CUAHSI

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FIFTH BIENNIAL COLLOQUIUM

JULY 24 - 27, 2016
NATIONAL CONSERVATION TRAINING CENTER
SHEPHERDSTOWN, WV

FINDING YOUR PLACE IN BIG DATA: USING OBSERVATIONS TO UNDERSTAND HYDROLOGIC PROCESSES FOR PREDICTING A CHANGING WORLD

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Agenda

Note: *Each session is 2-hours long with 30 minutes for each speaker, followed by 30 minutes of discussion at the end.*

Sunday, July 24

4:00 - 6:00PM	**Registration**	Main Lobby, Entry Auditorium Building
7:00 - 7:10PM	**Welcome Address** Speakers: David Hyndman, Michigan State University / Chair of CUAHSI Board of Directors and Holly Michael, University of Delaware / Chair of CUAHSI Biennial Planning Committee	Entry Auditorium Building
7:10 - 8:10PM	**Eagleson Lecture** *Land Water and Energy Cycles Coupling Diagnosed From Remotely Sensed Global Observations* Speaker: Dara Entekhabi, Massachusetts Institute of Technology	Entry Auditorium Building

Monday, July 25

7:00 - 8:30AM	**Registration**	Main Lobby, Entry Auditorium Building
	Breakfast	Commons
8:30 - 8:40AM	**Welcome Address** Speakers: Richard Hooper, Executive Director of CUAHSI and Thomas M. Graziano, Director of the Office of Water Prediction, NOAA	Entry Auditorium Building
8:40 - 9:40AM	**Wolman Lecture** *Intensively Managed Landscapes: Anthropocene in Action* Speaker: Praveen Kumar, University of Illinois at Urbana-Champaign	Entry Auditorium Building
9:40 - 10:10AM	**Morning Break**	Entry Auditorium Building
10:10AM - 12:10PM	**Large-Scale Data Mining and Synthesis** Session Chair: Scott Jasechko, University of Calgary	Entry Auditorium Building

Lessons learned from 30 years of developing basin to national-scale hydro-biogeochemical studies, generating huge datasets, and interpreting the data Speaker: Carol Kendall, USGS	
America's Water in the 20th Century: Measures to address climate induced risk Speaker: Naresh Devineni, The City University of New York	
Isotopic indicators of water ages, from minutes to millennia, in groundwater and streamflow Speaker: James Kirchner, ETH Zurich / Swiss Federal Research Institute WSL / University of California at Berkeley	

10:10AM - 12:10PM	**National Water Center Young Innovators Program: Summer Institute** Session Chair: David Maidment, University of Texas at Austin	Room #151 Instructional West Building
	Overview of the Summer Institute and the National Flood Interoperability Experiment Speaker: David Maidment, University of Texas at Austin (with student presentations)	
	Flood Modeling and Inundation Mapping Speaker: Adnan Rajib, Purdue University (with student presentations)	
	Forecast Errors and Flood Emergency Response Speaker: Peirong Lin, University of Texas at Austin (with student presentations)	
12:10 - 1:30PM	**Lunch**	Commons
1:30 - 3:30PM	**Big Data and Large-Scale Land Models** Session Chairs: Ying Fan Reinfelder, Rutgers University and Martyn Clark, UCAR	Entry Auditorium Building
	Towards seamless multi-model prediction of water fluxes in Europe and USA Speaker: Luis Samaniego, Center for Environmental Research - UFZ	
	Assessing the information efficiency of land surface models Speaker: Christa Peters-Lidard, NASA Goddard Space Flight Center	
	Large-scale hydrology processes in the Community Land Model version 5.0 Speaker: David Lawrence, UCAR	
1:30 - 3:30PM	**New Technologies and Techniques for Hydrology** Chair: Kamini Singha, Colorado School of Mines	Room #151 Instructional West Building
	Powerful hydrological datasets with novel observations under a small budget Speaker: Markus Weiler, University of Freiburg	
	Finding your place in the Big Sky: The development and application of small Unmanned Aircraft Systems (sUAS) for hydrologic science and engineering Speaker: Scott Tyler, University of Nevada at Reno	
	High resolution topography for measuring the response of a warming arctic landscape: A case study from Alaska and the promise of arctic-wide coverage Speaker: Ben Crosby, Idaho State University	
3:30 - 4:00PM	**Afternoon Break**	Physical Training Gymnasium
3:30 - 6:00PM	**Poster Session**	Physical Training Gymnasium
6:30 - 7:30PM	**Dinner**	Commons

Tuesday, July 26

7:00 - 8:30AM	**Breakfast**	Commons
8:30 - 10:30AM	**Subsurface Characterization** Session Chair: David Hyndman, Michigan State University	Room #151 Instructional West Building
	Subsurface Characterization over a Range of Temporal and Spatial Scales Speaker: Jim Butler, Kansas Geological Survey, University of Kansas	
	Exploring the Effects of Climate Change on Critical Zone Behavior Using Geophysical Approaches Speaker: Susan Hubbard, Lawrence Berkeley National Laboratory	
	Subsurface Imaging of the Critical Zone Speaker: Kamini Singha, Colorado School of Mines	
8:30 - 10:30AM	**Integrated Observation, Prediction, and Management of Water Resources in a Changing World: Big Data Opportunity or Paradox?** Session Chair: Pat Reed, Cornell University	Entry Auditorium Building
	The role of big data in building and applying the next generation of hydrologic models and soil databases over the globe Speaker: Nate Chaney, Princeton University	
	Decision support for multi-stakeholder drought management using high-performance computing and data mining Speaker: Jon Herman, University of California at Davis	
	Can big data bridge complex institutional contexts and fundamental hydrologic science to enhance our capability to predict and manage change in large basins? Speaker: Howard Wheater, University of Saskatchewan	
10:30 - 11:00AM	**Morning Break**	Entry Auditorium Building
11:00AM - 12:00PM	**Go Beyond One Site, One View: Perspectives from Pathfinder Fellows** Speakers: Todd Rasmussen, University of Georgia; Scott Allen, Louisiana State University and Christian Guzman, Cornell University	Entry Auditorium Building
12:00 - 1:30PM	**Lunch**	Commons
Field Trips *Pre-registration is required for field trips.*		
1:00 - 5:00PM	*Karst in the mid-Atlantic* Leader: Daniel Doctor, USGS	Off-Site
1:00 - 5:00PM	*Geomorphology of Shenandoah Valley* Leader: Steve Kite, West Virginia University	Off-Site

| Workshops		
1:30 - 5:45PM	*Do-It-Yourself, Open-Source Wireless Environmental Data Logging* Instructor: Anthony Aufdenkampe and Steve Hicks, Stroud Water Research Center *Pre-registration is required.*	Room #201 Instructional East Building
1:30 - 3:30PM	*CUAHSI Water Data Center (WDC) and HydroShare* Instructor: Martin Seul, CUAHSI and David Tarboton, Utah State University	Room #151 Instructional West Building
3:30 - 3:45PM	**Afternoon Break**	Instructional Buildings
3:45 - 5:45PM	*Modeling landscape response using big data with Landlab* Instructor: Erkan Istanbulluoglu, University of Washington	Room #151 Instructional West Building
6:00 - 7:00PM	**BBQ Themed Dinner**	Commons
7:30 - 8:00PM	**Awards Ceremony**	Entry Auditorium Building
8:00 - 9:00PM	**Let's Talk About Water and Panel Discussion** *Rebuild by Design: Scientific and Engineering Challenges for Social Adaptation to Climate Change* Hosted by Linda Lilienfeld, LTAW Director and Richard Hooper, CUAHSI Panelists: Isaac Stein, West 8 and Josh Harrison, Center for Force Majeure	Entry Auditorium Building

Wednesday, July 27

7:00 - 8:30AM	**Breakfast**	Commons
9:00 - 10:00AM	**Keynote** *Science at Extreme Scale: The Convergence of Big Data and Big Compute* Speaker: Lucy Nowell, U.S. Department of Energy	Entry Auditorium Building
10:00 - 10:30AM	**Morning Break**	Entry Auditorium Building
Workshops *Pre-registration is required for all workshops.*		
10:30AM - 12:30PM	*CUAHSI Data-Driven Education* Instructor: Jon Pollak, CUAHSI *Pre-registration is required.*	Room #105 Instructional East Building
10:30AM - 12:30PM	*Community Modeling Discussions* Instructors: Ying Fan Reinfelder, Rutgers University and Martyn Clark, UCAR	Entry Auditorium Building
10:30AM - 12:30PM	*Developing Apps Using Water Web Services* Instructor: Dan Ames, Brigham Young University *Pre-registration is required.*	Room #201 Instructional East Building
12:30 - 1:30PM	**Lunch**	Commons

2:00 - 4:00PM	**National Water Model** Session Chair: Richard Hooper, CUAHSI	Entry Auditorium Building
Implementation and Initial Evaluation of version 1 of the NOAA National Water Model Speaker: David Gochis, UCAR		
The National Water Model as a Framework for Innovation Speaker: David Maidment, University of Texas at Austin		
Open Discussion		
2:00 - 4:00PM	**Data Management - Advances in Managing Big Data from Environmental Sensors** Session Chair: Jeff Horsburgh, Utah State University	Room #151 Instructional West Building
Computing continuous record of discharge with quantified uncertainty using index velocity observations: A probabilistic machine learning approach Speaker: Touraj Farahmand, Aquatic Informatics		
Ensuring data integrity for the National Water Model through densified monitoring Speaker: Matt Ables, KISTERS		
Community-sourced tools for turning Big [sensor] Data into Big Science Speaker: Jordan Read, USGS		
4:00 - 4:30PM	**Afternoon Break**	Entry Auditorium Building
4:30 - 4:45PM	**National Science Foundation Closing Remarks** Speaker: Carol Frost, National Science Foundation	Entry Auditorium Building
4:45 - 5:45PM	**Graduate Student Panel Discussion** Moderator: Jeanne Van Briesen, Carnegie Mellon University Panelists: Christa Kelleher, Syracuse University; Luke Pangle, Georgia State University; and Jon Duncan, University of North Carolina at Chapel Hill	Entry Auditorium Building
6:00 - 7:00PM	**Dinner**	Commons
7:00 - 9:00PM	**Meet the CUAHSI Board of Directors**	Lounge
	Campfire and S'mores	Fire Pit

Thursday, July 28

7:00 - 8:30AM	**Breakfast and Adjourn**	Commons

NCTC Campus Map

Note: Utilized buildings are highlighted in yellow.
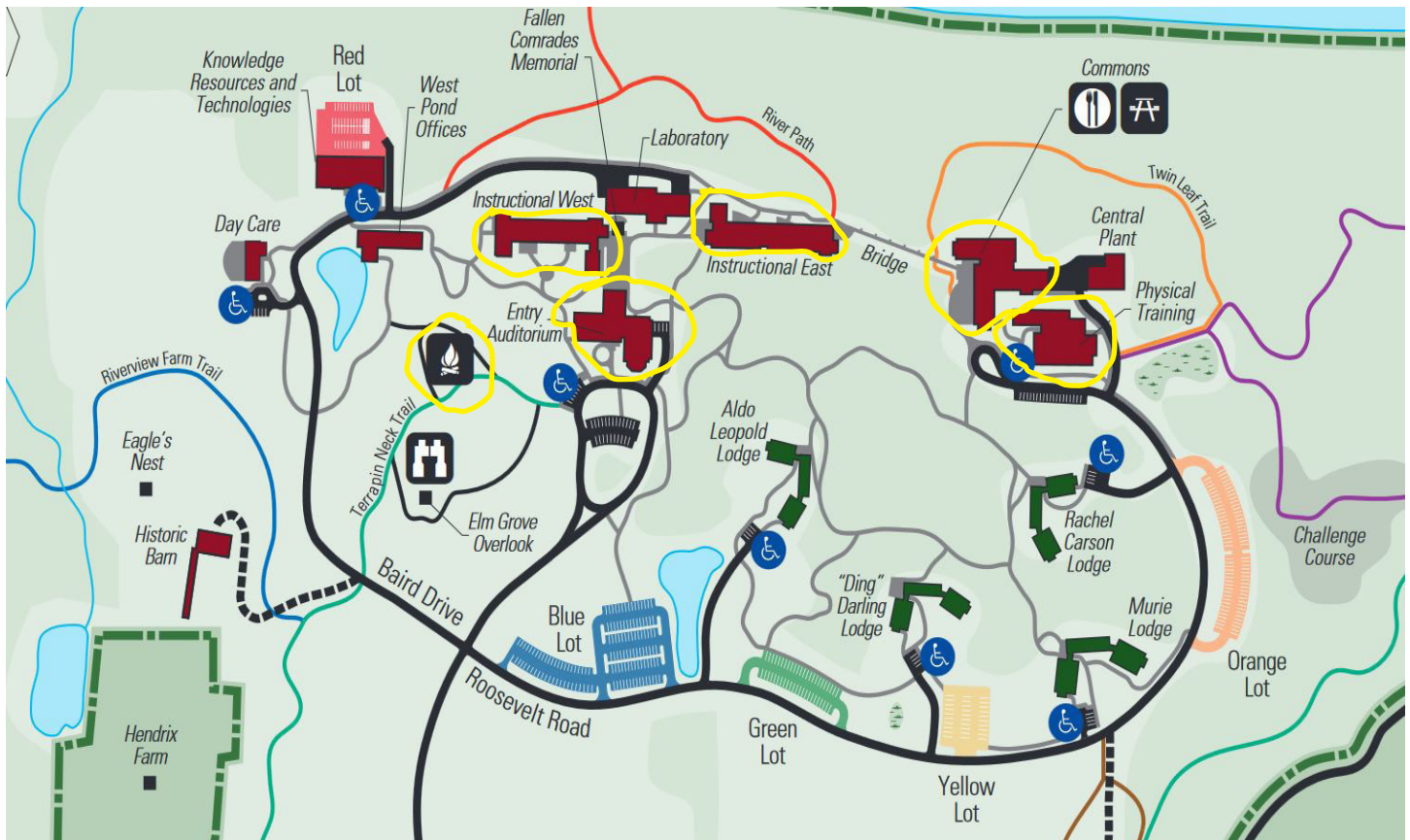
Dining Hours

Breakfast: 6:30- 9:00 a.m. Hot food until 8:30 a.m.

Lunch: 11:30- 1:30 p.m. Hot food until 1:00 p.m.

Dinner: 5:30-7:30 p.m. Hot food until 7:30 p.m.

Become a CUAHSI Member!

CUAHSI invites qualified institutions to apply for University, Non-profit, International, or Corporate Membership. University members can each designate up to three institutional representatives, who will represent the voice of their community when corporate matters are put before the membership and are eligible to stand for election to CUAHSI's Board of Directors.

CUAHSI has over 110 U.S. universities, non-profit and international affiliates, and corporate members. To learn more about becoming a CUAHSI member, please visit: https://www.cuahsi.org/Join-Cuahsi

SAVE THE DATE
for the
CUAHSI Membership Meeting

December 6, 2016

University representatives must attend to achieve quorum.

Keynote Abstracts

Eagleson Lecture

Background: The Eagleson Lecture is named after Peter S. Eagleson, a scientist who integrated ecology and hydrology and redefined hydrology from an ad hoc engineering speciality to a multidisciplinary, global environmental geoscience, in which the green, living features of the ecosystems have an important part to play. He has been seeking to develop new models of dynamic hydrology, looking at the hydrological cycle as the key process linking the physics, biology and chemistry of the Earth system.

Land Water and Energy Cycles Coupling Diagnosed From Remotely Sensed Global Observations

Speaker: Dara Entekhabi
Affiliation: Massachusetts Institute of Technology

The water and energy cycles - the two principal cycles of the Earth system – are coupled together over land through evaporation (latent heat flux). Evaporation – (transpiration where it occurs through vegetation) transitions from water-limited to energy-limited regimes depending on environmental conditions. The representation of transitions between these regimes and its dependence on soil moisture and other factors determines how the water and energy balance couple and vary at the land surface. This representation is the closure equation between the water and energy balance over terrestrial surfaces. The simulation of current weather and climate and model-based projections of future climate are highly dependent on the form of this closure equation. Important as this closure function is to Earth system science understanding and models for it, the function is mostly unknown. Most models currently use empirical relations for this important coupling and hence their representations of the terrestrial branch of the hydrologic cycle vary widely among the models. The focus of this talk is the observation-driven estimation of this closure relationship. In order to characterize this function across diverse climates and landscapes, remote sensing measurements are used. Multiple types of measurements from several different space-borne platforms are combined to constrain the estimation problem

Wolman Lecture

Background: The Wolman Lecture is named after M. Gordon "Reds" Wolman (1924-2010). Wolman was a prominent and much-beloved fluvial geomorphologist who taught at Johns Hopkins University from 1958 until his death in 2010. He advanced the quantitative and interdisciplinary study of rivers, contributed to solving a multitude of water management problems around the world, and was well-known for his insight, humor, and thoughtful mentoring of dozens of graduate students.

Intensively Managed Landscapes: Anthropocene in Action

Speaker: Praveen Kumar
Affiliation: University of Illinois at Urbana-Champaign

Intensively managed landscapes in the glaciated mid-western U.S. are relatively young. After the end of glaciation, rapid changes in soil and vegetation took place on these landscapes as climate transitioned. Wind driven soils (loess) provided a backdrop for the establishment of pioneer vegetation species followed with nitrogen fixing plants leading to the eventual establishment of climax species, the prairies. Loess deposited over glacial drift supported rich environment for biodiversity through competition, mutualism and mosaicking. In areas impacted by Wisconsian episode (latest glacial episode), this happened about eight thousand years ago. Heterogeneity of vegetation, soil organic carbon, nitrogen, etc. arose from differentiated accumulation over till, which has high water holding capacity, and outwash, which has lower water holding

capacity. Transformations and transport was dominated by large residence times over low gradient landscape. Since European settlement and the trajectory of large-scale adoption of industrial agriculture, these landscapes have been rapidly modified. Reduced residence time no longer mutes event scale response. Landscape has switched to transport dominated system due to anthropogenic modifications, which includes deployment of tile drains, ditching, and channel straightening. This amplifies event scale dynamics, changes dominant processes, and alters process connectivity across time and space with non-reversible, often threshold dominated, cascading effects. Annual tillage and nitrogen application alters the stocks and flows of carbon and nutrients through the soils and water bodies. Understanding the deep couplings between landscape evolution, climate change, and anthropogenically driven dis-equilibrium arising from the alterations of coupled water, carbon and nutrient cycles across scales remains a challenge. This talk will present insights gained towards this challenge from the efforts of the Intensively Managed Landscape Critical Zone Observatory.

Keynote Lecture
Science at Extreme Scale: The Convergence of Big Data and Big Compute

Speaker: Lucy Nowell
Affiliation: U.S. Department of Energy

Management, analysis and visualization of scientific data will undergo radical change during the coming decade. Coupled with changes in the hardware architecture of next-generation supercomputers, explosive growth in the volume and complexity of scientific data presents a host of challenges to researchers in computer science, mathematics and statistics, and application sciences. Failure to develop new data management, analysis and visualization technologies that operate effectively on the changing computer architecture will cripple scientific discovery and put national security at risk. Dr. Lucy Nowell will explore the technical and scientific drivers and opportunities for data science research funded by the Advanced Scientific Computing Research program in the Department of Energy Office of Science.

SAVE THE DATES

Geological Society of America (GSA) Annual Meeting and Exposition
September 25 - 28, 2016
Denver, Colorado

Come visit CUAHSI's booth!

American Geophysical Union (AGU) Fall Meeting
December 12 - 16, 2016
San Francisco, California

Come visit CUAHSI's booth, join us for our Early Career Luncheon,

and water science mixer!

4th CUAHSI Conference on HydroInformatics
July 2017
Logan, Utah

Session Abstracts

Large-Scale Data Mining and Synthesis
Session Chair: Scott Jasechko, University of Calgary

This session explores the development, analysis and value of large hydrologic datasets, which cover large areas or span long time periods. Data synthesis approaches include field-based water sampling campaigns at continental-scales or at high-frequencies, and compilations of previously published water data. The speakers show how large scale patterns of water chemistry, water fluxes and water demands can be used to better understand earth systems processes and to map hotspots and drivers of water stress.

Lessons learned from 30 years of developing basin to national-scale hydro-biogeochemical studies, generating huge datasets, and interpreting the data

Speaker: Carol Kendall
Affiliation: U.S. Geological Survey

Most of my research over ~30 years has been conducted at the regional to national scale by piggybacking multi-isotope and multi-tracer studies onto existing large-scale water quality, air, and ecological monitoring programs managed by federal and state agencies.

Isotopes are a potentially powerful component of monitoring and assessment programs aimed at quantifying and mitigating alterations to environments from human activities because locations exhibiting unusually high rates of biogeochemical cycling or elevated pollution levels usually have distinctive isotopic compositions that are suggestive or diagnostic of the reactions and pollution sources. Hence, isotopes facilitate the identification of hot spots and moments that otherwise would not be apparent, thereby providing a valuable addition to standard chemical and hydrological mass balance methods.

Among the many challenges of piggybacking our studies onto monitoring programs that are collecting and analyzing samples for their own objectives is integrating different kinds of data collected at a range of different spatial and temporal scales. There are a number of issues to consider, including testing whether the isotope and/or chemical data of interest are "gradational" in composition over the temporal and/or spatial scales of the sampling efforts or the questions being addressed. Spatial patterns of compositions in some environments (e.g., lakes and airmasses) are relatively easy to present as contour maps because the media are well connected and relatively isotropic. In contrast, rivers are characterized by linear connections of water, chemical constituents, and biota because of the unidirectional flow of water.

This presentation will (1) provide suggestions for successful piggybacking on monitoring programs; (2) explore several useful approaches for integrating diverse datasets using examples from large-scale atmospheric, wetlands, and watershed studies; and (3) show some simple ways of analyzing, plotting, and modeling large datasets that have proved particularly useful for generating testable hypotheses about nutrient and organic matter sources and biogeochemical processes.

America's Water in the 20th Century: Measures to address climate induced risk

Speaker: Naresh Devineni
Affiliation: The City University of New York

This work develops an understanding of water risk for USA considering linkages between water supply and competing demands. It explores how climate variability and changing water demands manifest as water deficits and how public-private management decisions determine regional water availability and drought resilience. We develop insights on regional water risks, infrastructure investments, sectoral allocation and policy modifications for America's future water sustainability. In this talk, I will focus on demonstrating how the variations in climate over the last century influenced changes in water use across the continent USA. A sneak peak into our interactive modeling environment for future evolution of water use and supply will also be provided.

