

Subsurface Biogeochemical Research

SBR/TES Joint Investigators Meeting

May 19, 2020

Paul Bayer, EESSD

Jennifer Arrigo, EESSD

Amy Swain, BSSD



U.S. DEPARTMENT OF
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Office
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and Environmental Research

Welcome

Jennifer Arrigo



Joins ESS team from the U.S. Global Change Research Program's (USGCRP) National Coordination Office

Co-managing SBR + Other

Formerly

- Manager, Climate Monitoring Program (NOAA)
- Deputy Director, Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI)
- Assistant Professor, Atmospheric Sciences (East Carolina University)
- Welcome

2020 ESS PI Meeting Abstract Book

Uploaded to the original ORISE
Registration Page

<https://www.ornl.gov/2020esspi/abstract-book.htm>

Also uploaded to the SBR and
TES web pages

SBR -

<https://doesbr.org/PImeetings/index.shtml>

TES -

<https://tes.science.energy.gov/PImeetings/index.shtml>

**2020 ENVIRONMENTAL SYSTEM
SCIENCE (ESS) VIRTUAL PRINCIPAL
INVESTIGATORS MEETING
ABSTRACT BOOK**

May 19-20, 2020

PI Awards and Publications

2019-2020



European Association of Geochemistry, H.C. Urey Award
J. Banfield (UC Berkeley) – 2020



Fellows

T. Bianchi (U. Florida) – 2019
R. Maxwell (CSM) – 2019
C. Steefel (LBNL) - 2019



2020 Darcy Lecturer
Reed Maxwell (CSM) - 2020



Academy Member
S. Hubbard (LBNL) – 2019



AAAS Fellow
A. Wolfe (ORNL) – 2019

HELMHOLTZ

RESEARCH FOR GRAND CHALLENGES

International Fellow
K. Maher (LBNL) – 2020



Fellows
D. Gochis (UCAR) – 2019

Geochemical Society – Fellows
B. Gu (ORNL) - 2020

Geochemical Society – Exec Editor GCA
J. Catalano (Washington U.)



Member
S. Hubbard (LBNL) – 2020



30 Under 30 List
F. Maina (LBNL) – 2020



PennState
College of Engineering

Engineering Alumni Assoc
L. Li (Penn State) – 2019



Fellowship, Univ Salzburg
I. Larsen (U. Mass) – 2020



Robert G. Wetzel Award
S. Hubbard (LBNL) – 2019

- 123 publications in 2018
- 103 publications in 2019
- 32 publications (so far) in 2020



AMERICAN
SOCIETY FOR
MICROBIOLOGY

American Academy of Microbiology Fellow
M. Podar (ORNL) – 2020

Updated SBR SFA Flyers

2020

LBNL SFA

IDEAS-W Project

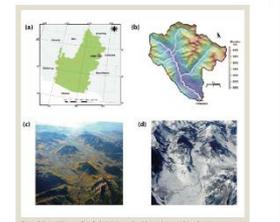
SLAC SFA

PNNL SFA

Watershed Function Scientific Focus Area
watershed.lbl.gov

Biogeological dynamics from genomes to watershed scales

Extreme weather, climate change, drought, fire, and other disturbances are significantly reshaping interactions within watersheds throughout the world. Watersheds are recognized as Earth's key functional unit for managing water resources, but their hydrological interactions also mediate biogeochemical processes that influence water quality and support all terrestrial life. Complex interactions between microbes, minerals, fluids, dissolved constituents, and plants occur across biologically-diverse and terrestrial-aquatic continents. These interactions lead to a cascade of effects on downstream water availability, nutrient and metal loading, and carbon and nitrogen cycling. The nature of these interactions, including their response to disturbance, varies throughout the watershed. Despite significant implications for energy production, agriculture, water quality, and other societal benefits important to U.S. Department of Energy (DOE) energy and environmental missions, uncertainty associated with predicting watershed hydro-biogeochemistry and its dynamic response to disturbance remains high. To address this response to disturbance, water throughout the watershed. Despite significant implications for energy production, agriculture, water quality, and other societal benefits important to U.S. Department of Energy (DOE) energy and environmental missions, uncertainty associated with predicting watershed hydro-biogeochemistry and its dynamic response to disturbance remains high. To address this



Watershed Function SFA research focuses on the snow-dominated, high-elevation East River Watershed of the Upper Colorado River Basin. Anamorph originating from snowmelt feeds much of the Colorado River, which in turn provides water to over 100 million people across seven western states and hydroelectric power to millions, irrigates over 5.5 million acres of agriculture, and supports over 51 million per year of economic activity. The complexity and vulnerability of this river basin to disturbance are emblematic of other high-mountain regions worldwide.

Functional Zone and Scale-Adaptive Approaches
The Watershed Function SFA is advancing a functional zone approach to improve characterization and modeling of hydro-biogeochemical

SFA Grand Challenge and Priorities
The Watershed Function SFA is developing a predictive understanding of how mountainous watersheds retain and release water, nutrients, and metals, with focus on the impacts of drought, fire, crop conversion, and other perturbations on downstream water availability and biogeochemical cycling over seasonal, seasonal, and decadal timescales. The current priorities are understanding how snow accumulation and distribution and snowmelt timing influence water and hydro-biogeochemical dynamics through three research priorities: predicting how snow dynamics impact aggregate water priority 1) and hydro (Priority 2) exports, and defining and testing a functional zone approach (Priority 3) for enabling tractable characterization and prediction of aggregate exports in response to snow dynamics.

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IDEAS-Watersheds Project
ideas-productivity.org/ideas-watersheds

Accelerating watershed science through a community-driven software ecosystem

Water resources are critically important for energy production, drinking water, agriculture, and ecosystem health, and they are under increasing pressure from growing demand, land-use change, and Earth system change. These stresses on the water supply are largely transmitted through the nation's watersheds. To enable a robust, predictive understanding of how watersheds function and respond to perturbations as integrated hydro-biogeochemical systems, challenges in multiscale and multi-physics modeling must be overcome. At the same time, disruptive changes in computer architectures are creating significant uncertainty in programming models. This coalescence of interdisciplinary challenges drives the Interoperable Design of Extreme-scale Applications Software (IDEAS) family of projects to provide community-based approaches to software development. Within the family, the IDEAS-Watersheds project seeks to enhance scientific productivity through an agile approach centered on adapting modern software engineering tools, practices, and processes to build a flexible scientific software ecosystem. By tightly integrating modeling with observations and experiments, the Subsurface Biogeochemical Research (SBR) program, within the Department of Energy (DOE) Office of Biological and Environmental Research (BER), advances systems-level understanding of how watersheds function and translates that understanding into advanced, science-based models of watershed systems.



