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Oral 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

SWESx Oral Presentations

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A collaborative investigation of climate change adaptation for the Pyramid Lake Paiute Tribe

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Resilience to environmental change is not a new concept for indigenous peoples, whose oral histories recall periods of extreme climate events in which cultural practices enabled adaptation. The impacts of modern climate change on indigenous peoples, however, have been severe and will worsen due to historical legacies of colonization, relocation to extreme marginal lands, resource exploitation, and a variety of socioeconomic challenges. The Pyramid Lake Paiute Tribe (PLPT) is committed to addressing climate change adaptation for water management. PLPT is a federally recognized tribe situated on the Pyramid Lake Indian Reservation in Nevada's Great Basin whose people are deeply connected to the Truckee River, Pyramid Lake, the endangered cui-ui fish (Chasmistes cujus), and the threatened Lahontan cutthroat trout (Oncorhynchus clarkii henshawi). For more than a century, PLPT has made substantial efforts to secure water rights to protect their fish and is collaborating with researchers to explore the potential for adaptation to environmental change. Climate change in the Great Basin poses complex water resource and land management challenges which threaten PLPT wellbeing. Rising temperatures will likely shift the timing and quantity of springtime snowmelt in the Sierra Nevada Mountains, which will have hydrologic and ecologic consequences for fish in Pyramid Lake and the Truckee River, and exacerbate other challenges like drought, wildfire, flooding, and socioeconomic concerns. This research considers how PLPT may address climate change vulnerabilities to water resources, both at small and broad scales.

Application of the PARSWMS Parallelized Code for Simulation of Three-Dimensional Water Flow and Solute Transport in Containerized Soilless Substrates

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Simulation of three-dimensional water flow and solute transport in containerized variably saturated soilless substrates with complex hydraulic properties and boundary conditions necessitates high-resolution discretization of the spatial domain, which commonly leads to several million nodes requiring numerical evaluation. Even today's computational power of workstations is not adequate to tackle such problems within a reasonable timeframe. Hence, parallelization of the numerical code and utilization of supercomputers are required. We modified and applied the PARSWMS parallelized code that was developed for Linux and is amenable for solving the 3D Richard's equation for water flow and the convection-dispersion equation for solute transport considering linear solute sorption. The code was modified to allow for nonlinear solute sorption behavior and applied to simulate water flow and nitrogen and phosphorus transport and transformations in containerized soilless substrates such as perlite, volcanic tuff, coconut coir, Growstones, and mixtures thereof with the University of Arizona El Gato high performance computer cluster. Application of simulation results for economically efficient growth module design and irrigation management, as well as for optimization of substrates via mixing of organic and inorganic constituents will be discussed. In addition, simulations will be compared with results of a well-controlled greenhouse experiment.

Removal of lead (Pb) from solution by corn and pea root border cells

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Most plants produce living cells programmed to disperse from root tips into the soil environment. Like neutrophils, these "border cells" export a complex that functions as a trap to prevent infection by pathogens. Border cells also trap diverse metals. The goal of this study was to determine if border cells trap Pb. Border cell responses to Pb were observed microscopically. Removal of Pb from solution after incubation with roots and root tips with or without border cells, was measured using inductively coupled plasma mass spectrometry. Speciation of Pb associated with border cells was evaluated by synchrotron X-ray absorption spectroscopy (XAS). Significant increases in extracellular trap size and number occurred in response to Pb but not silicon (Si). Significant removal of Pb, but not Si, occurred after incubation with whole roots, root tips with or without border cells, and border cells alone. The Pb speciation, measured with Pb L III XAS, altered when reacted with border cells, indicating direct binding by extracellular traps. Understanding root defense mechanisms may facilitate ongoing efforts to use phytoremediation to remove toxic metals from contaminated soils. Further studies are needed to assess Pb-root interactions in vitro and in situ.

