43rd Annual AGU Hydrology Days

March 21-22, 2023

ONE WATER SOLUTIONS INSTITUTE

COLORADO STATE UNIVERSITY

hydrologydays.colostate.edu

SCHEDULE: At-a-Glance

Tuesday March 21, 2023

TIME	LSC Ballroom D	LSC Room #322	LSC Room #324	LSC Room #300
8:00 - 9:00 am	*Registration*			
9:00am - 10:30 am		Hydrologic Systems Chair: Tyler Wible	Wildfires & Watersheds Chair: Ryan Morrison	Ecohydrology, Water, and Plants Chair: Tim Green
10:30 - 10:45 am	*Break*	*Break*	*Break*	*Break*
10:45 - 12:00pm		Hydrologic Systems Chair: Tyler Wible	Wildfires & Watersheds Chair: Ryan Morrison	Urban Water Systems Chair: Sybil Sharvelle
12:00 - 1:00 pm	*Lunch*			
1:00 - 2:00pm	**Borland Hydrology Keynote - Hoshin Gupta**			
2:15 - 3:15pm	*Student Showcase*			
3:15 - 3:30pm	*Break*			
3:30 - 4:30pm	*Student Showcase*			
4:30 - 6:00pm	**Reception & HD Award Presentation: Mary C. Hill**			

Wednesday March 22, 2023

TIME	LSC Ballroom D	LSC Room #322	LSC Room #300
8:00 - 9:00 am	*Registration*		
9:00am - 10:30 am		Climate & Meteorology Chair: Steven Fassnacht	Memorial Session Chairs: Vini Floris & Cinizia Miracapillo
10:30 - 10:45 am	*Break*	*Break*	*Break*
10:45 - 12:00pm		Climate & Meteorology Chair: Steven Fassnacht	Memorial Session Chairs: Vini Floris & Cinizia Miracapillo
12:00 - 1:00 pm	*Lunch*		
1:00 - 2:00pm	**Borland Hydraulics Keynote - Fred Ogden**		
2:15 - 3:15pm		Geoscience & Groundwater Chair: Ryan Bailey	Statistical/Stochastic Hydrology Chair: Mahshid Ghanbari
3:15 - 3:30pm	*Break*	*Break*	*Break*
3:30 - 4:30pm		Geoscience & Groundwater Chair: Ryan Bailey	Statistical/Stochastic Hydrology Chair: Mahshid Ghanbari

MEETING INFORMATION

Location

The conference will be held on **level 3** of the CSU Lory Student Center. Technical sessions will take place in rooms 322, 324 and 300 (see map). The Keynotes, lunches, and Student Showcase take place in Grand Ballroom D.

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!

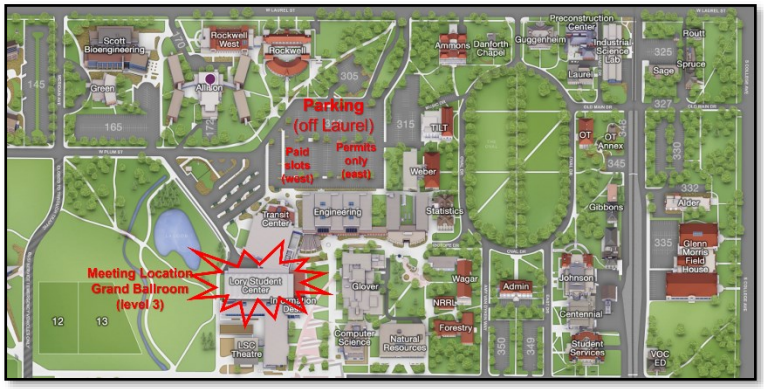
Parking Permits

- **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



PRESENTATION SCHEDULE

Tuesday March 21, 2022

Location	Session	Time	Presenter	Title
LSC Room #300	Ecohydrology, Water, and Plants	9:00 AM	Sean Gleason	Coordinated Crop Trait Assemblages: How Process-Based Modeling, Experimental Results, and Physiological Theory Can Help Us Design Better Plants
LSC Room #300	Ecohydrology, Water, and Plants	9:15 AM	Edson Costa Filho	Spatiotemporal Modeling of Maize Light Extinction Coefficient Using Sentinel-2 Multispectral Data
LSC Room #300	Ecohydrology, Water, and Plants	9:30 AM	Zaid Al-Majali	Preliminary Evaluation of aerial- and Spaceborne-based remote sensing estimation of Crop Biophysical Characteristics and Implications on Crop Water Use Estimates
LSC Room #300	Ecohydrology, Water, and Plants	9:45 AM	Mia Morones	A Broad Analysis of Total Suspended Solids in Colorado Agricultural Runoff: Insights and Trends
LSC Room #300	Ecohydrology, Water, and Plants	10:00 AM	Mahshid Mohammad Zadeh	Beyond Flood Control: Evaluating the Environmental, Economic, and Social Co-benefits of Stormwater Management Practices in Philadelphia
LSC Room #322	Hydrologic Systems	9:00 AM	Hoyong Lee	Case Study: On Flood Level Reduction by Nature-based Solutions in Hwang River, South Korea
LSC Room #322	Hydrologic Systems	9:15 AM	Reilly Miller	Floodplain analysis of extreme storm events and the challenges related to military installation floodplain modeling.
LSC Room #322	Hydrologic Systems	9:30 AM	Tyler Wible	Assessment of species specific aquatic and riparian habitats under a range of possible future hydrologic scenarios on the Verde River using the Riverine Environmental Flow Decision Support System (REFDSS)
LSC Room #322	Hydrologic Systems	9:45 AM	Salam Abbas	Implications of water management representations for watershed hydrologic modeling in Lower Arkansas River Basin
LSC Room #322	Hydrologic Systems	10:00 AM	Dave Barnard	Gridded versus station datasets yield divergent hydrological responses when modeling streamflow in a Colorado watershed
LSC Room #322	Hydrologic Systems	10:15 AM	Andrew Pineda	Cache la Poudre River Natural Flows: 1884 – 2022 Trends, Predictability, Management

LSC Room #322	Hydrologic Systems	10:45 AM	Matthew Bullock	Prediction of Strength of Surface Soils Using Temporally and Spatially Varying Landscape Attributes
LSC Room #322	Hydrologic Systems	11:00 AM	Faisal Alsultan	Effects of crest location and spillway-abutment shape on flow uniformity over a spillway crest
LSC Room #322	Hydrologic Systems	11:15 AM	Joseph Cook	Evaluating demand management at the field scale though direct and indirect measurements of conserved consumptive use
LSC Room #300	Urban Water Systems	10:45 AM	Donya Dezfooli	An Introduction to a Comprehensive Self-Assessment Framework and Rating System for One Water Cities
LSC Room #300	Urban Water Systems	11:00 AM	Josh Brekel	Streamlining Scheduling: How Python Transforms Water Balance Modeling and Evapotranspiration Estimation
LSC Room #300	Urban Water Systems	11:15 AM	Laura Supple	Participatory models of regenerative urban infrastructures as complex adaptive social-ecological-technological systems
LSC Room #300	Urban Water Systems	11:30 AM	Jumana Aljafari	Estimation of Stormwater Microbial Contamination to Help Develop Guidance for Stormwater Capture and Use Projects
LSC Room #324	Wildfires & Watersheds	9:00 AM	Sam Struthers	Cameron Peak Wildfire Riverine and Reservoir Water Quality Impacts
LSC Room #324	Wildfires & Watersheds	9:15 AM	Ryan Wells	Estimating changes in water yield and tracking hydrologic recovery in multiple watersheds affected by wildfire
LSC Room #324	Wildfires & Watersheds	9:30 AM	Marin MacDonald	High Elevation Post-Fire Landscapes on Snow Melt Trends in Seasonal and Transitional Snow Zones
LSC Room #324	Wildfires & Watersheds	9:45 AM	Megan Sears	Post-fire stream response to rainfall at Bennett Creek tributaries
LSC Room #324	Wildfires & Watersheds	10:00 AM	Jack Derbique	Post Wildfire Flow Resistance: Remote Sensed Data Comparison for 2D Hydraulic Model Calibration in Mountain Streams
LSC Room #324	Wildfires & Watersheds	10:15 AM	Nicholas Christensen	Importance of River Beads in Attenuating Floods in Headwater Systems

LSC Room #324	Wildfires & Watersheds	10:45 AM	Randall Wade	Modeling the Effects of Post-wildfire Rehabilitation Treatments on Hydrology and Nutrient Cycling in Experimental Watersheds in Colorado
LSC Room #324	Wildfires & Watersheds	11:00 AM	Sarah Dunn	Dammed ponds! Post-fire sediment dynamics in beaver ponds and their contributions to watershed resilience.
LSC Room #324	Wildfires & Watersheds	11:15 AM	Clint Carney	Recovery in the Post-Wildfire Environment: Policy Challenges and Opportunities
LSC Room #324	Wildfires & Watersheds	11:30 AM	Pinar Omur-Ozbek	When Fire Meets Water: Addressing Smoky Flavors in Tap Water Due to Wildfires in the United States
LSC Ballroom D	Showcase (A)	2:20 PM	Reid Maynard	Is Local Food More Sustainable? Comparing Local Food Production to Conventional Centralized Agriculture in the Contiguous United States Through Life Cycle Assessment
LSC Ballroom D	Showcase (A)	2:25 PM	Andrea Loudenback	Mad for Manure: How Precision Management of Nutrient Flows Can Mitigate Environmental Impacts of Manuresheds
LSC Ballroom D	Showcase (A)	2:30 PM	Curtis Kline	GMO-Free Territories and the Defense of Traditional Seed Systems
LSC Ballroom D	Showcase (A)	2:35 PM	Karen Gupta	The Relationship Between Portable Toilets in Construction and Sustainability Metrics
LSC Ballroom D	Showcase (A)	2:40 PM	Laura Supple	Participatory models of regenerative urban infrastructures as complex adaptive social-ecological-technological systems
LSC Ballroom D	Showcase (A)	2:45 PM	Cibi Vishnu Chinnasamy	Urban Scaling Patterns in Municipal Water Uses
LSC Ballroom D	Showcase (A)	2:50 PM	Marin Wiltse	Comprehensive characterization of oil-field produced water treated by nanofiltration and reverse osmosis membranes for potential reuse in agriculture
LSC Ballroom D	Showcase (A)	2:55 PM	Lucas Roy	A Climate-Centered Analysis of Historical Australian Streamflow and Population Density From 1980-2019
LSC Ballroom D	Showcase (A)	3:00 PM	Dixie Poteet	Past, Present, and Potential Future Flows of a Non-Perennial Stream

LSC Ballroom D	Showcase (A)	3:05 PM	Joseph Bindner	Predicting Soil Texture Using 1-D Convolutional Neural Networks based on Field Hyperspectral Images
LSC Ballroom D	Showcase (B)	3:30 PM	Brianna Corsi	Morpho-dynamic Processes in the Bernalillo Reach of the Middle Rio Grande
LSC Ballroom D	Showcase (B)	3:35 PM	Tristen Anderson	Middle Rio Grande Montaño Reach: Morphodynamic Processes and Silvery Minnow Habitat
LSC Ballroom D	Showcase (B)	3:40 PM	Chelsey Radobenko	Middle Rio Grande River Hydraulic Modeling: A comparison between 1D and 2D hydraulic modeling and the impacts to quantifying Silvery Minnow Habitat in the Bernalillo Reach of the Middle Rio Grande River.
LSC Ballroom D	Showcase (B)	3:45 PM	Helen Flynn	A Spatiotemporal Analysis of the Correlation Between Snow Water Equivalent and Baseflow in Colorado
LSC Ballroom D	Showcase (B)	3:50 PM	Alexis Foster	A Social-Climatological Study of Snow and Winter Weather Perspectives
LSC Ballroom D	Showcase (B)	3:55 PM	Abdullah Al Fatta	Assessing Aquifer Properties and Groundwater Storage Change in the San Luis Valley, Colorado from In-Situ and InSAR Data
LSC Ballroom D	Showcase (B)	4:00 PM	Cavin Alderfer	Analyzing Trends in Groundwater Storage and in Salt and Nutrient Concentrations in Surface Water and Groundwater Bodies in the United States from 1920-2020
LSC Ballroom D	Showcase (B)	4:05 PM	Mickey Means-Brous	Geomorphic influences on salmonid recolonization in a Colorado post-fire environment
LSC Ballroom D	Showcase (B)	4:10 PM	Phoebe White	Evaluation of sub-hourly Quantitative Precipitation Estimates in Colorado's mountains using machine learning

Wednesday March 22, 2023

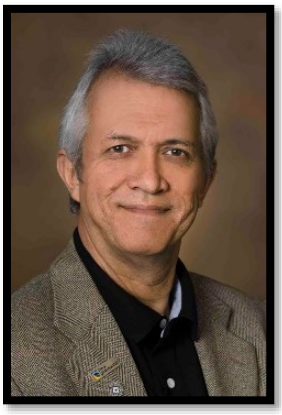
Location	Session	Time	Presenter	Title
LSC Room #322	Climate & Meteorology	9:00 AM	Kristie Davis	Water Year 2022 in Review
LSC Room #322	Climate & Meteorology	9:15 AM	Wangmo Ghalley	Streamflow alteration under hydropower dam operations and climate change projection: A case study in the Sesan River Basin, Lower Mekong Region
LSC Room #322	Climate & Meteorology	9:30 AM	Frances Davenport	HEC-HMS Gridded Temperature Index Snow Model for the Upper Indus River Basin in Pakistan
LSC Room #322	Climate & Meteorology	9:45 AM	Brian Steen	Increased Daily Temperature Variability in the Southern Rocky Mountains of Colorado
LSC Room #322	Climate & Meteorology	10:00 AM	Alexander Olsen-Mikitowicz	Shedding Light on Snow Accumulation: Considering Snowfall Topographic Resurfacing and Influence of Scale
LSC Room #322	Climate & Meteorology	10:15 AM	Randall Bonnell	Measuring Snow Mass from 12,000 m: Validating Airborne InSAR Measurements of Snow Water Equivalent at Cameron Pass, Colorado
LSC Room #322	Climate & Meteorology	10:45 AM	Helen Flynn	A Spatiotemporal Analysis of the Correlation Between Snow Water Equivalent and Baseflow in Colorado
LSC Room #322	Climate & Meteorology	11:00 AM	Steven Fassnacht	Diverging Aerodynamic Roughness over Varying Snow Surfaces
LSC Room #322	Climate & Meteorology	11:15 AM	Nolan Doesken	What came after the Flood? CoCoRaHS (the Community Collaborative Rain, Hail and Snow Network)
LSC Room #322	Geoscience & Groundwater	2:15 PM	Sayantan Majumdar	Integrating Remote Sensing and Machine Learning for High-Resolution Groundwater Use Estimation
LSC Room #322	Geoscience & Groundwater	2:30 PM	Joseph Bindner	Predicting Soil Texture Using 1-D Convolutional Neural Networks based on Field Hyperspectral Images
LSC Room #322	Geoscience & Groundwater	2:45 PM	Evan Schulz	Evaluating the Role of Floodplain Surface Water-Groundwater Interactions in SWAT+

LSC Room #322	Geoscience & Groundwater	3:00 PM	Shea Slonkosky	Baseflow Characteristics in a High Elevation Watershed with Wetland Contribution
LSC Room #322	Geoscience & Groundwater	3:30 PM	Isabella Ulate	Weathering in Rocky Mountain Alluvial Valleys
LSC Room #322	Geoscience & Groundwater	3:45 PM	Ibraheem Qurban	Simulating Nonpoint-Source Uranium Pollution in The Irrigated Stream-Aquifer System Along the Lower Reach of Colorado's Arkansas River Valley
LSC Room #300	Statistical/Stochastic Hydrology	2:15 PM	Samantha Fischer	Evaluating the Accuracy of Soil Moisture Downscaling for a Large Study Region in Northern Colorado
LSC Room #300	Statistical/Stochastic Hydrology	2:30 PM	Mahshid Ghanbari	Enhancing Community Resilience through Better Flood Hazard Communication: The Role of the Flood Potential Portal
LSC Room #300	Statistical/Stochastic Hydrology	2:45 PM	Joseph Cook	Analyzing mixed hydrographs using Rhodamine WT fluorescent tracer releases to separate native and imported irrigation flows.
LSC Room #300	Statistical/Stochastic Hydrology	3:00 PM	Hung Soo Kim	Measuring Nonlinear Dependence and Estimation of Delay Parameters for Attractor Reconstruction of Time Series
LSC Room #300	Statistical/Stochastic Hydrology	3:30 PM	Kyunghun Kim	On Estimation of Natural Disaster InterEvent Time Definition (NIETD) for Compound Natural Disaster Definition

KEYNOTE SPEAKERS

Borland Hydrology Award

Dr. Hoshin Vijai Gupta – Regents Professor of Hydrology and Atmospheric Sciences, University of Arizona



***Bio**: Hoshin Vijai Gupta is Regents Professor of Hydrology and Atmospheric Sciences at The University of Arizona. He received his BS in Civil Engineering from IIT Bombay, and MS and PhD degrees in Systems Engineering from Case Western Reserve University. His broad interest is in how "Learning" happens through the development and use of "Models", and more specifically in how to combine Physics-Based Knowledge with Machine Learning (via Information Theory) for developing Earth & Environmental Systems Models that can progressively learn from interactions with the environment. In 2017 and 2018, Hoshin was ranked in the top 1% on the Clarivate "Highly Cited Researchers List" for Environment/Ecology. He is a Fellow of the American Geophysical Union and the American Meteorological Society, recipient of AMS's RE Horton Lecture Award (2017) and EGU's Dalton Medal (2014), and has served as an Editor of Water Resources Research (2009-2013).*

Keynote Lecture: March 21, 2023 1pm – CSU Lory Student Center, Grand Ballroom

Towards Physical-Conceptual Modeling of Mass, Energy, and Information Flows Using Machine Learning Technology

Abstract: The success of any *Machine Learning* strategy depends on the conceptual and algorithmic *Representation* that is selected for Encoding and Processing Information. Further, the chosen encoding/representation completely determines the questions that can be asked, analyses that can be performed, and the answers that can be obtained. Ultimately, the effectiveness and efficiency of any ML strategy depends on *Information Theoretic* choices related to *what Information* we chose to encode (and store), the *form* in which we choose to encode that *Information,* and the method by which that encoded *Information* is processed. This raises interesting questions regarding (1) the kinds of *Informational Encoding* that are possible and useful when addressing a particular problem, (2) when and how Physics-based Encoding can synergistically interact with Data-based Information Processing strategies to achieve outcomes that are both *Interpretable* and *Non-Lossy* (ie., that achieve maximal possible performance), and (3) the value of multi-representational approaches to support/enable scientific discovery. My view is that by rooting the development of Machine Learning/Artificial Intelligence and Physics-Based Modeling in the fundamental perspectives and language of Information Theory, we can hope to achieve the most rapid progress in the Domain Sciences. While my thoughts may perhaps be speculative, I dont think I am alone in thinking this way, as evidenced by ML literature related to Information Bottleneck theory, and also to the fundamentals of Computational Science.

