

# 45<sup>th</sup> Annual AGU Hydrology Days

April 8-9, 2025



CIVIL AND ENVIRONMENTAL  
ENGINEERING  
COLORADO STATE UNIVERSITY

<https://www.engr.colostate.edu/ce/events/hydrology-days/>

## SCHEDULE: At-a-Glance

Tuesday April 8, 2025

Time	University Ballroom	LSC Room #372	LSC Room #374	LSC Room #390
8:30 - 9:00 am	<i>Registration</i>			
9:00am - 10:30 am		Remote Sensing of Consumptive Use and ET	Hydraulics & Geomorphology	
10:30 - 10:45 am	<i>Break</i>			
10:45 - 12:00pm		Remote Sensing of Consumptive Use and ET	Hydraulics & Geomorphology	Snow Hydrology
12:00 - 1:00 pm	<i>Lunch</i>			
1:00 - 2:00pm	<a href="#">Hydrology Days Award: Neil Grigg</a>			
2:15 – 3:15 pm		Climate & Meteorology		
3:00 – 5:00pm	Social Networking Event			

Wednesday April 9, 2025

Time	University Ballroom	LSC Room #372	LSC Room #374	LSC Room #390
8:30 - 9:00 am	<i>Registration</i>			
9:00 - 10:30 am		Data Science for Hydrologic Simulation, Forecasting and Optimization	Hydrologic Systems & Process Based Modeling	
10:30 - 10:45 am	<i>Break</i>			
10:45 - 12:00pm			Hydrologic Systems & Process Based Modeling	Urban Water & Integrated River Systems
12:00 - 1:00 pm	<i>Lunch</i>			
1:00 - 2:00pm	<a href="#">Borland Hydrology Award: Terri Hogue</a>			
2:15 – 3:30 pm		Hydrogeology & Groundwater	Wildfires & Watersheds	Ecohydrology: Soil Water, Plant Interactions
3:30 – 3:45 pm	<i>Break</i>			
3:45 – 5:00 pm		Hydrogeology & Groundwater	Wildfires & Watersheds	



# MEETING INFORMATION

## Location

The conference will be held on **level 3** of the CSU [Lory Student Center](#). Technical sessions will take place in rooms 372, 374, and 390 (see map). The Keynotes, lunches, and social networking will take place in the University Ballroom.

## Parking

**All vehicles parked on campus must have a valid CSU parking permit or park in designated hourly parking spaces and pay at a pay station!**

### Parking Permits

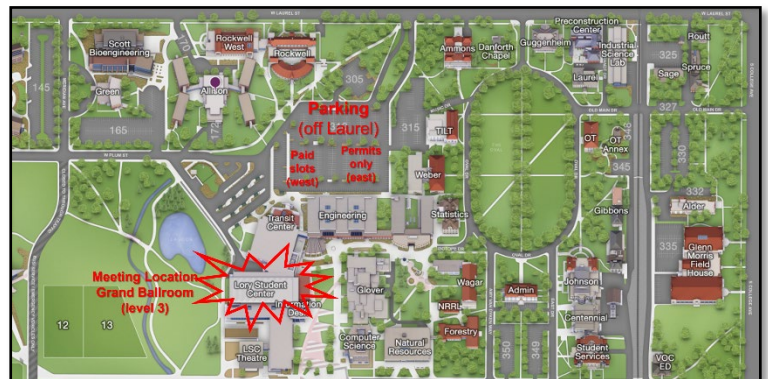
- **Hourly permit:** Hourly parking on campus is \$2. When you arrive in a lot with visitor parking, have your license plate number ready to enter into our hourly pay machines or you can download and use the [Park Mobile](#) app to pay by mobile phone. You can pay by credit card for the amount of time you wish to park. Your license plate number will serve as your permit. For more information visit [short-term parking](#).
- **Daily permit:** A daily permit can be purchased [online](#) or at Parking and Transportation Services, located in the Lake Street Garage at 1508 Center Avenue.

### Where is the easiest place to park on campus for visitors?

Visitor parking permits are available for the areas listed below, also noted on the university's parking map ([PDF](#) and [online](#)), and connect to [Around the Horn](#) to get you around campus:

- [Moby Lot #195](#)
- [Green Hall](#)
- [Engineering #310 \(recommended\)](#)
- [Ammons Hall # 315](#)
- [Administration #349](#)
- [MAX at University Station #440](#)
- [Lake Street Garage](#)
- [Voss Veterinary Teaching Hospital](#)
- [Research Blvd #740](#)

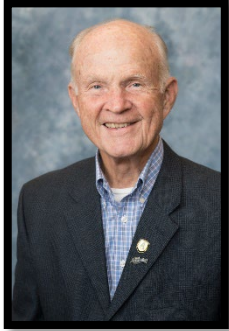
# 300 LEVEL



## KEYNOTE SPEAKERS

### AGU Hydrology Days Award

Dr. Neil S. Grigg, Professor of Civil and Environmental Engineering - Colorado State University



**Bio:** Neil S. Grigg is a Professor of Civil and Environmental Engineering at Colorado State University. He has experience as an educator, researcher, consulting engineer, and public official. His concentrations are in water management and institutions, water rights, water supplies, state water planning, water law, policy and regulation, infrastructure development and water security. His international water experience includes projects in Latin America, Africa, and Asia.

**Keynote Lecture:** April 8, 2025 at 1 PM – CSU Lory Student Center, University Ballroom

**Abstract:** *The Global Risks Report of the World Economic Forum identified extreme weather among the greatest risks facing the planet, second only to state-based armed conflict. Among these risks, flooding causes massive losses every year and has large impacts on lower income and disenfranchised populations. Flood professionals agree that solutions will require integrated management of land and water in river basins and urban areas, as well as efficient use of floodplains and flood warning systems to minimize loss of life. While much is known about such response measures, losses continue to rise. The question addressed is whether science and engineering can make significant improvements or whether climate change and governance disorder caused by urbanization and uncontrolled land use decisions will overwhelm ongoing efforts to reduce risk. The discussion will address whether comprehensive approaches based on systems methods can be effective to confront the disparate threats of flood risk reduction. The background of historic flooding and policy responses will be described, and experiences of recent disastrous floods will be reviewed. The Integrated Flood Management concept will be explained, and the status of forecasting, modeling, and data analytics will be discussed in the light of emerging databases, centers of excellence, and online resources. The difficult issues of floodplain mapping, flood insurance, and public involvement will be explained in the light of challenges to enact workable and just governance approaches. The conclusion will provide suggested pathways for rising flood risk researchers and professional practitioners.*



## Borland Hydrology Award

Dr. Terri S. Hogue, Dean of Earth and Society Program- Colorado School of Mines



**Bio:** Professor Hogue's research centers on understanding hydrologic and land surface processes, with much of her work focused in semi-arid regions. The overarching goal of her work is to improve the prediction of hydrologic fluxes for better management of water resources, to assess human impacts on the environment, and to mitigate the effects of natural hazards. Projects include investigating catchment response to wildfire, understanding the impact of urbanization on hydrologic fluxes, evaluating climate variability and response of land-atmosphere systems, and improving hydrologic forecasts. Professor Hogue and her research group use field and experimental methods, modeling and optimization techniques, as well as remote sensing data in their investigations.

**Keynote Lecture:** April 9, 2025 at 1 PM – CSU Lory Student Center, University Ballroom

### Modeling Hydrologic Impacts from Forest Disturbance: Progress, Challenges, and Paths Forward

**Abstract:** *Forest disturbances are increasingly prevalent in the western U.S., driven by prolonged droughts, wildfires, forest mortality from insects or disease, and urban expansion, all of which disrupt hydrologic behavior. Watershed impacts can be acute, such as wildfires or evolve more slowly, like insect-induced mortality. Quantifying the vulnerability of hydrological systems to forest disturbance is crucial for providing both short- and long-term information to stakeholders, aiding in decision-making for sustainable land and water management practices. Depending on the scale of the event, disturbances can significantly alter the magnitude and timing of water budget partitioning, with varying degrees of severity or predictability. Unfortunately, few if any hydrologic models have been developed or parameterized to capture forest disturbances. Both operational and research models suffer in their ability to capture altered hydrological, geochemical, or ecological processes.*

*Our recent work has focused on improving post-fire predictability in physically based models (i.e. Noah-MP and MIKE-SHE) and statistical models. We utilize machine learning, such as LSTMs, to inform model parameterizations and independently predict post-fire hydrologic behavior, including streamflow and stream water temperature. This presentation will give an overview of disturbance model development for headwater basins in Colorado, focusing on fire and other disturbance regimes, as well as national-scale studies using remote sensing data and statistical models. We also draw attention to watersheds experiencing compound or overlapping disturbance, such as insect-induced forest mortality and wildfire. Challenges and opportunities for improved hydrologic prediction in these systems will also be presented. Understanding the vulnerability of watersheds to disturbance is critical for effective adaptation and resilience-building efforts for regional water resources.*

# Presentation Schedule

Tuesday April 8, 2025

Location	Session	Time	Presenter	Title
LSC #372	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Adwoa Serwaa Amankwaa	<a href="#">Estimation of Effective Extreme Pixels for METRIC Application Using UAS Imagery: Enhancing Remote Sensing Crop Evapotranspiration Estimation in Diverse Environments.</a>
LSC #372	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Ryan Bailey	<a href="#">A watershed modeling approach to quantify agricultural groundwater pumping at the national scale</a>
LSC #390	Snow Hydrology	10:45am-12:15pm	Carson Bainbridge	<a href="#">Spatio-Temporal Variability Within Snowpack Properties</a>
LSC #372	Climate & Meteorology	2:15-3:15pm	Jeremy Barroll	<a href="#">Teleconnections and Topography: Exploring the Effect of Elevation and Aspect on Sea Surface Temperature-Snowpack Teleconnections in the Colorado Rocky Mountains</a>
LSC #374	Hydraulics & Geomorphology	9:00am - 10:30am	Khem Bhattarai	<a href="#">Propagation dynamics of gravity currents induced by successive release of two lock-fluids</a>
LSC #390	Snow Hydrology	10:45am-12:15pm	Christina Chow	<a href="#">Mapping Snow Water Equivalent Using a Cosmic Ray Neutron Rover on Plowed/Paved Roads in the San Juan Mountains</a>
LSC #374	Hydraulics & Geomorphology	10:45am-12:15pm	Nicholas Christensen	<a href="#">Examining the role of model type and resolution on flash flood routing</a>
LSC #372	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Jillian M. Deines	<a href="#">Understanding irrigation expansion in traditionally rainfed areas through Earth observations and machine learning</a>
LSC #390	Snow Hydrology	10:45am - 12:15pm	Steven Fassnacht	<a href="#">Snow Aerodynamic Roughness Length across Varying Surfaces</a>
LSC #372	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Muhammad Fawad	<a href="#">A Greenhouse Experiment to determine Salinity and Drought effects on Maize using Multi- and Hyper-Spectral Remote Sensing Data</a>
LSC #372	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Manish Giri	<a href="#">Daily Aerodynamic Surface Temperature Characterization over drip-irrigated Maize from Multispectral Remote Sensing, Eddy Covariance, and Ground Stations</a>
LSC #390	Snow Hydrology	10:45am-12:15pm	Evan Gouldey	<a href="#">Effects of Plowing on Snowpack Density</a>

<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Erin Haacker	<a href="#">Using Electrical Runtime Data from Center Pivots as a Proxy for Irrigation Water Use</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	10:45am-12:15pm	Aleah Hahn	<a href="#">Backwater Rise and Equivalent Roughness Generated by a Large Wood Jam</a>
<b>LSC #372</b>	Climate & Meteorology	2:15-3:15pm	Alex Hahnenberg	<a href="#">Trends versus Step-wise Changes in Central Chilean Water Resources</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Md Fahim Hasan	<a href="#">Physics-informed Machine Learning and Water Balance Approach to Estimate Groundwater Use for the Western United States</a>
<b>LSC #372</b>	Climate & Meteorology	2:15-3:15pm	Ryder Hunt	<a href="#">Seasonal and Diel Regional Temperature-Elevation Gradients across Northern Colorado</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Kieri Karpa	<a href="#">Using Remote Sensing to Map Soil Salinity over Irrigated fields in the South Platte River Basin of Colorado</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	9:00am - 10:30am	Jai Hong Lee	<a href="#">Interference Effects of Service and Emergency Spillways Reflecting Extreme Climate Events</a>
<b>LSC #390</b>	Snow Hydrology	10:45am-12:15pm	Juan Ignacio López-Moreno	<a href="#">Experiments to assess the effect of dust and black carbon on snowmelt</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Sayantan Majumdar	<a href="#">Assessing groundwater pumping, consumptive use, and irrigation efficiencies in the Western U.S.: Insights from high-resolution satellite remote sensing and climate data</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	10:45am-12:15pm	Connor Mertz	<a href="#">Restoration Prioritization of Upper Colorado Tributaries in the Kawuneeche Valley, Rocky Mountain National Park, CO</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	9:00am - 10:30am	Kiarash Nayebpashaei	<a href="#">A new formulation for an improved estimation of turbulent (diapycnal) diffusivity in stably stratified flows</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Soheil Nozari	<a href="#">Estimating Monthly Groundwater Withdrawals from Irrigation Wells in Southwest Utah Using Remote Sensing Data</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	10:45am-12:15pm	Rahel Pommerenke	<a href="#">Satellite Determination of Sub Field Water Management Zones for Irrigated Agriculture</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	9:00am - 10:30am	Joseph Pugh	<a href="#">Rethinking the Discharge Coefficient for Thin Weirs and Sills: A Fresh Look for Improved Flow Measurement</a>



<b>LSC #374</b>	Hydraulics & Geomorphology	10:45am-12:15pm	Towsibur Rahman	<a href="#">Effect of Plant Morphology on Vegetation Drag in River Channels</a>
<b>LSC #390</b>	Snow Hydrology	10:45am-12:15pm	Jesús Revuelto	<a href="#">First order snow depth distribution scale breaks and its relation with topography observed with three remote-sensing techniques</a>
<b>LSC #372</b>	Climate & Meteorology	2:15-3:15pm	Matthew Sabin	<a href="#">Investigating potential acceleration of the hydrologic cycle using drought indices</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	10:45am-12:15pm	Kayla Schultz	<a href="#">Historical Beaver Dam Impacts on Floodplain Connectivity in Colorado Headwater Streams</a>
<b>LSC #372</b>	Remote Sensing of Consumptive Use and ET	9:00am - 10:30am	Gabriel Senay	<a href="#">Remote Sensing-based Evapotranspiration for Crop Water Use Mapping</a>
<b>LSC #374</b>	Hydraulics & Geomorphology	9:00am - 10:30am	Chien-Yung Tseng	<a href="#">Harnessing the Flow to Maximize Energy Potential: The Synergy of Hydropower and Hydrokinetic Systems</a>
<b>LSC #372</b>	Climate & Meteorology	2:15-3:15pm	Ella Wehrlen	<a href="#">Frost Accumulation on Microclimates</a>



## Wednesday April 9, 2025

Location	Session	Time	Presenter	Title
LSC #372	Hydrogeology & Groundwater	2:15 - 3:30pm	Abdullah Al Fatta	<a href="#">Quantifying the Drivers of Groundwater Recharge Dynamics in the San Luis Valley, Colorado</a>
LSC #372	Hydrogeology & Groundwater	3:45 - 5:00pm	Dawit Asfaw	<a href="#">Assessing Major Drivers of Diffuse Groundwater Recharge Using Machine Learning Techniques</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Dave Barnard	<a href="#">From mountains to farms: topographic effects on micrometeorology are integral to ecosystem and watershed functioning</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Aylin Barreras	<a href="#">Species-specific tree water use in a subalpine forest: do trees employ different strategies to manage water loss throughout the day?</a>
LSC #374	Wildfires & Watersheds	2:15pm - 3:30pm	Joey Blumberg	<a href="#">Ash in the tap: the effect of increasing wildfire risk on the cost of clean drinking water</a>
LSC #374	Wildfires & Watersheds	3:45pm - 5:00pm	Carly Bonwell	<a href="#">Modeling the impacts of wildfire, forest recovery regimes, and climate change on hydrologic partitioning in a Colorado headwater basin using a fully integrated hydrologic model and simulated fire parameterizations</a>
LSC #390	Urban Water/Integrated River Systems	10:45am- 12:15pm	Mattheu Cibra	<a href="#">Enhancing Phosphorus Removal in Bioretention Systems with Water Treatment Residual Amended Soils</a>
LSC #374	Wildfires & Watersheds	2:15pm - 3:30pm	Eric Clark	<a href="#">Erosion and Sediment Delivery Over Time in Two Industrial Forested Watersheds in Northwestern California: What is the Role of the Road Network?</a>
LSC #372	Data Science for Hydrology Simulation, Forecasting, and Optimization	9:00am - 12:15pm	Olaf David	<a href="#">Persephone-M4: An AI-based River Forecasting System for Seasonal Water Availability in the Western US</a>
LSC #374	Wildfires & Watersheds	3:45pm - 5:00pm	M. Robert and Peter Delcau and Nelson	<a href="#">Grid Size Effects for Hydrologic Modeling in Support of Post-Wildfire Analyses</a>
LSC #374	Wildfires & Watersheds	3:45pm - 5:00pm	Helen Flynn	<a href="#">Updating landcover classifications in the iSnobal model to improve water forecasting in post-fire persistent snow zones</a>

