SIXTH BIENNIAL COLLOQUIUM
July 29 - August 1, 2018
National Conservation Training Center
Shepherdstown, WV

Hydrologic Connections: Climate, Food, Energy, Environment, and Society
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CUAHSI would like to acknowledge the contributions, support, and assistance from the following organizations and individuals:

CUAHSI Board of Directors
CUAHSI Member Institutions
National Aeronautics and Space Administration
National Conservation Training Center
National Science Foundation
National Weather Service
U.S. Department of Homeland Security

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President and Executive Director: Jerad Bales (CUAHSI)
Secretary: Adam Ward (Indiana University)
Treasurer: Audrey Sawyer (Ohio State University)
### Sunday, July 29

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<tr>
<th>Time</th>
<th>Event</th>
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<tr>
<td>3:00 - 6:00pm</td>
<td>Registration</td>
<td>Main Lobby, Entry Auditorium Building</td>
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<tr>
<td>7:30 - 9:00pm</td>
<td>Let’s Talk About Water Event and Reception</td>
<td>Roosevelt Room (Commons Building)</td>
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### Monday, July 30

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<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>7:00 - 8:30am</td>
<td>Breakfast</td>
<td>Commons</td>
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<tr>
<td></td>
<td>Registration</td>
<td>Main Lobby, Entry Auditorium Building</td>
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<tr>
<td>8:30 - 8:40am</td>
<td>Welcome Address</td>
<td>Entry Auditorium Building</td>
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<tr>
<td></td>
<td>Speakers: Jerad Bales (CUAHSI) and Gordon Grant (Chair of the CUAHSI Board of Directors)</td>
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<tr>
<td>8:40 - 9:40am</td>
<td>Reds Wolman Lecture</td>
<td>Entry Auditorium Building</td>
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<tr>
<td></td>
<td><em>A water-centric view of the climate-FEW-society nexus</em></td>
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<td></td>
<td>Speaker: George Hornberger (Vanderbilt University)</td>
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<tr>
<td>9:40 - 10:00am</td>
<td>Morning Break</td>
<td>Entry Auditorium Building</td>
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<tr>
<td>10:00 - 11:00am</td>
<td>NSF Perspectives and State of CUAHSI Presentation</td>
<td>Entry Auditorium Building</td>
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<td>Time</td>
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<td>11:00am -</td>
<td><strong>Pathfinder Presentations</strong></td>
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<td>12:00pm</td>
<td>Chair: David Freyberg (Stanford University)</td>
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<td></td>
<td><strong>Speakers:</strong></td>
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<tr>
<td></td>
<td><strong>Source water variability to soils of large, forested floodplains</strong></td>
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<td></td>
<td>Mary Lemon (Louisiana State University)</td>
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<td></td>
<td><strong>Temporal patterns of dissolved organic carbon and nitrate in discontinuous permafrost catchments</strong></td>
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<td>Peter Regier (Florida International University and University of New Mexico)</td>
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<td><strong>Evaluating the potential of a spatially explicit, high resolution, model of subcanopy solar radiation to better estimate the influence of vegetative shade on headwater stream temperature</strong></td>
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<td></td>
<td>Laura Belica (North Carolina State University)</td>
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<td></td>
<td><strong>Integrated modeling of surface-subsurface processes to understand river-floodplain hydrodynamics from reach to watershed scale</strong></td>
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<td>Siddharth Saksena (Purdue University)</td>
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<tr>
<td>12:00 - 1:15pm</td>
<td><strong>Lunch</strong></td>
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<tr>
<td>1:30 - 3:30pm</td>
<td><strong>Monday Afternoon Concurrent Sessions</strong></td>
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<tr>
<td></td>
<td><strong>CUAHSI Summer Institute at the National Water Center</strong></td>
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<td>Chair: Jerad Bales (CUAHSI)</td>
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<td></td>
<td><strong>Transforming National Oceanic and Atmospheric Administration (NOAA) Water Resources Prediction</strong></td>
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<td>Speaker: Thomas Graziano (National Water Center)</td>
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<td></td>
<td><strong>Exploration of Citizen Science Data and Potential Application to the National Water Model</strong></td>
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<td>Speaker: Elizabeth Del Rosario (Texas A&amp;M University Corpus Christi)</td>
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<td></td>
<td><strong>Evaluating Alternative Baseflow Estimation Methods for Improving National Water Model Forecasting</strong></td>
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<td>Speaker: Joseph M. Krienert (Southern Illinois University)</td>
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<td></td>
<td><strong>Incorporating Realistic Channel Geometry into Continental-Scale Hydrological Modeling</strong></td>
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<td>Speaker: Nishani Poorna Moragoda (University of Alabama)</td>
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<td>Other Session Speakers: Danielle Tijerina (CUAHSI)</td>
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<td></td>
<td><strong>Hydrologic Extremes and Society</strong></td>
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<td>Chair: Hilary McMillan (San Diego State University)</td>
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<td><strong>Building A Global Flood Observatory</strong></td>
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<td>Speaker: Robert Brakenridge (INSTAAR, University of Colorado Boulder)</td>
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<td></td>
<td><strong>Compound and Concurrent Climate Extremes: Detection, Modeling and Risk Analysis</strong></td>
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<td>Speaker: Amir AghaKouchak (University of California Irvine)</td>
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<td></td>
<td><strong>Tracking Drought Impacts Across Space, Time, Sectors and Scales</strong></td>
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<td>Speaker: Kelly Smith (University of Nebraska Lincoln)</td>
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<tr>
<td>3:30 - 4:00pm</td>
<td><strong>Afternoon Break</strong></td>
<td>Physical Training Gymnasium</td>
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<tr>
<td>3:45 - 4:30pm</td>
<td><strong>Town Hall: The U.S. Global Change Research Program’s Integrated Water Cycle Group</strong></td>
<td>Bar (Commons Building)</td>
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<tr>
<td></td>
<td>Moderator: Jennifer Saleem Arrigo (U.S. Global Change Research Program)</td>
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<td>Speakers: Stacey Archfield (USGS), Jared Entin (NASA), Karen Metchis (U.S. EPA), and Gary Geernaert (U.S. DOE)</td>
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<tr>
<td>4:00 - 6:00pm</td>
<td><strong>Poster Session</strong></td>
<td>Physical Training Gymnasium</td>
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<tr>
<td>6:00 - 7:30pm</td>
<td><strong>Dinner</strong></td>
<td>Commons</td>
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<tr>
<td>7:30 - 8:30pm</td>
<td><strong>Meet the CUAHSI Board of Directors for a CUAHSI Community Discussion</strong></td>
<td>Bar (Commons Building)</td>
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**Tuesday, July 31**

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<thead>
<tr>
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<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>7:00 - 8:15am</td>
<td><strong>Breakfast</strong></td>
<td>Commons</td>
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<tr>
<td>8:15 - 10:15am</td>
<td><strong>Tuesday Morning Concurrent Sessions</strong></td>
<td>Room #151 Instructional West Building</td>
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<tr>
<td></td>
<td><strong>Hydrologic Feedbacks with Ecosystems</strong></td>
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<td>Chair: Gretchen Miller (Texas A&amp;M University)</td>
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<td></td>
<td><strong>Coupling drives bifurcation: linked development and differentiation of fluvial delta islands, surface water-groundwater interactions, and freshwater marsh habitats at Wax Lake Delta, LA</strong></td>
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<td>Speaker: Kevan Moffat (Washington State University)</td>
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<td></td>
<td><strong>Improving the representation of vegetation-atmosphere interactions through plant-hydrodynamics models</strong></td>
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<td>Speaker: Ashley Matheny (University of Texas at Austin)</td>
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<td></td>
<td><strong>Plant water use and plant water status during protracted and seasonal droughts: A link between hydrological fluxes and ecological disturbance</strong></td>
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<td>Speaker: Sally Thompson (University of California Berkeley)</td>
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<td></td>
<td><strong>Water and the Changing Climate</strong></td>
<td>Entry Auditorium Building</td>
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<td>Chair: Jeanne VanBriesen (Carnegie Mellon University)</td>
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<td></td>
<td><strong>Positioning Risk – Climate variability, Nonstationarity and Hydrological Extremes</strong></td>
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<td>Speaker: Ana Barros (Duke University)</td>
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<td><strong>Probabilistic modeling of hurricane surge and rainfall flooding in a changing climate</strong></td>
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<td>Speaker: Ning Lin (Princeton University)</td>
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<td><strong>USACE Tools for Climate Change Adaptation</strong></td>
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<td>Speaker: Will Veatch (U.S. Army Corps of Engineers)</td>
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<tr>
<td>10:15 - 10:45am</td>
<td>Morning Break</td>
<td>Entry Auditorium Building</td>
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<tr>
<td>10:45 - 11:45am</td>
<td>Peter S. Eagleson Keynote Lecture</td>
<td>Entry Auditorium Building</td>
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<td></td>
<td><em>Ecosystem processes at the watershed scale: Hydrologic trade-offs on the urban range</em></td>
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<td>Speaker: Larry Band (University of Virginia)</td>
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<tr>
<td>11:45am - 1:00pm</td>
<td>Lunch</td>
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**Tuesday Afternoon Workshops**

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<tr>
<th>Time</th>
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<th>Location</th>
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<tbody>
<tr>
<td>1:15 - 3:30pm</td>
<td>CUAHSI Tools and Services for Managing Research Data</td>
<td>Room #151 Instructional West Building</td>
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<td></td>
<td>Instructors: Anthony Castronova (CUAHSI), Liza Brazil (CUAHSI), Miguel Leon (Luquillo Critical Zone Observatory), Jeff Horsburgh (Utah State University), David Tarboton (Utah State University)</td>
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<tr>
<td>1:15 - 3:30pm</td>
<td>Resources for Data-Driven Water Science Education</td>
<td>Room #114 Instructional East Building</td>
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<td></td>
<td>Instructors: Benjamin Ruddell (Northern Arizona University) and Adnan Rajib (U.S. EPA)</td>
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<tr>
<td>1:15 - 3:30pm</td>
<td>Expected hydrologic observations and data sharing capabilities for the Surface Water and Ocean Topography (SWOT) Mission</td>
<td>Room #201 Instructional East Building</td>
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<td></td>
<td>Instructors: Cédric David, Jessica Hausman, Frank Greguska, and Michael Gangl (NASA Jet Propulsion Laboratory, California Institute of Technology)</td>
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<tr>
<td>3:30 - 4:00pm</td>
<td>Afternoon Break</td>
<td>Entry Auditorium Building</td>
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<tr>
<td>4:00 - 5:30pm</td>
<td>Instrumentation Panel</td>
<td>Entry Auditorium Building</td>
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<td>Chairs: Scott Tyler (University of Nevada Reno) and Beth Boyer (Pennsylvania State University)</td>
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<td>Panelists: Russ Kelz (Earth Sciences, National Science Foundation), Bruce Beaudoin (IRIS PASSCAL), Glen Mattioli (UNAVCO), John Selker (CTEMPs), Janice Fulford (USGS Hydrologic Instrumentation Facility), Brigitte Baeuerle (NCAR), Craig Glennie (National Center for Airborne Laser Mapping), anders Noren (Continental Scientific Drilling Coordination Office), Marc Caffee (Purdue Rare Isotope Measurement Laboratory), Mike Olson (National Atmospheric Deposition Program), Nick Harrison (National Ecological Observatory Network), Thanos Papanicolaou &amp; Miguel Leon (Critical Zone Observatories), and Albert Kettner (Community Surface Dynamics Modeling System)</td>
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<tr>
<td>5:30 - 6:00pm</td>
<td>Awards Ceremony</td>
<td>Entry Auditorium Building</td>
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<tr>
<td>6:00 - 7:30pm</td>
<td>Dinner</td>
<td>Commons</td>
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<td>7:30 - 8:30pm</td>
<td>Graduate Student Career Panel</td>
<td>Commons (Treehouse Area)</td>
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<td></td>
<td>Host: Jon Pollak (CUAHSI)</td>
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<td>Panelists: Anthony Castronova (CUAHSI), Jennifer Saleem Arrigo (U.S. Global Change Research Program), Jesus Gomez-Velez (Vanderbilt University), Sally Thompson (University of California Berkeley), and Emily Trentacoste (U.S. EPA)</td>
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### Wednesday, August 1

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>7:00 - 8:30am</td>
<td><strong>Breakfast</strong></td>
<td>Commons</td>
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<tr>
<td>8:30 - 9:30am</td>
<td><strong>Keynote Lecture</strong></td>
<td>Entry Auditorium Building</td>
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<td></td>
<td><em>Engineering and Policy Decisions at the Energy-Water Nexus</em></td>
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<td>Speaker: Jeanne VanBriesen (Carnegie Mellon University)</td>
<td>Entry Auditorium Building and Instructional West Building</td>
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<td>9:30 - 10:00am</td>
<td><strong>Morning Break</strong></td>
<td>Entry Auditorium Building</td>
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#### Wednesday Morning Concurrent Sessions

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<tr>
<th>Time</th>
<th>Session</th>
<th>Chair:</th>
<th>Room</th>
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<tbody>
<tr>
<td>10:00am - 12:00pm</td>
<td><strong>Measurement-Monitoring-Sensing</strong></td>
<td>Branko Kerkez (University of Michigan)</td>
<td>Entry Auditorium Building</td>
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<td><em>Identification of the Burial Depth of Radio Frequency IDentification (RFID) Transponders in Riverine Applications</em></td>
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<td>Speaker: Chris Wilson (University of Tennessee)</td>
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<td><em>Applications of optical sensors for real-time water quality monitoring and research in rivers</em></td>
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<td>Speaker: Brian Pellerin (USGS)</td>
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<td><em>Development of Innovative Low-cost Hydrometeorological Sensors to Improve Monitoring in Data-sparse Regions</em></td>
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<td>Speaker: Paul Kucera (UCAR)</td>
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<td><strong>Energy-Water Systems</strong></td>
<td>Paul Block (University of Wisconsin Madison)</td>
<td>Instructional West Building</td>
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<td><em>Understanding the Food-Energy-Water Nexus – Opportunities for Water Resources Research</em></td>
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<td>Speaker: Ximing Cai (University of Illinois)</td>
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<td><em>Integrated Management of Water, Land, Energy, and Environmental Resources - It is now or never.</em></td>
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<td>Speaker: Aris P. Georgakakos (Georgia Tech)</td>
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<td><em>Conflict, Coordination &amp; Control: Do We Understand Risk and Resilience in Food-Energy-Water Systems?</em></td>
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<td>Speaker: Patrick Reed (Cornell University)</td>
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<td><em>Market Mechanisms to Manage Competing Uses of Water Resources</em></td>
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<td>Speaker: Frank Wolak (Stanford University)</td>
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<td>12:00 - 1:30pm</td>
<td><strong>Lunch</strong></td>
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Wednesday Afternoon Concurrent Sessions

1:30 - 3:30pm  Food-Water Systems

Chair: Megan Konar (University of Illinois)

FEWSION: An empirical description of the U.S. food, energy, and water system
Speaker: Benjamin Ruddell (Northern Arizona University)

Holistic Pathways for Achieving Food Security and Water Sustainability
Speaker: Kyle Davis (Columbia University)

Groundwater wells and withdrawal management in western USA food-producing regions
Speaker: Debra Perrone (University of California Santa Barbara)

Dynamic Connectivity in the Landscape

Chair: Adam Ward (Indiana University)

Ecohydrological connectivity between landscapes and riverscapes
Speaker: Doerthe Tetzlaff (University of Aberdeen)

Dynamic lateral, vertical, and longitudinal hydrologic connectivity drive runoff and carbon export across watershed scales
Speaker: Margaret Zimmer (University of California Santa Cruz)

Drivers of Dynamic Disconnectivity in Rivers
Speaker: Ellen Wohl (Colorado State University)

3:30 - 3:40pm  Closing Remarks

Speakers: Jerad Bales (CUAHSI) and Gordon Grant (Chair of the CUAHSI Board of Directors)

NEW! Enter CUAHSI’s Raffle

Enter for a chance to win the following:
• One free registration to a training workshop or short course of your choosing (for graduate students and post-docs); or
• One free registration to the CUAHSI Biennial (for professionals)

You’re already two-thirds of the way there for an entry!
The last step is to complete the feedback survey upon completion of the 2018 CUAHSI Biennial Colloquium. To access the feedback survey, visit: http://www.cvent.com/d/ktqv11/7E

Winners will be chosen at 10:00 a.m. on Wednesday, August 15 and notified by e-mail.

Terms and Conditions:
This contest is open to all attendees of the 2018 CUAHSI Biennial Colloquium with the exclusion of CUAHSI employees, officers, and Board of Directors. Must be affiliated with a U.S. university. Limitations apply with use of free registration to a training workshop or short course. Some training workshops or short courses have an application process. With this, you must be accepted in order to use the free registration. Registration to the CUAHSI Biennial will be awarded as a check mailed to your current mailing address.
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.
Reds 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.

A water-centric view of the climate-FEW-society nexus
Speaker: George M. Hornberger (Vanderbilt University)

Food, energy, and water (FEW) are primary resources required for human populations and ecosystems. The large and growing water demands for agricultural production are well known, water can be a significant constraint in electricity production, and the use of arable land for biofuels represents tradeoff decisions at the FEW nexus. Climate change will affect water availability. Increased demand for FEW resources from population growth and lifestyle changes will result in increased competition for limited resources, which will impact financial decisions. Both water quantity and water quality considerations of FEW interactions need to be taken into account explicitly because there are important feedbacks between quantity and quality aspects of the interactions. It is also important to take FEW resources into account during adaptation planning, as highlighted by recent events in the US when many citizens lost ready access to food, electricity, and drinking water in the aftermath of Hurricanes Harvey, Irma, and Maria.

Managing the FEW resources concurrently is a seemingly wicked problem involving an apparent trilemma from a sustainability and resiliency perspective. A core challenge is to develop an integrative understanding that embodies processes and feedbacks at a level of detail that allows evaluation of alternatives in these complex systems and therefore can support integrated management.

Advances in hydrological science clearly are critical to the enterprise of determining how to achieve global goals for developing and using FEW resources sustainably, especially in the face of a changing climate and a growing population. Among the needs are new and expanded data acquisition, analyses and syntheses of multi-sectoral data and information, and integrative modeling. In my presentation, I will review some of the critical needs and illustrate them using a few nascent research results.
Peter S. 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.

Ecosystem processes at the watershed scale: Hydrologic trade-offs on the urban range

Speaker: Larry Band (University of Virginia)

Ecosystem optimization to available resources, and the co-evolution of canopy, soil and landscape, is a topic pioneered by Pete Eagleson in a series of landmark papers. The extension of Eagleson's vision to understand the form, function and ecohydrological optimization of full landscapes, and adaptation to urban design is the major focus of this presentation. Management of urban and urbanizing watersheds involves balancing between values, perceptions, choices and constraints in terms of multiple objectives, environmental, financial and political conditions. The balance is true for any watershed management activity, but many urban areas are characterized by rapidly expanding populations and development into water supply areas. Compared to the industrial northeast and arid west, urbanization in the United States southeast was characterized by historically smaller urban areas with lower population densities, plentiful rainfall, and riparian rights leading to more localized water supply systems with small impoundments, in smaller watersheds. With more recent rapid growth of these cities, increased hydroclimate change and variability, and reduced ability to develop new water sources, the reliability of water supplies in terms of both quantity and quality is increasingly challenged. While urban areas are expanding in their own water supply catchments, dominant land use still includes forest, which significantly expanded in the 20th century, and residual agricultural land. A significant development in urban water management paradigms is the growing interest in green infrastructure (GI) as a source of multiple ecosystem services, including mitigation of stormwater production, urban heat islands, carbon sequestration, and water quality, habitat and air quality improvement. However, our understanding of how to design and optimize connected GI networks within the legacy of historical development, property ownership and competing goals is nascent. In this talk, we explore the translation principles of ecohydrological models of spontaneous ecosystem service production and optimization in unmanaged landscapes to the design and optimization of GI within the constraints of the urban environment. We use a combination of long term data and high resolution observations of streamflow and nutrient loading in a forest and urban LTER in Maryland and North Carolina, and in the water supply areas of the rapidly expanding North Carolina Triangle.
Coal-fired power plants are under increasing pressure to manage air quality emissions while remaining profitable in a competitive electricity market. Engineering and policy choices designed to support these objectives can have unexpected effects on pollutant discharges to surface waters that are used as sources at drinking water treatment facilities.

Of particular concern is the release of bromide from coal-fired power plants operating wet flue gas desulfurization (FGD) units. Bromide, while unreactive in surface waters, interacts with treatment chemicals at the drinking water facility to produce halogenated organic compounds called disinfection by-products (DBPs). DBPs containing bromide are more toxic and carcinogenic than chlorinated DBPs, and the current regulatory structure may not adequately protect drinking water consumers from this changing risk.

Bromine, which is naturally present in coals, is not removed in FGD wastewater prior to discharge. Recently, new technologies based on bromide addition have been deployed at power plants to reduce airborne mercury releases and to qualify for federal tax credits. The addition of bromide can significantly increase bromide loading to surface waters and negatively impact drinking water facilities and consumer risk.

