Progress Report:
Dissecting the Critical Links Between Ecology and Hydrology: Quantifying Spatial and Temporal Variability of Water Fluxes and Nutrient Distributions in Environmentally Sensitive Woodlands

University Campus: New Mexico Tech

Most Relevant IGPP Focus Area: Complex Dynamical Earth Systems

LANL PI: Brent D. Newman, EES-2, MS J495, Los Alamos National Laboratory, Los Alamos, NM 87545. bnewman@lanl.gov, (505) 667-3021

University PI: Andrew Campbell, Chairman, Earth and Environmental Science Dept., New Mexico Tech., Socorro, NM 87801. campbell@nmt.edu, (505) 835-5327

Graduate Student: Daniel Slattery, M.S. Program, Earth and Environmental Science Dept., New Mexico Tech

Project Abstract:
Recent research has shown that natural tracer modeling based on the analyses of soil water content, pore water stable isotopes (δD and $\delta^{18}O$), and pore water anion concentrations can produce information about the spatially and temporally variable dynamics of arid and semiarid near-surface environmental systems that have previously not been obtainable. Understanding such complex, nonlinear dynamics is a critical part of U.S. environmental and climate change science priorities. An existing piñon-juniper, paired watershed study site at Bandelier National Monument and a long-term piñon-juniper woodland study site at Los Alamos National Laboratory provide a unique experimental basis to implement these underutilized, but powerful modeling and analysis techniques with the goal of understanding the spatial and temporal variations in water content and nutrient (nitrogen) distributions, and evaporation and percolation fluxes. We expect these results to be a significant contribution to our understanding of complex linkages between ecological and hydrological processes and will provide critical information on basic and applied science questions in semiarid environments.

Progress:

Activities during the first year of this project consisted planning a sampling campaign, sampling, and sample analysis. The project called for quarterly sampling of soil profiles at the TA-51, piñon-juniper woodland site at Los Alamos National Laboratory (Figure 1), and a larger sampling effort during the summer in Bandelier National Monument. The focus of the Bandelier study was to examine impacts of thinning in the paired watersheds (Figures 2 and 3) and differences between canopy and intercanopy patches.

Sampling: During the first year, the quarterly samples we collected in February, May, and September. All of the quarterly samples were collected from a large intercanopy area in order to eliminate canopy-intercanopy spatial variability (Figure 1). This strategy allows us to better define seasonal temporal shifts in isotopic composition and evaporation that is the goal of the quarterly sampling. At each sampling date, paired soil cores were taken with 10 to 12 samples per core. During the spring, site reconnaissance at Bandelier was undertaken to select sampling sites in the paired watershed area (Figures 2 and 3). Once sites were selected, archeological clearance was obtained for the necessary sampling permit. In June, the Bandelier samples were collected over a one-week period. Sampling was performed by Danny Slattery and Brent Newman with some help from Bandelier and LANL employees. In total 18 soil cores were taken with 10 to 13 samples per core for a total of over 200 samples. These samples represent paired canopy and inter-canopy sites in different locations in treated and untreated paired watersheds. Samples were taken through the entire soil profile and into Bandelier Tuff.

Figure 1. One of the quarterly intercanopy sampling locations in the TA-51 piñon-juniper woodland.

Figure 2. Photo of the thinned Bandelier watershed. Most of the small trees were cut and the slash left on the ground. Note the lower tree density and greater groundcover compared to the unthinned watershed in Figure 3.

Figure 3. Photo of the unthinned Bandelier watershed.

Analytical Work: The remainder of the summer was devoted to the leaching and analysis of all of the cores utilizing laboratories at Los Alamos National Laboratory. The student on this project, Danny Slattery, spent 10 weeks at LANL working with the samples. A total of over three hundred samples were processed. This included leaching the samples for anion analysis, total carbon and nitrogen analyses on soil sample splits using dry combustion, and gravimetric moisture content. The anion analyses were conducted using ion chromatography and analytes include Br, Cl, NO_2, NO_3, PO_4, and SO_4. All of these analyses have been completed which was a substantial accomplishment.

