University of Arizona
School of Earth and Environmental Sciences (SEES)

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Joint Poster Session
Wednesday April 11th
9:00 AM – 12:00 PM
Student Union - South Ballroom
&
Departmental Poster Presentations

Presented by:

Department of Hydrology and Atmospheric Sciences
Department of Soil, Water and Environmental Science
Department of Geosciences
School of Natural Resources and the Environment
Laboratory of Tree-Ring Research
Estimating Potential Arsenic and Cadmium Exposure of Preschool-Aged Children Using a Dietary Assessment

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Dietary assessments are widely used to monitor and record a person’s usual dietary intake. These assessments can provide crucial information regarding potential exposures to contaminants of concern such as arsenic (As) and cadmium (Cd) through ingestion of foods shown to accumulate these metalloid(s). Dietary assessments commonly include a food frequency questionnaire (FFQ), 24-hour recall (24HR), and/or dietary record (DR) administered through a combination of self-reporting and computer-based tools. Current FFQs are designed as comprehensive national surveys that may not adequately represent the average diet of a minority population. Therefore, modification to these FFQs is required to consider regional, ethnical, cultural, economic status, and age influences of target study groups. The proposed dietary assessment is designed to estimate the potential exposure to As and Cd through diet of preschool-aged children neighboring mining waste in Nevada County, California.
Lithologic Control of Pedogenic Carbonate Accumulation in Southern Arizonan Alluvial Fans

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The accumulation of pedogenic carbonates is important to understanding carbon cycling, to include carbon sequestration, in arid and semi-arid regions. Carbonate accumulation in southern Arizona displays significant spatial variation, particularly in alluvial deposits that dominate basins in the region. Improved understanding of the controls on pedogenic carbonate accumulation is needed. We hypothesize that carbonate accumulation in alluvial fans is controlled significantly by parent material composition. To address this hypothesis, petrocalcic and calcic horizons from sites with various parent materials were sampled. Parent materials included rhyolite/andesite, basalt, limestone and mixed alluvium. Measurements included pH, loss on ignition (LOI), electrical conductivity, color and elemental composition (using pXRF; portable x-ray flourence). We also measured carbonate concentration using a traditional method of hydrochloric acid dissolution along with Ca and Mg concentrations determined by pXRF. This was compared to results generated with an ATR FTIR (Attenuated Total Reflectance Fourier-Transform InfraRed) spectral curve for calcium carbonate concentration. Future work will focus on buried calcic horizons near biosphere 2 that appear to span Quaternary soil evolution; this will include isotopic analysis for atmospheric C3 and C4 plant dominance, temperature, and atmospheric calcium contribution. Empirical dating via Uranium series and/or beryllium 10 will constrain episodes of sedimentation, to include dust accumulation from pXRF readings of titanium/zirconium.
In this greenhouse experiment, the translocation of Al, Zn, As, Pb, Cd and Ni by three crops related to different families is investigated. These crops are sesame (Sesamum indicum), corchorus (Corchorus olitorius), and arugula (Eruca vesicaria). Garden are mixed with mine tailings brought from Iron King Mine and Humboldt Smelter Superfund Site (IKMHSSS). Four soil treatments are made with 0%, 25%, 50% and 75% of mine tailing. The edible parts of each crop and soils are microwave digested and analyzed for the toxicants via inductively coupled plasma mass spectrometry (ICP-MS). The amount of plant-available phosphates in the soil is calculated using a water extract method. The accumulation pattern of the metals decrease in the order of Zn >> Al >> As >> Cd >> Pb >> Ni, and each plant has a different relative order of accumulation. Bio-concentration factor shows that Zn is hyper-accumulated by sesame seeds, each of Zn and Cd are hyper-accumulated by arugula, and Cd is hyper-accumulated by corchorus. The study highlights some interesting points such as decreasing contents of the plant-available phosphate in the soils does not affect the contents of P in the tissues, there is no statistical relationship between As and P, the absorption of Pb and Cd seems to be synergistic, and mostly the absorption of the metals depends on the contents in soils and pH.
Biochar application for treatment of Cu, Cd, and Pb contaminated soils

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Heavy metals in soil originate from either natural or anthropogenic sources. Mining is one of the main activities that contributes to the soil’s overall content of heavy metals. Elevated levels of heavy metals in soil can cause adverse health effects for people living in the contaminated areas. Biochar is produced by the combustion of biomass under limited supply of oxygen. Biochar amendments can reduce contaminant mobility and decrease availability to plants in the contaminated areas. Immobilizing mechanisms of biochar can be attributed to modification of soil pH and increase in adsorption capacity. Moreover, conversion of biomass to biochar can be used as a method for carbon sequestration which would help in moderating climate change. In this study, soil samples will be taken from a mining area in Arizona and will be amended with an industrially produced biochar. Total heavy metal content and CaCl2-extractable heavy metals will be analyzed using ICP-OES before and after amendment. The impact of biochar on bioavailability of metals to plants grown on agricultural lands and in home gardens near the mine will be characterized. This project is part of a larger investigation of cost-effective methods for treating soils contaminated by heavy metals and other constituents.
Algal culture begins with a pure stock or starter culture (innoculum) of the desired algal species. These starter cultures can be obtained from a number of institutions such as Universities, Commercial biological supply houses & government laboratories. When cultivating algae, the most common type of growing system used to achieve the desired results is a closed system. These systems are expensive to build and to maintain, and involve securing the algae environment against contamination by placing the system inside a building or other shelter out of the elements. Enclosing the large spaces necessary to harvest large amounts of algae is costly and impractical at commercial scale. The alternative is an open pond, ‘raceway’ algae farming, which is exposed to the elements and therefore is exposed to possible contamination.

Open raceway systems are much cheaper to construct and operate than closed systems and the motivation of this project is to monitor an experimental open algae bioreactor for contaminants and see whether the algae culture can survive and produce a useable strain when contaminated. Different contaminants reflect differently on the ‘health’ of the raceway system and steps can be taken to keep the raceway running more efficiently when contaminants are identified.

Our goal is to demonstrate that, with careful monitoring of contaminants and other variables in the raceway, an open air raceway can produce a relatively pure algae harvest. In addition, the goal is to see what the presence of certain contaminants means for the overall ‘health’ or production capacity of the algae culture in the raceway.
Can Remote Sensing Detect Fire Damage in Plants and Soil Microbial Activity?
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Remote sensing tools are valuable for monitoring disturbances such as fires on a landscape. With increasing shrub encroachment and fires changing the landscape of southwestern U.S. grasslands and deserts, it is important to understand how plant and soil microbial communities respond to and recover from these disturbances. Remote sensing is an advantageous tool for monitoring these changes because greater areas can be surveyed in shorter time periods than with hand-collected data. The goal of this project was to use remote sensing to investigate how vegetation recovers after a fire and infer how soil microbial activity responds based on plant regrowth. This was done by examining a temporal survey of the normalized differential vegetation index (NDVI) across burned and unburned sites using NASA’s Landsat satellite data and collecting soil samples within these locations. Soil biomass and exoenzyme activities were assayed from soils collected in various time increments after the 2017 Sawmill Fire and Unnamed Fire in 1994 on the Santa Rita Experimental Range, in accordance to the Landsat images processed. Microbial biomass and activity data were used to investigate how soils respond to fire, which was then integrated with land cover data to determine the correlation between vegetation and soil activity after a fire. A positive correlation between NDVI and soil microbial activity was predicted. Vegetation cover was low directly after a fire and increased over time, but ultimately remained lower than at sites that had not been burned. We also predicted that the vegetation type should influence microbial biomass and activity with higher microbial exoenzyme activities predicted near mesquites compared to grass or bare soil. These plant and microbial correlations can be used to map soil microbial activities after a fire based on the remote images of vegetation collected by Landsat. A future aim of this work is to determine the relative importance of vegetation and microbial activity in driving fire recovery. Understanding the relationship between soil microbial activity and plant regrowth after a fire can be a crucial aspect in recovery planning to prevent soil erosion. These correlations could be used to determine the ideal timing and locations to plant native
vegetation to prevent erosion, if need be, or to predict landscape changes in the absence of management.
Guayule (Parthenium argentatum), a woody shrub indigenous to SW Texas and the Chihuahuan desert, is being re-developed in the southwestern United States for rubber, resin, and biofuel production. Understanding the microbial contribution to soil health is key for optimizing guayule production. Microbial contributions include pathogen protection, nutrient availability, phytohormone production, and plant stress tolerance. Bacteria, fungal, and archaeal community profiles will be assessed to correlate crop biomass and yield to microbial composition and health. Agricultural management practices (irrigation) will be correlated to microbial health, and the sustainability of microbial health will be monitored over the course of the study.
Adsorption and Retardation of PFASs in Soils
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Per- and poly-fluorinated alkyl substances (PFASs) are emerging contaminants of concern that are present in the subsurface at numerous military and industrial facilities. Knowledge of the retention behavior of these compounds in the subsurface environment is critical for effective risk characterization and remediation. The objective of this research is to investigate the role of adsorption at the air-water interface on PFAS retention in vadose-zone systems. Surface tensions were measured for select PFAS to determine interfacial adsorption coefficients. Column experiments were conducted to characterize retardation and transport under saturated and unsaturated flow conditions. The impact of soil properties and groundwater constituents on surface tension, solid-phase adsorption, and interfacial adsorption will be investigated.
Mining educational modules for impacted tribal communities

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Tribal lands in the United States contain a tremendous amount of natural resources (e.g. copper, uranium). Historically, tribes were excluded from natural resource extraction decision-making processes that impacted their livelihoods, culture, health, and environment. Today, tribal participation is crucial. The University of Arizona Superfund Research Program and two collaborating Arizona tribal colleges are creating educational modules about fundamental mining concepts. These modules are targeted to Native American audiences and can be adjusted to complement K-12 and entry-level college education. Module topics include copper mining and processing, social and cultural impacts, environmental impacts, and mining reclamation. Each module contains an instructor’s guide, instructional PowerPoint, and hands-on activity to enhance understanding of complex mining concepts. For correctness, tribal representatives and technical experts review each module component twice. Future steps include online publication, development of a uranium mining module, and an evaluation of the learning effectiveness of the mining educational modules.

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Effect of Climate Change on Bees
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Climate change is playing a major role in declining populations of many bee species. Pollinators are some of the most important organisms economically and environmentally to this planet, and the most important are bees. As with many species, climate change affects each organism differently. Several studies link decreased range of living, increased disease, disrupted seasonal timing, and smaller overall bee populations to climate change. Here we accumulated multiple case studies and relevant information that shows how some of these factors are influencing bee species and how these factors are linked to climate change. The three studies examined here investigate the relationship between (1) increasing global climate and decreasing range limits, (2) rising temperatures and distribution based off elevation, (3) and mismatched seasonal timing between plant and bee species. Each case study presents new information on linkages between climate change and bee population decline. Research on the extent of the damage is ongoing, but it is nonetheless abundantly clear that climate change has altered bee populations unfavorably. Overall, each individual factor has a cascading impact on bee populations and although they may be separate influences, the key contributor, climate change, is the same.
Soil Fungal Community Profiling of Compost-Assisted Phytostabilization of Metalliferous Mine Tailings

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The Iron King Mine and Humboldt Smelter Superfund (IKMHSS) site, in Dewey-Humboldt, AZ is a legacy mine site with a 62 ha tailings pile characterized by low pH (2.5) and concentrations of lead, zinc and arsenic all above 2000 mg/kg. The heavy metals, the semi-arid climate, and poor soil structure of IKMHSS site make it a highly challenging environment for plants to become established, leaving tailings material open to transport into the nearby community. The specific aim of this study is to profile the fungal microbial community in the root zone of plants grown in the tailings over a six-year compost-assisted phytostabilization trial. Fungi play an important role as recyclers in ecosystems, breaking down plant debris to make organic carbon and nitrogen bioavailable to surrounding soils as an important step of maintaining soil fertility. They also may be plant pathogens or symbionts, which strongly influence plant nutrient uptake, especially in the low nutrient conditions which impede mine tailings phytostabilization. Characterizing these communities during phytostabilization allows better understanding of how belowground community development serves as an indicator of long-term aboveground success. To that end, DNA was extracted from IKMHSS soil cores taken annually from twelve plots and representing three treatment levels of compost amendment (10-20% w/w). Fungal targeted sequencing (Illumina Miseq) was done on the ITS genomic region and community analysis was conducted in context with previously determined site parameters, including: plant cover, pH, EC, and total carbon to nitrogen ratios.
Microbial ecology of soda lakes: investigating sulfur and nitrogen cycling at Mono Lake, CA, USA