AGU Hydrology Days Award

Dr. Mary C. Hill - Professor of Geology, University of Kansas

***Bio**: Mary C. Hill is a professor of Geology at the University of Kansas, Fellow of the American Geophysical Union, and member of the National Academy of Engineering. Professor Hill graduated from Hope College in Holland Michigan in 1976 with AB degrees in Business Administration and Geology, and spent a year at Michigan State University in Civil Engineering. She received her PhD in Civil Engineering – Water Resources from Princeton University in 1987 and was a Hydrologist with the USGS from 1981-2014 in New Jersey and then Colorado, achieving the level of GS-16, the highest level a scientist can reach in the US government. At the USGS she used the very popular model MODFLOW to focus on computer modeling of groundwater and groundwater-surface-water hydrologic systems, integration of models and data, and quantification of prediction uncertainty. Since 2014 at KU, Prof. Hill has focused on the integration of science and policy, with an emphasis on creating an environmentally and economically sustainable future for people on earth. To this end, she has worked to add associated human systems such as agriculture and renewable energy development to models and decision support systems. She has worked with very talented students to link data sets from these fields to create visualization software and applications (DiscoverFramework, DiscoverWater and DiscoverHABs) and agriculture-energy-water decision support (FEWCalc). She focuses largely on the food, energy, water (FEW) nexus.*

Keynote Lecture: March 21, 2023 4:30pm – CSU Lory Student Center, Grand Ballroom

A Strategy that Includes National Models to Evaluate Water Availability for Arid Agricultural Areas Being Impacted by Climate Change: The Case of FEWtures in the Central Arkansas River basin (CARB)

Abstract: The NSF FEWtures project seeks to evaluate potential ways to lower carbon production and enhance local economies and communities in arid agricultural regions using local renewable energy supplies. To serve this purpose, the study focuses on the Central Arkansas River basin (CARB) in the central USA, and explores the economics and stakeholder adoption potential of two local renewable energy powered enterprises: (a) locally produced green ammonia for use as fertilizer and energy storage, and (b) treatment of water that has been historically unusable due to salinity or other water quality issues. The system depends on water resources that have been dramatically depleted by irrigation, a characteristic it unfortunately shares with many other systems worldwide. This talk presents a strategy to quantify water availability under climate change developed by the FEWtures Water Supply and Treatment Teams, composed of Patience Bosompemaa, Sam Zipper, Andrea Brookfield, and Edward Peltier. Deep groundwater resources that are not highly interactive with surface water are evaluated using a water-balance method based on historical annual precipitation and head changes. Surface water resources and closely connected groundwater are evaluated using national models. Two national models are available: the USGS National Hydrologic Model (NHM) and the National Water Model (NWM). Adding to water supplies through treatment of saline groundwater, saline groundwater produced with oil and gas extraction, and water from feedlots is also considered. The strategy and approaches for addressing difficulties are discussed in this talk.

Borland Hydraulics Award

Dr. Fred L. Ogden – Chief Scientist, National Water Center Office of Water Prediction, NOAA

***Bio**: Raised in a farm and ranch family near Lamar, Colorado, Fred earned B.S. ('87), M.S. ('89), and Ph.D. ('92) degrees in Civil Engineering from Colorado State University. After a two-year post-doctoral research position at the Univ. of Iowa (1994) he accepted a tenure-track Civil Engineering faculty position at the Univ. of Connecticut in Storrs. At UConn he received the US Army Research Office (ARO) Young Investigator Award to study hydrologic applications of weather radar observations. In 2006 he moved his family to Laramie, where he held an endowed chair position at the Univ. of Wyoming until 2017. During his time in academia, Fred developed several hydrologic and hydraulic simulation models with students and collaborators that remain in use by the US Army Corps of Engineers and other federal agencies. Fred also has extensive field and laboratory experience in physical hydrology and hydraulics. He currently serves as co-chair of the Hydrology and Watershed Systems subcommittee of the US Global Change Research Program, and as a member of the NOAA Council of Fellows.*

Keynote Lecture: March 22, 2023 1pm – CSU Lory Student Center, Grand Ballroom

Transformative Infiltration Modeling using The Soil Moisture Velocity Equation

Abstract: Hydrologic predictability suffers from a lack of a comprehensive theory of stormflow generation. This is particularly true in situations where soil hydraulics dominate partitioning of rainfall into runoff and soil moisture. For this reason most hydrologic models use simplified methods to calculate infiltration. To model infiltration processes, rigorous hydrologic models often numerically solve some form of the Richardson/Richards Equation (RRE); the partial differential equation that describes the variation of water content over time at a point in unsaturated porous media in response to rainfall, plant water uptake, or groundwater table dynamics. Solving the RRE is one of the most challenging problems in hydrologic prediction because of the highly nonlinear dependence of hydraulic conductivity and capillarity on water content, plus numerical solver convergence challenges associated with steep gradients in water content or discontinuous media properties such as soil layering and tillage/compaction. One common method used to reduce computational effort and improve RRE solution robustness involves the use of a coarse spatial discretization of the soil. However, coarse discritizations can violate the Representative Elementary Volume (REV) assumption and can smooth heterogeneities, leading to inaccurate solutions. This presentation reviews a Lagrangian reinterpretation of the RRE called the Soil Moisture Velocity Equation (SMVE) which was first published in 2017 by Fred's research team. The one-dimensional vertical solution of the SMVE employs a finite water content discretization of the soil, which is advantageous because it avoids the need to discretize the soil in space. The SMVE advection-like term can be solved as an ordinary differential equation using standard numerical methods. The SMVE solution simulates infiltration in layered soils as well as the effects of groundwater on infiltration. It does this with guaranteed mass conservation, and without the numerical reliability issues that can impede RRE solutions. Compared to an appropriately applied RRE solution, the SMVE solution exhibits less than five percent difference in calculated infiltration over multi-month simulations. This presentation derives the SMVE from the RRE, and gives examples showing the advantages of this transformative new infiltration modeling tool.

A CELEBRATION OF LIFE: March 22, 2023

In Memoriam: Hubert Morel-Seytoux, Ignacio Rodriguez-Iturbe, Jorge Ramirez

Those fortunate enough to have known these giants have learned much from their wisdom and benefited greatly from their immense knowledge. We mourn the loss of these remarkable professionals and outstanding human beings and take solace in the fact that their indelible legacy will live on.

A special session at the 43rd Annual AGU Hydrology Days will be held on **Wednesday March 22, 2023, from 9am – 12pm (MT)** to acknowledge and celebrate these hydrology legends. Please join us in this important celebration of these pioneers reflecting on their life-accomplishments and service to field.

The session will be held in-person at the Colorado State University Lory Student Center, Room #300. If you cannot attend in person, a weblink to attend remotely is also included:

Weblink: https://zoom.us/j/3146437362?pwd=cGZnMVo1dEJKQVZMTUhHZkF4Vlpydz09

- Meeting ID: 314 643 7362
- Passcode: 030657

Session Schedule

Time	Speaker
9:00am (MT)	Vinio Floris: Welcome & Opening Remarks
9:05am (MT)	Rafael Bras (virtual): Session Introduction
9:15am (MT)	Family Introductions: Marie Morel-Seytoux, Claire Morel-Seytoux (virtual), Juan Rodriguez
9:30am (MT)	Bill Griswold
9:35am (MT)	Charles Shackelford (CSU-CEE Dept. Head)
9:45am (MT)	Amilcare Porporato (virtual)
10:00am (MT)	Cinzia Miracapillo
10:15am (MT)	Mike Applegate
10:30 am (MT)	Dana Miller
10:45am (MT)	Neil Grigg
11:00 am (MT)	Johannes Gessler
11:15am (MT)	Vinio Floris
11:30am (MT)	Reflection (lead by Vinio Floris & Cinzia Miracapillo)

Hubert Morel-Seytoux (1932 – 2022)

Professor, Colorado State University & Founder of AGU Hydrology Days (1980)

Hubert Morel-Seytoux was a faculty member at Colorado State University from 1966 to 1991. After earning his Ph.D. from Stanford University in 1962, he became a research engineer for the Chevron Oil Field Research Company from 1962 to 1966. His research in petroleum recovery led to his interest in hydrology. While serving as chair of the American Geophysical Union's Front Range branch, ***Morel-Seytoux founded Hydrology Days in 1980*** *to bring together regional hydrology-focused scientists, avoid the expense of traveling to far-away conferences and provide students with an opportunity to participate in a professional meeting. Hydrology Days is still hosted by CSU in partnership with AGU and still going strong, 42 years later.*

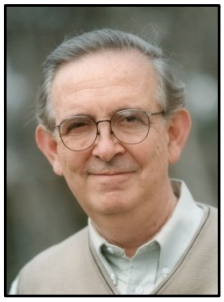
Following his tenure at CSU, Morel-Seytoux moved to California and became a hydrology consultant. He did consultancy work for agencies in Senegal, Saudi Arabia, France, India and throughout the United States. He has authored or co-authored more than 150 publications that have been cited more than 2,300 times. He received an ASCE best paper award for a study in Water Resources Planning and Management in 1999. Morel-Seytoux was a member of the American Geophysical Union, American Society of Civil Engineers, Society of Petroleum Engineers, American Meteorological Society and American Society of Agricultural Engineers. He received the Colorado State University College Engineering Abell Faculty Research Award in 1985. Morel-Seytoux was born in Calais, Artois, France. He turned 90 on Oct. 6, 2022 and passed away Oct. 22, 2022.

Morel-Seytoux Publications: https://www.researchgate.net/profile/Hubert-Morel-Seytoux

Morel-Seytoux, H. J. (2021). Combined Analytical and Numerical Methods in Regional Hydrologic and Water Resources Models", unpublished book, contract signed with Cambridge Scholars Publishing in December 11, 2021.

Ignacio Rodriguez-Iturbe (1942 – 2022)

Professor of Civil and Environmental Engineering, Princeton University



The prominent hydrologist (and father of modern eco-hydrology) Ignacio Rodríguez-Iturbe, passed away on September 28, 2022. He had recently retired as a professor from Texas A&M University in College Station, where he was posthumously honored on November 28, 2022. Prior to teaching at Texas A&M. Dr. Rodriguez-Iturbe was a distinguished professor and leading researcher at Princeton University.

Dr. Rodríguez-Iturbe obtained his civil engineering degree from the University of Zulia in Venezuela. He later earned his Master of Science degree from the California Institute of Technology and his Ph.D. in civil engineering from Colorado State University, where the renowned professor Vujica Yevjevich was his advisor. It was at CSU where his true passion for ecology blossomed and during his time there he discovered its relationship and dynamics to

water sciences. Ignacio passed away passed away Wednesday, Sep. 28, 2022 in his home country of Venezuela. He was 80 years old.

Rodriguez-Iturbe Publications:
https://scholar.google.com/citations?user=GSyUS9wAAAAJ&hl=en

Jorge A. Ramirez (1954 – 2020)

Professor of Civil and Environmental Engineering, Colorado State University

For nearly 20-years Dr. Ramirez served as the organizer of the internationally recognized, annual Hydrology Days Conference which brings world renowned experts to the CSU campus each spring semester. He took on Hydrology Days and raised the bar to serve students and university engagement clients at a higher level.

Over nearly three decades of service to Colorado State University, Dr. Ramirez led numerous research, education, and training efforts to establish CSU as a leader in water science and technology. His academic scholarship substantially expanded the University's research reputation in the fields of hydrology, hydrometeorology, and water resources planning and management, benefiting not only CSU students and his fellow faculty members, but the profession as a whole. Ramirez received the Oliver Pennock Distinguished Service Award from Colorado State University in 2019 for recognition of his academic scholarship and achievements. Jorge passed on Saturday March 28, 2020, in Fort Collins, surrounded by family. He was 65 years old.

Ramirez Publications: https://www.researchgate.net/profile/Jorge-Ramirez-14

Keeping the Momentum:

In 2019, after single-handedly managing AGU Hydrology Days for nearly 20-years, Dr. Ramirez stepped down as chair of AGU Hydrology Days and passed the coordination this important event onto the One Water Solutions Institute (OWSI) located within the Civil and Environmental Engineering Department at Colorado State University. OWSI will continue to carry the torch and endeavors to broaden participation in this 40+ year old legacy for the University. If you would like to be included in future Hydrology Days communications, please contact: hydrologydays@engr.colostate.edu

Hydrology Days Proceedings (2003-2022):
http://hydrologydays.colostate.edu/proceedings/

Climate & Meteorology

Water Year 2022 in Review

Kristie Davis, Alistair Vierod
Department of Atmospheric Science, Colorado Climate Center

Abstract. *Colorado is arguably the most geographically and hydrologically intriguing state of them all. The state's extreme topographic variation in combination with its mid-latitude interior continental location results in a cool, dry but invigorating climate. Colorado's world-famous mountains feed equally famous rivers that support communities and landscapes for thousands of miles. For this reason, climatic conditions in Colorado are directly consequential for the greater region and it is of the utmost importance to understand the climate behind these crucial watersheds. Kristie Davis, an intern at the Colorado Climate Center (CCC) and undergraduate student in the Warner College of Natural Resources, and Alistair Vierod, a CCC data analyst and field technician, will present a summary of Colorado's climate throughout the 2022 Water Year (October 2021 - September 2022) and discuss the hydrologic implications therein.*

Streamflow alteration under hydropower dam operations and climate change projection: A case study in the Sesan River Basin, Lower Mekong Region

Wangmo Ghalley[1,2], Jeffrey D. Niemann[1], Sangam Shrestha[2], and Robert Ettema[1]
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Abstract. *The construction and operation of dams coupled with the effects of anticipated climate change can significantly alter the natural flow regime in a river, leading to disruptions of downstream aquatic ecosystems and human livelihoods that depend on these ecosystems. Among the most vulnerable regions in the world to these changes is the transboundary Sesan River of the Lower Mekong region in southeast Asia, home to about a million people. This study assesses the impact of dam operations and climate change on the hydrologic alterations of Sesan River. Future climate projections are based on three climatic variables: rainfall, minimum daily temperature, and maximum daily temperature. These variables are estimated from an ensemble of five General Circulation Models from the Coupled Model Intercomparison Project - Phase 5 under two Representative Concentration Pathways (RCP): RCP 4.5 and RCP 8.5. The Soil Moisture Accounting model within the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) is used to conduct hydrologic simulations. Hydro-meteorological data and hydropower dam information are obtained from the Mekong River Commission. The geometric characteristics of the subbasins and reaches are estimated using USGS Digital Elevation Models (1 arc-sec grid resolution) and terrain processing tools within HEC-HMS. The upper half of the Sesan basin is steep and rugged, while the lower half is relatively flat. Soil parameters are estimated from the ISRIC-World Soil Information database. The basin is characterized by acrisol soils, which underlie around 80% of the basin. The land use / land cover data are obtained from the Food and Agricultural Organization database at spatial resolution of 30 arc-sec. Forests are the most dominant land cover in the basin. Once the model is calibrated against observed streamflow, it is used to estimate naturalized flows during the*

historical period in which the dams were operating and forecasted flows for the climate change projections. The observed and predicted flows are used in the Indicators of Hydrologic Alteration to quantify the degree of hydrologic alteration. Understanding hydrologic alterations and their drivers is essential in the water-energy-food nexus, as such understanding enables informed decision-making for long-term water resource management and aquatic ecosystem protection.

