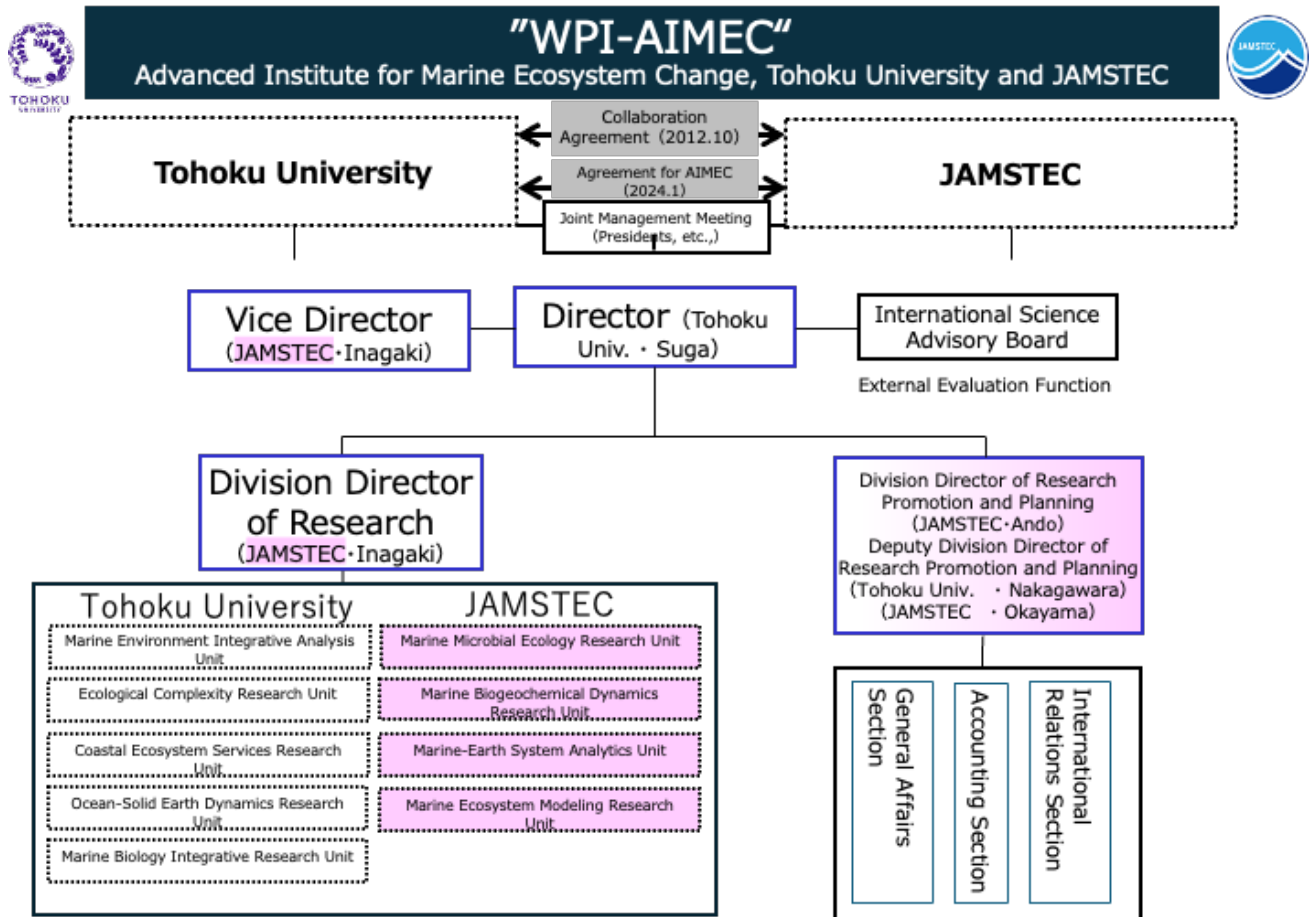
2. Holding international research meetings

- Indicate the number of international research conferences or symposiums held in FY2023 and give up to three examples of the most representative ones using the table below.