Research Activities
The IDEAS-Watersheds project is organized around six research activities to address important scientific challenges and advance software development methodologies and engagement in the growing community-driven software ecosystem. The first four of these research activities encompass partnership activities, each undertaken jointly with one of SBR's interdisciplinary Science Focus Areas (SFAs) at Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). They address biogeochemical cycling in streams across a wide range of stream orders in disparate climates and land-use conditions, and exert other controls on hydrological exchange, including interactions among variable river surface elevation ("stage"), hydrogeomorphic setting, and hydrological heterogeneity to determine how these interactions influence river corridor hydro-biogeochemical functions. Models must include land-surface and groundwater processes over domains much larger than the river corridor itself. The partnership

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LBNL Watershed Partnership SFA. Perturbations to mountainous watersheds (e.g., floods, drought, and early snowmelt) impact the downstream delivery of water, nutrients, carbon, and trace metals. Currently, no single model can capture all the relevant processes across this domain at the resolution. The partnership activity with the LBNL SFA aims to develop a multiscale modeling framework that enables

Hydro-Biogeochemical Coupling Mechanisms
Hydrological events such as daily evapotranspiration or flooding modify sediment moisture and transport dissolved solutes such as oxygen, major cations and anions, and trace metals across subsurface

Groundwater Quality Science Focus Area
www.srlac.stanford.edu/sfa

Understanding the hydro-biogeochemical maturity of subsurface interfaces

Groundwater in the western United States is increasingly threatened by intensifying drought and diminishing snowpack. The loss of subsurface moisture promotes oxidative transformations of trace metals such as iron, manganese, and copper, which are important both to microorganisms and, in some cases, as contaminants. Molecular transformations of these metals—mediated by microbial and abiotic processes—degrade groundwater quality, providing a major threat to water resources and, thus, U.S. energy and economic security. Moreover, hydro-biogeochemical processes promote the spread and persistence of uranium and radium in groundwater at contaminated Department of Energy (DOE) legacy sites, which are a major concern in mining-reprocessed and drought-stressed hydrological systems.

Key Concepts and Vision
The SLAC SFA is investigating the mechanisms by which hydrological and biogeochemical processes couple in flowpaths to understand their impact on groundwater quality. Accurate, observationally validated, molecular-scale process understanding is essential for predicting changes in groundwater quality and flowpaths subsurface functions over time and space in response to intensifying drought, warming soils, and more intense storm events. This program advances understanding of three key concepts:

- Subsurface flow events (seasonal, daily, or episodic) activate biogeochemical reaction networks and trigger myriad molecular-scale microbial and geochemical responses.
- Subsurface interfaces are the nexus where flow and biogeochemical reactions couple to control hydrological-groundwater quality.
- Reactive transport modeling provides a path for predicting groundwater quality responses to long-term hydrological and temperature changes in the Earth system.

Better understanding of these central concepts will transform the ability to forecast and manage subsurface groundwater quality.

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Translating Process Science to Policy
SFA research includes field-scale, integrated spatial scales, and an efficient multiscale data integration process in flow-modelling, combined through an iterative learning cycle of integrated models and experiments.

Watershed Disturbances
Watershed functions can be identified by various changes in conditions, including long-term transitions such as land-use changes or

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River Corridor and Watershed Hydrobiogeochemistry Science Focus Area
rivercwf.srlac.gov

Understanding and quantifying the role of river corridors in watershed function and dynamics

Exchange of water between rivers and the surrounding subsurface environment is a vital aspect of watershed function. These hydrological exchange flows (HIFs) stimulate biogeochemical activity in the subsurface adjacent to the river channel through provision of nutrients, mixing of dissolved reactants, and exposure to microbes. They also modulate water temperatures and thus play a key role in water quality, surface dynamics, and energy and material fluxes.

There is strong evidence that river corridor hydrobiogeochemical processes are highly variable among different river orders and climates, ecologies, and geographical settings; these processes are also hypothesized to be highly sensitive to various environmental and anthropogenic disturbances including floods, drought, wildfires, land-use changes, and water use and management. A science focus area (SFA) program led by Pacific Northwest National Laboratory (PNNL) aims to predict river corridor and watershed system responses to disturbances at scales relevant to natural water challenges. The SFA is supported by the Department of Energy (DOE) Office of Biological and Environmental Research (BER) as part of BER's Subsurface Biogeochemical Research (SBR) program.

The SFA is performing studies over various settings and scales within the Columbia River Basin (CRB) in the Pacific Northwest and in other major river basins across the contiguous United States, via inter through collaborations with other SBR SFAs. Research activities within the SFA focus on understanding processes in the river corridor— which includes the surface water channel and other functionally connected features such as the hyporheic zone, near-shore groundwater aquifers, and riparian zones— and quantifying their cascading effects at watershed and basin scales.

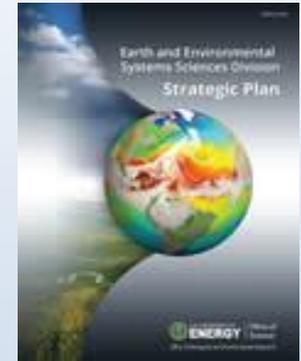
Key Scientific Questions
PNNL SFA researchers are developing mechanistic understanding of coupled hydrologic and biogeochemical processes across a wide range of river corridor and watershed settings and translating that understanding into predictive numerical models. Key research includes:

- How do HIFs, organic matter, chemistry, microbial activity, and watershed disturbances interactively influence river corridor hydrobiogeochemical function and dynamics from reaction to basin scales?
- How can mechanisms that govern river corridor hydrobiogeochemistry be efficiently and sufficiently represented in integrated land surface models at scales relevant to regional and national water challenges?

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<https://doesbr.org/research/sfa/index.shtml>

Earth and Environmental Systems Sciences Division Strategic Plan



Vision: Develop an improved capability for Earth system prediction on seasonal to multi-decadal time scales to inform the development of resilient U.S. energy strategies.

High level Grand Challenges

- **Integrated water cycle** – processes involving atmospheric, terrestrial, oceanic and human system components and their interactions and feedbacks across local, regional and global scales.
- **Biogeochemistry** – coupled biogeochemical processes and cycles across spatial and temporal scales by investigating natural and anthropogenic interactions and feedbacks.
- High Latitudes – quantify the drivers, interactions and feedbacks among the high latitude components and between the high latitudes and the global system.
- Drivers/Responses in the Earth System – next generation understanding of Earth system drivers and their effects on the integrated Earth-energy-human system.
- **Data-Model Integration** – develop a broad range of interconnected infrastructure capabilities and tools that support integration and management of models, experiments, and observations across a hierarchy of scales and complexity.

SBR Program Goals and Objectives

Goal: The SBR program seeks to advance a robust predictive understanding of how watersheds function as integrated hydro-biogeochemical systems and how these systems respond to perturbations such as changes in water recharge, availability and quality; contaminant transformation and transport; nutrient loading and cycling; land use and vegetative cover.

Five Priority Research Objectives:

- Quantify and predict the mechanisms by which hydrology drives fine scale biogeochemical processes and the exchange of water in coupled surface-subsurface systems;
- Quantify how biological behavior and feedbacks and abiotic-biotic interactions leading to molecular transformations influence mobility, transformation, fluxes, cycling, and fate of key nutrients (e.g., N, P, C), inorganic elements (e.g., S, Fe, Mn), and legacy DOE contaminants (e.g., U, Tc, Hg);
- Translate biogeochemical behavior across relevant molecular to watershed scales to accurately and tractably predict flows of water, nutrients, and contaminants;
- Identify, quantify and predict watershed response to natural and anthropogenic perturbations and shifts to new states; and
- Translate predictive understanding of watershed system function and evolution into near- and long-term environmental and energy strategies.



