IM3

INTEGRATED MULTISECTOR MULTISCALE MODELING

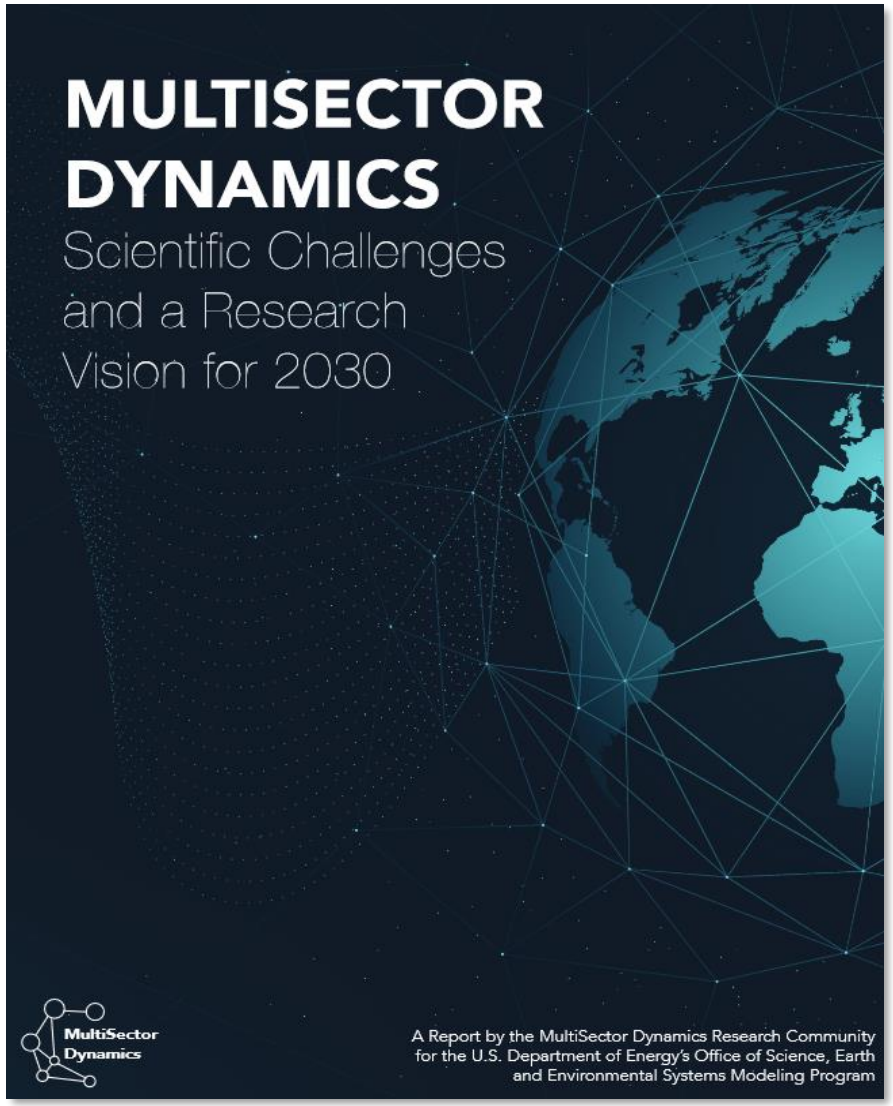
MultiSector Dynamics Community of Practice: Science Challenges and Research Vision for 2030

Patrick M. Reed and Chris R. Vernon

on behalf of the MSD CoP facilitation team

This research is supported by the U.S. Department of Energy, Office of Science, as part of research in MultiSector Dynamics, Earth and Environmental System Modeling Program

REPORT: SCIENTIFIC CHALLENGES AND A RESEARCH VISION FOR 2030



Scientific Challenges and a Research Vision for 2030

Released January 2022

Over 2000 Downloads

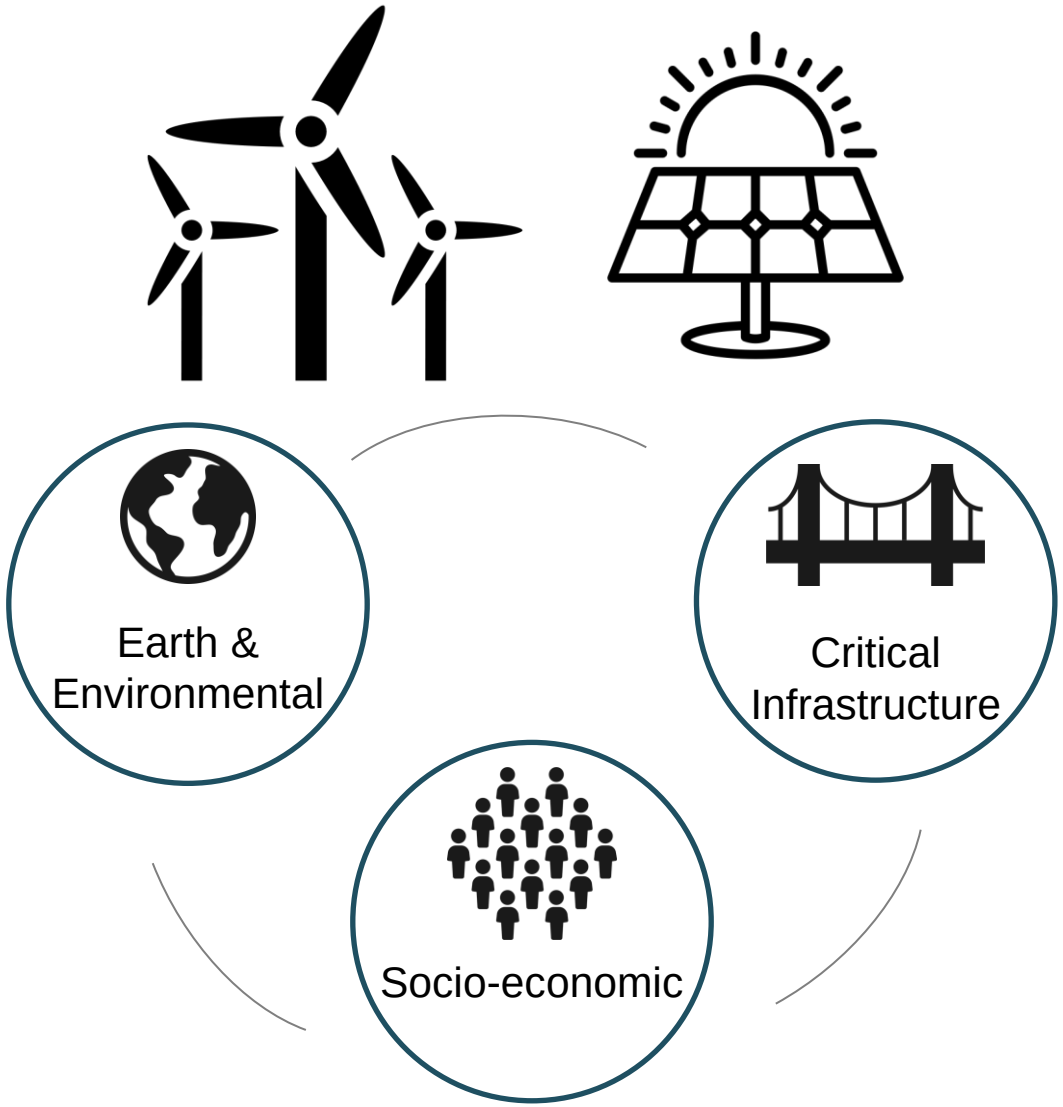
https://multisectordynamics.org/vision/

THE MSD VISION REPORT IN BRIEF

Managing Risks and Transitions in Complex Systems

The next decade represents a tremendous opportunity to **address climate, energy, and interrelated sustainability challenges**

Navigating these **transitions** will require a better understanding of the **interdependence** of **Earth and environmental systems** with critical **infrastructure** and **socio-economic systems.**



A recent example…

Source:
https://twitter.com/planet/status/1362183935309021185/photo/2

The temperature extremes and energy demands during the event were equivalent to past winter storms in Texas[1] but caused $195 billion and 246 deaths in Texas alone.

