Transport and dispersion scenarios of tritium from the radioactive water of the Fukushima Daiichi nuclear plant

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Abstract

Japan recently announced plans to discharge over 1.2 million tons of radioactive water from the Fukushima Daiichi Nuclear Power Plant (FDNPP) into the Pacific Ocean. However, the contaminated water can poses a threat to marine ecosystems and human health depending on their concentrations. To estimate the impact of the plan, here, we developed a three-dimensional global model to track the transport and dispersion of tritium released from the radioactive water of the FDNPP. The pollution scenarios for four release durations (1 month, 1 year, 5 years, and 10 years) were simulated. The simulation results showed that for the short release-duration scenarios (1 month and 1 year), the peak plume with high tritium concentration shifted with the currents and finally reached the northeastern Pacific. For the long release scenarios (5 years and 10 years), the peak plume of the contaminated water was confined to coastal regions east of Japan.

Model description

A three-dimensional global model based on the Princeton Ocean Model (POM) (Blumberg and Mellor, 1987) was developed to simulate tritium activity in global ocean. The model domain covers the quasi-global ocean of 78°S–65°N in latitude and 0–360°E in longitude, with a horizontal resolution of 0.5°×0.5°. The vertical resolution is 21 sigma levels with a fine resolution in the upper ocean and bottom layers. Advection and diffusion are two major processes that determine the transport and dispersion of tritium in the ocean. Self-decay and adsorption by suspended matters are the processes responsible for removing the tritium dissolved in seawater.

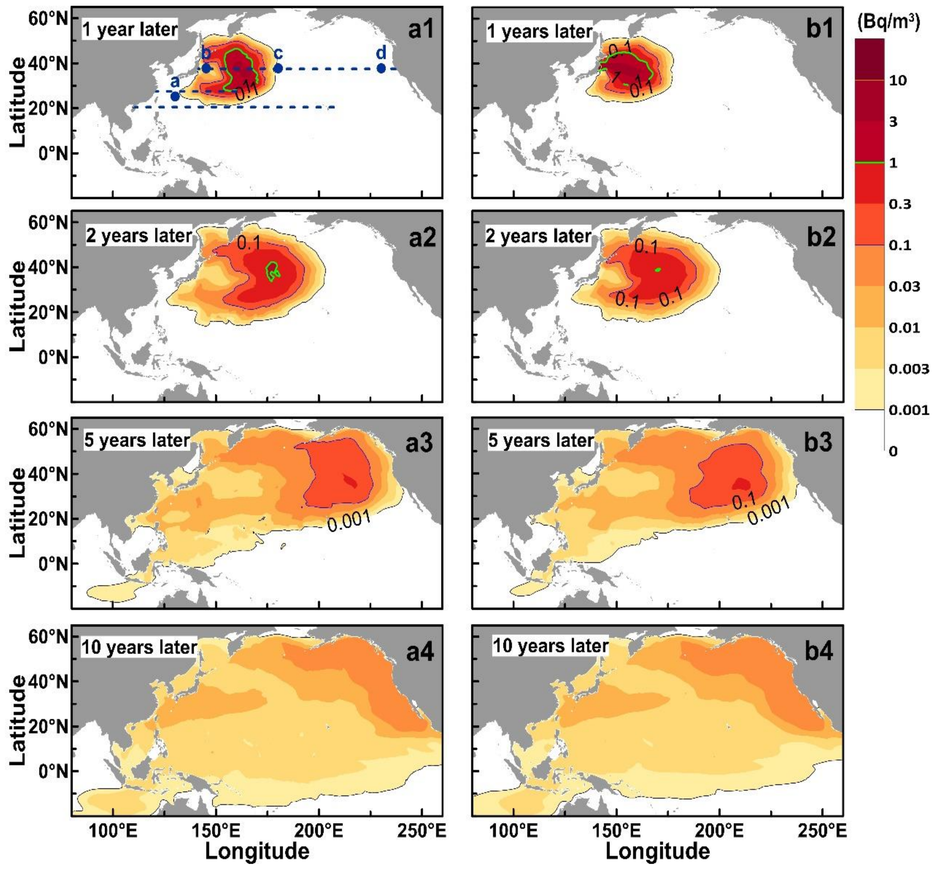
Numerical experiment design

The total amount of tritium contained in the tanks, as reported, is around 1.0 PBq (PBq = 1015 Bq) (TEPCO, 2020; Buesseler, 2020) and will be approximately 1.2 PBq in 2022. The Japanese government plans to dump the radioactive water into the ocean in 2 years. Thus, we set the initial value as 1.2 PBq in our numerical simulations. As the discharge procedure has not been announced yet, we ran the model through four scenarios with different release durations of the radioactive wastewater (Table).

