U.S. DEPARTMENT OF ENERGY

Earth and Environmental Systems Modeling

# Multisector Dynamics

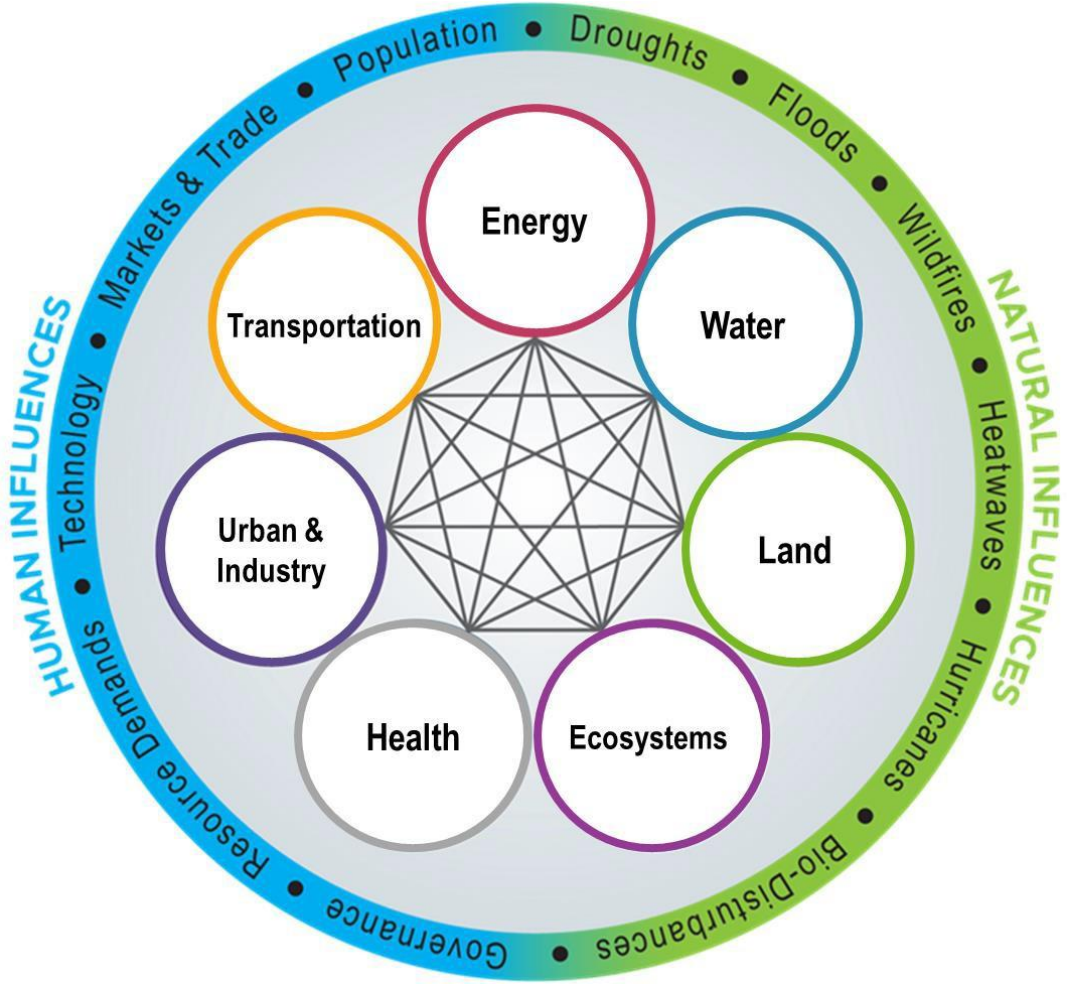
## Program Manager: Bob Vallario

EESM

EARTH & ENVIRONMENTAL SYSTEMS MODELING

# MultiSector Dynamics (MSD) Goal

Explore the *complex interactions and potential co-evolutionary pathways* within the integrated human-Earth system, including natural, engineered, and socioeconomic systems and sectors.



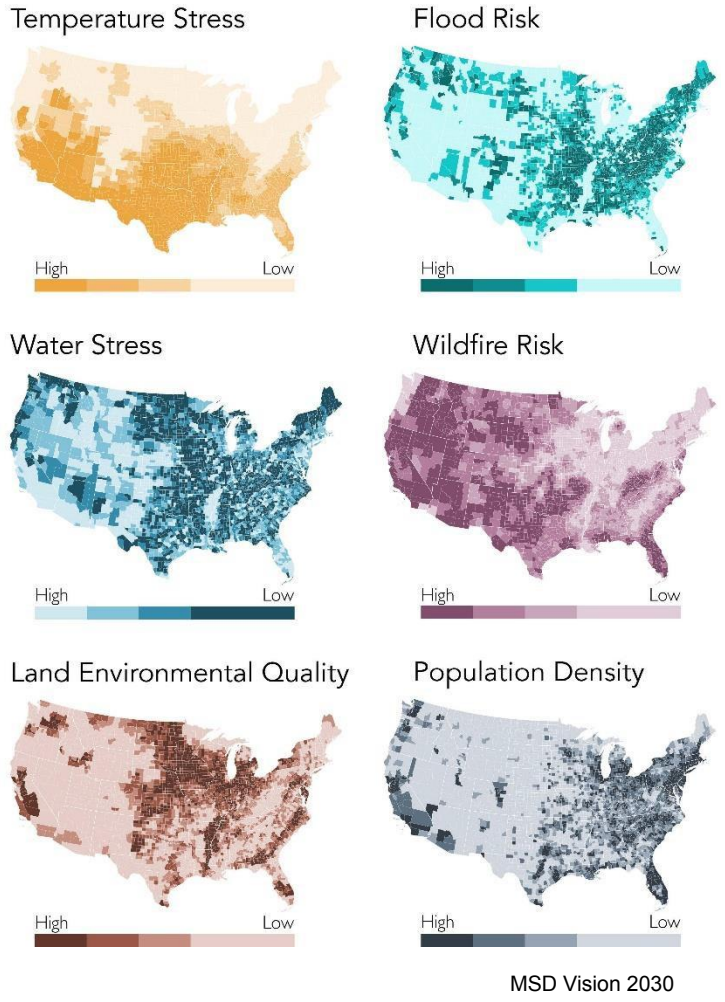

https://climatemodeling.science.energy.gov/program/multisector-dynamics

# Understanding influences, stressors, responses, and feedbacks

1. **Forces and Patterns.** Reveal the combination of factors, varying by geographies, that contribute most significantly to ***patterns of development in transregional, regional, and sub-regional landscape evolutions,*** including interactions and interdependencies among natural and built environments and human processes and systems.

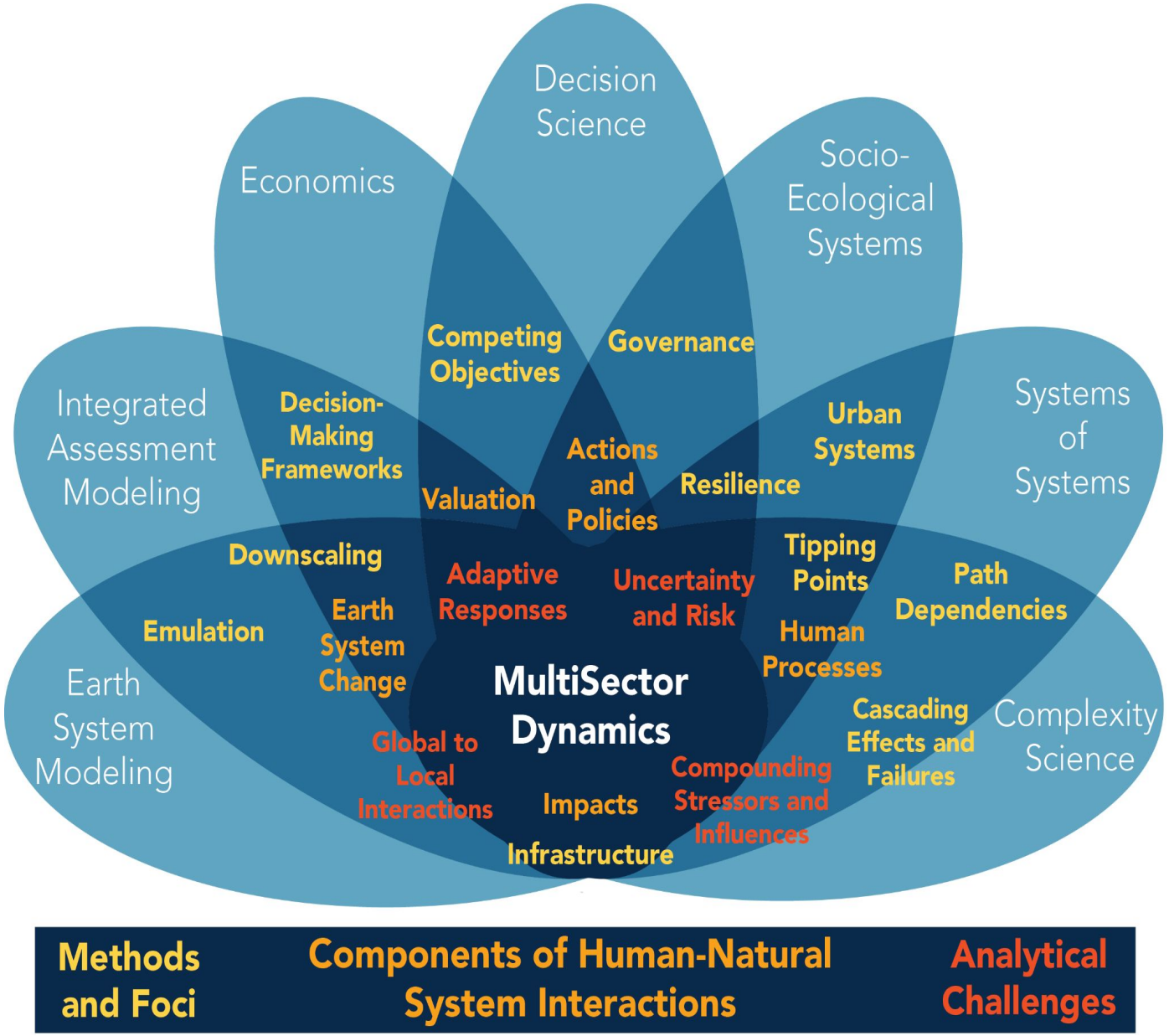
2. **Stabilities and Instabilities.** Identify the characteristics of interacting natural and built environments and human processes that lead to ***stabilities*** **and** ***instabilities*** **across systems, sectors, and scales**, and deliver new insights into the role of strong interdependencies, feedbacks, and compounding influences and stressors.

3. **Foresight**. Explore how development patterns, stabilities, instabilities, and *systems resilience* may evolve within multisector, multi-scale landscapes as a result of ***future forces, stressors, and disturbances…*** and reveal what pathways, characteristics, and risk profiles may emerge from ***both gradual and abrupt transitions***.