Watershed-, state-, and national-level analyses will be presented that highlight the critical characteristics of regions where current bromide loads are affecting drinking water consumers as well as regions at risk for impacts under future plans for bromide addition and FGD wastewater discharges. The work is particularly timely as the U.S. EPA is re-considering the Effluent Limitation Guidelines for Steam Electric Power Utilities, which currently do not require control of bromide discharges from FGD systems.
CUAHSI Pathfinder Fellowships
Chairs: David Freyburg (Stanford University)
Graduate training in water science often focuses on a single field site, analytical, or modeling approach. The CUAHSI Pathfinder Fellowship program provides an opportunity to extend the research of graduate students in water science by providing travel funds. Students use the Fellowship to make extended trips to enhance their research by adding a field site to conduct comparative research, collaborating with a research group, or working with researchers on adding an interdisciplinary dimension to a project. This session will include presentations from four Pathfinder Fellows, which will discuss each Fellow’s research project and how Pathfinder program impacted their work.

Source water variability to soils of large, forested floodplains
Speaker: Mary Lemon (Louisiana State University)
Co-Author: Richard Keim (Louisiana State University)

Forested wetlands are prominent features across floodplains of the southeastern United States. The importance of flooding in controlling community structure has been well documented, but the role of seasonal water limitation has been much less studied, even though it may become more ecologically important because of intensified river management and climate change. In particular, the source of soil moisture for tree growth during the late summer dry period is relatively unknown. Therefore, in this study we investigated source water to the root zone using stable isotopes of water to trace origin to precipitation, surface flood water, and shallow groundwater at the end of the growing season in the floodplains of the Tensas, Boeuf, and Sabine rivers in Louisiana and Texas. Preliminary results indicate dissimilar isotopic signatures and thus suggest low vertical connectivity between groundwater and ponded surface water and low horizontal connectivity with nearby floodplain surface water. At one of the two Louisiana sites, shallow groundwater isotope time series indicate spatial separation between a sandy ridge and a lower elevation back swamp, which suggests relatively greater importance of precipitation to shallow groundwater at the higher-elevation, coarse-textured site, and greater importance of flood water infiltration at sites with higher river connectivity. Ongoing analyses of soil and xylem water aim to clarify the relative importance of precipitation and surface flood waters late in the growing season.

Comparing high-frequency dissolved organic carbon dynamics in discontinuous permafrost catchments
Speaker: Peter Regier (Florida International University and University of New Mexico)
Co-Authors: Tamara Harms (University of Alaska Fairbanks), Audrey Mutschlecner (University of Alaska Fairbanks), Jeremy Jones (University of Alaska Fairbanks), Rudolf Jaffé (Florida International University)

In high-latitude catchments, global warming is leading to thawing of permafrost, which is expected to mobilize nutrients and organic matter currently stored in frozen ground. Changes in nutrients transported from thawing permafrost into headwater streams will affect biogeochemical cycles and productivity in local and downstream aquatic systems. However, nutrient dynamics in headwater streams exhibit high spatiotemporal variability due to complex interplay between hydrologic, chemical, and biological drivers. We used multi-sensor sondes to capture temporal behavior of proxies for dissolved organic carbon (fluorescent dissolved organic matter, or FDOM) and nitrogen (optically measured nitrate) at a sub-hourly time-scales draining watersheds varying from ~0 to 50% permafrost in the Caribou-Poker Creeks Research Watershed near Fairbanks, AK. Comparison of catchments underlain by low and high permafrost exhibited differences in solute concentrations throughout the summer for both FDOM and nitrate. Solute hysteresis responses to storms differed between low and high permafrost streams, with evidence of shifting carbon sources in the low permafrost stream not observed in the high permafrost stream. Findings highlight the importance of high-frequency measurements to accurately characterize temporally complex solute dynamics in headwater permafrost catchments.
Evaluating the potential of a spatially explicit, high resolution, model of subcanopy solar radiation to better estimate the influence of vegetative shade on headwater stream temperature
Speaker: Laura Belica (North Carolina State University)

Solar radiation is the main source of thermal energy to streams and a key parameter in deterministic models of stream temperature, however, in forested headwaters fine-scale variations in topographic and vegetative shading along a stream’s course makes estimating solar insolation difficult. A subcanopy solar radiation model, based on airborne LiDAR data, combines light attenuation through forest canopies with bare-earth estimates of solar radiation and could improve estimates of insolation used in deterministic stream temperature models. This Pathfinder award allowed the subcanopy solar radiation model to be evaluated with field measurements of solar radiation and stream temperature in two forested headwaters in the southeastern U.S. with different terrain and forest characteristics in different seasons. With one site in a rapidly developing area of the piedmont, where forested and agricultural lands are increasingly being converted to other land uses, and the other site in the Southern Appalachians, also experiencing land cover changes, the model will be assessed for deciduous forests in montane and piedmont topographies for a range riparian widths in winter and summer conditions. If the subcanopy solar radiation model estimates are validated for southeastern deciduous forests, the approach will be particularly useful in estimating solar insolation and heat flux in the small, but numerous forested headwater streams where the potential impacts of changes in forest cover on stream temperatures are of most concern.

Integrated modeling of surface-subsurface processes to understand river-floodplain hydrodynamics from reach to watershed scale
Speaker: Siddharth Saksena (Purdue University)

As the flood intensity and magnitude is expected to rise from urbanization and climate change, it is essential to develop flood inundation models that are reliable in predicting future flood risk. Additionally, with increasing focus on large-scale planning and allocation of resources for protection against future flood risk, it is necessary to analyze and improve the deficiencies in the existing flood modeling techniques and create a standard framework for identifying regions that are more susceptible to flooding. This study aims to evaluate the potential of integrated modeling in predicting flood outputs by incorporating the variability in physical processes. Additionally, this study focuses on investigating the effect of spatial scale on model performance by comparing the flood outputs for integrated models from reach to watershed scale. The results suggest that integrated modeling performs more accurately than the traditional flood modeling approach across multiple spatial scales. Also, the sub-surface storage plays an important role in influencing the flood responses across the entire watershed. This project is one of the first integrated modeling effort for a large watershed of 85000 km2 and presents a framework for creating, calibrating and simulating integrated models at large scales.
CUAHSI Summer Institute at the National Water Center

Chair: Jerad Bales (CUAHSI)

The 2018 CUAHSI Summer Institute (SI) was held June 10 – July 26, 2018 at the National Water Center on the Tuscaloosa campus of the University of Alabama. Twenty-five graduate students, two course coordinators, nine faculty theme leaders, and three CUAHSI staff participated, as well as a number of guests from the NWS, USGS, and elsewhere. Students at the 2018 SI focused on hyper-resolution modeling, groundwater – surface connections, data from volunteer monitoring, and river hydraulics. Students used National Water Model outputs and observations to explore potential improvements to the NWM and to describe uncertainty. Among the data sets utilized was the CUAHSI-curated Hurricane Harvey hydrometeorological data from 2017. The session will begin with a presentation from Dr. Thomas Graziano, Chief of the NWS Office of Water Prediction, followed by presentations by selected 2018 students.

Transforming National Oceanic and Atmospheric Administration (NOAA) Water Resources Prediction
Speaker: Thomas Graziano (National Water Center)

In response to growing demands for enhanced and integrated water resources forecasts and services to address increasingly complex societal issues related to too much, too little or poor quality water, NOAA has begun a transformation of its operational water prediction capabilities. Recent and ongoing engagements with water resources stakeholders across the United States have revealed the need for consistent, high space and time resolution, integrated water analyses, predictions and data to address critical unmet information and service gaps related to floods, drought, water quality, water availability, and a changing climate. To address these growing needs, the Office of Water Prediction (OWP) is leading a transformation and modernization of hydrology and water prediction services within NOAA’s National Weather Service. The OWP is playing a critical role in enhancing water-related products and decision-support services across the country in support of the NWS strategic objective of building a Weather Ready Nation. Leveraging the National Water Center (NWC), OWP is working to improve federal, academic and broader water enterprise coordination and collaboration around prediction and decision support to address 21st century water resource challenges.

The NWC supports water prediction nationwide, and is fostering scientific excellence and innovation by promoting research and collaboration across Federal water science and management agencies, academia, and the private sector to accelerate the transition of research to operational applications and forecasting. An example of this collaboration is the annual National Water Center Innovators Program and Summer Institute, conducted in partnership with the National Science Foundation (NSF) and the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI), with participation from the National Center for Atmospheric Research (NCAR), the U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE). The Innovator’s Program has two overarching goals: Provide a framework for collaboration between the federal and academic communities that fosters innovation and creativity; and Target emerging technologies such as advanced water resources modeling capabilities, cutting edge data and interoperability services, or interdisciplinary techniques aligned with NOAA and the OWP strategic science and service plans.

The Summer Institute is a highly competitive program attracting top faculty and graduate students from water resources program across the country which culminates in a seven week in-residence program focused on continued improvements in water prediction, hydroinformatics, and related decision support services. Additionally, OWP has worked with University Corporation for Atmospheric research (UCAR) to establish the Community Advisory Committee for the Office of Water Prediction (CAC-WP). The role of the CAC-WP is to conduct independent, routine, comprehensive reviews of the National Water Model (NWM), other modeling innovations, and related data and information services of OWP. The CAC-WP is designed to bring independent expertise and perspectives from across the community and includes membership from academia, federal agencies, NGOs, and the private sector.

As a significant step forward to transform NOAA’s water prediction services and address the growing stakeholder demands for enhanced water resources forecasts and services, NOAA implemented a new National Water Model (NWM) in August 2016. A continental-scale water resources model, the NWM is an evolution of the Weather Research and Forecasting (WRF)-Hydro modeling architecture developed by the NCAR and its global collaborator community. The NWM represents NOAA’s first foray into high performance computing for water prediction and expands NOAA’s current water quantity forecasts, at approximately 4000 U.S. Geological Survey (USGS) stream gage sites across the country, to forecasts of flow at 2.7 million stream reaches, and provides spatially-continuous forecasts of soil moisture, evapotranspiration, runoff, snow water equivalent and other parameters on a high resolution 1-km grid nationwide. The NWM is a NOAA-led interagency effort that relies on the National Hydrographic Dataset (NHD) Plus Version 2 of the USGS and Environmental Protection Agency (EPA), as well as the National Streamflow Information Program of the USGS. The development and implementation of the NWM Version 1.0 is the result of strong and sustained collaboration with NCAR, and a partnership with the CUASHI, NSF, and Federal Integrated Water Resources Science and Services (IWRSS) partners,
Exploration of Citizen Science Data and Potential Application to the National Water Model  
Speaker: Elizabeth Del Rosario (Texas A&M University, Corpus Christi)  
Co-Authors: Di Wu (Southern Illinois University Carbondale) and Christopher Lowry (University at Buffalo)

The National Water Model (NWM) is a hydrologic model that simulates observed and forecast streamflow for approximately 2.7 million streams, based on an observational network of nearly 8,000 United States Geological Survey (USGS) stream gages (NOAA 2016). This observational data network could be increased by integrating crowdsourced distributed hydrologic measurements on ungauged streams. Citizen Science (scientific work undertaken by members of the general public) engages the larger water community (at national, regional, and local scales), but comes with uncertainty (Law et al. 2017). In order to investigate this uncertainty, a decision tree method was applied to evaluate existing citizen science data of stream stage base on the CrowdHydrology network. Quality control (QC) flags were developed for data measurements to pass from L1 (raw dataset), to L2 (flagged dataset), to L3 (corrected dataset). QC flags were tested with synthetically generated crowdsourced stream stage measurements and unaltered USGS gage height. This methodology was than applied to CrowdHydrology sites and compared to co-located pressure transducer measurements. Percent error was calculated to determine uncertainty in the in the Citizen Science data at these sites. CrowdHydrology data was then compared to the NWM streamflow forecast by developing rating curves at each site to simulate streamflow. Using this methodology, the NWM can incorporate crowdsourced data as independent verification and validation points to increase accuracy in forecast predictions. In addition, this research advances the Office of Water Prediction’s goal of supporting a water-resilient nation by involving the public in the collaborative research process; allowing for better informed water management decisions, promoting water resource awareness / education, and increasing public trust.

Evaluating Alternative Baseflow Estimation Methods for Improving National Water Model Forecasting  
Speaker: Joseph M. Krienert (Southern Illinois University)  
Co-Authors: Minki Hong (Texas A&M University), Ritesh Karki (Auburn University), and Sama S. Memari (University of Alabama)

The National Water Model (NWM) became fully operational in August of 2016. This hydrologic model uses a framework of real time climatic data and observed physiographic attributes to produce forecasts of surficial fluvial systems across the Contiguous US. Comparison of the NWM streamflow estimations with USGS observed datasets has shown that the NWM estimates are not entirely accurate, especially during low flow conditions. A potential influence on this miscalculation lies in the NWM’s conceptual (not physically-explicit) estimation of baseflow to streams, and this non-linear conceptual baseflow model only expresses a part of the interaction between groundwater and surficial hydrology.  

This research evaluates the current representation groundwater discharge in the NWM with a case study of five watersheds located within the Northern High Plains region. A comparison between USGS observed stream flow, a systematically calibrated groundwater model (Peterson et al 2016), and the output hindcasts of the NWM will be used to evaluate the current model’s fitness in representing surface water - groundwater interaction in gaining streams; with a particular focus on baseflow estimation. Based on the results of this analysis, formulation of alternative functions representing the relationship between subsurface storage and groundwater discharge will be tested for potential improvements in future updates of the NWM.

Incorporating Realistic Channel Geometry into Continental-Scale Hydrological Modeling  
Speaker: Nishani Poorna Moragoda (University of Alabama)  
Co-Authors: John Brackins (Tennessee Technological University), Azbina Rahman (George Mason University), Sagy Cohen (University of Alabama), Christopher Lowry (University at Buffalo)

A key element in hydraulic and hydrologic modeling is the specification of representative channel geometry. Without adequate geometry information, it is difficult to reliably simulate hydraulic properties such as bankfull discharge and stage at which flooding commences. The traditional solution to the geometry problem has been topographic and bathymetric surveying, and floodplains have become increasingly resolved with the advent of lidar. For continental-scale hydrology and hydraulics, however, the large amount of high resolution data required, as well as the considerable computational effort needed to effectively incorporate such data, has led to simplifying assumptions such as rectangular or trapezoidal channels for long river reaches. The National Water Model (NWM) uses the simplified trapezoidal channel representation for 2.7 million river reaches, over which it forecasts water discharge for the entire continental United States. This has created uncertainties in when to initiate hydraulic predictions. The aim of this study is to: 1) evaluate the NWM predictions with the current trapezoidal channel representation and with real channel geometry (using HEC-RAS), and 2)
suggest an improved representation of channel geometry while maintaining parsimony. As a preliminary analysis, the HEC-RAS model outputs of discharge and stage were compared with the USGS observed records for three cases: trapezoidal, real, and proposed generalized geometry representations. A brief analysis of NWM Muskingum-Cunge routing parameters for varied geometry cases was also undertaken. Statistical analyses show that more realistic channel geometry not only improves stage and flow predictions, but also improves simulated routing parameters, indicating the potential for geometric improvements to enhance the current NWM products.

Other Session Speakers: Danielle Tijerina (CUAHSI)
Hydrologic Extremes and Society
Chair: Hilary McMillan (San Diego State University)

This session focuses on observations, prediction, communication and adaptation to hydrologic extremes. By bringing together ideas from flood and drought research, we analyze similarities and differences in societal impacts and interactions with these two extremes. We explore how providing observations and information about hydrologic extremes can change the way societies understand and react to crisis events.

Building A Global Flood Observatory
Speaker: G. Robert Brakenridge (INSTAAR, University of Colorado Boulder)

For many years, a global network of seismic stations has provided instantaneous notice of large earthquake locations and magnitudes. In contrast, the first notice of major floods, on an international basis, commonly arrives only via media reports. One reason for this is that real time data from in situ river gauging stations are not available for many nations. Also, high river stages do not always provide clear indication of flooding (e.g., levees may hold, or not, levee breaks cause falling stage at downstream stations).

Meanwhile, satellite flood alerts and measurements are possible and from a global constellation of relevant sensors. The data are there, but simply are not being processed for this purpose. Thus, geostationary satellites provide updates many times/day at optical wavelengths appropriate for water discrimination, and at resolutions of approximately 1 km. Also, passive microwave radiometers image all of the Earth on a daily basis without restriction by cloud cover. Their low spatial resolution data (pixels commonly at ~ 10 km) are, at certain frequencies, very sensitive to water extent. Monitoring of these pixels where located over floodplains can provide automated flood alerts. Finally, many other radar and optical imaging satellites are available for detailed and quick flood mapping of ongoing events, once the location is known. There is now the opportunity to link the various earth-observing technologies together: 1) to detect floods, automatically, as they occur, and provide public notice of their location and magnitude, 2) to produce flood extent mapping as an automated product, and 3) to preserve the observational record of such events for use in assessments of future flood hazard. Flood mapping, made newly practical in the latter part of the 20th century by the Space Age, can now be transformed into flood surveillance, wherein global surface water extent and major floods are routinely monitored, just as global seismicity is.

In the aftermath of the Great Flood of the Upper Mississippi Valley in 1993, I founded the Dartmouth Flood Observatory (DFO) for space-based measurement and mapping of surface water changes. This sustained effort moved to the University of Colorado in 2010 (http://floodobservatory.colorado.edu/). During 1993, we used orbital synthetic aperture radar (SAR) technology to map the flooding through heavy cloud cover. At that time, we also realized that, every week, >2 new major flood events occur somewhere on Earth and within the observational reach of satellite systems. DFO has since mapped inundation extents for many hundreds of events worldwide, and designed satellite observational systems to automatically monitor river discharge status. We have demonstrated that a truly operational and accurate global flood observatory is feasible. The difficult questions now concern who can operate such a system, and how should the results be disseminated, validated, and archived to serve both humanitarian and hydrological science purposes.

Compound and Concurrent Climate Extremes: Detection, Modeling and Risk Analysis
Speaker: Amir AghaKouchak (University of California Irvine)

Human activities in the past century have caused an increase in global temperature. Ground-based observations show a substantial increase in extreme rainfall events, hot spells and heatwaves. A combination of climate events (e.g., low precipitation and high temperatures) may cause a significant impact on the ecosystem and society, although individual events involved may not be severe extremes themselves – a notion known as compound event/extremes. Numerous studies have focused on how different types of extremes have changed or might change in the future. However, only few studies have addressed changes in compound and concurrent events. This presentation focuses on three different types of concurrent and compound extremes including drought-heatwaves, sea level rise-terrestrial flooding, and meteorological-anthropogenic drought. We present different methodological frameworks for detecting, modeling and risk assessment of concurrent and compound extremes using ground-based and remote sensing observations.
In the 1990s and early 2000s, drought disaster researchers called for creation of a comprehensive database of drought impacts. But creation of such a database presumes that there is a single perspective from which all impacts will be visible. In fact, drought impacts are like fractals – as you focus on smaller scales, new realms of detail become apparent. An individual farmer’s drought-related loss or the hardship that an agricultural community experiences may be completely lost when drought impacts are aggregated to a national scale. Furthermore, drought impacts occur within specific contexts – a household has to water landscape and garden plants more; a reservoir operator produces less hydropower; fish die because a river dried up; fewer lift tickets are sold when there is no snow; and so on. Decision-makers in each of these sectors may or may not consider drought – an abstraction, often one of many pressures – as causing a separate impact, and they typically describe its effects, nested within a context that includes both long- and short-term institutional effects. And many people have the adaptive capacity to foresee and prevent losses – a ski resort may offer hiking opportunities instead – so lack of water does not always translate into a drought impact. While this may seem obvious, it means there is no common framework for identifying, let alone quantifying, drought impacts. Sector and scale both matter. Large-scale commodity crops and hydropower production are some of the easiest drought impacts to quantify. Health effects to individuals and ecosystems are some of the hardest. Data collection requires resources, and in the absence of unlimited resources, we need to determine what data needs to be collected – or analyzed – to manage drought impacts.
Hydrologic Feedbacks with Ecosystems
Chair: Gretchen Miller (Texas A&M University)

Advancements in ecohydrology have highlighted the importance of feedbacks between vegetation and the hydroclimate, with their subsequent impacts on water and food supplies. In this session, we discuss these feedbacks across a range of ecosystems and scales, highlighting recent and developing improvements in their modeling.

