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Transport of surface seawater in the global ocean labeled by chemical tracer ^{137}Cs from 1957 to 2018

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Introduction

By the FNPP1 accident, large amount to Caesium-137 (^{137}Cs), with a half-life of 30.17 years, is released into the North Pacific Ocean. Before the FNPP1 accident, ^{137}Cs exist most abundant anthropogenic radionuclide by global and local fallout from atmospheric nuclear weapon tests, discharges from nuclear fuel reprocessing plants, and the fallout from the Chernobyl accident in the ocean seawater. ^{137}Cs is considered as one of the useful chemical tracers for the investigation of oceanic processes such as the transport of water masses over long distances, and processes occurring in the water column associated with the global ocean water circulation. In this presentation, we analyze spatial and temporal variations in ^{137}Cs activity concentrations from 1960 to 2018 in the surface water of the global ocean. The ^{137}Cs amount and transport released from the FNPP1 accident is also discussed.

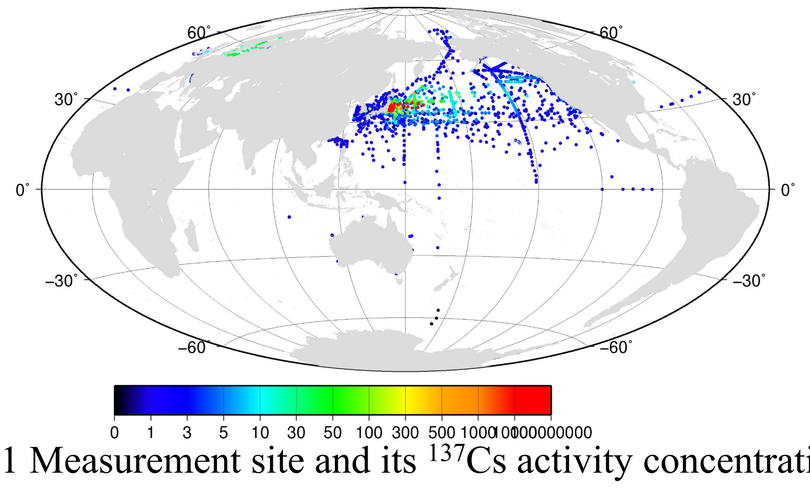

Fig.1 Measurement site and its ^{137}Cs activity concentrations in the global ocean in the 2010s.

Subdivided Box in the global Ocean

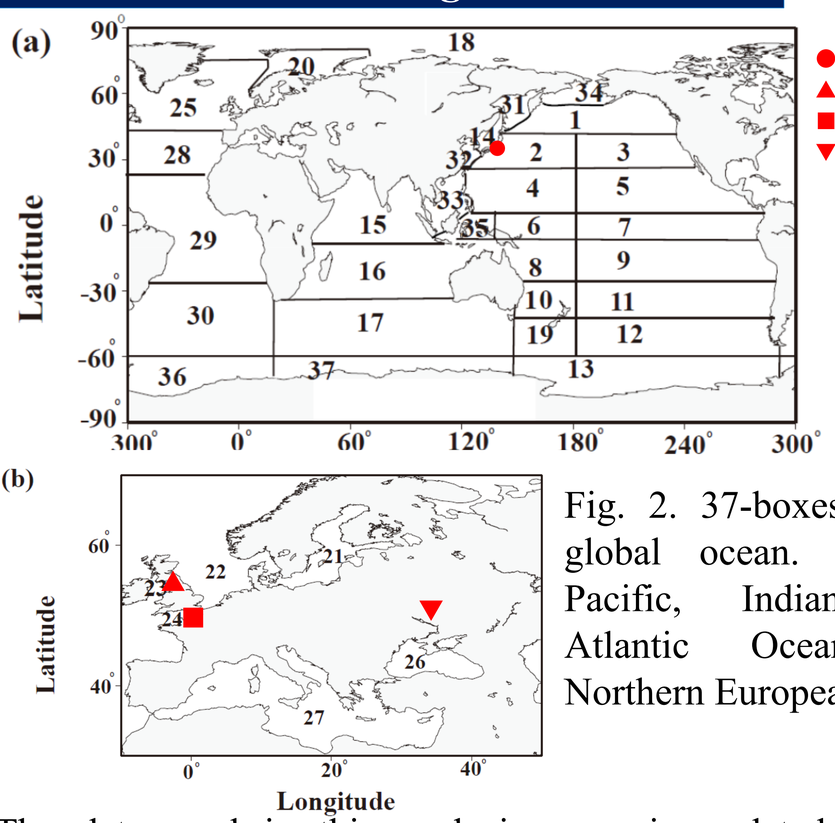

Fig. 2. 37-boxes in the global ocean. (a) the Pacific, Indian, and Atlantic Ocean, (b) Northern European Sea.

