Reconstruction of winter air temperature using O & H isotopic ratios of larch tree-ring cellulose in Kamchatka, Russia

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http://environ.lowtem.hokudai.ac.jp/nakatsuka/nakatsuka_top-e.htm

[Introduction] Tree ring is one of the most reliable proxies of past climate. However, it is usually difficult to reconstruct long-term climate variations from tree-ring width in densely populated forests due to inter-individual competition effects against tree growth. Recently, an analytical system consisting of pyrolysis-type of elemental analyzer and isotope ratio mass spectrometer was developed to make the analyses of O & H isotopic ratio of organic matter very rapid and precise. Both of O & H isotopic ratios of tree-ring cellulose can reflect two climatic factors, Isotopic Ratios of Precipitation and Relative Humidity, and are not affected by ecological factors in contrast to tree-ring width or C isotopic ratio. However, there remains a serious problem how to reconstruct two climatic factors separately. In this study, we focus on the slightly different hydrological and physiological behaviors between O & H isotope ratios and try to develop new indicators of past climate change.

[Materials and Methods] Tree ring samples were collected in 1998 and 2000 from larch forests of about 200 years old in Kozyrevsk, central lowland of Kamchatka. In order to check whether individual ecological characteristics affect tree-ring O & H isotopic ratios or not, we selected three samples which experienced completely different growth histories. Each year ring was cut out by razor blade and sliced using microtome into 20 um thick of thin sections, from which cellulose was extracted by sequential chemical treatments. Part of cellulose was analyzed for O isotopic ratio by ThermoElectron TCEA-Delta plus XL, and the rest was converted to nitrocellulose to exclude exchangeable H in hydroxyl groups before H isotopic measurement. O & H isotopic ratios were presented in delta notations against IAEA-VSMOW, and the reproducibility of O & H isotopic ratios are about 0.2 and 1.5 permil in 1 sigma, respectively.

[Results and Discussion] (1) There is a very good coincidence between variations in O isotopic ratio of 3 tree individuals irrespective of their large differences in growth histories (See in Figure), indicating that the tree-ring O isotopic ratio is not affected by ecophysiological condition of individual tree but regulated by common climatic factors. However, the O isotopic ratios do not show very high correlations with local climate conditions such as averaged monthly temperature or precipitation. In the middle latitude, tree-ring O isotopic ratio often has very high negative correlation with summer precipitation solely, because the O isotopic ratio of precipitation is also regulated by precipitation amount. In contrast, this apparent disagreement in Kamchatka suggests that tree-ring O isotopic ratios equally reflect inter-independent 2 climatic factors, the summer relative humidity and the O isotopic ratio of precipitation, which usually depends on air-temperature in high latitudinal areas. (2) Degree of the inter-individual correlation of H isotopic ratios was less than that of O isotopic ratio. It is because the post-photosynthetic isotopic fractionation makes the H isotopic ratio very high and the degree of this isotopic fractionation differs among trees. O & H isotopic ratios show similar variations in the case of a tree with less post-photosynthetic isotopic effect, except for early period of the tree life (Juvenile effect). (3) The combinational value of O & H isotopic ratios, d-value = dD - 8 x d18O, is usually utilized in hydrological studies, but it can be applied for tree-ring isotope studies too, resulting in a very good negative correlation (r~-0.6) with winter (Feb-Mar) air temperature in Kozyrevsk. The colder the winter air temperature is, the higher d-value of water vapor is evolved from sea surface by kinetic isotope fractionation effect. The reconstructed winter air temperature shows stepwise increases from later half of 19th century, suggesting the potentials to apply tree-ring isotopic ratios for winter climate study.