HEC-HMS Gridded Temperature Index Snow Model for the Upper Indus River Basin in Pakistan

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[3] Chairman, Federal Flood Commission, Ministry of Water Resources, Government of Pakistan

[4] U.S. Army Corps of Engineers

Abstract. *The U.S. Army Corps of Engineers has been asked to provide technical assistance to the Government of Pakistan on potential methods to provide flood warnings on the Indus River in Pakistan and explore the impacts of future climate scenarios on major monsoonal flooding events. This analysis includes the development of a gridded HEC-HMS temperature-index precipitation, snowpack, snowmelt, runoff model of the Upper Indus River Basin in Pakistan to be able to forecast future flood events on the Indus River. The model was calibrated to the 2022 major flood event in the Indus River Basin. Watershed delineation was performed directly within HEC-HMS using STRM 30-meter Digital Elevation Model (DEM). Gridded temperature and precipitation reanalysis data values were obtained from the ECWMF ERA5 data set. For the HEC-HMS model, infiltration was estimated using the deficit-constant method. The mod-Clark unit hydrograph method, using mountain regression equations for the Clark the rainfall-runoff transformation parameters of time of concentration and storage coefficient. For streamflow routings, the Muskingum-Cunge method was used. Temperature-Index parameters of base temperature, wet melt rates, dry melt rates, cold limit, and cold rate coefficients were applied to the model. The historic 2022 inflows to Tarbela Reservoir were used to calibrate the model. Historic 2022 daily inflows to Tarbela were taken from WAPDA records. Minor adjustments to the initial deficit and constant infiltration rates resulted in very close match of the historic Tarbela Reservoir Inflows. Future efforts involve validating the model to the 2010 inflows to Tarbela Reservoir and calibrating the downstream tributaries of the Kabul River, Jhelum River, and Chenab River. Once calibrated, the model can be used to simulate flooding under future climate scenarios. Additionally, the HEC-HMS model will be tied into an integrated suite of reservoir operational models, hydraulic routing models, and consequence models to give the Government of Pakistan a complete set of tools to provide accurate flood warning times and flood stages to minimize damages and lives lost along the Indus River in Punjab and Sindh Provinces.*

Increased Daily Temperature Variability in the Southern Rocky Mountains of Colorado

Brian Steen & Steven R. Fassnacht
ESS-Watershed Science, Colorado State University

Abstract. *While daily temperature variability has decreased in northern latitudes, variability across the western United States has increased. Mountainous areas are more sensitive to warming trends, but daily temperature variability in the Rocky Mountains is unknown. We investigate daily temperature trends across the Yampa and Rio Grande watersheds of the Southern Rocky Mountains in Colorado using Snow Telemetry stations (SNOTEL) at high elevation, snow-covered regions (2520-3540m) and Cooperative Observer Program (COOP) data at lower elevations (1960-2840m) from the mid-1980s to 2022. SNOTEL data were homogenized to account for temperature sensor changes that occurred between 2003 and 2006. Trends were analyzed using the Mann-Kendall significance test and Theil-Sen's rate of change. Results suggested statistically significant decreased daily temperature variability across both study areas. Homogenized SNOTEL data show increased daily temperature variability at both study areas, although several Yampa area stations exhibit decreases in variability. COOP stations at lower elevations demonstrate decreased variability, with the largest decreases in the winter season. The scattered decreases in the Yampa area and at lower elevations emphasize the spatiotemporal variability of montane climatology and suggest trends of increased daily temperature variability across the Rocky Mountain West.*

Shedding Light on Snow Accumulation: Considering Snowfall Topographic Resurfacing and Influence of Scale

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Abstract. *This study develops a scalable snow accumulation model to better estimate snowpack depth using an enhanced representation of actual processes. Current snow accumulation models use bare or "snow-off" surface properties derived from elevation, aspect, vegetation, and canopy characteristics to determine the drivers of snow distribution yet do not consider subsequent snowfalls that can reshape the initial terrain conditions. Such snowfall induced resurfacing can substantially alter the topographic characteristics onto which snow falls, accumulates, and redistributes. We hypothesize that a snow depth model that accumulates snowfall while accounting for the antecedent snow surface characteristics is more representative and consistent than current models that reference snow-off topography. We also hypothesize that surface topography controls on accumulation will remain relatively consistent across spatial scales.*
Terrestrial LiDAR was employed at two field sites following deposition events and captured a range of spatial extents and resolutions. The Upper Piceance Creek site near Meeker, CO covered approximately 10 m^2 at centimeter resolution; the Izas Experimental Catchment in the Spanish Pyrenees covered 1 km^2

at meter resolution. A decision tree machine learning model was applied using an array of topographic features to estimate accumulated snow depth. The observed surface elevation data were split into training and testing groups to produce topographic feature importance metrics. This process engaged in two mechanisms: 1. Snow height elevation (ds_t) differenced with the bare surface digital terrain model (ds_0) predicted with snow-off surface features and 2. Snow height elevation (ds_t) differenced with the previous snow height surface (ds_{t-1}) predicted with the dst-1 snowfall affected surface. Contrary to our hypotheses, surface feature importance showed more consistency in predictions made under Method 1 and surface feature importance rank was incongruent between sites in spatial scale comparison. Additionally, the importance of topographic features to the prediction model differed in magnitude and rank at each site with respect to methods 1 & 2.

Measuring Snow Mass from 12,000 m: Validating Airborne InSAR Measurements of Snow Water Equivalent at Cameron Pass, Colorado

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Abstract. *Mountain snowpacks provide water resources to more than 1.2 billion people. However, the mass of snow, termed snow water equivalent (SWE), is difficult to monitor accurately at regional to global scales. NASA SnowEx, a multi-year campaign, is evaluating promising remote sensing techniques for the measurement of SWE. The L-band interferometric synthetic aperture radar (InSAR) technique for measuring changes in SWE is particularly promising because SAR enables high spatial resolution (<100 m), and snow is nearly transparent at L-band wavelengths (~0.2 m). To test this technique, NASA UAVSAR flew a fully polarimetric L-band (1–2 GHz) SAR sensor over 13 sites in the western US, including Cameron Pass, CO, from January to March 2020. For each flight date, our team surveyed snow conditions at Cameron Pass using L-band ground-penetrating radar (GPR), manually probed snow depths, and snow pit observations along a ~1 km transect through both open and forested terrain. Additionally, terrestrial lidar was collected on 26 February and 12 March to derive spatially distributed snow depth changes. Here, we evaluate three InSAR pairs, collected on 12–19 February, 19–26 February, and 26 February to 12 March. Interferograms are corrected for atmospheric delays and SWE-change is subsequently calculated from the phase change and incidence angles, following Guneriussen et al. (2001). For ground-based measurements, SWE was calculated using the pit-measured bulk snow density. Ground-based SWE was then binned to the UAVSAR grid and compared with the UAVSAR SWE-retrievals. Ground-based measurements indicated that the 12–19 February interval yielded the largest SWE-change (+117 mm), while the 19–26 February and 26 February to 12 March were more modest, at –2 and +12 mm, respectively. When comparing UAVSAR SWE-changes with GPR SWE-changes, we find the root mean squared error for the 12–19 February UAVSAR SWE-retrievals is <20 mm, with the largest GPR/UAVSAR differences occurring in forests. If well-validated, the L-band InSAR technique would be a viable means*

for deriving global SWE estimates from the upcoming NISAR and ROSE-L SAR satellite missions, providing the next step towards real-time SWE estimates for regions dependent on snow water resources.

A Spatiotemporal Analysis of the Correlation Between Snow Water Equivalent and Baseflow in Colorado

Helen Flynn, Marin MacDonald, Anna K.D. Pfohl, Steven R. Fassnacht
Department of Ecosystem Science and Sustainability, Colorado State University

Abstract. *Baseflow is the primary source of water in snow-dominated watersheds for most of the year after the high-volume melt period has passed. The Colorado Front Range relies on low flows that result from late spring and early summer snowmelt for municipal, agricultural, and recreational purposes. Changes in the timing and amount of snowmelt due to climate change will impact water availability for millions of people on the Front Range. This study seeks to find the correlation between winter snow water equivalent (SWE) values and subsequent baseflow characteristics, including any yearly lag between the two variables. Streamflow data from US Geological Survey stations and SWE data from Natural Resource Conservation Service SNOTEL stations were examined for drainage basins of varying latitude, elevation, and area across Colorado. In snow-dominated ecosystems, the hydrograph shows a well-defined peak when snowmelt occurs in the spring that is followed by low flows in the fall and winter months. The traditional water year (WY, in the US October 1 through September 30) separates peak melt and baseflow into two different WYs. To reflect the hydrologic processes that are occurring in snow-dominated watersheds, we propose using a melt year (MY) beginning with the onset of snowmelt (the first deviation from baseflow) and ending with the onset of the following year's snowmelt. We identified the beginning of a MY and extracted the subsequent baseflow values using flow duration curves (FDC). This is a dynamic approach to analyzing the correlation between peak SWE and baseflow.*

Diverging Aerodynamic Roughness over Varying Snow Surfaces

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[2]Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
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[4]ESS-Watershed Science, Colorado State University

Abstract. *The snow surface is the interface between the atmosphere and the earth, when snow cover is present. To examine this interaction, a series of experiments were performed in the Snow and Ice Research Center Cryospheric Environmental Simulator (CES) in Shinjo, Japan. A flat snow surface was created using rounded snow grains in the wind tunnel. Wind speeds were measured at 10 to 35 mm intervals form the surface with a fine extent (10-mm resolution measurement) sonic anemometer in stable wind conditions with speeds of 2, 3, 4, 5, and 6 m/s. A 50-cm period and 4-cm amplitude sequence of 20 waves was subsequently created in the CES wind tunnel, with vertical wind profiles being measured at the windward, furrow (top), leeward, and trough (bottom) of a sequence of waves. Several downwind waves were manipulated to resemble snow drifts, and vertical roughness elements were added. Finally, fresh stellar snow (CES type A) was added to the winds tunnel and allowed to drift across the snow surface. Vertical wind profiles were again measured at various locations along the manipulated snow waves, and with fresh snow. The surface geometry was scanned with terrestrial lidar (TLS). The*

anemometric roughness length (z0-A) was computed for each vertical wind profiles (36 in total), and the geometric roughness length (z0-G) was computed from the TLS scans for each of the seven surface configurations. The values of z0-A varied by surface configuration and wind speed, while z0-G varied by configuration. The differences are not trivial. This has implications on how we model various components of the earth's global climate and energy balance.

What came after the Flood? CoCoRaHS (the Community Collaborative Rain, Hail and Snow Network)

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Abstract. *After the Fort Collins flash flood of July 1997, many things happened. For example, 1) the Design Storm rainfall for Fort Collins was updated (the 2-hour 50-year return period rainfall used heavily for storm water management), 2) the Lory Student Center and other campus structures were artfully bermed, 3) large storm water detention facilities were excavated, 4) large storm sewers for routing and removing storm water from campus and other parts of our city were installed, and 5) a major real-time flood warning system across our community was established and maintained. These actions have all helped immensely to make our campus and community better prepared to handle future heavy rain events and flooding. One other thing happened, too. CoCoRaHS was born. In this presentation we will show and describe the amazing growth and expansion of what began as a local volunteer rain gauge network here in Fort Collins. Now, in its 25th year, CoCoRaHS is a highly respected North American international "citizen science" network that still relies on manual rain gauge reports from volunteers. www.cocorahs.org Data are systematically quality controlled and data are all freely accessible. We will highlight some of the users and uses of CoCoRaHS data, and we will demonstrate some of the products that have been developed over this time period. Examples will be shown of storm events like Hurricanes Harvey (2017) and Ian (2022) that we have captured. Finally, we will end where we first started back in 1998 – by appealing to Hydrology Days participants to join in this fun and important project.*

Ecohydrology, Water, and Plants

Coordinated Crop Trait Assemblages: How Process-Based Modeling, Experimental Results, and Physiological Theory Can Help Us Design Better Plants

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Abstract: *Plant growth and yield are the ultimate outcomes of a complex set of physiological processes that begin with the exchange of water for atmospheric CO2. However, this basic understanding of plant growth oversimplifies the numerous combinations of physiological and structural traits, soil properties, and environmental conditions that influence plant performance. Given that it is impossible to test every combination of plant, soil, and climate variable, process-based physiological modeling provides a feasible alternative for identifying beneficial trait networks. Here, using this framework, I take a step back from simple single trait performance outcomes and ask, what specific traits and trait connections would confer improved performance in a particular climate context? Using the Terrestrial Regional Ecosystem Exchange Simulator (TREES), I focus on the evolutionary linkage between water expenditure and carbon income – water uptake, water transport to the sites of evaporation, and the exchange of water for CO2. Model results are compared against what we might expect from theory, as well as real world empirical results. Trait networks most likely confer success under hotter and drier climate scenarios are discussed in the context of current crop improvement efforts.*

Spatiotemporal Modeling of Maize Light Extinction Coefficient Using Sentinel-2 Multispectral Data

Edson Costa-Filho, M.Sc.[1], José L. Chávez, Ph.D.[1], Huihui Zhang, Ph.D.21[2], Allan A. Andales, Ph.D.[1,3], Ansley Brown, M.Sc.[2]
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Abstract. *Adequate vegetation growth of crops relies on plants effectively absorbing solar energy as photosynthetically active radiation (PAR), which directly impacts canopy ecological processes such as plant transpiration and soil carbon sequestration. The light extinction coefficient (k_p), a critical term for vegetation growth, ecosystem flux, and evapotranspiration modeling, is an important parameter to characterize canopy architecture. Classic modeling techniques for k_p do not account for spatial variability in canopy architecture, a complex feature in cropland fields across the globe due to factors such as soil texture differences and inadequate irrigation water management practices. This study proposed a modeling approach for maize k_p using Sentinel-2 multispectral data (10- m spatial resolution). The proposed maize k_p model has the Normalized Difference Vegetation Index (NDVI), green vegetation fractional cover (f_c), and leaf area index (LAI) as inputs. Two maize fields under different irrigation*

methods provided on-site measurements of canopy architecture as fc and LAI in Northern Colorado, USA. From July to August 2021, data collected from a surface (furrow) irrigated field were used to fit the k_p model. Data from a subsurface drip maize field (July to August 2020) were used to evaluate the accuracy of the predicted k_p values independently. The evaluation compared the estimated to observed k_p values from LAI and above and below canopy PAR measurements. Further k_p modeling performance evaluation was done when comparing the accuracy of the proposed k_p approach with the classical k_p model based on plant leaf geometry and solar angle. Preliminary results indicate that the overall maize k_p estimation error was -0.01 (-3%) ± 0.06 (11%). Among the k_p modeling input variables, LAI was estimated with somewhat large errors, 0.30 m2/m2 (9%) ± 0.85 m2/m2 (25%). The proposed k_p model outperformed the classical k_p approach by 39%. Thus, the proposed maize k_p model shows two significant advantages compared to the classic k_p modeling technique: It is more accurate and predicts spatiotemporal values of k_p. Further research is needed to develop a model for other remote sensing sensors (platforms) and to evaluate the proposed k_p approach for different crop types under different climate regimes.