Isotopic indicators of water ages, from minutes to millennia, in groundwater and streamflow

Speaker: James Kirchner
Affiliation: ETH Zurich / Swiss Federal Research Institute WSL / University of California, Berkeley
Additional Authors: Jana von Freyberg and Björn Studer, ETH Zurich; Scott Jasechko, University of Calgary; Chris Soulsby and Doerthe Tetzlaff, University of Aberdeen

Landscapes are characterized by preferential flow and pervasive heterogeneity on all scales. They therefore store waters over a wide spectrum of residence times, complicating efforts to understand hydrological processes and water quality trends. Here we present four vignettes, showing how observations and analyses of 18O, 2H, 3H, and 14C can be used to quantify hydrological dynamics over timescales spanning more than seven orders of magnitude. 1) We present first results from a "lab in the field" instrument package that uses laser spectroscopy to continuously measure isotopic dynamics in precipitation and streamflow, and simultaneously measures water quality using electrochemistry, ion chromatography, and UV/VIS spectroscopy. These observations reveal the detailed hydrological and water quality dynamics of catchment response to hydrological events. 2) Using 7-hourly isotope data from Plynlimon (Wales) and daily/weekly isotope data from Bruntland Burn and Burn of Bennie (Scotland), we demonstrate a new method of hydrograph separation that quantifies rainfall contributions to streamflow over a range of time scales, and quantifies how these contributions vary with antecedent moisture conditions. 3) We demonstrate how seasonal isotope cycles can be used to quantify the fraction of streamflow that is less than 2-3 months old, and we show that this "young water fraction" ranges from 4-53% in 254 global rivers. 4) We extend the "young water fraction" concept, showing how 3H and 14C can be used to quantify the pre-1950 and pre-Holocene fractions, respectively, in groundwater. Using a global survey of thousands of wells in hundreds of aquifers, we show that many aquifers are surprisingly old, but many of these same groundwaters contain significant 3H, indicating a substantial component of much more recent precipitation. These four vignettes illustrate the coupling between landscapes and the waters that drain them, and highlight the impact of subsurface heterogeneity on water fluxes, water age, and water quality.

National Water Center Young Innovators Program:
Summer Institute
Session Chair: David Maidment, University of Texas at Austin

The 2016 CUAHSI Summer Institute was held between 6 June and 20 July 2016 and involved 34 graduate students and 6 faculty advisors from 22 universities in a 7-week residential program at the National Water Center on the Tuscaloosa campus of the University of Alabama. This is an activity sponsored by NOAA and conducted by CUAHSI in which participation is open to students and faculty from all academic institutions in the United States. During the 2016 Summer Institute, the students accessed output from the National Water Model which continuously forecasts discharge, velocity and other hydrological variables on 5 million km of rivers divided into 2.7 million stream reaches of the continental United States. There were four themes for Summer Institute research: flood modeling, inundation mapping, forecast error and emergency response. Students formed project groups of 2-4 members from different universities and conducted research projects within these themes. This activity is a large-scale synthesis experience for graduate student research, and it enables enhancement of a National Water Model, both long-term goals of CUAHSI. The session will describe the overall context of the Summer Institute and the main achievements of the student research projects.

Overview of the Summer Institute and the National Flood Interoperability Experiment

Speaker: David Maidment
Affiliation: University of Texas at Austin

Flood Modeling and Inundation Mapping

Speaker: Adnan Rajib
Affiliation: Purdue University

The 2nd annual Summer Institute of the National Water Center's Young Innovators' Program during June 6 - July 20, 2016 hosted thirty-two student research fellows from 19 universities across the country. Students formed 12 teams focusing on to four different research themes leveraging the outputs of National Water Model, including flood modeling, inundation mapping, forecast errors and emergency response.

A number of projects were explored under the auspices of flood modeling and inundation mapping themes. One of the projects was to supplement shortage of available hydrologic observations (e.g. streamflow) with remotely sensed densified measurement network. Pertaining to similar motivation, high resolution LiDAR (Light Detection and Ranging) data was analyzed with the TauDEM toolset toward more accurate delineation of drainage network in a data-scarce region of Texas Lower Rio Grande Valley. One study evaluated the relative comparability of four different inundation mapping tools along with their sensitivity to complex geophysical and man-made attributes such as channel bathymetry, resolution of topography data and presence of hydraulic control structures. The outcome of this particular work would augment insights on the trade-off between accuracy and reliability of flood inundation mapping in large scales using simple, fast-computing topography-driven approaches with that from the detailed, slow-computing, relatively accurate physical hydrodynamic models. A case study to assess the accuracy of various flood inundation mapping tools were also evaluated using satellite remote sensing observations of inundation extents for a selected historical flood event. To augment rapid access and post-processing of satellite-based inundation observations, a suite of algorithms for multi-source image fusion and subsequent image classification was also developed. Considering the uncertainty involved in the flood modeling process, starting from weather forecast to inundation map, a new strategy of multi-model ensemble flood map was proposed.

The ideas being exercised during the NWC summer institute, as exemplified above, would essentially establish the National Water Model (NWM) as the new frontier of an efficient nation-wide flood forecasting and inundation mapping framework.

Forecast Errors and Flood Emergency Response

Speaker: Peirong Lin
Affiliation: University of Texas at Austin

The 2nd National Water Center (NWC) Young Innovator Program Summer Institute was held from June 6 – July 21, 2016. During the seven-week program, 32 graduate student research fellows from 19 universities gathered to work collaboratively on 12 projects. The 12 projects are categorized into four themes: flood modeling, inundation mapping, forecast errors, and emergency response. While a number of research efforts focus on evaluating different approaches for optimal flood modeling, forecast errors and emergency responses are also drawing increased attention in the research and operational community to truly translate useful information to decision makers.

"Forecast Errors" projects evaluated the uncertainties associated with flood inundation mapping, and investigated the role of assimilating stage height observations to improve water surface elevation prediction. "Emergency Response" projects contributed towards translating model results to the public and first responders through developing easy-to-access web-services and educational outreach materials. For example, one project focused on developing a mobile-app that can potentially operate along the full cycle of an extreme event with continuous information on preparedness, warning and response. Two other projects focused on developing an online visualization system and an online portal of advanced emergency response, taking into account social norms and human behavior during extreme events. In this presentation, I will summarize the main findings and outcomes from the six group projects that lie within the "Forecast Errors" and "Flood Emergency Response" themes. Collectively, these projects help establish a decision-support system of the National Water Model, which integrates nation-wide flood forecasting, inundation mapping, and flood emergency response.

Big Data and Large-Scale Land Models
Session Chairs: Ying Fan Reinfelder, Rutgers University and Martyn Clark, UCAR

This session focuses on fusing data and model at large scales, how one can inform the other, and how both can be advanced to advance large-scale water cycle research.

Towards seamless multi-model prediction of water fluxes in Europe and USA

Speaker: Luis Samaniego
Affiliation: Center for Environmental Research - UFZ

Developing the ability to seamlessly predict streamflow and other state variables like soil moisture at catchment, regional, continental or global scales with spatial resolutions varying from hundreds to thousands of meters is fundamental for improving our understanding of the water balance at scales relevant for decision making as well as for improving our understanding of the potential impacts of climate change on water resources. Hydrologic observations, however, are hardly available at the scale at which the predictions are needed. It is therefore necessary to develop frameworks that incorporate observations at their native resolutions into a hydrologic model without the need of using ad hoc up/downscaling techniques no match observations. Such frameworks should also be able to handle large amounts of spatio-temporal data in their native resolutions in an optimal and efficient way. The ultimate goals of these frameworks are to generate seamless parameter fields that enable us to obtain flux-matching, scale consistent flux fields, to ensure robust model performance across locations and scales and to allow us to perform multi-scale verification. The Multiscale Parameter Regionalization (MPR, Samaniego et al. WRR 2010), which is one of the main features of the mesoscale Hydrologic Model (www.ufz.de/mhm), allows us to achieve these goals.

In this talk, examples from on-going projects will be presented to illustrate these features. In the EDgE project (End-to-end Demonstrator for improved decision making in the water sector in Europe) we aim to generate high-resolution (5x5 km2) seamless simulations for the Pan-EU with three models: mHM, Noah-MP and VIC. Model transferability across scales and locations will be illustrated with recent experiments carried out by Rakovec et al. 2016 at NCAR in 400 MOPEX basins and previous experiments presented by Livneh et at. HP, 2015 and Kumar et al., WRR 2013b.

Assessing the information efficiency of land surface model

Speaker: Christa Peters-Lidard
Affiliation: NASA Goddard Space Flight Center
Additional Authors: Grey S. Nearing, David M. Mocko, Sujay V. Kumar, Youlong Xia, Michael Ek

The PLUMBER project demonstrated that decades of land surface model inter-comparison projects have resulted in little model improvement against a regression benchmark. Formal model benchmarking allows us to separate uncertainty in model predictions caused by model inputs from uncertainty due to model structural error. Nearing et al., recently extended this method with a "large sample" approach (using data from multiple field sites) to measure prediction uncertainty caused by errors in 1) forcing data, 2) model parameters, and 3) model structure, and used it to compare the efficiency of soil moisture state and evapotranspiration flux predictions made by the four land surface models in phase 2 of the North American Land Data Assimilation System (NLDAS-2). Parameters dominated uncertainty in soil moisture estimates and forcing data dominated uncertainty in evapotranspiration estimates; however, the models themselves used only a fraction of the information available to them. This means that there is significant potential to improve all three components of NLDAS-2. In particular, continued work toward refining the parameter maps and lookup tables, the forcing data measurement and processing, and also the land surface models themselves, has potential to result in improved estimates of surface mass and energy balances.

Citation:
Grey S. Nearing, David M. Mocko, Christa D. Peters-Lidard, Sujay V. Kumar, and Youlong Xia, 2016: "Benchmarking NLDAS-2 soil moisture and evapotranspiration to separate uncertainty contributions." J. Hydrometeor., 17 (3): 745-759 [10.1175/jhm-d-15-0063.1]

Large-scale hydrology processes in the Community Land Model version 5.0

Speaker: David Lawrence

Affiliation: UCAR

Additional Authors: Sean Swenson, Martyn Clark, Hongyi Li, Justin Perket, Yingfan Reinfelder

The Community Land Model (CLM5) is the land component of the Community Earth System Model (CESM). In this presentation, we will introduce CLM5 and briefly describe recent model improvements to the representation of hydrology and water cycle processes in CLM that have been developed in collaboration with the research communities that utilize CLM. Results from a set of offline simulations comparing several versions of CLM will be presented and compared against observed data for runoff, river discharge, soil moisture, and total water storage to assess the performance of the new model. In particular, we will demonstrate how comparisons to GRACE and FLUXNET-MTE evapotranspiration data contributed to the identification and correction of model deficiencies. The new model, CLM5 will be incorporated in CESM2 and provides the basis for improved large-scale modeling and study of energy, water, and biogeochemical (carbon and nitrogen) cycles. Example applications of CLM focused on hydrologic and vegetation response to drought, carbon / water interactions and land-use impacts on hydrology will be shown. Opportunities for further improvement and the CUAHSI – CLM partnership will also be discussed.

New hydrologic technologies for innovative data collection
Session Chair: Kamini Singha, Colorado School of Mines

New measurement methods are constantly being developed to help us to improve the estimation of hydrologic processes. Here, we explore new advances in spatial and temporal resolution of measurements, innovative sensors, and scaling of hydrologic data. This session will showcase three new methods for acquiring, processing, and visualizing information on hydrologic processes from emerging measurement technologies.

Powerful hydrological datasets with novel observations under a small budget

Speaker: Markus Weiler
Affiliation: University of Freiburg
Additional Authors: Stefan Pohl, Jakob Garvelmann, Nils Kaplan, Beat Lüthi, Theresa Blume, and Ernestine Lieder

There has been and always will be a need for long-term, precise and reliable hydrological measurements and data. However, to better understand and predict hydrological processes we need data with a high temporal and spatial resolution to observe complex, interacting patterns. Using convectional sensors, methods and approaches is often not possible, as the investment in such observation networks is too costly and could, if possible, only be done at one place not allowing comparative hydrological measurements. We have been trying to overcome this dilemma developing new sensors, modifying existing sensors and proposing new approaches allowing observations at a high spatial and temporal resolution appropriate to the variation of the process variables.

First we will highlight the use of the snow monitoring system (SnoMoS), which we developed in the past 10 years to observe meteorological variables including snow depth and snow temperature. There is a high potential of understanding process interaction deploying over 100 SnoMoS in a watershed over several winter observing a range of different processes related to snow accumulation, meld and rain-on snow floods.

As discharge measurements are one of the fundamental observations for hydrologists, time-laps cameras available nowadays at a very reasonable price for wildlife observation and hunting provide a very promising tool together with new approaches of image analysis to observe the occurrence of runoff, the water stage, the flow velocity distribution and discharge in rivers at a range of scales more or less continuously. Using cameras has some disadvantages, but the advantages when deploying for example 3d particle tracking velocimetry is quite surprising.

Finally, the use of modified light and temperature sensors to measure the river network patterns of temperature and electrical conductivity will be presented with an example form a deployment of over 100 sensors in a watershed in Luxembourg. This allows us for the first time to observe the spatial-temporal network pattern of water quality interaction at a whole watershed, but also by deploying the sensors strategically, to calculate the relative discharge contributions over time at the confluences in the river network.

To conclude, we will provide an outlook about other potential sensors and approaches which could be useful for a wider range of applications and approaches in the future.

Finding your place in the Big Sky: The development and application of small Unmanned Aircraft Systems (sUAS) for hydrologic science and engineering

Speaker: Scott Tyler

Affiliation: University of Nevada at Reno

Additional Authors: C.S. Sladek, and H. Pai, University of Nevada Reno; J.S. Selker, M. Wing, C. Higgins, and J. Burnett, Oregon State University

The intersection of huge advances in computational power, battery design and electronics has brought us a world of autonomous systems ranging from your coffee maker to Google's self-driving car. With these lightweight and low cost vehicles, it is no longer appropriate to view hydrologic remote sensing as the sole domain of satellites and manned aircraft or submarines. We now have the capacity to build or buy low cost air and water borne platforms that can be sent forth into the environment to measure hydrologic variables as basic as temperature to as complex as turbulence. In this talk, we will describe recent advances in small airborne platforms (sUAS's) and their sensors that may fundamentally change how we view the hydrologic world collect "Big hydrologic Data". Through a series of examples from AirCTEMPs, our NSF-supported community user facility, we will demonstrate the proven capabilities of sUAS and their potential for enhancing how we sense the hydrologic cycle. Examples will include topographic reconstruction from sUAS, balloon deployments of optical fiber and other sensors, as well as thermal imagery from sUAS. By the time of this presentation, new FAA regulations for sUAS are likely to be released, and these will also be analyzed in order to define the possibilities of opportunities for sUAS operations, as well as to place realistic bounds on their value in water resources.

High resolution topography for measuring the response of a warming arctic landscape: A case study from Alaska and the promise of arctic-wide coverage

Speaker: Ben Crosby

Affiliation: Idaho State University

Additional Authors: Theodore B Barnhart, University of Colorado; Joel C Rowland, Los Alamos National Laboratory; and Paul Morin, Polar Geospatial Center

Currently the Arctic is warming at more than double the rate observed at lower latitudes. This has significant implications for both global and arctic systems. Remote sensing data enable the reconstruction of thermal erosion features including lakes, shorelines and unstable hillslopes in remote Arctic locations, yet two dimensional data limit analysis to planform change. This talk explores what becomes possible when the third dimension of elevation is added to analyses.

We apply of varying techniques to reconstruct the three dimensional evolution of a single thermal erosion feature in NW Alaska. We apply a mixture of opportunistic oblique photos, ground surveys (LiDAR and total station) and stereo satellite imagery to recreate topographic surfaces spanning over a decade of feature growth. The upslope retreat of the headwall decreases over time as the slump floor progresses from a highly dissected gully network to a low relief, earthflow-dominated depositional fan. The decreasing slope of the slump floor diminishes transport capacity, resulting in the progressive burial of the slump headwall, thus decreasing headwall retreat rates and sediment production.

This local example of topographic evolution is simply a case study for a larger, upcoming revolution in arctic change detection. Stereo-photogrammetric digital elevation models (the Arctic DEM product) are currently being produced by the Polar Geospatial Center using sub-meter resolution DigitalGlobe imagery to create maps at unprecedented resolutions of 2-5 meters for the entire arctic. These new datasets will be publically distributed and provide the basis for geomorphic, hydrologic and ecological investigations that were previously limited by antiquated 60-90 meter resolution data. This novel example of Big Data will revolutionize our understanding of arctic surface processes and transform our ability to quantify change.

Subsurface Characterization
Session Chair: David Hyndman, Michigan State University

Subsurface properties are highly heterogeneous, which controls the fate and transport of water, nutrients, and other solutes. Characterizing the detailed three dimensional nature of subsurface properties such as hydraulic conductivity is critical to understand these rates and processes. In the last decade there have been significant advances in methods to image subsurface hydraulic properties using geophysical methods along with new direct methods of measuring hydraulic conductivity, including direct push profiling. This session explores emerging methods to characterize subsurface properties and understand how such heterogeneities influence flow and transport processes.

Subsurface Characterization over a Range of Temporal and Spatial Scales

Speaker: Jim Butler
Affiliation: Kansas Geological Survey, The University of Kansas

Virtually every hydrogeologic investigation requires information about the processes and properties affecting the flow of water in the subsurface. Whether the objective is assessment of the threat posed by sites of groundwater contamination, characterization of an aquifer's response to development, delineation of water-balance components, or some other task, hydrologists have expended considerable energy on subsurface characterization in pursuit of their goal. In this presentation, I will provide an overview of some recent developments of a multi-year program of data-driven research directed towards the development of new approaches for the physical characterization of subsurface flow systems over a range of spatial and temporal scales.

Over the last decade, we have developed direct-push (DP)-based, high-resolution field methods that allow characterization of the shallow (< 30 m depth) unconsolidated subsurface at a speed and resolution that has not previously been possible. Our emphasis has been on methods for characterizing hydraulic conductivity (K) and porosity (n) in support of investigations at sites of suspected groundwater contamination. I will focus on two tools for vertical DP profiling: a hydraulic-based tool for the high-resolution (0.015 m) characterization of K and a nuclear magnetic resonance tool for characterizing K and n at a coarser interval (0.5 m).

A concerted effort has been made in the United States to develop networks of observation wells to monitor water-level changes in our major aquifers. Many of these wells are equipped with sensors providing a continuous record of water levels through time. The maintenance of such networks is far from trivial, so considerable resources must be dedicated to the task of keeping network wells operational. The result is that little attention is given to the interpretation of acquired data. Changes in water levels in wells, however, provide a direct measure of the impact of groundwater development at a scale of relevance for management activities. We are actively engaged in assessing the information about an aquifer system that is embedded in hydrographs from continuously monitored wells. For this presentation, I will focus on the insights that can be gleaned from nothing more than a careful hydrograph inspection.

Aquifers are under stress worldwide as a result of large imbalances between inflows and outflows. These imbalances are particularly severe in aquifers in semi-arid regions that are heavily pumped for irrigation, such as the High Plains aquifer (HPA) in the United States. Information about the components of an aquifer's water budget is essential for the formulation of more sustainable management plans for these systems. We have developed a new approach for characterization of the net inflow (capture) term of the aquifer water balance over scales of hundreds to thousands of square kilometers using only water-level and water-use data. I will demonstrate the power of this approach for rapid assessment of the impact of proposed management actions and the prospects for sustainability in the data-rich portion of the HPA in Kansas.

Exploring the Effects of Climate Change on Critical Zone Behavior Using Geophysical Approaches

Speaker: Susan Hubbard
Affiliation: Lawrence Berkeley National Laboratory
Additional Authors: Baptiste Dafflon, Haruko Wainwright, Anh Phuong Tran, Emmanuel Leger, and Charu Varadharajan, Lawrence Berkeley National Laboratory

Quantifying how terrestrial systems respond to climate change and other perturbations is challenging due to the complexity of associated processes that occur from bedrock-to-canopy and over a wide range of spatial and temporal scales. This presentation will describe the development of new geophysical approaches to help bridge across relevant critical zone compartments and scales. We demonstrate the new geophysical approaches in an Arctic tundra ecosystem, where increasing temperatures are thawing the permafrost, potentially leading to significantly increased production of greenhouse gasses, and in a mountainous watershed in the Upper Colorado River Basin, where droughts and early snowmelt may influence downgradient hydrological and biogeochemical processes. The new approaches serve to integrate disparate geophysical, hydrological, geochemical and microbial datasets - many collected autonomously - to quantify the structure and function of important terrestrial systems as well as their responses to perturbations.

This presentation will describe the development of three new approaches to quantify terrestrial system behavior through integration of a wide range of point and geophysical measurements. We describe a new stochastic approach to estimate the distribution of terrestrial system functional zones using multi-type, multi-scale datasets. Functional zones are regions in the landscape that have unique distributions of properties that influence system behavior, such as carbon or water cycling. Identification of functional zones can be used to parameterize models and to guide optimized field campaigns. We also describe a networked system that jointly monitors above and below ground processes within critical zones (such as coincident variations in moisture and vegetation dynamics). The approach takes advantage of autonomous data acquisition approaches using platforms such as unmanned aerial systems and ground surface systems. The dense datasets enable the first 'visualization' of interactions that occur across key critical zone compartments in response to freeze-thaw and runoff processes. Finally, we describe the development of new approaches to jointly invert a range of streaming data (including geophysical, thermal, hydrological and meteorological data) to estimate key properties and to identify key system transitions.

We demonstrate how the three new methods are advancing our ability to remotely quantify critical zone properties and responses to perturbations - from local scales where native processes occur toward watershed scales that are relevant for managing natural resources and informing climate models.

Subsurface Imaging of the Critical Zone

Speaker: Kamini Singha
Affiliation: Colorado School of Mines
Additional Authors: Aaron Bandler, Holly Barnard, Rachel Mares, and Sydney Wilson

Geophysical methods have long been used to map subsurface heterogeneity. The development of Critical Zone Observatories worldwide has prompted the use of these tools in new systems and settings where broad, interdisciplinary problems are being explored. The data produced from these tools can provide new insight into subsurface processes, and provide tools for hypothesis testing. Here, we outline three projects exploring subsurface critical zone characterization and their importance to quantifying hydrologic processes within the Boulder Creek Critical Zone Observatory: (1) exploring the link between slope aspect and hydrogeology, (2) quantifying the impact of tree-water uptake on the subsurface throughout a growing season, and (3) mapping groundwater-surface interaction throughout baseflow recession.

In the first project, we investigate the relationship between slope aspect, subsurface hydrology, and critical zone structure by examining the orientations of foliation and fracturing and thicknesses of weathered material on north- and south-facing aspects based on borehole imaging and seismic refraction. Weathering models predict that north-facing slopes will have thicker and more porous saprolite due to colder, wetter conditions, which exacerbate frost damage and weathering along open fractures. We find that fracturing occurs in the same dominant orientations across slopes, but the north-facing slope

has more developed and slightly thicker soil as predicted, while the south-facing slope has thicker and more intact saprolite that is highly anisotropic in the direction of fracturing. Our data support hypotheses that subsurface flow is matrix-driven on north-facing slopes and preferential on south-facing slopes.

In the second project, we look at feedbacks among forest transpiration, soil moisture, and subsurface flowpaths. We investigate how soil moisture is affected by daily transpiration using time-lapse electrical resistivity imaging (ERI) on a highly instrumented ponderosa pine and the surrounding soil throughout the growing season. By comparing sap flow measurements to the ERI data, we find that periods of high sap flow within the diel cycle are aligned with decreases in ground electrical conductivity and soil moisture due to drying of the soil during moisture uptake. As sap flow decreases during the night, the ground conductivity increases as the soil moisture is replenished. The mean and variance of the ground conductivity decreases into the summer dry season, indicating drier soil and smaller diel fluctuations in soil moisture as the summer progresses. Sap flow did not significantly decrease through the summer suggesting use of a water source deeper than 60 cm to maintain transpiration during times of shallow soil moisture depletion.