**Coupling drives bifurcation: linked development and differentiation of fluvial delta islands, surface water-groundwater interactions, and freshwater marsh habitats at Wax Lake Delta, LA**
Speaker: Kevan Moffat (Washington State University)

Feedbacks between ecology, surface water, and sedimentation have been well documented in salt marshes, but vegetation’s role in freshwater delta hydrology and geomorphology is less well understood. More than a decade of sediment and vegetation change were studied and surface water flows modeled at Pintail Island in Wax Lake Delta, Louisiana, for preliminary insight into patterns of island sediment delivery. Sediment cores from the top meter of marsh were analyzed for organic matter, grain size distribution, and recent accumulation rates (using 210Pb), Landsat imagery was used to derive temporal change in island topography (1999-2010), and surface water levels were monitored for multiple years. Image analysis revealed island topographic progression from non-systematic elevations to discrete platforms corresponding to vegetation zones. Field measurements and a surface-and-groundwater flow model indicated substantial dynamic differences in island flooding from the main channel versus from the island’s interior lagoon, and so potential differences in sediment deposition. Significant organic matter and grain size trends with depth at multiple island elevations suggested historical changes in sedimentation concurrent with vegetation succession. Mineral sedimentation dominated over organic, and accumulation rates suggested that deposition was holding steady or accelerating over time, likely evidence of mineral sedimentation enhanced by vegetation as the islands emerged from the tidal range. This study highlights the continual interplay between, and provide a more detailed foundation for testing theories and developing models of, linked sedimentation, elevation change, succession, and flood frequency in delta wetlands.

**Improving the representation of vegetation-atmosphere interactions through plant-hydrodynamics models**
Speaker: Ashley Matheny (University of Texas at Austin)

Vegetation provides a critical pathway for water transport from the land surface to the atmosphere; yet, the ability of vegetation to actively modulate water uptake and release makes this a challenging process for land-atmosphere models to capture. Recently, a number of physical process models of water flow through vegetation have come to the fore. These models draw a parallel between vegetation’s conductive tissues and porous media. The FETCH2 scalable vegetation model uses a simplified form of the Richards equation to simulate water movement within trees while allowing for dynamic changes in hydraulic conductance and capacitance. In this manner, FETCH2 can capture divergent hydrodynamic behaviors among species in the same ecosystem in manners that standard land-atmosphere models cannot. FETCH2 and other mechanistic vegetation models stand to promote significant improvements to our ability to model transpiration at local to global scales. In particular, this new class of plant hydraulics models stands to revolutionize the way models capture the effects of drought, land use and land cover change, and climate change on the hydrologic and carbon cycles as well as on vegetation demography.

**Plant water use and plant water status during protracted and seasonal droughts: A link between hydrological fluxes and ecological disturbance**
Speaker: Sally Thompson (University of California Berkeley)

Ecohydrology has two important, related insights to offer the study of global change: (i) prediction of plant vulnerability to changes in the water cycle, and (ii) descriptions of the water cycle that account for the role of plants in regulating water fluxes. The link between these issues is the internal water status of plants, which controls water uptake and the physiological experience of stress. The relationship between water status and water uptake, however, is strongly mediated by plant physiological characteristics and a plant’s environmental setting. Here I will draw on a combination of modeling and observational studies of Californian vegetation during seasonal and multi-year drought to (i) show how different physiological characteristics can de-couple trajectories of plant water potential and transpiration, (ii) illustrate how different landscape and hydrological settings influence the crossing of water potential thresholds, xylem recovery and ultimately plant health during multi-year drought, and (iii) highlight some challenges associated with reconciling the ecohydrological and ecophysiological communities’ approaches to describing plants and plant water fluxes during drought.
Water and the Changing Climate  
Chair: Jeanne VanBriesen (Carnegie Mellon University)

Global climate change is changing the frequency and magnitude of precipitation events in many regions, and further change is expected. Effects on precipitation-dependent events (drought, flood) as well as on rainfall-dependent systems (water supply, energy systems, agriculture) will challenge our study and management of hydrologic systems. This session will explore methods to study, model, and plan for hydrologic systems under changing climatic conditions.

Positioning Risk – Climate variability, Nonstationarity and Hydrological Extremes  
Speaker: Ana Barros (Duke University)

The notion of positioning risk in the context of nonstationarity and future climate is based on the premise that the metrics of risk change conditional on climate regime. The IPCC defines climate regime as a state of the climate system that occurs more frequently than nearby states due to either more persistence or more frequent recurrence, that is a local maximum in the probability density function. First, Global climate Model simulations of past and current climate are analyzed against observations to assess the predictability of multi-decadal to century scale climate regimes relevant to hydrological extremes (precipitation and streamflow) in the Southeast US. Next, we separately address high and low precipitation statistics and space-time variability conditional on climate regime and physiography, and explore the development of a framework for adaptively positioning risk in the assessment of future extremes that also incorporates understanding of regional and local hydrology.

Probabilistic modeling of hurricane surge and rainfall flooding in a changing climate  
Speaker: Ning Lin (Princeton University)  
Co-Authors: Kerry Emanuel (Massachusetts Institute of Technology), James Smith (Princeton University), Joannes Westerink (University of Notre Dame)

Hurricanes, with their strong winds, heavy rainfall, and storm surges, cause much damage and loss of life worldwide. The impacts of these storms may worsen in the coming decades because of rapid coastal development coupled with sea-level rise and possibly increasing hurricane activity due to climate change. Here we present a framework of modeling hurricane hazards in a changing climate. We apply a statistical/deterministic hurricane model driven by global climate models (GCMs) to simulate large numbers of synthetic storms under various projected climate scenarios. We apply the hydrodynamic model ADCIRC to simulate the coastal storm surge induced by the synthetic storms. We apply a physics-based hurricane rainfall model coupled with a distributed hydrologic model to simulate the riverine flooding induced by the synthetic storms. Then we apply statistical analysis to estimate the rainfall and surge flood probabilities under the various climate conditions, based on the simulated synthetic rainfall and storm surge events. We are currently coupling the coastal storm surge and inland rainfall modeling to investigate the compound flooding induced by hurricanes under climate change.

USACE Tools for Climate Change Adaptation  
Speaker: Will Veatch (U.S. Army Corps of Engineers)

The assumption of hydrologic stationarity, that observed data from the past represents present and future conditions, has typically underpinned hydrologic and hydraulic design and planning. A growing body of scientific evidence is undermining that assumption, as certain variables critical to the design and evaluation of water resources projects are being impacted by climate change and anthropogenic watershed modifications such that future variability cannot necessarily be assumed to follow past observations. US Army Corps of Engineers (USACE) projects must, as a matter of policy, be designed for the full range of plausible future conditions that can be expected throughout their intended design lives, despite uncertainty regarding the exact nature of those future conditions. USACE has therefore released revised technical guidance related to the identification of observed changes and projection of potential future changes in hydro-climatic conditions. In addition to the written guidance, USACE has developed web applications that make it easier for water resources professionals to apply the techniques described in the guidance in a technically correct, timely, and reproducible manner. In this talk, USACE policy and technical guidance related to the incorporation of climate change impacts into hydrologic and hydraulic analysis for both coastal and inland waterways will be outlined, along with the web-based tools created to help implement these analyses. After attending this talk, the audience will be able to understand and use USACE technical guidance and publicly available tools for their own projects.
Measurement-Monitoring-Sensing
Chair: Branko Kerkez (University of Michigan)

This session will explore how the latest generation of sensors is reshaping the study hydrologic systems at unprecedented spatial and temporal resolutions. We will discover how the Critical Zone is being measured across massive scales. We will learn about 3D printed sensors, which to democratizing measurements across the world. We will also hear how federal researchers are using a new generation of water quality sensors to support discovery and management.

Identification of the Burial Depth of Radio Frequency IDentification (RFID) Transponders in Riverine Applications
Speaker: Chris Wilson (University of Tennessee)
Co-Authors: Thanos Papanicolaou (University of Tennessee), Achilleas G. Tsakiris (Northwest Hydraulics Consultants) and Benjamin K. Abban (University of Tennessee Knoxville)

Radio Frequency IDentification (RFID) technology enables bidirectional, remote communication between a reader and a transponder (or tag) with a unique ID via an excitation antenna. This study provides a framework for estimating the burial depth of a transponder from a fixed location, as a means of assessing scour depth or for other riverine applications. In doing so, we employ a Low Frequency (LF), passive RFID system, which operates at a resonance frequency of 134.2 kHz and can penetrate through saturated sediments. The objective of this research is the development and validation of a semi-theoretical expression that relates the decay of the received input voltage (VIN) at the reader with the transponder burial depth or detection distance, d, through a series of well-controlled experiments. We examine the correspondence between VIN and d in air, as well as in water, gravel and sand, and assess the role of transponder orientation (perpendicular and parallel with respect to the excitation antenna) on the received VIN. It is found that VIN exhibits a universal behavior as function of d, as it decays inversely with the cube of the distance (~d⁻³) not only for air but also for water, gravel and sand. More importantly, it is shown that the orientation angle between the excitation and the transponder miniature antennas as well as the sediment-bed composition/texture (e.g., sand, clay, gravel) surrounding the transponder can have a significant effect on the magnitude of the VIN and on the decay rate of the VIN vs. d curve. A change in the transponder orientation from perpendicular to parallel reduces the VIN by one order of magnitude and the maximum detection d by 26-76% for the different media. The greatest reduction in VIN occurs for sand, likely due to its smaller void ratio that causes excessive defragmentation of the RF waves. These promising findings allow a relatively accurate, remote estimation of d using the inexpensive LF, passive RFID technology and warrant future research and development on this topic.

Applications of optical sensors for real-time water quality monitoring and research in rivers
Speaker: Brian Pellerin (USGS)

Together with new techniques for data collection and analysis, in situ sensors provide an opportunity to monitor and report a wide range of water-quality constituents over time scales during which environmental conditions actually change. In particular, optical sensors that continuously measure constituents in the environment by absorbance or fluorescence properties are now sufficiently developed to warrant broader application for research and monitoring in rivers. Examples are numerous and range from the applications of nitrate sensors for calculating loads to estuaries susceptible to hypoxia to the use of fluorometers to estimate methymercury fluxes, the occurrence of harmful algal blooms (HABs) and the potential for disinfection byproduct formation. Transmitting these data in real-time provides information that can be used for early trend detection, help identify monitoring gaps critical for water management, and provide science-based decision support across a range of issues related to water quality, freshwater ecosystems, and human health.

Despite the value of these sensors, collecting data that meet high-quality standards requires investment in and adherence to tested and established methods and protocols for sensor operation and data management. For example, optical sensor measurements can be strongly influenced by a variety of matrix effects including water temperature, inner filtering from highly colored water, and scattering of light by suspended particles. Characterizing and correcting sensors for these effects – as well as the continued development of common methodologies and protocols for sensor use – will be critical to ensuring comparable measurements across sites and over time. In addition, collaborative efforts such as the Nutrient Sensor Challenge (www.nutrients-challenge.org) will continue to accelerate the development, production and use of affordable, reliable and accurate sensors for a range of environments.
Accurate and reliable real-time monitoring and dissemination of observations of atmospheric and hydrologic conditions in general is critical for a variety of research and decision support applications. Combined precipitation and stream gauge observations provide information about the hydrological cycle in a basin and are critical for a variety of hydrometeorological applications. In many regions of the World, weather station, precipitation gauge, and stream gauge networks are sparsely located and/or of poor quality. Existing stations have often been sited incorrectly, not well-maintained, and have limited communications established at the site for real-time monitoring. The University Corporation for Atmospheric Research (UCAR) with support from USAID, has started an initiative to develop low-cost hydrometeorological instrumentation including tipping bucket and weighing-type precipitation gauges along with stream gauges as solution to increase observation networks in sparsely observed regions of the world. The goal of the project is to improve the number of observations (temporally and spatially) in these regions to improve the quality of applications for environmental monitoring and early warning alert systems on a regional to global scale. One important aspect of this initiative is to make the data open to the community. The hydrometeorological instrumentation have been developed using innovative new technologies such as 3D printers, Raspberry Pi computing systems, and wireless communications. The presentation will provide an overview of the new observation technology and experiences with sensor the performances.
Energy-Water Systems
Chair: Paul Block (University of Wisconsin Madison)

Energy and water are inextricably linked: water is a key component of energy production, and energy is needed to clean and distribute water. Water and energy are also critical societal resources that can be damaging in abundance or shortage. This session will explore operations, design, tradeoffs, and implications of energy-water systems.

Understanding the Food-Energy-Water Nexus – Opportunities for Water Resources Research
Speaker: Ximing Cai (University of Illinois)

Studies on the food, energy, and water (FEW) nexus lay a shared foundation for researchers, policy makers, practitioners, and stakeholders to understand and manage linked production, utilization, and security of FEW systems. The FEW nexus paradigm provides water communities specific channels to move forward in interdisciplinary research where integrated water resources management (IWRM) has fallen short. How can water researchers identify, articulate, utilize, and extend our disciplinary strengths within the broader FEW communities, while informing scientists in the food and energy domains about our unique skillset? This presentation explores the relevance of existing and ongoing scholarship within the water community, as well as current research needs, for understanding FEW processes and systems and implementing FEW solutions through innovations in technologies, infrastructures, and policies. Following the historical efforts in IWRM, hydrologists, water resources engineers, economists, and policy analysts are provided opportunities for interdisciplinary studies among themselves and in collaboration with energy and food communities, united by a common path to achieve common sustainability development goals. In this presentation the following questions will be address to elucidate how water researchers and practitioners can uniquely contribute to emerging, transdisciplinary FEW nexus literature: How can water researchers contribute to FEW system understanding and management based on our existing experiences and skills? In what ways can we extend methodologies traditionally used to analyze water systems to now evaluate FEW systems? On what specific issues can water researchers collaborate with those from energy and food sectors? For hydrologists, how will fundamental hydrologic processes influence or be influenced by processes of other sectors? For water engineers and policy makers, what will be the new directions for technology, infrastructure, and policy development as FEW understanding improves?

Integrated Management of Water, Land, Energy, and Environmental Resources - It is now or never.
Speaker: Aris P. Georgakakos (Georgia Tech)

Water is the sine qua non of all life and all socio-economic sectors. Domestic water supply and sanitation, agriculture, livestock, fisheries, energy, transport, recreation, tourism, forestry, wildlife, and a wide array of diverse ecosystems—all vitally depend on the availability of enough clean water.

In recent decades sharply rising populations, economic development pressures, and myopic environmental management practices have been escalating the use and pollution of water resources worldwide. The consequences of these trends are alarming and include—among others—declining river flows and groundwater levels, drying of once perennial rivers, rising water scarcity vulnerability, wildlife and ecosystem stress, increasing numbers of endangered species, rising electricity and food prices, land erosion and river siltation, eutrophication of surface waters, toxic lake algal blooms, and intensifying water user conflicts. The more recent but undeniable challenge of climatic change promises to exacerbate all of the above environmental and socio-economic vulnerabilities, especially in developing world regions.

Just as undeniable is that past management approaches and practices have simply failed to cope with the unprecedented rise of water resources pressures and cannot be trusted to do so in the future. Many factors contributed to this failure: highly centralized decision making and implementation modalities; top-down flow of directives with little opportunity for bottom-up feedback; public sector dominance with little or no private sector involvement and role; exclusive focus on supply-driven solutions to water development; little consideration for environmental sustainability and its inescapable necessity for social well-being and economic prosperity; water resources planning along parallel sectoral tracks with little or no effort to coordinate across sectors; water, land, energy, forest, fishery, wetland resources—all separately managed; little effort to balance upstream and downstream water uses, benefits, and impacts; water development along political, not hydrologic, boundaries; and perfunctory stakeholder participation in water resources management.

Despite this disheartening experience, integrated water, land, energy, and environmental resources management remains the single most viable approach to current and emerging water resources challenges, including climate and demand change. This article reports the author’s experience and lessons learned from integrated planning and management projects in the Southeast US, California, and Africa. This experience involves the implementation of a comprehensive science and policy framework, in planning and operational
Multi-reservoir systems require adaptive control policies capable of managing evolving hydroclimatic variability and human demands across a wide range of time scales. However, traditional operating rules are static, ignoring the potential for coordinated information sharing to reduce conflicts between multi-sectoral river basin demands. In this study, we show how recent advances in multi-objective control enable the design of coordinated operating policies that continuously adapt as a function of evolving hydrologic inputs, diminishing tradeoffs between flood protection and hydropower production or water supply. We illustrate these benefits in the Red River basin of Vietnam, where four major reservoirs serve to protect the capital of Hanoi from flooding, while also supplying farmers with irrigable water supply and the surrounding region with electric power. Operating policies recently proposed by the Vietnamese government seek to improve coordination and adaptivity in the Red River using a conditional if/then/else rule system that triggers alternative control actions using information on current storage and recent hydrology. However, these simple, discontinuous rules fail to protect Hanoi to even the 100-yr flood, when the Vietnamese desire protection at the 500-yr flood level. Utilizing emerging simulation informed control optimization innovations, we are able to design policies that, using the same information, are able to not only provide protection to the 500-yr flood, but with lower supply deficits and greater hydropower production, fully dominating the proposed control rules. Our policy diagnostics using time-varying sensitivity analysis illustrate how our proposed operations make better use of coordinated system information to reduce food-energy-water conflicts in the basin. These findings accentuate the need to transition from static rule curves to dynamic operating policies in order to manage evolving hydroclimatic variability and socioeconomic change.

Many water storage facilities throughout the West must balance agricultural, urban, and environmental demands for water with the need to produce electricity by releasing water to drive a turbine. This need is becoming increasingly urgent as more states embark on ambitious renewable energy goals using intermittent wind and solar generation resources. Hydroelectric generation units with storage capacity are the best available resource for producing a substantial amount of electricity with short notice when the production of wind and solar energy declines. Unfortunately, rapid changes in the amount of electricity produced by a hydroelectric generation unit can run counter to the needs of other users of the water resource. This talk will discuss the potential for applying market-based approaches to managing these competing uses of the West's water resources.
Food-Water Systems
Chair: Megan Konar (University of Illinois)

This session will explore interactions and interconnections between food and water systems. Cutting edge research will focus on identifying resiliencies and vulnerabilities in the water-food nexus and opportunities to promote sustainable water use while enhancing food security.

FEWSION: An empirical description of the U.S. food, energy, and water system
Speaker: Benjamin Ruddell (Northern Arizona University)

After two years of work funded by the NSF, the FEWSION project is in 2018 releasing the first integrated datasets and visualization systems describing the (relatively) complete structure of the U.S. food energy and water system. This new resource places each community’s local economics and hydrology in a national and global context, by detailing the major linkages and connections, sources and sinks, and direct and indirect environmental footprints. This talk provides an introduction to the FEWSION project’s resources for the academic hydrologist, as well as a chance for discussion of new frontiers of hydrologic systems research that will be enabled by the “big data” treatment of the nation’s food energy and water system.

Holistic Pathways for Achieving Food Security and Water Sustainability
Speaker: Kyle Davis (Columbia University)
Co-Authors: Paolo D’Odorico (University of California Berkeley), Ashwini Chhatre (Indian School of Business, Hyderabad), Davide Danilo Chiarelli (Politecnico di Milano), Narasimha Rao (International Institute for Applied Systems Analysis), Brian Richter (Sustainable Waters), Lorenzo Rosa (University of California Berkeley), Maria Cristina Rulli (Politecnico di Milano), Antonio Seveso (Politecnico di Milano), Deepti Singh (Lamont-Doherty Earth Observatory of Columbia University and Washington State University), Ruth DeFries (Columbia University)

Global food supply has nearly tripled over the past half century, supporting massive population growth, richer diets, and the expansion of alternative crop-based energy sources. At the same time, one in nine people still cope with chronic undernourishment, and the environmental burden of agriculture has grown substantially. There is wide agreement that humanity’s rate of resource use exceeds what can be sustainably generated and absorbed by Earth’s systems. It is also clear that a continuation of current agricultural practices will enhance the vulnerability of the global food system to economic and environmental shocks. A radical transformation of the global food system is therefore required in order to increase nutritious food production while minimizing its impacts on water resources and the environment and accommodating uncertainties related to demand and climate change.

Aligning these goals demands a holistic perspective that combines diverse lines of scientific evidence with direct stakeholder engagement. I will present some of my recent research that attempts to address this challenge by quantifying historical impacts and tradeoffs of food systems, assessing solutions that can achieve co-benefits for food security, livelihoods, and water resources, and identifying potential suitable policy pathways for their implementation. Combining global assessments and case studies at policy-relevant scales, I will introduce a multidimensional framework that values multiple types of knowledge and that emphasizes interactions with local experts. This approach seeks to integrate food security, economic, social, and environmental considerations in order to examine the outcomes of existing agricultural policies as well as expand the suite of feasible solutions. In doing so, this work offers insights for developing effective food security strategies that are receptive and responsive to the priorities of local governments and communities and that enhance the sustainability and adaptability of food and water systems.

Groundwater wells and withdrawal management in western USA food-producing regions
Speaker: Debra Perrone (University of California Santa Barbara)
Co-Authors: Scott Jasechko (University of California Santa Barbara) and Rebecca Nelson (Melbourne Law School)

High groundwater demands combined with limited long-term management and changing hydrologic fluxes has led to aquifer depletion in many food-producing regions in the western USA. Nevertheless, very little is known about the (1) infrastructure fundamental to pumping groundwater (i.e., groundwater wells), and (2) regulatory frameworks available to manage groundwater withdrawals. We address these two knowledge gaps by systematically and rigorously collating and delineating western USA (1) groundwater wells used for agriculture, and (2) regulatory controls developed to manage new groundwater withdrawals. We find that regulatory controls have increased in space and time, covering a significant number of groundwater wells, but vast differences in the regulatory frameworks may be undercutting sustainable water use.
Dynamic Connectivity in the Landscape

Chair: Adam Ward (Indiana University)

Connectivity between different locations on the landscape is defined by the movement of water, solutes, energy, and organisms. The magnitude and persistence of connections is critical to prediction of ecological functions, many of which are mediated by hydrological stores and fluxes. In this session we consider connectivity as a spatially and temporally variable process in catchments and river systems.