Developing Microbial Bio-indicators of Soil Formation on Reclaimed Mine Tailings in Southern Arizon

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Mining reclamation aims to restore affected land to a condition capable of growing self-sustaining plant communities. A critical limitation to vegetation success in mining wastes is that these ‚Äúsoils‚Äù are deficient in the microbial communities necessary to support plant establishment. The goal of this research is to work with mining companies to develop microbial metrics that document soil formation improvements during the phytostabilization process. Metrics being evaluated include DNA biomass, particle size, pH, electrical conductivity, total nitrogen and 16S rRNA gene qPCR of bacterial abundance. By demonstrating temporal patterns that correlate with successful plant growth, we can understand which soil quality changes might indicate significant factors important to the selection of soil for mine waste coverage and long term plant establishment. Development of metrics for cover-material evaluation will facilitate more effective and economical reclamation strategies. Significant soil biogeochemical indicators have been identified over 4 years of data that correlate with successful plant growth on more established reclaimed areas. We have observed significant differences in some of these metrics that correlate with plant cover, demonstrating possible short term and long term indicators of re-vegetation success. While electrical conductivity and pH do not appear to be important indicators, we observed that nitrogen, biomass and 16S rRNA bacterial gene qPCR are positive metrics of successful plant cover that may be used to evaluate long term reclamation success.

Changing Winter Precipitation and Temperature Regimes Likely to Impact Arizona's Water Resources

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Snow that falls along the Mogollon Rim is a significant source of water for more than half of the 6.9 million people living in Arizona. Two basins fed by this region, the Salt and the Verde, together provide approximately 40% of the water used in the Phoenix area annually. At the midpoint of this research, trends toward an earlier onset of peak winter precipitation are apparent. Earlier peak precipitation has potential to affect spring snowpack by increasing the amount of snow that melts during the winter months primarily because the time frame over which dry ablation may occur is increased, but also because an earlier onset appears linked to a greater number of rain-on-snow events in early winter months, and rain-on-snow events may reduce snowpack. Additionally, we observed a decrease in overall precipitation from January to March during the most recent decade (2010's). Furthermore, winter temperatures in the region have increased by as much as 2 degrees Celsius since the 1980's, further contributing to snowmelt and leading to an earlier onset of the snow-free period. Ultimately, this research seeks to gain a deeper understanding of the relationship between changing winter precipitation and temperature regimes and Arizona's water resources.

Development of Native American Produce Safety and Agricultural Water Quality Trainings in Arizona

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The Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA) is the first major reform to the United States food safety laws in more than 70 years. It aims to ensure the U.S. food supply is safe by shifting the focus from responding to contamination to prevention. During governmental changes, Native American populations are the last demographic to be informed. With the implementation of FSMA, Arizona is unique situation because half of the farmers and ranchers are Native Americans. It is estimated that nearly 21 million farm acres in Arizona are tended to by state's twenty-two Native American tribes and nations. It is apparent that Tribal lands contribute to the overall success of the Arizona agriculture industry. Despite the strong presences of Native American farmers, there are *no hands-on delivery mechanisms of culturally sensitive resources for Tribal growers related to food safety and water quality principles in Arizona*. The central focus of this project is to give Native American growers the opportunity to assist in developing food safety trainings that is culturally sensitive. Native American tribes that we are focusing on are central Arizona tribes who will have the opportunity to attend 3 trainings in Summer 2018. The three trainings will highlight a different area of food safety and water quality. The classes will be based on the following topics: *Water microbiology for irrigation water, Possible farm intrusion from weather, animal and humans,* and *Writing an effective farm plan.* Each of the topics are essential elements in the FSMA that we decided these areas need to be the main focus of our culturally sensitive trainings. Our collection process will be to implement pre-questionnaire and discussion based on the topic and following the class to have a post-questionnaire. Any participant that improves on the questionnaire will measure using a paired t-test. After the trainings participants and stakeholders can attend an optional one-on-one assessment to express their opinions and recommendations for future trainings.

Title: Might Recycled Water Inhibit Toxin-Producing Algae?

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Cyanobacteria, or blue-green algae, is a phytoplankton phylum found in surface water bodies worldwide. For decades, blue-green algae has caused severe aesthetic water quality problems and induced water deoxygenation, leading to fish kills and other detrimental outcomes. Furthermore, some cyanobacteria genera, most notably several Microcystis species, are known to produce hepatotoxic peptides known as microcystins. Such toxin production is of critical and increasing public health concern, as hepatotoxic cyanobacterial blooms in freshwater lakes and streams have been implicated in human and animal sickness, and even death. Studies have correlated increased toxin production to enhanced temperature, nutrient concentrations, and light intensity, but research results examining microcystin toxin production in response to environmental stimuli have rarely been conclusive outside of the laboratory or over multiple seasons. Our research implemented advanced molecular techniques (real-time quantitative PCR) to detect and quantify cyanobacterial genes (*CYAN*) and toxin synthetase genes (*mcyD*) in water samples collected from recycled water retention ponds and groundwater-filled ponds. Water samples also underwent chemical and physical analyses to identify factors correlating to decreased toxin synthesis. Our preliminary results show similar concentrations of *CYAN* in both ponds but lower concentrations (sometimes below limits of detection) of *mcyD* gene markers in the recycled wastewater retention pond. Additional results obtained from a subset of samples analyzed using LC-MS showed average toxin concentrations of 6.702 ± 0.067 µg L^{-1} in the groundwater-filled pond while toxins were undetectable (detection limit $\geq$ 3 ppt) in the recycled water retention pond. Knowledge of the regulation of microcystin toxin biosynthesis may facilitate implementation of water management strategies to avoid environmental conditions that induce dangerous water quality conditions.

