COLORADO STATE UNIVERSITY

Presents

40th Annual AGU

Hydrology Days

April 13 – 14, 2020

Conference Proceedings

ONE WATER
SOLUTIONS INSTITUTE
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hydrologydays.colostate.edu

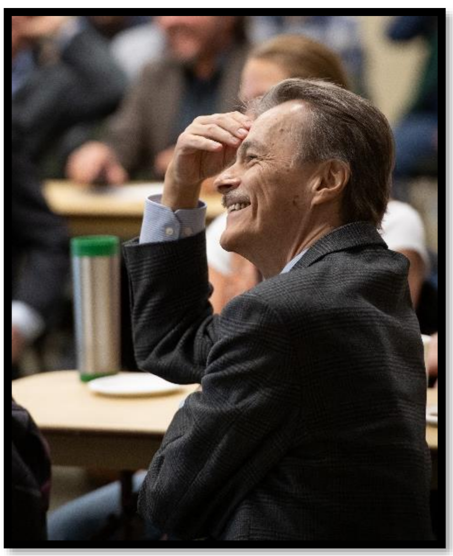
Executive Message

Due to the coronavirus (COVID-19) pandemic the 40th Annual American Geophysical Union Hydrology Days in-person meeting was canceled to protect public health and safety. The organizing committee is committed to sharing knowledge and ideas throughout our strong and vibrant scientific community. Therefore, the event was moved to voluntary online presentations to provide an opportunity for students and scientists to share their research. Conference proceedings for the webinar have been published in recognition of the hard work and outstanding efforts of our community.

The committee will continue to support another meeting in Spring 2021. The program will include presentation of the 2020 Hydrology and Borland awards and feature the previously announced world-class Keynote Speakers.

In Remembrance of Dr. Jorge Ramirez

Our esteemed colleague and dear friend Dr. Jorge Ramirez passed away on March 28, 2020. 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, benefitting not only CSU students and his fellow faculty members, but the profession as a whole.



Dr. Ramirez enjoying a special recognition session during Hydrology Days 2019. Photo: John Eisley (CSU).

His many awards include the Oliver P. Pennock Distinguished Service Award (2019), the Faculty Award for Excellence in Service from the Civil Engineering Department (2016), the George T. Abell Research Excellence Award of the College of Engineering (2011) and the Colorado Governor's Recognition Award for High Impact Research (2011). He was also listed by National Online Engineering Programs in 2016 as one of the Top 20 professors of civil engineering.

Jorge will be deeply missed but lives on forever in our hearts and minds. In February (2020), he had communicated that he wanted to share the following:

"Although it should have been evident over all these years, please convey to the rest of the faculty and the staff that I have been very lucky and always felt very proud of counting myself one of your team and that I always tried my best to make sure that CSU's and CEE's reputation as a premier department trying to improve the world and contribute to the greater good was maintained and enhanced in an ethical way.

For now, all my love and gratitude is with all of you! Thank you!"

SCHEDULE

Monday April 13, 2020

Agricultural Water 9:00am - 9:40am	9:00 am	*Comparing the Field-Level Profitability of Irrigated Cropping Activities for Temporary Water Transfers* **Daniel Mooney**, Colorado State University
	9:20am	*A Vision for Water-Limited Agroecological Systems Research* **Kyle Douglas-Mankin**, USDA - Agricultural Research Services
Hydraulics & Geomorphology 10:00am - 11:00am	10:00am	*Quantifying Uncertainty in the Measurement of Turbulent Flows to Enhance Water Resource Management* **Joseph Pugh**, Colorado State University
	10:20am	*Large-Scale Particle Image Velocimetry for Determining Vena Contracta Dimensions in Contracted Channels* **Alireza Fakhri**, Colorado State University
	10:40am	*Range-Wide Habitat Assessment of Greenback Cutthrout Trout Under Altered Hydrologic Flow Regimes* **Daniel White**, Colorado State University
Geoscience & Groundwater 11:00am - 12:00pm	11:00am	*Quantifying the Mass of Contaminants in Low-K Zones from Cryogenically Frozen Cores* **Eric Roads**, Colorado State University
	11:20am	*Developing a Method to Measure and Predict Moisture-Variable Soil Strength* **Joseph Binder**, Colorado State University
	11:40am	*The Potential for Restoring Thermal Refuges in Rivers for Cold-Water Fishes* **Joel Sholtes**, Colorado Mesa University/CU-Boulder
Hydrologic Systems 12:00pm - 1:20pm	12:00pm	*Improving Spatially Distributed Travel Time Methods for Hydrograph Prediction by Better Accounting for Upstream Flow Contributions* **Meshal Alothman**, Colorado State University
	12:20pm	*Assessing the Impacts of Climate Changes on the Regional Hydroclimatic Conditions of U.S River Basin Over the 21st Century* **Hadi Heidari**, Colorado State University
	12:40pm	*Temperature Informed, Mid-Term Flow Forecasts for the Upper Colorado River* **David Woodson**, University Of Colorado, Boulder