The data used in this analysis were in updated version "Historical Artificial Radionuclides in the Pacific Ocean and its Marginal Seas (HAM-global 2018)" and the database produced by IAEA Marine Radioacticity Information System. It contains a total of 80444 records of ^{137}Cs obtained from surface waters (0–20 m) in the global ocean between 1967 and 2018. We calculated 0.5-yr average values of the ^{137}Cs activity concentrations in each box taking into account the advection from the adjacent sea areas.

Long-term variation of ^{137}Cs (0.5yr average value)

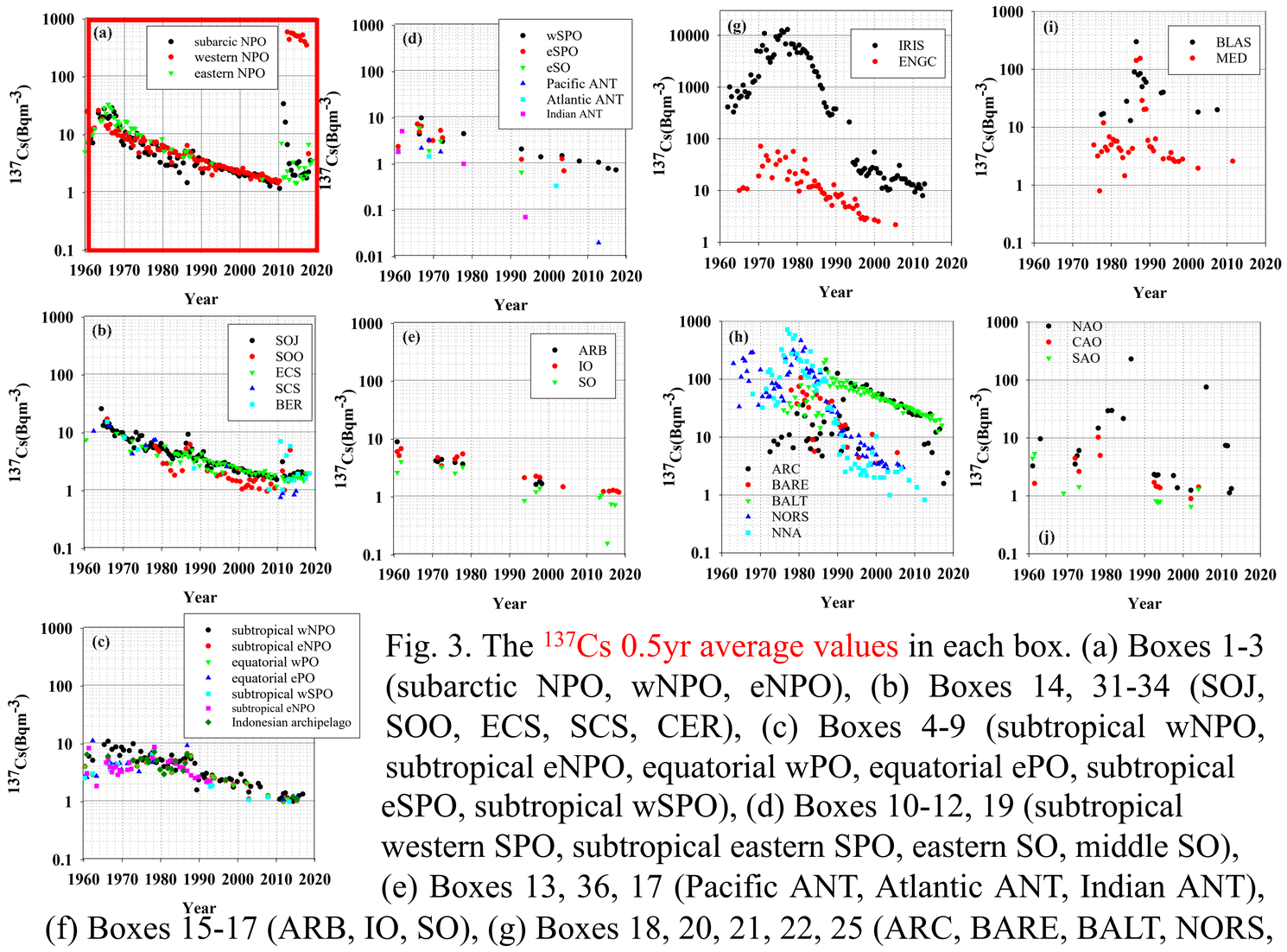

Fig. 3. The ^{137}Cs 0.5yr average values in each box. (a) Boxes 1-3 (subarctic NPO, wNPO, eNPO), (b) Boxes 14, 31-34 (SOJ, SOO, ECS, SCS, CER), (c) Boxes 4-9 (subtropical wNPO, subtropical eNPO, equatorial wPO, equatorial ePO, subtropical eSPO, subtropical wSPO), (d) Boxes 10-12, 19 (subtropical western SPO, subtropical eastern SPO, eastern SO, middle SO), (e) Boxes 13, 36, 17 (Pacific ANT, Atlantic ANT, Indian ANT), (f) Boxes 15-17 (ARB, IO, SO), (g) Boxes 18, 20, 21, 22, 25 (ARC, BARE, BALT, NORS, NNA), (h) Box 23, 24 (IRIS, ENGC), (i) Boxes 26, 27 (BLAS, MEDS), (j) Boxes 28-30 (NAO, CAO, SAO).

Significant feature of the long term variations of ^{137}Cs activity concentrations are

