The University of Arizona
Department of
Hydrology & Atmospheric Sciences
Presents

El Día del Agua y la Atmósfera

April 1, 2016
Student Union South Ballroom

"Lake in Badain Jardan Desert, China"
By Ning Ma

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Message from HASSA

On behalf of the Hydrology and Atmospheric Sciences Student Association (HASSA) at the University of Arizona, we would like to welcome you to our Annual Student Research Symposium, El Día del Agua y la Atmósfera, 2016. This joint symposium is the result of merging El Día del Agua, established by the Department of Hydrology & Water Resources' Student Association (HWRSA) in 1990, and AIR, established by the graduate students from the Department of Atmospheric Sciences (ATMO) in 1999.

El Día del Agua y la Atmósfera (EDDAA) is one of five symposia to be held during EarthWeek 2016, a collaborative conference organized by the School of Earth and Environmental Sciences (SEES). EDDAA is organized and managed in part by students from the Department of Hydrology and Atmospheric Sciences (HAS) and is the perfect opportunity for them to present their current work. It provides students with the opportunity to meet and network with their peers, prospective students, faculty members, alumni, and working professionals from within the fields of hydrology, atmospheric sciences, and other related disciplines.

The success of El Día is made possible through the continued support of our sponsors, the efforts of HAS students, faculty, and staff members, the School of Earth and Environmental Sciences, and the University of Arizona College of Science.

We hope you enjoy the symposium and thank you very much for attending El Día del Agua y la Atmósfera, 2016.

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HASSA Officers

From left to right: Ravindra Dwivedi: Vice President, Ben Paras, Marisa Earll and Brianna McClure: Social/Service Chairs; Francisco Balocchi: Treasurer;
Dr. Thomas Meixner: Adviser;
and Rodrigo Valdés: President

Below from left to right: Timothy Lahmers and Dean Pryles: Atmospheric Sciences Representatives

El Día del Agua y la Atmósfera 2016 Schedule

8:00- 9:00 **Conference Registration, Breakfast and Opening**

8:00-8:45 Registration and Breakfast

8:45-8:55 Opening and Welcome Speech: Eric Betterton, Department Head, Hydrology & Atmospheric Sciences

8:55-9:00 HASSA Officer Speech: Rodrigo Valdés

9:00-10:00 **Oral Session 1: Surface and Groundwater Hydrology:** Using experiments and models to understand hydrologic processes.

9:00-9:15 **Ravindra Dwivedi:** Importance of the hydrogeology laboratory in making well-trained hydrogeologists for tomorrow

9:15-9:30 **Runjian Wu:** Numerical simulation of colloidal particles release and deposition in 1D soil column

9:30-9:45 **Tirthankar Roy:** Probabilistic real-time streamflow forecasting in African basins

9:45-10:00 **Brianna McClure:** The best part of waking up: hydrology in your cup

10:00-11:00 **Poster Session 1:** All Atmospheric and Hydrologic Sciences Related Fields (Tucson Room).

11:00-11:45 **Oral Session 2: Atmospheric Modeling:** Analysis of regional atmospheric modeling methods for predicting weather and climate.

11:00-11:15 **James Moker:** mpact of precipitable water vapor into North American monsoon convective precipitation forecasts

11:15-11:30 **Konstantine Pryles:** Investigation of tropical cyclone extratropical transition and downstream flow effects

11:30-11:45 **William Cassell:** The effect of a changing climate on the military bases of the Southwest

El Día del Agua y la Atmósfera 2016 Schedule (continued)

11:45-12:00 **Lightning Round Session:** First Year Atmospheric Sciences Graduate Students Lighting Round (5-minute Presentation)

11:45-11:50 **James Fowler:** Ensemble-Based analysis of factors contributing to the development of tropical cyclones from African easterly waves

11:50-11:55 **Tyler Kranz:** Thunderstorm and terrain interactions in the grand canyon region

11:55-12:00 **Sujan Pal:** Improvement in summer seasonal streamflow forecasting in the Southwest United States using regional climate product

12:00-12:45 **Luncheon:** Lunch in South Ballroom with "Remarks over Lunch" by Dr. Eric Betterton

12:45-13:45 **Round Table Session:** Student and scientist roundtable discussion of the impacts of climate change in the southwest. Moderated by Professors Hoshin Gupta and Christopher Castro (Catalina Room).

13:45-14:45 **Oral Session 3: Hydrometeorology:** Observing and modeling water and energy fluxes between the atmosphere and the land surface.

13:45-14:00 **Jack Eyre:** Developing a Greenland near-surface air temperature dataset for climate monitoring and ice sheet mass balance modeling

14:00-14:15 **Rodrigo Valdés:** Multi-decadal 40- to 60-year cycles of precipitation variability in Chile (South America) and their relationship to the AMO and PDO signals

14:15-14:30 **Timothy Lahmers:** Optimization of precipitation and hydrologic forecasts in two regions of the Contiguous US

14:30-14:45 **Nicholas Dawson:** A new snow density model for land data assimilation and modeling

El Día del Agua y la Atmósfera 2016 Schedule (continued)

14:45-15:45 **Poster Session 2:** All Atmospheric and Hydrologic Sciences Related Fields (Tucson Room).

15:45-16:45 **Keynote Speaker:** Paul A. "Ty" Ferré, Darcy Lecturer Presenting Series in Groundwater Science 2016, "Seeing Things Differently: Rethinking the Relationship between Data, Models."

16:45-17:15 **Presentation of Awards and Prizes:**
Montgomery Prize
Hargis Award
HAS Best Oral and Best Poster Presentations
Donald R. Davis Undergraduate with Distinction
Eugene S. Simpson Best Undergraduate Poster
HAS Most Outstanding Instructor Awards, Aqua Person

17:15-19:00 **Post-Symposium Reception**
Please join us for Hors D'oevres and refreshments immediately following the awards ceremony at the Silver and Sage Room in Old Main.

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Awards and Prizes ~ Evaluation Committees

Students are recognized for their superior achievement in oral and poster presentations by juried committees. We are most grateful to the Judges for volunteering their time and expertise in selecting award winners. Their energy, enthusiasm, and constructive feedback inspire us all to achieve our personal best.

Montgomery Prize

Best Oral Presentation
Certificate and Award of $2,000
Judges: Jon Whittier, Martha Whitaker, Jeff Kennedy

Hargis Awards

Best Technical Presentation via Visual Communication
First Place Poster, Certificate and Award of $1,000
Second Place Poster, Certificate and Award of $400
Judges: Dennis Scheall, Chris Perkovac, Tim Corley

HWR Awards of Excellence

Best Oral and Poster (excluding Montgomery and Hargis winners)
Certificate and Award of $400 for each award
Oral Judges: Chris Magirl, Hsin-I-Chang, Brandon Forbes;
Poster Judges: Matej Drucik, Jim Washburne, Michael Brunke, Peter Hazenberg

Donald R. Davis Undergraduate Distinction Award

Outstanding Undergraduate Award (Academic or Research)
Certificate and Award of $400
Judges: Rodrigo Valdés, Francisco Balocchi, Brianna McClure

Eugene S. Simpson Undergraduate Poster Award

Best Undergraduate Poster in Hydrogeology, Subsurface Hydrology, or Groundwater
Certificate and Award of $400
Judges: Rodrigo Valdés, Francisco Balocchi, Brianna McClure

Aqua Person Award

HAS Most Outstanding Instructor Award **Judges:** HAS Students

The Montgomery Prize

We would like to thank Errol L. Montgomery & Associates, Inc.

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for their support. For many years, Montgomery & Associates has sponsored the premier cash award, *The Montgomery Prize*, for the Best Oral Presentation at our annual student research symposium.

This "best of the best" prize is made in addition to the departmental Awards of Excellence for best oral and best paper presentations and is presented to the winner by a representative from Montgomery & Associates. The award symbolizes the company's commitment to encouraging and rewarding excellence in oral presentation of hydrologic research. Montgomery & Associates offers similar awards during annual events at the University of Arizona and Northern Arizona University Geology Departments.

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for their support. For many years, Hargis+Associates has sponsored two generous cash awards, The Hargis Awards, for the First and Second Place Best Poster Presentations at our annual student research symposium.