LSC #374	Hydrologic Systems & Process-based Modeling	9:00am - 10:30am	Najam us Saqib Fraz	<a href="#">Developing a Conceptual Model to predict river Intermittency from Hydroclimatic Parameters</a>
LSC #374	Wildfires & Watersheds	2:15pm - 3:30pm	Steven Griffin	<a href="#">Precipitation Intensities Triggering Post-Wildfire Debris Flows Across 3 Burn Scars</a>
LSC #372	Data Science for Hydrology Simulation, Forecasting, and Optimization	9:00am - 12:15pm	Catalina Jerez	<a href="#">Enhancing Seasonal Water Supply Forecasts for the Upper Colorado River Basin Using Machine Learning and Multi-Model Ensembles</a>
LSC #374	Wildfires & Watersheds	3:45pm - 5:00pm	William Keenan	<a href="#">Modelling Post-fire Effects on Snowpack Across the Western US</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Suraj Khanal	<a href="#">Improving 5TE Soil Water Content Sensor Accuracy Using Neutron Probe Calibration Data and Machine Learning</a>
LSC #372	Data Science for Hydrology Simulation, Forecasting, and Optimization	9:00am - 12:15pm	Holm Kipka	<a href="#">Environmental Model Geo-Spatial Data Representation Using a Cloud Enabled Catchment Delineation Tool (Cadel)</a>
LSC #390	Urban Water/Integrated River Systems	10:45am- 12:15pm	Kenneth Laffite	<a href="#">Estimating discrete salt ion loads in a saline, highly managed river using a machine learning model and a mass balance approach</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Joo-Heon Lee	<a href="#">Sustainable River Management: Understanding the Effects of Weirs on Fish Habitat Connectivity</a>
LSC #372	Hydrogeology & Groundwater	3:45 - 5:00pm	Sayantan Majumdar	<a href="#">Integrating Satellite Remote Sensing and Groundwater Data for Assessing Land Subsidence in Diamond Valley, Nevada</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Catherine McClure	<a href="#">Effects of flow management on biogeomorphic feedbacks on the Green and Yampa Rivers in Colorado and Utah</a>
LSC #374	Hydrologic Systems & Process-based Modeling	10:45 am- 12:15pm	Robert Milhous	<a href="#">Seasonal Analysis of Peak Discharges</a>
LSC #374	Hydrologic Systems & Process-based Modeling	10:45 am- 12:15pm	J. Toby Minear	<a href="#">The NASA Surface Water and Ocean Topography (SWOT) Mission: Status and Hydrologic Science Contributions</a>
LSC #372	Hydrogeology & Groundwater	2:15 - 3:30pm	Cinzia Miracapillo	<a href="#">An analytical model for groundwater recharge purposes</a>



<b>LSC #372</b>	Hydrogeology & Groundwater	2:15 - 3:30pm	James Molloy	<a href="#">Linking Floodplain Processes to Hydrologic Modeling of the Lower Arkansas River Basin to Improve Management of Irrigated Stream-Aquifer Systems</a>
<b>LSC #374</b>	Wildfires & Watersheds	3:45pm - 5:00pm	Cooper Moon	<a href="#">Leveraging LSTM Networks to Capture Post-Wildfire Streamflow Changes in Watersheds</a>
<b>LSC #374</b>	Hydrologic Systems & Process-based Modeling	9:00am - 10:45am	Pratikshya Neupane	<a href="#">Understanding Water Interactions using modified SWAT model in Arkansas River Basin</a>
<b>LSC #374</b>	Hydrologic Systems & Process-based Modeling	9:00am - 10:45am	Emmanuel Opoku	<a href="#">Hidden Flows: Simulating the Hydrologic Impacts of Artificial Recharge in an Irrigated Semi-Arid Watershed</a>
<b>LSC #374</b>	Hydrologic Systems & Process-based Modeling	10:45 am- 12:15pm	Susmita Pant	<a href="#">Modeling Fifty-Two Years of Land Subsidence in the San Joaquin Valley, California</a>
<b>LSC #374</b>	Hydrologic Systems & Process-based Modeling	10:45 am- 12:15pm	Mark Perry	<a href="#">Application of extraordinary flood research and hydrologic risk to evaluate dams in Colorado</a>
<b>LSC #372</b>	Data Science for Hydrology Simulation, Forecasting, and Optimization	9:00am - 12:15pm	Daniel Philippus	<a href="#">Data-Driven Stream Temperature Forecasting for Ungaged Watersheds across the CONUS</a>
<b>LSC #374</b>	Hydrologic Systems & Process-based Modeling	9:00am - 10:45am	Muhammad Raffae	<a href="#">Exploring hydrological responses to water management scenarios in the Upper Colorado River Basin</a>
<b>LSC #372</b>	Hydrogeology & Groundwater	2:15 - 3:30pm	Dana Rastad	<a href="#">Innovative Neural Network Model for Accurate Estimation of Soil Fine Percentage in Parowan Valley, Utah</a>
<b>LSC #372</b>	Hydrogeology & Groundwater	3:45 - 5:00pm	Julianne Robinson	<a href="#">Illuminating Groundwater Recharge Dynamics with Time-Domain Electromagnetics</a>
<b>LSC #390</b>	Urban Water/Integrated River Systems	10:45am- 12:15pm	Samantha Rogaczewski	<a href="#">Hydrologic Monitoring of Pivot Management Strategies for Drought Resiliency in Wyoming</a>
<b>LSC #390</b>	Urban Water/Integrated River Systems	10:45am- 12:15pm	Amanda Salerno	<a href="#">Assessing the fate of stormwater contaminants in bioretention cells with varying media</a>

LSC #372	Data Science for Hydrology Simulation, Forecasting, and Optimization	9:00am - 12:15pm	Michael Talbot	<a href="#">Toward Improving Machine Learning Models for Predicting Streamflow Extremes</a>
LSC #374	Hydrologic Systems & Process-based Modeling	9:00am - 10:45am	Subash Thapaliya	<a href="#">Evaluation of Time-Domain and Signature-Domain Calibration Methods for Spatially Distributed Hydrological/Water Quality Modeling in a Highly Managed Watershed</a>
LSC #374	Wildfires & Watersheds	3:45pm - 5:00pm	Alex Thornton-Dunwoody	<a href="#">Post-Fire Channelized Erosion: Investigating Drivers Using High-Resolution Terrain Analysis</a>
LSC #374	Hydrologic Systems & Process-based Modeling	9:00am - 10:45am	Debashree Halder Tuli	<a href="#">Evaluating a Novel Approach for Determining Dynamic Zero-Plane Displacement Height to Improve Remote Sensing-Based Estimation of Latent and Sensible Heat Fluxes over Corn Fields</a>
LSC #374	Wildfires & Watersheds	2:15pm - 3:30pm	Phoebe White	<a href="#">Effectiveness of mulching under varying rainfall intensity</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Victoria Wojahn	<a href="#">Evaluating dynamics of tree water storage using Electrical Resistivity Tomography (ERT)</a>
LSC #372	Hydrogeology & Groundwater	2:15 - 3:30pm	Zaichen Xiang	<a href="#">Modeling Groundwater Hydrology and Legacy Phosphorus Transport in an Agricultural Watershed Using SWAT+gflow</a>
LSC #390	Ecohydrology: Soil, Water, Plant Interactions	2:15- 3:45pm	Zhiyi Zhou	<a href="#">The Competition Between Plant Water Stress and Stomatal Conductance Configurations: Which is More Important for transpiration?</a>

## Climate and Meteorology

### Investigating potential acceleration of the hydrologic cycle using drought indices

**Matthew Sabin**

University of Colorado, Department of Civil, Environmental, and Architectural Engineering

The velocity of the hydrologic cycle plays a critical role in water resources, influencing both ecosystems and water resource planning through the residence time of water and the magnitude of hydrologic fluxes. Recent research highlighting global trends in soil water residence times underscores the need to understand how the velocity of the hydrologic cycle has been changing. Here, we quantify the lag time between drought indicators to examine changes in the velocity of the hydrologic cycle. We generate daily time series of Standardized Soil Moisture Index (SSMI) and Standardized Precipitation Index (SPI) at

various accumulation periods from 1950-2020 using ERA5-Land reanalysis data for the contiguous United States (CONUS). The lag time of SPI that maximizes the Pearson correlation with the summer time series of SSMI is taken as our measure for the velocity of the hydrologic cycle. We compute lag times for an early period (1950–1984) and a late period (1985–2020) and find regional variability in the magnitude of shifts in lag times. For example, in the Northern Great Plains (NGP), lag times have become shorter, indicating an acceleration of the hydrologic cycle. For 90-day SPI in the NGP, the lag time was 14 and 2 days in the early and late period, respectively, a change of 12 days. For 30-day SPI, the lag time was 20 and 15 days in the early and late period, respectively, a change of 5 days. Although no CONUS-wide trend toward an accelerating hydrologic cycle is apparent, we find that specific regions are indeed experiencing an accelerating hydrologic cycle. These results may support long term planning and drought mitigation efforts, and lead into research analyzing how drought cascades through hydrologic systems.

### Trends versus Step-wise Changes in Central Chilean Water Resources

**Alex Hahnenberg**

Colorado State University- ESS Watershed Science

Chile is a major agricultural provider, but much of these areas are semi-arid. The water used for agricultural production comes from the mountains and is derived from snowmelt. However, there have been recent seasonal and temporal decreases to quantities of snow present in the central and southern Chilean Andes and as a result, stream flows have changed. To assess the nature of change, only monthly meteorological and streamflow data were available from the Chilean Water Resources Directorate (DGA) for the period between 1981 and 2022. We examined the magnitude of change to the meteorology of this area (precipitation, snow water equivalent (SWE), temperature), as well as the change in streamflow. We determined the rate of change using the Theil-Sen slope assessment and the significance of change using the Mann-Kendall test. Further, we used the Mann-Whitney-Wilcoxon test to assess if the changes in hydrometeorology are a trend and/or a stepwise change. We found significant decreasing trends for some months at some stations, as well as a stepwise change around 2010. The changes seen from the precipitation, snowpack, and streamflow data are similar to one another, but not the same.

### Seasonal and Diel Regional Temperature-Elevation Gradients across Northern Colorado

**Ryder Hunt and Ben Thompson**

Colorado State University- ESS Watershed Science

Air temperature decreases with increased elevation, and physics dictates that the change in temperature of free air is a function of the moisture in the air, called the lapse rate. For wet air, this is about 5.5 degrees Celsius per kilometer, and for dry air, it is about 9.8 C/km. However, for air temperature near the ground, this change in temperature with elevation can vary very locally, and even regionally. We used the hourly temperature data from 20 Natural Resources Conservation Service (NRCS) SNOTEL stations for six years (2019 to 2025) to assess the temperature-elevation gradient ( $\Gamma$ ) over Northern Colorado. We also examined the fit of the  $\Gamma$  correlation from the Pearson correlation coefficient ( $\rho$ ) as a function of time of day and time of year. It was found variability in the gradient ( $\Gamma$ ) and in the fit ( $\rho$ ) for day versus night (diel) and seasonally. Spring exhibited the strongest correlation ( $R^2$ )

in a regression model of mean seasonal temperatures and elevation. Further, certain stations were persistent outliers from the  $\Gamma$  correlation. We examined the specific location and magnitude of those outlier stations.

### Frost Accumulation on Microclimates

**Ella Wehrle**

Colorado State University- ESS Watershed Science

While the physics of the frost process is understood, estimating the occurrence and amount of frost deposition is difficult using standard meteorological data. Frost formation depends on complex interactions between temperature, night-time temperature changes, humidity, and surfacing cooling, and these data are typically not available. This study examines frost accumulation using daily visual observations, which are compared to weather station data to assess the correlation between frost occurrence and meteorological conditions. While discrepancies between observational methods exist, our analysis suggests that frost days may serve as indicators of forthcoming meteorological conditions, such as snowfall or increased humidity. This correlation underscores the role of microclimates in shaping local weather patterns, though the precise contribution of frost to overall water input remains uncertain. Additionally, differences in frost crystal morphology appear to reflect variations in atmospheric humidity and temperature, suggesting their potential as microclimatic indicators. These findings illustrate the need for improved measurement techniques to better incorporate frost into hydrological models and water balance assessments.

### Teleconnections and Topography: Exploring the Effect of Elevation and Aspect on Sea Surface Temperature-Snowpack Teleconnections in the Colorado Rocky Mountains

**Jeremy Barroll**

Colorado State University- Civil and Environmental Engin

Mountain snowpack in the Western US is difficult to predict in advance, especially for areas which have low correlation with El Niño Southern Oscillation (ENSO). This study investigates how the prediction of snow-water equivalent depth (SWE) using sea surface temperature (SST) varies on a kilometer-scale resolution across prominent crests in the Colorado Rocky Mountains. This region is topographically complex, important for water supply, and contains large variability in SST-SWE relationships within short distances. This variability is related to elevation, position relative to prominent crests and latitude/longitude within the larger region. Long term shifts in prediction skill are considered. Several seasonal lead times are tested for the sampling of SST and SWE data. For most slopes analyzed, the strongest prediction centers were the North Temperate Pacific East-West Dipole (Temperate Dipole) and the Atlantic Quadpole Moment (AQM), a pattern of alternating SST anomaly regions in the North Atlantic. Areas north and south of the Elk Range have inverse relationships with the AQM and a different Temperate Dipole layout. Slopes east of the Continental Divide have stronger Temperate Pacific teleconnections and are more likely to have significant correlations with the Tropical Pacific. SST-SWE teleconnection strength generally increases with elevation. However, this is not the case for areas where there is a shift in teleconnection pattern. The use of December SST in the North Pacific and North

Atlantic Oceans predicts April 1 SWE on the eastern slope of the Front Range in the Colorado Rocky Mountains with an R2 of 0.46 for the years analyzed. This suggests that it is possible to predict snowpack in small mountain watersheds with long lead times more accurately than for large regions, which may benefit reservoir operations in these settings.

## Data Science for Hydrologic Simulations, Forecasting and Optimization

### Environmental Model Geo-Spatial Data Representation Using a Cloud Enabled Catchment Delineation Tool (Cadel)

**Holm Kipka**

Colorado State University- Civil and Environmental Engineering

Cadel is open source, freely available to the scientific community, and implemented using Catena, an emerging platform based on the Environmental Resource Assessment and Management System (eRAMS3), and Cloud Services Integration Platform (CSIP) frameworks providing scalable geospatial analyses, collaboration, and model service capabilities. Seamless integration of generating spatial model parameters and providing input data is implemented with a strong focus on streamlining the workflow in Catena. Delineating a watershed area into discrete areas (e.g. Hydrological Response Units HRUs) with parameter attribute tables is essential to generate input parameter sets for distributed hydrological models. This presentation will introduce a generic methodology of such a delineation process and services workflow for the Agricultural Ecosystems Services (Ages) watershed model. A Digital Elevation Model (DEM) raster data are processed for the topology of flow paths, then combined with raster layers of land use, soils, and hydrogeology to generate HRU patterns for a watershed area. Based on the pattern of HRUs, the web service analyzes a topological routing scheme that allows multiple-flow directions and interactions between neighboring HRUs. The resulting HRU information is used to automatically generate input files for the Ages distributed watershed model. The tool is open source, available to the scientific community, and implemented using Catena, a web-interface and back-end platform based on the eRAMS3 and CSIP frameworks providing scalable geospatial analyses, collaboration, and model service capabilities. Seamless integration of (1) generating spatial model parameters, (2) connecting input data, (3) executing the model, and (4) analyzing model results will be presented with a strong focus on the workflow aspect of Catena. The HRU delineation tool can be adapted to any HRU-based hydrologic model.

Each of the 8 Cadel steps is set up as a CSIP service in Catena. Catena is a framework that is an additional layer on top of the programming experience of eRAMS. Catena is used as a graphical interface, whereof CSIP is used to run the geospatial analysis and computational workload. The Cadel CSIP services are available as server endpoint applications and can be run any JAVA or Python script.

### Persephone-M4: An AI-based River Forecasting System for Seasonal Water Availability in the Western US

**Olaf David**

Colorado State University- Civil and Environmental Engineering

Farmers' agricultural management decisions are often based on water availability due to climate conditions and water from irrigation sources such as rivers and reservoirs. Forecasting their expected streamflows prior and throughout the agricultural seasons helps in managing water allocation and distribution for later irrigation applications and an important aid in planning water storage and release as well as agricultural planting decisions.

Here, we present a large-scale AI-based operational hydrologic prediction system built to provide such capabilities for the western US using 1200+ river forecast points integrating real time data from 3500+ climate stations of several station networks for automated daily forecasts. This system, Persephone-M4, couples a new purpose-specific ML-driven prediction analytics engine, the multi-model machine-learning meta system (M4), with a new geospatially enabled web application interface (Persephone), incorporating a cloud-based model-as-a-service platform (Cloud Services Integration Platform, CSIP) supporting model training, model forecasting, and data aggregation services at scale using 400+ compute cores. Persephone-M4 may represent the largest migration of AI into operational watershed hydrology to date as it becomes the next-generation seasonal water supply forecast model of the USDA Natural Resources Conservation Service, which runs the largest stand-alone river forecasting system in the increasingly thirsty American West.