Architecture of the Deep Critical Zone, Valles Caldera, New Mexico

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The critical zone (CZ) has recently been the focus of interdisciplinary Earth systems science research that aims to describe coupled processes to understand the past and present CZ and the impact human activities will have on future CZ processes and ecosystem services. The Catalina-Jemez Critical Zone Observatory (CZO) has focused primarily on near surface processes; including remote sensing and direct sampling of vegetation, soils, saprolite and waters. However, water/rock interaction, weathering and solute mobility along flowpaths in the deep (>10 m) CZ that echo near surface CZ processes (i.e. water, energy, and mass fluxes) are not well understood. We postulate a deep groundwater reservoir in fractured rhyolite exerts strong controls on solute discharges in upland catchments of the Jemez CZO within the Valles Caldera National Preserve in northern New Mexico. To investigate weathering processes in the deep CZ, we extracted three continuous cores to 40-50 m depth in summer of 2016 in one of our instrumented forested sub-catchments prior to instrumenting the boreholes as monitoring wells. The research goal is to understand depth- and aspect-dependent trends in the physical, chemical and biological structure, identify mineralogy that results from hydrologic and bio-geochemical dynamics, and describe lateral and vertical groundwater flow and its contribution to the geochemical evolution of the deep CZ. We used multifaceted tools to deconvolute the impacts on observed variation of geologic origination versus subsequent weathering processes. Preliminary results show complex weathering profiles at each of the three watershed positions likely due to a combination of hydrothermal alteration, textural controls on weathering, development of preferential flowpaths, and differing hydrologic base levels. Observed zeolites and phyllosilicate clays infer a potential weathering trajectory and pathways that may play a critical role in solute transport as a function of depth.

Verification of virus removal by Soil Aquifer Treatment via non-human viruses used as conservative indicators

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Soil aquifer treatment (SAT) and Managed Aquifer Recharge (MAR) are widely used throughout Arizona. These systems are used as water resources for reclaimed water, impaired surface water or urban storm water to augment future supplies. In the context of reclaimed water reuse, SAT/MAR systems can aid in the removal of chemical and microbial contaminants. One of the difficult contaminants to remove from wastewater intended for reuse is human pathogenic enteric viruses. This is due to their resistance to disinfectants as well as their prolonged survival in the environment. Current and proposed regulations in California and Arizona require a minimum of 12-log removal of enteric viruses during treatment of reclaimed water for subsequent potable reuse. Survival and transport models have largely been used to estimate enteric virus removal due to past difficulties in virus recovery and detection. Because of the great variation in the heterogeneity of subsurface strata, the accuracy of these models for viruses is unknown. The goal of this project is to search for a virus(s) that could be used as a conservative indicator of enteric virus removal by SAT/MAR, such that the absence of the viral indicator would imply absence of human pathogenic virus. This information could then be used to give log credits for a specific SAT/MAR site.

Tucson Water has operated SAT/MAR sites at their Sweetwater Wetlands Reclamation Facility (SWRF) since 1987. For purposes of this study, four sites in or around Tucson Water's SWRF were sampled and analyzed for presence of viruses. Virus detection was accomplished using quantitative polymerase chain reaction (qPCR). While qPCR does not allow for determination of infectivity, it does offer detectability of a wide range of non-culturable viruses, as well as a more conservative estimation of viral reduction. Sample volumes of 400 to 2,000 liters were collected. Sampling of the SWRF monitoring well for over six months revealed the presence of all the major groups of enteric viruses and two non-human viruses at low levels. Virus removal varied from 3 to 5 logs depending on virus type. The two non-human enteric viruses detected were pepper mild mottle virus (a plant virus) and CrAssphage (a bacterial virus). Data will be analyzed from each site to compare removal of the enteric viruses and the non-human viruses to evaluate the efficacy of the non-human virus as conservative indicators of enteric virus removal.