FY 2023: 3 meetings	
Major examples (meeting titles and places held)	Number of participants
All-Hands meeting of WPI-AIMEC	From domestic institutions: 37 From overseas institutions: 9
Kick-off Symposium of WPI AIMEC	From domestic institutions: 360, including YouTube viewers From overseas institutions: 10
Mini Symposium by Marine Biology Integrative Unit of WPI-AIMEC	From domestic institutions: 31 From overseas institutions: 12

3. Diagram of management system

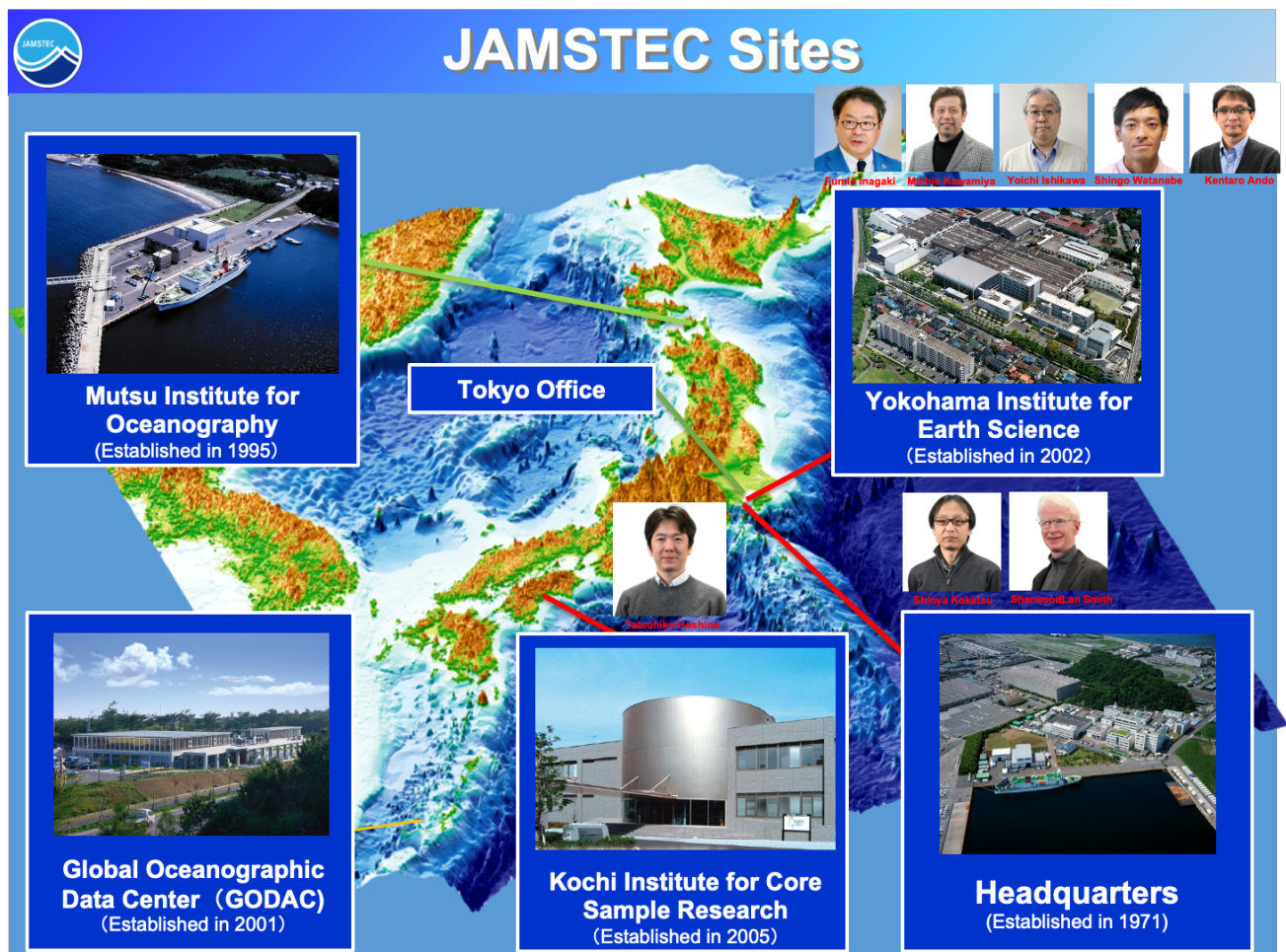
