Marine Radioactivity after the Fukushima Accident: Distribution of Radionuclides, Modeling and Assessment of Radiation Doses

Pavel P. Povinec

Comenius University, Bratislava, Slovakia

Katsumi Hirose

Sophia University, Tokyo, Japan

Sources of anthropogenic radionuclides (PBq)

	Nuclear Weapons Tests (atm+ocean)	Reprocessing (ocean)	Chernobyl (atm+ocean)	Fukushima (atm+ocean)
3H	186 000	1000	10	?
14C	213	10	?	?
^{131}I			1760	(130-160)+5
^{137}Cs	950+600	50	85+16	(13-15)+(3-6) direct 5-10 deposition
^{90}Sr	620+380	7	~20	0.14+(1-2)
^{239,249}Pu	10	1	~1	?

Povinec, Hirose, Aoyama: Fukushima Accident: Environmental Impact, Elsevier, 2013, 400p

Marine radionuclide databases

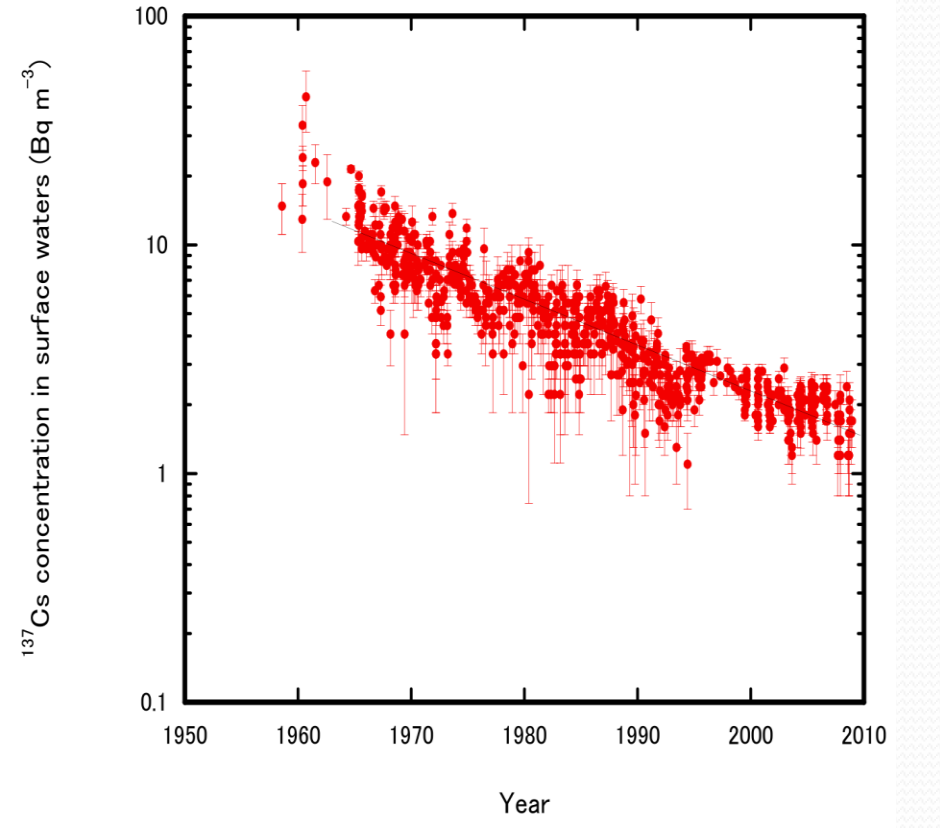
- **GLOMARD/MARIS – Global Marine Radioactivity Database – IAEA-EL Monaco**
  (Povinec et al., JER, 76(2004)113;

