Fukushima ocean impacts

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Accident at the Fukushima Dai-ichi Nuclear Power Plants

Tsunami
40-50
feet
tall

Loss of power,
overheating
& melt down

Airborne releases due to overheating, hydrogen explosions & fires

Water used to cool reactors is major pathway for radioactive contaminants to enter ocean

Cesium radionuclides in the ocean- what do we know?

- mostly from 1960's weapons testing but some local sources
- one of major Fukushima radionuclides of concern
- soluble in seawater

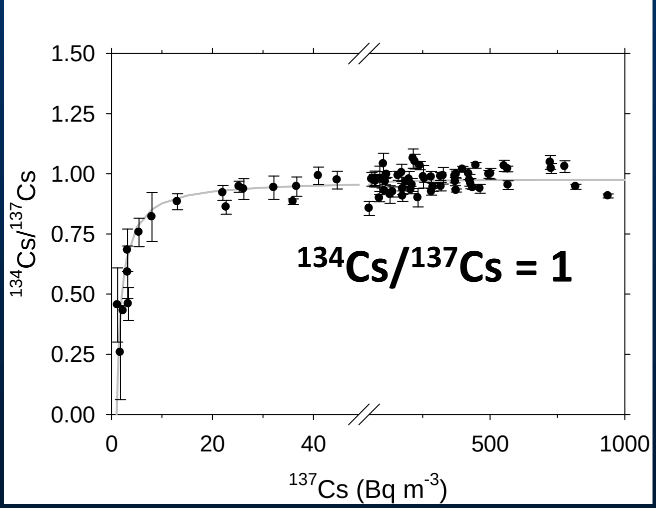
^{137}Cs half-life = 30 years

^{134}Cs half-life = 2 years

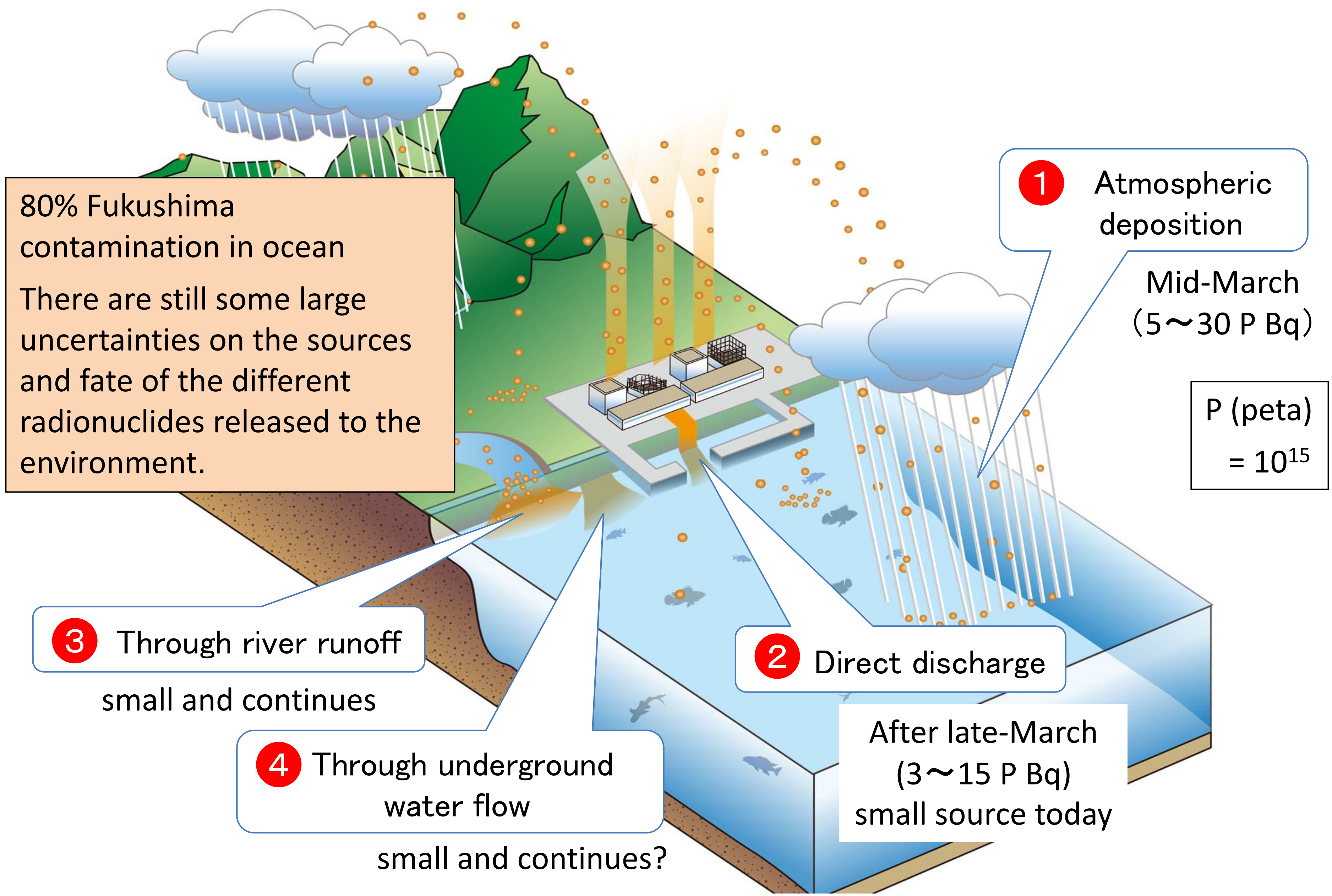
- both isotopes of cesium have same chemical properties

Fukushima Cs fingerprint

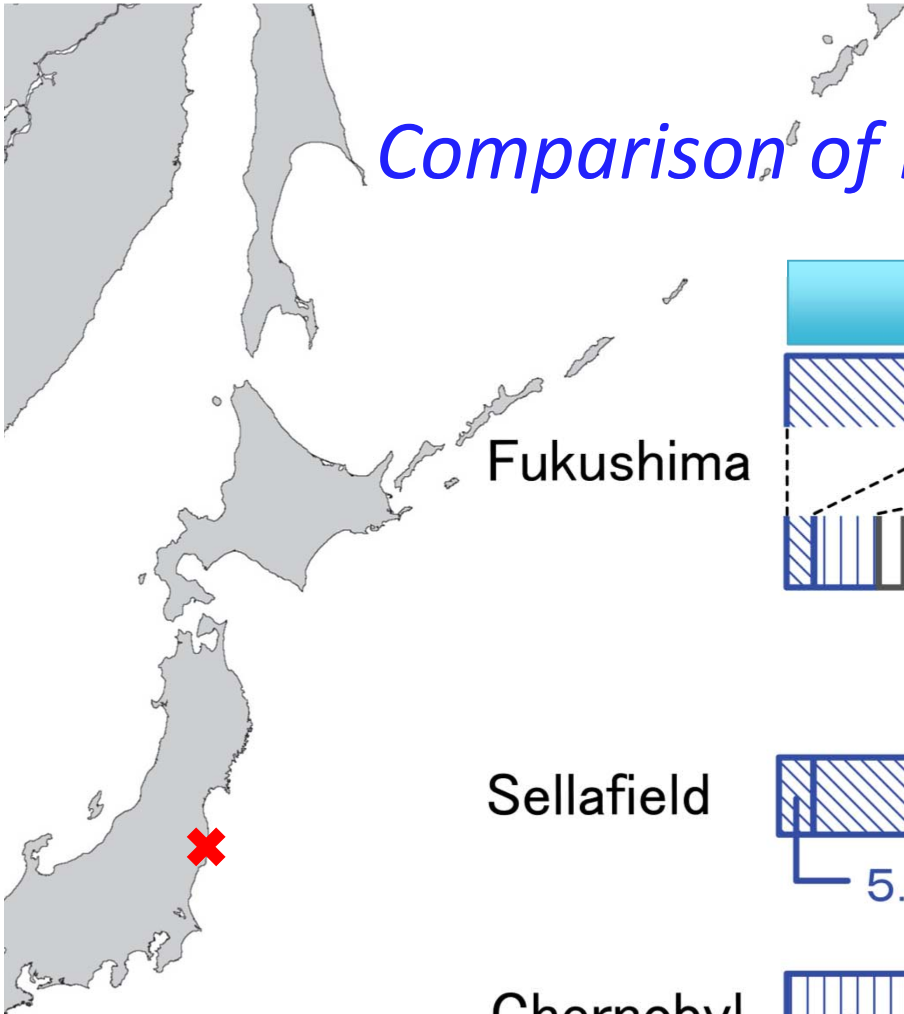
Because of the shorter half-life of ^{134}Cs and constant ratio of $^{134}Cs/^{137}Cs$ =1.0

