^{230}Th and ^{231}Pa in the sinking particles in the subarctic western North Pacific

1. Introduction

Global warming resulting from the increase in greenhouse gases, such as carbon dioxide, is of great concern to the world community. In the last few decades, the carbon cycle in the ocean has been studied to clarify the balance of carbon dioxide between the atmosphere and the ocean. One important issue is the quantification of the role played by the biological pump: how much atmospheric CO_2 is assimilated in the sunlit layer (euphotic zone) and how much carbon is exported to the deep ocean?

The northern North Pacific Ocean, especially its western part, experiences intense winter cooling and receives large supplies of nutrients through upwelling, resulting in high productivity in spring and summer. It is well documented that spring blooms, consisting mainly of diatoms, occur only in the western part of the subarctic Pacific (Saito *et al*., 2002; Yamaguchi *et al*., 2002). It has been suspected that diatoms in this area play a key role in transporting POC to the deep ocean, because of their relatively large size and resultant high settling velocity (*e.g*., Tsunogai and Noriki, 1991; Kemp *et al*., 2000; Smetacek, 2000; Honda *et al*., 2002). The large decrease of nutrients and surface pCO_2 from spring to autumn also support the high activity of the biological pump in the northwestern North Pacific (Louanchi and Najjar, 2000; Wong *et al*., 2002; Takahashi *et al*, 2002). Kawakami and Honda (2007) reported that seasonal variability in POC fluxes estimated from ^{234}Th was large (54–179 gC m^{-2} d^{-1}) and annual POC fluxes were estimated to be 31 gC m^{-2} y^{-1} in this region.

^{230}Th and ^{231}Pa are useful tracer of sinking particle flux in the ocean, and the trapping efficiency of the sediment trap is estimated from these radionuclides (*e.g*., Bacon *et al*., 1985; Yu *et al*., 2001).

We have made time-series sediment trap experiments in the subarctic western North Pacific since 2001 (Honda *et al*., 2006 and 2009). We determined ^{230}Th and ^{231}Pa in the sinking particles collected by the sediment traps in 2005–2008 (*e.g*., Shigemitsu *et al*., 2010).

In this dataset, we present the fluxes of ^{230}Th and ^{231}Pa collected by the sediment traps in the western North Pacific. These data will help further understanding of particle dynamics in the ocean.

May 2020

Hajime Kawakami
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

2. List of Investigators

Hajime Kawakami (JAMSTEC)

Makio C. Honda (JAMSTEC)

3. Sampling and sample analysis

Time-series sediment traps (McLane Mark7G) with 13 or 21 collecting cups were deployed and recovered at 300, 540, 1000, and 4810 m depths at station K2 (47°N, 160°E; bottom 5200 m) in February–March 2005 (MR05-01, doi: 10.17596/0001792), September–October 2005 (MR05-04, doi: 10.17596/0001793), May–June 2006 (MR06-03_leg1, doi: 10.17596/0001796), September–October 2007 (MR07-05, doi: 10.17596/0001803), and October–November 2008 (MR08-05, doi: 10.17596/0001809). The station K2 is in the subarctic part of the western North Pacific Ocean. Collected samples were preserved with seawater based buffered 10% formalin. The pretreatment procedures of samples (storage, sieving, splitting, and filtration) followed the methods described by Honjo *et al*. (1995). A part of sinking particle samples was digested with a mixture of concentrated HNO_3, $HClO_4$, and HF (1:1:1, v/v) in the presence of the ^{228}Th and ^{233}Pa yield tracers (^{228}Th: 5–10 dpm, ^{233}Pa: 400–1000 dpm). Radiochemical separation and purification of these nuclides were achieved by procedures similar to those of Anderson and Fleer (1982) using the anion exchange technique. The treated Th and Pa were electroplated onto stainless-steel planchets (Narita *et al*., 2003). The planchets for Pa were covered with polyethylene sheets (50 μm thick) and first beta-counted using a low-background (0.1–0.3 cpm) anticoincidence gas-flow beta detector (LBC-470, Aloka Co. Ltd.) to determine their ^{233}Pa (yield tracer) activity, and then the planchets for Th or Pa were alpha-counted with silicon surface barrier detectors (Octéte, Seiko EG&G Co. Ltd.) to determine their ^{228}Th (yield tracer), ^{230}Th, ^{232}Th, and ^{231}Pa activities. Excess ^{230}Th and ^{231}Pa were estimated from following equations (Yu *et al*., 2001):

$$\text{excess } {}^{230}\text{Th} = {}^{230}\text{Th}_T - 0.8 \bullet {}^{232}\text{Th}_T$$
$$\text{excess } {}^{231}\text{Pa} = {}^{231}\text{Pa}_T - 0.046 \bullet 0.8 \bullet {}^{232}\text{Th}_T$$

where $^{230}Th_T$, $^{230}Th_T$, and $^{231}Pa_T$ are the total activities measured. The precision of excess ^{230}Th and ^{231}Pa was one sigma of the counting error.

3. Dataset

Data obtained from sediment trap experiments were electrically compiled as an excel file “ST_230Th_231Pa.xls”, and were total mass flux, flux of excess ^{230}Th (ex230Th), and excess ^{231}Pa (ex210Pa). The data of total mass flux were excerpted from “JAMSTEC OceanSITES Sediment Trap data (netCDF format)” (https://ebcrpa.jamstec.go.jp/k2oceansites/). The errors of ^{230}Th and ^{231}Pa were estimated from counting error.