Preliminary Evaluation of aerial- and Spaceborne-based remote sensing estimation of Crop Biophysical Characteristics and Implications on Crop Water Use Estimates

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Abstract. *Remote sensing (RS) estimations of crop evapotranspiration (ET) are being used in soil water budgets to improve irrigation water management at different spatial scales. Most RS of ET algorithms incorporate crop biophysical characteristics (CBPC). However, the accuracy of CBPC estimates using multispectral data from different RS platforms has not yet been studied. This research aims to determine how the RS estimation accuracy of vegetation indices (VIs) affect the estimation of the Leaf Area Index (LAI) and Crop Height (HC), and ultimately the estimation of distributed ET. Evaluated VIs include the Normalized Difference Vegetation Index (NDVI) and Optimized Soil Adjusted Vegetation Index (OSAVI). These VIs were derived from the following RS platforms: Unmanned Airborne System (UAS), PlanetDove microsatellite, and Sentinel2 and LandSat8-9 satellites. RS multispectral images were acquired over fully and deficit drip irrigated corn fields located at a research facility near Greeley, CO, in 2022. These images were analyzed to estimate VIs based on surface reflectance data from Near Infra-Red) and Red bands. VIs from each RS platform was evaluated statistically by comparing RS-based estimates to observed field data. Then, VIs were used in LAI and HC models. Results of CBPC were compared with in-situ measurements for different days of the year, throughout the crop growth season, to determine the validity of different empirical functions that estimate LAI and HC spatially. In the evaluation of the different RS platforms' data and LAI and HC model accuracy, we discuss the effects of image pixel size, sensor calibration, vegetation growth stage, irrigation strategy, and weather conditions. Then, implications of the accuracy of LAI and HC estimates on the spatial determination of crop ET are also discussed.*

A Broad Analysis of Total Suspended Solids in Colorado Agricultural Runoff: Insights and Trends

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Abstract. *The hydrologic transport of soil from erosion is associated with degraded water quality, decreased soil fertility, and a loss of economic value in agricultural lands. The Agricultural Water Quality Program (AWQP) protects Colorado state waters and the environment from impairment or degradation due to the improper application of agricultural practices, while encouraging protective practices that preserve and improve water quality. One aspect of this work entails quantifying soil erosion, expressed as total suspended solids (TSS) from water quality samples taken in edge-of-field (EoF) settings around the state. Soil erosion is related to a number of site characteristics, including field management, cropping system, soil type, land slope, among other characteristics. In this analysis, trends in TSS concentration data are compared and discussed from water samples taken across a number of irrigated fields in CO operating under differing management styles. These management styles include: 1) mountain meadow hay and pasture, 2) row crops utilizing conservation tillage practices, 3) conventionally tilled row crops, and 4) agricultural fields implementing EoF vegetated buffer strips. Further analysis explores the relationship between TSS and the concentration of total phosphorus (TP), a nutrient pollutant understood to be associated strongly with sediment and the potential cause of environmental issues in receiving water bodies. Results are presented on a broad scale, encompassing a wide variety of ecosystems and cropping systems across the state in the context of water quality, soil fertility, and the lost economic value from soil and nutrient loss due to erosion.*

Beyond Flood Control: Evaluating the Environmental, Economic, and Social Co-benefits of Stormwater Management Practices in Philadelphia

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Abstract. *The increasing frequency and severity of urban flooding events have prompted municipalities to adopt sustainable stormwater management practices (SMPs) to mitigate flood risks and improve water quality. However, the potential co-benefits of SMPs beyond flood control have received relatively little attention. In this case study, we conducted a comprehensive assessment of the environmental, economic, and social co-benefits of SMPs in the combined sewer service area of Philadelphia. Using the CLASIC tool, we evaluated the benefits of existing SMPs and various alternative scenarios with different levels of vegetation diversity and tree planting. Several indicators have been considered in this study, including property value, avoided costs from illness, ecosystem services, thermal comfort, carbon sequestration, and increased employment opportunities. Our findings revealed that tree plantings as well as diverse vegetation could significantly improve measures of all three dimensions of co-benefits. While incorporating diverse vegetation and trees may result in higher costs, the substantial benefits can justify the investment. Furthermore, this study emphasizes that quantitative measures, in addition to qualitative Multi-Criteria Decision Analysis (MCDA) scores, are essential to making informed decisions*

and providing valuable insights into trade-offs between costs and co-benefits. This work has significant implications for decision-makers and urban planners in designing and implementing effective SMPs that maximize the environmental, social, and economic co-benefits while considering budget limitations.

Geoscience & Groundwater

Integrating Remote Sensing and Machine Learning for High-Resolution Groundwater Use Estimation

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Abstract. *Groundwater is pivotal to the water-food-energy nexus and is an essential component of the water budget required for sustainable water management practices. However, with increasing freshwater demands driven by a growing global population, dietary changes, and climate change, groundwater reserves are being heavily exploited in many basins. Hence, the adverse effects of groundwater overdrafts (such as land subsidence, aquifer depletion, and water contamination) are becoming increasingly significant worldwide. Although groundwater overdraft is prevalent in many regions, including the United States (US), proactive monitoring of groundwater withdrawals at scales appropriate for addressing water security concerns is limited. Thus, we need reliable and effective methods for accurate high-resolution groundwater use estimation. While process-based models have been successful in doing so, calibrating, and extending them to other regions or large areas can be costly due to their inherent complex workflow. With recent technological advancements, such as earth observation programs that use spaceborne remote sensing platforms, we can now monitor various critical components of the global water cycle at high spatiotemporal resolutions. Our research incorporates multiple passive and active satellite sensor data to estimate annual groundwater withdrawals across various spatial resolutions ranging from 1 km to 5 km. We developed an integrated approach combining multiple remote sensing, modeled, and gridded hydrometeorological datasets with a machine learning (ML) model that automatically identifies the inter-relationships among these variables and groundwater withdrawals. Some of the model predictors include Operational Simplified Surface Energy Balance (SSEBop) evapotranspiration, US Department of Agriculture (USDA)-National Agricultural Statistics Service (NASS) Cropland Data Layer (land use), and the Parameter-elevation Regressions on Elevation Slopes Model (PRISM) gridded precipitation data. We tested this approach in three different regions of the US, namely Kansas, Arizona, and the Mississippi Alluvial Plain. These regions were chosen because they have substantially different climates, aquifer characteristics, irrigation demands, and in-situ data sets. Here, we compared multiple ML models (e.g., Random Forests, Gradient Boosting Trees, and others) to obtain the most generalizable one. The validation results show a good match between the groundwater use estimates and the in-situ pumping data, with the coefficient of determination (R2) ranging from 0.5 to 0.8.*

Predicting Soil Texture Using 1-D Convolutional Neural Networks based on Field Hyperspectral Images

Joseph R. Bindner, Joseph Scalia IV, Jeffrey D. Niemann, and Brian Schaible
Department of Civil and Environmental Engineering, Colorado State University

Abstract. *The particle size distribution of soils is used to classify the soil into texture-based categories. However, the determination of soil particle size distribution using laboratory procedures can be costly, time intensive, and is often impractical across large spatial regions. While soil data products, such as the Soil Survey Geographic Database (SSURGO), can be used for geospatial analysis, many modeling applications require higher fidelity soil texture information. Hyperspectral images contain information on a material's reflectance at various wavelengths in the visible and near-infrared parts of the electromagnetic spectrum. Supervised machine learning models have shown promise for predicting soil texture from hyperspectral images captured in laboratory (controlled) environments; however, the prediction of soil texture using field hyperspectral images is less certain. The objective of this study is to better understand how one dimensional convolutional neural networks can be used to predict soil texture from field captured hyperspectral images. A published convolutional neural network modeling procedure for laboratory soil classification is adapted to predict soil texture based on field captured hyperspectral images. The field imagery was captured at two field sites located in Northern Colorado by passive hyperspectral cameras at semi-vegetated locations. Soil samples were collected at each imaging location, classified using laboratory procedures, and used to evaluate model performance. Results of the field adapted convolutional neural network indicate that field captured hyperspectral images may be viable for the prediction of soil texture for large scale modeling procedures.*

Evaluating the Role of Floodplain Surface Water-Groundwater Interactions in SWAT+

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Abstract. *Floodplains are essential ecosystems that provide a variety of economic, hydrologic, and ecologic services. Within floodplains, groundwater-surface water exchange plays an important role in facilitating biogeochemical processing and can have a strong influence on hydrology through infiltration or discharge of water. These functions can be difficult to assess due to the heterogeneity of floodplains and monitoring constraints, so numerical models are useful tools to estimate fluxes, especially at a large scale. In this study, the SWAT+ (Soil and Water Assessment Tool) ecohydrological watershed model is used in conjunction with an updated version of the gwflow module to evaluate model performance with and without the inclusion of floodplain-aquifer connectivity. The gwflow module is a spatially distributed groundwater modeling procedure that uses a gridded network and physically based equations to calculate groundwater storage, groundwater head, and groundwater fluxes in the watershed. The module was updated for this study to directly calculate floodplain-aquifer interactions during periods of floodplain inundation and applied to an area of approximately 7,515 km^2 in the Colorado Headwaters HUC8 watershed (14010001). The SWAT+ model was calibrated and tested against streamflow and*

groundwater head values from USGS gages in the watershed. Model performance was evaluated for scenarios with and without the inclusion of simulated floodplain-aquifer exchange, and for three grid cell sizes to assess the impact of spatial refinement on model outputs. Preliminary results suggest that models including floodplain-aquifer interactions perform similarly to those without, while also providing valuable information about floodplain inundation and exchange rates. Spatial refinement also showed similar performance across all sizes when compared to calibration metrics, but smaller cell sizes provide much more insight into local variations in groundwater fluxes, especially around floodplains.

Baseflow Characteristics in a High Elevation Watershed with Wetland Contribution

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Abstract. *High elevation watersheds, especially those that provide headwaters for four major drainage basins in Colorado, get a majority of their streamflow from snowmelt. However, baseflow from groundwater maintains streamflow during low flow periods, and these low flows often occur over two-thirds of the year, usually from September through April. As such, baseflow is an important contributor to streamflow. Many of these high-elevation watersheds contain wetlands and their interaction with groundwater is poorly understood. With future climate variability possibly influencing timing, amount, and phase of precipitation on the watersheds, it is crucial that we better understand these influences on baseflow contributions to streamflow, to improve water resource management. This research aims to quantify baseflow contributions to headwater wetlands and interpret how streamflow is maintained by baseflow recharge. Data are examined from Senator Beck Basin, located near Red Mountain Pass in southwestern Colorado, a snowmelt dominated watershed with several high elevation wetlands. End member mixing analysis was used to calculate hourly baseflow for a dry year (2018) and a wet year (2019) and results were combined with information on the snow regime collected by the Center for Snow and Avalanche Studies. We observe that baseflow began to dominate streamflow earlier in the year during the dry year than the wet year. Interestingly, we see diel fluctuations in streamflow and baseflow that are only partially correlated.*

Weathering in Rocky Mountain Alluvial Valleys

Isabella Ulate and Jeremy K.C. Rugenstein
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Abstract. *Silicate weathering is the primary mechanism that removes CO2 from the atmosphere on geological timescales. Most models of silicate weathering assume that exposure of fresh minerals on mountain hillslopes increases weathering rates. However, in many mountains, high-elevation alluvial valleys—often created by glaciation or faulting—store eroded material. The contribution of these alluvial floodplains to the weathering budget of a mountain range is not well constrained. We use a well-studied alluvial floodplain at the CSU Mountain Campus in the northern Front Range to constrain their role in the weathering budget of a major Colorado Front Range river. The study site is ideal for understanding how*

an alluvial valley contributes to weathering due to the active connection between the groundwater and surface water, the well-constrained groundwater dynamics, and the silicate lithology of the surrounding catchment. We collected meteoric, surface and ground water to determine if weathering reactions in the alluvial aquifer influence stream [C]. We hypothesize that the overwhelming influence of seasonal discharge from snowmelt combined with the relatively unreactive minerals present in the valley fill will result in only a small effect of alluvial weathering. Preliminary data shows higher alkalinity in the groundwater relative to the stream water and a newly drilled well installed near bedrock in the valley will permit additional study of the relationship between [C] and residence time in this aquifer. Quantifying the contribution of alluvial valley sediment weathering to the mountain's overall weathering budget is important for better understanding what role these types of mountain environments play in the global carbon cycle.

Simulating Nonpoint-Source Uranium Pollution in The Irrigated Stream-Aquifer System Along the Lower Reach of Colorado's Arkansas River Valley

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Abstract. *Over the last century, irrigation practices have allowed high agricultural productivity in southeastern Colorado's Lower Arkansas River Valley (LARV). Water quality issues related to the transport of nutrients and trace elements in irrigated agricultural systems have become a key concern to regulators and stakeholders here and in the LARV and other parts of the world. Intensive irrigation and fertilization have led to high concentrations of uranium (U), selenium (Se), and nitrate (NO3) in groundwater and surface water. These high solute concentrations pose a threat to aquatic life, livestock, and human health and have exceeded safety standards set by the World Health Organization (WHO) and the Colorado Department of Public Health and Environment (CDPHE). To investigate the current distribution of U, Se, and NO3, a computational model has been constructed for application to a 540 km² study region in the eastern LARV near Lamar, Colorado. The model simulates flow and solute reactive transport in a coupled irrigated stream-aquifer system, using the MODFLOW-UZF and SFR2 packages to predict groundwater and surface water flow. The RT3D-OTIS model to predict solute transport in the aquifer and the Arkansas River stream network. The model is like an earlier model applied in the LARV that simulates Se and NO3. However, the expanded model includes U transport and covers an extended period of 2003 to 2016 where observed data are available. Calibration is carried out using the latest version of Parameters Estimation (PEST++), with targets including groundwater hydraulic head, stream flow, groundwater return flow, U, Se, NO3 concentrations in the groundwater and the stream, and solute mass loading from the aquifer to the river. Preliminary results from model application to baseline conditions are presented. The calibrated model will be further used to investigate the effects of alternative best management practices (BMPs) in decreasing U, Se, and NO3 concentrations and mass loadings within the stream-aquifer system.*

Hydrologic Systems

Case Study: On Flood Level Reduction by Nature-based Solutions in Hwang River, South Korea

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Abstract. *Due to climate change and urbanization, the localized heavy rainfall frequently exceeded a design storm rainfall and flood damage has occurred in South Korea. In 2020 and 2022, we had 40 and 9 deaths from heavy rainfall. In general, the gray infrastructures such as levee and weirs are used for the flood prevention and flood control in the river. However, it is known that the gray infrastructure by river management plan emits carbon dioxide, increasing the occurrence of extreme weather due to climate change and intensifying flood damage and so it is not sustainable measure. A possibly sustainable solution may be the concept of Nature-based Solutions (NbS), which seeks to solve environmental and social problems through ecosystem services, and NbS receives attracting attention recently. Therefore, in this study, the flood reduction effect by river management using NbS was quantitatively analyzed for the Hwang River, which is directly downstream of Hapcheon Dam, South Korea. Floodplain excavation and dyke relocation, which are methods of the NbS, were applied to the flood risk area of the Hwang River. As a result of analyzing the flood level of the river through the unsteady flow analysis of HEC-RAS, we obtained flood level reduction by 5 cm at the confluence of the Nakdong River. The results of this study can be expected to be sufficiently utilized as a basis for use as a management plan through NbS rather than the river management with grey infrastructure.*

Floodplain analysis of extreme storm events and the challenges related to military installation floodplain modeling.

Reilly Miller
Department of Civil and Environmental Engineering CSU

Abstract. *Since 2016, the Center for Energy Water Sustainability (CEWS) at Colorado State University's (CSU) department of civil and environmental engineering (CEE) has been contracted by the Department of Defense (DoD), primarily the U.S. Air Force (USAF) to conduct floodplain analysis for USAF installations. The task is to identify flood risk associated with extreme storm events (100-year and 500-year) related to precipitation, stream and coastal flooding, to support military planning and preparedness for US air force bases all around the globe. Accurate floodplain modeling helps decision-makers identify high-risk areas, prioritize mitigation measures, and reduce potential damage to critical infrastructure. Although FEMA is the designated authority for developing flood maps for the USAF, FEMA flood maps for many USAF installations either do not exist or are severely outdated. Additionally, the process for developing and updating flood maps through FEMA is lengthy and only considered on an "as needed basis". The DoD does not depend on FEMA Flood Insurance Rate Map (FIRM) for their flood*

insurance. As a result, CSU has generated comprehensive flood maps for more than 50 USAF installations (and counting) using high-resolution elevation (1m LiDAR), precise land cover data (0.3 m), and sophisticated 2D hydraulic modeling. FEMA has performed a review of the CSU-generated flood maps and has provided a memo endorsing the models and methodology utilized. The flood maps produced are accompanied with flood depth, flood velocity, and flood shear stress information for the entire extent of base installations. However, there are many challenges involved in this process, including but not limited to, data availability, data sharing and very large study areas. Overcoming these challenges is crucial, particularly at military installations due to heightened security risk.