Lastly, we look at groundwater-surface exchange during baseflow recession. Field methods consisted of using streambed temperature profilers and performing three 24-hr conservative solute stream tracer tests that were paired with time-lapse ERI during the late summer season. Being in the rain-snow transition zone, which is highly sensitive to changes in precipitation as predicted by climate change scenarios, this work provides insights to changing ecosystem services. Transient storage areas and the exchange between the stream and the subsurface decreased as stream discharge decreased throughout the testing period.

Integrated Observation, Prediction, and Management of Water Resources in a Changing World: Big Data Opprortunity or Paradox?
Session Chair: Pat Reed, Cornell University

Water resources systems are evolving globally across a complex mixture of economic, climate, landscape, and institutional contexts. An important and very basic question when contemplating the sustainability of these systems: Are we advancing the critical knowledge resources needed to understand, predict and manage these systems globally? Our current understanding and predictive skill in managing floods and droughts from catchment to global scales provides an informative baseline. Using this baseline, this session seeks to facilitate a discussion on how our community can use our science to discover potential information gaps and enhance water related decisions processes. One major aspect in addressing these challenges is to shift to a more active design and evaluation of our information sources from a holistic systems perspective—jointly documenting emerging natural dynamics, their socio-economic contexts, and key scientific insights. Sustained and holistic observation, prediction, and management of water resources systems is fundamentally important for clarifying their risks as well as documenting the ex post validity of science informed policies aimed at improving their sustainability.

The role of big data in building and applying the next generation of hydrologic models and soil databases over the globe

Speaker: Nate Chaney

Affiliation: Princeton University

This presentation will discuss two specific examples where high performance computing resources and field-scale data from satellite remote sensing are making a difference: (1) developing a field-scale resolving global hydrologic model termed HydroBloks and (2) assembling POLARIS, a 30m soil database over the contiguous United States (CONUS). HydroBloks and POLARIS provide unique examples that demonstrate the important role that big data and high performance computing can play in providing solutions to longstanding challenges to not only flood and drought monitoring systems but also to numerical weather prediction, seasonal forecasting, and climate prediction.

Decision support for multi-stakeholder drought management using high-performance computing and data mining

Speaker: Jon Herman

Affiliation: University of California Davis

In this presentation, we demonstrate a decision support framework that combines parallelized multi-objective search and data mining tools to discover flexible, robust portfolios of drought management policies. The proposed framework is demonstrated for four water utilities in the "Research Triangle" region of North Carolina, USA. The utilities supply nearly two million customers and interact via transfer agreements and shared infrastructure. The proposed framework offers critical insight into the risks posed by rising water demands and climate uncertainties, highlighting the value of developing large simulation-based datasets for regions facing the challenge of impending water scarcity.

Can big data bridge complex institutional contexts and fundamental hydrologic science to enhance our capability to predict and manage change in large basins?

Speaker: Howard Wheater

Affiliation: University of Saskatchewan

This presentation will draw on experience of trans-jurisdictional river basins in western Canada and Canada's GEWEX Regional Hydroclimate Project to argue that big data can transform large scale water science and the delivery of new knowledge and tools to support management of water futures in large basins.

National Water Model
Session Chair: Richard Hooper, CUAHSI

This session focuses on the technical details of the current implementation of the National Water Model, which is based upon WRF-Hydro and explore the use of WRF-Hydro as a community model. During both 2015 and 2016, Summer Institutes were held at the National Water Center that prototyped new features of the National Water Model that were then considered for inclusion in the operational code. The National Water Model is now being run by the National Weather Service in four different configurations multiple times per day and are publically available. The academic research community is being invited to contribute to the development and refinement of the National Water Model.

Implementation and Initial Evaluation of version 1 of the NOAA National Water Model

Speaker: Dave Gochis
Affiliation: UCAR

The NOAA Office of Water Prediction has led the development and implementation of a new National Water Model designed to provide centralized, operational water analysis and forecasting guidance for the U.S. The main goals of this effort are to provide streamflow forecasting guidance in currently underserved areas, to provide spatially continuous, high-resolution analyses of hydrologic conditions such as soil moisture, evapotranspiration, snowpack and surface inundation waters, to link this forecast information into a geospatial intelligence framework and initiate the utilization of earth system modeling approaches for hydrologic prediction. Version 1 of the National Water Model (NWM) began producing analysis and forecast information in early May, running on NOAA's central computing facilities at the National Centers for Environmental Prediction (NCEP). The underlying modeling architecture of version 1 of the NWM is the community WRF-Hydro modeling system. In addition to adapting WRF-Hydro for a large, multi-scale, national implementation, a number additional hydrologic model pre- and post-processing tools have been developed which ingest operational radar and numerical weather prediction data also generated at NCEP. This talk will provide a detailed description of the NWM workflow, its underlying driving datasets, the set basic model configurations that have been used in Version 1 of the NWM and a description of the output datasets and value added products which are now being produced. Additionally, statistical results from retrospective model runs and currently operational forecasts will be presented along with a few case studies of some recent high impact flooding events.

The National Water Model as a Framework for Innovation

Speaker: David Maidment
Affiliation: University of Texas at Austin

The National Water Model is a framework for innovation in simulation of continental hydrology and river hydraulics. A Summer Institute for graduate students at the National Water Center is an innovation incubator in which new ideas from different people and universities can be synthesized in a rapid prototyping mode to generate new perspectives for development of the National Water Model and application of its results. The combination of geographic information system representation of the physical environment and high performance computing linking meteorology, hydrology and hydraulics in real-time is capable of generating real-time flood discharge forecasting meaningful for local streams and rivers in a consistent manner across the whole continental United States. Using the concept of Height Above Nearest Drainage, it appears that a system for real-time flood inundation mapping can be developed at continental scale.

Advances in Managing Big Data from Environmental Sensors
Session Chair: Jeff Horsburgh

As sensors become cheaper and easier to deploy, the volume of environmental sensor data is growing. The ability to observe more variables in more places with high temporal resolution will drive better understanding of hydrologic and other environmental processes along with new scientific advances. However, the increasing volume of data poses a burden that must be met by advanced software and tools for collecting, managing, visualizing, and analyzing the resulting data. This session will explore both commercial and existing/emerging open source software tools for managing and analyzing Big Data from environmental Sensors.

Computing continuous record of discharge with quantified uncertainty using index velocity observations: A probabilistic machine learning approach

Speaker: Touraj Farahmand
Affiliation: Aquatic Informatics Inc.

Application of the index velocity method for computing continuous records of discharge has become increasingly common, especially since the introduction of low-cost acoustic Doppler velocity meters (ADVMs). In general, the index velocity method can be used at locations where stage-discharge methods are used, but it is especially appropriate and recommended when more than one specific discharge can be measured for a specific stage such as backwater and unsteady flow conditions caused by but not limited to the following; stream confluences, streams flowing into lakes or reservoirs, tide-affected streams, regulated streamflows (dams or control structures), or streams affected by meteorological forcing, such as strong prevailing winds. In existing index velocity modeling techniques, two models (ratings) are required; index velocity model and stage-area model. The outputs from each of these models, mean channel velocity (Vm) and cross-sectional area (A), are then multiplied together to compute a discharge. Mean channel velocity (Vm) can generally be determined by a multivariate regression parametric model such as linear regression in the simplest case.

The main challenges in the existing index velocity modeling techniques are: 1) Preprocessing and QA/QC of continuous index velocity data and synchronizing them with discharge measurements. 2) Nonlinear relationship between mean velocity and index velocity which is not uncommon at monitoring locations. 3)Model exploration and analysis in order to find the optimal regression model predictor(s) and model type (linear vs nonlinear and if nonlinear number of the parameters). 3) Model changes caused by dynamical changes in the environment (geomorphic, biological) over time. 5) Deployment of the final model into the Data Management Systems (DMS) for real-time discharge calculation. 6) Objective estimation of uncertainty caused by: field measurement errors; structural uncertainty; parameter uncertainty; and continuous sensor data uncertainty used for real-time derivation. Model uncertainty is often ignored but it is in fact an important source of uncertainty caused by building imperfect regression models due to lack of measurement and/or overfitting/under-fitting on data produced by the level of complexity of the model (number of model parameters).

In this presentation, we demonstrate a solution to these problems using a novel machine learning techniques to use index velocity and field measurement observations with measurement uncertainty to build a non-parametric/nonlinear self-adaptive Bayesian.

Ensuring data integrity for the National Flood Model densified monitoring network

Speaker: Matt Ables
Affiliation: KISTERS

The success of the National Flood Interoperability Experiment (NFIE) sponsored by the National Weather Service (NWS) and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) over the past two years has paved the way for the emerging National Water Model. Implemented through the Office of Water Prediction and new National Water Center in Tuscaloosa, Alabama, the National Water Model expands the existing NWS forecast system from 3,600 forecast points to 2.7 million reaches based on the NHDPlus geospatial dataset. The expansion in the size of the monitoring network requires an equivalent expansion in input data and computing power. However, comparison and calibration of the model results to empirical stream gauge data is still based on approx. 6,000 USGS stream gauges.

The vast majority of stream monitoring networks are operated by private companies, municipalities, and other non-federal agencies. These sensors have the potential to provide critical new data to the model, but because they are operated for a variety of purposes and functions, the resulting data quality has a large variance. New tools and methodologies to validate data quality, including pattern recognition and machine learning, must be implemented on a large scale before this new dataset is fed into the model. Establishing this process will then allow additional monitoring stations to be added by cities, counties, and other agencies.

Community-sourced tools for turning Big [sensor] Data into Big Science

Speaker: Jordan Read
Affiliation: USGS Center for Integrated Data Analytics
Additional Authors: Luke Winslow, and Alison Appling

Rapid growth of environmental sensor data has created a need for tools to access, transform, visualize, and analyze these large datasets. Without development communities to respond to timely needs, tooling can lag behind data production and negatively impacts research progress. Tool development groups within federal and academic research organizations, including the U.S. Geological Survey, the Global Lake Ecological Observatory Network, and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. have created tools that harness Big Data for water resources and enable Big Science. Here, we discuss elements of the collaborative structure within these groups that supports the creation of community-sourced tools. A cross-section of scientific advances will be presented that underscore the importance of reusable tools for water science, and the key role of tool developers in science expeditions. Examples of reproducible science that uses community tools to leverage large volumes of water data will include a national-scale analysis of stream metabolism, and a global analysis of instrumented lakes. In the era of Big Data for environmental sensor networks, research communities should embrace collaborations with technologists to build high quality tools that leverage these data.

Tentative CUAHSI Trainings & Workshops in 2017

The Community WRF-Hydro Modeling System

Lead Instructor: David Gochis, UCAR

NASA Remote Sensing Hydrology Workshop

Lead Instructor: JT Reager, NASA Jet Propulsion Laboratory

Using In-Situ Water Quality Sensors: Legrangian and Eulerian Applications

Lead Instructor: Matthew Cohen, University of Florida

Water Sustainability in a Global Economy

Lead Instructor: Benjamin Ruddell, Arizona State University

Wireless Sensing Bootcamp: From Theory to Practice

Lead Instructor: Branko Kerkez, University of Michigan

For more information on our trainings and workshops, please visit:
https://www.cuahsi.org/InstrumentationTrainingAndWorkshops

Workshop Descriptions

Tuesday, July 26, 2016

Do-It-Yourself, Open-Source Wireless Environmental Data Logging

Instructors: Anthony Aufdenkampe and Steve Hicks, Stroud Water Research Center

Time: 1:30pm - 5:30pm

Requirements: None

*Pre-registration is required.

Scientists and educators around the world have been realizing the potential of open source electronics, such as the Arduino® platform, to enhance their work. In this hands-on workshop, we will introduce participants to the Stroud Water Research Center's approach to assembling and programing Arduino-compatible data logger boards to serve as a DIY freshwater or terrestrial monitoring system.

This workshop will lead participants through the process of building a monitoring station that includes a solar-powered data logger connected to radio telemetry that can flexibly connect to a wide variety of sensors. Each pair of participants will follow hands-on exercises using a supplied laptop, an Arduino-compatible EnviroDIY[1] Mayfly data logging board, a solar panel and battery, a radio module and 2-3 different types of sensors.

Participants will learn about commercially available sensors including for measuring water depth, temperature, specific conductivity, turbidity, dissolved oxygen, precipitation, soil moisture, and soil redox conditions, and the various deployment options/strategies for stream-side installations. Participants will also be introduced to an option for web-based data capture and live data streaming that can display graphs on custom web pages.

CUAHSI Water Data Center (WDC) and HydroShare

Instructor: Martin Seul, CUAHSI and David Tarboton, Utah State University

Time: 1:30 - 3:30pm

Requirements: Participants must bring own laptop.

Join us to learn how CUAHSI's data access and analysis tools can be incorporated into your teaching and research. During the first half the workshop, participants will learn how to discover and download data from the CUAHSI Water Data Center using CUAHSI's web application HydroClient and how to analyze data using the WaterML R Package. Workshop participants will be asked to provide feedback on these tools, and CUAHSI staff will explain how such feedback is incorporated into the development process, as well as how one can become more involved in guiding development choices.

Following this workshop, researchers from the University of Washington will demonstrate how a modeling system, Landlab, can be linked to CUAHSI resources for a user friendly approach to building numerical landscape models.

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1   http://envirodiy.org/introducing-mayfly/

Modeling Landscape Response Using Big Data with Landlab

Instructor: Erkan Istanbulluoglu, University of Washington

Time: 3:30 - 5:30pm

Requirements: Participants must bring own laptop. Installing Landlab onto laptop is recommended but not required.

A new paradigm in hydrologic and earth system modeling is emerging where complex systems once coded in Fortran, C++ and cryptic scripts developed for research are being reconfigured in Open Source Python component based systems. In this workshop, we will introduce participants to one example of how this new type of modeling system, Landlab, can be linked to CUAHSI resources, such as the Water Data Center for time series data and HydroShare to run models online, access model inputs, and publish outputs for research collaboration and public dissemination.

Participants will learn how Landlab, a Python-based modeling environment, allows building numerical landscape models of earth surface dynamics such as geomorphology, hydrology, ecohydrology, glaciology, and stratigraphy, and a rapidly expanding network of open source collaborators.

Wednesday, July 27, 2016
CUAHSI Data-Driven Education

Instructor: Jon Pollak, CUAHSI

Time: 10:00am - 12:00pm

Capacity: Registration for this workshop is closed. If you are interested in participating in this workshop, please contact Jon Pollak, CUAHSI Program Manager, at jpollak@cuahsi.org.

Requirements: Participants must bring own laptop.

***Pre-registration is required. Closed workshop.**

CUAHSI supports data-driven education by collaborating directly with educators to help develop lesson plans and by contributing to educational resources. CUAHSI's free web-based data tools allow students to discover diverse types of data from numerous data sources at once. A new CUAHSI initiative is supporting the development of educational materials for publication online through the Science Education Resource Center[2] (SERC), which is a pathway to the federated National Science Digital Library (NSDL). Examples of previously published materials covering undergraduate university hydrology topics can be found here: Data and Model Driven Hydrology Education[3] and Activities for Teaching about Water[4].

During the first half of the workshop, CUAHSI WDC staff will demonstrate how CUAHSI's data services can be used to create place-based, data driven exercises with specified learning outcomes that are flexible enough to be modified and adapted into an instructor's individual lesson plan. Modules and exercises submitted by members of the community[5] will also be shared and the following elements will be discussed:

- Conceptual/Learning Outcomes
- Practical Outcomes
- Content

During the second half of the workshop, we will have a collaborative discussion among participants to help shape the development of future Water Data Center education and outreach tools and initiatives.

Additionally, this workshop will provide the opportunity to solicit feedback on CUAHSI data tools and the SERC website.

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2   http://serc.carleton.edu/index.html
3   http://serc.carleton.edu/hydromodules/index.html
4   http://serc.carleton.edu/hydromodules/index.html
5   https://www.cuahsi.org/Posts/Entry/27305

Community Modeling Discussions

Instructor: Ying Fan Reinfelder, Rutgers University and Martyn Clark, NCAR
Time: 10:00am - 12:00pm
Capacity: Not applicable
Requirements: None

The past decades have seen a proliferation of hydrologic models, designed for different purposes and representing different processes at different spatial-temporal scales. Because water stores and fluxes also regulate energy and biogeochemical stores and fluxes, some form of hydrologic model is often included as a key component in land ecosystem and climate models, bringing hydrologic modeling "out of" traditional catchment hydrology. Many of these models are developed by small research groups to address certain research questions, and often they are inaccessible to the community, poorly documented, and rarely tested against observations or other models in meaningful ways. The time has arrived for our community to take a collective look at our rich, diverse but disorganized modeling landscape, to synthesize what we know and don't know, to agree upon a framework for developing, testing and maintaining a suite of community-level models or model components, so that we have systematic ways to translate discoveries from the fields and laboratories into theories and models.

In this workshop, participants will learn about how projects such as SUMMA and INSPIRE on CLM-Hydro can lead to a community watershed model that is more comparable in scale and complexity to CZOs and research watersheds. We will also have a collaborative discussion among participants in an effort to receive feedback from the community not yet involved in the CLM effort as things move more towards mainstream community modeling efforts at watershed scales.

Developing Apps Using Water Web Services

Instructor: Dan Ames, Brigham Young University
Time: 10:00am - 12:00pm
Capacity: Not applicable
Requirements: None
*Pre-registration is required.

This workshop introduces attendees to programming using Tethys to access web services offered by CUAHSI and HydroShare. Tethys is a platform that can be used to develop and host water resources web applications or web apps. It includes a suite of free and open source software (FOSS) that has been carefully selected to address the unique development needs of water resources web apps. Tethys web apps are developed using a Python software development kit (SDK) which includes programmatic links to each software component. Tethys Platform is powered by the Django Python web framework giving it a solid web foundation with excellent security and performance.

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- **Share** your data and models with colleagues.
- **Access** web apps for data visualization and analysis

When you become a *HydroShare developer* at **https://github.com/hydroshare/** you can:

- **Add** new modules and capabilities to HydroShare.
- **Learn** how to use the HydroShare programming API.

www.hydroshare.org

Field Trip Descriptions

Note: Pre-registration is required for all Field Trips.

TUESDAY, JULY 26, 2016 FROM 1:00 - 5:00PM

FIELD TRIP A: KARST IN THE MID-ATLANTIC

Field Trip Leader: Daniel Doctor, USGS

The Mid-Atlantic region is home to some great examples of karst landscapes in North America. During this field trip, participants will visit three sites to observe the local karst development in carbonate rocks. Discussions will focus around the links between karst landscape development, hydrologic dynamics, and water resource sustainability. If time allows, a stop will be made at the Antietam National Battlefield Visitor's Center, which provides a chance to learn about the historical significance of the area and take in a view of the surrounding landscape.

Sites that will be visited include the Karst Window, C&O Canal at McMahon's Mill, and Antietam Battlefield. For detailed information on these sites and the local karst topography, please review:
Doctor, Daniel H., Weary, David J., Brezinksi, David K., Orndorff, Randall C., Spangler, Lawrence E. Karst of the Mid-Atlantic region in Maryland, West Virginia, and Virginia[1]. Field Guides, 2015, 40, p. 425-484, doi:10.1130/2015.0040 (11)

Participants will be transported by bus between sites, but some walking will be required to access the site. Good shoes are necessary as some of the walk will be through wooded terrain. Two of the three sites are handicapped accessible.

FIELD TRIP B: GEOMORPHOLOGY OF SHENANDOAH VALLEY

Field Trip Leader: Steve Kite, West Virginia University

Harpers Ferry holds a significant place in American History. It has witnessed a diverse number of people and events including the arrival of the first successful American railroad, abolitionist John Brown's raid on the arsenal, and the largest surrender of Federal troops during the Civil War.

During this field trip, participants will explore Harpers Ferry National Park. Sites that will be visited include Virginius Island, the Shenandoah and Potomac Rivers near John Brown's Fort, and the Chesapeake & Ohio Canal Lock and Dam. Discussions will focus on flood impact, geology and geomorphology, and history of canal and floods in the area. If time allows, participants will have a chance to explore the historic town before departing.

Participants should wear good shoes as walking is required to access all sites in the National Park.

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6 http://fieldguides.gsapubs.org/content/40/425.full.pdf?ijkey=WjRH2MBMnL6F8IZ&keytype=finite

Community Service Awards

AWARDEE: DAVID TARBOTON

Affiliation: Utah State University

In recognition of continuing contribution to the design of community facilities, including observatories and cyberinfrastructure and, in particular, for his efforts to lead the design of HydroShare to permit data and model sharing among hydrologic scientists, as well as his long-standing support of terrain analysis software for the benefit of the water science community. Dr. Tarboton also served on the CUAHSI Board of Directors and was a co-PI on the Hydrologic Information System project.

AWARDEE: KENNETH POTTER

Affiliation: University of Wisconsin

In recognition of selfless service to the hydrologic community including leadership roles in CUAHSI (Chair, 2001) and the AGU Hydrologic Sciences Section (President, 2000-2002) and a career-long passion for translating the best science into practice as evidenced by his tireless service on 14 National Research Council Committees to improve decision making on topics including flood control, disaster protection and restoration of aquatic ecosystems.
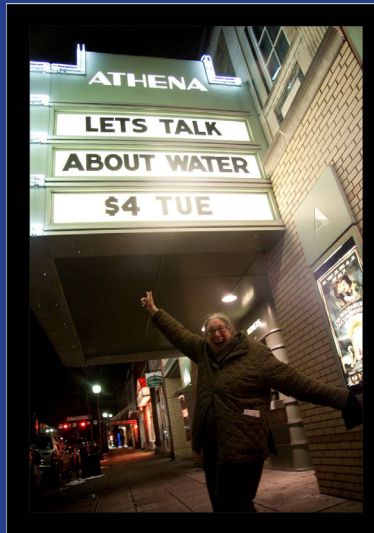
Let's Talk About Water

REBUILD BY DESIGN: SCIENTIFIC AND ENGINEERING CHALLENGES FOR SOCIAL ADAPTATION TO CLIMATE CHANGE

Hosted by Linda Lilienfeld, LTAW Director and Richard Hooper, CUAHSI
Panelists: Isaac Stein, Architect, West 8 and Josh Harrison, Senior Advisor, Center for Force Majeure

As a community, we are deeply involved in research into the effects of climate change. This event shifts the focus to changes society needs to make in infrastructure, urban design and in basic economic systems to adapt to a changing climate. Hurricane Sandy was a wake-up call for the vulnerability of infrastructure that supports basic services to coastal flooding. That event helps us focus on what aspects of prediction are important and how precise predictions must be to be useful to planners. We have invited two non-scientists to share their work on planning - for both urban and on economic systems - to address us this evening. Isaac Stein is an architect who worked on plans for Miami Beach for his PhD. His work has been featured in Vanity Fair. Josh Harrison is assisting his parents, the artists Newton and Helen Meyer Harrison, on a project that helps citizens visualize a changed world and asks questions of the kind of ecosystem and economic adaptations that are needed in the future. His work focuses in California with projects in the Sacramento Delta, the Sagehen site in the eastern Sierra Nevada and broader questions of sustainability of Western forestry in a changed climate.