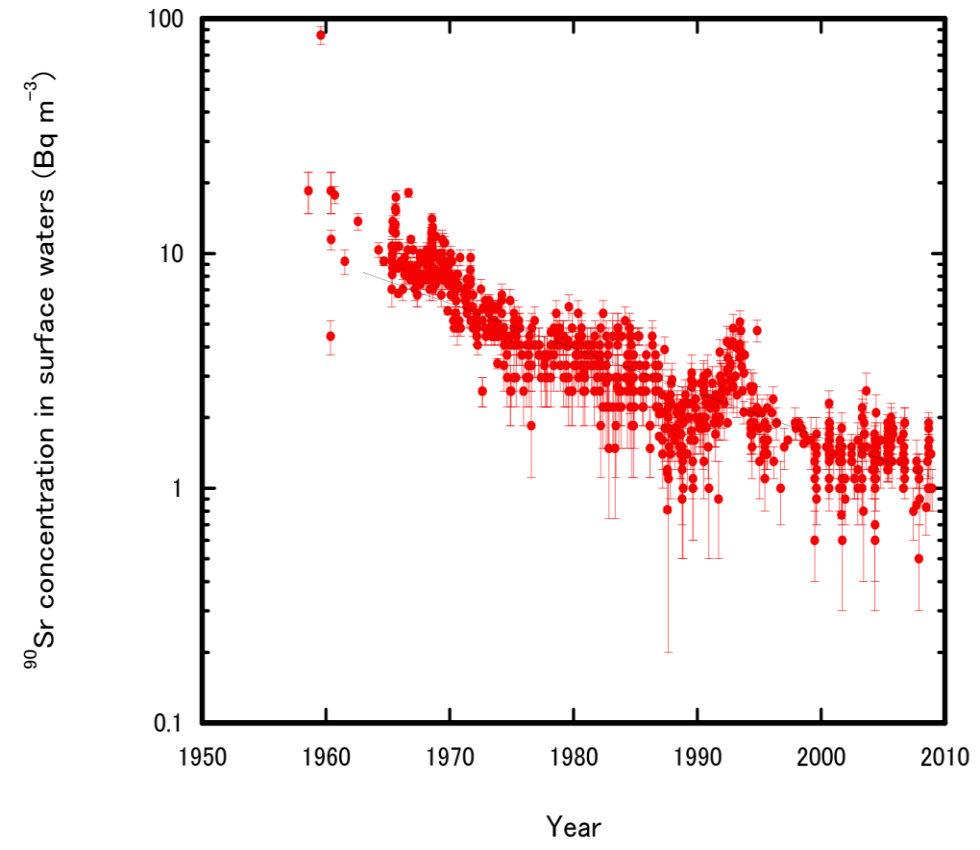
- **HAM – Meteorological Research Institute, Tsukuba**
  (Aoyama, M., Hirose, K., *TheScientificWorldJOURNAL*, 4, 200-215, 2004)

