

Research area in the Strategic Objective “*Elucidation of the relationship between the ocean and CO₂ and maximization of ocean functions*”

Exploring the potential of ocean blue carbon through investigation of ocean and carbon cycling interactions

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Outline of Research Project

This research project is aimed at understanding integrally the relationship of the ocean and CO₂ and creating innovations for climate change resilience by applying the maximum use of the ocean's potential. By making use of the project's transdisciplinary approach, it investigates carbon exchange process between atmosphere, land and ocean, and ocean response function including ecosystems towards atmospheric CO₂ concentration increasing.

Specifically, the following three research pillars are set for understanding the effects of increasing atmospheric CO₂ concentration on the ocean: 1) Clarification of the ocean processes involved in its carbon absorption, storage and sequestration, and the ocean feedback processes according to the carbon cycle due to ocean warming, acidification and deoxygenation; 2) Assessment of the effects on ocean ecosystem services resulted from ocean warming, acidification, and deoxygenation, and their feedback processes according to the carbon cycle; and 3) Development of innovative fundamental technologies to clarify and control the relationship between the ocean and CO₂.

For promoting this research project, researchers are required to quantitatively analyze various factors of the carbon cycle including CO₂ with high precision to establish new models and to verify various types of large-scale data. The project therefore welcomes researchers from diverse fields to "unravel the ocean", who have technologies and scientific knowledge such as forestry and agriculture related to terrestrial carbon cycle, information science including machine learning and engineering including measurement technology as well as oceanic research. Through the multidisciplinary research collaboration, the project will promote integrated and flexible management and will also collaborate with the PRESTO research project "Exploration of the blue biosphere-climate system towards carbon cycle management" to maximize outcomes to achieve our strategic goals.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Project

1. Background

Since the Industrial Revolution, the concentrations of greenhouse gases such as CO₂ have been increasing significantly in the atmosphere, and the effects of this increase are becoming a global cause for concern. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states, "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred." The report also concludes, "Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability." In order to reduce the progression of global warming caused by anthropogenic climate change, we have to reduce urgently the anthropogenic greenhouse gases, particularly the atmospheric concentrations of CO₂. While an accurate understanding of the global (atmospheric, oceanic, and terrestrial) carbon cycle system is essential for reducing the atmospheric CO₂ concentrations, the relationship between the ocean, one of nature's largest CO₂ sinks, and CO₂ still remains unclear. In particular, the physical, chemical, and biological processes in the oceans are intricately intertwined, and there are many unknowns regarding ocean's CO₂ absorption and storage capacities, so we don't fully understand the carbon cycle processes. In addition, ocean warming, acidification and deoxygenation associated with increased atmospheric CO₂ concentrations affect marine organisms and ecosystems. There is a possibility that they cause a reduction in the ocean's CO₂ absorption and storage capacity. On the other hand, studies regarding ocean negative emissions are being addressed, but more scientific verification is required to generate effective synergy with the ocean's inherent CO₂ absorption and storage capacity.

2. Principle of invitation project and selection

Based on the background described in 1. above, this research project focus on the following three themes as the project's research pillars regarding the effects of increasing atmospheric CO₂ concentrations on the ocean: (1) Clarification of the ocean processes involved in its carbon absorption, storage and sequestration, and the ocean feedback processes according to the carbon cycle due to ocean warming, acidification and deoxygenation, (2) Assessment of the effects on ocean ecosystem services resulted from ocean warming, acidification, and deoxygenation, and their feedback processes according to the carbon cycle and (3) Development of innovative fundamental technologies to clarify and control the relationship between the ocean and CO₂.

In the call for proposals in this research project, please keep these themes in mind and consider your research team formation that does not get caught up with conventional research frameworks and

propose your approaches to new multidisciplinary research collaboration. Emphasis will be placed on explaining what value will be created by advancing your research project, and how the team formation and the program investigator's leadership will add something of value.

Through this approach, we aim to acquire new discoveries and knowledge, develop new technologies, and create innovative fundamental technologies that make the most of the ocean's potential. We believe that these challenges will contribute to offer new viewpoints for climate change to domestic and global research activities.

The third phase of the call for proposals will have more emphasis on proposals from the following perspectives;

- ✧ Proposals that include new aspects to bridge the knowledge gaps between coastal and open ocean research.
- ✧ Proposals that include the development of sophisticated methods for the quantitative impact assessment of negative emission technologies on the marine environments by introducing big data analyses and AI technology.
- ✧ The proposal includes innovative negative emission technologies that maximize ocean potential.
- ✧ Identification and functional elucidation of new processes involved in ocean carbon sequestration using innovative analyses and measurement technologies and big data analyses.

Examples of research topics are listed below, but your proposal may include more than one topic.

