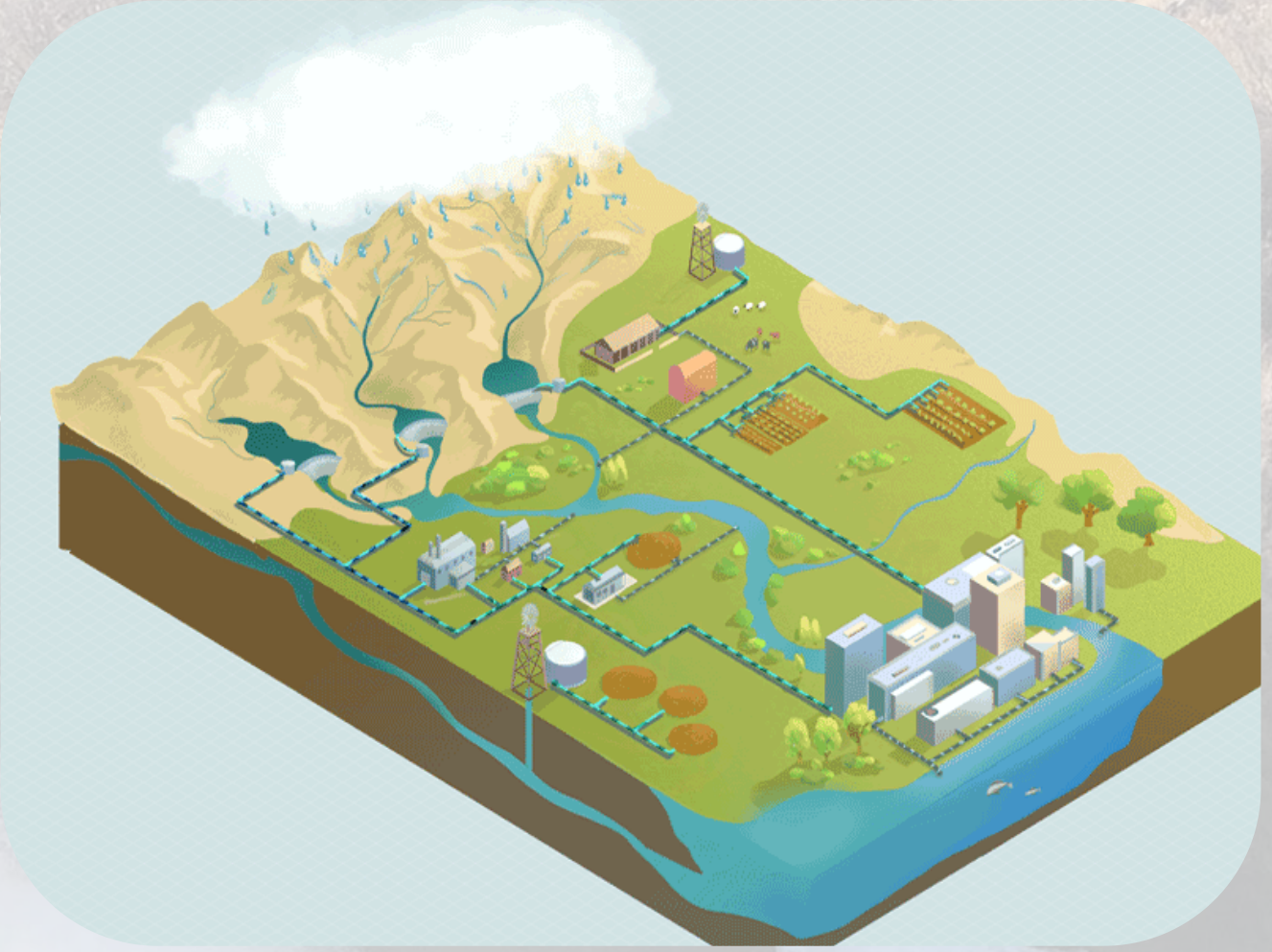
Vision: Hydrological Modeling and Water Resources Management with Machine Learning at the University of Alabama

Dr. Ryan Johnson
Research Scientist
The University of Alabama



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Civil, Construction and Environmental Engineering

