NWRRI - Desert Research Institute

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RFPs

If you have questions about submitting a NWRRI proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

For current RFP information, visit the NWRRI website (www.dri.edu/nwrri).

Controls on Hydrologic Partitioning, Residence Times, and Solute Export from a Snow-dominated Watershed

The Colorado River is a valuable water source and economic resource for the western United States, with the majority of the river's water originating in snow-dominated headwater basins of Colorado, Utah, and Wyoming. "Snow-dominated watersheds are experiencing climate induced changes in the timing, intensity, and duration of water inputs," explains Dr. Rosemary Carroll of Desert Research Institute (DRI), the PI of the project. "These changes are expected to alter water storage partitioning and the associated hydrologic connectivity, which cause dominant flow paths to adjust and residence times to change." Travel time distributions (TTDs) describe the length of time water and solutes spend in the watershed under various hydrologic conditions. This project—which also includes co-PI Dr. Rina Schumer and postdoctoral

Dr. Rosemary Carroll measuring stream discharge at the headwaters of the Colorado River (photo by Dr. Kenneth H. Williams of Lawrence Berkeley National Laboratory).

(Project Spotlight continued)

fellow Dr. Zhufeng Fang of DRI, and co-PI Dr. Chris Green of the US Geological Survey—will be the first to apply newly developed methods for streamflow time-varying TTDs to a snow-dominated watershed, and at a scale that is relevant for managing water resources.

Researchers determine TTDs by evaluating the levels of stable isotopes such as δ^2H and $\delta^{18}O$, and tracers such as chloride and bromide. "The TTDs reflect the integrated effects of watershed compartment connectivity and the degree of mixing of water (and solutes) of varying age in the watershed, and therefore they can be used to understand the watershed's sensitivity to climate change," Carroll says. "For this project, we are combining field observations with a variety of modeling strategies to quantify the sensitivity of TTDs to precipitation (type and magnitude), temperature, and vegetation type." Although previous research has applied advanced TTD methods to small, rain-dominated catchments, these methods haven't been applied to snow-dominated basins at larger scales because the complex terrain makes it difficult to quantify snow accumulation and melt, as well as assess isotopic content in snowmelt. "Other factors such as the mass flux out of the system through sublimation, soil evaporation, and plant transpiration are also difficult to quantify because of the tight coupling with snow accumulation and melt, and dependence on the scale of analysis," Carroll adds.

Dr. Carroll during a snow survey at the headwaters of the Colorado River.

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>
> ***– Rosemary Carroll***

Understanding watershed TTDs is not only important for determining the available water quantity, but also the quality of that water. "The TTDs of a watershed reflect water quality because many weathering processes and biogeochemical reactions are time dependent," Carroll explains. "Our hypothesis is that under warmer or drier conditions, stream discharge will decline but the fraction of streamflow routed through deeper sediments and fractured shale will increase. Longer subsurface residence times will result in a larger mean streamflow TTD and a decrease in water quality." To test this hypothesis, the researchers are developing response functions that compare seasonal streamflow age with streamflow characteristics such as peak discharge, annual volume, and baseflow onset, as well as the mass flux of principal ions, carbon, nutrients, and heavy metals.

So far, the project researchers have combined observed $\delta^{18}O$ in rain, snowmelt, and streamflow with the numerically simulated hydrologic boundary fluxes and the analytically derived transient TTD. "We are using hydrologic simulations for a Colorado River headwater basin (85 km^2) from 2006 to 2017 to test a

(Project Spotlight continued)

diverse set of snow accumulation scenarios. Preliminary results indicate that snow-dominated basins release water as a function of inverse storage across seasonal and annual timescales," Carroll says. "Specifically, more young water is released from storage during wet years than during dry years. During years with reduced snowpack, flow paths appear to become inactivated and snowmelt remains in the subsurface, and then becomes older water that is potentially reactivated in subsequent wet years."

The researchers have also simulated incremental warming to evaluate TTD sensitivity to the main form of precipitation changing from snow to rain. "Despite the changes in the timing of boundary fluxes because of warming, our preliminary results suggest that years with an average basin precipitation above 3.25 mm d^{-1} (1,200 mm y^{-1}) are more resilient to temperature increases with respect to annual water partitioning and streamflow TTD," Carroll says. "In contrast, years with less precipitation are sensitive to increased temperatures with water-limited conditions exacerbated through marked increases in the fraction of inflow that is lost to evapotranspiration, which appears to further decrease hydrologic connectivity in the basin and to propagate this effect further into the future." Based on these results, the researchers expect that the lag-response of snow-dominated basins to droughts will extend under climate warming.

