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BEE 6740: Week 13 Assignment
Application of Stable Water Isotope Tracers

Purpose:
Stable water isotopes can be used to track the movement of water in ecohydrologic systems. Local meteoric water lines (LMWL) can be used as a basis to compare water composition to that of rainwater, snow, soil, or plant water. The different fractionation tells important information about where the water originated and was drawn from, leading to insights about the water cycle overall.

Methods:
Data was provided for a soil water balance and plant stem xylem isotopes. Analysis was done following procedure explained in "Quantitative comparison of lake throughflow, residency, and catchment runoff using stable isotopes: modelling and results from a regional survey of Boreal lakes" by J.J. Gibson et al. Major model assumptions include neglecting lateral inflow and outflow and assuming that the soil is "well mixed." The LMWL was created using initial precipitation compositions, as shown in Figure 1. Typical characteristics of snow fit in the lower left corner of the graph, while seawater which is heavily enriched with isotopes fit in the upper right corner of the LMWL graph.

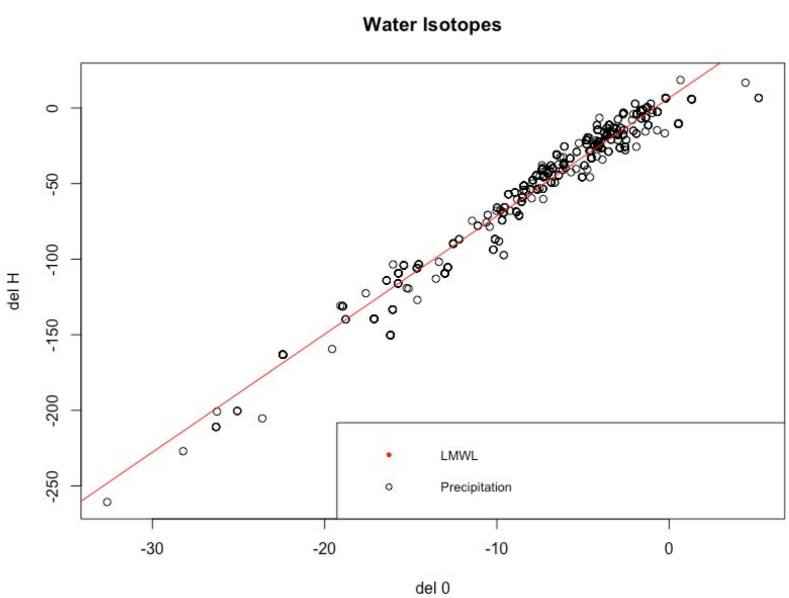

Figure 1: LMWL and precipitation water isotopes.

Initial isotopic composition for δ H and δ O were given as -100 and -10, respectively. The following equations were used to calculate relevant parameters. R_H is relative humidity and the rest of the variables are defined in the table.

Table 1: Water and tracer mass balances.

Evaporative fractionation	$term\ 1 = e^{(6.7123 * (10^3)/(T_{avg} + 273.15)/1000)}$ $term\ 2 = e^{(0.35041 * (10^9)/(T_{avg} + 273.15)^3/1000)}$ $term\ 3 = e^{(7.685/1000)}$ $term\ 4 = e^{(1.6664 * (10^6)/(T_{avg} + 273.15)^2/1000)}$ $\alpha^* = \frac{term\ 1 * term\ 2}{term\ 3 * term\ 4}$
Equilibrium and kinetic separation	$\varepsilon^* = (\alpha^* - 1) * 1000$ $\varepsilon_k = 1.047$ $\varepsilon = \varepsilon^* + \varepsilon_k$
Atmospheric δ H & δ O	$\delta_{atm} = \delta_{precip} - \varepsilon^*$
Evaporative δ H & δ O	$\delta_{evap} = \frac{\alpha^* \delta_{soil} - R_H \delta_{atm} - \varepsilon}{1 - R_H + 10^{-3} \varepsilon_k}$
Soil water isotopic competition	$\delta_{soil}(i) = \delta_{soil}(i-1) + ((Precip - Runoff) * \delta_O - (Recharge * \delta_{soil}(i))$ $- (Evap * \delta_{evap}) - (Transpir * \delta_{soil}(i-1)) / Soil\ water$

A subset of data for the Fall months (September through December) was plotted as shown in Figure 2. The soil water deviates from the LMWL in an expected way. Soil water differs from the LMWL because it is subject to evaporation processes which lead to kinetic fractionation. Isotopes that are heavier than the standard water molecule are less likely to evaporate and are more likely to concentrate in the soil. The soil water line typically follows the Local Evaporation Line (LEL).

Figure 2: Soil Water Isotopes in the Fall months, plotted against the LMWL.

Three plant species were tested for water isotope composition. Plants are a good measure of groundwater and soil isotope composition because they do not differentiate between different oxygen compounds (i.e. O^{18} or O^{16}). Plotting the isotope values for the different species together, as shown in Figure 3, indicates that the plants do not have significant varying preference by water type. It is not clear if the plants are drawing from shallow or deep water sources. Shallow water sources would likely have more evaporation and thus would fall closer to the LEL line; however, the plants do not clearly follow the LEL more than the LMWL.

Figure 3: Water isotope composition by different plant species.

Figure 4 shows the soil water broken up by season. As expected, the soil water in the winter is more negative on the plot as aligns with typical snow composition. In the summer when there is more evaporation, the soil water follows the LEL, which makes sense for kinetic fracturization trends.

Figure 4: Soil water isotopes by season compared with the LMWL.

Conclusion:

Water isotopes are a useful tool to analyze water movement in the watershed. They can be used to understand evaporation and plant uptake processes as related to precipitation events and seasons. While soils have different isotope profiles from precipitation and groundwater, plants do not differentiate between isotopes for uptake and can be used as a measure of soil and groundwater. Different plant species may draw on different water sources, prompting the question of what dominates the water cycle: do plants grow to water sources or do water sources move as a result of plants? The analysis above does not conclusively suggest either, and looking at both soil water and plant water are important hydrological considerations.