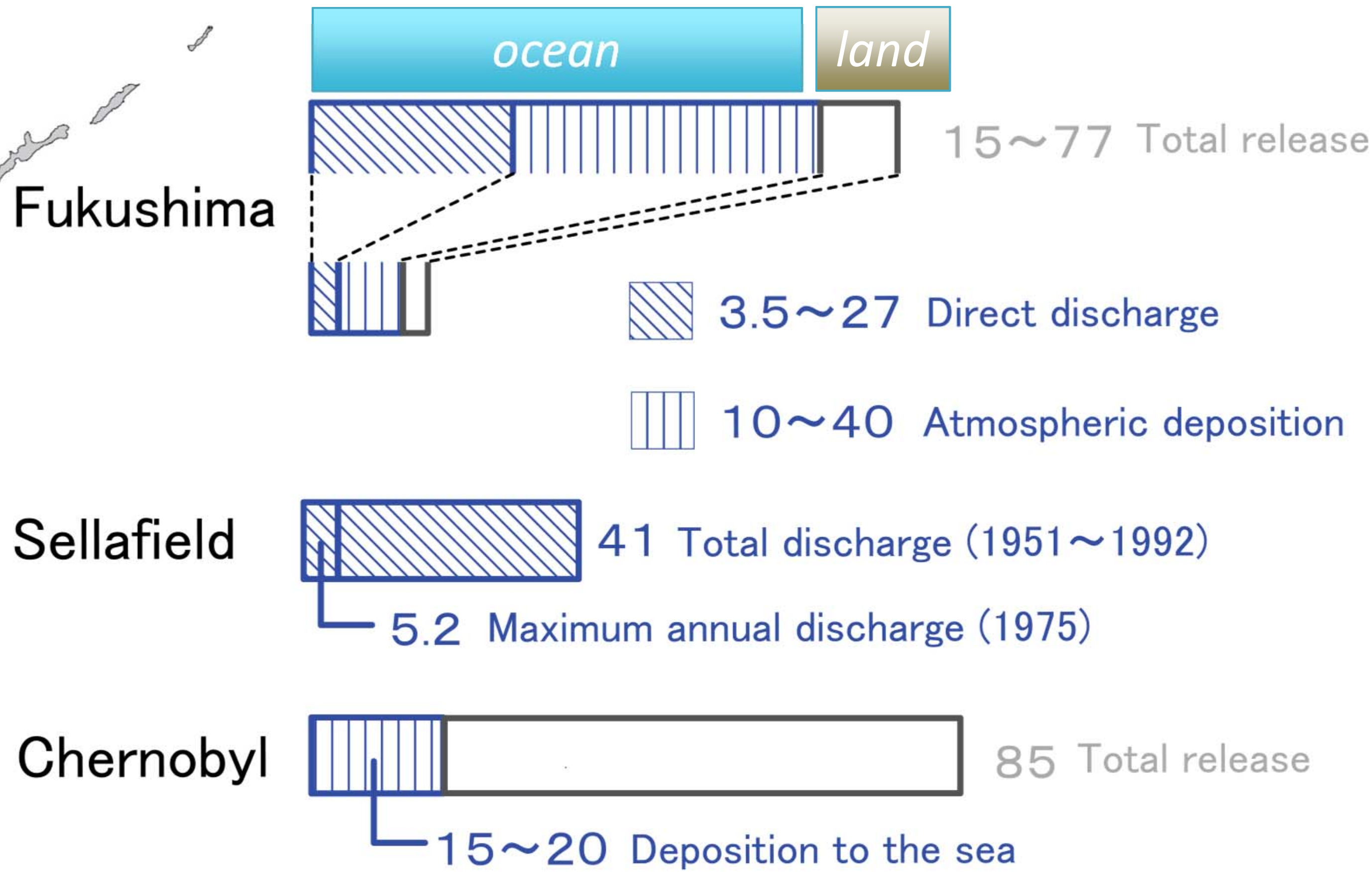


Various Routes to the Ocean: Boundary Conditions



Comparison of Fukushima to other sources



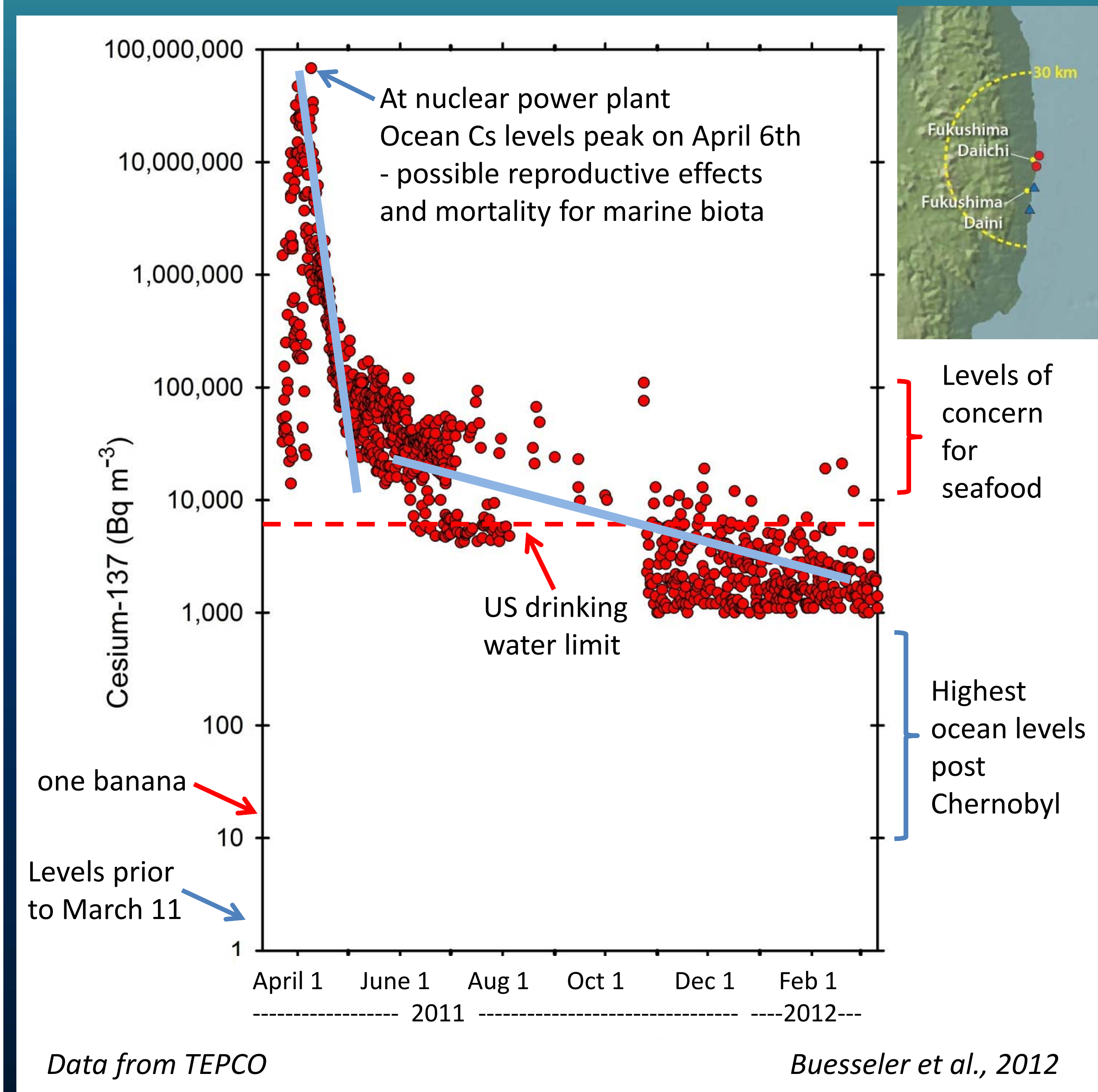


J. Kanda TUMST

^{137}Cs release to the sea (PBq)

Data sources: Chino *et al*. (2011), Tsumune *et al*. (2012), Bailly du Bois *et al*. (2012). Morino *et al*. (2011), Stohl *et al*. (2011), Gray *et al*. (1995), Aarkrog (2003), UNSCEAR (2000)

One year history of cesium-137 in ocean immediately off Fukushima



- Fukushima NPP represents unprecedented release of radionuclides to the ocean

- levels decreased rapidly, then leveled off

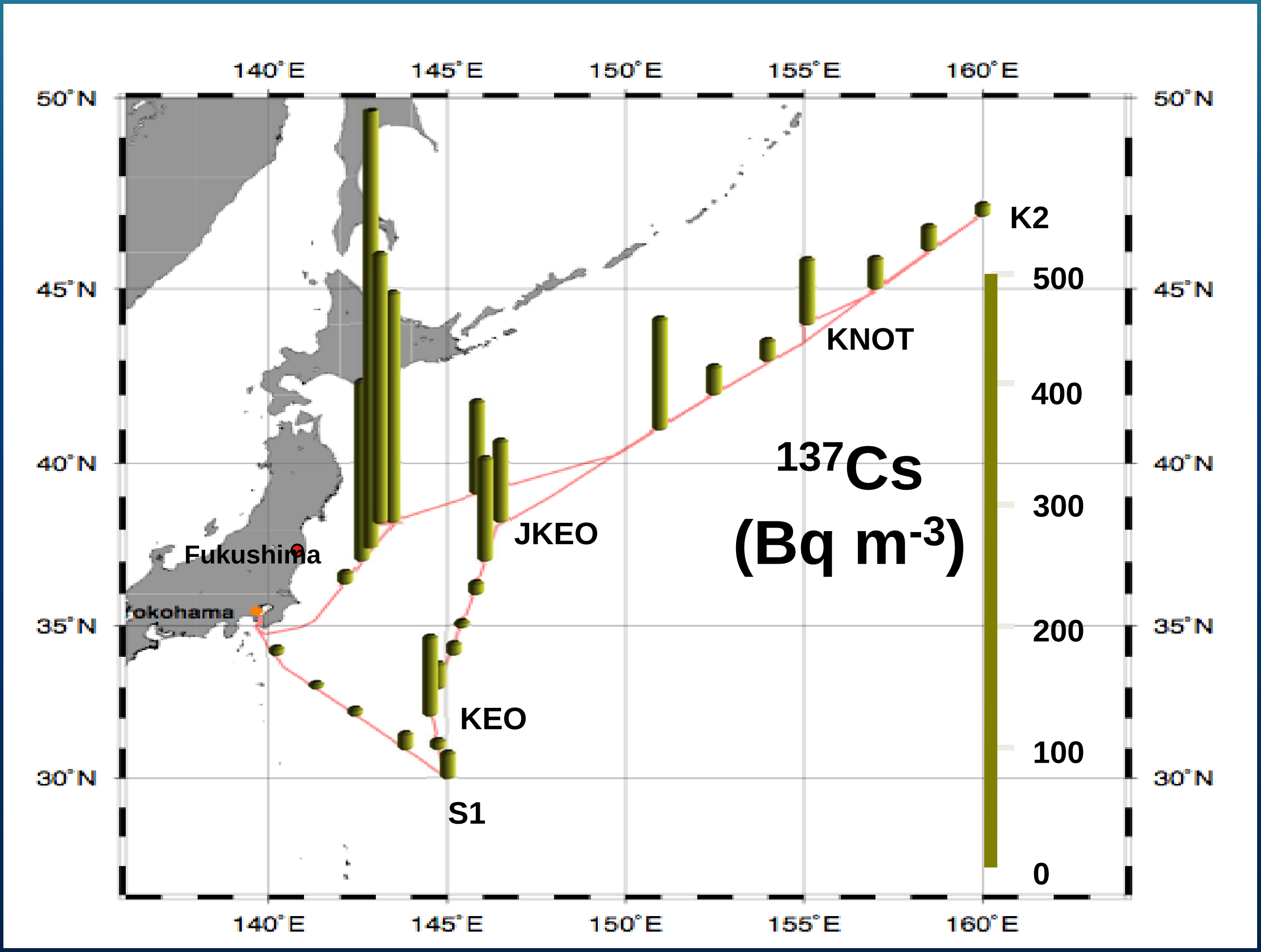
- remain at >1000 Bq m^{-3} through end 2012

- so reactor site remains a source

- but levels now safe for marine biota & human exposure

- what about seafood?

