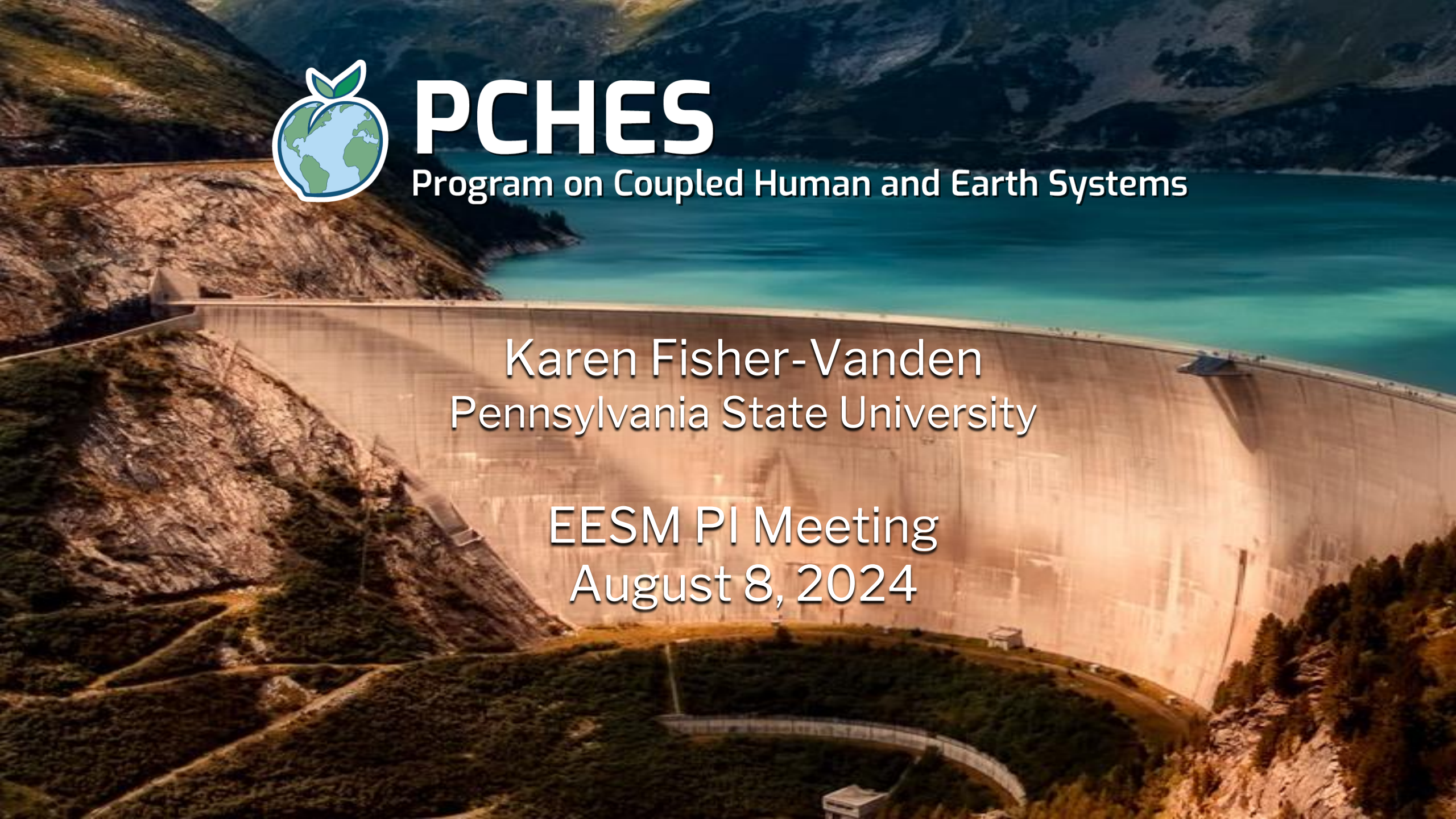

PCHES

Program on Coupled Human and Earth Systems

Karen Fisher-Vanden
Pennsylvania State University

EESM PI Meeting
August 8, 2024

Program on Coupled Human and Earth Systems (PCHES)

PCHES is university-based integrated research team:

- Supported by the US Department of Energy's Office of Science (Office of Biological and Environmental Research, Multi-Sector Dynamics Program) since 2010
- ~20 investigators, ~10 post-docs, and ~15 grad students from 9 research institutions
- Multidisciplinary: economists, engineers, earth system scientists, hydrologists, statisticians, computer scientists.

PennState
University of Illinois Urbana-Champaign
University of New Hampshire
Dartmouth
Stanford University
Harvard University
Purdue University
Boston University
Cornell University

DIRECTORS

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Mort Webster
Penn State

Douglas Wrenn
Penn State

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Lidiia Iavorivska
Penn State

Matthew Lisk
Penn State

Pamela McCroskey
Stanford

Polly Yan
Stanford

The PCHES Team

Program on Coupled Human and Earth Systems (PCHES)

Goal: To create new, state-of-the-art, integrated modeling tools and methods to capture

- cascading and compound stressors in interdependent systems;
- multi-scale and multi-sector dynamics; and
- risk and response behaviors.

Funded Research Projects:

- **PCHES-IAMDDI** (2010-2018): focused on analysis and diagnostics of integrated assessment modeling systems
- **PCHES-FRAME** (2016-2024): focused on innovations in the development of MSD modeling frameworks
- **PCHES-ADAPT** (2021-2026): focused on understanding adaptive response behaviors accounting for interconnected system feedbacks

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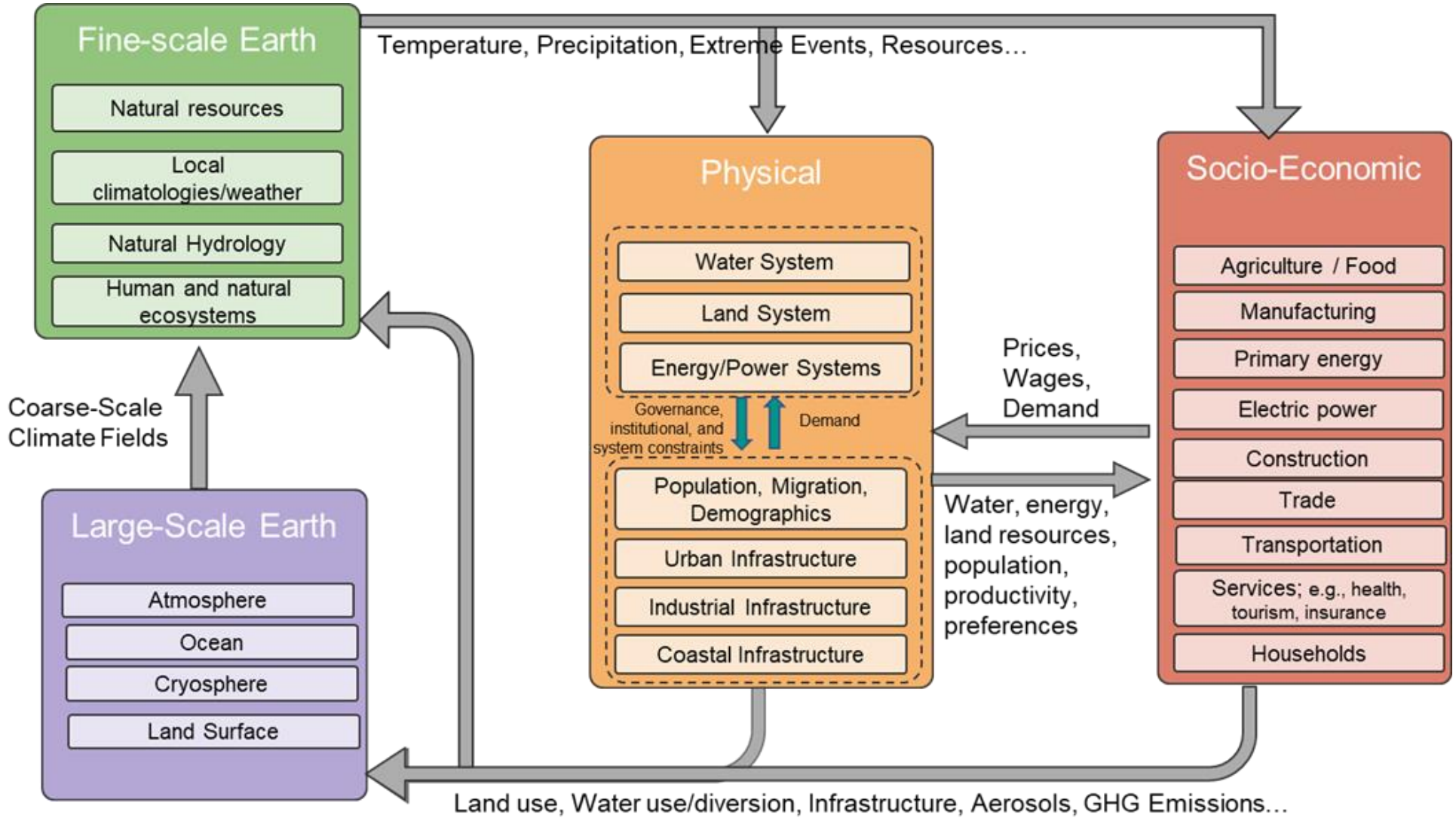
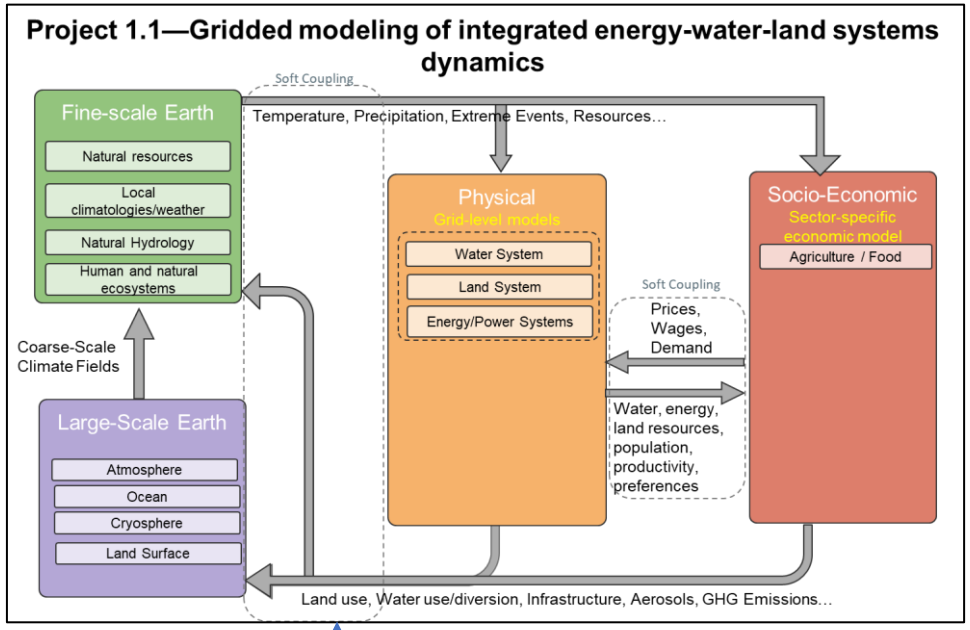
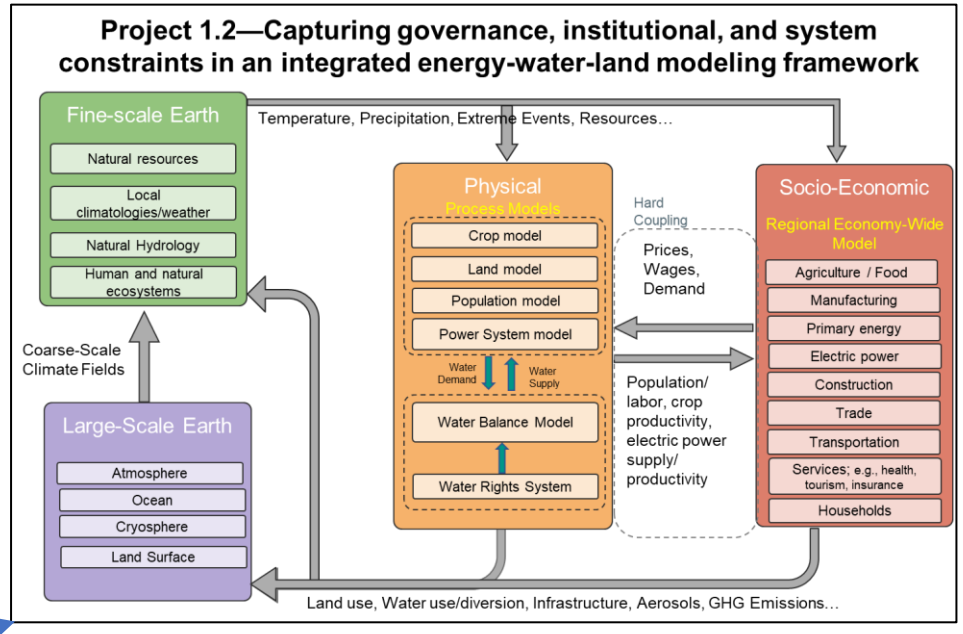
Boston University
Cornell University

