Dissolved Inorganic Radiocarbon Reveals Biogeochemical Non-Uniformity Within North Pacific Subtropical Mode Water

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The formation of North Pacific Subtropical Mode Water (STMW) is one of the most important sinks for atmospheric CO_2 in the Northern Hemisphere. Despite the oligotrophic conditions of the subtropical North Pacific (NP) Ocean, primary production rates are nearly identical to the nutrient-rich subarctic gyre. Previous studies suggest that STMW supplies nutrients from the subsurface to the euphotic zone via vertical diffusion during spring, thereby enhancing CO_2 uptake through primary production. However, it remains unclear whether this process occurs within STMW. The radiocarbon (delta^{14}C) in dissolved inorganic carbon (DIC) of seawater has been widely used as a tracer of vertical mixing. By using DIC delta ^{14}C to constrain water mass movement and ventilation age, the timescales of carbon cycling in this region can be assessed.

We report the DIC delta^{14}C in twenty seawater samples collected from two stations located in the western NP in May 2025. We combine our results with BGC-Argo profiles to observe mixing dynamics within STMW and elucidate its structure.

DIC delta^{14}C values ranged from −49.7 to 20.5‰ between 10 and 700 m depths and varied within the STMW layer (15.5 ±3.5‰) despite uniform physical properties. The STMW core, defined by a minimum potential vorticity (PV) of < 1 (10^{-10} s^{-1} m^{-1}), was located between 230 and 360 m. Positive DIC delta^{14}C anomalies of 20.1 ±2.4‰ and 20.5 ±3.1‰ were observed in the lower STMW layer (~400 m) at stations C1-2 and C3-1 respectively. Similarly, BGC-Argo profiles of nitrate, pH, and dissolved oxygen diverged below 360 m at station C1-2. This suggests that while STMW appears physically homogeneous (e.g., uniform temperature and salinity), it may vary biogeochemically.

The DIC delta^{14}C values combined with BGC-Argo observations show seasonal layering of STMW. An older STMW layer appears below the younger core, suggesting that the lower layer is from the preceding winter. This is consistent with the previously reported decline of DIC delta^{14}C values in western NP surface waters. The non-uniform distribution of DIC delta^{14}C may also be attributed to vertical mixing, suggesting that STMW may supply nutrients from the subsurface to the euphotic zone during spring. This study shows that DIC delta^{14}C is a sensitive tracer that can be used to detect seasonal layering and heterogeneity within STMW.

Keywords: Radiocarbon, North Pacific Subtropical Mode Water, Dissolved Inorganic Carbon, Carbon Cycle