	1:00pm	*Hydraulic Modeling Approaches and Challenges for Complex Floodplain Analysis of Cascading Dams within a Canal* **Jessica Seersma**, Colorado State University
Urban Water Systems 2:00pm - 3:00pm	2:00pm	*Using Dual-Drainage Modeling to Assess the Impact of Green Stormwater Infrastructure Networks on Events of Roadway Flooding* **Katie Knight**, Colorado State University
	2:20pm	*Mapping and Modeling of Interbasin Water Transfers within the United States* **Landon Marston**, Kansas State University
	2:40pm	*Development of a Long-Term Back-Casted Dataset of Water Use for Agriculture, Electric Power, And Public Supply Sectors in the Conterminous United States* **Ryan Mcmanamay**, Baylor University

Tuesday April 14, 2020

Statistical & Stochastic Hydrology 9:00am - 10:20am	9:00am	*A Data-Driven Approach to Identifying Post-Fire Landslide Triggers* **Elsa Culler**, University Of Colorado - Boulder
	9:20am	*Decision Support System Evaluating Habitat in Alternative Flow Scenarios* **Elaina Passero**, Colorado State University
	9:40am	*Increasing Risks of Compound Flooding under Climate Change and Sea Level Rise Scenarios* **Mahshid Ghanbari**, Colorado State University
	10:00am	*Predictability of Soil Moisture in Northern California* **Megan Fowler**, University Of Colorado, Boulder & NOAA ESRL/PSD
Snow Hydrology 11:00am - 11:40am	11:00am	*The Density of Fresh Snow in Fort Collins, Colorado USA* **Marcee Meinhardt**, Colorado State University
	11:20am	*How Do We Define Climate Change? Considering the Temporal Resolution of Niveo-Meteorological Data* **Steven Fassnacht**, Colorado State University

AGRICULTURAL WATER

Comparing the Field-Level Profitability of Irrigated Cropping Activities for Temporary Water Transfers

Daniel F. Mooney[1], Joey Blumberg[1], Timothy Kelley[2]
[1]Agricultural and Resource Economics, Colorado State University
[2]Public Regulation Commission, State of New Mexico

Abstract. *Temporary water leases are a potential source of revenue for Colorado farms, but also limit the amount of water remaining for irrigated crop production and may affect economic risk. We developed a framework to compare the risk-adjusted profitability of alternate cropping activities that differ by crop, harvest, and irrigation treatments, and could be adopted for temporary water transfers. We illustrate the framework by presenting a field-level case study comparing the performance of thirteen activities on a typical farm field in Eastern Colorado.*

A Vision for Water-Limited Agroecological Systems Research

Kyle R. Douglas-Mankin, David M. Barnard, Louise H. Comas, Kendall C. DeJonge, Sean M. Gleason, Timothy R. Green, Huihui Zhang
Water Management & Systems Research Unit, USDA-ARS, Fort Collins, CO

Abstract. *The Water Management and Systems Research Unit (WMSRU, USDA-ARS, Fort Collins, CO) pursues a broad research agenda with the goal of systems-level advancement of crop production and agroecosystem services in water-limited regions. Building on a century-long history of advances in water, irrigation, and agroecosystem science and management, the WMSRU now proposes a vision for waterlimited agroecological systems research, as discussed herein. We believe that major advances in semiarid/arid agricultural production will require not only advances in genetics, physiology, remote sensing, and modeling but, also, systems-level integration of those advances.*

Unit scientists have expertise spanning key processes that drive plant performance and ecosystem services (physiology, genetics, hydrology, meteorology). Data collected by experimental work in the WMSRU and compiled from various sources feed into an analytical framework that integrates plant physiology, growth, precision irrigation management, remote sensing, and watershed hydrology through the development and application of process-based models and artificial intelligence (AI). Primary scientific outputs of the analytical framework are improved understanding of systems function, including interactions of key plant traits and remote sensing metrics that align with crop stress and environmental responses to climate. From these outputs, a better understanding of gene by environment by management (GxExM) interactions is combined with climate projections to predict crop yields and water and nutrient cycling that is implemented in stakeholder-facing decision support tools available as web-based services. Finally, enhanced understanding of process interactions in space and time help us update existing models and refine future methodology.

To meet these goals, WMSRU scientists collaborate extensively with researchers and practitioners globally. We welcome new collaborations in synergistic fields related to systems-level advancement of water-limited crop production and semi-arid/arid agroecosystem services.

HYDRAULICS & GEOMORPHOLOGY

Quantifying Uncertainty in the Measurement of Turbulent Flows to Enhance Water Resource Management

Joseph E. Pugh, S. Karan Venayagamoorthy, and Timothy K. Gates
Department of Civil and Environmental Engineering, Colorado State University

Abstract. *The ability to accurately and reliably measure flow in open channels is essential to sound water resource management, especially in arid locations such as Colorado. The importance of this task has been exacerbated by growing competition for limited water resources and by temperature increases to the Earth's lower atmosphere which in turn increases evaporation rates. This has particularly negative consequences for an already arid Colorado where agricultural reliance on irrigation, the largest water demand, is amplified. Personnel tasked with managing scarce water resources must be prepared to develop a well-characterized quantification of flows to meet irrigation and lesser demands.*

In the last several decades, flow measurement utilizing acoustic Doppler technology has become ubiquitous, both in the United States and abroad. The common instruments in this class are the Acoustic Doppler Velocimeter (ADV), and the Acoustic Doppler Current Profiler (ADCP). They are used in open channel settings to calibrate existing flow regulating structures and develop stage-discharge rating curves and to directly measure flow when regulating structures are not present. The aim of this research is to quantify the uncertainty of acoustic Doppler flow measurements in comparison to non-intrusive and highly accurate laser imaging techniques available in the laboratory.