1. In the Pacific Ocean, most ^{137}Cs were originated from the release from the global fallout. These activity concentrations were decreased exponentially and the average value in the 2000s were about 1.5-2 Bqm^{-3}. The ^{137}Cs activity concentrations rapidly increased to 3263624 Bqm^{-3} in Box 2 due to the direct release and atmospheric deposition from the FNPP1 accident in 2011.
2. In the Atlantic Ocean, ^{137}Cs released from the nuclear fuel reprocessing plants caused to the release of large amount to ^{137}Cs. The ^{137}Cs activity concentrations in the 2010s has remain higher level in the ARC, BALT, and IRIS.
3. Detection of ^{137}Cs derived from the Chernobyl accident was only 1-2 yrs (1986-1987). The signature of the Chernobyl accident did not detect in the 2010s.

^{137}Cs inventory in the mixed layer

2min lon/lat ^{137}Cs deposition (577 ± 173 PBq) in the global ocean was re-constructed based on 10 deg log/lat deposition by Aoyama et al. (2006). The mixed layer depth was derived from the "Mixed Layer Climatology" constructed by French Research Institute for the Exploitation of the Sea (IFEMER).

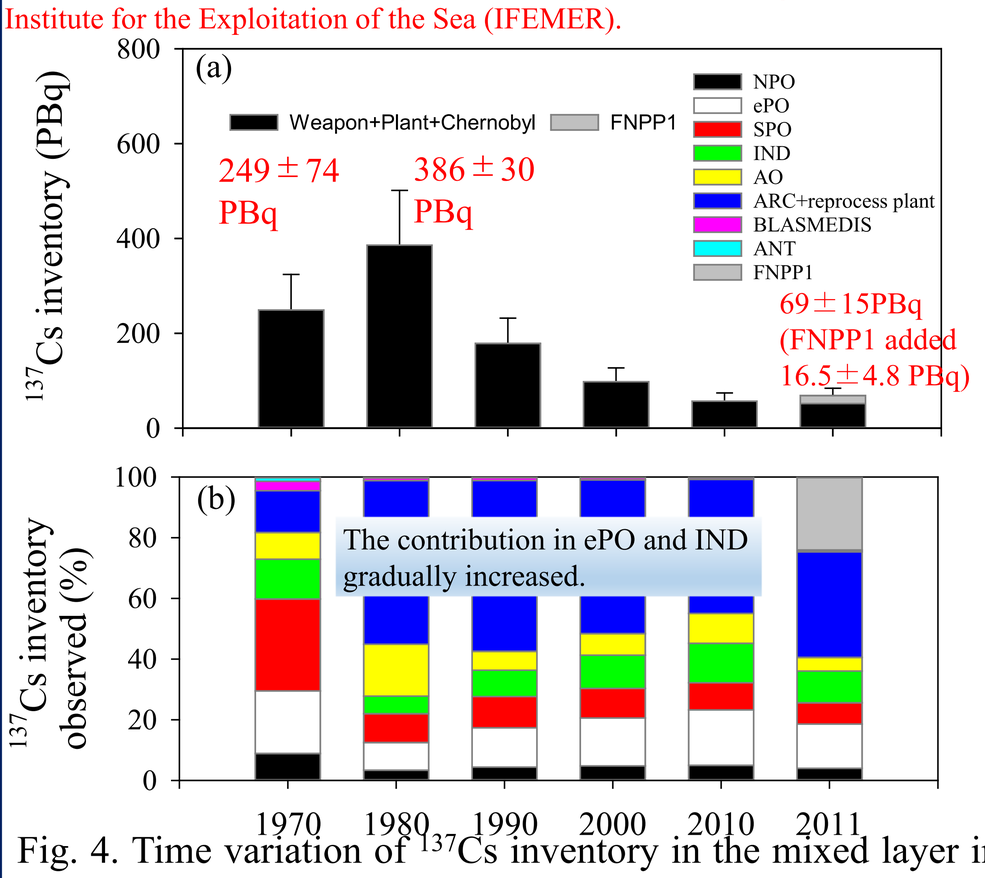

Fig. 4. Time variation of ^{137}Cs inventory in the mixed layer in the global ocean.