Evaluation of these awards is performed by a panel selected by HWR Alumnus Dr. David Hargis, President and CEO of Hargis+Associates, Inc., in San Diego, California. Hargis and his fellow HWRS Alumnus Dr. Leo Leonhart, Principal Hydrogeologist and Chief Technical Director, Hargis+Associates, Inc., in Tucson, annually present these awards. The Hargis Awards are made in recognition of the need for excellence in technical communication and serve as an incentive for participating students to demonstrate excellence in writing, visual presentation, and oral communication skills in support of their research projects.

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Donald R. Davis
Undergraduate Distinction Award

Donald R. Davis joined the UA Department of Hydrology and Water Resources in 1972 and was one of the most senior members of the faculty at the time of his death in February 2009. His primary research focus was decision making under hydrologic and other uncertainties, and his basic approach utilized Bayesian decision theory in a general system setting.

During the last decade of his life, even though the halcyon days of funded research were behind him, Don was still actively engaged in independent statistical studies with individuals both inside and outside the university. He continued to serve on MS and PHD exams and to advise masters and especially doctoral students who were majoring or minoring in Hydrology with the statistical aspects of their research projects. He was an active faculty examiner for the doctoral qualifying examinations in surface hydrology and water resources.

Don served as the Undergraduate Coordinator and was the primary advisor to undergraduates with a major or minor in Environmental Hydrology and Water Resources. He taught the year-long Senior Capstone and Senior Honors Thesis courses and, when the department was part of the College of Engineering, was a rotating instructor for the COE's freshman course, Engineering 102. With Gary Woodard, he designed and oversaw the Master of Engineering degree program in Water Resources Engineering and helped that fledgling program get off the ground.

Upon his death, he left an endowment to the Department of Hydrology and Water Resources specifically for undergraduates whom he especially supported and encouraged.

The evaluation for the Davis Undergraduate Distinction Award is made by a committee appointed by the department and recognizes an outstanding undergraduate who demonstrates excellence in writing, speaking, or technical communication or provides outstanding service through volunteerism or extracurricular activities that benefit the department or the profession.

Don will be remembered not only for his academic and advising contributions, but also for his love of the undergraduate program he nurtured.

Eugene S. Simpson
Undergraduate Poster Award

Eugene S. Simpson began his professional career with the U.S. Geological Survey in 1946 where he was involved with problems of migration and dispersion of radioactive wastes that might accidentally or operationally be discharged into groundwater.

In 1963, he was hired by Dr. John W. Harshbarger as a member of HWR's inaugural faculty, and he continued to pursue his research interests in aquifer mechanics, the migration of pollutants in groundwater, and the application of environmental tracers to problems of groundwater circulation. Simpson served as HWR Department Head from 1974-75 and 1979-81.

After his retirement in 1985, he remained active in the profession, serving the U.S. Chapter of the International Association of Hydrogeologists as Secretary-Treasurer from 1984-89 and as President from 1989-92. During his tenure as President, he became the Founding Editor and first Editor-in-Chief of the IAH journal, *Applied Hydrogeology*, which later became *Hydrogeology Journal* (Springer), the official journal of the IAH.

The Geological Society of America Hydrogeology Division honored him with the Distinguished Service Award in 1992, and the International Association of Hydrogeologists elected him an Honorary Member in 1993.

Following retirement, he resided in Tucson until his death at the age of 78 in December 1995. At that time, the Eugene S. Simpson Endowment was established to provide financial support for undergraduate and graduate students, especially those studying hydrogeology and subsurface hydrology.

In March 2012, the inaugural Eugene S. Simpson Undergraduate Poster award was made for the best undergraduate poster with priority given to hydrogeology, subsurface hydrology, or groundwater content, Simpson's areas of expertise. Evaluation for the award is made by a committee appointed by the department.

The department would like to thank the family, friends, and former students of Eugene S. Simpson for their continued support and contributions to this endowment fund.

El Día del Agua y la Atmósfera
Luncheon Speaker
"Remarks over Lunch"

Dr. Eric A. Betterton
Distinguished Professor and Department Head
Hydrology & Atmospheric Sciences

Dr. Betterton is University Distinguished Professor in the recently merged Department of Hydrology & Atmospheric Sciences, where he is currently the Head.. Dr. Betterton has held courtesy appointments in the Department of Chemical and Environmental Engineering, and in the Division of Community, Environment and Policy, Zuckerman College of Public Health.

Born and raised in Zimbabwe, I studied chemistry in South Africa, and environmental science at Caltech. Along the way, he worked in the platinum mining industry, and in cement and lime manufacturing. He joined the University of Arizona in 1988.
Dr. Betterton's research in the laboratory and in the field is focused on environmental pollutants, especially those found in the air and water that might affect people. For example, he studies toxic metals in airborne dust, the chemistry of rain and snow, and the environmental fate of sodium azide, the propellant used in certain automobile airbags.

Dr. Betterton teaches a large introductory course in weather and climate, and smaller, more advanced courses in atmospheric physics, atmospheric chemistry, and atmospheric particulate matter (dust and aerosols).

El Día del Agua y la Atmósfera
Keynote Lecturer

Dr. Paul A. “Ty” Ferré
2016 Darcy Lecture
Professor
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Ty Ferré, Ph.D., is a professor in the Department of Hydrology and Atmospheric Sciences at the University of Arizona. He received his bachelor's degree in geophysical engineering from the Colorado School of Mines and his Ph.D. in Earth sciences from the University of Waterloo.

“Seeing Things Differently: Rethinking the Relationship between Data and Models”
Ferré's lecture explores how the practice of hydrology depends on computer models while at the same time new methods have been adapted or developed for characterizing and monitoring the subsurface.

He notes these two areas have evolved almost completely independently of one another, but posits a unified approach is needed — designing measurement methods in the context of numerical analyses that address specific scientific and management questions. Accordingly, Ferré will present an integrated overview of the relationships among models, measurements, and decisions, including:

Discussing what is actually being measured when measurements are made, with a focus on the large scale from pumping tests to geophysics

Describing how these measurements currently are being merged with models and how this process could be improved

Covering how hydrogeologists can turn the standard approach to combining measurements and models around by using models to help identify more informative measurements

Exploring how the optimal design of a measurement and modeling campaign can, and should be, driven by the specific practical or scientific questions being asked.

Roundtable Session

Catalina Room from 12:45 - 13:45

The Departments of Hydrology and Water Resources and Atmospheric Sciences have merged to form the Department of Hydrology and Atmospheric Sciences. Our vision is that this new department will be well placed to answer the critical questions confronting society in the decades to come. This roundtable will enable us to explore our common ground through the overarching question: **"In what way do the problems related to "water provision" and "natural hazards" require a broader interdisciplinary perspective?"**

Roundtable Subtopics:

1. The changing nature of extremes (moderated by Dr. Christopher Castro).

2. Water sustainability in the Western US (moderated by Dr. Hoshin Gupta)

The roundtable will consist of introductions by the moderator and each student, followed by a 30-minute group discussion. Groups will come together at the end of the session to discuss their conclusions and ideas for research in these areas.

Oral Session 1:

Surface and Groundwater Hydrology:

Using experiments and models to understand hydrologic processes.

Importance of the hydrogeology laboratory in making well-trained hydrogeologists for tomorrow

Ravindra Dwivedi, Elizabeth Kahler, Jack Anderson, Oleksiy Chernoloz, Arianne DePauli, Xiaobo Hou, Mandla Kunnie, Edwin Norlin, Mekha Pereira, Rey David Reyes, Joseph Valachovic, and Marek Zreda

Department of Hydrology and Atmospheric Sciences
The University of Arizona, Tucson, AZ

In the age of fast computers and availability of sophisticated numerical algorithms for simulating challenging groundwater management problems, the value of simple laboratory experiments aiming to better understand the effects of varying hydrologic parameters on fate and transport of contaminants or groundwater flow processes themselves are often overlooked. Furthermore, given the user-friendliness of the latest computer codes, even the sophisticated ones, the value of analytical solutions remains largely untested. Through a rigorous syllabus for the Hydrogeology laboratory (course HWRS/GEOS: 431/531) we have attempted to break the aforementioned trends. We have tried to emphasize value of simple laboratory experiments, analytical solutions and graphical methods, in addition to groundwater flow modeling using industry-standard software. Along with the laboratory experiments, students are also enriched with respect to concepts such as scientific illustrations, report writing skills, and scientific presentation skills through invited talks. As a result, it is found that students are well aware of employers' expectations for becoming the potential employee of various environmental consulting firms in town. Students are further found to be better trained as a hydrogeologist, irrespective of their employment preferences.

