

## Morss Colloquium

# The Fukushima Disaster: An Overview

Mitsuo UEMATSU

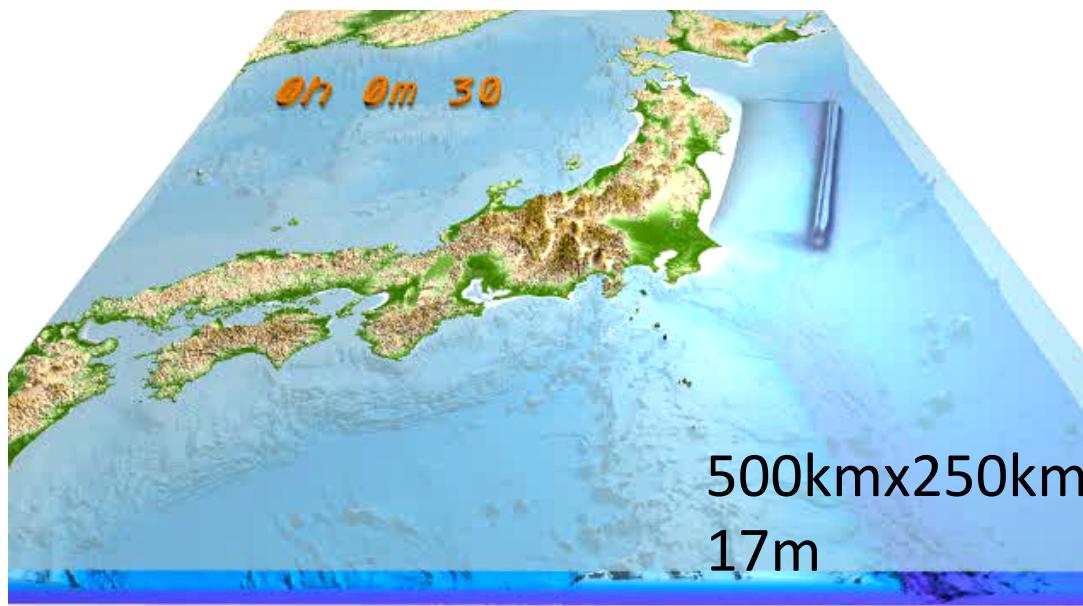
Atmosphere and Ocean Research Institute  
The University of Tokyo

at Woods Hole Oceanographic Institution  
Woods Hole, MA USA  
9 May 2013

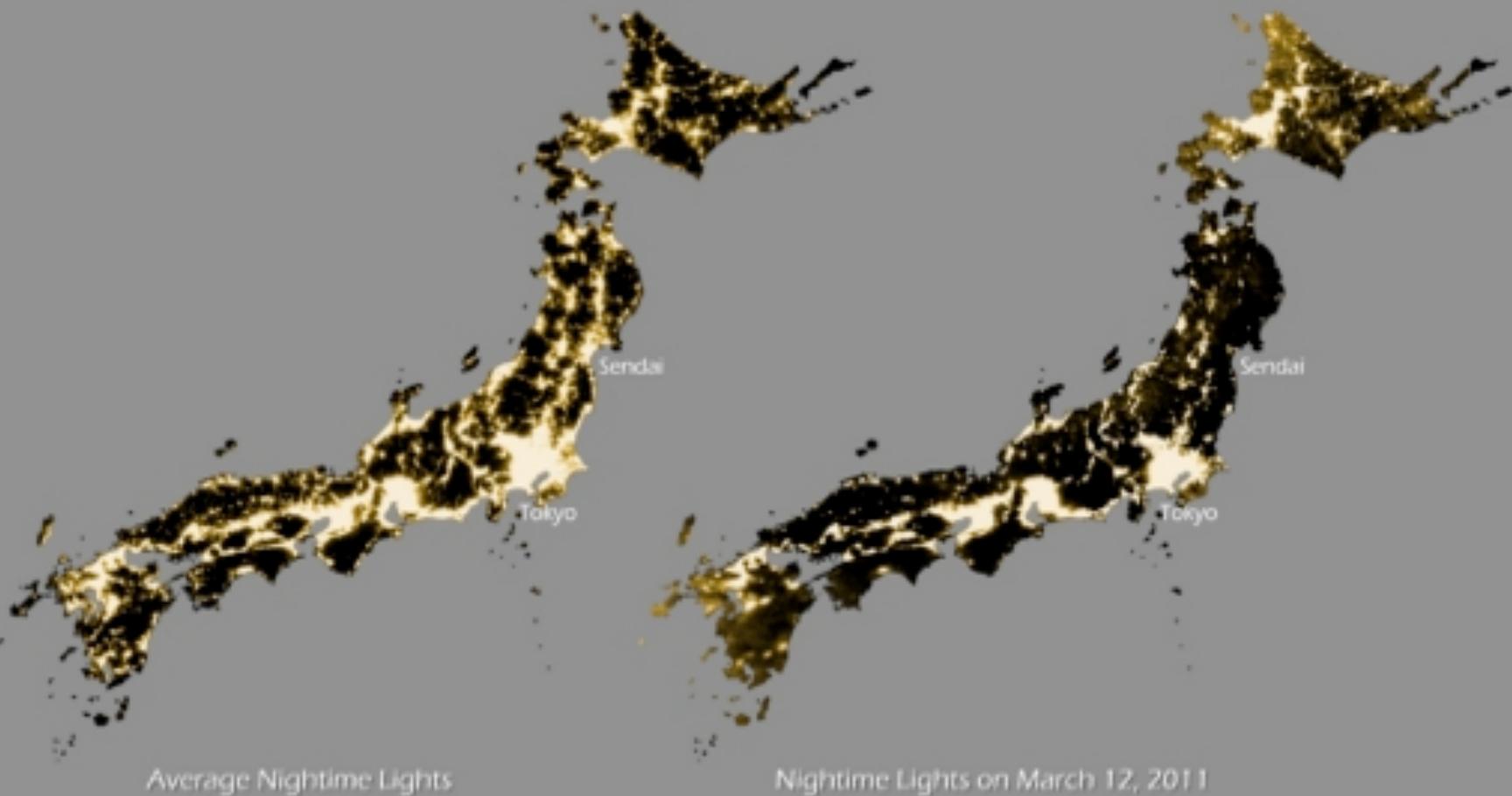


NEWS

# Great East Japan Earthquake/Tohoku Region Pacific Coast Earthquake



- Friday, March 11, 2011; 14:46 18.1"
- **Magnitude 9.0/Mj 8.4** (Chile 1960, 9.5; Sumatra 2004, 9.2; Kanto 1923, 7.9; Hanshin-Awaji, Mj7.3; Houei-Tounannkai 1707, 9.1?)
- Tsunami: 21m at Tomioka, Fukushima; 43m run-up height at Onagawa
- Casualties: 15,881, missing 2,668 (93% by Tsunami)



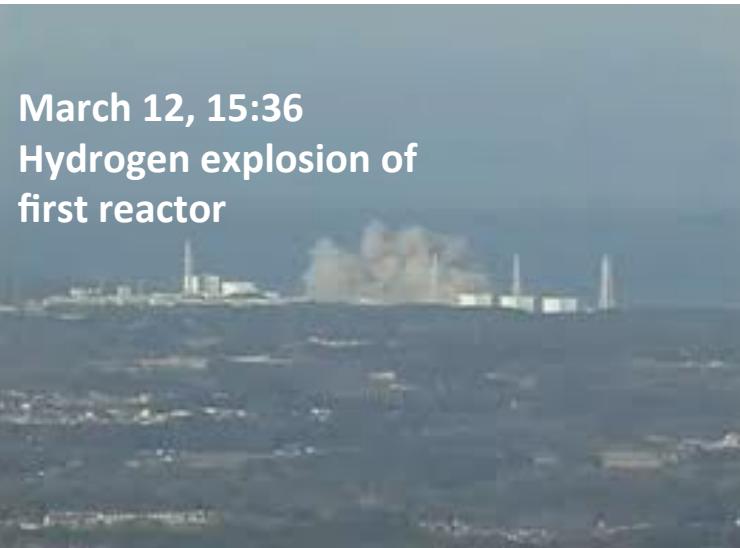
After the Earthquake on 11 March

# Tsunami approaching the Fukushima Dai-ichi Nuclear Power Plants 1 hour after the Earthquake on March 11

- 14:46 Earthquake
- 15:27, 1<sup>st</sup> Tsunami  
(5.1m spec vs 15.5m obs)
- 15:41 diesel generator  
malfunction



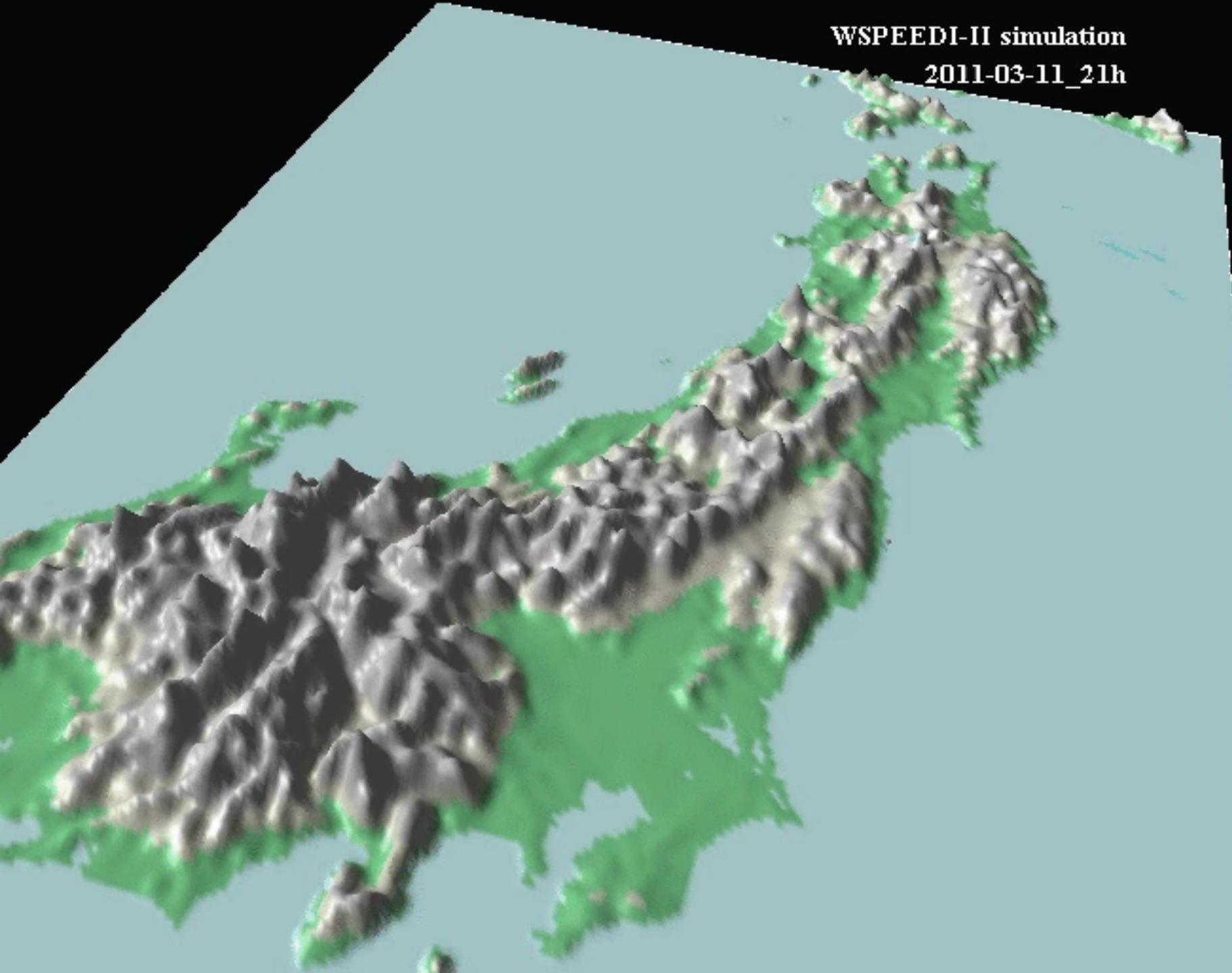
# Airborne Release of Radiation from Fukushima Dai-ichi



- \* Airborne releases due to overheating, hydrogen explosions & fires totaled approximately 8.8 PBq for both  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ .
- \* Largest releases on March 15 and 16.

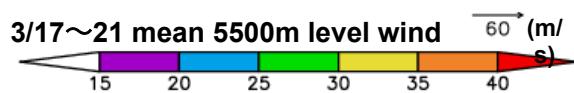
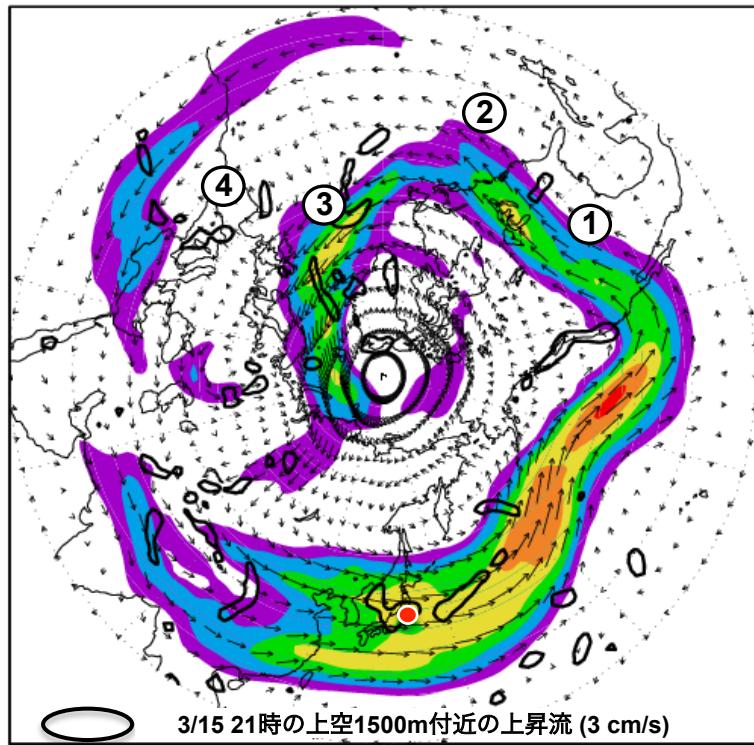
WSPEEDI-II simulation

2011-03-11\_21h

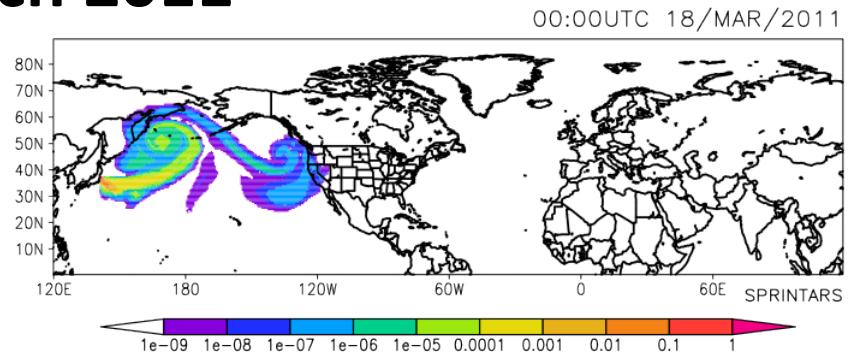


# Stronger jet stream and Atmospheric pressure system

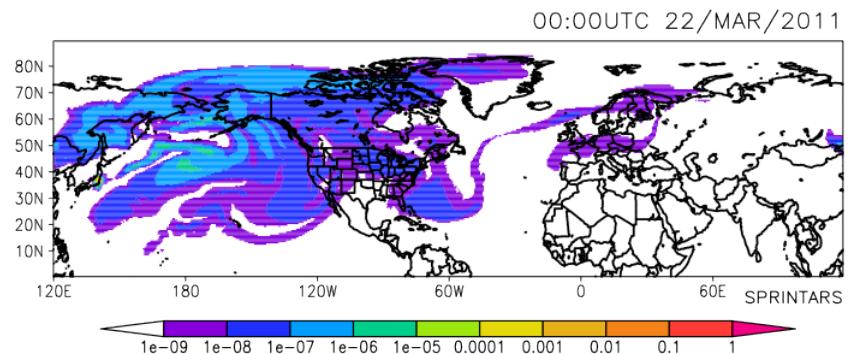
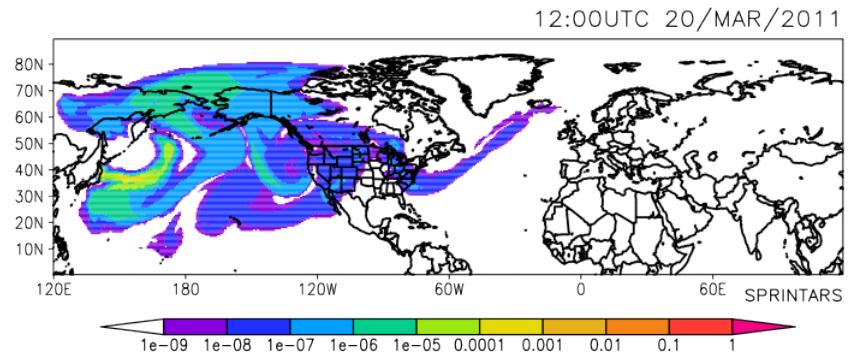
## 17-21 March 2011



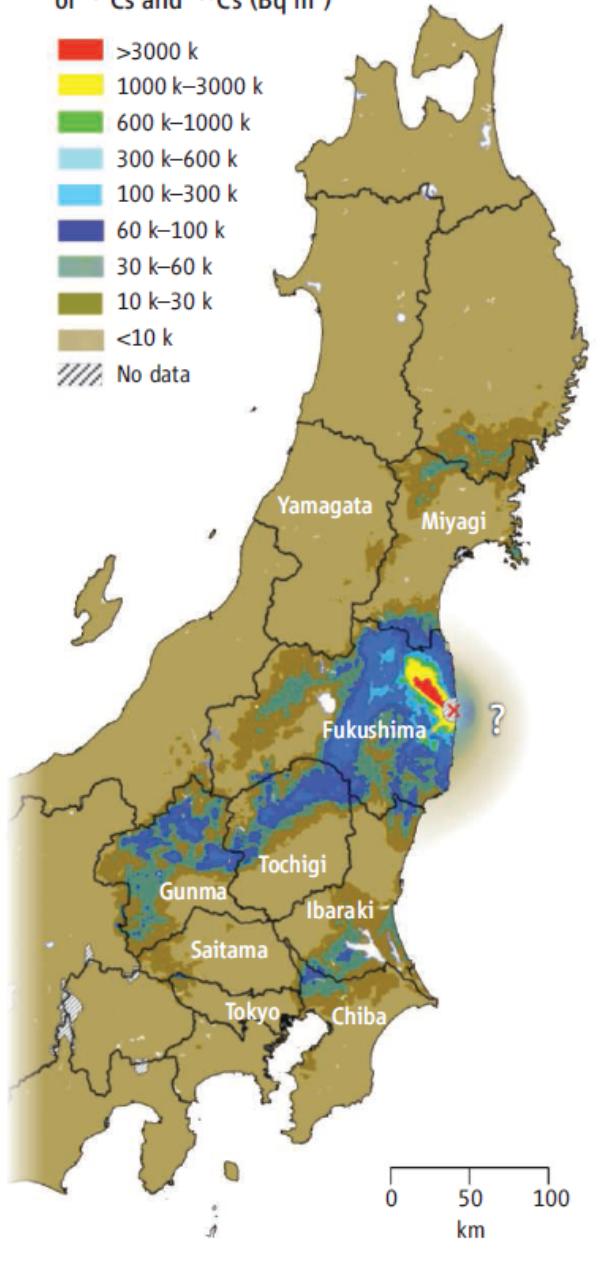
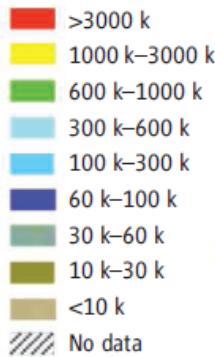
- ① California (3/17)
- ② Pennsylvania (3/18~19)
- ③ Iceland (3/20)
- ④ Switzerland (3/22)