Assessment of species specific aquatic and riparian habitats under a range of possible future hydrologic scenarios on the Verde River using the Riverine Environmental Flow Decision Support System (REFDSS)

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Abstract. *Hydrologic modification can have profound impacts on riparian and aquatic species in a river system through the change in availability of habitat characteristics. Through literature reviews and extensive field surveys, suitable habitat regimes have been developed for aquatic and riparian species along the Wild and Scenic Verde River in Arizona. Habitat suitability curves for physical properties like depth and velocity of flow as well as frequency of inundation can be combined with detailed hydraulic modeling data to establish locations and extents of preferred habitat for each species and life-stage of interest. The Riverine Environmental Flow Decision Support System (REFDSS) does just that to determine the extent of available habitat by discharge, as well as combining stream gage monitoring data, to assess overall frequency of occurence of preferred habitat by species and life stage. Further, multiple hydrologic modification scenarios can be overlaid on the historic stream data to assess the multiple future alternatives based on management actions. REFDSS can compare and contrast habitat availability impacts from competing management scenarios, allowing for a detailed assessment and understanding of hydrologic modification. In its simiplest form, this highlights hydrologic modification scenarios that are good or bad for suites of species as well as more subtle differences that are good for one species and less desirable for another. These side-by-side alternative outcomes of habitat availability can be used to inform managers on future environmental flow regulation for multiple aquatic and riparian species benefits.*

Implications of water management representations for watershed hydrologic modeling in Lower Arkansas River Basin

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Abstract. *Water management practices significantly modify natural regimes of streamflow through altering retention time and water exchanges among various components of the water cycle. Precise simulation of water cycling in intensively regulated river basins, such as the Lower Arkansas River basin (LARB), Colorado, United States, is important for water management in the face of land use change, climate change, and population change. In this study, we present a holistic integrated watershed model, the Soil and Water Assessment Tool (SWAT+) model, for the Lower Arkansas River Basin, augmented to include physically based spatially distributed groundwater modeling with the new gwflow groundwater module. For our assessment we use a collection of 8-digit watershed models from the National Agroecosystem Model (NAM). The NAM is a field-based, national scale hydrologic model to aid in conservation planning and policy. Main computed groundwater inflows and outflows include pumping, recharge, groundwater-surface water exchange, groundwater-lake exchange, boundary inflow, and transfer to soils. The models are tested against streamflow, reservoir storage, and groundwater head throughout the river basin, during the 2000-2015 period. The key parameters of SWAT+ and the gwflow module were optimized using the parameter estimation software programs PEST. The Nash–Sutcliffe efficiency coefficient (NSE), determination coefficient (R2), Kling–Gupta efficiency coefficient (KGE), and percentage bias (PBIAS) are used to evaluate streamflow and mean absolute error (MAE) for the evaluation of groundwater level. The results of this study highlight the importance of reliably representing irrigation management and reservoir operations for reliable hydrologic modeling of watershed. The findings of this hold promise to enhance water resources assessment that can be applied to other intensively highly regulated river basins.*

Gridded versus station datasets yield divergent hydrological responses when modeling streamflow in a Colorado watershed

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Abstract. *Hydrologic models can be forced with meteorological data from various sources including gridded climate products or ground-based station data. In mountainous areas with greater topographic and climate diversity, it is common to use gridded data at 4km2 resolution due to their spatial representation and lack of adequate station data. However, it is unclear how well gridded datasets*

capture spatial variability of precipitation or topoclimate and microscale variation such as cold air drainages or inversions. In this study, we evaluate gridded (PRISM and Daymet) versus station datasets over the years 2010-2020 in the 63.3 km2 Fourmile Creek watershed in northern Colorado that has >2000 m of relief. We tested for spatial biases between the gridded and station datasets and subsequent differences in model performance, parameter calibration, and water flux partitioning. Additionally, we performed a semi-probabilistic model calibration where one of the ten years of streamflow data was omitted from each calibration, plus an additional calibration with all years of streamflow included, for comparison of parameter estimates. The gridded dataset was biased towards warmer temperatures at lower elevations (up to 5º C difference) and cooler temperatures at higher elevations (1-2º C), compared to station data, whereas precipitation differences were less associated with elevation but did approach 100 mm y-1 in certain locations. Overall, model performance was comparable between the two datasets (KGE = 0.87 and 0.84 for gridded and station datasets, respectively) although excluding streamflow from 2012 (a low snowfall year with high summer precipitation) substantially reduced model performance more so than excluding 2013 (large flooding precipitation event in September). Calibrated parameter values differed substantially between the two datasets, especially for snowmelt, rain-snow partitioning, and flow routing parameters. These parameterization differences resulted in divergent hydrological responses with the gridded dataset partitioning water equally between interflow and ground water recharge, but with station data partitioning water almost entirely to interflow. It is clear that parameter calibration and water flux partitioning are sensitive to forcing datasets, even when model performance metrics show marginal differences. While multiple calibrations are often unrealistic due to processing times, these results highlight potential issues with model equifinality and interpreting results in changing or disturbed landscapes amid shifting climate patterns.

Cache la Poudre River Natural Flows: 1884 – 2022 Trends, Predictability, Management

Andrew M. Pineda, P.E.
Larimer and Weld Irrigation Company

Abstract. *The Cache la Poudre River is a major tributary of the South Platte River. One hundred thirty-nine years of natural flows, as measured at the canyon mouth gage, are presented here. The natural flow of the river is the result of many hydrologic processes within the basin including snow melt, precipitation, solar radiation, temperature, soil moisture, land use, and land cover. The natural flow of the river serves many decreed beneficial uses such as irrigation, municipal, industrial, and recreation as it flows from the canyon mouth to the South Platte River confluence. The objective of this presentation is to show graphically the time series of the annual flows, what if any changes in the monthly distribution of flow over time are observed, and what predictability do we have for managing these flows for irrigation purposes. The Larimer and Weld Irrigation Company is a major water user in the Poudre basin. The company manages several direct flow and storage right decrees on the river. This company serves approximately 60,000 acres of farmlands in Larimer and Weld counties through a supply and delivery network of canals and reservoirs. By studying and understanding the history of the natural flows and*

river diversions by the Larimer and Weld system, forecast tools can be developed to assist in the allocation of water for the upcoming year.

Prediction of Strength of Surface Soils Using Temporally and Spatially Varying Landscape Attributes

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Abstract. *Accurate estimation of surficial soil moisture and soil strength is integral in the determination of vehicle mobility across landscapes for applications from agriculture to national defense. Especially important is the ability to estimate trafficability over large spatial extents at fine resolutions (10-30 m, or finer, grid cells). While methods exist to estimate soil strength across landscapes, these methods are empirically based and rely on field calibration of soil strength parameters which are often difficult or impossible to acquire. In addition, modern machine-soil interaction models require moisture-variable soil parameters that cannot be acquired with simple field investigation. To tackle this issue, the Strength of Surficial Soils (STRESS) model was developed to estimate moisture-variable soil strength with a physics-based approach rooted in unsaturated soil mechanics. However, there is a lack of field soil moisture and soil strength data from a spatially diverse landscape with which to evaluate the STRESS model. To test the STRESS model, a field study was conducted at the 4,000 ha Maxwell Ranch near Livermore, Colorado. Soil moisture and soil strength were determined with HydraProbes and cone penetrometers, respectively, at 86 locations across the ranch on 10 dates from May to August 2022. Locations were selected to represent a wide range of topographical, vegetation, and soil types. The data were then used to test and improve the STRESS model and determine if soil strength trends could be estimated from topographical and soil textural differences across the landscape. Observed trends show a decrease in soil strength with an increase in soil moisture, lower strengths on steeper slopes, and an increase in strength with an increase in soil fines content.*

Effects of crest location and spillway-abutment shape on flow uniformity over a spillway crest

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Abstract. *This study investigates the impact of spillway-crest location (relative to spillway entrance) and spillway-abutment shape on uniformity of flow distribution over the ogee crest of a spillway. Circular and elliptical shapes of abutment were used. The base spillway used for the study was the modified spillway for Los Vaqueros Dam located on Kellogg Creek near Brentwood, California. The flow approach to this spillway is typical of many over-flow spillways. As often is the case for spillways associated with embankment dams, the spillway is built on an abutment of the dam itself and must deal with non-*

uniform approach flow from the reservoir retained by the dam to the spillway's location at the side of the dam. Consequently, the approach flow is non uniform, and design questions arise as to where to place the ogee crest for the spillway and what shape to use for a spillway. Though the investigation used the base spillway just mentioned, the results have general application. The experiments were performed using a spillway flume with a rectangular cross-section, a circular abutment intake and a controllable spillway crest with changing the crest location to four locations (one downstream of the selected location and two upstream of that location). Measurements included water profiles, velocity across transects downstream of the spillway's entrance. These measurements were made for a circular spillway-abutment and for an elliptical spillway-abutment. The results show that changing the crest location significantly affects flow uniformity and possible shed-vortex formation from the intake abutment. Therefore, the results also indicate that spillway crest location has a direct impact on the hydraulic performance of the spillway. Suitable selection of crest location can be used to minimize non-uniformity and vortex-related problems in spillway design. The findings from this study are significant for engineers and researchers involved in spillway design and generally in many aspects of hydraulic engineering design. The findings also demonstrate the importance of careful consideration of crest location in spillway design to mitigate problems related to vortex formation. Overall, this study adds to the knowledge base regarding spillways and their design. Spillways have been used for hundreds of years but there are many aspects of these hydraulic structures requiring continued research.

Evaluating demand management at the field scale though direct and indirect measurements of conserved consumptive use

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Abstract. *The Colorado River Basin has been experiencing drought for about two decades. The Upper Division States of the Colorado River Basin are collaborating with the Department of the Interior and their stakeholders to evaluate proactive options for protecting critical elevations at Lake Powell while avoiding forced curtailment. A Demand Management (DM) Program, a temporary, voluntary, and compensated program for the reduction in consumptive use is one of the options being evaluated by these States. Determining the feasibility of an Upper Basin DM program requires assessment of many outstanding questions: socio-economics concerns, hydrological effects, and legal frameworks. Critical to a DM program is the ability to measure and/or model consumptive use and the potential conserved consumptive use. Many of the Upper Division states are implementing field investigations to assess our ability to measure and model these processes. In Wyoming, we have initiated a measurement intensive study with the primary objectives to 1) quantify consumptive use under "normal" irrigation practices, 2) quantify changes in consumptive uses under fallow conditions, and 3) document any changes in vegetation characteristics (e.g., species composition) due to fallowing. The study is being implemented on six irrigated fields across the basin, capturing the regional temperature gradient, and include both flood and sprinkler irrigation, and bottomland and upland fields. The 2022 baseline year shows the consumptive use of the study sites during "normal" irrigation practices. We focus here on one of the*

fields to illustrate the methodologies used to account for the various hydrological components. This is accompanied by an initial comparison of evapotranspiration models to evaluate consumptive use calculation approaches: OpenET (with an emphasis on eeMetric), Large Aperture Scintillometers, Penmann-Monteith, and Evaporation Pan models.

Statistical/Stochastic Hydrology

Evaluating the Accuracy of Soil Moisture Downscaling for a Large Study Region in Northern Colorado

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Abstract. *Fine-resolution (10-30 m) soil moisture maps are useful for many applications, including decision making for off-road vehicle mobility or land management. Satellite remote sensing can be used to estimate soil moisture at coarse spatial resolutions (>1 km). However, these coarse-resolution estimates must be downscaled to produce useful fine-resolution soil moisture maps that capture the spatial variability of soil moisture conditions across large regions. The Equilibrium Moisture from Topography, Vegetation, and Soil (EMT+VS) model downscales coarse-resolution soil moisture estimates based on fine-scale datasets of topography, vegetation, and soil. Previous studies have assessed how downscaling methods perform over small catchments, but downscaling methods have not been adequately tested over large regions with greater spatial variability. The objective of this study is to test the EMT+VS soil moisture downscaling method at Maxwell Ranch, a 4,000-ha cattle ranch located in northern Colorado. To evaluate the fine-scale EMT+VS soil moisture estimates, in-situ surface soil moisture observations were collected for 10 summer dates at 86 locations using HydraProbe sensors. These locations were selected to capture diverse conditions across Maxwell Ranch, including variations in slope, aspect, contributing area, and vegetation cover. In the EMT+VS model, Soil Moisture Active Passive (SMAP) satellite data were used to estimate coarse-resolution average soil moisture across the ranch, and fine-resolution data for topography, vegetation, and potential evapotranspiration were applied to inform the downscaling algorithm. Model parameters were either calibrated or estimated based on available data. Fine-resolution estimates from the EMT+VS output are compared with summer field data at respective dates and point locations. Performance metrics including Nash-Sutcliffe coefficient of efficiency (NSCE) and root-mean-squared error (RMSE) are calculated to quantify model performance. EMT+VS fine-scale soil moisture patterns exhibit substantially more spatial variability and provide more accurate estimates of point soil moisture than the coarse-resolution input.*

Enhancing Community Resilience through Better Flood Hazard Communication: The Role of the Flood Potential Portal

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Abstract. *Understanding the expected magnitude and observed variability of floods in the United States is crucial to creating more resilient communities and safeguarding lives, property, and infrastructure. However, traditional flood frequency analyses have shortcomings for making predictions, accounting for*

observed trends, and effectively communicating flood hazards to practitioners, decision-makers, and the public. To address this challenge, a web-based decision support system called the Flood Potential Portal (https://floodpotential.erams.com/) has been developed. This map-based tool utilizes a novel flood prediction technique known as the flood potential method, as well as established flood frequency analyses such as USGS regional regressions and index-flood methods, to predict flood discharges at user-selected points of interest. The flood potential method quantifies the central tendencies of record peak discharges at streamgages within zones of similarly-experienced large floods. By introducing the term "expected flood potential", the Portal offers a clear and intuitive means of communicating the flood magnitudes that are generally expected based on maximum recorded streamgage floods in nearby watersheds. This terminology serves as a complementary alternative to the standard but frequently confusing terms "100-year" or "1% chance of exceedance" flood. In addition, the Flood Potential Portal features various indices and products for comparing flood hazards within and between zones, systematically identifying and ranking extreme floods, and presenting trends in flood magnitude, frequency, and flashiness. The Flood Potential Portal provides practitioners, policymakers, and the public with a comprehensive resource for selecting riverine flood discharges for floodplain planning and infrastructure design, as well as for developing a deeper understanding of how riverine floods vary across space and time in the United States.

Analyzing mixed hydrographs using Rhodamine WT fluorescent tracer releases to separate native and imported irrigation flows.

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Ecosystem Science and management, University of Wyoming

Abstract. *Differentiating flows in mixed hydrographs is a common problem when trying to determine the proportion of flows from varying sources. We used a snow driven mountain watershed in South-East Wyoming (27 km2, 2695m mean elevation) as a case study of using Rhodamine WT to separate the import signals of two irrigation ditches from the native flows in the watershed. Rhodamine releases at varying water levels were used to extract travel time signals from the two ditches at the downstream gauging station across expected flow ranges. Lognormal distributions were used to successfully model the normalized signals of the imports through the system (r2>0.99 on best models) to create unit hydrograph models. A random sampling of the lognormal distribution parameter space produced an ensemble of successful models for each flow. Using a weighted resampling of these successful models, we create 2000 global models (combining all four lognormal parameters) predicting the unit hydrograph as a function of flow. These models are then used for ensemble forecasting of hydrograph separation at the gauging station. While this method shows strong potential at high to medium flows, it breaks down at lower flows due to losses along the reach. Incorporating a loss model based on the Rhodamine recovery rate further improved forecasting results, allowing use even at low flows. By applying these models to real time flow data from the importing ditches, it is then possible to separate the hydrograph for irrigation management decisions, with each of the three components of the hydrograph going to different rights.*

Measuring Nonlinear Dependence and Estimation of Delay Parameters for Attractor Reconstruction of Time Series

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Abstract. The method of delays is widely used for reconstructing attractors from a time series. It requires delay parameters of τ_d (fixed delay time) or $\tau_w = (m - 1)\ \tau_d$ (fixed delay time window) which τ_d is changing as embedding dimension *m* is increased should be estimated for attractor reconstruction of a time series. Often, τ_d is estimated using the autocorrelation function(ACF); however, this does not treat the nonlinearity appropriately, and it may yield an incorrect value for τ_d. On the other hand, the correct value of τ_d can be found from the mutual information(MI) which is rather cumbersome computationally. The researches also suggested τ_w, which is the total time spanned by the components of each embedded point. Unfortunately, τ_w cannot be estimated using the ACF and MI, and no standard procedure for estimating τ_w had emerged. However, the C-C method which can estimate τ_d and τ_w simultaneously was developed. Basically, τ_w is the optimal time for independence of the data, while τd is the first locally optimal time. Therefore, the aim of this study is to introduce and apply the C-C method to hydrologic time series.

On Estimation of Natural Disaster InterEvent Time Definition (NIETD) for Compound Natural Disaster Definition

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Abstract. *Past natural disaster researches have been conducted under assumption that each natural disaster is independent to other natural disasters. However, the assumption has a problem of underestimating the risks of actual natural disasters by ignoring interaction between natural disasters. To solve the problem, the concept of compound natural disaster has been proposed, but there is no quantitative methodology in defining the compound natural disaster. Therefore, this study proposed a methodology for defining the compound natural disaster using InterEvent Time Definition (IETD) method used to separate continuous rainfall event into independent rainfall events. We calculated Natural disaster InterEvent Time Definition (NIETD), a criterion for determining the independence of natural disasters, through the IETD estimation methods, and defined natural disasters as a compound natural disaster if the duration between the natural disasters is less than NIETD. Based on natural disaster cases in South Korea between 2010 and 2019, the study calculated NIETD as 8 days and defined a total of 89 compound natural disasters of 14 different types such as rainfall and rainfall, rainfall and typhoon, and so on. The number of occurrences of the compound natural disasters consisting of rainfall and typhoon was the highest and at the same time, it caused the most damage. The most of victims and deaths was*

occurred by a compound natural disaster of consecutive rainfalls. The proposed compound natural disaster definition and concept could be useful for the future research of compound natural disaster.