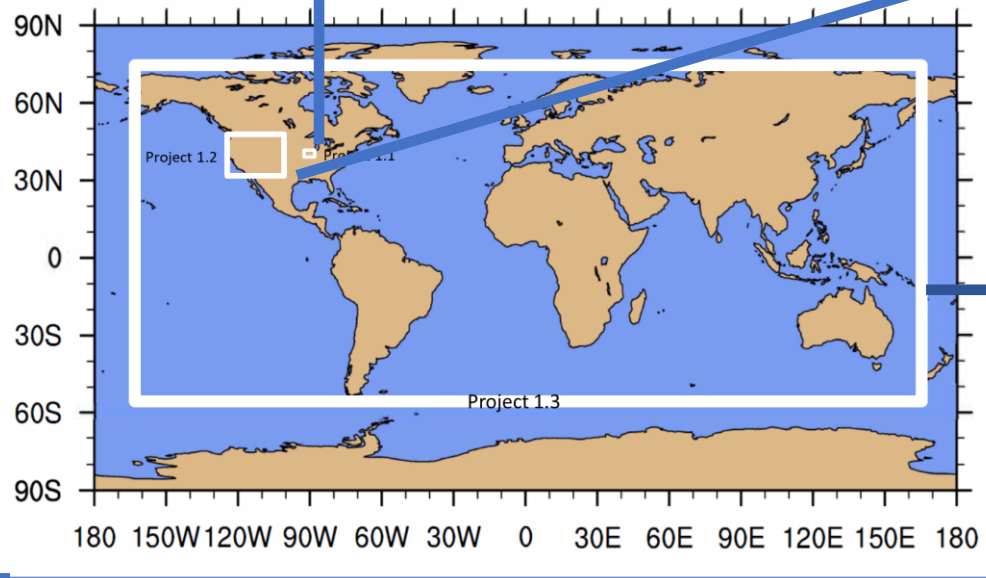
PCHES-FRAME: Integrated Framework to Capture the Propagation of Impacts and Risk across Sectors, Regions, and Time



PCHES-FRAME


Project 1.1—Gridded modeling of integrated energy-water-land systems dynamics
Soft Coupling
Fine-scale Earth
Natural resources
Local climatologies/weather
Natural Hydrology
Human and natural ecosystems
Temperature, Precipitation, Extreme Events, Resources…
Physical
Grid-level models
Water System
Land System
Energy/Power Systems
Socio-Economic
Sector-specific economic model
Agriculture / Food
Soft Coupling
Prices, Wages, Demand
Water, energy, land resources, population, productivity, preferences
Coarse-Scale Climate Fields
Large-Scale Earth
Atmosphere
Ocean
Cryosphere
Land Surface
Land use, Water use/diversion, Infrastructure, Aerosols, GHG Emissions…


Project 1.2—Capturing governance, institutional, and system constraints in an integrated energy-water-land modeling framework
Fine-scale Earth
Natural resources
Local climatologies/weather
Natural Hydrology
Human and natural ecosystems
Temperature, Precipitation, Extreme Events, Resources…
Physical
Process Models
Crop model
Land model
Population model
Power System model
Water Demand
Water Supply
Water Balance Model
Water Rights System
Hard Coupling
Prices, Wages, Demand
Population/ labor, crop productivity, electric power supply/ productivity
Socio-Economic
Regional Economy-Wide Model
Agriculture / Food
Manufacturing
Primary energy
Electric power
Construction
Trade
Transportation
Services; e.g., health, tourism, insurance
Households
Coarse-Scale Climate Fields
Large-Scale Earth
Atmosphere
Ocean
Cryosphere
Land Surface
Land use, Water use/diversion, Infrastructure, Aerosols, GHG Emissions…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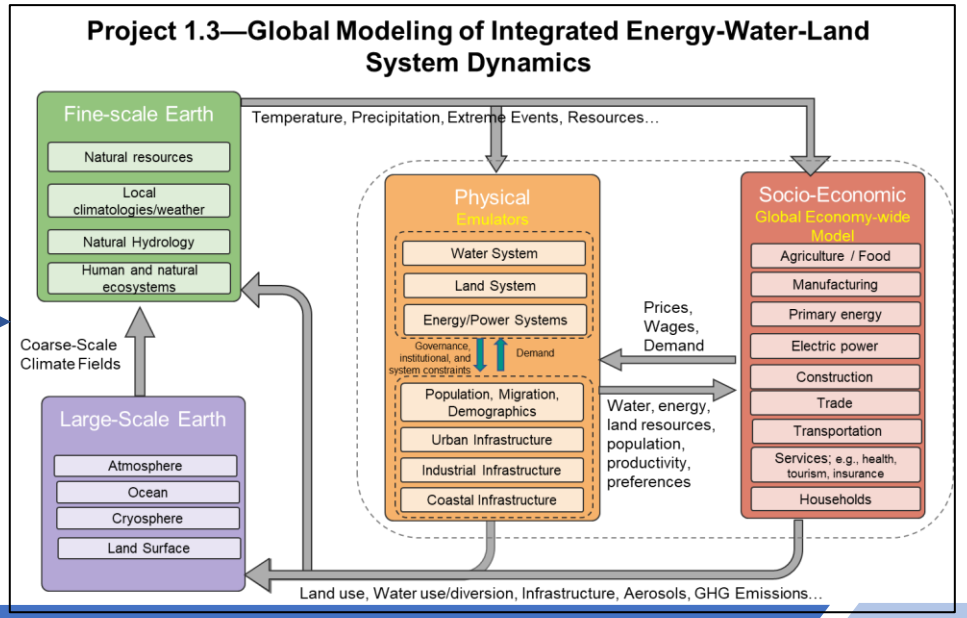
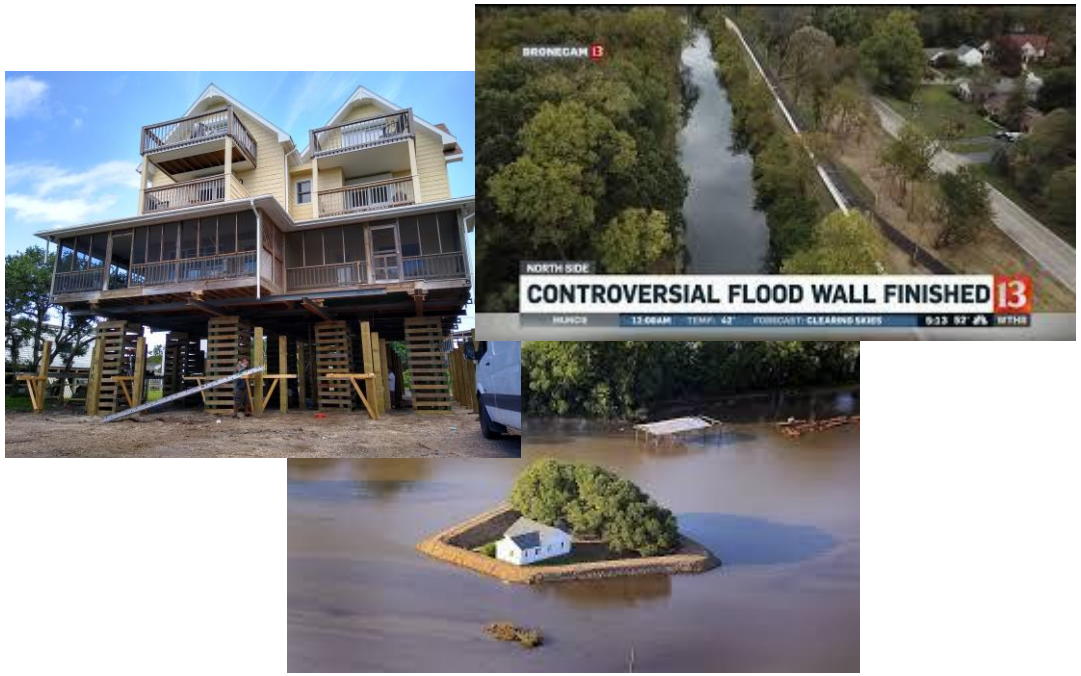
Project 1.2
Project 1.1
Project 1.3