- $10^{-8}$  order at US west coast area vs  $10^{-6}$  obs



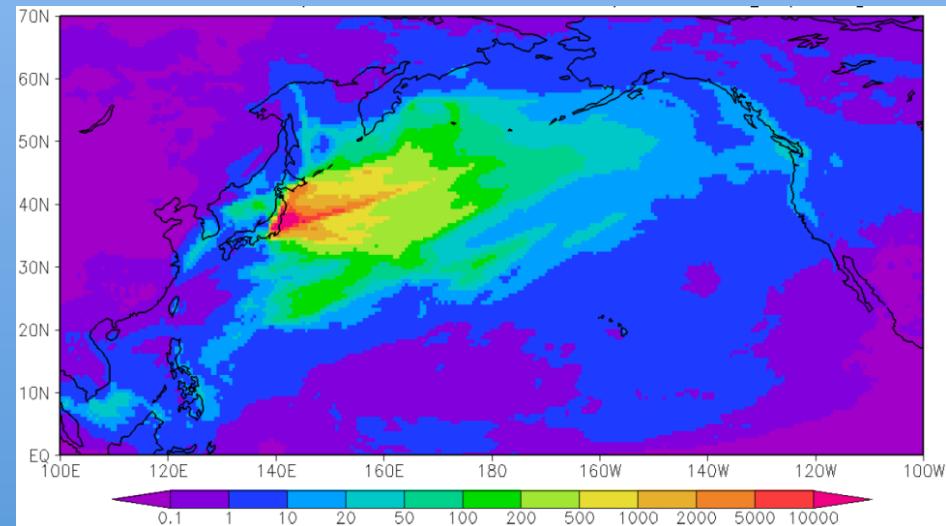
Total disposition  
of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  ( $\text{Bq m}^{-2}$ )



# Sources of radioactive contaminants

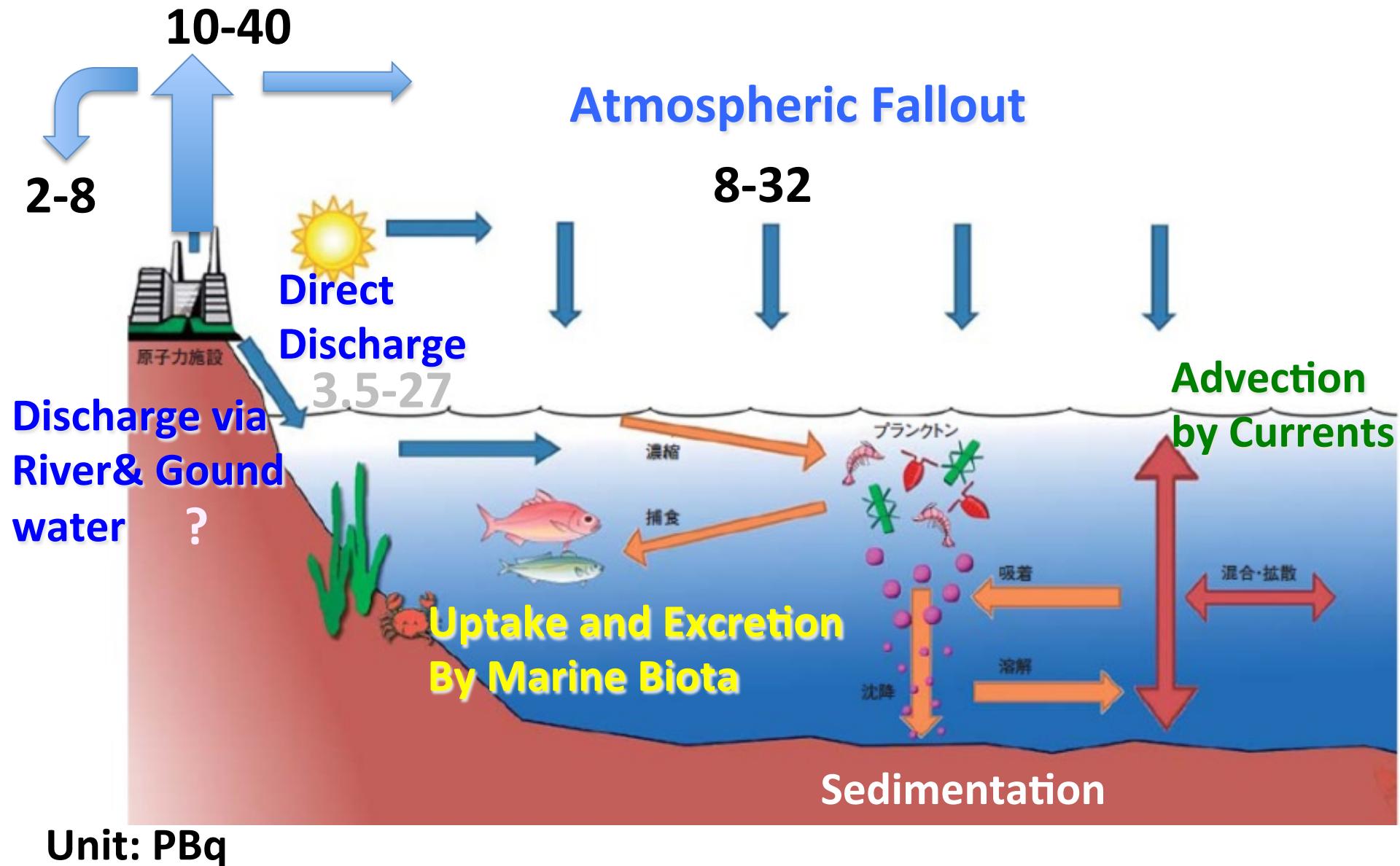
## Atmospheric deposition

- Rain on March 15th provided most contamination on land
- 80-85% fell on ocean



Simulated atmospheric deposition of  $^{137}\text{Cs}$   
( $\text{Bq m}^{-2}$ ) by Masingar II of MRI  
*Aoyama et al., 2013*

# Dispersion of radionuclides in the ocean caused by the FNPP accident





がんばれ、  
日本。

Don't give up, Japan  
Don't give up, Tohoku

A nation's rallying call



# Radionuclides in the ocean



Ken Buesseler

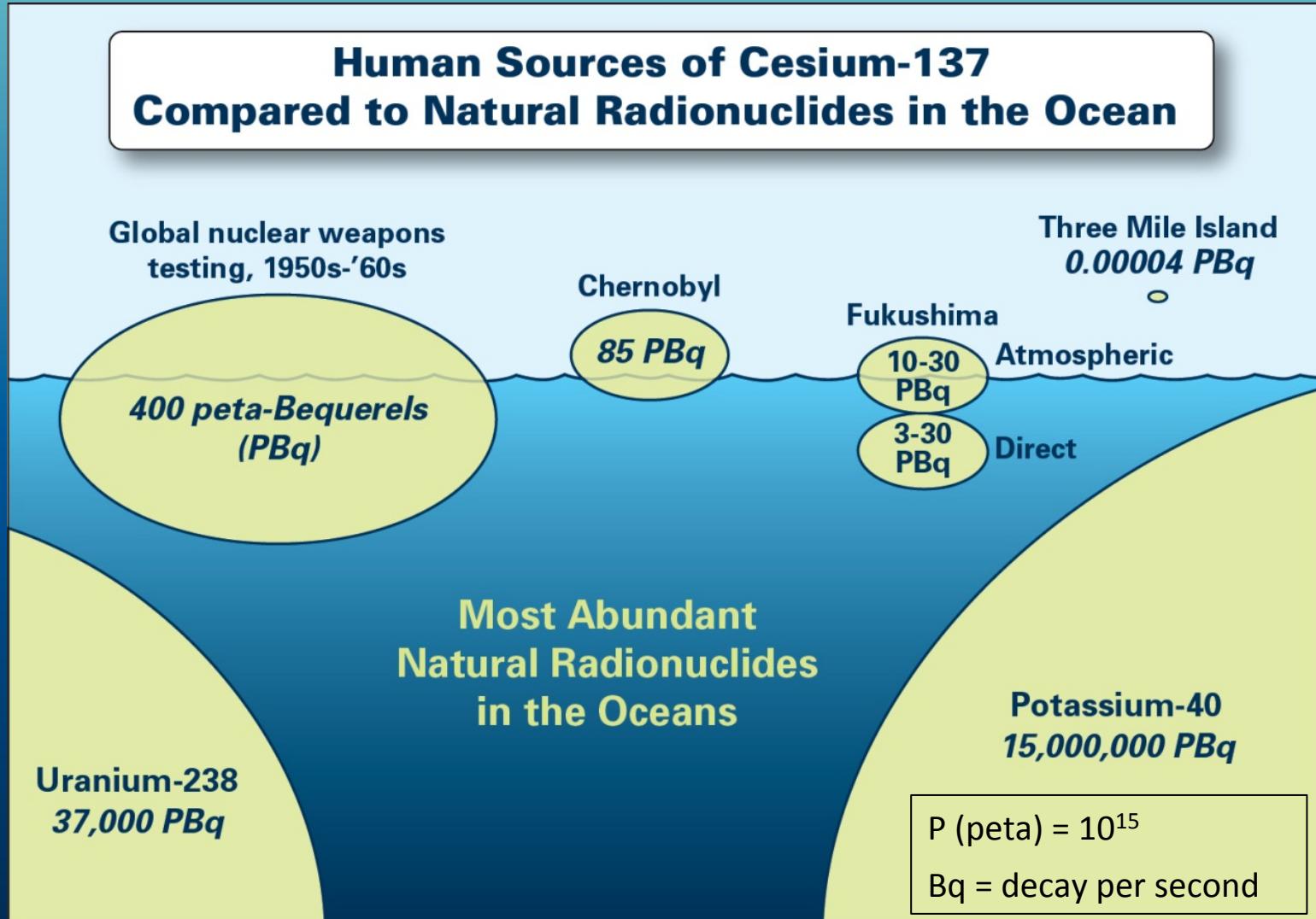
Department of Marine Chemistry and Geochemistry

