Global Environment Research Account for National Institutes

Studies of ocean surface CO_2 partial pressure and nutrients mappings using international integrated databases（Abstract of the Final Report）

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1. Introduction

The global ocean is the largest natural CO_2 sink, and its storage amount is so extensive. There has existed disequilibrium of the CO_2 concentrations between ocean and atmosphere with lower pCO_2 at the ocean surface than that at the atmosphere. The understandings of the temporal and spatial change in the oceanic sink and source of CO_2 are quite important for estimation of the future carbon balance, which could be significant for the necessary mitigation to ensure the safe stabilization level of atmospheric CO_2.

As the oceanic pCO_2 and nutrients are only measured by in situ observations on ships or buoys, global observations have been promoted under the international collaboration including Japanese institutions, which have been continuing important roles in the North and West Pacific regions. National Institute for Environmental Studies (hereafter, NIES) is operating North Pacific oceanic pCO_2 observation by volunteer observation ships (VOSs) since 1995. In 2007, an international integrated database project was proposed by UNESCO/IOCCP (International Ocean Carbon Coordination Project) as SOCAT (Surface Ocean Carbon Atlas). The project is effective for integration of global pCO_2 dataset and for international scientists to analyze and model the ocean carbon cycles. The data center for global database has been established, settling core offices in Bergen University, Norway, and NOAA/PMEL (National Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory), USA. On September 2016, the fourth version of SOCAT database was released. Now the SOCAT activity is preparing the fifth version of database planned to release on 2017 summer. NIES has been expected to contribute SOCAT, as not only a data provider of NIES VOSs, but also a data curator to maintain the data quality. In addition, constructing of nutrients database is getting more and more needed for understanding/predicting of global biogeochemical cycle since observation data is limited. For promoting the pCO_2 measurements and nutrient sampling in the North Pacific, Fisheries Research and Education Agency (FRA) also carried out pCO_2 monitoring in near-Japan western North Pacific regions by using fisheries research vessels in this project with NIES.

2. Research Objective

NIES VOSs, mainly planned for contributing the SOCAT project, are one of major data contributors of SOCAT project. It promotes a timely data submission of NIES pCO_2 observational dataset to SOCAT and also supports other Japanese institutes to submit pCO_2 data set, as a Pacific hub institute for SOCAT project.

The ocean surface as a CO_2 sink and source is an important component of ocean carbon cycle including physical and biological processes. This program also contributes data analysis using SOCAT database to estimate temporal and spatial variability of ocean surface pCO_2 in the global ocean using a neural network technique, which is suited for estimating non-linear relationship with ocean parameters and pCO_2.

This research program also promotes continuous measurements of nitrate concentration by a nitrate sensor and constructing of a sampling network of surface seawater for nutrients. The technique of the neural network and optimum interpolation are also applied to estimate distribution of the nutrients (Phosphate, Nitrate and Silicate) in the North Pacific where enough nutrients data in the regions are found by integrating the datasets of NIES and Institutes of Ocean Science (IOS), Canada.

3. Results and Discussion

(1) NIES VOS data management and the contribution of SOCAT

In the activity of SOCAT database, NIES takes responsibility in quality control (QC) of North Pacific dataset. NIES has completed QC more than 1250 cruises in the North Pacific, as well as in the equatorial Pacific, the North Atlantic and the Southern Ocean as SOCAT requested (Fig. 1). Most of NIES cruise data are evaluated as flags A or B and its percentage of all A and B cruises are about 23%. By recognition of NIES achievements, NIES was awarded the POMA Award from the PICES in 2014 and former representative investigator Dr. Nojiri was awarded a prize of Uda Award in 2015 from the Oceanographic Society of Japan for continuing VOS observations since 1995.

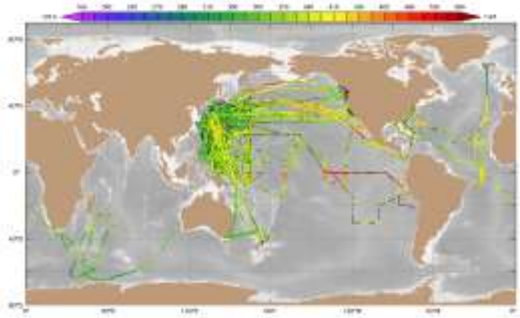

Fig. 1. Cruise tracks that NIES has confirmed the data quality for SOCAT version 5.

(2) Global scale estimation of pCO_2 distribution with the neural network technique

We have estimated the global monthly pCO_2 distributions from 1990 to 2014 using SOCAT database with some neural network methods (Back propagation, Self-Organizing Map, Support Vector Machine) and evaluated sea-air CO_2 exchange (Fig. 2). Fig. 2 clearly indicates that oceanic CO_2 uptake increase gradually since 2001. It also suggests oceanic CO_2 uptake is relatively high in 1998 on the El Niño period, and low in 2000 on the La Niña period due to the changes of ocean circulation.

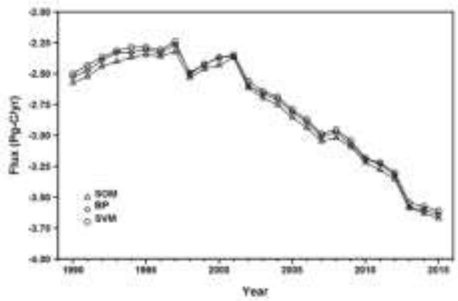

Fig. 2. Interannual variation of the global sea-air CO_2 exchange from 1990 to 2014.