Dr. Carroll conducting snowpack measurements.

Checking environmental monitoring equipment in the Colorado River Basin prior to snow accumulation.

Based on the work that they have completed so far, the project has produced some interesting results. In a previous study, Carroll *et al.* (2017) found that during years in which precipitation is below threshold levels, hydrologic partitioning in Great Basin watersheds is not sensitive to changes in temperature or vegetation type because water is limited and all precipitation is consumed. Only years in which precipitation is above a precipitation threshold is the water budget sensitive to change because there is enough water to generate change. "In contrast, the wet and cool climate of the Colorado River headwaters appears to experience large changes in hydrologic partitioning and associated stream TTDs only when the system is below a critical precipitation level and the basin shifts toward water-limiting conditions," Carroll says.

Managing irrigation, municipal, and recreational water resources as well as sustaining environmental water needs are high priorities in the western United States. "Given the anticipated water shortages, the Colorado Water Plan charges water

(Project Spotlight continued)

managers across the state to address the sustainability of current water uses," Carroll says. "Our work will refine the conceptual model of water movement and solute export through these snow-dominated basins and help water managers identify critical locations or periods of time for active management." As the project continues, the researchers will work with local and regional water managers in the Colorado River Basin to incorporate their results into water management planning so that water use can adapt to changing water resources. ■

Reference

Carroll, R., J. Huntington, K. Snyer, R. Niswonger, C. Morton, T. Stringham, 2017. Evaluation of Mountain Meadow Groundwater Response to Pinyon-Juniper and Temperature in a Great Basin Watershed. *Ecohydrology* 53, DOI:10/1002/eco.1792.

Postdoc Interview: Susan Stillman

We asked postdoctoral fellow Dr. Susan Stillman about her current research and her continuing research plans. Here's what she had to say:

1) What sparked your interest in water resources research?

Although I've always been scientifically inclined, water resources research was not always on my radar. I majored in physics in college, and as a freshman, I had planned on studying astronomy. However, as my college years came to a close, I realized that I'm living on a pretty awesome planet and that I didn't have to search faraway galaxies to find interesting research to pursue. Around the same time, I became interested in making our relationship with the earth more sustainable to allow future generations to enjoy this planet as much as I do.

2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?

I think it is amazing how various disciplines look at arid/semiarid hydrology from completely different points of view. It is fascinating that people from different fields—such as biology, hydrology, atmospheric science, ecology, geology, and paleoclimatology—can all look at a problem and have completely different ways to approach it.

3) What kinds of research are you currently working on and what have you learned so far from this research?

I'm currently working on flood frequency analyses over the southwestern United States, and I hope to make meaningful projections of future flood risks using observed and modeled data. Under a changing climate, the implications for precipitation in the Southwest have much less model agreement than for the Northeast, for which models and data suggest that precipitation changes are tied directly to anthropogenic heating. Although I've been working at DRI for only a little over a month, in that time, I have learned about the reasons it is so difficult for models to simulate precipitation changes in the western United States, and the work that has been done to infer future precipitation changes despite the lack of model agreement.

4) What do you hope to learn more about from the research you are doing?

I want to learn more about the atmospheric conditions that are favorable for heavy precipitation in the desert Southwest and how these

(Postdoc Interview continued)

conditions may change in the future. Given that the model projections for precipitation are so widely varied in this region, I'd like to better understand the physical mechanisms that allow heavy precipitation in the arid/semiarid Southwest and try to make inferences based on synoptic conditions that may show more consistency among models. I also want to learn from researchers in a variety of fields so that I have a better understanding of how the future climate will affect their fields and what climate data are most interesting to them.

5) Do you have a preference for lab work or fieldwork, and if so, why?

I spend most of my time at a computer because that is the nature of my work, but I do enjoy getting out in the field. I love being outside, but most of the fieldwork I've done has been along the lines of taking soil cores, which is not the most exciting outdoor activity. I love spending time outside, but because of what I do, the most exciting work is at my computer.

