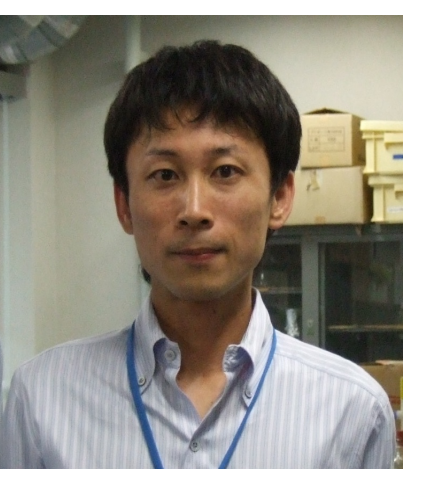


Oceanic dispersion of radioactive cesium around Japan and western North Pacific after the Fukushima Dai-ichi Nuclear Power Plant Accident

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Introduction

The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident after the Great East Japan Earthquake and tsunami on 11 March 2011 resulted in elevation of the level of anthropogenic radioactivity in the marine environment in the western North Pacific. Radioactive cesium (Cs) with relatively long half-life time (ca. 2.0 yr for Cs-134 and 30 yr for Cs-137) is a serious concern for people involved in fisheries and seafood safety. In this study, we report the concentrations of radioactive Cs (especially Cs-137) in seawater collected from western North Pacific, Japan Sea and East China Sea collected during June 2011 and August 2012. The concentrations of Cs-137 in the surface water around Japan before the accident (Background level) were almost 1-2 mBq/kg.

Materials and Methods

Seawater samples of 20L were mostly collected from sea surface around Japan and western North Pacific. In October-November 2011, samples were vertically collected from surface to 500 m depth off the coast of Tohoku area. The seawater samples were not filtrated and acidified to pH = ca 1.6 with HNO₃. Radioactive Cs in 18 kg of seawater with stable Cs added as carrier were concentrated by adsorption onto ammonium phosphomolybdate (AMP). The concentrations of Cs-134 and Cs-137 were measured by the HPGe detector. The detection limits of Cs-134 and Cs-137 were varied from 1.2 mBq/kg to 5.0 mBq/kg, due to the length of measurement time between 7,200 sec and 85,000 sec. All activities were decay corrected to the sampling date.

1. Around Japan

Off the coast of eastern Japan, Cs-134 and Cs-137 were detected from almost samples, and those were ranged from 2.4 to 208 mBq/kg and from 4.0 to 220 mBq/kg, respectively. On the other hands, only Cs-137 was detected at background level (up to 2.0 mBq/kg) in the Japan Sea, East China Sea and Seto Inland Sea.

The obvious elevation of the radioactive Cs in seawater due to the FDNPP accident seemed to be mostly limited in the area off the eastern Japan.