(1) Clarification of the ocean processes involved in its carbon absorption, storage and sequestration, and the ocean feedback processes according to the carbon cycle due to ocean warming, acidification and deoxygenation

We assume that the applicants are multidisciplinary collaborative research teams. The objective is not to expand conventional research, but to clarify yet-to-be-defined processes in the ocean carbon cycle system, the effects of increased anthropogenic CO₂ and greenhouse gases on ocean warming, acidification, and deoxygenation, and their feedback processes to the carbon cycle. We hope to invite widely research proposals that optimize and introduce state-of-the-art measurement and analytical techniques, considering the characteristics and geographical influences of the ocean area (coastal areas, continental shelf areas, open ocean, etc.) to be studied, while also making use of knowledge from marine geology and other disciplines.

Examples of the thematic study are:

1. Comprehensive understanding of the ocean carbon cycle system by integrating data from

physical, chemical, and biological observations in the ocean

2. Identification and functional investigation of new processes involved in ocean carbon storage and sequestration.
3. Understanding the biological pump, alkalinity pump, and solubility pump processes with high spatio-temporal resolution and accuracy.
4. Elucidation of the effects on ocean warming, acidification, and deoxygenation caused by increased anthropogenic CO₂ and greenhouse gases, and their feedback processes on the carbon cycle.
5. Approaches that incorporate the unique ocean characteristics such as ocean depth, topography, and ocean structure. Mapping of deep sea CO₂ storage.
6. Understanding the global carbon cycle by integrating information from micro to global scales.
7. Assessment of the ocean carbon cycle on a global scale using advanced AI-based models and satellite observation systems.

(2) Assessment of the effects on ocean ecosystem services resulted from ocean warming, acidification, and deoxygenation, and their feedback processes according to the carbon cycle

We assume that the applicants are multidisciplinary collaborative research teams. There is widespread concern that ocean warming, acidification, deoxygenation and other changes in the marine environment caused by increased atmospheric CO₂ concentrations make a variety of impacts on marine and other ecosystems. We hope to invite research proposals for these impacts:

1) understanding these impacts in detail by introducing state-of-the-art observation and modeling technologies, 2) understanding the feedback process caused by the impacts on marine ecosystems to the carbon cycle and 3) integrating evidence and models regarding the ecosystem impact at the laboratory level that assumes human intervention, such as negative emission technologies.

Examples of the thematic study are:

1. Quantitative assessment and future projections of the effects of ocean warming, acidification, and deoxygenation on marine biodiversity.
2. Relationships between increased CO₂ and other elements such as nitrogen and phosphorus, and their effects on marine ecosystems.
3. Understanding of feedback processes to the carbon cycle caused by the effects of global warming, acidification, and deoxygenation on marine ecosystems.
4. Improvement of the quantitative evaluation of the CO₂ absorption potential and CO₂

decomposition process of coastal and offshore blue carbon and future prediction using numerical models.

5. Improvement of the quantitative impact assessment of ocean acidification and hypoxia caused by the blue carbon.
6. Genomic analysis of the functions of coastal and offshore blue carbon.
7. Development of quantitative impact assessment methods and evaluation techniques for the marine environment due to the application of negative emission technology.

(3) Development of innovative fundamental technologies to clarify and control the relationship between the ocean and CO₂

The main applicants are expected to be research teams from a variety of research fields consisting of chemistry, physics, engineering, information and computational sciences (including data integration methods and machine learning), mathematics and statistics, civil engineering and environmental sciences. For example, innovative analytical and measurement techniques and sensors applicable to marine science, utilizing data science, and the development of computational and simulation technologies. In particular, we welcome proposals from researchers in applied physics and chemistry who have knowledge and experience in their research field but have not focused on marine science. We look forward to research proposals that try to horizontally deploy and apply proven technologies in academic fields such as electronics and quantum engineering for this research project. The applicants need to explain what ocean processes regarding the ocean and CO₂ relationships do you intend to apply the developed technologies, and what future technological advantages lies on marine sciences. Technological studies that control the relationship between the ocean and CO₂ do not need to reach the demonstration phase at specific marine environment, but they are required to show scientific evidence to do so.

Examples of the thematic study are:

1. Innovative analyses and measurement technologies, long-term stable sensors, low-cost gas flux measurement equipment
2. Quantitative continuous-automated monitoring systems and robotic technologies
3. Innovative technology developments for carbon capture and storage (CCS) in the ocean
4. Innovative negative emission technologies that maximize the ocean potential
5. Numerical simulations that link the overall view of the ocean carbon cycle system in a scaleless approach
6. Technology to enable sustainable use of marine ecosystem services under global climate

change.

The above are examples for reference only and are not limited to your research proposal and approach to be applied for.

3. Research periods and research funds

The research period begins in fiscal year 2023 and ends in fiscal year 2028 (five and a half years or lesser).

The budget for one research project at the beginning is 300 million yen at the maximum (direct expenses). The proposed research expenses should be required to accomplish the proposed research. Please note that the research budget may be adjusted after careful examination by the research supervisor when the proposal is adopted. The budget will be reviewed on an annual basis, which may be increased or decreased in accordance with the research progress.