Using total nitrogen and DNA biomass content as biogeochemical indicators of incipient soil development through measuring mining waste rock revegetation

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Mining is a crucial industry, but has long struggled with developing environmentally sustainable practices. After extraction is no longer economically feasible, mines are faced with the challenge of transforming their land back into a productive ecosystem. Revegetation is a key strategy to reintegrate mine sites into the surrounding environment. The Carlota Copper Mine in central Arizona is an open pit mine owned by KGHM International Ltd which operated from 2008 to 2014, and is now in the process of revegetating their waste rock material as required by the National Forest Service. Because Carlota has chosen to implement direct revegetation without applying a soil cap or amendments, this requires incipient soil development of waste rock to a soil matrix with potential to sustain plant growth. Studies have shown that soil microorganisms play a decisive role in controlling nutrient cycling and soil fertility, suggesting that characterizing the waste rock microbiome will help us identify belowground bioindicators to measure soil development and assess Carlota's revegetation progress. In their current efforts, Carlota has seeded one waste rock slope in 2009, and one in 2012, while one slope remains unseeded. The specific aim of this research is to determine whether total nitrogen and biomass content are significant biogeochemical soil quality indicators of waste rock revegetation development. DNA biomass content provides a preliminary estimate of total bacteria abundance, and nitrogen is a limiting plant nutrient that impacts the development of soil microbial communities. Plant cover analysis will be used to evaluate the progress of the revegetation efforts: I hypothesize that increasing biomass and nitrogen content is positively associated with increasing plant cover. This study analyzes four years of data from samples collected annually from the two seeded slopes and one unseeded slope, and two undisturbed locations used as controls. Current analysis shows that nitrogen content and biomass increase as the time since seeding increases. A significant outcome of this research would be to provide the mining industry with a soil quality indicator that can be used as a metric of soil improvement for the evaluation of revegetation management decisions.

The application of lower-cost remediation methods and of community-engagement efforts to enhance management of Superfund sites.

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A comprehensive community engagement project employing ISE (Informal Science Education) techniques as well as PPSR (Public Participation Scientific Research) methods was performed in Saint David and Benson, Arizona in the vicinity of the Superfund site Apache Powder. The engagement effort utilized specific incentives offered to different socio-demographic stratas of the community such as college students, well-owners, renters, and environmentally conscious activists within the community. Activities included offerings such as riverbed sediment, soil and water sampling, chemical testing of those samples, community talks providing updates on the contamination status, pilot study testing, and other group events. The pilot study was sponsored by The U.S. EPA. and the goal of the community engagement was to measure the outcomes, impact, and effect of the engagement activities. Expected results included improved EHS (Environmental Health Literacy and even improved sensitivity to Environmental Justice in this poverty-stricken, depressed area with under-represented populations.

Assessing the Feasibility of Using a Sealed Landfill for Agricultural Graze Land

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The average American produces approximately 4lbs of trash per day, most of which is buried in municipal solid waste landfills. Once full, these landfills are closed, sealed, and maintained according to the United States Environmental Protection Agency's standards and regulations, and then monitored or remediated as necessary. As a response to the rise of urban agricultural activities, this project assessed the feasibility of using a closed and sealed landfill to support safe goat browsing. A site assessment was conducted at the Harrison Landfill in Tucson, Arizona to characterize the soil quality and uptake of deleterious metals by the following plants commonly observed at the landfill: buffel grass, desert broom, Russian thistle, creosote, salt cedar, and Attriplex canescens. Site characterization data was combined with goat browsing and plant consumption patterns. It was observed that soil concentrations for (Al, Ag, As, Be, Ba, Fe, Co, Cu, Cr, Cd, Fe, Mn, Ni, V, Se, Mo, Sn, Sb, Pb) did not exceed Arizona remediation standards. Furthermore, no plants analyzed contained metal concentrations that exceed maximum tolerable levels for goats. After this project's careful assessment, it was determined that, after soil and plant assessment, historic arid landfills may be used for economic development through agricultural grazing ventures.

