Isotope Signatures of the Precipitation and Natural Waters in the Forests of North Florida

Glynnis Bugna[1], Johnny Grace III[2] and Yuch P Hsieh[1]

(1) Florida A&M University, (2) US Forest Service

Abstract

Hydrological process and water balances of forests are critical to their ecosystem functions and services. However, our understanding of those processes and balances is limited in the isolated wetlands in forests. We initiated a study to show hydrogen and oxygen isotopic tracers of waters are valuable indicators of the hydrologic processes and balances of those isolated wetlands. We report here the baseline information of the isotopic signatures of precipitation and waters in isolated wetlands and sinks in the ANF. Our results indicated a Local Meteoric Water Line (LMWL) of $\delta^2H = 7.6*\delta^{18}O + 8.8$ (r^2=0.96, n=206) that followed closely the Global Meteoric Water Line (GMWL) of $\delta^2H = 8*\delta^{18}O + 10$. Using monthly weighted $\delta^{18}O$ and δ^2H of rainwater samples collected from 2014 to 2017, we observed statistically significant negative linear correlations between monthly total rain amount and isotopic signature ($p<0.01$). Most depleted $\delta^{18}O$ and δ^2H values were observed from the largest and most intense rains like Tropical Storm Collin (June 2016) and Hurricane Hermine (September 2016). No significant statistical correlations were observed seasonally. We were also able to establish preliminary local evaporation lines (LEL) for some water bodies within the ANF like δ^2H = (5.2, 5.6, 4.5)*$\delta^{18}O$ + (–5.7, –5.6, –4.6) (r^2 = 0.64, 0.77, 0.58) (n=72, 34, 69) for Pond 55, Pond 12 and Blue Sink, respectively. These data along with groundwater isotopic signature that we are currently collecting, can help us better understand the hydrological processes and balances of those isolated wetlands in the Apalachicola National Forest.

Experimental

- Study sites (Pond 55, Pond 12 and Blue Sink), located within the Apalachicola National Forest south of Tallahassee, Florida, were sampled in 2014-2017. Online weather data were also collected from nearby weather stations.
- Surface water and rainfall samples were analyzed for $\delta^{18}O$ and δ^2H by off-axis integrated cavity laser spectroscopy developed by Los Gatos Research, Inc., San Jose, CA. The analytical precision for $\delta^{18}O$ and δ^2H are <0.3 and <2‰, respectively.
- Sample isotope ratios were expressed in del notation expressed relative to VSMOW.

$$\delta^{18}O = \left(\frac{\left(\frac{^{18}O}{^{16}O}\right)_{sample}}{\left(\frac{^{18}O}{^{16}O}\right)_{standard}} - 1 \right) * 1000\ ‰ \quad (1)$$

Evaporative Loss fraction, f_{ev}

At a given temperature T (in Kelvin units) and relative humidity h (as a fraction), the degree of primary evaporation of the water body based on the stable oxygen and hydrogen isotopes in the remaining water f_{rw} can be calculated using the equation below (Clark and Fritz, 1997; Gonfiantini, 1986; Majoube, 1971; Murad and Krishnamurthy, 2008). The term ε_{total} represents the equilibrium and kinetic fractionations in the water-vapor (w-v) and evaporation [i.e., vapor-boundary layer (v-bl)] interfaces, respectively.

$$\Delta = \varepsilon_{total} \times \ln(f_{rw}) = (\varepsilon_{w\text{-}v} + \varepsilon_{v\text{-}bl}) \times \ln(1 - f_{ev}) \quad (2)$$

Table 1. Δ and ε_{total} terms as shown in Eqn. 2 .

	Δ	$\varepsilon_{w\text{-}v}$ (‰)	$\varepsilon_{v\text{-}bl}$ (‰)
^{18}O	$\delta^{18}O_i - \delta^{18}O_0$	$(1.137\times10^6/T^2) + (0.4156\times10^3/T) + 2.0667$	(h–1) x 14.2‰
^2H	$\delta^2H_i - \delta^2H_0$	$(-24.844\times10^6/T^2 + (76.248\times10^3/T) - 52.612$	(h–1) x 12.5‰

Results

Local Meteoric Water Line (LMWL)

•Rain collected from different locations have similar LMWLs and overall follows closely the Global Meteoric Water Line (GMWL: $\delta^2H = 8*\delta^{18}O +10$, Fig. 1) as calculated by Craig (1961).