  Post-Fukushima: MEXT, TEPCO

90Sr and 137Cs time series in the NW Pacific

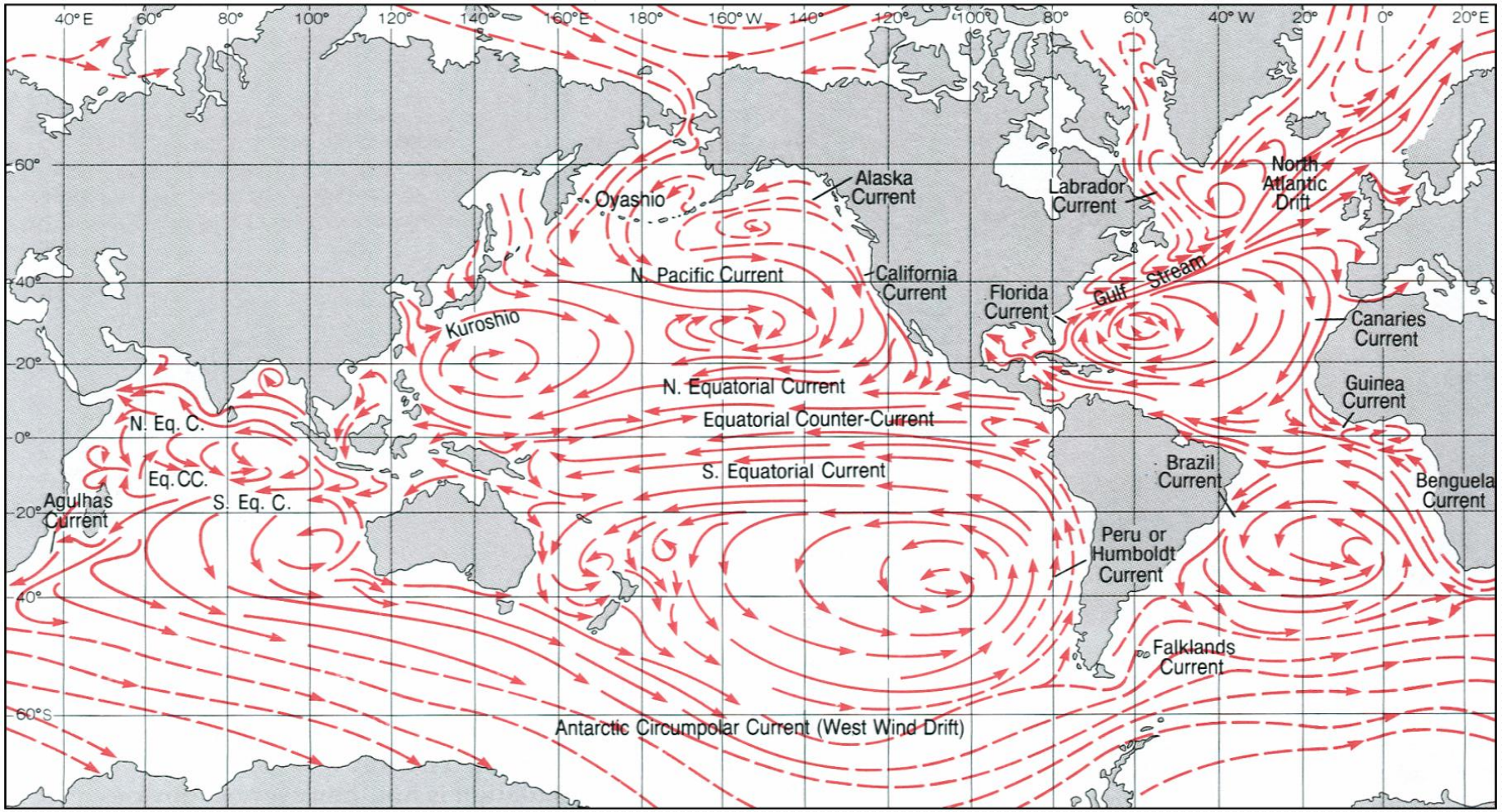
(Povinec PP, Hirose K, Aoyama M, ES&T, 2012)