After the adoption, an evaluation including a decision on whether or not to continue the proposed research will be conducted approximately three years after the beginning. Depending on the evaluation results, we may increase or decrease the research budget or reorganize the research team.

4. Points to be considered when making a proposal

The applicants to this research project “Exploring the potential of ocean blue carbon through investigation of ocean and carbon cycling interactions” should use the dedicated application form specified for the application. Please explain in your proposal clearly: “Background and Proposed Objective”, “target of proposed research project”, “research plans and approach”, “the proposed team formation: research infrastructure and readiness” and originality and novelty of the proposed research and comparison to current state of similar studies”. The research plan should be filled it out specifically.

- We welcome original and ambitious proposals from all researchers including female and young researchers to ensure a diverse and balance perspective.
- Proposals from other fields besides marine science, such as applied physics, chemistry, information and mathematical sciences, and engineering, are also welcome.
- Proposals should include proposed advantages of innovative fundamental technologies that take into consideration previous or similar studies and technologies.
- Proposals that take into account the development of human resources with cross-disciplinary expertise are also welcome.

5. Principle of research-area management

(1) R&D Management

In CREST, the entire research project is regarded as a network-type research institute, and each

proposal is operated in the form of comprehensive collaboration. When the adopted research team necessitates collaboration with other research teams due to the research progress, we will proactively support such collaboration. In addition, in order to maximize the research outcomes to achieve the strategic objective, we encourage not only collaboration within this CREST project, but also collaborative research in which CREST researchers and PRESTO researchers are able to progress their respective research activities. We are also considering research management for young researchers who will be able to get various knowledge and skills from our research advisors in different research fields in this project.

In order for researchers with high research ability to further develop their original research to innovation, we believe that it is important for different research fields to function as a multiplier, i.e., a mechanism and/or an opportunity that allows for transdisciplinary research collaboration. As our research management for that, we focus on research cooperation among researchers from different research fields as well as multidisciplinary research collaboration in each research team. For example, we hope to make observation/analysis/technical research bases that allow researchers from various research fields to implement actively research cooperation at one place with their open mind. It is also necessary to establish a database platform that enables sharing of various data and research resources, and a system that promotes research efficiency and data standardization to enhance the scientific reliability while sharing observation monitoring systems and data analysis tools. In addition, the researchers concerned will discuss how this research project can contribute toward open science in the ocean field that more international cooperation is desired.

(2) Activities in this research project after adoption

After the adoption of your proposal, we will hold progress meetings among the research supervisor, the research advisors, the principal investigators and the co- investigators in our project and will review appropriately the proposed research plans to make research the outcomes smoothly.

In particular, it is not so important to take a linear research approach that uses existing technologies and methods for breaking through the goal proposed in advance at the time of your application or adoption. We suggest that researchers of this research project review as appropriate: what needs to be done to reach the goal, before that, what goals are effective for your "innovation and future research vision". Our research management allows to redesign your proposed innovation and effectiveness depending on the research progress. As this research program emphasizes transdisciplinary approach, it may be possible that you encounter new measurement technologies that you have not considered when apply your research proposal. Since this program requires your highly challenging goals and approaches involving research elements that are different from own expertise, we suggest that the researchers check themselves the research progress continuously and update the goals as necessary. Therefore, at our progress meetings, rather than just presenting research in the form of academic

conferences, we will set "questions" to encourage the researchers revise and review their own research directions and plans through our discussion. In order to support such efforts, we value "opportunity" where research teams can casually discuss their research progress with the research supervisor and advisors.

We will also collaborate with other CREST and PRESTO research projects, programs conducted by other ministries such as the Environment Research and Technology Development Fund and will hold workshops and symposia in a view of collaboration with international organizations to share our research outcomes generated in this research project. As a Japan's marine research community, we hope to contribute actively to "United Nations Decade of Ocean Science " and the realization of sustainable use of the ocean.

(3) Collaboration within and outside the research area

We welcome proactive proposals for the use of ocean areas as hubs for research collaboration within and outside this program, and ideas regarding the support functions of oceanographic databases. For example, we will support research plans that researchers in the CREST and PRESTO research project can use and share ocean areas (e.g., specific coastal areas), joint research facilities and research vessels, which are supported by their research institutions. We also welcome research teams that have a common database and support functions such as data analysis and model building that are available to researchers in other teams in CREST and PRESTO research project.

(4) Message from the Research Supervisor

Time is running out for the global warming issue. As a member of Japan, a maritime nation surrounded by oceans on all sides, we must promote research on the relationship between the ocean and CO₂ through international cooperation, implement Nature-based Solutions based on the potential of the ocean, and realize Carbon Blue Transformation (Carbon Blue-X) that is resilient to climate change. In particular, because the "United Nations Decade of Marine Science for Sustainable Development" (2021-2030) is now being implemented, the leadership of Japan as a maritime nation is essential. I would be more than happy to play a role in this research program as the research supervisor.