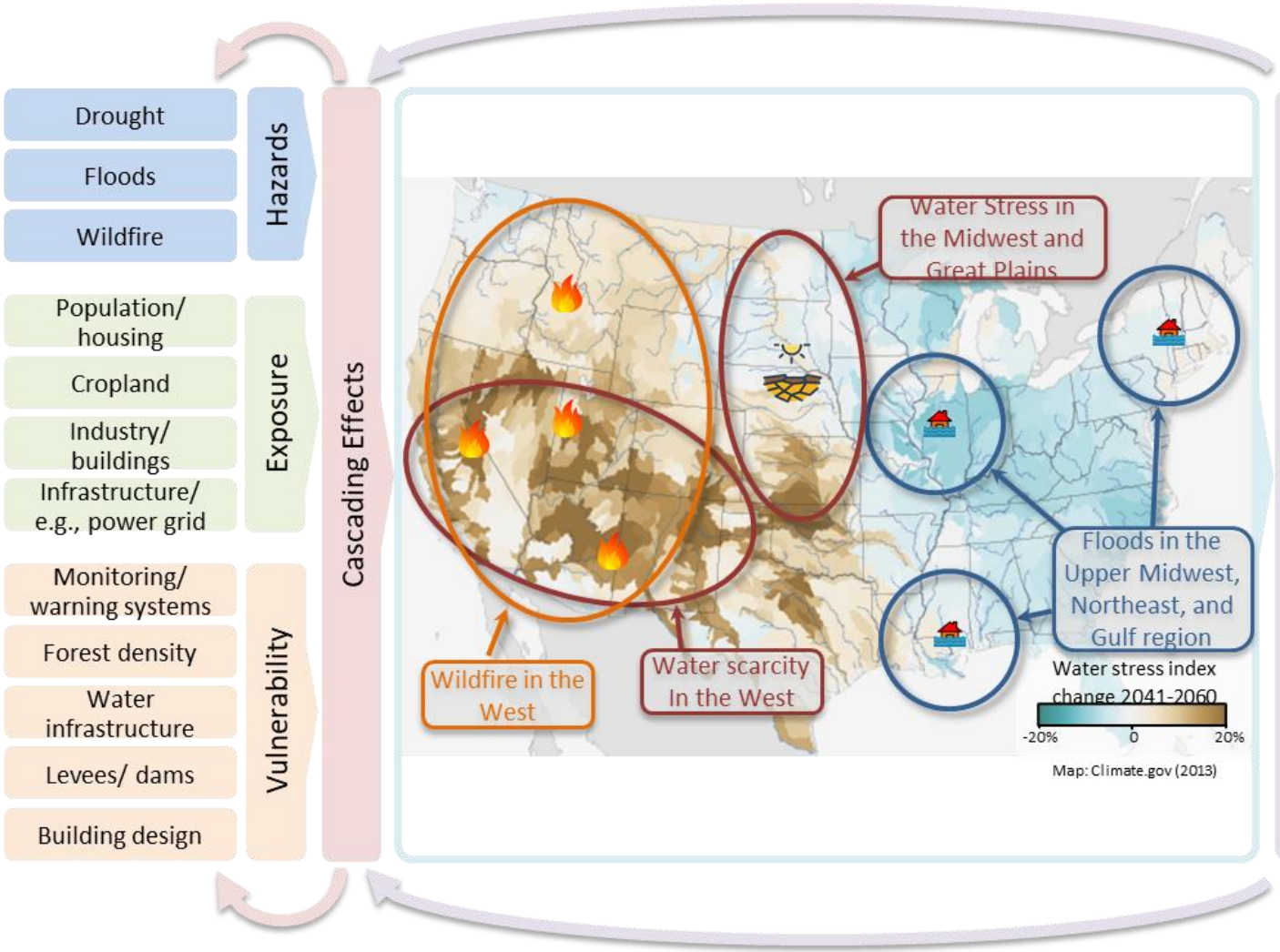

Project 1.3—Global Modeling of Integrated Energy-Water-Land System Dynamics
Fine-scale Earth
Natural resources
Local climatologies/weather
Natural Hydrology
Human and natural ecosystems
Temperature, Precipitation, Extreme Events, Resources…
Physical
Emulators
Water System
Land System
Energy/Power Systems
Governance, institutional, and system constraints
Demand
Population, Migration, Demographics
Urban Infrastructure
Industrial Infrastructure
Coastal Infrastructure
Prices, Wages, Demand
Water, energy, land resources, population, productivity, preferences
Socio-Economic
Global Economy-wide Model
Agriculture / Food
Manufacturing
Primary energy
Electric power
Construction
Trade
Transportation
Services; e.g., health, tourism, insurance
Households
Coarse-Scale Climate Fields
Large-Scale Earth
Atmosphere
Ocean
Cryosphere
Land Surface
Land use, Water use/diversion, Infrastructure, Aerosols, GHG Emissions…

PCHES-ADAPT: research questions

1. How does the propagation of hazards through the interconnected system affect the exposure and vulnerability of populations and physical systems?
2. How do populations and physical systems respond to these risks and how do these responses feed back to the interconnected system?

To address these questions, we will employ external/leveraged capabilities with new and enhanced frameworks, tools, and methods.





Adaptive Measures
(Choices and Actions)

Public adaptation responses; e.g.,

- Public safety power shutoffs
- Subsurface drainage
- New dams/reservoirs
- Infrastructure reinforcement
- Inter-basin water transfers

Private adaptation responses; e.g.,

- Building reinforcement/ modifications
- Migration
- Groundwater extraction
- Insurance

Economy/Regulation; e.g.,

- Building regulation/restrictions
- Water rights market
- Trade
- Water use restrictions

PCHES-ADAPT: visual project overview

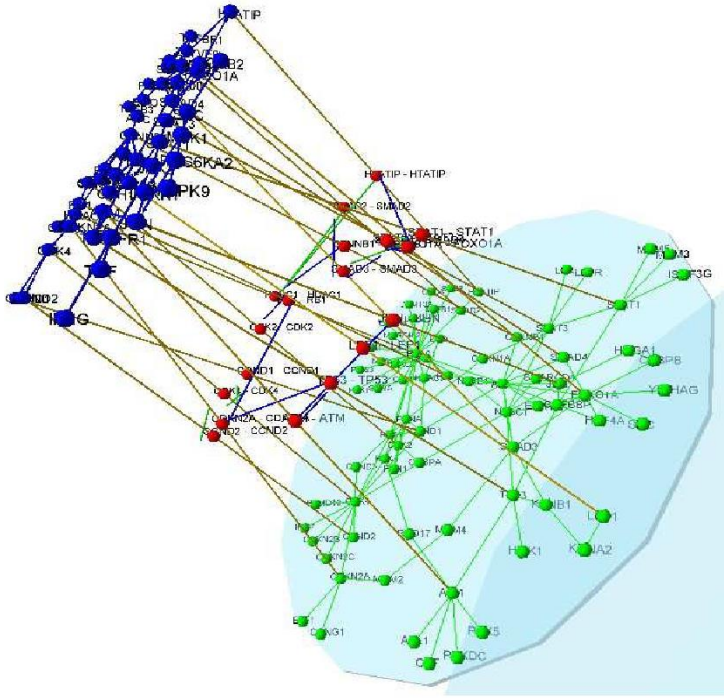
Characterizing the propagation of impacts and risk over sectors, space, and time

Key Science Questions:

1) What are the necessary spatial/temporal resolutions in each subsystem model?

2) What feedbacks between systems are important to capture?