A humped clay production model

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Traditional approaches of modeling clay production in soils have not yielded widely applicable results. Past attempts have focused on either specific locations or idealized landscapes or require a high degree of parameterization. We assumed a humped function to predict rates of clay production. As clay accumulates in the soil profile, pore spaces become restricted and water holding capacity is increased facilitating greater clay production; however, once a threshold amount of clay is produced, clay production slows as water flow through the profile becomes restricted and the supply of weatherable minerals declines. As such, we suggest that clay production is a function of the amount of clay present in the profile. We used a synthesis of chronosequence studies to calculate rates of clay production and to test the humped clay production model and validate the approach. The model contained two fitted parameters, 1. a maximum clay production rate (P_c, clay yr^{-1}), 2. a threshold clay amount (α, clay), and 3. a clay specific erosion rate (E/h, yr^{-1}). We empirically determined P_c values using a measure of matter and energy fluxing into the soil system, called effective energy and mass transfer, and the minimum age of the soil chronosequence with an r^2=0.59. We fitted the model to the calculated clay rates to determine an optimum α value of 0.12. We predicted the clay evolution of the soils in the chronosequence database with an r^2=0.59. This approach is widely applicable with a low degree of parameterization and a limited amount of required data to make the approach operational.

Meeting Arizona Water Management Objectives with Long-Term Storage Credits

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In Arizona, the 1980 Groundwater Management Act created Active Management Areas (AMAs), where groundwater use is regulated and enforced by the Arizona Department of Water Resources (ADWR). Since 1986 the ADWR has been administrating water storage for annual recovery, as well as for long-term storage credits (LTSC). As of 2014, 184 Long-Term Storage Accounts were registered in the three Central Arizona AMAs. Water can be recovered at a later time for the LTSC owner's use, or the LTSC can be sold. In this presentation, we report the activity of LTSC accounts since 2007. Many entities have accrued LTSC in Central Arizona: governmental agencies, such as the Arizona Water Banking Authority and the Central Arizona Groundwater Replenishment District, Native American tribes, municipalities, industries and investment firms. We investigate the rationale behind the transactions of LTSC by identifying buyers and sellers. We conclude on the effectiveness of LTSC in contributing to achieve Arizona water management objectives.

The relationship between chemodynamic solute behavior and hydrological flows of a controlled hillslope experiment

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The fast silicate weathering process of basaltic rock consumes a large proportion of CO2 and is a primary control on the global carbon cycling. The desilication process during the incipient basaltic soil genesis can be examined by coupling hydrologic variability and solute concentration measured down-gradient of reactive flow paths. The mechanisms associated with the influences of hydrologic factors on solute sources and geochemical weathering are evaluated by relating discharge volume and solute concentration during a periodic steady state hydrological experiment at the Landscape Evolution Observatory (LEO), the University of Arizona - Biosphere 2. LEO consists of three replicated, 330 m2 hillslope landscapes inside a 5000 m2 environmentally controlled facility. The engineered landscapes contain 1-m depth of basaltic tephra ground to homogenous loamy sand. Three sets of discharge samples were collected at the beginning, middle and the end of the experiment. Concentrations of major dissolved solutes are quantified and do not strictly follow the dilution process with increasing discharge in this study, and biogeochemical processes lead to variability in the concentration-discharge relationships throughout the experiment. Concentration of some chemical weathering products exhibit chemostatic behavior in response to increasing discharge volume. This is possibly due to hydrologic flushing of minerals, which increases the reactive mineral surface area. However, the differences of concentration discharge relationships among three initial identical LEO hillslopes suggest other contributing factors that control the geochemical weathering rate need to be determined.

Transport of graphene in porous media

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Graphene is a single-layer carbon nanomaterial that has drawn significant attention for a variety of applications. The industrial production of graphene is projected to increase greatly in the coming years. However, little is known about its transport and fate in the environment. In this study, miscible-displacement experiments were conducted to investigate the transport and retention of graphene in quartz sand and Vinton soil. Graphene was dispersed into solution comprising 500 mg/L of surfactant (an anionic surfactant, SDBS or a nonionic surfactant, Tween 80). The breakthrough curves for graphene transport in the sand exhibited typical colloid transport behavior, with a breakthrough at 1 pore volume (PV) and steady-state irreversible retention (~50% for SDBS-graphene and 20% for Tween 80-graphene). Conversely, for Vinton soil, the relative effluent concentration plateau increased slowly towards 1, which can be explained by the existence of a colloid blocking phenomenon. Large amounts of the retained graphene particles were remobilized after injecting deionized water again, indicating the retention was associated with the secondary minimum in DLVO theory.