Numerical simulation of colloidal particles release and deposition in 1D soil column

Runjian Wu and Guo-Yue Niu

Department of Hydrology and Atmospheric Sciences
The University of Arizona, Tucson, AZ

Colloidal particles are heavily involved in sediment processes in the subsurface soil among the natural system. Because of the importance of these processes in the subsurface environment transport of colloidal particles has been investigated in several disciplines, such as the soil sciences, and environmental engineering. The release and transport of colloidal particles and the consequent physical alteration of subsurface sediments are mainly controlled by the subsurface flow. Along with subsurface flow some released colloidal particles will deposit in places of low flow velocity, lowering the hydraulic conductivity of the porous medium. Here we studied the effect of colloidal particles during infiltration. The theory of mobilization (release, transport, and deposition) of colloidal particles is based on the sorptive transport model. The release and deposition process are interpreted as desorption and adsorption respectively. Through comparing the hydraulic conductivity and wetting front along the soil column, we found that the release and deposition of colloidal particles can cause development of heterogeneity in the initially homogeneous porous medium. We also explored the feedback of the resulting heterogeneity to the subsurface flow and soil moisture.

Probabilistic real-time streamflow forecasting in African basins

Tirthankar Roy, Aleix Serrat-Capdevila, Hoshin Gupta, and Juan B. Valdés

Department of Hydrology and Atmospheric Science
The University of Arizona, Tucson, AZ

We present a real-time probabilistic streamflow forecasting platform that utilizes cutting-edge remote sensing products and weather forecast model outputs to forecast streamflow with 7-10 day lead time. The platform incorporates three hydrologic models and four remote sensing -based precipitation estimates along with in-situ measurements to remove the bias inherent to the satellite-based estimates. We evaluate the advantages of bias correcting the model inputs and outputs, and seek the best possible way of merging multiple streamflow forecasts. The uncertainty bounds in the final forecasts relate to the amount of risk involved in decision making. The forecasting platform is currently operational, providing real-time streamflow monitoring facility and supporting the water management decisions of the local water managers.

The best part of waking up: hydrology in your cup

Brianna McClure, *Marisa Earll, Han Tang, P.A. Ty Ferré*

Hydrology and Atmospheric Sciences Department
The University of Arizona, Tucson, AZ

Many hydrologists in social situations are faced with the daunting task of explaining what it is, exactly, that we "do". The truth is that principles of hydrology have countless implications for everyday life, from the suds on the top of your beer, to the pattern of fans entering and leaving a sporting event, to game show games. Hydrology is everywhere, and it's so much more than water- it's coffee! This study uses a basic understanding of subsurface hydrology and a pinch of creativity to examine how the size of coffee grounds determines the concentration and volume of coffee brewed over time. Fine, medium, and coarse ground Arabica coffee were brewed and time interval fractions were collected. The fractions were then compared to prepared standards for each grind size. The transport process of diffusion, in combination with porous medium characteristics such as surface area, porosity, and storage, were used to describe how grind size impacts the brewing process and how drinking coffee can benefit your career as a hydrologist.

Oral Session 2:

Atmospheric Modeling:

Analysis of regional atmospheric modeling methods for predicting weather and climate

Impact of precipitable water vapor into North American monsoon convective precipitation forecasts

James M. Moker[1], Avelino Arellano[1], Christopher L. Castro[1], and Yolande Serra[2]

[1]Department of Hydrology and Atmospheric Science
The University of Arizona, Tucson, AZ

[2]Joint Institute for Study of the Atmosphere and Ocean (JISAO),
The University of Washington, Seattle, Washington, USA

Snow quantities are important to numerous stake holders, especially in mountainous environments where streamflow is dependent on snowmelt. However, initialization of these quantities in operational forecast models was found to be insufficient in a previous study. Snow depth (SD) initialization was too shallow and the application of a globally and temporally constant snow density compounded the problem for snow water equivalent (SWE). In this study we evaluate whether the NOAH Land Surface Model is suitable to replace the constant density approximation due to its inclusion in the Global Forecasting System, Climate Forecasting System, and North American Mesoscale models. First, the National Land Data Assimilation Systems NOAH median snow density is calculated for different snow classifications with mean absolute error (MAE) of 11.9 percent of the median observed SNOTEL snow density averaged across three water years. A systematic overestimation of snow density is also observed during snow melt. Daily NLDAS SD and SWE are then evaluated with a published method to upscale point observations to area averages. Results indicate that NLDAS is an improvement over National Centers for Environmental Prediction initializations, but still underestimates area-averaged SD and SWE in mountainous environments. The NOAH density formulation is then tested with observed SWE and 2m air temperature, but results in a similar MAE of 12.3 percent and overestimated density during snow melt. A new physically-based snow density model is developed which includes a memory of snow density not seen in previous models. The new model produces MAE of ~ 5 percent compared to median observed snow density. Additionally, the model outperforms the Snow Data Assimilation Systems density predictions and can be implemented into current NCEP initialization procedures.

Investigation of tropical cyclone extratropical transition and downstream flow effects

Konstantine Pryles[1], Elizabeth Ritchie[2], and Kimberly Wood[3]

[1]*Department of Hydrology and Atmospheric Science*
The University of Arizona, Tucson, AZ

[2]*School of Physical, Environmental, and Mathematical Sciences,*
UNSW Canberra, Canberra, Australia

[3]*Department of Geosciences, Mississippi State University, Starkville, MS*

As a tropical cyclone (TC) moves poleward and recurves to the east, it begins to interact with the baroclinic environment associated with the midlatitude regime. This interaction of the TC with the midlatitude environment can lead to the development of a hybrid extratropical cyclone that contains characteristics of both the original TC and a midlatitude cyclone in a process known as extratropical transition (ET). Recent studies have shown that there is potential for recurving TCs to perturb the midlatitude waveguide, which can result in a downstream high-amplitude response in the flow, and occasionally development of high impact weather events.

Here we present WRF-based case studies of two North Atlantic hurricanes from September 2011 that underwent ET and subsequently impacted Western Europe. Hurricane Katia (2011) moved into the midlatitude regime, interacted with an upstream trough, and developed into a significant extratropical cyclone that propagated east across the Atlantic and impacted the British Isles causing 1 death and $157 million USD in damages. A week later, Hurricane Maria was absorbed by the baroclinic regime over the Canadian maritimes during ET. However, the upper-level flow downstream of Maria became quite perturbed generating a midlatitude cyclone that impacted Europe approximately 3-4 days later. In this presentation, we will discuss the physical characteristics of each case and diagnose the physical processes that resulted in such different midlatitude evolutions and outcomes.

The effect of a changing climate on the military installations of the Southwest

William Cassell[1], Christopher Castro[1], Thang Luong[2], and Timothy Lahmers[1]

[1]*Department of Hydrology and Atmospheric Sciences, The University of Arizona, Tucson, AZ*

[2] *Centro de la Ciencias de la Atmósfera, The Universidad Nacional Autónoma de México, México DF, México*

Strategic Environmental Research and Development Project (SERDP) is a project funded by the United States Department of Defense (DoD) to develop methodology and implementation for dealing with climate change. How climate change will affect US military operations is of great concern. In the Southwest, it has been firmly established that summer precipitation is forced from the small scale and not the large scale. The General Circulation Models (GCMs) and other coarse models are fairly unanimous in their prediction of warming on the large scale; however, they fail when it comes to accurately predicting on the small scale. For the Southwest, namely, the models do not produce a monsoon. This is due to convection being parameterized at the smallest scales and not correctly predicting the small-scale variations. To remedy this, our group produced dynamically downscaled simulations using reanalysis data from the National Centers for Environmental Prediction (NCEP) as forcing data to the convective permitting level; i.e., cumulus parameterization disabled. This simulation is broken into a "historical" period and a "modern" period for point of comparison. Then a method developed by our group is applied to the two periods to assess days of greatest convective likelihood. Variables like maximum precipitation, DCAPE, etc. are statistically analyzed at different locations each corresponding to a given military installation. This serves as a baseline for each installation as to how the model predicts the changing climate will affect it.