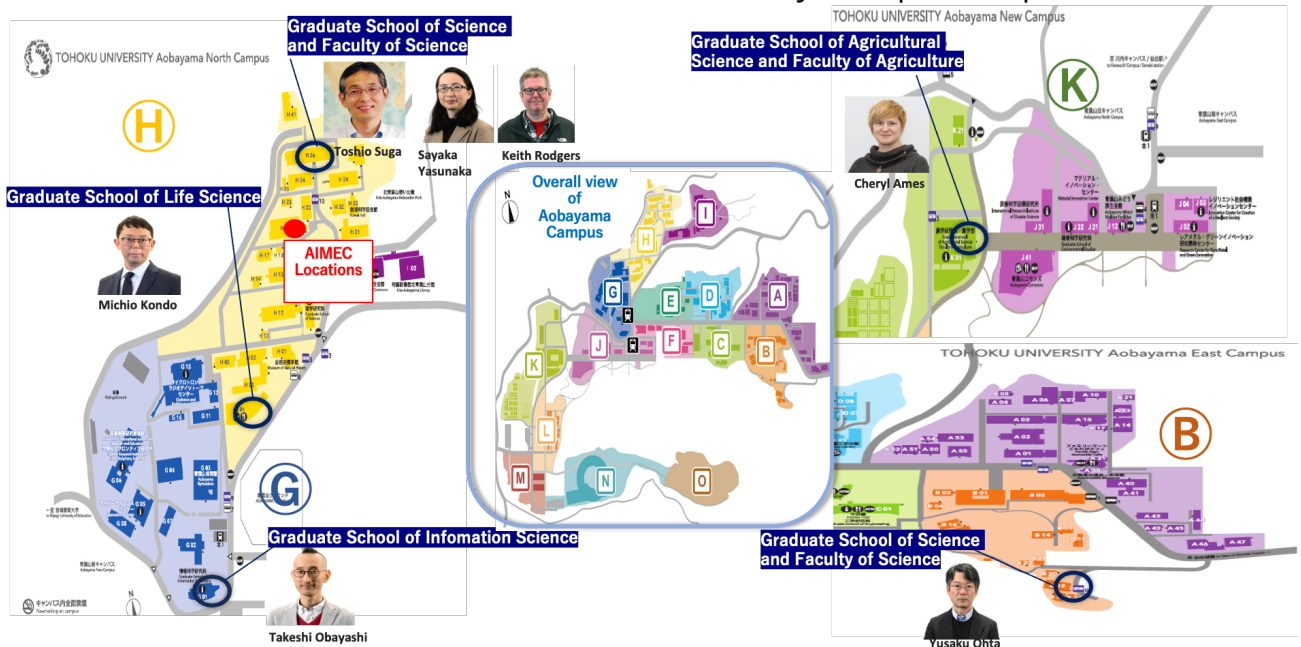
- Diagram the center's management system and its position within the host institution in an easily understood manner.
- If any new changes have been made in the management system from that in the latest "center project" last year, describe them. Especially describe any important changes made in such as the center director, administrative director, head of host institution, and officer(s) in charge at the host institution (e.g., executive vice president for research).