## Enhancing Seasonal Water Supply Forecasts for the Upper Colorado River Basin Using Machine Learning and Multi-Model Ensembles

**Catalina Jerez**

University of Colorado- Department of Civil, Environmental, and Architectural Engineering

Increased climate variability and rising water demands make effective water management in the Colorado River Basin (CRB) essential. However, seasonal streamflow predictions remain challenging due to complex hydroclimatic interactions across timescales. We develop a multi-model ensemble for seasonal streamflow hindcasting using machine learning (Random Forest (RF) and Gradient Boosting Machine (GBM)) for April–July runoff at Lees Ferry, Arizona. Using cross-validation framework, we train and validate models for lead times of 0–24 months (1983–2019), incorporating predictors such as antecedent basin conditions, Snow Water Equivalent (SWE), Ensemble Streamflow Prediction (ESP), North American Multi-Model Ensemble (NMME), and large-scale oceanic-atmospheric teleconnections (SST, PDO, AMO). Furthermore, we conduct an independent forecast validation for 2020–2024 using an ARIMA-based approach. Results show that at short lead times (0–3 months), ESP, SWE, and NMME provide the strongest predictability. At medium lead times (4–9 months), NMME and SST anomalies become significant, with SST anomalies dominating long lead times (>9 months). RF and GBM outperform climatological benchmarks and ESP, particularly for lead times beyond 6 months, with RF reducing median hindcast errors by 10% (~0.4–0.65 MAF) in RMSE. While GBM performs well at short lead times, RF outperforms it at longer lead times. The (Continuous) Ranked Probability Skill Scores confirm model reliability, with GBM having a slight edge at short lead times and RF capturing longer-term variability more effectively. The inclusion of NMME data improves predictive performance largely at mid-lead-times-results where RF and GBM both hone the integration of the climate signal.

## Toward Improving Machine Learning Models for Predicting Streamflow Extremes

**Michael Talbot**

Colorado State University- Civil and Environmental Engineering

Data-driven models are revolutionizing hydrology, enabling researchers to harness vast datasets to predict hydrologic responses without requiring prior knowledge of physical processes. Large-scale datasets, such as streamflow observations from USGS streamgages, provide unique opportunities to uncover the drivers of hydrologic variability and extremes, advancing regional-scale streamflow prediction and forecasting. This research applies Long Short-Term Memory (LSTM) neural networks to model streamflow variability and extreme runoff events by integrating USGS streamgage data with gridded meteorological datasets and watershed attributes. Recent studies have demonstrated the ability of LSTMs to skillfully forecast floods up to the 10-year return frequency globally. Building on this foundation, our initial goal is to explore options for enhancing model skill in predicting peak discharge values, including events exceeding the 10-year return frequency. Strategies include exploring alternative model architectures and loss functions, using domain-specific performance metrics, and applying statistical resampling techniques. Additionally, we are working to incorporate uncertainty quantification methods into LSTM predictions, potentially further improving model peak discharge prediction skill while at the same time enabling uncertainty-aware modeling and decision making.

## Data-Driven Stream Temperature Forecasting for Ungaged Watersheds across the CONUS

**Daniel Philippus**

Colorado School of Mines- Hydrologic Science and Engineering

Stream water temperature (SWT) is a key water quality parameter for both societal and ecosystem functions, informing processes ranging from reservoir releases to water treatment to lotic species mortality. The vital role of SWT in water chemistry and ecosystem function has motivated rapid development in SWT modeling in recent years, particularly with data-driven models. Large-domain and high-resolution models support evaluation of 1) current and future SWT conditions, 2) impacts of surface and climate disturbances, and 3) restorations across a range of spatiotemporal scales, particularly for ungaged watersheds (i.e., no SWT observations). In the last several years, daily-resolution, ungaged-watershed SWT models have been developed with ~km-scale resolution at near-continental scale (contiguous United States, CONUS) and 10 km resolution globally, but do not support SWT forecasting. Existing SWT forecasting models are restricted by lower spatial/temporal resolution or constrained to smaller domains, which impacts investigation of changing and future SWT conditions at large scales. Data-driven SWT models can scale well and are capable of generalization without local training data, which has the potential to improve SWT forecasting for ungaged basins.

To enable this improvement, we developed the first CONUS-scale, km-resolution, forecasting-capable, daily SWT model for ungaged watersheds, titled “temperature estimation: near-term expected temperatures” (TempEst-NEXT), using data-driven techniques. TempEst-NEXT is capable of hindcasting and near-term (1-16 day) forecasting, and is compatible with NOAA’s NextGen National Water Model framework for operational applications. Historical tests with forecasted forcing data (2-day lead) for mean daily SWT show a median R2 of 0.92, RMSE of 2.4 C, and bias of 1.7% for ungaged watersheds, with similar performance in preliminary real-time forecast runs (1-16 day lead). For watersheds with

training data across the CONUS, TempEst-NEXT has a median validation-period R2 of 0.95, RMSE of 1.4 C, and bias of 0.0073%. An advantage of TempEst-NEXT over comparable SWT models is that its forecasting capabilities can support real-time decision-making without local calibration for water-resource management, such as reservoir releases. Broadly, TempEst-NEXT stands ready to support efficient, flexible, large-scale prediction of stream thermal regimes, especially in watersheds where SWT observations are infrequent or unavailable.

## Ecohydrology: Soil, Water, and Plant Interactions

### From mountains to farms: topographic effects on micrometeorology are integral to ecosystem and watershed functioning

**Dave Barnard**

USDA Agricultural Research Service

The western United States is characterized by high topographic complexity, which drives variability in key hydrometeorological factors across a range of landscapes, from high peaks to prairie and farmland. This variability leads to spatial patterning of vegetation and significant differences in evaporative demand and moisture availability over relatively short distances. The resulting microclimates diverge from broader climatic conditions, thereby requiring careful study at different spatial scales to understand wider ecosystem and watershed responses. This talk will review both previous and ongoing research aimed at quantifying microclimate variability and effects across the western US, covering spatial scales from the rhizosphere to entire regions. The research integrates methods from plant ecophysiology, micrometeorology, ecology, remote sensing, geophysics, microbiology, and hydrology. The discussion will highlight impacts of microclimate variability relevant to ecohydrologic functioning of snow-dominated source water areas, land management, the recovery and restoration of ecosystems and watersheds following wildfire, and the availability of freshwater for agricultural production.

### Evaluating dynamics of tree water storage using Electrical Resistivity Tomography (ERT)

**Victoria Wojahn**

Colorado State University- Civil and Environmental Engineering

Forest headwater catchments are a vital source of water, but climate change can directly affect their ability to sustain water supply. Water stored in tree trunks plays an important role in the water use efficiency of woody plants by operating as an intermediate source for the transpiring leaves. The dynamic process of tree water balance can be a function of soil depth, type, and structure, and is also related to atmospheric conditions such as rainfall and vapor pressure deficit. It is still difficult to obtain data related to the amount of water stored in trees and understand its dynamic in daily and seasonal patterns. Geophysical data coupled with soil-plant-atmosphere models can help to better quantify and understand water cycle parameters to improve water management strategies for forest adaptation to climate change. Forest transpiration is a large component of the terrestrial water balance, and more realistic representations of tree water dynamics could provide more accurate earth system models to

better understand the critical zone processes. However, we still lack the knowledge to understand how this storage water within a tree influences the environment and if so, how this component modifies the water balance of forested areas. The objective of this work is to present a new way of investigating water storage dynamics in trees by using Electrical Resistivity Tomography (ERT), paired with typical eco physiological and hydrologic measurements, applied to a ponderosa pine tree at the Manitou Experimental Forest, Colorado.

### Species-specific tree water use in a subalpine forest: do trees employ different strategies to manage water loss throughout the day?

**Aylin Barreras**

Colorado State University- Forest and Rangeland Stewardship

An important question in ecophysiology is how plants respond to periods of limited water availability. Water availability in subalpine forests is largely determined by the snowpack, with snowmelt providing approximately 65% of the forests' water supply. Over the past decades, total snow accumulation has decreased, while rising summer temperatures have intensified atmospheric evaporative demand. Together, these factors have exacerbated the decline of water availability. Depending on the species, trees might employ different 'strategies' to manage water stress. Our goal is to investigate whether tree water use varies among species in response to water availability or rising atmospheric evaporative demand. We gathered continuous measurements of sap flow in two subalpine tree species, *Pinus contorta* and *Abies lasiocarpa*, from Sept-Oct, 2024. We compared sap flow data to air temperature, vapor pressure deficit (VPD) and soil moisture. Measured *Pinus contorta* trees showed 1-1.5 L/hr of sap flow during peak hours on most days. *Abies lasiocarpa* showed more variability; while two trees showed <0.7 L/hr of sap flow at peak hours on most days, another tree reached >2 L/hr in several days. Lodgepole pine peak hours of sap flow occurred between 12pm-2pm, when temperature and VPD were at their highest, suggesting that the species tolerates significant water loss. Subalpine fir peak sap flow occurred earlier in the day, between 10am-12pm, suggesting that the species avoided greater water loss. These results suggest that subalpine species might tolerate drought conditions using different strategies, which could have important effects on forest productivity especially as forest structure and function are forecast to change in the future.

### The Competition Between Plant Water Stress and Stomatal Conductance Configurations: Which is More Important for transpiration?

**Zhiyi Zhou**

Colorado State University- Ecosystem Science and Sustainability

Plant transpiration is an important component in the water cycle, which is mainly represented by stomatal conductance (GS) and plant water stress configuration (PWS) in the Community Land Model (CLM). From the empirical Ball-Berry (BB) model to the optimization-based Medlyn (MED) stomatal conductance model, and from soil moisture stress (SMS) to plant hydraulic stress (PHS), there has not been consistent improvement in transpiration simulations across all sites or species. To explore the impact of different configurations on transpiration, we conducted four offline CLM experiments at nine National Ecological Observatory Network (NEON) sites. By comparing the transpiration from

experiments with different GS or PWS configurations, we aim to quantify the influence of GS (PWS) by the differences between MED and BB (PHS and SMS). Vapor pressure deficit (VPD) and soil moisture are key climate factors that modulate the effects of GS (PWS). Our results show that VPD primarily alters the influence of GS (PWS) at southeastern US sites, while both soil moisture and VPD contribute to the impact of GS (PWS) at western US sites. Although further analysis is needed to account for parameter uncertainty, our findings suggest that careful consideration is required when selecting specific configurations.

## Effects of flow management on biogeomorphic feedbacks on the Green and Yampa Rivers in Colorado and Utah

**Catherine McClure**

Colorado State University- Civil and Environmental Engineering

Flow regulation of major rivers has resulted in changes to channel geometry and riparian vegetation. Along the Green River decreases in peak flows have promoted proliferation of riparian vegetation resulting in sediment deposition, channel narrowing, and channel simplification. To better understand the relationship between changes in flow regime and channel narrowing, we analyzed ten years of riparian plant data coupled with plot inundation-duration and elevation data along 19 sites on the Green River and three sites along the Yampa River. Sampling methods include local site surveys of 1-m<sup>2</sup> plots measuring plot elevation, riparian plant cover, and inundation-duration. The sampling years cover a range in peak flows from 2015 through 2023. For the sites along the middle Green River, we observed significant increases in total percent vegetative cover during the low and average flow years, while in the wetter year we observed a slight decrease in total percent cover. These results confirm that in low flow years reduced physical disturbance allows encroachment of riparian vegetation. Additionally, we observed an increase in elevation of more densely vegetated plots compared to sparsely vegetated plots in wetter years. These results suggest that vegetation establishment in low flow years is subsequently causing entrapment of sediment and reduced erosion in wetter years. These observed feedbacks between changes in flow regime and riparian vegetation result in channel narrowing and simplification within this typically complex channel system. Results from this study suggest that flow peaks with high magnitude and duration can promote wide, complex channels which ultimately improve habitat for threatened and endangered fishes.

## Improving 5TE Soil Water Content Sensor Accuracy Using Neutron Probe Calibration Data and Machine Learning

**Suraj Khanal**

Colorado State University- Civil and Environmental Engineering

Accurate soil water content (SWC, m<sup>3</sup>m<sup>-3</sup>) measurements are crucial for agricultural and environmental applications, yet capacitance-based sensors like 5TE often exhibit systematic errors. This study employs machine learning (ML) to enhance 5TE accuracy using concurrent Neutron Probe (NP) SWC readings as reference values. Key factors influencing 5TE errors—soil salinity, root zone depth, soil texture, temperature, and time since wetting event (irrigation or rainfall)—are analyzed. A Random Forest model predicts and corrects 5TE errors by incorporating these factors alongside 5TE readings. Field data from

USDA ARS "Limited Irrigation Research Farm (LIRF)" in Greeley, Colorado from 2017-2022 period, was used for training. Subsurface drip-irrigated maize fields under full and limited irrigation were instrumented in the field with both sensors at various depths and locations. Since NP sensors measure SWC over a broader volume, we trained ML models using both direct sensor readings and depth-averaged values based on irrigation conditions, comparing their correction performance. The ML model significantly improves STE accuracy compared to conventional regression by capturing complex error relationships. Results demonstrate the potential of ML-driven calibration to enhance SWC sensor reliability across diverse field conditions.

## Sustainable River Management: Understanding the Effects of Weirs on Fish Habitat Connectivity

**Joo-Heon Lee**

Joongbu University- Civil Engineering

With rapid urban expansion and increasing water resource demands, river weirs have become essential for regulating water levels and ensuring a stable water supply. While they provide economic and infrastructural benefits, weirs significantly alter river cross-sections, affecting hydraulic parameters such as flow velocity, water depth, and sediment transport. These changes disrupt aquatic habitats, reduce biodiversity, and impact fish habitat connectivity, making it essential to understand their ecological consequences for sustainable river management. This study evaluates the effects of weirs on fish habitat connectivity by analyzing variations in flow regimes and fluvial geomorphological characteristics. Unsteady flow analysis was conducted to simulate water depth and velocity changes under varying flow conditions. The findings indicate that in drought flow conditions, weirs expand smaller habitat patches, whereas at low-flow or higher flow conditions, habitat areas are larger without weirs, especially in larger patches. Additionally, medium to low sinuosity and gentle slope river sections support greater habitat connectivity in the absence of weirs. The study also incorporates the habitat suitability index (HSI) to assess how weirs influence the preferred habitats of dominant fish species. Results show that while some species benefit from deeper and more stable water created by weirs, others experience reduced mobility due to habitat fragmentation. However, this study does not fully consider fish critical swimming ability, the presence and functionality of fishways, or species-specific differences, which may influence habitat connectivity. Future research should address these factors and explore adaptive water management approaches, fish passage improvements, and habitat restoration to mitigate the ecological impacts of artificial river crossings. These findings highlight the ecological impact of artificial river crossing structures and provide insights for sustainable river management balancing human water use and aquatic biodiversity.

## Hydraulics and Geomorphology

### Harnessing the Flow to Maximize Energy Potential: The Synergy of Hydropower and Hydrokinetic Systems

**Chien-Yung Tseng**

Colorado State University- Civil and Environmental Engineering



Hydropower tailrace channels offer promising opportunities for hydrokinetic energy harvesting due to their fast currents, scheduled water releases, and proximity to existing infrastructure, all while minimizing additional environmental impacts. However, the deployment of energy-extracting devices can introduce flow resistance, leading to a slight increase in water levels that may reduce the hydraulic head and diminish traditional hydropower output. This study employs a one-dimensional momentum balance approach combined with the backwater equation to assess the impact of water level changes and identify optimal turbine placement strategies that maximize net energy production by balancing hydropower losses against hydrokinetic gains. The research provides a preliminary assessment of hydrokinetic potential in U.S. tailrace channels and explores two case studies. It advocates for integrating hydrokinetic turbines into existing hydropower facilities and Non-Powered Dams (NPDs) to enhance energy output with minimal infrastructure modifications, also highlighting these sites as ideal for large-scale hydrokinetic device testing.

## Rethinking the Discharge Coefficient for Thin Weirs and Sills: A Fresh Look for Improved Flow Measurement

**Joseph Pugh**

Colorado State University- Civil and Environmental Engineering

The accurate measurement of flow using hydraulic structures has long been central to both applied hydraulics and broader water resources management, such as the calibration of hydrologic models. This study offers a revised treatment of the classical discharge coefficient,  $C_d$ , traditionally used to predict weir discharge. Through dimensional analysis and the incorporation of new experimental and numerical data, we show that  $C_d$  is more appropriately understood as a weir Froude number,  $Fr_h$ , which reflects the combined influences of flow inertia, contraction, and viscous energy loss. This reinterpretation aligns with both historical treatments of the problem and modern physical understanding.