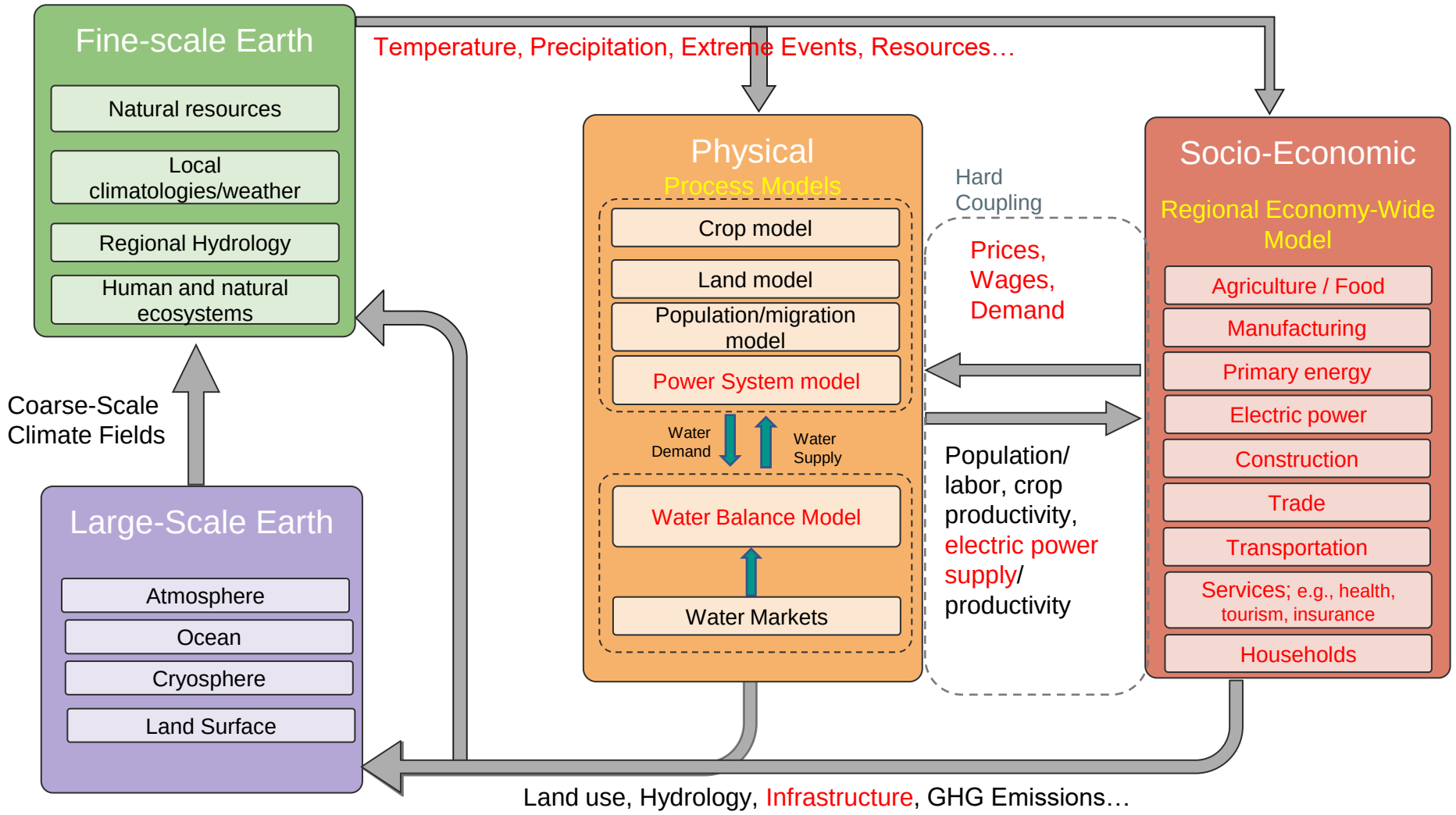
3) How does risk and uncertainty propagate across systems ?



Our “Mental Model”:

- Overlapping and Interacting Networks of Natural and Human Systems
- Each System has Distinct Spatial and Temporal Variability
- “Impacts” occur when these patterns converge at specific locations/times

Webster, M., K. Fisher-Vanden, V. Kumar, R. Lammers, J. Perla, "Integrated hydrological, power system and economic modeling of climate impacts on electricity demand and cost." ***Nature Energy***, Jan 2022.



Overlapping and Interacting Networks: Atmosphere, Hydrology, Power, Economy

Webster, M., K. Fisher-Vanden, V. Kumar, R. Lammers, J. Perla, "Integrated hydrological, power system and economic modeling of climate impacts on electricity demand and cost." *Nature Energy*, Jan 2022.

Atmosphere
(diffuse network)

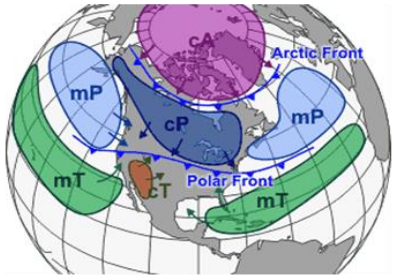


Image source: wikipedia.org

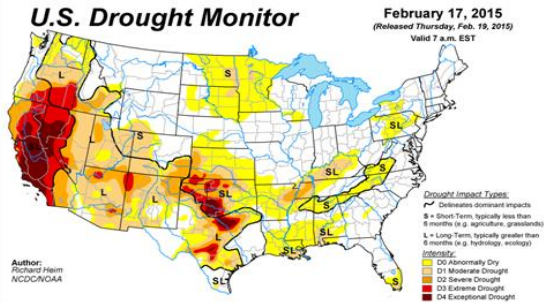
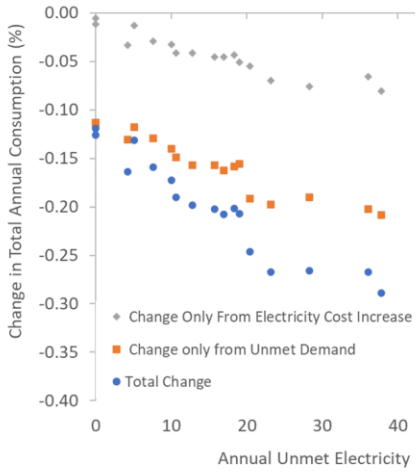
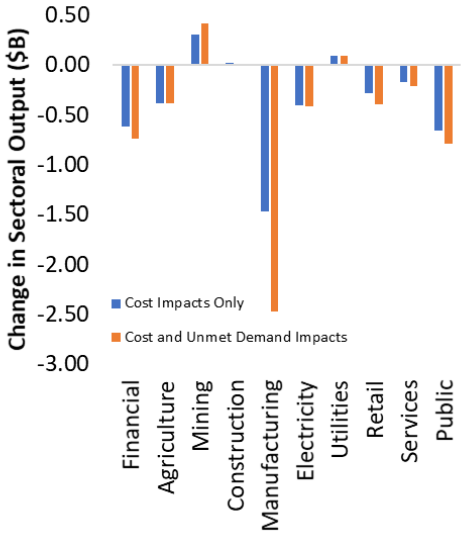
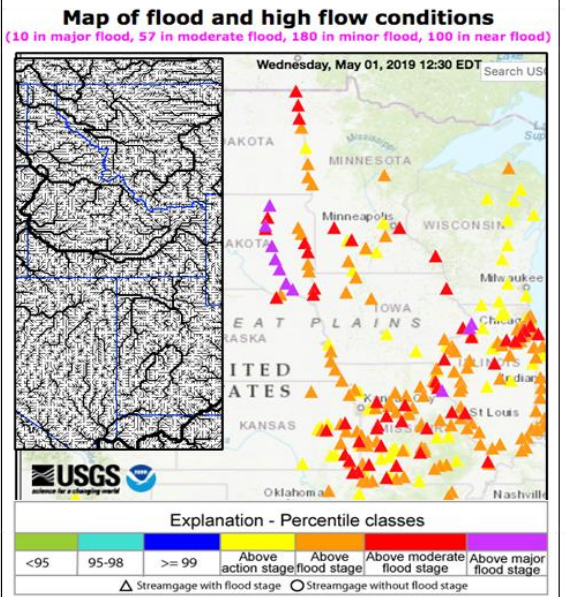


Image source: droughtmonitor.unl.edu

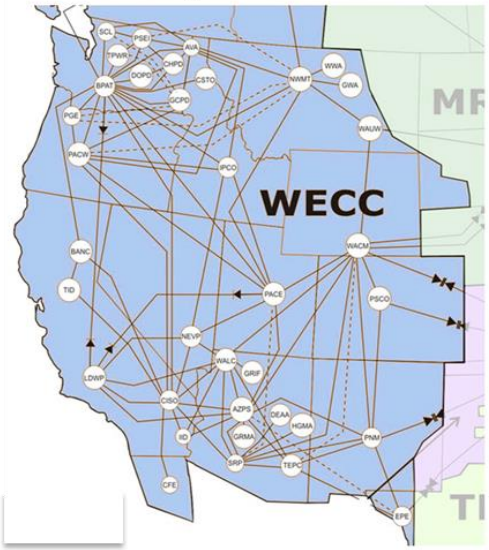




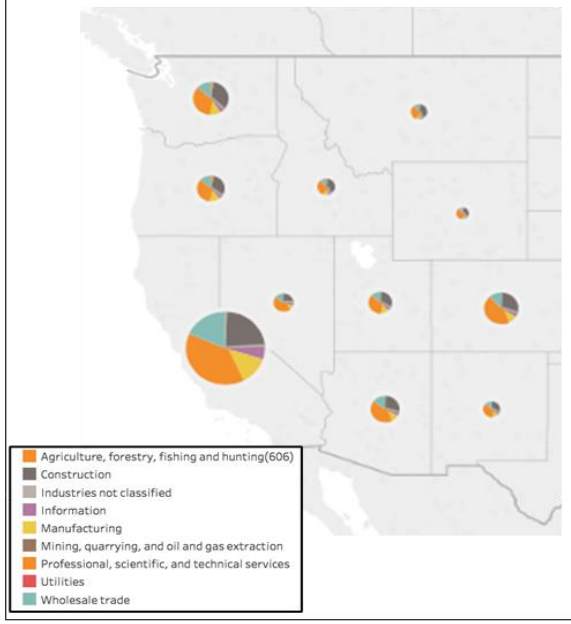
Drainage Basins
(River network)

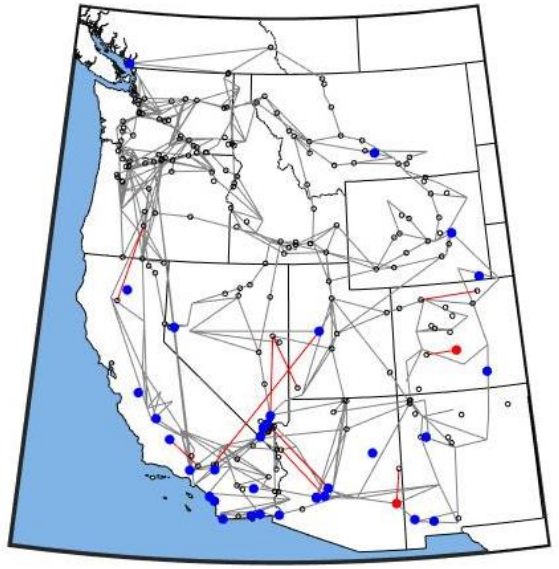


Electricity Power
(Power network)