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Presentation Outline

- Introduction
- Research Background
- Previous Accomplishments
- Active Areas of Research
- Research Program at the University
- Teaching Goals, Philosophy, Ideas

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Research Program at the University of Alabama

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Data Science and Machine Learning in Hydrology

- Machine Learning and Snow Modeling
- Season-to-Season Water Supply Forecasting
- Orographic Precipitation Gradient Downscaling

Programs for Empowering the Next-Generation of Hydrologists

U.S. National Science Foundation

Bureau of Reclamation

TVA

NOAA Climate Program Office

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Machine Learning for Snow Modeling

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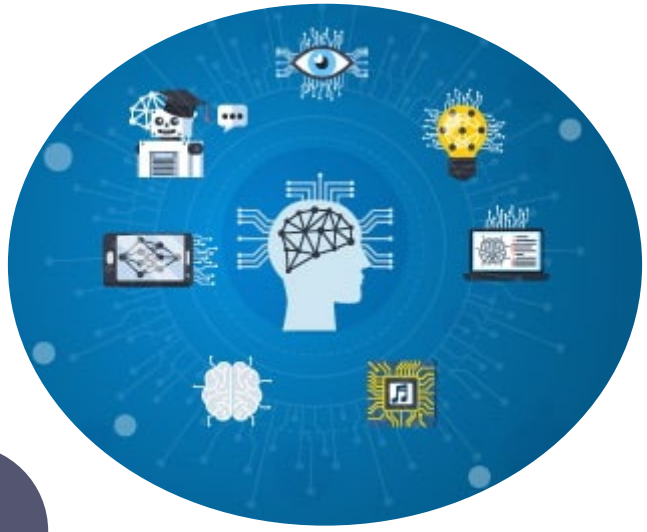
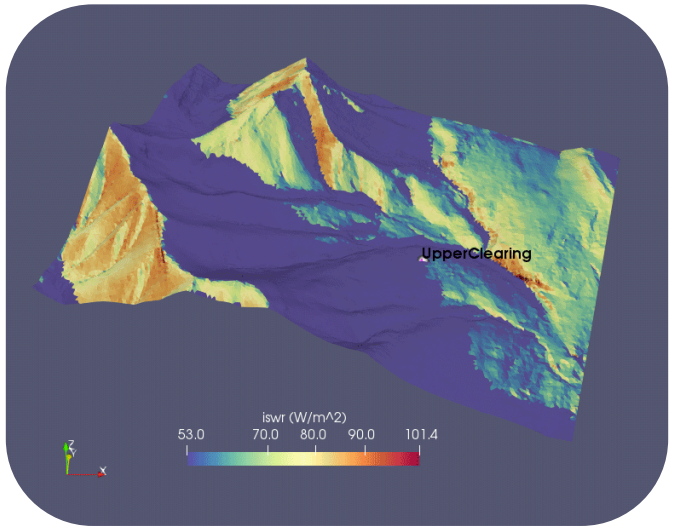
Themes:

- Redefining Snow Modeling Evaluation
- Snow/No-Snow Future
- Physical/ML hybridization
- Inter-model/method comparisons
- Catchment sensing deployment

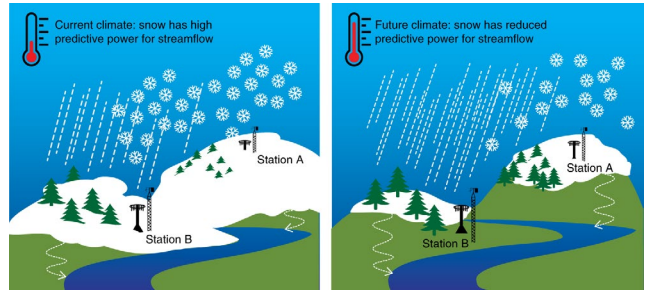
Research Activities:

- Cyber-sand box
- Datasets, products, and visualization
- Data collection
- Algorithm Exploration
- Regional/Spatial/Meshing optimization
- Physics-Informed ML





Marsh et al., 2020



Livneh et al., 2020

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Orographic Precipitation Gradient Downscaling