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Bioswales: Benefit or Burden?

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Green infrastructure has been a tool used by cities to mitigate runoff and improve water quality. However there are dozens of guides, both official manuals and informal neighborhood workshops, leading to a wide variety of design choices. This lack of uniformity can be seen in Tucson with the recent advent of bioswales: vegetated basins intended to capture and clean street runoff during precipitation events. With the lack of comprehensive studies, it is unclear if the hundreds of bioswales, representing thousands of dollars and many of hours of maintenance each year, are performing as their original designers envisioned. In order to test performance, bioswales were subjected to a combination of qualitative and quantitative tests. Based on preliminary results there is evidence that supports the use of large boulders and coarse soil for maximizing infiltration, while basins with high organic matter content may actually reduce overall infiltration. When attempting to balance runoff mitigation with street aesthetics in the form of mature vegetation, there is no single "best" bioswale, but standardization of a few designs can lead to better use of city and neighborhood resources.

The Skill of Statistically Forecasting the Early Monsoon Onset in the Southwestern United States at a Subseasonal to Seasonal Time Scale

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Forecasts at the subseasonal to seasonal timescales have been recognized by the scientific community as having significant socioeconomic value. However, although these forecasts are skillful at forecasting warm season atmospheric teleconnection patterns, they are less skillful at forecasting warm season precipitation, which puts in question their practicality. In this study, the observed 500-hPa atmospheric circulation anomalies in the Northern Hemisphere are related to the dominant patterns of the observed two-month standard precipitation index (SPI) in the continental United States during the early warm season (June and July) from 1979-2011. An empirical orthogonal function analysis and canonical correlation analysis are then applied to determine the dominant coupled modes between the observed teleconnection patterns and SPI with a focus on the southwestern United States. Next, the same procedure is performed on five ensemble members of the CFSv2 reforecast data at a week four to five forecast period from 1999-2010 to determine the dominant coupled modes between the modeled geopotential height anomalies and SPI. These modeled coupled modes are then correlated with the observed coupled modes to determine the statistically significant pattern correlations and whether the CFSv2 reforecast data has any skill in forecasting the early monsoon onset four to five weeks out.

Importance of soil and fractured bedrock storage in sustaining vegetation productivity and streamflow for sub-humid mountainous catchments

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Mountainous catchments provide critical water and ecosystem services for adjacent lowlands in xeric regions, yet a better understanding of the role of catchment water storage in provisioning these services remains a grand challenge for hydro-ecologists. Here, we performed catchment-scale water balance and baseflow recession analyses for understanding the role of ecohydrologic and hydraulic storages on ecosystem and streamflow sustainability within the high-elevation Marshall Gulch catchment in the Santa Catalina Critical Zone Observatory. Using long-term (2009-2017) observations of hydraulic fluxes and shallow water stores, results indicate that the ecosystem is not in a steady-state and is still responding to recent fire, i.e. Aspen fire in 2003. During the dry season, following spring snowmelt and before the summer monsoons, most of the vegetation productivity is maintained by shallow water storage providing water at a rate of 0.9 (±0.23) mm/day. A comparison of ecohydrologic and hydraulic storage estimates further shows a strong relationship (r^2=0.70) between the two reservoirs, with ecohydrologic storage being greater by a factor of 2.5. Finally, the results indicate groundwater storage available for vegetation productivity in this mountainous catchment is larger than the storage available for sustaining streamflow, which suggests greater resiliency of the terrestrial ecosystem to climate-induced water stresses.

Ocean Salinity Stratification in Models and Observations

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Salinity plays an important part in ocean vertical mixing processes, and therefore affects exchange of heat, momentum and moisture between the atmosphere and ocean. In turn, the atmosphere affects (surface) salinity through precipitation, which decreases salinity, and evaporation, which increases salinity. Some regions of the ocean, for example rainy regions in the tropics, have increasing salinity with depth in the upper ocean, which inhibits vertical mixing and may affect the propagation of internal waves that can play a role in climate variability.

The portrayal of such features, termed barrier layers, in coupled earth system models has not been widely studied, and here we present results from several models and observations. The questions we attempt to address are: Do models represent barrier layers in agreement with observations? Are biases in salinity related to biases in precipitation and/or sea surface temperature? Are there connections between salinity biases and SST and precipitation variability - for example El Nino Southern Oscillation or the Madden-Julian Oscillation?

