Non-Translatory Flow Patterns in Northwest Forest Ecosystems

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Introduction

Objective: to understand why water exiting forest ecosystems differs in isotopic character from water utilized by trees.

This experiment was designed to investigate the processes of non-translatory flow in moist forested ecosystems of the Pacific Northwest. It has recently been observed by Dr. Renee Brooks of the EPA's Western Ecology Division that water cycling in these ecosystems occurs atypically, leaving pools of tightly-bound water that does not take part in translatory flow.* When precipitation saturates the forest floor, it is expected that current soil moisture will exit to streams or mix with this new input of available water. Using isotope data collected at the H.J. Andrews experimental forest, Dr. Brooks was able to demonstrate that some water is retained and isolated from translatory flow by way of micro-pores in soil aggregates. This isolated moisture is usually deposited at the start of the rainy season and will remain unaltered throughout winter and spring seasons. The water is slowly lost due to transpiration over the course of several dry summers.

Our experiment involved saturating three different soil types over a period of 24 to 48 hours using both RO and enriched water. The water was then extracted and analyzed for isotopic composition. Since water contains both hydrogen and oxygen, we analyzed for the stable isotopes ^{2}H and ^{18}O. In each case, the extracted H_2O was depleted when compared to the source water (RO or enriched).

Because fraction will not occur during extraction, when all the inputted moisture is removed via vacuum, atomic exchanges between water and soil must cause this observation. Extraction after extraction continued to show this pattern. The heavy isotopes found in the source water were being retained by the soil samples. This pattern of depletion provides valuable insight into the world non-translatory flow of forest ecosystems.

**Translatory flow is the lateral displacement and mixing of water in soil throughout seasons. As new water enters the soil, old moisture is forced down and out, eventually reaching streams or tributaries. Non-translatory flow refers water that defies this process. Some soil moisture remains immobile regardless of the amount of entering precipitation.*

The w^{2}Hat and w^{1}Hy of is^{18}Ot^{16}Opes

Elements of the periodic table are composed of three subatomic particles: neutrons, protons and electrons. Important to this experiment are the elements hydrogen and oxygen. Hydrogen typically contains one proton and one electron (^{1}H) while oxygen is generally comprised of eight neutrons, eight protons and eight electrons (^{16}O).

While additions or subtractions of electrons produce ions, variations in neutron number will produce isotopes. That is, atoms of an element may show variability in the number of neutrons contained in the atom's nucleus. Atoms such as ^{16}O and ^{18}O, with the same number of protons but different numbers of neutrons, are mutual isotopes.

Isotopes are further subdivided into stable and non-stable categories. Where non-stable isotopes show radioactive decay.

Stable isotopes, namely those of hydrogen, carbon, nitrogen, oxygen and sulfur (HCNOS), provide increasing amounts of information to ecologists and environmental chemists. Although differences in neutron number do not significantly affect an element's chemical properties, they can affect reactivity rates which may result in isotope fractionation. For example, in kinetic reactions, lighter isotopes generally react faster causing a separation between light and heavy isotopes. This is fractionation.

By studying the fractionation and mixing patterns of light and heavy isotopes, ecologists can study long-term succession patterns, food web organization, animal migration, conservation, and much more.

Table 1. Data sets one and two for run one of water extraction

Sample ID	Drying type	Soil Type	$\delta^{2}H$ (avg)	$\delta^{2}H$ (std)	Diff from source	$\delta^{18}O$ (avg)	$\delta^{18}O$ (std)	Diff from source
A-1	Oven dried	Jory	-73.85	0.08	0.79	-10.36	0.08	0.42
A-2	Oven dried	Jory	-75.27	0.03	-0.63	-10.00	0.02	0.78
A-3	Oven dried	Chehalis	-74.05	0.18	0.59	-10.56	0.05	0.21
A-4	Oven dried	Chehalis	-76.81	0.19	-2.17	-11.07	0.01	-0.30
A-5	Oven dried	Bashaw	-79.41	0.17	-4.77	-11.15	0.09	-0.38
A-6	Oven dried	Bashaw	-78.95	0.38	-4.32	-11.19	0.13	-0.42
A-7	Oven dried	Ceramic rod	-74.84	0.22	-0.20	-11.28	0.09	-0.50
A-8	Oven dried	Ceramic rod	-74.48	0.05	0.16	-11.07	0.07	-0.29
B-1	Cryogenic	Jory	-76.17	0.10	-1.53	-10.56	0.01	0.21
B-2	Cryogenic	Jory	-78.09	0.12	-3.45	-10.78	0.04	-0.01
B-3	Cryogenic	Chehalis	-76.20	0.09	-1.56	-10.64	0.02	0.14
B-4	Cryogenic	Chehalis	-76.82	0.05	-2.19	-10.86	0.03	-0.08
B-5	Cryogenic	Bashaw	-77.67	0.12	-3.04	-10.80	0.03	-0.02
B-6	Cryogenic	Bashaw	-77.85	0.19	-3.21	-10.95	0.07	-0.17
B-7	Cryogenic	Ceramic rod	-73.01	0.16	1.63	-10.95	0.04	-0.18
B-8	Cryogenic	Ceramic rod	-73.66	0.19	0.98	-10.97	0.05	-0.19
Water Source			-74.52	0.10		-10.64	0.05	
Water Source			-74.75	0.13		-10.92	0.06	

Image 1. Section of glass line used for water extraction. Displayed are the sample holster (on left with glass wool) and water collection tube (on right)

Notation, notation, notation . . .