Understanding Integrated Watershed Function

Hydro-biogeochemical Processes

How “watersheds function”

- Structure underpins function
- Function (static) and dynamics
 - Headwaters to the mouth

“Integrated Systems”

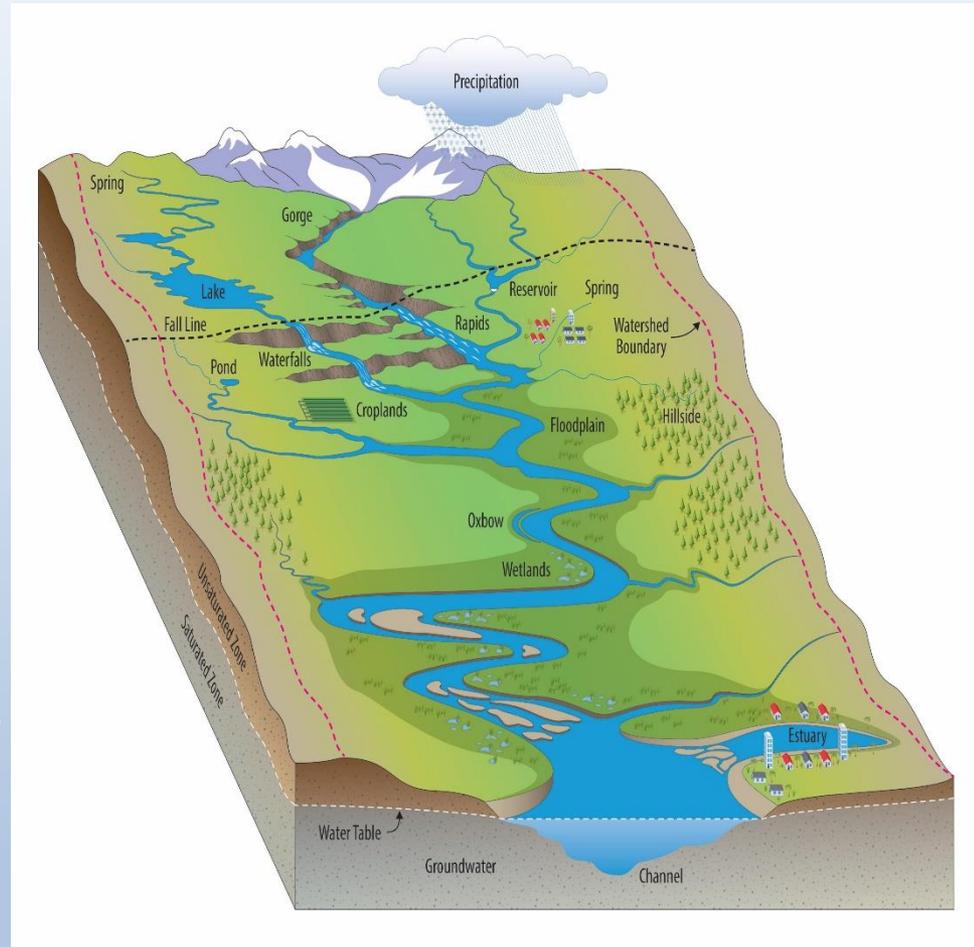
- Surface to subsurface processes

“Hydro-biogeochemical Systems”

- Scales of research
 - Molecular to watershed/basin
- Biotic to abiotic
- Key elements, nutrients, contaminants
 - BGC cycling and transport

“Response to perturbations”

- Water recharge, availability, quality
- Contaminant transformation and transport
- Nutrient loading and cycling
- Land use/change and vegetation cover



“Predictive Understanding”

- Interoperable codes to capture multi-temporal and spatial scales

SBR Science Focus Areas

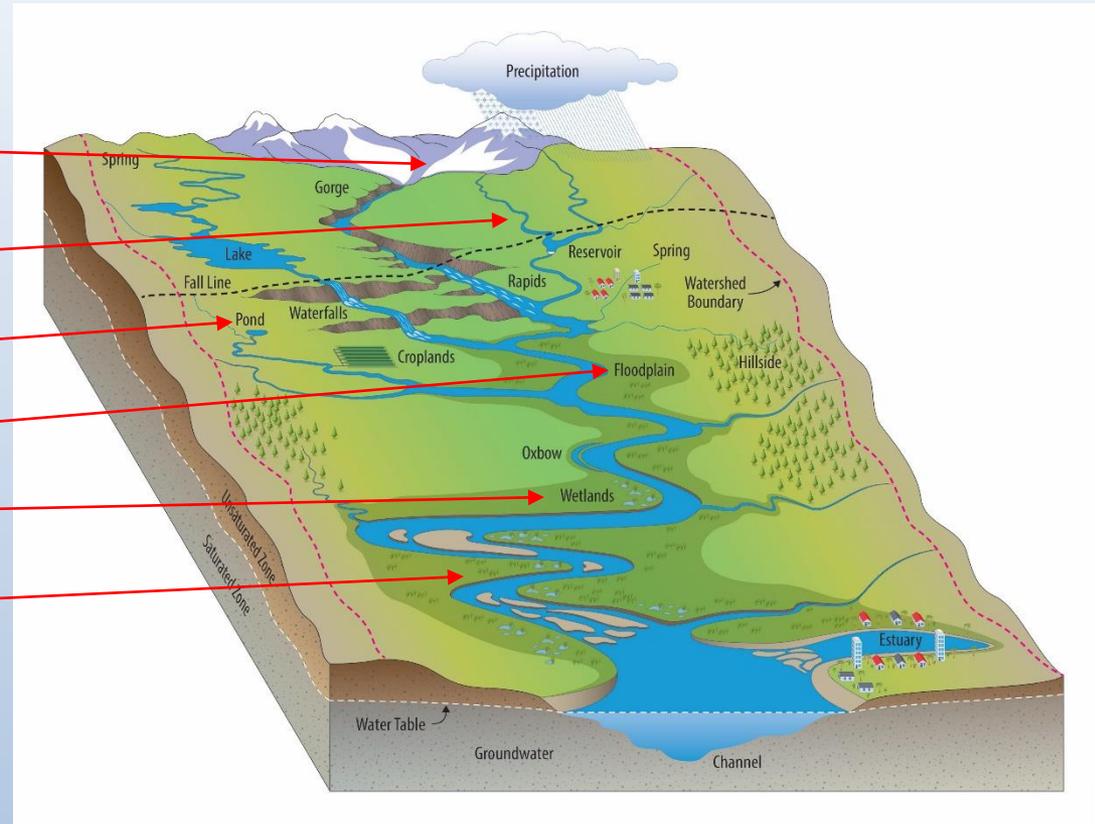
- **LBNL: Watershed Function (\$6.8M)**
 - Hydro-biogeochemical dynamics from genome to watershed scales.
- **PNNL: River Corridor and Watershed Hydro-BGC (\$5M)**
 - Understanding of coupled hydrologic and biogeochemical processes in large, dynamic rivers and associated watersheds and translating that understanding into multi-scale numerical models.
- **ORNL: Biogeochemical Transformations at Crit. Interfaces (\$3.5M)**
 - Determining the coupled hydro-biogeochemical processes controlling mercury transformations in metabolically active transient storage zones in low-order freshwater stream systems.
- **ANL: Wetland Hydro-Biogeochemistry (\$1.2M)**
 - Understanding the mechanisms of hydrologically-driven molecular- to core-scale biogeochemical transformations within redox-dynamic environments and the effect of hydrologically-driven Fe and S biogeochemistry on water quality.
- **LLNL: BioGeoChemistry of Actinides (\$1.1M)**
 - Understanding surface and subsurface actinide behavior to provide a basis for managing transport phenomena and long-term stewardship.
- **SLAC: Groundwater Quality (\$1M)**
 - Investigating the coupling of fine-scale hydrologic and biogeochemical processes in transiently saturated zones and impacts on water quality.