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Soda lakes represent unique ecosystems characterized by extremes of pH, salinity and distinct geochemical cycling. Despite these extreme conditions, soda lakes are important repositories of biological adaptation and have a highly functional microbial system. We investigated the biogeochemical cycling of sulfur and nitrogen compounds in Mono Lake, California, located east of the Sierra Nevada mountains (38°N, 119°W). Mono lake is characterized by hyperalkaline, hypersaline and high sulfate concentrations and can enter prolonged periods of meromixis due to freshwater inflow. Typically, the microbial sulfur cycle is highly active in soda lakes with both oxidation and reduction of sulfur compounds. However, the biological sulfur cycle is connected to many other main elemental cycles such as carbon, nitrogen and metals. Here we investigated the interaction between sulfur and nitrogen cycling in Mono lake using a combination of molecular, isotopic, and geochemical observations to explore the links between microbial phylogenetic composition and functionality. Metagenomic and 16S rRNA gene amplicon sequencing were determined at two locations and five depths in May 2017. 16S rRNA gene amplicon sequencing analysis revealed organisms capable of both sulfur and nitrogen cycling. The relative abundance and distribution of functional genes (\textit{dsrA}, \textit{soxAB}, \textit{nifH}, etc) were also determined. These genetic markers indicate the potential \textit{in situ} relevance of specific carbon, nitrogen, and sulfur pathways in the water column prior to the transition to meromictic stratification. However, genes for sulfide oxidation, denitrification, and ammonification were present. Genome
binning guided by the most abundant \textit{dsrA} sequences, GC content, and abundance with depth identified a \textit{Thioalkalivibrio paradoxus} containing genes capable of sulfur oxidation, denitrification, and nitrogen reduction. The presence of a large number of sulfur and nitrogen cycling genes associated with \textit{Thioalkalivibrio paradoxus} suggests thiosulfate oxidation may be coupled to nitrate oxidation despite the extremely low level of nitrate in Mono Lake. Our results illustrate the centrality of living organisms in both shaping and responding to geochemical cycles, as well as future directions for exploring coupled biogeochemical cycles in Mono Lake.
Dust Accumulation and Weathering Characteristics in a Chronosequence on the Colorado Plateau

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The pedological progression of soils on the Colorado Plateau offer a unique window to observe dust accumulation in various soils. For this surficial basalt flows ranging up to three million years from the San Francisco Volcanic Field are studied to determine patterns in soil evolution and aeolian contributions on basalt parent material. It is hypothesized that aeolian inputs provide a significant amount of material to the soil and demonstrates some control over soil chemical weathering. This was addressed by examining each horizon’s characteristics over the chronosequence. It is with these characterizations we discover that over the chronosequence pH and Ti:Zr ratios decrease, while electrical conductivity and clay content increases as the soils age.
Risk Assessment: *Legionella pneumophilia* exposure from irrigation with domestic roof-harvested rainwater

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In many desert areas, including Tucson, greywater is collected from rooftops and reused as irrigation water in order to conserve drinking water. This study performed a risk assessment to evaluate the risk of exposure to *Legionella pneumophilia* from greywater used for garden irrigation. *L. pneumophilia* is a waterborne bacterium which has been detected in numerous warm water environments and in nearly half of cold tapwater samples. It is contracted via inhalation of aerosols. An exposure assessment found that *L. pneumophilia* is likely to be found in pasteurized greywater and in irrigation hoses. The possible ranges of bacterial counts (in CFU) were estimated through a literature search of prior studies, with a determination of minimum and maximum CFU exposure. A Monte-Carlo simulation with a uniform risk distribution was then performed with the minimum and maximum CFU values to evaluate risk in two scenarios: hose irrigation and drip irrigation. The simulation determined that the mean risk of exposure to *L. pneumophilia* from hose irrigation was nearly 1, while risk of exposure from drip irrigation was negligible. This suggests that homeowners who utilize greywater for garden irrigation should consider using it solely for drip irrigation. A number of uncertainties remain which suggest directions for future research on *L. pneumophilia*.
Nanoparticle desiccation patterns as indicator of changing surface energy
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The technique of evaporative deposition is inexpensive, simple, and underutilized. The pattern from a desiccated droplet of solution indicates properties about the gas, liquid, and solid phase. When a droplet of liquid evaporates from a surface, the pattern left behind is unique to certain conditions. Research on the drying process and pattern formation benefit a range of industries including Inkjet Printers, material engineering, and medical applications. Scientists have researched evaporative deposition for decades and is still considered to be in the early stages of its potential for applications. Many factors in the surface-liquid interface affect the rate of evaporation, the drying motion, the droplet shape, the particle positioning, and the final desiccation pattern. The liquid phase was examined in several experiments using charged fluorescent microspheres. The cause of pattern variability on the mica can be studied by changing the pH, salt concentration, particle concentration, and particle type. The solid phase substrate was ruby red muscovite mica which presents a high energy surface when freshly cleaved. The surface energy of the mica was examined by aging the cleaved mica in the laboratory atmosphere as well as petri-dishes to observe the change with time. Additionally, the mica substrate was treated in an autoclave and an ethanol bath to investigate the use of freshly cleaved mica in virus fomite studies. The wettability and patterns are similar for the autoclave treated mica and air-cleaved mica of the same age. The ethanol bath mica had different wettability characteristics and desiccation patterns than the air-cleaved mica and therefore the ethanol bath is not a suitable technique for high surface energy experiments with viruses.
An Ecological and Health Risk Assessment of the Santa Cruz River using Environmental Management Tools
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Many cities are bolstering their local water recharge by directly discharging treated wastewater effluent into the environment. The treated water permeates through the vadose zone and into the aquifer, thereby recharging groundwater. The Santa Cruz River flows between the United States and Mexico through several metropolitan areas. Nogales International Wastewater Treatment Plant (NIWTP) releases treated effluent wastewater into the Santa Cruz River. An issue of critical concern is the long-term impact of the discharge of treated effluent from the NIWTP to surface water and groundwater quality in the region. Several factors including failing infrastructure, operational limitations, continued rapid population growth, and economic development impart complexity to this issue. The affected community is generally low- to middle-income, so the costs for obtaining and maintaining new and advanced treatment options necessary for the removal of contaminants of emerging concern is economically burdensome. A recent study has shown that the discharge point of the NIWTP is in an area of high aquifer vulnerability, and that there is evidence of environmental contamination from the presence of cadmium, arsenic, nickel, zinc, nitrates, nitrites, and other compounds. This objective of this study is to identify and assess areas of potential soil and groundwater pollution and associated risk to human health using modeling and environmental management tool analyses.
Plastic Pollution in the Environment
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Plastic is arguably the most ubiquitous and widespread pollutant in the environment and has now been found within the biomass of organisms living 10,000 - 20,000 ft (3,000 - 6,000 m) deep within the ocean abyssal zone. In 2016, the International Geological Congress declared that since 1950, Earth is considered to be within the Anthropocene Geological Epoch, due to mounting scientific evidence that humans’ presence on Earth has caused potentially irreparable and drastic changes to planetary energy and matter transformation systems. One of the defining characteristics of the Anthropocene Epoch is plastic pollution that has now been found in nearly every ecosystem. Even with undeniable influence, plastic as a pollutant is just starting to gain traction in the scientific and policy-making realm. Very little is known about its true biological harm as a pollutant. In order to understand plastic pollution, we first need to consider the basics - the estimated amount of plastic entering the environment, plastic composition, its break down and fate in the environment, and recent and future developments to reduce and remediate the plastic in the environment. Most importantly, it’s vital that the public is aware and educated about this problem because the largest driver of plastic pollution is through consumerism. If more people understood how their everyday-use plastic was affecting wildlife, much less plastic would be entering the environment and we could start removing/remediating what currently seems to be an insurmountable amount of plastic pollution in the environment.
Detection of Cyclospora in recycled waters
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Cyclospora cayetanensis is a protozoan parasite that has been linked to multiple foodborne and waterborne outbreaks. Recently, foodborne outbreaks in the United States were linked to the consumption of fresh produce from people that had no history of traveling overseas. Information on the sources and occurrence of this organism are very limited. Currently, only humans and possibly primates can be infected by this parasite, therefore sewage may be a major contributor. Our goal is to determine if Cyclospora can be found in recycled water proposed as an alternative source for agricultural irrigation. Tertiary treated effluent (100 L) from different water reclamation facilities in the Southwest were sampled using Envirochek HV cartridges to concentrate the oocysts. Water concentrates between 10 and 20 mL were obtained by centrifugation and aliquots were used for DNA extraction. Untreated sewage from the same facilities was also concentrated using membrane filtration and water concentrates obtained by thoroughly washing the membrane were used for DNA extraction. Genome copies (GC) of Cyclospora cayetanensis were quantified by a real-time polymerase chain reaction assay and the results were expressed as GC by the sample volume examined. qPCR signals were detected in untreated sewage and less frequently in treated effluent with concentrations ranging from 10^5 GC/L (sewage) to 101 GC/L or non-qPCR detects in treated effluent. Further confirmation of Cyclospora using DNA sequencing is ongoing. Our results have important implication for the safe and sustainable use of recycled water in agriculture.
Insensitive munitions are explosive formulations that are less sensitive to shock and heat than traditional explosives like 2,4,6-trinitrotoluene (TNT) and C4. They were developed to replace traditional explosives due to lower risk of accidental detonation, and thus, increased worker safety. Two IM formulations developed are IMX-101, composed of 2,4-dinitroanisole (DNAN), 1,2,4-triazol-3-one (NTO), and nitroguanidine (NQ) and IMX-104, composed of DNAN, NTO, and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). Both IM formulations contain DNAN as a major component. Partial detonations of IM formulations during training exercises result in solid residues being scattered across the soil surface where they are exposed to rainfall and sunlight. The majority of IM components are more soluble than traditional explosives resulting in increased potential for IM leaching through soils, reaching groundwater and leaving training ranges. In addition, IM components may transform via exposure to sunlight. The goal of this project is to identify phototransformation products of IM components and to determine the dissolution, sorption, and transport potential of the products and parent compounds in mixtures via outdoor phototransformation studies, batch soil adsorption studies and column transport studies. Here we describe work, where we exposed IMX-101 and 104 to natural sunlight at Biosphere 2, Oracle, AZ to identify and quantify phototransformation products that are being formed. We identified 2,4-dinitrophenol, 2-methoxy-5-nitroaniline, 4-methoxy-3-nitroaniline, 2-methoxy-5-nitrophenol, and 4-methoxy-3-nitrophenol using gas chromatography mass spectrometry. In a new set of experiments, the outdoor phototransformation studies will be set up in two additional locations with varying temperature and rainfall averages, in Tucson and Summerhaven, AZ, to show the effects of climate on the environmental fate of these insensitive munitions and potential environmental impacts of their use.
Biochar as a Means for Climate Change Mitigation and Adaptation
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Carbon dioxide (CO2) is the most abundant greenhouse gas in the atmosphere. Before the industrial revolution, atmospheric CO2 concentrations were around 280 ppm. As of July 2017, atmospheric CO2 concentrations were 407 ppm. Increased levels of greenhouse gases in the atmosphere have affected surface temperature and the hydrologic cycle. Instances of drought are more abundant and are becoming more frequent and prolonged. Soils are the largest terrestrial sink and can be used to mitigate the effects of climate change. Soils can be amended to store greater amounts of water and carbon. Biochar is a soil amendment that is produced through the burning of biomass in the absence of oxygen, a process known as pyrolysis. Biochar has been shown to increase the mean residence time in labile and stable carbon pools, increase organic carbon concentration and storage in soils, lower the amount of labile carbon and increase the half-life of soils. Biochar can indirectly sequester carbon by increasing net primary productivity through increasing water holding capacity and nutrient uptake.
Soil organic matter (SOM) an essential component of ecosystem health. Without it, soils lose the capacity to retain levels of moisture and nutrients necessary to maintain productivity in the face of a changing climate. SOM is vulnerable to loss via human activities such as overgrazing and unsustainable farming practices. Indeed, some sources claim we have already lost upwards of half of the SOM in global topsoils. Recovering this precious resource should be a global priority because of the ability of SOM to increase agricultural productivity and bolster the resilience of natural ecosystems to climate change and variable precipitation. Furthermore, when SOM is lost the carbon held within it (~50% C by weight) returns to the atmosphere as gaseous CO2 where it contributes to global warming. Arid and semiarid soils have low levels of SOM (>1% by mass) and are especially at risk of losing this precious resource. Many opportunities exist to increase the amount of SOM in arid soils: restoring the functioning and health of degraded ecosystems, implementing sustainable agricultural practices and adopting appropriate grazing management. However, there are many challenges to increasing SOM in arid and semiarid regions, both in terms of basic and applied science, which must be addressed if we are to effectively increase levels of SOM and sequester carbon in arid and semiarid soils.
Developing A Drought Monitoring Playbook For Rangeland Management Of Arizona’s Grasslands

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Arizona’s grasslands are an important ecosystem, managed for multiple uses, including forage for livestock, habitat conservation, and open space. Drought can impact grassland ecosystems in complex ways and land managers and livestock producers can benefit from drought monitoring strategies that help them anticipate and respond to changing drought conditions. Numerous drought indices based on temperature and precipitation anomalies or NASA satellite data, such as Soil Moisture Active Passive (SMAP) and MODIS Normalized Difference Vegetation Index (NDVI), are readily available to help managers and producers track drought conditions. These indices represent different aspects of hydroclimatic variability within soils and thus objectively identifying the indices that best represent drought effects on grassland ecosystems and inform range management activities remains a significant gap for applying available climate information to land management actions. Addressing this gap requires development of an educational tool that successfully communicates to land managers which index best represents drought stress conditions of their rangeland into a comprehensive resource. This will be accomplished by developing a Drought Monitoring Reference Guide (“playbook”) that identifies key indices and triggers to anticipate potential drought impacts and inform management decisions. Soil moisture climatology plots created using high-resolution soil moisture modeling (HYDRUS-1D) will be compared with ground-based vegetation observations, traditionally used drought monitoring indices and remotely sensed indices to identify the optimal method that best represents soil moisture status on grasslands. These results will be summarized in the playbook based on ecological site descriptions, which are extensively used by the rangeland management community today. This will allow for increased drought monitoring planning and decision making while removing the demand on users of needing to make complex interpretations between indices. Furthermore, this educational resource will help land managers make better use of NASA remotely sensed indices, such as SMAP and NDVI, and historical climate data to make informed decisions about managing their land.
Voices Unheard: Documenting the Human Experience of Living Near Arizona Superfund Sites
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National Priorities List Superfund sites are federally designated lands that pose a risk to human and environmental health due to the presences of hazardous contamination. People living alongside these sites experience daily an area of environmental risk and have come together to advocate for environmental health outcomes. As time passes, the memory of these people is lost as they age and/or leave the area. Consequently, oral history will be applied at two Superfund sites in Arizona that include the Iron King Mine and Humboldt Smelter and the Tucson International Airport Area.

