Characteristics of Radiocarbon from Nuclear Tests in East Asia Detected in Tree-Ring Cellulose

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Since the atmospheric nuclear weapons tests, the radiocarbon (^{14}C) calibration curve has been developed based on radiocarbon isotope ratios ($\Delta^{14}C$) in the atmosphere and tree-ring cellulose obtained worldwide, and it has been widely used as an environmental tracer because it is characterized by a steep spike called the Bomb peak. Regional $\Delta^{14}C$ calibration curves used as indices are provided based on the latitudinal gradient of $\Delta^{14}C$ seen in observational data, and further subdivision has been made taking into account atmospheric circulation elements such as the Intertropical Convergence Zone and the meandering of jets. However, in the East Asia region, validation of the boundary positions is still insufficient due to the lack of atmospheric $\Delta^{14}C$ data capturing the Bomb peak. In particular, although the polar front jet over East Asia, which intensifies from winter to spring, strongly affects the exchange rate between the stratosphere and the troposphere that is the main inflow source of nuclear-test-derived $\Delta^{14}C$, its influence has not been assessed.

Therefore, in this study, we obtained tree-ring cellulose $\Delta^{14}C$ from Hinoki cypress (Chamaecyparis obtusa) in Kyushu (Kumamoto) and Sawara cypress (Chamaecyparis pisifera) in central Chubu (Kiso), both belonging to NH2. Tree-ring cellulose $\Delta^{14}C$ does not necessarily directly reflect atmospheric $\Delta^{14}C$ of the same calendar year, because it is influenced not only by the timing of assimilation of current-year carbon but also by factors such as the mobilization of non-structural carbohydrates (NSC) fixed in previous years. Accordingly, we evaluated the climate response by conducting correlation analyses between interannual variations in the stable carbon isotope ratio ($\delta^{13}C$) and interannual variations in monthly sunshine duration, and thereby examined the timing of carbon assimilation. In addition, to quantitatively account for these mixing and seasonal effects, we developed a model that describes the assimilation (incorporation) of atmospheric $\Delta^{14}C$ into tree-ring cellulose. Using this framework, we compared atmospheric $\Delta^{14}C$ in East Asia with NH2 atmospheric $\Delta^{14}C$ by separating the effects attributable to mixing and seasonality from the measured tree-ring cellulose $\Delta^{14}C$.

In the assessment of the climate response of $\delta^{13}C$, significant positive correlations were confirmed with the 3-month mean sunshine duration for April–June for Kiso Sawara cypress and for March–May for Kumamoto Hinoki cypress; these were consistent with the photosynthetic and growth periods estimated from the model results. This suggests that carbon taken up by photosynthesis in spring of the current year is primarily used for cellulose formation. On the other hand, both the optimized NH2 atmospheric $\Delta^{14}C$ assimilation model results and the measured values for Kumamoto Hinoki cypress and Kiso Sawara cypress showed values more than 100‰ lower than the NH2 summer mean in 1963, corresponding to the onset of the Bomb peak, suggesting an influence of storage carbon that incorporated the low-$\Delta^{14}C$ atmosphere of the previous year.

Furthermore, East Asian $\Delta^{14}C$ corrected for assimilation effects by the model exhibited a bimodal peak centered on 1959 and 1963 relative to NH2 atmospheric $\Delta^{14}C$. In both cases, these peaks respond with a one-year lag relative to the peak of atmospheric nuclear tests in the Northern Hemisphere, and it is possible that nuclear-test-derived ^{14}C from the previous year is being observed with high sensitivity due to troposphere–stratosphere exchange associated with the polar front jet over East Asia that intensifies in spring. The findings obtained in this study are expected to be useful when updating the regional

boundaries of the ^{14}C calibration curve in the East Asia region since the 1950s.

Keywords: Cellulose, Radiocarbon, Atmospheric Nuclear Test, Model