Let's Talk About Water Challenge Grant Program

CUAHSI's Let's Talk About Water (LTAW) Program uses a simple film screening and panel discussion format to catalyze conversation between water science experts and the public. LTAW events have been a well-received and effective educational forum in which complex water issues are addressed through the use of film, followed by a moderated panel discussion related to the content of the film. By keeping the language simple and straightforward, the audience leaves with a deeper and more meaningful understanding of the complex water issues facing society.

The Challenge Grant Program helps support universities in the development of their own Let's Talk About Water water science outreach events. Primarily supported by the Johnson Family Foundation, the Challenge Grant program is awarded on a dollar for dollar matching basis - meaning that CUAHSI matches funds raised by the university (up to $3,000). Since its pilot year in 2012, CUAHSI has awarded Challenge grants to 17 Universities in the U.S. and Canada.

Applications for a new round of challenge grant funding will be accepted in the Fall of 2016!

For more information, visit: https://www.cuahsi.org/LTAWchallengegrants

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Posters are available for viewing throughout the duration of the Biennial Colloquium.
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Large-Scale Data Mining and Synthesis
Full-flow-regime Storage-streamflow Correlation Patterns with GRACE

Kuai Fang[1] (presenter) and Chaopeng Shen[1]

[1]Department of Civil and Environment Engineering, Pennsylvania State University

Streamflow is the component of the water cycle that is most accessible for human use. Tracking changes in the full range of streamflow regimes is crucial for a variety of practical purposes. However, a large proportion of basins in the world remain ungauged. Gravity Recovery and Climate Experiment (GRACE) provides information regarding terrestrial water storage (TWS) all over the world, which may provide insights for streamflow in ungauged area. We propose storage-streamflow correlation spectrum (SSCS), which contains correlations between TWS and full-range streamflow. We show that high correlations exist throughout the contiguous United States (CONUS), which can be exploited in the future to make predictions for ungauged basins. Varied and strong spatial patterns emerged under different climates. To interpret the large volume of SSCS data, we classified all catchments in CONUS based on SSCS and presented their spatial distribution. To further explore catchment characteristics that control SSCS, we trained a regression tree from USGS GAGES-II dataset, which provides a number of geospatial attributes of catchments. We found that the trained regression tree is able to reconstruct SSCS from catchment attributes. A few factors emerged as significant controls. Our work attempts to introduce a novel framework for analyzing relationships between terrestrial storage and streamflow in the full spectrum of flow regimes.

Integrating Massive Datasets into Operational Water Models: A Case Study on the Great Lakes

Kevin Fries[1] (presenter) and Branko Kerkez[1]

[1]University of Michigan

Hydrology has benefitted greatly from a wide array of observational datasets. But no two datasets are alike, with varying spatiotemporal resolution, observational noise, and bias. Additionally, operational models often require gridded data products to drive their predictions, yet observation networks are often sparse or irregular. As such, it is necessary to devise novel ways of integrating irregular datasets into models and regular spatiotemporally distributed data products. This poster demonstrates one such method through the use of a machine-learning framework with a case study on the North American Great Lakes. The Great Lakes contain 90% of the United States' and 20% of the world's fresh surface water, yet the hydrodynamics of the lakes are not well understood. One reason for this is a lack of open-water observations. By using Gaussian Process Regression, we demonstrate how a previously unused collection of over one million observations made by ships can be integrated into the Great Lakes Coastal Forecasting System's forcing data product to get improved estimates of wind speed, air temperature, surface temperature, and dew point. Additionally, we are able to characterize uncertainty spatiotemporally and thereby define where new observations are needed to further improve model predictions.

The quantification of land use change impacts to hydrology in Brazil

Morgan C. Levy[1] (presenter), Avery Cohn[2], Alan Vaz Lopes[3], and Sally E. Thompson[1]

[1]University of California, Berkeley
[2]Tufts University
[3]Water Management Agency, Brazil

In Brazil's rainforest-savanna (Amazon-cerrado) transition region, hydrological data are critical to the study of climate and land use change effects on components of the water cycle: rainfall, soil moisture, evapotranspiration, and streamflow, and industries and ecosystems reliant on those water cycle components. To date, there is only limited empirical understanding of land use change and hydroclimate dynamics in Brazil. Yet, understanding is important in this region, which is a global biodiversity center sensitive to climate and land cover, and where both agriculture and hydropower are expanding and in-

tensifying.

Until recently, empirical studies that compliment and validate model-based conclusions remained limited. Investigation of water resources, particularly rural and agricultural water use, has been data-limited at regional and global scales compared to other natural resource spaces for which data-intensive inquiry is now standard, such as in agriculture and energy. Nevertheless, relevant data is increasingly available, in part due to remotely-sensed data product availability and open data platforms. Therefore, a new space for empirical investigation and validation of hydrological model-based hypotheses of environmental change, specifically at regional and global scales, is now possible.

To observe the impact of land use changes on hydrology in Brazil, we synthesize a novel combination of ground network and remotely sensed data for land use/cover, climate, flow, soils, and topography. We connect temporal and spatial trends in LUCC occurring from 2000-2012 (and thus observable in the satellite record) to long-term historical flow records. Changes in hydrologic condition due to LUCC are observed in terms of a suite of novel statistics and regression-analyses at multiple temporal and spatial scales.

DEVELOPMENT AND APPLICATION OF A LINKED DATA MODEL FOR NHD AND RELATED DATASETS

Joshua Lieberman (presenter)

[1]Harvard University Center for Geographic Analysis

The hydrologic cycle is an intricate balance between precipitation and landforms that achieves its greatest expression in the linked hydrographic features that dominate most landscapes. Few datasets are more complexly linked than those that represent and characterize surface hydro processes, yet until now the mechanisms used to store and process such data have been mainly relational tables with increasingly involved schemes of foreign keys and classifiers. A new network or graph model for hydro data has been developed in the form of an RDF/OWL ontology that provides a natural form for the geometric and physics-based relationships that are characteristic of hydrologic processes. The model, an expression of the updated OGC HY Features domain model, represents connections between and among the fundamental entities of the catchment regions that receive water as precipitation, the landscape features that contain water flow, the surface water features that make up that flow, and topological connectivity that brings them all together. The ontological form of the model provides for expression of any number of relationships between these and other features, such gaging stations, sampling locations, and named places with distinct relationships to hydrography. Such relationships, in the form of subject predicate object triple statements, can be distributed widely between different datastores and hosts through URL's and linked data API's, or collected in one (physical or virtual) knowledgebase for automated inference of new relationships that are the logical consequences of existing ones. To test the new model, existing NHD and NHDPlus datasets, along with WBD datasets, NED elevation models, and GNIS placenames, have been transformed into RDF triples in a graph database where flow, nesting, and other connected feature collections as well as linked water data and geographic places can be quickly retrieved through SPARQL and similar graph query languages. Work is continuing to link additional observational datasets to the framework provided by the new hydro model. Progress is also being made in developing new capabilities for map data viewers to better take advantage of the feature and data relationships that are able to be expressed in the new model.

THE RELATIONSHIP OF DISSOLVED ORGANIC CARBON TO CATCHMENT CHARACTERISTICS IN THE NEVERSINK RIVER BASIN, NEW YORK

Kyongho Son[1,2] (presenter) and Karen Moore[1]

[1]New York City Department of Environmental Protection

[2]Hunter College, City University of New York

Recent studies of long-term trends have shown an increase in dissolved organic carbon (DOC) concentrations in surface waters (streams and lakes) across northern Europe and North America. This increase in DOC may be problematic for drinking water supplies due to the potential for a corresponding increase in disinfection by products (DBPs). In this study, a variety of alternative hypotheses are proposed and tested to explore the mechanisms for observed DOC increases in order to understand sources of variability and change in this important water quality parameter. This testing was based on DOC data from 11 USGS stream gauging stations within the Neversink River Basin, located in the Catskill Mountains, New York and included an analysis of the changes in DOC concentration at the event, seasonal, and annual scales. We examined the relationships

between DOC concentrations observed at these 11 sites and catchment characteristics. The catchment characteristics include topography (slope, elevation, and aspect), soil properties (soil hydraulic features and soil carbon content), vegetation (density and dominant species), and climate influences (precipitation, temperature, and atmospheric deposition). This study will increase our understanding of several factors influencing DOC concentrations in stream water in this locale. This is a first step in developing a model to accurately estimate DOC concentrations in an area that is an important drinking water source, beginning with headwater streams and scaling up to the whole watershed in an effort to inform future watershed management strategies.

Hydroclimatic assimilation of big data for inferring ecological controls on trigger of Zika Virus

Moiz Usmani[1] (presenter), Rifat Anwar[1], Md. Rakib Khan[1], Lian Shin Lin[1], Radhey Sharma[1], Antarpreet Jutla[1], and Rita Colwell[2]

[1]West Virginia University
[2]University of Maryland

Since the first case of Zika Virus (ZIKV) in Uganda in 1947, the disease has been reported in several regions of the globe. The etiological pathways of interaction of ZIKV with human population are largely unknown, primarily due to the fact that the disease was contained within Africa with relatively low incidence reported worldwide. Recent outbreak of ZIKV in northeastern coastal region of Brazil in 2015 has prompted calls for increased scrutiny of the trigger and transmission potential of the disease in the USA. ZIKV has been associated with Aedes mosquitoes but ecological and microbiological understanding of the virus is still emerging. Using principles of big data analysis, this study will provide insights of how disease triggers in a particular region. We have tracked almost all ZIKV outbreaks since 1947 using satellite data on temperature, precipitation and land cover to reach to conclusion that a comparatively drier condition supported the disease outbreak. We will show how big data was helpful to identify time lag between temperature and precipitation, that may provide conducive environment for growth of ZIKV. We will also discuss predictive spatial and temporal spread of this infection in the continental USA.

Characterization of Wyoming snow-water equivalent variability based on historical SNOTEL data

Denitza D. Voutchkova[1] (presenter) and Scott N. Miller[1]

[1]Department of Ecosystem Science and Management, University of Wyoming

The NRCS automated snowpack monitoring network (SNOTEL) encompasses 730 stations located in remote high elevation watersheds in the 11 Western states, providing open-access historical data (~30 years) and near-real time observations. The primary purpose of this monitoring is to deliver data for forecasting of water supplies in the West, where snowmelt is a dominating and crucial surface water source. When it comes to data volume, SNOTEL data can be considered the "younger sister" of Big Data, in that the overall volume of the data are not terrascale but the data exploration and analysis are challenging due to its scope. Issues relating to the use of historical time series data such as SNOTEL, including the variety, variability, and veracity of the data lead to issues in accurately managing the data with a high velocity, especially in the areas of exploratory mining and pattern recognition.

Our research focuses on characterizing the variability of several snow-water equivalent (SWE) derived parameters (e.g. : annual peak SWE accumulation, April 1st SWE, timing of peak SWE, period of snowmelt, rate of snowmelt, timing of snow disappearance) and identifying patterns in their temporal and spatial variability. The study exploits historical daily data from 70 SNOTEL stations located throughout Wyoming for 1978-2015.

We describe temporal and spatial variability in snowpack signals with the purpose of providing information that will improve the understanding of hydrologic response and streamflow response to snowpack dynamics. Regional heterogeneities and their importance for water management within the headwater state of Wyoming and downstream will be discussed. Special attention will be placed on the specific challenges and limitations of using this historical dataset for understanding the past and present snowpack and snowmelt variability and potential change due to climatic forcing and/or vegetation disturbances.

National Water Center Summer Institute
Relative Sensitivity of Flood Inundation Extent by Different Physical and Non-physical Models

Shahab Afshari[1] (presenter), Ehsan Omranian[2], and Dongmei Feng[3]

[1]City University of New York/City College

[2]University of Texas at San Antonio

[3]Northeastern University

Various hydraulic/GIS-based tools can be used for illustrating spatial extent of flooding for first-responders, policy makers and the general public. The objective of the current study is the comparison of four flood inundation modeling tools: HEC-RAS-2D, GSSHA, AutoRoute and HAND. In trade-off between accuracy and reliability of flood inundation models, simple and fast-computing non-physical models (AutoRoute and HAND) despite being insensitive to detailed topography and effects of hydraulic infrastructures (levee, dams, etc.) on flood dynamics, are highly demanded than detailed, slow-computing, relatively accurate physical models (HEC-RAS-2D and GSSHA). Current research was carried out on a 15km-long reach of Black Warrior River near the Northport levee and between Holt and Oliver dam and lock, in Tuscaloosa county, Alabama. Same geo-physical inputs (e.g. 10mX10m NED-DEM including river bathymetry and hydraulic infrastructure for physical models; low-, medium-, and high-friction values of bed-roughness associated with National Land Cover Dataset 2011 and inflow boundary conditions provided by the National Water Model for December 1st-31st 2015) were incorporated while setting up these models. Concerning the different response of the four models and the small magnitude of flood (less than 5-year return period) being considered, the water did not significantly overflow to the surrounding floodplains, however the inundation extents varies noticeably for low- to high-friction land cover settings. Comparability analysis between inundation extents produced by HAND and AutoRoute with either HEC-RAS-2D or its union with GSSHA (~66% overlapping), showed that in average, HAND has ~20% more non-overlapping area than AutoRoute. Besides, joint-inundated regions of the four models only occupy ~33% of overall flooded extent. Further research will be carried out focusing on a different study area in order to ascertain relative comparability of these models and their sensitivity to geophysical as well as man-made attributes.

Radar Measurement and Flow Modeling

Jim Coll[1] (presenter), Mike Johnson[2], and Paul Ruess[3]

[1]University of Kansas

[2]University of California, Santa Barbara

[3]University of Texas at Austin

Modern hydraulic model accuracy is limited by the quantity and density of measurements available within a reach. Currently the hydrologic community is reliant on a combination of USGS gage and field data used for modeling reach behavior and properties. Thus the most obvious way to improve upon the shortage of available data is to implement a more densified measurement network. While USGS stations are the industry standard, they are costly and their strength lies in collecting limited information very well. One way to supplement this foundational network is to install modern sensors, such as the Sommer GmbH RQ-30 radar sensor, which are cost-effective, measure continuous velocity and stage height, and operate autonomously. While in theory these sensors seem like the next logical step for the hydrology community, their reliability, accuracy, and potential must be more thoroughly evaluated before large-scale use is appropriate. This paper aims to evaluate three separate but related concerns: understanding how modern sensors compare with their traditional USGS counterparts, how they can be integrated with open source hydraulic modeling software to model small scale reaches, and to determine what data is needed to construct these models.

Object-based Flood Inundation Mapping

Krishna Gadiraju[2] (presenter) and Yan-Ting Liau[1]

[1]University of Texas at Dallas

[2]North Carolina State University

In an effort to prevent loss of life and property, flood inundation mapping is generated in order to assess the impacts and costs of flooding events. However, the spatial and temporal limitations of remote sensing platforms, offers little support towards instant mapping efforts. Optical satellites such as Landsat and MODIS perform poorly in the presence of cloud cover, but collect information across a wide spectrum. On the other hand, active sensors such as SAR are able to penetrate clouds and have high spatial resolution, but collect information only within a specific range. Object-based image classification has

been proposed to improve classification accuracy. However, most studies focus on a single source. Our study concentrates on combining multiple data sources, more specifically SAR and Landsat 8, in order to include the widest possible information set for improving the quality of segmentation. In the first step, existing image pre-processing techniques are applied. In particular, seven pan-sharpening techniques are used to improve spatial accuracy, while also retaining spectral characteristics. Image filtration techniques are used to reduce speckle noise in SAR imagery. In the second step, a new moisture enhancement index (MEI) was developed. Finally, several image segmentation algorithms including, but not limited to, Hierarchical clustering, Level-Set based techniques (Morphological Snakes), and Graph based techniques (Random Walker) are compared using unsupervised measures, as ground truth is not available. Initial results have shown the effectiveness of using image pre-processing techniques, as well applying different sources to detect water bodies. Using existing river shape-files and combing with MEI has proved useful in detecting small rivers, which are nearly invisible in both SAR and Landsat. SAR, on combination with other moisture indices by Principal Component Analysis accurately detects shapes of large water bodies.

Case Study: Delineating Stream Flowlines and Watershed Boundaries in the Lower Rio Grande Valley Using High Resolution LiDAR Derived Digital Elevation Models

Mark Hagemann[2] (presenter), Brenda Bazan[1] and Kyungmin Kim[3]

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Characterized by a very flat terrain, periodic heavy rainfall and clay soils, the Lower Rio Grande Valley (RGV) in Texas remains an area very prone to wide-scale flooding. It is imperative that existing hydrologic models are improved and refined to further understand the potential impact of flood events and, most importantly, provide as much lead-time as possible to its more than one million residents. The National Water Model's efforts to simulate real-time and forecasted streamflow might not be enough to model this intricate and underserved area since the scale of the model cannot account for the very mild, but significant, changes in elevation in the RGV. Taking this into consideration, high resolution LiDAR (Light Detection and Ranging) data of the RGV was analyzed using the ROGER CyberGIS supercomputer with the objective of more accurately representing drainage networks and flood vulnerabilities in the region. Using the TauDEM toolset, LiDAR-derived digital elevation models (DEMs) were processed into hydrologic features such as stream networks and sub-watersheds. Existing NDH flowlines in the area were compared visually to the high-resolution DEMs and to the TauDEM-derived drainage features. The NHD flow lines were modified in ArcGIS to pinpoint and enhance flaws, like breaks and missing lines, in the drainage systems. The NHD network used for the NWM was missing some of the main drainage features in the Brownsville Resaca Watershed. Some of these missing features were found in other NHD flowline vectors, however most were not consistent with the satellite images of the area. The RGV is an area difficult to model due to its unique features and lack of data. This study is a big first step in gathering, consolidating, analyzing and enhancing existing hydrologic data. The results of this study will be reflected in improved hydrologic models and flood forecasting in the RGV.

Translator TTX – Bridging the Communication Gap between Researchers and Emergency Responders

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This study focuses specifically on what emergency management agencies at all hierarchical levels consider to be a "gap" between the critical needs of first responders and the deliverables offered by advancing science. For this study, we posit that this gap is in fact not an engineering science problem but rather a communication problem. Social norms and human behavior hold the key to better understanding and reducing loss of life from flood events. The objective of this study is to develop a conceptual model to translate and interconnect the "science domain" (i.e., weather information sources) with the "social domain" (i.e. emergency managers, first responders and those affected by an event). To address communication problems between the science domain and the social domain, we adopt a "Rosetta Stone" metaphor and model paradigm. We refer to this "translation" concept as "Translator-TTX". The study has the potential to make a contribution through maximizing

the value of applied disaster science and management research and technology. Through simplification and efficient delivery of that knowledge, just-in-time techniques, and state-of-the-art algorithms, the needs of practitioners [first responders] will be met. Finally, through primary research conducted during the Summer Institute as rapid prototyping exploratory research, first responders were eager to close the gap between researchers and first responders. The main findings indicate opportunities to implement ESRI Story Maps for pre-planning tabletop exercises (TTX) as well as reverse look-up possibilities and spatial-temporal- locational 3D object analytics to provide emergency personnel at different levels in the hierarchical structure with enhanced visual perceptions and situational awareness. In conclusion, an expert decision support system utilizing a knowledge warehouse repository of events, scenarios, standard operating procedures (SOPs), and best practices is feasible to implement in several iterations including a serious game software platform. Connecting the efforts of engineering science to the people that need it most to enhance the first responder success is the motivation behind the study.

Reimagining Disaster Warning Systems – OPERA: Operational Platform for Emergency Response and Awareness

Mike Johnson[1] (presenter), Paul Ruess[2] and Jim Coll[3]

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Modern disaster alerts are primitive in comparison to the geospatial intelligence and forecasting capabilities of modern science. Alerts are often spatially vague and lag temporally, resulting in warnings that are confusing and often ignored. This research aims to bridge the gap between science and emergency alerts with a system that operates across the full life of an event including preparedness, warning, and response. The OPERA portal showcases a suite of systems and relevant functionalities for fire, flood, active shooter, and chemical spill emergencies, which can be easily translated to other disasters representable as polygons. Ultimately the goal is not to create a final solution for emergency response, but rather to reimagine emergency alert systems, demonstrate potential improvements, and inspire relevant institutions and researchers to believe in their viability.

HAND Flood Mapping through the Tethys Platform

Savannah Keane[1] (presenter), Christian Kesler[1], and Xing Zheng[2]

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The Height Above Nearest Drainage (HAND) is a method for generating flood inundation maps. Currently, HAND is calculated with a 10 meter digital elevation model (DEM) in ArcMap. The purpose of the project is to create an online application to easily view the flood maps generated from HAND. The online application is run through Tethys, which is a platform created by Brigham Young University (BYU). The online app uses streamflow forecasts generated by the National Water Model (NWM) to predict potential flooding.

The Modified HAND Method

Ryan McGehee[1] (presenter), Lingcheng Li[2], and Emily Poston[2]

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The National Water Model (NWM) is a hydrologic and hydraulic model that forecasts streamflow over the entire continental United States. Upon becoming fully operational one of the most anticipated products from the model will be live flood inundation mapping. This is a difficult task given the computational demand of hydraulic models. It is imperative that a simpler method be used for this task, that may otherwise be impossible given economic and computing constraints. Some have suggested that the height above the nearest drainage (HAND) method be used for this task, yet it is heavily criticized for its limitations. We propose that a modified HAND method—based on stream order—be used to complement the weaknesses of the original method. These enhancements include enabling non-uniform inundation within a catchment, accounting for backwater effects in catchments with precipitation and flooding downstream of the catchment, and bypassing hard flow paths that are shorted during large flooding events. We expect that other benefits that are not so obvious to become more apparent as the method is further analyzed. We have successfully generated the modified HAND rasters for all stream orders in Alabama and its related HUC4 basins (8 stream orders in total). We demonstrate that the modified HAND method retains

the strength of the original method in cases where the original HAND is more appropriate (e.g. uniform inundation conditions), but better represents cases in which the original HAND has performed poorly. There are two computational demands of these methods: setup and operation. The modified HAND method requires slightly more setup computation but certainly less than a 50% increase in computation (for initial raster creation at each stream order). The operational computation is comparable to the original method and can even be less due to the potential to group catchments and perform somewhat of a lumped parameter analysis. The main point here is that the modified HAND provides far more flexibility for a potential water balance computation, whereas HAND is at least more difficult to implement water accounting if it is even possible. We recommend that the modified HAND be implemented in any and all cases where HAND is currently employed for superior results and potentially smaller computational demand.