In April 2011, see both near shore and far field sources of cesium

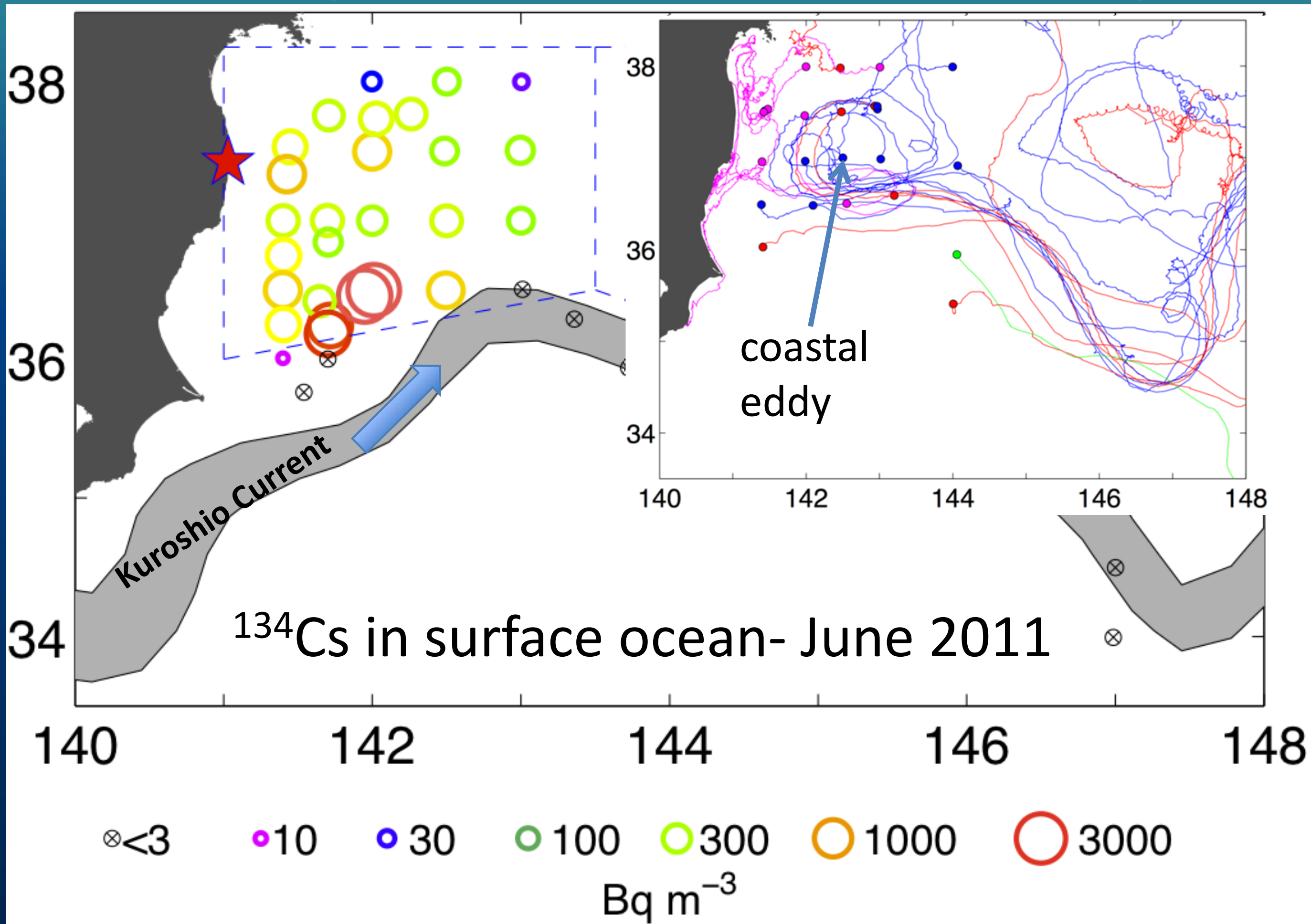


Cs in ocean at low levels at great distances in April 2011 due to atmospheric source

Higher Cs close to Japan due to direct ocean discharge

Honda et al. 2012

Spatial variability in Fukushima Cs determined by currents & mixing

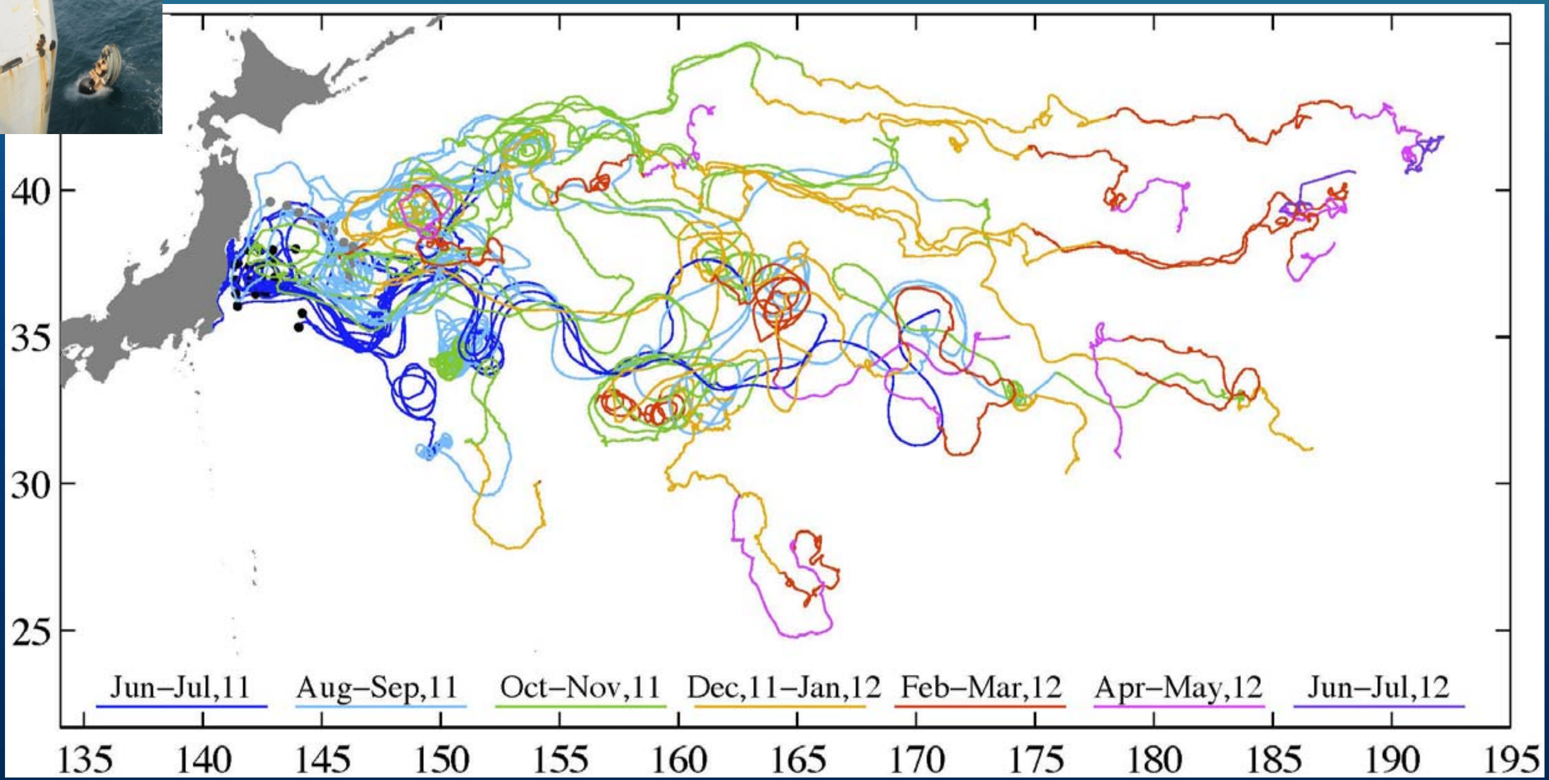


^{134}Cs $t_{1/2}$ = 2 yr
>99.5% soluble

^{134}Cs varies by 3 orders of magnitude- up to 4000 Bq m^{-3}
Kuroshio acts as barrier (if air deposition to south, not very much)
Highest values associated with near shore eddy

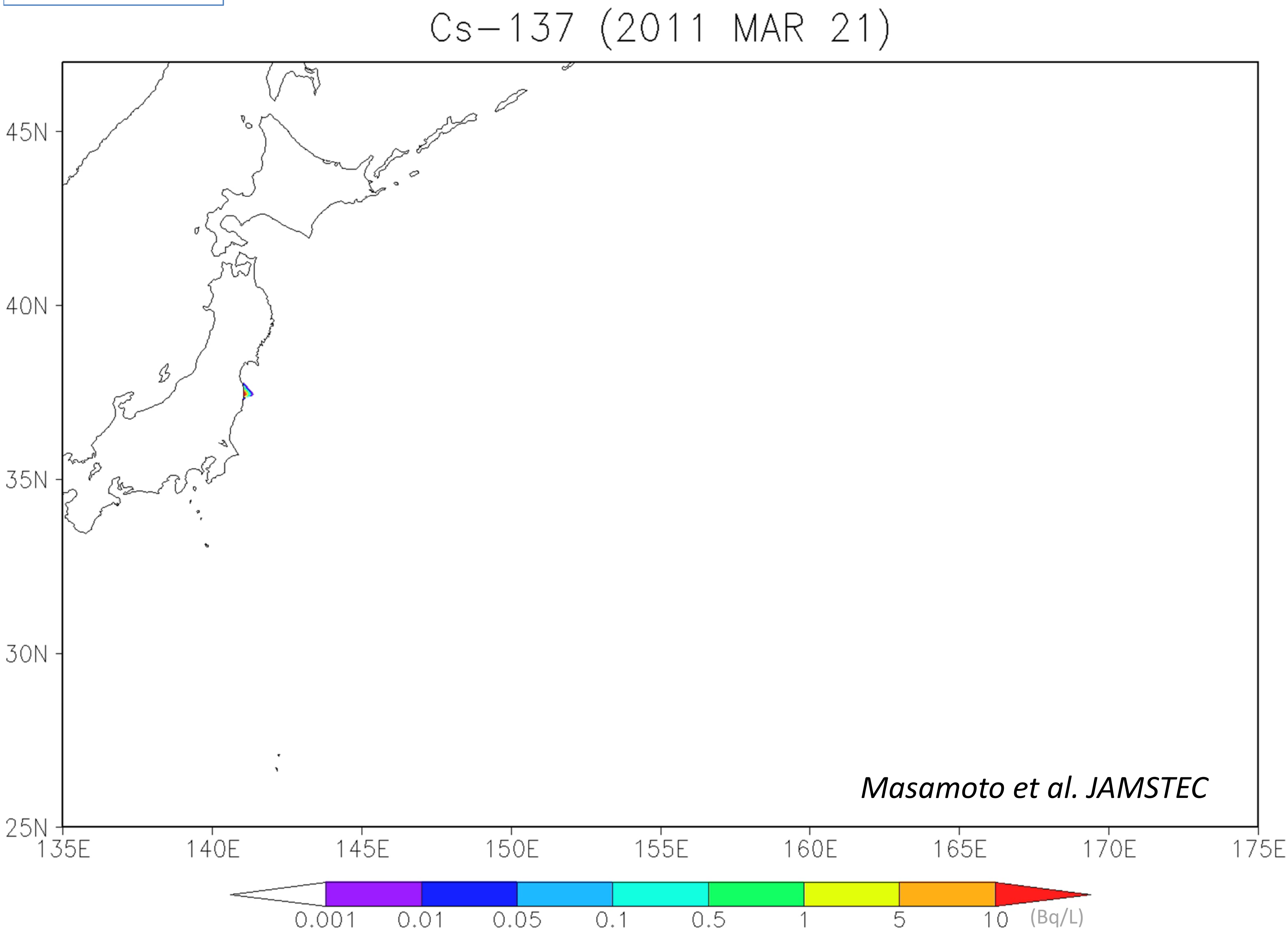
Buesseler et al. PNAS April 2012- data available on line