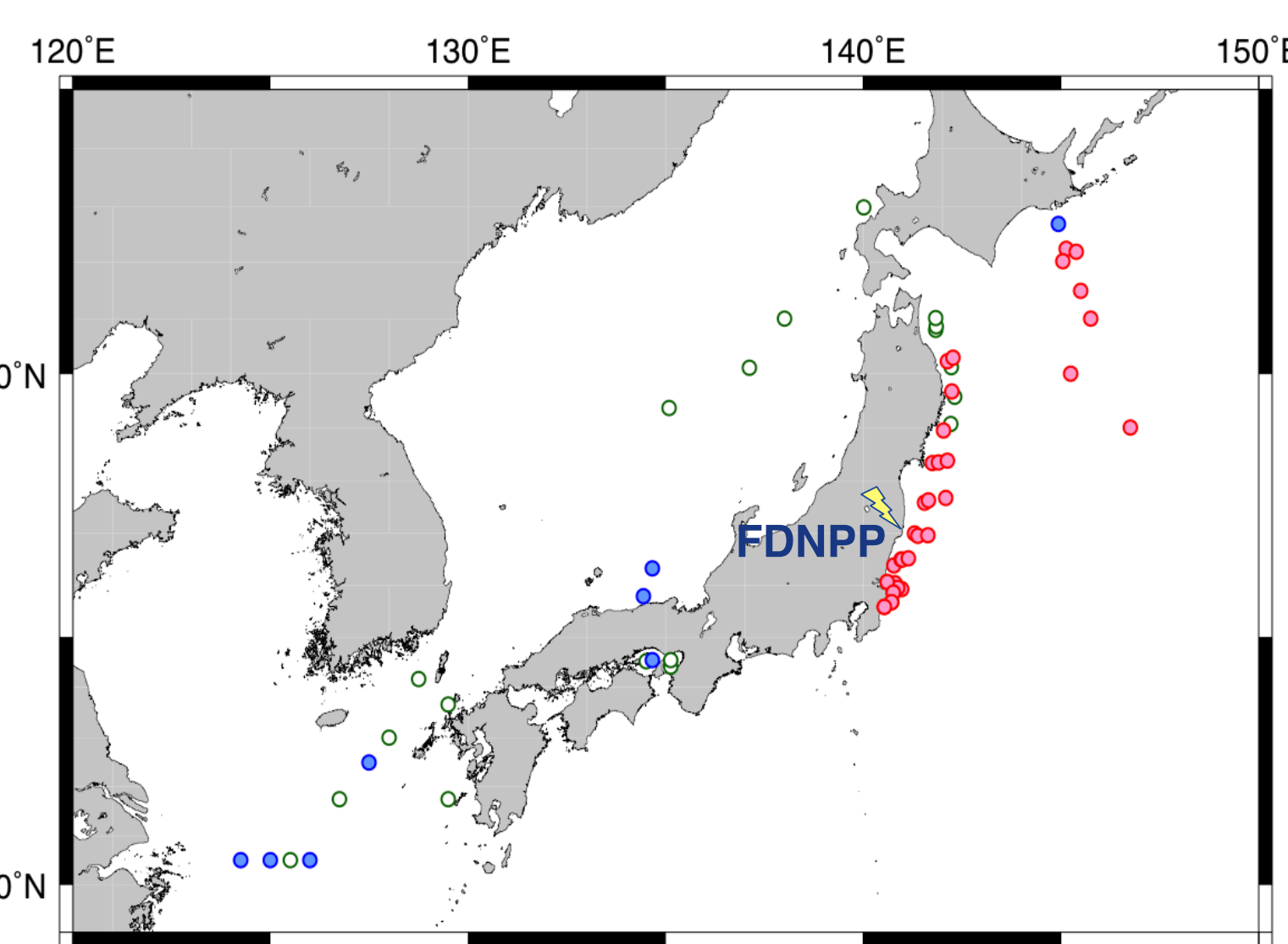


Fig. 1. Results of the radioactive Cs in the sea surface water around Japan. Samples were collected during June 2011 and July 2012. Red closed circles indicate Cs-134 and Cs-137 were detected, blue closed circles do only Cs-137 was detected at background level (~2 mBq/kg), whereas both Cs-134 and Cs-137 were under the detection limit (< 5 mBq/kg) in the green open circles as results of short time measurements.

3. Off Tohoku area (Vertical distribution)

The concentrations of Cs-134 and Cs-137 were highest at surface layer and decreased with depth at almost all stations. Near the cyclonic eddy front, Cs-134 and Cs-137 in surface water seemed to be dispersed to deeper layer due to the unstable state of water properties with mixing the differential water masses (Fig. 3 (b)).

Relatively complex pattern of Cs-137 were observed at the transects along with 37°25'N (Fig. 3(c)) and 147°E (Fig. 3(d)). The highest Cs-137 (70 mBq/kg) was observed from surface water at 37°30'N-147°00'E. On the other hands, Cs-137 were very low at 40°N-145°00'E, where the Oyashio water was dominant. The sub-surface peaks of Cs-137 were observed at 150m and 300m at the stations located near the Kuroshio axis (35°30'N and 34°30'N at 147°E) and at 100m of 37°25'N -147°E, those may be transported from shallower water of coastal area.

The horizontal and vertical distribution pattern of radioactive Cs off Tohoku area seemed to be affected by the water mass interaction among Oyashio water, Kuroshio water and heavily contaminated coastal water off the FDNPP.