Irradiance Forecasting Using Advected Satellite Images and Data Assimilation

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Satellite images provide a basis for estimating global horizontal irradiance and solar power output over areas on the scale of a city or larger. In this work, we aim to improve satellite derived irradiance forecasts by correcting cloud motion vectors which are used to advect an irradiance or clear sky index (CSI) field. In a data assimilation framework, we improve cloud motion vectors derived from the Weather Research and Forecasting (WRF) model (available every hour) by assimilating satellite images taken from the GOES-15 geostationary satellite (available every 15 minutes), and sparse optical flow vectors derived from successive satellite images. We use a data assimilation technique known as the Local Ensemble Transform Kalman Filter (LETKF). The LETKF is a square root filter in which calculations are performed in the space spanned by ensemble members, a lower dimensional subspace of the state space. This allows for a reduction in computational complexity because the number of ensemble members (around 50) is significantly lower than the dimension of the state space (hundreds of thousands or larger). We present preliminary results showing the effectiveness of this method to produce forecasts as well as to quantify the uncertainty inherent within these forecasts.

A survey of the atmospheric physical and dynamical processes key to the onset of Arctic sea ice melt in spring

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September sea ice concentration (SIC) is found to be most sensitive to the early melt onset over the East Siberian Sea and Laptev Sea (73°-84°N, 90°-155°) in the Arctic, a region defined here as the area of focus (AOF). Then four early melting years and four late melting years were selected and compared over this area. In the early melting years, the positive Arctic Oscillation (AO) phase is dominant during springtime, which is coupled with a poleward shift of storm tracks, intensified storm activity in the AOF and consequently enhanced northward transport of moist and warm air. As a result, positive anomalies of precipitable water vapor (PWV) and/or cloud fraction and cloud water path were found over the AOF, increasing downward longwave radiative flux at the surface. The associated warming effect further contributes to the initial melt of sea ice. In contrast, the late melt onset is linked to the negative AO phase in spring accompanied with negative anomalies of PWV and downward longwave flux at the surface. The increased downward shortwave radiation during middle to late June plays a more important role in triggering the melting, aided further by the stronger cloud warming effects than normal.

Application of feedback analysis in hydrological modeling

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Feedback analysis has been a standard element of the design of electrical systems for almost one hundred years and has been an important tool in climate change studies for decades. This study is motivated by the lack of feedback analysis in hydrologic science. We propose that feedback analysis can be applied to hydrologic models to identify the most and least stable parts of a hydrologic system. In this study, we f ocus on modeling groundwater flow systems and quantify a feedback strength, which is a relative index of the importance of a feedback mechanism in regulating the system response to an external stress. Resource managers may use the feedback strength as a tool to identify and protect the least stable areas, or identify the feedback mechanisms in stable areas that could be developed to enhance stability in more vulnerable areas. This project builds on feedback analysis of simple electronic circuits, borrows from advances in the atmospheric sciences, and develops a new feedback analysis for groundwater systems and models.

Enhancements to the WRF-Hydro Hydrologic Model Structure for Semi-arid Environments

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The NOAA National Water Center (NWC) implemented an operational National Water Model (NWM) in August 2016 to simulate and forecast streamflow and soil moisture throughout the Contiguous US (CONUS). The NWM is based on the WRF-Hydro hydrologic model architecture, with a 1-km resolution Noah-MP LSM grid and a 250m routing grid. The operational NWM does not currently resolve infiltration of water from the beds of ephemeral channels, which is an important component of the water balance in semi-arid environments common in many portions of the western US. This work demonstrates the benefit of a conceptual channel infiltration function in the WRF-Hydro model architecture following calibration. The updated model structure and parameters for the NWM architecture, when implemented operationally, will permit its use in flow simulation and forecasting in the southwest US, particularly for flash floods in basins with smaller drainage areas. Our results show that adding channel infiltration to WRF-Hydro can produce a physically consistent hydrologic response with a high-resolution gauge based precipitation forcing dataset in the USDA-ARS Walnut Gulch Experimental Watershed. NWM WRF-Hydro is also tested for the Babocomari River, Beaver Creek, and Sycamore Creek catchments.