Lightning Round Session:

First Year Atmospheric Sciences

Graduate Students

Lighting Round (5-minute Presentation)

Ensemble-based analysis of factors contributing to the development of tropical cyclones from African easterly waves

James Fowler and Thomas Galarneau

Department of Hydrology and Atmospheric Sciences
The University of Arizona, Tucson, AZ

More than half of all tropical cyclones (TCs) over the North Atlantic basin develop from westward-propagating disturbances that originate over west Africa. These disturbances, termed African easterly waves (AEWs), are initiated by mesoscale convective systems over the Sahel region of Africa. As these AEWs emerge from Africa over the eastern North Atlantic basin, some will quickly develop into TCs within 2 days, while others take longer to develop and some will not develop at all. Numerous previous studies have used model reanalyses and observations collected during field programs to examine factors that distinguish whether an AEW will develop into a TC or not. In general, these studies have shown that TC development is more favorable with stronger AEWs that have increased low-level moisture on their northwest flank compared to non-developing AEWs.

The prediction of TC development in operational global models continues to be a difficult forecast challenge. Previous studies have shown that the European Centre for Medium-range Weather Forecasts (ECMWF) and National Centers for Environmental Prediction (NCEP) global models both under-predict genesis in their day 1–5 forecasts. The science question that we aim to address is: What are the factors that determine whether an AEW will develop into a TC or not in a numerical model forecast? Are these factors consistent with those documented in observations and model reanalyses? Forecasts from the 50-member ECMWF global ensemble forecast system will be utilized to study this problem. In this presentation, we will examine ensemble forecasts for TC Earl (2010) by comparing ensemble members that developed Earl into a TC with those ensemble members that did not. Factors that distinguish development from non-development in the ensemble forecast, such as differences in storm environment and storm structure, will be discussed.

Thunderstorm and terrain interactions in the Grand Canyon region

Tyler Kranz, Ken Cummins, and Thomas Galarneau

Department of Hydrology and Atmospheric Sciences
The University of Arizona, Tucson, AZ

As thunderstorms traverse the Grand Canyon region located in northern Arizona during the monsoon season, defined here as June 15–September 30, they interact with extremely complex terrain. When observing the fate of these thunderstorms, a notable trend appears; the majority of these thunderstorms weaken or dissipate completely when moving over the canyon. The thunderstorms typically begin to weaken as they move over the rim of the canyon and experience a drastic change in terrain elevation of 1000–1500 m over a horizontal distance of < 500 m. As these thunderstorms weaken over the canyon floor, the occurrence of cloud-to-ground (CG) lightning also decreases. This presentation aims to address to the following science questions: What are the physical mechanisms and processes going on that cause these storms to dramatically weaken as they enter the canyon? How is the charging level within these thunderstorms behaving as they intersect the canyon? Is charge separation within these convective storms occurring over the canyon or near it?

To address these questions, we will focus on a geographic region that is a subset of the Grand Canyon, ranging from 35.7 to 36.2° N and 111.5 to 112.2° W. This domain captures the section of the canyon that separates the South Rim from the North Rim, which is one of the widest portions of the canyon. Analyzing and plotting the National Lightning Detection Network (NLDN) CG stroke count data over the Grand Canyon region for 2000–2015 shows there is a strong relationship between the topography of the canyon and the number of detected CG flashes. In fact, CG stroke counts along the rims of the canyon are nearly ten times greater than within the canyon at certain locations. A preliminary spatial radar climatology for the 2006 monsoon season, derived from the Next-Generation Radar (NEXRAD) site located at Flagstaff, AZ (KFSX), shows a similar relationship between topography and thunderstorm intensity. The CG lightning and radar climatology suggests there is a close relationship between the amount of moisture in the mixed-phase region and the underlying terrain.

Improvement in summer seasonal streamflow forecasting in the Southwest United States using regional climate product

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Accurate regional and local scale information about seasonal climate variability and its impact on water availability is important in many practical applications, including agriculture, water resource planning, long term decision making etc. Presently, the primary source for real time seasonal climate forecasts comes from the Climate Prediction Center (CPC) within the NOAA National Center for Environmental Prediction (NCEP) which uses North American Multi-Model Ensemble (NMME). But it has been observed that in comparison to the cool season, the level of skill in warm season seasonal forecasts of precipitation produced by the NMME is much lower (Kirtman et al. 2014) due to the poor climatological representation of warm season convective precipitation. To fully realize the potential in improving warm season seasonal forecasts using a dynamical modeling approach requires dynamical downscaling of NMME models to better improve their representation of convective precipitation. Specifically, a convective-permitting (3km) scale is required to explicitly represent thunderstorms in a regional model. Also, for basin scale study, coarse resolution models must be downscaled to create high spatial resolution information. This study addresses a method which can be useful to improve the seasonal forecasting and to get reliable streamflow projection for use in practical purposes. A decade long (which is to be divided into training and validation period) dynamically downscaled RCM simulation is generated using Weather Research and Forecasting model (WRF) with a 12 km spatial resolution covering the Colorado River basin by dynamically downscaling CFSR data. An additional convective-permitting nested domain (3km resolution) is included for the WRF simulation for specific sub basins of Southwest U.S region. The downscaled output will be used as the forcing data for calibrated hydrologic model WRF-Hydro in order to project the streamflow. This method also bypasses the need to perform bias correction which is mandatory for some statistically-based downscaling approach like Bias Corrected Statistical Downscaling (BCSD) which is commonly used in water resource planning. Thus a more straightforward, accurate representation of basin-scale climate features and reliable seasonal streamflow projection can be achieved by the exercise of performing high resolution WRF-Hydro-WRF-CFSR simulations.

Oral Session 3:

Hydrometeorology:

Observing and modeling water and energy fluxes between the atmosphere and the land surface.

Developing a Greenland near-surface air temperature dataset for climate monitoring and ice sheet mass balance modeling

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The Greenland ice sheet is a key indicator of climate change and its melting is a significant contribution to sea level rise. Uncertainty in surface mass balance (the component of ice sheet total mass variation most closely controlled by atmospheric forcing) is large and improving confidence in the climate and surface mass balance of the Greenland ice sheet is both a challenge and an opportunity. The goal of this research is to develop a value-added 10 x 10 km near-surface meteorological dataset, using multiple data sources, and assess its impact on ice sheet surface mass balance. To this end, three research questions will be addressed: (1) How well do different data sources represent climate as observed with in-situ weather stations? (2) How can the different data sources be combined to produce a high resolution (order 10 km) dataset? (3) What impact does the new dataset have on estimates of Greenland ice sheet surface mass balance?

In this talk I will show results that relate to the first two of these questions. Data sources are assessed based on three criteria: mean climate; diurnal cycle; and small scale (order 10 km) spatial variability. Satellite, reanalysis, model and gridded datasets show a wide range of error behavior in all three criteria, with MERRA2 having the best mean climate and CFSR having the best diurnal cycle. AIRS satellite data reflects mean climate better than several gridded temperature products, especially in summer. Different ways of combining and interpolating data sources are assessed using several groups of weather stations around the margin of the ice sheet.

Multi-decadal 40- to 60-year cycles of precipitation variability in Chile (South America) and their relationship to the AMO and PDO signals

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The high-frequency component of precipitation variability has been an important focus of study during the last few decades in Chile. Low-frequency variations, on the other hand, have received less attention, especially in association with multi-decadal cycles that can affect variability trends of precipitation in the long term.

This study analyzes these low-frequency patterns of precipitation in Chile (> 30 years), and their relationship to global Sea Surface Temperatures (SSTs), with special focus on associations with the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO) indices. Singular Spectrum Analysis (SSA) and its Multi-Channel version (MSSA) were applied to a dataset containing long instrumental records of monthly precipitation aggregated yearly and seasonally.

The relationships between the low-frequency variability of precipitation and the PDO are significant to the north of the country, whereas connections with the AMO are more significant to the south. This is also evident from the global spatial correlation analysis of low-frequency precipitation modes and SSTs, where the southernmost station shows a strong relationship with the Atlantic Ocean. We conclude that a significant multi-decadal precipitation cycle between 40 and 60 years is evident at the rain gauges located in low- and high- latitude regions of Chile. This low-frequency variability seems to be largely linked to PDO and AMO modulation.