Winter Storm Uri
February 13–17, 2021

AUSTIN, TEXAS · February 16, 2021

1 Doss-Gollin et al. (2021) https://doi.org/10.1088/1748-9326/ac0278

Sergio Flores for The Texas Tribune

Besides the environmental hazard, these impacts were due to several institutional, infrastructural and socio-economic reasons:

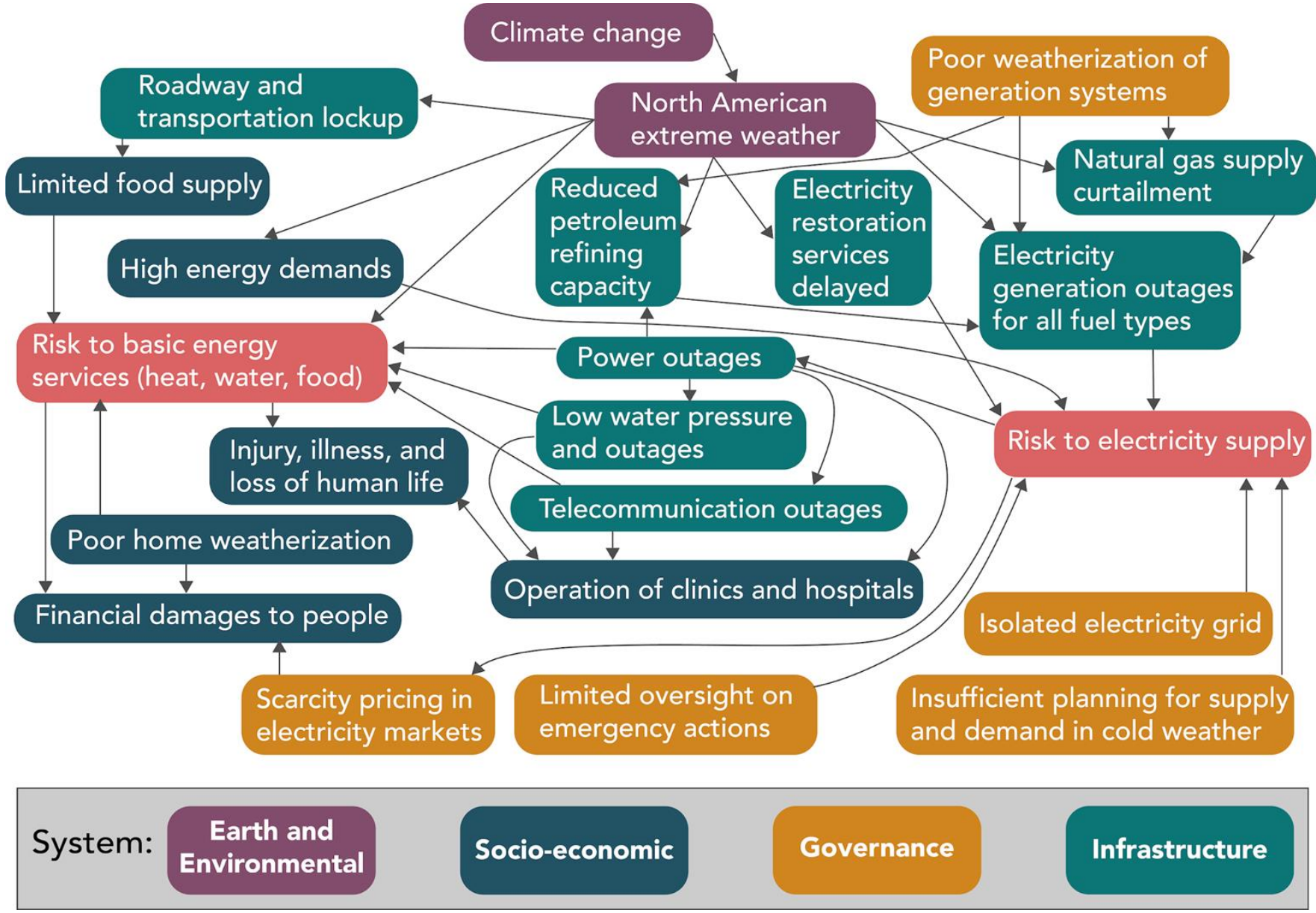
- Texas operates on an isolated power grid
- Power generation systems were not sufficiently weatherized
- Insufficient planning for high demands

Human response:

- Increased energy demands
- Buying additional fuel and generators
- Storing food and water
- Electricity scarcity pricing

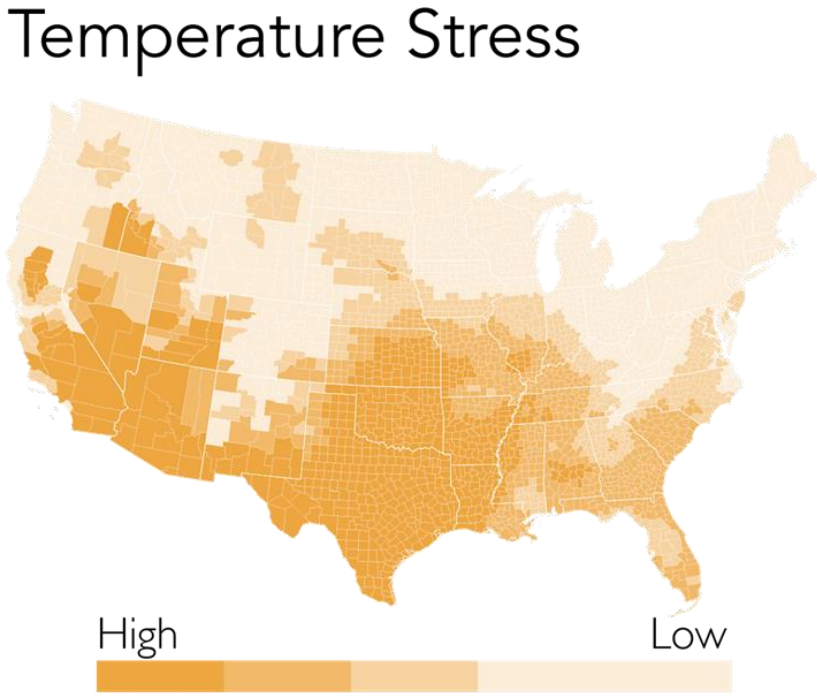
Propane tanks are placed in a line as people wait for the power to turn on to fill their tanks in Houston. (Mark Felix for The Washington Post)

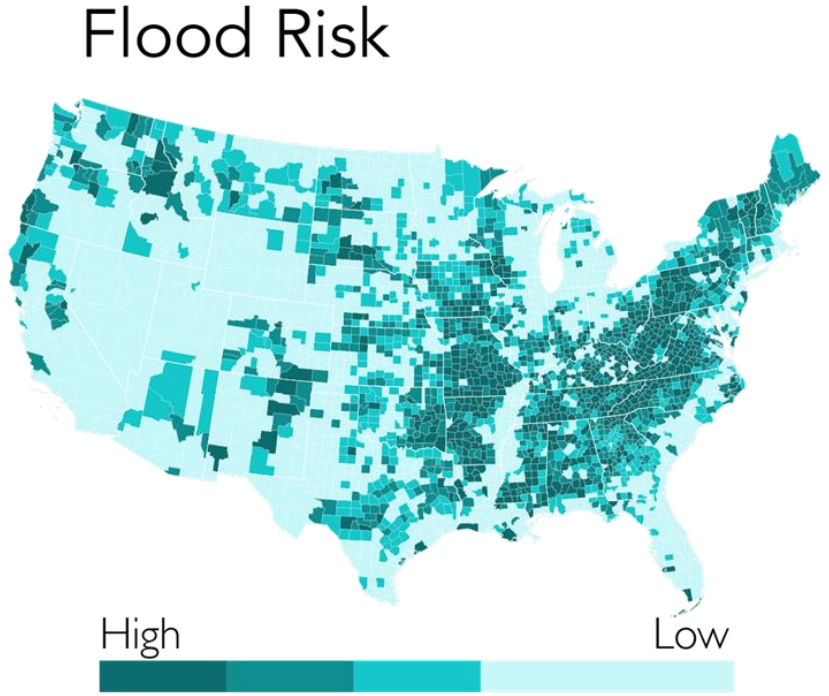
Risk emerged as a result of many **dynamic processes** and actions across many **systems** and across different **scales**