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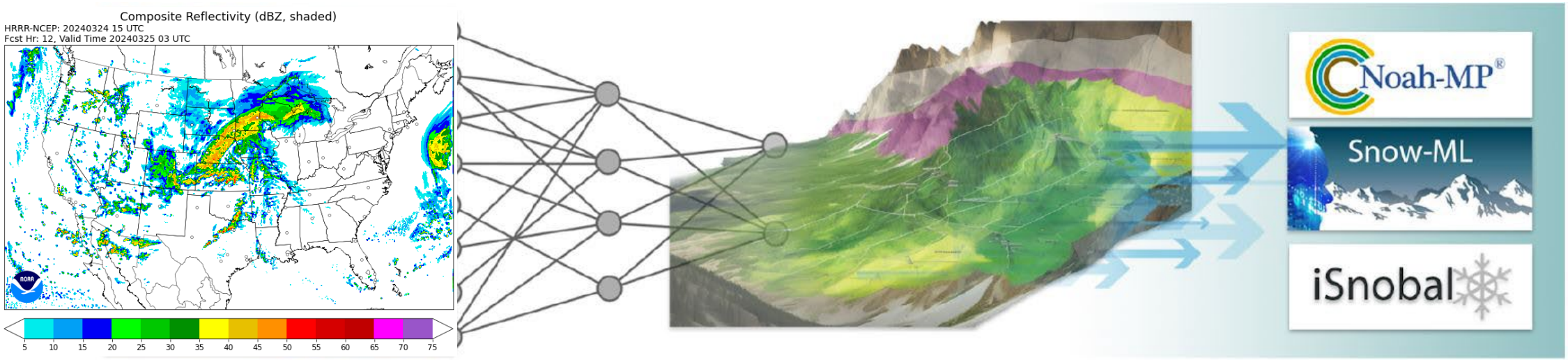

Themes:
- Optimal spatial resolution for precipitation products
- Physical/ML hybridization
- Impacts on snowpack evolution
- Phase partitioning
- Capabilities and applications of ML for downscaling

Research Activities:
- CNNs, other algorithm explorations
- Datasets, products, and visualization
- Citizen Science
- Snow model coupling
- Climate impacts on precipitation quantity and phase

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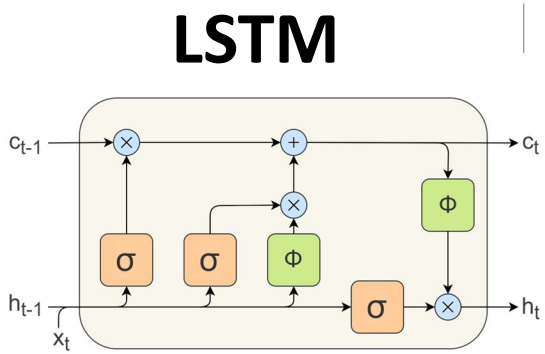
Season-to-Season Water Supply Forecasting

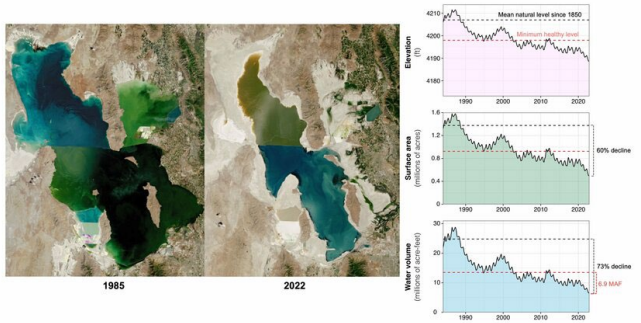
Themes:

- Physics-Informed ML for S2S Forecasting
- Modeling controlled basins
- Water resources management
- Urban Water Systems
- Reservoir operations