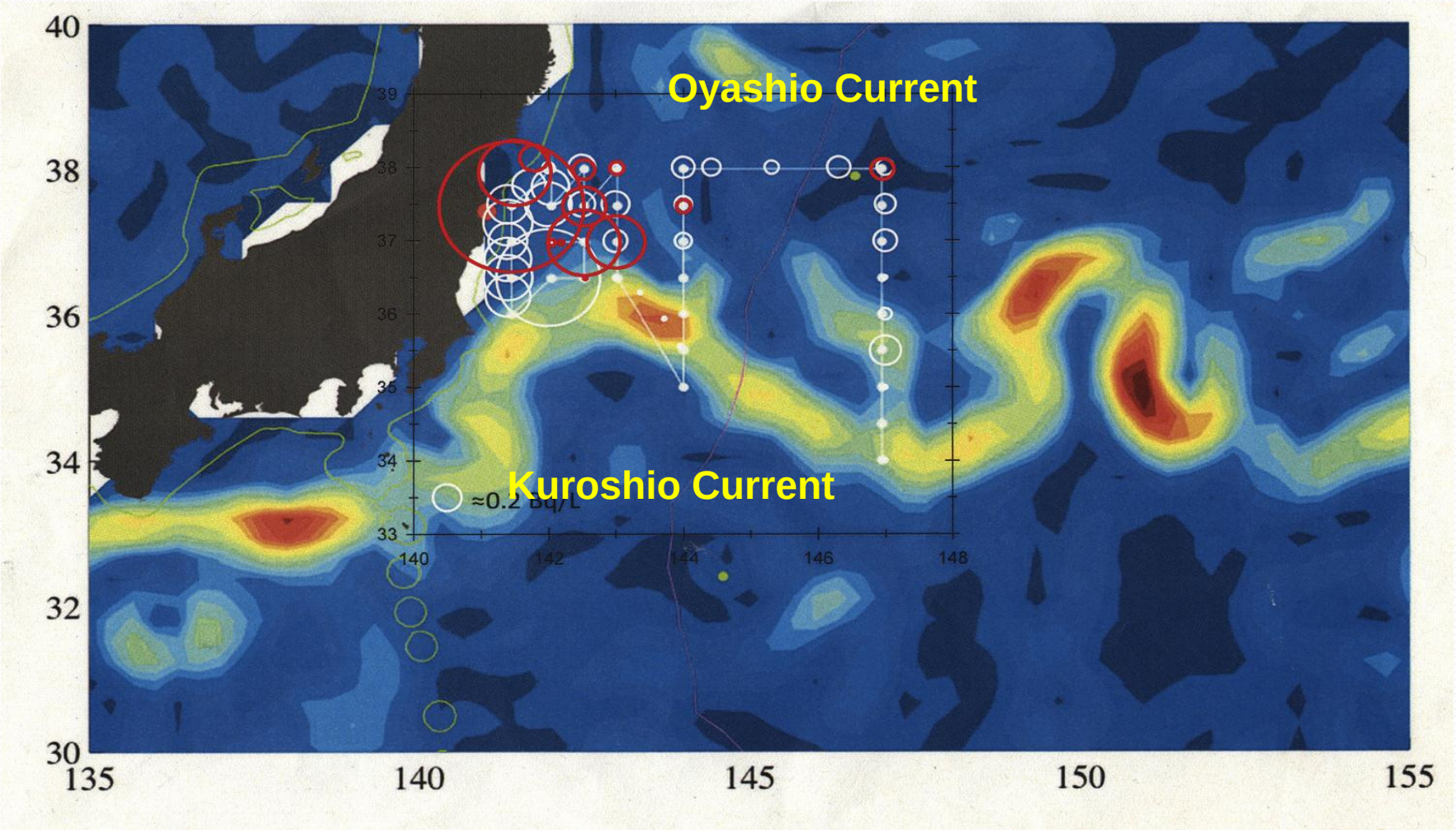
The global ocean surface current system

(Open University, 2009)