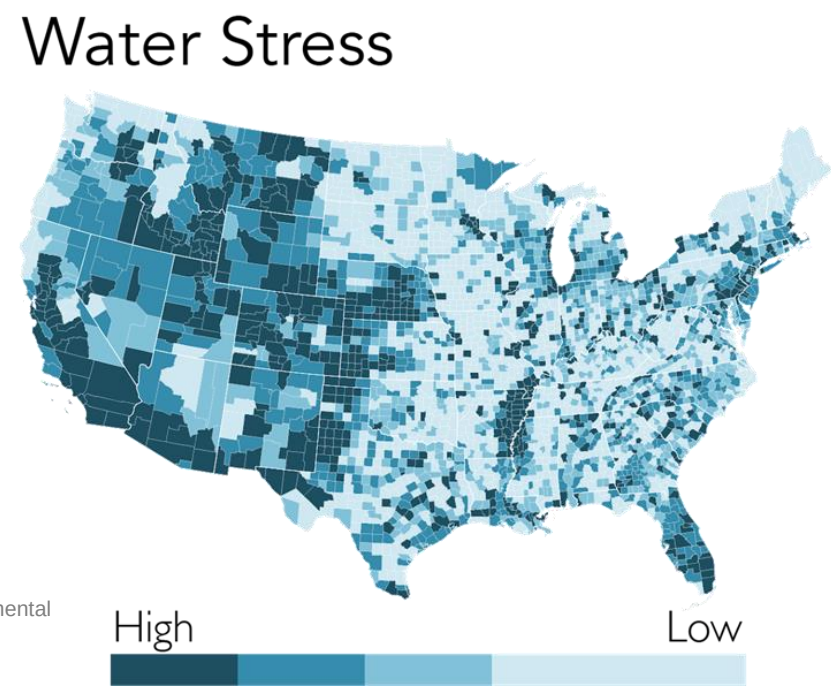


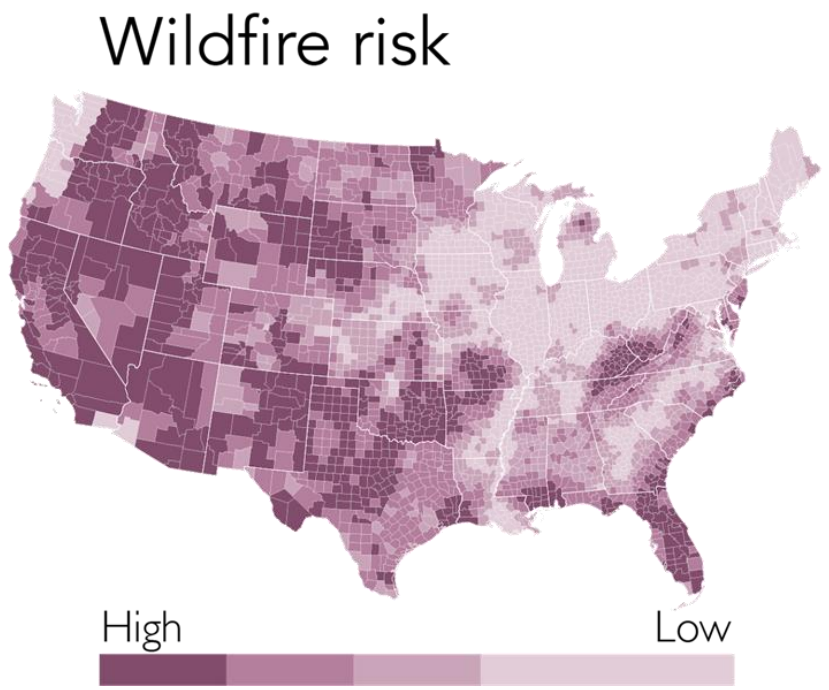
Reed et al. MultiSector Dynamics: Advancing the Science of Complex Adaptive Human-Earth Systems. Earth's Future (2022)

Winter storms are only one type of hazard potentially facing a region







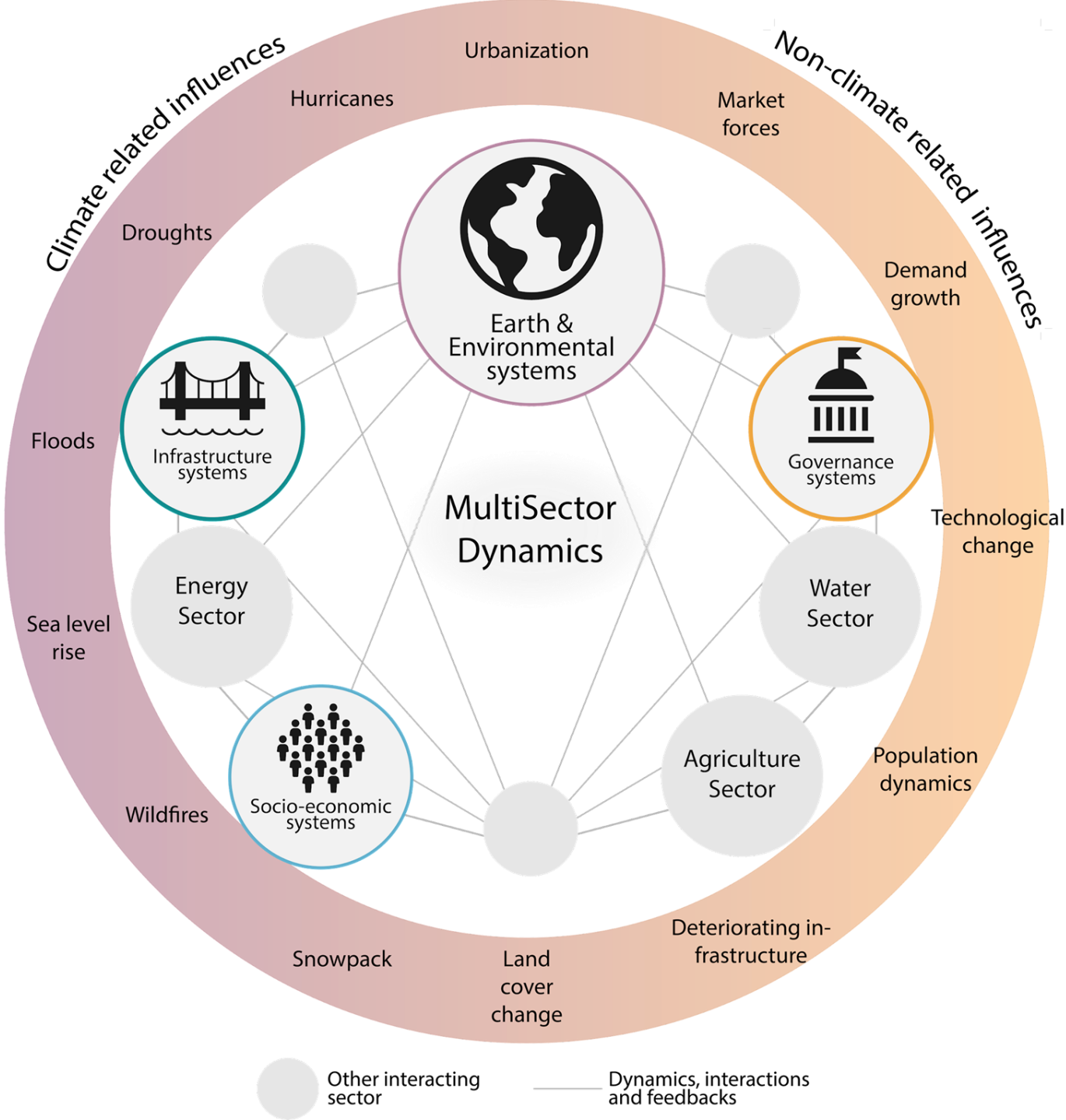


Created using data from the MIT Socio-Environmental Systems Risk Triage visualization platform at https://est.mit.edu

What is MSD?

The study of how complex built, natural, and socio-economic systems **co-evolve in response to change**.

MSD is a transdisciplinary research area that seeks to advance our understanding of how **human-Earth system feedbacks shape interdependent pathways of societal change across scales and uncertainties**.



Globally, we are facing interconnected, multisectoral risks.

