Global Environment Research Coordination System

Detecting the biogeochemical response to climate change through developing the ocean surface observation network and the international database
(Abstract of the Final Report)

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1. Introduction

Global warming and ocean acidification known as “Evil Twin” would affect oceanic ecosystem seriously as well as the carbon/nutrient cycles. In this program, National Institute for Environmental Studies (hereafter, NIES) and Fisheries Research and education Agency (hereafter, FRA) implement their observations and carry out seawater sampling for understanding the carbon dioxide (CO_2) /nutrient cycles. Furthermore, both institutes contribute the international partial pressure of ocean surface CO_2 (pCO_2) database named Surface Ocean CO_2 Atlas (SOCAT: https://www.socat.info, Bakker et al., 2016) by registering the observational data and NIES also contributes it as a data curator to maintain the data quality observed in the North Pacific. We also aim to estimate global pCO_2 and nutrient distributions based on the observation databases and try to detect biogeochemical changes due to the climate change.

2. Research Objectives

In this program, NIES aims to understand the carbonate system parameters such as pH and Dissolved Inorganic Carbon in the Pacific Ocean by collecting water samples for alkalinity as well as pCO_2 observation. NIES also examines the role of inner bays of Japan on carbon cycle. FRA aims to investigate the oceanic nutrient/carbon cycles, especially in the coastal regions where NIES cannot cover by its observation.

NIES also plans to contribute SOCAT by submitting its pCO_2 observation data as well as by checking the data quality.

NIES estimates the distributions of oceanic surface carbonate system and nutrients based on observation databases over a global scale and ties to detect biogeochemical response to climate change.

3. Research Methods

NIES has measured Alkalinity in the seawater samples and examines the observed alkalinity distributions etc. It also evaluates air-sea CO_2 exchange in the inner bays of Japan such as Tokyo Bay, Ise Bay and Osaka Bay using with pCO_2 data taken by NIES Voluntary Observing Ship program as well as carbonate data measured by other institutes. FRA has also implemented the pCO_2 measurements using its research vessels.

In order to contribute SOCAT database, NIES and FRA submit their pCO_2 datasets as soon as possible after they observe. Moreover, NIES implements the quality assurance of the pCO_2 data mainly observed in the North Pacific (north of 30ºN) by other institutes.

NIES evaluates the temporal and spatial variations of carbonate system parameters in the global ocean based on pCO_2 observations recorded in SOCAT.

4. Results and discussions

NIES has collected 254 samples for Alkalinity in the North Pacific, and some of them were obtained in areas where few observations have been made. The result shows that strong relationship between Alkalinity and salinity is apparent. In the analysis of air-sea CO_2 exchange in inner bays of Japan based on pCO_2 observations, NIES found that these bays strongly absorbed atmospheric CO_2, biological effects accounted for 6 %–27 % of the evaluated CO_2 absorption and had significant effects on its seasonal variation, and the biological effects seemed to be mediated mainly by the low degradable carbon/nutrient ratio in wastewater. This study should improve our understanding of the carbon flow in urbanized coastal areas, which are expanding globally.

FRA has obtained pCO_2 data and nutrient samples in 51 cruises by using two research vessels for 5 years. All pCO_2 data cruise has been sent to SOCAT after quality control. It examined the forcing factor that control spatial pCO_2 pattern based on the pCO_2 observations in southern Okhotsk Sea during summer season (Jun.–Aug.) in 2017, 2019 and 2020. Observed pCO_2 variation within the Kuril Basin Water was mostly explained by thermodynamic change of pCO_2 caused by water temperature warming from June to August. Both biological processes and water mixing made little contribution. In the 2018-2019 survey, pCO_2 data for the inner region during the Kuroshio meander in summer were obtained. Therefore, the differences in pCO_2 distribution patterns in the inner Kuroshio region during the meandering and non-meandering periods were analyzed by comparing this data with previous non-meandering pCO_2 observations registered in SOCAT. The spatial variation of pCO_2 in the inner Kuroshio during the meandering period was found to be within a relatively narrow range of about 380-400μatm compared to that during the non-meandering period.

NIES also has sent 198 cruises pCO_2 data to SOCAT for 5 years. It has assured the data quality taken by other institutes observed in the North Pacific as a responsible institute in the region and has supported the institutes to submit/improve their pCO_2 data. Using SOCAT pCO_2 data, NIES estimated the monthly distributions of pCO_2 and air-sea CO_2 flux from 2001 to 2019, and the evaluated oceanic CO_2 exchange. Temporal variation in the evaluated oceanic CO_2 uptake in the global ocean shows that it remains relatively stable within 2 to 2.5 PgC yr^{-1} from 2001 to 2011, then increased rapidly after 2012 and reaches 3.0 PgC yr^{-1} by 2019 (Figure 1). The evaluated values are good agreement with those of Global Carbon Budget 2021(Friedlingstein et al., 2022[2)]). It is found that CO_2 uptake is enhanced (otherwise CO_2 source is weakened) in many regions except the Indian Ocean, the tropical to subtropical Atlantic, and the subtropical to temperate North Pacific during the period.