Optimization of precipitation and hydrologic forecasts in two regions of the Contiguous US

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Convection during the warm season is an important source of precipitation throughout the contiguous US (CONUS), and it is often a cause of flash flooding. Forecasting precipitation and resultant streamflow is challenging for hydrologic and atmospheric models to resolve. In order to mitigate the effects of this problem, the National Oceanic and Atmospheric Administration (NOAA) National Water Center (NWC) is in the process of developing a national distributed hydrologic model using the Weather Research and Forecasting (WRF) Hydrologic modeling framework (WRF-Hydro) with forcing from the High Resolution Rapid Refresh (HRRR) mesoscale atmospheric model. We aim to improve this national hydrologic and atmospheric modeling framework through the calibration of the WRF-Hydro model for two regions of the CONUS for producing hydrologic forecasts and climate change projections.

The WRF-Hydro model, with a similar structure as the national configuration used by the NWC, is run in the Gila River Basin in Southern Arizona and the Iowa River basin in eastern Iowa. We demonstrate the utility of the model for forecasting high impact precipitation events in catchments with limited human modification. Atmospheric forcing for WRF-Hydro comes from the NASA Phase 2 North American Land Data Assimilation (NLDAS-2) dataset. The WRF-Hydro model is spun up and run for a single warm season using past precipitation from the National Center for Environmental Prediction (NCEP) Stage-IV and NLDAS-2 datasets. We demonstrate the effects of adjusting the model parameters on the local water balance, and thus the need for rigorous calibration. WRF-Hydro is also forced for selected events using a 3-km grid resolution Advanced Research WRF (WRF-ARW) atmospheric simulation. WRF-ARW is forced by downscaling the NCEP North American Regional Reanalysis (NARR) dataset. This methodology demonstrates the modeling framework that will be used for future parameter calibration of WRF-Hydro. We also demonstrate the need for an ephemeral channel loss function in the channel routing scheme, which would allow the model to realistically resolve streamflow and groundwater recharge in arid regions.

A new snow density model for land data assimilation and modeling

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Snow quantities are important to numerous stake holders, especially in mountainous environments where streamflow is dependent on snowmelt. However, initialization of these quantities in operational forecast models was found to be insufficient in a previous study. Snow depth (SD) initialization was too shallow and the application of a globally and temporally constant snow density compounded the problem for snow water equivalent (SWE). In this study we evaluate whether the NOAH Land Surface Model is suitable to replace the constant density approximation due to its inclusion in the Global Forecasting System, Climate Forecasting System, and North American Mesoscale models. First, the National Land Data Assimilation Systems (NLDAS) NOAH median snow density is calculated for different snow classifications with mean absolute error (MAE) of 11.9 percent of the median observed SNOTEL snow density averaged across three water years. A systematic overestimation of snow density is also observed during snow melt. Daily NLDAS SD and SWE are then evaluated with a published method to upscale point observations to area averages. Results indicate that NLDAS is an improvement over National Centers for Environmental Prediction initializations, but still underestimates area-averaged SD and SWE in mountainous environments. The NOAH density formulation is then tested with observed SWE and 2m air temperature, but results in a similar MAE of 12.3 percent and overestimated density during snow melt. A new physically-based snow density model is developed which includes a memory of snow density not seen in previous models. The new model produces MAE of ~ 5 percent compared to median observed snow density. Additionally, the model outperforms the Snow Data Assimilation Systems density predictions and can be implemented into current NCEP initialization procedures.

Hydrology & Atmospheric Sciences

Poster Presentations

Analysis of the spatial and temporal correlation statistics of soil moisture observed in the Russian River Basin, Northern California

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Statistical analyses have been used to study the seasonal variability of soil moisture in the Russian River watershed. The variability found in soil moisture measurements was compared to soil moisture variability simulated using the National Weather Service (NWS) Hydro Lab Research Distributed Hydrological Model (HL-RDHM). Soil moisture observation data for 2011 were obtained from the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorology Testbed (HMT), and evaluated for their utility in successive-correction data assimilation techniques. These data were collected at seven soil moisture observing stations in the Russian River Basin. The model was run using a-priori parameter estimates and atmospheric forcing grids supplied by the NOAA Office of Hydrological Development (OHD) and the California Nevada River Forecast Center (CNRFC). The spatial and temporal variability of soil moisture in the basin was analyzed using correlation statistics calculated for the four seasons during the study period. This poster will demonstrate how these analyses have been used to help determine whether or not soil moisture observations can be assimilated into the HL-RDHM, and thereby improve the quality of its soil moisture and streamflow simulations.

Vapor pressure deficits and transpiration rates of tree and vine species in the rainforest of Biosphere 2

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With an ever-changing climate and population growth, it is important to understand water's complete journey on Earth in order to help prepare for potential future water issues and to initiate studies to formulate solutions. Plants are an important part of our ecosystem, and transpiration by plants strongly influences the amount of water vapor in the air. The purpose of this project was to observe how transpiration rates of canopy and vine species are affected by environmental variables.

Biosphere 2 is a unique lab and field setting in which to study plant life and was utilized for this project. Relative humidity, temperature, time of day, location and sunlight availability were taken into account. Because of the multiple factors that affect transpiration rates, it was inappropriate to analyze vapor pressure deficits effect on transpiration rates exclusively. Multivariate analysis was used to analyze the trends between vapor pressure deficits and species transpiration rates. Since photosynthesis occurs when there is energy available, transpiration rates were naturally influenced by time of day and sunlight availability. Further analysis is needed to evaluate if vapor pressure deficits and transpiration rates can be related directly using only the current data set available.

Impact of the projected climate change on the hydrologic functioning of mountain catchments with application to the Marshall Gulch Catchment, Tucson, Arizona

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Mountain systems are critical sources of recharge to alluvial basins located in dryland regions. Unfortunately, Mountain Systems are threatened due to climate change in terms of reduced snowpack, precipitation changes, and increased temperatures. The climate risks to mountain systems are uncertain due to our limited understanding of natural recharge processes. Therefore, the main objective of this research is to improve our understanding of mountain system recharge processes through a multi-tracer approach coupled to numerical modeling of hydrologic processes. I will use: (a) multi-tracer approach involving 2H,3H/3He, and 14C tracers to improve an existing conceptual model of the Marshall Gulch Catchment (MGC) located within the Santa Catalina Mountains; and (b) simultaneous simulation of groundwater flow and transport of groundwater ages in MGC using COMSOL Multiphysics® software. With the proposed approach, it is expected that an improved conceptual model for MGC, which involves both shallow flow paths through the upper unconfined aquifer and deeper flow paths through the fractured-bedrock aquifers, can be developed. Such an improved conceptual model can then be used to understand the probable impacts of the climate change on mountain systems.

Determining the sources and bioavailability of nutrients to microbes in a coalbed methane

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Coalbed natural gas accounts for about 10% of natural gas production in the USA, 20% of which is microbial in origin (biogenic gas), produced by methanogens in sedimentary basins. Despite the importance of coalbed methane (CBM) as a natural gas resource, little is known about the microbial communities responsible for it's generation. It is thought they are limited by nutrients, such as nitrogen or phosphorus and trace metals, and it's not clear whether these nutrients are sourced from in-situ biodegradation of the coal or transported in from near-surface environments with groundwater recharge. This research explores these hypotheses by addressing the following key questions: 1) What is the source of nutrients available to microbes in CBM systems and how are they mobilized? 2) How does the biodegradation of coal organics affect the availability of nutrients for microbes? 3) How do these conditions evolve with depth and distance, regionally across a coal seam? Based on these questions this study will examine the organic content and nutrient and trace metal geochemistry of the solid coal and associated formation water from coalbed methane wells in the Powder River Basin across a hydrologic gradient within single coal seams. Sequential dissolution (leaching) experiments (chemical extraction of organic and inorganic constituents) of 8 core (coal and sandstone) samples will provide insight into what nutrients are present in coalbeds, what minerals they are associated with, and how they may be mobilized. Each extraction will be analyzed for total dissolved inorganic and organic carbon (TIC/TOC), N and P species, trace metals, extractable hydrocarbons, and humic and organic acids. Solid samples of coal will also be analyzed for organic and inorganic-N and P, and TIC/TOC. If significant concentrations of N, P and trace metals are present, in-situ sourcing of nutrients by microbes is highly probable. Water samples collected from 2 coal seam transects will be equally analyzed to investigate the biogeochemical evolution of coalbed methane systems from the recharge area to depth (at least 530 ft). If microbial-limiting nutrients are transported into coal seams with groundwater recharge, I would expect higher concentrations of nutrients in recharge areas compared to deeper coalbeds. This project will provide crucial understanding of a fundamental aspect of methane production not yet fully understood.