Archival work has been completed at both sites to establish a historical framework. Scoping interviews and surveys have also been conducted with key community members to explore the importance of undertaking such a project, how it should be developed, and who should be interviewed. The next steps include: 1) the capture of oral histories using audio and video recordings and personal photographs; 2) the completion of semi-structured interviews using audio recordings; 3) the development with community members of ways to share their histories with a broader audience; and 4) the establishment of an Arizona Superfund site digital repository, library archive and project website. Overall, the study will inform the fields of environmental literacy, environmental justice, and risk perception by analyzing the real-world experiences of those residing near toxic pollution.
As the scale of society has increased, so too has the need for expanding scientific research. To face this problem, scientists have begun to recruit citizens to help with project design, sample collection, and data analysis. Community based participatory research (CBPR), or citizen science as it is now coined, has enabled scientific research to expand its horizons of possibility. Citizen science encompasses several different participation models including: contractual, contributory, collaborative, co-creation, and collegial. These models serve as the basis for how scientists and citizens interact and help to identify the potential ethical dilemmas that arise with citizen participation. In present day, there are laws, institutional guidelines, and standard practices to protect citizens opting-in to participate in scientific research. Unfortunately, this was not always the case, and the numerous unethical case studies throughout the 19th and 20th century, such as the Tuskegee Syphilis Study and the U.S WWII Gas Experiments, stand testament to that. Many of the ethical concerns of CBPR have stayed in the past as it has emerged into the 21st century as citizen science, but not all of them. Most notably, consent and conflicts of interest pose just as much, if not even an even bigger threat in today’s changing society. Corporations have more clout and money to fund research for their own products. Scientists want to enroll citizens in studies who do not have the capacity to consent. In addition, privacy in the digital age has become increasingly difficult to deal with. Today, citizen science has become a valuable tool for researchers and institutions. Understanding how to navigate these ethical concerns will become critical to its successful implementation.
Soil microbial responses to seasonal precipitation dynamics in two adjacent sub-alpine catchments in northern New Mexico

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Forest catchments are important carbon sinks in the southwestern United States and are sensitive to changes in precipitation and fire disturbance. The responses of soil microbial communities and the enzymes that dictate the transformation of nutrients such as carbon (C), nitrogen (N), and phosphorus (P) have important implications for the functioning of these vital ecosystems. The goal of this study is to observe trends in soil microbial dynamics over spatial and temporal scales at the Jemez River Basin Critical Zone Observatory (JRB CZO) located in northern New Mexico. This study is part of a larger group of nationwide CZO efforts that aim to investigate the interactions between multiple components of the critical zone, defined as the area from bedrock to the top of vegetation canopy. We examined soil microbial response patterns in relation to precipitation pulse inputs in a post-fire disturbed landscape. Soils were collected during peak snowmelt, before, during and post-monsoon to test seasonal control over extracellular enzyme activity (EEA). Samples were collected from 12 sites from a north and south facing catchment across a topographic transect from surface (0-10 cm) and deep (30-40 cm) soil profiles. Samples taken from the south facing catchment were co-located with high temporal resolution CO2, O2, redox (platinum electrode) and temperature probes allowing us to examine the importance of pulse precipitation events on microbial activity and soil gas flux. Potential activities of seven hydrolytic enzymes were measured using established fluorometric techniques. Four of these enzymes hydrolyze C-rich substrates (β-glucosidase [BG], β-D-cellubiosidase [CB], xylosidase [XYL], and α-glucosidase [AG]), two hydrolyze N-rich substrates (N-acetyl-β-glucosaminidase [NAG] and leucine aminopeptidase [LAP]), and one hydrolyzes a P-rich substrate (acid phosphatase [PHOS]). The resulting fluorescence was measured on a fluorometer (Biotek Synergy 4, Winooski, VT, USA) set at 360 nm excitation and 450 nm emission. In addition, we collected gravimetric water content data and total organic content (TOC). Results show shifts in microbial nutrient acquisition strategies with
greater resources being put out towards acquiring N relative to C in summer growing season. Further, results show greater CO2 gas flux in the convergent depositional zones of the landscape occurring at deeper depths with simultaneous oxygen consumption. Enzyme activity measurements seem more sensitive to shifts in belowground nutrient inputs co-occurring with growing season and do not reflect precipitation pulse dynamics. Follow up work will target shifts and community functionality with fluctuating redox status.
Wildfire represents a disturbance that is becoming more prevalent as climate shifts to hotter and drier conditions in the southwestern US. It has profound and potentially long-term effects on the physical, chemical and microbiological properties of soil, including immediate surface deposition of lithogenic elements and incompletely combusted organic matter (i.e., black carbon or BC) previously held in biomass. The long residence time of BC mitigates oxidative release of carbon to the atmosphere and thus has implications for long-term climate forcing. Immediately following the 2013 Thompson Ridge wildfire in the Jemez River Basin Critical Zone Observatory, we sampled 22 soil profiles across a zero order basin at finely resolved depth intervals to 40 cm. Samples were collected again 12 and 24 months following the fire to assess redistribution of solutes and BC in the two years following fire. Water extractable anions, cations and carbon were measured for each sample and maps were generated by geostatistical interpolation. Additionally, the benzene polycarboxylic acid (BPCA) molecular marker method was employed for a selection of samples to quantify and characterize the BC content of the existing soil organic carbon pool as a function of landscape position and time. The ‘pulsed’ deposition of water-soluble ions and BC followed pre-fire vegetation structure as indicated by solution chemistry data for years one and two displaying elevated solute concentrations in surface depths proximal to dense vegetation. Vertical and lateral redistribution of the water extractable elements and BC were consistent with wetting front propagation and topographic trends (driven by erosion, overland flow and lateral subsurface flow). BC depth profiles indicate vertical infiltration and lateral transport with burial, the latter associated with surface erosion of sediment, as mechanisms for redistribution.
Soil organic carbon (SOC) sequestration has emerged as one of the best options for mitigating and adapting to global climate change. Soil contains more carbon than plants and the atmosphere combined, and there may be potential to store even more SOC with improved land management. For ecosystems in arid climates, SOC has the added benefit of increasing soil water retention, which could help alleviate plant water stress in the future as rainfall patterns continue to become more irregular. Because plant production is limited in arid ecosystems, compost from cities and industry is a possible large-scale source of organic carbon for soils, which has co-benefits for diverting waste from landfills and therefore promoting sustainability. Compost application has been shown to enhance SOC stabilization in wetter climates, but in arid regions like southern Arizona, compost application has not been examined. As a first step in determining the suitability of local compost sources for SOC stabilization, our objective was to determine, under irregular moisture conditions and hot temperatures, which sources of compost near Tucson emit the least amount of greenhouse gases. Otherwise, adding compost might actually accelerate global warming. We measured a total of 7 gases including carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) from four local composts that were generated from manure, food waste, pecan shells, and landscaping woody waste. The composts were applied to two local soils: a young sandy soil and old clay-rich soil. We found that all types of compost emitted slightly larger amounts of CO₂ after the initial wetting event, and then rates decreased to near baseline levels. The other measured gases varied by compost type. In addition, the older soil emitted less CO₂ than the young soil before wetting regardless of compost type. However, after the initial wetting, CO₂ emission in the old soil outpaced the young soil. These findings suggest that soil physical properties, compost ingredients, and climatic conditions impact the carbon sequestration potential of soil organic amendments.
Impact of soil contaminants on the viability and production of plant root border cells: Implications for phytoremediation.

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Most plant species produce specialized border cell populations programmed to disperse from the root tip into the external environment. Like neutrophil extracellular traps (NETs) in animals, an extracellular DNA-based matrix produced by border cells traps pathogens and toxic metals to prevent infection and injury. Previous studies showed that border cells of pea and snapbean trap aluminum rapidly and thereby prevent uptake into the growing root. Subsequent studies also documented border cell extracellular trapping of arsenic, cadmium, lead, and other contaminants. Our preliminary results revealed that border cells from a single corn or cotton root can remove up to 83% of 1.0 mM lead from a 1-ml sample during a 1-hour period of incubation. However, no significant uptake of silicon from the liquid surrounding border cells has been detected. Why this variation occurs is not clear. Studying the effect of toxic metals on border cell production will generate insights that may help to define the mechanisms and limitations of metal trapping by border cells, and thereby offer new avenues to improve the efficiency of phytoremediation.
Revegetation of Mine Waste Rock Slopes: Influence of pH and Bioavailable Phosphorus
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Waste rock piles consist of rock containing target minerals in concentrations too low for economic recovery and are a major waste stream left over from the mining process. Regulations often require revegetation of these piles prior to mine closure; most of which are not conducive to plant growth due to poor water holding capacity, lack of available nutrients, or deviations from an optimum pH for plant growth. These factors are especially limiting to vegetation in semiarid environments where water is not readily available.

This study evaluated parameters influencing reclamation success using four consecutive years of data from two hydroseeded waste-rock slopes compared to an unseeded slope at the Carlota Copper Mine in Miami, Arizona. Undisturbed off-site areas were used as a standard for a natural environment. Parameters used to evaluate success of plant establishment included substrate pH, electrical conductivity, plant cover, and plant species composition. Substrate alkalinity has been shown to limit the bioavailability of phosphorus, an essential plant growth nutrient. Thus, bioavailable phosphorus was measured on the slopes to determine if substrate pH affects phosphorus bioavailability.

The results indicate that the pH decreased over the four years for both the hydroseeded and unseeded slopes, whereas no significant difference was observed in the off-site areas. A strong negative correlation between the pH of the slopes and plant cover was observed. However, there were no significant differences in the decrease in pH over the four years between the hydroseeded and non-seeded slopes. This indicates that weathering alone may be driving the decrease. Analysis of electrical conductivity showed that all values were below the salinity threshold. The influence of substrate pH on bioavailable phosphorus was also reported for all slopes.
Public participation in science research or citizen science (CS) projects are primarily being organized as a means to increase a participant's scientific literacy, to collect field data to monitor a variety of environmental conditions, and as a framework to support and enhance decision-making in modern society. CS governance models range from scientist-driven research projects with moderate community engagement to ‘crowd-sourcing’ initiatives to ‘co-created’ projects that are community-driven and address their own research needs. CS projects can be divided into five governance models that differ by level of public participation: contractual, contributory, collaborative, co-created, and collegial. Though CS is a powerful tool for connecting people to science, unfortunately historically underrepresented groups in science are still missing from CS initiatives and this may be due to the misalignment of research and education goals with community priorities. Experience and research shows that the questions asked, partnership type, and research approach used are important elements in reaching ethnically diverse community groups. Asking questions that fail to address community concerns and using methods that dismiss public participation can perpetuate the separation between professional scientists and members of the public, especially those who are disenfranchised. Here, it is hypothesized that more collaborative, co-created and collegial CS projects will have a higher number of underrepresented individuals than contractual or contributory-type projects. To test this hypothesis, a literature review is underway and a survey will be administered to CS project managers globally and completed on behalf of their respective participants. The survey asks for the number of individuals who fall under certain categories, such as, but not limited to; ethnicity, gender, regional distribution of participants, and education level. This survey will be given through Qualtrics, an online survey dissemination tool and will be administered through the U.S. CS Association’s Inclusion, Diversity, and Equity
Group. The survey data will be combined with the socio-demographic distributions found in literature. We anticipate that CS projects that have more participant participation throughout the steps of the scientific process, will also have a greater percentage of historically underrepresented and underserved community members.
Correlating Belowground Microbial Community Capacity with Stability during Reclamation of Marginal Lands