4. Campus Map

- Draw a simple map of the campus showing where the main office and principal investigator(s) are located.

location of AIMEC shown on Tohoku University campus map



5. Securing external research funding*

External research funding secured in FY2023

Total: 274,820,735 yen

- Describe external funding warranting special mention. Include the name and total amount of each grant.

* External research funding includes "KAKENHI," funding for "commissioned research projects," "joint research projects," and for others (donations, etc.) as listed under "Research projects" in Appendix 3-2, Project Expenditures.

Grants-in-Aid for Scientific Research	122,966,268 yen	Grant-in-Aid for Scientific Research (S) 38,870,000 yen Grant-in-Aid for Transformative Research Areas (A) 21,450,000 yen Grant-in-Aid for Scientific Research (B) 11,180,000 yen Grant-in-Aid (A) 15,080,000 yen
Commissioned research funding	135,038,467 yen	JST COI NEXT 26,052,000 yen JST CREST 36,686,000 yen JST Life Science Database Integration Initiative (Life Science Database Togo Suishin Jigyoku, tentative translation) 19,500,000 yen
Collaborative research funding	3,291,000 yen	
Other (e.g. Donation)	13,525,000 yen	Donation 87,000,000 yen

Appendix 3-1a FY 2023 Records of Center Activities

Researchers and other center staff

Number of researchers and other center staff

* Fill in the number of researchers and other center staff in the table below.

* Describe the final goals for achieving these numbers and dates when they will be achieved described in the last "center project."

a) Principal Investigators

(full professors, associate professors or other researchers of comparable standing)

(number of persons)

	At the beginning of project	At the end of FY 2023	Final goal (Date: April 2027)
Researchers from within the host institution	10	15	10
Researchers invited from overseas	6	6	6
Researchers invited from other Japanese institutions	1	1	1
Total principal investigators	17	22	17

b) Total members

		At the beginning of project		At the end of FY 2023		Final goal (Date: April, 2027)	
		Number of persons	%	Number of persons	%	Number of persons	%
Researchers		49		51		91	
	Overseas researchers	11	22	13	25	37	41
	Female researchers	11	22	11	22	38	42
	Principal investigators	17		22		17	
	Overseas PIs	8	47	10	45	7	41
	Female PIs	5	29	5	23	4	24
	Other researchers	32		29		44	
	Overseas researchers	3	9	3	10	20	45
	Female researchers	6	19	6	21	24	55
	Postdocs	0		0		30	
	Overseas postdocs	0	0	0	0	10	33
	Female postdocs	0	0	0	0	10	33
Research support staffs		0		2		20	
Administrative staffs		7		14		39	
Total number of people who form the "core" of the research center		56		67		150	

		At the beginning of project		At the end of FY 2023		Final goal (Date: April, 2027)	
		Number of persons	%	Number of persons	%	Number of persons	%
Doctoral students		0		50		81	
	Employed	0	-	0	0.0	33	40.7

※b) The number of doctoral students in the lower table can be duplicated in the upper table of overall composition.

Appendix 3-2 Project Expenditures

1) Overall project funding

* In the "Total costs" column, enter the total amount of funding required to implement the project, without dividing it into funding sources.

* In the "Amount covered by WPI funding" column, enter the amount covered by WPI within the total amount.

* In the "Personnel," "Project activities," "Travel," and "Equipment" blocks, the items of the "Details" column may be changed to coincide with the project's actual content.

(Million yens)			
Cost items	Details (For Personnel - Equipment please fill in the breakdown of fiscal expenditure, and the income breakdown for Research projects.)	Total costs	Amount covered by WPI funding
Personnel	Center director and administrative director	9	5
	Principal investigators (no. of persons):9	25	9
	Other researchers (no. of persons):19	35	
	Research support staff (no. of persons):1	2	
	Administrative staff (no. of persons):16	11	4
	Subtotal	82	18
Project activities	Gratuities and honoraria paid to invited principal investigators (no. of persons):N/A		
	Cost of dispatching scientists (no. of persons):N/A		
	Research startup cost (no. of persons):27	201	201
	Cost of satellite organizations (no. of satellite organizations):2	25	25
	Cost of international symposiums (no. of symposiums):1	17	17
	Rental fees for facilities		
	Cost of consumables	1	1
	Cost of utilities		
	Other costs	10	10
	Subtotal	254	254
Travel	Domestic travel costs	3	3
	Overseas travel costs	2	2
	Travel and accommodations cost for invited scientists (no. of domestic scientists):N/A	18	18
	(no. of overseas scientists):14		
	Travel cost for scientists on transfer (no. of domestic scientists):N/A		
	(no. of overseas scientists):N/A		
	Subtotal	23	23
Equipment	Depreciation of buildings	30	30
	Depreciation of equipment	169	169
	Subtotal	199	199
Research projects (Detail items must be fixed)	Project supported by other government subsidies, etc. *1		
	KAKENHI	150	
	Commissioned research projects, etc.	326	
	Joint research projects	8	
	Others (donations, etc.)	14	
	Subtotal	498	0
Total		1056	494