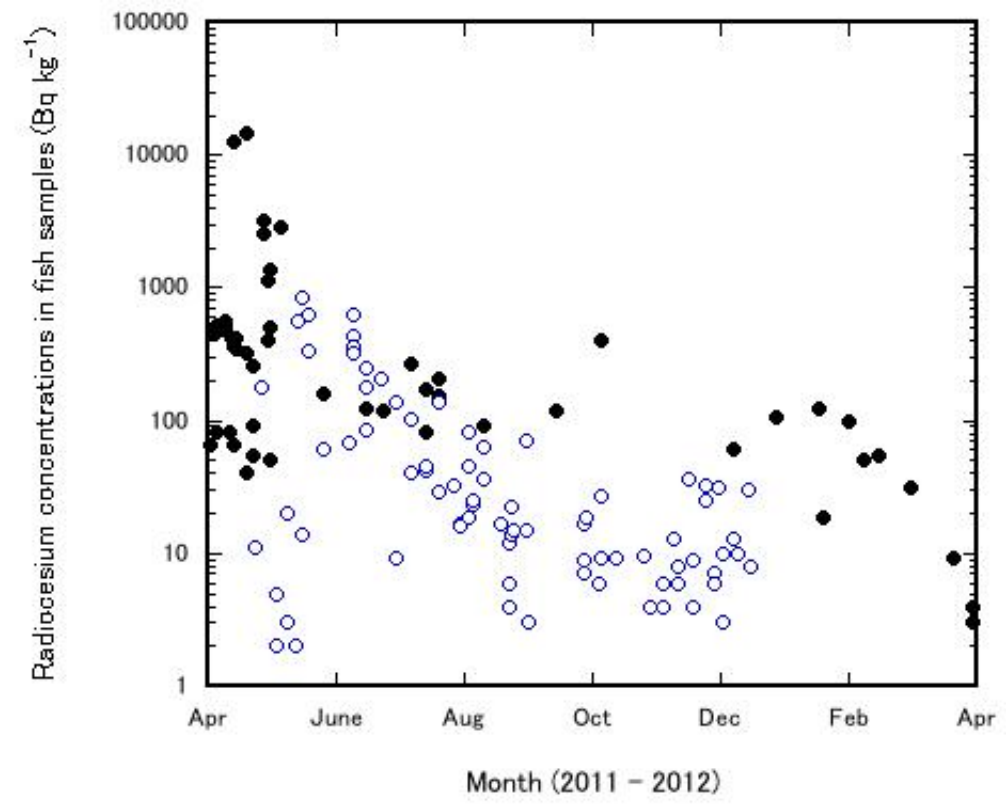
WHOI Sampling Cruise Offshore Fukushima – June 2011 (Hawaii Univ., SUNY, JAMSTEC, IAEA-EL, UNIBA,...)

137Cs in surface waters



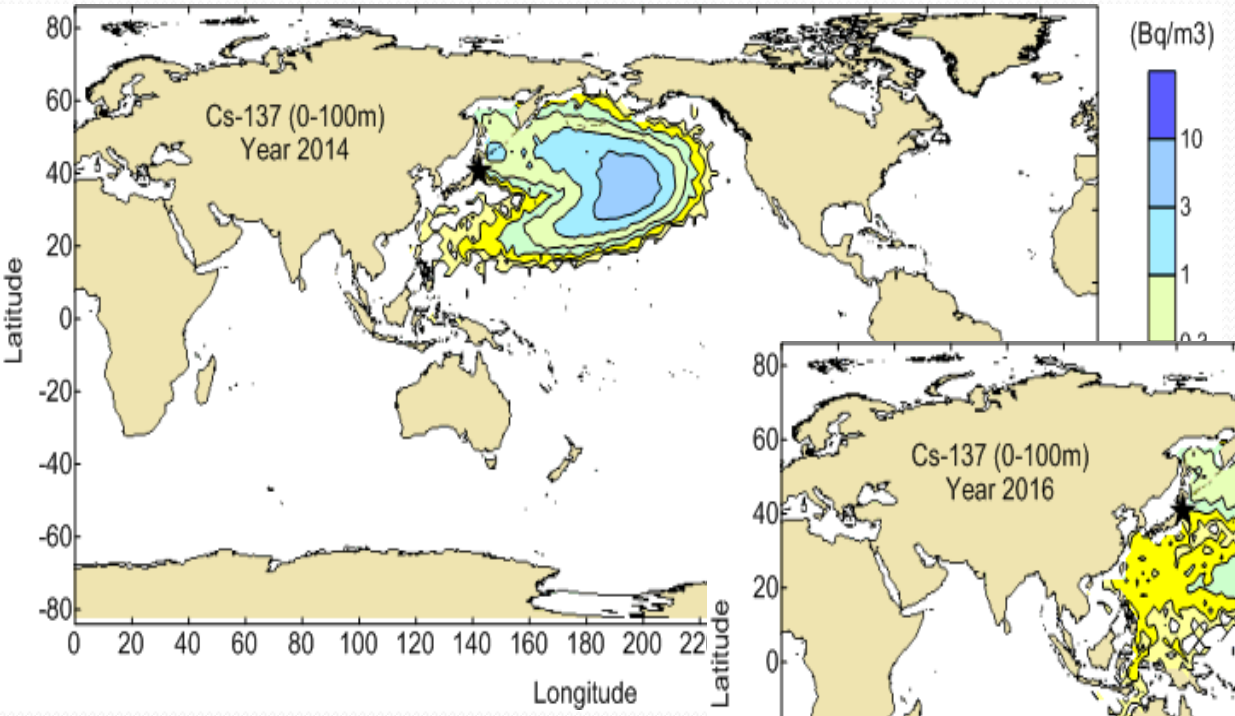
(Buesseler et al., PAS, 2012; Povinec et al., BGS, 2013)