Quantifying Uncertainty in Flood Inundation Mapping Using Streamflow Ensembles along with Coupled Hydrologic and Hydraulic Models

Christopher Zarzar[2] (presenter), Ridwan Siddique[1], Hossein Hosseiny[3] and Michael Gomez[1]
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[3]Villanova University

The National Water Model (NWM) provides a platform needed to operationalize nationwide flood inundation forecasting and mapping. The ability to model flood inundation on a national scale will put invaluable information into the hands of decision makers and local emergency officials. Often, forecast products use deterministic model output to provide a visual representation of a single inundation scenario, which is subject to uncertainty from various sources. While this provides a straightforward representation of the potential inundation, the inherent uncertainty associated with the model output also needs to be conveyed for better decision making support. To this end, our goal in this study is to produce ensembles of future flood inundation conditions (i.e. extent, depth, and velocity) to quantify and visualize uncertainties associated with the predicted flood inundation maps. The setting for this study is located in a highly urbanized watershed along the Darby Creek in Pennsylvania. A forecasting framework involving the NWM coupled with multiple hydraulic models was developed to produce ensembles of future flood inundation conditions. Time lagged ensembles from the NWM short range forecasts were used to account for uncertainty associated with the hydrologic forecasts. The forecasts from the NWM were input to the International River Interface Cooperative (iRIC) and HEC-RAS software packages, from which water extent, depth, and flow velocity were output. Quantifying the agreement between output ensembles for each forecast grid provided the uncertainty metrics for predicted water extent, depth, and flow velocity. For visualization, a series of flood maps that display flood extent, water depth, and flow velocity along with the underlying uncertainty associated with each of the forecasted variables were produced. The results from this study demonstrate the potential to incorporate and visualize model uncertainties in flood inundation maps in order to identify the high flood risk zones with critical thresholds.

Comparison of Flood Inundation Mapping Techniques between Different Modeling Approaches and Aerial Imagery

Jiaqi Zhang[1] (presenter), Dinuke Munasinghe[2], and Yufen Huang[3]
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Flood inundation extent serves as a crucial information source for both hydrologists and decision makers. Accurate and timely inundation mapping can potentially improve flood risk management and reduce flood damage. In this study, the authors applied two modeling approaches to estimate flood inundation area for a large flooding event that occurred in May 2016 in the Brazos River: the Height Above the Nearest Drainage combined with National Hydrograph Dataset (NHD-HAND) and the International River Interface Cooperative (iRIC). NHD-HAND features a terrain model that simplifies the dynamic flood inundation mapping process, which is suitable for large-scale application. iRIC is a hydraulic model that simulates flood extent under quasi-steady approximation using Flow and Sediment Transport with Morphological Evolution of Channels (FaSTMECH). In terms of data source, HAND and iRIC utilized the National Water Model (NWM) streamflow output data and the United States Geological Survey (USGS) stream gage data, respectively. The flood inundation extent generated from these two modeling approaches were validated against the Landsat Satellite Imagery data. Four remote sensing classification techniques were used to provide alternative observations: supervised, unsupervised, normalized difference water

index and delta-cue water change detection. According to the quantitative analysis that compares inundated and non-inundated areas with different remote sensing classifications, the fitness index of iRIC simulation ranges from 54.2% to 69.9% while that of NHD-HAND ranges from 47.3% to 55.5%. We found that even though HAND better captures some details than iRIC in the inundation extent, it has problems in certain areas where sub-catchments are not behaving independently, especially for extreme flooding events such as in May 2016 (water level reaching 16.8 meters at Brazos River near Hempstead). The iRIC performs better in this case, however, we cannot simply conclude iRIC is a better-suited approach than HAND considering the uncertainties in remote sensing observations and iRIC model parameters. Further research will include more comprehensive assessments based on a larger variety of flood events. The findings from this study indicate that, for extreme events, simplification on the intricacy of flow dynamics have relatively minor influence on prediction, which in the authors' opinion positively justifies the utility of HAND on large-scale riverine inundation mapping.

Big Data and Large Scale Land Models

Improving the representation of hillslope hydrology in an Earth System Model

Justin Perket (presenter)[1,2], Ying Fan Reinfelder[2], Martyn Clark[2], and David Lawrence[2]

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In most Earth System models, the rudimentary representation of lateral flow restricts the ability to accurately predict the water cycle. This limits our understanding of the impact of the terrestrial water cycle on climate and biogeochemical cycles. In order to better predict the global water cycle and its interactions within the Earth system, we have implemented a representation of hillslope hydrology into the Community Land Model (CLM). CLM divides the Earth's surface into gridcells, each with a (1-D) column representation of soil water and energy fluxes. This poster describes work completed to expand the structure of CLM to allow multiple columns with lateral hydrologic connectivity. By using representative hillslopes in each gridcell, each hillslope consisting of multiple soil columns, we are able to implement lateral saturated flow within the constraints of a global climate model.

The accuracy of steady-state transit time estimates in a non-steady climate: Modeling experiments in a Valley and Ridge agricultural watershed.

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The catchment transit time distribution (TTD) is the probabilistic distribution of water travel times through a watershed, from rainfall to discharge. TTD estimates are often used to parameterize water quality simulations that inform decision making. These TTD estimates are sometimes generated using process-based, numerical watershed flow models with particle tracking and a "steady-state" approximation. The steady-state approximation assumes that the time-variability of hydrologic fluxes and the catchment TTD is negligible. It is well known, however, that hydrologic fluxes and the catchment TTD can be highly transient due to variable climatic conditions. As a result, steady-state TTD estimates might be prone to significant "climate-induced" error. Model configurations that relax the steady-state approximation are available, but can be data and resource intensive. Here we present ongoing efforts to better understand the time-variability of transit time distributions, and the size and nature of consequent deviations from steady-state TTD estimates under various climatic and physiographic conditions. Towards this end, a virtual watershed testbed is being built using the fully distributed ParFlow watershed flow model with SLIM-FAST particle tracking code to produce and compare "approximate steady-state" and "virtually-true time-varying" TTD estimates for different time periods and flow pathways. To help corroborate the simulations, the model is being populated with over forty years of hydrometric data from the WE-38 subwatershed of USDA's Mahantango Creek experimental catchment in east-central PA. The model testbed is being forced with a design matrix of plausible climate scenarios (e.g., higher temperature and precipitation) and physiographic scenarios (e.g., varying topography and hydrologic conductivities) in order to gauge the significance of climate-induced transit time variability under a range of environments. The results are intended to help researchers and practitioners determine if and when steady-state TTD estimates provide

reliable information under a variable climate.

Big data and models for coastal communities

Xuan Yu[1] (presenter) and Holly Michael[1]

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Climate change and sea-level rise are likely to increase the frequency and intensity of land-ocean interactions along the coast. Ocean surges are one such interaction, which can severely damage coastal water resources in addition to surface infrastructure. Ocean surges introduce saltwater to surficial coastal aquifers. The subsequent flooding process is controlled by regional landscape features, which results in variable depth of saltwater inundation and heterogeneous infiltration of the saline water into the subsurface, resulting in groundwater salinization. Simulation of coastal hydrologic processes driven by ocean surges requires models that incorporate weather conditions, land surface data, subsurface characterization, etc. Prediction of coastal water resources vulnerability is a complicated problem at global to regional scales. To start from a simple system, we modeled a theoretical ocean surge event and variable-density groundwater flow and salt transport in 3D using the fully coupled surface and subsurface numerical simulator, HydroGeoSphere. The model simulates the coastal hydrologic process as an integrated system that includes overland flow, coupled surface and subsurface exchange, variably saturated flow, and variable-density groundwater flow. To represent various coastal landscape types, we simulated both synthetic fields and real-world coastal topography from Delaware, USA. The groundwater salinization assessment suggested that the topographic connectivity promoting overland flow controls the volume of aquifer that is salinized. In contrast, the amount of water that can be stored in surface depressions determines the amount of infiltrated seawater and the associated flushing time duration. Further study will scale up this regional modeling result to a global scale with integration of realistic ocean surge data and subsurface representations.

New Technologies and Techniques for Hydrology
Estimation of Land Surface Fluxes through Assimilation of Surface Temperature and Moisture States into Models of Terrestrial Water and Energy Balance via Variational Data Assimilation Approach

Abedeh Abdolghafoorian[1] (presenter) and Dr. Leila Farhadi[1]

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Accurate determination of water storage in the soil and accurate partitioning of evapotranspiration (ET) between evaporation and transpiration is crucial in various hydrological, meteorological, and agricultural applications. "In situ" measurements of evapotranspiration are costly and cannot be readily scaled to large areas. Remote sensing technology is recognized as the only viable means to map ET at the earth's surface in a globally consistent and economically feasible manner. Remote sensing technology can measure land surface state variables such as surface temperature and moisture but cannot directly measure the surface fluxes and the root zone soil moisture profile. Therefore, there is a need for techniques to make quantitative estimates of these variables using remotely sensed observations.

In this work, we applied a novel approach based on the variational data assimilation (VDA) methodology to estimate land surface fluxes including evapotranspiration. This approach accounts for the strong linkage between terrestrial water and energy cycles by coupling a dual source energy balance equation with a water balance equation through the mass flux of evapotranspiration. ET integrates water (evaporation and transpiration), energy (soil and canopy latent heat fluxes), and biological (root uptake) processes. Surface moisture and temperature data are assimilated into these models simultaneously. Heat and moisture diffusion into the column of soil are adjoined to the cost function as constraints. This coupling results in more accurate prediction of land surface heat and moisture fluxes and consequently soil moisture at multiple depths with high temporal frequency as required in many hydrological, environmental and agricultural applications. The assimilation algorithm is tested with a series of experiments using a synthetic data set generated by the simultaneous heat and water (SHAW) model. We demonstrate the VDA performance by comparing the (synthetic) true measurements (including profile of soil moisture and temperature, land surface water and heat fluxes, and root water uptake) with VDA estimates. In addition, the feasibility of extending the proposed approach to use remote sensing observations is tested by limiting the number of LST observations and soil moisture observations.

An urban flash flood warning system based on real-time sensor data

Matthew Bartos[1] (presenter), Brandon Wong[1] and Branko Kerkez[1]

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High resolution sensor networks are poised to change our understanding of floods—the number one cause of natural disaster fatalities worldwide. Existing flood forecasting techniques rely largely on modeling approaches—such as numerical weather prediction and hydrologic modeling—and lack the spatial and temporal resolution required to predict flash floods at intra-urban scales. To address this problem, we develop a wireless sensor network that can be deployed throughout urban areas to measure water levels in real-time. Our flood monitoring system consists of two components: (i) a network of custom low-cost wireless water level sensors, and (ii) a web-based data assimilation platform. This coupled system allows us to detect flood events at the level of individual roadways and at a minute-scale temporal resolution, allowing for (a) improved deployment of emergency services, (b) targeted warnings based on spatial location and (c) routing of traffic during storm events. We use the Dallas—Fort Worth area as a test case for this flood monitoring system, given that it has been historically susceptible to flash flood events. Deployment of the flood monitoring system is currently underway, with one water level sensor deployed in the Fort Worth area, and an additional nine nodes ready for installation.

DYNAMICS OF NITRATE CONCENTRATION-DISCHARGE PATTERNS IN AN URBAN WATERSHED

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Concentration-discharge (c-Q) relations have been used to infer watershed-scale processes governing solute fluxes. Quantifying solute fluxes is of interest in terms of satisfying regulatory drivers (Total Maximum Daily Loads) as well as advancing scientific understanding of nutrient export. Prior studies have documented inconsistent concentration-discharge patterns driven by changes in end-member concentrations. Here we examine three-years of high-frequency nitrate and discharge data for an urban stream in the Baltimore region to quantify temporal variability at storm-event, seasonal, and interannual time scales. On a storm-event scale, we calculate a watershed-specific dQ/dt threshold when storms switch from counter-clockwise to clockwise c-Q behavior. On a seasonal scale, nitrate concentrations are consistently highest in summer and lowest in winter, whereas nitrate loads are highest in winter and lowest in summer; this behavior differs from forested systems in this region. We have evaluated data in which a wet year (2014) is bracketed by two dry years (2013, 2015). The interannual variability is striking: 2014 is characterized by higher base flow, higher nitrate concentrations, and lower dissolved oxygen in summer months compared to 2013 and 2015. We propose two new hypotheses on the relative role of hydrologic and metabolic controls on stream nitrate concentrations and fluxes. This work highlights the value of long-term, high-frequency c-Q data collection for calculating and analyzing solute fluxes.

IDENTIFYING FOREST SUCCESSION TRENDS FROM STREAMFLOW RECESSION BEHAVIOR

Christopher Krapu[1] (presenter)
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Deforestation is known to influence streamflow and baseflow in particular in sub-humid environments. Baseflow contributions to the recession limb of a flood hydrograph convey information about subsurface stores from which trees also draw water. Recent works based on the assumptions outlined by Brutsaert and Nieber (1977) have proposed analyzing baseflow recession curves on a per-event basis. In this framework, each event's recession curve is governed by a power law relation with per-event scale and shape coefficients. As baseflow recession depends in part upon ET demand from trees, these coefficients are hypothesized to contain useful information about watershed vegetation. We conducted analyses of 13 small experimental catchments in the eastern United States with known forest treatment histories to determine whether or not baseflow recession behavior as observed from daily discharge records could serve as an indicator of deforestation in the drainage basin. Specifically, we calculated scale coefficients for each major stormflow event at each test site and examined the shift in their distribution between a pre-cut and post-cut period. We then modified this method to identify a timescale for recovery in two medium-sized watersheds in the North Carolina Piedmont which did not have extensive records of forest cover. We observed a statistically significant difference in coefficient values in 5/8 treatment watersheds and 0/5 control watersheds. This suggests that lesser alterations to forest cover may not be detectable yet this method is robust against changes in climatic forcings. Additionally, we found clear evidence that the vast majority of the forest regrowth in the Piedmont

sites took place before 1970. Our approach uses short snippets of streamflow data from storm events and does not require precipitation for closure. As a proof-of-concept, this work suggests that major alterations to forest cover can be inferred from daily data of stream discharge.

Exploring Mechanisms of Woody Plant Encroachment using Landlab Ecohydrology

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Arid and semi-arid grasslands of southwestern United States have changed dramatically over the last 150 years due to woody plant encroachment. Driven by overgrazing, reduced fire frequency, and climate change, shrub encroachment is considered as a major form of desertification. In Landlab (a Python toolkit for modeling earth surface processes), we represent ecohydrologic plant dynamics, fires, grazing, and resource distribution (erosion/deposition) in separate components. In this work, we demonstrate their utility for studying shrub encroachment using three examples. In the first example, physically based vegetation dynamics model is used to simulate biomass production based on local soil moisture and potential evapotranspiration driven by daily simulated weather, coupled with a cellular automata plant establishment. While climate is included as forcing, the model disregards resource redistribution, except for seed dispersal. In the second example, a simple stochastic cellular automata model with two state variables, vegetation cover and soil resource storage, are used to model shrub patterns based on probabilistic establishment-mortality interplay, mediated by resource redistribution, while explicit roles of climate were neglected. In the third example, we coupled the latter two models to examine the roles of disturbances and resource distribution in a dynamic ecohydrologic context. Inferences are drawn on how encroachment factors and model complexity affect shrub pattern in space and time.

Building sensor networks to enable bigger-data hydrology

Brandon Wong[1] (presenter)
[1]University of Michigan

As our understanding of storm variability and frequency continues to change, a reliable sensor platform is needed to improve our understanding and control of urban systems in an uncertain climate. We present an open-source, low-power sensor platform for the ubiquitous and long-term measurement of hydrologic systems. To resolve the uncertainty of hydrologic variables, each sensor node interfaces with a suite of environmental sensors -- including precipitation, soil moisture, stormwater flows and water quality -- while leveraging existing cellular networks for reliable bi-directional communication. The platform integrates with a flexible cloud-based framework that analyzes real-time data and estimates hydrologic variables in real-time. We discuss several applications of this platform, including (1) an existing flood monitoring and warning system and (2) the monitoring and control of both green and gray stormwater infrastructure.

Subsurface Characterization
Ion Mass Balance and Weathering Rates in Pond Branch, Maryland

Cassandra Cosans[1] (presenter), and Ciaran Harman[1]
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Fluxes of ions through a catchment can offer insights into chemical processes and flow paths contributing to stream discharge. In this study the mass balance of several cations (Na+, NH4+, K+, Mg2+, and Ca2+) and anions (Cl-, NO3-, PO43-, and SO42-) was examined for Pond Branch, a small, forested catchment in Oregon Ridge Park, Maryland. Weekly stream discharge grab samples and aggregate precipitation samples were used in concert with continuously gauged discharge and precipitation amounts to calculate the mass flux of each ion through the catchment. Sulfate was the only solute with a significant concentration-discharge relationship, with a positive linear correlation between discharge and concentration. Stream discharge flux of the other ions was estimated with uncertainty bounds based upon the mean and standard deviation of the measured concentration values. Over the spring and summer nitrate, potassium, calcium, phosphate, and ammonium had net positive fluxes, indicating that a larger mass flux entered in precipitation than flowed out in discharge.

Chloride, sulfate, and sodium had net negative mass fluxes through the catchment indicating that the mass flux out in discharge was larger than the precipitation inputs. The net flux of magnesium was nearly zero indicating a balance between inputs including weathering and outputs and biological storage. The solutes with net positive fluxes are likely temporarily stored through biological fixation or lost through denitrification in the case of nitrate and ammonium. For the solutes with net negative fluxes, sodium and sulfate may both be contributed as weathering products, while the source of excess chloride in the catchment is likely dry deposition. Stoichiometry of the weathering products generated through the chemical weathering of plagioclase to kaolinite in the catchment allows the weathering flux of calcium to be calculated through its ratio to sodium. Using this weathering flux the biological uptake of calcium can be calculated as the residual in the mass balance. The estimated calcium weathering rate during the spring and summer months is 1.35 kg per acre per year and the rate of calcium biological uptake is 2.39 kg per acre per year. These rates are significantly larger than published values from the 1960s, however the annual rates may be overestimates because they are based on the wetter and more biologically active half of the year. Comparison to historic data for the catchment also indicates that dry deposition of chloride may have increased. The magnitudes of the ion mass fluxes offer insights into rates of weathering, biological activity, and the climate sensitivity of catchment chemistry.

How climate change could affect the spatial pattern of transpiration due to uncertainty in plant accessible soil water storage, in a Mediterranean environment

Christopher Heckman[1] (presenter), Naomi Tague[1], and Alan Flint[1]

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Reservoirs are critical in supplying year round access to water for both human and ecological needs. In Mediterranean climates, where precipitation typically only falls in winter, both snowpack and soil water reservoirs, or storages, play a critical role in partitioning precipitation between evapotranspiration and runoff. When winter precipitation cannot be accommodated by storage, vegetation will have limited access to late summer water, when demands are high, and early season runoff will increase. As total storage decreases due to climate change's impact on snowpacks, subsurface storage of water that is accessible by plants (PAWSC) is likely to play a more primary role in the partitioning of incoming precipitation. Due to the highly heterogeneous nature of PAWSC and the difficulty of measuring it over large scales, we used a hydrologic model to estimate the impacts from a range of PAWSC on the partitioning of precipitation for latitudinal and elevation gradients across the Sierra Nevada of California. Our results highlight the impacts of climate change and its spatial pattern of where transpiration will increase, which leads to a reduction in downstream supplies, as well as areas where transpiration will decrease, increasing vegetation's vulnerability to fire and insect outbreaks. The magnitude and direction of how transpiration will react to increasing temperatures is dependent on interactions between PAWSC and patterns of precipitation, snow accumulation, and melt. Finally, our work highlights where future research should be focused based upon where uncertainties in PAWSC will have the greatest impact on partitioning between runoff and transpiration.

Big data in small spaces: using intensive experimentation and modeling to learn about the age structure of water discharged from hillslopes

Luke Pangle[1] (presenter), Minseok Kim[2], Marco Lora[3], Charlene Cordosa[4], Yadi Wang[4], Till Volkmann[4], Peter Troch[4], and Ciaran Harman[2]

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A contemporary challenge in scientific hydrology is to quantify the distribution of transit times that water and/or conservative solutes require to move from their points of initial contact with the land surface to their points of discharge into a body of surface water. The range of transit times and their likelihoods are represented in a probability distribution function called the transit time distribution (TTD). Travel times can have a strong influence on the solute chemistry of water emanating from hillslopes and low-order catchments. TTDs are often assumed time-invariant, though intuition and theory suggest their shapes should change in landscapes where flow velocities, and flow paths, are dynamic in time. There is a need to better understand how rainfall intensity and periodicity, and whole-system water storage, control the changing shapes of TTDs and associated storage-selection probability distributions (SAS distributions). We report results from a 28-day experi-

ment on a sloping lysimeter filled with 1 m3 of soil. The experiment including periodic-steady-state flow conditions and the introduction of multiple stable-isotope and ion tracers. This particular experimental design enabled application of a novel method for unmixing the overlapping tracer-breakthrough curves, which subsequently enabled quantification of time-variable TTDs and SAS distributions. We utilized a spatially-distributed, physically-based flow and transport model in an attempt to recreate these time-varying distributions. The calibrated model allows us to explore in fine detail how fluctuations in water storage and flow path orientations control the time-variable shapes of these age distributions.

Seeing the water in the trees: Challenges in estimating the impact of fuel treatments and fire on hydrology

Naomi Tague[1] (presenter), Max Mortiz[1], and Ryan Bart[1]
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Wildfire and fuel treatment impacts on forest structure both influence and are influenced by water availability, particularly in semi-arid environments. Declines in the water available during drought can increase forest vulnerability to a range of disturbances including fire. Forest recovery after fire and regrowth after fuel treatments may also be strongly influenced by water availability. At the same time, wildfire and fuel treatments alter forest evapotranspiration and runoff production, and this often has implications for streamflow and water resources. Coupled models of ecosystem hydrology and carbon cycling are tools that can help researchers understand these complex interactions and assist managers in reducing fire risk, maintaining ecosystem health, and regulating water resources. In this paper we present RHESSys-WMFIRE, a coupled model of ecosystem carbon cycling, spatially distributed hydrology, and fire spread. This model utilizes stateof- the art computing to develop integrated modeling tools, workflows, documentation, and visualization that support data assimilation, collaborative model development, and usage by a broader research community. We demonstrate the application of the model to a forested region of the southern Sierra Nevada Mountains of California. Results illustrate that two critical parameters for estimating hydrologic responses to changes in vegetation structure due to fire or fuel treatments are: (1) plant available subsurface storage capacity and (2) the extent to which neighboring trees share water. These parameters can determine whether transpiration increases rather than decreases following disturbance/treatments and these parameters can be as significant as inter-annual climate variation as a control on hydrologic impacts.. Both of these parameter are highly heterogeneous in space and vary with both plant species and geology. We conclude by presenting emerging strategies for estimating these parameters based on ongoing work at the Sierra Critical Zone Observatory.