Infiltration in ephemeral streams: quantifying the effect of gabions on vertical water flux using wildlife cameras and & temperature sensors

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In drylands prone to flash-flooding, simple rock structures called gabions can slow runoff and erosion in ephemeral-stream channels, increasing infiltration and recharge and improving riparian health. However, few quantitative studies assess the effectiveness of gabions. We aim to evaluate the impact of newly-installed gabions in an ephemeral-stream channel located on an Arizona grassland.

Five gabions were installed in May, 2015. We instrumented channel reaches upstream and downstream of one gabion with wildlife cameras, pressure transducers, and surface and subsurface temperature sensors. We also instrumented a control site on old agricultural fields in Tucson. We plan to infer vertical water flux through the subsurface using the temperature signal and analytical solutions of heat transport in soil. These methods use the extent to which daily temperature fluctuations are dampened and delayed with depth (because water transmits temperature changes more quickly than dry soil).

Novel to this study, we use repeat camera imagery to estimate ponded area through time, which can then be used to convert infiltration flux to total flow, with and without the gabion's influence. Additionally, we expect to see changes in infiltration flux through time, which will advance our understanding of the impacts of fine-sediment deposition upstream of the gabion.

Quantifying differences between cryogenic distillation and induction methods for stable water isotope analysis: implications for understanding plant-water dynamics

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In the environmental sciences much time, effort, and money are delegated to the analysis of stable water isotopes ($\delta^{18}O$ and $\delta^{2}H$), important tracers in understanding bio-physiological processes. Traditionally, water is extracted through the cryogenic vacuum distillation (CVD) process then sent to an isotope ratio mass spectrometer (IRMS) to measure the stable water isotopic composition.

However, in recent years Picarro Inc. has developed an Induction Module (IM) with a Cavity Ring-Down Spectrometer (CRDS), which work together as a quick one-step process for measuring stable water isotopic composition of various samples. This study compares the precision of the IM with that of traditional methods by comparing stable isotope values of waters extracted from stems, leaves, soils, and liquids.

Preliminary results from solid stem samples analyzed on the IM-CRDS and CVD distillate samples analyzed on the IRMS show a positive correlation. Differences between the isotopic values determined by these methods are partly due to (a) fractionations during water extraction and partly due to (b) spectral interference from organic contaminants. Results suggest that the IM is not as precise as the IRMS, but is a quick and relatively inexpensive alternative method of identifying trends in soil-plant-water dynamics.

Ecohydrological controls on understory greenness dynamics in subalpine mixed conifer ecosystems: A five-year study

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Subalpine mixed conifer forests are diverse ecosystems with distinct growth areas in the canopy and understory. As a key source of nutrient cycling in forests, foliage in the understory is especially important. While previous research has found that weather events and climate shifts can promote foliar development and greening in forest canopies, understory greenness dynamics have received less scrutiny.

In this study, we compare understory greenness, derived from time-lapse digital capture, with daily precipitation values, soil moisture content, and snow melt over five years in two subalpine mixed conifer ecosystems: the Santa Catalina Mountains (SCM) and Jemez River Basin (JRB) Critical Zone Observatories. We show that understory greenness is positively correlated with daily precipitation values and elevated soil moisture content in both systems.

Unlike at the JRB, understory senescence is consistently detected at the SCM in late July over five years, suggesting unique Ecohydrological controls. The SCM understory is dominated by ferns that may respond to the combination of high temperature and low precipitation experienced at this time of year. The importance of precipitation in understory greenness dynamics suggest that precipitation regime changes would have strong ecological implications for maintaining the healthy functioning of subalpine mixed conifer forests.

Tohono O'odham Nation Tribal water policy and water conservation: San Xavier district case study

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Water conservation is important to residents of Southern Arizona due to the sensitive nature water resources exhibits from anthropogenic uses. Better understanding tribal water allocations from the Central Arizona Project will allow tribal leaders to plan for future development and meet the consumptive needs of its citizens. This project identifies the Tohono O'odham's legal ability to lease water to off-reservation users, and proposes funds acquired from lease agreements to subsidize water conservation projects, like passive rainwater or greywater harvesting. The Tohono O'odham Utility Authority and San Xavier Cooperative Farm are undertaking an effort to conserve water on their land. Both entities are interested in pursuing water conservation measures to decrease irrigation leakage and promote local aquifer recharge. One way to conserve water is through passive and active rainwater harvesting including greywater systems – water harvested hand-washing sinks, showers, bathtubs and laundry machines. One project goal is to create a home water budget for a landscaping project on the San Xavier district of the Tohono O'odham Nation, and to investigate the amount of water needed to sustain vegetable gardens and food forests of various sizes. An implication of the project is to provide homeowners with a breakdown of inflow and outflow of water in a home landscape system to make a decision whether to pursue water harvesting and diminish the use of potable water for their outdoor needs.

Quantifying pecan water use in Southern Arizona: a two-year study

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Unregulated groundwater resources, favorable growing conditions, and an expanding export market have contributed to rapid growth in the Arizona pecan industry. Due to their long growing season, pecans are highly water consumptive; however, in Arizona, where growing season is particularly long, research quantifying actual pecan water use is lacking.

Therefore, it is unclear how new orchards might impact limited water resources. Using eddy covariance techniques, we measured pecan water use over two years (2014, 2015) in two sprinkler-irrigated orchards at different elevations (as a proxy for differences in growing season length). We also monitored phenological activity and canopy closure using time-lapse digital cameras. Despite differences in elevation, atmospheric demand, and precipitation, we found negligible differences in pecan water use (~ 49 in/yr) between the two sites.

However, while crop-coefficient curves increase similarly at the two sites, peak crop-coefficient values remain greater during the summer and decline more quickly in the fall at the higher elevation site, suggesting the influence of different growing season lengths. Canopy closure dynamics are similar to crop coefficient dynamics at the sites. This suggests that despite similar water use, crop-coefficients may be susceptible to changes in climate and management decisions that could ultimately impact pecan yield.

Economic evaluation of urban green-infrastructure systems: a case study in Tucson, AZ

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The urban landscape is comprised of impervious surfaces that promote surface runoff and flooding during rain events. Green-infrastructure (GI) provides an alternative to traditional storm water management by restoring the natural hydrologic processes of pre-development conditions.

In Tucson, AZ, a semiarid city that experiences pulse precipitation events, GI features provide flood mitigation, and improved environmental quality, among other ecosystem services. Because cities have limited resources for project development, quantifying the economic benefits of green-infrastructure is crucial to its implementation. Through a holistic cost-benefit analysis, economic modeling was done to assign a Net Present Value (NPV), or dollar value, to various GI features over a 40 year period in Tucson. The model finds positive NPVs for a rain garden, a rain garden with curb cut, and green streets; however, the rain garden retrofit, with its high cost of asphalt removal, produced a negative NPV.

This study suggests that investment in green-infrastructure would be a cost effective means of hazard mitigation for Tucson. As cities in the Southwest experience increasing pressures from scarce water resources and urban development, implementing sustainable development practices may be both environmentally and economically desirable.

Examining the impacts of wildfire on DOM quantity and quality in a southern Rockies forested catchment

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Wildfire frequency and intensity in the Western United States has increased in recent decades and has the potential to drastically alter soil and surface water chemistry. Dissolved organic matter (DOM) is an indicator of water quality and is essential to many environmental processes in the surrounding ecosystem. While it is likely that a fire causes shifts in processes governing DOM, it is unclear exactly how this occurs and what impacts are observed downstream. While other studies are limited to post-fire observations, this study involves pre-fire conditions as a foundation. The 2013 Thompson Ridge wildfire in the Valles Caldera National Preserve in the Jemez Mountains of New Mexico will serve as a focal point of this study in disturbance hydrology. This study seeks to (1) elucidate the impacts on DOM quantity and (2) describe DOM quality variations in typical catchment and post-fire processes. This study utilizes source water mixing analysis with fluorescence excitation-emission matrix spectroscopy (EEMs). Emphasis is put on changes in DOM quality as described by the fluorescence index (FI), humification index (HIX), and specific ultraviolet absorbance (SUVA). Trends between pre- and post-fire values will provide insight to shifts in hydrologic, biological, and chemical processes.