Understanding Integrated Watershed Function

Hydro-biogeochemical Processes

Existing Watershed Testbeds (Res Area 3):

- Mountainous headwaters (LBNL)
- 3rd order stream (ORNL)
- Ponds/Lakes (LLNL)
- Alluvial floodplain (SLAC)
- Wetlands (ANL/SRNL)
- 8th order river (PNNL)



Novel Structural Components of Watersheds (Res Area 4):

- Springs
- Gaining/Losing parts of streams
- Mouth of watersheds

FY19/FY20 SBR-Relevant Solicitations

FY19 ESS FOA 2035

- Two Topics:
 - Ecohydrology/Hydro-biogeochemistry
 - Geochemistry/Biogeochemistry
- Limitations:
 - Complementary to the SBR SFAs
 - Within the contiguous U.S.
- Awards
 - S. Fendorf (Stanford U.), DOM in floodplains (ANL, LBNL, PNNL)
 - M. Ginder-Vogel (U. Wisconsin), Particulate OM (PNNL)
 - Mike Goosef (U. Colorado), Groundwater inflows (PNNL)
 - C. Santelli (U. Minnesota), Fe-S-C cycling in wetlands (ANL)
 - L. Li (Penn State U.), Watershed-scale rate law for chemical weathering and nutrient export (LBNL)

FY20 ESS FOA 2184

- Two TES and Two SBR Topics:
 - Sci Area 3 – Existing Watershed Testbeds
 - Sci Area 4 – Novel Structural Components of Watersheds (Springs, Gaining/Losing stretches and Mouth)
- Limitations:
 - Sci Area 3 – Complementary to SFAs & Exploratory only
 - Both - within the continental U.S.
- SBR Review Panels May 5 and May 7-8, 2020
- Evaluating reviewer comments

FY19 ESS Early Career Solicitation

BER Early Career Solicitation FOA 2019 and Lab 19-2019

- BSSD & EESSD Topics – ESS for FY19
 - Limitations:
 - Complementary to the SBR and TES SFAs or major research projects
 - Within the U.S.
 - Awards:
 - Isaac Larsen, U. Massachusetts, Amherst
 - Abiotic and Biotic Controls on Chemical Weathering Rates and Solute Generation
 - James Stegen, PNNL
 - Multi-Watershed Perturbation-Response Traits Derived Through Ecological Theory
 - Charuleka Varadharajan, LBNL
 - Investigating the Impacts of Streamflow Disturbances on Water Quality using a Data-driven Framework
 - Congratulations!

EPSCoR - Established Program to Stimulate Competitive Research

<https://science.osti.gov/bes/epscor>

FY20 FOA2215 - applications submitted April 7, 2020 (extended)

Federal-State Partnership Program

- Designed to enhance the capabilities of designated states and territories to conduct sustainable and nationally competitive energy-related research
- 25 eligible states plus Puerto Rico, Guam and the U.S. Virgin Islands
- Support fundamental, early-stage energy research collaborations with the DOE national laboratories
- Any research areas relevant to an SC program. Special emphasis on:
 - QIS, Microelectronics, Data science/ML/AI, Energy storage, Plastics recycling

Project Funding

- \$150K - \$250K/year
- Aligned program kicks in 10% of the cost/year

Program Manager (BES) – Tim Fitzsimmons

ESS POC – Paul Bayer

Selections

- FY20 ESS-relevant applications - 6, one split with MSD
- FY19 ESS-relevant applications - 3, none selected
- FY18 ESS-relevant applications – 5, one selected (Rishi Parashar, DRI)

Award Search

<https://pamspublic.science.energy.gov/WebPAMSEExternal/interface/awards/AwardSearchExternal.aspx>

FOA Requirements and Limitations may vary from year to year

FY20 SBR-Oriented SBIR/STTR Solicitation

- **Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR)**
 - Annual Solicitation for Phase I, \$200K/1 yr projects
 - FY20 FOA2145 issued August 12, 2019.
 - Topic 26 - Technologies for Characterizing and Monitoring the Subsurface, Terrestrial Ecosystems and Watersheds
 - Two subtopics
 - Real-Time, In-situ Measurements of Hydro-biogeochemical and Microbial Processes in Watersheds and Subsurface Systems – 11 awards
 - Image Processing Improvements for In Situ Fine Root Measurements – 5 awards
 - Annual Solicitation for Phase IIA and IIB, \$1.1M/2 yr projects
 - FY20 FOA2155 issued October 22, 2019
 - IIA – within original scope; IIB – extension of original scope
 - ESS awards:
 - Vista Clara (E. Grunewald) - Switched-Field Surface NMR for Groundwater Resolution
 - Innovative Wireless (M. Fisher) - Integrated Env. Quality Sensing System (IEQS)
 - Physical Sciences (D. Sonnenfroh) - Ultra-compact Laser Ceilometer for Boundary Layer and Cloud Height Retrievals
 - CARES Act
 - InnoSense (A. Ray) - Portable Nanowire Platform for Quasi Real-Time and Ultrasensitive Detection of Microbes

SC Graduate Student Research (SCGSR) Program

<http://science.osti.gov/wdts/scgsr/>

2020 Solicitation 1: Due May 20, 2020 (extended)

Supplemental Awards

3-12 months conducting part of a doctoral thesis/dissertation research at a DOE lab (not the same as a field site)

Collaborate with a DOE laboratory scientist

BER Coordinator – Jay Hnilo

Environmental System Science - SBR

FY19, Round 1 (SBR)