Student Showcase & Competition

Is Local Food More Sustainable? Comparing Local Food Production to Conventional Centralized Agriculture in the Contiguous United States Through Life Cycle Assessment

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Abstract. *In recent years, local food production has seen growing interest as a pathway to sustainability. A variety of systems can enable local produce with varying sustainability impacts. Previous research indicates year-round Controlled Environment Agriculture (CEA) like greenhouses can have high environmental impacts due to significant energy intensity. Such studies focus on experimental performance or simulations in particular locations. Expanding beyond these case studies to capture regional variations would enable better stakeholder understanding of sustainability impacts and trade-offs. Our research presents a geographically resolved cradle-to-store life cycle comparison of four lettuce production systems: indoor plant factories, greenhouses, local outdoor cultivation, and centralized cultivation. Combining U.S. DOE EnergyPlus modelling with geographic resolution in climate, grid generation mix, and water scarcity, we estimate the global warming and water impacts of CEA lettuce production across the contiguous United States. Further, utilizing the Food and Agriculture Organization's AquaCrop model, we simulate seasonal soil cultivation of lettuce in the same locations. We compare these results to conventional cultivation and transportation from California, where most US lettuce is grown. Results indicate the average global warming impacts of CEA production are eight times higher than conventional systems. However, an 85% reduction in water footprints suggests energy-water tradeoffs. In contrast, local soil production reduces global warming impacts except where soil conditions greatly reduce yields. Variations in yields and precipitation lead to a range of water footprints for local outdoor cultivation, with most impacts lower than conventional usage. The high climate impacts of CEA systems indicate conventional production is more sustainable; CEA systems would need to improve energy efficiency and decarbonize energy sources. Local seasonal cultivation, meanwhile, can be more sustainable than conventional systems with the right growing conditions. All local production results suggest trade-offs at the water-energy nexus, as the water intensity of the conventional system could incentivize technologies with lower water requirements and locations with less water scarcity. Our results provide geographically resolved comparisons of local vs. centralized food production and can facilitate food-energy-water decision-making on emerging food production systems.*

Mad for Manure: How Precision Management of Nutrient Flows Can Mitigate Environmental Impacts of Manuresheds

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Abstract. *Manure fertilizer from livestock is a staple in getting nutrients to plants and soil. Annually, the U.S. produces up to 1.4 billion tons of manure, which serves as a cheap source of fertilizer for crop production (Pagliari, 2020). While manure is beneficial in many ways, it's received a negative reputation for its environmental impacts. Biological outputs associated with livestock manure include greenhouse gas emissions, leaching, and runoff that effect air quality, water quality, biodiversity, and soil health. In Colorado, a knowledge gap exists in managing livestock manure to effectively mitigate nutrient losses after application, creating a need to evaluate manure management practices that may reduce the state's environmental impacts associated with agriculture production. Variable rate manure application is one practice that has been done manually in the past, however, technology now exists that uses near infrared spectroscopy (NIRS) to adjust application rates in real time based on nutrient availability in the manure and plant nutrient needs. NIRS presents a novel solution for manure management that is highly sensitive and provides robust data. Additionally, manure application using NIRS increases precision of application while decreasing labor and time necessary for adequate fertilization of fields. This research uses the HarvestLab 3000 by John Deere and its new manure constituent system to validate if precision application of manure fertilizers compared to more traditional application methods can reduce environmental impacts associated with manure. The objectives driving this research are to 1) assess the capabilities of precision manure management technology that uses NIRS to mitigate nutrient losses from application of dairy cow manure on Colorado crop production fields and 2) conduct a return on investment and cost-benefit analysis for implementing this precision manure management technology for dairy and crop producers. When manure is managed properly it provides a valuable source of nutrients that can increase soil health and ecosystem biodiversity, provide economic prosperity, and influence policy or regulations surrounding sustainable food production. Pagliari, P., Wilson, M., He, Z. (2020). Animal manure production and utilization: impact of modern concentrated animal feeding operations. In: Waldrip, H.M., Pagliari, P.H., He, Z., editors. Animal Manure: Production, Characteristics, Environmental Concerns and Management. ASA Special Publication 67. Madison, WI: ASA and SSSA. p. 1-14. https://doi.org/10.2134/asaspecpub67.c1.*

GMO-Free Territories and the Defense of Traditional Seed Systems

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Abstract. *The controversies surrounding Genetically Modified (GM) seeds have intensified in the last decades. However, the regulation of their production, distribution, consumption, etc. varies from country to country and even between different sub-state territorial units within the same country. In fact, the beginning of the twenty-first century saw the emergence of an evolving process of different communities, regions, zones, municipalities, indigenous reserves, etc., different territorial entities, declaring themselves to be GMO-Free Territories. Such territories are described as: An area cultivated or*

not, where those who exercise control, individually or collectively, prevent the planting, use, or consumption of GMO seeds and foods. It is a preventive measure to protect native and local seeds, avoid genetic contamination, maintain conventional and organic agriculture, recover traditional knowledge, maintain healthy food, protect natural ecosystems from agrochemicals, strengthen regional and local food sovereignty, etc. Throughout Colombia, as of 2022, there are nine indigenous reservations and two rural municipalities declared as GMO-Free Territories. The construction of these territories as GMO-Free has included the development of seed houses which defend local community economies by maintaining autonomous seed production and distribution systems. Additionally, agro-ecological practices, the suppression of pesticide use, the promotion and recovery of traditional knowledges, local mechanisms for democratic participation, the sharing of best practices across territories, and forming national and international networks have been important actions. A GMO-Free Territory is an effort to materialize self-determination. It gets at the fundamental rights of farmers, indigenous communities, afro-descendant communities, and more. They are claiming the rights to decide how their lands and resources are managed. It is an effort at territorializing certain valuations of agrarian production, intellectual property, traditional knowledges, democratic participation, etc. Much is to be learned about the processes and the mechanisms involved in the development of GMO-Free Territories as strategies to defend livelihoods, culture, biodiversity, autonomy, etc. How did this dynamic process of the declaration and construction of GMO-Free Territories come about?

The Relationship Between Portable Toilets in Construction and Sustainability Metrics

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Abstract. *The construction industry in the United States is growing, and nearly every jobsite in the US utilizes portable, chemical toilets (commonly called porta-potties) for workers' primary sanitation requirements. Construction projects traditionally utilize these toilets for the duration of the project even though site utilities, including water and sewer, are traditionally the first component of construction. Despite the prevalence of portable chemical toilets, no research has considered the social, economic, and environmental aspects of the use of these toilets for workers and the surrounding communities. This research analyzes how 1. portable chemical toilets compare to flushing toilets from an environmental perspective, 2. municipal policies and alternative cost options affect construction sanitation choices, 3. these toilets impact construction workers' wellbeing, job satisfaction, and productivity, and 4. innovative policies could affect construction sanitation sustainability metrics. A water footprint and life cycle analysis will compare flushing toilets to portable toilets environmentally while a qualitative worker survey will analyze the impacts of these toilets on construction workers. Preliminary work suggests that outcomes could include a detrimental environmental impact from a life cycle perspective for these toilets over flushing toilets, and that worker wellbeing, productivity, and water use could be improved through municipal regulations on construction sanitation. This work includes significant potential to benefit workers physically and mentally and communities environmentally, and the research includes policy development for widespread implementation of sustainable toilet options for construction workers.*

Participatory models of regenerative urban infrastructures as complex adaptive social-ecological-technological systems

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Abstract. *Modern societies are situated within complex social, ecological, technological environments where humans act as "interconnected and omnipresent ecosystem engineers." Human activities have altered physical environments and ecosystems in nearly every corner of the globe, and modern quality of life is shaped by increasingly complex human-environment interaction. Increasingly confronted by "wicked challenges" resulting from an unprecedented convergence of disruptive forces and highly uncertain social, technological, and environmental futures, these pressures are reshaping urban life and exposing critical vulnerabilities in engineered infrastructure systems responsible for regulating metabolic flows, guarding against physical and biological hazards, and promoting social and emotional wellbeing. Preparing human society to adapt to and through complex and uncertain futures requires a paradigm shift in how infrastructure is designed, built, and managed to reposition built environments as multifunctional spaces of social and ecological regeneration. Drawing insights from transdisciplinary fields of urban ecology, environmental sociology, and systems science, this research identifies restorative functionalities needed to initiate and sustain infrastructure transformations towards living systems-of-systems. Informed by a relational understanding of human-environment interactions, we describe an alternative design paradigm for regenerative social-ecological-infrastructure systems, and frame a research agenda to address critical knowledge gaps and facilitate community-led transitions to regenerative futures through innovative stakeholder-driven methods, including collaborative design, participatory modeling, and citizen science.* *This material is based upon work supported by the National Science Foundation under Grant No. 1828902.*

Urban Scaling Patterns in Municipal Water Uses

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Abstract. *Urban scaling theory proposes that as a city grows and densifies over time, per capita usage of materials and energy, and cost of developing infrastructure reduces. In general, when city attributes, like, number of patents or inventions, crime rate, road infrastructure and energy use per capita, etc., are regressed with the corresponding city population over time, the trends can be linear, sub-linear or super-linear. It has been observed that city crime rate has a super-linear relationship, while the per-capita cost of developing transportation network has a sub-linear relationship with the city size. In this study, scaling theory is applied to the municipal water uses within the Contiguous United States, and the relationships between different water use metrics and city attributes are explored. Preliminary results show a decreasing linear relationship between city-level annual total water uses and city population over time, and interestingly, the slope of these trends uniquely vary across different eco-hydrological regions. Consequently, the gallons per capita of total water use metric when regressed over time shows a strong*

sub-linear relationship. This indicates that per capita water use in the urban United States is becoming smaller or more efficient over time. Therefore, given the increase in population and competition for natural resources amidst climatic variations, this study will be crucial for city planning and policy making that ties community resilience, technological advancements, and socio-economic equity with water resources sustainability.

Comprehensive characterization of oil-field produced water treated by nanofiltration and reverse osmosis membranes for potential reuse in agriculture

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Abstract. *Unconventional oil and gas (UOG) produced water is formed when water that exists in shales is mixed with water that is injected by the oil and gas company into the well itself. Currently, the UOG produced water is primarily managed via deep well injection, which can cause increased seismicity and groundwater contamination. Treatment and reuse of UOG produced water has grown in interest in order to address both water scarcity and pollution caused by oil and gas production. Due to the complexity of the produced water composition, it is challenging to treat produced water for potential reuse. In order to properly understand the efficacy of treatment options like reverse osmosis (RO) and nanofiltration (NF) membranes and the possibility of reuse, we measured various inorganic and organic constituents before and after treatment using numerous analytical techniques along with measuring toxicity on Daphnia magna via LC50 tests for 48 hours. A comprehensive characterization of the UOG produced water is required to better understand the feasibility of treated produced water for beneficial reuse, for example, internal industry reuse, crop irrigation, and livestock irrigation. The results showed that NF membranes could not treat the UOG produced water to a level that was acceptable for irrigation. RO membranes showed a reduction in toxicity, along with other pollutants. The RO membranes were able to meet most irrigation requirement, except chloride and boron, which remained above the typical irrigation levels. Some surfactants whose molecular weights were much larger than the molecular weight cut-off of membranes were able to pass through the membrane, indicating that membranes were not able to be perfect barriers for organic constituents. The results demonstrated that thorough and comprehensive analytical techniques and tests need to be completed in order to understand feasibility and potential risks of using treated UOG produced water for beneficial reuse.*

A Climate-Centered Analysis of Historical Australian Streamflow and Population Density From 1980-2019

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Abstract. *Australia is the driest inhabited continent in the world. 70% of its area is made up of arid regions and 80% of the country's 26 million people live within 50 kilometers (30 miles) of the coast. Little is known about how climate affects streamflow in Australia, yet its cities rely on surface water for most of their water supply. We summarize the past 40 years (1980 to 2019) of streamflow and population data to develop a series of maps displaying ten-year mean hydrographs for the country's thirteen river regions. Preliminary results found that Australia's monsoon-dominated northern regions have the highest mean monthly discharge in the country, indicating that rainfall may be the leading driver of streamflow. We also found that irrigated and densely populated basins ranked higher in median monthly discharge than mean monthly discharge, suggesting that agriculture may improve infiltration and lead to a slower, more consistent release of groundwater into river systems. Lastly, we observed a six-month shift in peak discharge from the northern coast of the country to the southern coast, which could be explained by differences in the timing of climate systems that deliver precipitation to each region. The connection between streamflow and regional climate drivers suggested by our preliminary results indicates that the future of Australia's surface water resources and the decisions that will be required by water managers are closely tied to climate change.*

Past, Present, and Potential Future Flows of a Non-Perennial Stream

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Abstract. *Despite the recognizable impacts urbanization has on stream morphology and flow patterns, there are many challenges when it comes to accurately predicting and quantifying these impacts. This is especially true for non-perennial streams in semi-arid rangelands. Non-perennial streams tend to lack complete records for streamflow presence and absence. Quantifying how stream channels change in developing landscapes can be problematic without a historical pre-development baseline to compare to. This project focuses on a non-perennial stream channel in West Stroh Gulch, located in Parker, Colorado, an area south of Denver, U.S.A. West Stroh Gulch is a semi-arid rangeland slated to undergo housing development within the next few years. Stream presence and absence is recorded at multiple locations along the stream network with time-lapse photography. Recorded precipitation events and corresponding photos are reviewed to quantify what storm intensities and cumulative depths do, or do not, trigger a flow response. Additional visual observations including soil moisture, standing water, and snow cover are recorded. After more than two years of field camera monitoring, one precipitation event with a total depth of 92-mm and maximum intensity of 50-mm per hour triggered streamflow in the channel. In comparison, there were 79 other rain events with depths ranging from 1-mm to 44-mm and intensities from 1-mm per hour to 34-mm per hour that did not lead to flow. Time-lapse observations will*

continue through the stages of development to capture future stream channel responses to precipitation events and a changing landscape. In addition to continuing time-lapse photography observations, a hydraulic model of the watershed will be built. Topographic pre-development data collected with drone flyovers is used to construct a DEM (Digital Elevation Model) surface of the watershed. This pre-development DEM surface will be combined with SWMM generated post-development flows in the hydraulic model to predict post-development changes to the channel morphology. Model predictions can be compared with actual channel changes over time. Combining model predictions with ongoing observations will create a valuable case study of predicting pre to post development changes in a semi-arid rangeland's non-perennial stream.

Predicting Soil Texture Using 1-D Convolutional Neural Networks based on Field Hyperspectral Images

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Abstract. *The particle size distribution of soils is used to classify the soil into texture-based categories. However, the determination of soil particle size distribution using laboratory procedures can be costly, time intensive, and is often impractical across large spatial regions. While soil data products, such as the Soil Survey Geographic Database (SSURGO), can be used for geospatial analysis, many modeling applications require higher fidelity soil texture information. Hyperspectral images contain information on a material's reflectance at various wavelengths in the visible and near-infrared parts of the electromagnetic spectrum. Supervised machine learning models have shown promise for predicting soil texture from hyperspectral images captured in laboratory (controlled) environments; however, the prediction of soil texture using field hyperspectral images is less certain. The objective of this study is to better understand how one dimensional convolutional neural networks can be used to predict soil texture from field captured hyperspectral images. A published convolutional neural network modeling procedure for laboratory soil classification is adapted to predict soil texture based on field captured hyperspectral images. The field imagery was captured at two field sites located in Northern Colorado by passive hyperspectral cameras at semi-vegetated locations. Soil samples were collected at each imaging location, classified using laboratory procedures, and used to evaluate model performance. Results of the field adapted convolutional neural network indicate that field captured hyperspectral images may be viable for the prediction of soil texture for large scale modeling procedures.*

Morpho-dynamic Processes in the Bernalillo Reach of the Middle Rio Grande

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Abstract. *This study was performed for the USBR to evaluate morpho-dynamic processes within the Bernalillo Reach of the Middle Rio Grande (MRG), which spans 16 miles from Highway 550 to the Montaño Bridge in Albuquerque, New Mexico. The Bernalillo reach was subdivided into 4 subreaches (B1,*

B2, B3, and B4) for this analysis. The MRG is a dynamic river that is still responding to anthropogenic impacts over the last century. Anthropogenic changes impacting the Bernalillo reach include the Cochiti dam completion along the MRG in 1973 (located 24.5 miles upstream of Highway 550) and construction of the Jemez dam along the Rio Jemez in 1953 (5 miles upstream) in addition to channelization, levee construction, urban development, and changes in channel maintenance activities. This analysis illustrates spatial and temporal trends of channel geometry and morphology by evaluating aerial imagery between 1918 and 2021 and channel geometry for 5 years between 1962 and 2012 (1962, 1972, 1992, 2002, and 2012). Channel geometry shows 3-8 feet of channel degradation in the two upstream-most subreaches (B1 and B2) and an average decrease in channel width from 1,100 feet in 1918 to 290 feet in 2019. A geomorphic conceptual model, developed by Massong et al. (2010), was used to interpret channel planform and profile changes over time. An overall trend of the channel degrading and progressing from wide and braided towards a single thread meandering (M) planform between 1972 and 2012 indicates that this reach has excess transport capacity. This has led to coarsening of the bed, increased flow conveyance within the channel, and greatly reduced floodplain connection at lower flood events (>3,000 cfs), which has implications to the endangered Rio Grande Silvery Minnow habitat. This planform shift is likely driven by changes to the sediment loads and peak flow events influenced by anthropogenic factors, and most notably by Cochiti dam. The reach as a whole follows a similar trend whereby the channel classifies as Massong Stage 1 (wide and braided) throughout the early- to mid-1900s and transitions towards Stages M4 and M5 (narrow, straight, and single-threaded) planform in the 1990s and 2000s.