Implications of statistical and dynamical downscaling methods on streamflow projections for the Colorado river basin

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Climate change prediction under various scenarios using Global Circulation Models (GCM's) have gained widespread attention in the past couple of decades. These models are either statistically or dynamically downscaled to incorporate regional effects and reduce the model bias. This study compares and contrasts the commonly used statistical downscaling methods with a new method of dynamic downscaling developed by the authors. Our dynamic downscaling methodology involves generating a Regional Climate Model (RCM) using WRF and applying a new method of bias correction that preserves the relative change in the GCM/RCM using parametric quantile mapping method. These different climate models are then used as forcings through the Variable Infiltration Capacity (VIC) model at 1/8th of a degree to generate streamflow for three catchments in the Colorado Basin. The results are then analyzed to find statistically significant changes in various hydrological signatures using both these methods, and how it would impact the current climate change projections for the Western United States.

Evaluation of passive capillary wick samplers for measuring deep infiltration

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Passive capillary wick samplers (PCAPs) are primarily used to sample water from the vadose zone through the use of a hanging water column formed by a fiberglass wick. Though PCAPs have been used to estimate soil water flux, the accuracy to which the PCAPs can estimate flux comes into question due to oversampling/undersampling dependent on the strength and duration of precipitation events and soil type. To explore the conditions that give rise to inaccurate sampling, extensive use of the HYDRUS2D/3D groundwater modeling software was used to simulate a 2-D axisymmetric flow model in a medium containing a PCAP in both steady-state and transient conditions through the application of various precipitation rates and periods across several soil textures. Results show that the PCAP does overestimate/underestimate flux with varying capture multipliers calculated from the ratio of simulated flux into the plate and the simulated flux from precipitation. Larger fluxes and longer time periods resulted in increased convergence of flux into the PCAP while smaller fluxes and shorter durations resulted in divergence of flux from the PCAP. In this study, we will examine soil hydraulic properties, across the soil texture triangle for the medium that the PCAP rests in, subject to a range of precipitation events in HYDRUS2D/3D. Based on these, we will provide a tool to correct measured fluxes for any PCAP installation.

An improved resolution, spatially-distributed global model of sediment discharge and forecasting under future climate scenarios

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The magnitude of sediment discharge of a river provides insight to many ongoing processes in the upstream basin, in particular the basin-averaged erosion rate and the pace of landscape evolution. Knowledge of sediment discharge is applied in agriculture, water quality, calculating dam life expectancy, delta and alluvial fan dynamics, long-term nutrient cycling, and coastal morphology and dynamics. However, few models of earth surface sediment processes have been created for the global scale. This project improves by a factor of 100 the resolution of a global, spatially-distributed sediment flux model developed by Pelletier (2012) that explicitly differentiates the detachment of sediment from hillslopes and the movement of sediment down-gradient via riverine transport. Using data for monthly precipitation, monthly vegetation cover, slope, soil grain-size distribution, and two free parameters, the model replicates the sediment yield of 128 global rivers. The model was run using CMIP5 forecasts of temperature, vegetative cover, and precipitation, allowing for analysis of sediment discharge under various potential climate change scenarios.

An analysis on the Colorado river and its forecasting methods

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River flow analysis and forecasting is an important task as it may help water resource management agencies determine a distribution budget for a given period of time as well as provide a warning system for possible drought or flood situations. Long term data collection on a river provides insight into its behavior from which a forecast model may then be derived. Many studies have attempted to provide an accurate forecast model for the Colorado River, e.g, Stanley et al., Zeng et al., and currently the Bureau of Reclamation (BoR) in collaboration with the National Weather Service (NWS) has developed a 24-month forecast model.

In this study, an analysis on the Colorado River flow was completed in order to understand flow patterns. In addition, this study compares predicted Colorado River flow as determined by various forecast models against the current BoR model. Results may suggest that the current model used by the BoR is best suited for current needs. Adding to the existing work, this study may help determine which Colorado River forecasting model is best suited for use by water management agencies.

Understanding processes of information of end-members in the critical zone: a case of study of Valles Caldera, New Mexico

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The Valles Caldera is a volcanic collapse feature located in the Jemez Mountains in northern New Mexico, southwestern United States. This region is characterized by a bimodal precipitation pattern, i.e. winter snowfall and summer monsoon rainfall. Climate change has been significantly affecting these precipitation inputs, which potentially alter how water partitioned within the catchment, shifting infiltration rates, evapotranspiration, groundwater recharge and overland flow. Nonetheless, the orientation of the land surface, i.e. terrain aspect, controls the partitioning of both energy and precipitation, influencing microclimate, vegetation characteristics and water preferential flowpaths. Redondo Peak is located in the center of the Valles Caldera, it has several springs that drain around all sides of the mountain with different hydrologic responses. The main catchments (headwaters) identified in Redondo Peak are: La Jara, Upper Jaramillo, History Grove and Upper Redondo. A Principal Component Analysis (PCA) approach is used to reproduce and End-Member Mixing Analysis (EMMA) and thus identify what end-member(s) control streamflow generation among these catchments with different aspects, analyzing different levels of information, i.e. retaining two or three principal components (PC).

Evaluation of 22 precipitation and 23 soil moisture products over a semiarid area

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Precipitation and soil moisture are rigorously measured or estimated from a variety of sources. Here we evaluate 22 precipitation and 23 soil moisture products against long-term daily observed precipitation (Pobs) and July-September daily observationally constrained soil moisture (SM) datasets over a densely monitored 150 km2 watershed in southeastern Arizona, USA. Gauge/radar precipitation products perform best, followed by satellite and reanalysis products, and the median correlations of annual precipitation from these three categories with Pobs are 0.83, 0.46, and 0.68, respectively. The CMIP5 model precipitation results are the worst, including their overestimate of cold season precipitation and the lack of significant correlation of annual precipitation with Pobs from all (except one) CMIP5 models.

Satellite soil moisture products perform best, followed by land data assimilation systems and reanalyses, and the CMIP5 model results are the worst. For instance, the median unbiased RMSD values of July-September soil moisture compared with SM are 0.0070, 0.011, 0.014, and 0.029 m3m-3 for these four product categories, respectively. All 17 (except 3) precipitation [15 (except 2) soil moisture] products with at least 20 years of data agree with Pobs (SM) without significant trends.

The uncertainties associated with the scale mismatch between Pobs and coarser resolution products are addressed using two 4 km gauge/radar precipitation products, and their impact on the results presented in this study is overall small. These results identify strengths and weaknesses of each product for future improvement; they also emphasize the importance of using multiple gauge/radar and satellite products along with their uncertainties in evaluating reanalyses and models.

Joint analysis of bulk wildfire characteristics from multiple satellite retrievals

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Biomass burning significantly impacts atmospheric composition, as well as regional and global climate. Here, we investigate the spatio-temporal trends in fire characteristics in several major fire regions using combustion signatures observed from space. Our main goals is to identify key relationships between the trends in co-emitted constituents across these regions, as well as linkages to main drivers of change such as meteorology, fire practice, development patterns, and ecosystem feedbacks. Our approach begins with a multi-species analysis of trends in the observed abundance of CO, NO2, and aerosols over these regions and across the time period 2005 to 2014. We use MOPITT multi-spectral CO, OMI tropospheric NO2 column, MODIS AOD, and MODIS FRP retrievals. The long records from these retrievals provide a unique opportunity to study atmospheric composition across the most recent decade. While several studies in the past have reported trends over these regions, most of these studies have focused on a particular constituent. A unique aspect of this work involves understanding co-variations in co-emitted constituents to provide a more comprehensive look at fire characteristics, which are yet to be fully understood. Here, we introduce a derived quantity (called smoke index) to represent bulk fire characteristics (e.g., flaming versus smoldering). The smoke index is calculated as the ratio of the geometric mean of CO and AOD fire enhancements to that of NO2 fire enhancements. Our initial results, which focused on the Amazon region, show that: 1) deforestation fires are dominantly flaming fires while non-deforestation fires are more likely to be dominantly smoldering fires; and 2) droughts have larger influence on non-deforestation (possibly understory) fires than deforestation fires. Here, we will present an extension of this analysis to other fire regions around the globe (tropical, temperate and boreal fires) and explore other measurements available during this period for comparisons. We will also compare with current fire emission models, such as GFED and FINN, to test the robustness of our findings. We note that this exploratory work provides a unique perspective of fire characteristics that will be useful to improve predictive capability of fire emission and atmospheric models.