-No awards

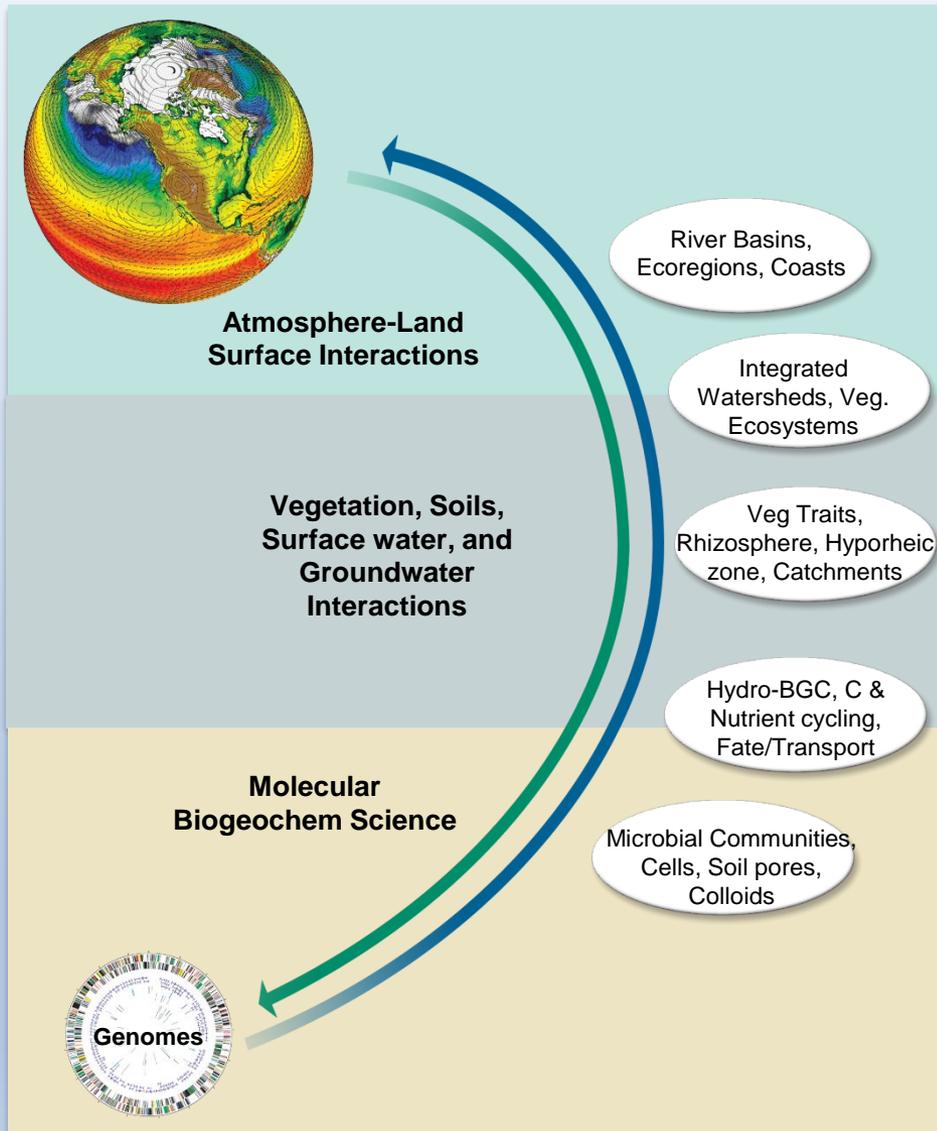
FY19, Round 2 (SBR)

- C. Anderson, U. Massachusetts-Amherst (E. Brodie, LBNL) - Deciphering metabolic constraints on soil carbon oxidation in hydrodynamic floodplain soils using an integrated multi-omics approach
- J. Stoll, Kent State University (S. Brooks, ORNL) – Direct and Indirect Effects of Micronutrients on Methyl Mercury Production

FY20, Round 1

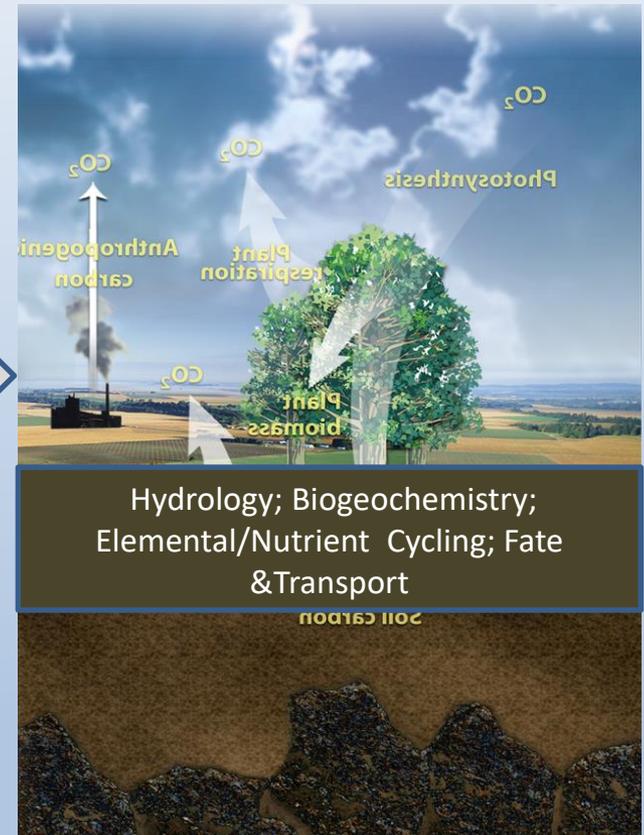
-Due May 20, 2020

Scales of BER Systems Science & ESS Scope



ESS Scope

TES
(Canopy=>Soils, Roots)

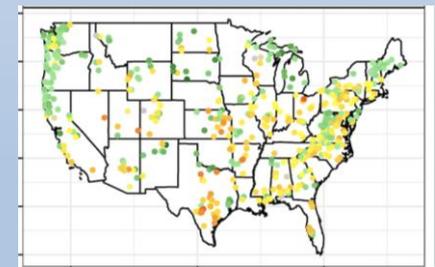
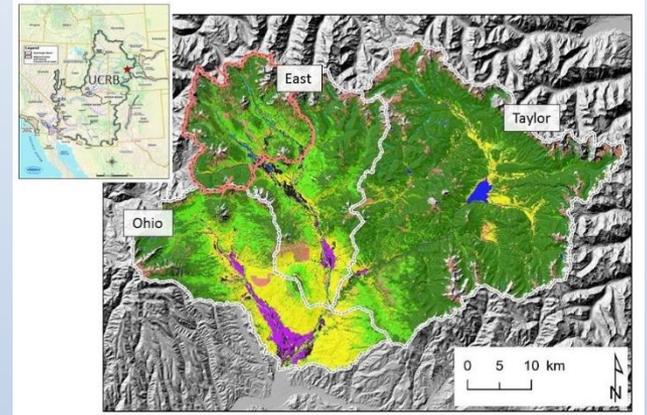


SBR
(Watersheds=>Soils, Sediments, Groundwater)

ExaSheds Pilot Project

ExaSheds Pilot: To advance Watershed System Science using Machine Learning and Data-Intensive Extreme-Scale Simulation

- Pilot initiated in 2019, 4 labs
- Co-led by C. Steefel (LBNL) and Scott Painter (ORNL)
- Funded by Data Management (J. Hnilo)
- Exploring strategies for learning-assisted simulation
 - Development of model inputs from sparse, coarse and indirectly-related information
 - Hybridization of process-resolving simulations and ML
- Working with data from:
 - East River, Colorado
 - Upper Colorado Water Resources Region
 - Continental U.S.
- Adapting DOE-developed watershed simulation tools to leadership-class computer architectures