Integrated Observation, Prediction, and Management of Water Resources in a Changing World

Long-term simulation of green infrastructure effects at a catchment-scale

Pedro M. Avellaneda[1] (presenter), Anne J. Jefferson[1], and Jennifer M. Grieser[2]
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In this study, we evaluated the cumulative hydrologic performance of green infrastructure in a residential area of the city of Parma, Ohio, draining to a tributary of the Cuyahoga River. Green infrastructure involved the following spatially distributed devices: 16 street side biorententions, 7 rain gardens, and 37 rain barrels. The catchment has an area of 7.2 ha, in which 0.7% is occupied by green infrastructure and 40% is covered by impervious surfaces. Green infrastructure is expected to treat 72% of impervious areas. The engineered soils for the bioretentions and rain gardens consisted of sand (~72%), organic matter (5-28%), and clay (~10%). Data consisted of rainfall and outfall flow records for a wide range of storm events from 0.3 mm to 81.3 mm of measurable precipitation including pre-treatment and treatment periods. The rainfall-runoff process was simulated for a 10 year period using the Stormwater Management Model (SWMM), a dynamic hydrology and hydraulic model that incorporates green infrastructure. Two scenarios were considered for the application of the SWMM model: pre-treatment, considering observed data before construction of green infrastructure; and treatment, considering observed data after installation of green infrastructure. The calibrated and validated SWMM model was used to evaluate using the same climate characteristics the long-term hydrologic alteration due to the green infrastructure. A 0.8% increase in evaporation, a 12% increase in infiltration, a 1.6% drainage from green infrastructure, and a 14.4% reduction in surface runoff were produced. A simulated flow duration curve for the treatment scenario was compared to that of a pre-treatment scenario. The flow duration curved shifted downwards for the green infrastructure scenario, with a 30% decrease in the $Q99$, $Q98$, and $Q95$ percentiles. Parameter and predictive uncertainties were inspected by implementing a Bayesian statistical approach.

Challenges of Spatial and Temporal Scaling of Nitrogen Flux in North Carolina's Coastal Plain Watersheds

Anna Ballasiotes[1] (presenter) and Jonathan M. Duncan[1]

[1]Institute for the Environment, University of North Carolina at Chapel Hill

Nitrogen fluxes are highly heterogeneous in space and time. Despite the widespread availability of high-resolution spatial and high-frequency temporal data, there are still many regions, including the Coastal Plain region of North Carolina, where there is a spatial mismatch between long-term observation sites at river basin scales and the scale of management and restoration activities, which often occur in smaller 1st-4th order catchments. This mismatch makes it a challenge to attribute environmental improvements to specific mitigation practices. Disparate data sources must be synthesized to address these gaps. We integrated water quality and discharge data from USGS gages, nitrogen inputs from the SPAtially Referenced Regressions On Watershed attributes (SPARROW) model, land use data, and animal operations spatial data. For temporal estimations, we employed Weighted Regressions on Time, Discharge, and Seasons (WRTDS) to quantify temporal variability at daily, seasonal, and inter-annual scales. In addition to synthesizing this data, we will examine a broader geography with similar hydrologic properties in order to mitigate challenges with lack of data. This project is a preliminary part of a larger effort through the Resource Conservation Partnership Program and will be used to select watersheds that fulfill criteria identified to show strong responses to best management practice implementation by grain farmers in the Coastal Plain region of North Carolina.

A mean field approach to watershed hydrology

Mark Bartlett[1] (presenter) and Amilcare Porporato[1]

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Mean field theory (also known as self-consistent field theory) is commonly used in statistical physics when modeling the space-time behavior of complex systems. The mean field theory approximates a complex multi-component system by considering a lumped (or average) effect of all individual components acting on a single component. Thus, the many body problem is reduced to a one body problem. For watershed hydrology, a mean field theory reduces the numerous point component effects to more tractable watershed averages resulting in a consistent method for linking the average watershed fluxes to the local fluxes at each point. We apply this approach to the spatial distribution of soil moisture and parametrize the numerous local interactions related to lateral fluxes of soil water in terms of the average soil moisture.

The mean field approach provides a basis for unifying and extending common event-based models (e.g. Soil Conservation Service curve number (SCS-CN) method) with more modern semi-distributed models (e.g. Variable Infiltration Capacity (VIC) model, the Probability Distributed (PDM) model, and TOPMODEL). We obtain simple equations for the fractions of the different source areas of runoff, the spatial variability of runoff, and the average runoff value (i.e., the so-called runoff curve). The resulting space time distribution of soil moisture offers a concise description of the variability of watershed fluxes.

Regional impacts of climate change on forest phenology in the Central Appalachian region, United States

Brandi Gaertner[1] (presenter) and Nicolas Zegre[1]

[1]West Virginia University

The timing of phenological parameters such as spring onset and autumn senescence are important controls on the partitioning of water into evaporation and runoff, forest health, and forest primary productivity. Climate largely drives seasonal characteristics of plants, and therefore, changes in phenological timing can be used to detect and understand the impacts of climate change on water balance controls. Field, station, and remotely sensed observations have found earlier spring onset, later autumn senescence, and longer growing season throughout the United states over the last century. However, research has primarily focused on agricultural- dominated regions, despite the complex interaction between geographic variability and vegetative timing. As a result, limited research is available for regions dominated by forest cover such as the central Appalachian region of the United States. To understand the impacts of climate change on phenological timing in the central Appalachian Mountains region, we used GIMMS AVHRR NDVI 13g data from 1982-2013 and the TIMESAT program to extract seasonality parameters. Results show that spring onset has advanced by 9 days and that later autumn senescence has been delayed by 11 days resulting in a longer growing season by 20 days. Autumn senescence had a stronger impact on

growing season length than timing of spring onset. The earliest spring onset occurred within the last five years by nearly 12 days but senescence and growing season length were variable over the study period, with the latest senescence occurring in years 1982-1986 and 2006-2012. Above 500 m elevation, spring onset occurs 2-3 days later; fall senescence arrives 1-2 days earlier, and growing season shortens by 3-5 days. The elevation patterns are roughly in agreement with Hopkins law, which states that for every 30-meter increase in elevation, there is a one-day delay in spring onset. However, research also shows that phenological timing is dependent on other factors that include urbanization, distance to coastal water, chilling degree date, and heating degree day. Regardless of the exact mechanism, an increase in growing season length has implications for water balance components and the supply of freshwater ecosystems services in a region that provides freshwater to both the Gulf of Mexico and Chesapeake Bay.

INFLUENCE OF LAND USE AND STORMWATER MANAGEMENT PRACTICES ON SEDIMENT AND NUTRIENT YIELDS IN URBAN STREAMS

Kristina Hopkins[1], J.V. Loperfido[2], Dianna Hogan[1], Greg Noe[3]

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Stormwater best management practices (BMPs) are becoming increasingly implemented in suburban and urban areas to mitigate the export of nutrient and sediment pollution to aquatic ecosystems. However, there are few studies examining the water quality impacts of installing stormwater BMPs at the watershed scale. We employed a watershed comparison approach to assess the influence of land use and BMP implementation on sediment, phosphorus, and nitrogen concentrations and yields during precipitation events. The study watersheds are located in Clarksburg, MD and Fairfax County, VA and include one forested reference watershed (For-MD), two suburban watersheds with centralized BMPs (Cent-MD and Cent-VA), and one suburban watershed with distributed BMPs (Dist-MD). Stream water samples were collected before, during, and after seven storm events in Cent-MD and For-MD, and five storms in Dist-MD and Cent-VA from 2010-2012. Water samples were analyzed for total suspended sediment (TSS), total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), and nitrate+nitrite. We estimated mean baseflow concentrations for all constituents and event mean concentrations, loads, and yields for each storm event. We then examined relationships between land use, stormwater BMP type, and nutrient and sediment trends among the study watersheds during baseflow and stormflow events. This included examining the influence of amount of impervious cover, BMP capacity, and long-term nutrient enrichment associated with an agricultural legacy as potential drivers of sediment and nutrient patterns in these study watersheds.

HYDROLOGIC NON-STATIONARY BEHAVIOR TO CLIMATE IS CLOSELY MEDIATED BY LONG-TERM VEGETATION DYNAMICS IN FORESTED WATERSHEDS

Taehee Hwang[1] (presenter) Katherine L. Martin[2], James M. Vose[2], David Wear[2], Brian Miles[3], Anika Tabassum[1], and Lawrence E. Band[3,4]

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In forested watersheds, evapotranspiration is mainly attributed to vegetation water use in the form of transpiration and interception. Therefore, hydrologic regime changes under ongoing climate change are closely mediated by long-term structural and short-term physiological responses, such as leaf area and growing season length. Changes in leaf area and duration can be remotely sensed and used as a unique indicator for hydrologic regime changes imposed by shifts in vegetation dynamics. Here, we report significant increases in precipitation and runoff deficit (defined as annual precipitation minus annual runoff) in two forested watersheds at the southern Appalachians over the last three decades. We found that this non-stationary hydrologic behavior is strongly correlated with long-term increase and interannual variability of growing season length from remote sensing data. In the modeling study, we further confirm that this non-stationary behavior have been closely mediated by long-term seasonal and structural changes in vegetation, rather than directly derived by climatic variables. This has been facilitated by the dominance of the minimum temperatures on green-up and senescence timing, which have been more manifested in the changes in temperature regimes than maximums. This study emphasizes the importance of understanding ecosystem responses to climate change for predictions of future freshwater resources. We

suggest that observational and modeling approaches to understand hydrologic non-stationarity under climate change are critical to detect and predict ecosystem water use and subsequent freshwater yields in forested watersheds.

Integrating data and observations for a more holistic understanding of watershed quality, function, and management

John Lovette[1] (presenter), Jonathan M. Duncan[1], and Larry Band[1]

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The holistic "health" of a watershed is necessarily driven by a wide range of environmental and anthropogenic forces acting on the landscape. Here we examine how a combination of modeled hydrologic conditions, nutrient input mechanisms, and indicator species-driven habitat models can help derive a metric for baseline watershed condition as well as uplift/management potential. Using regional, regression based models for hydrology (USGS StreamStats) and water quality (USGS SPARROW) and species distribution models of indicator species for habitat quality (MaxEnt), we map data onto catchments from the National Hydrologic Dataset v.2 to assess watershed quality across North Carolina (~ 70,000 catchments). The large-scale hydrology and water quality models respond to a variety of catchment characteristics to account for how each catchment responds to storm events and nutrient input sources, respectively, while the habitat model builds species likelihood metrics based on reported presences and catchment attributes. We further examine driving factors across the landscape that influence inclusion or exclusion of certain catchments from potential management scenarios. Patterns of watershed baseline condition largely follow patterns of land use, but emergent patterns of interaction between functions of watershed environmental quality suggest that this more holistic approach can be quite beneficial.

These top-down approaches can be especially impactful when paired with high-resolution, functionally based models. By screening catchments for management based on this large spatial scale approach, distributed models that make use of high spatio-temporal sensor data can then be used to develop a better understanding of watershed function. We begin to explore this top-down/bottom-up approach to watershed management in several Piedmont and Blue Ridge watersheds in North Carolina.

Simulating Nitrogen Loss in the Community Land Model: Analysis of soil pH impact on nitrification and denitrification models

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Nitrogen is an essential element for food production and ecosystem health and it's cycling is coupled closely with carbon. Climate change impacts to agricultural and forest lands are simulated using the Community Earth Systems Model and Community Land Model (CLM). Recent improvements to CLM have incorporated feedbacks of the terrestrial nitrogen cycling with great success, however the proportion of loss to atmosphere and water resources is grossly misaligned with observations and isotopic modeling. Specifically, the proportion of simulated nitrogen loss via denitrification is far too great.

In this study, the sensitivity to environmental conditions of the nitrification and denitrification submodels is tested by including a soil pH reduction factor. Acidic soils, where denitrification rates are expected to be greatly reduced, are found throughout the tropical forests. There is significant mismatch between modeled and observed denitrification rates in this area.

The results of this sensitivity analysis inform the options for improving the simulated nitrogen loss pools. By using environmental conditions that regulate denitrification we can make a simple adjustment before attempting to integrate more complex changes to the nitrogen cycle.

Linking land use / land cover to spatial variability in water quality along a blackwater stream

Justine Neville[1] (presenter), Dr. Ryan Emanuel[1], Dr. Jim Vose[2], and Dr. Elizabeth Nichols[1]

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Water quality and land use / land cover (LULC) are linked intimately in many watersheds, although exact relationships are often nonlinear and sometimes complex. Together with topological characteristics of watersheds, LULC can affect water quality in various ways. As such, attributing water quality characteristics to LULC variability (either in space or time) can be difficult. Many studies seek to understand these relationships from a Eulerian reference frame, which typically involves samples or observations through time at a fixed location. Here we explore an alternative approach to understanding relationships between LULC and water quality that relies on a Lagrangian, or moving, reference frame, in which the effects of LULC and watershed topology on water quality can be observed through a different lens. We studied three reaches of the Lumber River, a blackwater stream in North Carolina's Coastal Plain, to assess relationships between LULC and water quality in a watershed that is a patchwork of agriculture, forests, wetlands and development. Our study combines spatially intensive water quality measurements (including specific conductance, dissolved oxygen, pH and nitrate), collected by boat, with geospatial analyses of LULC and other watershed characteristics to understand influences on reach-scale water quality. This work has implications for the regulation and management of agriculture, wetlands, and forests in a region that has long struggled to balance agriculture, a major economic driver, with water quality, a major concern for recreation and cultural practices locally and for nutrient sensitive coastal environments downstream.

Multiscale Hydrologic Evaluation of Radar Rainfall for Flow Simulations

Felipe Quintero[1] (presenter), Witold Krajewski[1], Bong-Chul Seo[1], and Ricardo Mantilla[1]
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We evaluated the performance of a hydrologic model which produces real-time flow forecasts. The model was developed by the Iowa Flood Center (IFC) and it is implemented operationally to produce streamflow forecast for the communities of the state of Iowa in the United States. The model parameters are calibration-free. It has a parsimonious structure that reproduces the more significant processes involved in the transformation from rainfall to runoff. The operational model uses a rainfall forcing produced by IFC, derived from the combination of rainfall fields of seven NEXRAD radars. This rainfall forcing does not include bias adjustment from rain gauges, due to the non-existence of a raingage network that enable the correction in real-time. Therefore, the model was also evaluated using the bias-adjusted rainfall product Stage IV. We used six years of IFC rainfall and Stage IV to evaluate the performance of the hydrologic model and the sensitivity of the flow simulations to the model input. The model was not calibrated to any particular rainfall product. The distributed structure of the model allows obtaining results at any channel of the drainage network. We produced simulated hydrographs at about 150 locations with different sub-basin spatial scales, where USGS streamflow observations are available. We compared flow simulations to observations and obtained several metrics of error including Nash Sutcliffe efficiency, normalized root mean square error, volume error and time to peak error. We also evaluated the number of occurrences of hits and false alarms of discharge forecasts exceeding flood stage.

Use of Real-Time Sensor Data in City-Scale Water Modeling

Sara Troutman[1] (presenter), Nathaniel Schambach[1] Branko Kerkez[1], and Nancy Love[1]
[1]University of Michigan

We demonstrate how real-time, city-scale sensor data throughout an urban hydraulic network can be assimilated through a data-driven modeling framework. Our framework addresses a fundamental need to improve real-time forecasts of hydraulic and hydrologic loadings to reduce combined sewer overflows and improve wastewater treatment. The model is designed to analyze streams from hundreds of sensors to (1) forecast diurnal flow patterns, and (2) to learn the hydrologic response of the system. The data-driven nature of this framework does not require the parameterization of traditional physical models and, rather, enables predictions of flow to be continually updated, learning from the real-time sensor data to reflect the dynamic water system. Data from field-deployed sensors is ingested into a time-series database, where it is tagged with corresponding metadata, including latitude and longitude coordinates and nearby rain gauges. Using cloud-hosted visualization applications, this data is accessible from dynamic dashboards displaying flow and precipitation data from multiple sensors. To learn the dynamics of the combined sewer flow at each sensor site, the wastewater and stormwater components are decoupled through the use of signal processing and machine learning techniques. Using this sensor data together with precipitation gauges within the network, this framework is able to predict combined sewer flow under dry- and wet-weather scenarios across sites in the combined sewer network as the drainage system experiences developmental changes.

National Water Model
National Water Model Data Access and Visualization with Cloud-Based Tethys Apps

Michael Souffront[1] (presenter), Shawn Crawley[1], E. James Nelson[1], Daniel P. Ames[1], Norman L. Jones[1], Michael Stealey[2], Ray Idaszak[2], and Fernando Salas[3,4]

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The CUAHSI HydroShare Apps portal, built on the Tethys Platform software, includes a growing number of data visualization and analysis apps that provide access and visualization for the new National Water Model (NWM) being developed by the National Weather Service (NWS). New Tethys Apps supporting the NWM have been developed in preparation of the 2nd annual summer institute for the Young Innovators Program of the National Water Center organized by CUAHSI. These apps are instrumental in providing teams access to the forecast data in support of a variety of projects that will be developed, some of which will likely be included as part of this conference. This poster will describe both the organization of the data on the RENCI data servers and the HydroShare Apps developed for access and visualization.

The NWM is providing four different configurations to help meet different forecasting objectives. Included are: 1) a short range 15-hour forecast at hourly time steps produced each hour, 2) a medium range 10-day forecast at three hour time steps produced daily, 3) a long range ensemble 30-day forecast at six hour time steps with 16 ensemble members produced daily and 4) an analysis and assimilation that is essentially a running "0-hour" forecast and hourly time steps and provides the initial conditions for the short range forecast. As illustrated in the diagram below, the NWM data from these four configurations is moved from the NWS computers to NOMADS and mirrored by a secure server within RENCI's data center on an hourly basis.

From this mirror, subsequent scripts run to unzip and process the mirrored data into georeferenced netCDF files. The georeferenced netCDF files are output into corresponding data storage directories that are organized to best serve a variety of applications. Depending on use case, applications can either access the stored data directly, or by using an iRODS client. The data store contents are persisted for an N number of days where N depends on the type of data being held. The workflow is managed by a Jenkins automation server within RENCI's data center.

Two different applications have been developed to provide access and visualization for the YIP summer institute. The most basic is an application that acts as a file browser to search and discover individual forecast files and entire sets of forecasts through the use of filters so that they can be downloaded and used for further analysis and application of the YIP teams. This app also includes an application programmer interface (API) that will allow users to incorporate data access into their own projects without the need to download forecast data manually.

The second app provides a comprehensive search and visualization of the stream, reservoir, and individual grid cell forecasts for the four different configurations. The user interface includes a form that allows the user to specify forecast parameters; a map for data selection based on location; and a graph area to display the resulting forecast. The resulting plots can be downloaded as a .csv, .xls or WaterML files.

This Tethys app also provides access to the forecast data via an API. For example, data for a specific stream reach can be accessed by creating a URL similar to the following:
https://apps.hydroshare.org/apps/nwmstreamflowexplorer/api/getdata/?comid=123456&config=short_term&forecast=current&format=waterml.

The developed APIs provide a way for the user to simply access forecast data via a script, create a separate app, expand the functionality that the Tethys apps provide or write a MatLab or R script to automatically retrieve and analyze the NWM data. The URL end point will follow typical REST web services conventions where a data request includes the full server URL together with a query string that defines the data request.

Data Management - Advances in Managing Big Data from Environmental Sensors

Streams to servers to scientists: information infrastructure for a continental-scale monitoring network

Aaron Berdanier[1] (presenter), Eric Moore[1] (presenter), Emily Bernhardt[1], Jim Heffernan[1], and Brian McGlynn[1]

[1]Duke University

Our research group is deploying an intensive sensor network for continuous monitoring of metabolism at a continental scale. With additional data expected from other locations, this project aims to increase the availability of stream metabolism data by nearly two orders of magnitude. The scope of these data create challenges for storage and access. Here we present aspects of our data management plan, explaining the data and analysis pipeline from sensors to a CUAHSI HydroServer to outputs for research and public use. We emphasize the unique challenges of compiling consistent data from multiple locations and making this data accessible via visualizations and web interfaces. These products will facilitate the estimation of stream metabolic rates at timescales of days to years for spatial scales from reaches to river networks.

Collecting, Managing, and Publicizing Environmental Data from the Albemarle-Pamlico Peninsula

Theo Jass[1] (presenter), Ryan Emanuel[1], and Alex Moody[1]

[1]North Carolina State University

Access to data is important for maintaining public trust and increasing public buy-in for a project with a large social component, and advances in environmental monitoring and cellular modem technology allow these data to be made available in near-real time. We monitor environmental conditions (water and weather) at 5 sites across the Albemarle-Pamlico Peninsula and use cellular modem technology to relay data to a host server at NC State University every 4 hours (near real-time). An automated process using the Georgia Coast Ecosystems Data Toolbox in Matlab performs data QA/QC, plots environmental parameters for each site, and creates a user-friendly summary image at a public data portal. This data portal is accessible through a public map using ArcGIS online, a series of user-friendly NCSU GoLinks, and a QR code attached to the environmental enclosure at each site, providing a plethora of ways the public can access these data. Partnerships with Goose Creek State Park, NC Department of Transportation, The Conservation Fund, and the US Fish and Wildlife Service have made this possible.

HydroShare: Advancing Hydrology through Collaborative Data and Model Sharing

David G. Tarboton[1] (presenter), Ray Idaszak[2,5], Jeffery S. Horsburgh[1], Daniel P. Ames[3], Jonathan L. Goodall[4], Larry Band[15], Venkatesh Merwade[6], Alva Couch[7], Richard Hooper[8], David Maidment[9], Pabitra Dash[1], Michael Stealey[2,5], and Hong Yi[2,5]

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HydroShare is an online, collaborative system for open sharing of hydrologic data, analytical tools, and models. It supports the sharing of and collaboration around "resources" which are defined by standardized content types for data formats and models commonly used in hydrology. These include time series, geographic grids and shapes, multidimensional space-time data as well as models and model instances. This poster will illustrate the HydroShare collaborative environment and web based services developed to support the sharing and processing of hydrologic data and models, as well as future functionality under development. With HydroShare you can: Share your data and models with colleagues; Manage who has access to the content that you share; Share, access, visualize and manipulate a broad set of hydrologic data types and models; Uuse the web services application programming interface (API) to program automated and client access; Publish data and models and obtain a citable digital object identifier (DOI); Aggregate your resources into collections; Discover and access data and

models published by others; Use web apps to visualize, analyze and run models on data in HydroShare. The capability to assign DOIs to HydroShare resources means that they are permanently citable helping researchers who share their data get credit for the data published. Models, and Model Instances, which in HydroShare are a model application to a specific site with its input and output data can also receive DOI's. Collections allow multiple resources from a study to be aggregated together providing a comprehensive archival record of the research outcomes, supporting transparency and reproducibility, thereby enhancing trust in the findings. Reuse to support additional research is also enabled. Functionality under development in HydroShare will support web apps to act on resources for cloud (server) based visualization and analysis, including large scale geographic and digital elevation model analysis at the CyberGIS center at the National Center for Supercomputing Applications (NCSA) and execution of SWAT and RHESSys models.

PATHFINDER FELLOWS
CONTROLS OVER EVAPOTRANSPIRATION IN A FORESTED WETLAND

Scott T. Allen[1]

Hosted by: William H. Conner[2]

[1]School of Renewable Natural Resources, Louisiana State University

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Evapotranspiration (ET) is a primary water efflux from low-gradient swamps, especially ones that are impounded by anthropogenic activity. Vegetation type and condition of that vegetation is an important control over ET in most environments, however is not well known how vegetation, and responses to stressors —salinity, flooding, or drought— affect atmospheric water fluxes in wetlands. Even where stressors reduce transpiration, it is unclear that total ET would decrease because fluxes from other sources (e.g., flood waters) could compensate. My dissertation has focused on resolving wetland tree stress responses, and corresponding variability in evaporation and ET. As a CUAHSI Pathfinder grant recipient, I had the opportunity to work at the Baruch Institute for coastal ecology and forest science at a forested wetland where salinity was a severe disturbance factor. Primarily working with ecologists, we set up ET measurement systems complementing ongoing carbon-budget work to better understand the coupling of carbon-water dynamics. While still in the analysis stage, we are making progress towards better understanding water use efficiency and ecological controls over ET in wetlands.