The global distribution of Iodine-129 and its potential application as a radiogenic age tracer in the Tucson basin

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Radiogenic tracers help determine groundwater recharge rates and flow paths. Decreasing environmental tritium concentrations necessitate the use of a new radiogenic tracer. Iodine-129 (129I), a long-lived radioisotope generated by nuclear weapons and fuel reprocessing, offers a potential alternative. This study compared the isotopic ratio of 129I to stable 127I with ages previously calculated with tritium. A strong logarithmic correlation was found between the tritium ages and the isotopic ratio.

Precipitation and surface water samples from Sabino Canyon and Marshall Gulch, Arizona were compared to global values from published research and at both locations the isotopic ratios in precipitation were higher than the ratios observed in surface water, which were higher than ocean or groundwater values. These samples also show a seasonal variation in isotopic ratio between summer monsoon and winter frontal precipitation, with values significantly higher in the summer.

Mixing model analysis performed on Sabino Canyon surface water, using Marshall Gulch baseflow, precipitation, and soil water as end members, did not conclusively show a shift in source water between these seasons and cannot explain the variation in isotopic ratios. However, the difference in precipitation source between the summer monsoon and winter frontal precipitation may be a factor in the variations.

Using water chemistry and isotopic tracers to constrain regional hydrogeology of the Cienega Creek basin, South-Central Arizona

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Wetlands in the Cienega Creek Watershed (CCW) in south-central Arizona provide critical habitats for endangered species and multiple reaches of Cienega Creek and Davidson Canyon have been designated as "Outstanding Arizona Waters." These surface waters, cienegas, and underlying groundwater in the alluvial basin are under pressure from threats of increasing groundwater pumping, landuse, climate change, and potential mining. Little information is known about the regional hydrogeology, such as groundwater recharge rates, groundwater flow across the basin, and connection of groundwater and surface water, which are important for accessing and protecting the sustainability of natural resources in the areas. To address this knowledge gap, this study aims to: (1) determine if there is any seasonal or altitude variability in the isotopic composition of precipitation across the CCW; and (2) to determine the location and timing of groundwater recharge, and relative age of water from the mountain front to Cienega Creek in the center of the basin. In addition, we will test the utility of using SO4/Cl ratios and sulfur and oxygen isotopes of SO4 to distinguish contributions of basin groundwater versus monsoon floodwater recharge to alluvial aquifers, Cienega Creek, and nearby wetlands.

Initial results of spring samples indicate high elevation recharge. Based on tritium analysis groundwater is a mix of modern and "older" waters; future analyses of carbon-14 and δ13C values of dissolved inorganic carbon will help provide more quantitative residence times of groundwater. Approximately, 40 Groundwater well samples will be collected along a transect from the Santa Rita Mountains to Cienega Creek. Samples will be analyzed for major ion chemistry, stable isotopes (δ18O, δD, δ13C, δ34S) and radioactive isotopes (3H, 14C).

Cross-correlation analysis of observed heads from stream stage variation in confined aquifers

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Using cross-correlation analysis, the relationship between observed heads and hydraulic properties in the saturated zones at locations of a two-dimensional alluvial fan during seasonal stream stage variation was investigated. Cross-correlation is a weighted sensitivity analysis casted into a stochastic framework. It determines the relative importance of each parameter with respect to others in time and space on the observed heads according to uncertainty or spatial variability of each parameter. Cross correlation analysis carries out the information content in measured drawdown about heterogeneity during a stress in an aquifer. Based on the data collected from the alluvial fan, the spatial distributions of cross-correlation and subsurface characteristic (grain size) appear to have some overlapped region. The synthetic, numerical example also supports that cross-correlation analysis reveals that heads in the saturated zone at late times carry the greatest weighted information content about the diffusivity (D) distribution.

Pumping scenarios in the Middle San Pedro

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There have been several MODFLOW models created for the Upper San Pedro Watershed in Southern Arizona, the majority of which have focused on the Sierra Vista sub-watershed. These models have utilized to address concerns surrounding the effects of pumping on groundwater levels and the baseflow to the San Pedro River, the last free flowing river in Arizona.

Less modeling attention has been paid to the Middle San Pedro Watershed, which is includes parts of the Upper and Lower San Pedro Watersheds that comprise the greater Benson area. Due to proposed development plans that suggest the prospect of large population growth, this area is considered an important area for water resource management. Important environmental concerns to be addressed include the possible consequences of groundwater drawdown and the how it may affect sensitive riparian areas.

In this study, MODFLOW, 2005 is used to model several pumping scenarios in the Middle San Pedro Watershed. The model was run with different pumping rates based on possible population growth scenarios in the region. Understanding the response of the riparian system to different levels of groundwater pumping allows for better-informed management of water resources in Southern Arizona.

Examining the effects of water transit time, seasonality, and geothermal inputs on U-series isotopic compositions of natural waters

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Uranium-series isotopes have recently been shown to be a relatively novel tracer of water-rock reactions and source water contributions. In a volcanic catchment in the Jemez River Basin Critical Zone Observatory (JRB-CZO) within the Valles Caldera National Preserve, variations in U-series isotopes in surface waters were shown across seasons (wet vs dry) and it was suggested that these variations could be due to different flow paths (shallow vs deep) and thus different water transit times (WTT) across seasons. Therefore, this study seeks to further examine the relationship between seasonality, WTT, and U-series isotopes in several catchments within the JRB-CZO. U-series isotope analysis will be strengthened by and combined with strontium and sulfur isotope analysis as much is already understood about the controlling factors of Sr isotopes in natural systems; S isotopes are commonly used as indicators of geothermal waters which are known to exist within and around the Valles Caldera. A multiple isotope approach including U-series, Sr, and S isotopes will allow this study to explore seasonality, WTT, and geothermal inputs as controls of isotopic composition of natural waters.

Water samples will be collected from streams within three catchments during the dry season, spring snowmelt, and the summer monsoon season to establish how seasonality controls the isotopic composition of waters within the Valles Caldera. Water samples will also be collected from nine springs, for which WTT based on tritium analysis were recently published, in order to determine the effect of WTT on the isotopic composition of natural waters. Finally, samples from surface waters within and downstream of the Valles Caldera will be collected to define the impact of geothermal waters on the isotopic composition of waters in the area. Understanding the controlling factors of U-series, Sr, and S isotope variations in natural waters largely devoid of human interaction at the JRB-CZO will provide an important natural baseline for future studies exploring anthropogenic impacts downstream of the Valles Caldera in one of the nation's largest rivers, the Rio Grande.

Gregory High School

Poster Presentations

ReACT: a public water use and quality awareness campaign

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Tucson Water has identified reclaimed water as a renewable water resource and has a three-year plan to process reclaimed water for drinking purposes. However, people distrust the scientific process of cleaning water for household water or simply find the "toilet to tap" idea uncomfortable. The objective of our project is to create greater awareness and acceptance of reclaimed water for household uses in Tucson through the use of social media and citizen science. Here we present the conceptual model of a phone and web application (App) that will use a crowdsourcing method to test reclaimed water regularly for various contaminants. The water quality data would be generated using special citizen science testing kits and would include water quality parameters of total coliform, total hardness, nitrate and nitrite, acidity, arsenic, lead, and mercury. Water quality testing volunteers would upload their data to a server via the app, which would also map data in space and time from other people in their service area. In addition, the app would send periodic water conservation news and tips to users. This app and citizen science testing approach would raise awareness about reclaimed water safety, help eliminate the fear over the use the reclaimed water and would greatly enhance local water conservations efforts and the long term sustainability of water supplies in the Tucson Basin.

Conceptual model for an off the grid whole house water filtration system

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Water conservation is a critical component of long term sustainability of water resources in the Tucson area and most water limited urban centers. Here, we present a model for a filtration unit for the purpose of recycling grey water back through the household in order to make a house almost completely off the city's water supply. This filtration system will transport water through three stages: a sediment filter, an ultraviolet filter, and a charcoal filter in order to properly decontaminate the water so that it becomes potable. Water will flow constantly through these three filters, being stalled in the UV filter for proper treatment. We believe that by using this three-step filtration system in the household, water from sinks, showers, and laundry machines can be recycled and used in those appliances again because these filters will remove most or all of harmful bacteria and contaminants from the water. The filter will be constructed at the Fabrication Lab within our school and will be 36 inches long, 3 inches wide, and 3 inches deep. This filter will allow for reductions in the overall water consumption in a household, therefore increasing the amount of Colorado River water savings and increasing the water available for aquifer storage and future use.

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