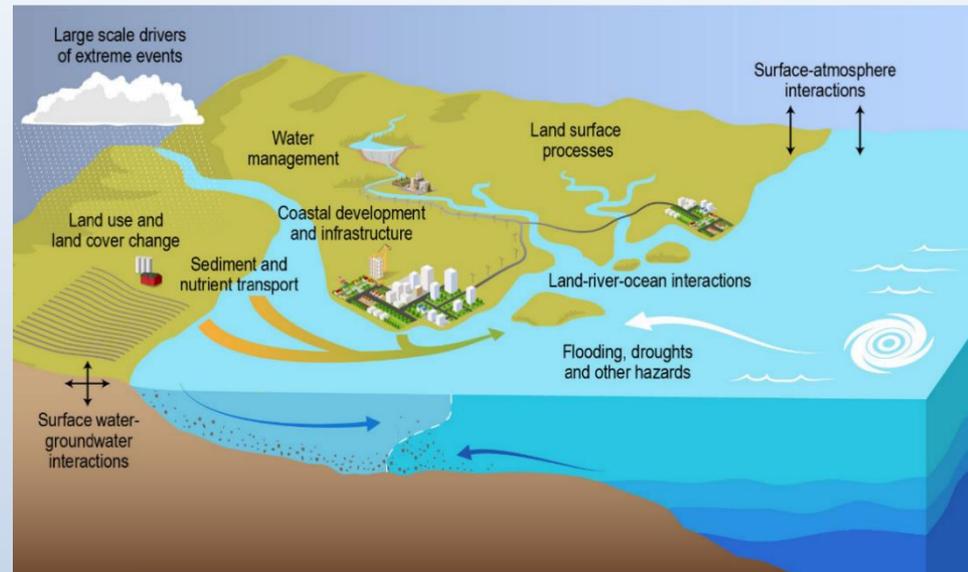


ExaSheds 

Integrated Coastal Modeling (ICoM) Project

“Deliver a robust predictive understanding of coastal evolution that accounts for the complex, multiscale interactions among physical, biological, and human systems.”

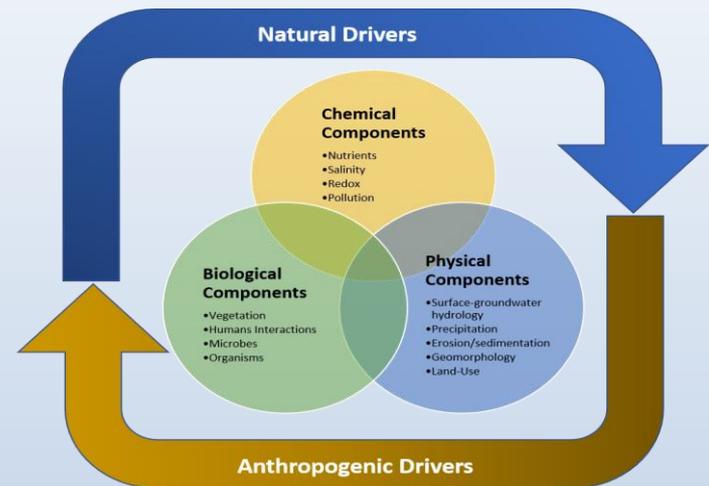
- **PNNL-led multi-institutional team** (LANL a major participant)...>40% funding awarded by PNNL to others
- **Mid-Atlantic regional focus** ... existing DOE capabilities, complex systems interactions, extensive data, and converging interagency activities
- **\$16.2M** over three years (\$5.4M/yr)
- **SBR (\$200K/yr)** to D. Moulton (LANL) for SW/GW interactions and coastal flooding.
- A **“federated” approach** spanning four distinct program areas within DOE’s CESD; requires foundational work in each area and substantial crosscut modeling work.
- **Informs potential follow-on observational and experimental work.**



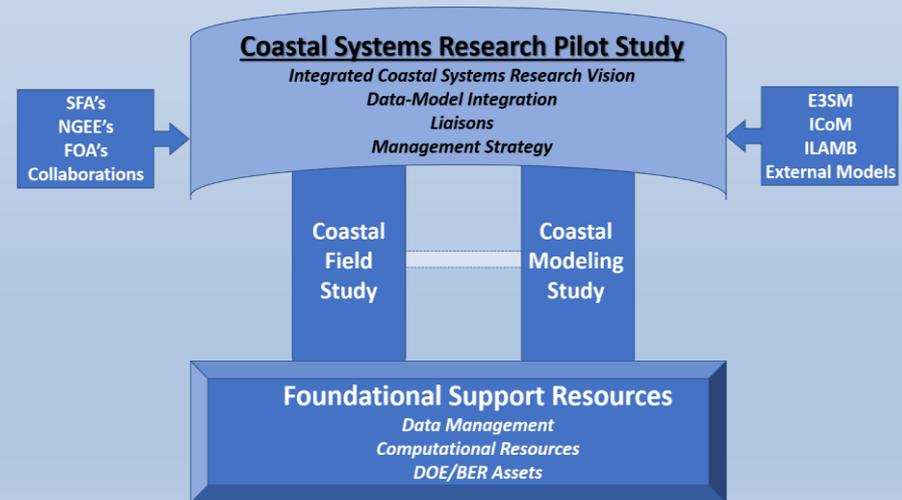
New EESSD “Coastal Systems” Project

FY20 Appropriation

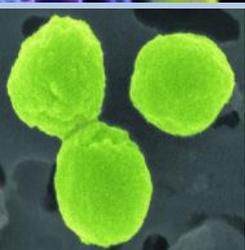
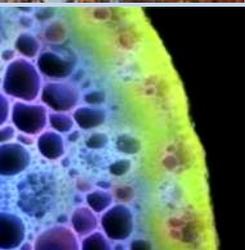
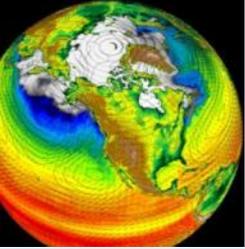
- Congressional direction to fund PNNL
- Most of the EESSD program managers will be involved in preparing guidance and in the future peer review process:
 - Dan Stover – leads team (mostly ESS PMs) for the field research/process modeling study
 - Renu Joseph – leads team (mostly EES modeling PMs) for the Great lakes regional modeling effort.
- Includes funding for mid-range compute resources, data management and software liaisons.



Coastal system components and drivers



Conceptual diagram of project structure



Questions?