We revisit the historical lineage of the weir-discharge equation, demonstrating that previously observed non-monotonic behavior in  $C_d$  across the weir-to-sill transition can be explained physically through changes in the separation zone, pressure distribution, and contraction dynamics. The result is a clarified delineation of practical operating regimes, including criteria for reliable flow measurement and an identification of the conditions under which traditional discharge equations become unreliable.

These findings help resolve long-standing ambiguities regarding the limits of classical weir flow theory, offering both field engineers and computational modelers improved predictive tools and clearer guidelines for applying weirs in practical flow measurement and water management applications.

**Practical Implications.** Weirs remain one of the most widely used flow measurement structures in practice, from small irrigation diversions to regulatory discharge monitoring. However, the discharge coefficient — a parameter often treated as little more than a calibration constant — is shown here to encapsulate rich physical meaning. Clarifying this meaning not only strengthens theoretical understanding but also enhances the reliability of discharge estimation in field applications where accurate flow data directly inform policy, ecological management, and infrastructure design.

## Interference Effects of Service and Emergency Spillways Reflecting Extreme Climate Events

**Jai Hong Lee**

Colorado State University- Civil and Environmental Engineering

An additional spillway next to an existing spillway may reduce the hydraulic performance of both spillways. Dual spillway interference refers to the loss of hydraulic performance of spillways when they are placed close together. Spillway interference is examined using both physical experiments and numerical simulations. Stage and discharge measurements from four physical models with dual spillways configurations are compared to the Flow-3D (three dimensions) computational results at four dam sites in South Korea. The conjunctive use of two spillways is compared with the singular operation of each spillway. When both spillways are operated at the same time, the total flow rate through the two spillways is reduced by up to 7.6%. Interference coefficients are most significant when the stage  $H_e$  exceeds the design stage  $H_d$  and when the distance  $D$  separating two spillways is short compared to the spillway width  $W$ . The parameter  $DH_d/WH_e$  correlates very well with the calculated and measured interference coefficients. A flood routing example for the design discharge at Andong dam shows a 42cm difference in reservoir water level with and without application of the interference coefficient. Consequently, the width of additional spillways (including the interference coefficient) should be increased for dam safety.

## Propagation dynamics of gravity currents induced by successive release of two lock-fluids

**Khem Bhattarai**

Colorado State University- Civil and Environmental Engineering

Gravity currents are ubiquitous in natural environments, playing a fundamental role in a wide range of geophysical and environmental processes. While single-lock-fluid configurations have been widely studied, the dynamics of multiple-lock-fluid scenarios, which more accurately represent real-world phenomena, remain largely unexplored, highlighting the need for a comprehensive study. This study employs high-resolution numerical simulations to examine three configurations of gravity currents: (a) simultaneous release of two lock fluids, (b) sequential release of two lock fluids, and (c) release of a single lock fluid with a density equivalent to the mean density of the two lock fluids. The findings indicate that as the denser lock fluid overtakes the lighter one, the propagation dynamics is altered, leading to an acceleration of the gravity current due to the accumulation of the denser fluid at the current head. A detailed examination of the flow structures at the head, body, and tail of the current reveals that maximum mixing and entrainment occur at the interface between the body of the current and the ambient, characterized by the formation of coherent Kelvin-Helmholtz billows. These insights enhance our understanding of multi-phase gravity current interactions, providing critical implications for environmental and engineering applications, including the prediction of density-driven flows in estuarine and reservoir systems.

## A new formulation for an improved estimation of turbulent (diapycnal) diffusivity in stably stratified flows

**Kiarash Nayebpashaei**

Colorado State University-Civil and Environmental Engineering

Quantifying turbulent mixing in stably stratified flows such as in estuaries, lakes, oceans and the atmosphere remains a challenging problem with important implications for circulation, mass and heat budgets, and transport of nutrients, this study presents a new approach for estimating diapycnal (turbulent) diffusivity using bulk turbulence parameters, avoiding limitations that are inherent in established methods such as the popular Osborn model. The proposed model establishes a relationship between the turbulent Froude number ( $Fr = \epsilon / Nk$ ) and the isotropy parameter ( $I = \langle w'^2 \rangle^{1/2} / \langle u'^2 \rangle^{1/2}$ ), where  $k$  is the turbulent kinetic energy,  $\epsilon$  is its dissipation rate,  $N$  is the buoyancy frequency,  $\langle u'^2 \rangle^{1/2}$  and  $\langle w'^2 \rangle^{1/2}$  are the root mean square horizontal and vertical velocity fluctuations. This allows for a link between the large-scale flow anisotropy to small-scale turbulent mixing, thus enabling a formulation for the estimation of turbulent (diapycnal) diffusivity without the need for direct dissipation measurements. Validation against two independent direct numerical simulation (DNS) datasets demonstrates that the model improves turbulent diffusivity predictions compared to the conventional approach using the Osborn model. The results provide a more accessible and reliable method for assessing turbulent mixing in stably stratified flows.

### Restoration Prioritization of Upper Colorado Tributaries in the Kawuneeche Valley, Rocky Mountain National Park, CO

**Connor Mertz**

Colorado State University- Geosciences

Collapse of tall willow habitat along the Upper Colorado River, Rocky Mountain National Park, CO has led to the loss of beaver and channel morphologic change. A diverse stakeholder group is pursuing restoration on Upper Colorado tributaries to improve willow habitat and downstream water quality. Utilizing historical records, field data, and flow inundation modeling, we investigate the processes driving channel incision and bank failure, levels of floodplain connectivity, and the extent of historical beaver activity. We develop and apply a restoration prioritization scheme based on geomorphic context of channel, floodplain, and watershed characteristics of three study sites: Upper Baker Creek, Lower Baker Creek, and Onahu Creek. Channel assessments indicate Onahu Creek has the steepest gradient, coarsest bed material, and experienced the greatest in-channel beaver dam density in 1990. Bankfull cross-sectional areas differ significantly between sites ( $p < 0.001$ ), a product of varying channel widths. Flow inundation modeling indicates that Upper Baker has the highest degree of floodplain connectivity with a 10.3x increase in surface water extent between observed base and peak flows, relative to a 5.2x increase at Lower Baker, and a 1.9x increase at Onahu. Based on our findings, process-based restoration is a suitable technique to reconnect the channel and floodplain and promote willow growth, but the degree of restoration effort required at each site varies. Onahu Creek has poor geomorphic condition with the greatest potential for floodplain reconnection through restoration. Upper and Lower Baker Creeks have good geomorphic condition which may benefit from less intervention to achieve the greatest river ecosystem benefit.

### Effect of Plant Morphology on Vegetation Drag in River Channels

**Towsibur Rahman**

Colorado State University- Civil and Environmental Engineering



Riverine vegetation plays an important role in flow dynamics, but the influence of vegetation on flow resistance and drag is not well understood. Morphological changes in vegetation influence velocity profiles and turbulence, making flow prediction challenging. The lack of research on vegetation structure's impact on flow resistance limits hydrodynamic modeling in river management. This knowledge gap hinders effective flood risk assessment, conservation of ecological habitats, and sustainable river engineering. To address this limitation, this study aims to investigate the morphology-dependent function of vegetation in affecting flow resistance in river channels, providing results that can improve hydrodynamic modeling and riverine ecosystem management. To study how vegetation morphology affects flow resistance, we first conducted a controlled experiment in a recirculating water flume under two vegetation density and submergence conditions. Cylindrical stems are used to simulate simplified-shape vegetation. Complex-shape vegetation surrogates will then be added to account for the complexity of natural morphology. To quantify detailed flow dynamics, we employ Particle Image Velocimetry (PIV), obtaining high-resolution velocity fields and visualizations of turbulent structures, enabling precise calculation of drag coefficients and turbulence analysis. The study enhances our understanding of how morphological factors affect drag resistance, providing valuable insights for parameterizing vegetation drag in flow resistance modeling, leading to more reliable predictions for river management, flood risk, and ecological conservation.

### Examining the role of model type and resolution on flash flood routing

**Nicholas Christensen and Ryan Morrison**

Colorado State University- Civil and Environmental Engineering

Intensifying flooding in the American West threaten human infrastructure, human life, and ecological integrity. Flash floods are a particularly dangerous form of floods as they rise quickly leaving little time to evacuate. Understanding the way in which flash floods propagate through mountain stream networks is essential to determining our management strategies. We further this understanding by contrasting the predictions of models with varying degrees of detail. We developed 7 models ranging in detail and physical realism for three sites in the Colorado front range, Beaver Creek (BC), Little beaver Creek (LBC), and Elkhorn Creek (EH). We developed a fine mesh 2D hydrodynamic model, a coarse mesh 2D hydrodynamic model, a spatially uniform 1D hydrodynamic model, and four formulations of Muskingum Cunge hydrologic routing. For each model we compared outputs to the most physically based model, the fine mesh 2D hydrodynamic model using Nash Sutcliffe Efficiency (NSE), difference in peak flow attenuation ( $\Delta Q_{(a/l)}$ ), and differences in predicted total volume retained within the model ( $\Delta V_r$ ). We found that model agreement varied nonuniformly between modeling strategies, with the site length, and flood magnitude. The simplified model which most effectively reproduced the fine detail 2D hydrodynamic model was a Muskingum Cunge routing scheme with a tiered mass loss system which activated higher transmission losses for flows above the bankful threshold. This method had an average  $NSE=0.945$ , average  $\Delta Q_{(a/l)}=2.2\%$ , and average  $\Delta V_r=1.7\%$ . The results of this study indicate that for routing flash floods in mountain streams simple schemes can improve performance including prediction of mass retention and peak discharge attenuation.

### Historical Beaver Dam Impacts on Floodplain Connectivity in Colorado Headwater Streams

**Kayla Schultz**

As ecosystem engineers, beavers significantly modify river corridor form through dam building. Beaver dams impound water which can increase surface water storage and divert water laterally into adjacent floodplains. When beavers are removed, their unmaintained dams wash out, altering the stream's hydrologic regime. Many contemporary river restoration techniques aim to restore natural functions historically provided by beavers without fully understanding the hydrological benefits of past beaver activity. Thus, we seek to quantify how the loss of beaver dams alters river-floodplain connectivity. We explore this objective at three headwater stream sites located in the Kawuneeche Valley, Rocky Mountain National Park, Colorado. These sites were historically occupied by beavers, but declines in tall willows have resulted in beavers abandoning the area. Channel incision, groundwater table lowering, and wetland degradation have been observed following the loss of beavers in the Valley. We developed a series of 2D hydraulic models in SRH-2D to compare metrics of floodplain connectivity under historical (beaver active) and present day (no active beaver) scenarios. Metrics included fraction of floodplain flow, floodplain water volume, floodplain residence time, and volumetric flux into the floodplain. Preliminary results show that the loss of beaver dams decreased floodplain volume by 12.0 to 84.6% and decreased the fraction of floodplain flow by 24.5 to 57.7%, depending on the site and modeled flood recurrence interval. Beaver dams consistently initiated the greatest change in floodplain connectivity at the lowest magnitude (2-year) flood, suggesting that the hydraulic benefit of beaver dams decreases as flood volume increases.

### Backwater Rise and Equivalent Roughness Generated by a Large Wood Jam

**Aleah Hahn**

Colorado State University-Civil and Environmental Engineering

Log jams create backwatering pools, increase hydraulic complexity, and provide key habitat for numerous species, yet log jams have been historically removed from rivers for navigation and flood control. Now, their ability to create habitat features, retain sediment, and improve floodplain connectivity has increased their popularity as a technique in river restoration. However, predicting backwatering depths and energy loss through jams remains poorly understood, and no established method exists for determining a roughness coefficient that accounts for jam characteristics and flow conditions. To address this gap, we analyzed 120 flume experiments conducted by Schalko (2018) and Follett (2019). Using paired upstream and downstream depths from the published flume experiments, we calculated Manning's  $n$  and the Darcy-Weisbach friction factor—two common roughness parameters in hydraulic modeling—and evaluated their relationship to jam characteristics. Our initial results suggest that decreased porosity and increased unit discharge contribute to greater upstream water depth. Our regression analyses to quantify relationships between jam and flow characteristics will be used to develop and validate a predictive model for friction factor. Future work will incorporate field data and assess the application of these roughness coefficients in two-dimensional hydraulic modeling. This study advances our ability to predict log jam backwatering, improving their design and implementation in river restoration.

# Hydrogeology and Groundwater

## Linking Floodplain Processes to Hydrologic Modeling of the Lower Arkansas River Basin to Improve Management of Irrigated Stream-Aquifer Systems

**James Molloy**

Colorado State University- Civil and Environmental Engineering

Floodplain landscapes have a significant role in hydrologic fluxes including connectivity to the alluvial aquifer and biogeochemical processing of solutes from irrigation return flows. Variable spatial extents and limited occurrence of active floodplains make quantifying their hydrologic and biogeochemical impacts problematic. To investigate, a surface-subsurface modeling practice was implemented to simulate hydrologic processes at the watershed scale in the heavily managed Lower Arkansas River Valley (LARV). The SWAT+ model accounts for spatial variability and fundamental physical processes while the gwflow module simulates groundwater head and fluxes in response to hydrology and irrigation at the surface. Objectives of this model are to improve implementation of floodplain landscapes in a modified version of SWAT+ with gwflow; and to assess the role of floodplains in controlling and mediating return flows, aquifer recharge, and solute transformation in the LARV. The model is run for the 1992-2020 period and tested for streamflow and groundwater head. Model performance improvements included PEST sensitivity analysis and PEST++ calibration of hydrologic parameters. Water balances reveal the largest daily groundwater flux is through active floodplains and only occurs once to twice in a year. Most years, flooding is insignificant, and few floodplain-linked cells are active. Next phases of the project include simulating artificial flood events and nutrient transport in the watershed system, with a special focus on nutrient exchange between the aquifer, floodplains, and stream channels, to determine the role of floodplains in potential nutrient management.

## An analytical model for groundwater recharge purposes

**Cinzia Miracapillo**

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An analytical solution to determine the water table mound underneath a rectangular recharging pond is presented. The following assumptions are made: the aquifer is homogeneous and isotropic, the water table is initially at rest and the aquifer bottom is horizontal. Even if the porosity is uniform, the effective porosity in the unsaturated zone may vary due to the interaction between surface water and groundwater. In case of groundwater recharge by means of a pond at the ground surface, the effective porosity of the unsaturated zone below the recharging pond is lower than the aquifer porosity, due to the water content associated to the descending water front. Thus the model presented takes into account two different values of the effective porosity for the unsaturated zone below the recharging area and for the unsaturated zone outside the recharging area. The mathematical formulation of the problem is based on the 2-dimensional groundwater equation, on the initial conditions and on the boundary conditions. The analytical solution is derived using the Laplace Transform and Fourier Transform.

## Quantifying the Drivers of Groundwater Recharge Dynamics in the San Luis Valley, Colorado

**Abdullah Al Fatta**

Colorado State University- Civil and Environmental Engineering

High-elevation mountains are vital water sources, supplying water to adjacent valleys through streamflow and groundwater recharge. In arid and semi-arid regions, groundwater from mountain-fed aquifers plays a critical role in agricultural irrigation. However, groundwater recharge mechanisms and their hydraulic connectivity to valley-fill aquifers remain understudied. Understanding the timing and magnitude of recharge processes, particularly temporal lags between mountain precipitation, snowmelt, and groundwater response, is crucial for sustainable water management. Climate-driven changes in snowpack accumulation and melt timing present a further challenge, as current dynamics diverge from historical patterns. This study examines groundwater recharge dynamics in the snowmelt-dominated San Luis Valley (SLV), Colorado, focusing on Subdistrict 1—an agriculturally intensive ~1250 km<sup>2</sup> area where extensive groundwater withdrawals have caused storage declines. We developed a statistical method to assess the effect of time-varying recharge on storage estimates, exploring correlations between snowpack metrics and groundwater level fluctuations. In the future, we aim to quantify recharge using in-situ measurements, gridded model-derived data, and satellite observations and evaluate the temporal lag between snowmelt and groundwater response. The findings will enhance our understanding of groundwater recharge in snow-dominated regions and support sustainable water management.

## Innovative Neural Network Model for Accurate Estimation of Soil Fine Percentage in Parowan Valley, Utah

**Dana Rastad**

Colorado State University- Civil and Environmental Engineering

Understanding the spatial variability of soil properties is essential for effective groundwater modeling, contaminant transport, and environmental assessment. In this study, lithological data from Parowan Valley, Utah, were utilized to compute the fine percentage in each stratigraphic layer. A hybrid convolutional neural network (CNN)-based model was developed to estimate and interpolate texture across the study area. A novel training approach was implemented, wherein the model is iteratively trained over multiple runs using different borehole-based random splits. At each iteration, the initial model weights are reloaded to ensure consistency and prevent overfitting. This iterative training strategy not only averages out spatial variability but also significantly enhances the model's generalization capability across diverse data partitions.

Performance evaluation revealed that the hybrid CNN model markedly outperformed traditional geostatistical methods such as kriging. Specifically, the model achieved a root mean square error (RMSE) of 7.68 during calibration and 7.57 during validation, compared to an RMSE of 34.12 for the kriging approach in both periods. Moreover, the model effectively captured the physical soil characteristics inherent to the study area, demonstrating its robustness in modeling complex spatial relationships.