Ocean currents transport cesium across Pacific



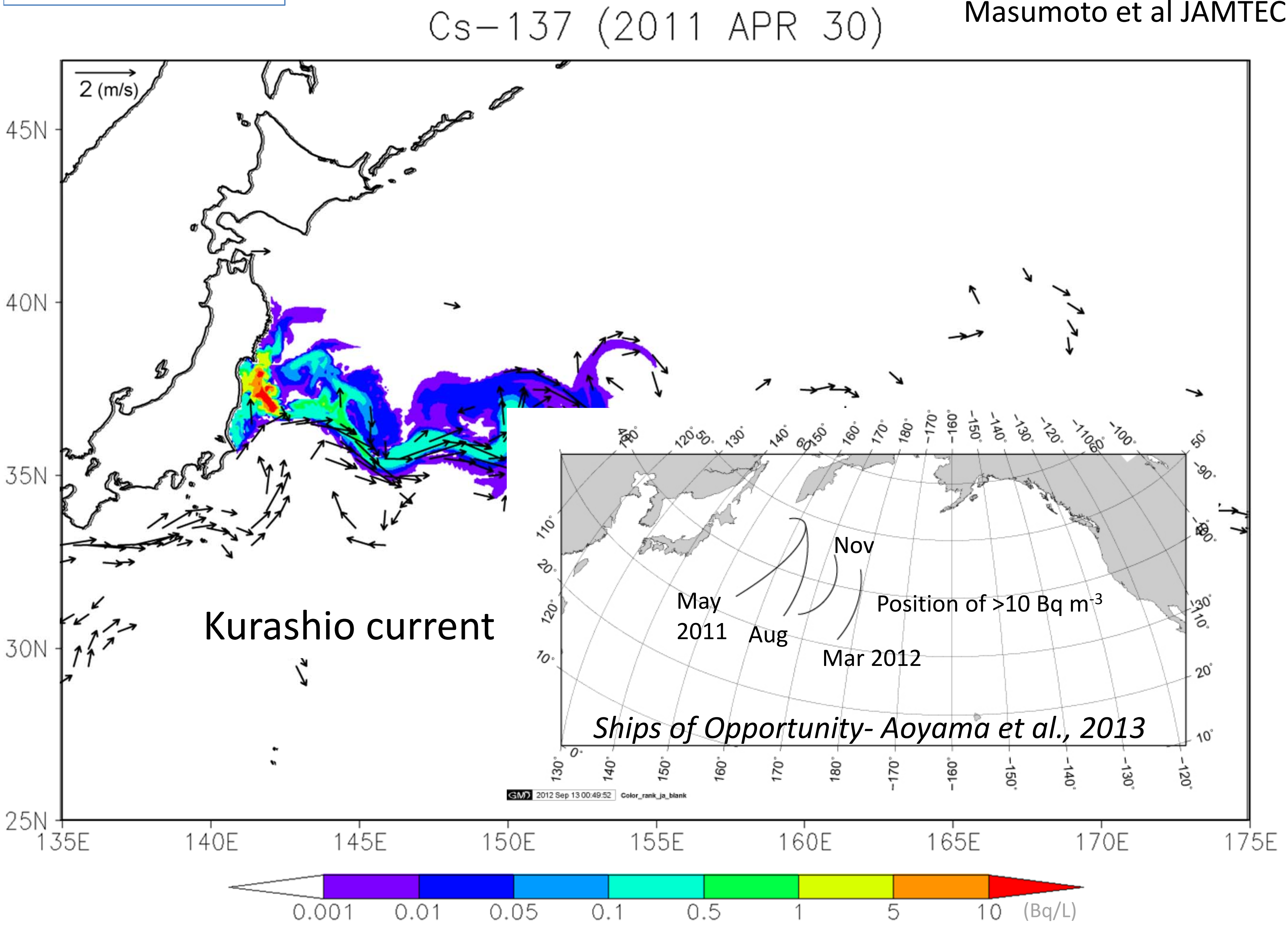
Drifters were released off Japan in June 2011
Map shows surface ocean drifter tracks as of July 2012
Provides direct measure of transport times
Note - debris moves faster due to winds
Rypina et al., 2013

JCOPE2 model

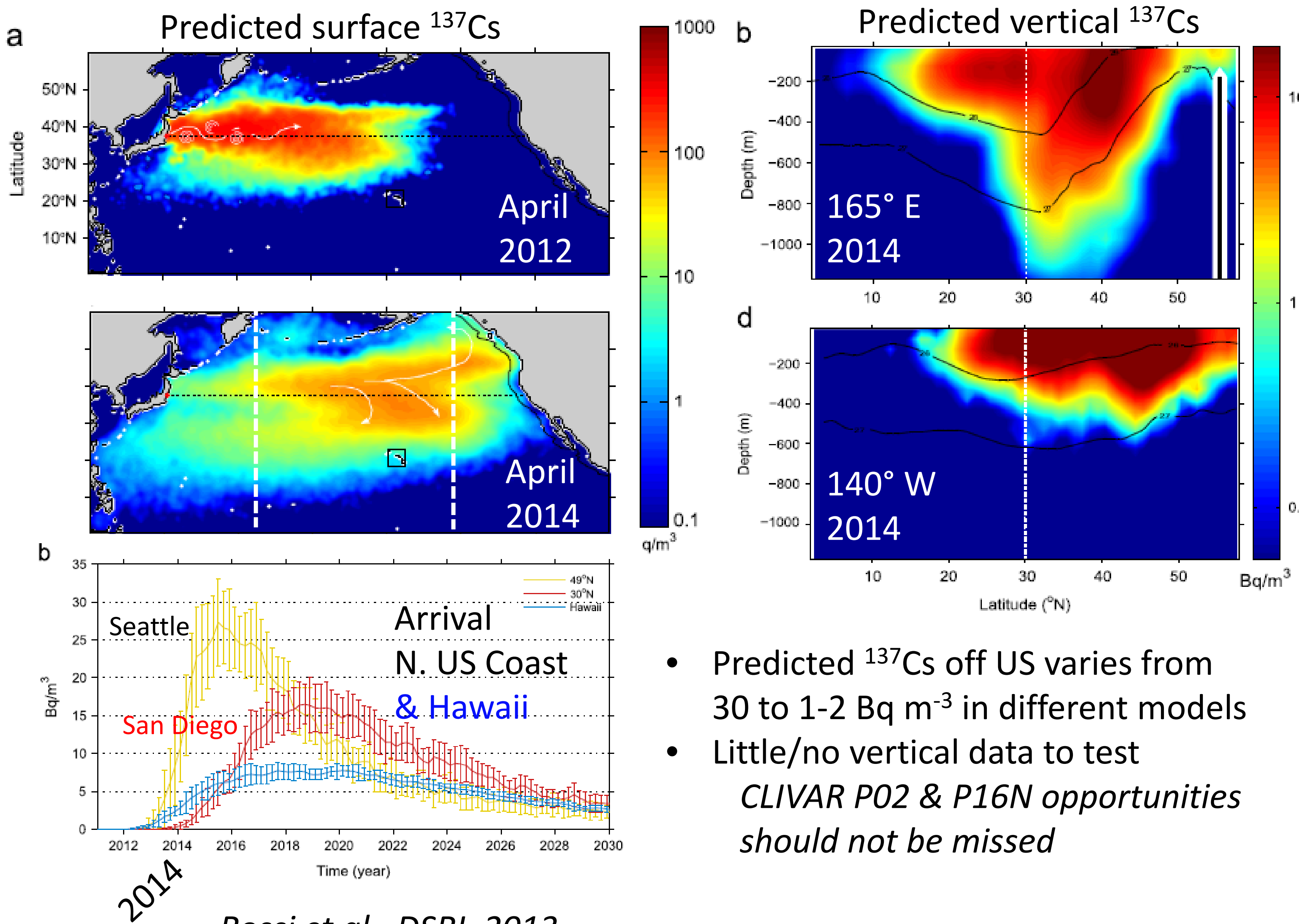


JCOPE2 Tracer-Run

<Observed data is assimilated till June 16, 2012>
Masumoto et al JAMTEC



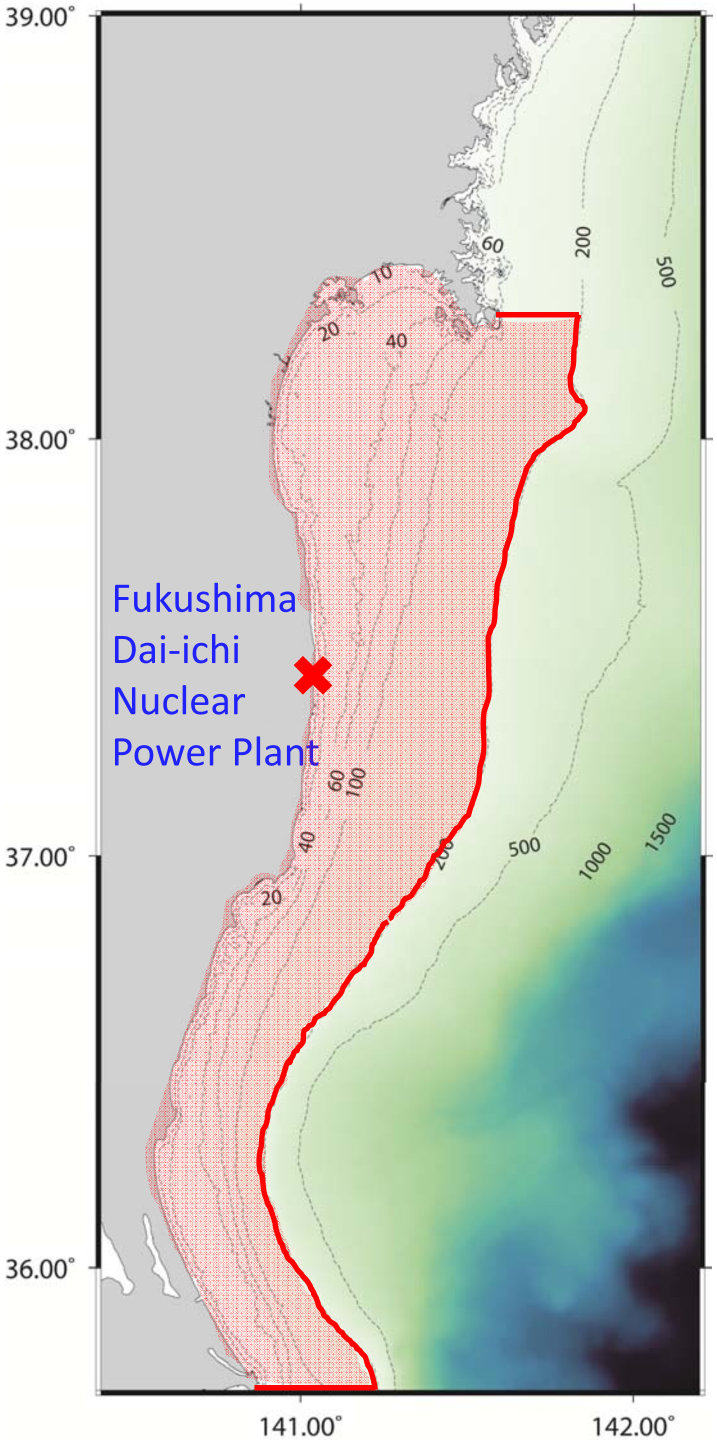
Fukushima Cs as a tracer- significant models differences