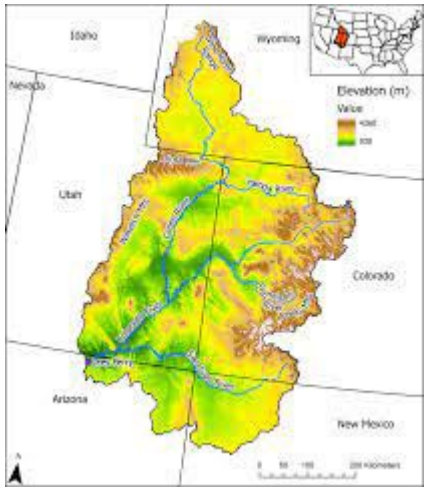
Research Activities:

- Explore and optimize ML Algorithms
- Scale modeling efforts to the Upper Colorado
- Great Salt Lake Management
- Coupled Snow-Streamflow-Management workflows
- Cyber-sand box





Abbot et al., 2023



Miller et al., 2021

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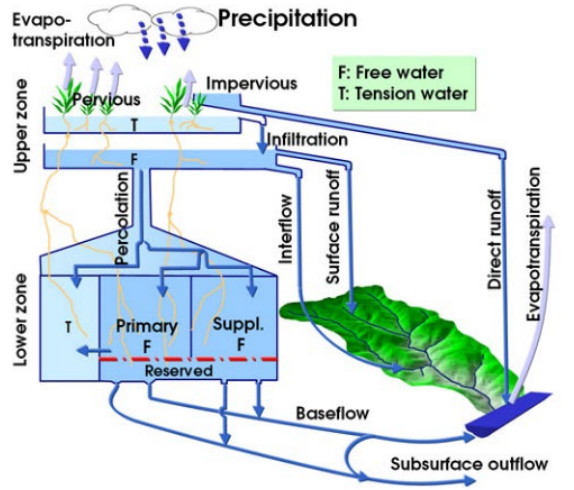
Hydroinformatics: Community Streamflow Evaluation System: CSES

Hub for interactive hydrological model evaluation

- Improve hydroinformatics
- Streamflow models
- Other evaluation tools



Sacramento Soil Moisture Accounting Model (SAC-SMA)

HYDROSHARE

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Programs for Empowering the Next-Generation of Hydrologists

- Networking
- Hands on connections to research
- Leadership
- Hackweeks
- Diversity, Inclusion, Equity

Location: Antelope Island State Park

2023 GeoSMART Hackweet at the University of Washington

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Research Vision: ML in Hydrology