Woods Hole Oceanographic Institution

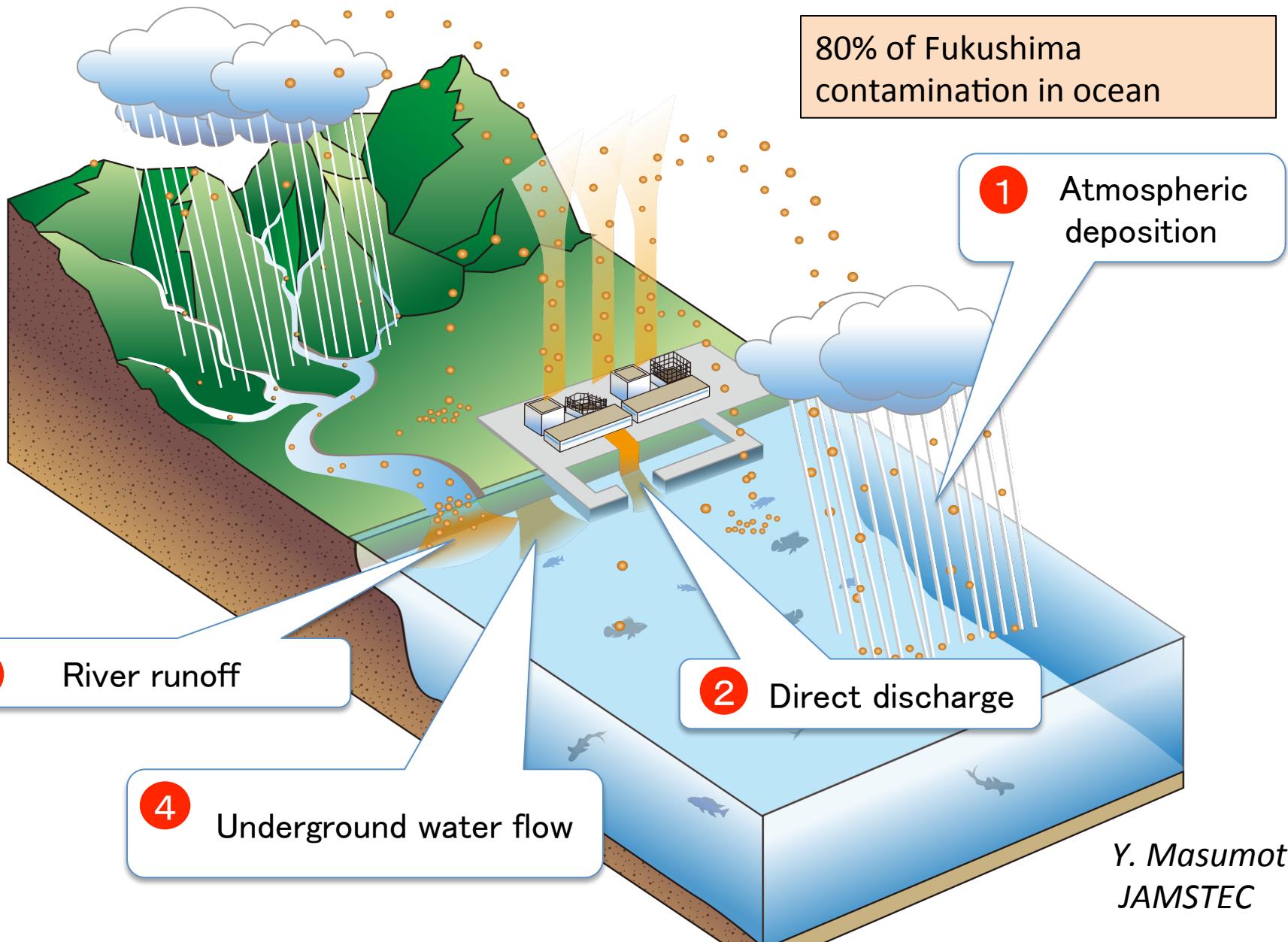
<http://cafethorium.whoi.edu>



# Many sources of radioactivity

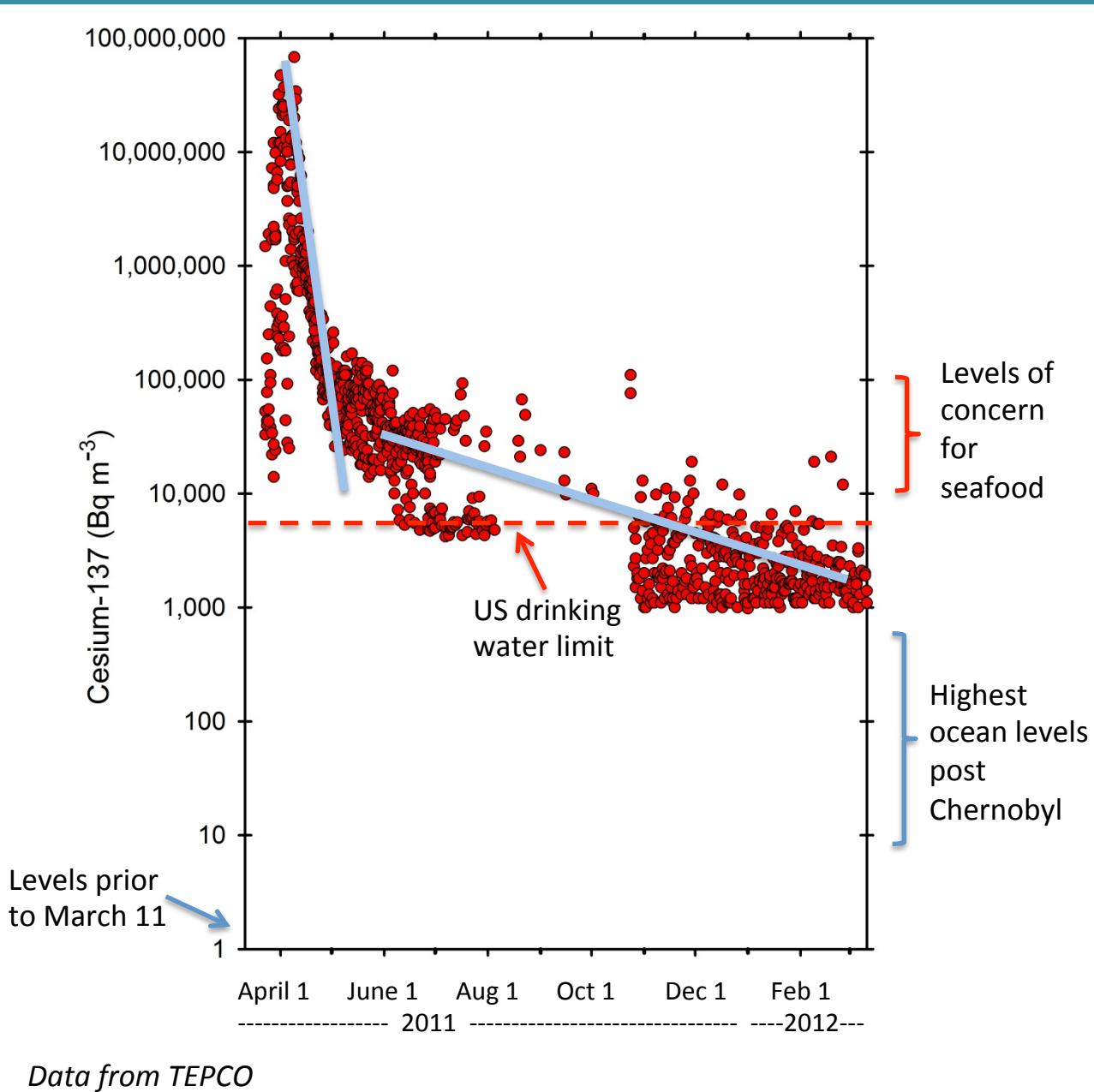


# Fukushima Dai-ichi sources to the environment

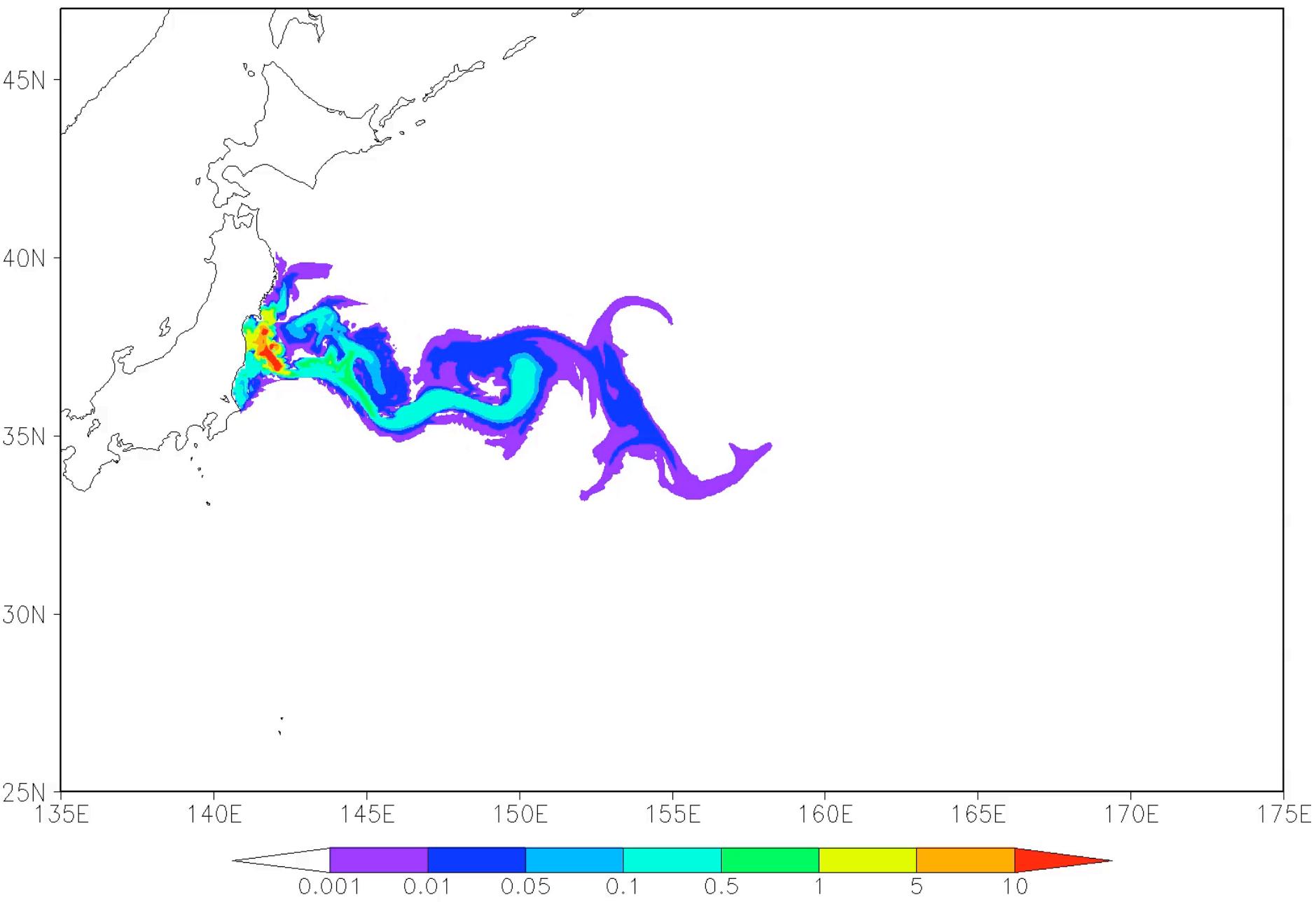


Y. Masumoto  
JAMSTEC

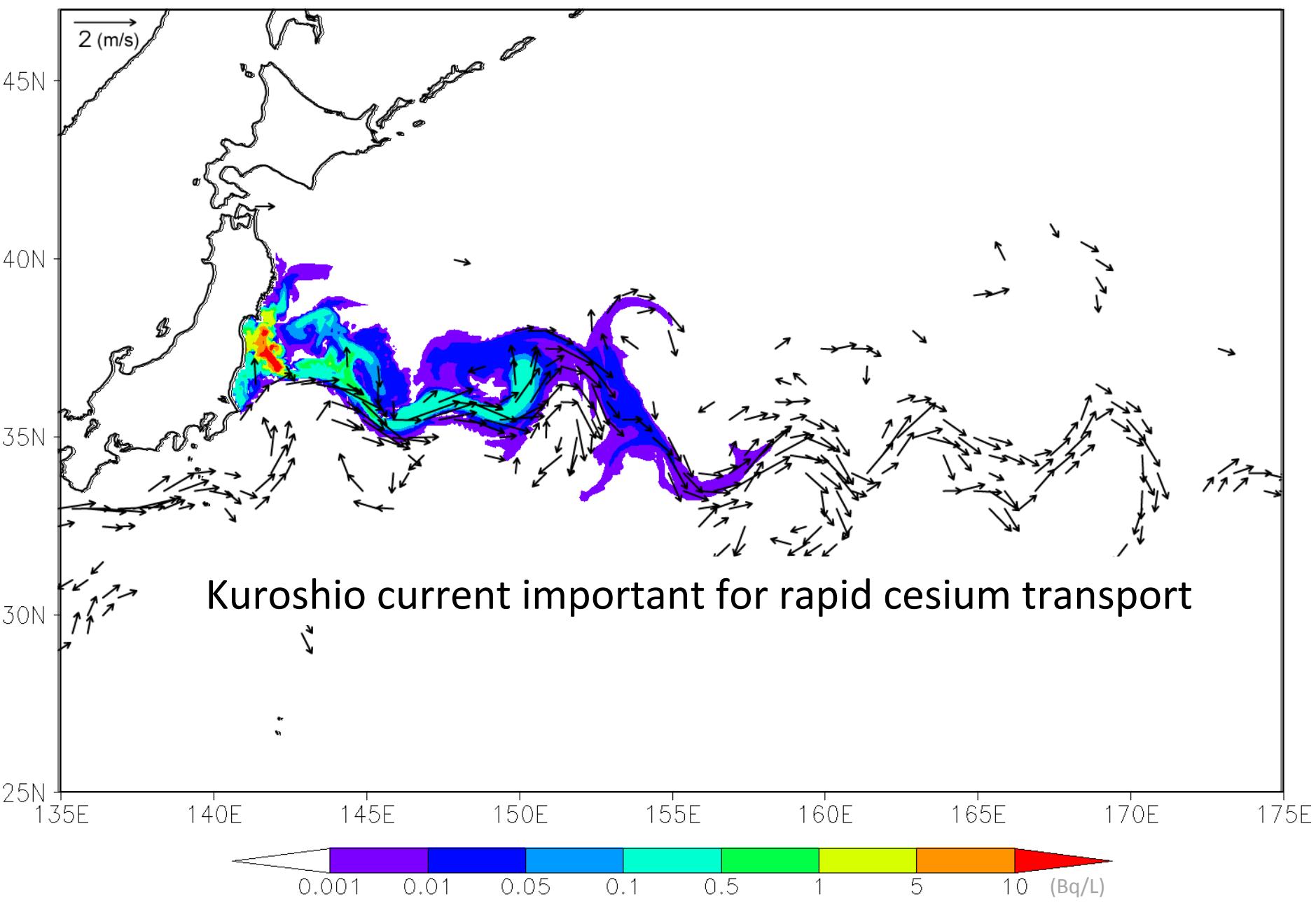
# One year history of cesium-137 in ocean immediately off Fukushima



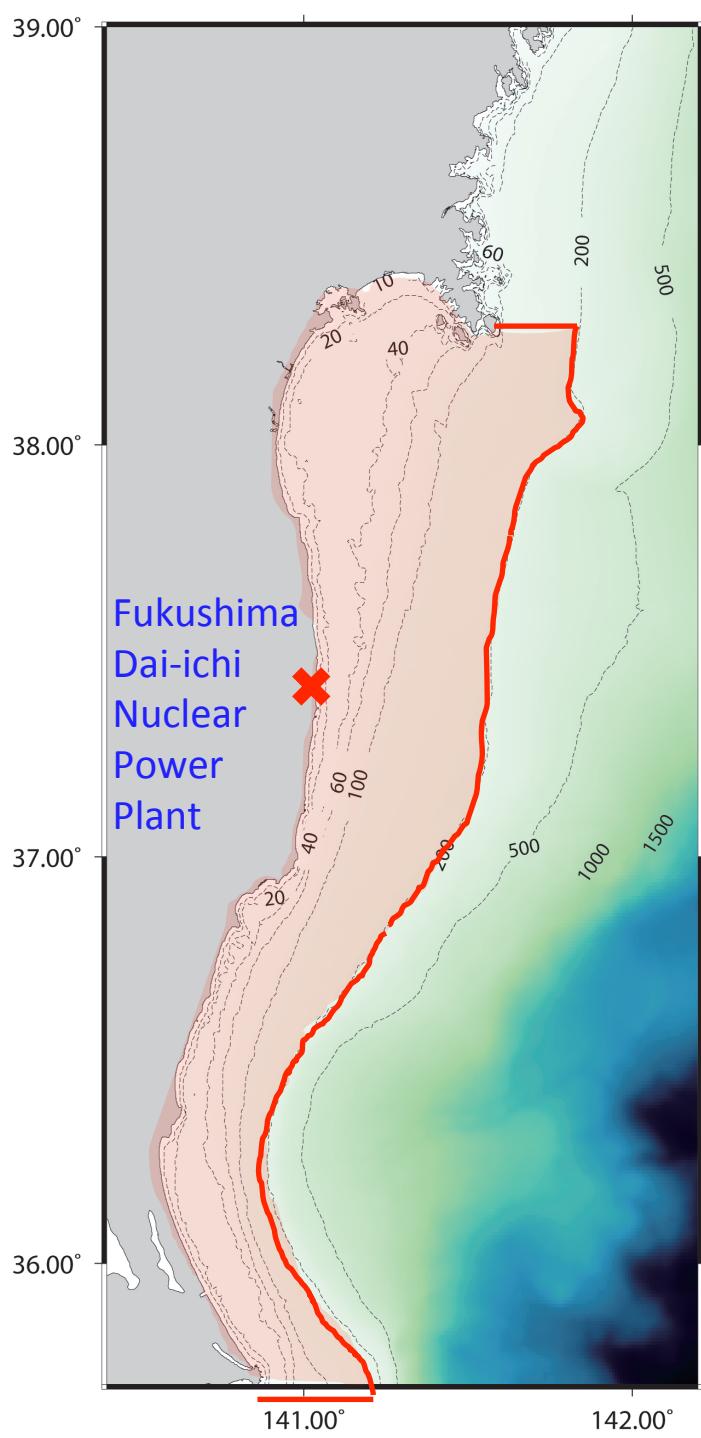
Cs-137 (2011 APR 30)



# Cs-137 (2011 APR 30)



# Continued sources of $^{137}\text{Cs}$



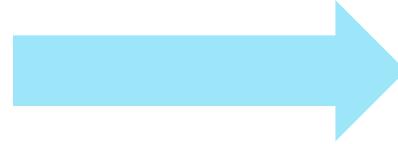
Fukushima  
Dai-ichi  
Nuclear  
Power  
Plant

*Kanda et al, TUMST*

Power plant  
 $>0.24 \text{ TBq/month}$



River water  
 $<1.3 \text{ TBq/month}$



River sediment  
 $0.8 \text{ TBq/month}$



Seawater  
 $15 \text{ TBq}$



Sea floor  
 $94 \text{ TBq}$

$T (\text{tera}) = 10^{12}$

## **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/predictions of 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

Where do we go from here?



## Mission Statement

The Center for Marine and Environmental Radioactivity is dedicated to increasing scientific and public understanding of the sources, fates and consequences of natural and human-made radioactive elements in the environment, in particular the oceans

## Goals-

Public education

Training the next generation of marine radiochemists

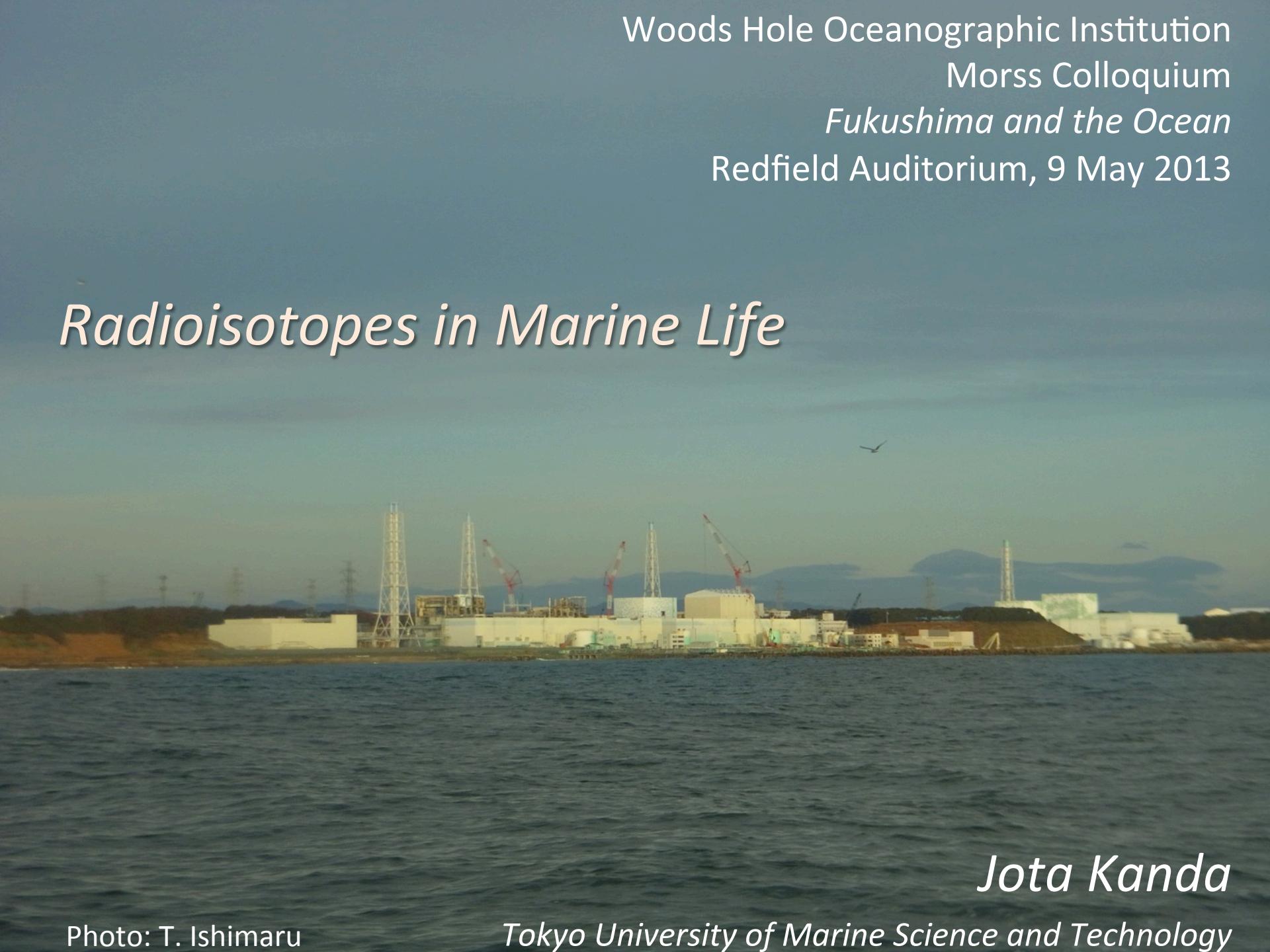
Support research and engineering in ocean environmental radioactivity

<http://www.whoi.edu/CMER>



Woods Hole Oceanographic Institution  
Morss Colloquium  
*Fukushima and the Ocean*  
Redfield Auditorium, 9 May 2013