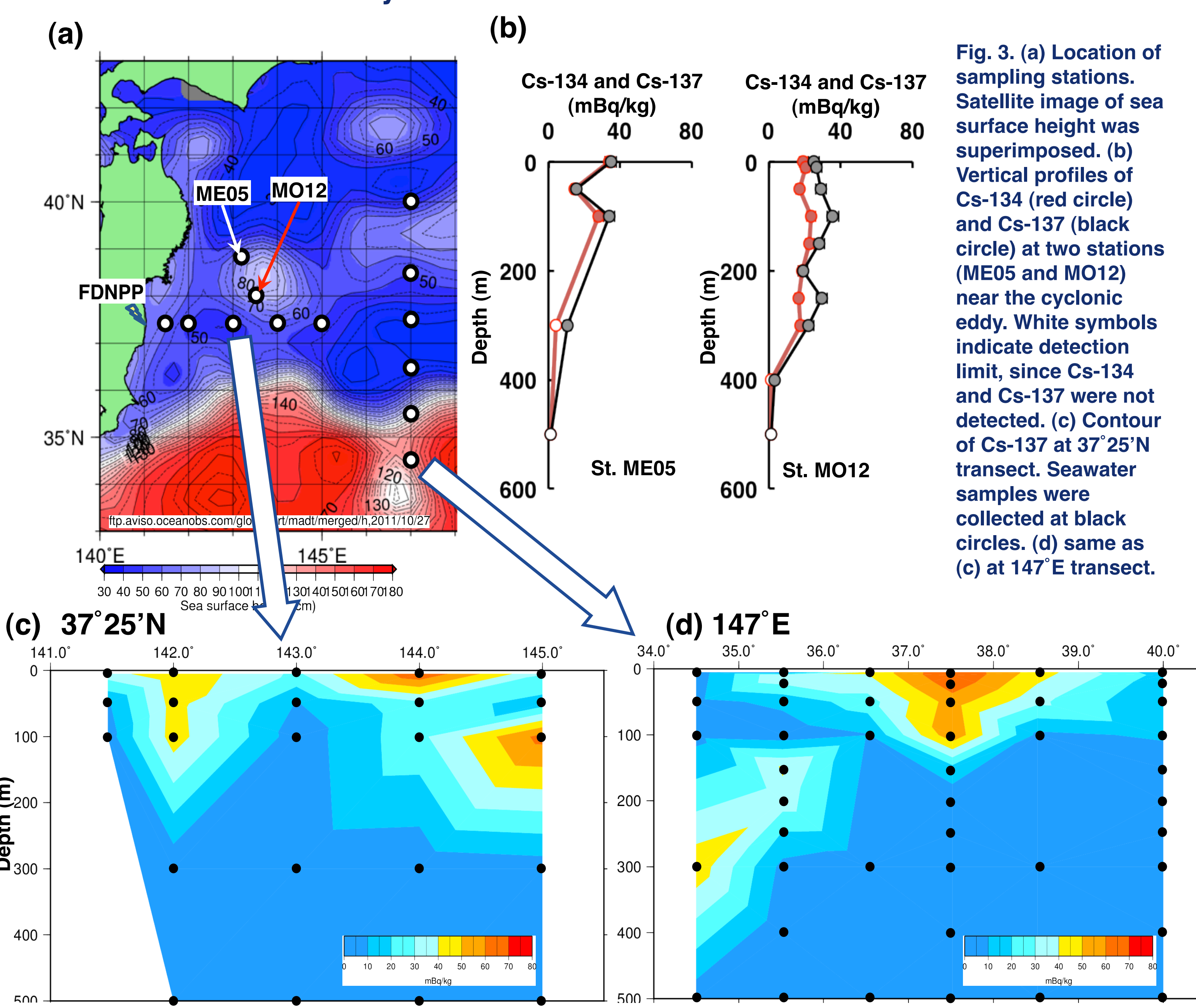


Fig. 3. (a) Location of sampling stations. Satellite image of sea surface height was superimposed. (b) Vertical profiles of Cs-134 (red circle) and Cs-137 (black circle) at two stations (ME05 and MO12) near the cyclonic eddy. White symbols indicate detection limit, since Cs-134 and Cs-137 were not detected. (c) Contour of Cs-137 at 37°25'N transect. Seawater samples were collected at black circles. (d) same as (c) at 147°E transect.

2. Western North Pacific

Cs-134 and Cs-137 were detected from broad range of latitude at 144°E, 155°E and 175°E. In 2011, high concentrations of Cs-137 were observed at northern part of the Kuroshio extension in 144°E and 155°E, and Cs-137 at the 175°E line were almost one order of magnitude lower than those of 144°E and 155°E (Fig. 2(a) and (b)). The concentrations of Cs-137 at the Kuroshio extension and its southern part were lower than those of the northern stations at 144°E. The Kuroshio extension seemed to prevent the southward dispersion of radioactive Cs. After one year, the high concentration area seemed to be moved to 155°E and 175°E, and the level of Cs-137 at 144°E line was declined one order of magnitude. Our results showed similar dispersion patterns with the simulation model (Fig. 2 (c), Kobayashi et al., 2012), and these results strongly suggest that the high Cs-137 water masses (ca. 10 mBq/kg) are located at the center of North Pacific after one year from the FDNPP accident.

