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

Exploration of the blue biosphere-climate system towards carbon cycle management

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Overview

In this research area, we set our target to the ocean, and pursue sustainable mitigation of global warming. Our main subject is an accurate comprehension of the huge system of ocean and marine life, extending to the climate-induced changes of the ocean and subsequent interaction between the ocean and climate. We also address mitigation technology by artificial control of ecosystems on the line of enhancement of carbon dioxide absorption in the ocean.

The ocean is a highly significant component of the Earth's climate system, owing to its vast surface area that interacts with the atmosphere by exchanging heat and substances such as carbon dioxide. In particular, the marine carbon cycle, which is driven by biological activities, reduces the greenhouse effect by retaining carbon dioxide as inorganic and organic carbon within the ocean interior. At present, however, the global warming has induced changes in this marine environment ("blue biosphere") through modification in physical structure and enhanced carbon dioxide dissolution; the induced changes include sea level rise, more frequent extreme weather events, subsurface oxygen depletion and surface nutrient limitation with the enhanced stratification, and seawater acidification. It is essential to correctly understand these climate-induced oceanic changes and their impact on global climate, or the interaction between the ocean and climate.

In addition to the research concerning the interaction between the ocean and climate, we promote research on possible artificial control of marine ecosystems, or development and assessment of technology for artificial manipulations of marine carbon cycle towards global warming mitigation. Research proposals with employment of advanced technology in data science, artificial intelligence, information communication, material and device engineering, and in other areas are welcome. In addition to environmental science, meteorology, physical oceanography, analytical chemistry, ecology and life science, proposals from all the research disciplines will be considered. Also considered will be various research approaches including observation, theoretical analysis, numerical simulations,

laboratory experiments, and shipboard experiments. Research covering any of spatial scales from the local to the global and any of time scales from the geological past to the future are also welcome. With all the research integrated, our understanding of marine carbon and other material cycles will contribute to the artificial regulation of them. Additionally, we achieve our strategic goals by full collaboration with the CREST research area "Exploring the potential of ocean blue carbon through investigation of ocean and carbon cycling interactions".

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

1. Background and Objectives

Anthropogenic changes in global environment evolve as carbon dioxide (CO_2) and other greenhouse gases accumulate in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) expressed concern that, even with the substantial reduction of emissions under international agreements in the future, the impact on the environment and the ecosystem will be enormous. Climate is literally controlled by the ocean; it covers 71% of the earth's surface and exchanges heat and various substances such as CO_2 with the atmosphere, and thus is a crucial component of the earth's climate system. In fact, the IPCC AR6 stated that the ocean absorbs approximately one-quarter of the annual anthropogenic CO_2 emissions. Additionally, the marine carbon cycle, which is driven by biological activities, plays a vital role in retaining CO_2 as inorganic and organic carbon in the intermediate-deep seawaters and seafloor sediments, thereby isolating it from the atmosphere; this carbon sequestration is estimated to be equivalent to 150 to 200 ppmv in the atmosphere.

The global and hence the oceanic warming will cause more frequent extreme weather events and sea level rise, posing a direct risk to human society. Furthermore, the enhanced stratification due to the surface ocean warming causes subsurface deoxygenation and surface nutrient limitation. Concurrently, the enhanced dissolution of the increased atmospheric CO_2 promotes the seawater acidification. All of these changes have significant impacts on marine life, and increase the risks to biodiversity and ecosystem services. More importantly, however, the effects of the changes in oceanic system may return to the climate subsequently, likely through changes in the marine carbon cycle. We would call this whole oceanic system, including marine life and material cycles, the "blue biosphere".

Accurate understanding of the blue biosphere, including its transformation and its interaction with climate, is crucial to the highly accurate future predictions which would help human society in their adaptation and mitigation of the climate change. Mitigation measures would possibly include artificial enhancement of the oceanic CO_2 absorption. Successful development of the measure would significantly contribute to humanity's goal of curbing global warming. In this research area, the main emphasis lies on development of technology that enables control of CO_2 absorption through artificial manipulation of the carbon cycle. The artificial control should be based on full comprehension of the blue biosphere, and of course the main emphasis lies equally on a wide range of basic research of the blue biosphere and its interactions with climate.

With these backgrounds, we focus on cross-disciplinary research on the following three areas.

(1) Understanding climate-induced changes and predicting the future

Climate-induced changes in the marine environment include warming, acidification, and deoxygenation. They impact on physical ocean structure and seawater circulation, and on cycling of carbon and other materials, and hence affect the exchange of heat and CO_2 with atmosphere. Understanding the interaction between the ocean and climate will be the key to highly accurate predictions about the future.

(2) Assessing impacts of marine life and ecosystem changes

Climate-induced changes in the marine environment impact on marine biological communities. Change of marine life affect the cycling of carbon and other materials, and consequently, the climate. A comprehensive assessment that includes impacts on biodiversity, marine fisheries resources, and human society will be essential to future predictions.

(3) Verifying, evaluating, and innovating marine negative emission technology

Artificial control of CO_2 and other greenhouse gases would play a central role in mitigation of climate change. Strategies and technology seeds will be developed by verifying, evaluating, and innovating technologies that utilize ocean and/or its organisms (or biological communities).

