Export fluxes of organic carbon in the Western North Pacific determined by drifting sediment trap experiments and ^{234}Th profiles

Koh Harada

Yoko Shibamoto

Introduction

The s of carbon cycling on the Earth's surface is becoming more important because of increasing attention to the global climate change caused by the increasing CO_2 level in the atmosphere. Oceans are one of the largest sinks for atmospheric CO_2 making carbon cycling in the ocean also as important. Inorganic and organic carbon concentrations in seawater are controlled not only by physical and chemical processes, but also by biological processes. The biological processes vary season by season and day by day. This is a reason why a shorter time scale observation is needed.

In JGOFS studies, a time series observation in the subtropical region near Hawaii has been conducted (Karl and Lukas, 1996) and the Canadian group continues the observation at a station in the subarctic eastern North Pacific (Wong *et al.*, 1998). Since the difference between the eastern and western sides of the Pacific has been recognized, the Japanese group decided to initiate the time series

observation in the western side of the Pacific. We started the observation from June 1998 at 44°N, 155°E in the western North Pacific, where the biological activity in the surface ocean is relatively high. The station is named Stn. KNOT which means "Cooperative North Pacific Ocean Time Series".

In this time series study, we are investigating carbonate chemistry, gas constituents, nutrient dynamics, primary, new and export productions and biological communities.

In this paper, I will introduce primary results of the export flux. The export flux is a flux of materials from the surface layer to the deeper ocean, and it is mainly controlled by settling particles that is produced in the euphotic layer in the ocean surface. This process is very important because it controls the concentration of inorganic carbon in surface water and the concentration controls CO_2 exchange rate with the atmosphere. The drifting sediment tap experiment is very useful to estimate the export flux because we can collect the settling particles directly and many chemical components can be analyzed. However, the export flux estimated by the shallow sediment trap was doubtful because of the complicated flows in the upper ocean (Buesseler, 1991). Recently, ^{234}Th, a short-lived insoluble natural radionuclide in the uranium decay series, is widely used to estimate particulate fluxes and to calibrate the sediment trap fluxes (e.g. Coale and Bruland, 1985, Buesseler *et al.*, 1992, Cochran *et al.*, 1993). In this paper, I introduce the primary results of estimation of the export fluxes in the western North Pacific by the drifting sediment trap and ^{234}Th profiles.

Methods

Station KNOT, which is a station for time series observations of Japanese JGOFS activity, is located at 44°N, 155°E in the western North Pacific (Figure 1).

The drifting sediment trap experiments were carried out three times in November, December 1998 and May 1999 at the station in the