## *Radioisotopes in Marine Life*

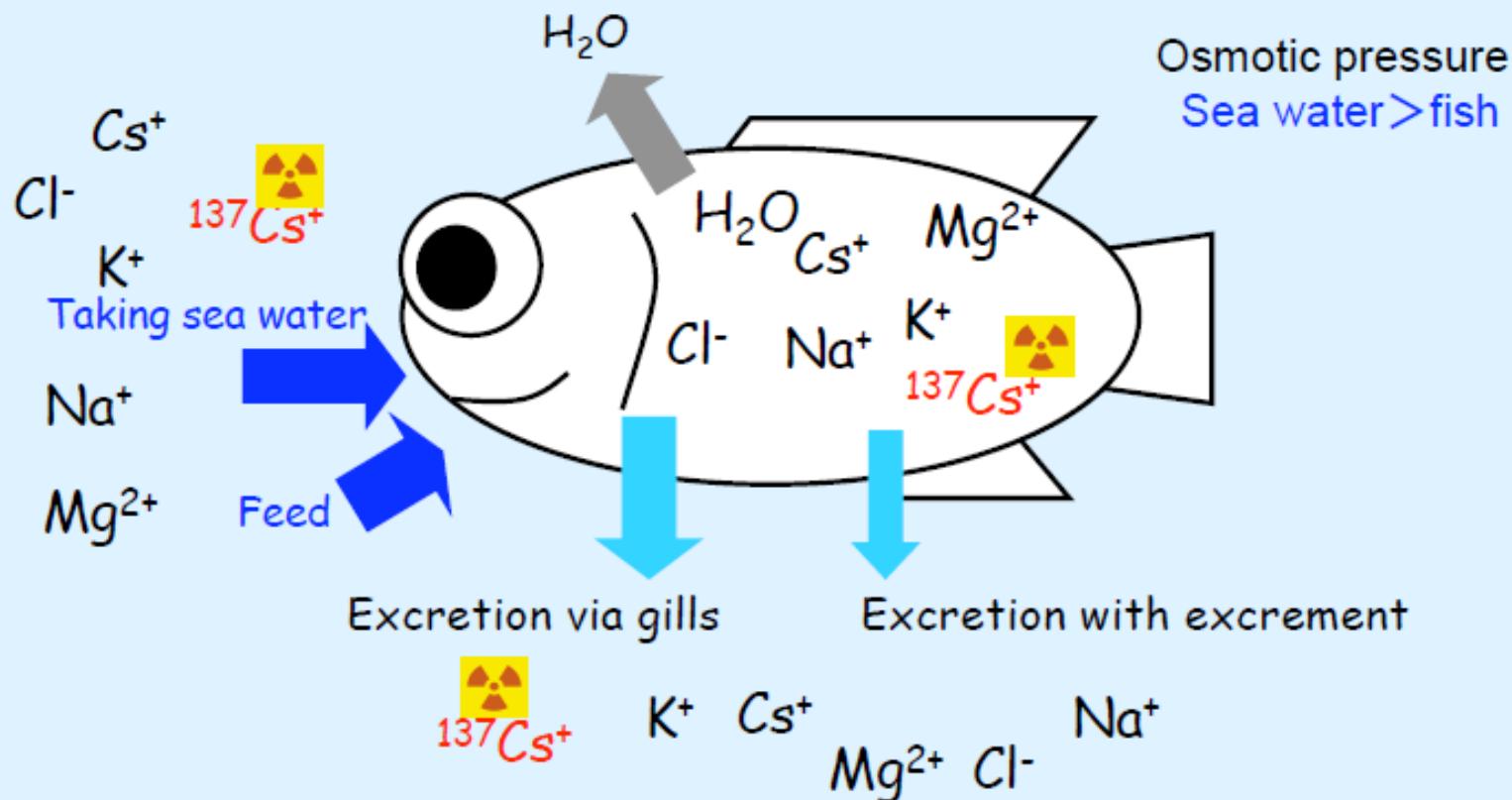


*Jota Kanda*

Photo: T. Ishimaru

*Tokyo University of Marine Science and Technology*

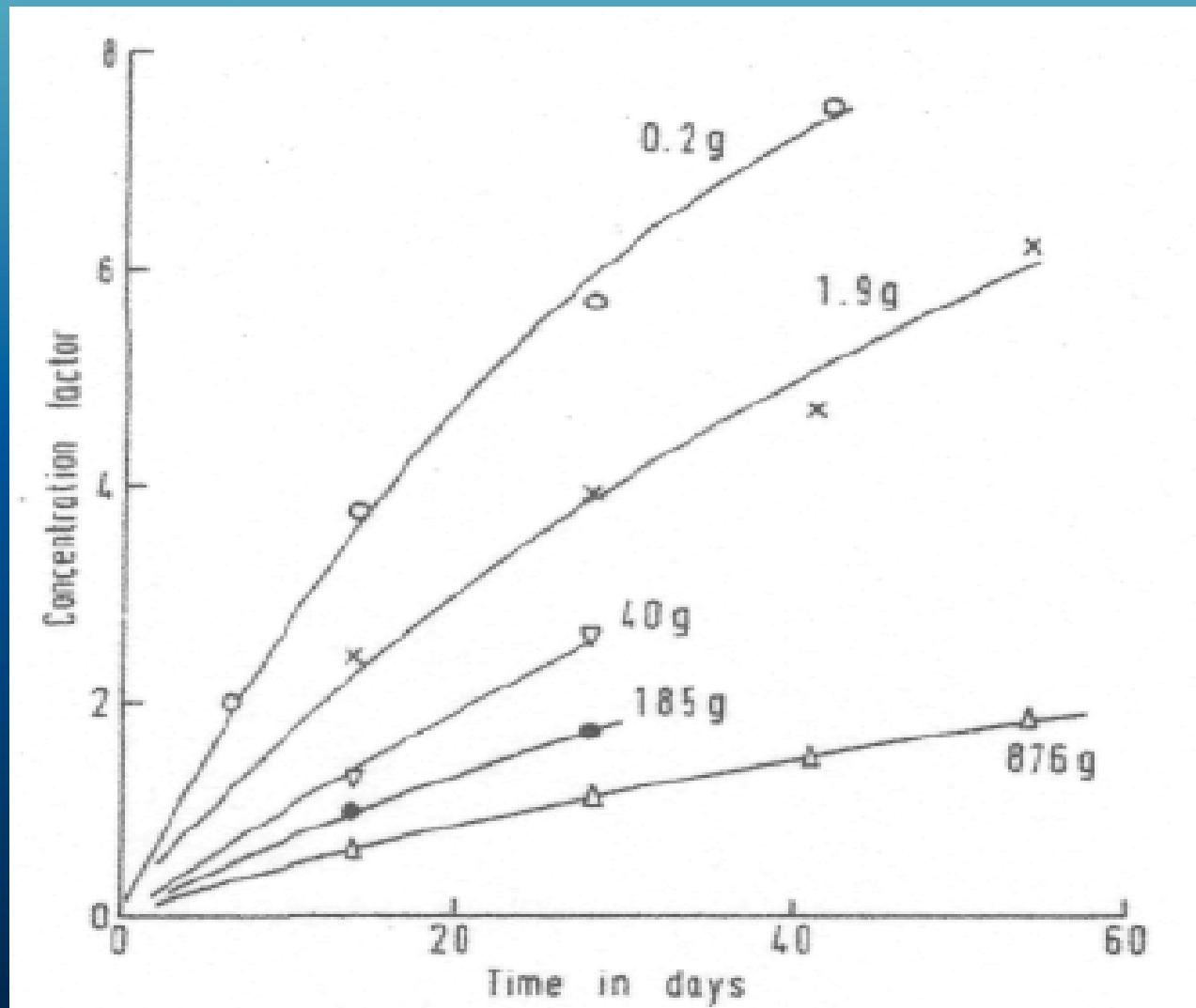
# The flow of salts in marine fish body



- Radioactive cesium excretes, and thus does not accumulate.
- Concentration in fish depends on that of ambient water.

(Reference: Fundamental physiology of fish, Edit. K. Aida)

# Uptake of $^{134}\text{Cs}$ from sea water by flatfish (plaice) of different weights (from Pentreath, 1975)



# Ikanago fish shipments banned in Fukushima Prefecture

© April 20, 2011

Tweet 0   Recommend 0   +1 0

In Japan's first restrictions on seafood related to the nuclear crisis, Prime Minister Naoto Kan on April 20 ordered a suspension of shipments and consumption of "ikanago" (sand lance) caught off Fukushima Prefecture.

The order was relayed to Fukushima Governor Yuhei Sato, Chief Cabinet Secretary Yukio Edano said, based on the special measures law concerning nuclear energy preparedness.

On April 13, 12,500 becquerels of radioactive cesium per kilogram was detected in ikanago caught off Iwaki, Fukushima Prefecture. That was 25 times the interim legal limit of 500 becquerels per kilogram.

The prefecture is home to the crippled Fukushima No. 1 nuclear power plant, where large volumes of contaminated water have been discharged into the sea.

Shipments of vegetables and milk produced near the nuclear power plant had also been suspended. Doubts had been raised about enforcing restrictions for fish because they can travel long distances. But the Ministry of Agriculture, Forestry and Fisheries said ikanago generally stay within the same area.

The government said the ban will apply to "those landed in Fukushima Prefecture." Since ikanago fishing requires the governor's permission, the ban targets fish "caught in the sea off Fukushima Prefecture."



Previous Article

Government to designate 20-km radius off-limits in Fukushima

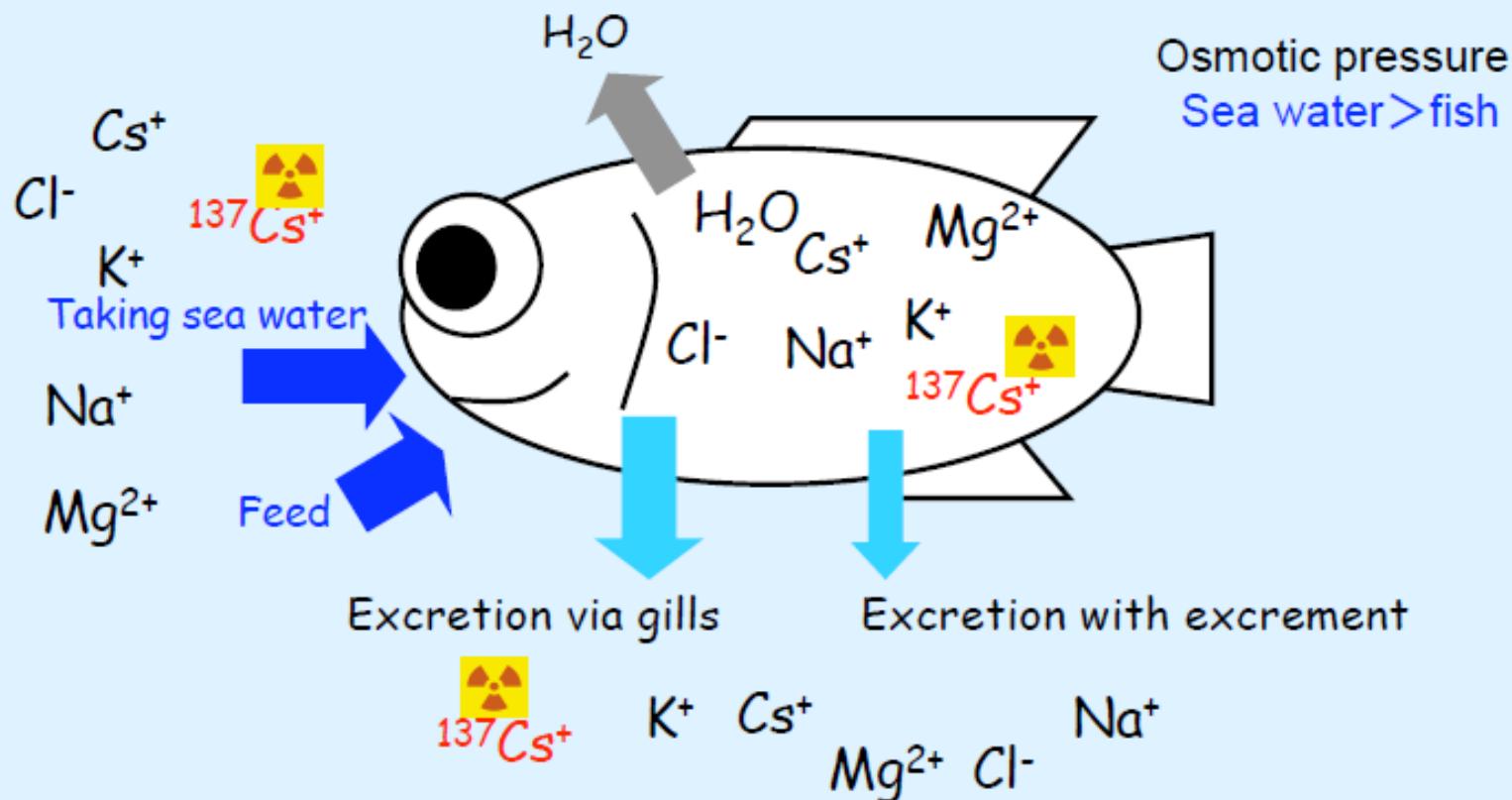
Next Article

Long process starts transferring radioactive



"Ikanago" (sand lance) in Oarai, Ibaraki Prefecture, is checked for radioactivity on April 13. (Photo by Tomoyuki Yamamoto)

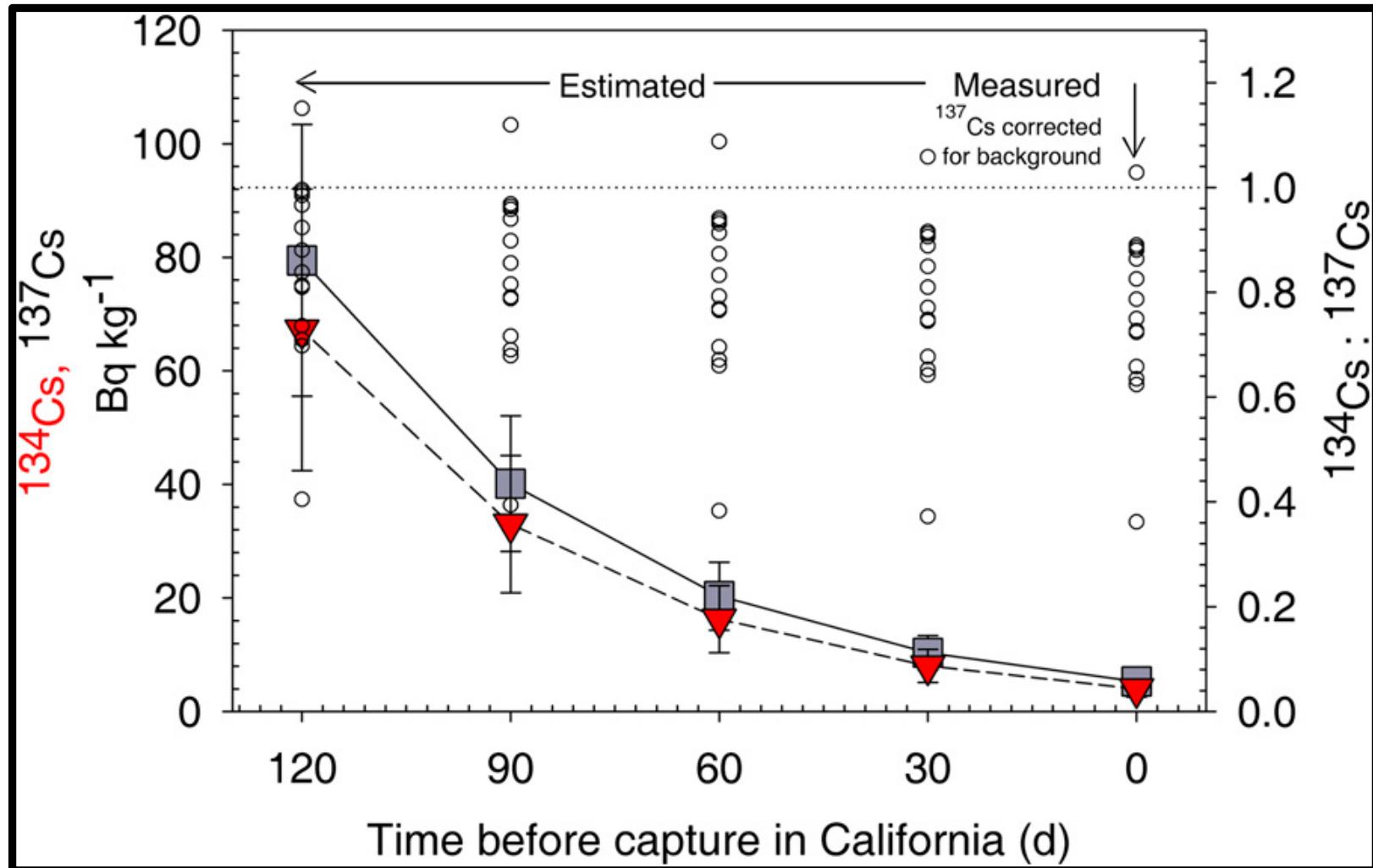
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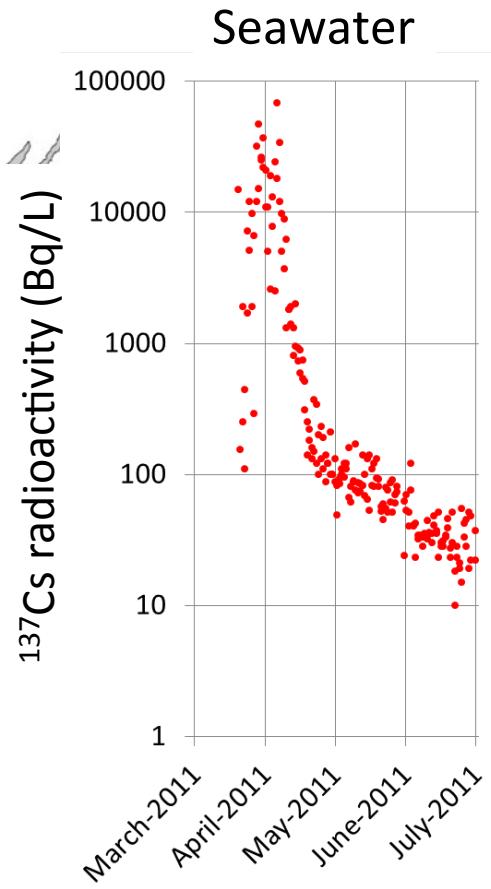
# Cesium concentrations in post-Fukushima bluefin tuna



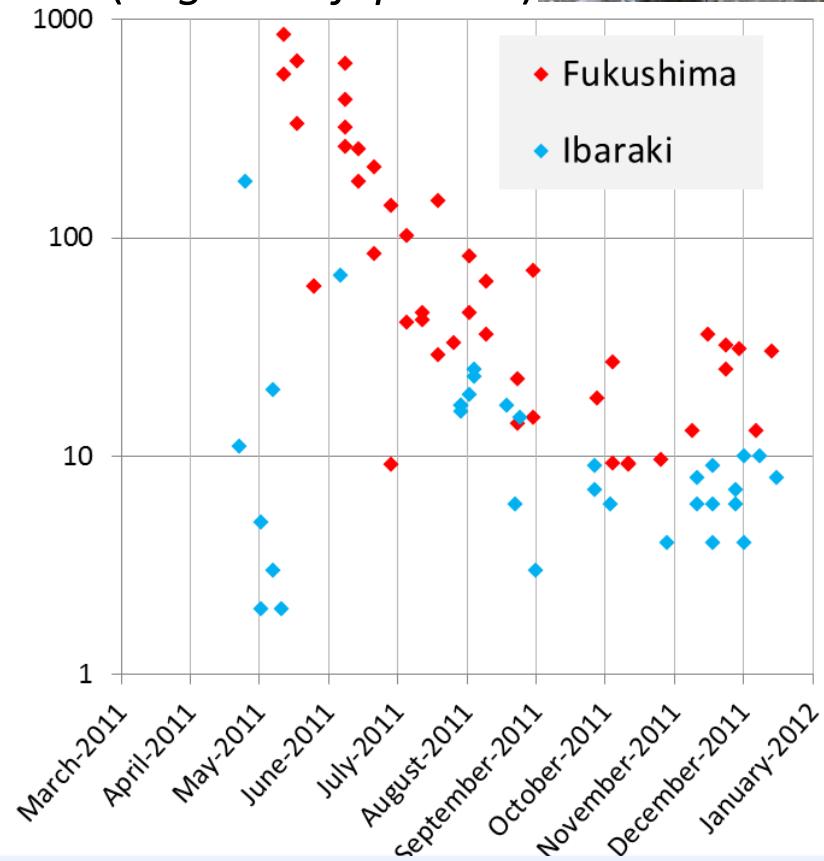
$^{134}\text{Cs} : ^{137}\text{Cs}$  in myctophid fish off Japan = 0.9; in plankton = 1.1; in water = 1.0

Japan safety limit: 100 Bq kg $^{-1}$  wet wt ( $\sim 410$  Bq kg $^{-1}$  dry wt)

# Rapid flushing of radioactive water followed by fish radioactivity



Larvae of  
Japanese Anchovy  
(*Engraulis japonica*)