(Million yens)

Costs (Million yens)

WPI grant in FY 2023	198
Costs of establishing and maintaining facilities	19
Establishing new facilities 395: m ²	5
Repairing facilities (electricity):761.4m ²	14
Costs of equipment procured	179
multifunctional printer: unit	1
digital white board: unit	12
paper shredder: unit	0
booth style workspace: unit	11
Storage・Server:unit	75
BioScience AFM System	57
Oxygen sensor	18
CTD Probe	5

*1. Management Expenses Grants (including Management Enhancements Promotion Expenses (機能強化経費)), subsidies including National university reform reinforcement promotion subsidy (国立大学改革強化推進補助金) etc., indirect funding, and allocations from the university's own resources.
*2 When personnel, travel, equipment (etc.) expenses are covered by KAKENHI or under commissioned research projects or joint research projects, the amounts should be entered in the "Research projects" block.

*1 運営費交付金(機能強化経費を含む)、国立大学改革強化推進補助金等の補助金、間接経費、その他大学独自の取組による学内リソースの配分等による財源
*2 科研費、受託研究費、共同研究費等によって人件費、旅費、設備備品等費を支出している場合も、その額は「研究プロジェクト費」として計上すること

2) Costs of satellites

(Million yens)			
Cost items	Details	Total costs	Amount covered by WPI funding
Personnel	Principal investigators (no. of persons):N/A		
	Other researchers (no. of persons):N/A		
	Research support staff (no. of persons):N/A		
	Administrative staff (no. of persons):N/A		
	Subtotal	0	0
Project activities	Subtotal		
Travel	Subtotal		
Equipment	Subtotal		
Research projects	Subtotal		
Total		0	0

Appendix 3-2

Appendix 4 FY 2023 Status of Collaboration with Overseas Satellites

1. Coauthored Papers

- List the refereed papers published in FY 2023 that were coauthored between the center's researcher(s) in domestic institution(s) (include satellite institutions) and overseas satellite institution(s). List them by overseas satellite institution in the below blocks.
- Transcribe data in same format as in Appendix 1. Italicize the names of authors affiliated with overseas satellite institutions.
- For reference write the Appendix 1 item number in parentheses after the item number in the blocks below. Let it free, if the paper is published in between Jan.-Mar. 2024 and not described in Appendix 1.

Overseas Satellite 1 University of Hawai'i at Mānoa (Total: 1 paper)

1) Iskandar, MR; Jia, YL; Sasaki, H; Furue, R; Kida, S; Suga, T; Richards, KJ, 2023, J. Geophys. Res.-Oceans, 128, 5, e2022JC019610, Effects of High-Frequency Flow Variability on the Pathways of the Indonesian Throughflow.

Overseas Satellite 2 (N/A)

2. Status of Researcher Exchanges

- Using the below tables, indicate the number and length of researcher exchanges in FY 2023. Enter by institution and length of exchange.
- Write the number of principal investigator visits in the top of each space and the number of other researchers in the bottom.

Overseas Satellite 1: University of Hawaii at Mānoa

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2023	2				2
					0

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2023	5	3			8
					0

Overseas Satellite 2: N/A

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2023					

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2023					

Appendix 5 FY 2023 Visit Records of Researchers from Abroad (1/2)

* If researchers have visited/ stayed at the Center, provide information on them in the below table.

* Enter the host institution name and the center name in the footer.