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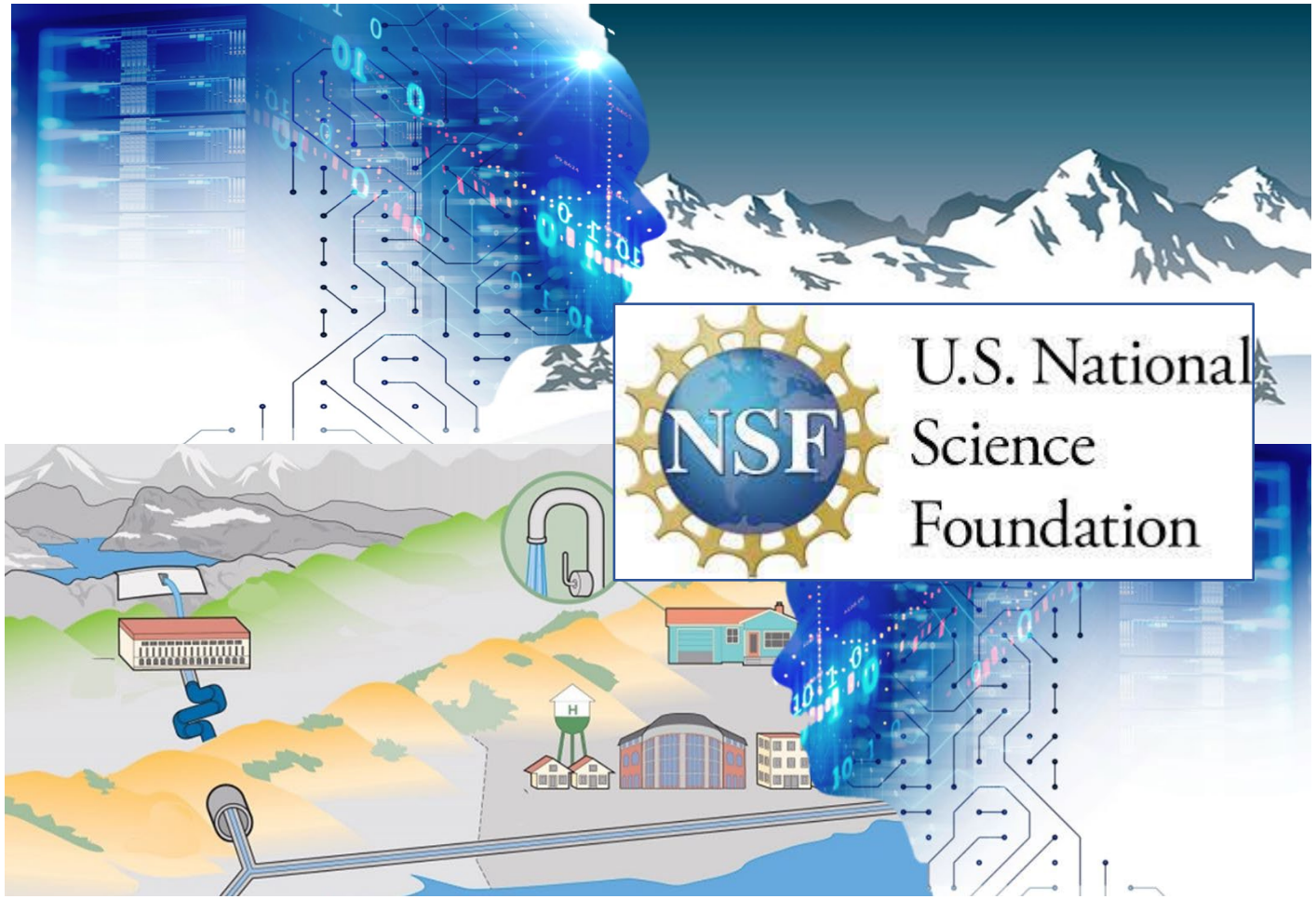
Hydrologic Sciences: Advancing research in Geosciences using Ai/ML

Engineering Directorate: Environmental Sustainability

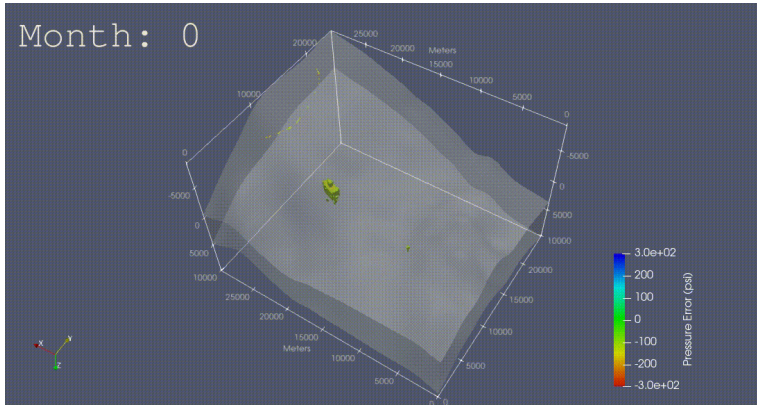
Contact: Hendratta Ali



Other funding Opportunities

BUREAU OF RECLAMATION

U.S. DEPARTMENT OF ENERGY | U.S. DEPARTMENT OF ENERGY Office of Fossil Energy | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY



NSF U.S. National Science Foundation

SEAL OF THE TENNESSEE VALLEY AUTHORITY — TVA — PROGRESS THROUGH RESOURCE DEVELOPMENT — 1933

NOAA CLIMATE PROGRAM OFFICE

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Teaching Goals, Philosophy, and Ideas