Hydrologic assessment of biogeochemical interactions at the sub-meter scale

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The understanding of processes in the critical zone (CZ) is dependent on studies linking the fields of hydrology, microbiology, geochemistry and soil development. Additionally, there is needed to integrate hydrologic information into biogeochemical analysis of subsurface environments. This study investigated potential hydrological indexes that help explaining spatial biogeochemical patterns observed at the sub-meter scale. The miniLEO is a 2 m^3, 10 degree sloping lysimeter located at Biosphere 2 - University of Arizona. The lysimeter was initially filled with pristine basaltic soil and subject to intermittent rainfall applications throughout the period of 18 months followed by its excavation, resulting in a grid-based sample collection at 324 locations. As a result, spatially distributed microbiological and geochemical patterns as well as soil physical properties were obtained.

A hydrologic model was developed to simulate the history of the system until its excavation. Following the model calibration, the resulting distributed fields of flow velocities and moisture states were retrieved and translated into hydrologic indices. This study explores what are the relevant hydrologic mechanisms controlling the biogeochemical signatures at the sample scale.

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QBO/Solar modulation of the Madden-Julian Oscillation: A composite analysis

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The Madden-Julian Oscillation (MJO) is the primary driver of intraseasonal weather and climate variability in the tropics, and has been linked to weather variability in the midlatitudes. Recent studies have shown that the stratospheric quasi-biennial oscillation (QBO) modulates the amplitude of the MJO in Northern Hemisphere winter, where larger amplitudes occur during the easterly phase of the QBO (QBOE) compared to the westerly phase (QBOW). Evidence has also been presented that indicates changes in vertical motion in the lower stratosphere are linked to the 11-year solar cycle, where increased (decreased) ascent and reduced (increased) static stability occurs during solar minima (maxima). The largest MJO amplitudes and occurrence rates, and weakest static stabilities in the lower stratosphere occur during the QBOE phase at solar minimum conditions, while the opposite is true during QBOW at solar maximum conditions.

The aim of this presentation is to compare MJO events during the above conditions using atmospheric dynamic diagnostics. Preliminary results suggest that the MJO influence on midlatitude flow may be modulated by the QBO and solar cycle. It is suggested that these results are potentially useful for weather and climate applications regarding the effects of stratospheric processes on tropical deep convection and seasonal-to-subseasonal variability.

Intensified Atmospheric Rivers due to a Warmer Climate: What are the potential hydrological changes in the SRP Basins?

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Recent studies have found that Atmospheric Rivers can be intensified as a consequence of a warmer climate. These intensified narrow bands of enhanced water vapor transport lead to spatio-temporal changes in precipitation and temperature; and these changes are strongly related to the spatio-temporal distribution of hydrologic fluxes at catchment scale i.e. streamflows, snow water equivalent, evapotranspiration, and soil moisture distribution, among others. The objective of this talk is to describe and quantify the hydrological changes derived from the five most intense ARs events that affected the Salt and Verde River basins in Central Arizona between 1980 and 2010. These two basins are important for the Salt River Project (SRP) that produces hydroelectricity and store water for the megacity of Phoenix. The intense ARs events were simulated for a control and a future scenario using the WRF regional climate model. Deltas in precipitation and temperature were calculated for each AR event, and then used to generate perturbed daily precipitation and temperature fields to feed the Variable Infiltration Capacity (VIC) Model. The model was calibrated and validated to simulate control and future scenarios of daily streamflows for both basins. The changes of the hydrological fluxes derived from the VIC model results (control versus future scenario) are analyzed and discussed in terms of their spatio-temporal distribution, and their potential effects in the storage capacity of the SRP system.

Characterizing hydrologic flow paths and groundwater-surface water dynamics in a high elevation volcanic catchment

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In a high elevation volcanic catchment in the Jemez River Basin Critical Zone Observatory within the Jemez Mountains of Northern New Mexico, a bimodal precipitation pattern creates different hydrologic flow regimes during spring snowmelt and summer monsoon events. Previous work using concentration-discharge relationships and end member mixing analyses has suggested that hydrologic flow paths vary seasonally. This study tests that hypothesis and explores the hydrologic connection of surface water and groundwater from various depths by examining their major ion chemistry and elemental ratios. Downhole neutron probe surveys in three groundwater wells are used to investigate how wetting fronts propagate through the vadose zone via vertical infiltration or lateral subsurface flow. This study also combines observations of groundwater table elevations, streamflow, and precipitation accumulation to test the hypothesis that the highly heterogeneous structure of the subsurface controls its hydrologic response and the response time of surface water and groundwater to precipitation events. I further hypothesize that fracture versus matrix flow controls water chemistry as water transports solutes through different weathering environments as water table depths rise and fall seasonally.