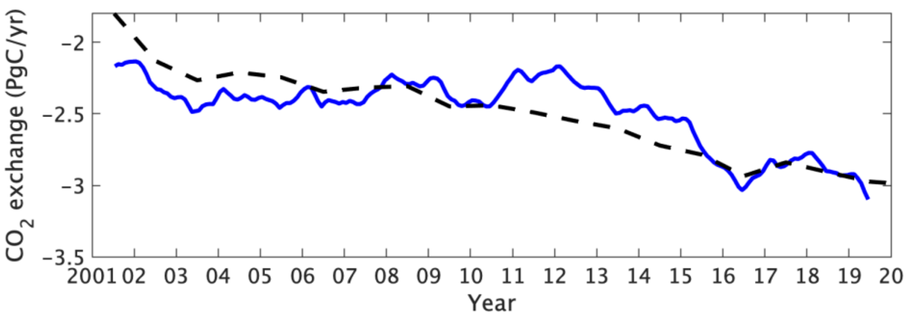

Figure 1. Temporal variation in the evaluated oceanic CO_2 uptake in the global ocean. The blue line represents estimate of this work and the black dotted line values reported by Global Carbon Budget 2021 (Friedlingstein et al., 2022[2)]).

Then the distributions of Dissolved Inorganic Carbon (DIC) concentration, pH, and aragonite saturation (Ω_{ar}) etc. were evaluated based on the estimated pCO_2 distribution. The mean secular trends of DIC, pH, Ω_{ar} in the global ocean surface layer were 0.73 μmol kg^{-1} yr^{-1}, -0.0018 yr^{-1} and -0.0076 yr^{-1}, respectively, which were good agreement with reported pH and Ω_{ar} of Iida et al., (2021). NIES evaluated when the growth of aragonite-forming organisms (e.g., scallops, oysters, sea urchins, corals) would be affected by ocean acidification based on the evaluated trend (Figure 2). The result suggested that the growth of organisms might have already been affected in the mid- to high-latitude zones in both the Northern and Southern Hemispheres. It also suggested that some areas of the mid-latitudes that were currently unaffected would be affected in the coming decades. Since this kind of expectation based on only observations is rough, cooperation with marine biophysical-chemical models and biogeochemical observations is essential for more precise future predictions of ocean acidification.

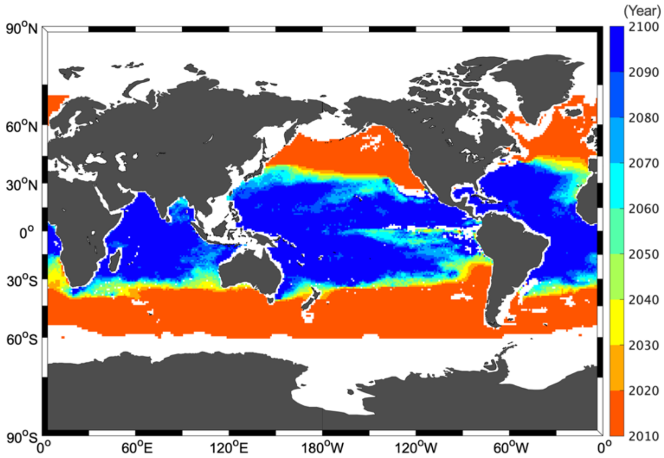

Figure 2. Distribution of periods when the maximum seasonal change in Ω_{ar} is below 3.

Finally, NIES also estimated the nutrient distributions based on the observations. The results clearly suggested that the relationships between climate change factors such as PDO, NPGO, and ENSO and each nutrient concentration variation were clarified, and the evaluated trends implied the possibility of reduced nutrient supply from the sub-surface due to warming and increased nitrate supply due to nitrogen deposition from the atmosphere.

References

1) Bakker et al. (2016) A multi-decade record of high quality fCO_2 data in version 3 of the Surface Ocean CO_2 Atlas (SOCAT). Earth System Science Data, 8: 383-413. https://doi.org/10.5194/essd-8-383-2016.

2) Friedlingstein, P., et al.,(2022) Global Carbon Budget 2021, 14, 1917–2005, https://doi.org/10.5194/essd-14-1917-2022.

3) Iida et al., (2021) Global trends of ocean CO_2 sink and ocean acidification: an observation-based reconstruction of surface ocean inorganic carbon variables. Journal of Oceanography, 77: 323-358, https://doi.org/10.1007/s10872-020-00571-5