The innovative training methodology, combined with the hybrid CNN architecture, facilitates robust learning of the relationships between input variables, namely spatial coordinates, average depth, slope,

and soil type—and fine percentage, without succumbing to overfitting. These findings highlight the potential of deep learning techniques to serve as a powerful alternative to conventional interpolation methods in geostatistical applications.

## Modeling Groundwater Hydrology and Legacy Phosphorus Transport in an Agricultural Watershed Using SWAT+gwflow

**Zaichen Xiang**

Colorado State University- Civil and Environmental En

Excessive use of phosphorus-rich fertilizers in agricultural watersheds has led to groundwater contamination, posing challenges to water quality management. This study applies the SWAT+gwflow model, enhanced with a phosphorus transport module, to simulate groundwater phosphorus dynamics. The Choptank River Watershed (CRW), a 2,600 km<sup>2</sup> tributary of the Chesapeake Bay, faces persistent legacy phosphorus pollution, making it an ideal case study. Before simulating groundwater phosphorus transport, we assessed the hydrologic performance of SWAT+gwflow in the CRW. A global sensitivity analysis (GSA) of 85 parameters across nine groups over 10-year simulations identified key hydrologic parameters for calibration. Streamflow discharge and groundwater table elevation were calibrated at multiple USGS gages and monitoring wells (2004–2010) with a three-year warm-up (2001–2003), then tested using observed data (2011–2020). Additionally, data for dating groundwater movement generated through the metolachlor ethane sulfonic acid (MESA) approach served as a key calibration and validation tool for groundwater travel time in irrigated agricultural aquifer systems. Key findings include: (1) aquifer properties (specific yield, hydraulic conductivity) and surface hydrology parameters (esco, can\_max, perco) influence groundwater table elevation, while runoff lag time predominantly controls streamflow discharge; (2) model calibration showed strong agreement with observed data. Next steps involve simulating phosphorus transport and quantifying phosphorus residence time in soils and aquifers. This study provides a robust hydrologic foundation for managing legacy phosphorus pollution in agricultural watersheds.

## Illuminating Groundwater Recharge Dynamics with Time-Domain Electromagnetics

**Julianne Robinson**

Colorado State University- Civil and Environmental Engineering

The ability to measure groundwater availability, extraction, and recharge is becoming increasingly critical as the climate changes and reliance on groundwater in water-stressed regions increases. Geophysical measurement methods like time-domain electromagnetic surveys can address the need for cost-effective, high-resolution hydrostratigraphic data collection with greater spatial and temporal coverage than direct-sampling methods. Among other applications, these data can be used to delineate the infiltration front in the vadose zone and improve targeting of managed aquifer recharge. This study uses geophysical datasets collected with towed time-domain electromagnetic (tTEM) surveys to map infiltration at managed recharge sites in the San Luis Valley in south-central Colorado. Study sites were surveyed with tTEM approximately every six weeks over the course of the irrigation season to provide time-lapse datasets. A customized inversion approach is being implemented to capture time-varying changes in resistivity. Results enable estimation of seasonal changes in subsurface resistivity and

estimation of changes in saturation resulting from various sources of recharge. The increased spatial and temporal coverage of tTEM compared to other measurement methods makes it possible to rapidly assess hydrogeologic characteristics and improve understanding of site-specific infiltration over larger geographical regions. This information can serve as an important addition to other forms of data to inform water management in the San Luis Valley and other arid and semi-arid regions dependent on groundwater.

## Integrating Satellite Remote Sensing and Groundwater Data for Assessing Land Subsidence in Diamond Valley, Nevada

**Sayantana Majumdar**

Desert Research Institute- Division of Hydrologic Sciences

Diamond Valley (DV), a key agricultural basin in Central Nevada, relies entirely on groundwater for irrigating alfalfa and grass hay. Over the past fifty years, excessive groundwater pumping, has caused almost 25 m (80 ft) drops in groundwater levels. Recognizing the severity of these groundwater overdrafts, the Nevada State Engineer's office designated DV a "Critical Management Area" in 2015. Despite the implementation of a groundwater management plan, the region lacks research on pumping-induced land subsidence. This study presents the first short baseline subset (SBAS) interferometric synthetic aperture radar (InSAR) time series analysis in Nevada. Here, we conducted standard SBAS InSAR analysis using Sentinel-1 data, acquired via the Alaska Site Facility (ASF) Vertex portal. A dense network of 843 SLC pairs was created with 800m/47-day spatial/temporal baselines. These pairs were processed using ASF HyP3 to generate 80m interferograms, applying a 0.6 phase filter, 20x4 multilooking, and a 0.5 coherence threshold. Our analysis (2014-2024) revealed significant land subsidence in central Diamond Valley (DV), exceeding 400 mm (1.4 ft), with the average subsidence being ~300 mm (1 ft). This pronounced subsidence primarily occurs on the valley floor, where unconsolidated clays and basin-fill deposits are prevalent. We also observed that the InSAR-derived subsidence and groundwater level changes show a strong correlation (Pearson's  $r = 0.98, 0.96$ ) at two co-located sites, where groundwater pumping (derived from OpenET) nearly doubled between 1985 and 2023. Thus, our study provides a foundational framework for monitoring land deformation across Nevada, offering a valuable tool for evaluating infrastructure risks statewide.

## Assessing Major Drivers of Diffuse Groundwater Recharge Using Machine Learning Techniques

**Dawit Asfaw**

Colorado State University- Geoscience

Sustainability of groundwater resources is threatened by increasing groundwater demand and changing climate. Appropriate groundwater use can be guided through understanding of the different aquifer water budget components. Due to the complex nature of groundwater recharge process, groundwater recharge estimates are challenging. The accuracy of groundwater recharge estimates depends on understanding of major drivers including climatic, topography, geology, and land use. The study aims to identify major drivers of diffuse groundwater recharge in Arkansas River Basin using the Random Forest machine learning (ML) algorithms. The machine learning algorithm is trained using computed recharge fluxes from a process-based model. Several predictor variables are considered, including precipitation,

air temperature, evapotranspiration, soil hydrologic group, and slope. The period of study considered is from 2008 – 2020. The dataset has an annual temporal and 500 m spatial resolution. Data is split into 70% training and 30% testing datasets to train and test the model's performance, respectively. The preliminary result of our model showed an R2 value of 0.91 for training and 0.68 for testing. Feature importance analysis results showed that precipitation and minimum temperature are considered important variables. Evapotranspiration has moderate importance whereas slope and saturated hydraulic conductivity are considered least important. Partial dependence plots indicated that higher precipitation values correlated with greater recharge values. Comparison of simulated and ML estimates of recharge shows strong temporal and spatial correlation. ML models are computationally efficient and provide sensitivity analysis framework. Thus, the relative importance of key variables that determine groundwater recharge in different basin subregions can be evaluated using ML models.

## Hydrologic Systems & Process Based Modeling

### Exploring hydrological responses to water management scenarios in the Upper Colorado River Basin

**Muhammad Raffae**

Colorado State University- Civil and Environmental Engineering

The Upper Colorado River Basin (UCRB) is a vital source of water for agricultural, municipal, industrial, and ecological needs, contributing 90% of the total streamflow in the Colorado River system. However, increasing water demand, prolonged droughts, and climate change necessitate informed decision-making to ensure sustainable water management. One key challenge is evaluating the hydrological impacts of different irrigation and water management strategies. In this study, we utilize the Soil and Water Assessment Tool Plus (SWAT+), augmented with the gwflow module, to simulate surface and subsurface hydrological processes in the UCRB under varying management scenarios. The model captures key dynamics, including surface and subsurface flows, groundwater-surface water interactions, reservoir operations, agricultural groundwater pumping, and canal seepage. After calibration against historical streamflow and groundwater head data, we assess the impacts of shifting from flood irrigation to pressurized irrigation on wetlands, wildlife habitats, and environmental flows. Additionally, we examine three distinct water-use scenarios: (1) utilizing all saved water from improved irrigation efficiency, (2) conserving all saved water, and (3) using only the consumptive portion of the saved water. These scenarios will help explore potential shifts in water distribution, flow timing, and groundwater recharge across the basin. By identifying the possible trade-offs between water conservation and hydrological resilience, this study aims to provide insights into the implications of different irrigation and conservation policies. The findings will contribute to a more comprehensive understanding of integrated groundwater and surface water management, supporting future decision-making for sustainable water use in the UCRB.

### Understanding Water Interactions using modified SWAT model in Arkansas River Basin

**Pratikshya Neupane**

Colorado State University- Civil and Environmental Engineering

The Arkansas River Basin in Colorado is a vital, heavily managed watershed critical to the state's water resources. Irrigation in the Arkansas River Valley, from Pueblo to the Colorado-Kansas state line, dates to the 1800s, primarily relying on river diversions and shallow aquifer wells. This study examines water flux in a 6,132-square-mile section of the basin (1990–2014), including 165 square miles of irrigated land. A modified Soil and Water Assessment Tool (SWAT) models water dynamics, calibrated with observed flows at six watershed locations. Key water balance components—surface runoff, evapotranspiration, soil moisture, lateral flow, and groundwater return flow—are analyzed across sub-watersheds and the irrigated corridor. Wet and dry years are identified statistically, and their water balance compared. The study finds over 90% of precipitation is lost to evapotranspiration, leaving minimal runoff. Groundwater return flows are generally higher in dry years, as groundwater discharge into streams increases when flow is low. Return flow is significantly higher in the irrigated corridor, likely due to year-round canal recharge. Various management scenarios are modeled to assess impacts on water dynamics. The developed model offers a valuable tool for understanding past water interactions and predicting future flux variations under extreme climate conditions.

### Hidden Flows: Simulating the Hydrologic Impacts of Artificial Recharge in an Irrigated Semi-Arid Watershed

**Emmanuel Opoku**

Colorado State University- Civil and Environmental Engineering

Artificial recharge ponds are increasingly used to augment groundwater resources, significantly impacting stream and aquifer systems. This study presents an improved numerical modeling approach by integrating a newly developed recharge pond routine into the coupled SWAT+gwfmodel. The routine simulates seepage from recharge ponds to aquifers and streams, capturing surface-groundwater interactions across space and time. Applied to the 7440 km<sup>2</sup> Middle South Platte–Cherry Creek watershed in Colorado, the model simulates 93 recharge ponds, calibrated with USGS and Colorado Division of Water Resources data. Results show rapid groundwater head increases near ponds and enhanced groundwater discharge to streams, mitigating stream depletion from pumping. The findings underscore recharge ponds' potential to sustainably manage groundwater resources in irrigated areas. This enhanced SWAT+gwfmodel provides a powerful tool for assessing artificial recharge projects across diverse regions.

### Evaluation of Time-Domain and Signature-Domain Calibration Methods for Spatially Distributed Hydrological/Water Quality Modeling in a Highly Managed Watershed

**Subash Thapaliya**

Colorado State University- Civil and Environmental Engineering

Hydrological and water quality models are crucial for managing complex watersheds affected by human activities. This study evaluates time-domain and signature-domain calibration methods using the fully distributed Agricultural Ecosystems Services (AgES) model. A key challenge in this system is data unavailability at inlet and outlet structures, leading to misinformation. To address this, signature-based evaluation metrics Probability Weighted Error (PWE) of the Flow Duration Curve (FDC) and Load

Duration Curve (LDC) were employed to assess model performance, ensuring deficiencies stem from structural issues rather than data flaws.

The key objectives of the study include evaluating the robustness of parameter estimation using FDC and LDC signatures, developing uncertainty analysis procedures, analyzing error metrics and reconciling noncommensurable metrics through multi-objective calibration. Results show that signature-based calibration enhances parameter identifiability, with PWE of FDC being most sensitive for 24 of 34 parameters. LDC-based calibration had the highest information content. FDC and LDC based methods outperformed time-based calibration in generating FDC and LDCs, while LLQ achieved better Nash-Sutcliffe Efficiency (NSE) for flow but underperformed in load simulations.

Multi-objective optimization balanced performance across time-series, FDC, and LDC simulations. Integrating likelihood, FDC, and LDC improved FDC simulation, whereas integrating only the likelihood of flow and LDC resulted in superior NSE for flow. Overall, the findings advance calibration techniques for spatially distributed hydrological models, enhancing their predictive accuracy and utility in watershed management.

### Developing a Conceptual Model to predict river Intermittency from Hydroclimatic Parameters

**Najam us Saqib Fraz**

Colorado State University- Civil and Environmental Engineering

Approximately half of the global river network is classified as intermittent, and the frequency and duration of river intermittency are expected to increase due to climate change, land-use changes, and water abstractions. This study aims to understand the landscape and climatic interactions, shaping river intermittency. Our conceptual model treats streamflow as a sequence of discrete jumps, where each peak flow is followed by an exponential recession, governed by a linear reservoir. This assumption allows us to write simple analytical formulations to predict streamflow intermittency as a function of key river parameters—such as peak flow rate, the number of peak flow days, and the mean streamflow. The conceptual model will be tested using real-world data from multiple stream gages across the United States and will be further used to estimate the probability of future river intermittency under varying climatic and hydrological conditions.

### Application of extraordinary flood research and hydrologic risk to evaluate dams in Colorado

**Mark Perry**

State of Colorado Division of Water Safety- Colorado Dam Safety

Colorado has experienced extraordinary floods producing near-record upper tail ratios (peak flow/10% chance flood) for the Continental U.S. Moisture flow from the east and dramatic terrain changes create ideal flood conditions. Colorado Dam Safety regulates nearly 2,000 dams, many with life-loss consequences. Estimating extreme floods here has proved difficult, and accommodating floods is a major cost of water storage. The previous probable maximum flood approach was plagued by its disregard of the observed flood record. By the 1990s a multi-disciplinary effort was afoot to understand extreme floods in Colorado. Colorado State University and CDS played important roles, producing extreme precipitation studies, an extraordinary flood database, paleoflood research, and extreme flood

modeling. Simultaneously the dam safety industry moved to risk-based evaluation, and the question shifted from what is the worst possible flood to what is the likelihood of a given flood? The latter question proved easier to answer with observed flood data and hydrological modeling. The research resulted in important discoveries: modeling correct physical processes of flood production matters, storm types and seasonality matter and can be informed by the historical flood record, large regional variations in maximum floods exist, and extraordinary floods like those of June 1965 involve non-linear response and may lie beyond risks of concern. CDS has applied these research outcomes to new regulations, which has caused both significant cost savings and improved confidence in flood estimates. Future work is needed to augment extreme hydrology data sets, incorporate non-stationarity, and further improve confidence in estimates of extremes.

### Modeling Fifty-Two Years of Land Subsidence in the San Joaquin Valley, California

**Susmita Pant**

Colorado State University- Civil and Environmental Engineering

In California's San Joaquin Valley, alarming rate of groundwater overdraft has resulted in significant subsidence since the 1920s. Long term-rapid subsidence has exacerbated flood risks in the valley, damaged infrastructure and permanently altered the aquifer dynamics. Hence, it is important to understand the pattern and magnitude of such ground deformation in the region. Most of the present models developed to quantify deformation in the valley use the explicit finite difference method, which requires finer time steps, is inefficient and infeasible for long-term simulations over a vast region. On the other hand, finite difference techniques like the implicit method are unconditionally stable for larger time steps, faster for long-term simulations and better suited to handle stiff problems. In this study, we compute fifty-two years of yearly change in ground deformation from 1971 to 2023 in the Southern San Joaquin Valley across broad spatial scales using the implicit finite difference method. In addition, we calibrate and validate the developed model using InSAR-derived ground deformation. Moreover, we also compare the developed Implicit Model with the currently implemented Explicit Model based on the quantity of data required, time for running the simulation, calibration efficiency, and validation accuracy with the InSAR result. The outcome of the research will provide extensive ground deformation estimates in the valley.

### Evaluating a Novel Approach for Determining Dynamic Zero-Plane Displacement Height to Improve Remote Sensing-Based Estimation of Latent and Sensible Heat Fluxes over Corn Fields

**Debashree Halder Tuli**

Colorado State University- Civil and Environmental Engineering

Accurate estimation of latent heat flux (LE) and sensible heat flux (H) is critical for understanding crop water use for irrigation management. However, these fluxes are sensitive to surface and aerodynamic properties, particularly the zero-plane displacement height ( $d_0$ ), which introduce uncertainties in energy balance (EB) calculations. This study evaluates a proposed  $d_0$  model and its influence on LE and H estimation in a corn field under full and deficit irrigation. Field experiments were conducted in 2024 at the USDA-ARS Limited Irrigation Research Farm in Greeley, Colorado, where soil heat flux plates, net radiometers, and eddy covariance (EC) systems measured key EB components. To track crop growth,

weekly multispectral radiometer (MSR) and leaf area index (LAI) readings were collected, and MSR-based calibrated PlanetScope satellite imagery was used to estimate continuous net radiation ( $R_n$ ). Since EC systems measure fluxes from multiple upwind areas (fetch), wind direction data were used to partition  $R_n$ , ensuring accurate attribution of energy flux contributions from different irrigation zones. To refine  $d_o$  estimates, fractional cover (fc), and crop height (hc) were incorporated into a newly developed do model, with unmanned aerial system (UAS) imagery deriving dynamic canopy porosity ( $\Phi_{dp}$ ). The new do model was used to estimate H, and H was then used to determine LE by applying the EB closure method. Estimates of H and LE will be statistically compared to the measured fluxes for accuracy determination. Incorporating  $\Phi_{db}$  and fc in a  $d_o$  model is expected to improve the H and LE estimation accuracy, enhancing EB modeling for irrigated agriculture and supporting sustainable water management in water-scarce regions.