MSD Vision 2030

# Analytic challenges and disciplinary breadth




Source: Reed et al., 2022
https://doi.org/10.1029/2021EF002621

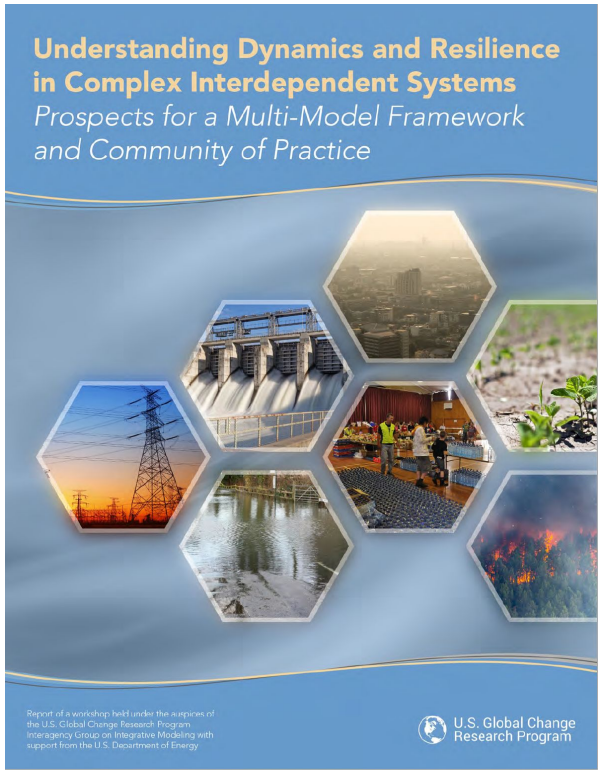
# Illustrative topics and methods (parallels to this meeting)

**Illustrative Topical Domains**

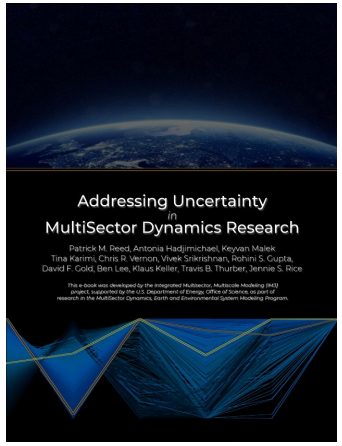

**Methods & Tools**

- **Functional, collaborative community-of-practice and working group structure**
- **Hierarchical frameworks** and use-inspired tools (emulators, sensitivity research, etc.)
- **Distributed science mechanisms** (i.e., open-source models, software couplers, interoperability, modular methods, community data and computation
- **Complexity theory and science** (networks, collective behavior, evolution and adaptation, pattern formation, systems theory
- **Data-driven AI/ML** and ML-model fusion methods
- **Scenario methods and development** with implications for uncertainty framing/analysis, complex storylines, modeling experiments, and more.
- **"Telescoping" resolution and fit-for-purpose process details** across spatial and temporal scales – local to global (e.g., energy, water, land, economics, population, land use, technology
- **Significant coupled systems behaviors**, such as found among energy, water, land and socioeconomic systems with non-linear responses, e.g., induced by extremes
- **Test-beds** for advancing "actionable science", stakeholder engagement, multi-scale awareness, and issues in extensibility

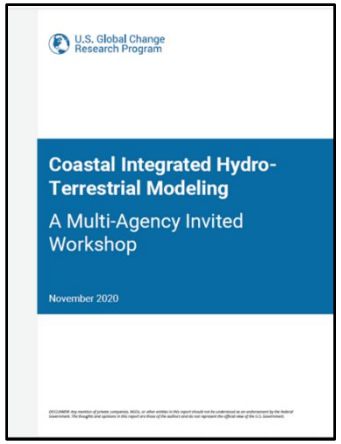
# Evolving interests and capabilities



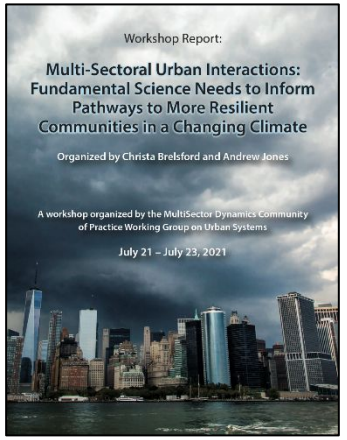

https://climatemodeling.science.energy.gov/understanding-dynamics-and-resilience-complex-interdependent-systems




https://immm-sfa.github.io/msd_uncertainty_ebook/

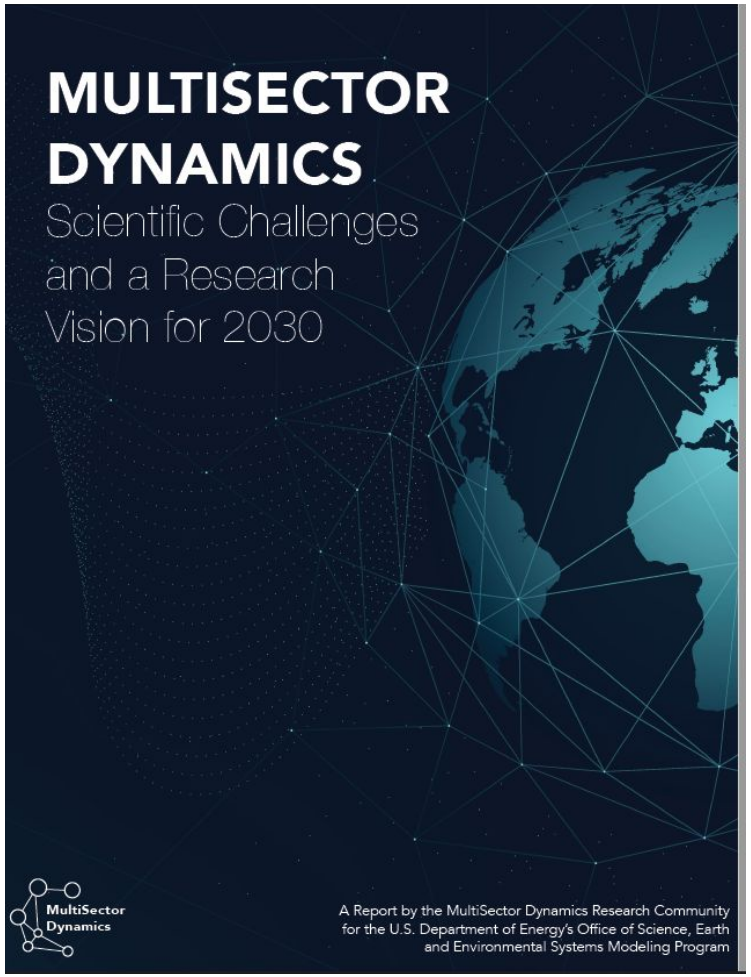



https://downloads.globalchange.gov/coasts-IG/workshop-report/C-IHTM_Workshop_Report_Nov2020.pdf




https://multisectordynamics.org/working-groups/urban/workshop-report-multi-sectoral-urban-interactions/

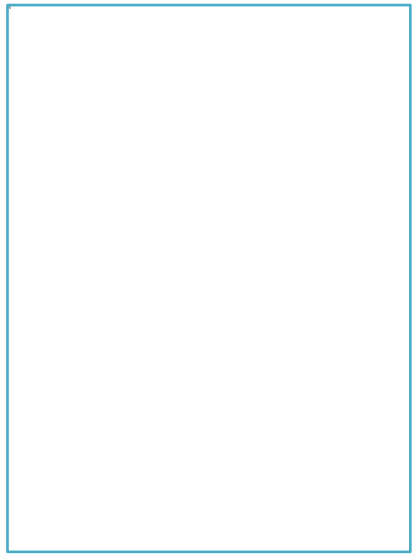
# A community driven 2030 strategic vision for MSD research

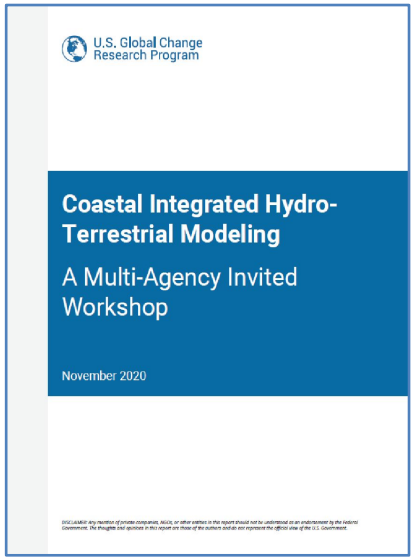


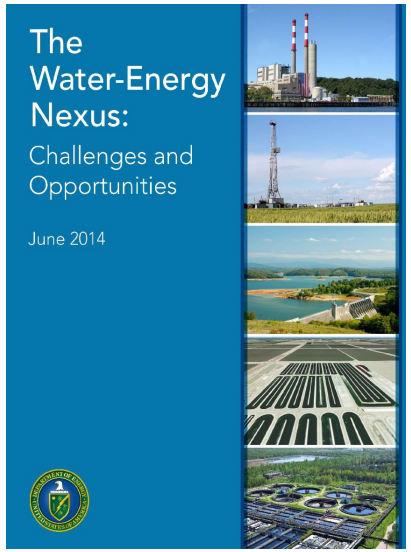

https://multisectordynamics.org/community-resources/

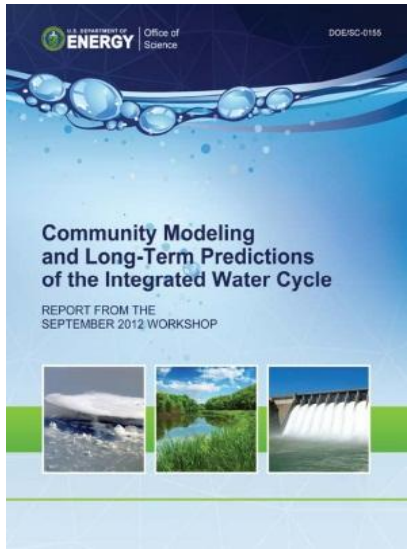
- Organized and drafted by the entire MSD Community
  - Facilitation Team
  - Scientific Steering Group
  - PI Leadership Team
  - MSD Working Group Co-Chairs
  - All MSD Participants
- A compelling roadmap
  - Scientific grand challenges
  - Frontier methods
  - Frontier tools and resources
  - Foundations from which to build
  - The essential, future Human Capital
  - A participatory, open community invitation and environment
  - A community-built structure for leadership, progress, and success (the MSD CoP)
- Innovative, bottom-up and top-down process for identifying opportunities and outlining the needs and potential actions for transformational change
- Inclusive process with a notable focus on providing opportunities for early career researchers and developing the next-generation MSD, multi-disciplinary research scientists

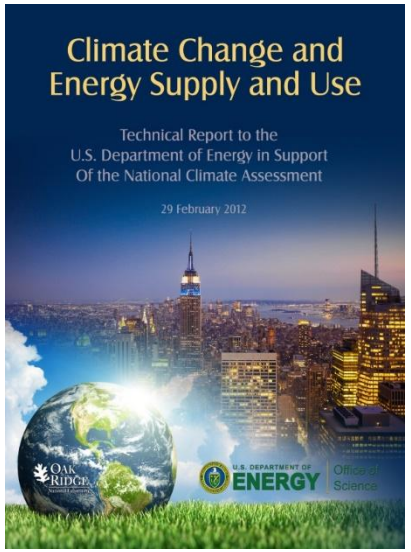
# MSD's role and leadership in inter- and intra-agency efforts - examples

