Diurnal variations in O and H isotopic ratios of various forms of water in Tomakomai larch forest

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1. Introduction

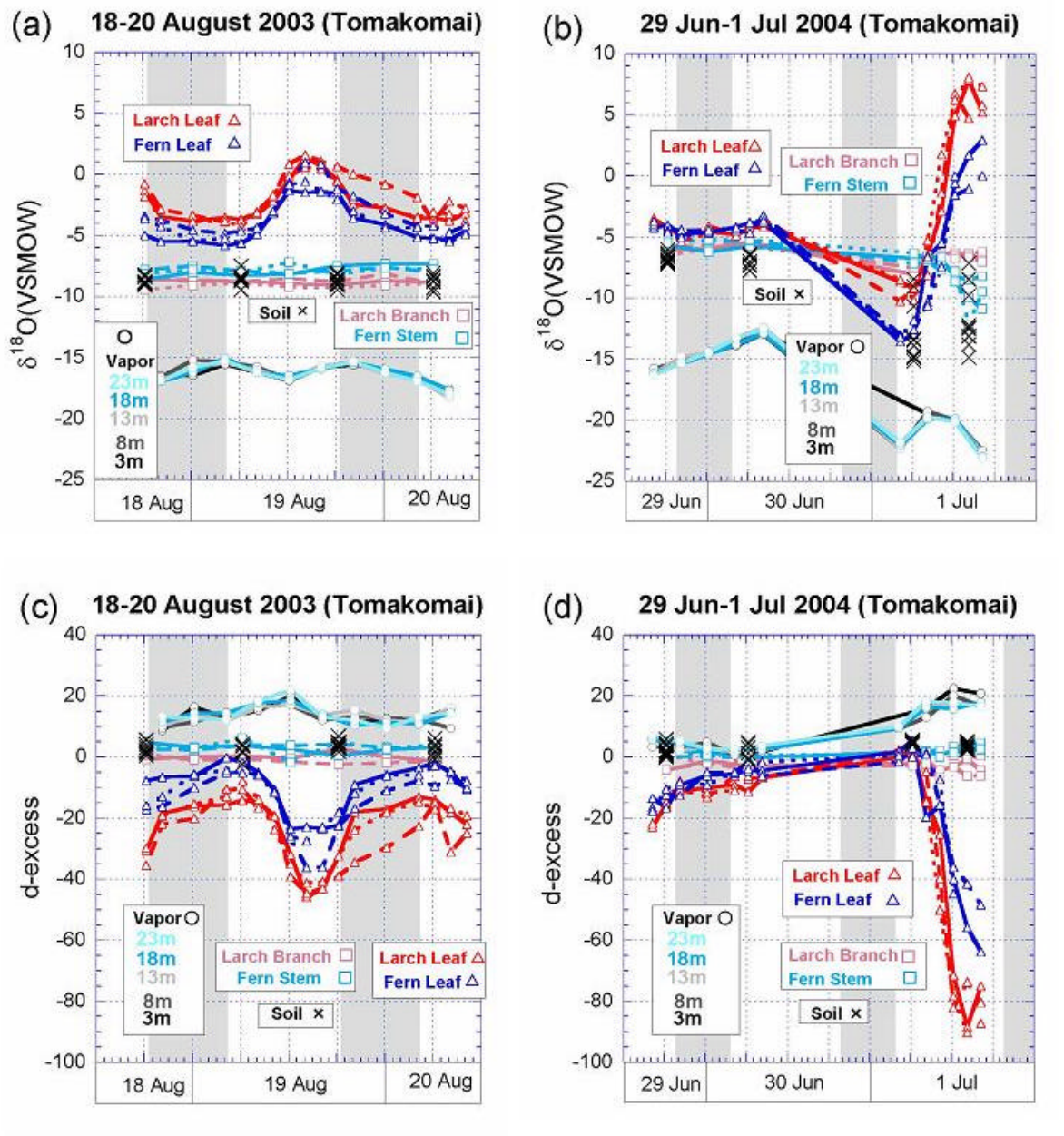
In forest, water exists as various forms such as rain water, soil water, xylem water, leaf water and water vapor which are circulating through infiltration, root uptake, evaporation, transpiration and condensation. Because isotopic ratios of rain water varies temporally and large isotope fractionations occur during evapo-transpiration and condensation processes, spatial and temporal distributions of oxygen and hydrogen isotopic ratios of various forms of waters in forest must provide us of valuable information for understanding forest water cycle. The isotopic ratios of water are also very important to understand the isotopic signatures of various compounds produced by plants and soil microorganisms and to establish the basis of reconstruction of past climate using tree-ring isotopic ratios. However, there have been very few reports of water isotope studies in forest environment with high temporal resolution because it was very difficult to conduct continuous samplings of canopy leaves and airs. In this study, we carried out diurnal samplings of various forms of water and analyzed their oxygen and hydrogen isotopic ratios in a larch forest of Tomakomai Flux Research Site (Hokkaido, Japan) of National Institute for Environment Studies.