Ecohydrological connectivity between landscapes and riverscapes

Speaker: Doerthe Tetzlaff (University of Aberdeen)

It is increasingly recognised that the processes and connections in our landscapes are influencing the functioning of aquatic ecosystems. Fundamental scientific understanding of the functioning of both aquatic and terrestrial ecosystems is required for an integrated and sustainable management of landscapes and riverscapes to maintain their ecosystem services and biological integrity at multiple scales. This talk will show how the connectivity in ecohydrological systems can be quantitatively assessed through a number of novel, integrated approaches. Importantly, this talk will discuss the need to understand the role of vegetation in regulating the connectivity between terrestrial and aquatic ecosystems. Environmental tracers are valuable tools to understand the functioning of ecohydrological systems at the landscape scale in terms of understand flow paths, sources of water and associated biogeochemical interactions. Extensive empirical studies were conducted at the plot and hillslope scale to understand ecohydrological systems, and in particular, soil-vegetation-water connections. This empirically based understanding was then integrated into spatially distributed, tracer-aided models to understand mixing of water, flows to the stream and water age distribution at the catchment scale. We use the physically-based, distributed tracer-aided ecohydrologic model (EcH2O-ISO) which we have extended to track 2H and 18O (including fractionation processes) and water age. EcH2O-ISO combines a hydrologic scheme with an explicit representation of plant growth and phenology while resolving the energy balance across the soil-vegetation-atmosphere continuum. We also implemented isotope routing, mixing and fractionation (and used flux tracking for mean water age calculation). This tracer-aided modelling allows us to simulate stream and soil isotope responses very well and at some sites can account for the composition of xylem water. Our simulations showed contrasting time-variant age distributions of water exiting catchments as evapotranspiration and stream flow; these differences are strongly influenced by vegetation cover and other landscape controls (topography, soils, geology).

Dynamic lateral, vertical, and longitudinal hydrologic connectivity drive runoff and carbon export across watershed scales

Speaker: Margaret Zimmer (University of California Santa Cruz)

The influence of temporally dynamic lateral, vertical, and longitudinal connectivity of runoff source areas on hydrologic and biogeochemical fluxes across watershed scales is poorly understood. To address this, we monitored the timing, magnitude and chemical composition of precipitation, runoff, and runoff-generating flow paths in nested 3.3 and 48.4 ha watersheds (North Carolina, USA). These watersheds are comprised of ephemeral and intermittent runoff-producing headwaters and perennial runoff-producing lowlands. We monitored the active surface drainage network, which reflected connectivity to, and contributions from, runoff source areas that shifted within baseflow and stormflow conditions. The overall importance of deeper, baseflow-associated and shallower, stormflow-activated source area contributions varied across watershed scales and influenced dissolved organic carbon (DOC) export. The dominant temporal variability of in-stream DOC was driven by frequent event-based flushing of shallow soil zones and annual replenishment. Our findings suggest that hydro-biogeochemical signals at larger watershed outlets can be driven by the expansion, contraction, and connection of lateral, longitudinal, and vertical source areas that reflect distinct runoff generation processes.
As the science of hydrologic connectivity has developed, there is sometimes a tendency to under-emphasize the importance of disconnectivity. Connectivity and disconnectivity can both be characterized in terms of magnitude, frequency, duration, timing, directionality, and dimension. The latter characteristic is important because features that create longitudinal disconnectivity in rivers, for example, can enhance lateral and vertical connectivity. Here, I discuss naturally occurring processes that limit longitudinal connectivity in river corridors and the effect of these longitudinal disconnections on river form and function. Examples of such processes include lateral channel movement and the associated secondary channels, avulsions and cutoffs; lateral sediment inputs from tributaries or adjacent hillslopes that create alluvial fans in the river corridor; logjams; and beaver dams. I focus on logjams and beaver dams using case studies from mountain streams in the Southern Rockies. River networks in this high-relief terrain are predominantly steep, narrow canyons with high longitudinal connectivity and limited lateral connectivity between channels and floodplains or vertical connectivity between channels-floodplains and the hyporheic zone. Wide, low-gradient valley segments scattered throughout the network provide retention zones in mountainous river networks and typically exhibit greater lateral and vertical connectivity than the intervening steep, narrow segments. The details of connectivity, however, and the magnitude of retention and the partitioning of retained water, solutes, sediment, and organic matter among alluvial storage and atmospheric emissions depend in large part on the presence of features that limit longitudinal connectivity, as such as logjams or beaver dams. Through research conducted during the past decade, we have found that channel-spanning logjams and beaver dams substantially decrease downstream transport of water, solutes, sediment, and organic matter during both base flows and snowmelt peak flows. At the same time, logjams and beaver dams substantially increase channel-floodplain and channel-hyporheic exchange and thereby increase retention and long-term (102-103 year) alluvial storage of sediment and organic carbon. One implication of these findings is that river management can be designed to limit longitudinal connectivity in ways that foster ecosystem services such as flood attenuation, reduction of downstream sediment, nitrate, and carbon fluxes, and increased habitat abundance and diversity.
Town Hall: The U.S. Global Change Research Program’s Integrated Water Cycle Group
Moderator: Jennifer Saleem Arrigo (U.S. Global Change Research Program)

The USGCRP Integrated Water Cycle Group (IWCG) coordinates research that will help us better understand global change effects on the water cycle and the impacts of those changes through collaborative, interdisciplinary approaches. Membership in this federal interagency group include both science producing and science utilizing agencies.

The IWCG seeks to:
- coordinate research relevant to understanding the integrated water cycle, how it changes in response to short-term and long-term perturbations, and the associated local, regional and global impacts of those changes;
- advance capabilities and research infrastructure that support water cycle observation, modeling and predictability at a range of scales; and
- develop approaches to apply and translate our understanding and inform decisions concerning resilience and water security.

To balance the need to study specific components of the water cycle and its linkages with other important earth system components, as well as maintain an ability to look holistically, i.e. with end-to-end inclusion of science, science translation, and decision, the IWCG will support three workstreams and integrative activities among them – Climate Water and Energy eXchanges (CWEX), Hydrology and Watershed Systems (HWS), and Resilience, Adaptation, INformation, and Social Sciences for decision makers (RAINSS).

This session will be organized as a moderated listening session with federal agency managers and scientists that are leading these three workstreams, as a chance for the CUAHSI community to learn more about the IWCG and for federal agencies to hear from the CUAHSI community perspectives on the state and direction of water science.

Speakers:
Stacey Archfield (USGS and Hydrology and Watershed Systems)
Jared Entin (NASA and Climate, Water and Energy Exchanges)
Karen Metchis (U.S. EPA and Resilience, Adaptation, Information, and Social Sciences for decision makers)
Gary Geernaert (DOE Office of Science, and USGCRP Interagency Integrated Water Cycle Group)
Instrumentation Panel
Chairs: Elizabeth Boyer (Pennsylvania State University) and Scott Tyler (University of Nevada Reno)

National Scale Multi-User Facilities of Interest to the Hydrological Community
Investments from the National Science Foundation and other agencies provide state-of-the-art tools and models for research and education. This session will feature an overview of multi-user research facilities, distributed instrumentation networks, collaboratories, and laboratories of interest in the hydrologic sciences. Representatives of each facility will describe their capabilities and the process for using the facility, and will provide examples of applications in the hydrologic sciences. We encourage all meeting participants to make use of these facilities, and to help spread the word about their availability.

Panelists:
Russ Kelz (Earth Sciences, National Science Foundation)
Bruce Beaudoin (IRIS PASSCAL)
Glen Mattioli (UNAVCO)
John Selker (CTEMPs)
Janice Fulford (USGS Hydrologic Instrumentation Facility)
Brigitte Baeuerle (NCAR)
Craig Glennie (National Center for Airborne Laser Mapping)
Anders Noren (Continental Scientific Drilling Coordination Office)
Marc Caffee (Purdue Rare Isotope Measurement Laboratory)
Mike Olson (National Atmospheric Deposition Program)
Nick Harrison (National Ecological Observatory Network)
Thanos Papanicolaou & Miguel Leon (Critical Zone Observatories)
Albert Kettner (Community Surface Dynamics Modeling System)

Graduate Student Career Panel
Chair: Jon Pollak (CUAHSI)
Join us for an informal hour of discussing career paths with a diverse panel of CUAHSI community members. Participants will have opportunities to gain insights from our panelists that work in academia, government, and non-profits. Learn from those that have built successful careers in water science, while you build yours!

Panelists:
Anthony Castronova (CUAHSI)
Jesus Gomez-Velez (New Mexico Tech, CUAHSI BOD)
Jennifer Saleem Arrigo (U.S. Global Change Research Program)
Sally Thompson (University of California Berkeley)
Emily Trentacoste (U.S. EPA)
CUAHSI Tools and Services for Managing Research Data
Instructors: Anthony Castronova (CUAHSI), Liza Brazil (CUAHSI), Miguel Leon (Luqillo Critical Zone Observatory), Jeff Horsburgh (Utah State University), David Tarboton (Utah State University)

Scientists are faced with many data-centric challenges in their day-to-day research including, but not limited to, management, collaboration, archival, and publication. This is complicated by the disparate and diverse nature of earth surface data which typically makes a single repository less than ideal for all data used and created for a given study. In recent years, initiatives such as National Science Foundation data management plans and the American Geophysical Union findable, accessible, interoperable, and reusable (FAIR) principals have incentivized researchers to explore solutions for archiving data that will improve future research capabilities. In kind, CUAHSI has been developing a collection of single purpose, interoperable, software tools that form an ecosystem for researchers to advance science through data management, collaboration, and publishing for a variety of earth surface data and models that enable reuse by other researchers. This workshop will introduce these services which include the hydrologic information system (HIS), observations data model version 2 (ODM2), ODM2Admin data management portal, and HydroShare. Attendees will be given an overview of CUAHSI’s efforts to support research activities by participating in a series of interactive presentations that progress from (1) simple time series data, to (2) advanced earth observations, and finally to (3) complex data types. We welcome novice and advanced data creators, users, and managers to join us in this workshop.

Resources for Data-Driven Water Science Education
Instructors: Benjamin Ruddell (Northern Arizona University) and Adnan Rajib (U.S. EPA)

This workshop will introduce several resources for data-driven education at both the undergraduate and graduate level. Attend this workshop to learn new methods for integrating real data into your curriculum and how you can become involved in a community of educators developing new tools to teach scientific concepts. Workshop leaders will introduce several community resources that contain guided activities, allow access to data, as well as enable modeling and analyses. Participants should expect to learn (1) how to access these tools for their own use, (2) the topic(s) and student level(s) these resources have been used, and (3) how to get support from the CUAHSI community to integrate data tools and services in your classroom.

Expected hydrologic observations and data sharing capabilities for the Surface Water and Ocean Topography (SWOT) Mission
Instructors: Cédric David, Jessica Hausman, Frank Greguska, and Michael Gangl (NASA Jet Propulsion Laboratory, California Institute of Technology)

The Surface Water and Ocean Topography (SWOT) mission is a joint effort by NASA and the French Space Agency (CNES), with contribution from the Canadian (CSA) and British (UKSA) space agencies, that is currently scheduled to be launched in 2021. SWOT is being designed to observe the Earth’s surface waters on land and in the oceans. The SWOT observations that are of interest to the hydrological sciences community include the horizontal extent and water surface elevation of the world’s largest rivers and lakes at unprecedented spatial resolution. Estimates of surface water slopes as well as river width and river discharge are also planned as part of the mission. This session is designed to foster conversations between members of the CUAHSI and the SWOT communities to best prepare for SWOT. The transformative hydrologic observations of SWOT will be introduced, and the strategic challenges faced by the data center in charge of archiving and sharing SWOT data will be presented. A discussion of potential collaborative efforts on SWOT hydrologic data services will follow.
Awardee: Scott Tyler (University of Nevada Reno)
In recognition of your outstanding vision, leadership, and enthusiasm in the development of community resources to support hydrologic science.

Awardee: David Gochis and the NCAR Team
In recognition of your leadership, vision, and collaboration in the development of the WRF-Hydro modeling system to support atmospheric and hydrologic sciences.
In October 2016, Hurricane Matthew brought more than 35 cm in rainfall in 24 hours and caused over $1.5B in damage to eastern North Carolina. The 3000 km² Lumbee River basin, located in southeastern NC, is home to over 60,000 members of the Lumbee Tribe of American Indians and the region has some of the highest densities of concentrated animal feeding operations in the United States. This region has high rates of poverty and large disparities in healthcare, education, and infrastructure, and the compromised infrastructure brought on by this extreme flooding increased the social and hydrologic vulnerability in the Lumbee River basin. To assess impacts of this extreme hydrologic event on water quality and society over the year following Hurricane Matthew, we collected water samples from co-located sources of surface, ground, and tap water across the Lumbee River watershed. In this substudy, we evaluated spatial and temporal variability in specific conductance, stable water isotopes (18O and 2H), nitrate, and coliforms (total coliforms and E. coli). Preliminary results show the evolution through time of water quality in each hydrologic pool as the system recovers from the floods and hydrologic connectivity recedes, thus improving our understanding of linkages between hydrologic connectivity and water quality.

Application of water resources agent typologies for modeling water resources in the Western US

Presenter: Kendra Kaiser (Boise State University)
Co-Authors: Alejandro Flores and Vicken Hillis (Boise State University)

Modeling water resource management necessitates integration of complex social and hydrologic dynamics. Simulation of these socio-ecological systems requires characterization of the decision-making process of relevant actors, the mechanisms through which they exert control on the biophysical system, their ability to react and adapt to regional environmental conditions, and the plausible behaviors in response to changes in those conditions. Agent based models (ABMs) are a useful tool in simulating these complex adaptive systems because they provide relatively straightforward ways to dynamically couple hydrological models and the behavior of decision-making actors. However, the variability in behavior of water management actors across systems makes characterizing agent behaviors and relationships challenging. Agent typologies group together individuals and/or agencies with similar functional roles, management objectives, and decision-making strategies, thereby simplifying the representation of water management across river basins, and increasing transferability and scaling of ABMs. Here we present a framework for identifying and classifying major water actors and apply this modeling framework to the Boise River Basin in southwest Idaho. Precipitation in the upper basin supplies 90% of the surface water used in the basin, thus managers of the reservoir system (located in the upper basin) must balance flood control for the metropolitan area with water supply for downstream agricultural and hydropower use. We have incorporated the reservoir rule curves to govern when and how much water is released from the reservoir, and water rights data to determine the day of allocation and associated curtailments of junior water rights. This modeling exercise demonstrates the utility of ABMs to represent coupled natural-human systems and the potential for agent typologies to increase the transferability and scaling of water management ABMs in the western US.
Economic impacts of drought forecasting using integrated hydrological modeling experiments in a changing climate
Presenter: Hyunwoo Kang (Virginia Tech)*
Co-Author: Venkat Sridhar (Virginia Tech)

Short-term drought forecasting using hydrologic modeling and climate forecast is helpful for establishing drought mitigation plans and for managing risks that often ensue in water resource systems. In this study, the Soil and Water Assessment Tool (SWAT) and Variable Infiltration Capacity (VIC) models are used for short-term drought forecasting in the contiguous United States (CONUS). Weekly-to-seasonal meteorological inputs are provided by the Climate Prediction Center (CPC) for the retrospective period (January 2012 to July 2017) and Climate Forecasting System version 2 (CFS v2) for the forecasting period (August 2017 to April 2018), and these inputs are used to estimate agricultural and groundwater drought conditions. For drought assessment, three drought indices, namely, the Standardized Soil Moisture index (SSI), the Multivariate Standardized Drought Index (MSDI), and the Standardized Baseflow index (SBI) were analyzed. Generally, eight weeks of lead time forecasting showed good drought predictability from both the SWAT and VIC models for the MSDI simulations (62% for SWAT and 64% for VIC for all drought categories). Besides, the second objective of this study is to evaluate the impacts of climate change on future agricultural drought conditions and their economic consequences in several congressional districts in northern Virginia. The VIC model was applied to estimate the SSI for both historic and future periods along with data from the Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models. Additionally, a linear regression analysis was carried out to determine the relationship between the annual mean values of SSI and agricultural production ($) for a seven-year period (2010-2016). The results of the SSI indicated that there was an overall increase in agricultural droughts due to decreases in soil moisture during the crop growing season because of decreases in precipitation and increases in temperature in the future. Based on the estimated results of SSI and agricultural production for the future periods, there was a 9.4% to 15.9% decrease in the VA06 district, 0.5% to 4.1% decrease in the VA11 district, and 65.0% to 78.1% increase in the VA08 district. The presented analysis emphasizes that there was a strong correlation between the agricultural drought index and agricultural production, but more extended and fine resolution observations are required for more reliable regression analysis and economic impact assessment.

Do urban desert streams in Arizona experience the ‘urban stream syndrome’?
Presenter: Lauren McPhillips (Pennsylvania State University)
Co-Authors: Nancy Grimm (Arizona State University), Rebecca Hale (Idaho State University), Stevan Earl (Arizona State University)

It is almost dogma that the ‘urban stream syndrome’ results in dramatic changes in stream hydrology, such as higher peak flows, lower base flows, and greater flashiness. However, this has not been definitively tested for aridlands, which are themselves characterized by these very same hydrograph properties. We analyzed long-term (>15-year) records of streamflow in 34 watersheds of central and southern Arizona to determine how hydrograph characteristics varied across a range of development. We found no relationships of hydrologic parameters to urbanization when we considered all catchments; however, when we considered only catchments small enough (<10,000 ha; n=15) to escape major hydrologic alteration (such as damming or diversion), we found that flashiness index and coefficient of variation of daily flow both decreased with % development in the watershed. This relationship is opposite that found for many streams in more humid regions. We found evidence that engineered retention basins may be driving these observations. Like in humid systems, we did observe more high flow events in the urban desert streams. We conclude that the urban stream syndrome manifests differently in aridland systems; instead, urbanization may in fact increase water retention and drive less variable flows in stream ecosystems.
Hydrologic Feedbacks with Ecosystems

Evaluating tree growth and groundwater use along a depth to groundwater gradient in sandy Wisconsin forests

Presenter: Dominick Ciruzzi (University of Wisconsin Madison)*
Co-Author: Steven P. Loheide II (University of Wisconsin Madison)

Prolonged water stress in trees can have profound impacts on forest function, including substantial reductions in forest productivity. However, trees can avoid the adverse effects of water stress by using available shallow groundwater. While water stress is not expected to frequently occur in temperate forests, it may be more common under future climatic regions. Exacerbating water stress in temperate forests are fast-draining sandy soils. Here, we investigated bi-directional groundwater-tree interactions in sandy Wisconsin forests: the extent to which groundwater influences tree growth and we quantified groundwater use by the forests. We hypothesize that trees in areas of shallow groundwater are more productive than trees without access to groundwater because these trees are frequently using higher quantities of groundwater to maintain transpiration. Further, we suspect these groundwater-tree interactions diminish as groundwater deepens and become non-existent past a threshold. Tree growth response from tree cores was examined across sites covering a 1-9 m depth to groundwater gradient. Further, diurnal water table fluctuations were analyzed to quantify the amount of groundwater consumed by trees for evapotranspiration. In general, trees in areas of shallow groundwater showed high growth and consumed high quantities of groundwater. As groundwater deepened, we observed lower growth and little to no groundwater use in trees. Our research aims to provide a basis for understanding these groundwater-tree interactions in temperate forests to help guide sustainable water and forest management decisions.

Remediation practices in coal mine subsidence impacted streams and implications for hyporheic function

Presenter: Marja Copeland (University of Pittsburgh)*
Co-Author: Daniel J. Bain (University of Pittsburgh)

In Pennsylvania, ~5000 hectares of land was undermined in longwall mining operations between August 2008 and August 2013, potentially impacting over 80 kilometers of streams during the 5-year period. During longwall mining, the entire coal seam is extracted and the overlying rock strata is allowed to collapse. The associated land subsidence redirects hydrologic flowpaths and in particular, reduces flow in small streams. Restoration of these streams is often required to reestablish stream flow and to maintain habitat. One of the primary remediation technologies used in restoration is stream grouting, a technique where fractures are sealed by pumping a cement mixture into the alluvial sediments to plug fractures in the underlying bedrock. While this technique effectively prevents flow loss, a comprehensive assessment of implications for other hydrologic processes (e.g., hyporheic exchange) does not exist. Here, we reconstruct patterns of reported flow loss over longwall mining operations in Pennsylvania and estimate the extent of stream grouting in this region. This ongoing reconstruction results in an unintended, replicated experiment on stream subsidence impacts and remediation practice that can provide powerful insight into hyporheic function and stream resilience.

Sulfate stream exports from the Piedmont critical zone along gradients in time and suburban to forested land use.