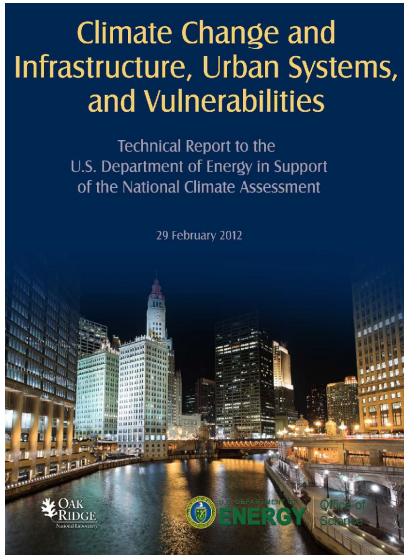


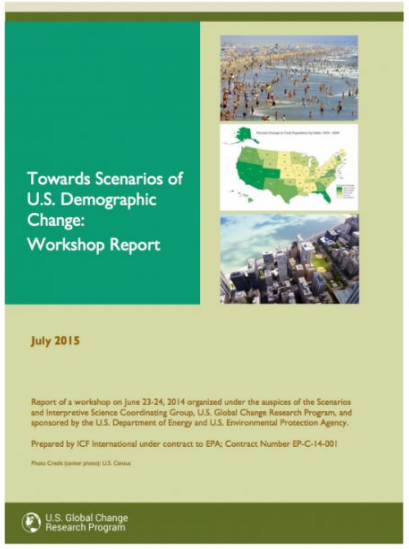


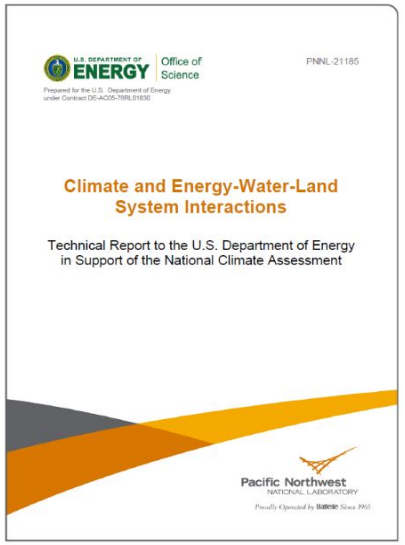



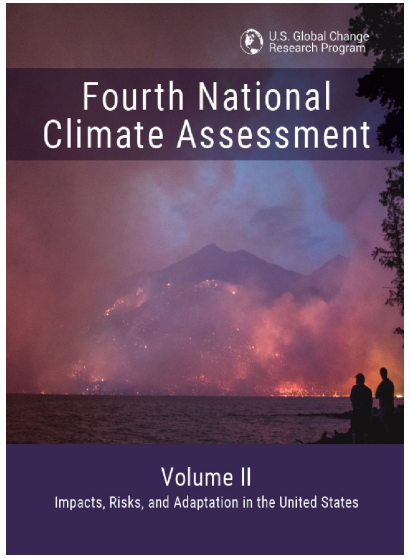



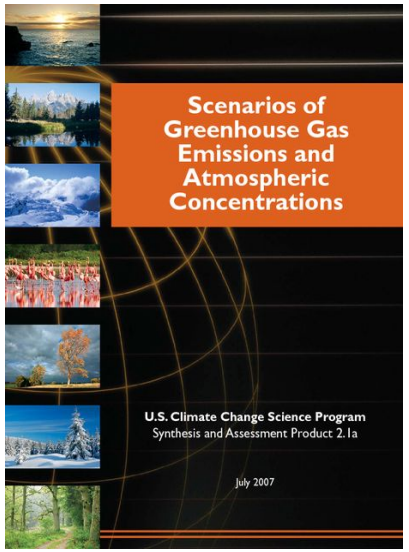



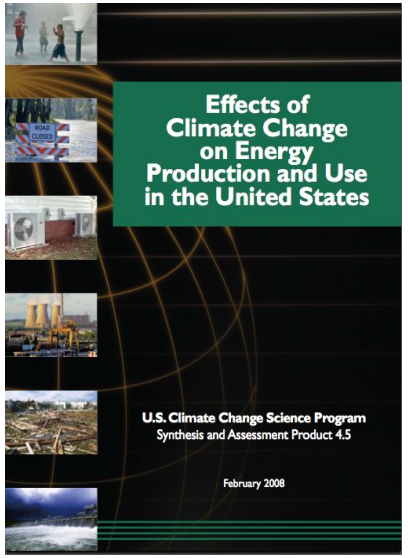







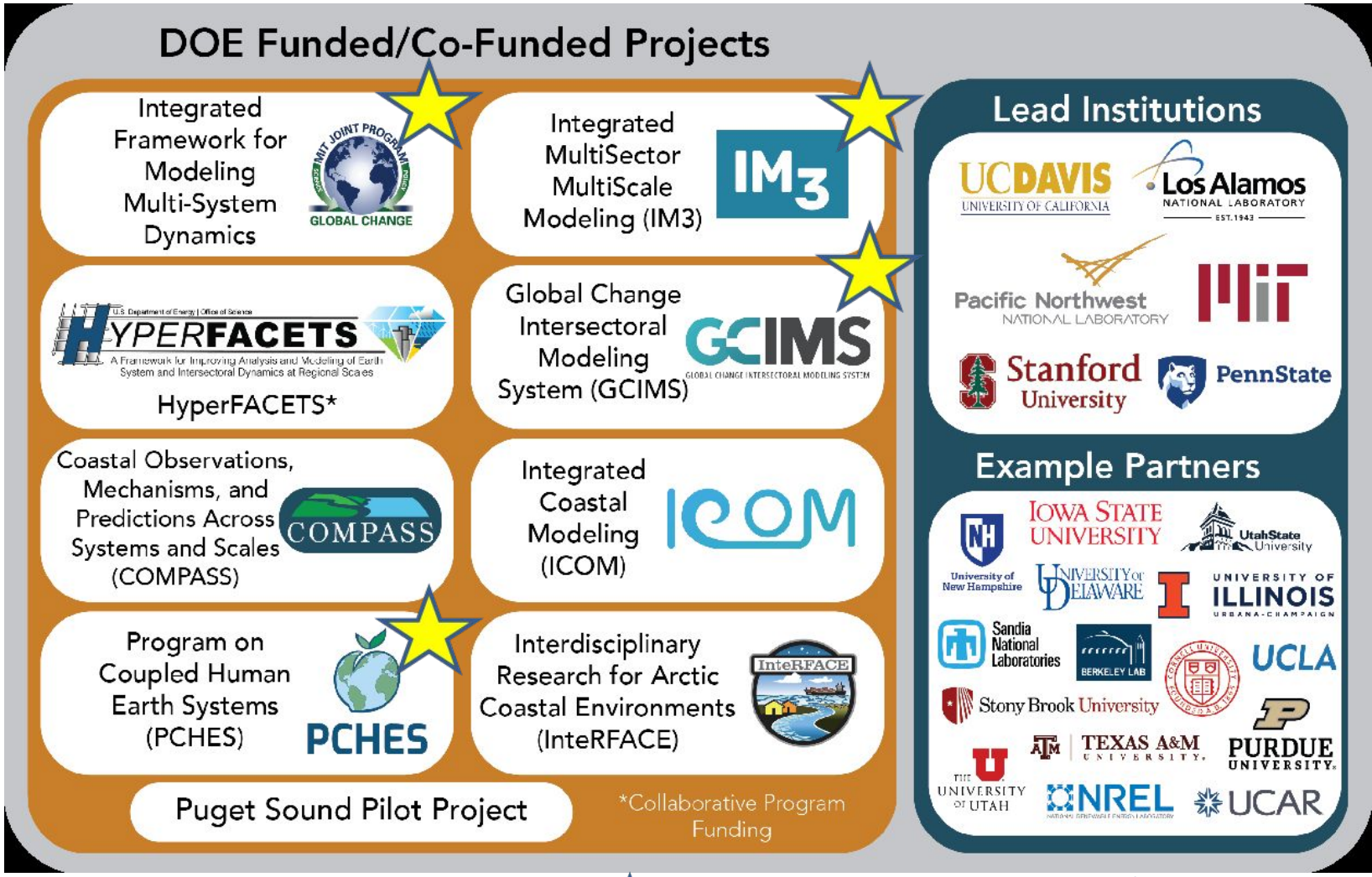



# MSD funded/co-funded projects

- A broad range and diverse set of MSD funded and co-funded teams
- Increasingly strong partnerships across MSD, EESM, EESSD, DOE, interagency, and intergovernmental.
- A focus on large, multi-institutional teams…national laboratory-led Scientific Focus Areas (SFAs) and University-led Cooperative Agreements.
- Growing interest in regional and sub-regional studies on climate and multi-stressor challenges and responses.
- Coordinated through regular and targeted events and the DOE funded MSD Community-of-Practice



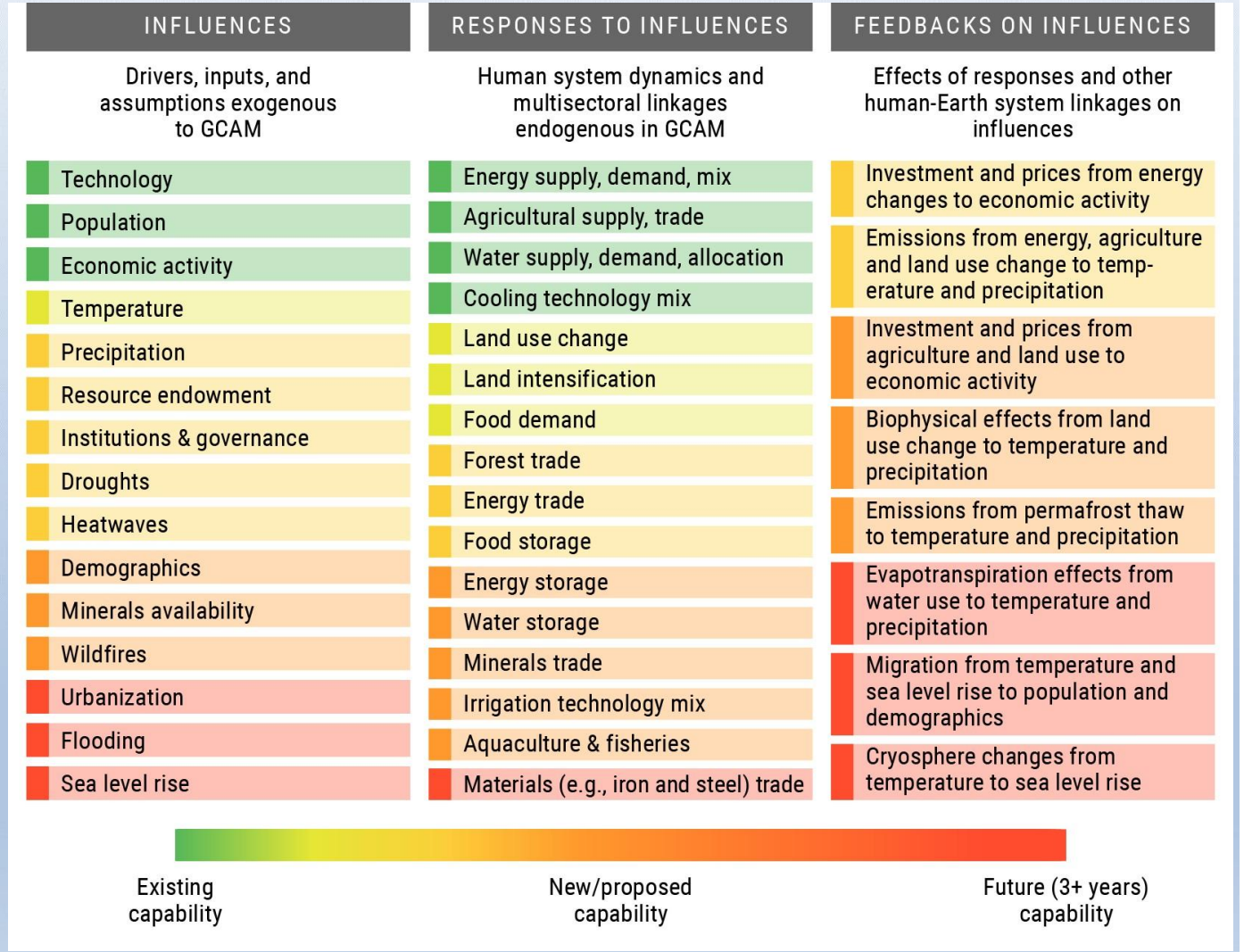

MSD LIVE

MSD MultiSector Dynamics Community of Practice

= foundational MSD

# Global Change Intersectoral Modeling System –Laboratory Scientific Focus Area

- Focuses on long-term evolution of the coupled human-Earth system
- An integrated framework to investigate the interplay between influences, responses, and feedbacks
- Internally consistent, tightly coupled, computationally efficient framework
- Regional to global spatial scales and seasonal to multidecadal timescales
- Major research experiments:
  - Compounding Influences
  - Regional
  - Human Responses
  - Human–Earth System Feedbacks
  - Links to flagship Energy-Exascale Earth System Model




gcims.pnnl.gov

# Toward a modeling framework and ecosystem of tools

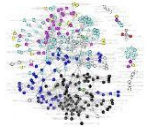
## Dynamic Integration

GCAM: Global Change Analysis Model

GCAM-USA: 50 U.S.-State Version of GCAM

Cassandra: Model Coupling Framework

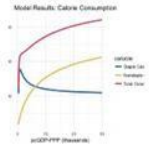
## Data Development



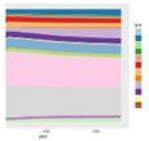
gcamdata: GCAM Data System

Moirai: Land Data Amalgamation for GCAM's AgLu Module

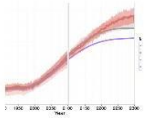
## Component System



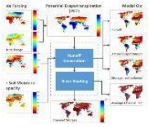
Ambrosia: GCAM Food Demand Model



gcamland: GCAM Land Allocation Model

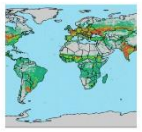


Hector: Reduced-Form Climate Model

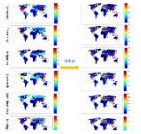


Xanthos: Global Hydrologic Modeling Framework

## Disaggregation

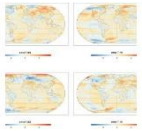


Demeter: Land Use and Land Cover Change Disaggregation

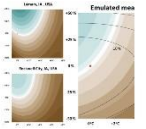


Tethys: Spatial and Temporal Sectoral Water Demand Downscaling

## Statistical Emulators



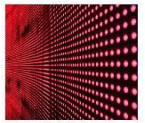
fldgen: Earth System Model Emulator for Temperature and Precipitation



