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Reconstruction of ^{137}Cs activity in the ocean following the Fukushima Daiichi Nuclear Power Plant Accident

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A series of accidents at the Fukushima Dai-ichi Nuclear Power Plant following the earthquake and tsunami of 11 March 2011 resulted in the release of radioactive materials to the ocean by two major pathways, direct release from the accident site and atmospheric deposition. We reconstructed spatiotemporal variability of ^{137}Cs activity in the ocean by the comparison model simulations and observed data. We employed a regional scale and the North Pacific scale oceanic dispersion models, an atmospheric transport model, a sediment transport model, a dynamic biological compartment model for marine biota and river runoff model to investigate the oceanic contamination. Direct releases of ^{137}Cs were estimated for more than 2 years after the accident by comparing simulated results and observed activities very close to the site. The estimated total amounts of directly released ^{137}Cs was 3.6$\pm$0.7 PBq. Directly release rate of ^{137}Cs decreased exponentially with time by the end of December 2012 and then, was almost constant. The daily release rate of ^{137}Cs was estimated to be 3.0 x 10^{10} Bq day^{-1} by the end of September 2013. The activity of directly released ^{137}Cs was detectable only in the coastal zone after December 2012. Simulated ^{137}Cs activities attributable to direct release were in good agreement with observed activities, a result that implies the estimated direct release rate was reasonable, while simulated ^{137}Cs activities attributable to atmospheric deposition were low compared to measured activities. The rate of atmospheric deposition onto the ocean was underestimated because of a lack of measurements of dose rate and air activity of ^{137}Cs over the ocean when atmospheric deposition rates were being estimated. Observed ^{137}Cs activities attributable to atmospheric deposition in the ocean helped to improve the accuracy of simulated atmospheric deposition rates. Although there is no observed data of ^{137}Cs activity in the ocean from 11 to 21 March 2011, observed data of marine biota should reflect the history of ^{137}Cs activity in this early period. The comparisons between simulated ^{137}Cs activity of marine biota by a dynamic biological compartment and observed data also suggest that simulated ^{137}Cs activity attributable to atmospheric deposition was underestimated in this early period. In addition, river runoff model simulations suggest that the river flux of ^{137}Cs to the ocean was effective to the ^{137}Cs activity in the ocean in this early period. The sediment transport model simulations suggests that the inventory of ^{137}Cs in sediment was less than 10