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Teaching Goals

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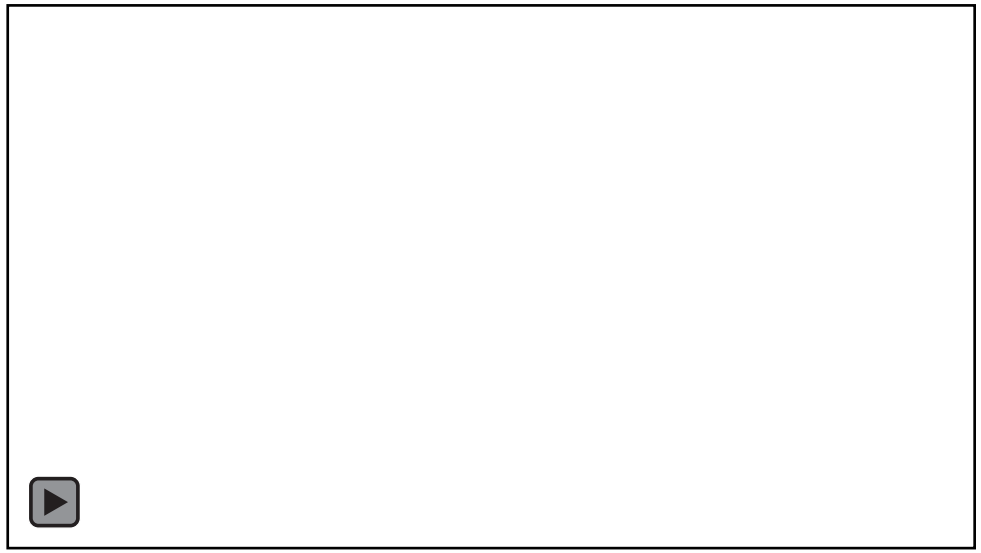
Capable, **confident**, and **successful** students are the product of a University.

1. Intrinsic motivation to learn
2. Fundamental Positive Action principles into students' cognitive, affective, and behavioral learning domains
3. Enhance critical thinking and analytic skills
4. Foster student development and personal growth
5. Be a role model



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Teaching Goals

College of Engineering
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- Develop a lifelong love of learning
- Apply principles, concepts, theories, and generalizations to new problems and situations
- Analytic and problem-solving skills
- Draw reasonable inferences from observations
- Synthesize and integrate information and ideas
- Think holistically: to see the whole as well as the parts
- Think creatively
- Enhance concentration, listening, speaking and writing skills

- Develop appropriate study skills, strategies, and habits
- Learn techniques and methods used to gain new knowledge
- Informed understanding of the role of science and technology
- work productively with others
- Grow management and leadership skills
- Commitment to organization, efficiency, skillful, and accurate work
- Improve ability to follow directions, instructions, and plans
- Commitment to personal achievement
- Improve self-esteem/self-confidence

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Motivation to Teach and Teaching Philosophy

Fundamentals of success learning

- Diagnose problems (topic knowledge)
- Formulate solutions (hypothesis)
- Execute a plan (methodology)
- Confront adversity and critically evaluate

Philosophy

- Inspire
- Strive for excellence
- Nurture critical thinking
- Passion for the learner
- Empathy
- Strong work ethic
- Treat everyone with respect and as friends

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Teaching Philosophy

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Creating a stimulating learning environment

- Interactive lectures
- Thought provoking activities
- Active learning examples and demonstrations
- Creative and collaborative working sessions
- Project-based learning

Engaging classroom experience

- Defined learning objectives
- Frequent assessments to identify gaps in student learning
- Encourage questions
- Share views, ideas, challenges
- Peer learning and shared experiences

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Teaching at the University of Alabama

College of Engineering
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Applications of Machine Learning in Environmental Engineering

- Data Science in Civil Engineering
- Data acquisition and processing
- Machine Learning

HYDROLEARN

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Teaching at the University of Alabama

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HydroInformatics

- Python
- Data Visualization
- Data Processing
- HydroShare
- AWS
- Cloud Computing

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Teaching at the University of Alabama

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Field and Lab Methods in Environmental Practices