Presenter: Cassandra Cosans (Johns Hopkins University)*
Co-Authors: Joel Moore (Towson University), Maya Gomes (Johns Hopkins University), Ciaran Harman (Johns Hopkins University)

Piedmont landscapes are out of mass balance equilibrium with respect to sulfate due to declining inputs from anthropogenic sources over the last several decades. Stream concentrations are decreasing in response to reductions in atmospheric inputs but there is a significant lag. Correlation between increasing stream sulfate concentrations and higher levels of land development have been observed, but the source of additional sulfate has not been demonstrated. The study catchment, Baisman Run, is underlain by medium to fine grained schist. Sulfate fluxes from two small headwater catchments nested in the 3.79 square km catchment were compared. One headwater catchment is primarily suburban land use, while the other is fully forested. Continuous discharge measurements are available from stream gauges for both headwater catchments and the outlet of the larger scale study catchment. Samples were collected over the course of spring storms in both the suburban and forested headwater catchments to compare concentration-discharge relationships. Historical data published in 1970 by Cleaves et al. was used to determine past concentration discharge relationships in the forested headwater catchment. A positive concentration-discharge relationship that may be explained by a flushing mechanism from shallow soils was observed for both modern and historic data and across land uses. This positive trend was present at both the time scale of a storm and across seasonal timescales of discharge.
Sulfate concentrations in the suburban catchment stream were consistently nearly triple those in the forested catchment stream. We model how end-member mixing analysis utilizing sulfate sulfur and oxygen isotope ratios can be used to differentiate between potential sources of additional sulfate in the suburban catchment. Explored sources included road salt, fertilizer, and building materials. Understanding how sulfate from different sources is transported through the landscape will improve prediction of how stream sulfate concentrations will change with changing inputs. Sulfate concentrations have important ecosystem impacts including effects on pH and phosphorous mobility.

**An enhanced representation of forest cover for distributed hydrologic modeling**

Presenter: Sara Goeking (U.S. Forest Service and Utah State University)*
Co-Authors: David G. Tarboton (Utah State University)

Forest disturbances such as fire and insect epidemics have measurable effects on snowpack and streamflow. To accurately simulate the ecohydrologic effects of forest disturbances in distributed hydrologic models, hydrologists need pre- and post-disturbance maps of leaf area index (LAI) at sufficiently fine resolution to indicate loss of tree cover. Although several existing hydrologic models include spatially distributed representations of LAI, existing LAI datasets do not link changes in LAI to the type or severity of forest disturbance. Therefore, LAI input datasets must be improved to capitalize on the ability of hydrologic models to represent the linkage between forest disturbance and streamflow. One dataset that can potentially provide temporally specific estimates of forest cover and disturbance is the US Forest Service’s Forest Inventory and Analysis (FIA) program, which measures tree-level and plot-level attributes on permanent plots at a spacing of approximately 5 km throughout the USA. However, FIA does not measure LAI directly, so LAI must be estimated from tree-level or plot-level forest measurements. The objective of this study was to compare three alternative methods for estimating LAI from ground-based forest measurements, all of which have been used in previous studies, to estimate LAI from ground data for hydrologic modeling purposes: 1) a linear function of tree canopy cover constrained by known local maximum LAI; 2) an empirical, nonlinear estimation method relating tree canopy cover to LAI, with no local maximum required; and 3) an empirical estimation method based on stand basal area and forest type. For each of the three methods, plot-level LAI and spatial variables that constrain vegetation – including topographic and climatic variables – were combined in a Random forests model to interpolate LAI at 30-m resolution throughout a test watershed in northwestern Montana. Comparative analysis of the three interpolations was based on 10-fold cross-validation. The outcome of this study is the development of a method for using a permanent network of forest monitoring data to represent temporally-specific LAI at 30-m resolution. Enhanced representations of LAI will allow hydrologists to simulate and assess the effects of forest dynamics, such as fire and insect epidemics, on ecohydrologic fluxes and streamflow.

**Positive feedback between crabs and carbon efflux in coastal marshes**

Presenter: Julia Guimond (University of Delaware)*
Co-Author: Holly Michael (University of Delaware)

Carbon sequestration and storage in tidal marshes is a valuable carbon sink on the global scale, yet, due to their location on the land-ocean margin, these fragile ecosystems are threatened by climate change and anthropogenic influences. Large uncertainties in the present-day salt marsh carbon budget and mechanisms mediating the magnitude and direction of carbon fluxes limit the efficacy of conservation efforts, investment in tidal wetlands for long-term carbon storage, and our ability to predict carbon budget feedbacks with climate change. In an effort to mechanistically link ecosystem components and enhance future carbon budget predictions, we assess the interactions between crab activity, water movement, and biogeochemical conditions in a mid-Atlantic salt marsh. We show that crab burrows increase the permeability of the marsh platform in the summer by an order of magnitude, resulting in an increase in the volume of groundwater-surface water exchanged and in the depth of oxic and suboxic zones – conditions that enhance organic matter decomposition and vertical and horizontal carbon export. Thus, we identify a positive feedback mechanism between crab activity and carbon efflux. On the global scale, we calculate that burrows of marsh crabs are responsible for a 0.3 – 5.5% decline in salt marsh carbon burial, a number that could grow to 11% or more in the coming century.
Incorporating vegetation water stress to estimate residential water use in Research Triangle Region, North Carolina
Presenter: Laurence Lin (University of Virginia)
Co-Authors: A. R. El-Khattabi, Lawrence E. Band, and Andrew J. Yates (University of Virginia)

Understanding residential water use (RWU) is critical for water resources management in fast-growing regions where forested lands are converted to urban lands. Unlike water use by industrial sector, RWU is less studied. As a rapidly developed region in southeast of U.S., the Research Triangle Region (RTR), North Carolina is facing challenges to maintain water supply for urban expansion and development. In this study, we developed four regression models to estimate water use in the RTR. All four models included the same set of census information predictors such as household income, household population, but differed by the environmental predictors. The first model (Model 1) incorporated only meteorological information as environmental predictors, such as temperature and precipitation. This approach is commonly used but lacks spatial resolution in estimation of RWU because meteoroidal information may not vary substantially spatially across study region. The second model (Model 2) added the normalized difference vegetation index (NDVI) as an additional environmental predictor. The NDVI measures the timing of vegetation turning green, which improves Model 1 by incorporating vegetation information and refining spatial resolution of RWU estimation. In the third model (Model 3), a water stress index (WSI) was used as the only environmental predictor. In this study, we estimated the WSI using the Reginal Eco-Hydrological Simulation System (REHSSys), a spatially distributed eco-hydrological model that synthesize information of meteorology, soil, land-cover and vegetation to simulates complex ecological and hydrological processes in ecosystems such as flow dynamics, soil moisture, vegetation and evapotranspiration. The WSI was estimated for each vegetation patch (10m by 10m) in the RTR, and considered as a more precise and finer spatial scale predictor for estimating RWU, compared to meteorological or NDVI. A basin-scale WSI was used in Model 3. The fourth model (Model 4) is similar to Model 3 except that a WSI was estimated for lawn patch only and at census-block scale. We compared the four models in terms of capturing the observed water use pattern in the RTR. This study highlights the importance of water stress and provides alternatives for better estimating and understanding RWU.

Promoting Successful Urban Watershed Restoration through Enhanced Bioretention Cell Modeling
Presenter: Whitney Lisenbee (University of Tennessee)*
Co-Authors: Jon Hathaway (University of Tennessee) and Ryan Winston (Ohio State University)

According to the most recent National Water Quality Inventory, 44% of assessed streams throughout the United States are listed as impaired. Urban runoff and stormwater is one of the top ten leading causes of water quality impairment in lakes, estuaries and streams in the United States (USEPA 2004). Over the last decade, bioretention systems have become a leading stormwater control measure that contributes to the restoration of urban streams and watersheds. Bioretention cells increase infiltration of stormwater thereby reducing urban runoff volumes and peak flows which alter the hydrology of local waterways. Although these systems have proven to perform well in many site-scale field studies, less is known about how well these systems work when implemented en masse. Modeling of bioretention allows designers to better optimize the function of bioretention cells, provide guidance for design standards, and scale local impacts to the larger watershed. However, current hydrologic models with bioretention capabilities consist of lumped parameters and simplifications that do not fully account for fundamental hydrologic processes. DRAINMOD is an agricultural drainage model that has shown promise when applied to bioretention systems. It has the capability of using the soil-water characteristic curve to obtain detailed water balances over a continuous time period (both advances over other models for bioretention). However, because DRAINMOD was designed for agricultural purposes, it cannot currently accommodate the rapid response time of an urban runoff hydrograph, instead aggregating data to a daily time frame. For this study, DRAINMOD has been recoded to allow high temporal resolution inputs and outputs, more closely matching the travel times of urban systems. DRAINMOD simulations were conducted both with and without the time scale modifications (original vs. bioretention-specific model) to determine if improvements in site-scale modeling were realized. Future work will compare these results to those of simplistic, lumped-parameter bioretention modeling.
Groundwater Dependent Ecosystems’ Resistance and Resilience in Southern Great Basin: Evidence through Integration of Hydrogeology and Aquatic Ecology
Presenter: Khaled Pordel (University of Nevada Reno)*
Co-Authors: Donald Sada (University of Nevada Reno)

Groundwater dependent ecosystems (e.g. Springs) occur throughout the Great Basin, and some have persisted for millennia and support aquatic life whose ancestral arrived during the late Miocene/early Pliocene. We investigate, for the first time, the relationship between aquatic life in springs, tectonic development, climate, groundwater geochemistry, and groundwater residence time in arid region spring ecosystems. These relationships will be examined by determining biological characteristics of spring systems in context of isotope hydrology, geochemistry, and evidence of paleo-drainage system.

Role of hydraulic disturbance and fine sediment dynamics in ecological alteration of urban headwaters
Presenter: Jordan Psaltakis (USGS)
Co-Authors: Jud Harvey (USGS), Laurel Larsen (University of California Berkeley) Katie Skalak (USGS), Jay Choi (USGS)

Urbanization contributes to some of the nation’s most ecologically impaired aquatic ecosystems, however little is known about the role urbanization plays in altering fine sediment dynamics and its effect on aquatic health. We investigated the influence of short-term disturbances by floods and longer-term geomorphic alteration on fine sediment dynamics and stream metabolism in two neighboring headwaters of Fairfax, VA. The watersheds were similar sized, however the more urbanized watershed had a more uniform channel planform shaped by channel engineering whereas the less urbanized stream had numerous emergent bars, channel spanning riffles, bank slumps and fallen riparian trees, and a broader range of bed sediment textures with greater contributions from sand and fine particulate organic matter (FPOM). We found that higher urbanization promoted higher stream GPP (gross primary productivity) as a result of greater light availability and less disturbance of GPP by small floods. The more urbanized stream also had lower than expected ER (ecosystem respiration) caused by chronic effects of floods and channel engineering that lessened FPOM storage in the bed of the urbanized stream. There also were more frequent periods of autotrophy in the more urbanized stream, with greater flow alterations contributing to a greater loading of FPOM and its associated oxygen demand to a sensitive downstream estuary. These findings highlight the importance of light, hydraulic disturbance, and FPOM storage dynamics in the streambed in affecting stream health. We conclude that hydraulic and geomorphic alteration of urban streams manifests itself with direct effects on GPP through increased light and more frequent bed scour that decrease FPOM storage, with cascading influences on stream metabolism, downstream loading of FPOM, and stream ecological function.

Simulations of the plants response to different extreme events and subsequent water conditions
Presenter: Jianning Ren (Washington State University)*
Co-Authors: Jan Boll (Washington State University) and Jennifer Adam (Washington State University)

The extreme events (flood, drought) that happened at the growing season can have important effects to the plants both short term and long term. It can also alter the plant response to different future water conditions. It has been observed that the trees from flooded forests have higher tolerance to inundation, but more vulnerable to drought stress, compared to species from drier environment. Researchers have investigated the impact of early extreme events (drought, moderate, flood) on the subsequent response of plant to different conditions (same, opposite, favorable) with a field experiment. This paper will use an ecohydrological (RHESSys) model to simulate these plant responses to check if the model can reproduce the similar responses. We mainly answering the following questions: does early inundation or drought affect the later growth of plants under inundation, drought or moderate conditions? Are the impact on later responses different for different late conditions? Are these impact different for trees and grasses?
Non-stationarity of stormflow thresholds – a close
Presenter: Charles Scaife (University of Virginia)*
Co-Author: Lawrence Band (University of Virginia)

Top-down approaches in catchment hydrology have revealed widely observed stormflow thresholds that are a function of rainfall characteristics and antecedent soil moisture. Our recent work has shown that stormflow thresholds vary over long measurement periods indicating non-stationarity of stormflow generation linked to vegetation-climate interactions (Scaife and Band, 2017). This prior research used long term daily timesteps to match extensive continuous soil moisture data spanning 15-years. Recently, rainfall intensity at sub-hourly to hourly timesteps was identified as a secondary threshold for characterizing stormflow response (Janzen and McDonnell, 2015; Saffarpour et al., 2018). The goal of this study is to further investigate thresholds of stormflow production using higher resolution hourly rainfall, soil moisture, groundwater, and discharge data in a long term instrumented catchment at the Coweeta Hydrologic Laboratory located in Southwest North Carolina, USA. We use a subset of the initial 15-year study for which we have hourly measurements to revisit an important conclusion from our earlier study – that interannual variation of stormflow thresholds is a function of ecosystem transpiration. Using hourly data, we hypothesize that antecedent conditions of unsaturated and saturated storage combined with rainfall intensity account for differences in stormflow thresholds. We also hypothesize that interannual transpiration dynamics influence long-term stormflow thresholds by changing streamflow recession characteristics. We extend prior modelling work to show a competition between transpiration and subsurface flows contributing to streamflow recession characteristics.

Determination of tree and understory water sources and residence times using stable isotopes in a southern Appalachian forest
Presenter: Andrea Stewart (North Carolina State University)*
Co-Authors: Jennifer D. Knoepp (USDA Forest Service), Chelcy F. Miniat (USDA Forest Service), Andrew C. Oishi (USDA Forest Service), Theo L. Jass (North Carolina State University), Ryan E. Emanuel (North Carolina State University)

The development of accurate hydrologic models is key to describing changes in hydrologic processes due to land use and climate change. Hydrologic models typically simplify biological processes associated with plant water uptake and transpiration, assuming that roots take up water from the same moisture pool that feeds the stream; however, this assumption is not valid for all systems. Novel combinations of climate and forest composition and structure require a better understanding of sources of water for transpiration in order to accurately estimate impact on forest water yield. Here we examine red maple (Acer rubrum), rhododendron (Rhododendron maximum), tulip poplar (Liriodendron tulipifera), and white oak (Quercus alba) trees at Coweeta Hydrologic Laboratory, a long-term hydrological and ecological research site in western NC, USA, and explore whether source water use differs by species, hydraulic strategy, and landscape position. We analyzed stable isotopes of water (18O and 2H) in tree cores, stream water, groundwater, soil water, and precipitation using laser spectrometry and compare the isotopic composition of the various pools. We place these results in a broader context using meteorological and ecophysiological data collected nearby. These findings have implications for plant water stress and drought vulnerability. They also contribute to process-based knowledge of plant water use that better captures the sensitivity of transpiration to physical and biological controls at the sub-catchment scale. This work aims to help establish novel ways to model transpiration and improve understanding of water balance, biogeochemical cycling, and transport of nutrients to streams.

What determines the success of soil and water conservation practices? A case study from the Tana and Beles sub-basins, Ethiopia
Presenter: Liya Weldegebriel (University of California Berkeley)*
Co-Author: Sally Thompson (University of California Berkeley)

Environmental degradation endangers the livelihood of millions of people who are heavily dependent on natural resources. Soil and water conservation practices (SWCP) are intended to reduce runoff production and erosion in order to address such degradation. However, the success of such practices is variable. Moreover, information about the implementation and effects of SWCP are only rarely available to offer insight into what determines the success or failure of these interventions, and to improve the design and implementation of future SWCP.

To address this knowledge gap we analyze five well-monitored watersheds where SWCP were implemented to reduce surface runoff and soil erosion in The Tana and Beles Integrated Water Resource Development Project (TBIWRDP) in the Abay (Blue Nile) basin,
Ethiopia. TBIWRDP employed three soil and water conservation practices: terracing, agroforestry and check-dams. We investigate changes in stream flow and sediment concentration over three intervention years and find that the effects of the interventions on runoff and sediment production diverge across the watersheds. We explore how these divergent changes relate to: (1) the nature of the interventions employed, such as the area and density of terrace construction, or check dam location with respect to watershed outlet, and (2) intrinsic watershed characteristics such as topography, soil properties, land use and baseline degradation level.
**Water and the Changing Climate**

*Simulation of Groundwater across the United States using MODFLOW-OWHM*

Presenter: Mustafa Alattar (Lehigh University)*
Co-Authors: Tara Troy (Lehigh University)

Many regional studies have been conducted to support the water management efficiency of surface and groundwater supplies to meet the water demands, and to understand the change of groundwater due to the climate variability (precipitation and evaporation), and other surrounding factors such as crops irrigation demands, the population change, and land use. In this study, we will simulate and analyze groundwater availability on large scale (across the United States) using MODFLOW-OWHM from 1950 to 2010 with monthly time step. The model will analyze how climate variability and human activities can affect recharge and groundwater flow and how irrigated crop choices impact surface and ground water sustainability due to the irrigation water demand and supply.

*Streamflow Forecasting using Gaussian Process Regression*

Presenter: Hamid Bashiri (University of Houston)*

Streamflow is a main part of the hydrologic cycle and defines as water flow through a stream. Streamflow forecasting is critical in hydropower generation, flood control, reservoir operation, wastewater management, and water quality, and it depends on the meteorological and regional geographical features. The aim of this study is to evaluate the ability of a Machine Learning approach for the forecasting of streamflow using climate data adopted from NOAA. The prediction structure of streamflow was trained and tested from long-term time series data for 1988-2002. The authors used a data series from 2002-2017 for evaluation of their model. The Gaussian Process Regression developed to predict streamflow at French Broad River basin in Asheville, North Carolina. Comparisons with the observed data indicated that Gaussian Process Regression approach performed well in streamflow forecasting. Like most of the previous studies, there was a lack between forecasted and observed data for peak streamflows. In the further research, the authors are going to improve their model for those peaks.

*Effects of seasonal and long-term climate variability on nitrate export in the Chesterville Branch catchment of the Eastern Shore, MD*

Presenter: Shuyu Chang (Johns Hopkins University)*
Co-Authors: Daniel Wilusz and Ciaran Harman (Johns Hopkins University)

During the past several decades, human activity increased the input of nitrogen (N) to aquatic ecosystems through land clearing, application of fertilizer, discharge of waste water, etc. In the Chesapeake Bay watershed, a large portion of nitrogen originates from the Eastern Shore with highly agricultural land use. According to some research, it is observed that time of nitrate arriving at the Chesapeake Bay would affect the amount of eutrophication. i.e. Earlier arrival of nitrate would worsen the eutrophication. And climate change could have a significant effect on both the amount and seasonal timing of NO3 in streamflow. The main objective of this research is to observe the seasonality of rainfall, temperature, discharge, evapotranspiration, nitrate discharge and nitrate loads in a well-studied watershed, and use a model to explore how the seasonal timing might shift under climate change. Change of precipitation and temperature could alter several hydrological and N-Cycle processes, including lag time and transit time, streamflow and runoff generation, mineralization, and plant uptake, which are modeled by SWAT (Soil and Water Assessment Tool) in this research. The model was calibrated and validated by monthly stream gauge data and water quality monitoring data from USGS gauge through both manual calibration and auto-calibration. Climate sensitivity analysis was performed first by running scenarios with extreme high and low changes in temperature and precipitation and fitting all seasonal signals into trigonometric function to get basic information. After that, we simulate model response to possible changes climate by projected climate scenarios where projected climate changes were obtained from the range of ensemble of climate scenarios from 1980-2099. Through climate sensitivity analysis, we quantify the sensitivity of amount and timing for each response variable. For example, it is observed that the amount of discharge and NO3 loads are the most positive sensitive to precipitation while the seasonal timing of ET and NO3 concentration are the most negative sensitive to temperature. Based on our model assumptions and reasonable climate projections, we found amount of hydrology and nitrate is more sensitive than seasonal timing. However, there exists large uncertainty of seasonality in the future depends on climate scenarios. And other preliminary results will be displayed.
**Water level changes in the Amazon River Basin headwater streams under climate change**
Presenter: Dongmei Feng (Northeastern University)

In this work, the impacts of climate change on flow regimes in Amazon Basin headwater streams are investigated. The results suggest that annual precipitation in the northwestern Amazon will increase by roughly 35%, while in the southwestern basin, annual precipitation will increase by only 4%. Although there is an increase in precipitation, the wet season will be about 1 month shorter largely due to a delay in the start of the wet season. The change in seasonality is most obvious in the southern part of the study domain where the wet season starts about 3 weeks later and ends about a week earlier. For streamflow, the number of days with flow depths greater than 1 m will increase by 10–20 days (14 – 98 %) in the north while there is essentially no change in the south. However, the number of days with flow depth greater than 1.5 m and 2.0 m shows increase at almost all of the study sites. This implies that the high flow may occur more frequently in the future. The timing of high flow (depth >1.5 m) period is also influenced by climate change, especially in the north where the high flow period will start about a month early and end almost two weeks later, which lengthens high flow period by about 5-6 weeks. The length of high flow period in the south shows little change, but the frequency of high flow years (during which the number of high flow days is larger than 0) increased at a third of the sites by almost 50%. The results in this study imply that migratory fish species (e.g., catfish) will have more opportunity over a longer period to access upstream spawning reaches in the northwestern Amazon which could leading to the timing of reproductive activity of migratory fish being altered in the future (i.e., start earlier and end later).