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Plant-microbe interactions are important contributors to ecosystem sustainability in semi-arid to arid landscapes and may inform management practices for the recovery of degraded lands. The belowground microbial communities of semi-arid and arid ecosystems are less robust than those of temperate climates and thus more vulnerable to environmental stress and anthropogenic disturbance. Study of the microbial changes that accompany ecosystem degradation during the transition from semi-arid to arid landscapes may provide critical insights applicable to the reclamation of marginal lands, such as those compromised by mining activities. The specific aim of this research is to evaluate soil properties that correlate with progress in revegetation of marginal lands. Properties evaluated include pH, electrical conductivity, total nitrogen and biomass. In future work, these metrics will be compared to undisturbed soils to evaluate the status of the respective belowground microbial communities. The comparison of an undisturbed sustainable semi-arid and arid microbial community to that of a disturbed microbial community from different stages of site reclamation can improve understanding of the significance of the microbial community to reclamation success.
Fresh produce demand has increased over the years which also increases the demand for irrigation water. Many produce farms use irrigation canal waters as well as the runoff water from the field and recycle it back onto the produce fields. In Arizona return flows are not currently used and are collected in drainage canals; however, this could change in the future. The purpose of this research was to evaluate the microbial and general water quality in canal water in comparison to this drainage water which could potentially be used for return flow. Irrigation canal and drainage samples were collected during the growing season and non-growing season in Southern Arizona and were then evaluated for microbial content and for general water quality parameters. There was a significant difference where conductivity, salinity and total dissolved solids were twice as high in return flow waters. In addition, higher levels of total coliforms and Escherichia coli were found in the return flow waters. Salmonella species were found in both water types, but with a higher occurrence in return flow water (14.2%) than primary irrigation canals (10.8%). These drainage (return flow) waters could therefore potentially be used to irrigate food crops in the future, but farmers would need to monitor the quality more frequently and possibly take further steps such as water treatment or allowing more time for microbial die-off between the last irrigation event and harvest to ensure the safety of food crops.
Struvite as P fertilizer source for irrigated vegetables on calcareous soils
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Struvite derived from a proprietary fluidized bed reactor system that recovers ammonia and phosphate from nutrient rich waste streams, is a granule-like based P fertilizer marketed as “Crystal Green®”. However, little was known about the efficacy of this product as a P source on calcareous soils of the southwestern United States. We initiated field experiments on calcareous soils of Arizona and California to evaluate the responses of vegetable crops to Crystal Green (CG) in comparison to conventional P fertilizers. Iceberg lettuce (Lactuca sativa), carrot (Daucus carota sativus), onions (Allium cepa) and potato (Solanum tuberosum) were test crops. Treatments included comparisons of CG, triple superphosphate (TSP), mono-ammonium phosphate (MAP) alone, in physical blends of CG and MAP, or co-granulated formulations of CG and MAP applied at rates between 0 and 140 kg P/ha. Overall, CG compared favorably to TSP but not to MAP when applied as a sole source. However, certain blends or co-granulated formulations of MAP and CG often provided superior yields than MAP alone. Using CG as P source for vegetables as a sole source or in concomitance with conventional P fertilizers is a viable P management strategy on calcareous soils. Struvite may serve as an environmentally sound alternative to the readily soluble P fertilizers. One outstanding issue for economic viability may be the current higher cost of CG compared to conventional P sources derived from mined phosphate.
Perfluorooctanesulfonic acid (PFOS) is one chemical of many that are classified as per- and poly-fluorinated alkyl substances (PFAS). These compounds are of concern because of their persistent nature, widespread contamination, and potential risks to human health. Their persistence in the environment results from the presence of strong carbon-fluorine bonds that are resistant to chemical and biological transformation. PFAS have been widely used for their nonstick and stain, grease, and water-resistant properties. They have been used in many household products, including cookware, clothing, furniture, and food packaging. PFAS are present at many Department of Defense (DOD) sites, where PFAS-containing fire-fighting foam was used for training purposes. These compounds may also be found at industrial sites or airports. PFOS, along with perfluorooctanoic acid (PFOA), is one of the primary PFAS of concern, as it has a long history of use and has been observed at many sites. In 2016 the Environmental Protection Agency (EPA) issued a lifetime health advisory of 0.07 µg/L for PFOS and PFOA combined. Many people in the U.S. are supplied with drinking water that exceeds this advisory. The objective of this project is to improve our understanding of the processes that mediate the transport and attenuation of PFOS and PFOA in subsurface systems. Experiments are being conducted with water-saturated columns packed with natural porous media to characterize retardation processes of PFOS. Sorption processes of PFAS compounds are impacted by subsurface conditions, including geochemical properties of the porous media, physical and chemical properties of the contaminant, and water chemistry characteristics. Experiments will be conducted to evaluate how transport and fate behavior of PFOS changes with varying subsurface conditions, including the presence of multiple PFAS compounds and the presence of immiscible liquids such as chlorinated solvents and hydrocarbon fuels, which often co-occur at PFAS-contaminated sites. Characterizing these conditions will help increase understanding of PFOS behavior in real sites with complicated and heterogeneous conditions.
Investigating emerging organic contaminants in harvested rainwater via Co-Created Citizen Science: What is in your rainwater?

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Today, about 40% of the global population lives in arid and semi-arid environments. In these geographic areas, water scarcity concerns are common. Rainwater harvesting has been used as a water conservation measure, particularly where other water resources are scarce. As water scarcity increases steadily, we search for alternatives to conserve and collect water. Harvested rainwater (HRW) is one possible alternative to address this global issue. In arid climates like the Sonoran Desert, HRW can provide a vital component of water resources. National water quality standards for both potable and non-potable domestic usages are yet to be determined as HRW is a quite new developing practice worldwide. Project Harvest (PH) is a citizen scientist driven program that teaches communities across the state of Arizona the scientific method. Over a course of three years, participants will collect rooftop HRW samples and send them to be analyzed for bacteria, organic and inorganic contaminants at University of Arizona by our team of scientists. PH addresses water conservation and environmental education in underserved communities. Herein the organic chemistry aspect of this project is described including HRW sample collection, preparation, and analytical method development. We aim to investigate the presence of thirty target analyte chemicals in HRW by applying high-resolution liquid chromatography-tandem mass spectrometry (HRLC-MSMS).
Particles: Where they are, Where they are going, How they are made, What they do…

*A collaborative mindmap project of the students in ENVS/CHEE 572 – Interfacial Chemistry of Biomolecules in Environmental Systems*

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A mindmap was created collaboratively and simultaneously as a class project to explore the topic of particles. It was created as a class project in a relatively short period of time (a number of hours). Student-led questions guide each thought strand. The mindmap is created using Mindomo, an intuitively accessible mind mapping software program. Using “Nanoparticle Aggregation: Challenges to Understanding Transport and Reactivity in the Environment” (2010) as a student chosen starting point, all aspects of nanoparticles become open to questions. How do nanoparticle properties influence their reactions and transport in the environment? The attempt to model these effects in lab experiments are in progress around the world. The shape, size, charge, composition, and concentration of particles will have a role in how they react. Additionally, the properties of the suspension and its components will affect the reactivity (e.g. ionic strength). Did you know nanoparticles can be coated to change the surface properties? Nanoparticles can aggregate or disperse, depending on their surrounding environment. The range of nanoparticle applications include drug delivery, bioimaging, tissue replacement, and electronics. Novel types of particles include core/shell composites and quantum dots. In later stages of mindmap development the links between topics emerged. The software tool easily and seamlessly allows true collaboration.
Aquatic and riparian ecosystems are valuable and critical in arid environments, supporting a diverse suite of resident and migratory species over different life stages. Ecological connectivity is an important property in the functioning of these ecosystems, and a significant subject of interest for researchers, managers, practitioners and other stakeholders. Furthermore, a variety of perceptions exists on aquatic and riparian connectivity among stakeholders, and connectivity of aquatic and riparian ecosystems in arid landscapes is a relatively unexplored subject. We focused on these questions in the US portion of the Madrean archipelago, using a combination of quantitative spatial analysis and qualitative methods, to capture the diversity of perspectives on aquatic and riparian connectivity among experts. We synthesized these perspectives into a connectivity framework that deconstructs aquatic and riparian connectivity in arid landscapes into connectivity components and their dimensions. We applied this framework to a case study of the threatened Chiricahua leopard frog (*Rana chiricahuensis*) in the Cienega Creek basin in Arizona. Using regression analysis and GIS, we created connectivity indices for the focal species based on variables identified in the regression analysis. This connectivity framework and the related indices provide customizable options for stakeholders to assess aquatic and riparian connectivity multidimensionally using readily available data. These tools can be used by stakeholders for exploratory analysis, assessment and visualization of aquatic and riparian connectivity, especially in arid landscapes.
Earlier springs are occurring at different rates across the northern hemisphere, due to shifts in jet stream position: high-speed winds traveling from West to East about the height airplanes fly. Besides influencing flight times, jet stream position characterizes surface temperatures and precipitation levels. The jet stream interacts with the land surface to influence how long weather stays in place—with implications from changing plant growth and harvest dates to hurricane intensity. Most research on the jet stream focuses on the winter months, however, jet stream and vegetation interactions occur over multiple seasons. In Belmecheri et al. (2017), we established that poleward (equatorward) spring jet stream position over the western US correlates strongly with earlier (later) modeled spring onset (Schwartz et al. 2013).

Here, we present differences between modeled spring onset and satellite-observed spring onset (Didan and Barreto, 2016), and their spatial correlation with the position of the spring jet stream. Modeled spring onset—based on temperature—show more spatially cohesive correlations than the finer resolved satellite-observations. Beyond potential limitations of each dataset over the Rocky Mountains, slight spatial correlation discrepancies may be highlighting lower-elevation phenoregions that are water dependent, detectable only at finer spatial resolutions. We show that robust understanding of regional jet stream-vegetation interactions requires the use of multiple spatial resolutions and metrics.
Differential Impacts of Passive versus Active Irrigation on Semiarid Urban Forests