A group of refugees and migrants walk towards the border of Greece and North Macedonia. Credit: UNHCR

Need to Capture Compounding or Cascading Risks

Interacting risks can **emerge** across scales, systems, and sectors

Human responses can be strong determinants of risk

Combinations of multiple risks pose challenges for model-based insights

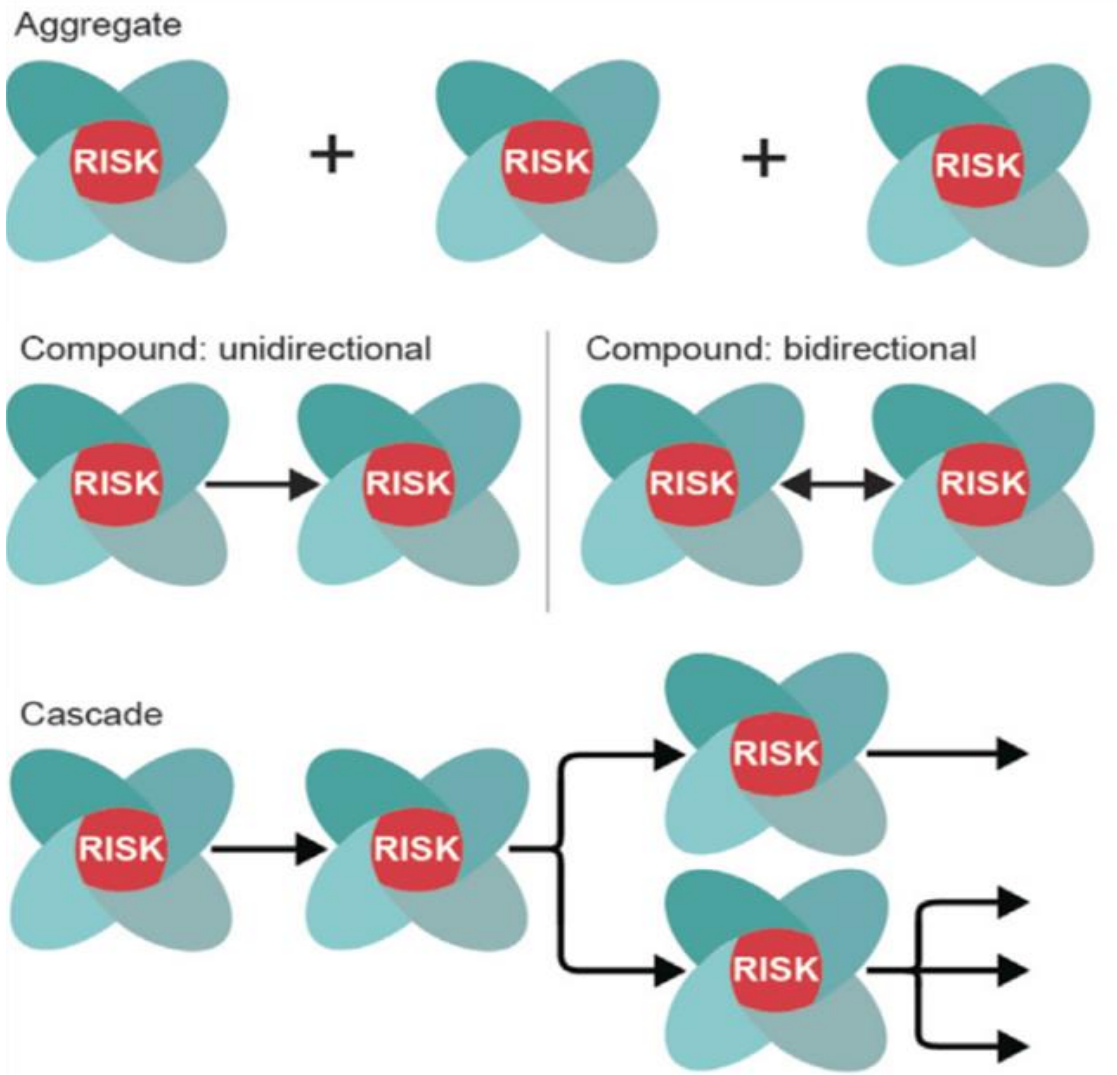


Figure adapted from Simpson et al. (2021). “A framework for complex climate change risk assessment”. In: One Earth 4.4, 1648 pages 489–501. ISSN: 2590-3322.

The **MSD Community of Practice** (MSD CoP) represents an effort to accelerate development of needed foundational capabilities to address these challenges through open science and growing a diverse transdisciplinary workforce.

https://multisectordynamics.org/join-us/

MSD COMMUNITY OF PRACTICE STRATEGIES

Communication
- Website
- Newsletter
- Webinars
- Outreach

Coordination
- Workshops
- Conference forums
- Linking research communities

Conceptual Framework/SSG
- Vision reporting
- FT & SSG drafting
- Review process

Technical coordination
- Working groups

MSD COP FACILITATION TEAM

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MSD COP SCIENTIFIC STEERING GROUP (SSG)

Nathalie Voisin, PNNL
Core Member

Klaus Keller, Dartmouth
Core Member

Nicole Jackson, Sandia
Core Member

Casey Burleyson, PNNL
Core Member

Jen Morris, MIT
Core member

Andy Jones, UC Berkeley
Core member

Rebecca Saari, U. of Waterloo
Core Member

David McCollum, Oak Ridge
WG Representative

Wei Peng, Princeton University
WG Representative

Julia Szinai, LBNL
WG representative

Vivek Srikrishnan, Cornell University
WG representative

Christa Brelsford, LANL
WG representative

Jim Yoon, PNNL
WG representative

ESTABLISHED 8 THEMATIC WORKING GROUPS

Connecting MSD Research to Operations

Early Career Development

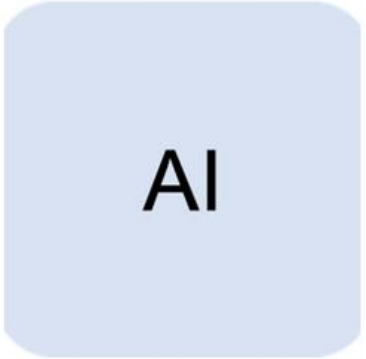
Equity in MultiSector Dynamics

Human Systems Modeling

Multisector Impacts of Energy Transitions

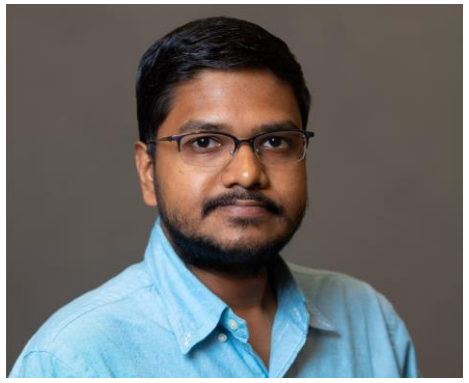
Uncertainty Quantification and Scenario Development

Urban Systems



Using AI to Enhance MSD Research

CONNECTING MSD RESEARCH TO OPERATIONS WG



David McCollum (ORNL), Gokul Iyer (PNNL)

Aims to further the **R2O2R ('research-to-operations-to-research')** mission by identifying **collaborations**, **communicating insights**, and **bridging expertise**. Reaching out to federal and subnational agencies and multilateral institutions down to individual US- and non-US-based researchers, domain experts, and implementation specialists.

EARLY CAREER DEVELOPMENT WG

Julia Szinai (LBNL), Tom Wild (PNNL)

The mission of this WG is to support the success of early career researchers in fields related to MultiSector Dynamics. Foster **capacity building across institutions and scientific focus areas** through hosting professional development workshops and forming a community of practice for MSD researcher-teachers.

EARLY CAREER DEVELOPMENT WG

AGU Fall 2023 MSD Meet Up: had over 60 participants. Ongoing plans for 2024.