This work is accomplished by constructing models of hydraulic structures at a laboratory scale and comparing stage-discharge rating curves found from laboratory experimentation using acoustic Doppler devices to those developed in the field. Additionally, the non-intrusive laser imaging techniques, such as particle image velocimetry and laser Doppler anemometry allow for the calculation of higher-order statistical quantities, such as vorticity and Reynolds stresses, from velocity vector fields of flow through the structures. Results are compared to those found using the FLOW 3D computational fluid dynamics model. The outcome is a better characterization of flow measurement uncertainty, along with guidelines for decreasing uncertainty to enhance water management.

Large-scale Particle Image Velocimetry for Determining Vena Contracta Dimensions in Contracted Channels

Alireza Fakhri, Dr. Robert Ettema
Department of Civil and Environmental Engineering, Colorado State University

Abstract. *This presentation shows the utility of Large Scale Particle Image Velocimetry (LSPIV) for determining the dimensions, especially the width of vena contractas formed in contractions of open-channel flows. LSPIV is an image-based method that non-invasively measures two-dimensional instantaneous freesurface velocities of water flow using inexpensive standard video equipment. This method is an advantageous technique for illuminating the flow field at the surface of the water body. The vena contracta of a contracted flow is the narrowing of flow as it passes through a contracted area of flow and then spreads downstream to occupy the full width of the contracted channel. A common occurrence for vena contracta is in bridge waterways over rivers. Of practical concern for such locations is the contraction scour that can occur in the vena contracta region. To estimate the depth of scour, in order to design bridge foundations, it is necessary to determine the width of vena contracta associated with the contraction-scour formation. The three main goals of this presentation regarding LSPIV use are as follow: determine the width of the vena contracta formed for three values of contraction ratio ([contraction width]/[approach channel width] = 25%, 50%, and 75%) associated with contraction scour of bridge waterways; determine pre- and postscour values of vena-contracta width for one contraction ratio; and, identify limitations to the LSPIV method when used for determining vena-contracta dimensions.*

Range-Wide Habitat Assessment of Greenback Cutthrout Trout Under Altered Hydrologic Flow Regimes

Daniel White[1], Ryan Morrison[1], James Roberts[2]
[1]Department of Civil and Environmental Engineering, Colorado State University
[2]Colorado Water Science Center, U.S. Geological Survey (USGS)

Abstract. *Colorado's native Greenback Cutthroat Trout (Oncorynchuss clarkii stomias; GBCT) is listed as threatened under the Endangered Species Act. The listing is largely due to competition with non-native species, hybridization, and habitat loss and fragmentation as a result of hydrologic alteration. An interagency work group is implementing recovery plans with immediate goals to establish stable populations in streams throughout the upper South Platte River Basin (the native range of GBCT). Currently there are 4 GBCT populations in existence. Although there is significant effort to quickly restore populations to the streams identified as suitable, there is much uncertainty regarding the long-term habitat quality under future climate scenarios. Geographically, potential restoration sites vary in terms of elevation, channel geomorphology, and local climate patterns. Given these variations in landscape characteristics, potential reintroduction sites will likely respond differently to climate induced changes in flow regime. We are investigating this at 10 sites of high conservation priority for GBCT in the upper South Platte River Basin. To improve our understanding of future habitat conditions, we are creating 1D hydraulic models that simulate projected hydrologic conditions in years 2040 and 2080 using*

downscaled climate simulations developed by the U.S. Forest Service. Here we present preliminary results of the 1D hydraulic models and provide implications for the range of hydrologic impacts both through time and space. Channel geometry data used in the hydraulic models were collected at each site using an automatic optical level and survey rod at 10 cross sections. The hydraulic models will be calibrated with a developed stagedischarge curve using flow measurements taken with a Flowtracker2 handheld acoustic Doppler velocimeter and pressure gauge. The data obtained from the model output will be used to describe overall habitat volume at baseflow. It will then be coupled with temperature data and other measured habitat metrics and used in Bayesian Network model to describe probability of Greenback Cutthroat Trout persistence at each study site. Overall, we hope to inform native trout restoration and management under future climate conditions.