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Urban forests provide benefits such as heat island reduction and carbon uptake. However, the need to irrigate trees in dryland regions presents a tradeoff between ecosystem services and water scarcity. Infiltrating stormwater runoff has become common in dryland communities as a sustainable water source for trees, but the performance of this ‘passive irrigation’ versus active irrigation is largely unknown or unquantified. We assessed the ecohydrology of urban forest systems in semiarid Tucson, AZ under these contrasting irrigation regimes. Focused on responses of dryland-adapted mesquite trees (Prosopis spp), measurements included micrometeorology, soil moisture, stem sap flow, canopy greenness, and leaf-area index. We expected both irrigation types to provide additional deep soil moisture (>20 cm) compared to natural conditions, and that urban trees would be dependent on this deep soil moisture for transpiration and phenological activity. Current results show that urban mesquite trees respond to increases in deep soil moisture via increased sap flow and greenness. We have also observed differences in seasonal greenness between passively and actively irrigated mesquites. Active mesquites exhibited prolonged greenness in the early growing season and a modest response to the monsoon rainy season; passively irrigated trees were more strongly coupled to precipitation inputs. This research aims to contribute empirical observations of green infrastructure performance and improved understanding of urban forest function and water conservation tradeoffs.
Seed balls are an ancient method of sowing seed, especially in areas with compacted or dry soils. This method encapsulates seed in a substrate that will potentially reduce predation by insects and rodents while allowing for increased water retention and seed-soil contact. Seed balls often combine three components: seed, clay, and nutrient-rich organic matter such as compost or humus. Seed balls are strewn in the desired location and remain inactive until heavy rains arrive, washing away the clay and allowing the seeds to germinate. This method of sowing seeds does not require any tilling or soil preparation, desirable aspects for restoration work, urban planting and sustainable farming practices. It is also cheap and relies on a few simple components which can be attained just about anywhere in the world. However, making seed balls by hand is extremely time consuming and often requires a large group of volunteers. To make large amounts of seed balls in a reasonable amount of time, we constructed a bicycle-powered seed pelletizing machine that effectively coats seed in clay and compost materials. The bicycle spins a barrel containing the seeds and coating materials while the operators periodically mist the contents with water. The result is coated seed balls that can be used in a desired area. This poster details how to make and operate the seed pelletizing machine for use in gardening or revegetation projects.
Knowledge of ecological and behavioral processes are essential for the conservation of species at risk of extinction. Approximately one third of all amphibian species are threatened or endangered, and those with limited distribution or population size are particularly vulnerable. To develop effective conservation strategies for at-risk amphibians, managers need to understand their ecological requirements. The Sonoran tiger salamander (STS; *Ambystoma mavortium stebbinsi*) is a federally endangered subspecies found only in the San Rafael Valley of southeastern Arizona and northern Sonora, Mexico. The STS was listed as endangered in 1997 due to highly restricted distribution, dependence on human-constructed environments, invasive species, genetic swamping by non-native salamanders, and disease. Cattle tanks created by ranchers to hold water have taken the place of natural springs in the area, and are now primary breeding sites for STS. The terrestrial life stage is the only means of responding to pond drying or die-offs and thus is critical to the maintenance of population dynamics. However, the ecology of metamorphosed salamanders outside of breeding tanks is virtually unknown. We are using radio-telemetry to assess STS terrestrial movement patterns, habitat preferences, and life history traits. Preliminary movement metrics, and home-range data will be presented. Spatial information is important for wildlife managers to develop effective management strategies to conserve the Sonoran tiger salamander and other isolated amphibians.
Acoustic Investigation of a Southern Arizona Bat Roost
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In a time of shrinking budgets, there is an increasing need for information to instruct the allocation of limited resources to provide the maximum benefit to wildlife. To guide management decisions, we used full-spectrum passive ultrasonic acoustic recorders to assess bat species diversity and potential vulnerability in an abandoned mine complex in the Las Guijas Mountains in southern Arizona. Recordings took place during summer, fall, and winter between May 2015 and August 2016. We monitored the main mine entrance and a nearby side shaft with ultrasonic passive recorder. Exiting bats were recorded for two hours starting at sunset, and datasets were processed using Sonobat 3. Five species were documented using the main mine: Myotis velifer, M. thysanodes, Antrozous pallidus, Corynorhinus townsendii, and Tadarida brasiliensis. Myotis velifer, M. thysanodes, and Parastrellus hesperus were detected utilizing the side shaft. Both M. velifer and M. thysanodes inhabit the mine year-round. The high numbers of exiting individuals and numerous M. velifer calls coupled with prior observations of pregnant and lactating females suggests that this is a maternity roost for this species. Because of the possibility of disrupting the maternity roost we decided a bat gate would not be appropriate for the site and a fence will be installed instead. This project demonstrates that the use of non-invasive acoustic sampling to inform project planning can minimize negative effects on local bat species and would be a valuable addition as a standard pre-planning activity.
Resilience and the potential for species distribution shifts under the effects of climate change is a pressing concern for forests. The effects of increasing temperature and changing precipitation patterns are compounded by the legacy of disturbance and altered fire regimes, which gives us the forest present on the landscape today and the likelihood of future changes. We considered how climate variation influences tree ring growth in a mixed conifer forest in northern New Mexico. We studied tree growth responses along a biophysical gradient in a watershed that spans from near the lower to upper elevation range for two species, ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). We combined this response with stand dynamics and regeneration patterns of the six major tree species found in the study area to predict species shifts in dominance within the watershed and the potential for future climate-driven mortality. Tree-rings integrate climate and limited resources into a time series of growth that can be related to many factors influencing forest dynamics. To analyze growth, we split 1040 trees from 58 sites into groups using CART analysis driven by elevation and aspect. We examined whether species-specific mean tree-ring series by group were better modeled by PRISM-derived temperature or precipitation metrics using AIC model selection, and applied the findings using GIS to show the areas across the watershed that fit each climate-growth model. We found changes in species distribution between mature trees and seedlings across the elevation-aspect groups, notably increases in pinyon pine (*Pinus edulis*) and white fir (*Abies concolor*) while ponderosa pine made up a smaller percentage of seedlings relative to mature trees. New tree establishment was concentrated in mid-elevation southwest sites, reflecting a combination of microclimatic optima and available resources. Considering past tree growth, we found differences in models selected across species and elevation-aspect groups; for example, on southwest slopes at lower elevation Douglas-fir ring growth responded to precipitation while ponderosa pine in the same group responded primarily to maximum temperature. Ring growth in both species was modeled best by temperature at northeast sites at low elevation and southwest sites at mid elevation,
and by precipitation at northeast sites at mid elevations and at high elevations. Differences in modeled climatic drivers indicate species-specific stressors on tree growth at the lower elevational limits of species distribution, which has implications for species-level resilience with differential establishment and survival across a given range, under future conditions.
Remote sensing observations and eddy covariance measurements are both widely used in ecology to improve understanding of biosphere-atmosphere-hydrosphere interactions across scales and in various ecosystems. Continuous measurements from flux towers facilitate exploration of the exchange of carbon dioxide, water and energy between the land surface and the atmosphere at fine temporal and spatial scales, while satellite observations can fill in the large spatial gaps of in-situ measurements and provide long-term temporal continuity. Here we demonstrate a machine learning approach to upscale ecosystem-scale carbon flux estimates to the Southwest (SW U.S and NW Mexico) regional scale using remotely sensed and gridded meteorological inputs. Our upscaling method leverages the strengths of both the satellite and flux data, producing spatially and temporally continuous high-resolution estimates of Gross Primary Productivity (GPP). We focus here on water-limited ecosystems, which have been shown to disproportionately impact variability in the global terrestrial carbon sink. Existing upscaled flux products are sparsely informed by water-limited ecosystem measurements. Our machine learning approach was designed specifically for semi-arid ecosystems: with explicit consideration for the impacts of the water balance and drought on carbon dynamics, and validation procedures that assess both interannual and seasonal variability in vegetation carbon uptake. Our spatially and temporally continuous upscaled GPP product help us understand linkages between the carbon and water cycles in semi-arid ecosystems and informs predictions of vegetation response to future climate conditions. By including a multi-scalar drought index (SPEI; Standardized Precipitation Evapotranspiration Index) at multiple timescales as a predictor in our machine learning models, we captured the response of vegetation to short-term drought, seasonal water availability, and interannual precipitation variability. We found that our 1km spatial resolution was necessary to accurately quantify drought impacts on carbon uptake in the Southwest due to spatially heterogeneity in vegetation and topography. Our product improves on existing globally upscaled
products, which do not generally perform well in semi-arid regions. Our machine-learning approach using moderate-resolution (i.e. 1km) satellite and meteorological inputs combines ground measurements of carbon fluxes and spaceborne estimates of vegetation productivity to produce continuous estimates of GPP through space and time that reflect semi-arid ecosystem dynamics. Machine learning approaches can bridge ground and spaceborne observations, with potential applications to improve estimates of ecosystem processes across spatial and temporal scales.
Biophysical and Vegetative Controls on Soil Carbon Dioxide Efflux in the
Semiarid Southwest U.S.
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Soil efflux of carbon dioxide (CO2) is a major component of total ecosystem respiration, which strongly influences the carbon dynamics of ecosystems. Increased understanding of the controls on soil efflux in water-limited regions could lead to improved predictions of carbon emissions from semiarid ecosystems, which have been shown to influence the interannual variability of the terrestrial carbon sink. When not limited by other factors, soil efflux is often assumed to increase exponentially with temperature. However, in water-limited ecosystems, dynamics in water availability and vegetation activity associated with pulsed precipitation events may complicate the temperature response of soil efflux. Here we combine automated soil chamber and flux tower data in the southwest U.S. to investigate the role of soil temperature, soil moisture, and ecosystem photosynthesis on soil efflux from multiple semiarid sites with contrasting vegetation type and carbon inputs. Data were collected in 2012 from Lucky Hills (Ameriflux site US-Whs; Chihuahuan Desert shrubland), where comparisons were made between soil chambers adjacent to shrubs and those in bare, inter-canopy space. During 2016-2017, soil chambers were deployed next to grass patches at Kendall Grassland (Ameriflux site US-Wkg; warm season grassland). For the 2017 growing season at Kendall Grassland, we added a root-exclusion experiment by placing additional soil chambers in bare, weeded plots with trenched perimeters. Preliminary results indicate that soil moisture strongly regulated the temperature sensitivity and magnitude of soil efflux. We also found that during the growing season, total soil efflux was greater for sites with higher cumulative ecosystem photosynthesis. When moisture was ample, baseline soil efflux (Rbase) at the grassland was greater for grass plots (Rbase = 0.38 µmol CO2 m-2 s-1; 95% CI: 0.32-0.44), relative to bare soil (Rbase = 0.18 µmol CO2 m-2 s-1; 95% CI: 0.15-0.20), while for the shrubland, Rbase was greater for shrub plots (Rbase = 0.85 µmol CO2 m-2 s-1; 95% CI: 0.64-1.06) than bare soil (Rbase = 0.22 µmol CO2 m-2 s-1; 95% CI: 0.16-0.28). Total soil efflux was 59% and 39% greater for vegetated plots than bare plots at the grassland and shrubland sites, respectively, highlighting the effect of vegetation activity on soil efflux. Accounting for the
effects of soil moisture and vegetation improved model performance and the prediction of temporal dynamics in soil efflux (adj.R2 = 0.86), relative to a model based solely on soil temperature (adj.R2 = 0.20). Together, these findings highlight the importance of moisture and vegetative controls on soil efflux in semiarid ecosystems. These results suggest potential changes in the carbon dynamics of southwest US ecosystems in response to changes in soil moisture and vegetation composition associated with changes in climate and/or land use.
Adaptive management (AM) theory is a popular management and conservation tool favored by many land managers and scientists. Its influence is widely observed in the policies and goals of many federal land management agencies. Rangeland management in the west is no exception. AM has been proposed for use in grazing management because it recognizes that rangelands are not static. AM allows land managers to respond to unexpected environmental stressors, such as drought, by adjusting the intensity, season, or duration of grazing. Despite its widespread adoption in policy, implementing AM on the ground has proven to be a difficult task. We hypothesize that some of this difficulty stems from a misunderstanding of what practices are consistent with AM and because of an under-emphasis on the different approaches to AM, ranging from passive (informed by best practices; includes monitoring, reflection and incorporating learning into management) to active (focused on learning and hypothesis testing; emphasizes formulation and testing of hypotheses, and incorporates knowledge and experiences from a wide range of stakeholders; embraces interdisciplinarity and complexity). This research presents a thorough review of AM implementation on rangelands in theory and practice. Through this review, we have compiled all available literature on AM practices used in rangeland management, evaluated the characteristics of typical AM approaches, and proposed an *adaptive management rubric* for use in assessing the presence or absence and qualities of AM in management documents. This review and AM rubric can be used in determining the degree to which AM is being implemented in rangeland management and other natural resources management settings and contributes to efforts to evaluate the efficiency and efficacy of institutionally mandated AM policies.
Small Mammalian Herbivores Inhibit Grass Establishment in an Arid Shrubland

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Shrub encroachment in southwestern grasslands has negatively impacted ranching, soil conservation, and grassland dependent species. Past research suggested that a complex interaction between grazing, altered fire regimes, and changing climates maintained shrublands once they established. Understanding the ecological interactions that maintain shrub dominance is critical for grassland restoration efforts to be successful. To assess the impact of native herbivores on grass reestablishment in an arid shrubland, we established an herbivore exclosure experiment on a 10.92 ha parcel on the USDA-ARS Walnut Gulch Experimental Watershed near Tombstone, Arizona. Cattle were removed from the site over 50 years ago, yet the intershrub areas remain devoid of an herbaceous layer. We hypothesized that at this site, herbivory pressure of native mammals is significant enough to suppress the reestablishment of an herbaceous strata, which provides a positive feedback for the continued displacement of grasslands by native shrubs. We constructed herbivore exclosures with 5 treatment levels which corresponded to herbivory pressure among size classes of mammalian herbivores. The levels were: small (e.g. kangaroo rats [Dipodomys merriami]), medium (e.g. desert cottontails [Sylvilagus audubonii]), and large (e.g. mule deer [Odocoileus hemionus]). Two control levels (total access and total exclosure) were included as well. We used a two-way repeated measures ANOVA with trial date and exclosure type as our factors, and found a significant difference in grass utilization among exclosure types (F(4,45)=14.38, p<0.001). A Tukey’s post-hoc analysis indicated that utilization was significantly higher in exclosures that allowed access to small and medium sized mammals, relative to our control (p<0.001). This pattern disappeared following the monsoon rains (p=0.96), suggesting that forage demand shifts significantly depending on season. Our results suggest that herbivory pressure from small and medium sized herbivores may impede the reestablishment of grasslands in an arid shrubland.
Novel Photo-ID Approach for Monitoring Population Health and Dynamics of Ganges River Dolphins