•A significant direct correlation was observed between $\delta^{18}O$ and δ^2H ($p<0.01$). Most depleted isotopic signatures were associated with known tropical storms and hurricanes (inlet box, Fig. 1).

•A similar LMWL was observed by Florea and McGee (2010, $\delta^2H = 7.6*\delta^{18}O + 11.3$) in south Florida. However, Onac et al. (2008) observed a combined LMWL of $\delta^2H = 5.6*\delta^{18}O + 3.2$ (r^2=0.96) for rain collected in north and central Florida in 2006-2007.

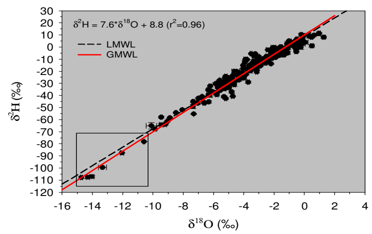

Fig. 1. $\delta^{18}O$-δ^2H plot from rainwater samples collected in north Florida from 2014 to 2017.

Seasonal trends and rain amount effect

•We observed no significant statistical correlations between season and either rain amount and stable oxygen and hydrogen isotopes. Rain also showed similar LMWLs during the different seasons (Table 2).
•We observed a significant inverse correlation between monthly rain amounts and monthly weighted stable oxygen and hydrogen isotopes ($p<0.01$, Fig. 2).

Table 2. Measured LMWL during different seasons in north Florida.

Season	LMWL
Winter	$\delta^2H = 7.2*\delta^{18}O + 9.1$ (r^2 = 0.94)
Spring	$\delta^2H = 7.1*\delta^{18}O + 6.7$ (r^2 = 0.86)
Summer	$\delta^2H = 7.6*\delta^{18}O + 8.4$ (r^2 = 0.97)
Fall	$\delta^2H = 7.3*\delta^{18}O + 6.2$ (r^2 = 0.98)

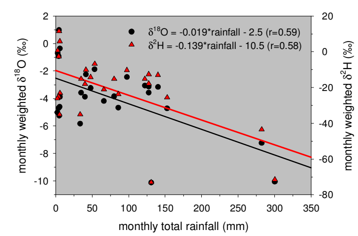

Fig. 2. Monthly rain amounts vs $\delta^{18}O$ and δ^2H in rainwater samples collected in 2014-2017.

Local Evaporation Line (LEL)

•The LELs of ponds and sinks in the ANF showed slopes much lower than the LMWL, an indication of enrichment of the isotopes due to evaporation (Fig. 3).

•Pond 55 (Fig. 3, top graph) and Pond 12 (middle graph) show similar LELs. Both graphs also showed that the dominant source of water to the ponds is rain instead of groundwater.

•Blue Sink (Fig. 3, bottom graph), on the other hand, showed that groundwater input is also an important source of water.

•Assuming the intersection of the LMWL-LEL lines as the initial water isotope signature to the ponds and sink and using the median average temperature and relative humidity of 23.4 °C and 78%, respectively, evaporative losses from the selected sites (Eqn. 2 and Table 1) range from 21±3 to 57±2%.

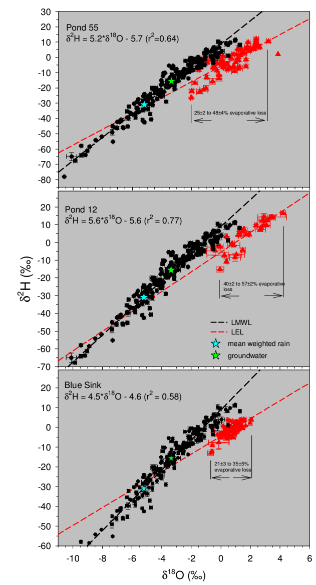

Fig. 3. $\delta^{18}O$-δ^2H LMWL-LEL in selected ponds and sinks in north Florida in 2014-2017. Evaporative losses from the selected sites range from 21±3 to as high as 57±2 %.

Summary

- The Local Meteoric Water Line (LMWL) in north Florida is $\delta^2H = 7.6*\delta^{18}O + 8.8$ (r^2=0.96), which is similar to the Global Meteoric Water Line (GMWL).
- Rainfall amount has a statistically significant inverse correlation with $\delta^{18}O$ and δ^2H ($p<0.01$). We did not observe a seasonal effect.
- Precipitation is the dominant source of water in the isolated ponds; however in a sink, groundwater input maybe important as well.
- Approximate evaporative loss of water in ponds and sinks range from 21±3 to 57±2%.

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