## The NASA Surface Water and Ocean Topography (SWOT) Mission: Status and Hydrologic Science Contributions

**J. Toby Minear**

University of Colorado-CIRES

Launched in December 2022, the Surface Water and Ocean Topography (SWOT) Mission houses a first-of-its-kind satellite instrument, KaRin, with an interferometric Ka-band active radar and a near-nadir look angle. Most importantly, SWOT's KaRin instrument measures coincident water surface elevation and widths at high elevation precision, and over a large 120 km swath every 10 days on average, enabling estimation of volume change in waterbodies and discharge in rivers. SWOT measures 0.5% earth's surface area per hour and offers stunning new insights into ocean and inland waterbodies. Less well known are SWOT's capabilities for rivers, particularly rivers that are otherwise difficult to sample with field equipment. Using SWOT and field data, this presentation will discuss the hydrologic and geomorphic implications of one and a half years of SWOT measurements, including data from rivers, lakes and reservoirs in Western North America.

## Seasonal Analysis of Peak Discharges

**Robert Milhous**

Torries Peak Analysis

This paper explores the possibility that a seasonal analysis of peak flows might be useful. The idea is that knowing the probability distribution of peak discharge by season would be useful when the impacts of the peak discharges on the aquatic ecosystem are different by season and when the economic impacts are different by season. The case study approach is used. The cases are a comparison of the annual peak discharges to the seasonal peak distributions of five rivers: Yakima and Teanaway Rivers in Washington State, Pipestem Creek in North Dakota, Tippecanoe River in Indiana, and Tar River in North Carolina. The Yakima River is the a river with fall/winter peaks mostly caused by rain and spring peaks caused by snow-melt. The peak discharges for both seasons are similar. The Yakima River peaks are modified by reservoir storage and diversions. The Teanaway River is in the Yakima River watershed and is not as modified by water management as the Yakima River but much smaller. The fall winter seasonal peaks for a give return period tend to be larger than the peak based the whole year for the longer return

periods. Pipestem Creek is the case where there is a sudden arrival of a fall season with significant peak discharges. Is this a result of climate change or a previously unrecognized season with significant peak discharges? The Tippecanoe River has two seasons: a rain on frozen ground season in the winter and the rest of on the year. There a problem. June also has high peaks in some Indiana rivers that is not reflected in the Tippecanoe River data. This is considered in evaluating the Tippecanoe River results. The Tar River in North Carolina has two seasons: a tropical cyclone season and the rest of the year. The maximum annual peak discharges are in the tropical cyclone seasons. It is of interesting that many of the annual peak discharges are outside the tropical cyclone season. Even though the peak discharges in the non-tropical cyclone season are smaller than during the tropical cyclone season they may be important for the aquatic ecosystem. There is no common reason for doing a seasonal analysis of the peak discharges applicable to all five rivers. Each of the rivers is unique and the reason a seasonal analysis might be appropriate must be based on the characteristics of the specific river.

## Urban Water & Integrated River Systems

### Assessing The Fate Of Stormwater Contaminants In Bioretention Cells With Varying Media

**Amanda Salerno**

Colorado State University- Civil and Environmental Engineering

To protect the surface and underground watersheds from serious harm, it is necessary to implement intentional infrastructures that allow interception and treatment of water in urban areas. This research aims to evaluate bioretention systems as an alternative to reduce stormwater runoff while also improving water quality. The bioretention facilities for this research are localized at the Hydro Building backyard, SPUR Campus, with two different selected media, MHFD media + 5% compost (SSC) and Amended Fort Collins Mix (SBZ), with the same plant selection. Each bioretention facility receives stormwater runoff from the surrounding area, and the outflow is analyzed to evaluate heavy metals and nutrients, such as phosphorous and nitrogen, COD, TSS, and E.coli. Using ISCO Samplers, the drain time of runoff from the bioretention facilities is analyzed to evaluate runoff peak reduction and detention time from the systems. The different bioretention media present different water quality treatments and detention times. SSC has a shorter runoff time than SBZ. TSS levels show a decrease of 70% in the outflow of both bioretention facilities. With all the outflow samples, there is an increase in total nitrogen (70%) and total phosphorous concentrations (35%) in the runoff. COD has a reduction in the outflow from all analyses (15%). Finally, E.coli levels also reduce in the outflow runoff, 30% less in the SBZ, and 60% in the SSC. Fe, Mn, Cu, Al, Mo, and Ni increase concentration in the outflow runoff compared to the inflow; on the other hand, Zn and As decrease in both bioretention facilities. Further data collection is needed to understand the fate of contaminants in those bioretention facilities.

### Enhancing Phosphorus Removal in Bioretention Systems with Water Treatment Residual Amended Soils

**Mattheu Cipra**

Colorado State University- Civil and Environmental Engineering

Bioretention cells (BRCs) are a stormwater control measure that can reduce stormwater runoff volumes as well as improve water quality by removing pollutants from runoff. However, BRCs lack consistent

removal and retention of phosphorus (P) species and in some cases leach P into stormwater. This study investigated the effectiveness of aluminum water treatment residuals (Al-WTRs) as a BRC soil media additive to improve P removal. A laboratory column experiment was conducted to evaluate the effectiveness of a 1.27 cm (0.5 in) surface application, a 2.54 cm (1 in) surface application, a mixed application, and a 2.54 cm (1 in) bottom application of Al-WTRs to remove dissolved phosphorus (DP). While all columns leached DP, when compared to the control columns effluent (1.438 mg/L), all columns containing Al-WTRs exhibited significantly reduced DP concentrations (0.866, 0.844, 0.367, and 0.288 mg/L, respectively). A field study was also conducted to evaluate the P removal efficiency of a BRC retrofitted with a 1.27 cm (0.5 in) surface application of Al-WTRs. Although DP and TP concentrations were observed to increase by 78.2% and 5.8%, the mass loading of each pollutant decreased by 87.1% and 88.6%. Furthermore, when compared to historical data collected at the site, which showed significant increases to effluent P concentrations, the Al-WTR retrofit reduced P concentrations by 45% and 65%, respectively. Lastly, while sampling was limited during the monitoring period, no detrimental effects to water quality were observed from the Al-WTR application. Ultimately, this study shows that surface applications of Al-WTRs can effectively improve P retention in BRCs without compromising other water quality standards.

### Estimating discrete salt ion loads in a saline, highly managed river using a machine learning model and a mass balance approach

**Kenneth Laffite**

Colorado State University- Civil and Environmental Engineering

Salinity in river water within semi-arid basins can adversely affect the environment, fish, and crop production. Accurately quantifying salt mass loadings in these river systems is vital for understanding salt sources and proposing mitigation strategies. However, salt ion concentration data is often sparse in these regions. In this study, we present a method for estimating daily loads of individual salt ions along the Arkansas River in southeastern Colorado, one of the most saline rivers in the western United States. Salinity in irrigation water is the primary concern for farmers, as high concentrations of salt ions adversely affect crop production. Salt ion concentration data is limited at several USGS stations along the river channel, which hinders the accurate evaluation of salt loads. To address this limitation, a Random Forest Regressor machine learning model was employed to generate synthetic data in the form of daily salt ion concentrations for stations with sufficient data. The independent variables used for the model are discharge and specific conductance, while discrete salt ion concentrations serve as the dependent variables. Subsequently, a mass-balance approach was utilized to calculate the average salt ion loads throughout the river channel. The results indicated that water quality deteriorates further downstream, characterized by significantly reduced water flux carrying higher salt loads. This pattern is often associated with impaired streams. The synthetic data generated by the model can be used for further research, such as calibrating hydrological models to enhance the understanding and prediction of salt movement throughout the watershed.

### Hydrologic Monitoring of Pivot Management Strategies for Drought Resiliency in Wyoming

**Samantha Rogaczewski**

University of Wyoming- Ecosystem Science and Management

With increasing drought intensity and frequency, Wyoming must find solutions to improve water efficiency in the Colorado River Basin to maintain agricultural productivity and Colorado River Compact compliance. Strategies that increase Wyoming's drought resiliency are needed; such strategies being

considered include nighttime and deficit irrigation. Nighttime irrigation avoids water application during periods of high evaporative demand, while deficit irrigation limits the amount of water applied by matching or going below a crop's irrigation requirements. These approaches will be studied on a 140-ac pivot field located near Mountain View, Wyoming, sitting at 7075 feet. The field grows a mix of sainfoin, alfalfa, and grasses, producing two hay cuttings a year with additional grazing in the fall. Over three years, from April through October, this study evaluates the on-field water savings by measuring evapotranspiration, precipitation, irrigation application, soil storage, and groundwater levels. The first year of monitoring normal irrigation practices has been completed, providing baseline conditions. The second year will switch to a systematic 24-hour rotation that separates the field into nighttime (study) and daytime (control) application areas. The third-year irrigation schedule is dependent on second year results, and will study either nighttime, deficit, or a combination of these methods. Initial monitoring from year one developed a water balance for the field under normal conditions, enabling the characterization of the field's vegetation and soils. An application rate imbalance across the field was found, necessitating a pivot assessment and upgrades to ensure consistent application rates.

## Remote Sensing of Consumptive Use and ET

### Remote Sensing-based Evapotranspiration for Crop Water Use Mapping

**Gabriel Senay**

U.S. Geological Survey- Earth Resources Observation and Science Center

The estimation and mapping of spatially explicit actual evapotranspiration (ET<sub>a</sub>) is an active area of research and development in eco-hydrology and water resources studies. ET<sub>a</sub> represents the response of the landscape to moisture availability and its spatiotemporal distribution depending on vegetation condition and composition in a particular climatic setting. Moisture sources of a landscape vary from direct precipitation, shallow groundwater, to irrigation applications or a combination of all sources. One of the key concepts in agricultural water management is crop consumptive use (CU) which represents the amount of water removed from the landscape in a form of evapotranspiration (ET) and not available for other uses. Water managers are specifically interested in irrigation consumptive use (ICU) which refers to CU from irrigation (blue water) only, without contribution from precipitation (green water). The determination of ICU requires the quantification of ET<sub>a</sub> from precipitation to obtain CU as the difference between total ET and green water ET. The study presents the estimation of ICU by combining diagnostic and prognostic ET models. The diagnostic Operational Simplified Surface Energy Balance (SSEBop) model was used to estimate total ET regardless of the sources of water while the VegET daily water balance model was used to determine green water ET. Illustrative examples of ICU, calculated as the difference between SSEBop and VegET, will be presented for the agricultural regions with supplemental irrigation in the United States at multiple spatial scales. The joint use of energy and water balance models has the potential to be applied over irrigated areas around the world because of the availability of global datasets for the two modeling approaches. Model estimation biases can be corrected through cross-calibration procedures using independent ET datasets.

## Assessing groundwater pumping, consumptive use, and irrigation efficiencies in the Western U.S.: Insights from high-resolution satellite remote sensing and climate data

**Sayantana Majumdar**

Desert Research Institute- Division of Hydrologic Sciences

Developing reliable and efficient solutions for monitoring groundwater withdrawals is paramount in addressing the urgent water management concerns in the Western U.S. The existing methods for estimating withdrawals either entail significant costs and time (e.g., process-based models) or are not suited to support local-scale water management. Building on our prior research, here, we rely on Landsat actual evapotranspiration (ET) from OpenET, annual Landsat-derived irrigation masks (IrrMapper), land use (USDA NASS CDL and USGS NLCD), irrigation data (field boundaries, water source type), and climate datasets (gridMET) to estimate annual groundwater pumping, consumptive use, and irrigation efficiencies in Nevada, Oregon, and Arizona. We use statistical (linear regression and bootstrapping) and machine learning (Random Forests) approaches and compare our groundwater withdrawal estimates with in-situ meter data at multiple spatial scales— field (30 m-100 m), local (2 km), and individual groundwater basin scales. We also evaluate these regression models based on temporal (leaving out multiple years from the model training) and spatial holdouts (leaving out multiple groundwater basins from the model training). Our models can explain 50%-80% variance in withdrawal depths and 90% variance in withdrawal volumes across these spatial scales and evaluation strategies. The estimated irrigation efficiencies (80%-90%) also align with known irrigation system efficiencies in the study areas (Nevada, Oregon, and Arizona). With this research, we aim to empower water resource communities by improving water budget information and facilitating the implementation of groundwater management plans throughout this region.

## A watershed modeling approach to quantify agricultural groundwater pumping at the national scale

**Ryan Bailey**

Colorado State University- Civil and Environmental Engineering

Estimates of groundwater pumping volumes for irrigation are essential for water management and water supply forecasting, but challenging to estimate if wells are not metered. In this study we provide estimates of monthly and annual groundwater pumping rates for irrigation for the conterminous 48 states, at a 500-m scale. The approach uses the SWAT+ hydrologic model, with the use of the gwflow subroutine for simulating spatially distributed groundwater storage, flow, and interaction with surface water features (channels, lakes, reservoirs, canals). Using one SWAT+ model for each 8-digit watershed, pumping rates are estimated for the 2000-2020 period using datasets of soil, land use, crop type, management practice, and water, in combination with the auto-irrigation and water allocation routines of SWAT+. The approach is both demand-driven, using crop growth algorithms and soil moisture conditions to trigger irrigation events, and supply-limited, using simulated groundwater storage to constrain irrigation extraction volumes. Each model is tested for hydrological processes and fluxes using watershed water budgets, streamflow (USGS gaging stations), and groundwater head (USGS monitoring wells), and for measured pumping rates in several regions with available pumping data (Mississippi Delta, High Plains Aquifer, southern Arizona). The approach shows good results for monthly and annual

pumping volumes. The resulting national dataset can be used in watershed and aquifer water balance analysis, and to quantify the impact of pumping on groundwater depletion. The modeling framework can also be used to predict pumping rates and groundwater storage trends for future conditions of climate, land use, and irrigation practices.

### Using Electrical Runtime Data from Center Pivots as a Proxy for Irrigation Water Use

**Erin Haacker**

University of Nebraska-Lincoln- Dept. of Earth & Atmospheric Science

Irrigation is among the most important human-mediated fluxes in the water cycle. It is also uniquely visible with remote imagery, unlike other water usage such as withdrawals for drinking water and industry. However, despite the visibility of irrigation water use, farm decisions around water application remain poorly constrained. This is challenging both for interpretation of remote imagery and for numerical models, which are often used in water management. This presentation will demonstrate the potential for electrical energy use to serve as a proxy for groundwater consumption in agricultural settings. Overall, when estimates of water use were derived from an algorithm using electrical runtime records calibrated to annual ultrasonic flow meter measurements, water consumption was within about 6.6% of water use measured from permanent flow meters installed in wells. The variation between estimates from electrical runtime versus average flow meter measurements was on the same order of magnitude as the variation between flow meter measurements. This method is extremely promising as a cheaply implemented, independent estimate of water withdrawals that can be used in conjunction with remote sensing; however, it is highly dependent on sensitive information that requires agreement with both farmers and electrical utility corporations. Widespread use of this data would be very beneficial to the scientific community, and ultimately to farmers, but is dependent on clear communication and strong safeguards for data privacy.

### Estimation of Effective Extreme Pixels for METRIC Application Using UAS Imagery: Enhancing Remote Sensing Crop Evapotranspiration Estimation in Diverse Environments.

**Adwoa Serwaa Amankwaa**

Colorado State University- Civil and Environmental Engineering

Accurate crop evapotranspiration (ET<sub>a</sub>, mm/d) estimation is essential for effective water resource management, agricultural planning, and climate modeling. This is achieved by routinely monitoring the water conservation strategies adopted by farmers, particularly as they navigate seasonal water shortages and participate in system conservation programs that involve temporary irrigation withdrawals from the Colorado River. The METRIC (Mapping Evapotranspiration at high Resolution with Internalized Calibration) model relies on extreme pixels representing the hottest and coldest agricultural surface conditions to calibrate the one-source surface energy balance. However, selecting and producing effective extreme pixels remains a challenge, particularly in heterogeneous landscapes and at a very high pixel spatial resolution from unmanned aerial systems (UAS). The impact of different selection methods on METRIC-derived ET estimates is being assessed through comparisons with ground-based reference measurements, using statistical metrics such as root mean square error (RMSE) and correlation coefficients. Data collection has been conducted across multiple irrigated pastures and hay

meadows in Colorado such as the Western Colorado Research Center (WCRC) in Fruita, the Orchard Ranch at Harts Basin in Eckert, and Banner Ranch in Olathe. These fields support a mix of grass pastures, alfalfa, sainfoin, and grasses, providing a practical setting to test extreme pixel selection methods across diverse environments. Additionally, integration of ancillary data from ground-based sensors and weather stations is underway to refine extreme pixel identification and improve ET estimation accuracy.

