Press Release

Simulation of Radioactivity Concentrations in the Pacific Ocean

June 17, 2011
Japan Atomic Energy Agency

1. Outline

The Ministry of Education, Culture, Sports, Science and Technology (hereafter referred to as "MEXT") has been conducting monitoring studies in the sea area off the coast of the Fukushima Dai-ichi NPP since March 23, 2011. It reveals that the concentration of the radioactive substances has been lower than the detection limits since this May. On the other hand, it is evident that the radioactive substances are slowly dispersing in the Pacific Ocean. Japan Atomic Energy Agency (hereafter referred to as "JAEA") has carried out annual basis simulation of cesium-137 dispersion released from Fukushima Dai-ichi NPP accident using the coarse (about 200 km) grid system, considering the deposition of the radioactive substances from the atmosphere in a simplified manner. This press release presents the outline of this simulation.This is the preliminary simulation adopting the simplified model. JAEA will carry out further simulation of the dispersion by using more sophisticated model in corporation with the US National Oceanic and Atmospheric Administration etc., and the result will be evaluated by Japan and US mutually in the future.

In that case, JAEA is going to simulate the realistic radioactive material dispersion in the North Pacific using a high accuracy datasets prepared by the collaborative work of the Japan Agency for Marine-Earth Science and Technology and Kyoto University.

This simulation was performed by using the calculation code LAMER (Note1) developed by JAEA, based on the radioactive release information published by both the Ministry of Economy, Trade and Industry (hereafter referred to as "METI") at 6th June and Tokyo Electric Power Company (hereafter referred to as "TEPCO") at 21st April and 21st May.

As a result, the cesium-137 concentration in the Pacific Ocean in April 2012 is 0.023 Bq/L at maximum, which is less than one third of the cesium-137 concentration in the Kuroshio region in around 1960. According to this estimation, the internal exposure by the intake of the marine products would be the comparable to the value in the early 1960's (estimated value by calculation).

(Note1) LAMER: Long-term Assessment Model of Radionuclides in the Oceans, developed by JAEA to predict the radioactive dispersion in global scale with the annual mean three dimensional velocity fields. (The grid size of the velocity field is 2 degrees (200km*200km) horizontally and 15 layers vertically.)

2. Method

This simulation is based on the following assumptions since the purpose of this simulation is to understand the dispersion in global scale and the internal exposure by the intake of the marine products.

- The cesium-137 release scenario: The amount of release was estimated by using the values disclosed by METI at 6th June and as well as by TEPCO at 21st April and 21st May. 8.45PBq (=15PBq×0.5(note2)(deposition from atmosphere)+(0.94+0.0096)PBq (directly as effluent)), all of the cesium-137 was assumed to be released off shore the power plant at 1st April 2011, then no release occurred after that date.
- The advection and diffusion was evaluated by the particle tracking model in LAMER. The horizontal and vertical diffusion coefficients used were 1.3×10^{4} m^2/s and 3×10^{-5} m^2/s, respectively, and the surface mixed layer was also considered.
- The sedimentation to the seafloor, the resuspension from the seafloor, the adsorption and the desorption with the particulate, and the inflow from rivers were not considered This is because the purpose of the simulation was the estimation of seawater concentration in the open ocean.
- With regard to the estimation of internal exposure from the intake of the marine products, the internal dose was estimated by multiplying averaged diet amounts of the marine products of Japanese, Conservative concentrations of the radioactivity in the marine products estimated by multiplying the

maximum concentration of the radioactive substances in the sea and their accumulation factor, and the effective dose coefficients (see appendix). The concentrations of iodine-131, cesium-134 was derived from the concentration of cesium-137 in April 2012 with decay and release amount correction.

(note2) ×0.5：From the author's rough estimation based on the equivalent dose at thyroid (trial calculation by SPEEDI from 6 o'clock in 12th March to 0 o'clock in 24th March) published by the Nuclear Safety Commission at 23rd March, it was suggested that Approximately 50% of the atmospheric release was flowing to the ocean.