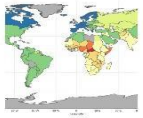
Persephone: Crop Model Yield Change Emulator

## Supporting Tools

GCAM Interactive Visualization Dashboard: A Scenario Explorer

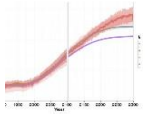


gcam_reader: GCAM Data Extraction Python Package



gcammaptools: Geospatial Visualization R Package

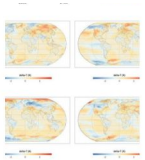
pygis: Python GIS Utilities



Pyhector: Python Interface for Hector

rgcam: GCAM Data Extraction R Package

rgis: R GIS Utilities



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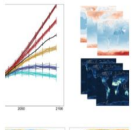

STITCHES: A comprehensive solution to climate model output emulation

# Some recent publications

2024

**Hydropower expansion in eco-sensitive river basins under global energy-economic change**

A. F. M. Kamal Chowdhury; Thomas Wild; Ying Zhang; Matthew Binsted; Gokul Iyer; Son H Kim; Jonathan Lamontagne

Nature Sustainability

READ | DATASET | CODE

2024

**The future evolution of global natural gas trade**

Brinda Yarlagadda; Gokul Iyer; Matthew Binsted; Pralit Patel; Marshall Wise; Jeff McLeod

iScience, 27(2)

READ | DATASET | CODE

2023

**Agriculture, bioenergy, and water implications of constrained cereal trade and climate change impacts**

Ying Zhang; Stephanie Waldhoff; Marshall Wise; Jae Edmonds; Pralit Patel

READ

2023

**Non-parametric projections of national income distribution consistent with the Shared Socioeconomic Pathways**

Kanishka Narayan; Brian O'Neill; Stephanie Waldhoff; Claudia Tebaldi

Environmental Research Letters, Volume 18, 4

READ | DATASET

2022

**Doubling protected land area may be inefficient at preserving the extent of undeveloped land and could cause substantial regional shifts in land use**

Alan Di Vittorio; Kanishka Narayan; Pralit Patel; Katherine Calvin; Chris R. Vernon

GCB-Bioenergy, Volume 15,2

READ

2022

**STITCHES: creating new scenarios of climate model output by stitching together pieces of existing simulatior**

Claudia Tebaldi; Abigail Snyder; Kalyn Dorhe

Earth System Dynamics, Volume 13, 4

READ | HIGHLIGHT | DATASET | CODE

2022

**GCAM-USA v5.3_water_dispatch: integrated modeling of subnational US energy, water, and land systems within a global framework**

Matthew Binsted; Gokul Iyer; Pralit Patel; Neal T Graham; Yang Ou; Zarrar Khan; Nazar Kholod; Kanishka Narayan; Mohamad Hejazi; Son H Kim; Katherine Calvin; Marshall Wise

Geoscientific Model Development, 15

2023

**Seasonality and Trade in Hydro-heavy Electricity Markets: A case study with the West Africa Power Pool (WAPP)**

Franklyn Kanyako; Jonathan Lamontagne; Erin Baker; Sean Turner; Thomas Wild

Applied Energy, Volume 329

READ

2023

**Global monthly sectoral water use for 2010–2100 at 0.5° resolution across alternative futures**

Zarrar Khan; Isaac Thompson; Chris R. Vernon; Neal T Graham; Thomas B. Wild; Min Chen

Scientific Data, Volume 10

READ | DATASET | CODE

2023

**Quantifying Airborne Fraction Trends and the Destination of Anthropogenic CO2 by Tracking Carbon Flows in a Simple Climate Model**

Leeya Pressburger; Kalyn Dorheim; Trevor F Keenan; Haewon McJeon; Steven J. Smith; Ben Bond-Lamberty

Environmental Research Letters, Volume 18, 5

READ | HIGHLIGHT | DATASET

2022

**Long-term basin-scale hydropower expansion under alternative scenarios in a global multisector model**

Ying Zhang; Matthew Binsted; Gokul Iyer; Sonny Kim; Thomas B. Wild; Mengqi Zhao

Environmental Research Letters, Volume 17, 11

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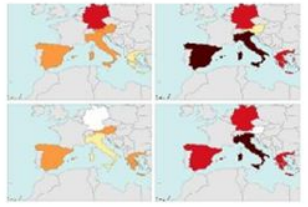


2022

**rmap: An R package to plot and compare tabular data on customizable maps across scenarios and time**

Zarrar Khan; Mengqi Zhao; Chris R. Vernon; Thomas B. Wild; Brinda Yarlagadda

Journal of Open Source Software, 7(77)

READ | HIGHLIGHT | CODE

2022

**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 Lamontagne; Julianne D. Quinn; Sanjib Sharma; Nusrat J. Molla; Jonathan D. Herman; Ryan Sriver; Jennifer Morris; Ben Seiyon Lee

Earth's Future, Volume 10, 8

READ | CODE

2022

**Future bioenergy expansion could alter carbon sequestration potential and exacerbate water stress in the United States**

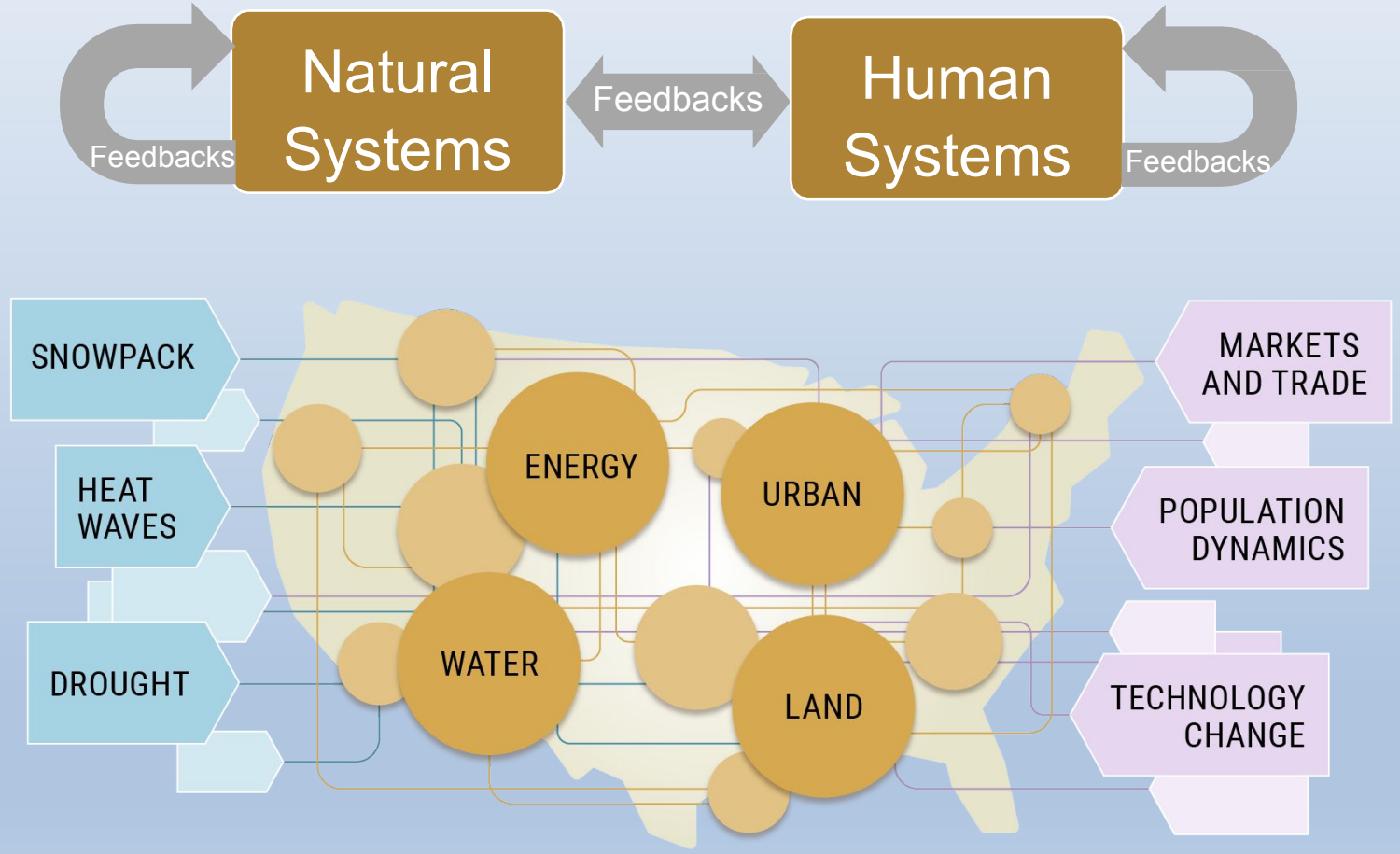
Yanyan Cheng; Maoyi Huang; David M. Lawrence; Katherine Calvin; Danica L. Lombardozzi; Eva Sinha; Ming Pan; Xiaogang He

Science Advances, Volume 8, 18

READ | CODE

# Integrated Multisector, Multiscale Modeling System –Laboratory Scientific Focus Area

1. **Develop flexible, open-source, integrated modeling capabilities** that capture the structure and dynamic behavior of the multiscale interactions within and between human and natural systems.
2. **Use these capabilities to study the evolution, vulnerability, and resilience** of interacting human and natural systems and landscapes due to long-term influences and short-term shocks, from local to continental scales.
3. **Explore how uncertainty** in data, model structure, model parameters, multi-model coupling strategies, and spatial and temporal resolutions influence projections of human-natural systems evolution.




im3.pnnl.gov

# Some recent publications


2022

## Addressing Uncertainty in MultiSector Dynamics Research

P Reed, A Hadjimichael, K Malek, T Karimi, CR Vernon, V Srikrishnan, RS Gupta, DF Gold, B Lee, K Keller, TB Thurber, JS Rice

2023

### Harmonized geospatial data to support infrastructure siting feasibility planning for energy system transitions

Vernon CR, K Mongird, KD Nelson, and JS Rice

*Scientific Data 10, 786.*

> READ | CODE | DATASET

2023

### Continental United States climate projections based on thermodynamic modification of historical weather.

Jones, AD, D Rastogi, P Vahmani, A Stansfield, K Reed, T Thurber, PA Ullrich, and JS Rice

*Scientific Data 10(1): 664*

> READ | CODE | DATASET

2023

### Deciphering the sensitivity of urban canopy air temperature to anthropogenic heat flux with a forcing-feedback framework.

Wang, L, T Sun, W Zhou, M Liu, and D Li

*Environmental Research Letters 18, 094005*

> READ | CODE

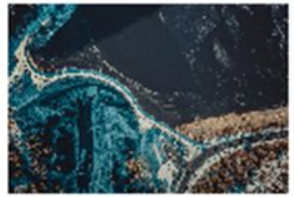
2023

### osiris: An R package to process climate impacts on agricultural yields for the Global Change Analysis Model

Ahsan, H, Z Khan, A Snyder, P Kyle, and CR Vernon

*Journal of Open Source Software 8(85), 5226.*

> READ



2022

### Revised monthly energy generation estimates for 1,500 hydroelectric power plants in the United States

Turner, SWD, N Voisin, and K Nelson

*Scientific Data 9, 675*

> READ | HIGHLIGHT | CODE

2022

### Generative Adversarial Networks for Ensemble Projection of Future Urban Morphology

Allen-Dumas, MR, AR Wheeler, LT Sweet-Breu, J Anantharaj, and KR Kurte

*ARIC '22: Proceedings of the 5th ACM SIGSPATIAL International Workshop on Advances in Resilient and Intelligent Cities*

> READ | HIGHLIGHT

2022

### The Role of Regional Connections in Planning for Future Power System Operations under Climate Extremes

Dyreson, A, N Devineni, SWD Turner, T De Silva, A Miara, N Voisin, and S Cohen

*Earth's Future 10, no. 6 e2021EF002554*

> READ | HIGHLIGHT | CODE | DATASET

2022

### Urban land teleconnections in the United States: a graphical network approach

McManamay, RA, C Brinkley, CR Vernon, S Raj, JR Rice

*Computers, Environment and Urban Systems 95, 101822*

> READ | HIGHLIGHT

2023

### Large ensemble diagnostic evaluation of hydrologic parameter uncertainty in the Community Land Model Version 5 (CLM5)

Yan, H, N Sun, H Eldardiry, TB Thurber, PM Reed, K Malek, R Gupta, D Kennedy, SC Swenson, Z Hou, Y Cheng, and JS Rice

*Journal of Advances in Modeling Earth Systems 15, e2022MS003312*

> READ

2023

### Characterizing Uncertainty in Community Land Model Version 5 Hydrological Applications in the United States

Yan, H, N Sun, H Eldardiry, TB Thurber, PM Reed, K Malek, R Gupta, D Kennedy, SC Swenson, L Wang, D Li, CR Vernon, CD Burleyson, and JS Rice

*Scientific Data 10, no. 187*

> READ | HIGHLIGHT

2022

### Exploring the Consistency of Water Scarcity Inferences between Large-Scale Hydrologic and Node-Based Water System Model Representations of the Upper Colorado River Basin

Hadjimichael, A, J Yoon, PM Reed, N Voisin, and W Xu

*Journal of Open Source Software*

> READ | HIGHLIGHT | CODE

2022

### tell: a Python package to model future total electricity loads in the United States

McGrath, CR, CD Burleyson, Z Khan, A Rahman, T Thurber, CR Vernon, N Voisin, and JS Rice

*Journal of Open Source Software*

> READ | HIGHLIGHT | CODE | DATASET

2022

### Diagnostic framework for evaluating how parametric uncertainty influences agro-hydrologic model projections of crop yields under climate change.