Regional Sectors
(Economic network)





PCHES @ 2024 EESM PI MEETING

Water Cycle and Hydroclimate

- "Transdisciplinary collaborations for sustainable management of an Invisible Resource," **Lidiia Iavorivska**, Poster (MSD)
- "Combined climate and hydrologic uncertainties shape projections of future soil moisture extremes," **Ryan Sriver**, Poster (MSD)

Energy, Water, and Land System Transition

- "How does crop production adapt with groundwater restrictions in the West?" **Femeena Pandara Valappil**, Oral Presentation (MSD)
- "Statistical Learning Applied to Climate-Water-Energy Impacts Scenarios," **Mort Webster**, Oral Presentation (MSD)
- "Economic Impact on Residents from Public Safety Power Shutoffs (PSPSs)," **Tiemeng Ma**, Poster (MSD)
- "Testing the conditional skill of a hydro-economics model system for food, land, and water sustainability research," **Shan Zuidema**, Poster (MSD)

Extreme Events

- "Wildfire Risk and Home Prices: The Case of California Building Codes," **Edouard Mensah**, Poster (MSD)
- "Relationship between mid-latitude temperature distributions and meridional wind variability," **Keiko Kircher**, Poster (MSD)

Model Uncertainties, Model Biases, and Fit-for-Purpose

- "Probabilistic Downscaling for Flood Hazard Models," **Samantha Roth**, Oral Presentation (MSD)
- "Combined climate and hydrologic uncertainties shape projections of future soil moisture extremes," **Ryan Sriver**, Oral Presentation (MSD)
- "US western physical wildfire risk variability and projections in statistically downscaled and bias-corrected climate model ensembles," **Theo Avila**, Poster (MSD)

PCHES Synergies with Meeting Sessions

Methodology Sessions:

(1) Metrics, Benchmarks and Credibility of model output and data for science and end users

(2) Innovative and Emerging technologies: ML/AI, Digital Earth, Exascale and Quantum Computing, advanced software infrastructures

(3) Methods in Model Integration, Hierarchical Modeling, Model Complexity

Topical Sessions:

(1) Coastal

(2) Impacts, Tipping Points and Systems Responses and Resilience

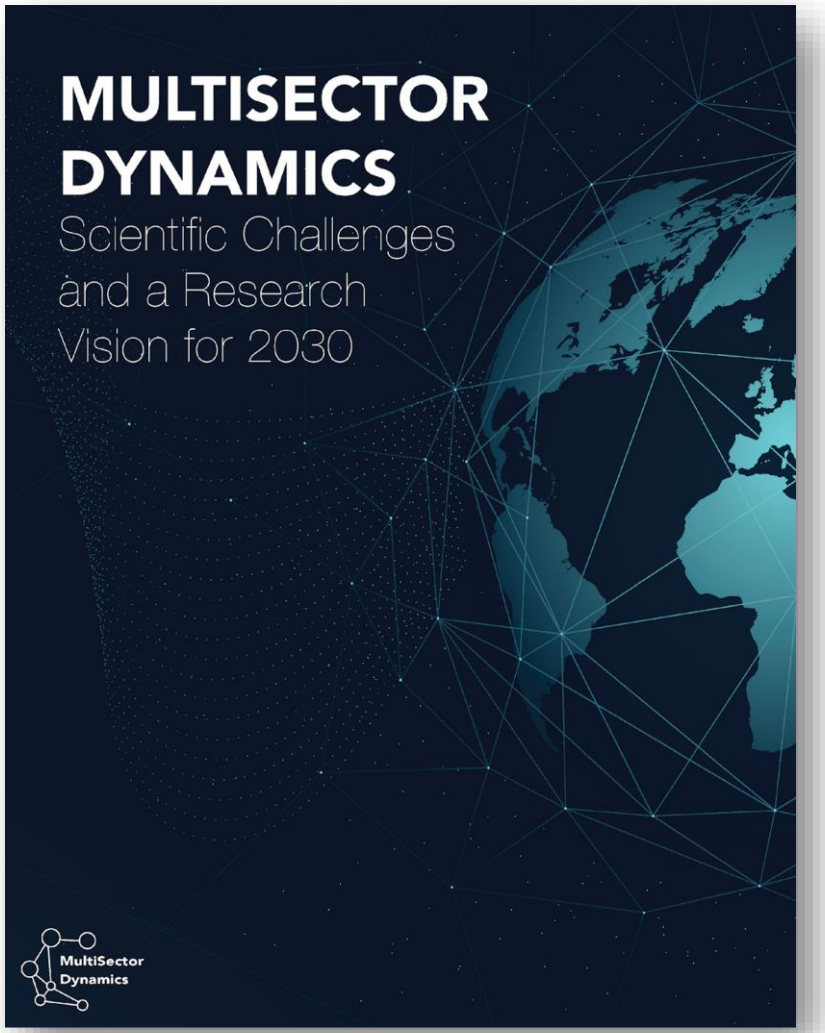
(3) Modes of Variability and Teleconnections, Trends

(4) Strengthening EESM Integrated Modeling Framework – Towards a Digital Earth

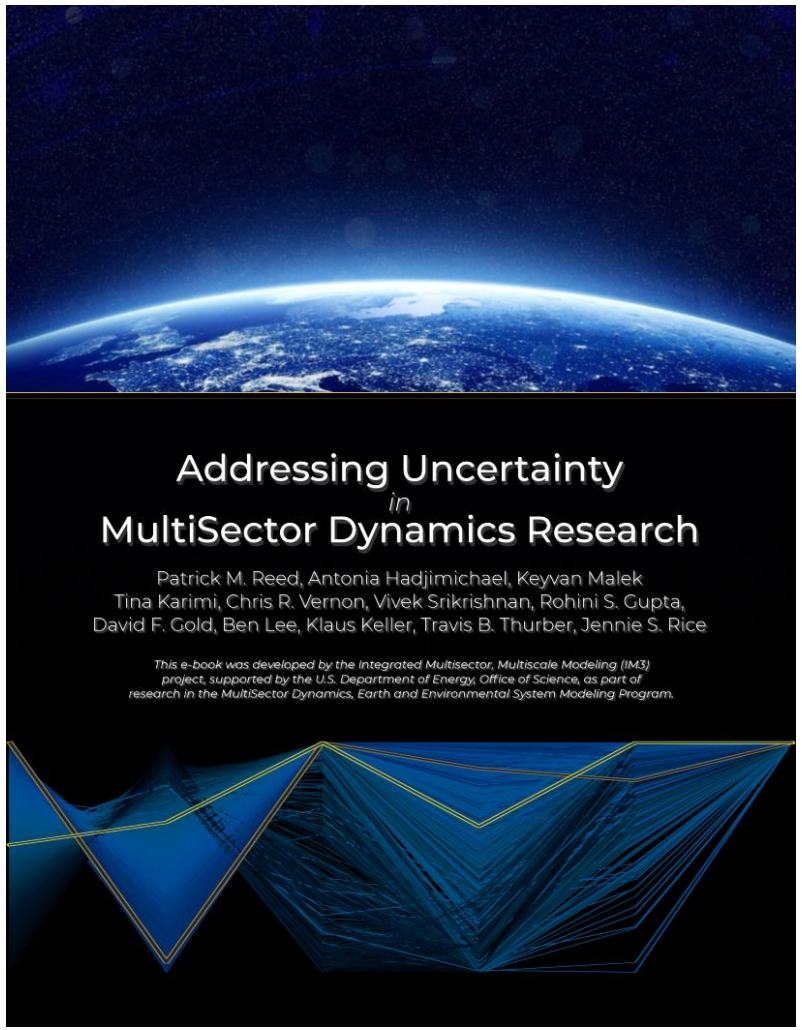
PCHES Accomplishments

- ~130 publications since 2012. Many in the top journals shown on the right
- ~45 dissertations and master theses
- ~15 PCHES students/post-doc alums now early and mid- career faculty
- Best student paper awards
- Nobel Prize in Economic Sciences awarded to PCHES alum, William Nordhaus in 2018

PCHES and the MSD Community of Practice



https://multisectordynamics.org/vision



https://uc-ebook.org/


Earth's Future

Review Article | Open Access

Uncertainty Analysis in Multi-Sector Systems: Considerations for Risk Analysis, Projection, and Planning for Complex Systems

Vivek Srikrishnan, David C. Lafferty, Tony E. Wong, Jonathan R. Lamontagne, Julianne D. Quinn, Sanjib Sharma, Nusrat J. Molla, Jonathan D. Herman, Ryan L. Sriver, Jennifer F. Morris, Ben Seiyon Lee

First published: 13 August 2022 | https://doi.org/10.1029/2021EF002644 | Citations: 1