3. Result

- This study shows that the maximum concentration of cesium-137 in the Pacific Ocean would be 0.023 Bq/L in April 2012. This value is about 14 times higher than the present background level (0.0017 Bq/L), but less than one third of the peak concentration observed in 1957. (The concentration in September 2011 would be 0.072 Bq/L, comparable to that in 1957. [Figure 1-1]~ [Figure 1-2]
- It is expected that water mass containing cesium-137 moves to eastward in the Pacific Ocean by Kuroshio current, its extension and north pacific current, then the center of the water mass would reach at the east of the north Pacific in 3 years. The water mass of about 0.0002 Bq/L (one tenth of the present background) would arrive at the west coast of US in 5 years. The radioactive concentration in all part of the Pacific Ocean would be less than 0.002 Bq/L in 7 years, and diluted into low level that we cannot discriminate from the present background. [Figure 2-1]~ [Figure 2-4]
- The trial calculation shows that the internal exposure by the intake of the marine products would be 1.8 micro Sv per year , when adopting the maximum concentration (Cesium-134: 0.020 Bq/L, Cesium-137; 0.023 Bq/L) and the averaged Japanese diet referred from the national health and nutrition examination survey in 2008. Additionally, the internal exposure in 1960's was estimated about 1.7 micro Sv/a by the same procedure.

4. Discrepancies with the previous simulation

"The simulation in the Sea Area", which was published five times by MEXT, described the coast region rather precisely with a fine grid system, and the simulated dispersion generally agreed with the observed data. It evaluated the dispersion at the sea surface based on the concentration of the surface beach water, but did not consider the deposition from the atmosphere and the vertical dispersion.

Even though this simulation can not describe the detailed distribution of the radioactive concentration along the coast, it included the deposition pathway from the atmosphere in a simple manner and the vertical dispersion process was evaluated.

In the MEXT's simulation, the prediction period is short (up to two months) from the view point of the calculation creditability of JCOPE2 code.

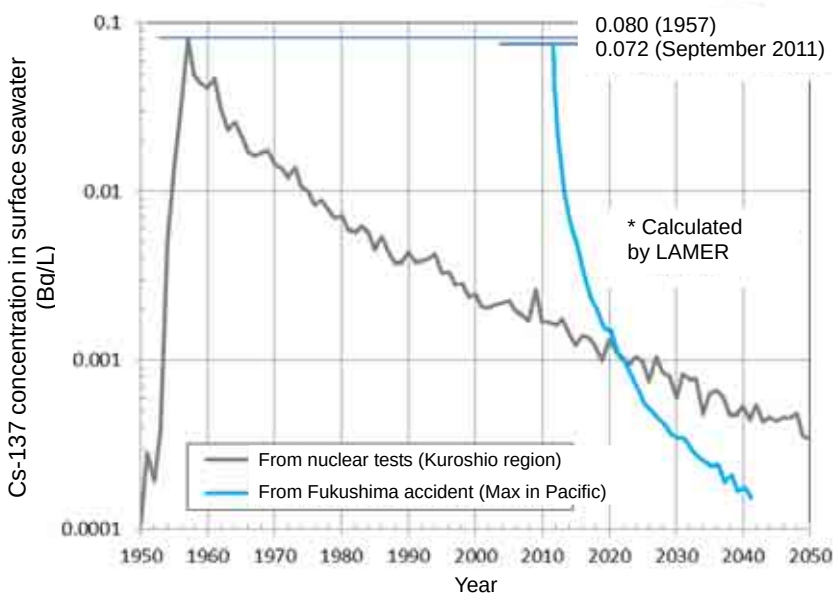
On the other hand, this simulation is carried out with annual basis, therefore it is suitable for the middle- and long-term prediction. It can predict the water behavior containing cesium-137 in the whole Pacific Ocean.

According to this simulation, it would take several years for the water mass containing cesium-137 to arrive at the west coast of US.