Karimi T, PM Reed, K Malek, and J Adam

*Water Resources Research 58(6), e2021WR031249*

> READ

2021

### Technology Pathways Could Help Drive the U.S. West Coast Grid's Exposure to Hydrometeorological Uncertainty

Wessel, J, JD Kern, N Voisin, K Oikonomou, and J Haas

*Earths Future 10 (1)*

> READ

2022

### U.S. national water and energy land dataset for integrated multisector dynamics research

Sturtevant, J, RA McManamay, and CR DeRolph

*Scientific Data 9, 183*

> READ | HIGHLIGHT

2022

### Anthropogenic heating of the urban environment: An investigation of feedback dynamics between urban micro-climate and decomposed anthropogenic heating from buildings.

Vahmani P, L Xuan, AD Jones, and T Hong

*Building and Environment 213, 108841*

> READ | HIGHLIGHT | CODE | DATASET

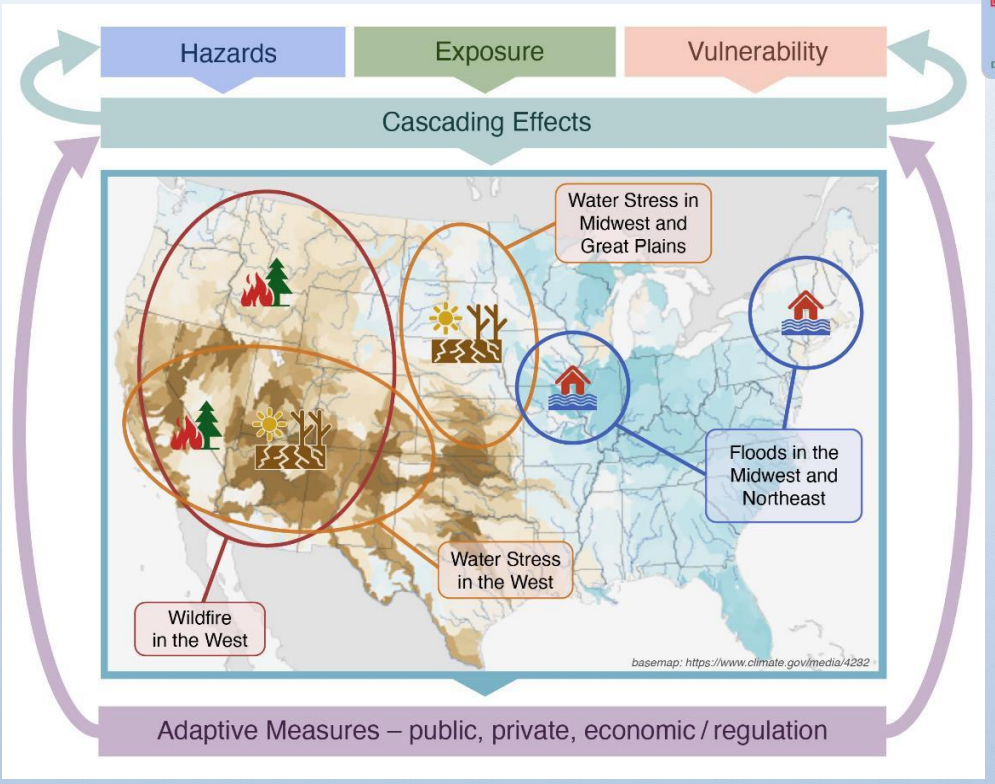

# Program on Coupled Human Earth Systems –University Cooperative Agreement

PennState · ILLINOIS · Stanford University · TEXAS · BOSTON UNIVERSITY · PURDUE UNIVERSITY · DARTMOUTH · COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

https://www.pches.psu.edu/

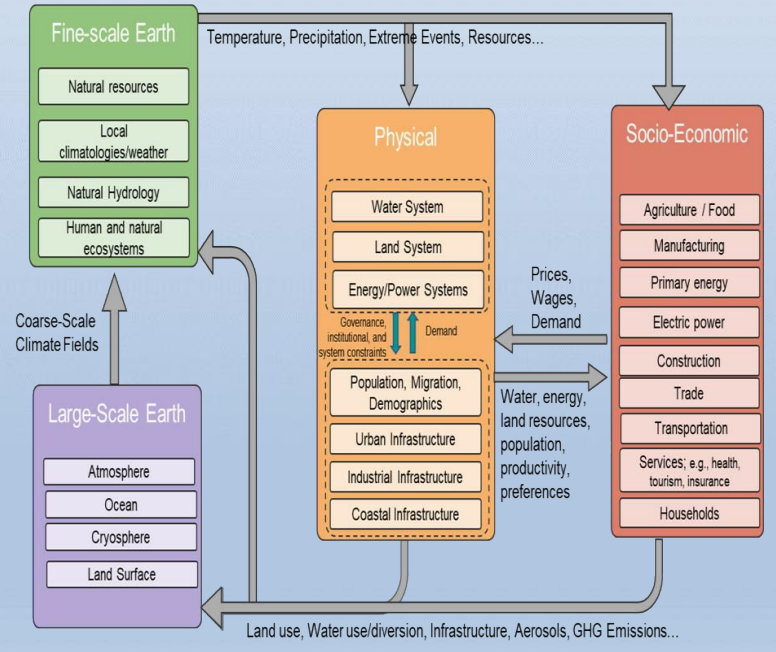
Goal of ADAPT: To understand multi-stressor and multiscale drivers of feedbacks, cascading failures, and risk management pathways within complex MSD systems

## PCHES – ADAPT




## PCHES – FRAME

Goal: To build a next generation integrated suite of science-driven modeling and analytic capabilities, and a more expanded and connected community of practice, for analyses of compound stressors related to integrated Energy-Water-Land systems dynamics and interdependent infrastructures.




## PCHES – PIAMDDI

- science and technology
- impacts and adaptation
- regional integrated assessment modeling
- key energy-related intersecting systems
- uncertainty

# Some recent publications

https://www.pches.psu.edu/

2023 PCHES-ADAPT

Population Aging and Heat Exposure in the 21 st Century: Which U.S. Regions Are at Greatest Risk and Why?

Carr, D, G Falchetta and IS Wing

*Gerontologist*

2023 PCHES-FRAME

Air-conditioning adoption and electricity demand highlight climate change mitigation-adaptation tradeoffs

Colelli, FP, IS Wing and E Cian

*Scientific Reports*

2023 PCHES-ADAPT

Local, regional, and global adaptations to a compound pandemic-weather stress event

Haqiqi, I, DS Grogan, MB Horeh, J Liu, UL Baldos, R Lammers and TW Hertel

*Environmental Research Letters*

2022 PCHES-FRAME PCHES-ADAPT

Aggregation bias and its drivers in large-scale flood loss estimation: A Massachusetts case study

Pollack, AB, I Sue Wing and C Nolte

*Journal of Flood Risk Management*

2022 PCHES-FRAME

Heterogeneous climate change impacts on electricity demand in world cities circa mid-century

Romitti, Y and I Sue Wing

*Scientific Reports*

2022 PCHES-FRAME

Inequality in the availability of residential air conditioning across 115 US metropolitan areas

Romitti, Y, I Sue Wing, KR Spangler and GA Wellenius

*PNAS Nexus*

2023 PCHES-FRAME PCHES-ADAPT

Potential Benefits in Remapping the Special Flood Hazard Area: Evidence from the U.S. Housing Market

Pollack, AB, DH Wrenn, C Nolte and IS Wing

*Journal of Housing Economics*

2022 PCHES-FRAME

Global gridded crop harvested area, production, yield, and monthly physical area data circa 2015

Grogan, D, S Frolking, D Wisser, A Prusevich and S Glidden

*Scientific Data*

2022 PCHES-FRAME PCHES-ADAPT PCHES-IAMDDI

Water balance model (WBM) v.1.0.0: a scalable gridded global hydrologic model with water-tracking functionality

Grogan, DS, S Zuidema, A Prusevich, WM Wollheim, S Glidden and RB Lammers

*Geoscientific Model Development*

2022 PCHES-FRAME PCHES-ADAPT

Flood hazard model calibration using multiresolution model output

Roth, SM, BS Lee, S Sharma, I Hosseini-Shakib, K Keller and M Haran

*Environmetrics*

2022 PCHES-FRAME PCHES-ADAPT

Neglecting model parametric uncertainty can drastically underestimate flood risks

Sharma, S, BS Lee, I Hosseini-Shakib, M Haran and K Keller

*Earths Future*

2022 PCHES-FRAME

Integrated hydrological, power system and economic modelling of climate impacts on electricity demand and cost

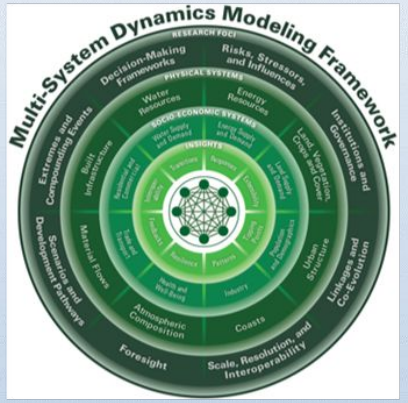
Webster, M, K Fisher-Vanden, V Kumar, RB Lammers and J Perla

*Nature Energy*

# Sectoral Interactions, Compounding Influences and Stressors, and Complex Systems: Understanding Tipping Points and Non-Linear Dynamics - University Cooperative Agreement

With a focus on the Mississippi River

***Advance and utilize multi-system, multi-sector modeling framework to explore stressors, risks and responses of complex, interconnected physical and socioeconomic systems***

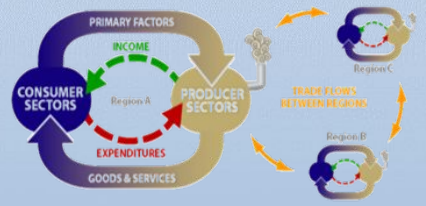



## Multi-Scale Interactions

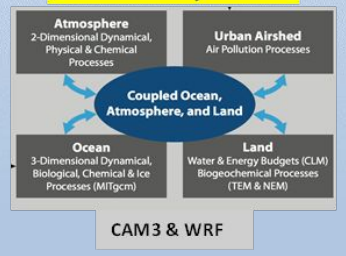
Global Drivers » Teleconnections » Local Systems » Decision-Making