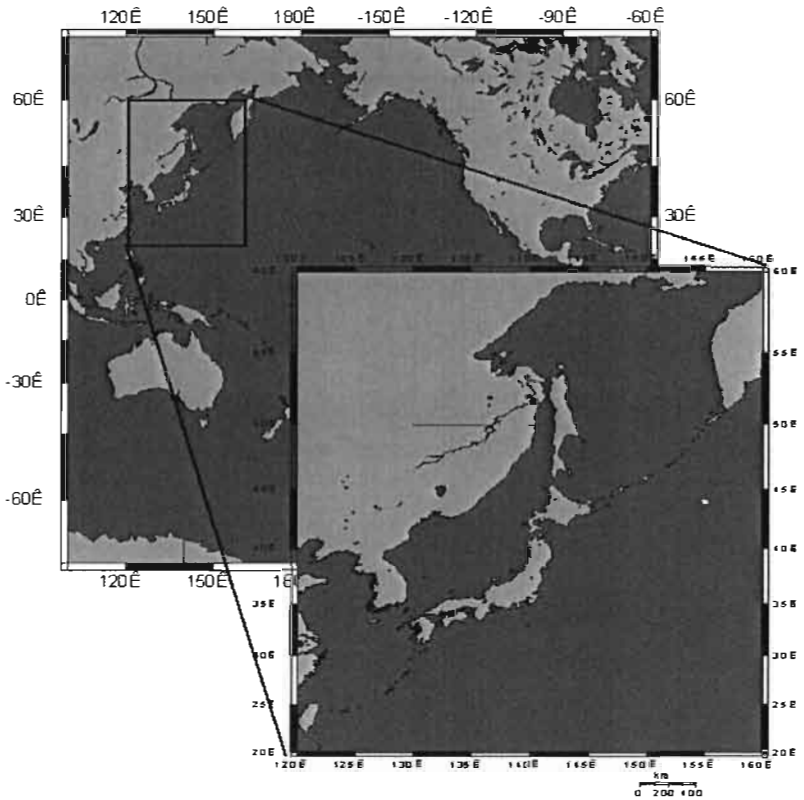

Figure 1
Map of the northwestern North Pacific showing a core location.

cruises of R/V Mirai. The sediment trap we used (Figure 2) is almost same design as one by Knauer *et al.* (1979). The array was deployed for two to three days at each experiment. Immediately after recovering the traps on the deck, particle samples were filtered on GF/F filters for organic carbon analysis and on Nuclepore filters for chemical and radiochemical analyses. The filter samples were brought to land laboratories and organic carbon and ^{234}Th were analyzed in Nagoya University and NIRE, respectively.

About 20 l of seawater samples were collected from 13 layers down to 300 m depth by Niskin bottles attached in a CTD-RMS. The seawater samples were through GF/F filters, and the filters

Figure 2
Picture of a drifting sediment trap used.

were used to determine "particulate ^{234}Th". "Dissolved ^{234}Th" was determined from the filtered seawater by the method of Harada and Tsunogai (1985) with some modification with liquid scintillation counting system.

Results and discussion

Vertical distributions of ^{234}Th in water column

In Figure 3, vertical distributions of particulate and dissolved ^{234}Th in the water column obtained in November 1998 were shown. The

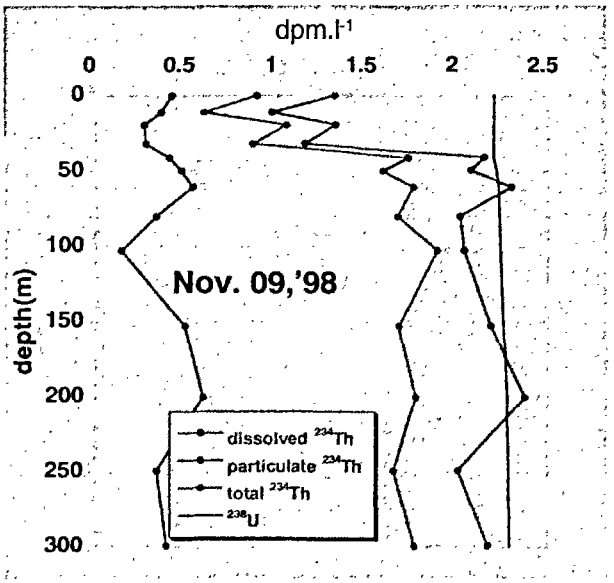

Figure 3
Vertical distributions of particulate, dissolved and total ^{234}Th at Stn. KNOT observed on November 9th 1998.

particulate ^{234}Th ranged from 0.2 to 0.6 dpm.l^{-1} and had no typical vertical trend. On the other hand, dissolved ^{234}Th in surface 30 m layer was significantly lower than one in the layer below 40 m depth. The sum of the concentrations of particulate and dissolved ^{234}Th in the deeper layer is almost the same as ^{238}U concentration, showing ^{234}Th is in equilibrium with its precursor. The removal flux of ^{234}Th can be calculated from a balance of ^{234}Th in the upper layer as follows, if steady state is assumed,

$$F_{Th} = \lambda_{Th} A_U - \lambda_{Th} A_{Th}$$

where, F_{Th} is ^{234}Th flux (dpm.m^{-2}.day^{-1}), λ_{Th} is decay constant of ^{234}Th (day^{-1}) and A_U and A_{Th} are activities (dpm.l^{-1}) of ^{238}U and ^{234}Th (total). From the vertical profile of ^{234}Th in November 1999, the ^{234}Th flux was calculated as 1,070 dpm.m^{-2}.day^{-1} and the estimations for other profiles are summarized in Table 1.