However, in the southwestern headwaters region, the timing of fish migration may not change, but there may be more opportunities for larger fish to get access to spawning reaches. Although the lengthening of the dry season in the southern and southwestern Amazon is projected for the future under emission scenario RCP 8.5, the "drying effect" does not appear to affect the high flow dynamics. This suggests that the future climate may be favorable to the migratory fish species from the perspective of stream connectivity. This study provides valuable information for maintaining Amazon native ecosystem and developing sustainable adaptation strategies to accommodating climate change.

**Projecting water resources changes in potential agricultural investment areas of the Kafue River Basin in Zambia**
Presenter: Yuri Kim (Indiana University)
Co-Authors: Anne M. Trainor and Tracy J. Baker (The Nature Conservancy, Africa Program)

Climate change impacts regional water availability through the spatial and temporal redistribution of available water resources. This study focuses on understanding possible response of water resources to climate change in regions where potentials for large-scale agricultural investments are planned in the upper and middle Kafue River Basin in Zambia. We used historical and projected precipitation and temperature to assess changes in water yield, using the Soil and Water Assessment Tool (SWAT) hydrological model. Some of the Coupled Model Intercomparison Project Phase 5 (CMIP5) climate model outputs for the Representative Concentration Pathway (RCP) 4.5 and 8.5 scenarios project a temperature warming range from 1.8 – 5.7 °C over the region from 2020 to 2095. Precipitation projection patterns vary monthly but tend toward drier in dry seasons with a slight increase in precipitation during the rainy season as compared to the historical time series. The best five calibrated parameter sets generated for the historical record (1965 – 2005) were applied for two future periods, 2020 – 2060 and 2055 – 2095, to project water yield change. Simulations projected that the 90th percentile water yield would be exceeded across most of the study area by up to 800% under the medium-low (RCP4.5) CO2 emission scenario, whereas the high (RCP8.5) CO2 emission scenario resulted in a more spatially varied pattern mixed with increasing (up to 500%) and decreasing (up to -54%) trends. The 10th percentile water yield indicated spatially varied pattern across the basin, increasing by as much as 500% though decreasing in some areas by 66%, with the greatest decreases during the dry season under RCP8.5. Overall, available water resources in the study area are projected to trend toward increased floods (i.e. water yields far exceeding 90th percentile) as well as increasing drought (i.e. water yield far below 10th percentile) vulnerability. Because surface water is a primary source for agriculture in this region, planning must focus on simulating the potential range in spatial and temporal variability of water resources for different agricultural production schemes, their infrastructure requirements, and attendant influence on water resources in the basin.
Effects of Climate Change on Water Balance in a Fire-prone Montane Watershed

Presenter: Ekaterina Rakhmatulina (University of California Berkeley)*
Co-Authors: Sally Thompson, and Gabrielle Boisrame (University of California Berkeley)

The state of California has a long history of fire suppression. At the same time, a large portion of California’s water comes from montane watersheds where fire suppression policies have drastically changed forest structure, and consequently water balance over time. Illilouette Creek Basin in Yosemite National Park is a unique watershed that lacks fire suppression since 1972 and has an extensive climatic, remote sensing, and hydrologic monitoring record that allows for fine spatiotemporal modeling.

RHESSys, a distributed hydro-ecological model, was used to compare water balance between fire suppressed and fire unsuppressed Illilouette Creek Basin. In the first modeling step, a fire suppressed landscape prior to 1972 was compared to a historical fire landscape of Illilouette Creek Basin, using observed climatic inputs from 1972 to 2012. In the second modeling step, the same comparison was made, however within the context of future climate; ensembles of future climate predictions for both medium and severe emission scenarios were used as model inputs for a period from 2030 to 2070.

Historical modeling results show that introducing natural fires to a montane watershed increases streamflow and soil storage, and decreases transpiration along with the climatic water deficit. Future climate modeling results show that Illilouette Creek Basin would experience even greater increase in streamflow and soil water storage, and equal transpiration decrease as compared to the historical modeling. However, while climatic water deficit initially decreases due to fires, it increases over time starting in the 2050’s and beyond.

The results of this study can aid forest managers in making decisions within the context of future climate. While natural fires will continue increasing downstream water yields, there will be more stress on the landscape due to an increase in climatic water deficit.

A comparison of approaches to long-term flood projection

Presenter: Katherine Schlef (CUAHSI)
Co-Authors: Baptiste François, Sungwook Wi, and Casey Brown (University of Massachusetts Amherst)

The possibility of non-stationarity in climate is a challenge to long-term projection of flood events, which are necessary for effective flood risk management. This work compares two leading approaches to long-term flood projection. The first is the model chain approach, in which bias corrected and spatially downscaled projections of temperature and precipitation from general circulation models are used to force a hydrologic model to project streamflow. The second is the climate informed approach, in which a statistical model of flood events is forced with general circulation model projections of large-scale climate patterns that are mechanistically linked to flood events. This work applies both methods to flood events in a set of hydro-climatologically diverse basins across the United States. The results focus on comparing the flood projections (change in both magnitude and sign), attribution of projected change to predictors, and the propagation of bias and uncertainty. Importantly, this work contributes new insights regarding the (dis)advantages and credibility of each approach to long-term flood projection for hydro-climatologically diverse basins.

Streamflow dynamics explained by rainfall in Hawaii

Presenter: Yinphan Tsang (University of Hawaii Manoa)
Co-Author: Hannah Clilverd (University of Hawaii Manoa)

Streamflow in Hawaii is strongly influenced by the rainfall, driven by a large climate system that operates across the Pacific and resulting northeasterly trade winds that bring moisture to the islands and create high amounts of orographic rainfall in windward regions. Recent studies have found that long-term trends of stream baseflow and runoff across the five main Hawaiian Islands were aligned with the documented declines in rainfall, with variation due to island age and volcanic geology. However, little has been done to understand the streamflow dynamics and its association with rainfall dynamics. This study gathered monitored daily streamflow from 1990 to 2014, and flow metrics that describe different aspects of flow regime (i.e., magnitude, frequency, duration, timing, and rate of change) were calculated. Daily rainfall time series of the respective watersheds were extracted from 250 by 250 grids of daily rainfall data layers that are available across state for the same period. Similar rainfall metrics that describe the rainfall regime were developed to accompany the same measures of streamflow regimes. The association between streamflow and rainfall dynamics were compared and investigated and the differences were described across islands. The results of this study will assist our understanding of
streamflow dynamics at ungagged watersheds across the state. This is particularly useful as many streamflow monitoring gages have been discontinued due to lack of funding. Improved understanding of the rainfall-runoff relationships will allow us to estimate water resources, to predict flood prediction, and to assess stream habitat availability for aquatic fauna across Hawaii.

**Role of precipitation and irrigation in a changing climate to assess the nexus between water and food systems**
Presenter: Prasanath Valayamkunnath (Virginia Tech)*
Co-Author: Venkataramana Sridhar (Virginia Tech)

Global climate change is a change in the long-term weather patterns that characterizes distinct temperature and precipitation patterns around the world. The climatic change could affect transpiration rates, moisture availability hence quantity and quality of crops. Agricultural irrigation practices will likely be affected by climate change. Several studies have quantified the impacts of irrigation on precipitation. However, feedbacks between land surface cooling and irrigation water requirement via evapotranspiration and variable precipitation on crop yield can important in assessing the nexus between water and food systems. We will evaluate the precipitation (totals, number of wet and dry spells) evapotranspiration over the irrigated regions in the US and assess the relationship between US Department of Agriculture crop yield and rainfed lands. We will use an efficient irrigation model and the within coupled land-atmosphere modeling framework to simulate the irrigation effects. The results will be evaluated in the context of water and food systems impacted by climate change and climate variability. The outcome of this study is useful to understand future irrigation water requirement which can be directly related to agricultural water management.

**What’s the weather like? How climate affects the hydrologic outcomes of low-impact practices on residential parcels**
Presenter: Carolyn Voter (University of Wisconsin Madison)*
Co-Author: Steven P. Loheide II (University of Wisconsin Madison)

Low-impact stormwater management practices are often expected to both reduce stormwater runoff and, due to increased infiltration, produce secondary hydrologic benefits in below-ground fluxes. It is reasonable to expect that the partitioning of below-ground fluxes to deep drainage and evapotranspiration is strongly controlled by climatic conditions, but this has not been systematically explored for low-impact practices. We aim to describe how hydrologic outcomes of low-impact practices – namely, change in annual surface runoff, deep drainage, and evapotranspiration – are affected by different climatic settings. To do this, we modeled a representative residential parcel with and without low-impact practices – specifically, disconnected impervious surfaces and amended soil – using ParFlow.CLM, a process-based hydrological model. To represent the range of U.S. climates, we forced these simulations with weather data from the 50 largest U.S. cities for the 2014 water year. Here, we present descriptions of how climate moderates the shift in the annual water balance due to low-impact practices and what hydrologic outcomes are most likely for different regions of the U.S.
Recent advances in sensor network development have been more technology-oriented and often left out important aspects such as data management thus lowering the ease of sensor network deployment. In addition, multidisciplinary expertise is currently needed to streamline commercially-available environmental monitoring systems and implement a data-from-sensor to storage-and-proper-annotation approach, equipped with data mining techniques for decision making. This is a complex process that involves continuous and often arduous manual data exports and organization, and also is inherently subject to frequent break-downs and human errors. To address these issues, we introduce TranscodX, a cost-effective solution that promotes the seamless integration of the front-end (field equipment) and the back-end (standard data management) of a sensor network with support for data stewardship. Our hardware solution, which is aware of a standard data management system, is dubbed a transcoder rather than a data logger. The reason is that, not only it is designed to perform the tasks of a data logger, it is also capable of capturing, transcoding, and streaming field observations data and corresponding metadata to an embedded standard data management framework based on the CUAHSI Observations Data Model (ODM) along with the ability to integrate with legacy sensing equipment. Overall, our solution integrates the collection, transmission, management, analysis, discovery and delivery into a full stack system designed to support automatic field data streaming into data management system. We are currently planning to engage a group of beta tester that will deploy and test the device under “real-world” conditions before we move to the production phase.

Revealing spatial and temporal controls on dissolved oxygen and temperature in the Savannah River using the Intelligent River® sensor network
Presenter: Michael Cope (Clemson University)*

Dissolved oxygen and water temperature are important indicators of river water quality. This study investigated average weekly dissolved oxygen (AWDO) and average weekly water temperature (AWT) in the Savannah River during 2015 and 2016 using data from the Intelligent River® sensor network. Preliminary analyses revealed seasonality that impacts both AWDO and AWT regardless of location along the river. Analysis of components of variance using mixed models revealed that seasonality and sensor location are the dominant sources of variation in AWDO and AWT. When mixed models were fit in a spatial context, a substantial portion of total observed variance in AWDO arose from spatial correlation among sensor sites after seasonal variation was removed. Low and high river flow conditions had a significant impact on AWDO and AWT, but these predictors explained only a small portion of the total observed variance. Spatial linear mixed effects models yielded model parameter estimates that were effectively the same as non-spatial linear mixed effects models. The combined use of water quality sensor networks and SSN modeling can help managers understand and predict when and where water quality problems may be anticipated so that specific management strategies can be formulated.

These Are Not the Fluxes You Are Looking For: Impacts of Low Fluxes on the Temperature Amplitude Ratio Method
Presenter: Thomas Glose (University at Buffalo)*
Co-Authors: Christopher Lowry (University at Buffalo) and Mark Hausner (Desert Research Institute)

Quantification of fluxes across the groundwater-surface water interface is a vital component of a robust analysis of the mechanisms that control processes such as nutrient cycling, ecological niches, and near-surface heterogeneity. The use of heat as an environmental tracer to quantify these fluxes has seen a resurgence in the past decade as low-cost, waterproof sensors have become ubiquitous. When using at least two vertically stacked sensors, temperature time-series data are recorded and analyzed using signal processing methods, such as the amplitude ratio method, to provide accurate flux rates. Heat as an environmental tracer is advectively transported across the groundwater-surface water interface in the vertical direction. However, as flux rates approach near-zero values conductive transport becomes the primary method of transporting heat, resulting in errors in the fluxes inferred from temperature data. The effects of these near-zero fluxes on the amplitude ratio method have not been fully explored, and a lower limit at which this method is applicable has not been identified. To address this, synthetic temperature-time series data were generated at varying precisions for various combinations of head gradients, sensor spacing, and thermal conductivities of the sediment using a numerical model. Fluxes were subsequently inferred using the amplitude ratio method and the dimensionless Péclet number (the ratio of advective to conductive
heat transport) for each scenario was found. Using the Péclet numbers, criteria were established to identify the extent to which conduction controls the transport of the thermal regime. Results provide bounds on when and under what conditions these generated fluxes can be considered true and representative of the system.

**Application of Learning Systems in Water Quality Monitoring of Green Bay Estuary, US**

**Presenter:** Bahram Khazaei (University of Wisconsin Milwaukee)*

**Co-Author:** Sajad Ahmad Hamidi (Indiana University of Pennsylvania)

Nutrient loading into Green Bay of Lake Michigan has produced several environmental issues including deposition of sediments, hypoxia, and reduced water quality. Fox River originated from Lake Winnebago, WI, carries hundreds of tons of sediments to the Green Bay each day that contains high concentrations of contaminants and inorganic pollutants. A significant portion of the particulate matter is mostly originated from Lake Winnebago, but it can also be transported to the Fox River reach between the Lake Winnebago and Green Bay in its halfway—a process that has been intensified by human activities such as agricultural works and urban/industrial land development. There are current monitoring programs by different agencies to observe the water quality variations in the bay and at the mouth of Fox River. The goal of this study is to develop a computational tool for conversion of continuous records of discharge and turbidity at the Green Bay estuary into water quality parameters such as total suspended sediments. This includes the application of the Adaptive-Network-based Fuzzy Inference System as a robust learning procedure to detect the relationship between pairs of water quality data and turbidity or discharge measurements. The proposed method is a learning technique and sensitive to the model parameters; hence, sensitivity of the method to these parameters was evaluated before selection of the best model and application. The method was then applied to the measurements of 2011-2016 water quality data. Our analysis indicates that the model is able to estimate total suspended sediments with normalized root mean square error of less than 0.38, which denotes an accurate predictive power of the model. Cross-validation also shows that the model is capable of providing robust estimations of the water quality data.

**Migrating CZO data to HydroShare**

**Presenter:** Miguel Leon (Luquillo CZO, University of Pennsylvania)

**Co-Authors:** Louis Derry (CZO National Office), Jerad Bales (CUAHSI), David Lubinski (University of California Berkeley), Collin Bode (eel River CZO), and Christian Camacho Colon (Cornell University)

CZO data are currently spread across the CZO network in an ad hoc manner. Most data are stored on multiple computers at the ten individual observatories (including the inactive Christina CZO). Only a fraction of data are stored in a long-term archive, usually at a discipline-specific repository (i.e. LiDAR data in OpenTopography.org). Although larger CZO databases are likely to be maintained for quite a while, numerous smaller datasets are at risk of becoming inaccessible as data authors switch jobs, observatories become inactive, etc. To help solve CZO's needs, we propose to migrate both the CZO centralized metadata catalog and some of the CZO data files to HydroShare (https://hydroshare.org), a modern and flexible website for hosting, sharing, and discovering science data. Although HydroShare’s focus has mostly been on hydrologic data so far, it supports interdisciplinary science via many data types (time series, GIS, models and more). HydroShare will make more CZO datasets accessible and easier to use. It will also help preserve many CZO datasets that are at risk of becoming inaccessible. Moreover, HydroShare helps CZO satisfy NSF requirements for data archiving. Examples from the Luquillo CZO are presented with data from Hurricanes Irma and Maria. Database integration between ODM2 Admin (used by LCZO and Catalina Jemez CZO) and Hydroshare are also described.

**Environmental monitoring cyberinfrastructure of the Texas Water Observatory**

**Presenter:** Gretchen Miller (Texas A&M University)

**Co-Authors:** Nandita Gaur, Georgianne Moore, Gretchen Miller, Cristine Morgan, Mark Everett, and Binayak Mohanty (Texas A&M University)

Variability in the precipitation and drought patterns throughout the southeast United States, combined with increasing water demand continue to have significant social, political, economic, and environmental impact on the 50 million people who live in Texas and Gulf states (Hess, Wold et al. 2016). A greater understanding of the water availability, storage, usage, and quality, in both space and time, is critical for ensuring a sustainable future. To address those challenges efforts have emerged to implement observatory networks to coordinate mechanistic approaches to provide long-term, high frequency, near-real-time information available in standardized formats and tools to integrate and assimilate data across different spatiotemporal scales representative of land use and basins. In
this paper, we describe the design and implementation of the cyber infrastructure of the Texas water observatory. We implemented a unified framework for long-term, remote, and near-real-time monitoring, including site selection, data collection, data management, visualization, dissemination. Initial field testing results are also presented. Also, we describe a framework to leverage efforts of TWO and other cyber infrastructure ongoing efforts within several scientific domains to support operational network activities.

**Development of an Urban Land Cover Temperature Model using Drone Imagery**
Presenter: Joe Naughton (Marquette University)*
Co-Author: Walter McDonald (Marquette University)

Temperature represents one of the largest impairments for rivers and streams across the United States. In western states like New Mexico it can make up nearly half of the total impairments, and even in Wisconsin, over 17 miles of rivers are impaired for temperature. This situation is projected to get worse as land development and climate change accelerate thermal stress on aquatic environments. Solutions will require accurate and reliable models that represent rainfall-runoff temperature dynamics – particularly the characterization of urban terrain or land surface temperatures. However, existing empirical terrain temperature models are limited by the point-based data they are built upon, and limited studies have considered the high-resolution spatial distribution of temperature across homogenous land surfaces, which are known to be significant. This can be overcome with drone and thermal camera technologies that collect spatially distributed temperatures accurate to fractions of a degree Celsius. Therefore, this study addresses this knowledge gap by using a drone to collect high-resolution thermal orthoimagery and applying the data to develop an empirical terrain temperature model. Experimental sites include Marquette University and the University of Texas El Paso, two distinct geomorphic and climatic regions. The outcome is a more accurate and reliable empirical model for terrain temperatures that accounts for high-resolution variability across homogenous land surface types. This terrain-temperature model will ultimately be integrated into the Heat Orthoimagery Terrain Temperature Water (HOTT Water) model, a novel comprehensive watershed temperature tool.

**Characteristics of river discharge series derived from the unique space-time sampling of the Surface Water and Ocean Topography (SWOT) Mission**
Presenter: Cassandra Nickles (Northeastern University)*
Co-Authors: Yuanhao Zhao (Northeastern University), Edward Beighley (Northeastern University), Michael Durand (Ohio State University), Cedric David (NASA Jet Propulsion Laboratory), Hyongki Li (University of Houston)

Expected to launch in April 2021, the Surface Water and Ocean Topography (SWOT) satellite mission is jointly developed by NASA, the French space agency (CNES), with contribution from the Canadian and UK space agencies. The SWOT mission will measure global surface water extents and elevations (lakes/reservoirs, rivers, estuaries, oceans, sea and land ice) at a finer spatial and temporal resolution than is currently possible enabling hydrologic discovery. Although the mission will provide global cover, analysis and interpolation of the data generated from the irregular space/time sampling represents a significant challenge. In this study, we explore the applicability of the unique space/time sampling for understanding river discharge dynamics throughout the Mississippi River Basin. River network topology, SWOT sampling (i.e., orbit and identified SWOT river reaches), USGS streamflow data and discharge uncertainty metrics are used to generate SWOT-like river discharges in gauged reaches. Streamflow statistics for the SWOT generated river discharge time series are compared to statics derived from continuous USGS daily river discharge series. Results show high correlations for several commonly used statistics: annual maximum, mean, median and standard deviation (R2 > 0.98). Correction factors (CFs) are generated to transform SWOT streamflow statistics to equivalent continuous daily discharge time series statistics intended to support hydrologic applications.