## Toolbox for Multi-Sector Modeling

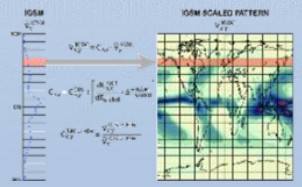
### Human Systems



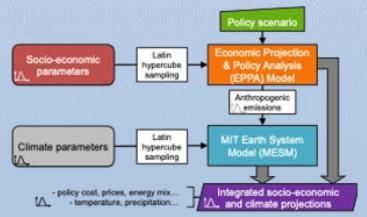

### Natural Systems



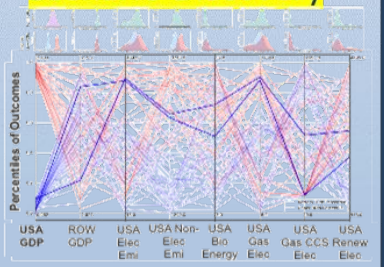

### Pattern Scaling Extremes



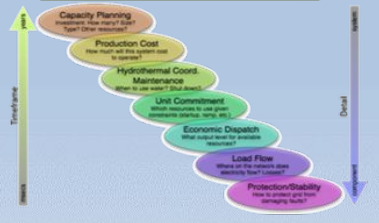

### Probabilistic Ensembles



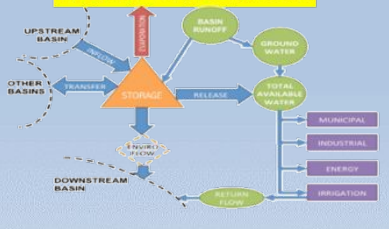

### Scenario Discovery



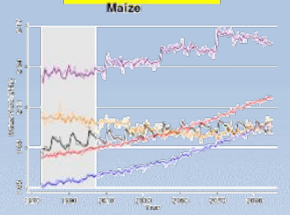

### Electricity Models




### Water Resources

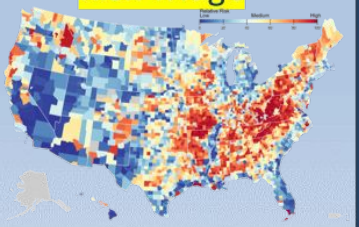



### Emulators




### Decision Frameworks

### Risk Triage



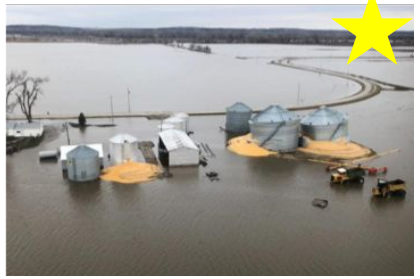
## Major Tasks:

- Human-Natural System Interactions
- Transportation Infrastructure
- Stress-Testing Paired Systems

https://globalchange.mit.edu/research/research-projects/integrated-framework-modeling-multi-system-dynamics

U.S. DEPARTMENT OF ENERGY | Office of Science

# Some recent publications



Assessing Compounding Risks Across Multiple Systems and Sectors: A Socio-Environmental Systems Risk-Triage Approach

Schlosser, CA, C Frankenfeld, S Eastham, X Gao, A Gurgel, A McCluskey, J Morris, S Orzach, K Rouge, S Paltsev and J Reilly

The Changing Nature of Climate-Related Risks in Global Wind Power Resources

Schlosser, CA, S Uzquiano Perez and A Sokolov

*MIT Joint Program Report 357*

Representing Socio-Economic Uncertainty in Human System Models

Morris, J, J Reilly, S Paltsev, A Sokolov and K Cox

*Earth's Future*


Toward a just energy transition: A distributional analysis of low-carbon policies in the USA

García-Muros, X, J Morris and S Paltsev

*Energy Economics*

Agricultural and forest land-use change in the continental United States: Are there tipping points?

Gurgel, AC, JM Reilly and E Blanc

*iScience*

Predictability of U.S. regional extreme precipitation occurrence based on large-scale meteorological patterns

Gao, X and S Mathur

Challenges in simulating economic effects of climate change on global agricultural markets

Gurgel, AC, J Reilly and E Blanc

A consistent framework for uncertainty in coupled human-Earth system models

Morris, J, A Sokolov, A Libardoni, C Forest, S Paltsev, J Reilly, CA Schlosser, R Prinn and H Jacoby

The role of cross-border electricity trade in transition to a low-carbon economy in the Northeastern U.S.

Yuan, M, K Tapia-Ahumada and J Reilly

*Energy Policy*

Statistical emulators of irrigated crop yields and irrigation water requirements

Blanc, E

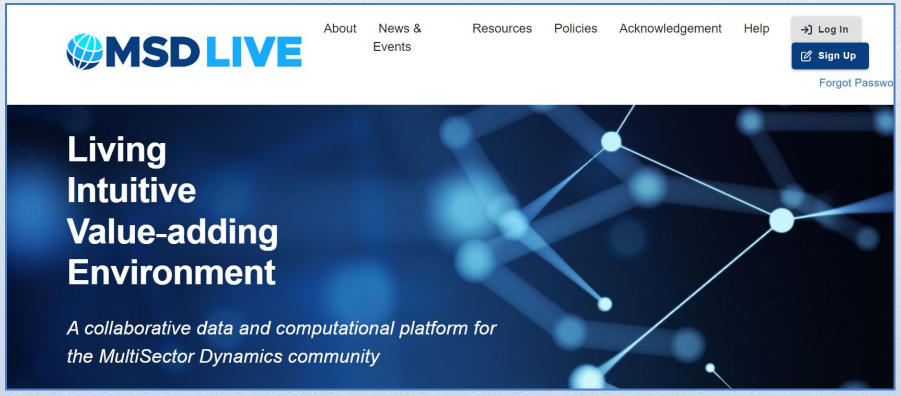
*Agricultural and Forest Meteorology*

**https://globalchange.mit.edu/research/research-projects/sectoral-interactions-compounding-influences-and-stressors-and-complex**

# MSD LIVE – a lab-led project

You are invited to attend Thursday's tutorial during the networking session

1. Quickly and easily find datasets produced by other users and projects.
2. Permanently archive small (<250 MB), medium (250 MB - 50 GB), and large (50 GB to 20 TB) final-form datasets and generate data Digital Object Identifiers to meet journal requirements for data sharing.
3. Use an intuitive web-based user interface to document and share versioned datasets and associate data with the code used to produce it.
4. Train new team members on MSD projects to effectively manage data and code and capture the institutional knowledge of members that leave a project.
5. Create and manage teams that cross institutions to quickly and easily grant access to data and code without having to obtain multiple sets of institutional credentials.
6. Share working datasets across multiple institutions collaborating on a project in real-time.



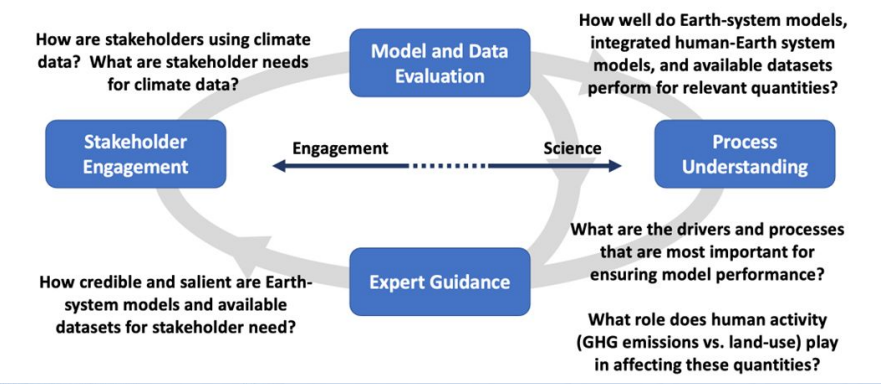

**Living**
There should be continuous interaction with the platform throughout the data and code lifecycle rather than only storing the final product.

**Intuitive**
Using the platform should not require a steep learning curve.

**Value-adding**
There should be tools built into the platform that enhance the ability of the MSD community to do their work.

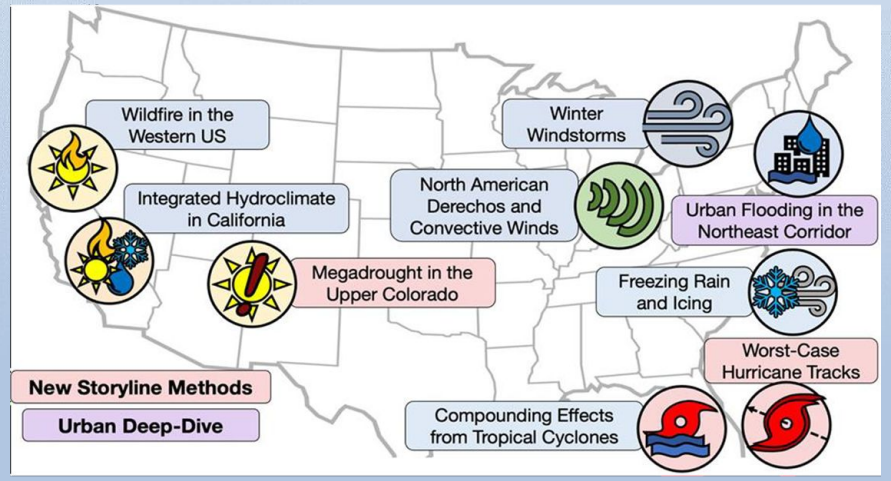
**Environment**
The platform should include a computational component that delivers an integrated data-work environment as opposed to a stand-alone data repository.

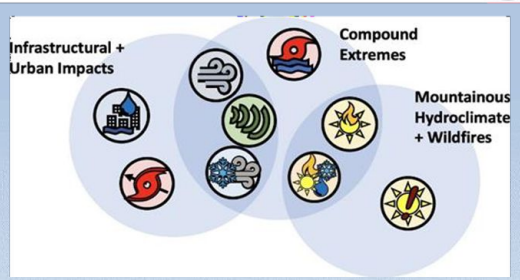
# MSD in *HyperFACETS* – a large, "federated", university cooperative agreement




**Goals:**

1. **Advance our understanding of processes at the atmosphere-water-energy-land interface.**
2. **Fundamentally understand and evaluate our ability to perform credible climate modeling of particular regions and their associated processes, especially in the extreme.**
3. **To strengthen stakeholder engagement in model development, evaluation and application. Engage effectively in co-production: Together enforcing the science and meeting real needs.**



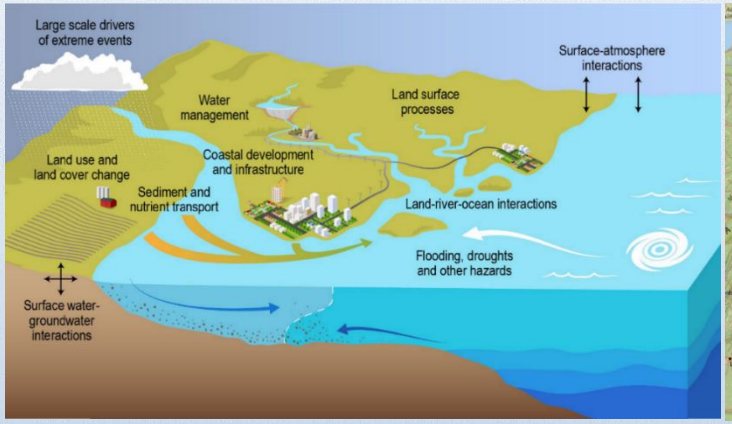





- (Under Review) Jones, A.D., D. Rastogi, P. Vahmani, A.M. Stansfield, K.A. Reed, T. Thurber, P.A. Ullrich and J. Rice (2023) **"Continental United States climate projections based on thermodynamic modification of historical weather"** Submitted to Scientific Data.
- (Under Review) Srivastava, A.K., P.A. Ullrich, D. Rastogi, P. Vahmani, A. Jones and R. Grotjahn (2023) **"Assessment of WRF dynamically downscaled precipitation on subdaily and daily timescales over CONUS"** Submitted to Geosci. Model Dev.
- (Under Review) McGinnis, S., L. Kessenich, L. Mearns, A. Cullen, H. Podschwit, and M. Bukovsky (2023) **"Future regional increases in simultaneous large Western US wildfires."** Submitted to Int. J. Wildland Fire
- (Under Review) Gao, J. and M. S. Bukovsky (2023) **"Urban land patterns can moderate population exposures to climate extremes"** Submitted to Nature Communications.
- (Under Review) Song, Y., T. W.-P. Tsai, J. Gluck, A.M. Rhoades, C.M. Zarzycki, R. McCrary, K. Lawson and C. Shen (2023) **"LSTM-based data integration to dramatically improve one-month-ahead snow water equivalent forecast and diagnose error sources"** Submitted to J. Hydrometeor.
- (Under Review) Siirila-Woodburn, E.R., P.J. Dennedy-Frank, A.M. Rhoades, P. Vahmani, F. Maina, B.J. Hatchett, Y. Zhou and A.D. Jones (2023) **"The role of atmospheric rivers on groundwater: Lessons learned from an extreme wet year"** Submitted to Water Resour. Res.
- (Under Review) Wang, S. S.-C., L.R. Leung, and Y. Qian (2023) **"Extension of intense fire emissions from summer to fall and its drivers in western US"** Submitted to Earth's Future.
- (Under Review) McClenny, E. and P.A. Ullrich (2023) **"Response of atmospheric river width and intensity to sea-surface temperatures in an aquaplanet model"** Submitted to J. Geophys. Res. Atm.
- (Under Review) Stuivenvolt-Allen, J., Y. Chikamoto, S.-Y. Wang and A. Timmerman (2023) **"Emergence of a decadal hydroclimate regime in the western United States"** Submitted to Geophys. Res. Lett.
- (Under Review) Yates, D., J.K. Szinai, and A.D. Jones (2023) **"Modeling the water systems of the Western US to support climate-resilient electricity system planning"** Submitted to Earth's Future.
- (Available) Pryor S. C., J. J. Coburn, R. J. Barthelmie and T. Shepherd (2023) "**Projecting future energy production from operating wind farms in North America: Part 1: Dynamical downscaling**" J. Appl. Meteor. Climatol. 62, 63-80 doi: 10.1175/JAMC-D-22-0044.1.
- (Available) Coburn J.J. and Pryor S.C. (2023) "**Projecting future energy production from operating wind farms in North America: Part 2: Statistical downscaling**" J. Appl. Meteor. Climatol. 62, 81-101, doi: 10.1175/JAMC-D-22-0047.1.