RESOLVING SPATIAL AND TEMPORAL SCALE MISMATCHES AMONG HYDROLOGIC FLUX DATASETS ACROSS A HETEROGENEOUS SITE

Scott T. Allen[1] (presenter), Alexandria G. McCombs[2], April L. Hiscox[2], Ken W. Krauss[3], Jamie Duberstein[4], William H. Conner[4], and Richard F. Keim[1]

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Field measurements are often used for model calibration, remote sensing validation, or some other up-scaled interpretation at a relatively coarse "pixel" scale. Critical assumptions need to be made about the field data to interpret and properly upscale datasets to a common temporal and spatial resolution. In evapotranspiration measurements, the temporal and spatial scales of field results must be compatible to derive meaningful insight at the ecosystem level because of disparate measurement scales. For example, evapotranspiration is often measured in the field by micrometeorological techniques with a spatiotemporally varying footprint. Understory and soil fluxes are measured similarly, but represent a much smaller footprint. Transpiration is often measured by sapflow at tree scale. Interception loss generally is spatially averaged to constrain errors due to small scale spatial variability. The importance of these variations is especially crucial in highly heterogeneous systems. While small-scale vegetation heterogeneities are a common focus in ecology, differences in surface-atmosphere hydrological exchanges at the same scale are difficult to examine because of the dominant role of meso-scale boundary layer feedbacks. We present results of multi-scale evapotranspiration measurements made along a gradient from a forest to a salinity-affected shrub / marsh zone in coastal South Carolina. Here we focus on the effects that these scale mismatches have on the goal of trying to examine fluxes along this gradient.

Investigating the impact of soil erosion in Ethiopia and cloud forests in Honduras for improved water quality management

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Clean drinking water for many parts of the global south still depends on the natural capacities of forests, indigenous vegetation, and soils to filter and retain particulate matter that may pollute the quality of the water source. In mountainous regions, like Honduras with roughly 60% of the population residing in rural areas and Ethiopia with 80% of the population dependent on agriculture for their livelihood, these natural capacities must be preserved. My principal dissertation research investigated the causes and effects of soil degradation in the Ethiopian highlands by erosion and its impact on waterways through sediment yield and ground water table measurements. The CUAHSI Pathfinder Fellowship allowed me to enhance this research by providing a global comparison between monsoonal tropical watersheds, expanding my understanding of runoff-baseflow relationships in forested regions, and by advancing the assessment of cross-scale, multisite conservation practices. More specifically and tangibly, my activities in Zamorano, Honduras entailed gaging and initiating two watershed research stations, engaging with the university researchers and students in applied settings, and establishing a research protocol for continued monitoring and comparison of sediment transport dynamics. The typical differences in responses during rainfall between the two watersheds (El Zapotillo: 123 ha, heavily forested; El Capiro: 240 ha, lower percentage of forest cover) can be illustrated in the graph below. The El Capiro watershed had low flow or was dry, while El Zapotillo had consistent stream flow and heightened stream flow after initial weeks of heavy rain. This was most likely related to the differences in connectivity and base flow dynamics between the larger and smaller watershed. These activities later contributed to my ongoing endeavor to further engage in cross-scale, multi-site research as I returned to Ethiopia following this trip to conducted a larger-scale project and moreover engaged in new projects with the International Center for Tropical Agriculture (CIAT) in the southwestern Colombian Andes. The sociological, hydrological, and geographical similarities and differences in each of the study areas evoked new linkages in my understanding of how critical mountainous regions are for the provision of water in the global south and sharpened my desire to continue exploring these connections. The experiences afforded to me by the Pathfinder Fellowship ultimately expanded my knowledge of the challenges and rewards involved in international research and illustrated how vital university partnerships are for addressing the complex issues surrounding the design and management of conservation practices.

Education and Outreach Examples, Recommendations, and Opportunities

TeenShale Network: Combining Hands-on Field Experience with Data-Driven Hydrology Education Tools

Sharon Dykhoff[1] (presenter), Jennifer Z. Williams[1], Liza Brazil[2], Jon Pollak[2], Eugene Ruocchio[3], Yvonne Pickering[3], and Susan L. Brantley[1]

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When high school students slip their feet into waders and step into a cold Pennsylvania stream to retrieve a data sensor, their learning leaps out of the textbook and beyond the classroom. Data-driven, place-based education connects students to real-world issues in their local communities through experiential learning that actively engages them with authentic scientific data. In the field, students learn to quantify their observations as they use standard instruments to collect data first-hand. As they share data and interact with researchers, they expand their knowledge, following the practice of scientists who collaborate with each other to understand complex systems.

The TeenShale Network is a multi-year project that focuses on two primary objectives: first, to monitor the quality of water in the Black Moshannon Creek in central Pennsylvania, located in close proximity to active hydraulic fracturing sites, and second, to engage students in authentic field research in collaboration with experts. Students practice water quality monitoring techniques used by academics and government agencies, communicate their research in the news and scientific meetings, and use CUAHSI hydrology tools for analysis and visualization of datasets, large and small. Using CUAHSI tools,

students experience the complete lifecycle of data, from creation to publication to analysis to reuse.

This study seeks to understand the perceived impact of outdoor classroom projects by asking "How does working with authentic data in place-based scientific inquiry affect student perception about their role in scientific research?" Research indicates that data-driven, place-based learning builds enthusiasm for scientific endeavors as it equips students to join the conversation about local environmental issues. In the process, they become more active citizens, better stewards of the natural world, and perhaps even scientists themselves.

General Water Science
Temporal Variations in Discharge and Chemistry at Cave Drips in Grand Caverns, VA

Joshua Benton[1] (presenter), Daniel Doctor[2], and Benjamin Hardt[3]

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Stalagmites provide important proxies for reconstructing past climate by recording changes in isotopic and elemental values along their growth axes. In order to interpret such records, we must understand the dynamics of the drip waters from which these geochemical signals originate. Two ceiling drips within Grand Caverns, Virginia have been monitored simultaneously for changes in drip rate, electrical conductivity, and geochemistry from February, 2014 to the present. Water samples are collected on a monthly basis, and the air temperature, pressure, relative humidity and CO_2 concentration within the chamber are recorded. Both drips feed actively growing stalagmites that are located within 5 meters of each other in the same chamber. Drip rates are monitored using a tipping bucket rain gauge stationed directly below the drips, and conductivity and water temperature are continuously measured in a reservoir above the rain gauge.

Preliminary results show marked heterogeneity in both water chemistry and drip rate between the two sites. One site exhibits two different flow regimes, with a higher flow (0.29 L/h) during spring and early summer and a lower flow (0.019 L/h) during summer, winter, and fall. The other drip shows nearly constant flow of 0.018 L/h, and conductivity between 420 to 490 uS/cm. The dynamic drip shows a seasonal shift in conductivity, averaging 300 uS/cm during the winter and 414 uS/cm throughout the remainder of the year; also, an inverse relationship between cave air pressure and drip rate is observed at this site. The higher flow regime of the dynamic site may be a response to recharge during the spring, which provides enough water to the soil zone and epikarst for drainage into the cave to occur. This regime continues until the increase in evapotranspiration on the surface during the growing season creates a net water deficit above the cave. This moisture deficit is not fully recharged again until winter and early spring. Despite the observed flow variability between the two sites, the oxygen isotope compositions of both drips are nearly equal and constant at -8.1 ± 0.1 permil. This value supports the hypothesis of a cool-season bias in recharge to the drips, as it equals the amount-weighted average oxygen isotopic composition of cool-season precipitation collected in 2007 nearby at the same elevation as the cave.

CUAHSI's Data Services: Enabling Data Publication, Discovery, and Development

Liza Brazil[1]
[1]CUAHSI

CUAHSI provides data services to the hydrologic science community and other critical-zone science communities that require access to various sources of water data to perform research on fundamental challenges in hydrology and Earth System science. We outline our services and resources, including data publishing support, data access tools, and more.

CUAHSI HIS Catalog based on Apache Solr

Alva Couch[1,2] (presenter), Yaping Xiao[2], Martin Seul[2], Brian Cummings[2], Jon Pollak[2], Liza Brazil[2], and Richard Hooper[2]
[1]Tufts University
[2]CUAHSI

The existing CUAHSI catalog based upon SQL has proven to be difficult to scale. We have successfully replaced the search functions of that catalog with an instance of the Apache SOLR search engine. This change makes our catalog more scalable

and easier to adapt to changing situations in the future. We outline the internal design of this implementation and several lessons learned in building this subsystem.

Intensive data collection to characterize the spatial variability of submarine groundwater discharge: Field experiments and numerical modelling

Carlos Duque[1] (presenter), Christopher Russoniello[1], Thomas W. Brooks[1], and Holly Michael[1,2]

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Submarine groundwater discharge is measured directly in the field with seepage meters. Usually the repetition of measurements in approximately the same location or in closely-spaced seepage meter nests show differences in flux that can be of up to a few orders of magnitude. This variability limits the extrapolation of these results to larger scales, such as a stretch of coastline or entire bays or estuaries. It is therefore necessary to characterize the source of spatial variability of submarine groundwater discharge. In this work, a study area of 150 m2 is monitored in Indian River Bay (Delaware) with 30 seepage meters to systematically quantify the spatial variability in submarine groundwater discharge. Seepage meters were installed in a grid of 5 rows and 6 columns, each separated by 3 m. Fluxes, electrical conductivity, and nutrients were measured during two field campaigns. We collected flux measurements spanning a tidal cycle on two days, which were 3 weeks apart, to capture the effect from varying surface water hydrodynamics, terrestrial hydraulic gradient, and diurnal and spring-neap tidal oscillations. In order to explain flux differences at a scale of meters, a numerical model was built with SEAWAT to provide a potential explanation based on modifications of the hydraulic conductivity of the sediments below the bay bed. The objective is to provide an indication of at what depth the hydraulic conductivity controls the variability of submarine groundwater discharge measured with seepage meters. In addition, several hypothesis are tested, such as the dimensions of low hydraulic conductivity sediments, the contrast in low/high hydraulic conductivity and the connectivity in the vertical and horizontal directions. The analysis of the results indicates that thin layers of low hydraulic conductivity, depending on their location, their shape, and extent, impact the variability of submarine groundwater discharge fluxes. This study highlights and quantifies the importance of characterizing heterogeneity in subsurface geology and groundwater discharge, both of which require large numbers of measurements.

Spatial Characterization of Reactivity in an Intertidal Beach Aquifer

Kyra Kim[1] (presenter), Holly A. Michael[1], and William J. Ullman[1]

[1]University of Delaware

The intertidal zone of sandy beach aquifers hosts spatially and temporally dynamic mixing zones between fresh groundwater (FW) and saline seawater (SW). Seawater, driven up the beachface by wave and tidal action, infiltrates into the sand and meets the seaward-discharging fresh groundwater. This creates a biogeochemically-reactive brackish mixing cell in the intertidal zone. Within the mixing cell, land-borne nutrients carried by groundwater such as nitrate have the potential to be transformed utilizing oxygen and reactive organic carbon from seawater. Samples were collected from multi-level wells along a beach-perpendicular transect near Cape Henlopen, Delaware, to create a cross-sectional profile of various solutes and entrained particles. Porewater incubation experiments were conducted for each well port to determine the relationship between mixing cell reactivity and physical characteristics of the cell. The results show distributions of porewater-entrained carbon hotspots that are heterogeneous in their locations and concentrations. The highest reaction rates did not correlate with the highest concentrations of mobile carbon detected from porewater, but were instead elevated along the FW-SW contact boundary. This was supported by highest rates of N2 gas production also along the contact boundary, suggesting denitrification. This highlights the importance of FW-SW mixing in overall beach reactivity. The geometry and position of the contact boundary is influenced by the topography, geology, and hydrology of the intertidal mixing cell, which is altered on a number of characteristic timescales (tidal, spring-neap, seasonal). Therefore, a better understanding on the location and magnitude of reaction zones relative to the intertidal mixing cell will yield valuable insight for the prediction and quantification of beach reactivity and solute discharge to coastal systems.

Hydrologic, climatic, and biotic drivers in a shallow tidal creek: a seasonal balancing act underlying dissolved oxygen dynamics

Natalie Nelson[1] (presenter), Rafael Muñoz-Carpena[1], Patrick Megonigal[2], Patrick Neale[2], and Maria Tzortziou[3]

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Dissolved oxygen (DO) dynamics are classically explained as biologically-driven: photosynthetic activity exceeds respiration during the day, resulting in daytime peaks of DO, whereas nighttime DO steadily declines due to continued consumption of oxygen in the absence of photosynthesis. However, not all aquatic systems obey this textbook explanation of diel DO patterns. Sub-hourly (15 min.) data collected in a tidal creek of a Chesapeake Bay salt marsh (Maryland, USA) reveal that, contrary to convention, DO peaks both at night and during the day. These observed DO signatures highlight the role of abiotic processes in mediating tidal marsh DO dynamics – but, to what extent are these variables important as descriptors of DO? In the present work, we seek to answer this question by quantifying the relative importance of biotic and abiotic variables as drivers of DO in shallow tidal creeks. Furthermore, we evaluate how the relative importance of these factors changes across seasons by analyzing data collected on hourly and sub-hourly timescales from July through December (2015). To perform this analysis, we utilized time series analytics and parsimonious explanatory modeling, and considered a suite of explanatory variables including flow, stage above bankfull, stage below bankfull, chlorophyll-a, DO from the adjacent estuary, rainfall, wind speed, and average net radiation. The separation of stage into "above" and "below" bankfull conditions added novelty to the analysis by allowing for in-creek and over-marsh processes to be evaluated distinctly. Study results show that hydrologic variables, specifically below bankfull conditions, increase in relative importance as descriptors of tidal creek DO dynamics when transitioning from summer to winter, whereas biological variables explained the majority of DO variance in the summer months. The findings of this study underline the need to consider a wide range of DO drivers in regularly-flushed wetland systems. Knowing the relative importance of abiotic and biotic DO drivers enables greater understanding of the ecological functioning of salt marshes and their resiliency to projected global change.

Complex terrain mediates the climate sensitivity of ecosystem carbon fluxes

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Uncertainty in the response of terrestrial ecosystems to climate remains a major roadblock to predicting the future behavior of the global carbon cycle. Hilly and mountainous landscapes of the world are characterized by complex terrain, which can influence soil, vegetation and atmospheric characteristics of these regions. Within these areas, spatial gradients and heterogeneities in water, energy, and other environmental resources can give rise to complex, emergent ecological behavior. Hilly and mountain environments have also been identified as significant terrestrial sinks for atmospheric CO_2, and recent work demonstrates that terrain complexity influences the spatial and temporal dynamics of ecosystem carbon fluxes. Apart from a few isolated case studies, the role of terrain in mediating the sensitivity of carbon fluxes to climate is unknown. Here we show that in complex terrain, topographic variables associated with energy, water, and nutrient availability can predict responses of ecosystem carbon fluxes to variations in temperature and precipitation. For a subset of AmeriFlux tower sites characterized by terrain complexity, topographic slope surrounding each tower predicted the sensitivity of daily carbon fluxes to temperature variability, and upslope drainage area surrounding each tower predicted the sensitivity of annual carbon fluxes to precipitation variability. This work challenges conceptual frameworks and models that assume ecosystem carbon fluxes in complex terrain derive from soil, plant and climate factors alone. Instead, this work suggests that in certain ecosystems, terrain itself plays a significant role in mediating ecological responses to climate. In the conterminous US alone, this work has implications for a 14% of land area, responsible for 1.13 Gt of carbon sequestration per year.

A grid-based, modeling analysis of transpiration controls on local and baseflow generation in a forested, headwater catchment

Charles I. Scaife[1] (presenter), Arik Tashie[1], Adam Gold[1], and Lawrence E. Band[1]

[1]University of North Carolina at Chapel Hill

Transpiration plays a critical role, both spatially and temporally, in catchment water supply. This role is well-studied, particularly in the spatial distribution of soil moisture observed during the growing season versus the dormant season. Local

generation, defined as net water from wetting due to throughflow minus water consumed locally, varies across a hillslope as a function of soil moisture downslope. One application of replicating local generation spatially is in urbanizing catchments where the arrangement of water balances between parcels down hydrologic flowpaths is important for understanding streamflow response to storm events. Whether from transpiration or groundwater pumping, local consumption within a parcel varies with land use and ultimately controls baseflow contribution to streams. The goal of this research is to model and characterize the role of transpiration on local streamflow generation and baseflow contribution at the parcel scale within a forested catchment at the Coweeta Hydrologic Laboratory in Southwest North Carolina. We implement a modeling framework using grid-based parcels in the Regional Hydro-Ecological Simulation System (RHESSys) to simulate hydrologic routing over wetting and drying sequences, including severe droughts in 2001 and 2007. We examine the effects of seasonal transpiration on parcel scale local generation and baseflow contribution across the watershed. We also analyze the variation in streamflow recession between growing and dormant seasons and interannual variability in these relationships. Lastly, we explore how prolonged dry periods influence transpiration rates even following drought cessation and how this reduction is manifested in our recessional analysis. Preliminary results show local generation of streamflow varies with respect to topography during the dormant and growing seasons, but also with transpiration and leaf area index during the growing season. Recession curve analysis of modeled data demonstrates hysteretic behavior with streamflow decaying faster following storms in the growing season relative to the dormant season. These results suggest that seasonal transpiration rates are responsible for local generation within parcels, which drive larger, catchment-scale patterns of hydrograph recession.

Evaluating Bioretention Cell and Green Roof Hydrologic Performance in northeastern Ohio

Laura L. Sugano (presenter)[1], Anne J. Jefferson[1], Lauren E. Kinsman-Costello[1], Pedro Avellaneda[1]

[1]Kent State University

In urban areas, increased runoff from storm events is a significant concern due to flooding, erosion, ecosystem disturbance, and water quality problems. Green stormwater infrastructure is designed to ameliorate these effects by decreasing the flow rate and overall volume of runoff. We compared the effectiveness of a co-located green roof and bioretention cell in order to understand their relative capacities to decrease stormwater runoff, when subjected to the same weather conditions. Our field site was the Cleveland Metroparks' Watershed Stewardship Center in Parma, Ohio. Beginning in June 2015, rainfall, underdrained outflow, groundwater levels, and soil moisture have been measured on 1-5 minute intervals during 84 storms. Event sizes spanned from 0.25 mm to 54 mm. The bioretention cell completely retained flow from 75% of the storm events, and the green roof retained 49% of storms. The bioretention cell completely retained all events smaller than 3.05 mm and the green roof completely retained all events smaller than 0.51 mm, though some larger events were also completely retained. For storms where underdrain outflow occurred, the average retention was 25% for the bioretention cell and 79% for the green roof. The bioretention cell completely retained 64% of the storm events in summer 2015, 90% in fall 2015, and 77% in winter 2015-2016. The green roof completely retained 37% of the storm events in summer 2015, 48% in fall 2015, and 89% in winter 2015-2016. The groundwater level in the bioretention cell increases in response to storm events and lowers between storms. The soil moisture in the green roof increases during storm events and slowly decreases between storms. My study suggests that bioretention cells can mitigate stormwater issues better than green roofs because they have the capacity to retain more stormwater due to their thicker substrate and their ground-location allows it to retain surface runoff as well as direct precipitation.

Analysis of National Weather Service Stage Forecast Error

Grace Zalenski[1] (presenter) and Witold F. Krajewski[1]

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Hydrologic forecasts produced by the National Weather Service are used by decision-makers and the general public for purposes ranging from routine flow control to emergency response in extreme events. Despite their importance however, there is little documentation of the real-time forecasting skill of the NWS streamflow models. This research aims 1) to begin to fill this gap and provide a better reference against which to measure future advances in stage forecasting, and 2) to better understand how skill varies between forecast points and what factors can help predict the accuracy of stage forecasts. Single statistics such as RMSE which are most commonly used for verification are not sufficient to characterize forecast skill. We focus on analyzing the distribution of forecast errors conditional on 1) physical characteristics such as drainage area, 2) current conditions such as flood level and rainfall near the time of forecast, and 3) other considerations, such as the number

of upstream gages that provide information to a forecast point. The data for this study consists of stage forecasts and observations issued and recorded at 51 NWS forecast locations in central and eastern Iowa over the years 1999-2014. We find that although specific predictive relationships are difficult to quantify, the behavior of forecast error distributions across flood stages often differs distinctly according to these conditional factors.

Research Experience for Undergraduates (REU)/Research Experience for Teachers (RET)

The Periglacial Legacy of Vernal Pools in the Ridge and Valley Province of Pennsylvania

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The ridge and valley physiographic province runs through large swaths of central and eastern Pennsylvania, and has undergone erosion and deposition for millions of years. The folded strata of the region is mainly comprised of limestone valleys and shale slopes capped with erosion resistant sandstone. Scattered on the ridge tops and flanks are vast boulder fields, a result of the expansion and contraction of water during the freeze-thaw cycles of periglacial permafrost during the Last Glacial Maximum. Wetland depressions situated on shale valleys between parallel sandstone ridges are another feature considered to be a legacy of periglacial conditions. The depressions exist on drainage saddles between the parallel ridges and are interpreted to have been prime locations for the formation of pingos, mounds of ice that grew from the forced upwelling and freezing of groundwater in areas affected by permafrost. The wetland depressions (vernal pools) in these headwater areas are vital to the life cycle of many organisms living upland from streams. To locate, map and describe potential vernal pool sites, topographic maps, digital elevation models, soil surveys, bedrock geologic maps, and field verification are utilized. The focus of this summer 2016 project is to inventory, describe, and measure wetland depressions in this unique setting to gather information that will further understanding of the conditions necessary for formation of these sensitive wetland areas. Beyond understanding the driving force behind the formation of these vernal pools the primary goal is to document their existence so that future human activity will not cause further degradation.