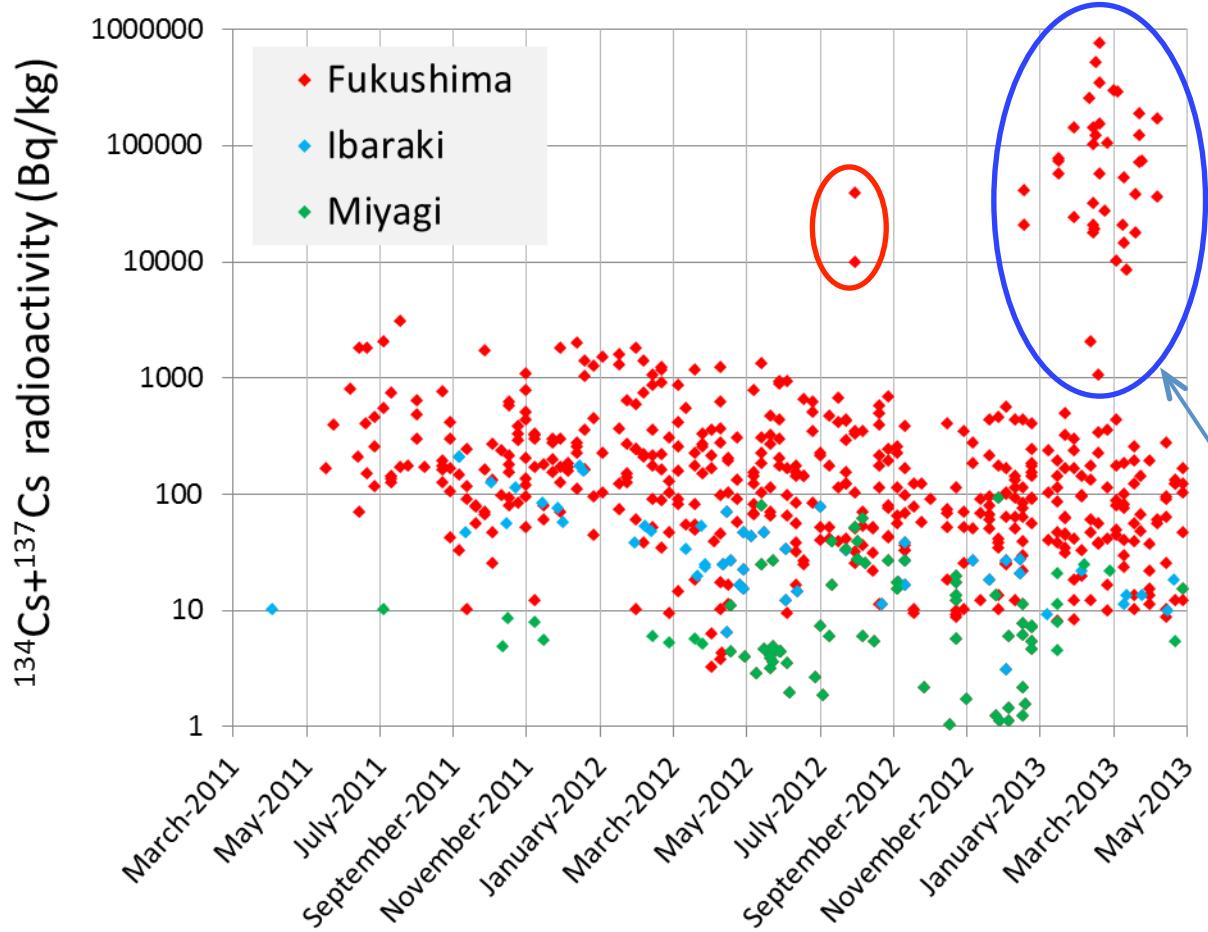
$^{137}\text{Cs}$  in seawater and  $^{134}\text{Cs} + ^{137}\text{Cs}$  in fish

Seawater: immediate vicinity of the plant

Data sources: TEPCO, Fisheries Agency of Japan

Fish: off Fukushima and Ibaraki

..... not necessarily in some fish species



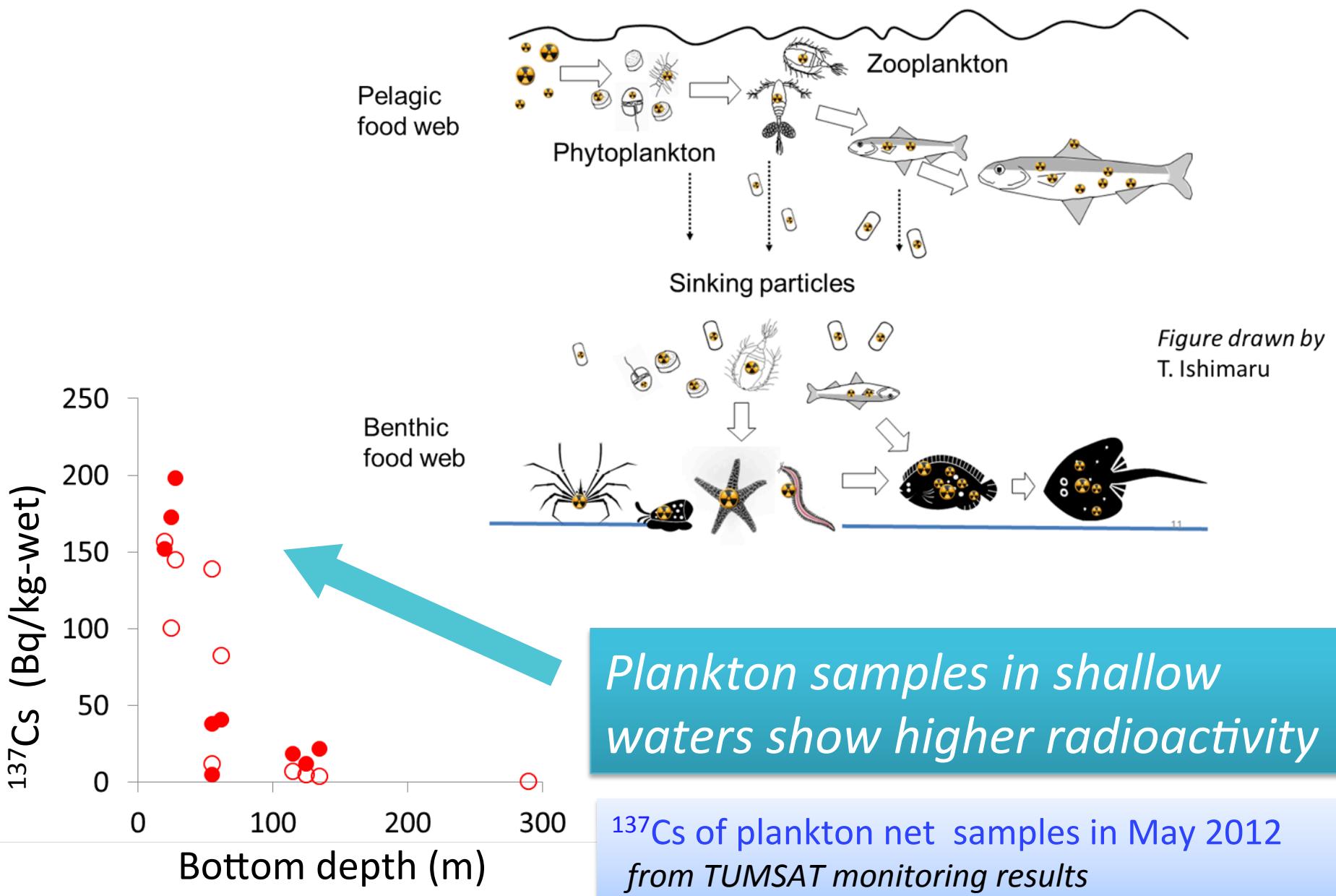
Fish from the plant harbor

TEPCO found a fish with 38,000Bq/kg on 1 August 2012 at about 18km north from the plant, and later on 21 February 2013 they found one with 740,000Bq/kg in the plant harbor.

$^{134}\text{Cs} + ^{137}\text{Cs}$  in Greenling fish (*Hexagrammos otakii*)

Data sources: TEPCO, Fisheries Agency of Japan

# Fish radioactivity is likely sustained by radioactive food



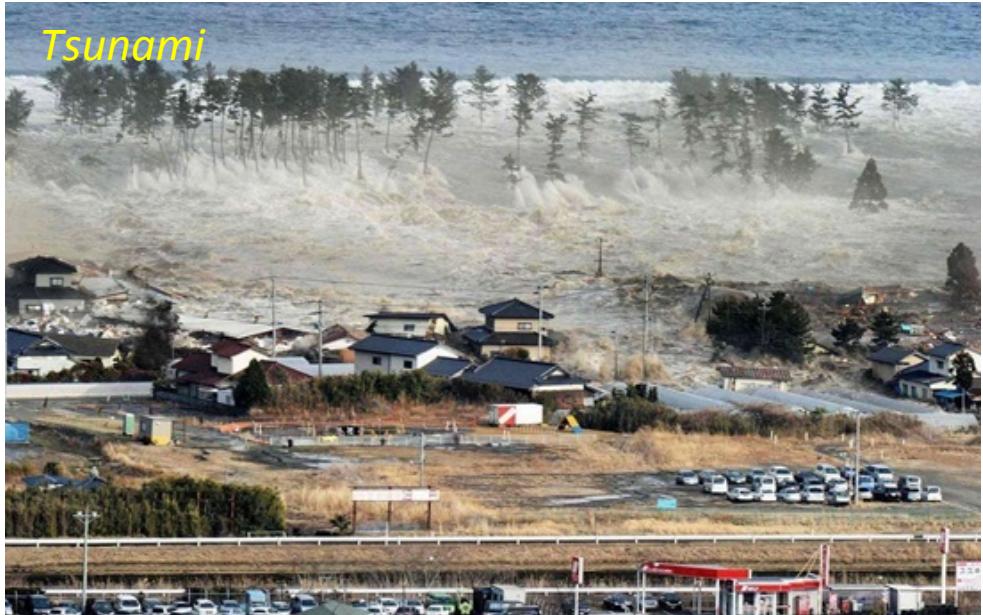




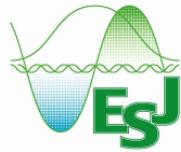
# Seafood Safety and Public Policy



A screenshot of the UNITE FOR JAPAN website. The top navigation bar includes links for Home, News, Get Involved, Donate, Video, Auction, Blog, and Photos. Below the navigation, there is a video player showing a woman holding up a sign that reads "My heart is with Your Heart" in English and Japanese. The video player shows a play button and a timestamp of 0:00 / 3:59. The overall theme is earthquake and tsunami relief for Japan.



**Prof. Hiroyuki MATSUDA**  
Yokohama National University  
President, Ecological Society of Japan  
Chair, Fisheries Policy Committee, JSFS  
Pew Marine Conservation Fellow 2007



# Concentrations in real meal in Fukushima

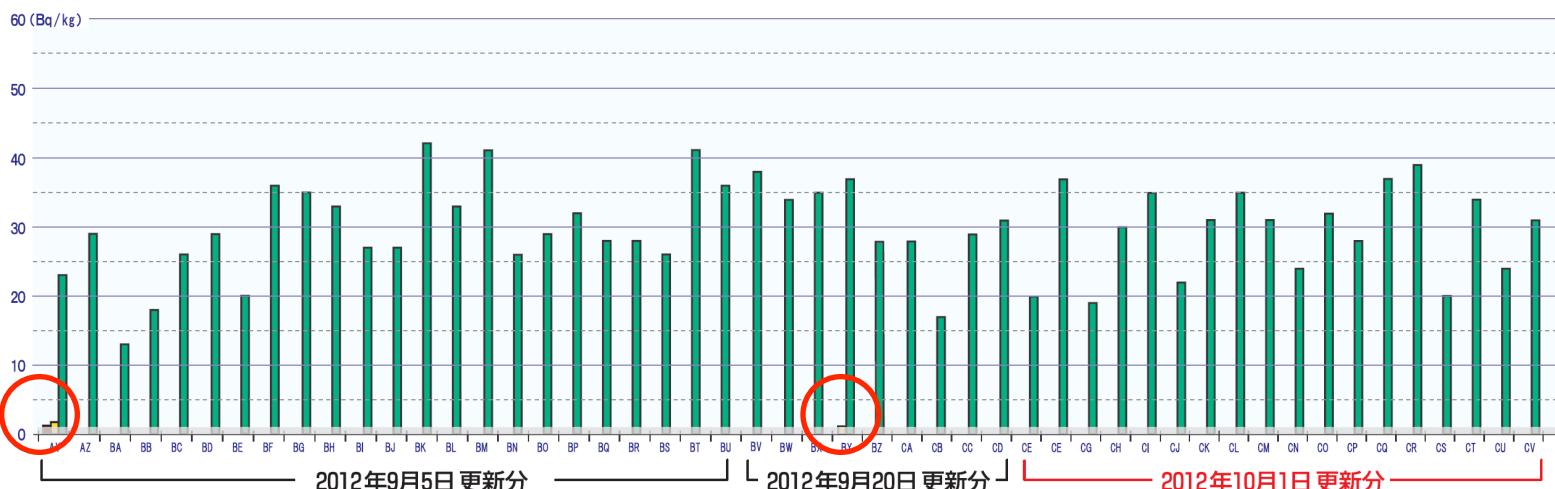
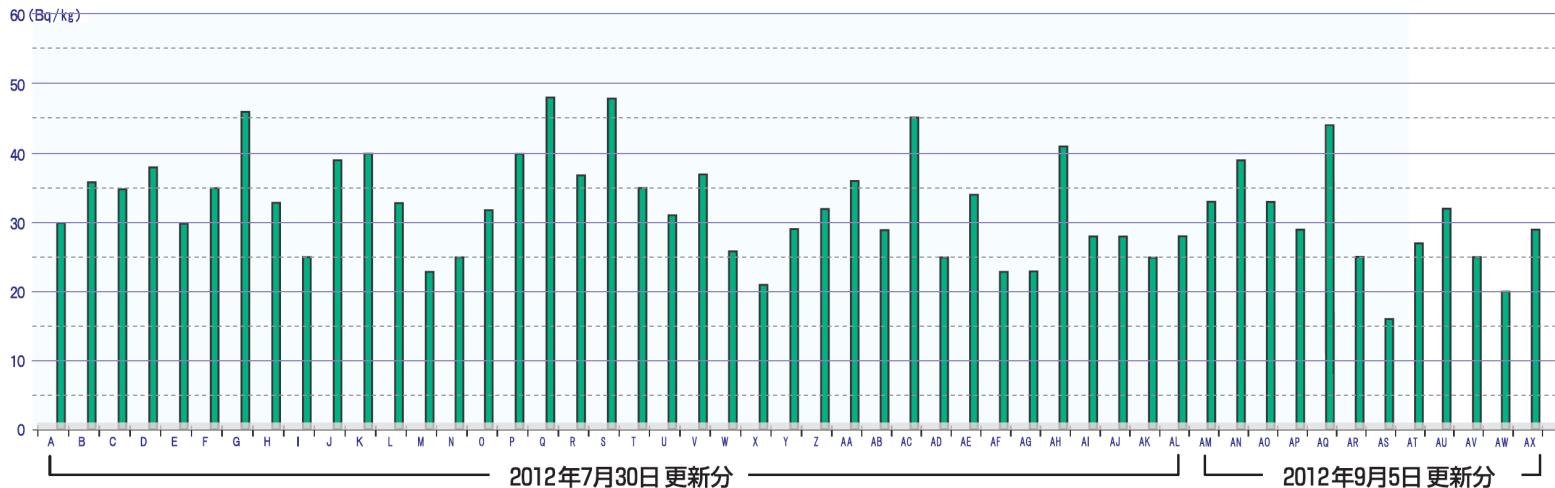
■ Cs-137

■ K-40

■ Cs-134

Actual internal exposure level: 1/40 of 1mSv/yr

Much smaller than natural exposure level.



# Comparison of regulatory limits for fishery products

	Cs <sup>134</sup> + Cs <sup>137</sup> (Bq/kg-wet)
Codex	1000 *
Japan	500 → 100
USA	1200
EU	1250
Thai	500
Singapore	500
South Korea	370
Hong Kong	1000
Chinese Taipei	370
Philippines	1000
Vietnam	1000
Malaysia	1000
China	800

\*This index includes S-35, Co-60, Sr-89, Ru-103, Ce-144, Ir-192

## Restricted distribution of cod

Prefecture	Production value in 2010 (billion yen)	Restricted distribution
Hokkaido (Pacific side)	4.68	-
Aomori (Pacific side)	0.86	2012.8.27~10.31
Iwate	1.04	2012.5.2~ 2013.1.17 (some areas)
Miyagi	2.12	2012.5.2~2013.1.17
Fukushima	0.29	After accident ~
Ibaragi	0.04	2012.11.9~

Takami Morita



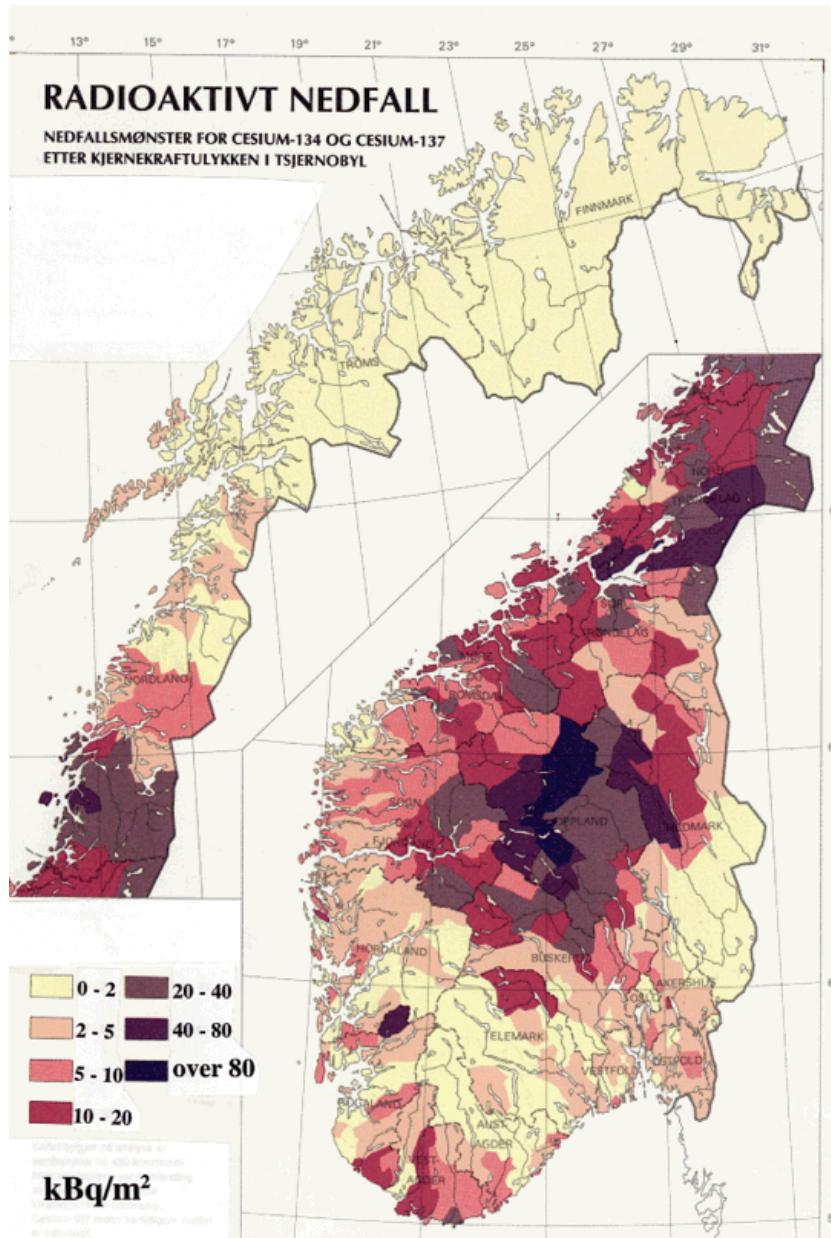
# Chernobyl: Radioceasium deposition in Norway, 1986