# MSD in *Integrated Coastal Modeling* – a large, "federated", lab-led multi-institutional project

Goal: To deliver a robust predictive understanding of coastal evolution that accounts for the complex, multiscale interactions among physical, biological, and human systems.





- **Pacific Northwest National Laboratory led multi-institutional team** (LANL a strong participant)… >60% funding awarded by PNNL to others
- **Mid-Atlantic regional focus** … existing DOE capabilities, complex systems interactions, extensive data, and converging interagency activities
- **A "federated" approach** spanning four distinct program areas within DOE's EESSD; requires foundational work in each area and substantial crosscut modeling work.
- **Informs potential follow-on observational and experimental work.**

**Cross-Cutting Topics**

Long-term changes in flooding, drought, hypoxia, and other coastal hazards

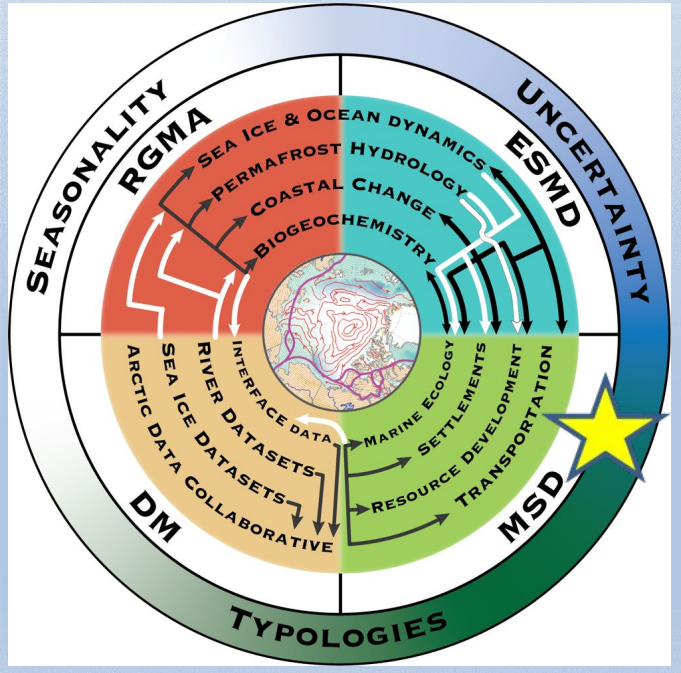
Impacts of urbanization, development, and other land use changes on coastal systems

| Regional & Global Modeling & Analysis (RGMA) | MultiSector Dynamics (MSD) | Earth System Model Development (ESMD) | Subsurface Biogeochemistry Research (SBR) |
|---|---|---|---|
| Large-scale drivers of storms, droughts, and other extreme events | Interactions between coastal development, critical infrastructure, and natural systems | Earth system drivers of coastal flooding | Influence of surface water – groundwater interactions and lateral flow on coastal flooding |
| Influence of surface-atmosphere interactions on extreme events | Probabilistic natural hazard characterization | Land-river-ocean interactions affecting coastal salinity gradients | |
| Influence of land surface process on land-atmosphere interactions | Ability of adaptation to reduce risk or enhance resilience | Controls on fate and transport of sediment and nutrients | |

**icom.pnnl.gov**

# MSD in *Interdisciplinary Research for Arctic Coastal Environments (InteRFACE)* – a large, "federated", lab-led multi-institutional project

The InteRFACE project focuses on how the coupled, multi-scale feedbacks among land processes, sea ice, ocean dynamics, coastal change biogeochemistry, atmospheric processes, and human systems will control the trajectory and rate of change across the Arctic coastal interface.




**Earth System focus on:**

- Sea ice and ocean dynamics
- Coastal Change
- Permafrost Hydrology
- Marine Biogeochemistry

**Multi-sector dynamics focus on:**

- Shipping
- Settlements
- Resource development


InteRFACE

Los Alamos NATIONAL LABORATORY

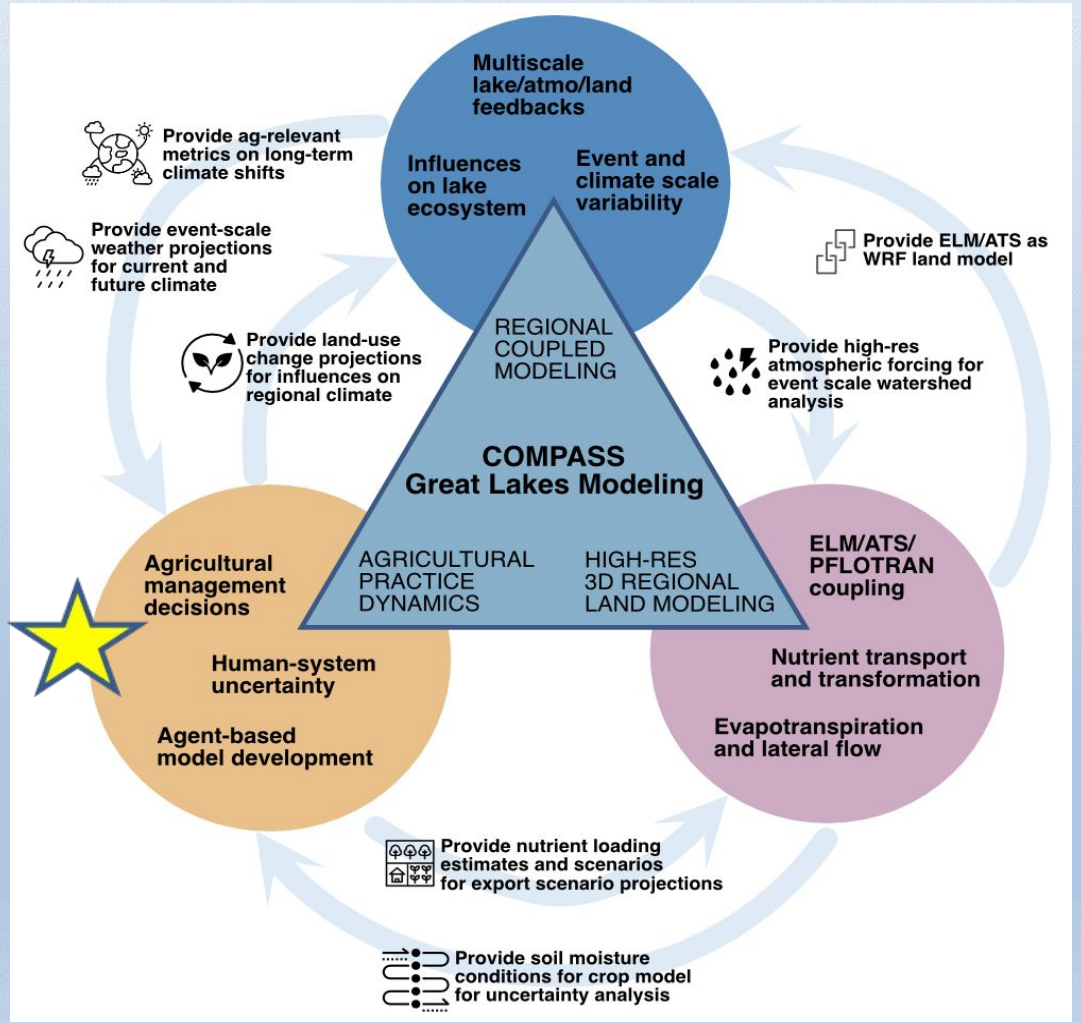
Oak Ridge National Laboratory

Pacific Northwest National Laboratory

Sandia National Laboratories

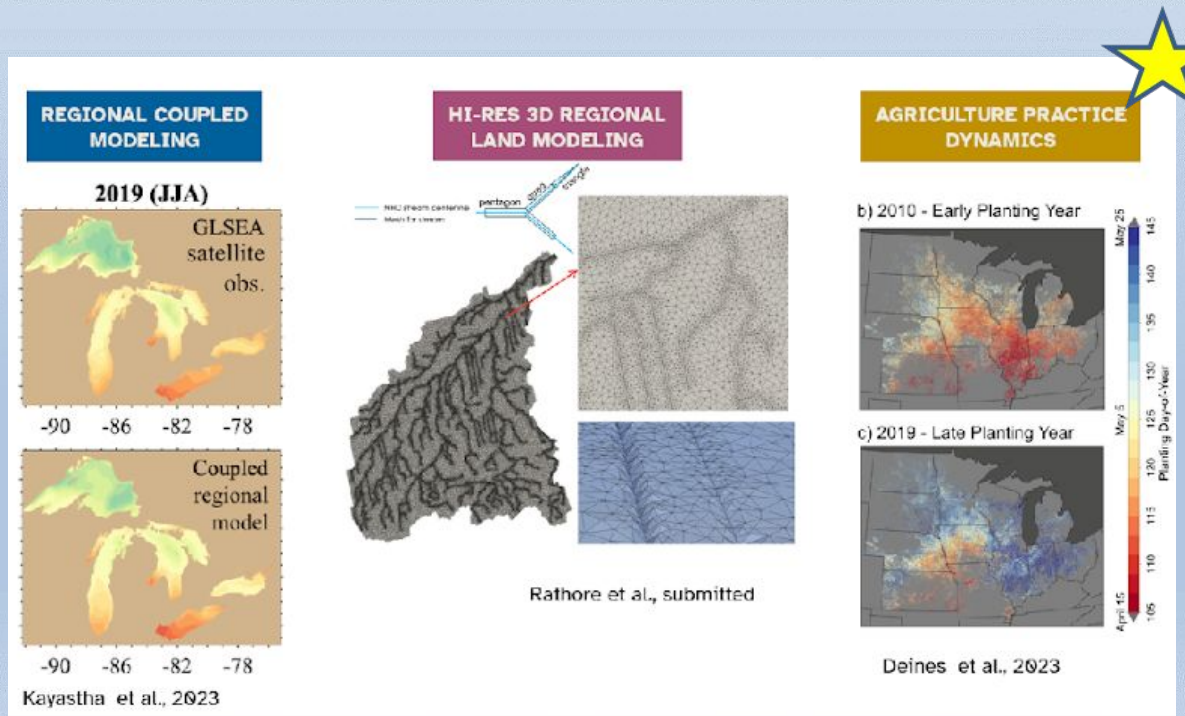
UAF University of Alaska Fairbanks

# MSD in *Interdisciplinary Research for COMPASS Great Lakes Modeling* – a large, "federated", lab-led multi-institutional project




*GLM Long-term goal:*

Improving predictive understanding of coastal systems by coupling Earth system components, each with application-appropriate detail, to understand the co-evolution and interdependencies of coastal regional processes and human systems, using the Great Lakes Region as a test bed.



