

Reconstruction of summer precipitation during last two millennia in central Japan by tree-ring oxygen isotope ratios

NAKATSUKA, Takeshi^{1*} ; SANO, Masaki¹ ; XU, Chenxi¹ ; OHISHI, Kyohei² ; SAKAMOTO, Minoru³ ; NAKAO, Nanae⁴ ; YOKOYAMA, Misao⁵ ; HIGAMI, Noboru⁶ ; MITSUTANI, Takumi⁷

¹Research Institute for Humanity and Nature, ²Grad. Sch. Env. Studies, Nagoya Univ., ³National Museum of Japanese History, ⁴Musashi University, ⁵Grad. Sch. Agriculture, Kyoto Univ., ⁶Aichi Pref. Center for Archaeol. Operations, ⁷Nara Nat. Res. Inst. Cultural Properties

Introduction

To establish long-term plans of flood control by river management and/or water supply by dam construction, it is necessary to predict future change in precipitation due to global warming. Because precipitation can change at various time scales, it is important to understand the statistical probability of giant flood occurring once a century or millennium. However, due to the shortage of hydrological and meteorological records, it has been difficult to understand statistical characteristics of precipitation in very long time scales. Recently, we have found that tree-ring cellulose oxygen isotope ratios (d18O) record summer precipitation in the corresponding years very precisely and started reconstructions of long term summer precipitation changes in annual time resolution all over Asia monsoon area. Here, we present the two millennial data of summer precipitation in central Japan based on the tree-ring d18O of Hinoki cypress samples obtained from various periods and discuss its meanings in historical hydrology.

Fundamental of precipitation reconstruction

Because cellulose is produced from carbohydrate originally photosynthesized in leaf, its d18O records changes in leaf water d18O. Leaf water d18O is controlled by two meteorological factors, precipitation d18O and relative humidity. It is positively correlated with precipitation d18O and negatively correlated with relative humidity due to the transpiration process. Because there are negative correlation between rain amount and precipitation d18O (amount effect) and positive correlation between rain amount and relative humidity, we can finally realize that there is distinct negative correlation between rain amount in growing season and tree-ring cellulose d18O.

Tree ring samples for long d18O time series

Because trees can seldom live more than several hundred years, we must collect many tree-ring samples during various periods to establish reliable time series of tree-ring d18O beyond last two millennia, not only from living trees, but also from old architectures, archaeological remains, tree logs buried by landslides and so on. Tree-ring samples of Japanese cypress were collected from a certain wide area in central Japan, where we can find consistent tree-ring d18O variations among different trees at different sites and combine many d18O time series, according to the consistent d18O patterns, to establish statistically reliable two millennia length of tree-ring d18O time series.

Application to historical hydrology

The time series of tree-ring d18O was first compared with various meteorological, historical and archaeological evidences on summer precipitation in Japanese history, including modern instrumental meteorological records, summer rainfall amounts quantitatively reconstructed from early modern diary weather notes, medieval documentary records on notorious flood and drought, and pit-house number in lowland plains of ancient Japan, and it was demonstrated that the tree-ring d18O coincides those records very well and successfully reconstruct past change in summer precipitation irrespective of reconstructed periods. However, the tree-ring d18O of Japanese cypress has a distinct age effect where it decreases gradually during its all life time, so that we cannot extract real precipitation trends more than 200 years periodicity from the cypress data. By comparing the tree-ring d18O time series with historical flood records in various rivers in central Japan, we found that there are very good coincidences in decadal time scale before 11th century, but the relation becomes diverse in 18th century, so that good coincidence disappeared in highly developed area where artificial flood control and/or excess logging might have influenced river hydrology. The summer precipitation records based on tree-ring d18O are useful to elucidate both of natural variability and human responses on the historical precipitation changes.

Keywords: two millennia, precipitation, central Japan, tree ring d18O