## Maximum values 1986-87

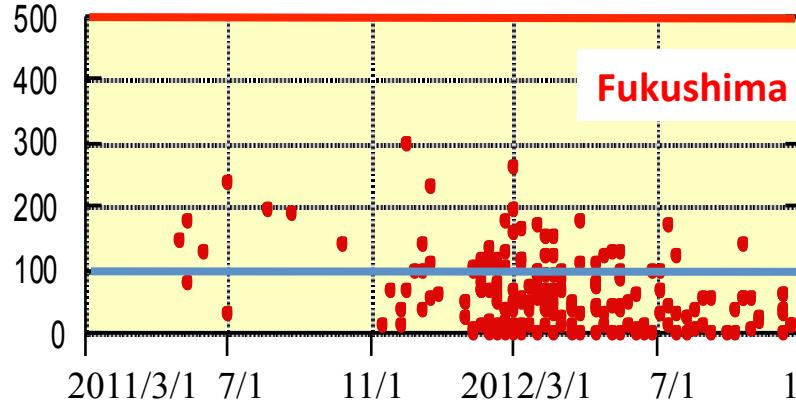
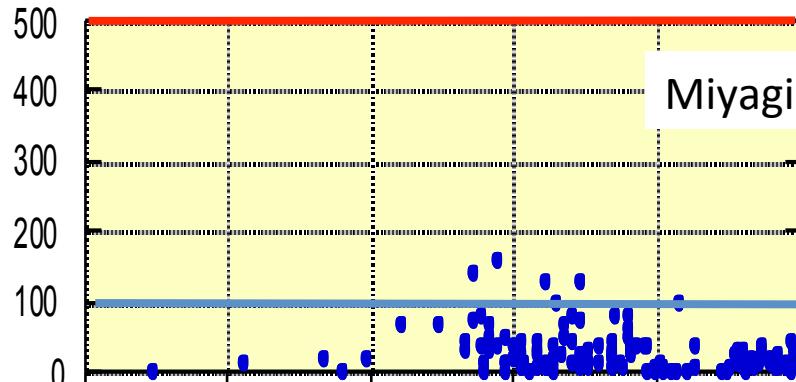
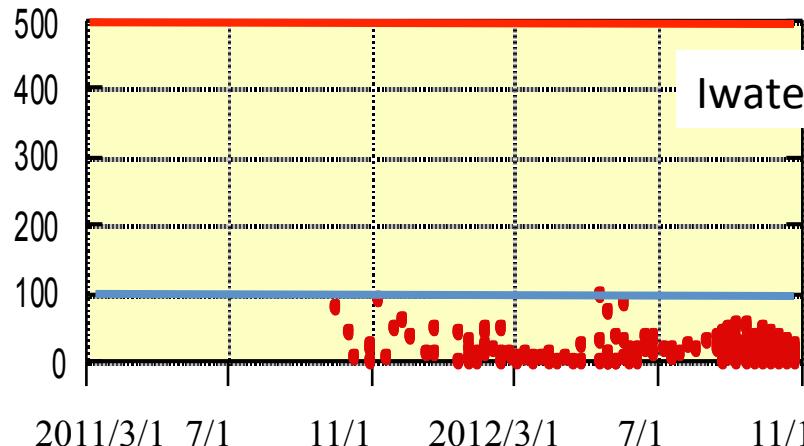
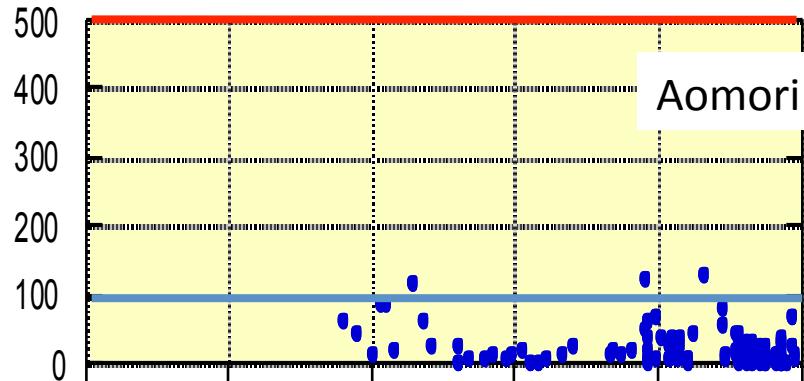
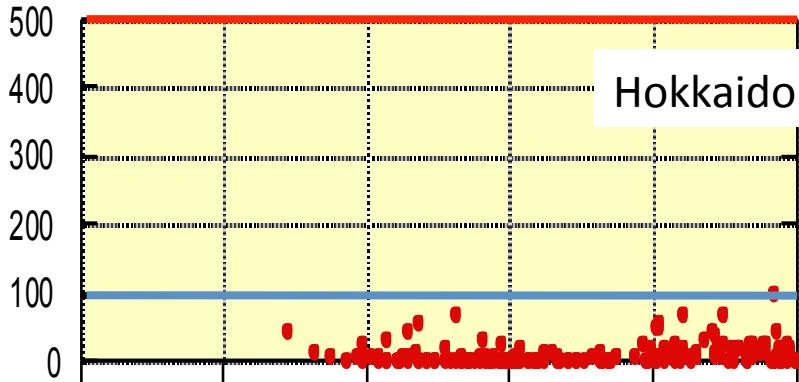
- Cow milk: 650 Bq/kg
- Goat milk: 1350 Bq/kg
- Freshwater fish: 30,000 Bq/kg
- Lamb: 40,000 Bq/kg
- Reindeer: 150,000 Bq/kg
- Mushrooms: 1-2 MBq/kg

Permitted levels: 600 Bq/kg (general foodstuffs)

Raised permitted levels to 6,000 Bq/kg in reindeer (+mushrooms, game, and freshwater fish)



# Cs137, Cs134 contamination in cod

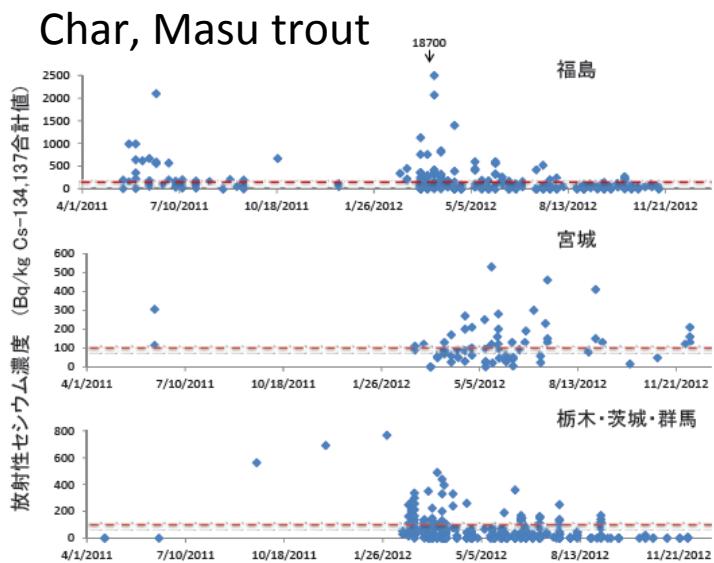
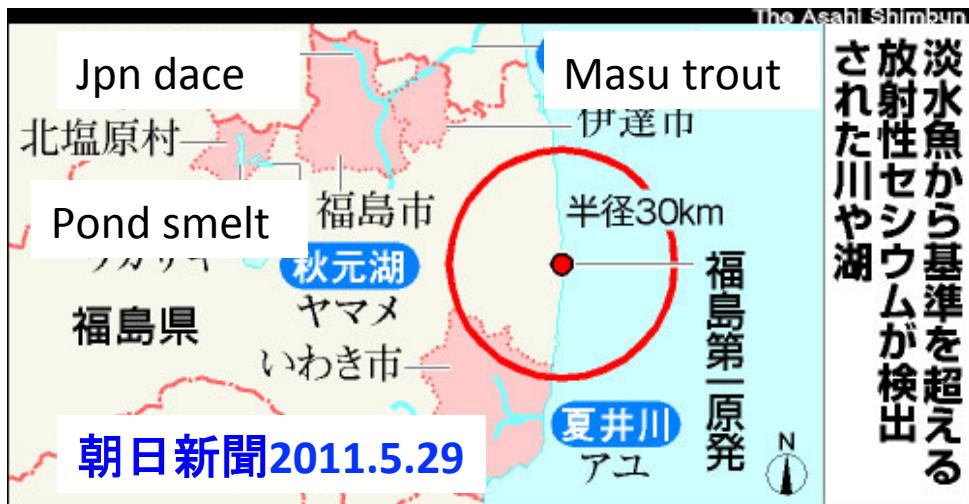


500Bq/kg (Provisional regulation value)

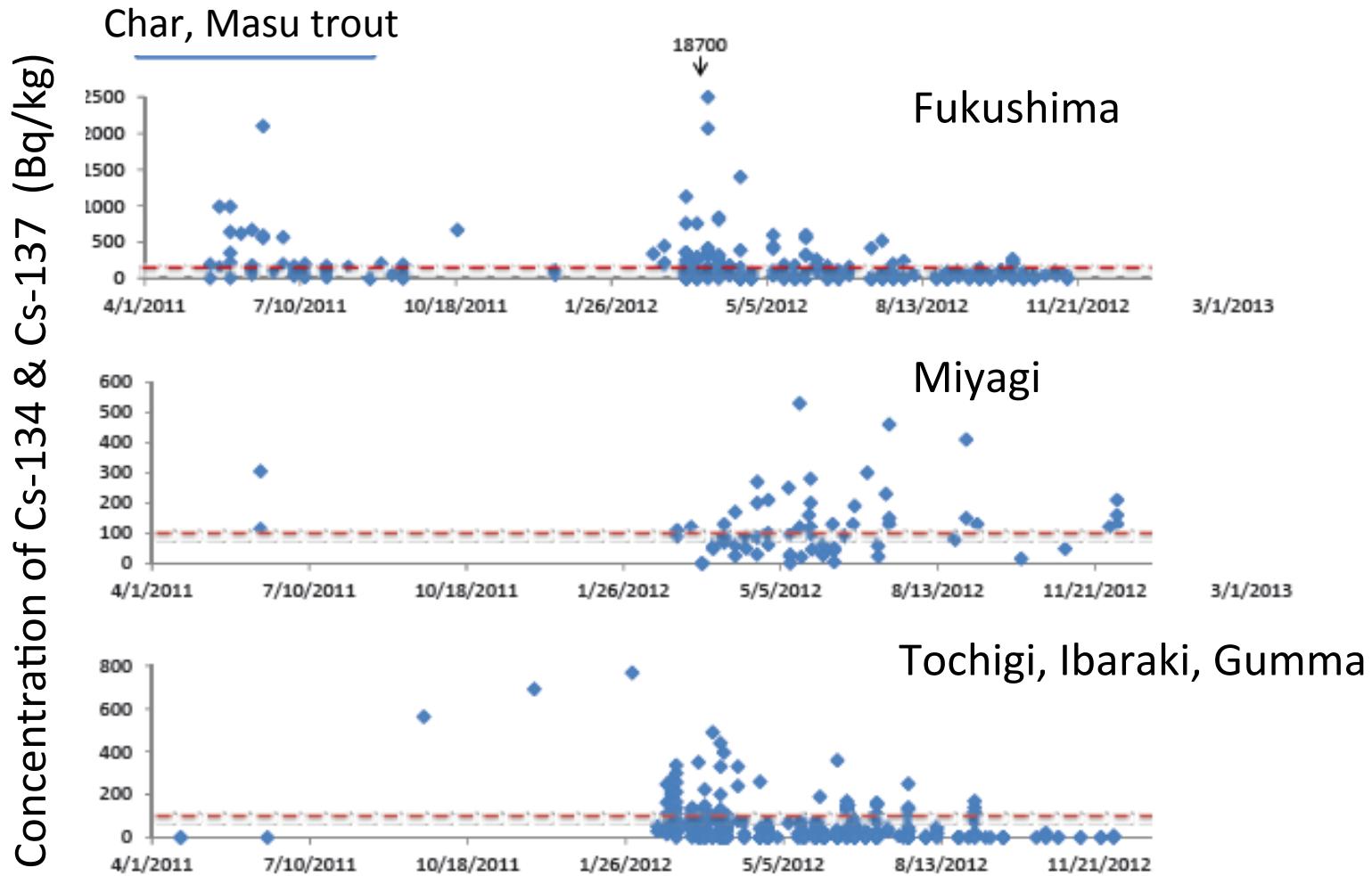
100Bq/kg (Regulatory limit)

# Contamination in inland fish

- Game fishing must release in Nikko, 150km far from F1NPP
- ↓ Inland fish is still contaminated.
- ↓ Rivers and lakes where  $^{134}/^{137}\text{Cs}$  conc. > 100Bq/kg



# Radioactive Cs Contamination in inland fish



Radioactive Cesium concentration of char and masu trout in rivers of Tochigi, Ibaraki, Gumma Prefectures. Broken Lines mean the 100Bq/kg standard

# Key Points

- Actual risk of radioactive Cs is much smaller than K-40 in bananas and mercury in fish
- Citizens distrust the government and scientists
- Distribution restriction discourages farmers/fishers
- Respect both sides of freedom of choice
  - A home delivery company 大地を守る会 sells (and labels) BOTH less contaminated foods and foods from Fukushima

◎ 少しでも安心できる青果物をお届けしたい  
子どもたちへの安心野菜セット

◎ 福島と北関東の農家  
がんばろうセット

- Explain risk and benefit of eating fish and supporting Fukushima.