# MSD in *Puget Sound Scoping & Pilot Project* - a "federated", lab-led project

## *Project Objective*

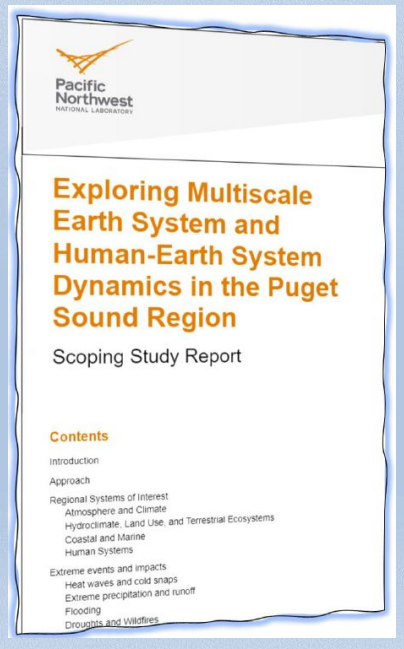
Improve understanding and modeling of Earth-Human System in Puget Sound Coastal Environments, and their vulnerability to climate change and other stresses.

**Scoping Study** (FY22)

Identify key knowledge gaps, modeling challenges, and research opportunities

**Pilot Research** (FY22 –FY24):

Regional-to-local hydroclimate and hydrological extremes




## *Scoping Report*

Regional Systems: Atmosphere & climate, Terrestrial Systems, Coastal systems, Human systems

- Extreme Events: Atmospheric river, rain-on-snow, flooding, Heatwave, drought, Wildfire
- Modeling Challenges and Opportunities: Predictive understanding of extreme events, Human system modeling on the terrestrial-coastal interface, Human-Earth interactions



Voisin N., D.J. Rose, D.P. Broman, N. Sun, I.P. Kraucunas (2023). "Exploring Multiscale Earth System and Human-Earth System Dynamics in the Puget Sound Region". https://doi.org/10.2172/1906804

Role of cloud processes on Atmospheric River precipitation modeling over the Northwest Pacific (*Taraphdar et al., in prep*)

Investigating climate-induced modulation to compound flooding events in the Duwamish River, WA (*Preston et al., in prep*)

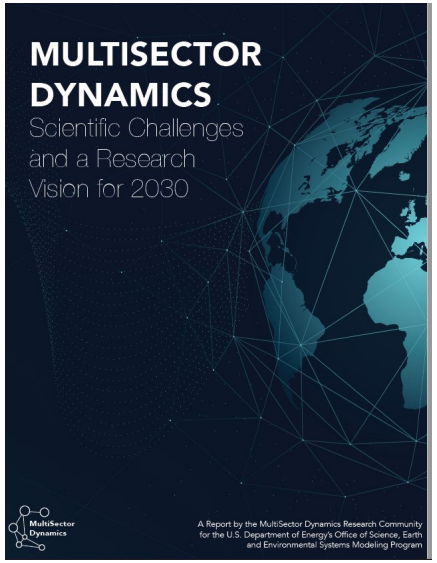
# Major Community Milestones – "We bring good things to life!"

You are invited to attend Thursday's tutorial during the networking session

## MSD Community of Practice (COP)

Active Working Groups

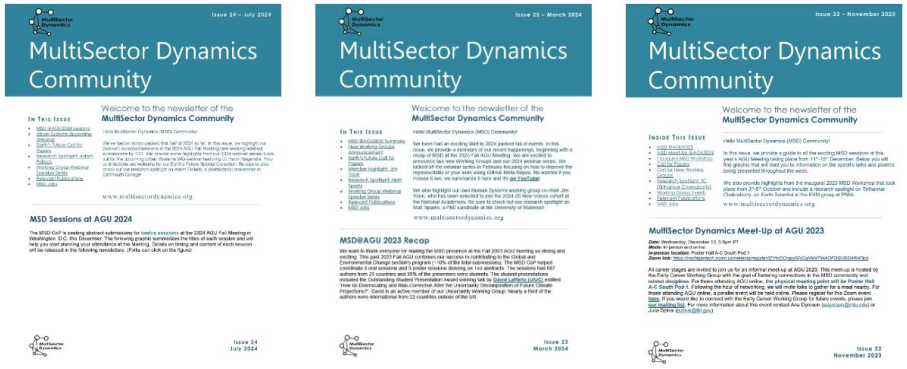
- Connecting MSD Research to Operations
- Early Career Development
- Equity in MultiSector Dynamics
- Human Systems Modeling
- Multisector Impacts of Energy Transitions
- Uncertainty Quantification and Scenario Development
- Urban Systems
- AI to Enhance MSD Research




https://multisectordynamics.org/community-resources/


https://immm-sfa.github.io/msd_uncertainty_ebook

All previous newsletters can be downloaded below:




https://multisectordynamics.org/

MSDLIVE


https://msdlive.org/

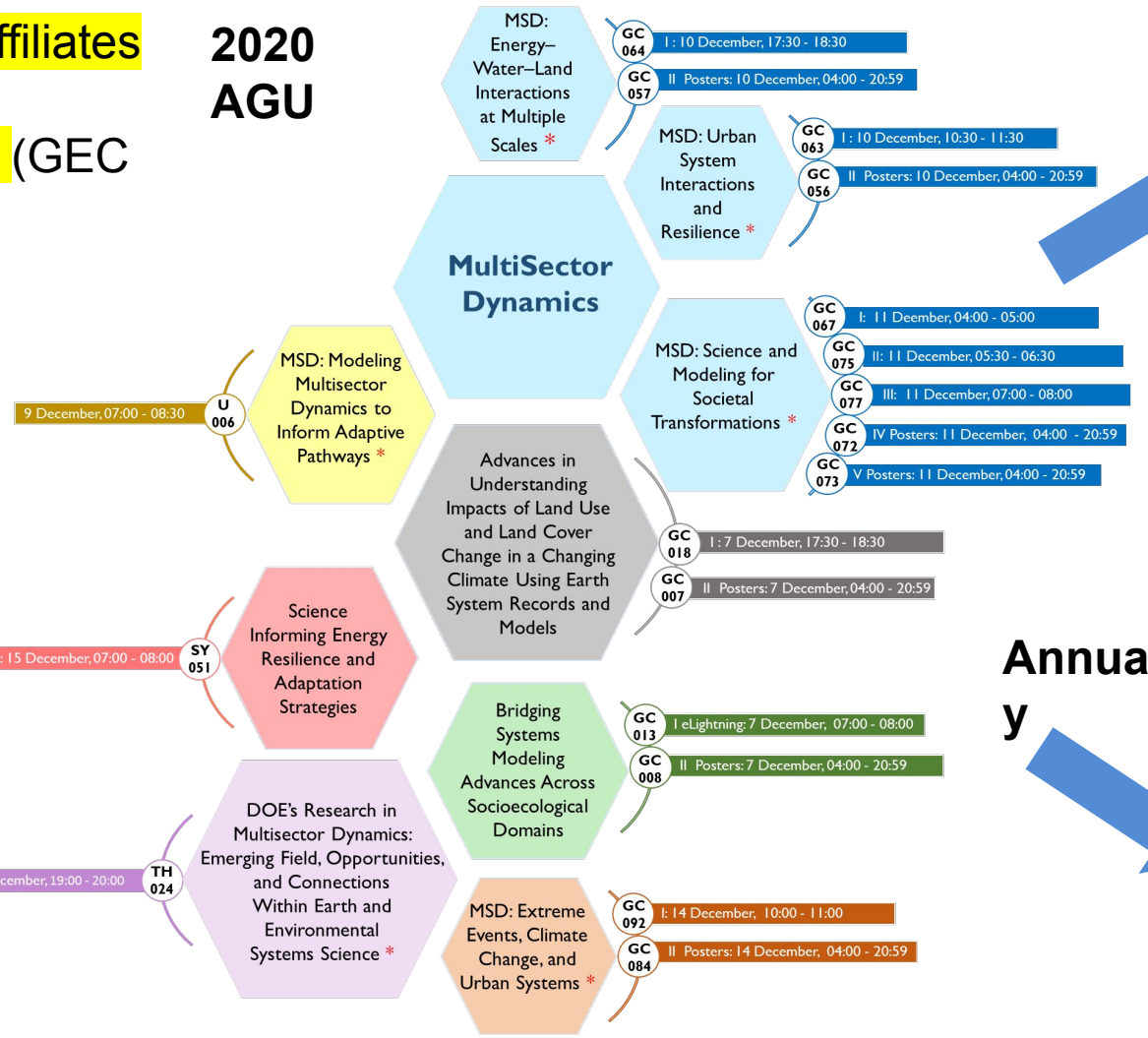
# Inaugural MSD CoP participation at 2020 AGU and Major Presence Since

MSD direct-funded and close affiliates comprise 10% of 2020 Global Environmental Change Section (GEC is 4th largest of AGU Sections)

Union Session

MSD convened DOE Town Hall

**2020 AGU**




**AGU *Earth's Future* Special Edition publication on MSD**

Multi-Sector Dynamics: Advancing Complex Adaptive Human-Earth Systems Science in a World of Interconnected Risks: Earth's Future (wiley.com)

**Annually**


www.multisectordynamics.org

# Select, additional notables

- Chapter authors on the U.S. National Climate Assessment - Sector Interactions, Multiple Stressors, and Complex Systems
- Council of Economic Advisors Technical Report on Climate Macro Effects and Risks within Long-Term Economic Projections
- EU-US bilateral research cooperation between MSD and the European Commission's (EC) Joint Research Centre on modeling of energy transition pathways
- Numerous engagements with DOE's applied research organizations and  and interagency collaborators
- S-4 EW-SETT collaboration on prognostic, model-driven, energy-water Sankey Diagrams
- Innovations in AI/ML scenario discovery and outcome-based scenarios with broad interest and applications
- Significant advances in emulation
- Substantial new code deposited in GitHub
- Inaugural MSD CoP Workshop with an emphasis on early career scientists, postdocs, and students.
- New technologies and applications for network analysis of research communities
- Foundational support for IHTM 2.0, Mountainous Hydroclimate, AI4ESP, and other major workshops.
- Large and increasing number of new, high-impact MSD-sponsored publications
- Strategic, MSD topical workshops, e.g., Snowmass 2024 on coastal, urban, and extremes
- Advances in modeling visualization
- Involvement/engagement/support for EESSD priority new initiatives:
  - Urban IFLs - Urban Integrated Field Laboratories (IFL)**
  - CRCs - Climate Resilience Centers.

# A parting resource…compilation of MSD weblinks

DOE Multisector Dynamics (MSD) Program Area portal:
https://climatemodeling.science.energy.gov/program-area/multisector-dynamics
Multisector Dynamics Community of Practice (CoP) - funded by MSD Program Area through IM3 project – below):
https://multisectordynamics.org/
https://multisectordynamics.org/community-resources/
Integrated Multisector, Multiscale Modeling (IM3) – Scientific Focus Area (SFA) project:
https://im3.pnnl.gov/
Global Change Intersectoral Modeling System (GCIMS) - Scientific Focus Area (SFA) project:
https://gcims.pnnl.gov/
Program on Coupled Human and Earth Systems (PCHES) - Cooperative Agreement project:
https://www.pches.psu.edu/
Sectoral Interactions, Compounding Influences and Stressors, and Complex Systems: Understanding Tipping Points and Non-Linear Dynamics - Cooperative Agreement project
https://globalchange.mit.edu/research/focus-areas/multi-sector-dynamics
https://globalchange.mit.edu/research/research-projects/sectoral-interactions-compounding influences-and-stressors-and-complex
Integrated Coastal Modeling (ICoM) – MSD co-funded Earth and Environmental Systems Sciences Division project:
https://icom.pnnl.gov/
A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales – MSD co-funded Earth and Environmental Systems Modeling Program Cooperative Agreement project:
https://hyperfacets.ucdavis.edu/
Coastal Observations, Mechanisms, and Predictions Across Systems and Scales (COMPASS) Great Lakes Modeling Project – MSD co-funded Earth and Environmental Systems Sciences Division project:
https://compass.pnnl.gov/GLM/COMPASSGLM
Interdisciplinary Research for Arctic Coastal Environments (InteRFACE) project – MSD co-funded Earth and Environmental Systems Sciences Division project:
https://arcticinterface.org/
Living Intuitive Value-adding Environment: A collaborative data and computational platform for the MultiSector Dynamics Community project
https://msdlive.org/