5. Remarks

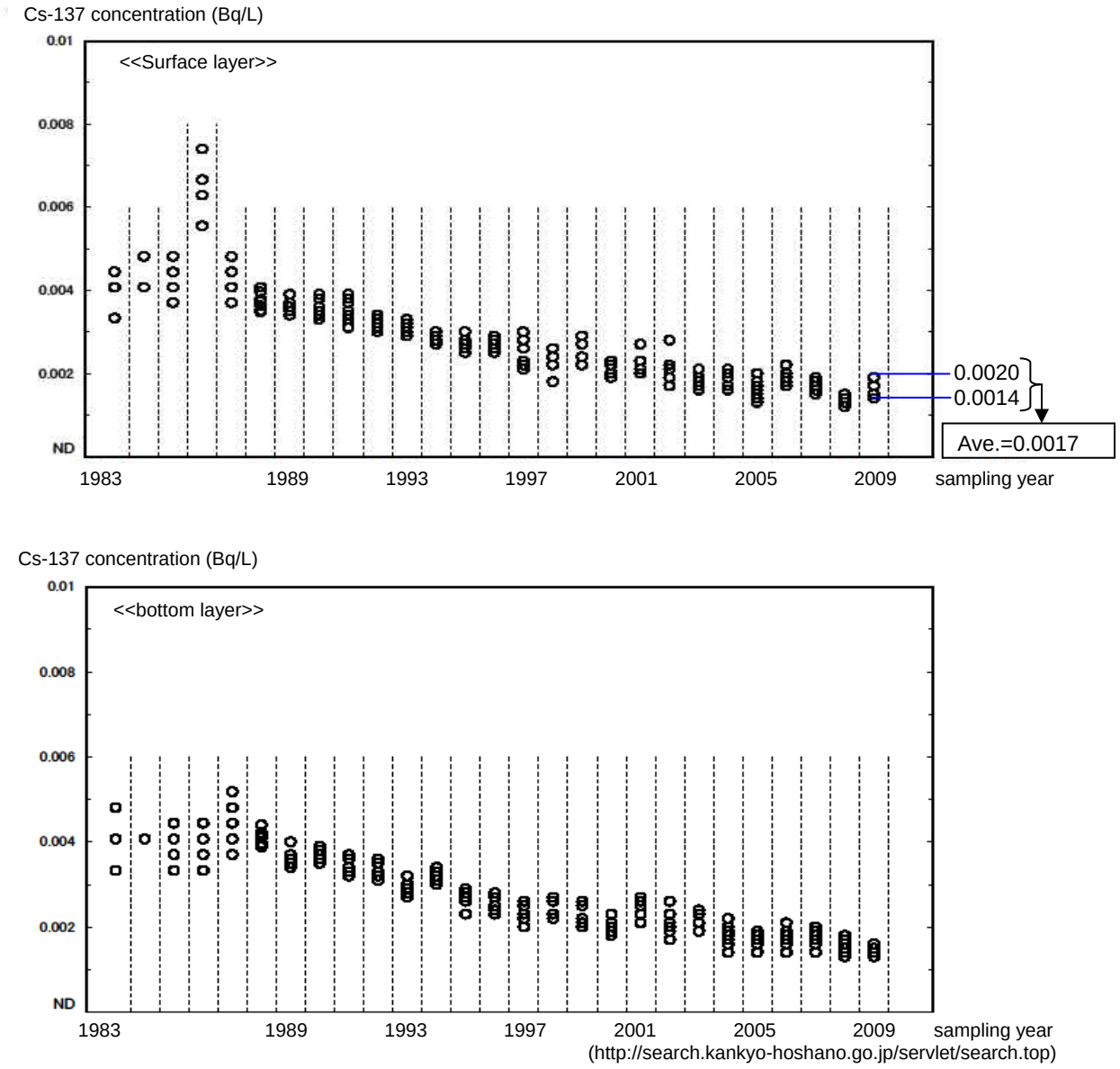
Concerning the validation of used model, evaluation of cesium-137 concentration in the seawater which was released from the past atmospheric nuclear tests was carried out by using LAMER code, and the obtained results were compared with the observations.

