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Three-dimensional modeling of oceanic dispersal of land-derived multi-class suspended radionuclides after the Fukushima Dai-ichi accident

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Several oceanic dispersal modeling have been conducted on dissolved radionuclides leaked from the Fukushima Dai-ichi Nuclear Power Plant (FNPP) where the direct release of radionuclides from the FNPP and atmospheric deposition are major sources. In the present study, we view freshwater discharge from the rivers as a missing piece for the inventory of the radionuclides in the ocean. The land-derived input introduces a time lag behind the direct release through hydrological process because these radionuclides mostly are attached to suspended particles that are transported quite differently to the dissolved matter. We thus develop a multi-class, non-cohesive sediment transport model based on ROMS along with a wave-enhanced bed boundary layer model of Soulsby (1995) and a stratigraphy submodel proposed by Blaas *et al*. (2007). Suspended ^{137}Cs attached to the sediment is evaluated with an empirical power law proposed by Onda *et al*. (2014) as a function of specific surface area of the suspended particles. A 128 x 256 km domain with the grid resolution of dx = 250 m centered at the FNPP is configured as a test bed nested in the existing double nested ROMS domain with dx = 1 km (Uchiyama *et al*., 2012, 2013). The wave field is computed with an operational wave model SWAN (Booij *et al*., 1999) embedded in the JMA GVP-CWM wave reanalysis. A total of 20 rivers in the domain are configured as point sources of freshwater and sediments by exploiting a surface runoff model HYDREEMS (Toyoda *et al*., 2009) and an empirical discharge to sediment flux relation (Takekawa and Nihei, 2013). Fractions of three sediment classes, *viz*., fine sand, silt and clay, in the riverine discharge are determined empirically based on the outcome of a USLE-based river sediment modeling conducted by JAEA.

The developed model successfully reproduces the dispersal of the land-derived sediments and their recirculation processes associated with resuspension and deposition in the Fukushima coast for 4 months after the accident. The discharged sediments can be transported about 50 km from the shore with prominent patchiness of deposition and erosion near the mouth of each river. For instance, the offshore region of the mouth of the Niida River is evaluated to be erosion dominated, consistent with the measurement. Misumi *et al*. (2014) estimated sedimentary ^{137}Cs in the bed with a model accounting for static adsorption and desorption of ^{137}Cs by using dissolved ^{137}Cs model result of Tsumune *et al*. (2012). The inferred bed ^{137}Cs agrees well with the observation in the shallow area, whereas substantially underestimated in the offshore area at depth deeper than 200 m. They attributed the reason of the underestimate to the ^{137}Cs due to sediment transport that is omitted in their model. We carefully diagnose our model results and find that although the clay-class sediments reach the deeper area, the time-integrated deposition has a minor contribution. It is therefore suggested that detritus and debris of organic matters rather than land-derived minerals likely cause the offshore ^{137}Cs deposition.