Middle Rio Grande Montaño Reach: Morphodynamic Processes and Silvery Minnow Habitat

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Abstract. *The Middle Rio Grande (MRG) traverses through an urban corridor in New Mexico, spanning 190 miles from Cochiti Dam to Elephant Butte Reservoir. Over the last century, anthropogenic impacts (dams, levees, river straightening) have significantly impacted the river ecosystem, especially the endemic and endangered Rio Grande Silvery Minnow (RSGM). The Montaño reach of the Middle Rio Grande spans approximately 19 miles through Albuquerque, NM. The objective of this research is to summarize the flow and sediment regimes and relate these morphodynamic conditions to estimate available RSGM habitat in the Montaño reach. River straightening techniques were implemented for flood control in the 1950s. Historical aerial imagery, maps, and survey data quantify changes in the average channel width (defined by vegetation). From 1918 to 1962, the width decreased from 1470 ft to 500 ft. The construction of Cochiti Dam (1973), in addition to diversion and tributary dams, further reduced the magnitude and frequency of large flow events and the natural sediment supply to the MRG. Subsequently, the channel continued to narrow from 1962 to 2019, to an average of 375 ft. HEC-RAS models were used to process survey data from 1962, 1972, 1992, 2002, and 2012 LiDAR and determine the changes in the channel bed elevation. The Montaño reach aggraded ~1 ft from 1962 to 1972. The channel incised ~2.5 ft from 1972 to 2002. The channel aggraded ~1 ft from 2002 to 2012. The narrowing and incision experienced in this reach emphasize the transition from a naturally wide and braided system*

to a more narrow and deep single-thread system that occurred. One-dimensional hydraulic models (HEC-RAS) were used to estimate the velocity and depth variations across each cross-section for a range of flow rates up to 10,000 cfs. The results were filtered through RSGM velocity and depth criteria to quantify the hydraulically suitable habitat. More hydraulically suitable habitat is available for all life stages of the RSGM before Cochiti Dam (pre-1973) across all the flows except for 10,000 cfs. For example, ~4.5 million sq. ft/river-mile in 1972 versus ~0.5 million sq. ft/river-mile in 2012 at 4,000cfs for the juvenile life stage.

Middle Rio Grande River Hydraulic Modeling: A comparison between 1D and 2D hydraulic modeling and the impacts to quantifying Silvery Minnow Habitat in the Bernalillo Reach of the Middle Rio Grande River.

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Abstract. *This study was done in conjunction with a larger Bernalillo Reach Report (Radobenko and Corsi, 2023) that was prepared for the United States Bureau of Reclamation (USBR) that presents a summary of the morpho-dynamic processes within the Bernalillo Reach. The Bernalillo Reach spans approximately 16 miles of the Middle Rio Grande (MRG), from the Highway 550 Bridge to the Montaño Bridge crossing in Albuquerque, New Mexico. The MRG has been affected by continual human development/agriculture. Levees and channelization efforts have been constructed through the reach for flood control. These efforts have impacted the habitat quality and quantity that is available for the endangered Rio Grande Silvery Minnow (RGSM or silvery minnow) which is native to the Middle Rio Grande. One-dimensional hydraulic models, developed with Hydrologic Engineering Center's River Analysis System (HEC-RAS) software, estimated habitat availability for the endangered Rio Grande Silvery Minnow (RGSM) within the Bernalillo Reach. A previously developed width-slice method in HEC-RAS was applied to calculate the hydraulically suitable RGSM habitat based on flow velocity and depth criteria for the larval, juvenile, and adult stages at various discharges. Detailed mapping for year 2012 was performed based on detailed LiDAR data to illustrate the RGSM habitat areas within the Bernalillo Reach. Due to the nature of procedure used to create these "pseudo" 2D habitat maps, several sections of the floodplain show areas that meet the RGSM velocity and depth criteria but remained disconnected from the main channel. A 2D hydraulic model using SRH-2D was used to compare the accuracy the disconnected areas and the assumptions made in the 1D model. When quantifying the silvery minnow habitat availability, the pseudo 2D mapping created by the 1D HEC-RAS model resulted in an underestimation of the habitat availability for all life stages. For example, at 1,500 cfs, the HEC-RAS model predicted about 40 acres less of adult habitat. However, the relative increases and general locations of available habitat followed similar trends between the 1D and 2D models for all of the life stages. These generalized locations of habitat availability could help river managers and biologists identify locations of future river restoration efforts.*

A Spatiotemporal Analysis of the Correlation Between Snow Water Equivalent and Baseflow in Colorado

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Abstract. *Baseflow is the primary source of water in snow-dominated watersheds for most of the year after the high-volume melt period has passed. The Colorado Front Range relies on low flows that result from late spring and early summer snowmelt for municipal, agricultural, and recreational purposes. Changes in the timing and amount of snowmelt due to climate change will impact water availability for millions of people on the Front Range. This study seeks to find the correlation between winter snow water equivalent (SWE) values and subsequent baseflow characteristics, including any yearly lag between the two variables. Streamflow data from US Geological Survey stations and SWE data from Natural Resource Conservation Service SNOTEL stations were examined for drainage basins of varying latitude, elevation, and area across Colorado. In snow-dominated ecosystems, the hydrograph shows a well-defined peak when snowmelt occurs in the spring that is followed by low flows in the fall and winter months. The traditional water year (WY, in the US October 1 through September 30) separates peak melt and baseflow into two different WYs. To reflect the hydrologic processes that are occurring in snow-dominated watersheds, we propose using a melt year (MY) beginning with the onset of snowmelt (the first deviation from baseflow) and ending with the onset of the following year's snowmelt. We identified the beginning of a MY and extracted the subsequent baseflow values using flow duration curves (FDC). This is a dynamic approach to analyzing the correlation between peak SWE and baseflow.*

A Social-Climatological Study of Snow and Winter Weather Perspectives

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Abstract. *As the interdisciplinary expansion of conservation research between social science and natural science continues, the need for social awareness is becoming more prevalent as climate change impacts are increasing. Over the past decade, three surveys were conducted to gauge how citizens of the Front Range identify with snow and winter, specifically inter-annual differences and trends in temperature and precipitation patterns for both the Front Range and the mountains. Surveys were administered in April 2012, 2021, and 2022 to the citizens of the Front Range of Colorado. Weather station data from three different stations were used to represent the mountain winter weather and the Fort Collins weather station was used to represent the Front Range. Overall, people tended to not have an extensive understanding of winter weather and snow, regardless of how long they had lived in the area, whether they participated in winter recreation, age, or what sources they used to obtain weather information. However, those that identified as women tended to have a better understanding of snow and winter weather conditions. We conducted this research to better understand individuals' perceptions of climate change and to gauge how attuned they are to changes within their environments. This type of information should inform social scientists, conservationists, and other researchers about the public's*

understanding which will improve communication regarding science and scholarship to the public. By better understanding our audience we will be better able to implement solutions that have legacy effects, create educational programs that are comprehensible and contain relevant context, and be better collaborators across disciplines.

Assessing Aquifer Properties and Groundwater Storage Change in the San Luis Valley, Colorado from In-Situ and InSAR Data

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Abstract. *The growing demand for food due to increasing population has led to expanded and intensified agriculture, resulting in higher irrigation needs. Groundwater is a crucial source of irrigation water. Increased irrigation demands and droughts driven by climate change are leading to depletion of groundwater levels, putting future water availability at risk. This is particularly concerning for regions with limited precipitation where crop production heavily relies on irrigation during growing seasons. Lowered groundwater levels can lead to reduced crop yields and negatively impact the surrounding ecosystems as well. To address these challenges, sustainable water management practices are needed to balance the needs of agriculture with ecological protection. In this study, we assessed the relationship between groundwater extraction, changes in water levels, and aquifer storage in the San Luis Valley, Colorado. We found a linear relationship between the average annual change in head and annual groundwater extraction and used this to determine aquifer storage properties. We also compared the change in groundwater storage determined from in-situ data with the ground subsidence measured by satellite interferometric synthetic aperture radar (InSAR) observations. Ultimately, this study can help determine the safe yield necessary to maintain a balance between pumping and recharge to keep the water levels stable. It can be used to maintain aquifer sustainability and develop viable water management practices in heavily irrigated areas like the San Luis Valley.*

Analyzing Trends in Groundwater Storage and in Salt and Nutrient Concentrations in Surface Water and Groundwater Bodies in the United States from 1920-2020

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Abstract. *Groundwater is a vital source of water for agricultural, domestic, and industrial use in the United States, but quantifying fluctuations in groundwater storage over time is difficult, especially in large regions. In addition, few datasets exist of temporal changes in salt and nutrient concentrations for both surface water and groundwater bodies across the United States. Fortunately, a significant amount of groundwater storage measurement data is readily available through the United States Geological Survey, and an impressive number of salt and nutrient concentration measurements are made available*

through the National Water Monitoring Council's Water Quality Portal. In our study, we couple data retrieved from the USGS with ArcGIS geoprocessing methods to outline trends in groundwater storage using data from wells in unconfined aquifers. In addition, we investigate trends in the concentrations of eight salts (calcium, chloride, magnesium, potassium, sulfate, sodium, carbonate, and bicarbonate) and two nutrients (nitrate and phosphorus) in surface water and groundwater bodies across the United States. To determine whether each USGS well lies in an unconfined aquifer, well depth data and national raster maps of land surface elevation and unconsolidated sediment thickness are used, resulting in 356,785 wells with measurement data over the period 1920-2020. Groundwater head, aquifer saturated thickness, and water table depth measurements are averaged temporally, by decade, and spatially, according to the 2,139 8-digit hydrologic unit code (HUC8) subbasins in the conterminous United States. Salt and nutrient concentration data is filtered to contain measurements only for our eight salts and two nutrients of study, and measurements are then converted to units of milligrams per liter and sorted by year. Temporal averages for each individual salt and nutrient are calculated, and ArcGIS shapefiles are generated for each salt and nutrient according to the surface water or groundwater source type (e.g., springs, groundwater wells, and lakes and reservoirs). The results of our trend analysis depict spatiotemporal trends in water quality and groundwater storage. These trends can be used to guide surface water and groundwater remediation efforts and can aid in improving sustainable water management practices at a local, regional, and national scale.

Geomorphic influences on salmonid recolonization in a Colorado post-fire environment

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Abstract. *Little Beaver Creek (LBC) is a third-order tributary within the Cache la Poudre River basin in the Colorado Front Range, USA. In 2020, the Cameron Peak Fire ignited and continued to burn through late October 2020 in the LBC watershed. Rugged terrain and beetle-killed forests in the fire perimeter made it difficult to suppress the burn and contributed to the large percentage of high severity burn areas. Before the fire, LBC had ongoing research on water quality, wood dynamics, historic beaver-influenced valley morphology, and hyporheic exchange. Although this research has continued to monitor post-fire conditions, little has been done to understand the relationship between conditions and salmonid recolonization. LBC contains high quantities of relic beaver dams which create obstructions where wood and sediment are readily captured. These areas develop anastomosing channels which return to single thread in the interim reaches. My work will synthesize previous research with a complete census of channel adjustments, hydrologic connectivity, habitat heterogeneity, and salmonid abundance (Salvelinus fontinalis and Salmo trutta) to understand the relative importance of heterogeneity on success after a major disturbance. We show that the presence of geomorphically heterogenous reaches increases the spatial scale and distribution of habitat refugia for salmonids and increases resilience for the whole system. Due to retention of fire related inputs, preliminary results show these areas are providing new habitat, corroborated by higher abundance of fishes at these sites, as well as overall*

geomorphic stability in the face of watershed adjustments. These trends are seen even while overall simplification and habitat loss is seen in other locations in the system. Not only are third-order streams important to the health and quality of downstream rivers, but trends show that large fires will become more common in Colorado. Prolonged drought, increased impacts on forests, increased water demand, and regional warming from climate change will continue to put pressure on already sensitive river systems and salmonids. If we can show that the preservation of functioning, heterogenous reaches has a positive impact on watershed and salmonid recovery post-disturbance, then we will provide insight for management of watersheds that directly increases resilience.

Evaluation of sub-hourly Quantitative Precipitation Estimates in Colorado's mountains using machine learning

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Abstract. *Precipitation gauge networks are often sparse or nonexistent in mountainous regions, resulting in a problematic data gap when accurate local precipitation data is required. Quantitative Precipitation Estimates (QPEs) derive precipitation from remote sensing data as well as climate models and have been used where ground observations are lacking. These datasets are spatially continuous but are subject to various sources of measurement error, especially in complex terrain. In recent decades QPEs have been improving in accuracy and resolution, but performance evaluations are limited to specific regions and events. The Multi-Radar Multi-Sensor (MRMS) product incorporates radar, climate model, and gauge data at a high spatiotemporal resolution for the contiguous United States. The goal of this study is to provide a framework for predicting the performance of MRMS where no gauges exist. Additionally, we identify the most important drivers of performance and present the spatiotemporal variation in performance. Using precipitation gauges throughout the mountains of Colorado, we compare MRMS and gauge 15-minute intensity time series and label each sample as "good" or "bad" matches based on relative error in peak intensity and total accumulation. For each sample, various features are calculated from the topography, surrounding storm, and point rainfall. Several types of machine learning classifiers are trained for comparison using the labels and features. A gradient boosting classifier was able to identify patterns which produce a quality match to ground truth with high predictive power. This classifier was used to evaluate drivers in performance and predict where, when, and how often MRMS is expected to match gauge values throughout the mountains. The results suggest that machine learning algorithms are useful in evaluating performance of complex datasets.*

Urban Water Systems

An Introduction to a Comprehensive Self-Assessment Framework and Rating System for One Water Cities

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Abstract. *Urban water systems around the world are facing several environmental and societal challenges. To mitigate these pressures, a transition from traditional water management systems to a more integrated approach is crucial. This new approach, known as "One Water," is being strategically explored and implemented around the globe. Although several sustainability frameworks have been developed so far, there is not yet an established self-assessment framework to support the transition to sustainable, resilient, and equitable urban water systems. This study, therefore, presents the One Water Cities (OWC) self-assessment framework that provides opportunities for utilities to develop a coherent One Water vision, attainable goals, strategies, and monitoring plans to assess progress across collaborating organizations. The suggested framework encompasses a broad set of outcome-oriented indicators to measure progress toward implementation of the One Water approach through different levels (Onboarding, Progressing, and Advancing) by which cities can evaluate their One Water strategies, practices, and outcomes against appropriate expectations of performance. These assessment indicators are organized based on the OWC key elements, which represent information gleaned from a broad review of One Water literature, targeted expert interviews with progressive utilities, and a national survey of water stakeholders. Furthermore, the OWC self-assessment framework includes five categories (One Water Planning, Organizational Culture, One Water Planning, Stakeholder Engagement, Informed Actions, and One Water Monitoring) within which clear expectations are defined. These categories enable cities to appropriately assess their level in their One Water journey and pave the transient path to the next level. The final product will help water managers and authorities to overcome barriers and enable them to benchmark and measure their progress toward the One Water paradigm shift.*

Streamlining Scheduling: How Python Transforms Water Balance Modeling and Evapotranspiration Estimation

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Abstract. *Water balance models are useful tools for irrigation scheduling and estimation of water use, but they vary in complexity. Typically designed for a single field or plot, water balance models often fail to account for spatial variability of soils and crop status. In an effort to address this challenge, the USDA-ARS Water Management and Systems Research Unit developed and utilized a spreadsheet-based daily*

water balance model to assist in irrigation experiments and quantification of crop evapotranspiration (ETc). Although the spreadsheet-based water balance model provides a vital tool to the Unit, the spreadsheet environment makes it labor-intensive to maintain and troubleshoot the model. Consequently, the Unit began transitioning the soil water balance model to a Python-based environment by contributing to the development of pyfao56. Pyfao56 is an open-source Python package designed to run daily soil water balance models conducive to the Python-programming language, which makes troubleshooting and innovating the model more straightforward. This presentation provides insight into the Unit's transition from the spreadsheet-based model to a Python-based model for soil water balance and water-use estimation. In particular, I will demonstrate how to use the pyfao56 Python package to maintain a daily soil water balance that closely adheres to the methodology outlined in Irrigation and Drainage paper No. 56 of the Food and Agriculture Organization of the United Nations (also known as FAO-56). The ultimate goal of the presentation is to show the ways that continued development of pyfao56 can eventually lead to the creation of water balance models with better spatial resolution and assimilation of observed data.

