**Impacts of climate change in the North Pacific: which are the most important anthropogenic radionuclide tracers of oceanic change?**

**Katsumi Hirose,1,\* Yayoi Inomata,2 Pavel P. Povinec,3 Daisuke Tsumune,4 Masatoshi Yamada5 and Jian Zheng6**

*1Laboratory for Environmental Research at Mount Fuji, 169 0072 Tokyo, Japan*

*2Kanazawa University, 814 99 Kanazawa, Japan*

*3Comenius University, 842 48 Bratislava, Slovakia*

*4Tsukuba University, 305 8572 Tsukuba, Japan*

*5Marine Ecology Research Institute, 299 5105 Onjyuku, Japan*

*6National Institute for Quantum Science and Technology, 263 8555 Chiba City, Japan*

\* *e-mail:* *hirose45037@mail2.accsnet.ne.jp*

Increasing anthropogenic greenhouse gas emissions (mainly carbon dioxide and methane) into the atmosphere have accelerated global warming with serious impacts on Earth ecosystems. Changes in precipitation patterns have increased flooding, and draught events on the other sides resulted in melting of glaciers and sea level rise. Oceans have been experiencing serious changes, such as frequent marine heat waves on a global scale, which could slow the Global Meridional Overturning Circulation (GMOC), disrupting thus the ocean circulation with many accompanying changes in biogeochemical processes, including surface ocean acidification. Anthropogenic radionuclides, released to the marine environment mainly after atmospheric nuclear weapons tests, have been used as sensitive tracers, which could register some of the climate-change impacts on the world ocean (e.g., seawater circulation patterns) as well as on regional seas (e.g., processes in the water column). Climate change affects the time revolution and the distribution of anthropogenic radionuclides in the ocean. Therefore, anthropogenic radionuclides (3H, 14C, 90Sr, 137Cs, 129I, 236U, 237Np and Pu isotopes) have been useful tracers, providing important information on processes in the Pacific Ocean.

The North Pacific Ocean (NPO) is a key area in the GMOC path because of the return of deep water to the surface. However, there is no clear picture of GMOC in NPO. The subarctic circulation (SAC) is the largest cyclonic circulation in the NPO, which is characterized as an upwelling region high in nutrients. On the other hand, the North Pacific Subtropical Gyre (NPSTG) is an anticyclonic circulation, which is characterized as a downwelling region low in nutrients. Assuming that the subarctic circulation is an outlet of deep water for the GMOC, a weakened deep-water formation in the North Atlantic and Antarctic Oceans would lead to a decline of upwelling of deep water in the NPSAC, which can weaken the cooling of surface waters and supply of nutrients. Therefore, it is important to better understand the changes in NPSAC and NPSTG accompanied by climate change.

Although Pu has been recognized as a useful tracer of biogeochemical processes because of its high chemical reactivity, it has also been an important tool to trace the motion of water masses. Plutonium isotopes in the Pacific Ocean were primarily injected by global fallout from 1961-62 large-scale atmospheric nuclear tests carried out by the Soviet Union in the Arctic at Novaya Zemlya Island, although a significant amount of Pu was also released owing to close-in fallout from the US thermonuclear tests in the Pacific Proving Grounds (PPG) conducted in the 1950s mainly on Bikini and Enewetak Atolls. Global fallout Pu was deposited mainly in the NPSAC, whereas ~~PPG~~ the Pu of PPG origin was injected mainly in the NPSTG. Since the 240Pu/239Pu isotope ratio (0.18) of global fallout was different from that of PPG (0.33), the 240Pu/239Pu isotope ratio and Pu activity concentrations in seawater and sediment have been tracking the time revolution of the water masses in the North Pacific Ocean.