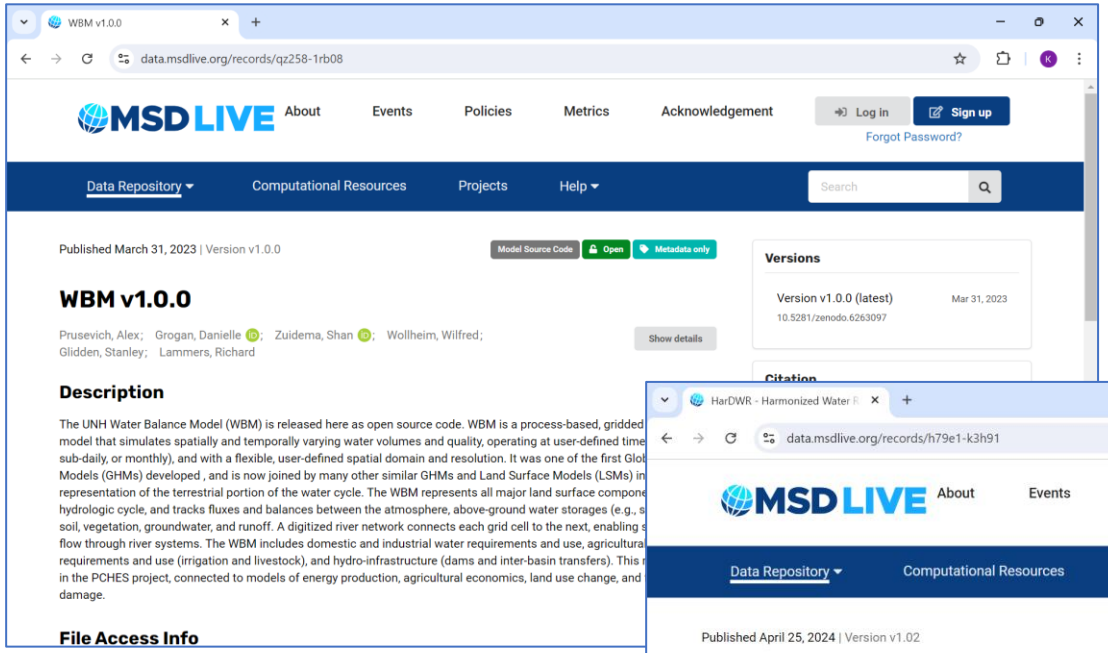
PCHES-funded co-authors of:

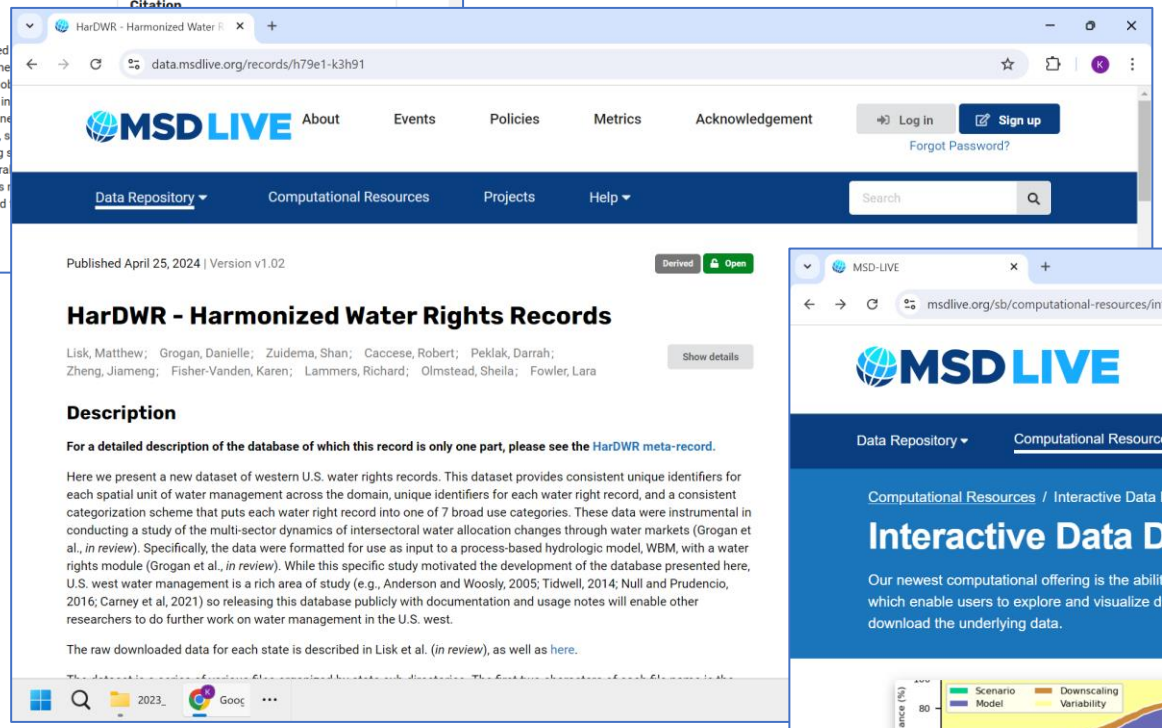
- MSD CoP Vision Report
- MSD Uncertainty Characterization e-book

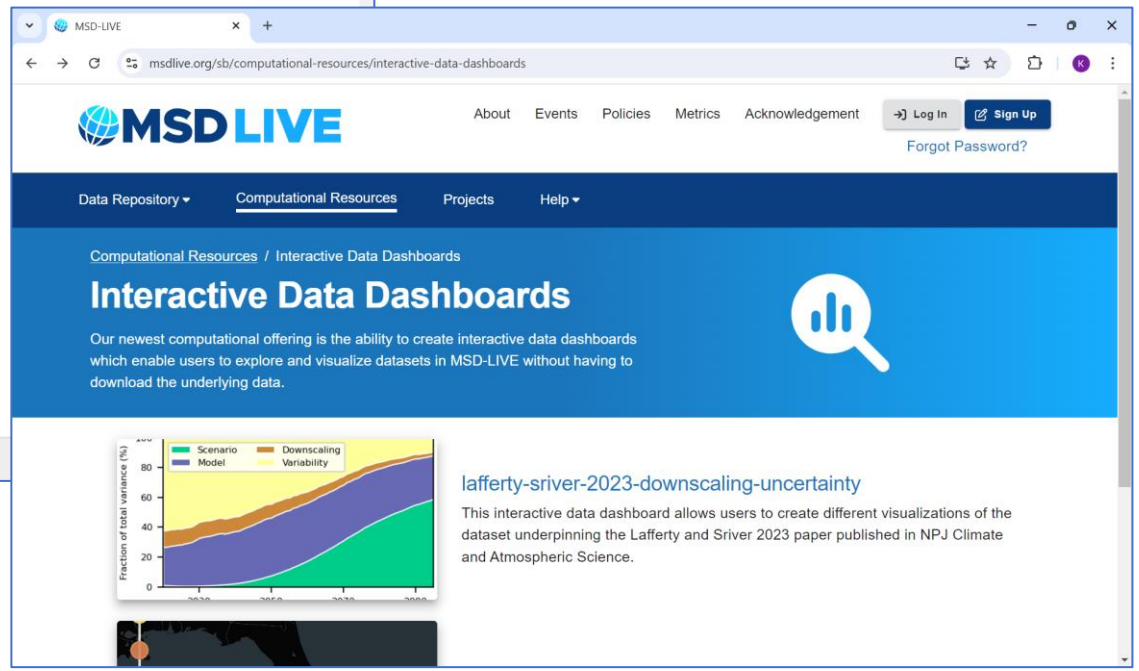
Leadership in:

- MSD Scientific Steering Group
- Uncertainty Characterization and Quantification MSD Working Group

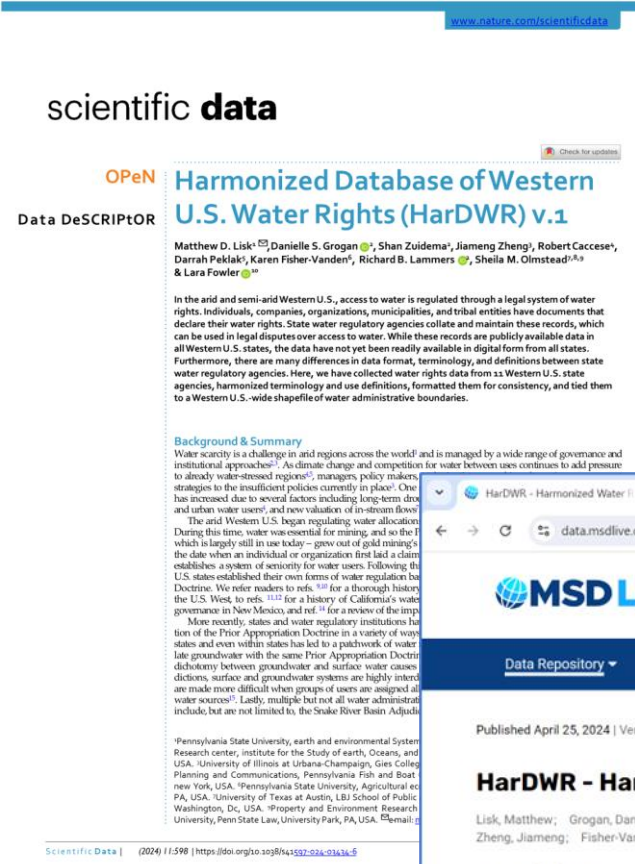
PCHES is an active contributor to open access platforms like **MSD-Live**, a flexible and scalable data and code management system combined with an advanced computing platform







Harmonized Database of Western U.S. Water Rights (HarDWR)


www.nature.com/scientificdata

scientific data

OPeN Data DeSCRIPtOR

Harmonized Database of Western U.S. Water Rights (HarDWR) v.1

Matthew D. Lisk, Danielle S. Grogan, Shan Zuidema, Jiameng Zheng, Robert Caccese, Darrah Peklak, Karen Fisher-Vanden, Richard B. Lammers, Sheila M. Olmstead & Lara Fowler

In the arid and semi-arid Western U.S., access to water is regulated through a legal system of water rights. Individuals, companies, organizations, municipalities, and tribal entities have documents that declare their water rights. State water regulatory agencies collate and maintain these records, which can be used in legal disputes over access to water. While these records are publicly available data in all Western U.S. states, the data have not yet been readily available in digital form from all states. Furthermore, there are many differences in data format, terminology, and definitions between state water regulatory agencies. Here, we have collected water rights data from 11 Western U.S. state agencies, harmonized terminology and use definitions, formatted them for consistency, and tied them to a Western U.S.-wide shapefile of water administrative boundaries.