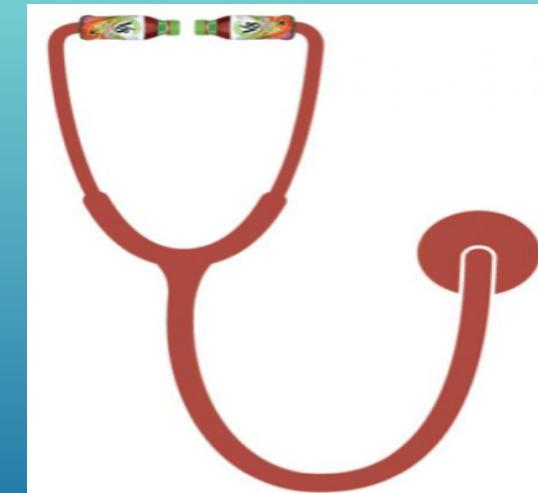
Kizuna311

<http://kizuna311.com>



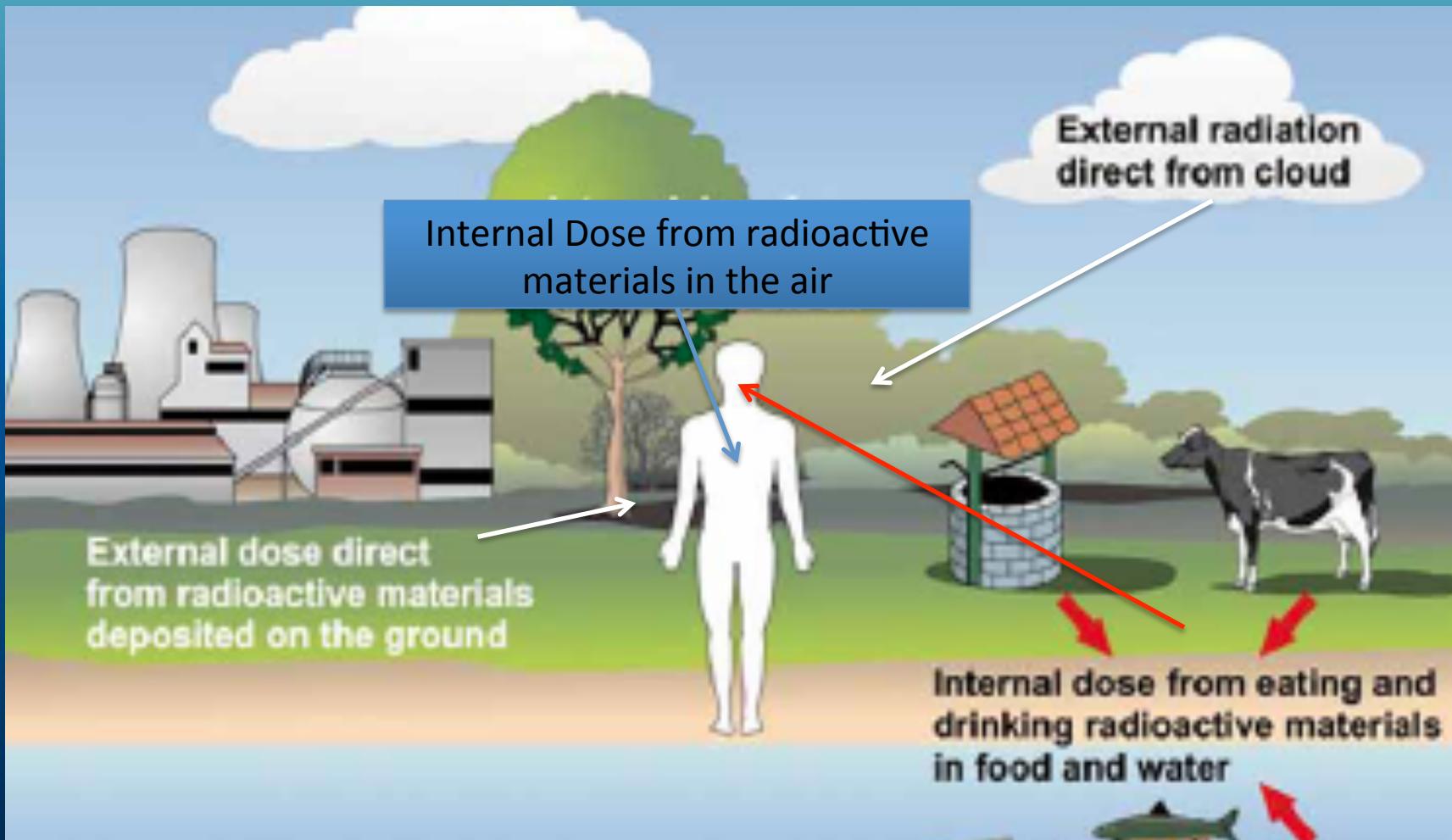


# The accidents at Fukushima Dai-Ichi Summary of Health Discussions

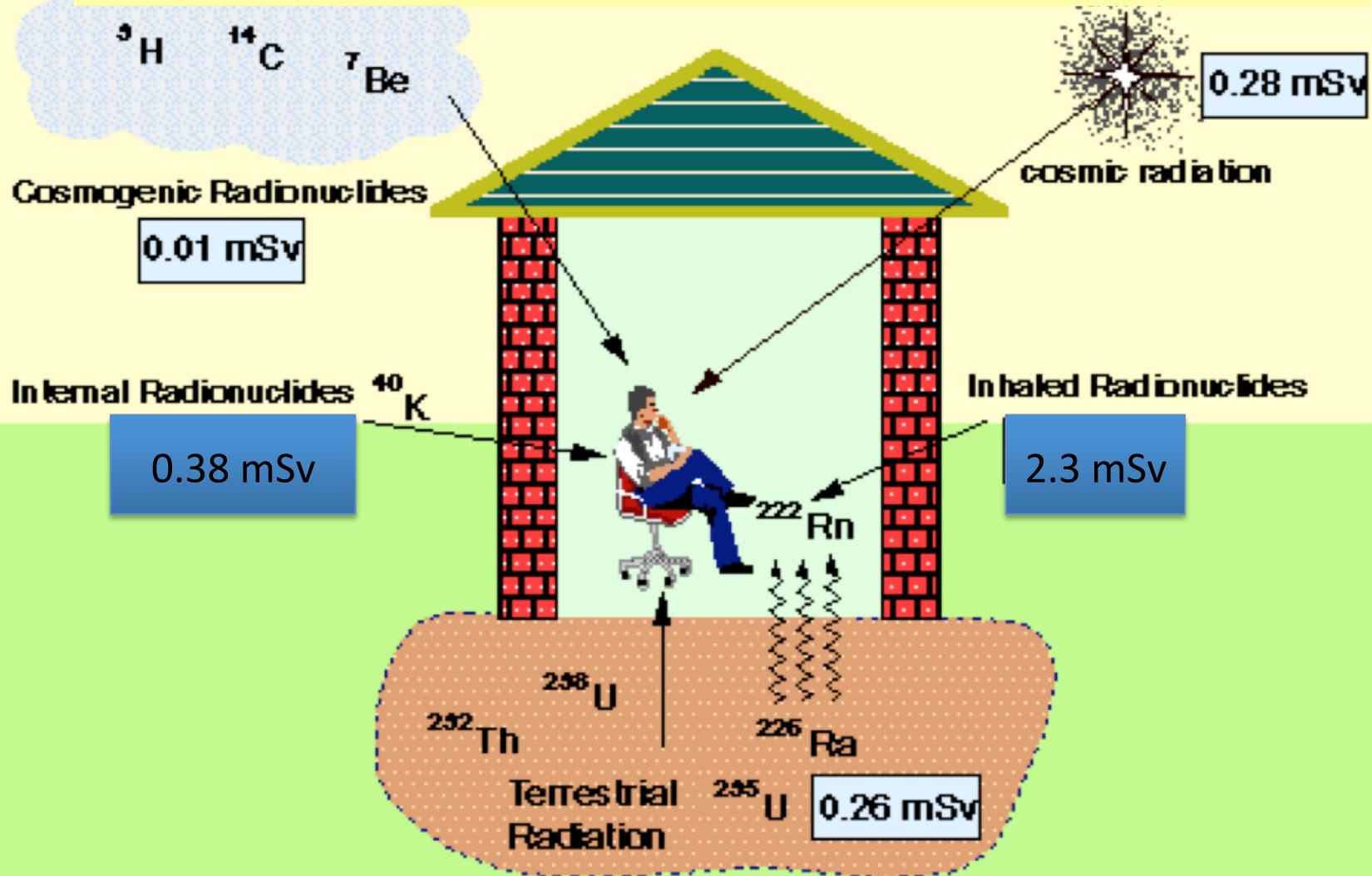


James Seward, MD MPP  
Medical Director, Lawrence Livermore National Lab.  
Clinical Professor of Medicine, UCSF  
WHOI Colloquium  
May 9, 2013

# Environmental Pathways for Radiation Exposure



Natural background radiation dose approx 3 mSv/year  
(range 1-10 mSv) without known health effects



Man-made sources add 3 mSv = 6 mSv total background dose

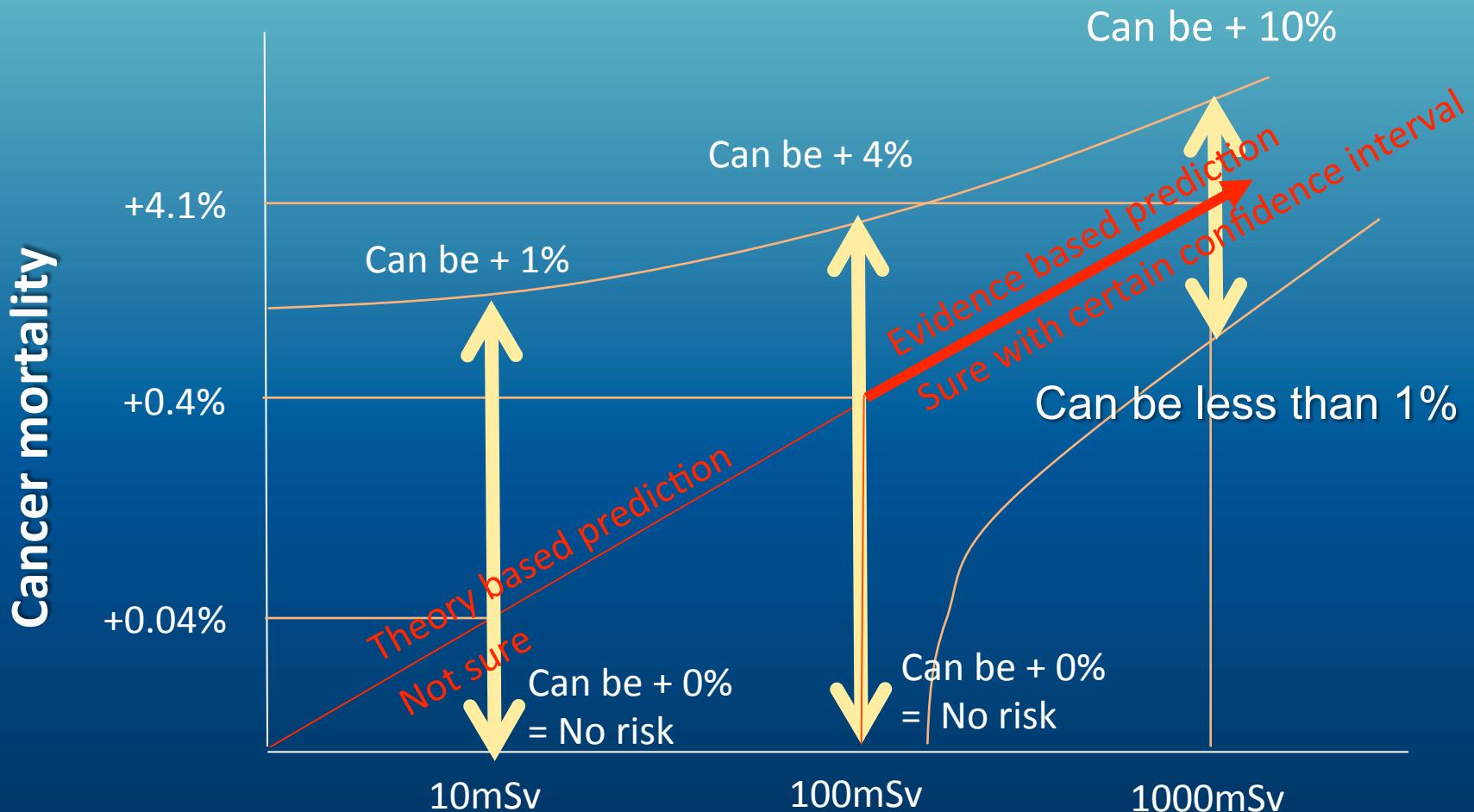
# Health Concerns for >20,000 Fukushima Workers

- No acute health effects from exposures
- Two workers received high thyroid dose from radioactive iodine at beginning of reactor accident
- 75 workers exposed over 100mSv
- Ongoing worker health and psychological monitoring needed



# Radiation and Cancer

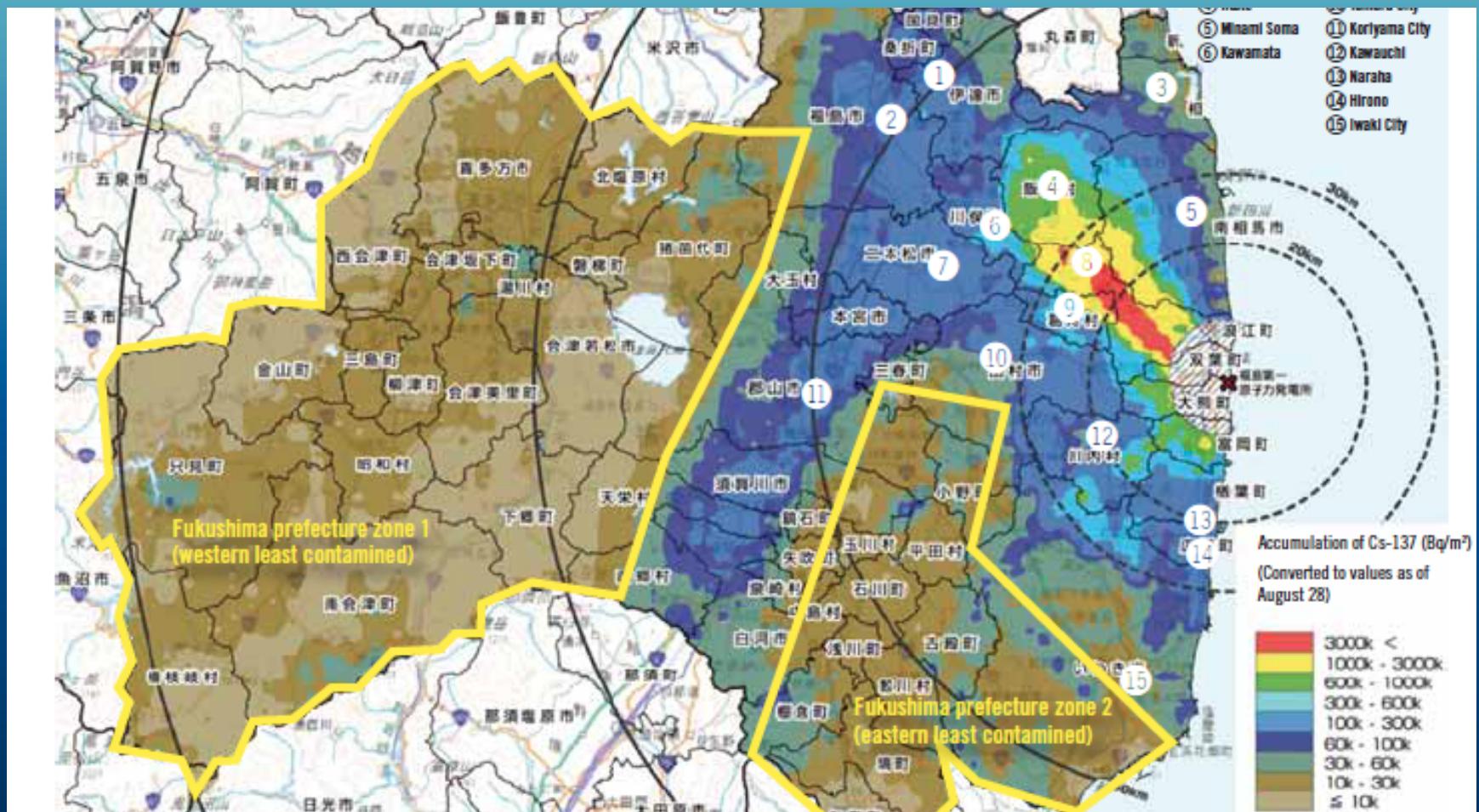
## The “No Threshold” model and uncertainty



# Low Dose Radiation cancer effects (below 100mSV) are found in some human studies

- 80% Hiroshima & Nagasaki survivors exposed to lower doses
- Techa River study and some occupational studies show cancer trend at dose below 100mSv
- Studies of people living in high natural background areas (> 10 mSv) do not show increased risk

# WHO Preliminary Dose Reconstruction Whole Body—All Key Radioisotopes



High Areas: 10-50 mSv effective dose—mostly external  
Lower areas: 1-10 mSv effective dose—mostly internal

# What does this mean for People living near Fukushima Dai-ichi?

- Radiation-related cancer risk is very low overall
- Lifetime thyroid cancer risk for most highly exposed children may increase. (World Health Org.)
- It may be difficult to measure any increase in cancer rate
- Health studies are underway
- Preventing significant additional exposures is important



# Fukushima and the Ocean

## The Role of the Media in Disasters

Woods Hole Oceanographic Institution

May 9, 2013

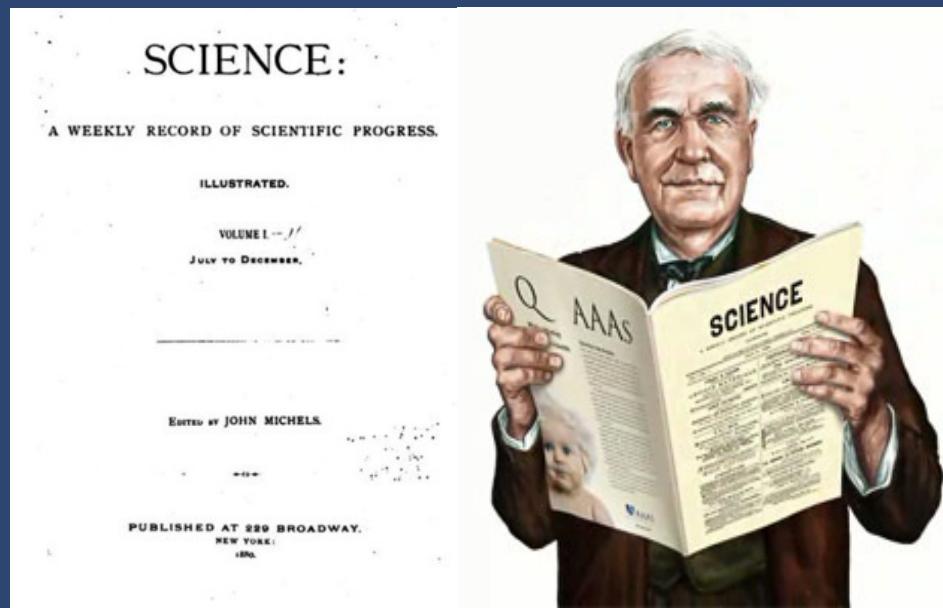
Dennis Normile  
Science

Japan News Bureau Chief

# About Science

- I. Founded by Thomas Edison in 1880
- II. Now published by the American Association for the Advancement of Science
- III. Science is:
  - a peer-reviewed journal
  - a weekly news magazine
  - an online news site

[www.sciencemag.org](http://www.sciencemag.org)



# Fukushima Daiichi Unit 3 Explosion



# Eggman Power Plant



# Over the Top Headlines

My Nightmare Trapped in City of Ghosts--Tokyo

Just 48 Hours to Avoid 'Another Chernobyl'

Radiation Detected in U.S.

Brave Workers Expect to 'Die Within Weeks'

# The Role of the Media

Get the Facts Straight

Don't Sensationalize

Provide Context



# Tsunamis and nuclear power in the US

Jian Lin

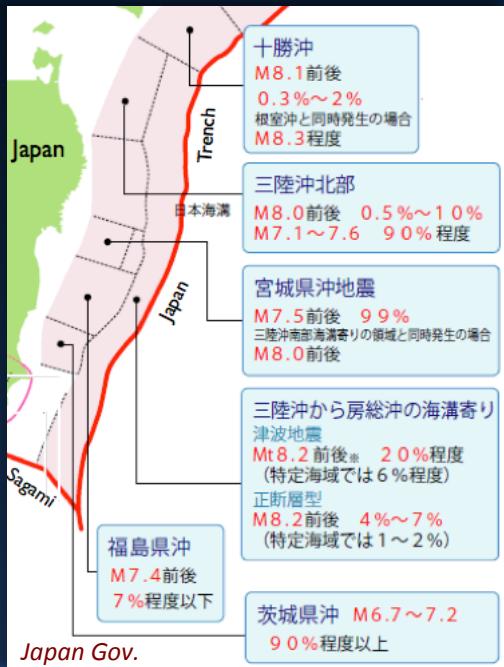
Woods Hole Oceanographic Institution

Committee on Tsunami Warning and Forecasting  
US National Research Council of National Academies

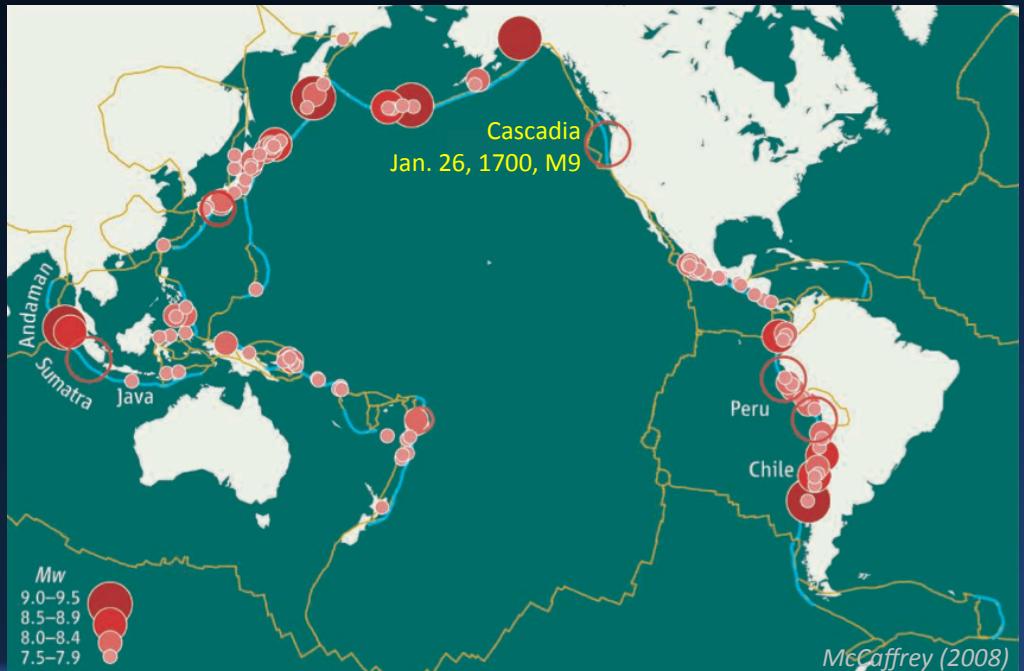


# Lessons from Japan

- Must improve assessment of earthquakes and tsunamis threats in the US.
- Must address the vulnerability of US nuclear power plants to natural disasters.
- Must start hazard mitigation before tsunamis.