## Understanding irrigation expansion in traditionally rainfed areas through Earth observations and machine learning

**Jillian M. Deines**

Pacific Northwest National Laboratory- Earth Systems Predictability and Resiliency Group

Irrigation boosts crop productivity and stabilizes yields amid weather variability, making it a vital tool in global food systems. In recent years, irrigation has been expanding in the traditionally rainfed and temperate US Corn Belt, a major global producer of maize and soybeans. Although still relatively rare on the landscape, it is important to quantify the drivers and effects of Corn Belt irrigation as farmers adapt to global change to better predict future changes to production, farm economics, and regional water hydrology. Unfortunately, agricultural statistics on irrigation are lagging in this traditionally rainfed region. Here, we analyze remotely sensed annual maps of field-level irrigation expansion across the US Corn Belt since 2000 to identify correlative factors in irrigation expansion. We then combine these with remotely sensed maps of annual field-level crop yields to quantify yield impacts, using a machine learning causal inference approach to isolate heterogeneous treatment effects. We conclude that substantial irrigation expansion is likely to continue in this region and that more study is needed to inform policies promoting sustainable growth in irrigation practices.

## Physics-informed Machine Learning and Water Balance Approach to Estimate Groundwater Use for the Western United States

**Md Fahim Hasan**

Colorado State University- Civil and Environmental Engineering

The Western United States (Western US) contains some of the most heavily pumped aquifers in the country. A significant portion of the groundwater pumped are used for irrigation. Yet, the current capacity for groundwater monitoring is insufficient, with good-quality pumping records available in only a few states. Previous studies have leveraged these datasets to develop data-driven approaches to estimate groundwater pumping for respective states, but these approaches lack transferability to regions where in-situ records are limited. To fill this gap, evapotranspiration-based consumptive water use estimates, provided by OpenET, offers a way to monitor water consumption across the Western US. However, distinguishing precipitation vs. irrigation-sourced consumptive use remains a challenge. In this study, we address this challenge by implementing a satellite data-driven and physics-informed effective precipitation method for the Western US. Effective precipitation, defined as the fraction of precipitation that supplements irrigation, can be used to estimate consumptive use of irrigation water as ET less effective precipitation. Our machine learning model uses gridded precipitation, weather, and land use products as input variables and generates high-resolution (~2 km) long-term (2000-2020) effective precipitation estimates over the irrigated croplands of Western US. In the next step, these estimates,

along with surface water irrigation estimates from the U.S. Geological Survey, are applied in a water balance equation to measure consumptive groundwater use. We convert the consumptive groundwater use estimates into groundwater withdrawal using irrigation efficiency factors over multiple basins and compare with in-situ records, resulting in reasonable agreement that validates our effective precipitation and consumptive groundwater use estimates. Thus, our study offers a step forward toward producing historic groundwater pumping estimates for the entire region.

## Estimating Monthly Groundwater Withdrawals from Irrigation Wells in Southwest Utah Using Remote Sensing Data

**Soheil Nozari**

Colorado State University- Civil and Environmental Engineering

Irrigated agriculture in semi-arid southwest Utah has been sustained at the cost of significant groundwater storage loss in basin-fill aquifers, threatening rural community livelihoods. To address this issue, both process-based and data-driven groundwater models can be used to inform effective groundwater management strategies. The reliability of these models depends heavily on the accuracy of historical groundwater extraction data from irrigation wells, which are often unavailable in the western U.S., including southwest Utah. As a result, estimates of groundwater diversion data with fine spatiotemporal resolution are critical for constructing reliable groundwater models. In this study, we introduce a method for downscaling regional groundwater withdrawal estimates across space and time using satellite-based remote sensing data. Specifically, we use the IrrMapper, LANID, and OpenET datasets to compute well-level monthly pumping from irrigation wells based on consumptive water use. We apply this method to the three subregions of Beryl-Enterprise, Cedar City Valley, and Parowan Valley in southwest Utah. A comparison of the results with USGS pumping estimates derived from power consumption records shows a reasonable match between the downscaled pumping data and the USGS estimates, particularly for modeling purposes.

## Daily Aerodynamic Surface Temperature Characterization over drip-irrigated Maize from Multispectral Remote Sensing, Eddy Covariance, and Ground Stations

**Manish Giri**

Colorado State University- Civil and Environmental Engineering

Accurate estimation of surface energy fluxes is fundamental for understanding land-atmosphere interactions and improving irrigation management strategies. Aerodynamic surface temperature is used in determining the sensible heat flux (H) dynamics, which is crucial in the accurate determination of the latent heat flux (LE) or evapotranspiration (ET) to improve crop water management. This study estimates the aerodynamic surface temperature ( $T_o$ , °C) in a drip-irrigated corn field (4.2 ha of full and deficit irrigation) at the Limited Irrigation Research Farm (LIRF), near Greeley, Colorado. Land surface energy balance principles are applied, incorporating field data from fixed stations, including infrared thermometry (IRT), net radiation ( $R_n$ ), soil heat flux ( $G$ ), and eddy covariance (EC) based heat fluxes measurements. Other measurements include proximal remote sensing using a Multispectral Radiometer (MSR5), an Unmanned Aerial System's (UAS) surface thermal and reflectance imagery, and mini-satellite (mSat) multispectral imagery from Planet Labs. The mSat data were used for distributed thermal

emissivity calculations and for spatial extrapolation of point data. Measured H and LE were obtained from two EC stations, while Rn and G were measured at separate fixed stations. Results indicate that  $T_o$  varies systematically with irrigation levels, with higher temperature differences between  $T_o$  and air temperature ( $T_a$ , °C) associated with increased H and reduced ET, reflecting differences in surface moisture availability. The integration of multi-source remote sensing and energy balance modeling improves thermal characterization by incorporating spatial variations, supporting irrigation optimization and crop stress monitoring.

## Satellite Determination of Sub Field Water Management Zones for Irrigated Agriculture

**Rahel Pommerenke**

Colorado State University- Civil and Environmental Engineering

Development of irrigated lands in the Western U.S. occurred in a period of long-term, uncharacteristically wet conditions, resulting in over-allocation of water supplies. Multi-year droughts, reduced surface water supplies, and depleted groundwater supplies across the U.S. have exposed vulnerabilities in the water sector, necessitating more precise irrigation strategies. Management zones (MZs)—subdividing fields based on physical characteristics—offer a useful solution for optimizing irrigation. Methods for delineating MZs often require significant data inputs such as dense soil or yield measurements. However, data collected using remote sensing can potentially be used to inform zone delineation.

This study aims to (1) develop a clustering framework that utilizes remote sensing data as inputs at a high spatial resolution (10 – 30 m) across multiple fields with different crop types and management processes, (2) identify physical characteristics driving clustering and determine essential input data, and (3) assess how much historical data is needed to establish effective MZs. Clustering is performed on topographic attributes from Light Detection and Ranging data, evapotranspiration estimates from OpenET, and vegetation indices (VIs) from multi-spectral satellite imagery using principal component analysis and fuzzy c-means. To enable comparison across different fields, only irrigated lands are included, and VIs are normalized by crop type, resulting in an irrigated, crop-normalized index for each input VI. This methodology is tested in two arid, irrigated, agricultural regions—Gem Valley, Idaho and San Luis Valley, Colorado. Preliminary results show relationships between cluster locations and physical field characteristics & in situ soil moisture information in Gem Valley. The framework offers a scalable and adaptable tool for growers, policy makers, and researchers working to enhance water efficiency in agriculture.

## Using Remote Sensing to Map Soil Salinity over Irrigated fields in the South Platte River Basin of Colorado

**Kieri Karpa**

Colorado State University- Civil and Environmental Engineering

Like many regions of the world, Colorado's South Platte River Basin (SPRB) is experiencing increased soil and water salinity, which can lead to reduced crop yields. Therefore, there is a need to develop remote sensing (RS) models to monitor salinity throughout the SPRB. To obtain soil salinity maps, existing

models were applied and an attempt to develop a local salinity model was pursued. Approximately 20 years of RS data from Landsat 5, 7, 8, and 9 satellites and 5 years of data from Planet Labs's mini-Satellites constellation were used. Further, field surveys of soil salinity (soil saturation extract electrical conductivity or ECe, dS/m) were obtained with an electromagnetic induction device and calibrated with soil samples. Measured ECe values were used to evaluate the accuracy of existing models and to develop a new approach. Only data from the crop growing season (March – October) were included in the study. In addition to weather station data, the normalized differential vegetation index, crop response to salinity index, and crop water stress index were used as explanatory variables in the ECe mapping efforts. Results indicate that the existing ECe models did not perform well under the conditions encountered in the SPRB. The accuracy of the local modeling of ECe using the Planet Labs data are presented and discussed.

### A Greenhouse Experiment to determine Salinity and Drought effects on Maize using Multi- and Hyper-Spectral Remote Sensing Data

**Muhammad Fawad**

Colorado State University- Civil and Environmental Engineering

Human-induced salinization affects approximately 20% of global croplands and 30% of irrigated lands (~1 billion hectares), with an annual increase of 10%. Regions like Colorado's South Platte River Basin (SPRB), similar to other intensively irrigated stream-aquifer systems, are experiencing escalating soil and water salinity, reducing crop yields. A controlled greenhouse experiment is being conducted, to evaluate maize responses to salinity and drought stress using spectral reflectance and thermal data from maize leaves. The data will be used to develop a remote sensing model for mapping salinity in the SPRB. The experiment consists of two maize varieties, Dekalb 51-91 (non-drought tolerant) and Pioneer 487Q (drought tolerant), five salinity levels (1–10 dS/m), two irrigation treatments (full and deficit), and five replicates. Soil saturated paste extract electrical conductivity (ECe, dS/m), pH, and leachate volume and salinity (ECw, dS/m) are monitored. Plant spectral responses are assessed using hyperspectral cameras, multispectral reflectance and thermal sensors, and spectroradiometers. A deep-learning-based multi-modality remote sensing framework will be developed to analyze the relative contribution of salinity and drought stress on maize. The measured soil ECe values will be used both in the salinity mapping algorithms and also to evaluate the performance of the developed ECe models. The experiment layout and preliminary data will be shown and discussed. This data-driven approach will provide actionable insights for predicting field-scale plant responses in SPRB, guiding farmers, scientists and policymakers in developing strategies to mitigate salinity-related challenges in irrigated agricultural systems.

## Snow Hydrology

### Experiments to assess the effect of dust and black carbon on snowmelt

**Juan Ignacio López-Moreno**

Instituto Pirenaico de Ecología



During the snow seasons of 2022/23, 2023/24 and 2024/25, we performed experiments to isolate the role of different concentrations of dust and black carbon on the evolution of snow temperature (ST), specific surface area (SSA), liquid water content (LWC), hyperspectral albedo, and ultimately the total melted water during the experiments. The results illustrate significant variations in the effects of LAIs on snow properties and melting, depending on their type and concentrations applied, initial snow conditions and incoming energy. Effective melting was observed only on days when the snow approached isothermal conditions; however, changes in ST, SSA, and LWC were noted even during the coldest periods of the season. Differences in snow properties and melting rates among various concentrations of D and BC were consistent across most days, allowing us to establish statistical relationships between LAI concentrations and melt rates. The presentation will also show our initial efforts to analyze how the impact of dust changes according to differences on mineralogy of the dust, and when experiments are prolonged for prolonged periods of time.

### Spatio-Temporal Variability Within Snowpack Properties

**Carson Bainbridge**

Colorado State University- Watershed Science

Snowpack properties vary over both space and time and are important to quantify for water resource management, understanding and modeling climate, estimating ecological health, and managing for winter recreation. We used data that were collected during the NASA Cold Land Processes Experiment (CLPX) in 2002 and 2003 in late February and late March. The data were obtained from the National Snow and Ice Data Center (NSIDC) for in the Rabbit Ears-Buffalo Pass Colorado intensive study area (ISA). Ground-based sampling measured snowpack density, depth, temperature and stratigraphy. Snowpack density was measured at 16 randomized locations over a one square kilometer area. The Rabbit Ears Pass dataset was analyzed spatially and temporally to illustrate patterns and trends within and amongst different land cover, terrain, and elevation. These variability patterns will inform future sampling snowpack work in high elevation areas, such as providing ground-truth.

### First order snow depth distribution scale breaks and its relation with topography observed with three remote-sensing techniques

**Jesús Revuelto**

Instituto Pirenaico de Ecología

Understanding snowpack evolution in heterogeneous mountain areas is highly challenging and requires suitable observation techniques to retrieve snow properties at various spatial scales. Once the reliability of these techniques is established, analyzing snowpack scaling properties helps identify the dominant processes controlling snow distribution and its temporal evolution. In this study, we examine scale breaks derived from variogram analysis of snow depth at the Izas Experimental Catchment (Spanish Pyrenees) and from 2019 to 2023 using 3 observation techniques: Terrestrial Laser Scanning (TLS-LiDAR, 12 acquisitions), Unmanned Aerial Vehicles (UAV-SfM, 20 acquisitions), and satellite stereo imagery (4 Pléiades acquisitions). First, we assess the consistency among these observational techniques. Then, we explore potential drivers of detected scale breaks through variogram analysis at scales up to 4000 m. The three techniques yielded similar results, demonstrating the use of variograms for evaluating

observation techniques. We found a strong agreement between the search distance used to compute the topographic position index (TPI), the first scale break length, and the mean distance between maximum snow accumulations (15 to 25 m), across the entire study domain and within manually delineated (sub)watersheds. Differences are linked to mean snow accumulation in the study area, with higher values corresponding to greater snow accumulation. These analyses will be extended to other study areas and applied to different simulation approaches (with and without data assimilation) to assess their ability to reproduce snow depth distribution in heterogeneous mountain environments.

## Mapping Snow Water Equivalent Using a Cosmic Ray Neutron Rover on Plowed/Paved Roads in the San Juan Mountains

**Christina Chow**

Snow water equivalent (SWE) is a key reservoir supplying agriculture and cities, particularly in the Western U.S. SWE is highly variable across watersheds and throughout the winter making it difficult to estimate. Cosmic Ray Neutron (CRN) rovers can potentially provide SWE data at a spatial scale that have not been previously available. A CRN rover operates by counting the neutrons within a specific energy range. These neutrons have been slowed by interacting with hydrogen, and most hydrogen in the environment occurs as water. Thus, the counts indicate a spatially weighted average of water within about a 200 m radius of the sensor. Because the counts are collected every minute, CRN rover can be mounted on a vehicle and used to map SWE across a large area. Stationary CRN sensors have been used to estimate SWE, but few studies have utilized this technology as a mobile rover on plowed/paved roads. The objective of this study is to test the capabilities and limitations of a CRN rover for mapping SWE around plowed/paved roads. The study area is in the San Juan Mountains on a 73 km highway between Ironton Park (2938 m elevation) and Purgatory ski area (2492 m elevation). The rover was driven at 40 km/h along the highway and parked at 10 field sites situated along the highway. Road and snowbank biases are corrected to produce SWE values of the undisturbed snow. At the field sites, snow cores and snow depth measurements were used to estimate SWE. A comparison of field estimates and corrected rover estimates was then performed to quantify the accuracy of the CRN method.

## Effects of Plowing on Snowpack Density

**Evan Gouldey**

Colorado State University- Civil and Environmental Engineering

Snowpack is a critical source of water for communities in the West, but snowpack can vary substantially in space and time. Thus, accurate estimation of snow water equivalent (SWE) across watersheds for water resources planning remains difficult. Cosmic ray neutron rovers have been proposed as a method for mapping SWE. These sensors can be mounted on vehicles and used to estimate the snowpack within a radius of about 200 m around the vehicle. However, the measurements of such sensors are affected by snow plowing on the roads. As such, the impacts of plowing on the snowpack need to be understood so that more accurate estimates of the undisturbed SWE can be obtained. This study aimed to quantify the effects of snow plowing and augering on the shape, size, density, and SWE of snowbanks and how they vary throughout the winter season. A location on Highway 14 near Cameron Pass in northern Colorado was selected for observation. These quantities were assessed by extracting snow cores and

measuring their mass and the snow depth. At specified intervals away from the snowbank, three snow core samples were extracted as replicates, and a fourth was taken if one core undersampled the snowpack, i.e., was too light. The density and SWE of the snowbank increased up to the peak of the snowbank. As measurements moved farther out from the snowbank, the density and SWE tapered off. Finally, once measurements were taken in the undisturbed area, the density and SWE became almost constant. It was found that the maximum SWE and density at the top of the snowbank was approximately double the SWE and density of the undisturbed. The snowpack has varied as expected with the snowpack becoming denser as the snow melted throughout the season.