Because, for 90% of observed data, the doubled calculation results by LAMER is greater than the actual observed values. It implies that the radiation dose would be less than twice of this estimation in case of taking only the marine products with high concentration of cesium-137.

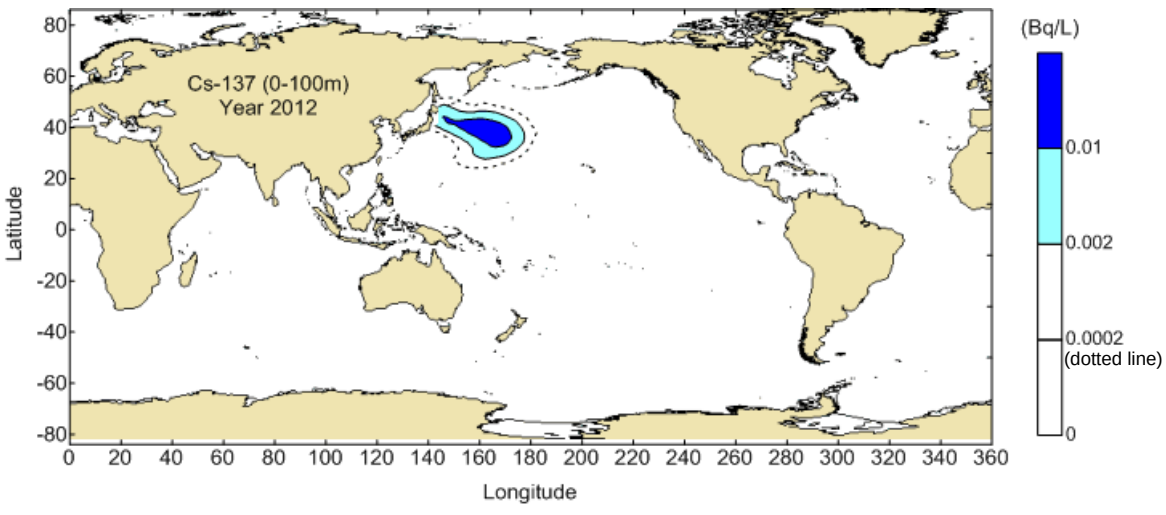


[Figure 1-1] Change of cesium-137 concentration in seawater – chronological prediction –

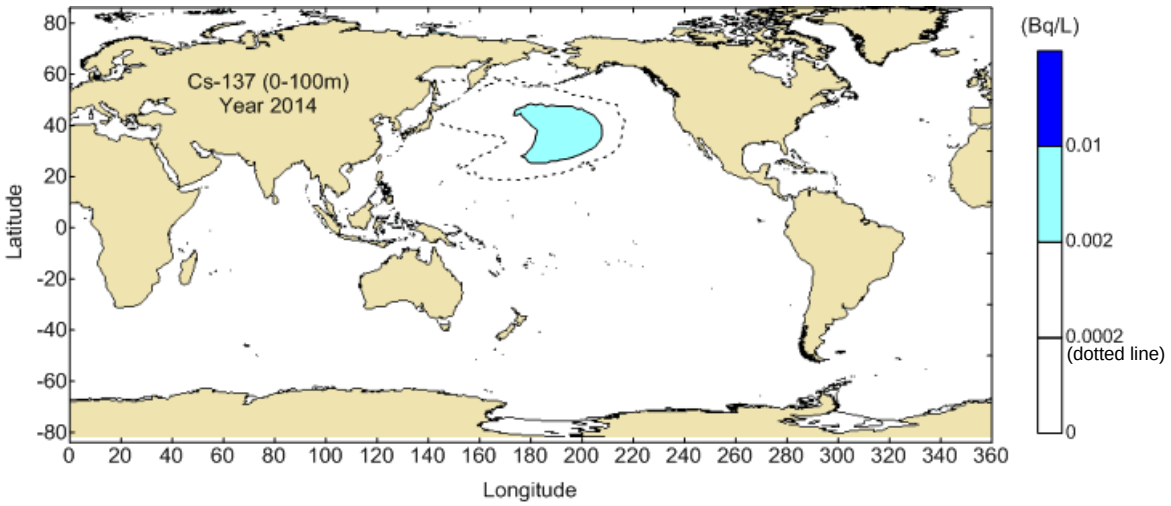
The radioactive material from the nuclear tests has already dispersed in the world, so will not dilute more. But the radioactive material from Fukushima Dai-ichi NPP is diluting rapidly. It is predicted that the maximum concentration in September 2011 would be the same level with that in 1957, and that the maximum concentration in 2023 would be lower than the background level.