A model secondary education curriculum for advancing do-it-yourself (DIY) environmental sensing networks and empowering teachers and students to monitor water quality and quantity in streams and rivers

Dan Bondanza[1] (presenter), Steve Hicks[1], Dave Arscott[1], Anthony Aufdenkampe,[1] David Bressler[1], Tara Muenz[1], Peter Wise[1], Sara Damiano[1], and Steve Kerlin[1]

[1]Stroud Water Research Center

The interest in and accessibility to open source software/hardware electronics and micro-manufacturing has increased sharply over the last 5 years. As a result, scientists and educators around the world are now building their own dataloggers and devices using a variety of open source platforms like Arduino®. Here we present a curriculum targeted for secondary education that introduces our "EnviroDIY" approach to building and deploying custom datalogger boards and environmental monitoring systems (see www.EnviroDIY.org). This curriculum focuses on water quality monitoring and enables students to collect advanced water quality information on healthy and impaired waterways throughout the U.S., while also teaching critical thinking skills, data interpretation, watershed science, and technology. The sensors that form the core of the monitoring component include water depth (via either ultrasonic or pressure transducer sensors), air and water temperature, specific conductivity, turbidity, dissolved oxygen, precipitation, solar/light levels, and/or soil moisture. Students will learn about water quality and quantity and how naturally occurring conditions differ from human impacted conditions. The curriculum covers the entire STEM spectrum and can be implemented at various time scales that are adaptable for a teacher's desired time horizon (days, weeks, months, and/or annually recurring). Further, the curriculum can be adapted into a theme that may be integrated across several courses/subjects (different subjects like chemistry, math, or other STEM-specific classes). The scientific component focuses on learning about water quality and quantity along streams/rivers; the technology component includes learning about Arduino-based datalogging boards and programming skills/languages; the engineering component includes learning about the components of the data logging boards and connecting various peripheral devices to the boards and then fabricating waterproof housing and brackets for mounting sensors in the environment for deployment; math skills are developed during units that introduce techniques for the management and analysis of time-series data recorded from various environmental sensors. In addition, students will use web-based data capture services and live data

streaming that can display graphs on custom web pages and all participants are introduced to an online community (http://enviroDIY.org), where all members can share new ideas about open-source hardware and software solutions for observing environmental conditions. EnviroDIY members can describe and showcase their gadgets, ask questions, or access helpful tutorials. Extensions of this curriculum will include service projects to encourage both students and local community members to monitor and learn about their local waterways. Service projects include freshwater clean ups, working with local businesses to help change practices, creating and monitoring stormwater management systems, and implementing a supporting network of local volunteer monitors.

Assessing methods for studying submarine groundwater discharge: prefilling of bags in seepage meters, tidal impact over measured fluxes and use of radon

Riley Brown[1] (presenter), Carlos Duque[1], Christopher Russoniello[1], Mahmoud Sherif[1], Usama Abu Risha[1], Karen Knee[2], Neil C. Sturchio[1], and Holly Michael[1,3]

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Submarine groundwater discharge (SGD) is the flow of groundwater into coastal seawater irrespective of salinity, origin, or driving force. The study of SGD requires specific methods as it takes place underwater and its quantification can be challenging. In this work, we evaluate the following two SGD measurement methods: seepage meters and measurement of radon as a tracer. Seepage meters are the only method to directly measure SGD. Seepage meters are constructed from steel drum ends and are installed in the seabed. A bag is affixed, which fills or empties as water flows out of or into the seabed. Traditionally, seepage meter bags are prefilled with an initial volume of water to limit internal-frictional resistance and permit measurement of recharge. However, that water differs in salinity from the SGD, which introduces uncertainty into groundwater flux and salinity measurements. Another issue observed in previous studies is that the hydraulic gradient between terrestrial freshwater and seawater change with tides, which affects SGD rates and measurements thereof. Quantification of SGD in connection with the magnitude of tidal oscillations can help provide more accurate fluxes of submarine groundwater discharge at larger temporal and spatial scales. Radon-222 (half-life = 3.82 days) in surface water is commonly measured as a proxy to estimate SGD. It enters groundwater through the natural radioactive decay of radium present in aquifer sediments, and leaves by decay or by escape to the air. Thus, radon activity of groundwater is indicative of contact with sediments and diagnostic of groundwater residence time, and higher radon values in surface water are associated with higher SGD. SGD has terrestrial freshwater and surface-water saline sources, and radon activities are expected to be lower in shallow saline groundwater with short residence times than in deeper saline and fresh groundwater with longer flowpaths and residence times. Thus, while surface water radon activity is typically considered a proxy for "total" SGD, this method may underestimate SGD associated with shorter saline flowpaths in which groundwater radon values are not at equilibrium. SGD was measured at Holts Landing State Park (Delaware) 10m seaward of the intertidal zone across the transition between fresh and saline groundwater. Thirty seepage meters were deployed and spaced 3m apart in a homogeneous five row by six column grid. Fluxes were measured over five approximately 2-hour measurement periods on each of two consecutive days with bags that were initially empty and prefilled, respectively. Tides were monitored and compared to measured fluxes. Groundwater samples collected 25 cm beneath each seepage meter, on a shore-perpendicular transect at varying depths and directly from seepage meter bags were analyzed for salinity and radon activity. The results of this study are compared with those of previous studies in order to assess and provide general guidelines for using these methods in measurement and characterization of SGD.

Are forests more nitrogen stressed on sandstone than on shale?

Jennifer Christhilf[1] (presenter), Warren Reed[1], Margot Kaye[1], and David Eissenstat[1]

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As a major component of chlorophyll and amino acids, nitrogen is a vital plant nutrient that is commonly limiting in temperate forests. Lack of available soil nitrogen for uptake increases plant stress, and can be measured as a decrease in leaf chlorophyll. We examined the effect of lithology (shale and sandstone) on nitrogen status of forests in central Pennsylvania. Using a combination of remotely sensed leaf area index (LAI) and canopy chlorophyll content, we estimated nitrogen stress experienced by canopy trees. In situ measurements of nitrogen in canopy leaves were used to assess the accuracy of the

remote sensed estimates. Available soil nitrogen content (KCl extractable) was compared across lithologies. We hypothesize that trees growing on sandstone-based soils are more nitrogen stressed than those growing on shale-based soils due to less nitrogen availability in the sandstone soil.

Effectiveness of two herbicide treatments on the invasive plant, mile-a-minute (Persicaria perfoliata), and implications for successful survival of restored buffers.

Jill Dunscomb[1,2] (presenter), Joe Receveur[2], Dave Wise[2], and Tara Muenz[2]

[1]Bayard Rustin High School

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Riparian buffers are valuable to the overall health of stream ecosystems providing reduced nutrient inputs to streams, habitat for wildlife, and detrital contributions which provide food for aquatic macroinvertebrates. Additional benefits include regulation of stream temperatures and algal production through shading, and protection from bank erosion. Many streams in Pennsylvania have been degraded due to intensive landscape alterations, and there is a large effort to bring back streamside forests. When restoring a streamside buffer, there are many issues to consider, including competition of weed growth. One such weed, Mile-a-minute (Persicaria perfoliata), is an herbaceous, annual, invasive vine from eastern Asia which grows up to six inches a day and can quickly smother plantings. In this study, trials are underway comparing the use of two pre-emergent herbicides Preen® and Snapshot® with regard to reducing weed competition with the newly planted trees. In June 2016 three sets of 50 planted tree seedlings were treated with Preen®, Snapshot® or left untreated. Preen® (trifluralin) promotes cellular damage due to its direct action on microtubules, thus inhibiting cell division and root growth. Snapshot® contains trifluralin as well as isoxaben, which is a selective cellulose biosynthesis inhibitor. We will present results on the effectiveness of these two herbicides on the P. perfoliata growth.

Bacterial Contamination in Headwaters at White Clay Creek

Kathleen Fisher[1] (presenter), Laura Borecki[2], and Dr. Jinjun Kan[2]

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Bacteria and pathogen contamination has been ranked the leading cause for impaired and threatened waters nationwide by U. S. EPA (Environmental Protection Agency). However, most current available data has relied on the collection and analysis of single grab samples at discrete times for various locations. Effective restoration and watershed managements require a comprehensive understanding of the origin, transport and dynamics of these bacterial contaminants. In this study, we monitored fecal indicator bacteria (FIB) including total coliform, E. coli and Enterococcus at 18 sites across White Clay Creek. The data indicated a recent increasing occurrence of high FIB in the watershed. The concentrations of total coliform, E. coli and Enterococcus were significantly higher than the EPA standards, suggesting a rising public health threat, a potential risk for surface-fed drinking water suppliers, and a challenge for watershed managers. In addition, molecular source tracking methods were used to identify the possible sources for FIB contamination, and our results indicated that the bacterial contaminations likely related to local landuses including agriculture, urbanization, mushroom operations, and wildlife.

Geomorphic and Hydraulic Controls on Temperature Regimes in Pool Habitats

Emma Gibson[1] (presenter), Dr. Valerie Ouellet, Dr. Melinda D. Daniels, and Nathan Watson

[1]Pennsylvania State University

A stream pool serves as habitat for diverse communities of microbes, macroinvertebrates, and fish. Every pool has a different interplay of hydraulics and geomorphological features, and each pool habitat hosts a unique biological community. These biotic communities are tied to the physical characteristics of their habitat. Many organisms in these communities are highly sensitive to water temperature. The effects of geomorphology and hydraulics on water temperature dynamics in pools are not well understood. In this study, the relationship between pool thermal regimes and abiotic geomorphic and hydraulic characteristics is explored in a representative sample of pool habitats in White Clay Creek in Chester County, Pennsylvania. These pools represent fluvial habitats in meadow and restored forest environments. Detailed metrics of pool hydraulics are measured using an acoustic Doppler velocimeter. Pool habitat morphology and substrate are quantified using total station surveying and dry sieving. Vertical stacks of shielded Onset HOBO V2 Pro water temperature loggers are used

to record pool thermal regimes at 15 minute intervals over a multi-week summer heat stress period. Statistical analysis explores the relationship between thermal regimes and abiotic pool characteristics.

Mapping and chemical analysis of soil and shallow lithology in a CZO catena

Bryan Heyer[1] (presenter), Tess Russo[1], Susan Brantley[1], and Beth Hoagland[1]

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Abstract: As a part of a the greater Shale Hills Critical Zone Observatory project, the soil layer and relatively shallow rock lithology along the Garner Run catena will be analyzed with hope to advance geochemical and hydrologic comprehension of the sandstone catena. This is a somewhat new research site and, along with complimenting projects, will pave the way for future investigations. One specific focus will be the difference in distance from the organic layer of soil to bedrock on the ridgetop of the catena compared to that of the valley floor; due to weathering and erosion, the sandstone cap would be closer to the surface on the ridge than in the valley. In order to measure this, a backpack drill such as the Shaw Portable Core Drill will be used to extract cores between 1 to 5 m below ground surface. Additionally, an auger will be used to quickly and easily isolate shallow soil samples from a great deal of various locations. Rock and soil cores will analyzed for physical texture and chemical composition. Different samples from varying depths and locations along the catena can be compared to construct a map of soil properties on distinct areas of the slope. We expect location along the catena will affect soil composition, texture, and other properties. Subsequently, predictions can be then be made and tested about water flow and groundwater chemistry within the catena based on soil moisture data obtained through GroundHOG equipment and samples extracted through drilled wells. The compilation and analysis of these near subsurface data will allow us to improve our understanding of hydrologic flow paths, residence time, and geochemical reactions along the Garner Run catena.

The Use of Gravitational Filtration to Preserve Water Samples to Measure High-Frequency Dissolved Organic Carbon and Nutrients

Uma Lad[1,2] (presenter), Hyojin Kim[1,2], and Susan Brantley[1,2]

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Despite extensive employment of automated water samplers, the temporal variability of dissolved organic carbon (DOC) and nutrient species e.g., nitrate at a high-frequency during storm events, is rarely documented. These elements are biologically active: microorganisms readily utilize DOCs and nutrient species, causing their concentrations to decrease over time. Water samples collected for such analyses must be filtered immediately and acidified (for DOC). In this study, we will evaluate the validity of a gravitational filtration system (GFS), which is an amended sampling method for automated samples that filter water samples by gravity (Kim et al., 2012), in the preservation of a sample for DOC and nutrient species. This evaluation will be carried out by collecting water samples from sites that display a range of DOC and nutrient concentrations such as streams, lakes, and ground water in Central Pennsylvania. We will monitor the concentration these elements in the GFS samples over three weeks and compare them to reference samples collected by a standard method. High-frequency DOC and nutrient species observations may contribute to our understanding on the dynamics of trace metals and the role of biology in geochemical processes.

Assessing spatial variations in pore water salinity across a tidal salt marsh: insights to ground water-surface water interactions

Cate Medlock[1] (presenter), Julia Guimond[1], Holly Michael[1], and Shailja Gangrade[1]

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Tidal salt marshes are hydrologically complex systems due to their location between terrestrial and coastal ecosystems. High tides transport saline surface water that periodically inundates the marsh platform and mixes with fresh groundwater. The interactions between fresh groundwater and saline surface water are important hydrological processes in salt marshes that control the sediment biogeochemistry, and nutrient and carbon fluxes. We measured pore water conductivity, dissolved oxygen, temperature, and redox potential at multiple depths between 0 and 2.25m across a tidal salt marsh. Our transects extend from the tidal channel to the forest boundary in order to understand how the freshwater-salt water boundary varies with both elevation and distance from the tidal creek. Results from this study will provide insight to how sea level rise from storm events affect salt marsh hydrology.

Mapping the Pleistocene periglacial imprint on modern soil properties at Garner Run, Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA

Connor Martin[1] (presenter), Perri Silverhart[2], Sarah Granke[3], Joanmarie Del Vecchio[14], Roman DiBiase[4]

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In the Garner Run subcatchment we are interested in near surface hydrologic properties and how they control the flux of water, solutes, and sediment through the critical zone. In doing this, many upland landscape soil maps are insufficient for characterizing key scales of heterogeneity.

In this case, we look at Garner Run, a first order catchment in the Susquehanna Shale Hills Critical Zone Observatory in central Pennsylvania underlain by the Tuscarora sandstone. The surface texture of soils and hillslope morphology in Garner Run preserves a history of Pleistocene periglacial processes, including boulder fields, solifluction lobes, and other mass wasting features.

To further understand this subcatchment we mapped in detail the spatial patterns in surface texture, ranging from clay rich soils without rock fragments, to open boulder fields, in order to evaluate the record of periglacial landscape processes and for input into modern critical zone models. These maps, along with soil cores and shallow soil pits supplement ongoing efforts to characterize the near surface properties of Garner Run using a suite of geophysical surveys and hydrologic experiments.

Numerical Modeling of the agricultural-hydrologic system in Punjab, India

Madeline Nyblade[1] (presenter), Dr. Tess Russo[1], and Dr. Ludmil Zikatanov[1]

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The goal of food security for India's a growing population is threatened by the decline in freshwater resources due to unsustainable irrigation use. Groundwater overdraft occurs in several regions of India, and the issue is acute in parts of Punjab, India, where a major quantity of India's food is produced with canal and declining groundwater resources. Conversely, other regions of the state are experiencing groundwater logging and salinization, leading to a regionally complicated hydrologic system. The lack of water use records presents a challenge for predicting future groundwater depletion and establishing potential solutions under continued agricultural growth. For this study, groundwater consumption is therefore estimated with available data on crop yields, precipitation, and total canal water delivery. The hydrologic and agricultural system are modeled using MODFLOW-OWHM and the Farm Process. To our knowledge, this is the first state-wide hydrologic model of Punjab that accounts for multiple aquifer layers, agricultural water demands, and interactions between the surface canal system and underlying groundwater. The results of this model can be used to further understand the hydrologic system response to groundwater consumption throughout Punjab and assess the effectiveness of possible water conservation solutions. This research also provides a foundation for future developments in the design of accurate numerical models for understanding groundwater flow given relatively sparse data.

Water Movement Through a Catchment During a Storm Event: Rate, Travel and Solute Concentrations

Sophia Ryan[1] (presenter), Beth Hoagland[2], Tess Russo[2], Hyojin Kim[2], and Susan Brantley[2]

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High frequency measurements of stream solute concentrations during the course of a storm event can improve our understanding of hydrologic and geochemical conditions in the Garner Run Watershed. We will observe how major anions, cations, stable isotopes ($2H/1H$, $18O/16O$) and DOC vary throughout the storm event. Alkalinity, pH, temperature, turbidity, and conductivity will also be measured during these events. We will use an automated sampler to take high frequency samples, thus providing data for the beginning of the storm, the middle of the storm and several measurements capturing the tail of

the storm. The autosampler has been modified to include filtering, allowing us the collect iron and other trace metals and preserve them in the field. Sample concentrations will be used to determine the concentration-discharge relationships for each solute. We will also test StorAge Selection (SAS) functions, which provide a model for water source age throughout the catchment. The non-stationary SAS model structure allows us to account for "old water" as a factor affecting stream chemistry during a storm event. The main goal of these analyses is to determine how quickly and where water travels through the catchment during a storm event.

Characterizing hydrologic properties of rocky surface soils in Garner Run, Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA

Perri Silverhart[1] (presenter), Connor Martin[2], Joanmarie Del Vecchio[3], Li Li[3], and Roman DiBiase[3]

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Soil hydrologic properties determine how water, solutes, and sediment move through the near surface environment. While robust methods exist for characterizing the hydrology of homogeneous, fine-grained soils, it is less clear how to incorporate rocky soils into critical zone models.

Here we characterize soils and coarse colluvium from Garner Run, a sandstone study catchment in the Susquehanna Shale Hills Critical Zone Observatory. This landscape was strongly influenced by Pleistocene periglacial processes, and exhibits a strong heterogeneity in surface cover ranging from clay rich soils to open boulder fields. In this catchment, the relationship between surface and subsurface material and hydrologic properties must be understood to calibrate critical zone models.

This study aims to constrain the hydrologic properties of specific surface textures by conducting sprinkling experiments in order to test how water moves through various surface types, including soil, soil with boulders, and just boulders. We will then pair these hydrologic parameters with ongoing efforts to map spatial variations of surface texture and to image the subsurface using shallow geophysics. From this, we can use hydrologic models to evaluate the influence of the observed heterogeneity in surface material properties on critical zone processes.

Critical Zone Science: Creating an Interdisciplinary Approach to Teaching Science in Secondary Schools using NGSS

Lauren McCall Smith[1] (presenter), Dr. Tim White[2], Dr. Don Duggan-Haas[3], and Sarah Sharkey[2]

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The Critical Zone (CZ) is defined as the permeable layer from the top of the vegetation canopy to the bottom of freely circulating groundwater where rock, soil, water, air and life overlap. Critical Zone Observatories (CZO) are research field sites spanning a range of climatic, ecologic, geologic, and physiographic environments where scientists look to understand coupled physical, chemical, and biological processes. Interdisciplinary expertise and collaboration are required to understand and visualize these complex processes, which can be challenging for the general public. One approach uses Virtual Field Experiences (VFE) to expose people to different landscapes to answer: "Why does this place look like it does?" To develop a VFE on the Susquehanna-Shale Hills CZO (Shale Hills), information on the data, instrumentation and research questions at this site were compiled to explain the interconnectedness of the CZ in central Pennsylvania. This Shale Hills VFE was developed for a secondary education classroom; however, VFE's can be modified to a broad range of educational settings. Teachers and students both benefit by the affordability, flexibility, and relevance to the Next Generation Science Standards (NGSS). The Shale Hills VFE allows students to gain a better understanding of asking and answering questions through CZ research.

Understanding Nitrogen Removal Pathways in Agricultural Soils through 15N tracer Additions

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Until recently, denitrification has been the major focus of study in order to understand how nitrogen is removed from eco-systems. However, this does not account for the conversion of organic nitrogen to inorganic nitrogen that is seen in aquatic ecosystems, and recent studies have shown that alternative pathways of organic nitrogen loss are important in accounting for this discrepancy. Biological processes that happen at a microbial level in soils, such as dissimilatory nitrate reduction to ammonium (DNRA) and anaerobic ammonium oxidation (annamox), are alternative pathways that could impact loss of nitrogen. Through 15N tracer additions to soils from the Shaver's Creek floodplain in the Critical Zone Observatory, an area impacted by agricultural land use, this experiment aims to better understand these alternative pathways. The experimental method will be closed mesocosm systems, where nutrient rich water will be pumped through soil columns for varying amounts of time while samples are taken periodically. Samples will be taken of dissolved oxygen, dissolved organic carbon, and major ions. The major goals of this endeavor are to test an experimental design to measure alternative pathways for nitrogen, determine what conclusions can be made from non isotopic measurements (as well as some limited isotopic measurements), and correlate nitrogen cycling activity to soil conditions in each mesocosm, such as water, nutrient, and redox conditions.

How do pool hydraulic, thermal and geomorphic properties affect bacterial distribution?

Nathan Watson[1] (presenter), Dr. Melinda Daniels[2], Dr. Jinjun Kan[2], Emma Gibson[3], and Valerie Ouellet[2]

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Previous studies have shown that microbial community composition varies across a range of stream habitats. It is also known that these communities can vary within a given habitat, based on whether they inhabit sediment or rock biofilm. Little is understood about how varying hydraulic and geomorphic factors within local habitats influence the local microbial community distribution. The purpose of this study is to examine how geomorphological and hydraulic habitat variables may drive bacterial community composition within stream pool habitats. Ten pools were selected at 3rd order of the White Clay Creek, PA. Microbial community structures from rock biofilm and sediment samples within each pool were determined by PCR-DGGE (polymerase chain reaction-denaturant gradient gel electrophoresis), a quick fingerprinting technique based on 16S rRNA genes. The grain size distributions, organic matter content, hydraulic flow fields, temperature regime, and morphology of each pool were quantified to document variations among the pool habitats. Multivariate statistics will be applied to determine the nature and strength of the relationships between the bacterial distribution and abiotic habitat factors.

A low-cost, open source approach for utilizing industrial Modbus RS-485 sensors for environmental science with the Arduino-compatible EnviroDIY Mayfly datalogger

Peter Wise[1,2] (presenter), Steve Hicks[2], and Anthony Aufdenkampe[2]

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Scientists and educators around the world have begun to use the the Arduino open source electronics platform to build a variety of do-it-yourself (DIY) devices. Our new Arduino-compatible EnviroDIY Mayfly datalogger board (http://envirodiy.org/mayfly/) expands the potential for DIY environmental monitoring by connecting to a wide variety of analog and digital sensors, streaming data live from remote locations, and not requiring significant modification or additional components in order to function.

Here we present a set of new low-cost software and hardware approaches to expand the EnviroDIY Mayfly logger's digital

sensor capabilities to the wide variety of industrial sensors that operate using the Modbus RS-485 communication protocol. Our analysis will compare the performance of Yosemitech RS-485 sensors (http://www.yosemitech.com/en/) with other sensors familiar to the environmental monitoring community. The Mayfly's RS-485 compatibility will make environmental monitoring more feasible, allowing more researchers and scientists from a broad range of backgrounds to collect high quality, high resolution data.

The EnviroDIY webpage (http://envirodiy.org/) has more information, tutorials, and forums for people to share ideas, get help, and present their gadgets.

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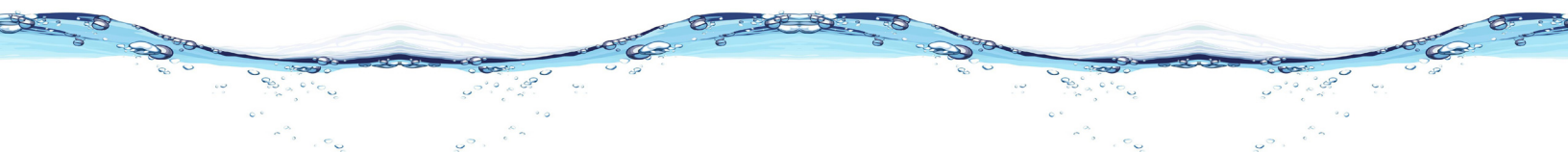*Program Manager*
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