GEOSCIENCE & GROUNDWATER

Quantifying the Mass of Contaminants in Low-k Zones from Cryogenically Frozen Cores

Eric Roads, Tom Sale, Maria Irianni Renno
Department of Civil and Environmental Engineering, Colorado State University

Abstract. *Contaminant hydrology has been challenged by the common perception of homogeneous subsurface media. Previous sampling methods neglect the importance of differentiating transmissive and low-k zones. CryoCore is a high-resolution sampling technique that can highlight the occurrence of transmissive and low-k zones as well as the distribution of contaminants in transmissive and low-k zone. CryoCore uses a CSU patented process that preserves core samples downhole using liquid nitrogen. Frozen cores are shipped to CSU on dry ice. Cores are cut into subsamples and analyzed to determine geology, physical properties, contaminant concentrations, and microbial ecology. The data is processed into Excel™ and then stored in gINT™, a relational database. Here, consideration is given to 390 feet of collected core from 31 boreholes from 5 hydrocarbon and 2 chlorinated solvent sites. Data analyses include intra-site and inter-site comparisons.*

Tools are developed in gINT™ to automate transformation of collected data into vibrant visual graphical outputs. First, for every borehole, a graphic is generated that includes a comprehensive panel of geology, contaminants of concern and fluid saturations properly presented by depth. Building on this, distributions of contaminants as a function of transmissive or low-k zones are resolved. Lastly, key attributes of mass distribution are compared across individual sites (intra-site comparisons) and between sites (inter-site comparisons).

Our analysis presents a first-ever quantification of contaminant distribution in transmissive and low-k zones. Key insights include the following. First, the fraction of low-k zones at the study sites range between 0% and 94% with a median value of 52%. Secondly, the fraction of contaminant stored in low-k zone range from 0% to 96% with a median value of 46%. Lastly, the total mass of contaminant in low k zone ranges between 0 and 120000 kg/acre with the median value of 1500

kg/acre. Overall, CryoCoring and advanced analytics provides a practical means of quantifying contaminant occurrence in low-k zones and an improved basis for selecting site remedies.

Developing a Method to Measure and Predict Moisture-Variable Soil Strength

Joseph R. Binder, Joseph Scalia IV, and Jeffery D. Neimann
Department of Civil and Environmental Engineering, Colorado State University

Abstract. *Spatial prediction of moisture-variable soil strength is critical for predicting the trafficability of vehicles across terrain. Current state-of-practice vehicle trafficability models rely on soil strength measured using rating cone index (RCI), which is used as an empirical model input and does not directly relate to soil strength properties such as friction angle and cohesion. The RCI is determined by pressing a small cone into surficial soil layers to yield a single value correlated to the trafficability of a given vehicle on a soil of same RCI. Because RCI depends on both soil composition and soil moisture, predicting RCI based on remote sensing data is difficult. The Strength of Surface Soils (STRESS) model calculates soil strength properties as a function of soil texture from SSURGO data and soil moisture from the Equilibrium Moisture from Topography, Vegetation, and Soil (EMT+VS) model. The STRESS model yields soil strength properties (friction angle and moisture-variable cohesion) that vary with soil texture and moisture conditions. However, the STRESS model is hindered by a lack of surficial soil strength data linked to soil characteristics. The objective of this study is to compile a dataset of surficial soil strength properties across a variety of soil types and moisture conditions to improve prediction of near-surface moisture-variable soil strength. This dataset is developed in part using a Bekker Value Meter (bevameter), which is a test apparatus that measures in-situ surficial soil strength properties by rotational shearing under a constant normal force at a constant rate. The bevameter allows for the determination of MohrCoulomb strength properties at a given moisture content in the lab or field. By developing a dataset of soil strength properties across a range of soil textures, the STRESS model can better predict moisture-variable soil strength properties.*

The Potential for Restoring Thermal Refuges in Rivers for Cold-Water Fishes

Joel Sholtes[1], Caroline Ubing[2], Michael Knutson[2], Ian Wilson[3]
[1]Civil Engineering, Colorado Mesa University – University of Colorado Boulder
[2]Bureau of Reclamation
[3]Confederated Tribes of the Umatilla Indian Reservation

Abstract. *Human impacts to rivers have resulted in increased water temperatures. This threatens coldwater aquatic species such as salmonids and reduces their viability by influencing fitness and fecundity, resulting in localized extirpation of certain species and overall reduction in available habitat and fish production basin wide. If cold-water aquatic species recovery programs are to meet their long-term goals, they must consider mitigating the impacts of warming waters with "thermal restoration" and creation of thermal refuges. Thermal refuges are defined as discrete patches of habitat within a river corridor where temperatures are different (warmer in winter, cooler in summer) relative to surrounding water. Thermal restoration has two primary mechanisms: (1) reducing solar insolation by reducing channel width-todepth ratios and increasing shading by riparian vegetation, and (2) enhancing exchange of surfacesubsurface*

water (i.e., hyporheic flow) within the channel bed, banks, and floodplain. We present a conceptual model of how river restoration practices can bring about thermal restoration and create thermal refugia from the reach, meander wavelength, and geomorphic unit scales. An initial analysis of pre- and post-restoration temperature and groundwater monitoring data from a reach-scale restoration project in the Grand Ronde River basin, Oregon indicates that meander- and geomorphic unit-scale thermal refuges can be achieved but that reach-scale reductions in or buffering of temperature may be difficult to demonstrate. We outline our next steps to evaluate how water and temperature fluxes within the hyporheic zone are mediated by channel and floodplain restoration at these three scales.