*Clearly wrong:  $M \leq 8.2$*

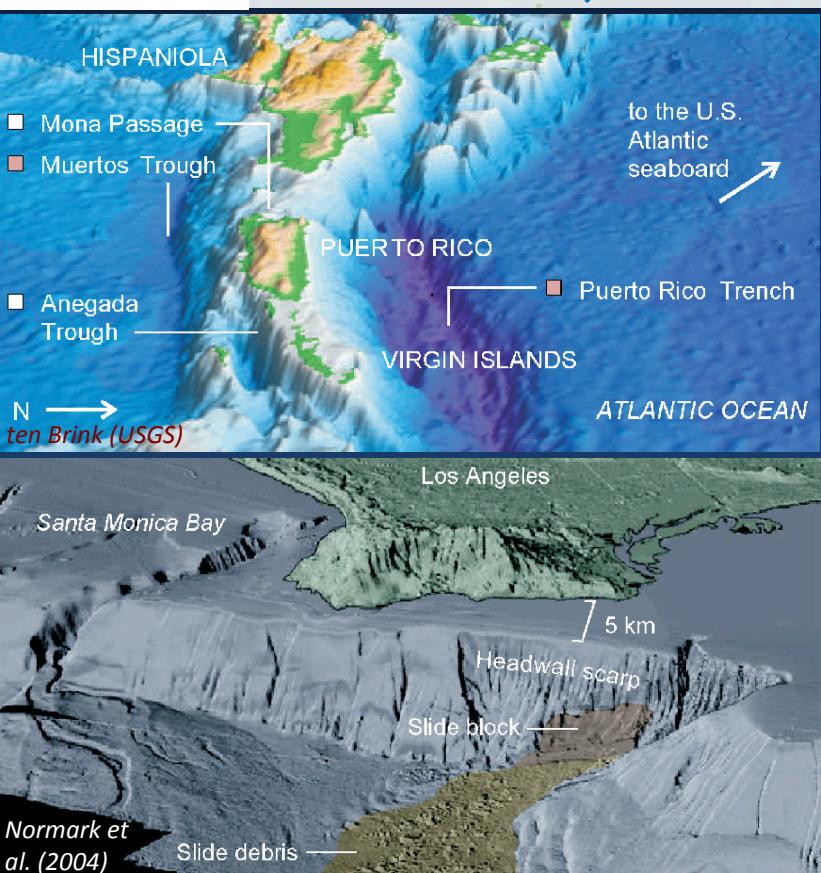


*Probably right:  $M \sim 9$  in any subduction zone*

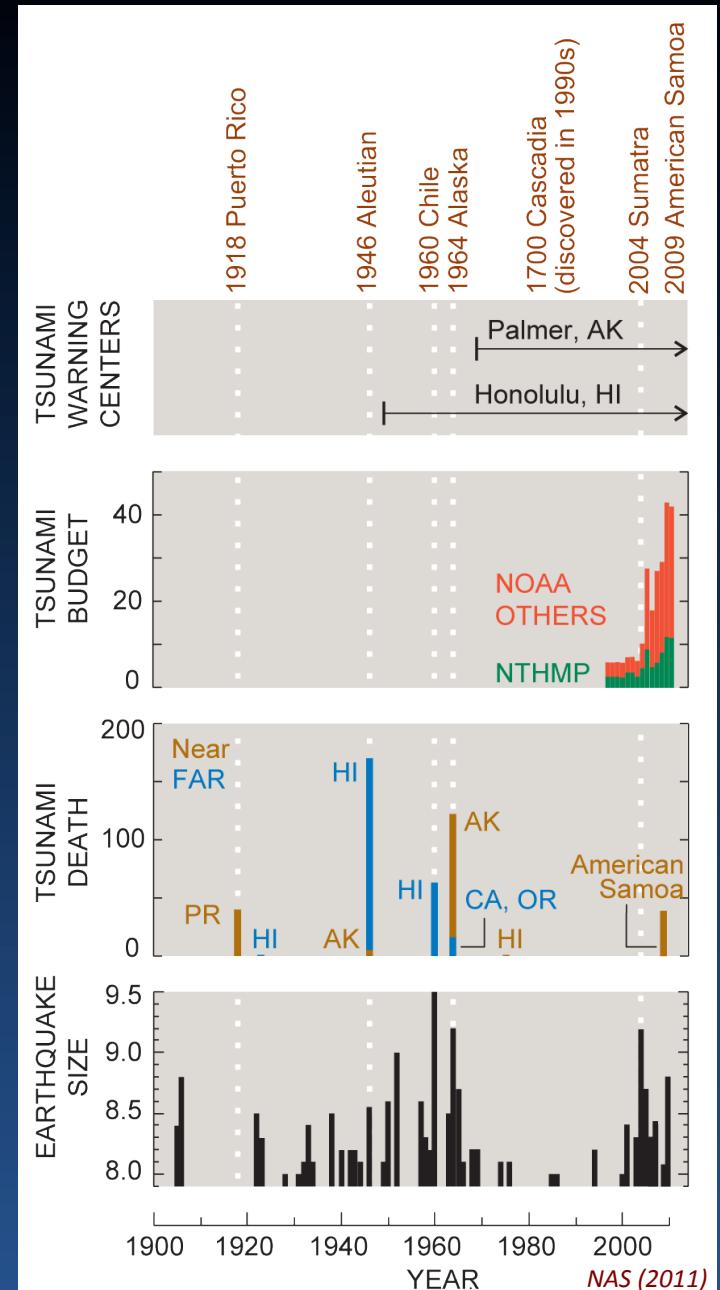
# US tsunamis sources



## 1. "Ring of fire" earthquakes



## 2. Caribbean earthquakes

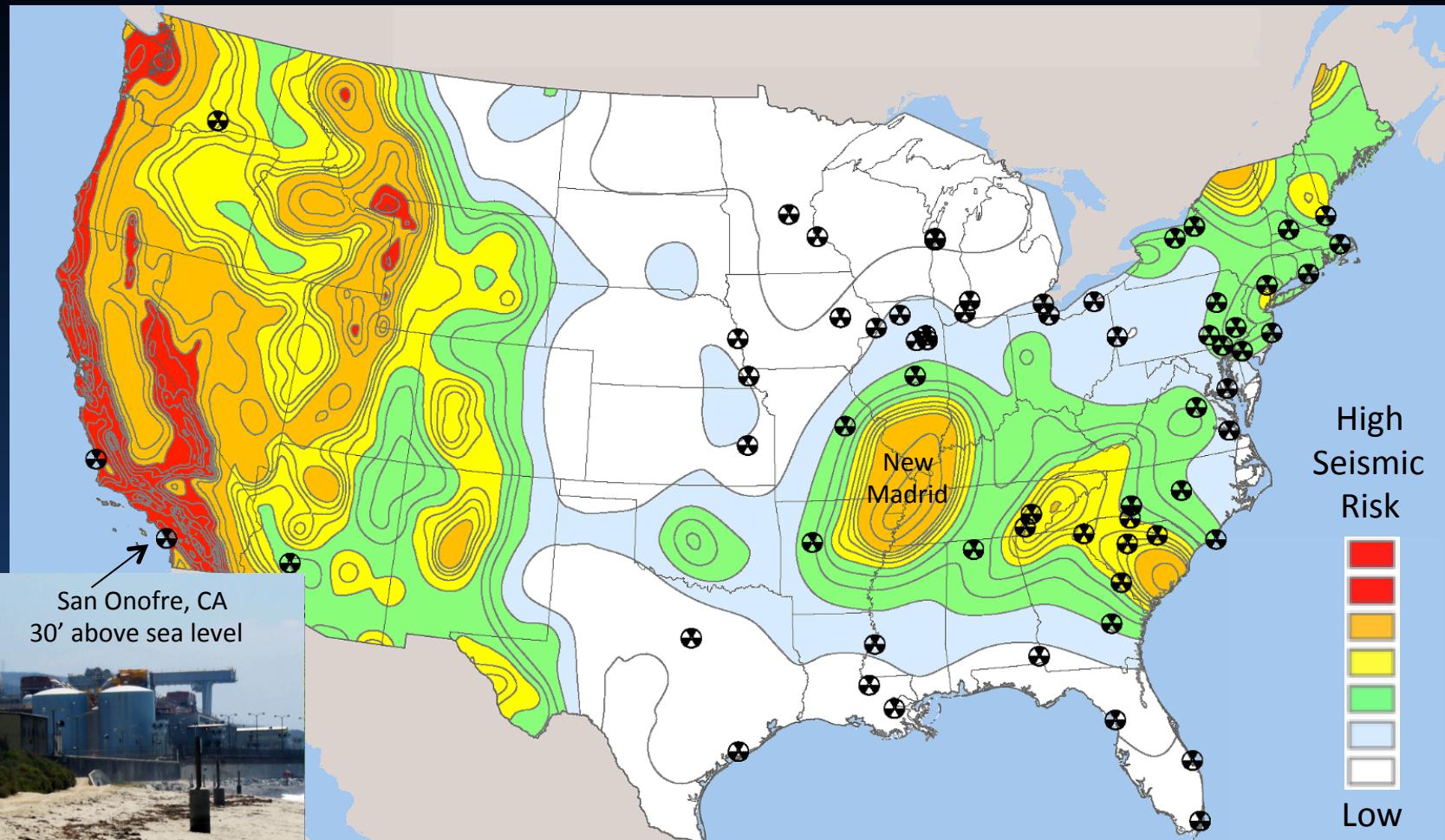


# US nuclear power plants are vulnerable to severe accident



- 104 reactors, 65 nuclear power plants.
- 35 reactors are Fukushima-type Boiling Water Reactors, including **Plymouth, MA**.
- In 2011, five US NPP lost primary power due to earthquakes (North Anna, VA), tornados, hurricanes, and flooding.
- 6 million living within 10 miles of a NPP, 120 million within 50 miles.

# Western US and New Madrid: Tornados, earthquakes, tsunamis

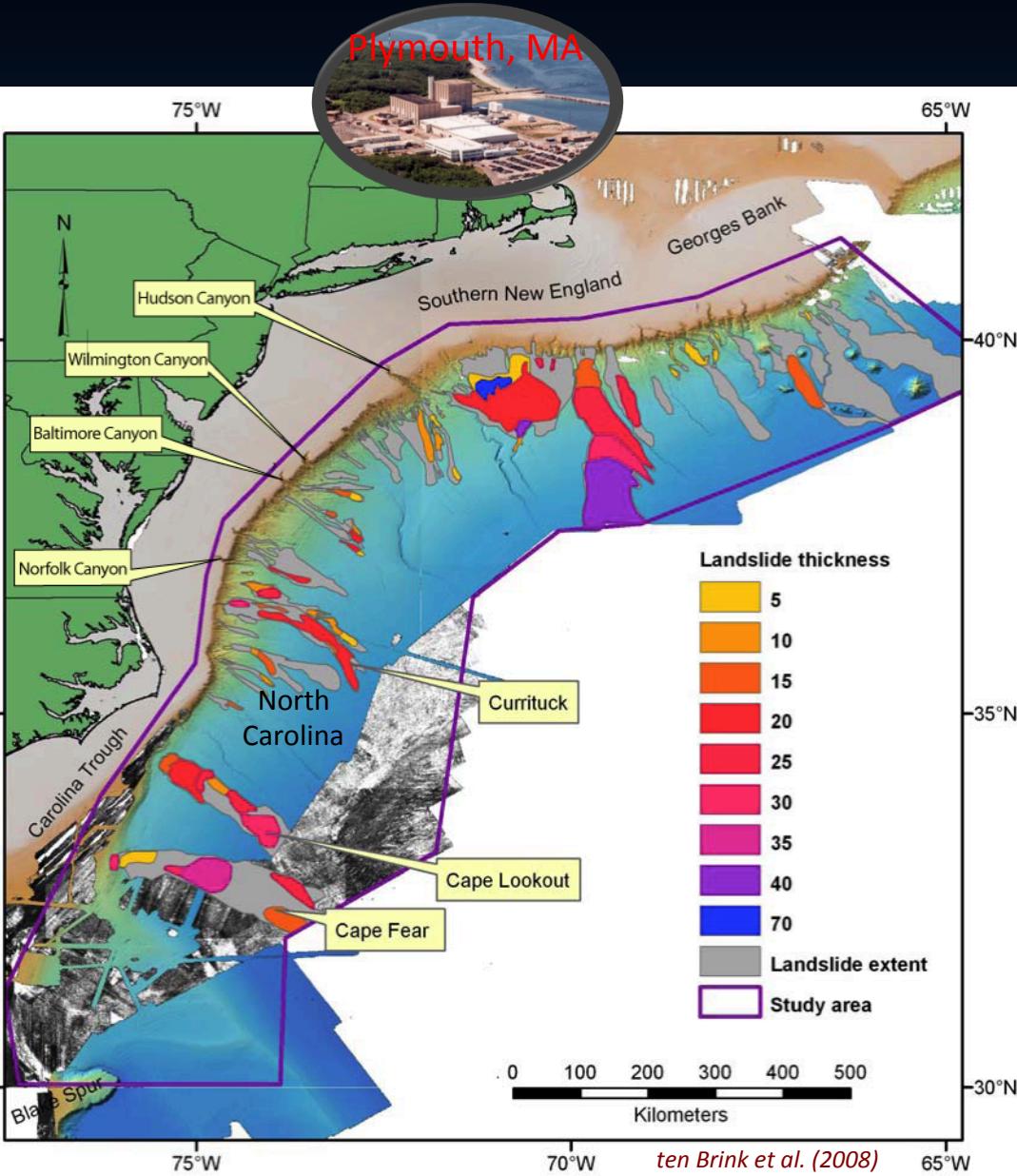


**Alaska:** 1964 M9.2, 1965 M8.7, 1957 M8.6, 1938 M8.2, 1946 M8.1

**Cascadia:** 1700 M~9 **Hawaii:** 1868 M7.9 **California:** 1857 M7.9, 1906/1892 M7.8

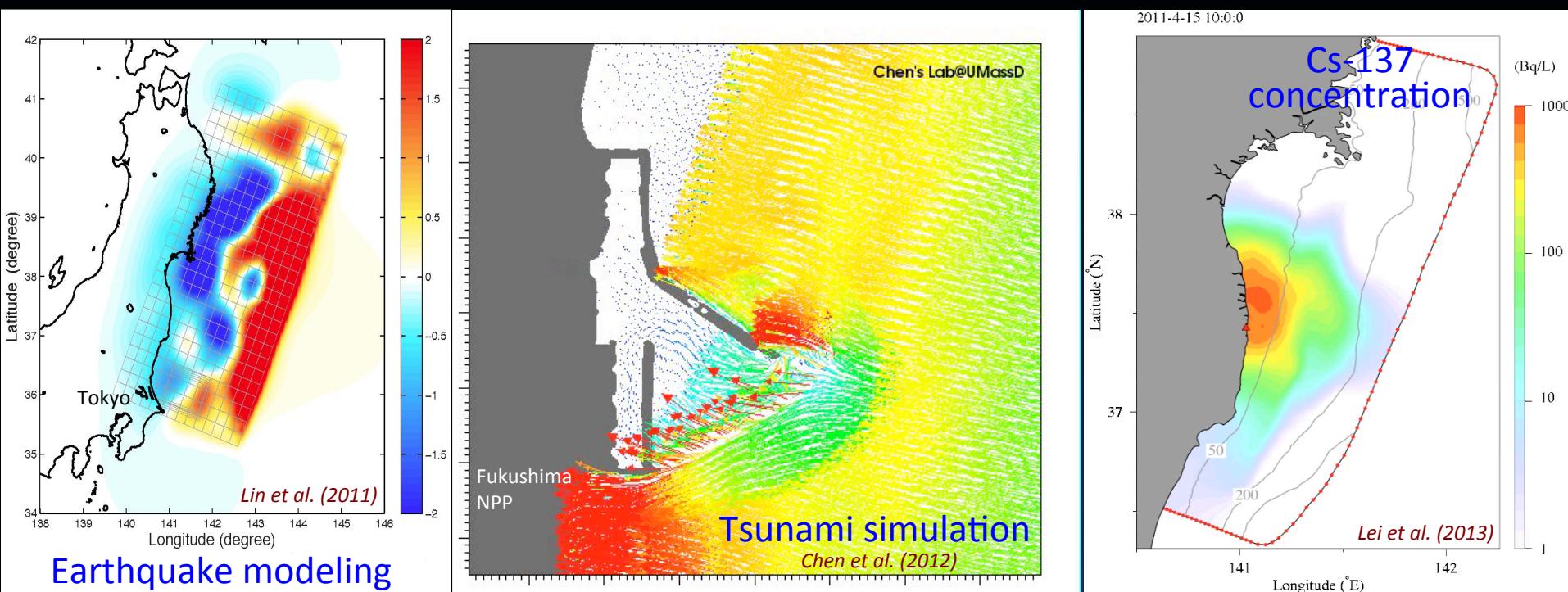
**New Madrid:** 1811/1812 M7.7; 1812 M7.5

# US Atlantic Coast: Hurricanes, tsunamis triggered by submarine slides

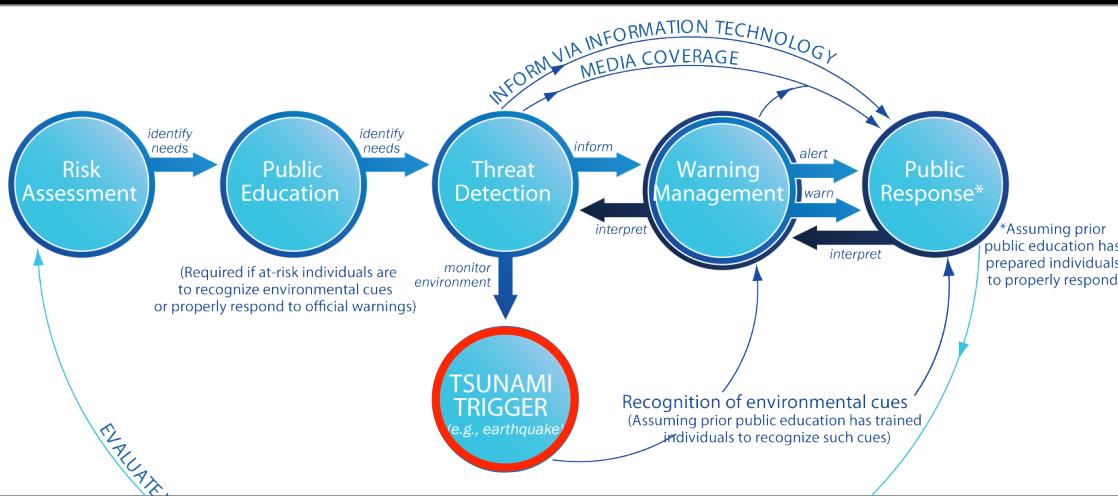


- Submarine slides cover a large area:  
1/3 off New England,  
1/6 off the Middle Atlantic,  
1/8 off the Southeast.
- The Currituck slide, ~25-50 k years ago; tsunami crest ~6 m above sea level.
- Most before 5,000 years ago; in 1929, a slide off Grand Banks, Canada, triggered a tsunami that killed 28.

# An integrated science approach



Hazard mitigation must start before tsunamis!



- Risk assessment
- Public education
- Threat detection
- Warning management
- Public response

