JMA ENHANCED SHIP-BASED OBSERVATION FOR CLIMATE/CARBON IN THE WESTERN NORTH PACIFIC

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1. INTRODUCTION

The Japan Meteorological Agency (JMA) has conducted ship-based hydrographic observations along several sections in the western North Pacific, including the meridional section of 137ºE, for more than 40 years. It is notable that repeat observation of CO_2 in the air and surface seawater has been conducting since 1980s, and the carbon-related observations such as total inorganic carbon since 1990s. The long-term repeat observation revealed high variability in mass/heat transport and water property associated with broad range of variations from seasonal to decadal time scale over the North Pacific. JMA distributes their hydrographic data through online archives: http://www.data.kishou.go.jp/kaiyou/db/vessel_obs/data-report/html/ship/ship_e.php.

In recent years, the drastic innovation related to ocean observations/data such as satellites, Argo, and data assimilation system is ongoing, and the social concern on climate issues, in particular, on global warming is increasing. In these circumstances, JMA decides to enhance its ship-based hydrographic observation with focus on carbon cycle and its variability in the western North Pacific.

2. OCEAN VARIABILITY IN THE WESTERN NORTH PACIFIC

JMA's observation shows that the transport of the Kuroshio, the western boundary current in the subtropical North Pacific, has a strong seasonal variability. In regard to the interannual variability, the Kuroshio transport varies with a lag of 3 years after the wind stress curl in the central North Pacific, as a result of a dynamical adjustment through large-scale Rossby waves [1, 2].

There exist several subsurface water masses in the western North Pacific, such as the North Pacific Intermediate Water (NPIW) and Subtropical Mode Water (STMW). The observation shows the interannual variations of these water masses in their properties and/or distributions, that are strongly correlated with the change of climate variations over the North Pacific such as ENSO and PDO [3, 4].

3. pCO$_2$ VARIABILITY IN THE WESTERN NORTH PACIFIC

JMA Research Vessels Ryofu Maru and Keifu Maru have collected CO_2 data in the air and seawater of the western North Pacific for more than 25 years.

At mid-latitude, partial pressure of carbon dioxide (pCO_2) in the surface seawater has a strong seasonality: low pCO_2 in winter and high in summer. In winter, despite of a large supply of carbon from deep layer, high solubility in low temperature overwhelms the supply and pCO_2 is decreased. As a result, in winter a large amount of carbon is absorbed.

As for the interannual variability, pCO_2 in the equatorial region shows large variations, depending on oceanographic conditions related to ENSO. Meanwhile, pCO_2 variations in the subtropics have less correlation with ENSO, but correlate with mixed layer depth changes there [5].

The oceanic CO_2 concentration averaged between 7ºN and 33ºN along 137ºE in winter has increased by 40 ppm from 1984 to 2009. The growth rate is comparable to that in the atmospheric CO_2. This implies that the western North Pacific remains to act as a sink for the atmospheric CO_2.

4. CARBON UPTAKE IN THE WESTERN NORTH PACIFIC

Seasonality is important in carbon cycle in the North Pacific, since a huge amount of surface water is subducted around the Kuroshio Extension region in the western Pacific. Subducted water such as STMW and the Central Mode Water would play a major role to transport carbon from the surface into the subsurface layers. In fact, the analysis based on the WOCE-P2 data along 30ºN shows that the anthropogenic CO_2 inventory increase from 1994 to 2004 is larger in the western Pacific than that in the eastern Pacific, because the ventilated Mode waters are occupied in the western Pacific [6].

In the northern subtropical gyre at 137ºE and at 165ºE, an increasing trend of dissolved inorganic carbon (DIC) has been detected on isopycnal layers above the upper NPIW at $26.6\sigma_\theta$ [7]. In order to clarify the impact of anthropogenic CO_2, we subtract the biological uptake