HYDROLOGIC SYSTEMS

Improving Spatially Distributed Travel Time Methods for Hydrograph Prediction by Better Accounting for Upstream Flow Contributions

Meshal Alothman[1], Jeffrey D. Niemann[1], and Jorge Gironás[2]
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[2]Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Santiago, Chile

Abstract. *Spatially distributed travel time (SDTT) methods have been proposed as an alternative between lumped unit hydrographs and fully distributed hydraulic routing methods in rainfall-runoff modeling. SDTT methods transform a basin's runoff into stormflow at the outlet by calculating the flood wave travel time within each cell of a digital elevation model and then summing the travel times from each cell to the outlet. A controversial aspect of SDTT methods is that they approximate the upstream flow contributions when calculating the flood wave travel time in each cell. In reality, the upstream contribution varies with time and space in a watershed, which alters the travel times of the flood wave. SDTT methods either assume all upstream areas simultaneously contribute flow to a point, a static portion of upstream areas contribute, or no upstream contributions occur. Assuming full upstream contributions usually overestimates travel times, while neglecting upstream contributions underestimates travel times. Thus, a key question is how should the partial contribution of upstream areas be estimated? In this study, two approaches are considered: a fraction approach that assumes a constant fraction of the upstream area contributes flow and a power approach that estimates the upstream contribution using a power function. These methods are applied to multiple synthetic basins with different geomorphic characteristics (e.g., uplift rate, material erodibility, etc.). For each basin, four storm hyetographs and three different average intensities for each hyetograph are applied. A fully distributed kinematic wave model is used as a benchmark to assess the performance of the methods for each case. Results show that the fraction and power value can change with the basin characteristics, storm duration, and storm intensity. However, the fraction value usually remains within a narrower range than the power value. Thus, the fraction approach provides a better approximation when applying SDTT methods.*

Assessing the Impacts of Climate Changes on the Regional Hydroclimatic Conditions of U.S River Basin over the 21st Century

Hadi Heidari[1], Mazdak Arabi[1], Travis Warziniack[2], Kao Shih-chieh[3]
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[2]Rocky Mountain Research Station, U. S. Forest Service, Fort Collins, CO, USA
[3]Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN, United States

Abstract. *Changes in hydroclimatic conditions may have substantial impacts on freshwater availably and basin characteristics. Assessment of long-term shifts in hydroclimatic conditions in advance can help to mitigate potential consequences on agriculture, environment, economy, society and ecosystem. This study assesses hydroclimatic changes of U.S river basins over the 21st Century induced by shifts in the Budyko space. The hydrologic responses of three climate change emission scenarios ranging from the driest to wettest conditions are projected using the Variable Infiltration Capacity (VIC) model with climate forcing from Multivariate Adaptive Constructed Analogs (MACA) dataset. Then, shifts in hydroclimatic characteristics of U.S river basins are evaluated by magnitude and direction of changes in the Budyko space. The results indicate hydroclimatic responses vary from a river basin to another because of differences in geographical characteristics, regional climate and physical processe. However, HUC08 river basins in the same neighborhood follow a systematic movement in the Budyko space indicating that there should be a common water and energy balance adaptation to regional climate changes. Systematic hydroclimatic shifts can be a sign for initiation of prolonged drought and land-use changes. Under all climate projections, the majority of river basins in the south of the U.S are likely to experience warmer and drier conditions. Under the driest scenario, most river basins in the southeast of the U.S are changing from Temperate to Continental climate zone. Additionally, aridity increases in the middle of the U.S, leading to expansion of Arid climate zones. This study can help decision-makers to assess and improve the ability of various water supply systems to mitigate or adapt to the impacts of regional climate changes*

Temperature Informed, Mid-Term Flow Forecasts for the Upper Colorado River

David Woodson, Dr. Balaji Rajagopalan
University of Colorado, Boulder – Department of Civil, Environmental, and Architectural Engineering

Abstract. *Mid-term forecasts of Colorado River Basin (CRB) flow (i.e. monthly or annual flows over the next oneto five-years) are an important and elusive component of water management in the Western US. Current methods such as Ensemble Streamflow Prediction perform no better than climatology past year 1 and do not consider the effect of a warming climate on streamflow, an important consideration for basins with moderate- to high- temperature sensitivity like the CRB. A K-nearest neighbor block bootstrap (KNN-BB) algorithm was developed to resample annual Upper Colorado River Basin (UCRB) naturalized flows based on simulated temperature from the Community Earth System Model (CESM) Large Ensemble (LE), which covers 1920-2100. The KNN-BB algorithm is forced with a future 5-year mean seasonal temperature to generate a 5-year block of annual flow ensembles which can be used as a mid-term forecast. Two forecast skill metrics, mean squared skill score (MSSS) and continuous ranked probability skill score (CRPSS), found several covariate selections (e.g. fall, winter, and spring average temperatures) to have* *good skill relative to climatology for years 1 and 2, and lower but acceptable skill for years 3 through 5. Global temperature data from the CESM Last Millennium Ensemble was clipped to the UCRB and paired with paleo reconstructed UCRB flows to significantly extend the historical period from which to sample, leading to an increase in forecast skill for the selected covariates. A separate K-nearest neighbor algorithm was used to disaggregate the annual flow forecasts for the entire UCRB into monthly, sub-basin forecasts for use in a US Bureau of Reclamation operational model. Finally, an uncalibrated Variable Infiltration Capacity (VIC) model of the UCRB was forced with CESM-LE precipitation and temperature data for comparison with the KNN-BB hindcasts. The VIC simulations resulted in extreme overprediction of basinaggregated flows, necessitating quantile mapping bias correction.*