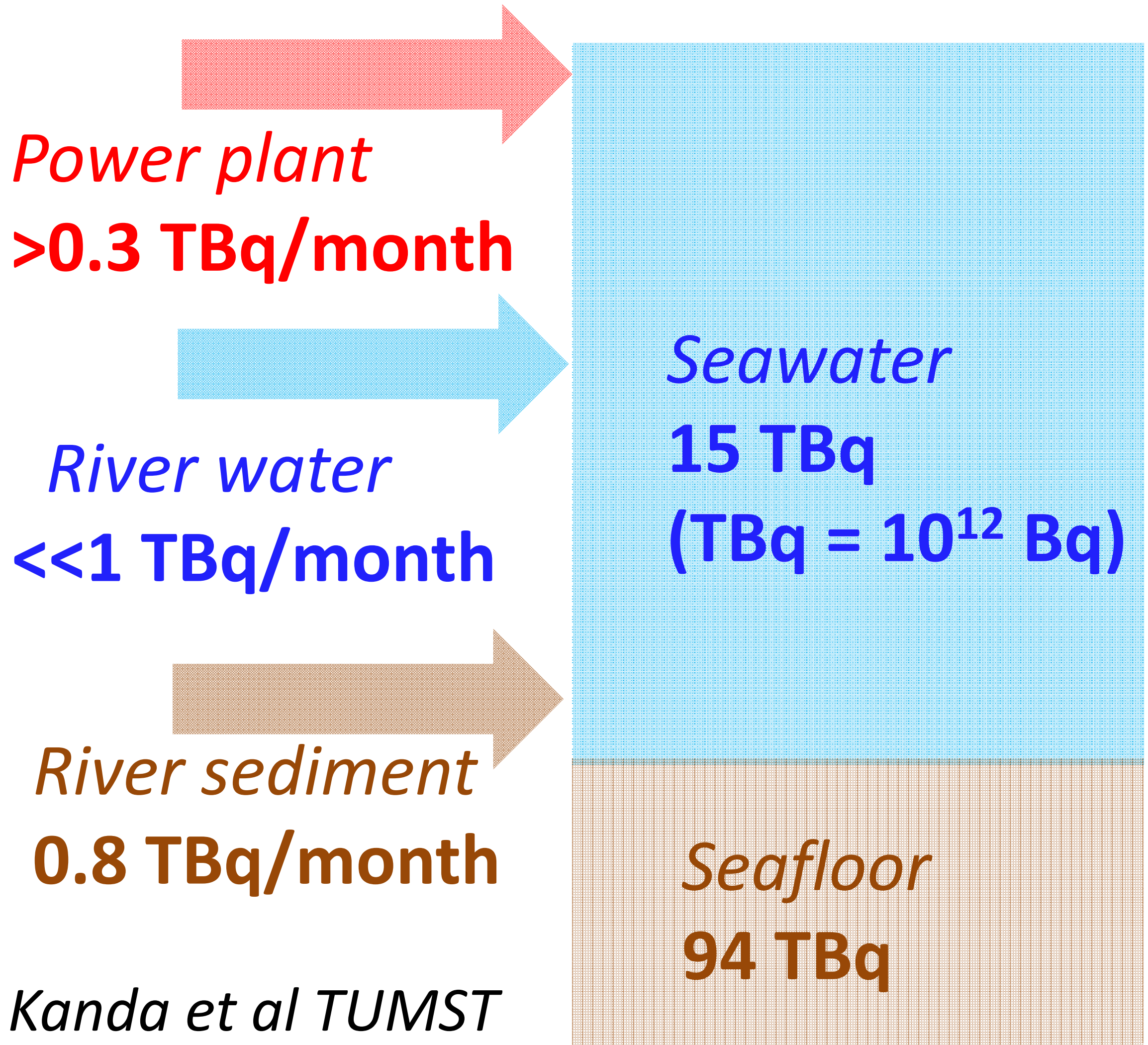


Rossi et al., DSRI, 2013

- Predicted ^{137}Cs off US varies from 30 to 1-2 Bq m^{-3} in different models
- Little/no vertical data to test
  CLIVAR P02 & P16N opportunities should not be missed

Cesium-137 today off Japan (Nov. '12)





Kanda et al TUMST

Leak from the plant

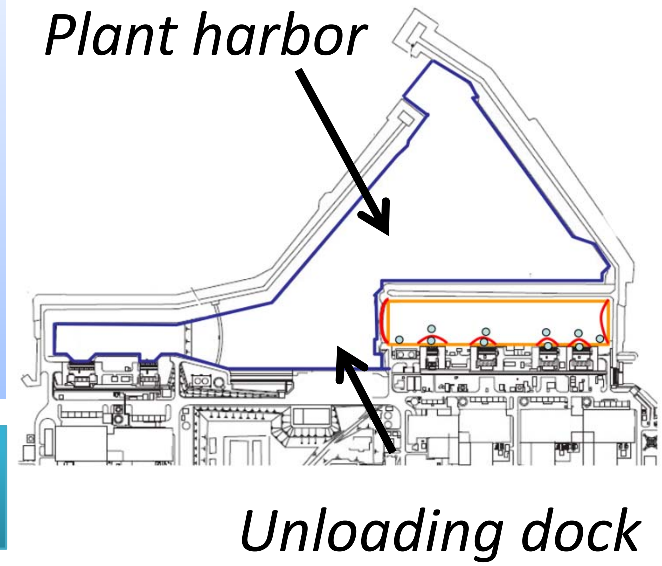
^{137}Cs release in summer 2012

Harbor-water: 2.3×10^6 m^3

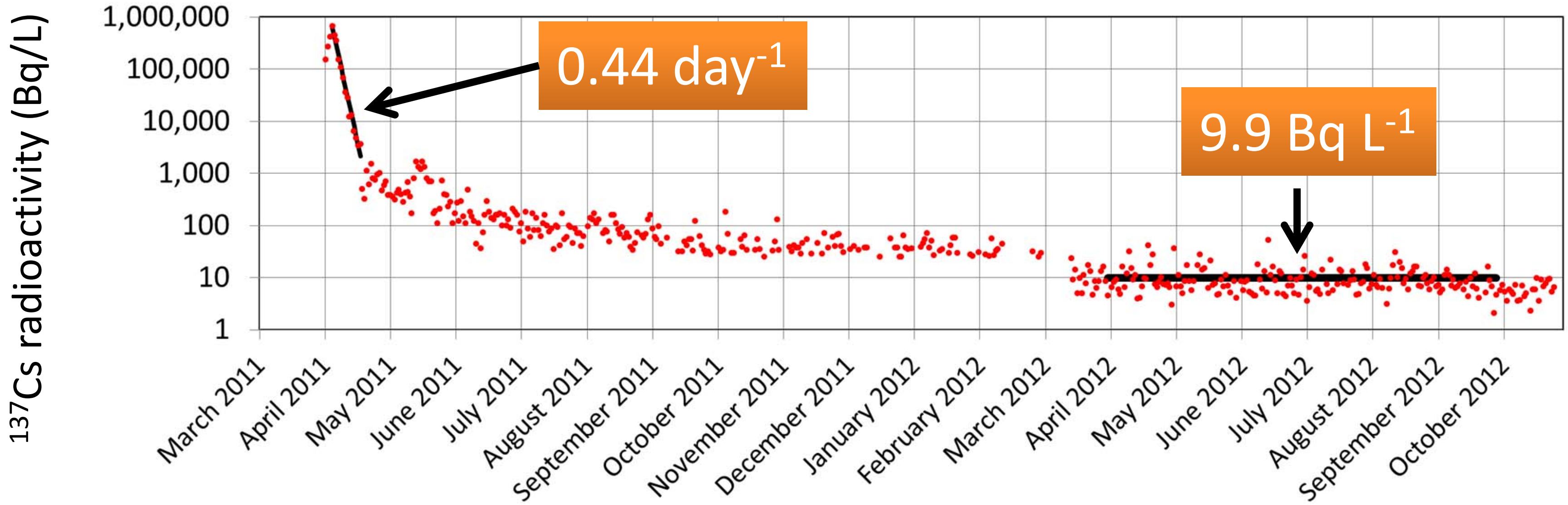
Exchange rate: 0.44 day^{-1} (6～19 April 2011)

Average ^{137}Cs at *"Unloading dock"*:

9.9Bq L^{-1} (1 April～30 September 2012)



10 GBq day^{-1} 0.30 TBq month^{-1}



^{137}Cs radioactivity at "Unloading dock" inside the plant harbor

Data source: TEPCO

Japanese Nuclear Plant May Have Been Leaking for Two Years
By HIROKO TABUCHI
Published: July 10, 2013

Increasing groundwater concentrations would increase continued source at NPP site

Reports of >10x increase in GW concentrations

Tritium readings inside port facility

Until April: relatively stable at 100 bq/l

June 21: 1,100 bq/l

July 3: 2,300 bq/l

GW are relatively high are ^{90}Sr and tritium

^{137}Cs/^{90}Sr in initial release = 40

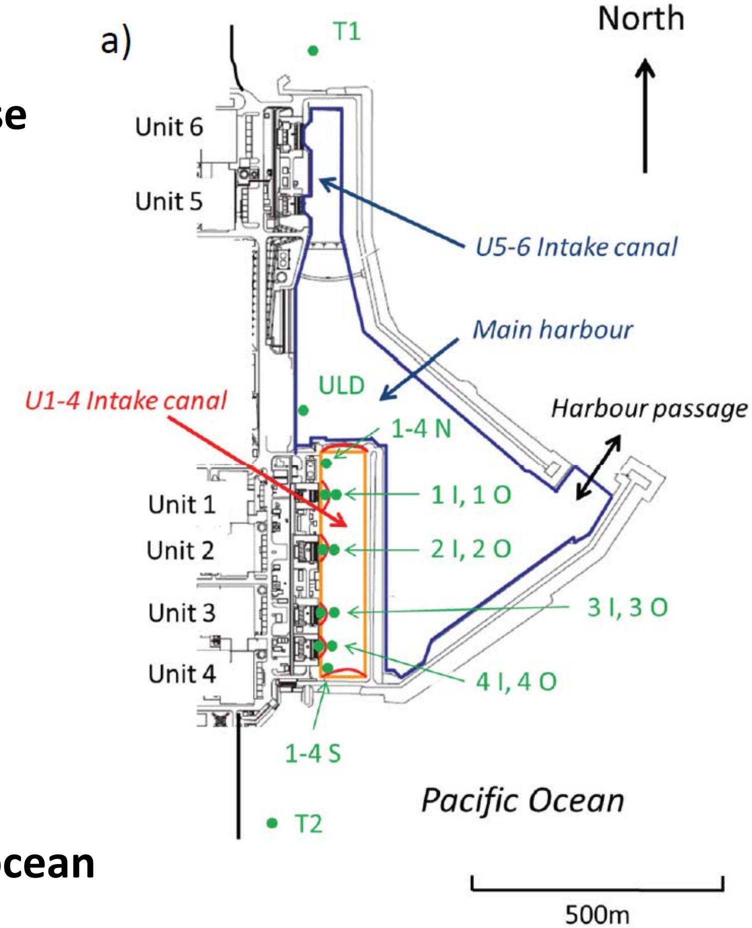
^{137}Cs/^{90}Sr in GW <0.01

TEPCO building containment wall between NPP and ocean & removing Cs (so far) from cooling waters

