**Modeling the Fate of Cs-137 in the Ocean: Toward Detection of Climate Variability**

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Cesium-137 (¹³⁷Cs) is a long-lived, soluble anthropogenic radionuclide introduced into the world’s oceans since 1945. A significant pulse of ¹³⁷Cs was supplied by atmospheric nuclear weapons testing in the early 1960s, followed by a steady decline. Additional localized increases in ¹³⁷Cs concentrations resulted from reprocessing plant discharges starting in the 1970s and from the Fukushima Daiichi Nuclear Power Plant accident in 2011. By 2025, except in limited areas such as parts of the Arctic Ocean and coastal regions near Fukushima, the impacts of these inputs have largely diminished. Due to its conservative behavior in seawater and long half-life, ¹³⁷Cs serves as an effective tracer for studying ocean circulation processes. In this study, we simulated the spatial and vertical distribution of ¹³⁷Cs from 1945 to 2030 using a global ocean general circulation model (OGCM) driven by Ocean Model Intercomparison Project (OMIP) Normal Year Forcing (NYF), and compared it to results using OMIP Global Interannual Atmospheric Forcing (GIAF) from 1958 to 2007. Model outputs were validated against an extensive observational database containing more than 19,000 ¹³⁷Cs measurements. Simulated distributions showed good agreement with observations, particularly at basin scales in the North Pacific and North Atlantic. In the North Pacific, subduction was identified as the dominant mechanism transporting ¹³⁷Cs into the intermediate layers, whereas deep convection controlled its distribution in the North Atlantic deep ocean. The model developed in this study enables derivation of key diagnostic metrics that characterize tracer transport properties, such as the apparent half-life (Tap) and the first-moment depth of cesium-137 (¹³⁷Cs). These metrics are highly sensitive to the strength of ocean circulation and vertical mixing, suggesting comparisons with observational datasets could facilitate detection of changes associated with climate variability. Through the application of these tracer diagnostics, it may be possible to detect phenomena such as the Pacific Decadal Oscillation (PDO) in the North Pacific, variability of the Atlantic Meridional Overturning Circulation (AMOC) in the North Atlantic, and the formation of Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) in the Southern Ocean. In the comparison between the Global Interannual Atmospheric Forcing (GIAF) and Normal Year Forcing (NYF) cases, the tracer diagnostics did not clearly detect the PDO signal, possibly due to relatively weak tracer response to decadal-scale variability or limitations in model resolution and temporal sampling. However, in the North Atlantic and Southern Ocean, the first-moment depths were found to be deeper in the GIAF case than in the NYF case, suggesting enhanced subduction under interannual variability. Although no vertical profiles of ¹³⁷Cs have been observed in these key regions since the 1970s, future observations could reveal changes in tracer-based indicators critical for understanding climate variability. Therefore, integration of long-term ¹³⁷Cs observational data with climate-sensitive modeling frameworks will be essential for improving detection and attribution of ocean circulation changes under global warming scenarios. In addition, from the perspective of preparing for future uncertainties, maintaining long-term ¹³⁷Cs monitoring is crucial to establish a baseline for detecting potential future releases associated with severe nuclear accidents.