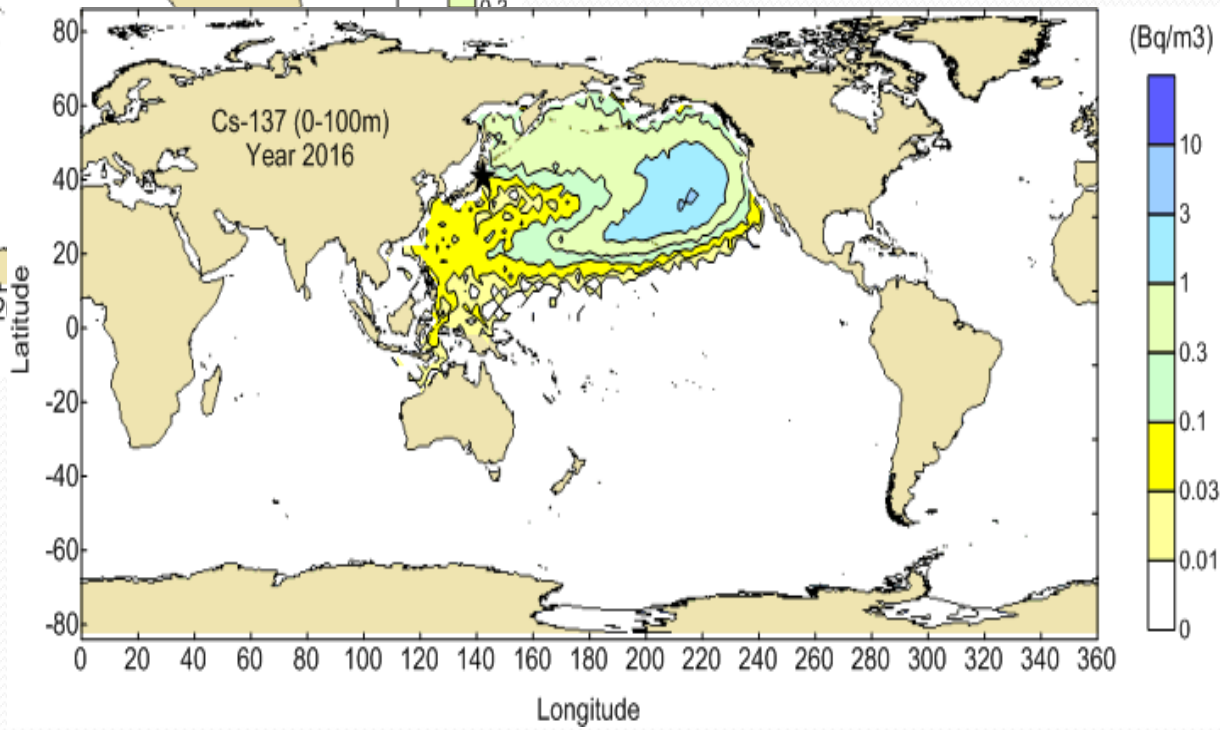
137Cs levels in surface (black dots) and bottom (blue circles) fish offshore Fukushima