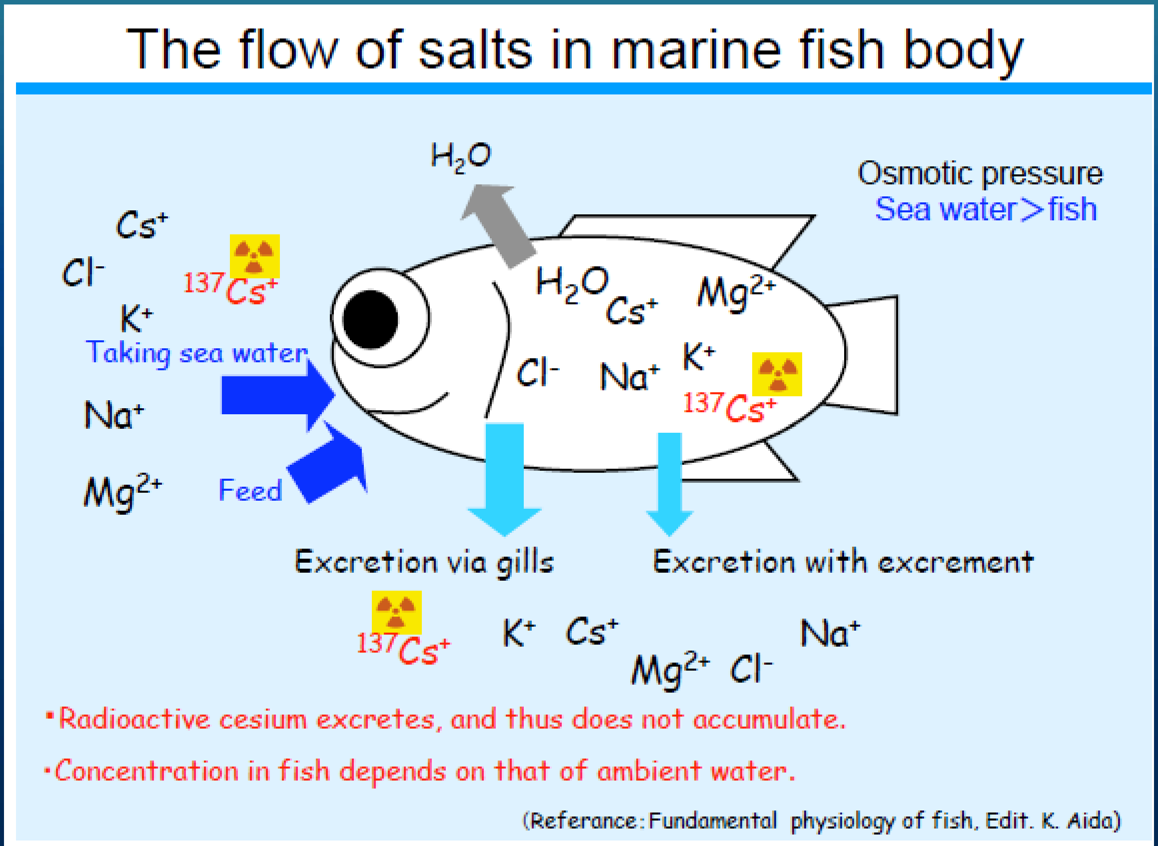
New concern about ^{90}Sr in fish

Cs contamination has already led to fisheries closures

Fisheries losses >$10 Billion



What about Fish and cesium accumulation?



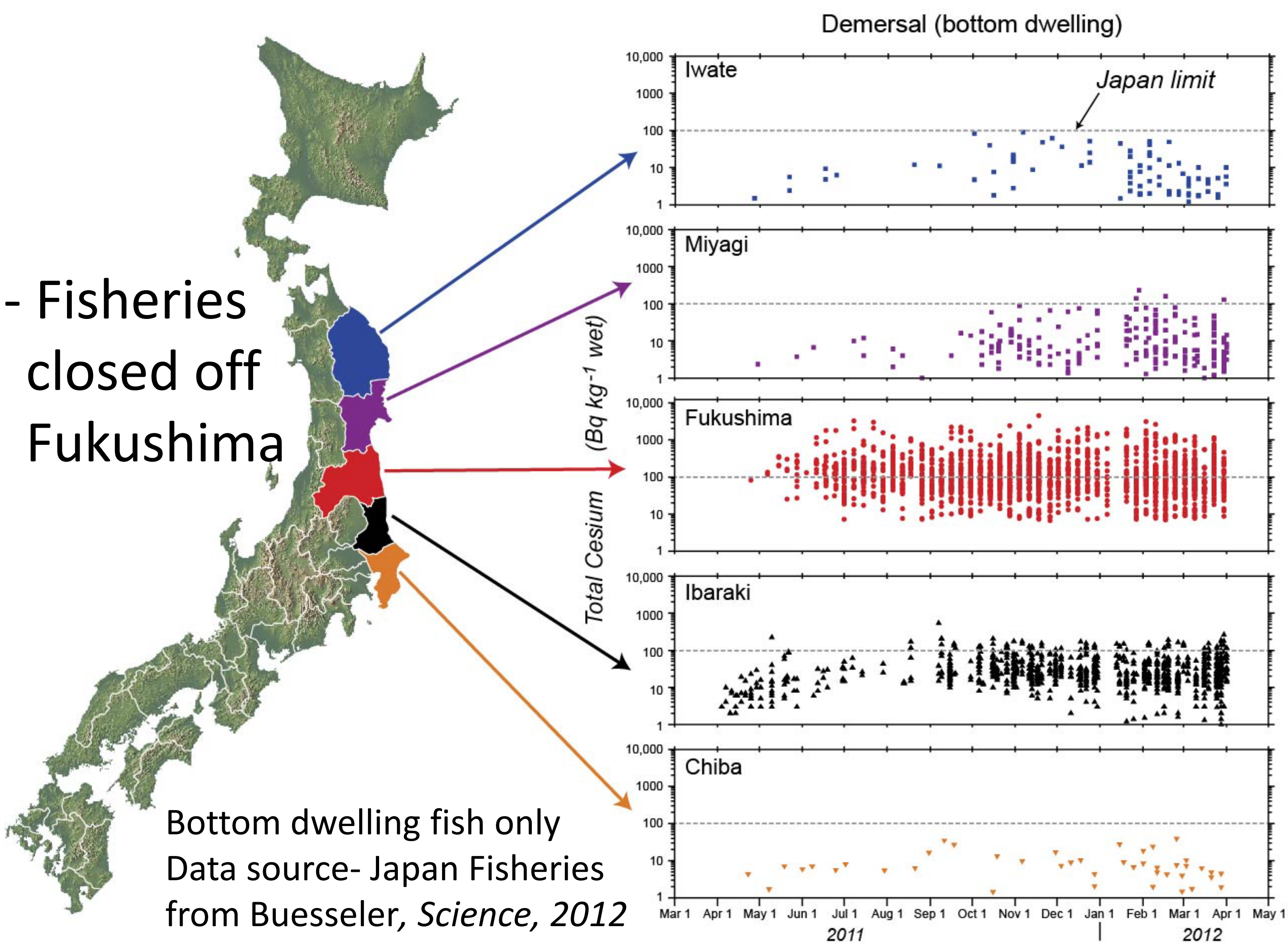
Biological half time of Cs-137 = about 50 days

The half of Cs-137 is excreted in 50 days (in laboratory)

Cesium uptake and loss from fish is rapid

information page from Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF)

What about fish off Japan- where do fish have highest cesium?



- Fisheries closed off Fukushima

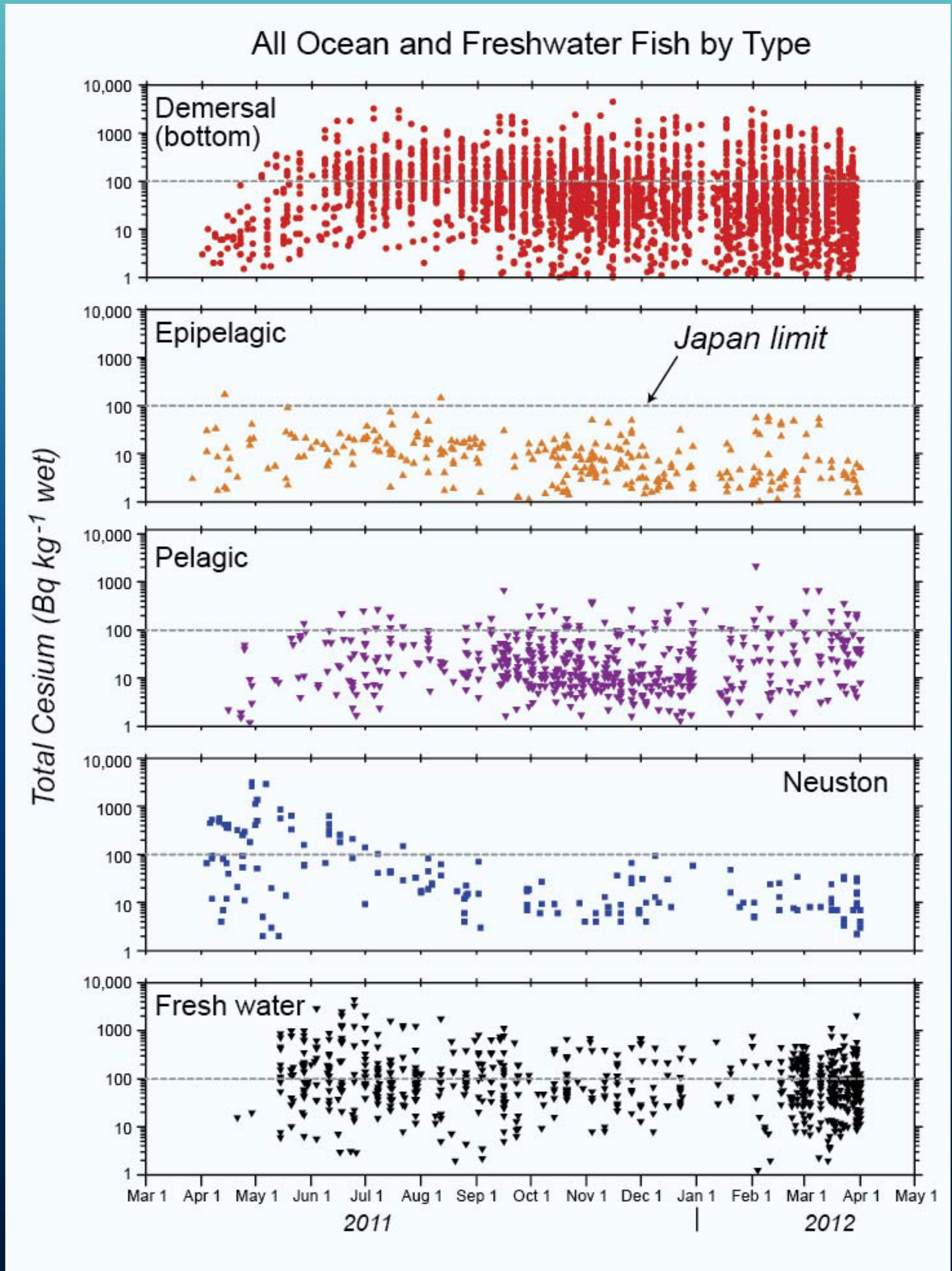
Bottom dwelling fish only
Data source- Japan Fisheries
from Buesseler, *Science, 2012*

Which type of fish off Japan are most contaminated?