(3) Constructing ocean surface sampling network and its application

A continuous nitrate sensor was installed on New Century 2 in 2014 and continues to measure ocean surface nitrate concentration in the North Pacific. In this study, we have improved the accuracy of the sensor especially in the low concentration. As a result, the nitrate concentrations by UV sensor are corresponded well with sub-sampling results (Fig. 3), having a linear relationship with high correlation (r^2=0.86). Through the measurements, we successfully captured the spatial change of the nitrate concentration due to the eddies by the warm core and the cold core (Fig. 3).

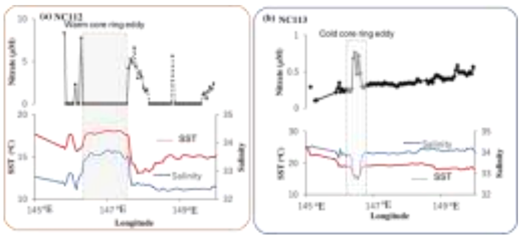

Fig. 3. (a) Longitudinal distributions of nitrate concentration, SST and salinity at 112 cruise. (b) The same as figure (a), but at 113 cruise.

We also estimated nutrients (Phosphate, Nitrate and Silicate) distributions in the North Pacific using a Self Organizing Map technique with integrated observation dataset among NIES, IOS and PACIFICA. The results clearly showed that the seasonal changes agreed with the measurements (Fig. 4) and firstly showed that the North Pacific could be divided into nine regions based on their concentrations and their seasonal variations. Furthermore, we applied nutrients (Phosphate, Nitrate and Silicate) distributions in the North Pacific using the optimal interpolation technique (OI) with the integrated observation dataset. The results clearly indicate that the OI technique is not suitable for basin-scale nutrients mappings but clearly useful for examining trends and interannual variability in nutrients caused by climate oscillation such as the Pacific Decadal Oscillation.

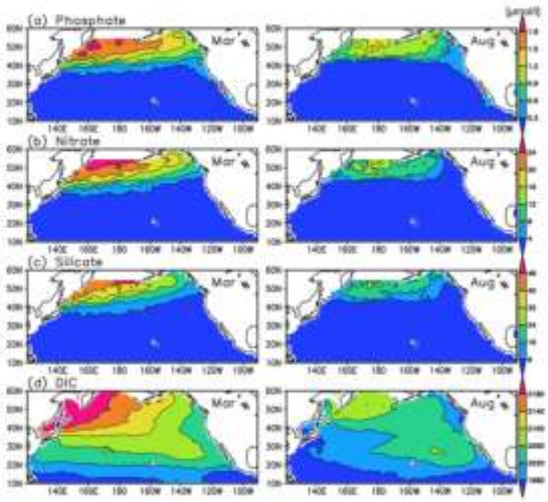

Fig. 4. Long-term mean monthly nutrient concentration distributions of Phosphate (a), Nitrate (b), Silicate (c) and DIC (d) in March (left) and August (right) by this study.

(4) pCO_2 observation and surface water sampling by fishery research ships

Although the NIES VOS program has a big advantage for ocean surface measurements, the data are still limited especially off the coast of Japan. Therefore, we have promoted pCO_2 measurements and water sampling using two fishery research ships by the Fisheries Research Agency through this research program. As a result, pCO_2 data and continuous nitrate data were obtained in near-Japan western North Pacific area, 26°N - 44°N and 127°E – 161°E (Fig. 5). Part of the obtained data were already submitted and published in SOCAT while the remaining ones will be published in SOCAT ver.5. We also installed a nitrate sensor on Soyo-maru and have measured continuous surface nitrate concentration. Analysis of historical pCO_2 data in Suruga-nada area suggested the 20-years increasing rate of pCO_2 differs by month, probably reflecting long-term transformation of seasonal pCO_2 variation. We also observed latitudinal distribution of pCO_2 and nitrate concentration measured by the sensor along 138°E. Variation of nitrate concentration is strongly correlated that of pCO_2 and they increase on the north of 33.2°N.

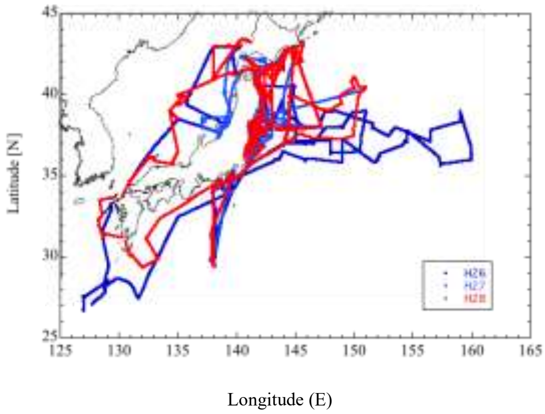

Fig. 5. Map of pCO_2 observation by FRA fisheries research vessels.

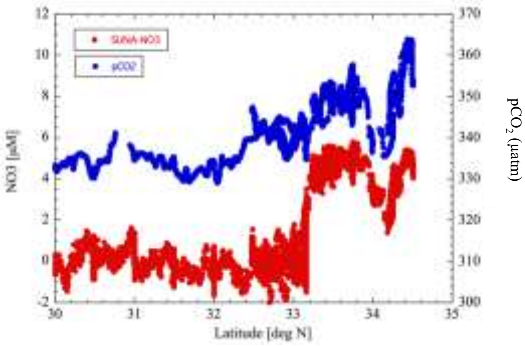

Fig.6. Latitudinal distributions of pCO_2 (blue) and nitrate concentration (red) observed by the sensor along 138°E.