Global ocean circulation modeling

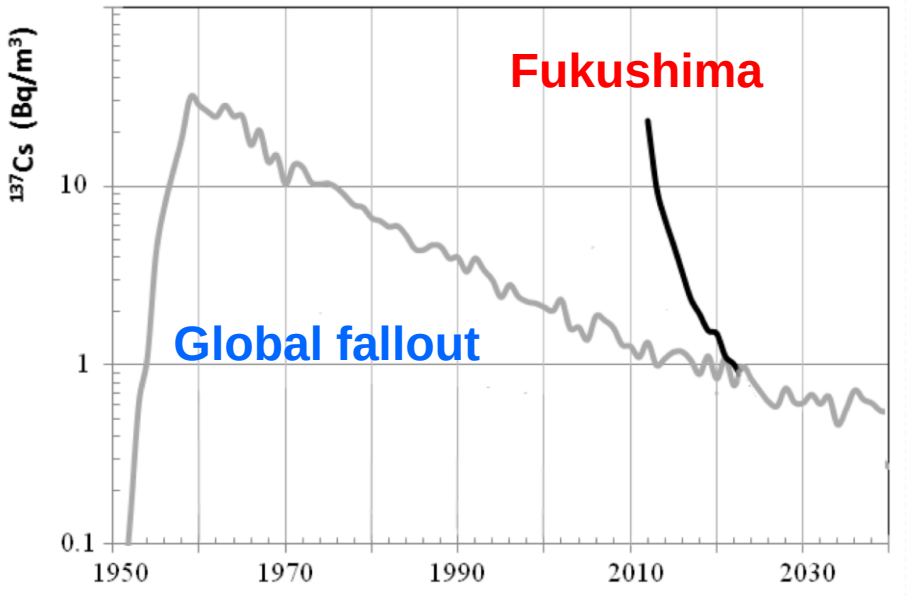
(Nakano M., Povinec P.P., JER, 2012)

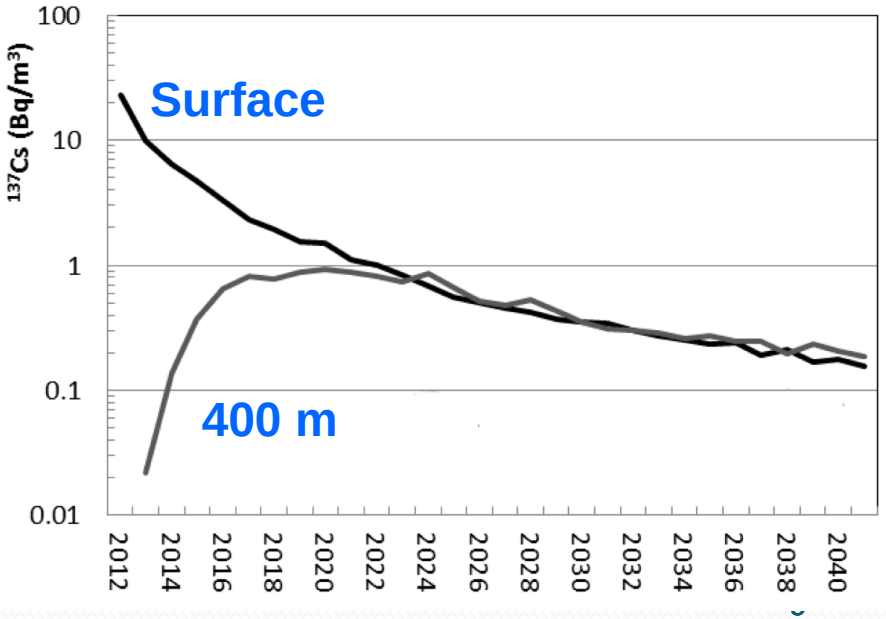




Fukushima impact on surface and subsurface Pacific waters (40°N, 164°E)

(Nakano&Povinec, JER, 2012)





Marine dose assessments

Following the IAEA´s MARDOS (Marine Radioactivity Dose Assessment) project, the radiation doses from consumption of marine food were calculated by two different methods:

(i) using the estimated activity concentrations of 137Cs in seawater and by applying recommended concentration factors,
(ii) using the estimated radionuclide concentrations in the marine products (e.g. in fish and shellfish)

Effective dose commitment (S) from consumption of marine products

- $S = \Sigma_{j,k} (DC)_j (IN)_k (CF)_{j,k} (C_w)_j$,

- $(DC)_j$ represents the dose coefficients for a radionuclide j (^{137}Cs and ^{134}Cs: 1.3x10^{-8} Sv/Bq and 1.9x10^{-8} Sv/Bq),
- $(IN)_k$ represents the averaged intake rate of a marine product k (kg/y),
- $(CF)_{j,k}$ represents the concentration factor for a radionuclide j and a product k, and $(C_w)_j$ represents the concentration of a radionuclide j in seawater (Bq/kg).

Diet habits and concentration factors

Seafood	Food intake (g/day)	Conc. factors ^{134}Cs	Conc. factors ^{137}Cs
Fish	64	100	100
Crustaceans	5.4	50	50
Shellfish	3.5	60	60
Seaweed	10	50	50

Regulations for radionuclide content in seafood adopted by Japan and some other countries

Country	$^{134}Cs + {}^{137}Cs$ (Bq/kg ww)
Codex	1000
Japan	500 ↦ 100
EU	1250 ↦ 100
USA	1200
Hong Kong	1000
Malaysia	1000
Philippines	1000
China	800
Thailand	500
Singapore	500
South Korea	370

Estimated effective dose commitments (EDC) from consumption of seafood collected in Japan coastal waters of the Pacific Ocean

Seafood	EDC – method 1 @ ^{134,137}Cs activity in seawater of 1 Bq/kg (mSv/y)	EDC – method 2 @ ^{137}Cs activity in fish of 1000 Bq/kg (mSv/y)
Fish	0.6	0.6
Shellfish	0.04	~0.05
Seaweed	0.08	~0.05
Total	0.72	0.7

Estimated effective dose commitments (EDC) from consumption of seafood collected in the open Pacific

^{134}Cs and ^{137}Cs content in seawater of 25 Bq/kg), and during the pre-Fukushima time (^{137}Cs content in seawater of 1 mBq/kg)

Seafood	EDC – method 1 @ ^{134,137}Cs activity in seawater of 25 mBq/kg (µSv/y)	EDC – method 1 @ ^{137}Cs activity in seawater of 1 mBq/kg (µSv/y)
Fish	1.8	0.03
Shellfish	0.06	0.001
Seaweed	0.12	0.002
Total	2	0.033

Effective dose commitment for a critical group

^{137}Cs content of marine biota: 1000 Bq/kg ww

Total consumption of seafood: 100 kg/y (by a factor of 4 higher as the Japanese average per year)

The annual dose from ^{137}Cs will be about 1.3 mSv, or the total dose including ^{134}Cs and other pathways will be about 2.9 mSv/y

Slightly higher than the world average dose from natural sources (2.4 mSv/y).

Comparison of radiation doses from consumption of seafood contaminated by Fukushima accident with pre-Fukushima doses

Individual dose commitment (IDC) from consumption of ^{134}Cs and ^{137}Cs in seafood collected in Japan coastal waters – post Fukushima: < 0.7 mSv/y

Pre-Fukushima dose: 0.03 µSv/y

IDC from consumption of $^{137,134}Cs$ in fish caught in the open North-western Pacific Ocean: 2 µSv/y)

IDC from the consumption of natural ^{210}Po in fish and shellfish: 0.7 mSv/y

Outlook

- Radiation doses from ingestion of marine food are under control, and they will be negligible
- Historical radionuclide record available for assessing Fukushima impact on the Pacific
- Ocean general circulation models available
- Fukushima impact on radionuclide climate change studies (^{14}C, ^{129}I, etc.)
- More water column sampling in the NW Pacific is needed:

  - to catch the ^{134}Cs signal (discriminate against the global fallout)

  - to catch the deposition over the Pacific