EQUITY IN MSD WG



Rebecca Saari (Univ. of Waterloo), Sarah Fletcher (Stanford), Amanda Giang (University of British Columbia)

This WG is focused on assessing the current status of MSD equity research, identifying key research frontiers, and supporting community members in advancing these frontiers. Strong focus on **modeling advances** that are needed to capture distributive **social impacts** on systems with **multiple stressors** and **interconnected risks**

HUMAN SYSTEMS MODELING WG

Jim Yoon (PNNL), Christian Klassert (Helmholtz-Centre)

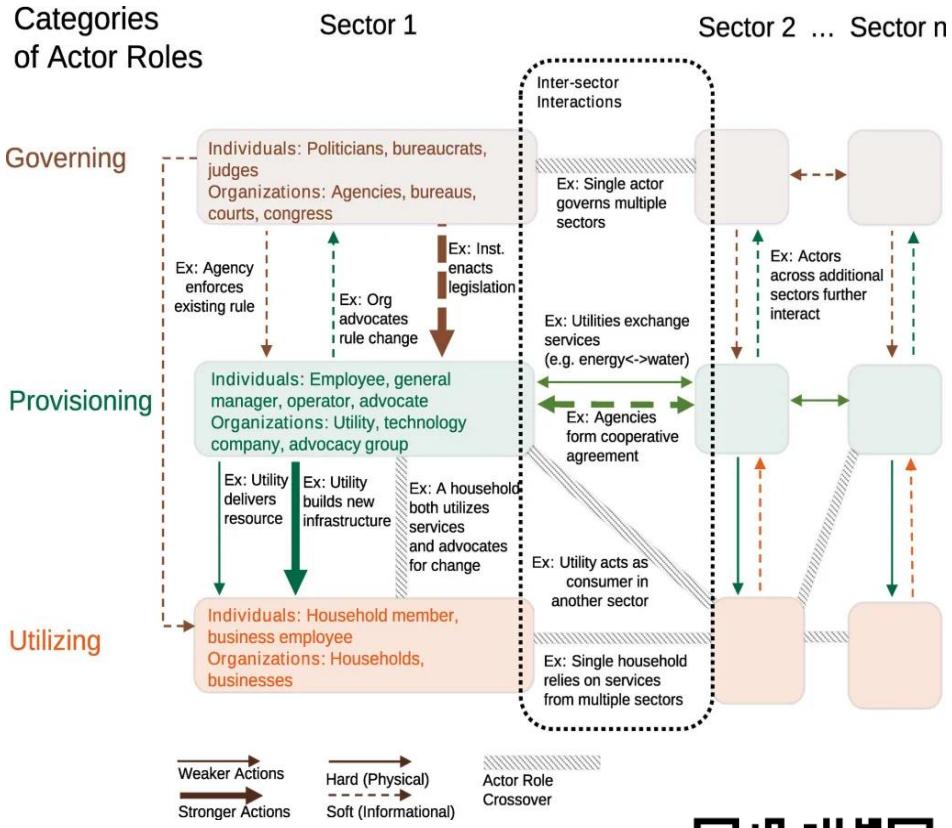
This WG explores **state of the art modeling methods** that can improve **representation of human decision making** and **adaptation** in multi-sector systems, drawing from advances in economics, social sciences, computer science, and statistics. Investigates a range of modeling techniques and their integration with physical energy-water-land models for capturing human response to **short-term shocks** and **long-term change**.

A TYPOLOGY FOR CHARACTERIZING HUMAN ACTION IN MULTISECTOR DYNAMICS MODELS

Human Systems Modeling WG

Lays out typology for classifying how human systems are represented in models

Provides a review of human systems abstractions in different bodies of literature



Yoon et al (2022) Earth's Future, https://doi.org/10.1029/2021EF002641

MULTISECTOR IMPACTS OF ENERGY TRANSITIONS WG

Wei Peng (Princeton), Jordan Kern (NC State)

This WG is focused on advancing understanding of the multisectoral impacts of energy transitions by building a diverse team to identify what human-natural systems **feedbacks**, **sectors**, and **societal constructs** are **missing** from existing analytical approaches and **define new research pathways** towards a more holistic understanding of the **multi-sector impacts of energy transitions**.

UNCERTAINTY QUANTIFICATION & SCENARIO DEVELOPMENT WG

Vivek Srikrishnan (Cornell), John Lamontagne (Tufts)

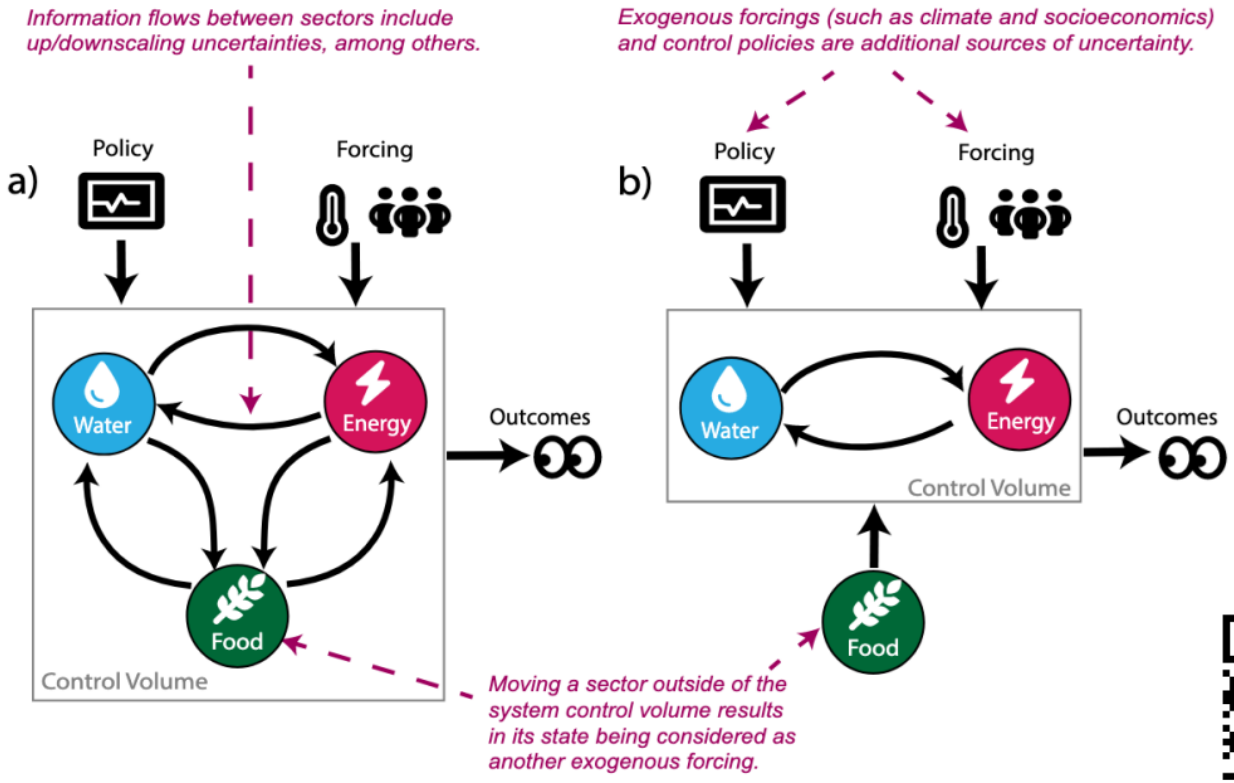
This WG studies the **propagation of uncertainties**, including deep uncertainties, **through multi-sector systems**. We are interested in understanding how uncertainty interacts with complex system dynamics and **cross-sectoral feedback mechanisms** to affect the **robustness and resilience** of these systems. We also conduct research into the construction of scenarios to capture the range of uncertainties in outcome space in the presence of deep uncertainty.

UNCERTAINTY ANALYSIS IN MULTI-SECTOR SYSTEMS: CONSIDERATIONS FOR RISK ANALYSIS, PROJECTION, AND PLANNING FOR COMPLEX SYSTEMS

Formal review article

Focuses on challenges for quantifying MSD uncertainties

- Inference
- Model calibration
- Projecting outcomes
- Scenario discovery
- Identification of risk regimes



Srikrishnan et al (2022) Earth's Future, https://doi.org/10.1029/2021EF002644

URBAN SYSTEMS WG

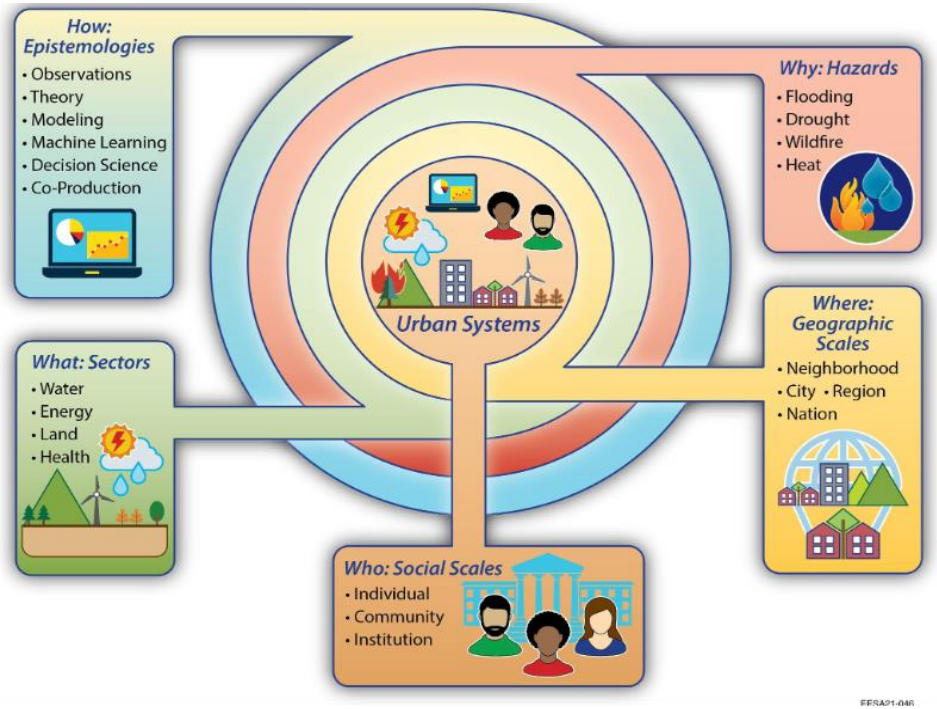
Christa Brelsford (LANL), Pouya Vahmani (LBNL)