1. In 1970, about 57% of ^{137}Cs deposited in the global ocean were transported into the ocean interior within 10yr scale.
2. The increased ^{137}Cs inventory in 1980 were caused by the nuclear fuel reprocessing plants, Shellafiled and La Hague.
3. By the FNPP1 accident, 16.5 ± 4.8 PBq of ^{137}Cs were released into the North Pacific Ocean, and then, the ^{137}Cs inventory in 2011 account to 69 ± 29 PBq.

Conclusion: ^{137}Cs transport in the surface seawater in the global ocean

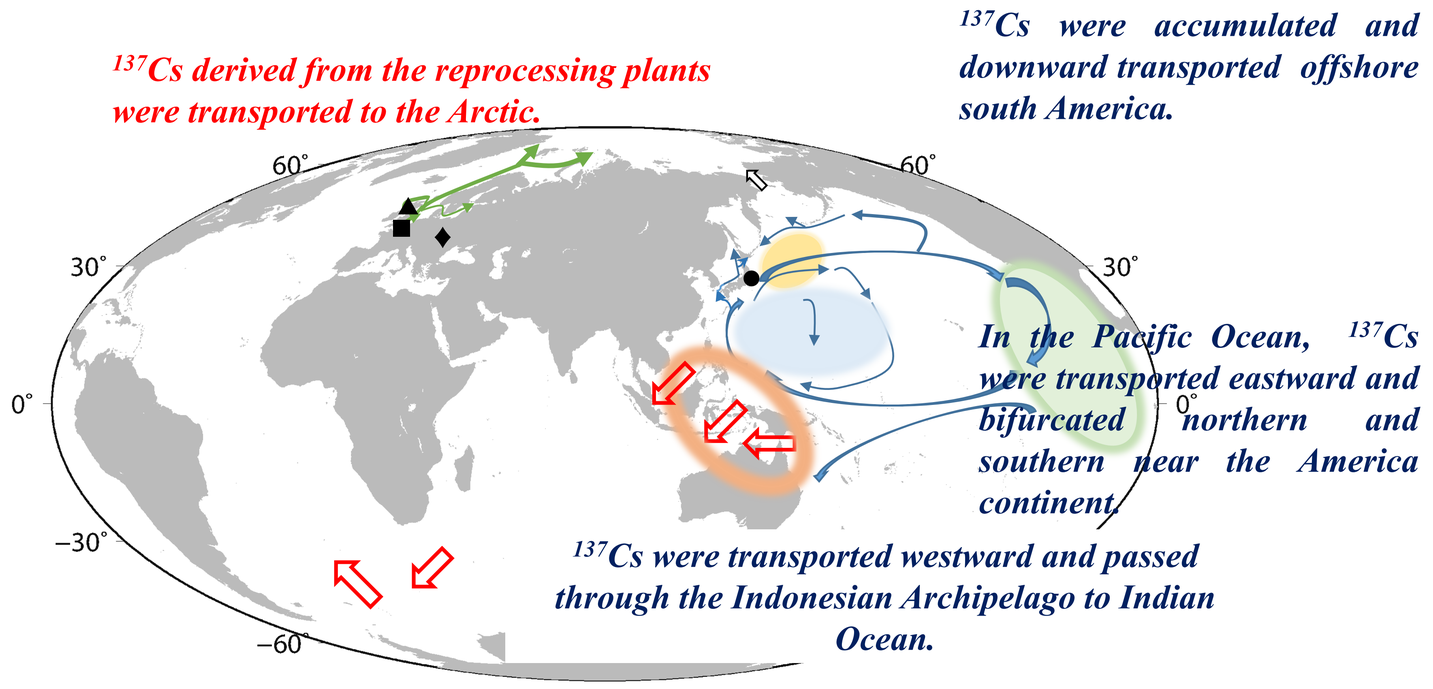

Fig. 5. Schematic diagram of ^{137}Cs transport in the surface mixed layer in the global ocean.