- bottom fish
  & freshwater fish

- still high after 1 year
- variability unpredictable
- 18% of fish reported
  are above limit

Data source- Japan Fisheries
from Buesseler, *Science, 2012*



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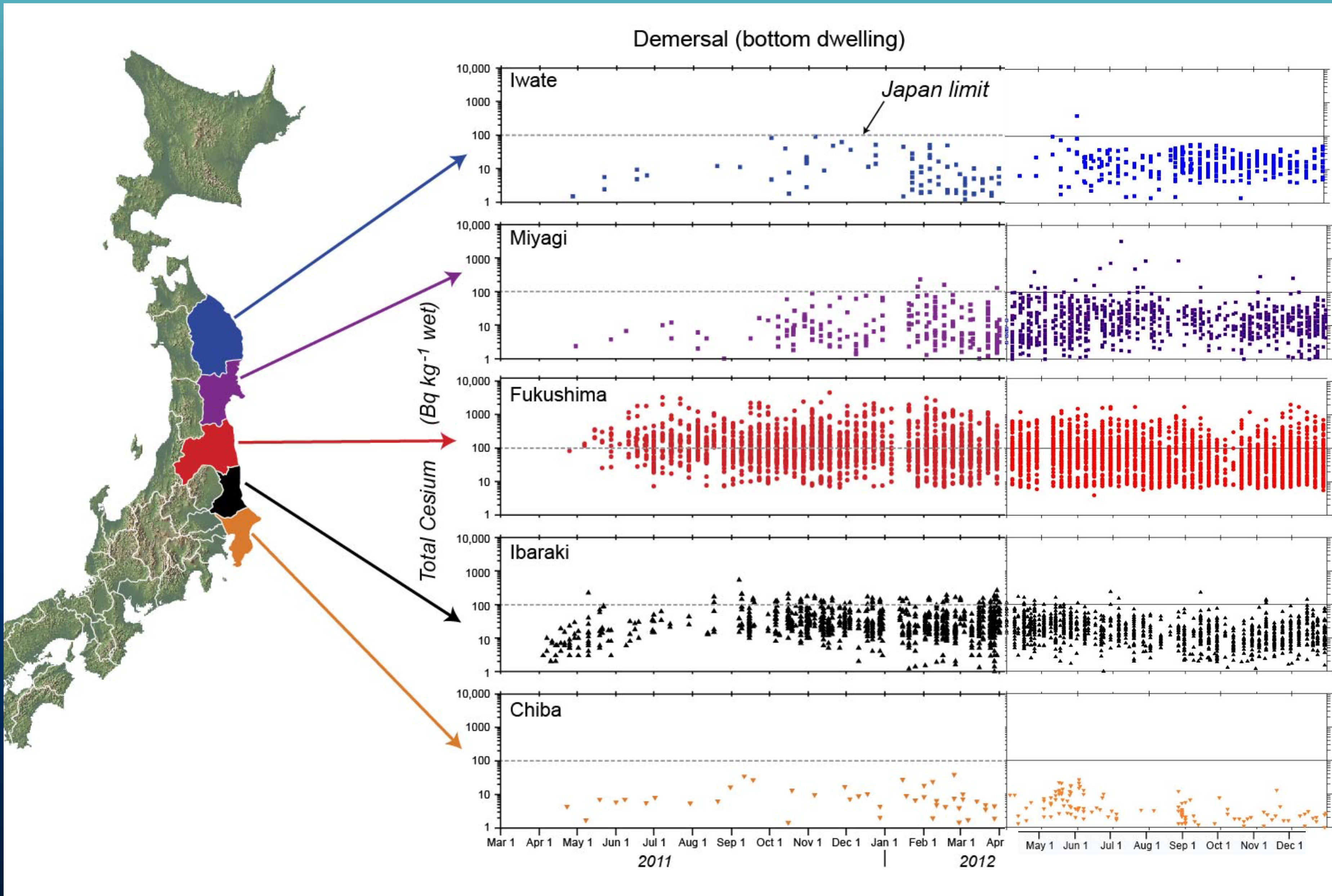
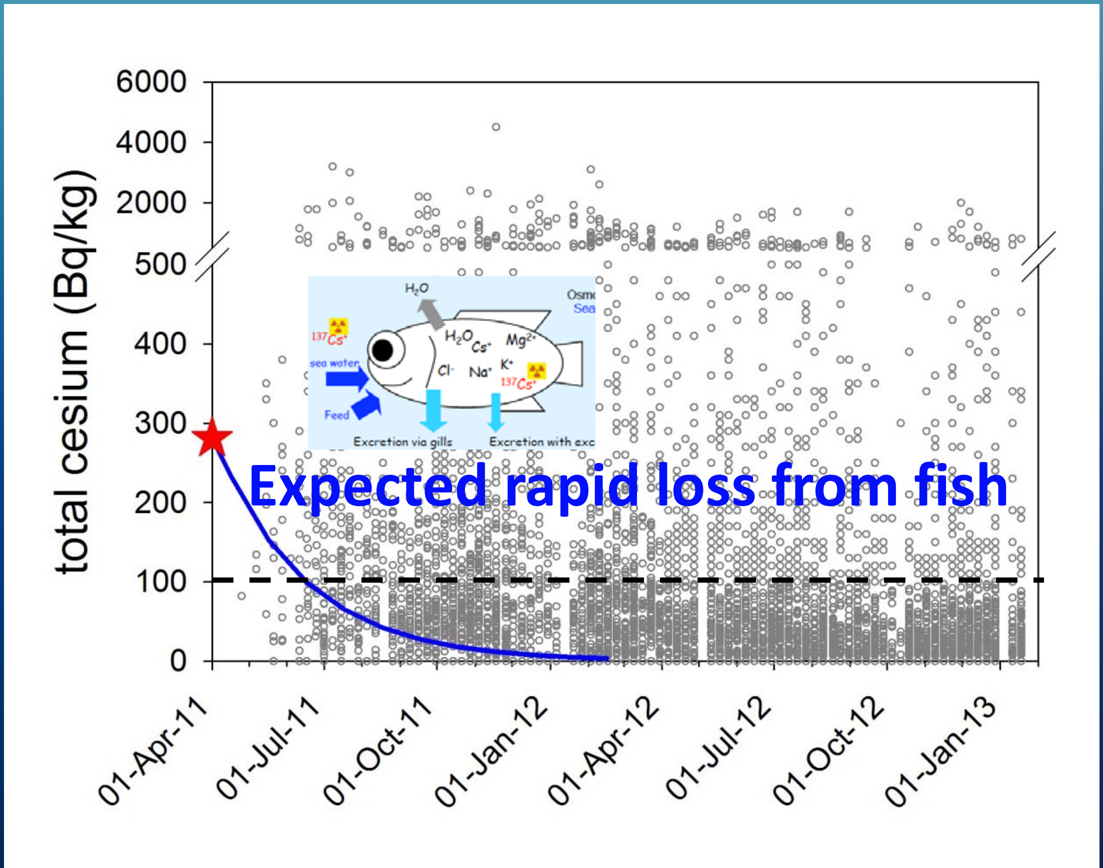
WHOI

How have the trends continued through end 2012?



A closer look at Fukushima bottom fish



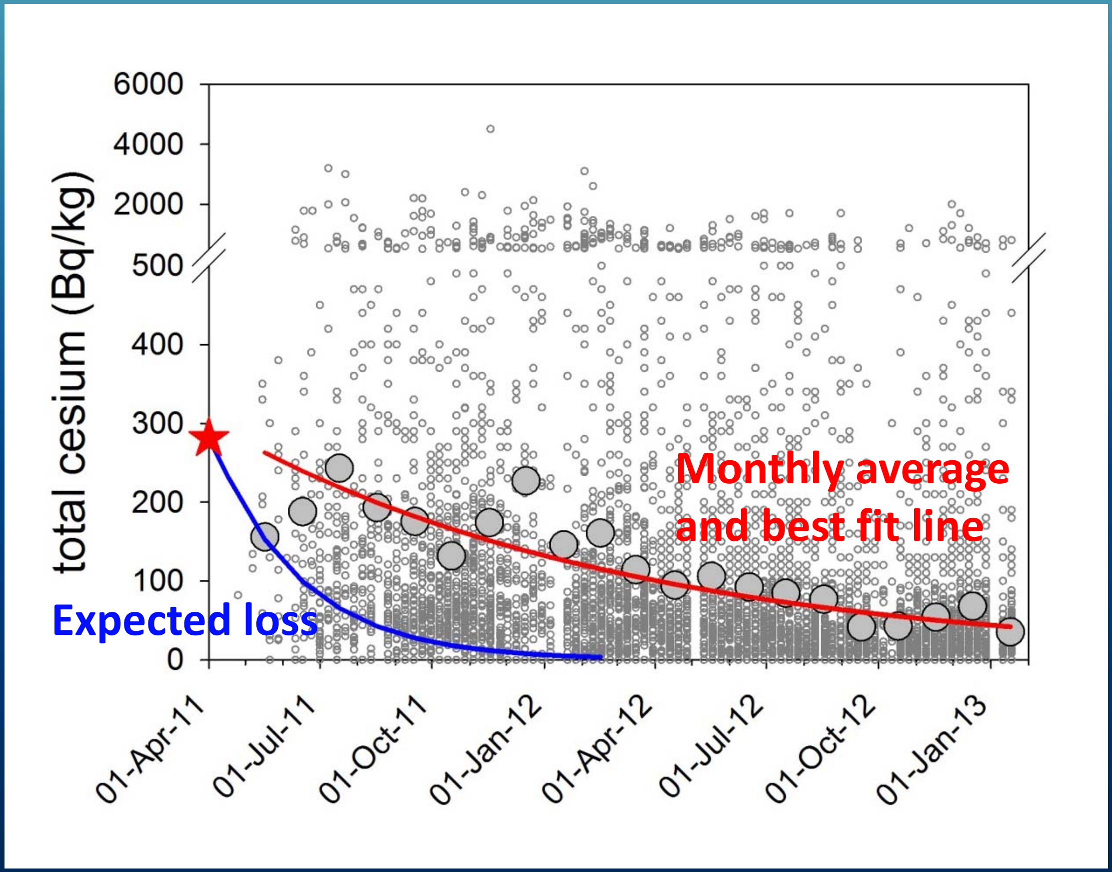
Cesium levels are not decreasing as fast as expected