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Designing an effective conservation plan for rare, endangered Ganges River dolphins in Nepalese waterways requires a precise understanding of population abundance, social structure, and health conditions. As a part of regular monitoring of this small population, we applied the first ever non-invasive and cost effective photographic identification technologies for Ganges River dolphins following a focal animal sampling approach. We focused on a single group or individual until we collected high quality images, and then moved on to another cohort. We identified seven distinct animals and we observed unique skin lesions, abrasions, and physical injuries in five out of seven individuals. Our results offer support that individuals can be identified and re-captured from photographs, via skins lesions and unique injury marks as references, allowing more accurate estimates for temporal analyses. Moreover, formation of such skin lesions may indicate an association between the presence of skin disease and environmental parameters or anthropogenic factors (e.g., contaminants and pollutants). As skin lesions in wild dolphin populations may indicate the emergence or persistence of infectious disease, using photo-Id data to detect and monitor lesions could facilitate more informed disease surveillance in future. Intense interaction of river dolphin with illegal fisheries gillnets may intensify negative impacts over time for the remaining individuals in the Koshi River system including groups from India. However, more research in these areas is needed to confirm direct anthropogenic impacts. With the threat of extinction exacerbated, it is imperative for wildlife managers to consider extending the extent of the Koshi Tappu Wildlife Reserve to the southern areas below the Koshi Barrage area to preserve this imperiled creature.
Grasslands across the US and globally have experienced marked increases in woody-plant cover. Causes are highly debated and include changes in climatic, grazing, and fire regimes. Investigations have focused on these factors in isolation of each other. Here, we examine how climate-herbivore interactions at the critical establishment phase of the shrub life cycle influences shrub encroachment in semi-arid grasslands where plant recruitment is often presumed to be episodic with respect to precipitation (PPT). We ask the following question: “How do PPT, ant/rodent herbivory, and livestock grazing interact to influence velvet mesquite (*Prosopis velutina*) recruitment?” We test the hypothesis that mesquite recruitment is contingent on the coincidence of high PPT, livestock grazing, and lows in rodent/ant populations. Automated Rainfall Manipulation Systems (ARMS) manipulated PPT, wherein 10 plots received +65% ambient PPT, 10 received -65% ambient PPT, and 10 received ambient PPT. Half of each plot was clipped to simulate heavy ungulate grazing; the remaining half was unclipped. Exclusion treatments (None, Rodents, Ants, Rodents+Ants) were installed within each PPT x Grazed combination. Mesquite seeds (n=5) were placed within each treatment combination in July 2017. Seedling recruitment and herbivory were recorded daily for the first four days, then weekly through September 2017. Precipitation and herbivore exclusion significantly ($p \leq 0.0003$) impacted velvet mesquite seedling recruitment ($F_{23, 240} = 2.62; p = 0.0001$), but simulated ungulate grazing of grasses did not ($p = 0.26$). Recruitment on drought (-65% ambient) treatments (mean ± SE) was significantly ($p < 0.005$) lower than that on +65% ambient and ambient treatments (45.4 ± 1.6% vs. 54.4 ± 2.2% vs. 55.6 ± 2.2%, respectively). Herbivory on seedlings was lowest under drought conditions (18.3 ± 1.5%, $p < 0.005$) and highest under wetter/supplemented conditions (25.9 ± 1.9%). Recruitment declined 67% over the 2.5-month observation period. Highest
levels of seedling herbivory occurred during wetter periods (Jul. 2017) compared to the dry period (Aug.-Sept. 2017). Seedling herbivory was highest on plants accessible to both rodents and ants (39.8 ± 0.8%) compared to one or the other (rodent accessible: 28.4 ± 1.3%; ant accessible: 20.3 ± 0.9%). These preliminary data demonstrate that short-term, monsoonal recruitment of mesquite in grasslands was (i) only modestly reduced by drought with insignificant differences between ambient/wet condition (ii) was not influenced by grass defoliation and (iii) was modestly constrained by rodent/ant herbivory. Collectively, results suggest short-term mesquite recruitment can potentially occur under most PPT-livestock grazing-herbivore combinations.
Remote sensing of vegetation seasonal dynamics
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Rapid climate change in the past half-century has significantly modified vegetation phenology. Lengthening of the growing seasons and shifts in plant development stages have been found around the world. Normalized difference vegetation index (NDVI) has been providing good estimates of these phenology changes for many biomes. However, this index suffers from seasonally changing contamination by shadows, snow, atmosphere, and other canopy backgrounds, non-photosynthetically active plant materials. In addition, it is a challenge for the NDVI to provide an unambiguous index on when actual photosynthesis starts or ends with the weak seasonality of vegetation in evergreen biomes. Complementarily to that, solar-induced fluorescence (SIF) enables to detect vegetation leaf physiology – photosynthesis, the key process for maintaining plant growth and offering the possibility to better monitor the phenological characteristics. An alternative data source for land surface phenology monitoring is vegetation optical depth (VOD), which is derived from microwave remote sensing and insensitive to solar illumination and atmospheric effects. It is an indicator of vegetation water content and above-ground biomass. These last two proxies are expected to avoid several limitations in phenology estimations using NDVI. We accessed to GOME-2, AMSR-E and AMSR2, and Global Inventory Monitoring and Modeling System (GIMMS) databases, employed 2007-2015 SIF, VOD and NDVI, estimated the phenology derivation using the three indices for different biomes globally, and identified the characteristic responses of SIF, VOD and NDVI to inform the vegetation phenology. We found that compared to the other two, SIF derived later start of growing season globally, and earlier end of growing season except in tropical regions; VOD derived the latest end of growing season in most biomes. Furtherly we compared ground GPP data to the three datasets at flux tower sites from 2007 to 2015, and found that the SIF and NDVI can better capture bi-seasonal and weak seasonal signals than the VOD in drylands.
Urban Lizard Ecology on the University of Arizona Campus
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Urban development disrupts wildlife species because, it limits the natural habitats that they once inhabited. It is important to understand how the disruption of a natural habitat due to urban development affects different wildlife species, because strides can then be made to create buildings and areas that still cater to the preservation of that wildlife. An urban population of Desert Spiny Lizards (Sceloporus magister) was studied on the University of Arizona campus. We readily observed S. magister to be abundant at several sites, including in the vicinity of Old Main and Yuma Residence Hall. Lizards were captured using a noose attached to a long, telescoping fishing pole. We weighed, measured, determined sex, and obtained temperature and humidity data on all lizards captured. Microchips (PIT-tags) were implanted under the skin of lizards to allow for individual identification. Small, 1.4-gram radio transmitters were attached to the backs of selected lizards, allowing a total of 10 lizards--one female and nine males--to be radio tracked from August to October. Individuals will continue to be monitored throughout the year. Up to six different lizards were radio tracked at a time, with surveys occurring six times per week in the morning, afternoon, and evening. UTM coordinates were recorded using handheld GPS receivers each time a lizard was located. The location data were used to determine activity patterns and home range characteristics, mapping the lizards' movements on Google Earth. On average, the home ranges of the lizards were 1,225.87 square meters, revealing that these lizards do not regularly travel long distances. Our results also indicate that lizards were more active in the summer than in the fall and that the lizards maintain exceedingly small home ranges. Time was also spent observing their behaviors, such as push-ups and head bobs, which are associated with territoriality. We plan to continue this study throughout the winter and the following year to obtain more data on the urban ecology of S. magister.
Phenology has become an ever important aspect of ecology, specifically in terms of the assessment of the effects of climate change. Phenology helps determine if the timing of life cycle stages of organisms has been shifted in relation to seasonal climates, which may result in a phenological mismatch. The National Phenology Network focuses on this studying this mechanism through a multitude of local projects, including the Flowers for Bats Project. This project particularly looks at the timing of the migration of the lesser long-nosed bat species and the flowering times of their forage species. The lesser long-nosed bat females migrate from Mexico to Arizona in order to feed on the nectar of agaves and columnar cacti and give birth to their young. If flowers of these forage species emerge at an earlier time due to changing temperature and precipitation values, the bats may miss their window of foraging upon their arrival in Arizona. NPN is collaborating with the US Fish and Wildlife Service and several parks and national monuments to tackle the question: “Are flowering times being affected by the gradual change in temperature and precipitation?” NPN is currently using the application called Nature’s Notebook to collect observations on the flowering phenophases of Agave palmeri, Agave deserti, Agave parryi, and Carnegiea gigantea. We are looking at phenology data of agaves presently as well as analyzing climate patterns of the saguaro data we have attained through Nature’s Notebook. Although there may not be many datasets on agave phenology, NPN hopes to begin the process of collecting such data. This project will help better the management of the lesser long-nosed bat.
High-Elevation Sierra Nevada Conifers Reveal Increasing Reliance on Snow Water with Changing Climate

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Snowpack in the Sierra Nevada Mountains accounts for around one third of California’s water supply. Melting snow can provide water into dry summer months characteristic of the region’s Mediterranean climate. As climate changes, understanding patterns of snowpack, snowmelt, and biological response are critical in this region of agricultural, recreational, and ecological value. Tree rings can act as proxy records to inform scientists and resource managers of past climate variability where instrumental data is unavailable. Here we investigate relationships between tree rings of high-elevation, snow-adapted conifer trees (\textit{Tsuga mertensiana}, \textit{Abies magnifica}) and April 1\textsuperscript{st} snow-water equivalent (SWE) in the northern Sierra Nevada Mountains. The 1\textsuperscript{st} principal component of 29 highly correlated regional SWE time series was modeled using multiple linear regression of four tree-ring chronologies including two lagged chronologies. Split-period verification analysis of this model revealed poor predictive skill in the early half (1929 – 1966) of the calibration period (1929 – 2003). Further analysis revealed a significant (p < 0.01) change in correlation between the \textit{Tsuga mertensiana} chronology and SWE during early (1929 – 1970) and late (1971 – 2013) periods. Running 31-year correlations between this chronology and SWE rose from $r = 0.10$ in 1950 to $r = 0.77$ in 1996. This strengthening relationship is coincident with a positive trend in temperature, a negative trend in SWE, and increased variability in precipitation through time. Snow water is becoming a more limiting resource to tree growth as average temperatures rise and the hydrologic regime shifts. These results highlight the need for resource managers and policy makers to consider that biological response to climate is not static.
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Strain Drain along the southern San Andreas Fault: Investigating strain transfer using geologic and geodetic observations of the Eastern Transverse Ranges, Joshua Tree National Park, CA

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To better evaluate the distribution and transfer of strain and slip along the Southern San Andreas Fault (SSAF) zone in the northern Coachella valley in southern California, we integrate geological and geodetic observations to test whether strain is being transferred away from the SSAF system towards the Eastern California Shear Zone through microblock rotation of the Eastern Transverse Ranges (ETR). The faults of the ETR consist of five east-west trending left lateral strike slip faults that have measured cumulative offsets of up to 20 km and as low as 1 km. Present kinematic and block models present a variety of slip rate estimates, from as low as zero to as high as 7 mm/yr, suggesting a gap in our understanding of what role these faults play in the larger system. To determine whether present-day block rotation along these faults is contributing to strain transfer in the region, we are applying $^{10}$Be surface exposure dating methods to observed offset channel and alluvial fan deposits in order to estimate fault slip rates along two faults in the ETR. Initial results of site mapping and preliminary $^{10}$Be geochronology (N=7) reveal at least two stages of offset for one site along the Blue Cut Fault, with a preliminary slip rate estimate of 0.5 – 1.75 mm/yr. This geologic slip rate data, combined with our new geodetic surface velocity field derived from updated campaign-based GPS measurements within Joshua Tree National Park will allow us to construct a suite of elastic fault block models to elucidate rates of strain transfer away from the SSAF and how that strain transfer may be affecting the length of time between earthquakes along the SSAF.
Investigation of seismicity and velocity structure of the forearc of the Cascadia Subduction Zone in Central Oregon
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A major event in the evolution of the Cascadia subduction zone involved the accretion of a large igneous province known as Siletzia around 50 Ma onto the west coast of North America. This terrane is thought to extend as far north as Vancouver Island and as far south as Oregon and varies in thickness from 10-32km (Wells et al., 2014). Several studies have argued that deformation, volcanism, and seismicity all focus around the boundaries of this terrane, though these boundaries are not well defined in many areas. In the summer of 2017, a seismic line of 175 nodal seismometers was deployed in central Oregon that extended from the coast to 130 km inland with a station spacing of ~0.5km. In this study, we use this data to investigate the lateral and depth extents of Siletzia using the detection and location of local earthquakes, as well as seismic velocity modeling using travel times from these events. A short-term average, long-term average (STA/LTA) method is used to detect earthquakes recorded by several stations in our arrays (Allen, 1978). Using this method, 50 local earthquakes are detected and then located using the inversion of manual P and S wave travel time picks and the HYPOINVERSE package in SEISAN, a seismic analysis software package (Havskov & Ottemöller, 1999). Preliminary results show that most of these events are occurring within the upper plate (<20km depth) and not at the subduction interface or within the subducting slab. Future work will focus on relocating earthquakes using a double difference method and seismic velocity modeling using P, S, and PmP (Moho reflections) travel time picks.
The Santa Rita Fault is a west-dipping low angle normal fault located near Sahaurita, Arizona, west of the Santa Rita Mountains. Fault scarps in this area indicate that this fault has produced M 6-7 earthquakes during the past 100 kyr, though no events, large or small, have ever been detected by modern seismic instruments (Pearthree and Calvo, 1987). In 2017, 88 5-Hz, 3-component nodal seismometers were deployed over a 10 by 15 km region of the Santa Rita Fault. The instruments were deployed in 11 sub-arrays and continuously recorded for 30 days allowing for a thorough evaluation of the seismic activity on the fault. Data from this deployment is initially analyzed using a short-term average, long-term average (STA/LTA) auto detection algorithm that detects over 300 seismic events that were recorded across the entire array (Allen, 1978). Manual inspection of these events indicates that the majority of them are likely blasts from local mining activities, with 14 events considered as possible earthquakes. Using the program package SEISAN and HYPOINVERSE, manual P- and S-wave travel time picks are made on these 14 events then travel times were inverted for earthquake locations (Havskov and Ottemoller, 1999). All of these events are located in an area directly west of the southern portion of the fault at depths ranging from 0 and 15 km. The estimated horizontal and vertical errors associated with these locations are between 2-10 km and 0-8 km, respectively. Previous seismic reflection work in the northern section of the Santa Rita Fault indicates a westward dip of ~20° (Johnson et al., 1993). Extrapolating this dip to the southern portion of the fault, the preliminary earthquake locations are consistent with an on-or near-fault source for these events, suggesting that the Santa Rita Fault is currently seismically active.
Reconstruction of normal fault blocks in the Ann-Mason and Blue Hill areas, Yerington district, Nevada

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The Yerington district is a classic area of continental extension, having been extended more than 150% by multiple generations of Cenozoic east-dipping normal faults that penetrated a minimum of 8 km depth into the crust, initiated at high angles, and rotated to shallower dips until being locked and cut by younger sets of faults. This study examines the Cenozoic normal faults in the vicinity of the Ann-Mason and Blue Hill areas through detailed mapping of two major faults, logging intervals of drill core containing the fault damage zones, and constructing fault surface maps, i.e., geologic maps of the proximal footwall and hanging wall of faults superimposed on structural contour maps of the fault planes. Six normal faults, representing four geometric sets or temporal generations of faults, are analyzed and described from youngest to oldest in this study, with particular emphasis on the oldest two generations. Fault surface maps constrain their slip vectors and their variability along strike. Faults of the latest three generations strike northerly and dip easterly. Faults of the second generation, which are of middle Miocene age, include the Blue Hill (~2.8 km slip with increasing displacement to the north) and Singatse (3.7 km slip) faults. These second-generation faults have damage zones that persist ~15 m on either side of the fault and have hanging-wall splays that merge into the main fault surface. The first generation faults are represented by the 1A fault, which is one of a series of sub-parallel, generally small-offset faults that presently strike southeast and dip steeply to the southwest. Analysis of drill hole data indicates that the 1A fault, which might have the most amount of slip of any fault in the set, has ~230 m of apparent sinistral separation. The incremental untilting of the three later generations of faults restores the 1A fault to a steeply south-dipping fault with normal, dip-slip displacement. The 1A fault appears to connect with a fault that is exposed at the surface west of the area of drill hole constraints and cuts the Weed Heights member of the Mickey Pass Tuff (27 Ma) and is cut by the middle Miocene Singatse fault, bracketing its timing.