**Estimating Dew Point Temperature Using MODIS Land Surface Temperature and SMAP Soil Moisture**
Presenter: Roozbeh Raoufi (Northeastern University)*
Co-Authors: Edward Beighley (Northeastern University)

Humidity is a key variable in numerous process models specific to hydrologic and atmospheric dynamics. It is particularly an important for modeling evapotranspiration. In the present study, humidity is estimated globally for application in an evapotranspiration model. Here, humidity is estimated using only remotely sensed products for the period 2015 to current. Land Surface Temperature (LST) derived from NASA’s MODerate resolution Imaging Spectroradiometer (MODIS) sensor onboard the Aqua and Terra satellites and soil moisture derived from NASA’s Soil Moisture Active Passive (SMAP) mission are the primary input variables. Other variables
such as land cover and albedo from MODIS are also used. Humidity is determined by estimating the dew point temperature, which is assumed to be a function of minimum daily temperature, soil moisture, land cover, and ground elevation. To estimate the minimum daily temperature, which commonly occurs at or slightly after sunrise, a regression relationship is developed using nighttime LST data from both Terra and Aqua satellites, with approximate overpasses at solar local times of 10:30 pm and 1:30 am, respectively, and half-hour air temperature data from AmeriFlux and EuroFLUX network tower measurements (i.e., a total of 68 eddy covariance towers). The relationship uses a sinusoidal daily variation curve to account for measurements having specific overpass times that do not necessarily occur at the desired time of minimum temperature. The estimated minimum daily temperatures are validated with the tower measurements. The difference between daily minimum temperature and dew point temperature ($T_{min} - T_{dew}$), which is always greater than or equal to zero, is then estimated using soil moisture from the SMAP am dataset with an approximate overpass time of 6:00 am. The validation and calibration datasets are randomly selected to insure an independent validation and calibration process. The resulting relationships and corresponding performance metrics are presented.

**US EPA’s Interoperable Watersheds Network**

Presenters: Dwane Young and Britt Dean (U.S. EPA)

The Interoperable Watersheds Network (IWN), created by US EPA’s Water Data Integration Branch, is a national data sharing platform that seamlessly links continuously monitored sensor data from multiple agencies into one searchable location. The completed IWN will allow water quality managers to better evaluate the health of local water resources by providing them with near real-time access to watershed-level monitoring data. Stakeholder workgroups were engaged to assist with developing requirements for the three major project components: required attributes and query capability for a centralized metadata catalog, technological and data requirements for data providers, and desired functionality for a web-based discovery tool that provides access to the catalog services and provider data.

The pilot implementation of IWN uses the Open Geospatial Consortium (OGC) Sensor Observation Service (SOS) 2.0 and WaterML2 standards as the foundation for a distributed sensor data sharing network. Data owners have published their continuous sensor data and related metadata either through “data appliances”, running the open-source 52° North implementation of SOS, or using commercial software, like Kisters’ KiWIS product.

Metadata are harvested into a centralized catalog that provides a REST Service API, where users can discover data by querying for specific parameters or using spatial boundaries. The sensor results are returned as GeoJSON, which can be displayed in data discovery maps. The API also provides the service endpoints for the sensors, which can be used to access the continuous data to create charts or download the data. The IWN discovery tool, “Currents”, utilizes these web services to provide access to 15,678 sensors nationwide from 8 data providers, including state, local, and federal agencies.
Energy-Water Systems

Renewable Energy from Wastewater: Biotech to Convert Pyrolysis Liquid to Methane Fuel

Presenter: Saba (Seyedehfatemeh) Seyedi (Marquette University)*
Co-Author: Daniel Zitomer (Marquette University)

The volume of sludge being produced during water reclamation processes is increasing due to population increase and strict effluent requirements. Many conventional methods are being used to process biosolids such as incineration, landfills, or direct use of biosolids in agriculture. However, due to health and environmental concerns from pathogens, micropollutants, and excess nutrients in the environment as well as the desire for energy and resource recovery, other technologies that destroy pathogens and micropollutants while generating energy, such as thermochemical processes, are being investigated. Pyrolysis is a conversion process that transforms wastewater solids to biochar, py-gas, py-oil and an aqueous phase liquid. Biochar, py-gas and py-oil can be processed and used as renewable fuel. Aqueous pyrolysis liquid (APL), however, has no apparent use but it is a potential source for energy generation. Additionally, if APL is discharged without processing or treatment, it can pollute the environment because of its high organic strength and result in decreased water quality in receiving water bodies because of oxygen depletion. Therefore, it would be beneficial if organics in APL could be converted via anaerobic biotechnology to yield additional useful renewable fuel in the form of methane. The goal of this study was to determine if APL can be converted to methane fuel via anaerobic biotechnology. The results showed that the APL inhibits anaerobic digestion at high concentrations. Either high pH and/or other constituents, such as nitrogen-containing organics in the APL, inhibited the activity of methane-producing microbes. Continuous digestion of APL and synthetic wastewater sludge was also performed to determine if APL resulting from various pyrolysis conditions inhibited anaerobic biodegradability/toxicity. The results showed that APL from a specific, catalyzed pyrolysis process was more inhibitory to methane production than non-catalyzed APL.
The Mekong river basin is one of the largest river basins in the world supporting a population of more than 60 million people. The food security of such a large population is dependent on fisheries and agriculture production. Irrigated wet season rice is the primary crop, which is grown throughout the year in the Mekong Delta region. Vietnam is the largest producer of the rice in the Mekong basin and the second highest exporter globally with 10% of the world rice market. The immense pressure due to increasing population is causing the harvest up to seven rice crops every two years. At present, major land transformation is observed in the basin in form of conversion of forest and grassland areas to the agricultural land. The proposition of more than 400 dams in the Mekong River was meant to utilize the high hydropower potential of the Mekong River Basin. However, these dams are also expected to satisfy the water requirement for the irrigation purpose. The availability of the water in the basin is also altered by the changing climate conditions. It is important to analyse the cumulative effect of the water requirement by the increasing agricultural area and hydropower production under the influence of climate change. In this study, we enhance a model based on hydrodynamic of the region by combining the supply and demand from different sectors for the water management. The SLEUTH model was applied to the lower Mekong Basin to predict the land transformation during the period 2016-2050. The hydrological model (Variable Infiltration Capacity, VIC) was coupled with the SLEUTH model with the meteorological data from different General Circulation Models (GCMs) using the commercially available package Structural Thinking, Experiential Laboratory with Animation (STELLA).

Understanding NO3 Dynamics in an Arid Irrigation Network and Linking them to FEW Resource Management

Understanding how rivers and river-dependent systems such as irrigation networks process nutrient loads from Wastewater Treatment Plants (WWTPs), usually the main nutrient sources to arid rivers, is key to developing effective management strategies to holistically optimize food, energy and water resources. We estimated monthly processing of NO3- discharged by the Albuquerque WWTP over the course of a year along 20km of the Rio Grande River and two adjacent, major agricultural canals connected to it. We determined source/sink NO3 seasonality using the stable isotopes δ15N-NO3 and δ18O-NO3. The WWTP discharges NO3- with a distinct, semi-constant isotope signature (δ15N: 12.1‰, δ18O: -3.5‰), which we use as boundary conditions to estimate nitrate processing in the network by tracking longitudinal, lateral and temporal changes in the δ15N-NO3 and δ18O-NO3 along our three reaches. Results from the winter and spring indicate the system is transitioning from a NO3 source to a NO3 sink, and isotope analyses indicate that this transition is led by primary productivity. Pairing stable isotope analyses with nutrient budgets over time provides insight into the dynamic mechanisms controlling nutrient source/sink behavior within the river network. This mechanistic understanding sheds light on engineering solutions to couple agricultural canal networks with reclamation systems through the use of treated WWTP effluent as water and nutrient source to crops, thus reducing the amount of energy required to treat water (secondary vs. tertiary treatment), synthesize nutrients (Haber-Bosh process) and transport them to the crop fields while directly addressing the call to close environmental nutrient loops.

Demand for freshwater from high-value irrigated vegetable crops in the context of food-energy-water nexus

Maintaining a balance between the growing demand for food, water, and energy production with limited resources is a challenge for humans and community well-being. The water–energy–food nexus is increasingly challenged by high constrain on resources resulting from both population growth and extreme weather events. To effectively adapt to this change requires efficient management of water, energy, and land resources and coordinated efforts to minimize trade-offs and maximize synergies. Vegetable production remains underdeveloped in irrigated Central Washington State (ICWS), even though other out-of-state producers face challenges due to extreme droughts. We are evaluating the introduction of new high-value vegetable crops in ICWS. In this study, we focus on tomato production and use CropSyst (Cropping Systems Simulation model) to assess production and water footprint when tomatoes are included in the annual crop rotations utilized in the region. We defined a boundary for tomato production from seeding to the
final packaging before market distribution. The water footprint at regional scale provides a useful assessment of consumptive water use compared to current land use. The study will be augmented with a complete life cycle assessment, including comparisons with greenhouse vegetable production utilizing different levels of technology.

**Modeling future scenarios of snow, forests, streamflow, energy, agriculture, and water rights to explore the Food-Energy-Water nexus in the Willamette River Basin, Oregon**

Presenter: Anne Nolin (University of Nevada Reno)
Co-Authors: Chad Higgins (Oregon State University), Adell Amos University of Oregon), Greg Characklis (University of North Carolina Chapel Hill), Jordan Kern (University of North Carolina Chapel Hill), David Hulse (University of Oregon), Cynthia Schwartz (Oregon State University), David Rupp (Oregon State University), David Conklin (Oregon Freshwater Simulations), Steve Drake (University of Nevada Reno)

Like many places in the West, the Willamette River Basin (WRB) faces multiple issues such as declining snowpacks, stressed forests, and increasing wildfires; urban growth, irrigated agriculture, federally managed reservoirs, warming rivers, and endangered fish. Using Envision, our unique multi-module, social ecological systems model we are exploring alternative future scenarios of the Food-Energy-Water (FEW) nexus and policy implications in concert with a diverse set of stakeholders. The WRB is small enough (29,728 km2) to be tractable within Envision, yet large and complex enough to incorporate key attributes, connections, and feedbacks in the FEW nexus. Envision comprises four software subsystems: a geographic information system that manages data through space and time, a standard interface for plugging in models that simulate natural, engineered, and social systems, a model of social mechanisms (laws, policies, regulations, etc.) that create opportunities and constrain private actions, and a system for compiling model output and visualizing alternative scenarios. Envision also integrates and coordinates the operation of models that each focus primarily on a single domain. To optimize it for studies of the food-energy-water (FEW) nexus, we are enhancing it with an improved snow model, an energy model, a comprehensive food and agriculture model, a groundwater model, and a stream temperature model. This enhanced version of Envision is allowing us to test the following five FEW hypotheses:

**Hypothesis 1:** Forest management strategies that address the combined effects of canopy structure and climate can improve snowpack accumulation and retention, thereby increasing water yields for agriculture and decreasing the requirement for costly and energy-intensive forest fire suppression.

**Hypothesis 2:** Current operational guidelines at multi-purpose dams will fail to balance defined objectives for flood control, power generation, water supply, and environmental stream flows when confronted with climate change, population growth, a shifting power generation mix (e.g., more solar) and more stringent environmental regulations.

**Hypothesis 3:** Growers can conserve substantial quantities of their local groundwater resource by shading a portion of their plants with photovoltaic panels, thereby mitigating the plants’ exposure to excess solar radiation and generating renewable energy.

**Hypothesis 4:** Decision makers exercising their discretionary authorities within existing law can destabilize the FEW nexus.

**Hypothesis 5:** Future urbanization will shift water demand from agricultural applications (consumptive use) toward urban applications (non-consumptive use). This can raise stream temperatures above established thresholds for federally protected native cold-water fish.

This work will present updates on the current status of Envision sub-models and results from our proto-scenarios including a) impacts of changing snow-wildfire-forest management relationships; and b) impacts of converted water rights on downstream water use.
**The Virtual Water Content of Grain Storage in the United States**  
*Presenter: Paul Ruess (University of Illinois Urbana-Champaign)*  
*Co-Author: Megan Konar (University of Illinois Urbana-Champaign)*

Virtual water content represents the water consumed in the production of a commodity. While many studies focus on understanding and managing volumes of water stored in dams, surface waters, and aquifers, this paper instead quantifies virtual water stored in the form of grain storage in the United States. Using various agricultural datasets, the distribution of crops within grain storage facilities is estimated, and the equivalent crop water demands of these crops (dependent on local climates) is used to determine the volume of virtual water stored in this way. The results show that these volumes are comparable in magnitude to other forms of reservoirs within the United States, highlighting their importance for understanding water availability.

**Assessment of Risk on Agricultural Products using Remote Sensing**  
*Presenter: Erfaneh Sharifi (University of Houston)*

Crop production heavily depends on weather condition. Drought, floods, and heavy rainfall as the major weather risks negatively affect the agribusiness. Agricultural damage data are studied for different crops in different areas of Iran. Heavy rainfall resulting in flooding and pounded water that damage crops has the highest effect on rice product among other events in the north of Iran where rice is the main agricultural products. Landsat images are used to identify the damage on rice products in Gilan province in the north of Iran. A supervised classification and temporal change detection were performed to estimate the loss. Results can be compared with the damage and indemnity data obtained from the insurance company and may lead to better quantifying the rainfall and other weather-related risks on different products.

**Characterizing tradeoffs between water and food in the Mississippi River basin**  
*Presenter: Tara Troy (Lehigh University)  
*Co-Author: Xiao Zhu (Lehigh University)*

As water demand approaches or exceeds the available water supply in many regions of the globe, water stress will become increasingly prevalent with potentially necessary tradeoffs required between water prioritization amongst sectors. Agriculture is the largest consumptive water user in the US, and irrigation plays a vital role in ensuring a stable food supply by buffering against climate extremes. However, it also plays a negative role in inducing water stress in many regions. Much research has focused on reducing agricultural water use, but this needs to be complemented by better quantifying the benefit of irrigation on crop yields under a range of climate conditions. Regions are identified with significant irrigation benefits with and without water stress to parse apart the role of climate, crop choice, and water usage to then evaluate tradeoffs with food production in a climate-water-food nexus.

**Alternative agricultural management practices on dairy cropping systems in the Northeastern United States: Nutrient and sediment losses from the field to the watershed.**  
*Presenter: Cameron Twombly (University of Vermont)*  
*Co-Authors: Joshua W. Faulkner and Stephanie E. Hurley (University of Vermont)*

Dairy cropping systems are among the largest sources of phosphorus (P), nitrogen (N), and sediment into freshwater systems in the Northeastern United States. Conventional agricultural management practices used for dairy feed production have been shown to cause changes in watershed hydrology and water quality, including the increase of eutrophication. Alternative agricultural management practices have the potential to decrease runoff, and associated export of nutrients and sediment from agricultural fields, reducing their contribution to water quality degradation. The objectives of this project are 1) to quantify the effects of commonly used alternative agricultural management practices on surface runoff and subsurface leaching, as well as P, N, and sediment exports from dairy cropping systems in the Northeastern United States, and 2) to model and evaluate effects of the large-scale adoption of the studied management practices on water quantity and quality for a selected agricultural watershed in the Northeast. The management practices being evaluated in this study are soil aeration prior to surface manure application on hay fields, and the combination of no-till, manure injection, and cover cropping on corn fields. Edge-of-field (EoF) monitoring techniques and passive-capillary lysimeter systems are being used to continuously measure the losses of surface runoff and subsurface leachate from two dairy cropping systems in the Lake Champlain Basin in Vermont. Remaining components necessary to construct a P mass balance for the fields are also being measured.
Storage Induced Behavior at the Food, Energy and Water Nexus: An Integrated System Dynamics Approach  
Presenter: Mengqi Zhao (Washington State University)*

Growing demands and interactions across food, energy and water (FEW) systems require effective storage management in anticipation of undesired effects of slow and fast variables in order to maintain or achieve system stability. Inner causalities and feedbacks within the FEW systems constitute complex non-linear connections where system behavior under constraints and uncertainties is difficult to foresee. System dynamics (SD) modeling is a practical method to gain insights into interactions between components from reference modes of system behaviors. Currently, however, SD models are spatial lumped and not easily adapted to spatially distributed biophysical simulation. In this study, an integrated approach, called dynamic data exchange (DDE), connecting SD models with process models is developed. We seamlessly combined SD and hydrologic models, thus capitalizing on the advantages of feedback mechanisms in the SD framework. Feedbacks among generic FEW systems models focused on the dynamics of storage (e.g., reservoirs, aquifers, and grain elevators) affected by supply and demand, water rights, flow rules, and management. Behaviors of FEW systems corresponding to various storage scenarios demonstrate the important role of storage in improving reliabilities of water supply to other sectors. Assessment of variables altering thresholds of storage reliability through sensitivity analysis informs dominant factors in influencing sustainable water use at the FEW nexus.

Evaluation of projected agricultural climate risk over the continental US  
Presenter: Xiao Zhu (Lehigh University)*  
Co-Authors: Tara Troy (Lehigh University) and Naresh Devineni (City College of New York)

Food demands are rising due to an increasing population with changing food preferences, which places pressure on agricultural production. Additionally, climate extremes have recently highlighted the vulnerability of our agricultural system to climate variability. This study seeks to fill two important gaps in current knowledge: how we can best account for uncertainty in yield responses to climate and how the widespread response of irrigated crops differ from rainfed. We developed a statistical approach to evaluate climate risk quantitatively to better understand the historical impacts of climate change and estimate the future impacts it may bring to agricultural systems. Our model consists of multiple linear regression, distribution fitting, and Monte Carlo simulation to simulate rainfed and irrigated crop yields at the US county level. The model was fit using historical data for 1970-2009 and was then applied over different growing regions in the continental US using the CMIP5 climate projections. The relative importance of many major growing season climate indices, such as dryspells and hot days, were evaluated to determine what climate indices play a role in affecting future crop yields. The statistical modeling framework also evaluated the impact of irrigation by using county-level irrigated and rainfed yields separately. Furthermore, the projected years with negative yield anomalies were specifically evaluated in terms of magnitude, trend and potential climate drivers. This framework provides estimates of the agricultural climate risk for the 21st century that account for the full uncertainty of climate occurrences, range of crop response, and spatial correlation in climate. The results of this study can contribute to decision making about crop choice and water use in an uncertain future climate.
Dynamic Connectivity in the Landscape

Reconstructing Sediment Supply and Transport Behind the Elwha River Dams
Presenter: Claire Beveridge (University of Washington)*
Co-Authors: Erkan Istanbulluoglu and Christina Bandaragoda (University of Washington)

The removal of two massive hydropower dams on the Elwha River of Washington State in 2013 marked the largest dam removal in history. Over the century long lifespan of the dams, approximately 21 million cubic meters of sediment was impounded behind them. In this study, we aim to reconstruct sediment supply, transport and deposition behind the Glines Canyon Dam (most upstream dam) over its lifespan using a watershed modeling approach. Long term erosion rates documented in this region along with observational data (DEM, channel morphology, meteorology, streamflow, bedload transport, suspended sediment transport, and reservoir sedimentation) give unprecedented opportunities to test watershed sediment yield models and examine dominant processes that control sediment yield over human time scales. These opportunities are relevant to the impacts, productivity, and lifespan of dams, which are integral components of coupled food-energy-water-society systems.

Relative Contributions of Early Industrialization and Modern Transportation to Legacy Metal Contamination
Presenter: Memphis Hill (University of Pittsburgh)*
Co-Authors: Daniel Joseph Bain (University of Pittsburgh) and Robert Rossi (Stanford University)

Road networks are one of the most dominant drivers of landscape change over the past 150 years and have contributed substantial contaminant loads to nearby surface waters. Before road construction, soil and sediment contamination was dominated by early industrial inputs. The relative role of road contaminants and their accumulation in urban ecosystems is not well understood. For example, reactive nitrogen is generally deposited within 10 m of roadways and can have substantial effects on the mobility of metals in near-road systems. Coupled metal and nitrogen dynamics have emerged as a key, but poorly characterized, driver of these systems. The combination of chemical stressors in roadside soils likely causes remobilization of legacy metal contaminants. Pittsburgh has an extensive industrial history, yet little is known about historical metal loadings and accumulation of metal contaminants. In this study, the history of legacy metal contamination is reconstructed from a sediment core with a focus on major and trace metal concentrations. The core collection site, in Harmar Township, is downwind from early industrial activities and downstream from a major highway, the Pennsylvania Turnpike. Reconstruction of the metal deposition history in this sediment core reveals rapid and substantial shifts in metal content coincident with early industrial activities and road construction. Chromium and Zn peak several times throughout the 1800s, likely from local glass manufacturing. Phosphorous, Mo, and W peak in the late 1930s potentially from sediments deposited during the Great St. Patrick’s Day Flood of 1936. The Pennsylvania Turnpike was expanded through Harmar by 1952 and a suite of metal concentrations increase around the same time. Cadmium, Cr, and Cu all increase significantly in the late 1940s and stay elevated for the remainder of the sediment record. Although Cd and Pb remain above pre-industrial concentrations, there is a clear decline in their concentrations since 1946, reflecting the removal of cadmium from tires and lead from gasoline. Calcium, Mg, and Sr increase in the 1990s and remain elevated. This may reflect the installation of smoke stack scrubbers at the nearby Cheswick coal-fired power plant. Reconstruction of trace metal contamination in this core suggest dominant contributions from modern road inputs that eclipse historical industrial inputs.