Hydraulic Modeling Approaches and Challenges for Complex Floodplain Analysis of Cascading Dams within a Canal

Jessica Seersma
Department of Civil & Environmental Engineering, Colorado State University

Abstract. *Grid based numerical modeling capabilities coupled with the implementation of mesh and surface creation and editing graphic user interfaces in open source and proprietary software packages along with advancements in computer processing capabilities have resulted in the increased availability and access to 1D, 1D/2D, 2D, and 3D hydraulic modeling options. In evaluating which approach to use there are multiple considerations to account for in best representing the hydraulic conditions and impacts of hydraulic structures. For complex hydraulic systems and analyses while it may be desirable to create one model that could be used for multiple purposes the constraints within the model can make this unfeasible, or could result in tradeoffs with respect to the accuracy of results for different types of analyses. Additionally, in a single purpose complex model there are constraints and tradeoffs when it comes to the representation of certain hydraulic features in utilizing different modeling approaches. Understanding the sensitivity, impact, and feasibility of various approaches to the hydraulic structure representations and dimensionality on achieving the overall goal, and providing the most realistic yet conservative results is paramount. A cascading dam breach analysis for the five dams located in the portion of the Erie Canal originating at the Crescent Dam to its confluence with the Hudson River was performed using HEC-RAS. This stretch of the Erie Canal contains five locks, two additional gates that control flow coming from the Crescent Dam reservoir, several bridges, a few ninety degree bends, and a culvert that is lateral to the canal. The Champlain Canal that intersects with the Erie Canal just upstream of Lock E-2 is also a consideration. The goal of this analysis was to determine the timing, magnitude, and flood extents of the flood wave resulting from the worst case scenario to the town of Waterford; a cascading dam breach of the ½ Probable Maximum Flood. An iterative approach that combined the use of 1D and 1D/2D connections was ultimately applied. The computational challenges and limitations of HEC-RAS, the sensitivity on the overall results associated with the various representations of hydraulic structures and use of multi-dimensional modeling, and various representations of boundary conditions obtained as a result of this study can be useful in determining the best approaches to use in similar situations and improvements that can be made to hydraulic modeling software.*

URBAN WATER SYSTEMS

Using Dual-Drainage Modeling to Assess the Impact of Green Stormwater Infrastructure Networks on Events of Roadway Flooding

Katie Knight, Aditi Bhaskar
Department of Civil & Environmental Engineering, Colorado State University

Abstract. *Roadway flooding occurs during storm events when the stormwater network does not have sufficient capacity to drain all runoff. The roadway flooding that results from these system failures is not necessarily catastrophic, but the effects of smaller flooding events, often called nuisance flooding, are cumulative. The addition of Green Stormwater Infrastructure (GSI) to a stormwater network has the potential to help decrease events of nuisance flooding. GSI has been shown to reduce flooding at a single structure or small-scale, but the effect of GSI networks on flooding at a catchment-scale is less established. The ultimate goal of this study is to examine how GSI may influence events of roadway flooding, but additionally whether the modeling techniques are adequate to visualize impacts of GSI on roadway flooding across the watershed. In order to assess the interactions between the 1D flow in the stormwater network and the 2D overland flow within the watershed, a dual drainage model was developed in PCSWMM for the Harvard Gulch watershed in Denver, Colorado. Following calibration, a theoretical green stormwater infrastructure network will be added to the model. The location of the GSI will be determined using critical link analysis to assess where the most frequent and significant interactions between roadway flooding and traffic are occurring. A challenge in modeling urban flooding is a lack of validation data; this study will utilize citizen reports from the Flood Tracker app, social media posts, and municipal records to qualitatively assess flood model results. Following the evaluation of GSI network impacts on roadway flooding, the flood model results will be used in a probabilistic traffic model to analyze the effect of roadway flooding on traffic patterns under hazardous conditions.*

Mapping and Modeling of Interbasin Water Transfers within the United States

Landon Marston[1], Tamara Ivahnenko[2], Molly Maupin[3], and Benjamin Ruddell[4]
[1]Civil Engineering Department, Kansas State University
[2]Colorado Water Science Center, United States Geological Survey
[3]Idaho Water Science Center, United States Geological Survey
[4]School of Informatics, Computing, and Cyber Systems, Northern Arizona University

Abstract. *Interbasin water transfers (IBTs) can have a significant effect on the hydrology, environment, water supplies, and economies of the basins importing and exporting water, as well those downstream of the transfer. Though there is often local knowledge of water transfers, we lack a comprehensive national understanding of the role IBTs play in supplying water for society, as well as the collective hydrologic impact of IBTs. To meet this need, we are creating a centralized, publicly accessible database and visualization of IBTs within the United States, which will be used to understand the impact of IBTs on society and the environment. This data product will enable closure of water budgets and improve estimates of water availability and use. Specifically, our work will enable quantification of IBTs impact on water resources at the regional*

and national scale and model how these impacts may evolve under changing climate, population shifts, and land use changes. Moreover, this study will provide an empirical basis for modeling IBTs, improve the overall fidelity of hydrologic models, and thus, enhance approaches for estimation of water supply and demand. We anticipate the new data and knowledge created by our study will serve as a catalyst for new research surrounding IBTs and, more generally, human influences on water resources.