Participatory models of regenerative urban infrastructures as complex adaptive social-ecological-technological systems

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Abstract. *Modern societies are situated within complex social, ecological, technological environments where humans act as "interconnected and omnipresent ecosystem engineers." Human activities have altered physical environments and ecosystems in nearly every corner of the globe, and modern quality of life is shaped by increasingly complex human-environment interaction. Increasingly confronted by "wicked challenges" resulting from an unprecedented convergence of disruptive forces and highly uncertain social, technological, and environmental futures, these pressures are reshaping urban life and exposing critical vulnerabilities in engineered infrastructure systems responsible for regulating metabolic flows, guarding against physical and biological hazards, and promoting social and emotional wellbeing. Preparing human society to adapt to and through complex and uncertain futures requires a paradigm shift in how infrastructure is designed, built, and managed to reposition built environments as multifunctional spaces of social and ecological regeneration. Drawing insights from transdisciplinary fields of urban ecology, environmental sociology, and systems science, this research identifies restorative functionalities needed to initiate and sustain infrastructure transformations towards living systems-of-systems. Informed by a relational understanding of human-environment interactions, we describe an alternative design paradigm for regenerative social-ecological-infrastructure systems, and frame a research agenda to address critical knowledge gaps and facilitate community-led transitions to regenerative futures through innovative stakeholder-driven methods, including collaborative design, participatory modeling, and citizen science.* *This material is based upon work supported by the National Science Foundation under Grant No. 1828902.*

Estimation of Stormwater Microbial Contamination to Help Develop Guidance for Stormwater Capture and Use Projects

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Abstract. *Stormwater capture and use (SCU) offers a wide range of benefits; the practice is gaining national attention as an approach to manage stormwater runoff and expand local water supply sources. Despite SCU's benefits, lack of regulatory frameworks and consistent water quality targets serve as barriers to widescale application. The purpose of this research was to summarize and synthesize current research on stormwater microbiological characteristics and estimate the contamination of stormwater with raw sewage (human fecal matter). The human fecal contamination analog (HFCA) was used as an estimate of stormwater contamination with raw wastewater. The contamination analog is defined as a ratio of concentrations of human microbial source tracking markers (MSTs) and potentially human infectious pathogens (PHIPs) observed in stormwater samples collected nationally to those in raw sewage. Human MSTs were identified as the most reliable microorganisms to estimate HFCA, resulting in a 95th percentile estimate of HFCA of 10-1.5 (i.e., 3.2% raw sewage), with a median estimate of 10-4.5 (i.e., 0.0032% raw sewage). The range of the calculated HFCA is consistent with recommendations from 2017 guidance to select a contamination level between 10-1 (i.e., 10% sewage) and 10-3 (i.e., 0.01% sewage; Sharvelle et al., 2017). The HFCA estimates can be applied to select appropriate pathogen treatment targets for SCU projects. Furthermore, a review of existing SCU systems revealed that few apply disinfection processes, and monitoring of SCU projects for removal of microbial constituents is not a common practice. This further demonstrates the need for additional guidance on SCU projects.*

Wildfires & Watersheds

Cameron Peak Wildfire Riverine and Reservoir Water Quality Impacts

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Abstract. *The Upper Cache la Poudre (CLP) River watershed is an important regional drinking water supply to the Colorado Front Range, with over 300,000 users relying on it as a source of water. Drinking water utilities depend on several high mountain reservoirs to capture and store this water during spring's snowmelt and then use it as a major water supply from mid-summer through winter as part of their diversions directly off the Poudre River. In 2020, the Cameron Peak Wildfire burned 209,000 acres of the CLP watershed, including 44% of the headwaters that feed these high mountain reservoirs. Because of the fire's likely long-lasting impacts of elevating nutrient delivery to reservoirs, the fire may exacerbate the occurrence of algae blooms that occur when summer temperatures are elevated, and reservoirs are nutrient rich. We hope to better understand the pre-fire reservoir water quality dynamics that led to algae blooms in the first place, but also identify the true risk of these algae blooms becoming more frequent now that the watershed has been impacted by wildfire. For the last two years, in collaboration with the Rocky Mountain Research Station (USFS), we have conducted a two year sampling campaign of various reservoir, tributary, and mainstem sites of the CLP watershed. This field campaign allows us to analyze trends in water quality focusing on nutrients and other key constituents mobilized post-fire by using a study design that includes reservoirs with varying burn extent and severity. Through our two years of sampling, we have found increased nutrient delivery to both reservoir and mainstem sites after monsoonal rain events and snowmelt. There have also been increases in chlorophyll-a, a measure of algal growth, in reservoirs that burned at a higher extent and severity than unburned. Additionally, this study has shown that increased chlorophyll-a in reservoirs can be propagated downstream into mainstem locations, even in steep headwater regions.*

Estimating changes in water yield and tracking hydrologic recovery in multiple watersheds affected by wildfire

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Abstract. *Concerns about the impact of wildfire on water supply are growing as wildfire and water shortages become increasingly common throughout the American West. Because more than half of the West's water supply is sourced from forested lands under elevated wildfire risk, accurately predicting changes in streamflow following wildfire is becoming increasingly important. To address these concerns, the Ages watershed model was used to estimate changes in water yield and track hydrologic recovery in multiple watersheds affected by wildfire. Six burned watersheds across the western U.S. were studied: North Fork Eagle Creek, NM (2012 Little Bear Fire); Lopez Creek, CA (1985 Las Pilitas Fire); and City Creek, Devils Canyon Creek, East Twin Creek, and Plunge Creek, CA (2003 Old Fire). For each watershed, the*

Ages model was calibrated to fit streamflow for pre-fire conditions. The pre-fire models were applied to the post-fire periods, resulting in daily simulations estimating streamflow for an unburned condition during the post-fire period. The simulation of "unburned" post-fire streamflow (without the impact of wildfire) was compared to observed post-fire streamflow for the same period to provide an estimate of the hydrologic impact of wildfire. Results demonstrate that following wildfire, water yield can noticeably increase for a decade or longer, then briefly decreases, until the watershed finally returns to pre-fire hydrologic behavior.

High Elevation Post-Fire Landscapes on Snow Melt Trends in Seasonal and Transitional Snow Zones

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Colorado State University

Abstract. *Snowpack is one of Colorado's main forms of water storage and availability, and changes in landscape and climate impact the amount of water stored and available as runoff in the spring months. This research explores the relationship between high elevation post wildfire landscapes and the impact which they have on the onset of snowmelt in the spring months. The project focused on key snow dates and zones in relation to burn severity, aspect, and slope, with the main question being: do post wildfire landscapes impact the timing of onset of snowmelt? The main burn area of focus is the Cameron Peak Fire, which was the largest fire in Colorado history. To find the onset of melt date, imagery collected from Sentinel-1 was analyzed for the transitional and seasonal snow zones for one year pre-burn and one year post-burn. After these dates were collected, histograms depicting date for pre- and post-burn were compared to topographic variables.*

Post-fire stream response to rainfall at Bennett Creek tributaries

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Abstract. *Post-fire mulch applications can reduce soil erosion on plots and hillslopes. However, the effects of these mulch treatments on catchment-scale streamflow have not been studied. In this research, we examined whether mulch treatments affected streamflow responsiveness at the catchment scale. We instrumented six adjacent tributary catchments to Bennett Creek within the Cameron Peak fire boundary. Three of the tributaries received post-fire mulch treatments over 23 to 33 percent of their catchment areas, and three were left untreated. We monitored rainfall and stream stage in each catchment in 2021 and 2022. To supplement the rain gauge data, we used the Multi-Radar/Multi-Sensor (MRMS) gridded rainfall product to analyze the spatial variability of convective storms. For each rainfall event, we computed the 60-minute maximum intensity (MI60) rainfall and stream stage response. For summer 2021 and 2022, the tributary MI60s range from 20 to 26 mm hr-1, with averages ranging from 3.1 to 3.3 mm hr-1. Two of the mulched catchments had the largest stream stage response to rainfall (maximum response of 106 cm; average responses of 5.0 and 7.9 cm), whereas two of the untreated*

catchments had limited stream responses (maximum responses of 34 and 35 cm; average responses of 2.5 and 2.6 cm). We tested a logistic regression model to predict the likelihood of streamflow response to rainfall using MI60, Bennett Creek antecedent streamflow, and day of year as predictors. The initial findings suggest that mulch treatments did not affect streamflow responsiveness to rainfall, and other catchment characteristics such as shape, slope, and bedrock geology likely account for the differences in streamflow.

Post Wildfire Flow Resistance: Remote Sensed Data Comparison for 2D Hydraulic Model Calibration in Mountain Streams

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Abstract. *Regions affected by wildfires may experience dramatic flooding in subsequent years. Following large floods, it is often important to characterize the channel response and predict future flow conditions using hydraulic models, but data collection for streams in remote areas that have experienced recent wildfires and floods can be challenging for access constraints and safety concerns. This study provides preliminary guidance for using remotely sensed data to develop and calibrate two-dimensional hydraulic models in recently burned areas. Remotely sensed data allow for minimal time spent on site in dangerous areas affected by wildfire and flooding. Specifically, this study evaluates the applicability of remotely sensed data to develop hydraulic models of stream reaches within two small catchments of the Poudre River basin, Black Hollow and Little Beaver Creek. These watersheds represent endmembers to wildfire response. Specifically, Black Hollow experienced a debris flow in July of 2021 following the Cameron Peak fire of 2020 that resulted in four fatalities, whereas Little Beaver Creek stabilized more quickly due to less severe burn intensity and rapid riparian vegetation recovery. A presented calibration framework exhibits tiers of data collection that correlate to accuracy of model results. In general, the framework recommends approaches for using different collected datasets for two-dimensional hydraulic model calibration for watersheds affected by wildfires. Tier 1 encompasses strictly remotely sensed data. Tier 2 allows for minimizing time on site to conduct salt tracer tests and collect discharge, and Tier 3 involves in-depth data collection of bathymetric survey. This framework aims to assist post-wildfire flood prediction efforts in a streamlined manner for researchers, consultants, and other interested parties.*

Importance of River Beads in Attenuating Floods in Headwater Systems

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Abstract. *Post-wildfire landscapes are susceptible to intense flooding and sediment loads (Moody & Martin, 2001). Current river management often disrupts river-floodplain connectivity, leading to floods that cause immense damage to riverine ecosystems and public infrastructure (Sholtes, 2009; Woltemade & Potter, 1994). However, connected floodplains are able to attenuate floods, preserving infrastructure*

and providing ecosystem services (Dadson et al., 2017; Lane, 2017; Puttock et al., 2017). Within headwaters river corridors, valley geometry can alternate between narrow canyons (sometimes referred to as strings) and wider meadows (referred to as beads) (Wohl et al., 2018). We hypothesize that healthy river beads are disproportionately important for floodwater and sediment attenuation during post-fire flooding (Wohl et al., 2018). Using 2-dimensional hydraulic models, we investigated two different river beads' ability to attenuate flood waters and compared their morphology. The first bead, located on Little Beaver Creek, attenuated 11% of a 2-year return period flood. The second bead, located on Beaver Creek, is heavily incised due to elk overgrazing and beaver extirpation. Hydraulic models of the incised stream showed almost complete containment of the two-year peak flow and only a 5% attenuation. Models of a planned restoration project in Beaver Creek show increases in flood wave attenuation, up to 12% of the 2-year return period flood. The differences in flood wave attenuation between these sites highlights the importance of conserving riparian vegetation and preventing channel incision.

Modeling the Effects of Post-wildfire Rehabilitation Treatments on Hydrology and Nutrient Cycling in Experimental Watersheds in Colorado

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Abstract. *The number of seasonal wildfires and their total burned area has been increasing in Colorado. This trend is mostly driven by climate change, increasing human activities in the urban/wildland interface, and the carryover effects early 1900s forest management. Besides disturbing vegetation, wildfires have both immediate and long-term effects on hydrologic and biogeochemical cycles of forested mountainous areas. Severe fires reduce water infiltration into the soil, causing nutrients and sediments to wash away and compromise the quality of downstream water resources (in addition to creating landslide and flood hazards). After wildfires, agencies rapidly act to minimize nutrient loss and topsoil erosion using different slope-stabilization methods. Surprisingly, the long-term biogeochemical effects of post-fire rehabilitation techniques such as mulching (among the most commonly used) are not well understood. We have applied the Agricultural Ecosystems Services (AgES) distributed ecohydrology model to simulate long-term post-fire nitrogen and hydrological responses at sites affected by the Cameron Peak fire in Colorado. We investigate the influence of post-fire rehabilitation techniques in severely burned areas on hydrology and nitrogen cycling dynamics (e.g. dissolved and total fluxes) by collecting samples and using field measurements from sensor networks in mulched and un-mulched hillslopes to calibrate models, which can be scaled to simulate full watersheds. We have partnered with the US Forest Service (USFS), Colorado State University (CSU), and USDA Agricultural Research Service (ARS) to access previously instrumented and treated sites, as well as sites with ongoing instrument installation and mulch application. This research helps advance hydrologic and water quality modeling and informs agencies of the impacts of best practices in critical zone rehabilitation treatments post wildfire.*

Dammed ponds! Post-fire sediment dynamics in beaver ponds and their contributions to watershed resilience.

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Abstract. *Beaver dams alter the hydrological, sediment, and biotic regimes of riverscapes, yet little is known about how beaver ponds respond to wildfire. Excess sediment generated by wildfires threatens water quality, riparian habitat, and infrastructure. Beaver ponds may contribute to post-fire recovery and watershed resilience by providing sediment storage. We tested the hypotheses that (1) post-fire sedimentation rates exceed pre-fire rates and (2) burned ponds contain higher volumes of sediment compared to unburned ponds. We surveyed 48 beaver ponds in the Colorado Rocky Mountains, approximately half of which burned in 2020 wildfires. We measured water depth and sediment thickness to compute the relative pool volume (percent of total pond volume filled by sediment). We collected sediment cores from 37 of the ponds and analyzed stratigraphy. Charcoal distinguished pre- and post-fire sediments while the time elapsed since fire and pond establishment gave sedimentation rates. Additionally, we assessed each pond's position in relation to the channel and other ponds, and watershed characteristics including drainage area and burn severity. At the pond scale, we documented a significant difference in relative volume ($p < 0.05$) in burned ponds (82%) compared to unburned ponds (56%). Relative volume also varied between young (60%) and old ponds (75%), and actively maintained ponds (48%) and ponds abandoned by beaver (78%). The position of the pond and its surface area did not relate to relative volume. Sedimentation rates were an order of magnitude higher following fire (12.3 cm/yr) compared to pre-fire rates (1.6 cm/yr). Pond sedimentation rates were greater in on-channel ponds (8.7 cm/yr) than off-channel (1.9 cm/yr) and in young ponds (14.3 cm/yr) compared to old (1.96 cm/yr). Beaver activity and pond surface area did not relate to sedimentation rate. Neither relative volume or sedimentation rates related to watershed characteristics including drainage area, percent of watershed burned, and percent burned at moderate or high severity.These findings indicate that beaver ponds capture large volumes of post-fire sediment, temporarily preventing transport downstream. The sediment storage efficacy appears to be governed by pond rather than watershed-scale processes. Beaver-based restoration may provide much needed watershed resilience as wildfires become increasingly common.*

Recovery in the Post-Wildfire Environment: Policy Challenges and Opportunities

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Abstract. *The 2020 Cameron Peak wildfire (CPW) burned across a mosaic of public and private lands situated across multiple northern Colorado watersheds. The span of the CPW's burn scar over various land ownership types yielded substantial post-fire response and recovery challenges at varying scales. Post-fire programs at the federal level often dictate the types of measures allowed within a watershed, the information available for affected communities, and how recovery actions are funded in the*

aftermath of fire. While existing programs such as the Natural Resource Conservation Service's Emergency Watershed Protection (EWP) program or the U.S. Forest Service's Burned Area Emergency Response (BAER) program are well-established, little is understood regarding the performance of these programs at the scale of fires now encountered in the western United States and how they integrate with local and state level recovery initiatives. We conducted 23 semi-structured interviews with key stakeholders in government, non-government organizations, and academia who were involved in the CPW aftermath and other large-scale incidents in northern Colorado to assess the performance of EWP, BAER, and other aspects of post-fire governance to determine where policy reforms could improve operational efficiency and outcomes in the context of increasingly larger and more severe fires now encountered in the region. We found challenges to post-fire recovery, including 1) administrative issues with the amount and timing of funding available for recovery; 2) jurisdictional rules that limit collaborative and timely response to needs across different land ownerships; 3) a lack of holistic watershed recovery planning, and 4) the separation of subsequent "spinoff" disasters (i.e. flooding, debris flows) sourced from burn scars for years after an incident that can result in watershed scale impacts. Stakeholders suggested several policy reforms that could alleviate many of these challenges, including changes in the federal funding mechanisms for post-fire disaster, rules to allow cross-jurisdictional use of federal funds, modification of rules and protocols within individual programs, and further investment in longer-term recovery programs that consider watershed health post-emergency stabilization. These findings are directly relevant for informing adaptive governance theory, by exploring how to improve policies to overcome persistent scalar mismatches in environmental governance.

When Fire Meets Water: Addressing Smoky Flavors in Tap Water Due to Wildfires in the United States

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Abstract. *In recent years, wildfires have become more frequent and severe in the United States. One consequence of these wildfires is the presence of smoky flavors in tap water, which can be a source of serious concern for the consumers. In areas affected by wildfires, consumers have reported presence of smoky flavors in their tap water, and this results in considerable number of complaints to the drinking water treatment plants (DWTP) from concerned citizens, who are worried about the safety of their drinking water. The smoky flavor is usually described as a burnt, ashy, or smoky taste, which is unpleasant and can make the water unpalatable. DWTP operators, prompted by the concerned consumers, collect water samples and conduct sensory and instrumental analyses. The two best ways to detect and measure these compounds are to utilize a sensory panel of individuals trained to perform flavor profile analysis (FPA), and to conduct instrumental analysis with gas chromatography-mass spectrometry (GC- MS). The compounds identified that are believed to cause smoky flavor are: guaiacol and 4- methylphenol. Guaiacol is a compound that is formed when wood is burned, while 4-methylphenol is produced by the combustion of vegetation. Both of these compounds can end up in surface waters which are used as the source of tap water in many areas affected by wildfires. Typically these compounds can go through the treatment processes with minimal removal and end up at the taps*

of the consumers. Once the cause of the smoky flavor is identified, DWRP operators take steps to address the issue. One of the methods that can effectively remove these compounds from water is activated carbon filtration. Another technique utilized is the increased dosing of chlorine, which helps to mask the smoky odors. These measures have been proven effective in removing the smoky flavor and ensuring that the tap water is safe and palatable for the consumers. It is important for DWTP operators to continue to monitor the quality of their water in areas affected by wildfires, and communicate the findings with the public, in order to ensure that consumers have access to safe and high-quality drinking water.