Background & Summary

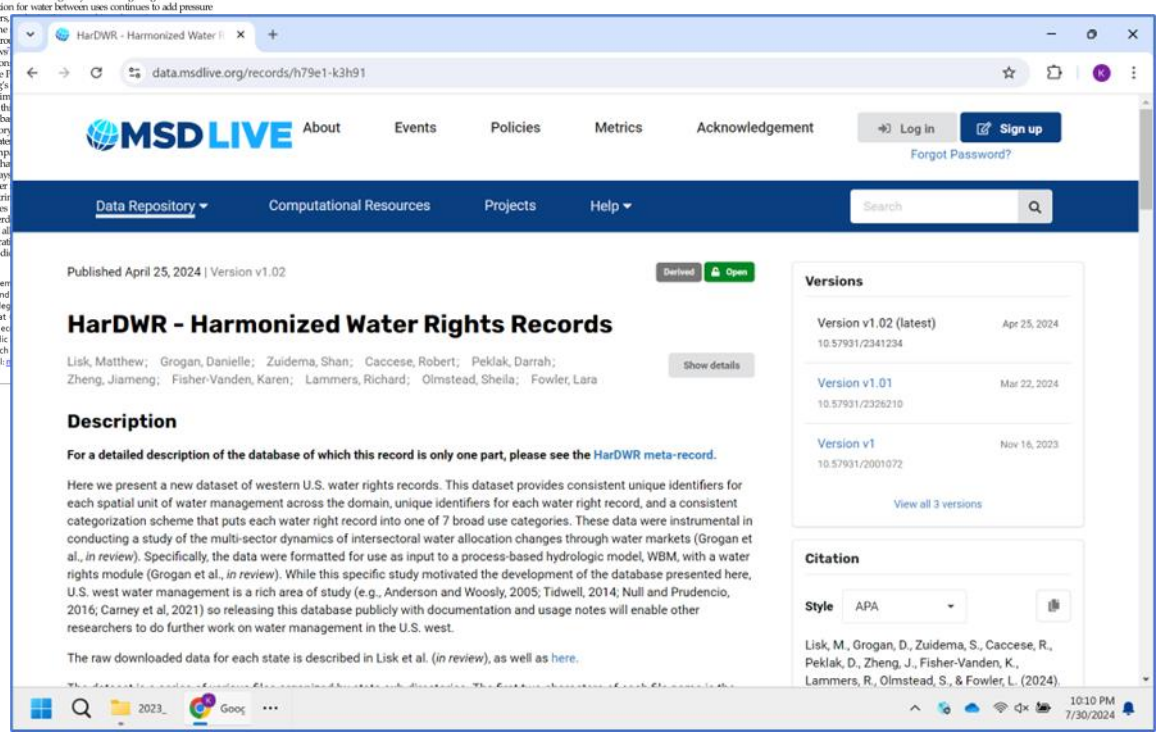
Water scarcity is a challenge in arid regions across the world and is managed by a wide range of governance and institutional approaches. As climate change and competition for water between uses continues to add pressure to already water-stressed regions, managers, policy makers, strategies to the insufficient policies currently in place. One has increased due to several factors including long-term dro and urban water users, and new valuation of in-stream flows

The arid Western U.S. began regulating water allocation During this time, water was essential for mining, and so the which is largely still in use today – grew out of gold mining's the date when an individual or organization first laid a claim establishes a system of seniority for water users. Following th U.S. states established their own forms of water regulation ba Doctrine. We refer readers to refs. for a thorough history the U.S. West, to refs. for a history of California's wate governance in New Mexico, and ref. for a review of the imp

More recently, states and water regulatory institutions ha tion of the Prior Appropriation Doctrine in a variety of ways states and even within states has led to a patchwork of water late groundwater with the same Prior Appropriation Doctrin dichotomy between groundwater and surface water causes dictions, surface and groundwater systems are highly interc are made more difficult when groups of users are assigned al water sources. Lastly, multiple but not all water administrati include, but are not limited to, the Snake River Basin Adjudi

Pennsylvania State University, earth and environmental System Research center, institute for the Study of earth, Oceans, and USA. University of Illinois at Urbana-Champaign, Gies Colleg Planning and Communications, Pennsylvania Fish and Boat new York, USA. Pennsylvania State University, Agricultural ec PA, USA. University of Texas at Austin, LBJ School of Public Washington, Dc, USA. Property and Environment Research University, Penn State Law, University Park, PA, USA.

Scientific Data | (2024) 11:598 | https://doi.org/10.1038/s41597-024-03434-6



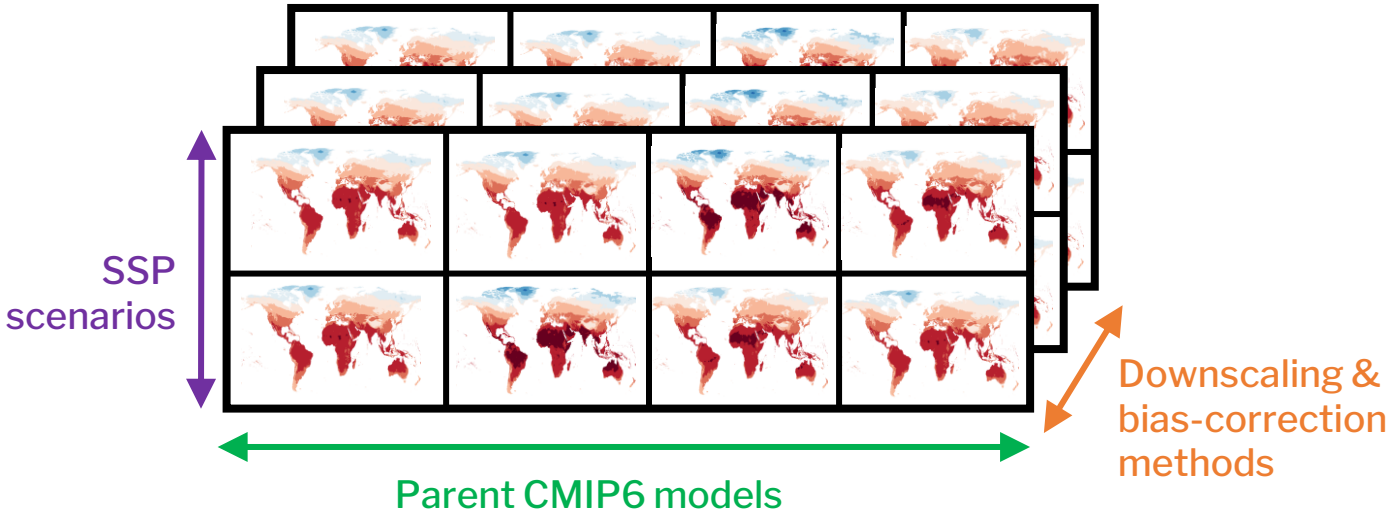
Lisk, M.D., Grogan, D.S., Zuidema, S. et al. Harmonized Database of Western U.S. Water Rights (HarDWR) v.1. *Scientific Data*, 11, 598 (2024). https://doi.org/10.1038/s41597-024-03434-6

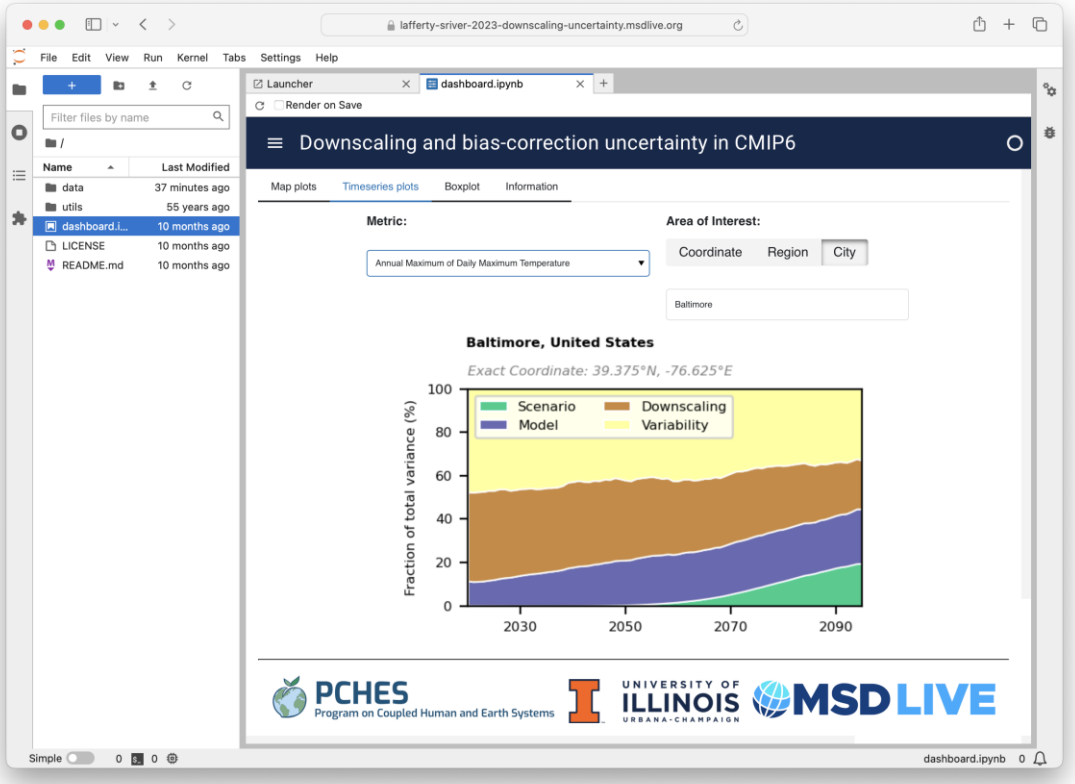
How do climate model uncertainties affect hazard characterization for MSD systems?