Development of a Long-Term Back-Casted Dataset of Water Use for Agriculture, Electric Power, and Public Supply Sectors in the Conterminous United States

Ryan A. McManamay[1,2], Binita KC[2,3], Melissa R. Allen-Dumas[4], Shih-Chieh Kao[2], Christa M. Brelsford[5], Jibonananda Sanyal[4], Robert N. Stewart[5], Budhendra L. Bhaduri[5], Benjamin L. Ruddell[6]

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Abstract. *Accurate, long-term, and consistent assessments of water is essential for developing reliable models of water resource availability in relation to growing demands and changes in climate regimes. Indeed, these models commonly rely on retrospective historical analyses that provide insights into shifting human population demands and adaptions to water shortages. However, such spatially and temporally comprehensive datasets are rarely available. Herein, we present a new long-term annual (1950 - 2016) dataset on agriculture, electric power, and public supply water use within the conterminous United States (US) at the county-level and, in some cases, site-level (for power plants). To generate the electricity production water use dataset, we synthesized a historically comprehensive list of generators and historic patterns in generation across fuels, primary movers, and cooling technologies. To determine the amount of water used for agriculture, we compiled historical information on crop and golf acreage, irrigation, and climate information to use in a crop-demand model that considered crop type and water use per growth stage. We modeled public water supply use by developing a random forest model constructed from information on population, infrastructure information, climate, and land cover. Our estimates show agreement with county and state water use information provided by the US Geological Survey, depending on sector. However, we also observed discrepancies in estimates that likely emerged from differences in source information and methodology. The long-term water use dataset described herein should be useful to enhance research by the multisector dynamics and hydrologic modeling communities.*

STATISTICAL & STOCHASTIC HYDROLOGY

A Data-Driven Approach to Identifying Post-Fire Landslide Triggers

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Abstract. *Wildfire can alter the hydrologic and geomorphic response of watersheds, resulting in a cascade of increased hazard for floods, sedimentation, shallow landslides, and debris flows. This fireflood sequence has been studied in detail in regions like Southern California where landscape evolution is driven by a pattern of such events. In spite of this attention, most landslide inventories cover limited regions and timeframes, presenting a challenge for transferring knowledge on triggering mechanisms for mass movement hazards across multiple regions. In this study, we use the NASA Global Landslide Catalog in conjunction with large-scale remotely sensed gridded precipitation and fire datasets for comparing the hydrologic conditions preceding 6041 landslides that occurred in 120 countries between 2000 and 2019. We use a Mann-Whitney test to compare the relative precipitation prior to the landslides with randomly selected samples from the same location and time of year. We find that post-fire landslides are generally preceded by smaller precipitation events relative to landslides not associated with fire. Furthermore, post-fire landslides tend to occur earlier in the wet season, suggesting that fire increases susceptibility to rainfall-driven landslide in a variety of climates. Finally, we present a discussion of the seasonal and spatial differences in landslide triggers.*

Decision Support System Evaluating Habitat in Alternative Flow Scenarios

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Abstract. *There is a need for environmental flow tools that consider both instream and floodplain habitat. A decision support system (DSS) that evaluates fish and vegetation habitat availability in alternative flow scenarios has been developed to support improved habitat management and protection of naturally variable flows. This system uses the results of high resolution 2-D hydrodynamic models to quantify and map suitable habitat for fish and floodplain vegetation at a range of discharges in a reach. The habitat preferences of fish are cross-referenced with the spatial distribution of flow characteristics generated by the hydrodynamic model and, optionally, a map of substrate types in the reach to map suitable habitat at each modeled discharge. Suitable habitat is quantified and used to develop curves of habitat area by discharge. The total suitable habitat area available at any flow within the modeled range can be estimated from these curves. Probability of occurrence of vegetation guilds is related to long term inundation patterns. Floodplain inundation is mapped for each modeled discharge. Probability of occurrence of each guild is mapped based on the exceedance probability of inundation calculated from the flow scenario. Supplying alternative flow scenarios with the historic flow record enables the DSS to describe long-term impacts of withdrawals, reservoir operations, or climate change. These impacts include the potential for vegetation encroachment and changes in monthly fish habitat*

and probability of occurrence of vegetation guilds. An additional component is in development that will compare alternative flow scenarios based these impacts. This demonstration of the DSS uses the Verde Wild and Scenic River, but the system is applicable to rivers across the country.