4. Contact persons

Hajime Kawakami (E-mail: kawakami@jamstec.go.jp)

Japan Agency for Marine-Earth Science and Technology
3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa, 236-0001, Japan

5. Acknowledgments

We thank the captains, the officers, and the crew of R/V *Mirai* for their help and support during the cruises. We also thank the marine technicians of Marine Works Japan Ltd. and Global Ocean Development Inc. for their on-board analysis and deck work.

References

Anderson, R.F., Fleer, A.P., 1982. Determination of natural actinides and plutonium in marine particulate material. Analytical Chemistry 54, 1142–1147.

Bacon, M.P., Huh, C.-A., Fleer, A.P., Deuser, W.G., 1985. Seasonality in the flux of natural radionuclides and plutonium in the deep Sargasso. Deep-Sea Research A 32, 273–286.

Honda, M.C., Imai, K., Nojili, Y., Hoshi, F., Sugawara, T., Kusakabe, M., 2002. The biological pump in the northwestern North Pacific based on fluxes and major components of particulate matter obtained by sediment-trap experiment (1997-2000). Deep-Sea Research II 49, 5595–5625.

Honda, M.C., Kawakami, H., Sasaoka, K., Watanabe, S., Dickey, T., 2006. Quick transport of primary produced organic carbon to the ocean interior. Geophysical Research Letter 33, 10.1029/2006GL026466.

Honda, M.C., Sasaoka, K., Kawakami, H., Matsumoto, K., Watanabe, S., Dickey T.D., 2009. Application of underwater optical data to estimation of primary productivity. Deep-Sea Research I 56, 2281–2292.

Honjo, S., Dymond, J., Collier, R., Manganini, S. J.: Export production of particles to the interior of the equatorial Pacific Ocean during the 1992 EqPac experiment, Deep-Sea Res. II, 42, 831–870, 1995.

Kawakami, H., Honda, M. C., 2007. Time-series observation of POC fluxes estimated from ^{234}Th in the northwestern North Pacific. Deep-Sea Research I 54, 1070–1090.

Kemp, A.E.S., Pike, J., Pearce, R.B., Lange, C.B., 2000. The “Fall dump” – a new perspective on the role of a “shade flora” in the annual cycle of diatom production and export flux. Deep-Sea Research II 47, 2129–2154.

Louanchi, F., Najjar, R.G., 2000. A global monthly climatology of phosphate, nitrate, and silicate in the upper ocean: Spring-summer export production and shallow remineralization. Global Biogeochemical Cycles 14, 957–977.

Narita, H., Abe, R., Tate, K., Kim, Y-I., Harada, K., Tsunogai, S., 2003. Anomalous large scavenging of ^{230}Th and ^{231}Pa controlled by particle composition in the northwestern North Pacific. Journal of Oceanography 59, 739–750.

Saito, H., Tsuda, A., Kasai, H., 2002. Nutrient and plankton dynamics in the Oyashio region of the western subarctic Pacific Ocean. Deep-Sea Research II 49, 5463–5486.

Shigemitsu, M., Watanabe, Y.W., Yamanaka, Y., Kawakami, H., Honda, M.C., 2010. Relationship between Sinking Organic Matter and Minerals in the Shallow Zone of the Western Subarctic Pacific. Journal of Oceanography 66, 697–708.

Smetacek, V.S., 2000. The giant diatom dump. Nature, 406, 574–575.

Takahashi, T., Sutherland, S.C., Sweeny, C., Poisson, A., Metzl, N., Tilbrook, B., Bates, N., Wanninkhof, R., Feely, R.A., Sabine, C., Olafsson, J., Nojiri, Y., 2002. Global sea-air CO_2 flux based on climatological surface ocean pCO_2, and seasonal biological and temperature effects. Deep-Sea Research II 49, 1601–1622.

Tsunogai, S., Noriki, S., 1991. Particulate fluxes of carbonate and organic carbon in the ocean. Is the marine biological activity working as a sink of the atmospheric carbon?. Tellus 43B, 256–266.

Yu, E.F., Francois, R., Bacon, M.P., Honjo, S., Fleer, A.P., Manganini, S.J., Rutgers van der Loeff, M.M., Ittekot, V., 2001. Trapping efficiency of bottom-tethered sediment traps estimated from the intercepted fluxes of ^{230}Th and ^{231}Pa. Deep-Sea Research I 48, 865–889.

Wong, C.S., Waser, N.A.D., Nojiri, Y., Whitney, F.A., Page, J.S., Zeng, J., 2002. Seasonal cycles of nutrients and dissolved inorganic carbon at high and mid latitudes in the North Pacific Ocean during the *Skaugran* cruises: determination of new production and nutrient uptake ratios. Deep-Sea Research II 49, 5317–5338.

Yamaguchi, A., Watanabe, Y., Ishida, H., Harimoto, T., Furusawa, K., Suzuki, S., Ishizaka, J., Ikeda, T., Takahashi, M.M., 2002. Structure and size distribution of plankton communities down to the greater depths in the western North Pacific Ocean. Deep-Sea Research II 49, 5513–5530.