David Lafferty and Ryan Sriver, University of Illinois

Lafferty, D. C., & Sriver, R. L. (2023). Downscaling and bias-correction contribute considerable uncertainty to local climate projections in CMIP6. *npj Climate and Atmospheric Science*, *6*(1), 1–13. https://doi.org/10.1038/s41612-023-00486-0

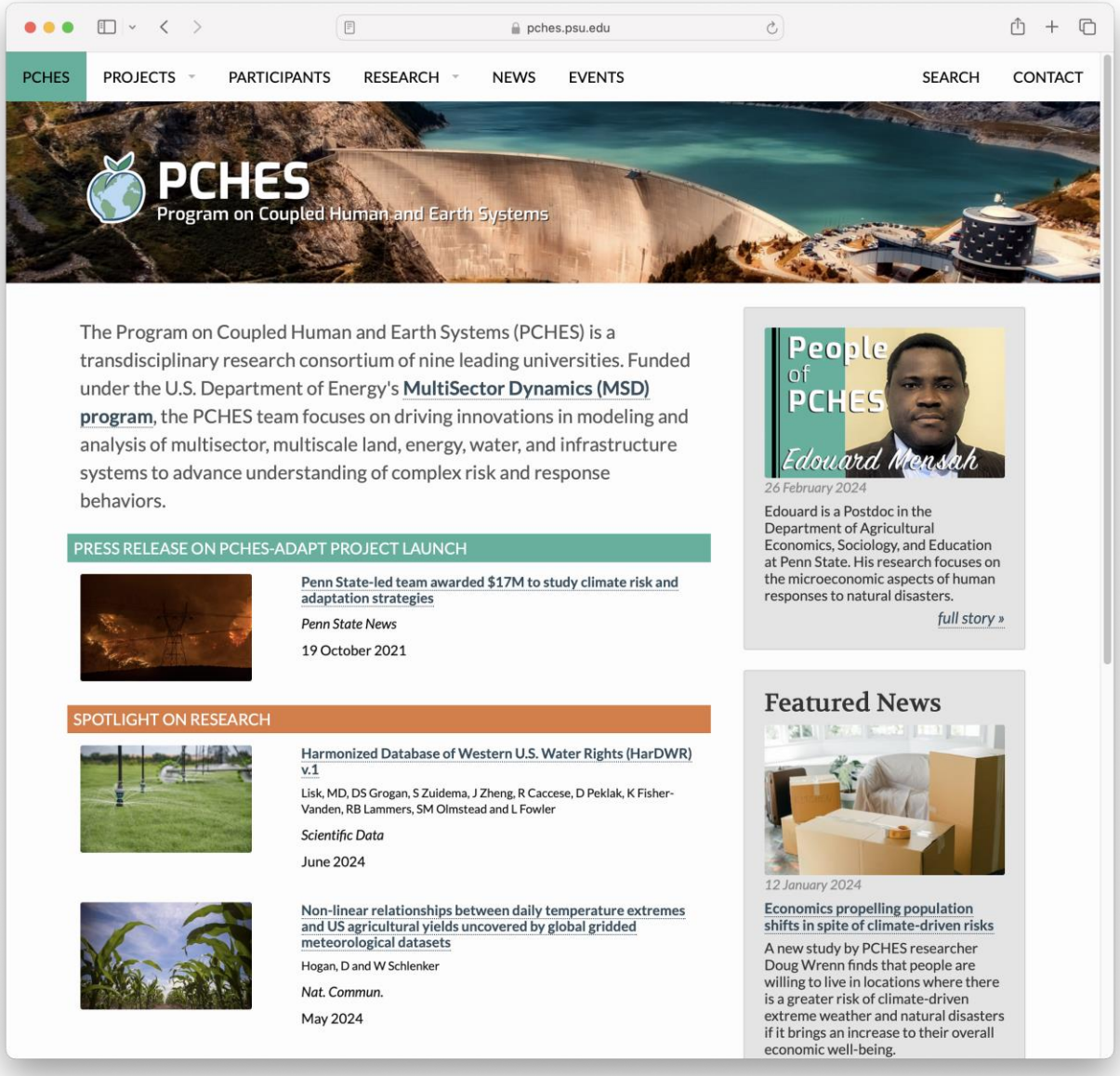
1. Utilize Earth system model ensembles and downscaled data products
2. Focus on hazard metrics relevant to case studies: **wildfire risk**, **extreme heat**, **drought**, etc.
3. Create workflows to quantify climate hazard uncertainty across different models, scenarios, ensembles, and downscaling methods





Partition total uncertainty using a simple variance decomposition approach…

- Model uncertainty: variance across models, averaged over SSPs and downscaling methods
- Downscaling uncertainty: variance across downscaling methods, averaged over SSPs and models
- Scenario uncertainty: variance across SSPs of the multi-model, multi-downscaling method mean
- Internal variability: variance arising from the chaotic nature of the Earth system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CONTACT
PCHES
Program on Coupled Human and Earth Systems
The Program on Coupled Human and Earth Systems (PCHES) is a transdisciplinary research consortium of nine leading universities. Funded under the U.S. Department of Energy's MultiSector Dynamics (MSD) program, the PCHES team focuses on driving innovations in modeling and analysis of multisector, multiscale land, energy, water, and infrastructure systems to advance understanding of complex risk and response behaviors.
PRESS RELEASE ON PCHES-ADAPT PROJECT LAUNCH
Penn State-led team awarded $17M to study climate risk and adaptation strategies
Penn State News
19 October 2021
SPOTLIGHT ON RESEARCH
Harmonized Database of Western U.S. Water Rights (HarDWR) v.1
Lisk, MD, DS Grogan, S Zuidema, J Zheng, R Caccese, D Peklak, K Fisher-Vanden, RB Lammers, SM Olmstead and L Fowler
Scientific Data
June 2024
Non-linear relationships between daily temperature extremes and US agricultural yields uncovered by global gridded meteorological datasets
Hogan, D and W Schlenker
Nat. Commun.
May 2024
People of PCHES
Edouard Mensah
26 February 2024
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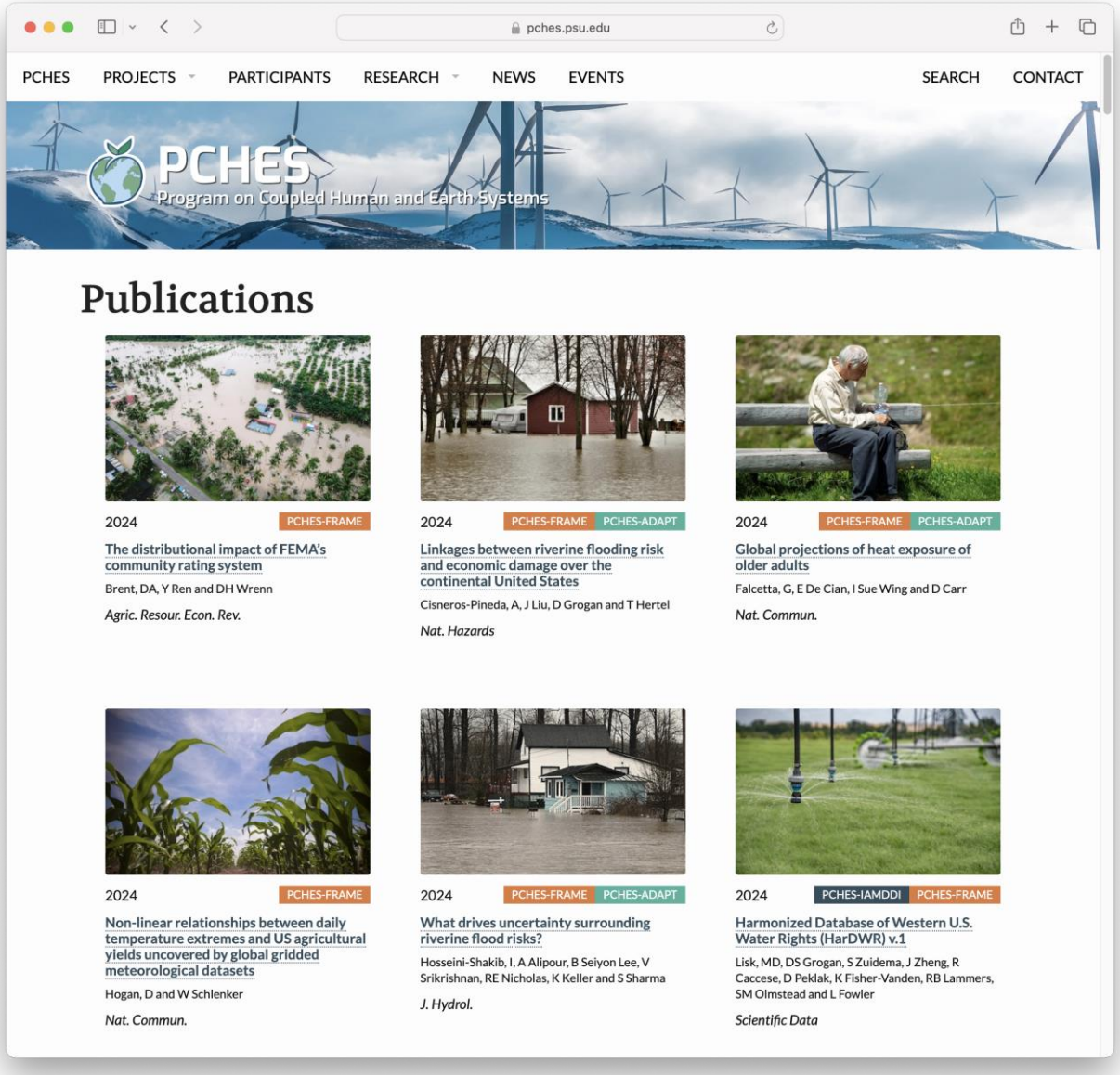
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Brent, DA, Y Ren and DH Wrenn
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Nat. Commun.
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Hosseini-Shakib, I, A Alipour, B Seiyon Lee, V Srikrishnan, RE Nicholas, K Keller and S Sharma
J. Hydrol.
2024 PCHES-IAMDDI PCHES-FRAME
Harmonized Database of Western U.S. Water Rights (HarDWR) v.1
Lisk, MD, DS Grogan, S Zuidema, J Zheng, R Caccese, D Peklak, K Fisher-Vanden, RB Lammers, SM Olmstead and L Fowler
Scientific Data