How Wetland Persistence in the Dry Season Influences Growing Season Length and Cropland Productivity in Southern Africa
Presenter: Lauren Lowman (Duke University / Wake Forest University)*
Co-Author: Ana P. Barros (Duke University)

In Southern Africa, wetlands serve important functions as freshwater storage, sites of groundwater recharge, and arable land areas for planting crops. Previous work evaluated how land-atmosphere interactions in the Upper Zambezi River Basin (UZRB) extended ephemeral wetland areas well into the dry season. Specifically, mid-afternoon convective storms during the transition from wet to dry seasons correspond with wetland presence well into the dry season months in the UZRB. As mid-day temperatures are similar in dry and wet seasons in this region, the expected outcomes of persistent wetland areas include a longer growing season and higher crop yields. However, the role of wetlands as indicators for agricultural outcomes in this region has yet to be studied. By modeling the phenology of wetland vegetation with the Duke Coupled Hydrology Model with Predictive Vegetation (DCHM-PV), we quantitatively determine how growing season onset, length, and end differs for years with high and low wetland persistence. Further, we directly simulate gross primary productivity (GPP), or carbon uptake, to determine how productivity varies across years as a result of varying
wetland extents and lifespans. The goal of this presentation is to better understand coupled human-natural systems where human food requirements are limited by ecosystem water availability. Ultimately, we are building towards a framework to evaluate water demands and forecast ecosystem water availability while balancing needs for agriculture and human health with the needs of the natural environment.

*Geochemical Variability in Roadside Infiltration-Based Green Infrastructure in Pittsburgh, PA*
Presenter: Angela Mullins (University of Pittsburgh)*
Co-Author: Daniel Bain (University of Pittsburgh)

Infiltration-based green infrastructure (GI) has become a popular means of reducing stormwater hazards in urban areas. However, the long-term effects of green infrastructure installation on geochemistry in unique roadside environments are poorly defined, particularly given the considerable roadside legacy metal contamination (e.g., lead). Most current research on GI geochemistry is restricted to relatively short time periods or limited sets of chemical species. This limits our understanding of these systems that evolve as they age and are strongly influenced by seasonal mechanisms. This work evaluates chemical transport in two infiltration trenches in Pittsburgh, PA, specifically infiltration rates and dissolved contaminant concentrations through time. Trace metal concentration patterns seem to be driven by road salt application in the winter and the emergence of reduced aqueous environments during the summer. Further, seasonal patterns in chemistry interact with road sourced and legacy metal contamination and seem to increase trace metals content for specific metals at different times of the year. Accurate characterization of GI geochemistry requires year-round measurement of a broad range of chemical species to capture relevant variability.

*Characterizing Hydraulic and Geologic Controls driving Knickpoint Migration in a Channelized Western Iowa Stream*
Presenter: Thanos Papanicolaou (University of Tennessee)
Co-Authors: Benjamin Abban (University of Tennessee), John Thomas (Hungry Canyons Alliance), Christopher Wilson (University of Tennessee), E. Arthur Bettis III (University of Iowa), and Mohamed Elhakeem (Abu Dhabi University)

Estimates of knickpoint migration in intensively managed landscapes are normally made under the assumptions that surface erosion processes are the predominant driving mechanisms. However, field evidence suggests that subsurface processes can also play a significant role in knickpoint migration. This study examines controls on the migration of a knickpoint in the Deep Loess Region of Iowa, USA, over five-and-a-half year periods in which it migrated 48 m despite persistent lows flows observed throughout the period. The knickpoint was monitored from May 2006 – November 2011 using repeat channel surveys, photographs, and a laser distance sensor. Geologic controls at the site were established using field and laboratory characterization of borehole cores, while surface hydraulic conditions were determined using stage/flow measurements. Estimates of knickpoint migration assuming dominant surface erosion driven control could only account for 38% of the total migration. This study explores additional geologic controls that explain the remaining 62% of the migration, and examines the importance of accounting for these controls in intensively managed systems with hydraulic and geologic characteristics similar to the one studied. A detailed account of the processes that resulted in the net migration rate is constructed and presented.

*Critical Zone Observatories: Studying where rock meets life*
Presenter: Sarah Sharkey (Pennsylvania State University)

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 meet. Critical Zone Observatories (CZO)s, supported by the U.S. National Science Foundation’s Geosciences Directorate, are natural laboratories that aim to provide infrastructure, data, and models to gain an understanding of the evolution and function of the CZ from grain-to-watershed scales. Nine U.S. observatories span a range of climatic, ecologic, geologic, and physiographic environments from California to Puerto Rico, working on site-specific hypotheses and network-scale goals. Each observatory strives to apply common infrastructure, protocols, and measurements that help quantify the composition and fluxes of energy, water, solutes, sediments, energy, and mass across boundaries of the CZ system through both space and time. CZO research infrastructure allows for teams of cross-disciplinary scientists at each site to further CZ science using field and theoretical approaches, education and outreach, and cross-CZO science. Cross-site research initiatives have been actualized through data collection campaigns, post-doc research, and student funding aimed at cross-CZO questions. The CZO network includes a national office and funds to develop international collaborations, and currently is working to develop strong ties with entities including
the LTER network and CUAHSI.

Legacy Metal Contamination Transfer to Agricultural Soils During Basin Sediment Dynamics  
Presenter: Rebecca Tisherman (University of Pittsburgh)*  
Co-Author: Dan Bain (University of Pittsburgh)

Legacy trace metal contamination of soils is a documented global problem that affects environmental systems, including food security risks when the metals interact with agricultural systems. However, remobilization of metal contamination and the chemistry of fluvially transported, eroded sediments are not well understood. The resulting risk to prime agricultural areas from the erosion and sedimentation of legacy contaminated sediments is also not well documented. Legacy heavy metal contamination in Yunnan, China has existed since metallurgy started around 1500 B.C., and has been widely studied in regional lake core records. A spatial estimate of the amount and type of contamination in the study watersheds of Yunnan, China is derived from the previously sampled lake cores, reconstruction of metallurgy location and intensity from historical maps, and meta-analysis of modern soil chemistry data. To estimate the sediment erosion, erosion matched to regions of legacy contamination, and the mobilization of legacy metals, GeoWEPP, a soil erosion modelling system, is utilized. These data are subsequently used to predict the chemistry of the sediments in the stream and then reconstruct contaminant loadings to agricultural lands. Quantification of historical rates of metal contamination clarifies a fundamental driver of modern crop contamination risk.

Understanding Hydrobiogeochemical Dynamics Using an Upscaled Simple Model  
Presenter: Hang Wen (Pennsylvania State University)*  
Co-Author: Li Li (Pennsylvania State University)

Complex process-based models have been developed to explicitly understand the regulation of hydrological processes on solute transport and mineral dissolution/weathering. However, the application of complex process-based models is still quite limited, due to the demand on a large number of model parameters and field data, and high computational and labor cost. In this work, we developed an upscaled simple model to answer two questions: 1) what are the key parameters/processes that capture hydrobiogeochemical dynamics at the watershed scale? 2) How much dynamics can we capture using the simple model? We focused on the discharge, the nonreactive chloride (Cl) and reactive magnesium (Mg) in the Susquehanna Shale Hills Critical Zone Observatory (CZO). Results show that the upscaled simple model captures the trends of discharge, and concentrations of Cl and Mg in stream. Sensitivity analysis reveals that the most dominant soil type plays a critical role in capturing hydrobiogeochemical dynamics. Considering that stream hydrology and chemistry data have become largely available, this simple model can be a potential tool for further exploring the general principles across different CZOs.

Hydrologic Partitioning Across the CZO Network: Transforming Knowledge of Water and Energy Fluxes Through Earth’s Living Skin  
Presenter: Adam Wlostowski (University of Colorado)  
Co-Authors: Ciaran Harman (Johns Hopkins University) and Noah Molotch (University of Colorado)

The capacity of the critical zone to store and transmit water and water potential is central to many landscape functions in the short term, and to critical zone evolution over the long term. However, understanding the mechanisms linking critical zone architecture and water storage/transmission is often hampered by inadequate subsurface characterization. Consequently, despite a multitude of small catchment studies, we still lack a deep understanding of how variations between landscapes’ critical zone architecture lead to variations in hydrologic states and fluxes. As a way forward, this study characterizes the hydrologic dynamics of fifteen intensively studied catchments of the NSF’s Critical Zone Observatory (CZO) Network. The CZOs are collecting datasets that simultaneously characterize the physical, chemical, and biological architecture of the subsurface, while also monitoring common hydrologic fluxes such as streamflow, precipitation, and evapotranspiration. The goal of this work is to 1) synthesize hydrologic data from across the CZO network, providing a network-level quantitative summary of hydrologic behavior, and 2) generate and inspire testable hypotheses for how CZ architecture controls (and is controlled by) water storage and transmission.
3-D Modeling of the Coevolution of Landscape and Soil Organic Carbon in Intensively Managed Agricultural Landscapes
Presenter: Qina Yan (University of Illinois Urbana-Champaign)*
Co-Authors: Dong Kook Woo (University of Illinois Urbana-Champaign), Praveen Kumar (University of Illinois Urbana-Champaign, China Academy of Sciences), Phong V. V. Le (Vietnam National University, and Timothy Filley (Purdue University)

Soil, as the largest reservoir of carbon in the terrestrial system, is going through rapid erosion due to anthropogenic influences. Understanding how erosion-induced soil organic carbon (SOC) redistribution influences SOC stock and transformation is critical to our food security and adaptation to climate shift. The important roles of erosion and deposition on SOC dynamics have drawn increasing attention in the past decades, but quantifying such dynamics is still challenging. Here, we build a process-based 3-D model that couples landscape evolution, surface water runoff, organic matter transformation, and soil moisture to understand the SOC dynamics by natural forcing and farming practices. We applied this model to a sub-catchment at the Clear Creek Watershed in Iowa. It shows that in an agricultural landscape, the physical SOC transport is dominant on SOC dynamics rather than the biogeochemical transformation. At depositional sites, the vertical SOC profiles have 'bumps' mainly caused by fast SOC deposition. This is consistent with the soil cores sampled at the same sites. In general, the rate of SOC decomposition at erosional sites is slower than the rate of accumulation from plant residues, and vice versa at depositional sites. This implies local net atmosphere carbon sink at erosional sites and source at depositional sites, but exceptions exist. Further, the mechanical mixing arising from tillage enhance SOC stock at erosional site and reduces SOC stock at depositional sites. This study not only helps us understand the SOC cycle but also serves as an instrument to develop practical means for protecting carbon loss by human activities.

Capturing landscape surface roughness effects on the connectivity and travel times of water and sediment fluxes in intensively managed landscapes
Presenter: Shengnan Zhou (University of Tennessee Knoxville)
Co-Authors: Thanos Papanicolaou, Benjamin Abban, Christos Giannopoulos, and Christopher Wilson (University of Tennessee)

This study is evaluating the effects of landscape surface roughness attributes on the connectivity and travel times of water and sediment fluxes in intensively managed landscapes (IMLS). We follow a three-pronged approach that utilizes (a) ultra-high resolution surface roughness data collected for mapping and characterizing the landscape (b) field-based observations of water and sediment fluxes, and (c) state-of-the-art numerical modeling that captures the space/time variant resistance effects of landscape attributes for scaling up the findings from the field-based component of the study to larger, watershed scales. The study site is the South Amana Sub-watershed, located in the headwaters of the Clear Creek Watershed, which is part of the Critical Zone Observatory for Intensively Managed Landscapes. An enhanced version of the Water Erosion Prediction Project (WEPP) model has been developed to account for space and time variant hillslope roughness effects on flow due to changes in landscape attributes and curvature along the hillslope profile. This model has been demonstrated to be particularly beneficial in IMLS, where an assumption of space/time invariant resistance can lead to errors of up to 65% in predicted fluxes. On-going field-scale efforts are being used to generate high-resolution DEMS and material flux data for characterizing the travel time distributions of different soil size fractions, including micro and macro aggregates, under different types of roughness. The study will also be performed in the Upper Sangamon River Basin (also part of the Critical Zone Observatory), which is distinctly different in terms drainage network characteristics, for comparing and contrasting of the effects of human activity under different types of landscape conditions.
General Water Science

Learning About Water - Interactive Computer Modules for Understanding Groundwater Flow and Transport
Presenter: Andy Banks (University of Kansas)*
Co-Author: Mary C. Hill (University of Kansas)

In this work, flow and transport through groundwater systems are communicated to students through interactive visualizations focused on students learning how the underlying physics connect model input values to the resulting heads, flows and motion of particles. These interactive visualizations include the effects of confined and unconfined conditions, illustration of potentiometric surfaces and water tables, the effects of pumping and the transport of particles from three origination sites. Students need to figure out how much can be pumped without capturing too many particles given different values of hydraulic conductivity, storage properties, pumping rates and recharge rates. The visualization will also provide a framework for displaying the use of advanced mathematics to illustrate main features of dynamic groundwater systems, such as Lyapunov vectors, but that is for a different audience entirely.

Impacts of preferential flow on pumping-induced groundwater salinization in nearshore volcanic aquifers
Presenter: Xiaolong (Leo) Geng (University of Delaware)

Groundwater is an important resource for drinking, irrigation, and domestic and industrial needs. In coastal regions, pumping groundwater from aquifers can cause saltwater intrusion, and therefore threatens nearshore freshwater resources. In volcanic aquifers, the hydrogeologic system is characterized by lava flows which can form continuous, connected geologic structures in the subsurface. Understanding the role of this geological heterogeneity and associated preferential flow in groundwater salinization due to nearshore pumping is essential for effective assessment and management of water resources in coastal volcanic aquifer systems (e.g., volcanic Hawaiian Islands). In this study, surface-based geostatistical techniques were adopted to generate geologically-realistic model realizations of hydrogeologic systems in volcanic aquifers. The density-dependent groundwater flow and solute transport code SEAWAT was used to perform 3D simulations to investigate pumping-induced saltwater intrusion through these random realizations. Our results show that nearshore groundwater pumping in volcanic aquifers causes significant landward horizontal movement of salt, due to the geological heterogeneity. The horizontal expansion of salt significantly deteriorates nearshore freshwater resources (especially for the shallow regions of aquifers) and increases the spatial variability of pumping-induced groundwater salinization compared to equivalent homogeneous aquifers. Our results also show that compared to surface-based geostatistical techniques, sequential indicator simulations underestimate the landward movement and expansion of salt due to the nearshore pumping, highlighting the importance of the continuous, connected geologic features in quantifying various groundwater flow and salt transport processes in nearshore volcanic aquifers.

Choosing hydrologic signatures for model evaluation and catchment description: an approach based on ecosystem services theory
Presenter: Hilary McMillan (San Diego State University)
Co-Author: Ida Westerberg (IVL Swedish Environmental Research Institute)

Hydrologists frequently need to evaluate whether their computer models or theories properly represent catchment function, and frequently seek to compare catchment function across time or space. An increasingly popular method for model evaluation and catchment description is to use ‘Hydrologic signatures’: metrics based on hydrologic data that quantify individual aspects of catchment function. By linking individual signatures to individual parameters, this method reduces the high dimensions of the model selection and calibration problem. The increased use of hydrologic signatures raises the question of how to choose which signatures to use. A very large number of signatures have been proposed, and authors often select appropriate signatures based on those used in previous studies, and using broad requirements such as capturing a wide spectrum of hydrologic behaviors (e.g. high and low flows, flow timing). However, a lack of agreement on signature choice has led to multiple different, sometimes partially overlapping, sets of signatures used by authors seeking to evaluate models and theories. In this paper, we propose the use of ecosystem services theory as a framework to determine standard sets of hydrologic signatures that fully capture catchment function. Using the Millennium Ecosystem Assessment classification, we divide water-related services into Provisioning, Regulatory, Cultural and Supporting types. We demonstrate that these ecosystem services can be matched to the hydrologic processes that control water movement through the hydrologic cycle, and therefore used to define a common set of signatures. We believe that increased agreement on signature choices will facilitate structured model evaluation and easier comparison between hydrological studies.
Adsorption of Pharmaceuticals using Surfactant Modified Palygorskite-Montmorillonite Clay Particles
Presenter: Emmanuel Tetteh (Miami University)*
Co-Authors: Mark P. S. Krekeler, Jonathan Levy, and Neil D. Danielson (Miami University)

Pharmaceuticals and endocrine disrupting compounds (EDCs) are among the most frequently detected organic micropollutants in natural waters. One of the main drivers of pharmaceutical pollution in the aquatic environment is the inability of wastewater treatments plants to effectively remove these contaminants. There is a demonstrated need to improve the removal efficiency of these contaminants to protect both public and ecosystem health. Clay minerals are inexpensive materials that have been used for the removal of water contaminants due to its high cationic exchange capacity and surface area. However, because of their hydrophilic nature, their use for the removal of organic contaminants is restricted. One way of overcoming this limitation is by surface modification of the clay mineral through surfactant-intercalation. Preliminary investigations on the sorption of four pharmaceuticals (atenolol, carbamazepine, ibuprofen and sulfamethoxazole) and two EDCs (bisphenol A and prednisolone) were performed using two anionic (RA-600 and sodium dodecyl sulfate), two non-ionic (Brij-58 and Triton X-114), and two cationic (cetyltrimethylammonium bromide, CTAB, and tridodecylmethylammonium chloride, TDMAC) surfactant-intercalated palygorskite-montmorillonite (PM) clay particles. Preliminary results show that the data best fitted the linear and the Freundlich models except for bisphenol A, where the Freundlich and the Langmuir correlated best with the sorption data. The results show that except for atenolol, CTAB-intercalated PM had the highest removal rate of the compounds from water. However, for atenolol, TDMAC-intercalated PM showed an enhanced removal twice that of the CTAB-intercalated PM. The results indicate that surfactant-intercalated PM, especially CTAB and TDMAC-intercalated PM, can be used to improve the removal efficiency of the compounds. Further studies are being conducted using a zwitterionic surfactant-intercalated PM which should have broader applicability for cationic, anionic, and neutral organic compounds.

Improving US national water modeling: an intercomparison of two high-resolution, continental scale models, ParFlow-CONUS and the National Water Model v1.2 configuration of WRF-hydro
Presenter: Danielle Tijerina (CUAHSI)
Co-Authors: David J. Gochis (NCAR), Laura E. Condon (University of Arizona), Aubrey Dugger (NCAR), Katelyn FitzGerald (NCAR), and Wei Yu (NCAR), and Reed M. Maxwell (Colorado School of Mines)

Continental scale hydrology models at high spatial resolution are increasing in application. We compare streamflow output from models developed for the continental US: ParFlow-CONUS using the integrated model ParFlow and a configuration of the National Water Model version 1.2 using the National Center for Atmospheric Research, Weather Research and Forecasting hydro extension package, WRF-Hydro. Accurately representing large domains remains a challenge considering the difficult task of representing complex hydrologic processes, computational expense, and extensive data needs. Intercomparing models helps disentangle process, parameter, and formulation differences. Results show that WRF-Hydro and PF-CONUS generally capture flow magnitude, but WRF-Hydro better captures flow timing. Spatial differences exist as well—both models accurately simulate the humid east, but struggle with the Great Plains and intermountain west. Simulations such as these will help improve physical process representation in hydrologic models and give greater confidence in large-scale forecasts.

Upscaling Surface and Subsurface Runoff Process Using a Travel Time Matching Strategy Based on Simulation of Average Velocity: Application to the Ohio River Basin
Presenter: Yuanhao Zhao (Northeastern University)*
Co-Authors: Edward Beighley (Northeastern University)

Computational efficiency is still a challenge for the hydrologic and hydraulic modeling community, especially at continental and global scales. Upscaling is an effective approach to shorten the computational cost. This research presents a runoff flowpath travel-time matching method based on the simulation of average velocities to upscale hydrologic response characteristics of surface and subsurface runoff from fine to coarse model resolutions. Five model resolutions are investigated in this study: 10, 32, 100, 320, 1000 sqkm, where model resolution represents the threshold areas used to define the underlying river network and catchment boundaries. Here, the 1 km2 mode resolution is set as the reference model. A case study in the Ohio River Basin (roughly 500,000 sqkm) is presented using a synthetic 2-year rainfall event. The velocities of surface and subsurface runoff from Hillslope River Routing (HRR) model operating at 1 sqkm resolution is determined using a high-performance computing cluster. Using these simulated velocities and 90-m Digital Elevation Model (DEM), pixel level velocities are determined separately for hillslopes (surface and subsurface) and
Cumulative Probability Distributions (CDFs) for surface and subsurface travel times based on the gridded 90-m velocities and conceptualized model units representing individual catchments in the HRR model are matched by adjusting surface roughness and subsurface hydraulic conductivity along HRR hillslopes in the courser model resolutions. The beta distribution is applied to approximate the CDF travel time to reduce pixel-level processing time for large model units. Simulated hydrographs at the outlet of the Ohio River Basin for the five coarser model resolutions are shown to have nearly identical peak discharge and time-to-peak discharge values as compared to the reference model. The proposed upscaling method can reduce the computation time by transferring the hydrologic characteristics captured at fine scales to select coarser scale models, where parameter calibration, uncertainty or sensitivity analyses can be performed at a fraction of the computation cost required for the reference model.
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