## Snow Aerodynamic Roughness Length across Varying Surfaces

**Steven Fassnacht**

Colorado State University- ESS Watershed Science

When snow is present at a location on the earth, the snow surface is the interface between atmosphere and the earth. This controls the energy balance of the earth and the snowpack. Most earth system, and even snow, models consider the roughness of the snow surface to be uniform. We performed a series of experiments in the Cryosphere Environmental Simulator (CES) in Shinjo Japan to compute the anemometric-based aerodynamic roughness length ( $z_0$ ). In the CES cold room wind tunnel, we measured the wind profile to compute  $z_0$  for a used a variety of snow surface configurations that we created. These surfaces included i) flat, old snow, ii) regularly undulating (sinusoidal) snow dunes, iii) snow drifts created from the snow dunes, iv) solid obstacles, and v) fresh snow on top of the various configurations. Surprisingly,  $z_0$  varied less than anticipated, but varied nonetheless illustrated that the snow surface is dynamic and should be modeled as such. We are currently assessing the magnitude of the vertical wind component and possible wind pumping through the fresh snow surface.

## Wildfires and Watersheds

### Erosion and Sediment Delivery Over Time in Two Industrial Forested Watersheds in Northwestern California: What is the Role of the Road Network?

**Eric Clark**

Colorado State University- Ecosystem Science and Sustainability

Reducing road erosion and sediment delivery in intensively-managed forested watersheds is a major regulatory concern due to potential adverse effects on water quality, stream habitat, and threatened salmonids. The objectives of this study are to: 1) quantify changes in road networks in two watersheds; 2) model changes in sediment production and delivery over a roughly 20-year time period; and 3) compare modeled road sediment values with measured suspended sediment loads and long-term erosion rates.

The two study areas in northwestern California are the 107 km<sup>2</sup> upper Elk River watershed and two ~14 km<sup>2</sup> tributaries in the nearby Little River watershed; both are steep, redwood-dominated, and highly productive. GIS and other data were compiled to quantify changes in road lengths, types, usage,

proximity to streams, and road-stream crossings. Road sediment production and delivery was modeled using GRAIP-Lite (<https://www.fs.fed.us/GRAIP/>).

From 2002 to 2020 active road length in the Elk River watershed decreased by only 7%, but 82 km of mostly dirt roads were decommissioned, road-stream crossings decreased by nearly one third, and the percentage of active roads within 30 m of a stream dropped from 30% to 24%. In the two Little River tributaries active road length decreased by 16% from 1998-2018, 32 km of roads were decommissioned, road-stream crossings decreased by 30%, and active roads within 30 m of a stream dropped from 19% to 17%. These changes plus extensive rocking reduced the predicted road sediment delivery 23% in the Elk River watershed and 71% in the Little River watersheds. Predicted road sediment delivery at the end of our study periods was less than 3% of the measured suspended sediment yield in the Elk River watershed and only 2% of the long-term erosion rate. In the Little River watersheds natural erosion rates are less and predicted road sediment delivery was 16% of the measured suspended sediment yield and just under 10% of the long-term erosion rate. Our results show substantial reductions in road sediment production and delivery over the study periods, and that roads generate a relatively small proportion of current and long-term sediment yields.

### Ash in the tap: the effect of increasing wildfire risk on the cost of clean drinking water

**Joey Blumberg**

US Forest Service- Human Dimensions of Natural Resources

This study quantifies the economics costs of increasing wildfire risk on public drinking water systems in the United States (US). Using a process-based erosion model (Disturbed WEPP), we simulate wildfire-driven sediment yield at the HUC12 subwatershed scale, integrating probabilistic wildfire risk from the Wildfire Risk Simulation Project (FSim), along with land cover, soil type, slope gradient, and climate data. Sediment estimates for 2011 and 2020 conditions are routed to public water intakes using the EPA's Safe Drinking Water Information System and a hydrologic connectivity model. Changes in sediment loads are then translated into water treatment cost increases based on established sediment-cost elasticities. Results indicate that rising wildfire risk over the past decade has increased annual water treatment costs by over \$100 million, with impacts concentrated in the western US. These findings highlight the vulnerability of drinking water supplies to wildfire-driven sedimentation and reinforce the importance of proactive landscape management in mitigating economic and public health risks.

### Effectiveness of mulching under varying rainfall intensity

**Phoebe White**

Colorado State University- Civil and Environmental Engineering

Wildfires alter the runoff and erosion potential of watersheds through the removal of vegetation and alteration of soil physical and chemical properties. Changes to the soil composition and the vegetative cover removal can result in debris flows from relatively common storms and flooding that exceeds historic records prior to the burn. Various soil and water conservation practices have been used to attempt to mitigate these post-fire hazards. Field and lab experiments have shown that mulching can be effective at specific application rates. However, results vary significantly based on environmental factors, many of which have not been thoroughly tested. The significant cost of mulching over large burn areas has driven continued interest in developing a fully quantitative approach to planning mulching

operations. One of the most critical yet underexplored factors is rainfall. Field studies typically assess the influence of precipitation using long-term accumulations, while laboratory rainfall simulations often rely on uniform intensities. Non-uniform rainfall profiles result in significantly higher runoff and erosion rates compared to uniform intensities. In this study, we use a rainfall simulator capable of generating multiple intensities to create time varying intensity profiles similar to storms observed by gages in the mountains of Colorado. We examine the effects of time-varying rainfall intensity on both mulched and bare soil on a steeply sloped flume. Preliminary results indicate a significant difference in runoff ratio and sediment yield between uniform and time-varying rainfall intensities for both surface conditions.

### Precipitation Intensities Triggering Post-Wildfire Debris Flows Across 3 Burn Scars

**Steven Griffin**

Colorado State University- Civil and Environmental Engineering

Convective afternoon summer storms, often powered by monsoonal weather patterns, can produce storms over post-wildfire burn scars of short duration but of sufficient intensity to trigger debris flows. These flows often occur down steep side canyons and tributaries to the receiving waters, carrying significant sediment loading and woody material. The magnitude of these triggering intensities remains an open question, dependent upon multiple site-specific variables – thus, confirmed debris flow events tied to a given rainfall event are of immense value. Throughout the spring, summer, and early autumn of 2024, we tracked precipitation amounts and intensities in portions of the Cameron Peak (CO), East Troublesome (CO), and Hayden (ID) Fire burn scars using both tipping buckets (HOB0) and data provided by external agencies. We additionally recorded data via water level loggers (U20, HOB0) and timelapse cameras to pinpoint the specific instances of debris flow on multiple burned watersheds. In this presentation, we aim to provide the precipitation intensities which triggered individual slides, as well as those instances where a slide did not occur despite significant precipitation intensities. Our hope is that this information will be useful for other teams and scientists involved in post-wildfire recovery studies as well as agencies such as the National Weather Service, which provide hazard forecasting data to local communities and State/Federal agencies.

### Grid Size Effects for Hydrologic Modeling in Support of Post-Wildfire Analyses

**M. Robert Delcau and Peter Nelson**

Colorado State University- Civil and Environmental Engineering

Wildfires are commonly followed by elevated runoff and erosion rates, posing potential hazard to downstream water users and infrastructure. Physically based distributed hydrological models have the potential to be useful tools in predicting the magnitude of post-fire changes and therefore inform post-fire management decisions and restoration projects. The accuracy of model predictions will depend on the size of the grid cells used in the model.

Here we examine spatial variability, process representation, and computational time to select appropriate grid cell sizes to use for process based distributed hydrologic modeling in mountain regions. GSSHA from the US Army Corps of Engineers is used in conjunction with the GIS package WMS to conduct simulations in Kyle Gulch, a tributary of Bennett Creek of the Poudre River Basin in the

Roosevelt National Forest in Colorado which burned in the 2020 Cameron Peak Fire and where we have been monitoring flow, precipitation and collecting UAV imagery and topography since 2021.

Eight grid resolutions (30m, 25m, 20m, 15m, 10m, 5m, 3m, and 2m) were generated and analyzed. Sensitivity analyses were performed by simulating each grid in GSSHA with a uniform surface roughness of 0.05. NOAA Atlas 14 provided synthetic precipitation for 24-hour Type II Design Storm for six recurrence intervals. Initial simulations revealed persistent ponding across all grids, preventing complete water delivery to the basin outlet. Therefore, a secondary program adjusted grid elevations to facilitate drainage. Additionally, a time-based analysis determined that, after 14 days, residual water volumes were below  $1\text{m}^3$ , leading to the adoption of 14-day simulations.

Results indicated that smaller grid sizes yielded higher peak flows at the outlet due to reduced per-cell water retention, thereby enhancing surface water delivery. Conversely, coarser grids failed to capture critical topographic variability. Moreover, decreasing grid size significantly increased computational demands, with runtimes varying from minutes to hours depending on watershed scale. Consequently, resolution choices may be constrained by project budgets and computational resources, impacting hazard assessment accuracy. Finally, for wildfire-affected landscapes, such as post-Cameron Peak Fire terrain, fine-resolution grids are essential for accurately predicting erosion rates, mitigating the risk of underestimating downstream hazards

### Modeling the impacts of wildfire, forest recovery regimes, and climate change on hydrologic partitioning in a Colorado headwater basin using a fully integrated hydrologic model and simulated fire parameterizations

**Carly Bonwell**

Colorado School of Mines- Hydrologic Sciences and Engineering

As temperature and precipitation regimes change, the duration, size, severity, and frequency of fire is increasing in the Western US, putting watersheds at risk of altered hydrologic functioning. The San Miguel Basin (SMB), a snowmelt-dominated and heavily forested watershed located in southwestern Colorado, is one such headwater tributary of the Colorado River at risk of wildfire occurring in its montane ecosystems. Wildfire greatly impacts watershed function by altering runoff generation processes and vegetation cover in the years, and often decades, after fire. While the effects of fire on soil properties tend to be restored within the first decade post-fire, forest recovery often takes much longer. Moreover, climate-induced stressors can decrease the ability of a forest to regenerate and lead to new steady state ecosystems in fire-impacted landscapes. With these threats to water supplies, a robust predictive framework is needed to inform climate and fire-resilient watershed management. In this study, a fully integrated and physically based hydrologic model (MIKE SHE) was developed for a relatively undisturbed sub-basin (Beaver Creek) within the SMB to better understand watershed dynamics following fire and changing climate. With the use of FlamMap, we simulated a probable fire scenario within the basin and used the fire behavior model's outputs to inform fire parameterization within the MIKE SHE model. We utilize a novel approach to holistically calibrate and assess impacts to the entire water budget and aims to capture complex spatial and temporal variations in soil, overland flow, and vegetation dynamics that occur following wildfire. Findings will help stakeholders within the SMB build a climate and disturbance-resilient water management plan and, more broadly, provide

valuable wildfire parameterization methods transferable to other hydrologic modeling and watershed management efforts.

## Leveraging LSTM Networks to Capture Post-Wildfire Streamflow Changes in Watersheds

**Cooper Moon**

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Forest disturbances, such as wildfire, insect outbreaks, and disease-induced mortality, are increasingly affecting large parts of the United States. Wildfires, in particular, are a unique form of disturbance due to their sudden onset and unpredictable nature. Their hydrologic impacts—such as reduced infiltration, increased runoff, and elevated sediment transport—are immediate but can also persist for extended periods, leading to abrupt and long-lasting effects on watersheds and surrounding communities. Streamflow simulations after wildfire are crucial for mitigating flood risks, managing water resources, and protecting downstream communities and ecosystems. Despite advances in research and operational models, accurately predicting post-fire streamflow remains a challenge. Existing literature shows the direction and magnitude of hydrologic changes depend on the extent and severity of the fire, as well as the geophysics of the watershed system. Use of machine learning (ML) techniques in hydrology has significantly enhanced streamflow simulation capabilities. ML models excel at extracting and utilizing information from complex, dynamic systems, often identifying patterns that traditional hydrologic models overlook. For this work, we utilize long-short term memory (LSTM) networks to simulate post-wildfire streamflow. LSTMs are a type of recurrent neural network (RNN) specifically designed to retain and utilize long-term information, making them well-suited for modeling streamflow, as it uses past hydrologic and climatic conditions. Our goal is to identify the primary controls on post-wildfire flow—such as watershed attributes or climate forcings—and determine how they differ from those governing pre-wildfire flow. Here, we assess the influence of training data and physical watershed attributes by comparing two LSTM models: one trained on pre-fire streamflow and climate data, and another trained on post-fire data. Preliminary results show that the model trained on post-fire observations outperforms the pre-fire-trained model, despite being trained on half the amount of data (5 yrs post-fire vs. 10 yrs pre-fire). Findings suggest that wildfire-induced changes to watershed characteristics render pre-fire data less relevant for accurate post-fire streamflow simulation. Leveraging LSTMs could improve watershed-scale streamflow simulation following wildfire events and provide insights that enhance parameterization of traditional hydrologic models.

## Post-Fire Channelized Erosion: Investigating Drivers Using High-Resolution Terrain Analysis

**Alex Thornton-Dunwoody**

Colorado State University- Civil and Environmental Engineering

Wildfires drive significant soil erosion and land degradation by removing vegetation and organic litter that typically buffer rainfall impacts. Without this protective cover, bare soil is exposed to direct raindrop impact, disrupting soil aggregates and accelerating particle detachment. Moderate- to high-severity fires further alter soil structure by combusting organic matter and breaking down mineral bonds, reducing infiltration and creating water-repellent layers or even impermeable crusts. These changes promote rapid runoff, increasing the risk of channelized erosion that can degrade water quality

and threaten downstream communities—especially as wildfire frequency and intensity rise with shifting climatic patterns.

This study examines the drivers of channelized erosion in post-fire landscapes using high-resolution terrain analysis. We co-registered drone-based structure-from-motion (SfM) digital surface models with LIDAR-derived digital elevation models to generate fine resolution digital elevation models of difference (DoDs). Vegetation masking was applied to isolate geomorphic changes in six watersheds within the East Troublesome burn scar and six within the Cameron Peak burn scar. Using generalized linear mixed-effects models in the SSN2 R package, we aim to identify the primary controls on channelized erosion across these sites. Preliminary results are under analysis and are expected to provide new insights into how wildfire severity influences post-fire erosional processes, informing risk mitigation strategies for vulnerable downstream areas.

### Updating landcover classifications in the iSnoval model to improve water forecasting in post-fire persistent snow zones

**Helen Flynn**

Colorado State University- Geosciences

Snow is an essential water resource in the western US, accounting for over half of streamflow. High-elevation forests in the mountain west act as cold-season snow reservoirs which then melt out in the spring providing water for municipal, recreational, and agricultural uses. However, recent trends indicate critical changes to snowpack dynamics including less accumulation and earlier meltout. Not only does this complicate the management of snow as a water resource, but it also has ecological implications. Earlier meltout is associated with late growing season aridity, increasing risk of high-intensity wildfire. Wildfire prevalence and intensity has increased in the western US in recent years due to decades of fire suppression. This has implications for decreases in forest resilience and potential shifts from forest to non-forest landscapes. The locations of these fires have also begun to shift upwards in elevation into the persistent snow zone, indicating the possibility of long-term forest declines in a critical snow zone. Wildfire has been found to impact snow dynamics in several key ways: decreasing snow albedo and canopy interception, and increasing solar radiation and accumulation. A variety of snow modeling techniques have been used for accurate water forecasting in the western US. The iSnoval model, which derives landcover classifications from the 2016 version of LandFire, has been found to be an effective tool for operational water forecasting. This study analyzes the snow model outputs after running iSnoval using an updated (2023) version of the LandFire dataset with the same climate forcings. These results will potentially improve the accuracy of the model in high-elevation post-fire landscapes.

### Modelling Post-fire Effects on Snowpack Across the Western US

**William Keenan**

Colorado State University- ESS Watershed Science

Recent studies indicate that wildfire is increasingly affecting the high elevation forests of the Western US where the majority of the water supply originates as snow. The burn scars left behind change the energy balance of the watersheds they impact by altering the rate at which snow accumulates in the winter and melts in the spring. Knowing where and when snowpack may increase, decrease, or stay the

same after a fire is crucial for water supply managers in both burned watersheds and those at risk for future wildfires. Studies that have examined post-wildfire effects on snowpack have found varying levels of response depending on the eco-region and the sensors used to measure snow metrics. However, few studies have attempted to quantify snowpack risk to wildfire across the Western US based on snow zone, topography, climate, and burn severity. This study uses a combination of remotely sensed snow cover from MODIS and in-situ data from SNOTEL sites to model the effect of wildfire on snow metrics including snow disappearance date (SDD), peak SWE, and snow-water-storage (SWS). Random forest models trained on pre-fire data indicate that wildfire promotes earlier SNOTEL derived snow disappearance by 10 days on average, and preliminary results show this effect is relatively uniform across the Western US. SWS shows an average post-fire decrease of 3 cubic meter days (m<sup>3</sup> d) but may be disproportionately impacted in the early snow-zone. Additionally, the models generated can be extrapolated to areas not monitored by SNOTEL sites and used to assess how much a watershed's snowpack would be impacted by wildfire. Our results demonstrate an improvement in understanding around how snow hydrology changes after wildfire.

## Thank you and Acknowledgements

We would like to thank the organizing and planning committees for the work and dedication to a successful 45<sup>th</sup> Hydrology Days.

Morgan Stout  
Mazdak Arabi  
Ryan Bailey  
Ryan Smith  
Jeff Niemann  
Steven Fassnacht  
Rahel Pommerenke

Sarah Millonig  
Antonio Alves Meira Neto  
Frances Davenport  
Tim Green  
Peter Nelson  
Sybil Sharvelle  
Chuck Shackelford