Hydroclimate variability over the last two and a half centuries inferred from oxygen isotope records of tree rings in southwestern Japan
(樹木年輪の酸素同位体記録が示す過去 2 世紀半の西南日本における水循環変動)

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Abstract

Using pine and oak trees as representatives of the gymnosperms and angiosperms, respectively, this thesis examines the similarities and differences in the relationship between the variability of oxygen isotope ratios ($\delta^{18}O$) preserved in their tree-ring cellulose and various climate parameters in the two species. Tree-ring $\delta^{18}O$ in pine (*Pinus densiflora*) and oak (*Quercus serrate* and *Quercus variabilis*) growing in Nagoya from 1970 to 2011 share a common interannual variation among different cores in a tree, different trees in a species, and different species in a forest. The high correlation between the two radii of individual trees and the low standard deviation of two measurements for the same year from the two radii reveal the reliability and representativeness of a single core measurement. The statistically significant correlation between the pine and oak $\delta^{18}O$ time series provides us with a unique dendrochronological crossdating tool that extends beyond a single tree species and indicates that $\delta^{18}O$ levels preserved in tree-ring cellulose are controlled by common external factors.

The $\delta^{18}O$ series analyzed here were negatively correlated with relative humidity from April to September for pine, and in June and July for oak, suggesting different lengths of growing season for these species. The $\delta^{18}O$ series in both the pine and oak were negatively correlated with precipitation from June to August, which can be attributed to the precipitation amount effect that is driven mainly by a stagnant rain front (the Baiu) in early summer, and typhoons in late summer in this region. These relationships mean that tree-ring cellulose $\delta^{18}O$ series can be used as a proxy for the historical hydroclimate related to the East Asian summer monsoon (EASM). Although multiple regression analysis revealed that tree-ring $\delta^{18}O$ values of pine and oak in this region are governed mainly by summer precipitation, relative humidity does not appear to greatly affect the tree-ring $\delta^{18}O$ of oak, in contrast to pine, which may be interpreted in terms of differences in leaf morphology and/or cellulose synthesis processes between the two species.

In order to reconstruct past changes in hydroclimate using tree-ring $\delta^{18}O$, we measured several tree ring samples growing from 1765 to 1998 at Kamegamori Mountain in Shikoku, southwestern Japan. The tree-ring $\delta^{18}O$ chronology covering most of the last two and half centuries was derived from the 6 living Nikko fir (*Abies homolepis*) trees samples. The influence of various climate parameters was examined by correlation analysis using a climate dataset comprising monthly local observations of average temperature, precipitation, and relative humidity. The tree-ring cellulose $\delta^{18}O$ record is negatively correlated with summer precipitation from the current year over the period 1951–1998, and also (though less so) with relative humidity. Spatial correlation analysis indicated that moisture supplied into the study area originates from the Pacific Ocean. The tree-ring $\delta^{18}O$ chronology is consistent with local climate-related disasters recorded in many historical documents in this region. The low tree-ring cellulose $\delta^{18}O$ values correspond to those years that experienced a prolonged duration of the Baiu front, an early summer stationary front that develops over East Asia, indicating that the isotope ratios are controlled mainly by the location of the Baiu front and moisture supply into the front. Historical variations in tree-ring $\delta^{18}O$, representative of the location of the Baiu front and its activity over southwestern Japan, are closely correlated with the El Niño–Southern Oscillation (ENSO). However, the correlation coefficient is variable and has reversed with a periodicity of 30–40 years over the 234-year study period. Climatological analysis of two recent periods with positive (1976–1991) and negative (1960–1975) correlations indicates that teleconnections between the tropical and extratropical western Pacific regions through the atmosphere and ocean may control summer precipitation in southwestern Japan.