In addition to the analysis performed at Los Alamos National Laboratory, stable isotope analysis (O and H) of the soil water is being performed at New Mexico Tech. This involves extracting the water from the soil sample by vacuum distillation and subsequent analysis on the mass spectrometer for hydrogen and oxygen isotopic analysis. To date, analysis is finished for the four cores from the first two quarterly sampling periods (February and June 2005), and the vacuum distillations are underway for the remainder of the samples. We anticipate that the distillation and subsequent isotopic analysis will be done by early spring. Two undergraduate geoscience students have been trained to help in the laboratory with this aspect of the analytical work.

Results: The attached graphs show the variations in hydrogen and oxygen stable isotopic compositions of the soil waters. Figures 4 and 5 show δD and $\delta^{18}O$ variation in soil water as a function of depth for the cores sampled in the piñon-juniper site at LANL. PJQ-1 and PJQ-2 are cores taken in February 2005and PJQ-3 and PJQ-4 were both sampled in June 2005. Two cores were taken at each quarter to look for lateral variations. In PJQ-1 and –2 the isotope depth profiles are quite similar and show near surface evaporation (isotopically heavy values) and a lower bulge of isotopically light water, characteristic of winter precipitation. By June, the surface samples show much more extreme evaporation and the light winter precipitation has moved down in the soil. The downward movement of the water is better defined in the $\delta^{18}O$ profile than in the δD profile. In these two cores the position of the isotopically light bulge is the same but the magnitude differs, overall below about 20 cm. PJQ-4 is lighter than PJQ-3. This may be due to lateral variation is soil characteristics. Soil descriptions of the cores were taken but have not yet been plotted with depth.

Figure 6 plots δD versus $\delta^{18}O$ of the soil waters with respect to the Meteoric Water Line (MWL). The lightest isotopic values plot on the MWL and represent the winter precipitation. The effects of evaporation are evident from the trend of the isotopic values. The MWL has a slope of 8 and evaporation tends to enrich the soil water isotope values along a line with a slope of less than 8. The slope of the evaporation trend can approach 8 as the relative humidity approaches 100%. The trend of the data from cores collected in February have a slope closer to 8 than the trend of the June samples, indicating drier conditions in the summer than the winter.

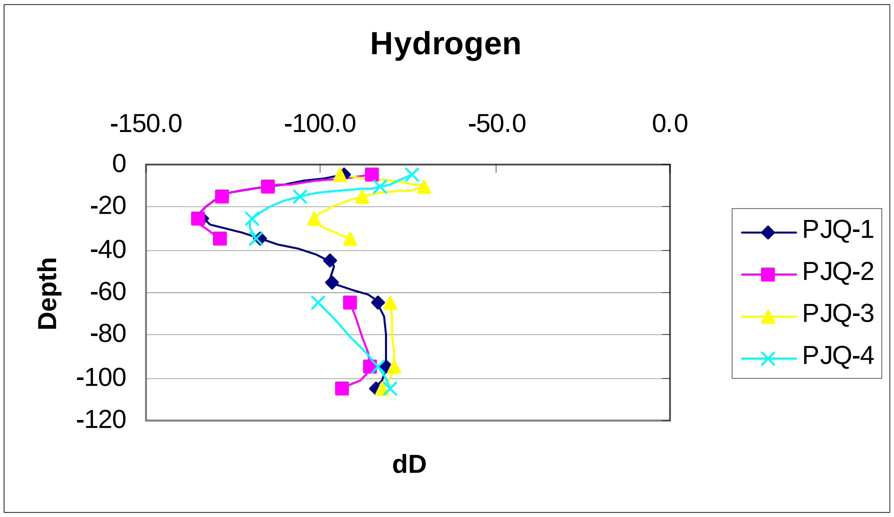

Figure 4. Variations in porewater δD (permil) with depth (cm) from cores taken in February 2005 (PJQ-1 and PJQ-2) and June 2005 (PJQ-3 and PJQ-4).