Paul Bayer, EESSD

paul.bayer@science.doe.gov

Jennifer Arrigo, EESSD

Jennifer.Arrigo@science.doe.gov

Amy Swain, BSSD

amy.swain@science.doe.gov

SBR Website: doesbr.org

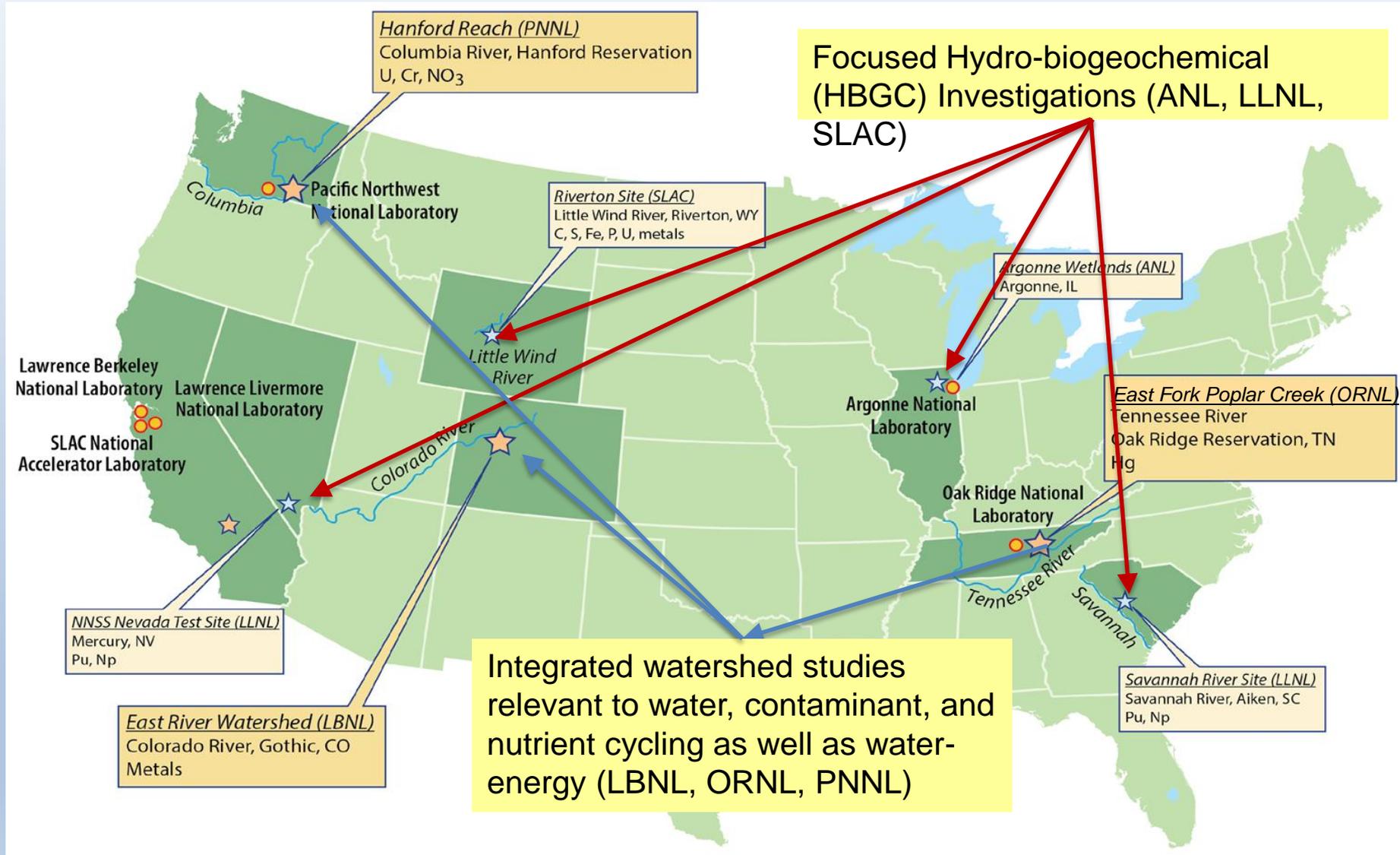


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SBR Network of Complementary Terrestrial Testbeds



IDEAS – Watersheds Project

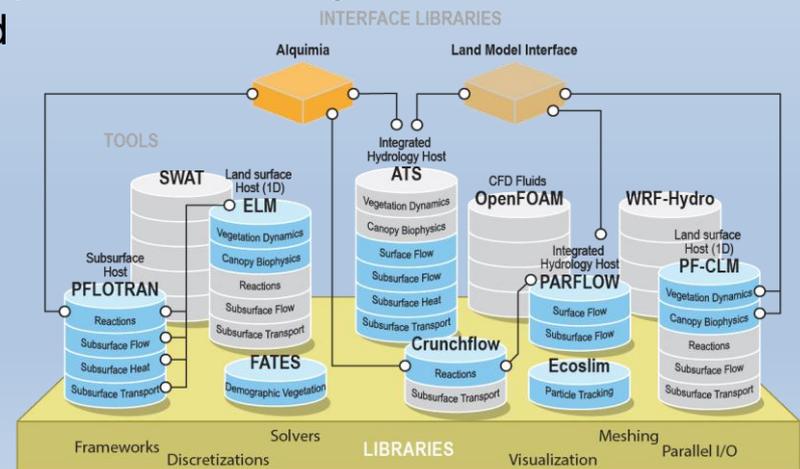
IDEAS – Interoperable Design of Extreme-scale Application Software

- Joint SBR/ASCR funding
- 2014-2018
- A software ecosystem of interoperable components, built on 3 SBR/TES use cases, started with “libraries”
- Spawned IDEAS-ECP, xSDK4ECP and IDEAS-Watersheds
- SW Productivity & Sustainability Plans



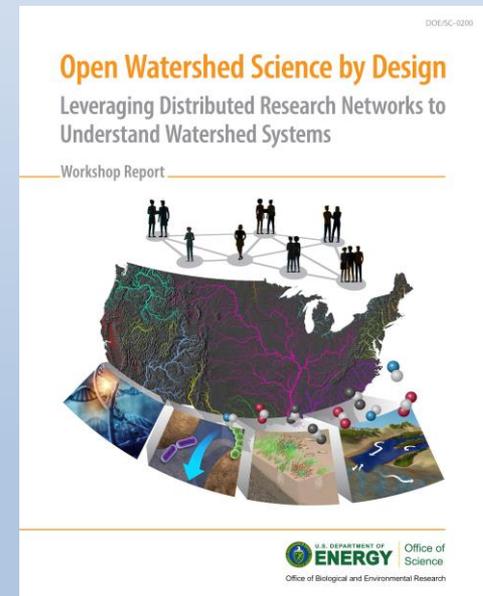
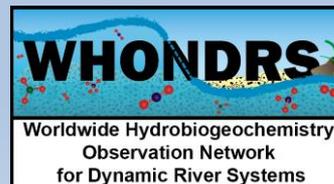
IDEAS – Watersheds

- Reviewed in 2019, 5 labs and 2 universities
- Led by D. Moulton (LANL)
- From Silos to an interoperable systems of codes/code components
- Enable integration of hydro-biogeochemical process modeling across scales
- Designed to address fragmented codes and changing HPC architectures
- Focused on specific several scales
 - Reaction-scale
 - Watershed-scale
 - CONUS-scale
 - Multi-scale
- In partnership with all 6 SBR SFAs