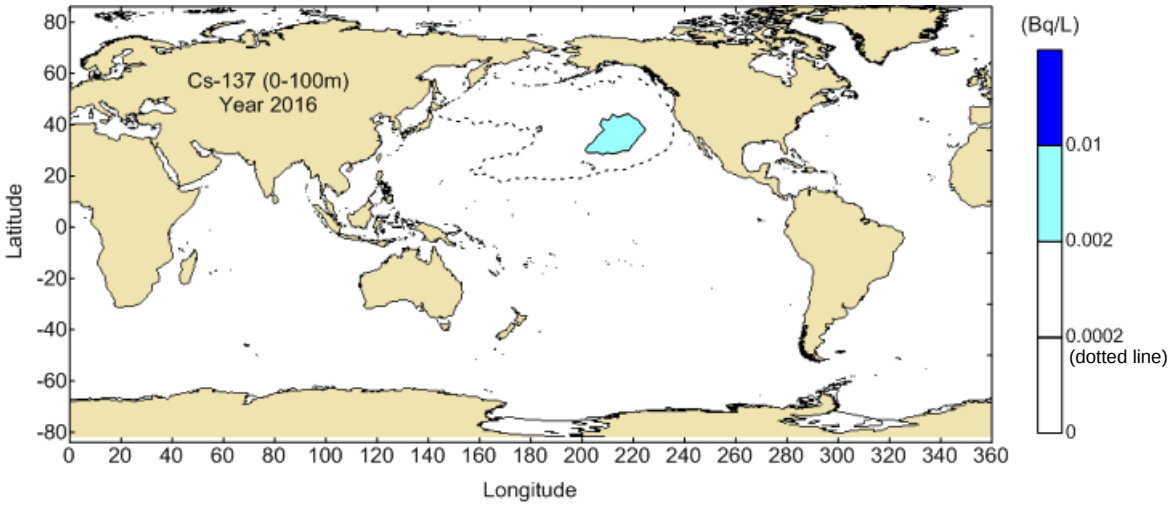
[Figure 1-2] Change of cesium-137 concentration in seawater – observed data, offshore Fukushima –



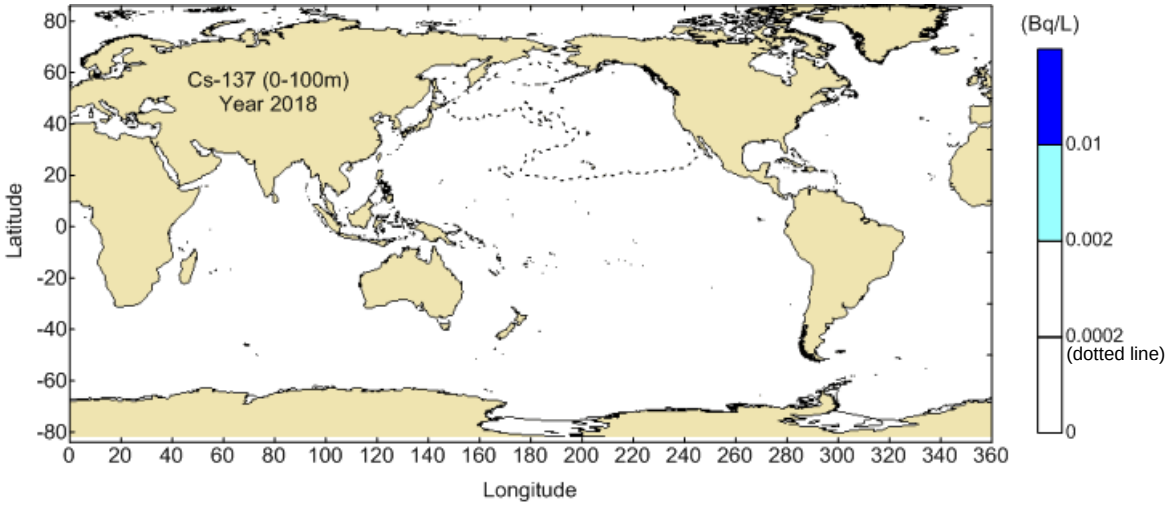
[Figure 2-1] Distribution of cesium-137 concentration in the seawater – 1 year later –