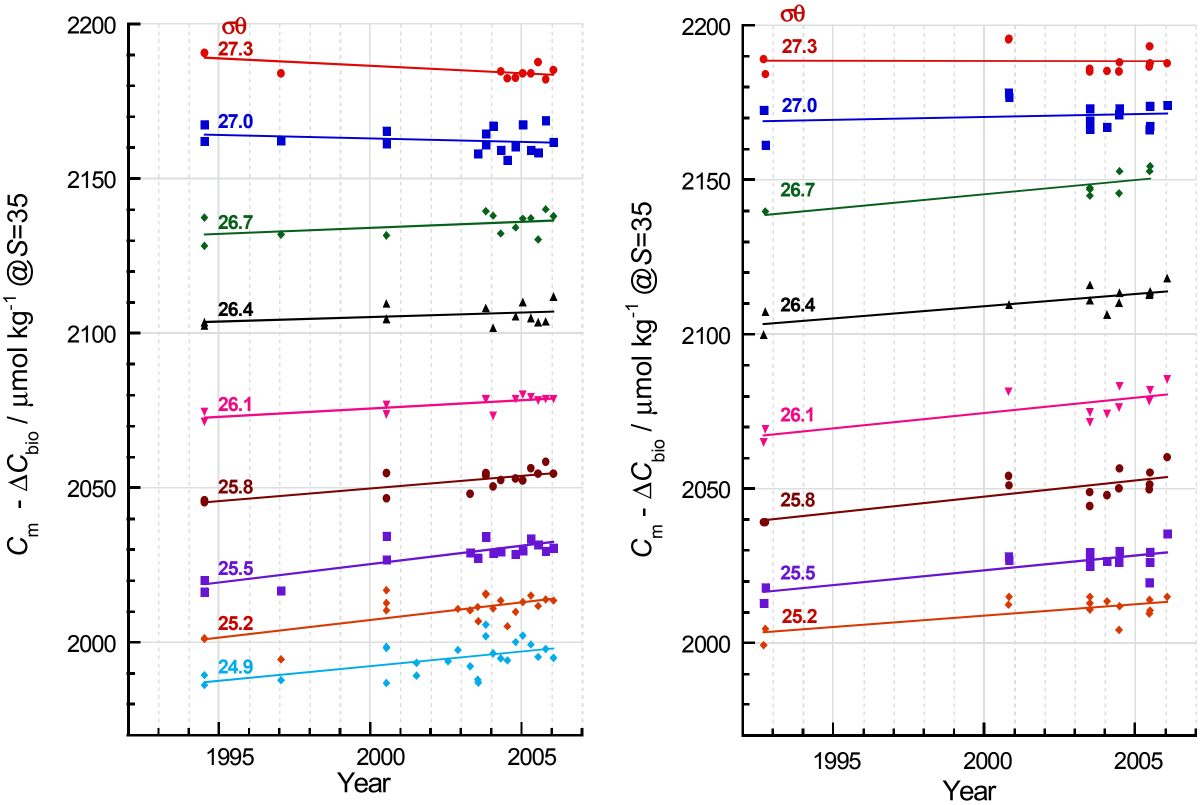

Figure 1. Trend of preformed DIC on isopycnal surfaces [7]
(left) 137ºE, 27.5-31.5ºN and 135.25ºE,29.5ºN from 1994 to 2006.
(right) 165ºE, 28-30ºN from 1993 to 2006.

using dissolved oxygen data from observed DIC to estimate "preformed" DIC. The change in the preformed DIC reflects the change in DIC due to anthropogenic CO_2 invasion. At the same area, dissolved oxygen in the subsurface depth shows a gradual decreasing tendency. This decrease may be attributable to the increase in biological carbon uptake in the STMW layer [8].

Fig. 1 illustrates that a significant increasing trend of the preformed DIC (+0.8 to +1.5 μmol kg^{-1} yr^{-1}) is found in the layer above the NPIW (lighter than 26.6σ_θ). In contrast, no significant DIC increase has been observed on the isopycnal surfaces below the NPIW (denser than 27.0σ_θ) which does not outcrop in the Northern Pacific [7].

At high latitudes, biogeochemical process associated with spring blooming may play an important role in carbon cycle. In this regard, the in-situ data of biogeochemical parameters is valuable for validating the satellite data.

5. ENHANCED SHIP-BASED OBSERVATION NETWORK

For comprehensive survey for the climate and carbon cycle in the western North Pacific, JMA will enhance ship-based observation network, consisting of long-term monitoring sections (137ºE and 165ºE) and supplemental zonal/meridional sections as shown in Fig. 2 from 2010. All the sections will be occupied semi-annual or annual basis for upper 2000m water column with nominal 60 nautical mile spacing. Measuring parameters are DIC and alkalinity in addition to the minimum core variables; temperature, salinity, oxygen and nutrients. Underway measurements consist of following parameters; pCO_2, SST, SSS, chlorophyll (fluorescence) and ocean currents. In addition, WHP-spec survey will be conducted for one specified section each year. That is, each section will be observed by the WHP-spec with 6 year interval. The WHP-spec means full-depth and full core variables (i.e., T, S, oxygen, nutrients, CFCs, DIC, alkalinity and pH, etc.) observation with nominal 30 nautical mile spacing.

Due to strong seasonality in carbon cycle, time-series observation is important in the subarctic region. Combination with time-series stations data such as Station K2 will help understanding interannual to decadal variability as well as long-term trend that are associated with the atmospheric CO_2 increase and ocean climate change.

Based on the ship-based and other observations such as Argo and satellites, we will analyze and provide the information in the western North Pacific including carbon inventory, CO_2 fluxes, and mass/heat transport. It is also noted that the data from our network would contribute to calibration of Argo sensor.

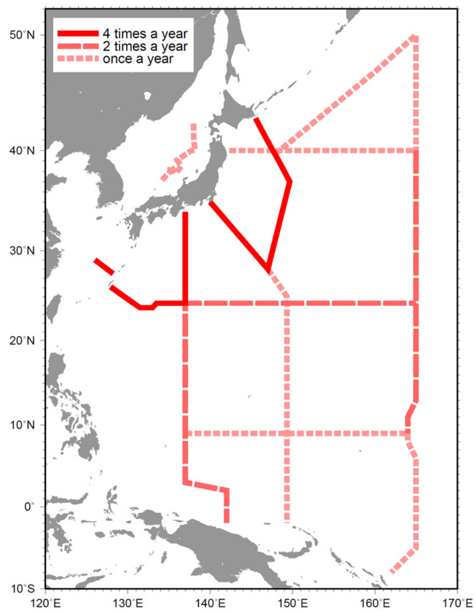

Figure 2. JMA enhanced ship-based observation network

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