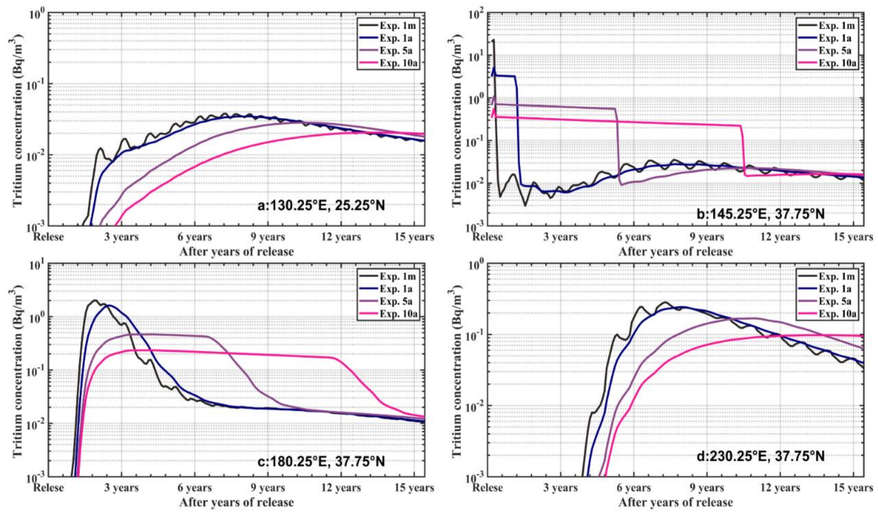
Experiment Name	Release duration of the radioactive water	Total amount of tritium (PBq)
1m	One month	1.20
1a	One year	1.17
5a	Five years	1.04
10a	10 years	0.91

Results and Discussion

The horizontal potential polluted areas and pattern at the sea surface from 1 year to 10 years after tritium emitted from the FDNPP with four emission scenarios are presented in Figs. 1 to 2. The main tritium plume emitted from coastal Japan was transported rapidly along the Kuroshio extension during the first year (Fig. 1, a1 and b1). Subsequently, the contaminated water spread gradually and reached the northeastern Pacific Ocean within 4–5 years with the North Pacific Current (Fig. 1, a3 and b3). Almost the entire North Pacific Ocean was contaminated after 10 years owing to the advection and diffusion processes (Figs. 1, a4 and b4). It should be noted that the shift of the contaminated seawater core was different in the four emission scenarios. For the short release-duration scenarios (1 month and 1 year, Fig. 1), the contaminated water core shifted with the current; it started in coastal Japan, was transported to the middle North Pacific Ocean after 2 years, and finally reached the west coast of America after 4–5 years.



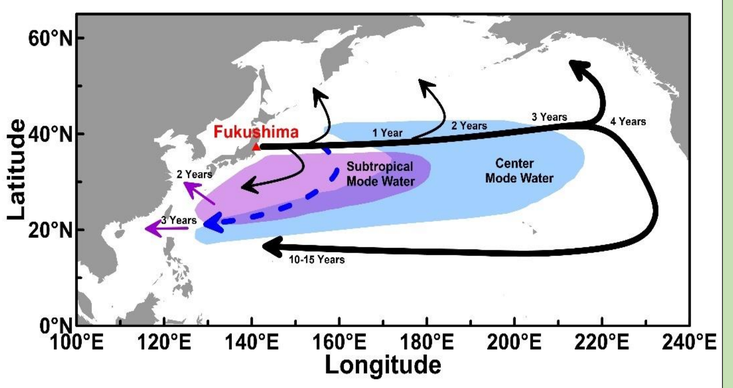
Simulated tritium concentrations in sea surface water by Exp. 1m (a1–a4) and Exp. 1a (b1–b4).



Chronological change in the tritium concentrations in the sea surface water of the North Pacific

Conclusion

A schematic view of spreading channels of tritium with the FDNPP radioactive water in the North Pacific Ocean, the time means the averaged time reaching the located region after discharging from the FDNPP. The thick solid arrows indicate main channels in surface mixed layer. The thin solid arrows show spreading directions in surface mixed layer.



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