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福島から海洋へ漏洩した放射性核種の初期分散メカニズム
Initial oceanic dispersion mechanism of radionuclides released from Fukushima

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The 2011 earthquake off the Pacific coast of Tohoku, Japan, and the subsequent tsunami caused a severe nuclear accident at the Fukushima Daiichi Nuclear Power Plant (FNPP), leading to radionuclides leaking into the coastal ocean. A retrospective, double-nested high-resolution numerical model at 1 km horizontal resolution based on the JCOPE2-ROMS downscaling framework (Uchiyama *et al*., 2012) is utilized to evaluate oceanic/coastal dispersion of the released cesium-137 (^{137}Cs) from FNPP. A rational leakage submodel proposed by Tsumune *et al*. (2011) based on the iodine-cesium ration is employed for the realistic cesium-137 release. Among several oceanic radionuclide dispersal models including the present one, there still is a discrepancy in the prevailing direction of initial dispersion (for the first several weeks) of the leaked materials, which remains an open question.

The present model successfully reproduces the overall oceanic structure as well as the dispersal of cesium-137, according to an extensive model-data comparison exploiting the satellite altimetry, the *in situ* cesium-137 concentration monitored by TEPCO and MEXT, and the aerial snapshot taken by NSSA. Alongshore distribution of the concentrations is found to be highly inhomogeneous with diluted patterns distributed widely in the south of FNPP, while medium concentration appears in the north. The initial dispersion predominantly occurs in the northward direction for the first 30 days, followed by the southward cesium-137 transport down to the Kuroshio extension to be drifted far to the North Pacific. The model also demonstrates that an isolated, anti-cyclonic mesoscale eddy persists off Kashima Coast (south of Fukushima) shed around Cape Inubo where the Kuroshio separation takes place. This standing anti-cyclone enhances the poleward coastal jet about less than 50 km from the shore, especially 3-4 weeks after the accident. A cross-spectral analysis exhibits a prominent correlation between northward wind and along-shelf oceanic currents in a fairly broard period band of 72 - 240 hours peaked at 168 hours. The highest coherence ($coh^2 > 0.92$) is most evident in the nearshore area within about 10 km from the shore, while it exponentially decreases offshore. This result strongly suggests the presence of wind-driven shelf waves as a potential agent of the alongshore cesium transport as argued by Miyazawa *et al*. (2012). In contrast, a positive buoyancy input through four major rivers discharging into Sendai Bay (about 80 km north of FNPP) is found to be substantial to the southward cesium transport. This buoyancy input is attributed to a prevailing equatorward flow contracted in a quite narrow coastal strip within about 10 km from the shore.

In summary, the initial dilution and dispersal of the leaked radionuclide from FNPP are primarily constrained in the nearshore area around Fukushima Coast with reduction of the equatorward transport. The narrow coastal strip of the predominant alongshelf transport is characterized by the "three-layered system" in the cross-shelf direction consisting of (1) the innermost southward transport by the positive buoyancy (about 0-10 km off the shore), (2) the prevailing poleward coastal jet associated with a standing anti-cyclonic mesoscale eddy formed off Kashima Coast that most likely influenced by wind-driven shelf waves, and (3) the overall equatorward transport in the offshore farther than about 50 km.

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