Time-series observation for biogeochemistry in the Western Pacific Subarctic Gyre

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Based on the time-series observation for the biogeochemistry at station KNOT (44N/155E) between 1998 and 2001, which was Japanese national project under an umbrella of Joint Global Ocean Flux Study (JGOFS), it was verified that the North Pacific Western Subarctic Gyre (WSG) has large seasonal variability in nutrients, pCO_2, primary productivity and particulate organic carbon flux, and that time-series observation is very important in order to quantify carbon cycle in the ocean and air-sea exchange of CO_2 by, especially, the biological activity (biological pump). Since 2001, time-series observation has been conducted at station K2 (47N/160E) (Fig. 1) by using the subsurface mooring systems (Fig. 2) and research vessel. Our subsurface mooring system consists of various automatic sensor or samplers such as an optical sensor package (BLOOMS), a water sampler (RAS) and sediment traps deployed at multiple layers. Time-series observation of optical field and nutrients at ~ 35 m by BLOOMS and RAS, respectively, revealed that phytoplankton increases and nutrients, especially silicate, decreases largely between late June and early July (Fig. 3). During this time, increase of fluxes of particulate organic carbon and biogenic opal at ~ 150 m was observed by sediment trap. It is indicative of that primary produced or assimilated organic carbon is transported quickly to the ocean interior. Multiple sediment traps from 150 m to 5000 m revealed that 1) biogenic materials are transported vertically without significant lateral transport (Fig. 5), 2) sinking velocity of particles increases with depth, and 3) biogenic opal plays an important role in organic carbon transport (Fig. 4). Seasonal observation of primary productivity, nutrients and natural radionuclide (thorium 234) by research vessel has also revealed that new production, export flux and export ratio are higher than those in other oceans, indicating that the biological pump at station K2 is very efficient for uptake of atmospheric CO_2. On the other hand, long-term increase of dissolved inorganic carbon following increase of atmospheric CO_2 has been observed at station K2 (Fig. 6). It is noted that increase rate of atmospheric pCO_2 ($pCO_{2(air)}$) in winter was higher than that of sea surface pCO_2 ($pCO_{2(sea)}$) in winter. Though $pCO_{2(sea)}$ in winter has been higher than $pCO_{2(air)}$ in winter until now, it is predicted that $pCO_{2(sea)}$ will be higher than $pCO_{2(air)}$ all year round after the middle 21 century. It is indicative of possibility that the ocean acidification will be accelerated after that period and ocean ecosystem will change in the WSG. In order to predict change in the biological pump and its feedback to the global environment, time-series observation should be continued with a new mooring system (optical sensor package including FRRF supported by underwater winch: Fig. 7) at not only station K2, but also a new station located in the Western Pacific Subtropical Gyre as a counterpart of station K2 (Station S1: 30N/145E).

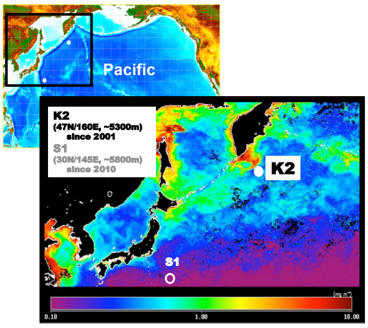

Fig. 1 Time-series station K2 (47°N / 160°E, ~5300 m). This station is located in the Western Pacific Subarctic Gyre. Time-series observation for biogeochemistry with mooring systems and R/V has been conducted since 2001. From 2010, time-series observation will be also conducted at comparative time-series station S1 (30°N / 145°E, ~ 5800m) in the Western Pacific Subtropical Gyre. Ocean color is monthly composite of SeaWiFs chlorophyll-a data in October 2001.

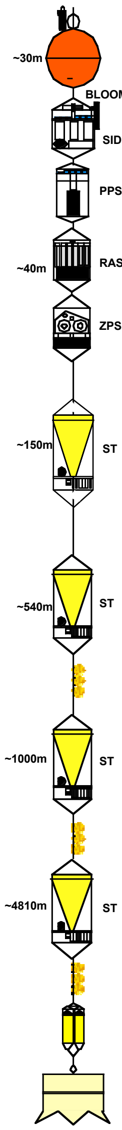

Fig. 2 Subsurface mooring system for the study of biogeochemistry. BLOOMS: optical sensor package, SID: subsurface incubation device, PPS: phytoplankton sampler , RAS: automatic water sampler , ZPS: zooplankton sampler, ST: time-series sediment trap. The depth of top buoy was ~ 30 m and BLOOMS, SID, PPS, RAS and ZPS were located in the euphotic layer (upper 50 m).