Total: 16

	Name	Age	Affiliation		Academic degree, specialty	Record of research activities (Awards record, etc.)	Time, duration	Summary of activities during stay at center (e.g., participation as principal investigator; short-term stay for joint research; participation in symposium)
			Position title, department, organization	Country				
1	Suzana G. Leles		Post-Doctoral Researcher, University of Southern California	U.S.A.	Ph.D., Oceanography	Plankton Ecology, biogeography and eco-physiology, including analysis of data from oceanic observations as well as developing models of the adaptive response of phytoplankton to changing environmental conditions	7 days	Seminar Presentation: 2024.01.16, Title: Reconciling theory to predict microbial responses to ocean warming
2	Aletta Yñiguez		Professor, University of Philippines	Philippine	Ph.D., Marine Biology and Fishery	Plankton Ecology, including observations and model-based studies of HABs, marine heat waves, and coral reefs	7 days	Seminar Presentation: 2024.02.09, Title: Advancing technologies and tools for ocean resource management in the Philippines: Ongoing developments and challenges
3	Subhendu Chakraborty		Post-Doctoral Researcher, ZMT-Bremen	Germany	Ph.D., Ecosystem Modelling	Ecosystem modeling, plankton eco-physiology, marine ecology, HAB modeling	7 days	Seminar Presentation: 2024.03.04, Title: A New Horizon in Oceanic Diazotrophic Research
4	Bo Qiu		Professor, University of Hawaii	U.S.A.	Ph.D., Physical Oceanography	https://www.researchgate.net/profile/Bo-Qiu	5 days	Presentation at the 1st All-Hands meeting
5	Kelvin Richards		Professor, University of Hawaii	U.S.A.	Ph.D., Physical Oceanography	https://www.researchgate.net/profile/Kelvin-Richards	5 days	Presentation at the 1st All-Hands meeting
6	Serafini Angelina Margreta		Graduate Student, MIT	U.S.A.	Graduate Course	na	25 days	Discussion at the 1st All-Hands Meeting, and at the Kochi Core Institute of JAMSTEC
7	Manlin Xu		Graduate Student, MIT	U.S.A.	Graduate Course	na	25 days	Discussion at the 1st All-Hands Meeting, and at the Kochi Core Institute of JAMSTEC
8	MinYang Wang		Researcher, South China Sea Institute of Oceanography	China	Ph.D., Physical Oceanography	na	5 days	Discussion at the 1st All-Hands Meeting
9	Shang Ping Xie		Professor, University of California San Diego	U.S.A.	Ph.D., Physical Oceanography	https://www.researchgate.net/profile/Shang-Ping-Xie	4 days	Presentation at the 1st All-Hands meeting
10	Niklas Schneider		Professor, University of Hawaii	U.S.A.	Ph.D., Physical Oceanography	https://www.researchgate.net/profile/Niklas-Schneider	5 days	Presentation at the 1st All-Hands meeting

Appendix 5 FY 2023 Visit Records of Researchers from Abroad (2/2)

* If researchers have visited/ stayed at the Center, provide information on them in the below table.

* Enter the host institution name and the center name in the footer.

Total: 16

	Name	Age	Affiliation		Academic degree, specialty	Record of research activities (Awards record, etc.)	Time, duration	Summary of activities during stay at center (e.g., participation as principal investigator; short-term stay for joint research; participation in symposium)
			Position title, department, organization	Country				
11	Angelique White		Professor, University of Hawaii	U.S.A.	Ph.D.	https://www.researchgate.net/profile/Angelique-White	4 Days	Presentation at the 1st All-Hands meeting
12	Shuhei Ono		Professor, Massachusetts Institute of Technology	U.S.A.	Ph.D.	https://www.researchgate.net/profile/Shuhei-Ono	15 days	Presentation at the 1st All-Hands meeting
13	Allen Collins		National Oceanography & Atmospheric Administration (NOAA), Office of Science & Technology Director, Smithsonian NMNH, Curator, University of Maryland, Associate Professor	U.S.A.	Ph.D. Marine Systematics & Evolution	Research Gate: https://www.researchgate.net/profile/Allen-Collins	7 days	2023/03/24-30 participation as collaborator; short-term stay for joint research planning; student mentoring; visit to survey site & field center; participation in symposium
14	Karen Osborn		Smithsonian NMNH, Curator & Monterey Bay Aquarium Research Institute Professor	U.S.A.	Ph.D. Marine Biodiversity & Evolution	Research Gate: https://www.researchgate.net/profile/Karen-Osborn	7 days	2023/03/24-30 participation as collaborator; short-term stay for joint research planning; student mentoring; visit to survey site & field center; participation in symposium
15	Jimena García-Rodríguez		Department of Zoology, Sao Paulo University, Postdoctoral Fellow	Brazil	Ph.D.	Research Gate: https://www.researchgate.net/profile/Jimena-Garcia-Rodriguez	7 days	2023/03/24-30 participation as collaborator; short-term stay for joint research planning; student mentoring; visit to survey site & field center; participation in symposium
16	Bastian Bentlage		Marine Laboratory, University of Guam, Assistant Professor	U.S.A.	Ph.D. Marine Ecology, Evolution & Bioinformatics	Research Gate: https://www.researchgate.net/profile/Bastian-Bentlage	3 days	2023/03/6-9 participation as collaborator; short-term stay for joint research planning; participation in symposium