6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?

I'm interested in land surface–atmosphere interactions and I plan on continuing to pursue these interests. My current research obviously deals with how the atmosphere affects the land surface (i.e., precipitation), but I also want to continue to look at how the land surface affects the atmosphere. For example, I'm interested in how soil moisture modulates the energy budget at the land surface and how orography changes the likelihood and intensity of precipitation.

7) What is something that nobody knows about you (hobbies, interests, etc.)?

I am really good at handstands and would bet (it's Vegas, so that's okay, right?) on myself to win in a handstand contest against anyone here. Any takers?

8) If you had six months with no obligations or financial constraints, what would you do with the time?

I would probably spend a month or two traveling the world, and then I would spend the rest of my time alternating between camping/hiking/climbing adventures with my dog and picking up hobbies such as cooking, painting, and dancing (all of which I am terrible at, but they sound fun). ■

"I want to learn more about the atmospheric conditions that are favorable for heavy precipitation in the desert Southwest and how these conditions may change in the future."

– Susan Stillman

Upcoming Events

2018 AWRA Spring Specialty Conference: GIS & Water Resources X
April 22-25, 2018
Orlando, FL
www.awra.org/meetings/Orlando2018/index.html

16th Annual Truckee River Field Study Course
May 3 & 4, 2018
Reno, NV
www.nvwra.org/truckee-river-tour

2018 Gold Quarry Mine Tour
May 14 & 15, 2018
Elko, NV
www.nvwra.org/2018goldquarryminetour

2018 GSA Combined Cordilleran & Rocky Mountain Meeting
May 14-17, 2018
Flagstaff, AZ
www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/rm/2018mtg/home.aspx

2018 Well Design, Construction & Rehab Workshop
May 17, 2018
Reno, NV
www.nvwra.org/2018well-design

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Events Continued

North American Forest Soils Conference: International Symposium on Forest Soils
June 10-16, 2018
Quebec City, Quebec, Canada
www.cef-cfr.ca/index.php?n=Colloque.NAFSC-ISFS2018

2018 June Well & Water Week
June 11-15, 2018
Reno, NV
www.nvwra.org/2018-june-well-water-week

The New MODFLOW Course: Theory and Hands-On Applications
June 19-22, 2018
Las Vegas, NV
www.ngwa.org/Events-Education/shortcourses/Pages/258jun18.aspx

AWRA Summer Conference: The Science, Management, and Governance of Transboundary Groundwater
July 9-11, 2018
Fort Worth, TX
www.awra.org/meetings/FortWorth2018/index.html

AGU Chapman Conference: Hydrologic Research in the Congo Basin
September 25-27, 2018
Washington, D.C.
chapman.agu.org/congo-hydrologic-research/

2018 Fall Week of Water Events
September 24-28, 2018
Reno, NV
www.nvwra.org/2018fallweekofwater

2018 GSA Annual Meeting
November 4-7, 2018
Indianapolis, IN
www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2018.aspx

2018 ASA and CSSA Meeting: Enhancing Productivity in a Changing Climate
November 4-7, 2018
Baltimore, MD
www.acsmeetings.org/

2018 AWRA Annual Conference
November 4-8, 2018
Baltimore, MD
www.awra.org/meetings/Baltimore2018/index.html

NGWA Groundwater Week
December 3-6, 2018
Las Vegas, NV
groundwaterweek.com/

2018 AGU Fall Meeting
December 10-14, 2018
Washington, D.C.
fallmeeting.agu.org/2018/

2018-2019 SSSA International Soils Meeting: Soils Across Latitudes
January 6-9, 2019
San Diego, CA
www.sacmeetings.org/

Success and the dedication to quality research have established the Division of Hydrologic Sciences (DHS) as the Nevada Water Resources Research Institute (NWRRI) under the Water Resources Research Act of 1984 (as amended). As the NWRRI, the continuing goals of DHS are to develop the water sciences knowledge and expertise that support Nevada's water needs, encourage our nation to manage water more responsibly, and train students to become productive professionals.

Desert Research Institute, the nonprofit research campus of the Nevada System of Higher Education, strives to be the world leader in environmental sciences through the application of knowledge and technologies to improve people's lives throughout Nevada and the world.

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www.dri.edu/nwrri

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