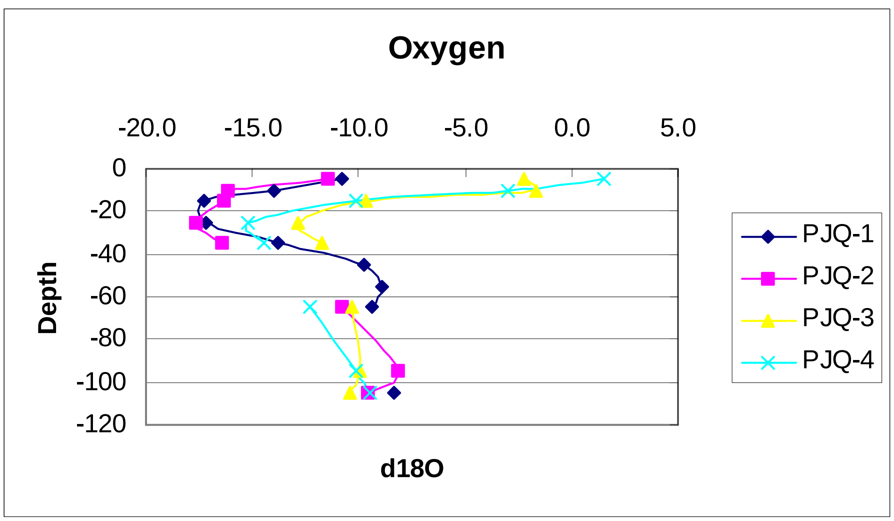

Figure 5. Variations in porewater $\delta^{18}O$ (permil) with depth (cm) from cores taken in February 2005 (PJQ-1 and PJQ-2) and June 2005 (PJQ-3 and PJQ-4).

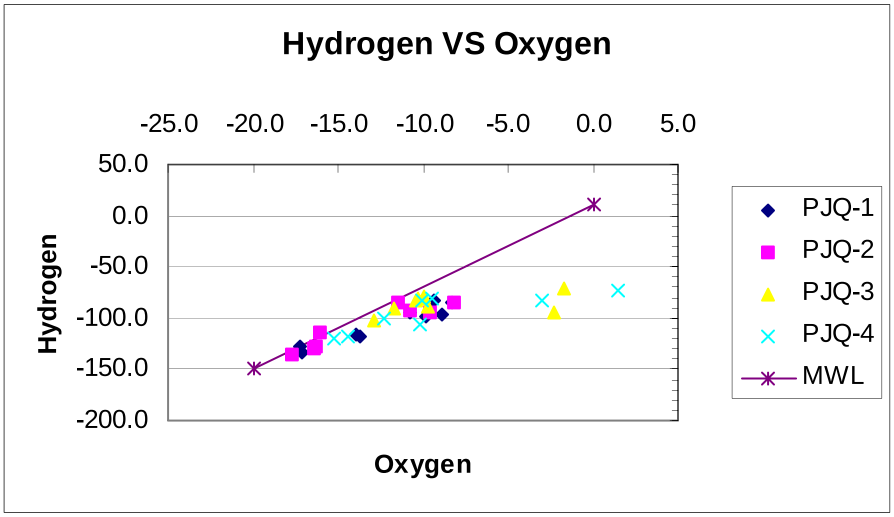

Figure 6. Meteoric water diagram of oxygen and hydrogen isotopes (permil) from the February and June, 2005 core samples.

Future Work:

As discussed above, the majority of the year 1 work focused on sample collection and analysis. Because a substantial amount of the laboratory work has been accomplished, year 2 will focus mainly on data interpretation, statistical analyses, and modeling. Some of the major year 2 activities include:

1. Converting the anion leachate data to pore water concentrations so that depth profiles of anion concentration can be constructed.

2. Calculating downward water fluxes for each borehole using the chloride mass balance modeling technique.

3. Results from 1 and 2 in addition to the total carbon and nitrogen, and stable isotope data will be used to conduct statistical analyses to evaluate canopy and intercanopy differences and to assess the impact of thinning at Bandelier.

4. Collecting the final 2 sets of quarterly samples at LANL, completing the associated laboratory work, and assessing seasonal differences in biogeochemical and hydrological processes.

5. Complete a final report/MS Thesis

As the data analysis and interpretation proceeds we will also identify possible journal article subjects.