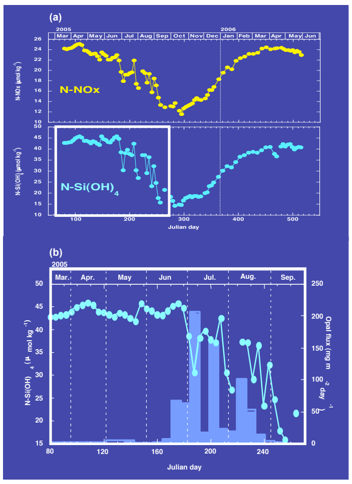

Fig. 3 (a) Seasonal variabilities in sum of normalized nitrate and nitrite (N-NOx) (upper) and normalized silicate (N-Si(OH)$_4$)) (lower) between Mar 2005 and May 2006. These were observed by automatic water sampler (RAS). It is suspected that decrease in nutrients from March 2005 to October 2005 was attributed to uptake of nutrients by biological activity and increase in nutrients was attributed to supply of nutrients from subsurface by winter vertical mixing.

Fig. 3(b) Seasonal variabilities in N-Si(OH)$_4$ (circles) and biogenic opal flux at 150 m observed by time-series sediment trap (bar graphs) between March 2005 and September 2005. Increase in biogenic opal flux synchronized well with decrease in N-Si(OH)$_4$.

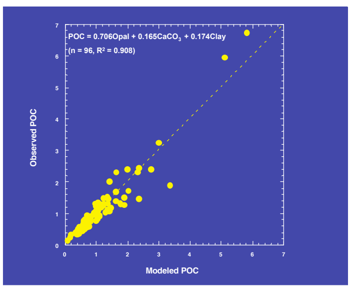

Fig. 4 Observed particulate organic carbon (POC) flux obtained by time-series sediment trap since 1998 and modeled POC flux. Modeled POC fluxes were estimated under assumption that POC flux were transported by ballasts (opal, $CaCO_3$ and clay minerals) and with multiple regression analysis. It was suspected that approximately 70% of POC were transported by opal.

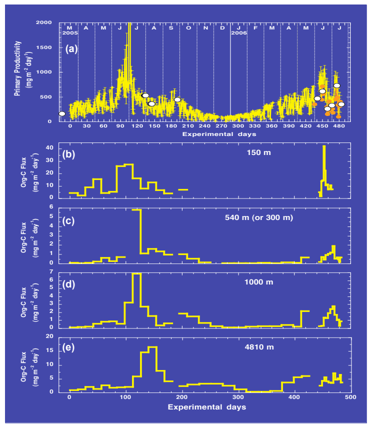

Fig. 5 (a) Seasonal variability in primary productivity estimated with underwater optical data obtained by BLOOMS between Mar 2005 and July 2006
. Circles are primary productivity observed on board.
Fig. 5 (b) ~ (e) Seasonal variability in POC flux at 150 m, 540 m (or 300 m), 1000 m and 4810 m obtained by time-series sediment traps between Mar 2005 and July 2006. Increase of primary productivity in the euphotic layer in June and July was propagated to deeper depths as increase of POC flux with time lag.

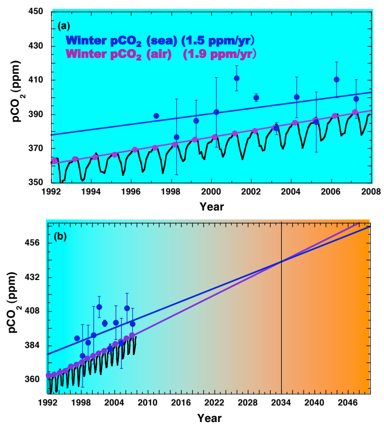

Fig. 6 (a) Time-series data of winter sea surface-pCO_2 estimated with carbonate chemistry in the water temperature minimum layer (blue circles) and winter atmospheric pCO_2 (purple circles). Winter sea surface pCO_2 is higher than winter atmospheric pCO_2 and K2 is a source of CO_2 in winter. Both pCO_2 increases gradually. However increase rate of winter sea surface pCO_2 is smaller than that of winter atmospheric pCO_2.

Fig. 6 (b) Predicted winter surface pCO_2 and atmospheric CO_2. If these increase trends continue, at the middle of this century, winter sea surface pCO_2 will be lower than winter atmospheric pCO_2. It means K2 will be a sink of CO_2 even in winter.

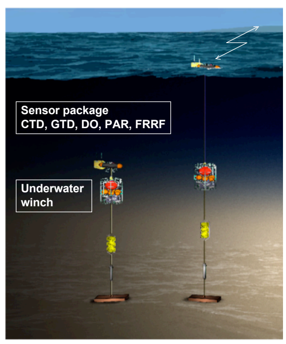

Fig. 7 New mooring system (POPPS) that will be deployed at stations K2 and S1. Sensor package consists of CTD, gas tension device (GTD), fluorometer, DO, PAR and fast repetition rate fluorometer (FRRF). Sensor package is usually located at around 100 m and ascends once a day with observation. After transmitting data via satellite, sensor package descends to the home position. Communication between mooring and land office is interactive.