The structural contour maps reveal new insights into the subsurface geometry of several faults. The Blue Hill fault presently dips ~22° southeast along the northwestern side of a mullion in the fault plane. A stepwise reconstruction indicates
that all faults had initial dips of $\geq 60^\circ$, with the Singatse initiating at 73°. The significance of the first generation of faults at Yerington, though poorly understood, may have counterparts in eastern Nevada, where sets of easterly striking normal faults also formed prior to periods of extreme extension. The restorations demonstrate that mineralization in the Ann-Mason and Blue Hill areas originated in the same dike swarm and thus are genetically related and that another dike swarm to the south passing near the Casting Copper-Ludwig septum could have porphyry mineralization to the northwest at depth on one or both sides of the Blue Hill fault.
Genetic algorithm optimization applied to back-projection sub-array selection

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The back-projection method uses the orientations of nonplanar wavefronts recorded at dense seismic arrays to image the sources of seismic energy in space and time (Ishii et al., 2005). Data from seismic stations at teleseismic distances (30°–90°) from the event of interest are typically used in this method. P waves recorded within this distance window at different seismic stations usually have very similar waveforms, which enhances the imaging process. Outside of the teleseismic distance range, waveform similarity can degrade significantly due to interference between P waves and other seismic phases. Though the incorporation of this data into back-projection analyses can theoretically improve resolution, the degradation of waveform similarity can cause artifacts in the back-projection results.

This study removes data that causes these artifacts using an approach to seismic array selection that focuses on the quality of the source image that the data produces, as opposed to the data itself. The key idea behind this approach is that small earthquakes should be imaged as point sources in back-projection results, and any additional imaged energy is likely an artifact caused by poor data quality. Using a genetic algorithm, an optimization method inspired by natural evolutionary processes such as selection, crossover, and mutation, an array of seismic stations is chosen that optimizes the point source nature of the back-projection results of small events within a region of interest. For this study, an optimal subarray for the source region of the 2017 Mexico earthquake (M8.2) is presented. This subarray is determined by optimizing the point source nature of aftershocks that followed the M8.2 event. Future work will focus on applying the optimal subarray to image details of the rupture properties of the M8.2 event that have not been resolvable in previous studies of this event (e.g. Ye et al., 2017).
Human exposure to lead (Pb) is a global-priority environmental health concern. Lead (Pb) is a known neurotoxin, and has been linked to diminished IQ and serious health problems, affecting the welfare of millions of people worldwide through natural and anthropogenic contamination of drinking water sources. This project will investigate metal-microbe phytoremediation (removal) of Pb from drinking water using common freshwater algae. The preliminary data show that wet algae packed on filter paper can remove nearly 100 µg Pb per gram of algal biomass. Removal of lead increased with algae availability, as 1.0 mg Pb in a 1-liter water sample was reduced to Pb = 0.45, 0.30, 0.26. Furthermore, a kinetic response was observed for increased reaction durations, indicating that control of Pb sequestration in algae is driven by both diffusion and biochemical interactions. Lead removal by algae showed an inverse relation with free-sulfur, possibly indicating that the mechanism of Pb bioremediation by fresh water algae involves sulfur functional groups. This project investigates contact time, algal species, and removal mechanisms under expected water chemistry conditions of drinking water to further characterize Pb removal, information that will be critical to the development of cost effective and sustainable bioremediation strategies.
In arid regions, sustainable water management practices are critical for a future with climate change. Several neighborhoods in Tucson, Arizona have implemented green infrastructure designs in order to collect the untapped, renewable resource of rainwater. Neighborhood-scale green infrastructure in the form of curb cuts connected to rainwater-harvesting basins have been shown to successfully capture storm runoff and create appreciable green spaces. However, the maintenance of curb-cut basins have been left to nearby homeowners, and after almost a decade, some basins show signs of neglect. Little is understood about how continued upkeep affects the function of a rainwater-harvesting basin. It appears that a degraded basin cannot properly capture rainwater. This presentation will assess how volunteer homeowner maintenance influences the functionality of Tucson’s green infrastructure, as well as make recommendations to the City of Tucson for basin maintenance. Infiltration rates – measured with an air permeameter - will serve as a metric for basin function, while a qualitative analysis of the basin’s appearance will gauge the apparent homeowner care. Numerous curb-cut basins in three Tucson neighborhoods will be evaluated, and the results will be compared to assess any potential correlation between a basin’s routine maintenance and its ability to infiltrate water.
Graduates

Sensitivity Analysis on the Hybrid 3D Hillslope Hydrological model

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Earth System Models (ESMs) are evolving to resolutions of a few kilometers. In this context, one challenging task is to update the parameterizations used to represent the subgrid processes. In particular, Land Surface Models (LSM) included in the ESMs, traditionally have been represented as 1D-columns accounting for fluxes inside the column just in the vertical direction. The subgrid heterogeneity of the soil properties greatly influences the boundary fluxes, hence Hazenberg et al. (2015) developed a computationally efficient hybrid 3D hillslope hydrological model (h3D) for rainfall-runoff processes at hillslope scale, coupling a 1D-column with a pseudo-2D lateral flow (for overland and the saturated zone). The h3D model brings more realistic results for subsurface and overland water flows than the LSMs currently used in the ESMs. This study presents a sensitivity analysis (for an idealized study case) of the h3D model to the initial conditions and to several soil characteristics, including Hydraulic conductivity, rooting depth, soil anisotropy, hillslope shape and slope among others. Quantification of the sensitivity of the h3D model will allows to better conducts the efforts in the implementation of this model into a full LSM, the development of its initialization datasets, and the adjustment of its parameters.
Using Neutrons as a Rain Gauge: New Method for hectare-scale Average Rainfall Estimation

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Rainfall distribution has been shown to be highly heterogeneous and therefore point measurements can poorly represent rainfall when applied to field scales. We modified a cosmic ray neutron detector (CRD) to produce soil moisture data for a 10-cm control volume. From the soil moisture time series, we developed an empirical relationship relating soil moisture to the flux of moisture leaving the control volume due to drainage. Using mass conservation principles, a model was developed using superposition of drying curves to inverse model the rainfall fluxes needed to produce the soil moisture time series. This approach was applied to the monsoonal period for three years, from 2010 to 2012, at the Manitou research site. The model has trouble predicting the exact timing of events on an hourly scale but performs better at 6-hour, 12-hour, and 24-hour integrated scales. The model tends to overpredict the magnitude of events smaller than 5 mm and underpredict larger magnitude events. Applying a scaling function that takes into account the changes in the CRD sensitivity as a function of water content improves results. These estimations represent rainfall, spatially averaged at a hectare scale, and further research is needed to assess the validity of these estimations.
Heap leaching is an unsaturated flow metal recovery process, in which mined ore is irrigated with a lixiviant to dissolve metal contained in the ore. The metal is then extracted from solution. Heterogeneities within the stacked ore can lead to uneven wetting and the formation of preferential flow pathways, which reduces solution contact and lowers metal recovery. Many mine operators believe that slow initial irrigation rates help minimize permeability loss and increase metal recovery rates, but it has not been studied in detail. Experiments were conducted with three different initial irrigation rates in large columns (1.5 m high, 0.5 m in diameter) packed with crushed ore samples that are known to have permeability constraints. Columns were monitored to assess changes in physical and hydraulic properties spatially and temporally. Water content was measured capacitance soil moisture sensors at 9 depths; a neutron probe to periodically log every 30 cm from four different directions; and electrical resistivity sensors to create a 2-dimensional tomography profile of water content over time. A non-reactive tracer was used to characterize advective-dispersive transport under unsaturated conditions. A dye solution was introduced at the end of each experiment to map preferential pathways.
Helping a town with culvert design and small-scale flooding issues over a roadway critical to emergency services

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For my Master’s report, I am working with the small mining town of Superior, Arizona to help with the small-scale flooding issues and a culvert design to mitigate said issues. Every year during the monsoon season the crossing of Queen Creek over Mary Drive floods and is impassable for around eight to ten days in total. This presents a serious problem for emergency services, as the town’s only fire station lies on the south side of the crossing. When the crossing floods, the fire trucks or law enforcement have to take a detour lasting at minimum five minutes. These few minutes are very precious in an emergency situation. Seeing a problem and wanting to help find a solution, I got into contact with the county engineer and the town manager to come up with a plan. The first step was to determine the peak flow values for storms of various return intervals. This involved the SCS Curve Number method and HEC-HMS. The next step was to use FHWA’s HY-8 program to create some preliminary culvert designs. And the last and current step is to use HEC-RAS to better model Queen Creek with the peak flows and the culvert designs.
Extent of salt dissolution and brine flushing to the Dolores River in the Paradox Valley, Colorado

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The Dolores River in Colorado is a tributary to the Colorado River and is widely known for its high salinity content, particularly in the Paradox Valley where the salt-containing Paradox Formation comes close to the surface. Previous research has identified dissolution of halite and gypsum as the main contributor to salinity in the shallow aquifers and Dolores River. This study aims to determine the contribution of deeper fluids such as, connate brines, associated with the Paradox Formation into shallow aquifers and the river. In addition, we aim to constrain the extent of halite and gypsum dissolution and removal of salt over geologic time; and circulation patterns and rates of solute transport associated with the salt diapir. Water samples will be collected from brine pumping wells maintained by the Bureau of Reclamation, natural springs, and the Dolores River in the Paradox Valley. Samples will be analyzed for their salinity content, solute and isotope chemistry and age tracers (^{4}He, ^{81}Kr, ^{14}C). Results are expected to increase understanding of fluid and solute transport associated with salt diapirism, and salinity loading to the Dolores and Colorado rivers.
Analysis of water stable isotopes and solute chemistry can reveal the source of water in surface water systems, and the nature of the hydrologic connection between surface water and local and regional groundwater. This research uses water stable isotopes (18O, 2H, 34S, 13C), solute chemistry, and tritium to investigate the seasonal sources of water in wetlands (cienegas), Cienega Creek, and the riparian aquifer within the Las Cienegas National Conservation Area (LCNCA) in the upper Cienega Creek Watershed, an area of unique biodiversity in Southern Arizona. Seasonal samples of streams, springs, and shallow groundwater from piezometers along the length of Cienega Creek were analyzed. Wells tapping into basin groundwater were also sampled. Preliminary results suggest that surface water and water in the shallow alluvial aquifer is a mixture of primarily basin groundwater recharged prior to the 1950’s with a smaller component of more recent recharge. The apparent reliance on basin groundwater implies that surface water in LCNCA could be impacted by changes in the regional water table. This insight, as well as baseline hydrologic data that this research provides, will aid research efforts and help inform groups interested in the preservation of surface water within LCNCA regarding future management decisions.
Comparison of Runoff Data to Assess Impact of Stormwater Green Infrastructure

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To address impacts of stormwater on water quality and quantity, urban areas have developed policies and approaches to increase stormwater capture for use and/or infiltration (Miles and Band, 2015). Infrastructure used to promote on-site retention of stormwater for infiltration, harvesting, and/or evapotranspiration is referred to as green infrastructure, or more specifically, stormwater green infrastructure (SGI, e.g. Jaffe et al., 2010, Pennino et al., 2016). In arid and semi-arid environments such as the southwestern United States, SGI is implemented to address issues related to water retention, groundwater recharge, urban heat island effects, and nuisance flooding as a result of intense rainfall. Taking advantage of the City of Tucson as a living laboratory, the impact of SGI on stormwater runoff is investigated. Stormwater infrastructure in Tucson is dominated by drainage from roadways to ephemeral stream channels. In order to assess the affect of SGI on hydrological processes, runoff stage data is being collected in two urban, ephemeral washes, both upstream and downstream of SGI installation. This poster discusses methods and preliminary results of assessing variability in runoff volumes and hydrographs of these washes attributed to contributing area, contributing land use cover, and contributing area SGI installation.
Modern fluid indicators of sources and migration of paleofluids in the Colorado Plateau