	234Th flux at 100m depth ($dpm.m^{-2}.day^{-1}$)		
	From Profile in water column	By sediment trap	ratio
November 1998	1070	730	0.68
December 1998	1050	710	0.68
May 1999	1490	1120	0.75

Table 1
Comparison of ^{234}Th flux obtained from water column profiles and sediment traps.

^{234}Th in the settling particles collected by the sediment trap

Results of the drifting sediment trap experiments are shown in Figure 4 and 5. The total mass fluxes decreased rapidly from surface to 100 m depth and below the depth the fluxes were almost constant or decreased gradually. The concentration of ^{234}Th in the settling particles were relatively constant in the surface layer, however, it tended to increase below the 100 m depth. The ^{234}Th flux by the traps was calculated multiplying the ^{234}Th concentration in the settling particles and the total mass flux. In Table 1, the ^{234}Th fluxes at 100 m depth are also summarized.

The ^{234}Th fluxes determined by sediment trap were always smaller than those obtained from ^{234}Th profiles in the water column. From this comparison, it was concluded that the trapping efficiency of the sediment trap we used was about 70 %.

Export flux of organic carbon at Stn. KNOT

Vertical profiles of organic carbon concentration and organic carbon/^{234}Th ratio in the settling particles are shown in Figure 6 and 7. The organic carbon concentration in the settling particles was almost constant at least down to 400 m depth and the POC/^{234}Th ratio decreased from the surface to 300 m depth gradually. If the ^{234}Th flux obtai-

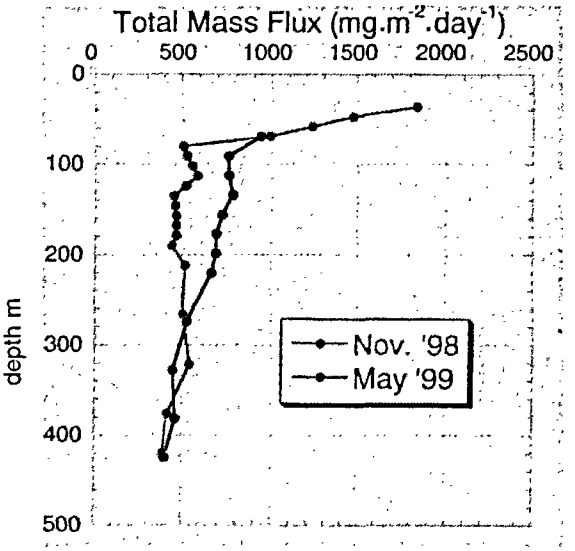

Figure 4
Total mass fluxes observed by the drifting sediment traps at Stn. KNOT in November 1998 and May 1999.

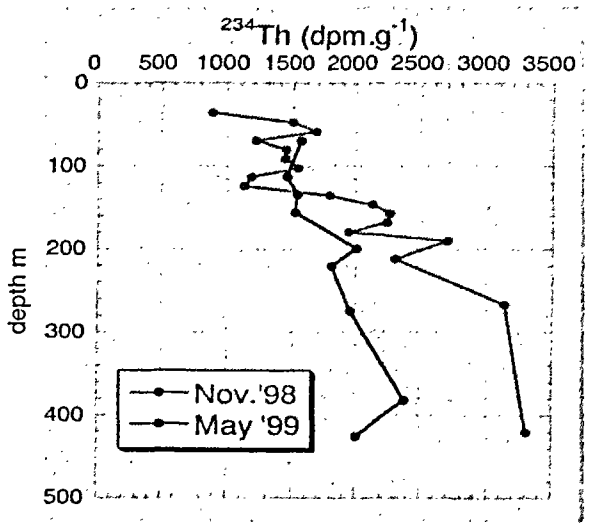

Figure 5
Concentration of ^{234}Th in the settling particles observed by the drifting sediment traps at Stn. KNOT in November 1998 and May 1999.

	^{234}Th flux ($dpm.m^{-2}.day^{-1}$)	POC/^{234}Th ($mmol.dpm^{-1}$)	POC flux ($mmol.m^{-2}.day^{-1}$)
November 1998	1070	6.1	6.5
December 1998	1050	5.2	5.5
May 1999	1490	6.2	9.2

Table 2
Estimation of export flux of organic carbon from ^{234}Th flux and org.C/^{234}Th in the settling particles.