- Arduino IDE
- Environmental sensors and programming
- Field trips

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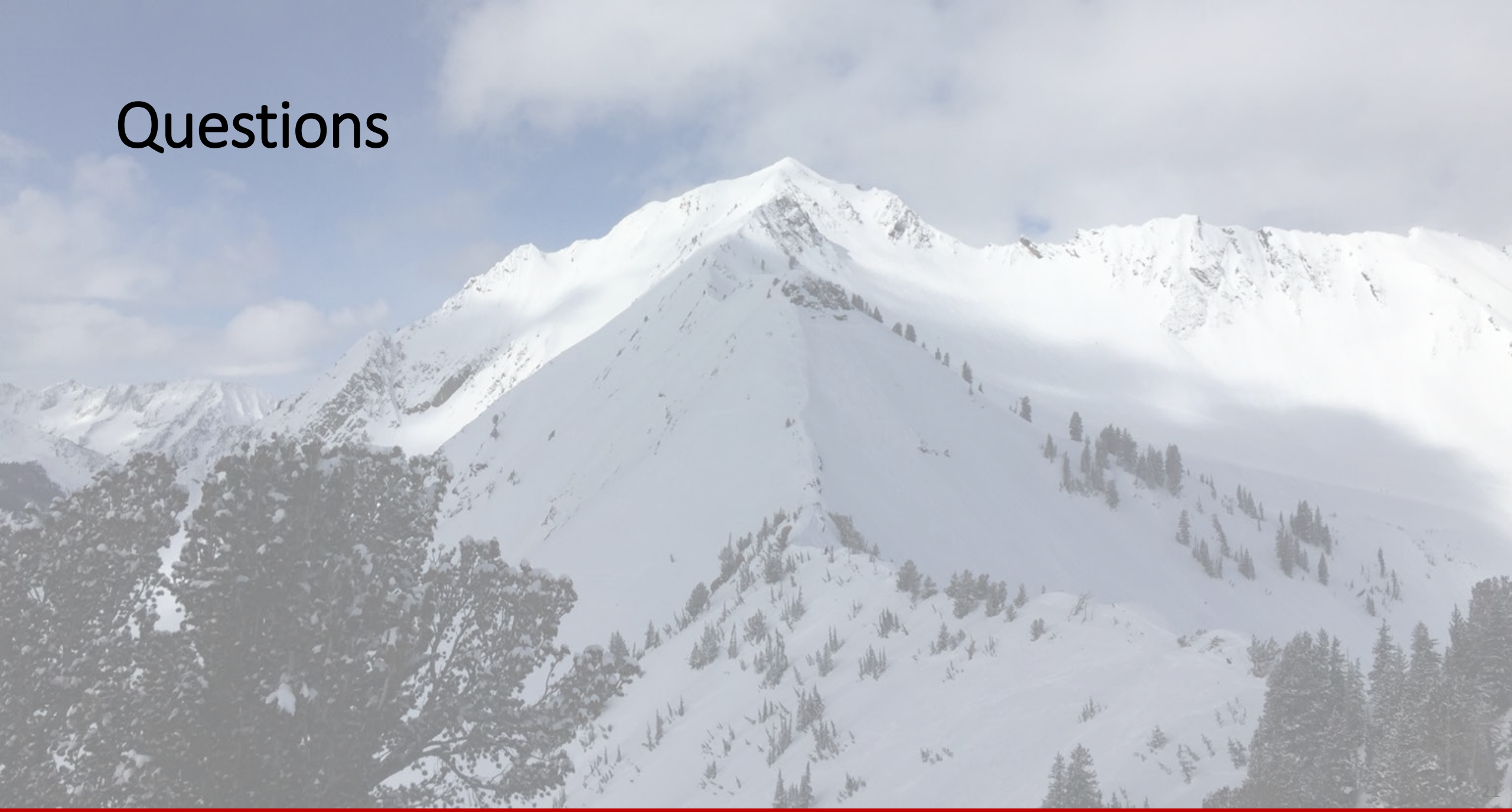
Questions



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U.S. National Science Foundation

Advancing Research in Geosciences using AI/ML

Summary: Connections with snow and streamflow AI/ML methods to advance the understanding of geosciences using AI/ML methods.
- Advance core geosciences program goals and use AI/ML methods for addressing scientific problems. Build the capacity of AI/ML to explore and/or emulate physically based models.