Appendix 6 FY2023 State of Outreach Activities

* Fill in the numbers of activities and times held during FY2023 by each activity.

* Describe the outreach activities in the "3-1. Societal Value of Basic Research" of Progress Report, including those stated below that warrant special mention.

Activities	FY2023 (number of activities, times held)
PR brochure, pamphlet	1, one brochure published
Lectures, seminars for general public	1, Kick-off Symposium at Sendai on March 8 th
Teaching, experiments, training for elementary, secondary and high school students	0
Science café	0
Open houses	0
Participating, exhibiting in events	1, posters at the WPI symposium
Press releases	2, one at the adoption and one at the signing ceremony by two host institutes
Publications of the popular science books	0
Others (Newspaper advertisement)	2, Nikkei and Sankei newspapers

*If there are any rows on activities the center didn't implement, delete that (those) row(s). If you have any activities other than the items stated above, fill in the space between parentheses after "Others" on the bottom with the name of those activities and state the numbers of activities and times held in the space on the right. A row of "Others" can be added, if needed.

Outreach Activities and Their Results

List up to three of the Center's outreach activities carried out in FY 2023 that have contributed to enhancing the brand or recognition of your Center and/or the brand of the overall WPI program, and describe its concrete contents and effect in narrative style. (Where possible, indicate the results in concrete numbers.)

Examples:

- As a result of using a new OO press-release method, a OO% increase in media coverage was obtained over the previous year.
- By holding seminars for the public that include people from industry, requests for joint research were received from companies.
- We changed our public relations media. As a result of using OO to disseminate information, a OO% increase in inquiries from researchers was obtained over the previous year.
- As a result of vigorously carrying out OO outreach activity, \OO in external funding was acquired.

On the occasion of the Kick-off Symposium, the Kick-off Symposium for WPI-AIMEC was advertised in the Nikkei (national edition) and Sankei (Tohoku region edition) newspapers, and the number of registrations per day for the symposium was almost double the usual number for the three days following the advertisement. This resulted in almost the same number of participants as at the venue we had prepared.

Appendix 7 FY 2023 List of Project's Media Coverage

* List and describe media coverage (e.g., articles published, programs aired) in FY 2023.

* Enter the host institution name and the center name in the footer.

	Date	Types of Media (e.g., newspaper, magazine, television)	Description
1	Feb. 21st, 2024	newspaper, Nikkei Shinbun	Advertizement of the outline of the WPI-AIMEC science and the Kickoff Symposium of the WPI-AIMEC on March 8th in Sendai, Japan
2	Mar. 1st, 2024	newspaper, Sankei Shinbun	Advertizement of the Kickoff Symposium of the WPI-AIMEC on March 8th in Sendai, Japan
3			
4			
5			
6			
7			
8			
9			
10			

List of Errata			
Location	Original Text	Correction	Remarks
P1 and P6	Jonathan	Derot	Jonathan and Derot were the first and family name of the author.
P6	Advancing Research of the Highest Global Level	Marine Biogeochemical Dynamics Research Unit	Marine Biogeochemical Dynamics Research Unit is the correct name of the unit.
P6	The one review	The review	Using “one” made different meaning
P13	Cross-Appointment (CloAp)	Cross-Appointment	(CloAp) did not have meaning in this sentence.
Corrected on January 23, 2025			