[Figure 2-2] Distribution of cesium-137 concentration in the seawater – 3 years later –



[Figure 2-3] Distribution of cesium-137 concentration in the seawater – 5 years later –



[Figure 2-4] Distribution of cesium-137 concentration in the seawater – 7 years later –

Appendix

Internal exposure (committed effective dose) from marine products (trial calculation)

1. Committed effective dose

The lifetime effective dose expected to result from an intake.

2. Equation of "committed effective dose"

Committed effective dose (mSv/y)

= dose coefficient (mSv/Bq) *×daily intake activity (Bq/d)** ×dilution by market and cooking×365 days

*：dose coefficient (dose by 1Bq of oral intake)

Iodine131: 2.2×10^{-5}(mSv/Bq)

Ceasium134：1.9×10^{-5}(mSv/Bq)

Cesium 137：1.3×10^{-5}(mSv/Bq)

**：daily intake activity (Bq/d)

＝averaged nuclide concentration in food(Bq/kg)***×daily diet of food(kg/d)

***：averaged nuclide concentration in food (Bq/kg)

＝ nuclide concentration in seawater (Bq/kg)×concentration factor****

***：concentration factor (from IAEA Technical Report Series No.422)

・Iodine131：fish9、crustcean3、cephalopod(3)、shellfish10、seaweed10000

・Cesium 134：fish 100、crustacean 50、cephalopod 9、shellfish 60、seaweed 50

・Cesium 137：fish 100、crustacean 50、cephalopod 9、shellfish 60、seaweed 50

3. Calculation example of "committed effective dose"

<< scenario >>

① Daily intake of marine products (from the national health and nutrition examination survey in 2008).

Assumption of daily intake of "fish 64g, crustacean 5.4g, cephalopod 5.5g, shellfish 3.5g, and seaweed 10g" for 1 year.

② Dilution by market and cooking, etc.

No consideration of these dilutions (conservative assumption)

③ Assumption of radioactive concentration in water

Assumption that marine products continued to live in the maximum concentration in April 2012 (conservative assumption).

・Iodine131：4.7×10^{-15} Bq/L

・Cesium 134：0.020Bq/L

・Cesium 137：0.023Bq/L

<<equation>>

dose coefficient × daily intake activity × dilution by market and cooking × 365 days = committed effective dose

Iodine 131 : $2.2\times10^{-5}\times4.7\times10^{-15}\times(64\times9+5.4\times3+5.5\times3+3.5\times10+10\times10000)\ /1000\times365$

$=$ about 3.8×10^{-15} mSv/y

Cesium 134 : $1.9\times10^{-5}\times0.020\times(64\times100+5.4\times50+5.5\times9+3.5\times60+10\times50)\ /1000\times365$

$=$ about 1.0×10^{-3} mSv/y

Cesium 137 : $1.3\times10^{-5}\times0.023\times(64\times100+5.4\times50+5.5\times9+3.5\times60+10\times50)\ /1000\times365$

$=$ about 0.82×10^{-3}mSv/y