Core geoscience goal: Advance the representation of snow on the earth's surface to support water supply forecasting and explore the impacts of a changing climate.

Broader impacts: developing AI/ML training datasets, python-based tools (evaluation), open source software, supporting workforce development. Supporting the greater hydro-meteorological practioning and research community.

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Environmental Engineering

Summary: Investigation of a no-snow future within the western US, beginning with the Great Salt Lake using SNOTEL to investigate precipitation phase during the snow season (October to July).

Research questions: how has precipitation phase changed in the past half century and what can we expect in a changing climate in montane, high elevation watersheds. Most studies relate a no snow future to the impacts of temperature on snow melt, investigation peak SWE and the duration of snow. However, snowmelt is primarily driven by the energy from SW radiation.

Applications benefits: connect newfound knowledge related to precipitation phase (or at least the temperature when precip is occurring) to naturalized and managed water systems. How much snow can we expect to occur in the future and relate it to the quantity of melt to fill reservoirs/GW recharge,

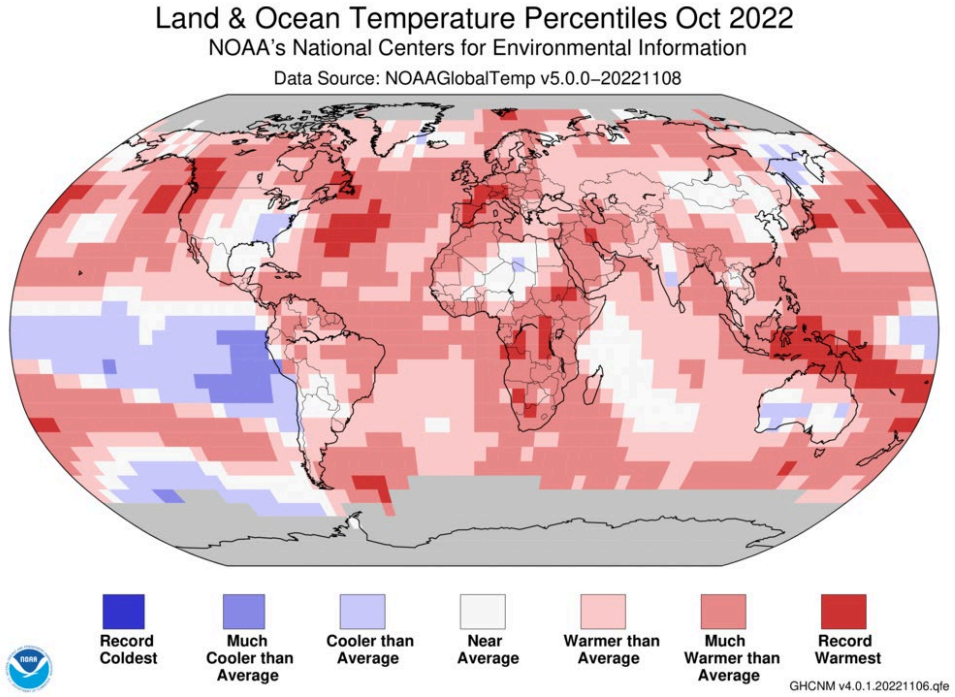
Environmental Sustainability: GSL sustainability, no snow future, climate change/scenarios/impact of scenarios on water resources management.

NIDIS: future drought risk across the West and in the context of a changing climate

- Drought vulnerability assessments
- Developing drought plans and communication plans
- Identifying primary drought impacts
- Optimal drought indicators and/or triggers and improving monitoring
- Developing drought dashboards with relevant tools and information and demonstrating the application of drought data to enhance decision-making

CVP – Advancing the Understanding of multi-year to decadal climate variability and predictability for US climate predictions

- Data analysis and investigation focused on mechanisms that govern the variability of the coupled climate systems and its predictability on the multi-year to decadal timescale with long-term observation data and or model data.
- Investigation of the relationship between the Atlantic meridional overturning circulation (AMOC) and impacts on the cryosphere and hydroclimate in the Western US



Positive Action Principles

1. Positive actions for your mind
2. Responsible self-management
3. Continuous Improvement