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Summer monsoon destabilization at 400 years intervals recorded by tree-ring oxygen isotope ratios in central Japan

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[Introduction] So far, there have been few tree-ring based attempts in Japan to reconstruct past summer climate, because of its weak sensitivity. However, oxygen isotope ratios of tree-ring cellulose have been recently proven to reflect summer precipitation even in warm and humid region such as Japan, and promoted long-term high-resolution climate reconstructions all over Asia. Here, we have reconstructed past inter-annual variations in summer precipitation during last 2 millennia using the tree-ring oxygen isotope ratios of many Japanese cypress trees in central Japan and discovered many epoch-making facts on archaeology, history and climatology.

[Material and Method] We have analyzed many tree-ring samples of Japanese cypress (Chamaecyparis obtusa) from living trees, old architectural woods, archaeological remains and buried woods in central Japan covering more than last 2 millennia. After slicing of those woods into 1mm thickness of plate perpendicular to cellulose fibers, we have removed lignin, hemicellulose and resins by sequential chemical treatments and obtained plates consisting only of pure cellulose fibers. We have cut the cellulose ring one by one and measured the oxygen isotope ratio using TCEA-Delta V (Delta plus XL). Although some of tree-ring samples had not been dated by traditional dendrochronological method, we could determine ages of the samples with almost 100% accuracy by overlapping of the measured oxygen isotope time series with those of the predated samples. To combine the many time-series which show different mean oxygen isotope ratios between samples reflecting original growth altitude or physiological condition, we have shifted each time series up and down to make the averaged values equal in the overlapped period between the two different samples and finally completed continuous time-series of tree-ring oxygen isotope ratios during more than last 2 millennia.

[Result and Discussion] The time-series of tree-ring oxygen isotope ratios are correlated well with changes in summer precipitation estimated by various instrumental, historical and archaeological methods irrespective of the age. The similar pattern with variations in oxygen isotope ratios of Chinese and Indian stalagmites suggests that it is mainly controlled by changes in Asian summer monsoon. Moreover, the 2 millennia length of tree-ring oxygen isotope chronology provides us of many progresses in the studies of archaeology, history and climatology. In archaeology, this chronology makes us enable to date any wooden materials in Japan with annual time resolution since 2000 years ago because of its universal use independent from tree species in contrast to the case of tree-ring width. In history, we can propose a new hypothesis that many historical disturbances in Japan, such as civil wars and regime shifts, were caused by abrupt activation and destabilization of East Asia summer monsoon. In climatology, we can find two types of summer climate variability by comparison of the historical change in tree-ring oxygen isotope ratio with that of newly reconstructed East Asia summer temperature based on Asian wide tree-ring width database (Cook et al., 2012). One is the monsoon-type of variation where temperature and precipitation vary with positive correlations. The other is the variation with negative correlations between temperature and precipitation, found in the cases of volcanic eruptions and recent global warming. Especially, the monsoon-type variability shows predominant amplifications of multi-decadal components at exactly 400 years intervals, suggesting the existence of some astronomical pacemaker. Because of the fact that the destabilizations of summer monsoon activity often preceded the major historical disturbances in Japan and Asian countries and the next destabilization is predicted to occur in early 22nd century, it is very important to elucidate the mechanism underlying the 400 years periodicity.

Keywords: tree ring, cellulose, oxygen isotope ratio, East Asia, Japan, summer monsoon