2. Samplings and analyses

Larch trees were planted about 40 years ago and trees of about 17 m height were covering over several kilometers around the flux research site at the time of samplings. A kind of fern occupied at the ground layer. We collected leaf and xylem waters of larch and fern and water vapor and soil water at 2 or 4 hours intervals in 2003 (August 18-20) and 2004 (June 29-July 1). In 2004, we interrupted the sampling due to a heavy rain fall on the second day. Air samples were drawn from 5 layers of 25m of meteorological observation tower by a diaphragm pump through cold traps of -100 C for 30 min to collect water vapor vertically. Leaves and branches (xylem) at canopy layers of three larch trees were collected using a 15m height of canopy observation frame. Leaves and stems (xylem) of the fern together soil samples were collected at three locations around the tower and frame. Leaves, branches (stems) and soils were inserted into glass tubing immediately after sampling and tightly capped with silicon rubber caps. Waters were extracted from the solid samples by the vacuum-distillation method in laboratory and analyzed for their oxygen and hydrogen isotopic ratios using Isoprime-PyrOH mass spectrometer equipped with pyrolysis and reduction furnaces (GV-instrument). The accuracies of oxygen and hydrogen isotopic measurements were about 0.1 and 0.5 permil, respectively.

3. Results and discussions

Figures (a) and (b) show the diurnal variations of oxygen isotopic ratios of various forms of water. Oxygen isotope ratios in leaf water are generally higher than those of xylem water because of isotopic fractionation during transpiration process, but it was lower in July 1st when isotopic ratios of water vapor dropped. This suggests that leaf water is affected more directly by water vapor than by precipitation via soil and xylem. Isotopic ratios of leaf water become higher in daytime and lower in nighttime, but it was not predominant in a cloudy day. Measured isotopic ratios of oxygen and hydrogen in leaf water of both larch and fern could be predicted by Craig-Gordon Equation, suggesting that theoretical relationship between environmental parameters and leaf water isotopic ratios are common irrespective of plant species. Figure (c) and (d) show the changes in d-excess values. While d-excess values of soil and xylem water are concentrated near 0, d-excess of leaf water and water vapor show negative and positive values in daytime (afternoon and noon), respectively. By comparison of isotopic ratios of water vapor and leaf and soil waters, we can estimate the source and flux of water vapor released into the atmosphere from the forest in daytime.


(a)
18-20 August 2003 (Tomakomai)
δ18O(VSMOW)
Larch Leaf
Fern Leaf
Soil
Larch Branch
Fern Stem
Vapor
23m
18m
13m
8m
3m
18 Aug
19 Aug
20 Aug
(b)
29 Jun-1 Jul 2004 (Tomakomai)
29 Jun
30 Jun
1 Jul
(c)
d-excess
(d)