Non steady-state food web model explains some of this (Tateda et al. 2013)

There must be a continued cesium source

- contaminated seafloor
- nuclear power plant site

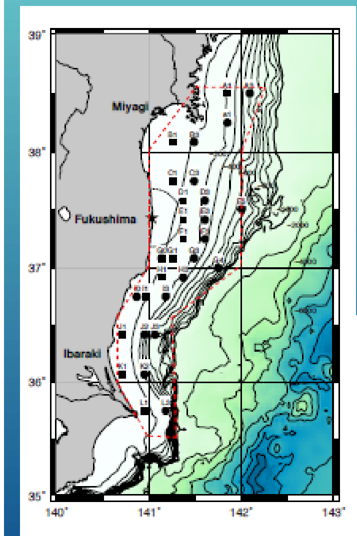
A closer look at Fukushima bottom fish



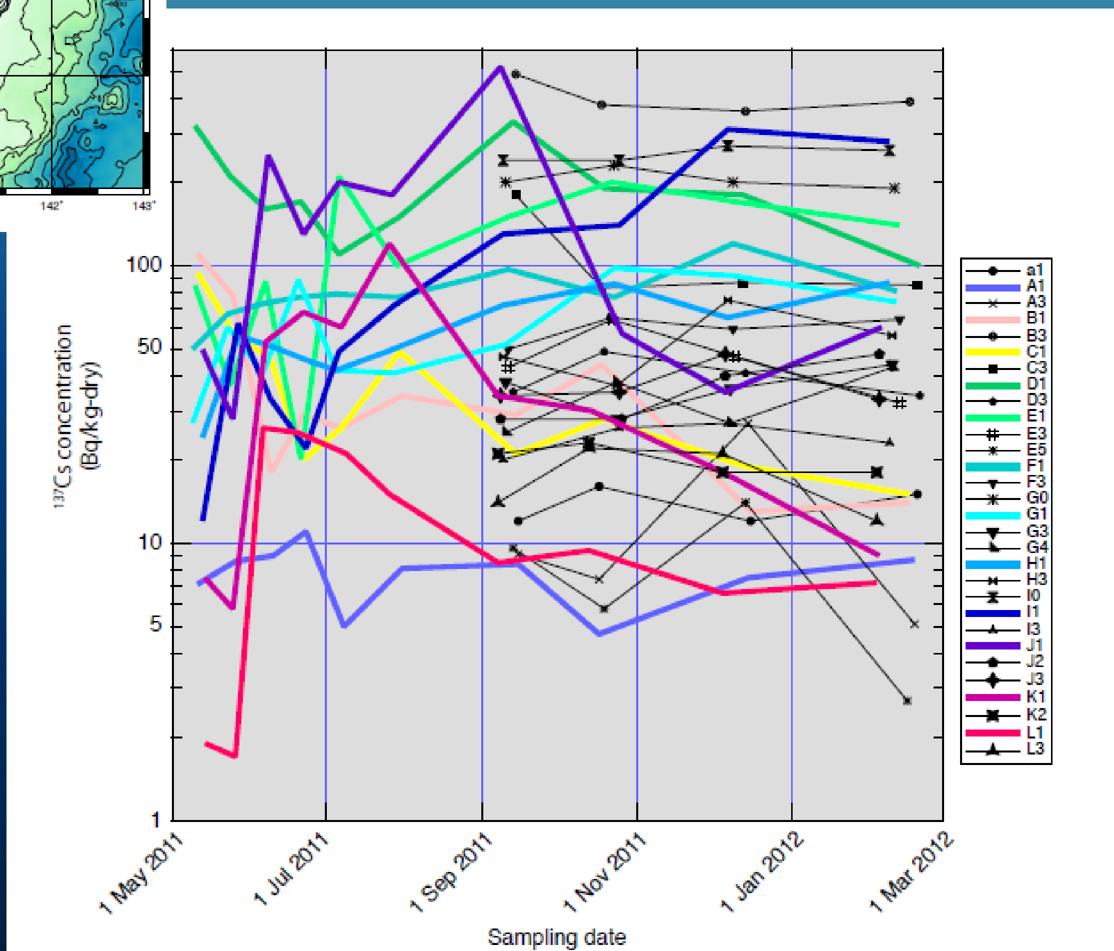
Cesium decrease is slower than expected
- 50% in 330 days

- many fish still above legal limits

- highest values to date in Feb. 2013 740,000 Bq/kg in NPP embayment



What about Fukushima Cs in Sediments?



Kusakabe et al., BGD, 2013

Significant variability between sites & at any one site/time

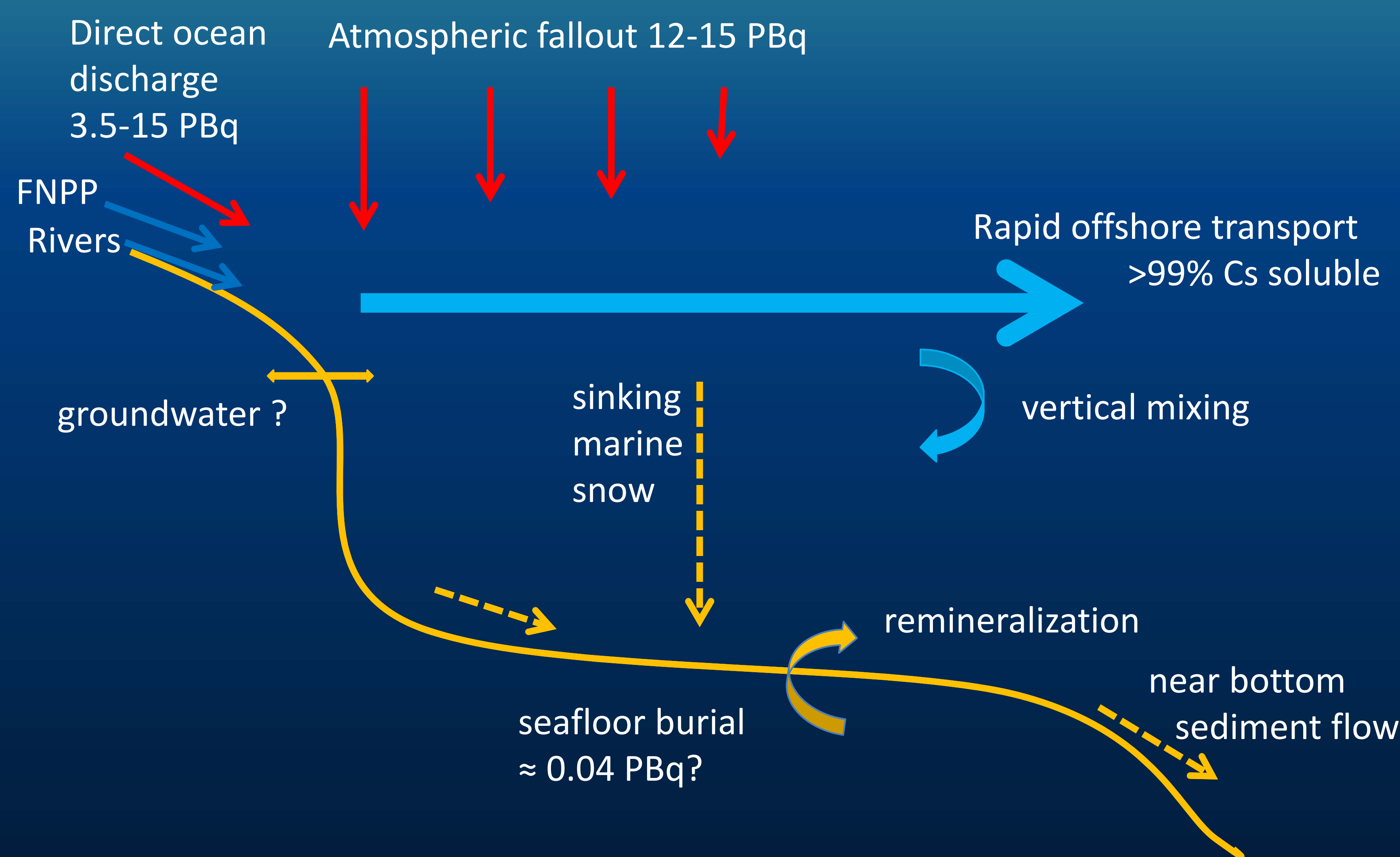
No close correlation with distance from NPP

No obvious decrease with time

<1% of total Cs ended up in sediment

still important source for seafloor biota

Summary of sources and fate of Fukushima Cs in the ocean



Many uncertainties remain about long term fate of cesium & other radionluclides

Lessons learned

Fukushima NPP represents unprecedented release of radionuclides to the ocean off Japan

Many reasons for study-

- Human health- internal/external dose assessments
- Radioecology- marine biota & fish
- Modeling- new ocean tracers & future accidents

Japan is leading studies, but more work is needed than any one lab, or any one country can take on

Confirmation by multiple international and independent labs will build public confidence in Japan (and increase scientific insights)

Studies of fish are not enough- need long term studies of ocean, seafloor, rivers, etc.

Easier to measure Cs than to determine health effects

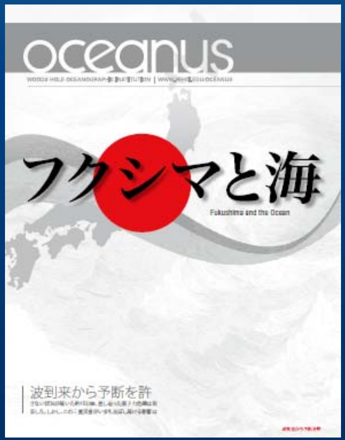
Nov. '12 Tokyo & May '13 WHOI

Scientific assessment of Fukushima radionuclides- sources, fate, impacts on marine ecosystems and human health, public policies and communication

Short presentations
Panel Q&A

CGP The Japan Foundation Center for Global Partnership 国際交流基金日米センター

GORDON AND BETTY MOORE FOUNDATION



Center for Marine & Environmental Radioactivity

Mission is to increase our understanding of the sources, fates and consequences of natural and human-made radionuclides in the environment, in particular the ocean

http://www.whoi.edu/CMER

THANKS to many in US, Japan, EU…..