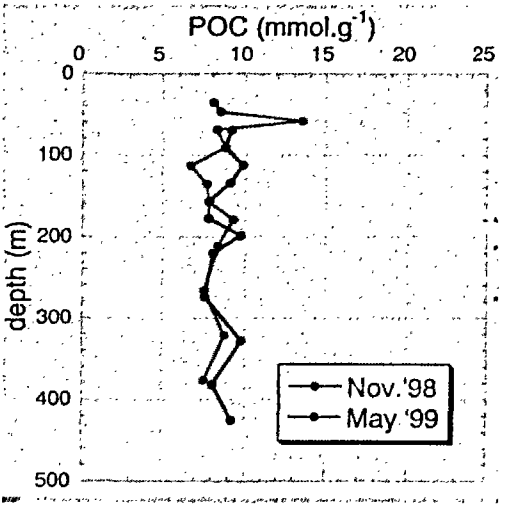

Figure 6
Concentration of organic carbon in the settling particles observed by the drifting sediment traps at Stn. KNOT in November 1998 and May 1999.

ned from the vertical distribution of ^{234}Th in seawater is correct, the organic carbon flux can be estimated from a the following equation,

$$F_{org.C} = F_{Th} \times (C_{org.C} / C_{Th})_{particle}$$

where $F_{org.C}$ is the organic carbon flux ($mmol.m^{-2}.day^{-1}$), F_{Th} is the ^{234}Th flux obtained from the water column profiles ($dpm.m^{-2}.day^{-1}$) and $(C_{org.C} / C_{Th})_{particle}$ is the organic carbon/^{234}Th ratio in the settling particles ($mmol.dpm^{-1}$). The estimated organic carbon flux was about 6 $mmol.m^{-2}.day^{-1}$ in winter and 9 $mmol.m^{-2}.day^{-1}$ in spring.
In the time series observation, primary production in the surface

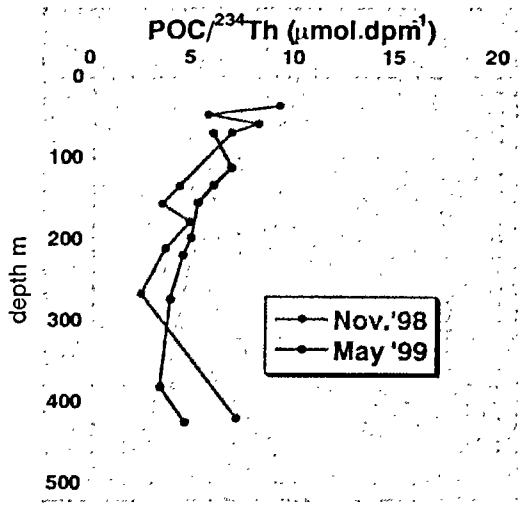

Figure 7
Ratio of organic carbon and ^{234}Th in the settling particles observed by the drifting sediment traps at Stn. KNOT in November 1998 and May 1999.

layer was also measured (Imai *et al.*, personal communication) and the export flux obtained here can be compared with the primary production. E-ratio, which is the ratio of the export flux to the primary production rate is 0.75 in winter and 0.21 in spring. In the observation in May 1999, we found many patches of phytoplankton bloom near Stn. KNOT although there was no bloom at St. KNOT, itself. From this observation, the western North Pacific near Stn. KNOT was in biologically active condition. In this condition, both the primary production and the export flux increase. However, it seems that the ratio becomes low, since regeneration of particulate organic matter in the surface layer also increases.

Conclusion

To investigate the export flux in the western North Pacific, drifting sediment trap experiments and 234Th observations were conducted.
1.Trapping efficiency of the drifting sediment trap was estimated as about 70 %.

2.Organic carbon flux at Stn. KONT was about 6 mmol.m^{-2}.day^{-1} in winter and 9 mmol.m^{-2}.day^{-1} in spring.
3.E-ratio in spring (0.21) was significantly lower than in winter (0.75), although the export flux in spring was high.

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