2. Examples of research projects

Regarding areas (1) and (2), we will accept physical- oceanographic and meteorological studies to comprehend the ocean-climate system and flow and exchange of heat, carbon, and other substances. Physical, chemical, and biological processes that constitute and drive the system, as well as the exchange processes with land, atmosphere and seafloor, will be also accepted as research subjects. We

will not set limits on spatial or temporal scales; they may range from the local to the global, and from the geological past to the future. Regarding the biological activities that drive carbon and other material cycles, research at various levels, ranging from biological communities to individuals and cells, are equally considered. All the research approaches, including laboratory experiments, shipboard experiments, observations, theories, and numerical models, are also taken into consideration. We also welcome proposals of novel observation technology, and of innovative model and computational technology that significantly improves the ability of numerical simulations.

Regarding area (3) or technology for artificial control of carbon cycle, we will consider a broad range of proposals from conceptual stage to improvement of an existing technology, if the proposal has potential to contribute to global warming mitigation along with reasonable energy budget and environmental impact.

Furthermore, we anticipate research and technology development that incorporates currently advancing technology such as data science, artificial intelligence, information communication, material and device engineering. While the primary outcome is climate change mitigation, we also welcome research on management of fishery resources and prevention of disasters. Since social and international processes also play a significant role in climate adaptation and mitigation, research in the humanities and/or social sciences and interdisciplinary research will be considered as well.

Examples of themes that can be considered include:

(1) Highly accurate reproduction and prediction of changes in physical oceanographic processes, carbon cycles, or marine ecosystems, through numerical simulations and data assimilation with coupled atmosphere-ocean or with ecosystem modelling

(2) Physical and other oceanographic research on changes in the ocean-climate system

(3) Investigation of control processes of vertical mixing, biological activity, and carbon cycle through mesoscale physical processes

(4) Research based on data/information science toward understanding and controlling the marine carbon cycle using huge oceanographic data

(5) Understanding and modeling the dynamics of nutrients and trace metals that drives primary production and carbon dioxide absorption

(6) Quantitative evaluation of organic carbon burial in coastal sediments and organic carbon export to the open ocean

(7) Development of sensors for nutrients, carbon dioxide, and other relevant parameters, as well as development of observation platforms utilizing robot technology

(8) Reconstruction of the interaction between climate and marine ecosystems through proxy analysis of microfossil compositions, biomarkers, isotopes, etc. of seafloor sediment cores

(9) Prediction of atmospheric deposition or terrestrial load of materials to the ocean, and assessment of their impact on the ecosystem and carbon cycle

(10) Modifications in interactions between terrestrial and coastal systems due to climate and marine environmental changes

(11) Changes in biological communities and ecosystems due to marine heat waves, acidification, deoxygenation, etc., and projections of changes in the carbon cycle

(12) Quantitative understanding of population dynamics or metabolic activities in surface marine plankton communities using molecular biological techniques

(13) Quantitative observation and simulation of the organic carbon sequestration process in seaweed (or seagrass) beds

(14) Evaluation of carbon burial/sequestration and application to CCS by elucidating sedimentation processes on the seafloor

(15) Quantitative evaluation of carbon sequestration by formation of persistent dissolved organic matter in seawater

(16) Development of carbon dioxide absorption technology by creating an artificial coastal marine ecosystem

(17) Functions and carbon budgets of distinctive coastal ecosystems such as coral reefs and mangrove forests, and use of these systems for mitigation of climate change

(18) Development of aquaculture systems and marine structures that have synergistic effects with blue carbon

(19) Regional and international efforts of coastal ecosystem conservation and/or fishery resource management that contribute to the mitigation of greenhouse gas emissions and social adaptation to global warming

(20) Humanities or social scientific research on economic incentives and international cooperation to promote blue carbon and CCS in marine areas

*The above items are examples for reference, and the research themes and approaches in proposals are not limited to these.

3. Selection policies

We invite proposals from all research fields, regardless of the applicants' experiences in ocean studies. Successful applicants may understand the crucial necessity for research and technology development concerning the blue biosphere and its carbon cycle. They are expected to have strong motivation to join in the areas of ocean studies. The marine research field has historically been biased in terms of gender. As we seek to foster researchers who will lead the next generation of science and technology, we strongly encourage applications from female researchers. Furthermore, since climate and marine ecosystem change has significant societal and cultural impacts, and involves social or international responses, we welcome research proposals from the fields of humanities and social sciences.

In this call for proposals, we are particularly looking for proposals in fields which have not seen a sufficient number of proposals accepted over the past two years; these fields include physical oceanography and meteorology, humanities/social sciences or related interdisciplinary research, and negative emission engineering at the ecosystem and oceanic scales.

In the selection process, we prioritize the following three criteria:

(1) Academic significance

Beyond unveiling novel features of the marine environment and biological communities, we will evaluate proposals based on the novel ideas and approaches that lead to a paradigm shift and with high significance in the academic field.

(2) Innovative technology

In the case of research proposals focused on technological development, we will assign high priority to those with clear advantage over prior or similar technology and those with original ideas.

(3) Strong motivation and ability to conduct research

Both established marine researchers and those new to the field are equally eligible for application. We will evaluate proposals from individuals who demonstrate a strong motivation for their research or who could enjoy their research. Successful applicants may also have the ability to overcome problems and constraints during their research.

4. Research periods and research expenses

The research period shall be limited to three and a half years from the fiscal year of selection, and

the total allocated research expenses shall not exceed 40 million yen (excluding indirect expenses). During the selection process, we will assess whether the proposed research expenses are aligned with the research plan. The research expenses guideline do not exclude proposals with smaller budget sizes.