Several isotope notations exist and are currently in practice. We will use *del* notation as denoted by a lower case delta (δ). *Del* notation simply reads ‰ Heavy Isotope and carries the units ‰ (read *per mil*).

$$\delta = \left[\frac{Rsa - Rstd}{Rstd}\right] * 1000 \quad OR \quad \left(\frac{Rsa}{Rstd} - 1\right) * 1000$$

Where R is a ratio of heavy to light isotope ($^{2}H/^{1}H$, $^{18}O/^{16}O$, etc.). R_{sa} being the isotopic ratio of the sample and R_{std} being the isotopic ratio of some standard value.

Standard values typically rest around or at zero while measured values may range between +/- 100 ‰. The lower the experimental value, the more depleted or lighter the sample is. A high positive value indicates an enriched sample with more of the heavy isotope. Remember by the following: lower lighter, higher heavier.

Image 2. Section of glass line showing five stations used for water extraction

Methodology

Two separate rounds of water extraction were done. In each run, we extracted water twice for a total of four data sets. Three of the four data sets appear here—the fourth is still undergoing isotopic analysis.

The first run was done using RO water. All samples, including two ceramic rods, were hydrated to 60% field capacity (FC) with 5ml RO H_2O. They were allowed to soak for 24 hours. It should also be noted that the soils had been dried at 50°C for 24 hours before this.

The water was then extracted over the course of four hours and the extracted water analyzed.

This process was repeated to gain a second data set for Run 1.

Run 2 was done much the same way. Half the samples and one ceramic rod were hydrated using 5ml RO H_2O. The other half and remaining ceramic rod were hydrated to 60% FC using enriched (Mara) H_2O with the values $\delta^{2}H$ 21.26‰ and $\delta^{18}O$ 3.51‰. All samples and rods were allowed to soak for 48 hours.

Once again, the water was extracted over a period of four hours and then then analyzed.

This process was also repeated for an extra data set. In this repetition however, ALL samples and rods were hydrated to 60% FC using 5ml RO H_2O and allowed to soak for 48 hours. No enriched H_2O was used for this fourth data set.

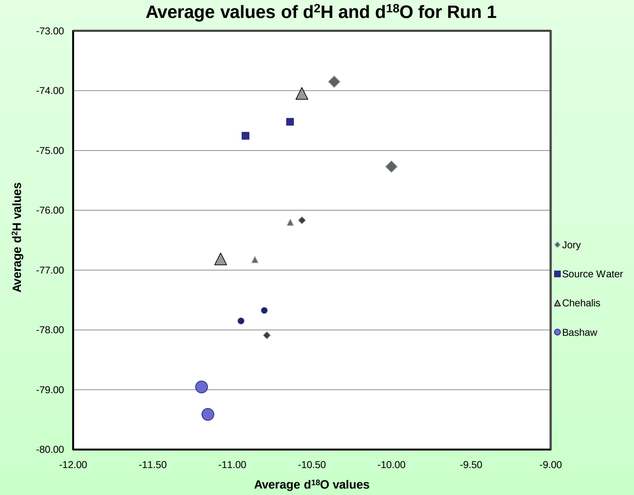

Figure 1. Plot of the average values for $\delta^{2}H$ and $\delta^{18}O$ collected from experimental run No. 1. Larger points represent data from oven dried soils and smaller points represent data from cryogenically dried soils

Table 2. Data set one for round two water extraction

Sample ID	Drying type	Soil Type	$\delta^{2}H$ (avg)	$\delta^{2}H$ (std)	Diff from source	$\delta^{18}O$(avg)	$\delta^{18}O$ (std)	Diff from source
C-1 (Mara)	Cryogenic	Jory	15.84	0.15	-6.9677	3.27	0.06	-0.82621
D-1	Cryogenic	Jory	-76.00	0.31	-1.37	-11.05	0.07	-0.28
C-2 (Mara)	Cryogenic	Chehalis	17.61	0.25	-5.19222	3.80	0.04	-0.29899
D-2	Cryogenic	Chehalis	-74.97	0.22	-0.34	-10.61	0.07	0.17
C-3 (Mara)	Cryogenic	Bashaw	13.86	0.19	-8.94455	3.30	0.09	-0.79383
D-3	Cryogenic	Bashaw	-76.82	0.08	-2.18	-10.94	0.06	-0.16
C-5 (Mara)	Cryogenic	Ceramic rod 1	22.34	0.41	-0.46488	4.15	0.06	0.051848
D-5	Cryogenic	Ceramic rod 2	-74.27	0.25	0.36	-10.89	0.11	-0.11
C-4		Mara Water Source	23.04225	0.39	0.237959	4.22	0.04	0.122681
D-4		RO Water Source	-74.4176	0.193176	0.22	-10.8524	0.204418	-0.08
Mara Source Water			22.8043	0.46153		4.10	0.19	

Conclusions and future work

Our preliminary findings show that atomic exchanges are occurring between water and soil. This process causes the source water to appear enriched when compared to the water which was extracted. In a forest ecosystem, the extracted water is that of streams and rivers. Our data suggests that a stream will have lower $\delta^{2}H$ and $\delta^{18}O$ values than those of the precipitation which originally entered the soil. We have begun to understand what happens to water as it travels through soil, but do not know what exchanges are occurring to make these findings possible. In the future we hope to answer these and more questions such as what changes occur to tightly-bound water over extended periods of time.

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