Increasing Risks of Compound Flooding Under Climate Change and Sea Level Rise Scenarios

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Abstract. *The coincidence of fluvial and coastal flooding leads to compound flood events with substantial impacts on human life, property, and infrastructure in low-lying coastal areas. Climate change and sea level rise (SLR) can put greater pressure on these areas by increasing the frequency and intensity of coastal and fluvial flooding. In this study, we develop a bivariate non-stationary flood risk assessment that accounts for compound flooding from fluvial and coastal events with consideration of impacts of climate change and SLR. Extreme sea water level (SWL) data are identified using peak over threshold method and are paired with the corresponding highest river depth within ±1 days of these events. The statistical dependence between the paired data is assessed using Kendall's rank correlation coefficient. The best copula fit is used for bivariate dependence analysis by assuming non-stationarity in the (1) marginal distribution of SWL data and (2) marginal distribution of SWL and river depth data. The nonstationary Generalized Pareto Distribution with SLR as the covariate is used to incorporate the non-stationary coastal flood frequency. In the part (1) the future probability of compound major coastal and fluvial flooding under different SLR values is estimated regardless of projected time to certain sea-level conditions. In the part (2), simulated streamflow discharge data driven by the Variable Infiltration Capacity (VIC) hydrologic model with 10 downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) dataset are used to incorporate nonstationarity in the marginal distribution of river data. Also, six regional SLR projections are considered to perform an assessment of expected time to certain rises in mean sea level. Finally, the future risk is assessed using the notation of failure probability, which refers to the probability of occurrence of at least one major coastal or fluvial flooding for a given design life. The application of the model is shown for Washington, DC. The results indicate that the joint exceedance probability of fluvial and coastal flooding could be higher when SLR and climate change are considered. Ignoring the effects of SLR and climate change may inappropriately underestimate the compound flood probability at locations that flood hazard can be influenced by the interaction of fluvial and coastal events.*

Predictability of Soil Moisture in Northern California

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Abstract. *Soil moisture anomalies underpin a number of critical hydrological phenomena with socioeconomic consequences, yet systematic studies of how predictable soil moisture can be are limited. Here, we use empirical-dynamical Linear Inverse Modeling, which has proved useful as* *an indication of predictability in other fields such as sea surface temperature, to investigate the predictability of soil moisture in northern California. This approach yields a model of soil moisture at 11 stations in the region, with results that indicate the possibility of skillful forecasts at each for lead times of 1-2 weeks. The model also enables a priori identification of forecasts of opportunity – conditions under which the model's forecasts may be expected to have particularly high skill. Given that forecast errors (and inversely, their skill) can be estimated in advance, these findings have the potential to greatly increase the utility of soil moisture forecasts for practical applications including drought and flood forecasting.*

SNOW HYDROLOGY

The Density of Fresh Snow in Fort Collins, Colorado USA

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Abstract. *The depth of snow is easy to measure. However, hydrologists want to know the snow water equivalent (SWE) of the snowpack, which requires measuring the mass of the snow by extracting a core, using a snow pillow with a pressure transducer or a snow scale, or by remote sensing. Measurements of fresh SWE added to the snowpack have often used depth measurements and an estimate of the density of fresh snow ($\rho_{s\text{-}fresh}$). Until recently such estimates have used a simple 10:1 rule, based on 1839 measurements in the City of York in Upper Canada, which equates to a $\rho_{s\text{-}fresh}$ of 100 kg/m^3. This current work uses the long time series of meteorological and snowpack data collected at the Fort Collins weather station on the Colorado State University campus. We follow previous investigations that correlated ρs-fresh with air temperature (Ta) during each snowfall event. We complement the Fort Collins dataset with several additional in situ measurements. Our $\rho_{s\text{-}fresh}$ versus T_a correlation is statistically stronger than those that appear in the literature.*

How Do We Define Climate Change? Considering the Temporal Resolution of Niveo-meteorological Data

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Abstract. *Snow is important in cool and cold regions at elevation as the headwaters where the snowpack is stored, and the presence of a snowpack alters the local energy balance. For regions with extended periods of snow cover, a common date is used to represent peak snow water equivalent (SWE). In the Western United States, April 1st is often used as SWE data have been collected on or about this date at over 2000 locations since as early as 1936. Trend analyses have shown a decrease in April 1st SWE across much of this domain. However, recent analysis indicate that this surrogate date does not represent peak SWE due to non-stationarity of the timing of peak SWE. Further investigations of monthly SWE, precipitation, and temperature data illustrate that snowpack changes are complex. For example, in Northern Colorado there was little net change in winter precipitation with some warming in the winter, yet there were monthly variations: November and March were warmer and drier, December and January were warmer and wetter, while February and May were cooler and wetter. While the monthly analysis is at a finer temporal resolution, a month is still an arbitrary human-define time step. Therefore, this work examines the patterns of daily trends in SWE, cumulative precipitation and temperature. Net temperatures are warming, but trends are consistent, yet chaotic over shorter time periods. SWE and precipitation trends do illustrate temporal patterns that are scaled based on location. Lower elevations stations are tending to record more snowfall while higher elevation stations are recording less.*