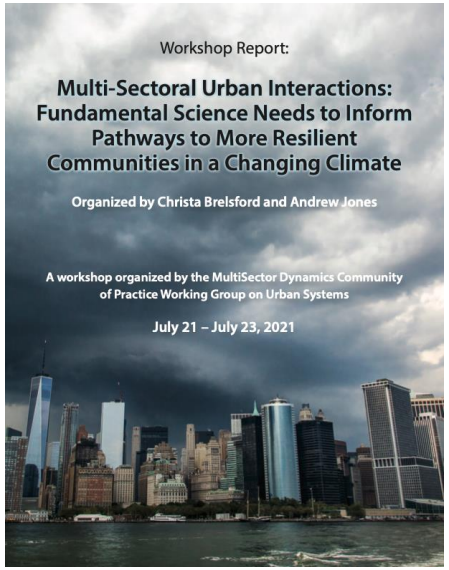
This WG studies **cities as focal points** for addressing questions related to **system dependencies, tipping points, and uncertainties**. Cities are also a fruitful context to explore **model coupling across sectors and scales**. However, efforts to combine multi-sector urban tools and insights to examine key uncertainties, interactions, and tradeoffs.

URBAN SYSTEMS WORKING GROUP REPORT

Publication in-review with Earth's Future:

"Cities are Concentrators of Complex, MultiSectoral Interactions within the Human-Earth System." (Brelsford et al.)





28

USING AI TO ENHANCE MSD WG

Stefano Galelli (Cornell), David Gold (Utrecht University)

This WG is exploring AI techniques that **expand the current tools** available for **control problems** (e.g., **Reinforcement Learning**), thereby allowing us to operate and plan **highly nonlinear and interconnected Human-Earth systems**. We seek to clarify opportunities and risks associated with recent AI advances and their implementation in MSD science.

MSD EARTH'S FUTURE SPECIAL ISSUES

EARTH'S FUTURE SPECIAL ISSUE

18 open-access research articles submitted from a mix of MSD supported researchers and other global researchers

Published September 2020 – April 2023

Earth's Future
AGU ADVANCING EARTH AND SPACE SCIENCE

NEW EARTH'S FUTURE SPECIAL COLLECTION

Organizers

- Patrick Reed (Cornell)
- Nicole Jackson (Sandia)
- Katharine Mach (U Miami)
- Nicholas Simpson (U Cape Town)
- Nathalie Voisin (PNNL)
- Jennifer Morris (MIT)
- Ryan McManamay (Baylor)
- Marjolijn Haasnoot (Deltares)

Earth's Future

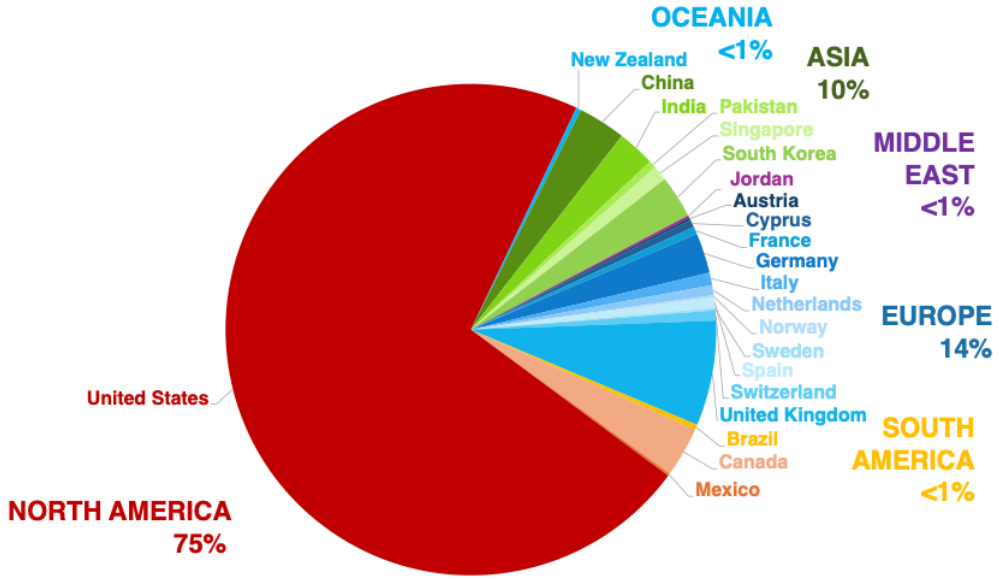
AGU ADVANCING EARTH AND SPACE SCIENCE

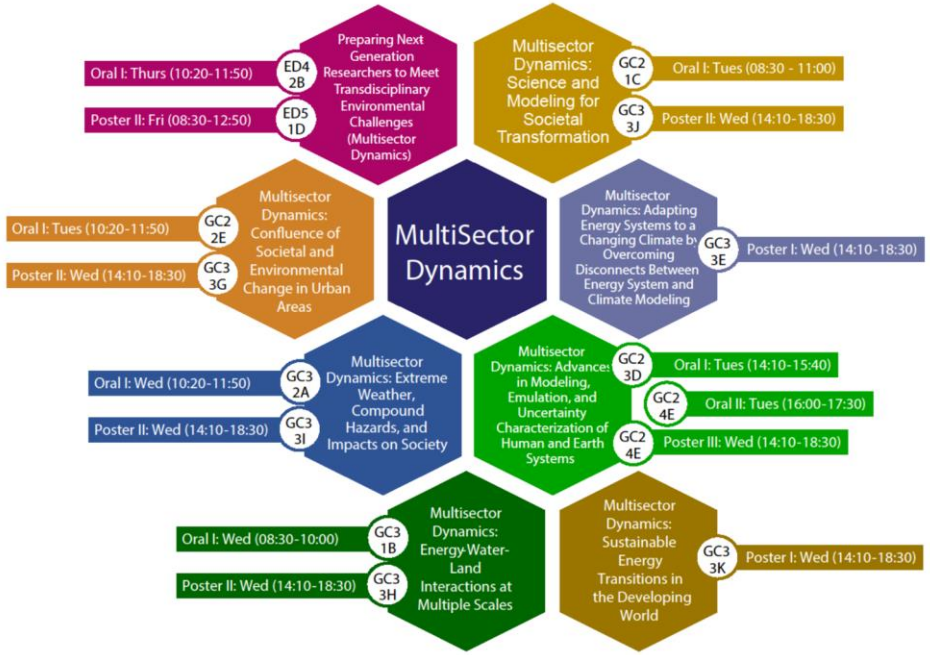
Submission window: May 2023-December 2024, Published 12 papers so far

AGU HIGHLIGHTS

2023 AGU FALL MEETING

One of the largest coordinated topical areas in Global Environmental Change!