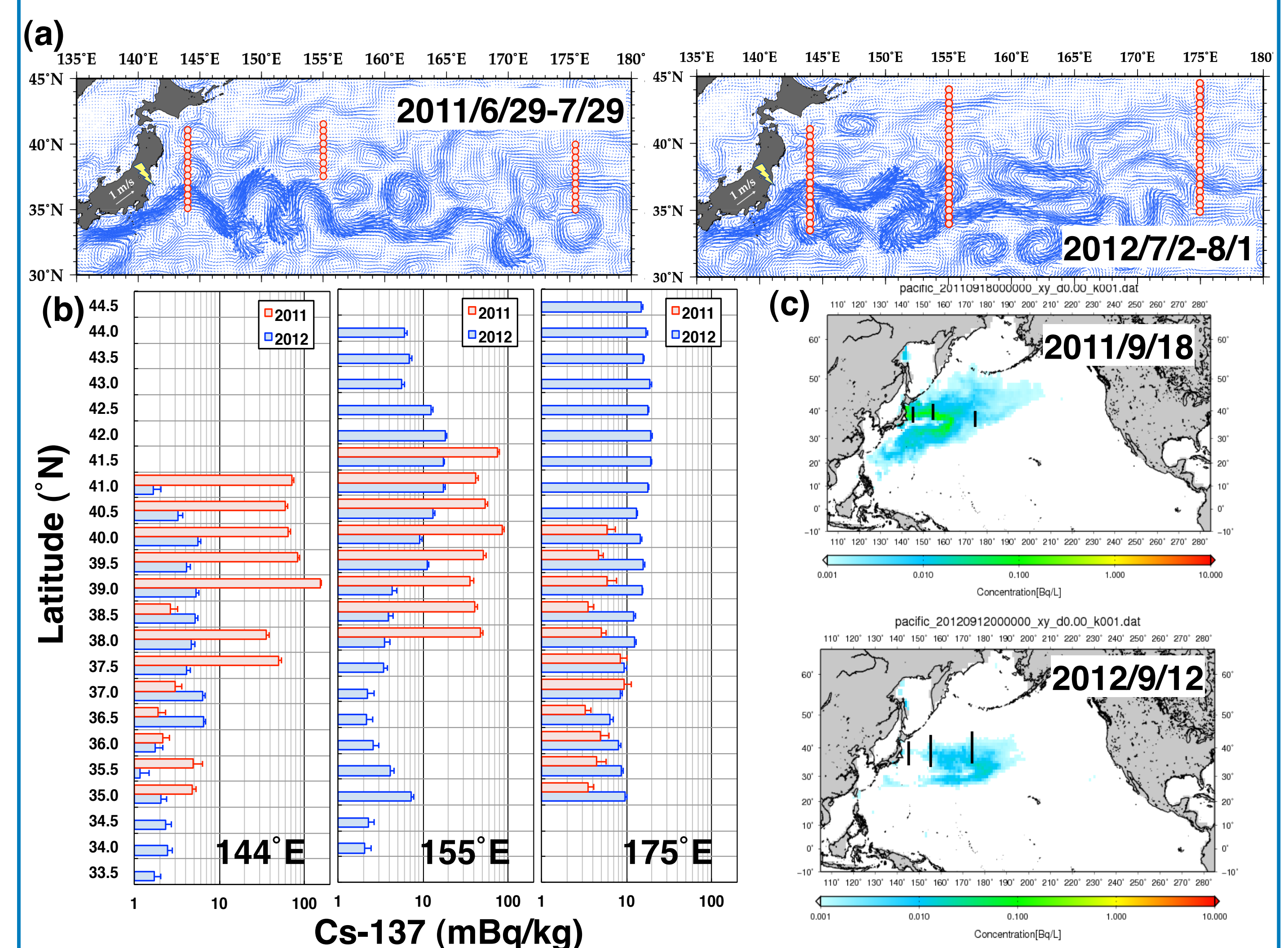


Fig. 2. (a) Location of sampling stations in 2011 and 2012, sea surface current estimated from sea surface height were superimposed. (b) Concentration of Cs-137 at each station. Error bars indicate counting error (1σ). (c) Model results of Cs-137 dispersion in the North Pacific on September 2011 and September 2012, model calculation based on JAMSTEC/DrC and WSPEEDI (Kobayashi et al., 2012). Sampling area of this study were shown as black lines.

*Kobayashi et al., 2012: Public WS presentation file, <http://nsed.jaea.go.jp/ers/environment/envs/FukushimaWS/jaea3.pdf>

Summary

- The elevation of the radioactive Cs was observed off the eastern Japan coast, but no increase of radioactive Cs was observed in the Japan Sea, East China Sea and Seto Inland Sea
- After one year from the FDNPP accident, the high radioactive Cs water seemed to be located at the center of North Pacific
- Complex vertical distributions of radioactive Cs observed off Tohoku area, are suggesting that Oyashio-Kuroshio transition zone plays an important role to decide the vertical distribution patterns of radioactive Cs in the North Pacific
- Continuous monitoring of radioactive Cs in seawater should be important to comprehensively understand the impact of FDNPP accident to the oceanic environment