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The Paradox Basin, located in SE Utah and SW Colorado, contains iconic regional sandstone bleaching, evidence of basinal-scale hydrocarbon and metal migration, and extensive evaporite deposits. Brines associated with the Paradox Formation (salt) are mostly connate waters derived from evaporated paleoseawater. There is also evidence of brines formed by salt dissolution associated with meteoric recharge. As part of a large, interdisciplinary project recently funded by the Keck Foundation, we aim to identify the sources, residence time, and migration mechanisms of modern (remnant) fluids in the Paradox Basin to better understand the paleofluid flow history of the Colorado Plateau. Our study will focus on characterizing the chemical and isotopic composition of formation waters and associated hydrocarbons, noble gases, and carbon dioxide. Krypton isotopes (⁸¹Kr) will be used for the first time to ‘date’ near-surface saline fluids and better constrain crustal ⁴He fluxes and ‘ages’ of deeper fluids. Various sample locations and depths will be considered to characterize the spatial and depth distribution of modern fluids. Results will be used to validate a basin-scale hydrodynamic model and coupled to evidence of paleofluid flow in the rock record.
Towards Understanding Hydrologically-Significant Geologic Connectivity

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I am investigating how geologic structures can influence subsurface flow behavior. Using MODFLOW, I simulate flow through randomly-generated, heterogeneous conductivity fields. Then, I investigate the relationship between geologic connectivity and effective hydraulic conductivity. The goal is to identify how structure impacts flow. Ultimately, this could allow for the use of geophysical images to better predict field-scale subsurface flow behavior.
Paleoflood hydrology on the lower Green River, upper Colorado River, Utah

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Through a comprehensive paleoflood investigation, employing the abductive mode of inference, we document natural evidence of 70 paleofloods at six sites on the Lower Green River, Utah. Hydraulic analysis, using the Sedimentation and River Hydraulic-2D model (SRH-2D), shows that the responsible peak paleoflood discharges ranged between 507 and 7499 m\textsuperscript{3}/s. At least 14 of these paleoflood discharge peaks exceed a level twice that of the maximum systematic gauged flow of 1929 m\textsuperscript{3}/s. Geochronological analysis, employing optically stimulated luminescence (OSL) and radiocarbon dating techniques, demonstrates that these 14 paleoflood peaks occurred in the past 700 years. Integrated of these paleoflood data into flood frequency analyses (FFA) showed higher values for the upper tails of the flood distribution than did an FFA based only on the systematic record, showing that extreme floods are more frequent than indicated by the relatively short gauged records. Through philosophical examination the three approaches to extreme flood estimation, FFA, probable maximum flood estimation, paleoflood hydrology, we show the significance of the natural evidence for advancing the scientific understanding of extreme floods.
Investigation of hydrological response of three identical artificial hillslopes at the Landscape Evolution Observatory

Katarena Matos, Antonio Alves Meira Neto, Peter Troch, Till Volkmann

Hydrological processes at the hillslope scale are complex and monitoring hillslopes with a large number of sensors or replicate experimental designs is rarely feasible. The Landscape Evolution Observatory at Biosphere 2 consists of three, large (330 m$^2$) artificial hillslopes packed with 1-m depth of initially homogeneous, basaltic soil. Each landscape contains a spatially dense network of sensors capable of resolving meter-scale lateral heterogeneity and sub-meter scale vertical heterogeneity in moisture content and water potential, as well as the hillslope-integrated water balance components. The three hillslopes are thought to be nearly identical, however recent data showed significant differences in discharge and storage behavior. A 45-day periodic-steady-state tracer experiment was conducted in November and December of 2016, where a 3.5-day long, identical irrigation sequence was repeated 15 times. Each sequence’s rainfall, runoff, and storage dynamics were recorded, and distributed moisture characteristics were derived using paired moisture content and matric potential data from 496 positions in each hillslope. In order to understand why the three hillslopes behave hydrologically different, we analyzed soil water retention characteristics at various scales ranging from individually paired moisture and matric potential to whole-hillslope soil water retention characteristics. The results confirm the distinct hydrological behavior between the three hillslopes.
Comparison of Daytime Low-Level Cloud Properties Derived from GOES and Surface Instruments at ARM SGP

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The daytime single-layered low-level cloud properties retrieved by the Geostationary Operational Environmental Satellite system (GOES) are compared with ground-based observations and retrievals over the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) Central Facility (SCF) from June 1998 through December 2006. The GOES retrievals are made via the Visible-Infrared Solar-infrared Split-window technique (VISST). Collocated pairs of GOES and ARM cloud properties are produced and comparisons are made for monthly means, diurnal means, and one-to-one for GOES and ARM collocated pairs. The parameters of interest are cloud temperature ($T_{\text{eff}}$ for GOES and $T_{\text{top}}$ for ARM), height ($H_{\text{eff}}$ and $H_{\text{top}}$), cloud-droplet effective radius ($r_e$), optical depth ($\tau$), and liquid water path (LWP). GOES retrieved $T_{\text{eff}}$, $\tau$, and LWP have excellent agreement with ARM retrievals. Results also show that GOES retrieved mean $r_e$, $\tau$ and LWP values increase with increased solar zenith angle (SZA).

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Utilization of environmental isotopes, water geochemistry, and hydrogeologic properties to assess the interconnectedness of shallow aquifers at a copper mining site

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Assessing the interconnectedness of aquifers is an important water resource management practice to mitigate potential migration of contaminants from a mined aquifer (e.g. in-situ copper mining) to adjacent aquifers. This study is focused in the metal-rich Lisbon Valley of the Paradox Basin in southeastern Utah where numerous faults may act as conduits or barriers to cross-formational flow. Tritium, $^{14}$C, and $^{81}$Kr lay a foundational groundwork to assess the relative ‘ages’ of two distinct aquifers separated by an aquitard of varying thickness. Analysis of isotopes such as $\delta^{18}$O/$\delta^{16}$D, $\delta^{34}$S-$\text{SO}_4$, and $\delta^{18}$O-$\text{SO}_4$ provide insight into the climate during recharge, regions of source-water recharge, and groundwater flowpaths. Assessment of geochemistry data extending back decades indicates that these two aquifers have distinct geochemical signatures; the upper Burro Canyon aquifer has a calcium-sulfate signature with high TDS and basic pH, while the lower Navajo aquifer has a sodium-bicarbonate water with low-to-moderate TDS and near-neutral pH. Uncorrected radiocarbon ‘ages’ from 16,000-20,000 BP in the Burro Canyon aquifer and 32,000-42,000 BP in the Navajo aquifer, coupled with low $\delta^{18}$O/$\delta^{16}$D values relative to modern precipitation, suggests both aquifers contain fossil groundwater recharged during the Pleistocene. Future work may include noble gas age tracers and hydrologic modelling.
North American Monsoon Precipitation that annually occurs from early July to mid September impacts the water supply, severe weather, droughts, and wildfires in the arid regions of Southwestern US and Northwestern Mexico (Adams and Comrie 1997). The challenge has been how to better forecast the precipitation when the monsoon season comes. Consortium of Arizona-Mexico for Arid Environment (CAZMEX) conducted a field campaign in Sonora, Mexico from June to September 2017 by collecting meteorological data from 15 installed GPS meteorological sites. We look closely at two cases of precipitation, i.e. precipitation generated by inverted trough (27 to 28 July) and precipitation without inverted trough (9 to 10 August). We run WRF model for both cases with data input from GFS and NAM. For validation we use rain gauge data from 25 meteorological sites including our GPS sites in Sonora, four satellite products, i.e GPM-Early, GPM-Final, CMORPH, and PERSIANN, and radar data of NEXRAD in Tucson. The preliminary results show that GPM-Early has less bias against the rain gauge measurement, and WRF-NAM performs better than WRF-GFS in forecasting the 24 hour total of precipitation and hourly precipitation. Data assimilation is being conducted to achieve better forecast.
**Populus fremontii** tree ring analysis and semi-arid river water source variability over time, San Pedro River, Arizona

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Summer floods are an important source of sustained streamflow in arid and semi-arid rivers of the American Southwest and Northwest Mexico. How much of this importance is a natural function of these systems versus artifact of human alterations to the system is not known. Environmental information in the tree ring cellulose of *Populus* can be used to investigate the variation in water sources over time in these areas. Past research has shown that streamflow sources in the San Pedro Basin of Arizona vary isotopically between a source water of basin ground water and a summer flood water source. This study uses isotopic analyses of *Populus fremontii* and atmospheric data in the San Pedro Basin to determine the water source of the trees and the river water source condition. After analyzing weather data within the basin, an inversion of the Barbour model will be used to invert tree ring cellulose isotopes to obtain the water source isotopic composition. The variation in water source composition as inferred from the model will then be compared to the river composition over time. By drawing this comparison, it will aide in anticipating consequences from human driven modification including climate change on the river systems.
What defines the effective hydraulic conductivity of a heterogeneous medium?

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Most geologic processes produce heterogeneous porous materials; therefore, these media have different characteristics, which make them complex systems to analyze. This research is focused on the bulk behavior of these heterogeneous media, which mostly depends on the particle size distribution and the spatial distribution of the particle size fractions. Thus, we study a medium comprised of two particle sizes as simplest of heterogeneous systems, in order to examine the effect of the percent composition of small and large particles on the bulk hydraulic properties, which are characterized by the effective hydraulic conductivity ($K_{\text{eff}}$). The methods are based on upscaling of an alpha or connectivity parameter to weight the $K_{\text{eff}}$. For this, we examine the full range of geometries that lies between the two end members of a binary medium, when the conductivity (K) is distributed parallel and perpendicular to the flow direction. The results are computed by using groundwater numerical model (MODFLOW) and they validate the hypothesis that one important method analyzed (energy dissipation) explains the $K_{\text{eff}}$ by computing the volume weighting of K. This energy dissipation, the alpha parameter, and the changes in the fraction and the distribution of the K inclusions, could make significant changes in $K_{\text{eff}}$ results.
Natural tracer study to constrain transit times and flowpaths of groundwater from Davidson Canyon to Lower Cienega Creek

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Multiple reaches of Cienega Creek and Davidson Canyon Wash, located in the Cienega Creek Watershed, Arizona, have been designated as “Outstanding Arizona Waters.” These surface waters, riparian areas, and underlying groundwater in alluvial basins are under pressure from threats of increasing groundwater pumping, land use and climate change, and potential mining. Yet, little information is known about the regional hydrogeology, which is important for accessing and protecting the sustainability of natural resources in the area. This study investigates the hydrologic connection between the Santa Rita mountains and lower Cienega Creek, along the Davidson Canyon subwatershed. Davidson Canyon is an intermittent stream with seasonally sustained baseflows and is a large tributary to Lower Cienega Creek.

This research aims to: (1) identify areas of recent recharge; (2) determine the relative age and transit time of groundwater; (3) better constrain the Local Meteoric Water Line; and (4) use hydrochemistry and isotopes to evaluate the flowpaths and mixing of groundwater and interaction with surface waters. To address these aims, groundwater and surface water samples were collected seasonally in 2017-2018 and analyzed for major ion chemistry, stable isotopes ($\delta^{18}$O, $\delta$D, $\delta^{13}$C, $\delta^{34}$S) and radioactive isotopes ($^{3}$H and $^{14}$C).
Does soil moisture affect warm season precipitation over the Southern Great Plains?

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Numerous observational and modeling studies have addressed the impact of soil moisture on subsequent precipitation (primarily its initiation), yet consensus remains elusive. Here we quantify the effect of soil moisture on precipitation amplification over the U.S. Southern Great Plains, long considered as one of the global "hot spots" of land-atmosphere interaction, though more recent studies have questioned this designation. Warm season (June-September) days for the 2002-2011 period (with ~1220 total days) are partitioned into low, medium, and high dynamic regimes, among which certain days are identified as afternoon rainfall event days based on simple criteria. We find that antecedent soil moisture conditions are negatively correlated with subsequent afternoon precipitation magnitude for low dynamic regimes, but this correlation becomes positive for high dynamic regimes. In contrast, this correlation is markedly reduced in magnitude and becomes insignificant when all regime days are considered. These results are also confirmed by simple statistics and examination of the diurnal cycle. Furthermore, different pathways are provided for precipitation amplification for low and high dynamic regimes.
As the amount of excess CAP water available to farmers shrinks and the possibility of a shortage declaration on the Colorado looms, farmers in Central Arizona face a loss of Central Arizona Project water. Many will have the ability to replace CAP water by pumping groundwater, which will have an impact on reductions in groundwater overdraft in the region. This study looks at how the economics of farming cotton in the Pinal Active Management Area are affected under different water sources. Crop-water production functions for cotton in the Pinal AMA are estimated using Aquacrop and the profit maximizing level of water applied is calculated under different scenarios.