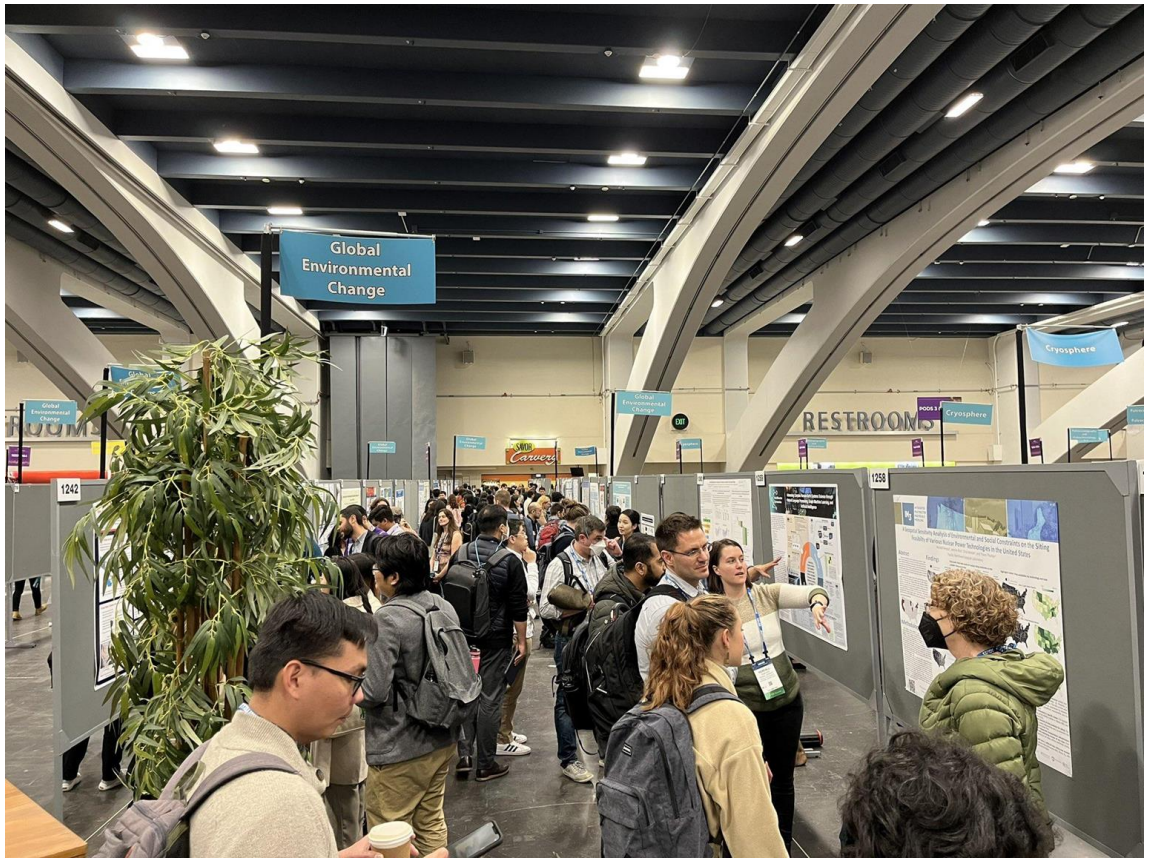




- 22 countries
- 37% student presenters
- 28% international authors

- 7 oral sessions
- 8 poster sessions
- 133 abstracts from 606 authors

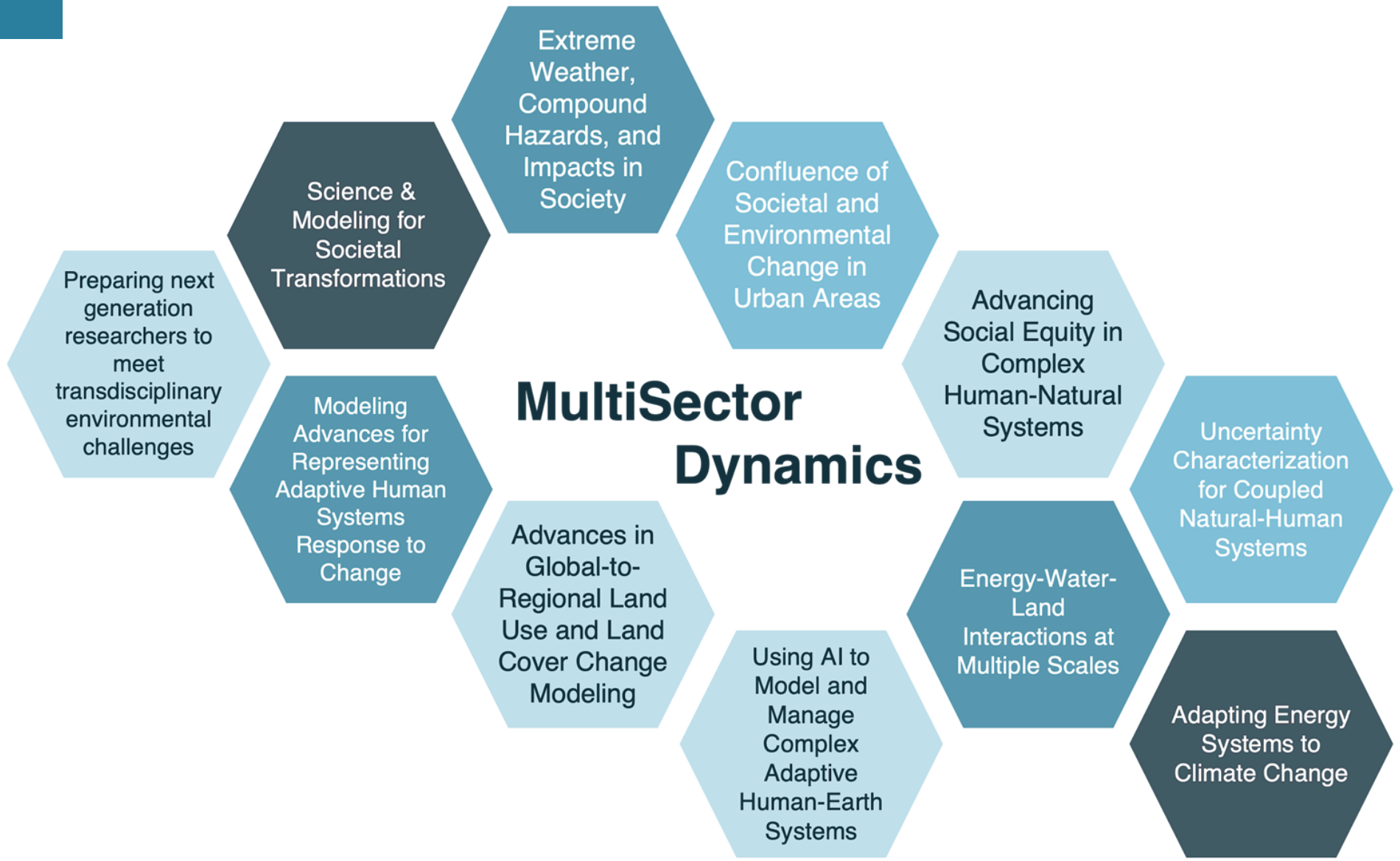
2023 AGU FALL MEETING HIGHLIGHTS



MSD Global Environmental Change Poster aisle at AGU 2023

MSD meetup snapshot at AGU 2023

AGU 2024 SESSIONS



INAUGURAL MSD WORKSHOP

(UC DAVIS, OCT 3-5, 2023)

WORKSHOP TURNOUT (DAVIS, CA)

- 96 attendees
- 29 students, 43 early career
- 6 DOE National Laboratories
- 25 U.S. Universities
- 5 International Universities
- 1 Federal, 1 State Agency, 1 NPO

WORKSHOP REPORT NOW OUT!

Key Themes:

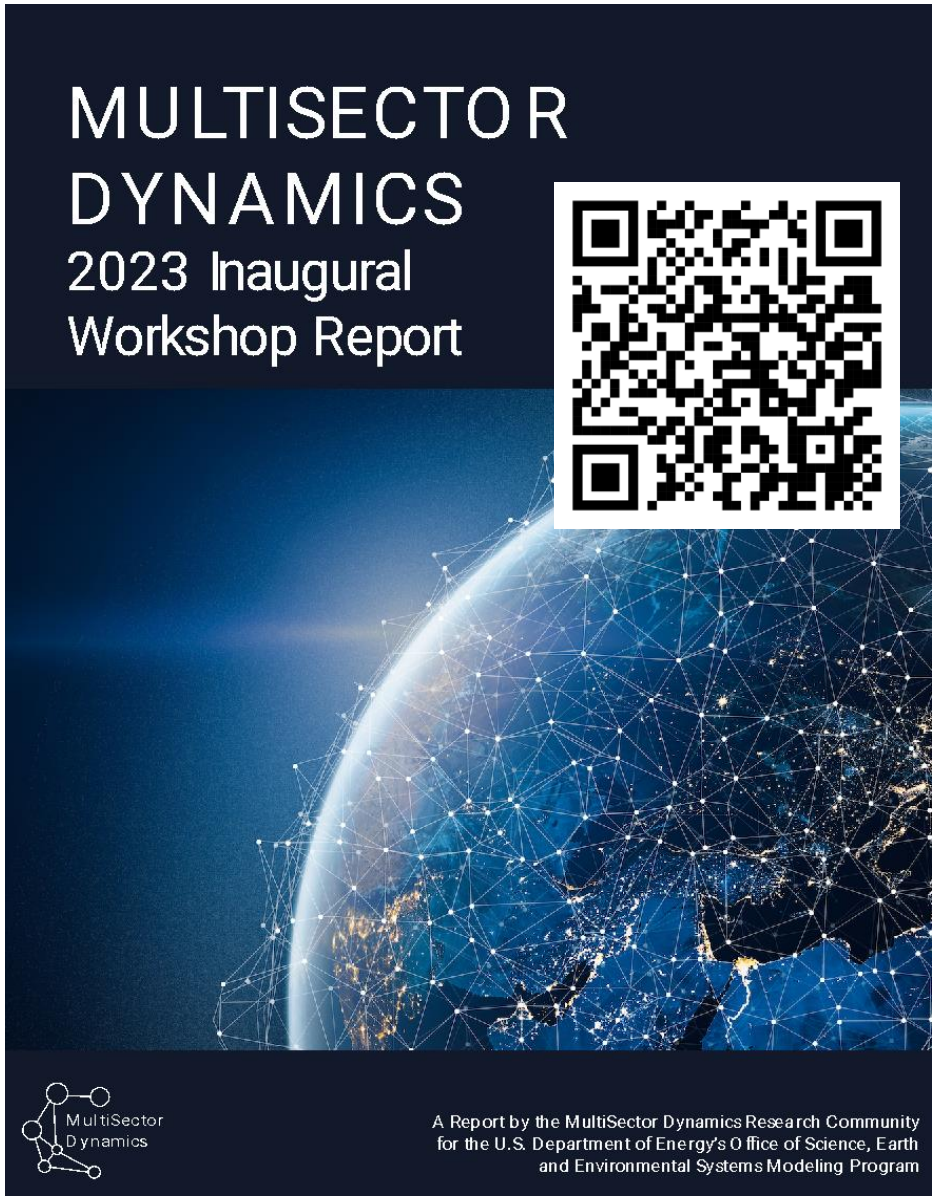
Improving the operational relevance of MSD research related to climate change and energy transitions

Better capturing human actors' responses to emergent risks

Understand how human and natural drivers and uncertainties shape global-to-local dynamics

Challenges to analyze equity in MSD research

Using AI to advance modeling of complex adaptive Human-Earth systems

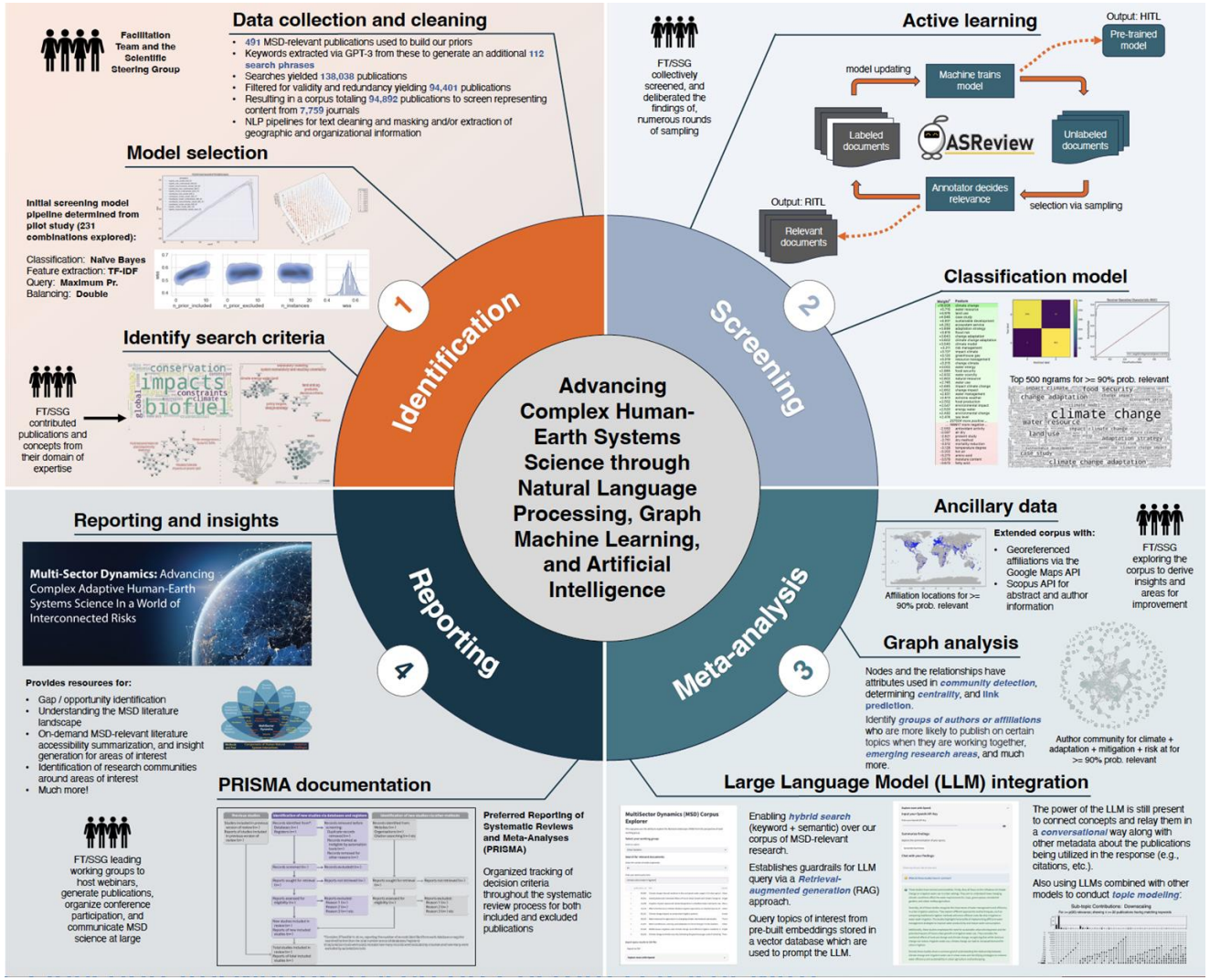


Monier et al. (2024) MultiSector Dynamics: 2023 Inaugural Workshop Report. MSD-LIVE Data Repository. doi:10.57931/2371710.

CURRENT RESEARCH

AI-ENABLED SYSTEMATIC REVIEW OF MSD

- Collaborative effort with our SSG and FT members
- **Fully transferable framework** using Large Language Model and Graph, and other ML innovations to understand the MSD literature landscape at large for **105,336** publications
- Identify gaps and opportunities for collaboration
- Article in preparation for this Earth's Future special collection



MORE INFORMATION

MultiSector Dynamics

Issue 24 – July 2024

MultiSector Dynamics Community

In This Issue

- MSD @AGU2024 Sessions
- Urban Systems Upcoming Webinar
- Earth's Future Call for Papers
- Research Spotlight: Adam Pollack
- Working Group Webinar Speaker Series
- Relevant Publications
- MSD Jobs

Welcome to the newsletter of the MultiSector Dynamics Community

Hello MultiSector Dynamics (MSD) Community!

We've had an action-packed first half of 2024 so far. In this issue, we highlight our (twelve!) accepted sessions at the 2024 AGU Fall Meeting now seeking abstract submissions by 7/31. We provide some highlights from our 2024 webinar series. Look out for the upcoming Urban Systems WG webinar featuring Dr Harini Nagendra. Your contributions are welcome for our Earth's Future Special Collection. Be sure to also check out our research spotlight on Adam Pollack, a postdoctoral researcher at Dartmouth College!

www.multisectordynamics.org

https://multisectordynamics.org/join-us/

MSD Sessions at AGU 2024

The MSD CoP is seeking abstract submissions for twelve sessions at the 2024 AGU Fall Meeting in Washington, D.C. this December. The following graphic summarizes the titles of each session and will help you start planning your attendance at the Meeting. Details on timing and content of each session will be released in the following newsletters. (Folks can click on the figure)

MultiSector Dynamics

Issue 24
July 2024

A WORKING GROUP SUCCESS

Sunset Working Group

Open Science and FAIR Data

→ MSD LIVE

Casey Burleyson (PNNL), Adam Schlosser (MIT)


THANK YOU