SEAWATER CARBON DIOXIDE DYNAMICS IN STRATIFIED SHALLOW COASTAL WATERS: FIELD MEASUREMENT AND NUMERICAL MODELING IN THE YATSUSHIRO SEA, JAPAN

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（成層した沿岸浅海域における海水中 CO_2 動態：八代海における現地観測と数値モデリング）

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論　文　内　容　の　要　旨

In recent decades, climate change has affected natural and human systems on all continents and oceans. The global climate change observed since the beginning of the 20th century has been mainly driven by human activities, especially the burning of fossil fuels, which increase the greenhouse gases in the Earth's atmosphere. Carbon dioxide (CO_2) emissions, which account for more than 70% of greenhouse gas emissions, are considered one of the most important contributors to global warming and climate change. From the Mauna Loa Observatory in Hawaii, atmospheric CO_2 concentrations have jumped from 315 ppm in 1958 to 411 ppm in 2019 over the past 60 years. Therefore, controlling the increase of CO_2 in the atmosphere has become an urgent issue that the world needs to face together.

The ocean, which stores and sequesters large amounts of CO_2 in the form of dissolved inorganic carbon (DIC), can buffer the increase in atmospheric CO_2 concentration. A lot of studies have indicated that the global ocean hosts a substantial reservoir of CO_2 that is 50 times greater than that in the atmosphere and is considered an extremely significant net sink of atmospheric CO_2.

Meanwhile, several studies have demonstrated that shallow coastal waters with vegetation such as seagrass, mangroves, and salt marshes contribute more than half of the total oceanic carbon storage despite making up only 0.5% of the ocean area, owing to them having the highest carbon burial rates in the ocean. Therefore, the shallow coastal waters are also considered to be potentially the most efficient carbon sink on the Earth. In order to assess the contribution of these waters to the reduction of atmospheric CO_2, CO_2 fluxes (F_{CO2}) are being estimated globally in various regions. However, due to the complexity of the biogeochemical processes in these waters, the distribution and dynamics of CO_2 in seawater have uncertainty. Stratification, which often occurs in shallow coastal waters, is considered to be one of the important factors affecting the biochemical dynamics in seawater. In order to better understand the carbon cycle in shallow coastal waters and improve the accuracy of F_{CO2} estimation, it is necessary to grasp and analyze the carbon dioxide dynamics in seawater by considering the effects of stratification.

In this research, we selected the Yatsushiro Sea as the target area, which is highly enclosed and susceptible to stratification in summer. Through a combination of field measurements and 3D numerical simulations, we aim to address the following scientific questions: Does stratification affect seawater CO_2 dynamics of the Yatsushiro Sea, and how does it do so? What are the other influencing factors? What are the characteristics of CO_2 distribution in the bay throughout the year, and what are the factors that affect it? Is

the bay a source or sink of atmospheric CO_2 throughout the year? How strong is its intensity?

For answering these questions, the study was divided in some chapter in this thesis, and described as follows:

Chapter 1 explains about research background, research status and issues, research objectives, and also the overview of the thesis as an introduction.

Chapter 2 shows several previous researches related to our study. Also, a definition of blue carbon in shallow coastal waters is indicated. Methods and shortcomings of the current stage of calculating seawater F_{CO2}, the main factors influencing the seawater partial pressure CO_2 (pCO_2) and potential relationship between stratification and seawater pCO_2 in shallow coastal waters are described.

Chapter 3 indicates pCO_2 in the Yatsushiro Sea under density stratification conditions from three field measurements. Moreover, by calculating two indicators of biological processes (ΔDIC and ΔTA(Total Alkalinity)), we revealed the possibility that the CO_2 dynamics at the measurement points are simultaneously influenced by biological processes and other hydrodynamic effects.

Chapter 4 evaluates the effects of seawater inflow from the Ariake Sea and the amount of freshwater inflow from rivers other than the Kuma River through simulations with 3D numerical hydrodynamic and particle tracking models. The results show that the inflow impacts of both components are small enough to be negligible. This result supports our focus on studying the influence of biological processes on seawater CO_2 dynamics only in the Yatsushiro Sea.

In **Chapter 5**, a 3D numerical hydrodynamic-ecological coupled model of the CO_2 dynamics in the Yatsushiro Sea based on the results of field measurement was developed. The developed model reproduced well the distribution of pCO_2, salinity, density, and temperature under different stratification conditions. Furthermore, we confirmed that the CO_2 sequestration around the estuary fluctuates greatly in space and time with the flooding event from the hindcast calculation through the numerical model.

In **Chapter 6**, we further improved the performance of the numerical model to simulate the CO_2 dynamics over the full range of the Yatsushiro Sea. From the simulation results, we can see that stratification has even opposite effects on surface pCO_2, depending on the duration and intensity of the freshwater inflow impact. Moreover, we used the model to estimate the annual pattern of CO_2 flux in the bay in 2018. The results show that the Yatsushiro Sea becomes a source of atmospheric CO_2 in June and July when the freshwater inflow is high and a sink of atmospheric CO_2 at all other times.

Chapter 7 concludes all chapters in this thesis, and also proposes some recommendation for future works.