L132-007 Room: 101A Time: May 24 10:45-11:00

Summer relative humidity in northern Japan, inferred from oxygen isotope ratios of the tree ring cellulose in oak (1776-2002)

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For the forecast of future climatic impacts of global warming on Asian monsoon area including Japan, it is helpful to understand past changes in water cycles for last few centuries in this region. We focused on oxygen isotope ratios of tree ring cellulose. The tree ring d18O are negatively and positively correlated with relative humidity (RH) and rainfall d18O, respectively. Because the latter is negatively correlated with rainfall in the monsoon area, the tree-ring d18O can be a reliable proxy for past RH and/or rainfall there. Tsuji et al. (2006) indeed indicated that d18O of oak tree rings in northwestern Hokkaido correlate well with summer RH. In this study, we try to reconstruct change in summer hydro-climate for last 227 years using oak tree-ring d18O in northwestern Hokkaido and discuss its relationship with changes in atmospheric circulation.

Tree-ring disks of oak were collected from stumps in a newly lumbered natural conifer-hardwood mixed forest in June 2003 in Teshio Experimental Forest of Hokkaido University in northwestern Hokkaido, Japan (45_03'N 142_06'E, asl 66m,Fig 1(filled circle)). Two oaks of age about 270 and 230 years were used for analysis. Cellulose of annual rings was extracted by chemical treatments and its d18O was determined by a pyrolysis-type elemental analyzer and an isotope ratio mass spectrometer. We extrapolated the correlation established between the mean d18O of two oaks and the mean summer RH in Sapporo and Asahikawa (1889-2002) to the whole period (1776-2002) of the tree rings to reconstruct summer RH.

The reconstructed summer RH shows larger variability in the first half of 19th century and smaller variability since its second half(Fig 2). The periods of high RH are 1797-1812 and 1857-1894. Those of low RH are 1831-1836 and 1900s. The spectral analysis indicates that the reconstructed summer RH mainly composes of low frequency components. We explored the relationships between low frequency components (11-250-year cycles) of summer RH and indices of atmospheric circulation (annual Pacific Decadal Oscillation (PDO) and summer Arctic Oscillation (AO)), which are reconstructed by D'Arrigo et al., (2001) and D'Arrigo et al., (2003), respectively. The low frequency component of the summer RH is negatively correlated with that of annual PDO index during the all period (1781-1997). This is probably because the wet southerly wind from the western Pacific Ocean strongly blows toward northern Japan with the intensified Pacific high when the PDO index is lower and vice verse. Further, the low frequency component of summer RH is positively correlated with that of the summer AO index during the earlier period (1781-1930) but is negatively correlated with that of the summer AO during the later period (1940-1997). 1930s was the time, when the AO index changed from negative to positive on average. This shift can be explained by the difference in atmospheric circulation between the negative (1899-1930) and the positive AO period (1970-1997). During the positive period, the Pacific high becomes stronger in the year of higher AO index and a stronger southerly humid wind blows toward northern Japan and vice verse. During the negative period, humid wind from the south to northern Japan strengthens in the year of lower AO index due to the development of a stronger low pressure in northeast China and vice verse. The shift of relationship between regional atmospheric circulation and AO in 1930s causes the change in correlation between hydro-climate in northern Japan and summer AO. The summer RH in northwestern Hokkaido was correlated mainly with the summer AO during the earlier period (1781-1930) and the annual PDO during the later period (1940-1997), respectively. With global warming, the mid-latitude forcing might become stronger than the high-latitude forcing on the hydro-climate in northern Japan. Our results show that the global warming has actually influenced the regional water cycles in northern Japan.

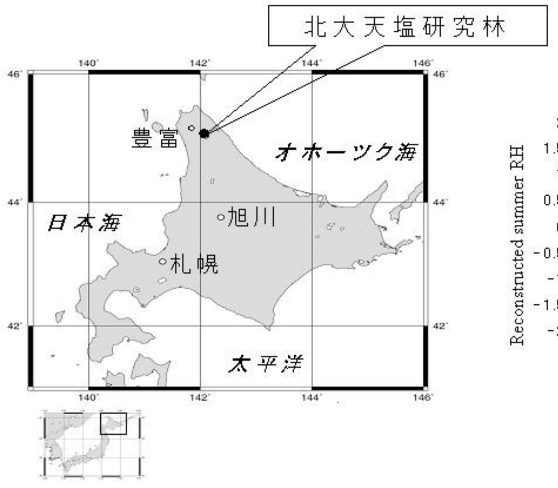

図 1(Fig 1)

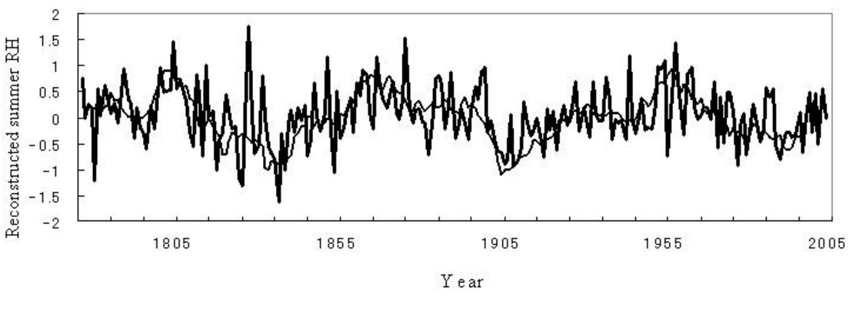

図 2(Fig 2)