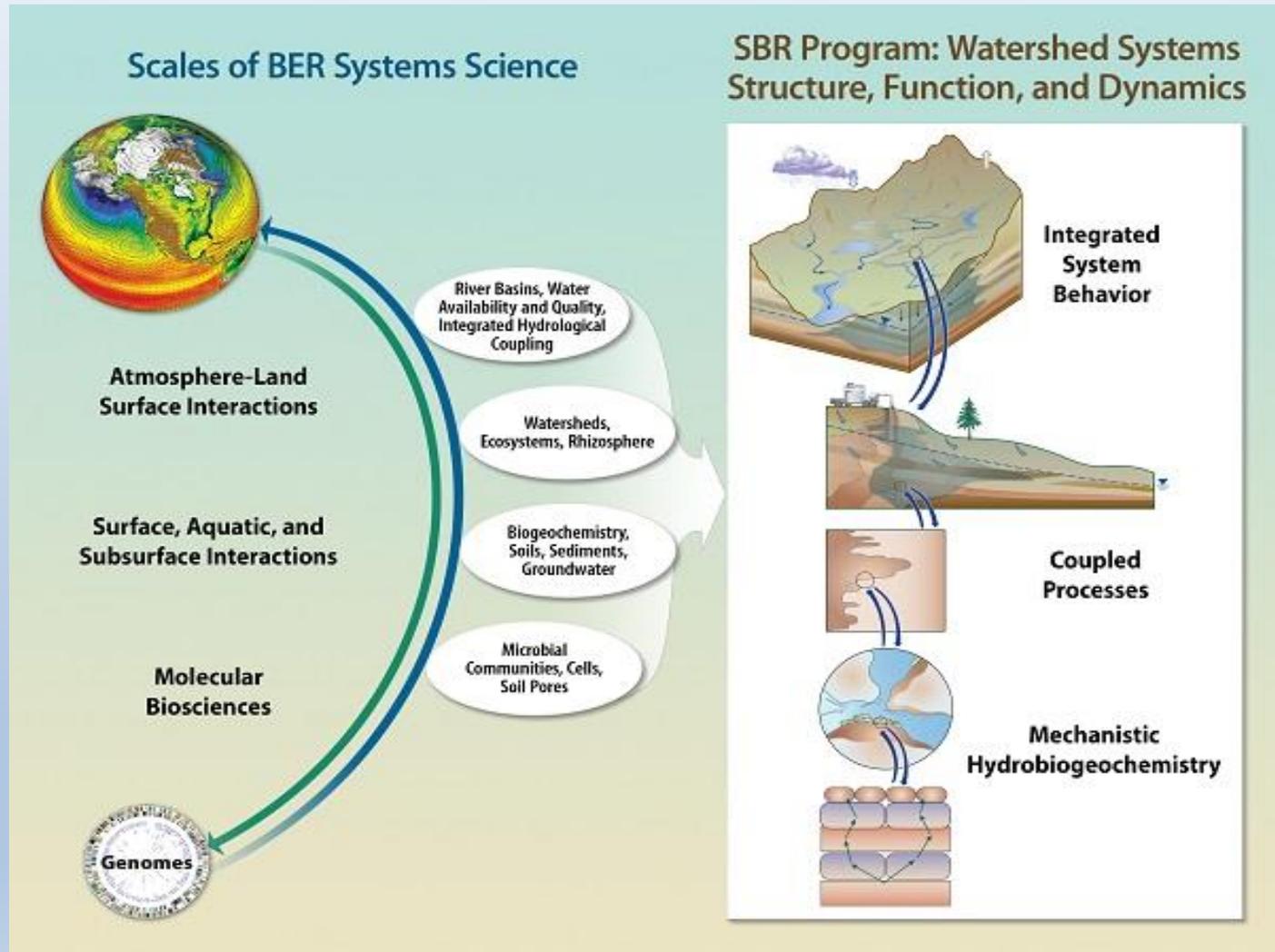
Open Watershed Science by Design & WHONDORS

- SBR Workshop – Jan 2019
- Leveraging Distributed Research Networks to Understand Watershed Systems
- James Stegen, Kelly Wrighton, Eoin Brodie
- In Google Docs reading file
- Presented at the Spring 2019 BERAC meeting & 2019 AGU
- Recommendations
 - Promoting FAIR data principles
 - Introduced ICON data principles
 - Integrated
 - Coordinated
 - Open
 - Networked
- Combines open science data principles with design thinking techniques
- Five use cases to do together what is not possible alone
 - WHONDORS example
 - Reaction-scale
 - Watershed-scale
 - Basin-scale
 - Multi-scale



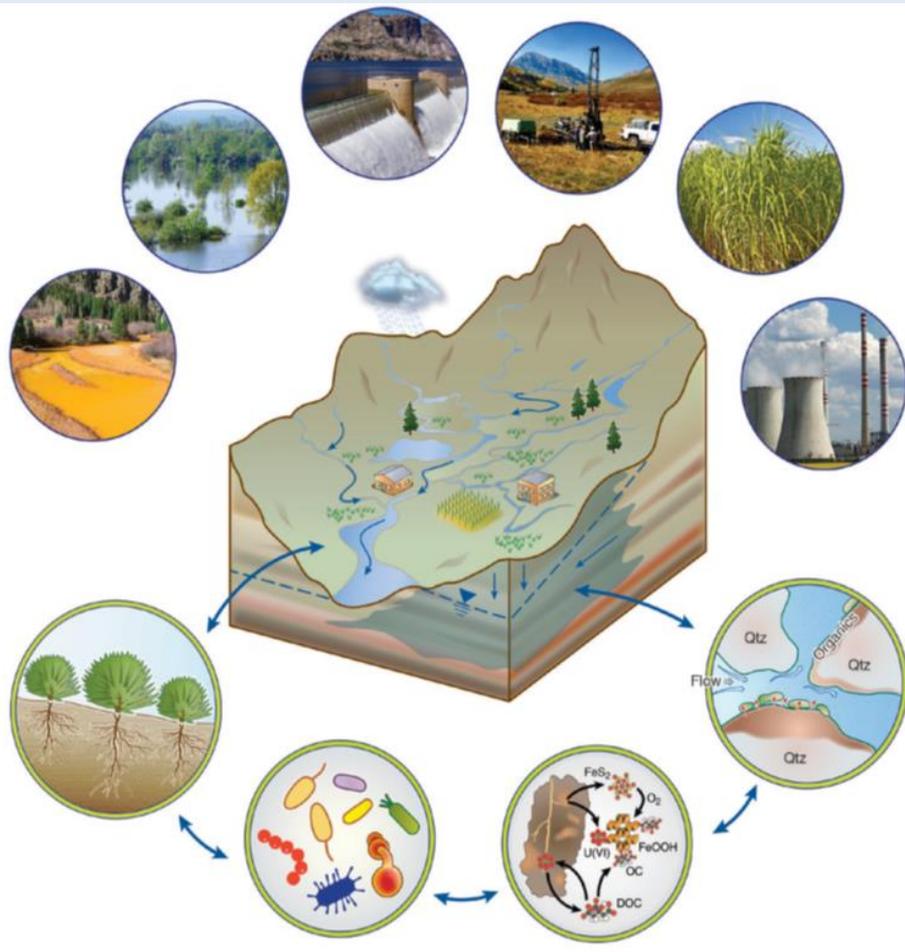
Subsurface Biogeochemical Research (SBR) Program

Predictive understanding of how watersheds function as integrated hydro-biogeochemical systems and how they respond to perturbations.



SBR Program: *Watershed System Science for Energy*

Scientific Understanding Enables U.S. Water and Energy Security



Addressing DOE and National Needs in:

- Contaminant management
- Clean water availability
- Safe storage of energy and nuclear byproducts in the subsurface
- Nutrient availability for sustainable biofuel crops
- Recovery of subsurface energy resources

Advancing a mechanistic understanding of Hydro-BGC that extends from plume to watershed to CONUS scales.