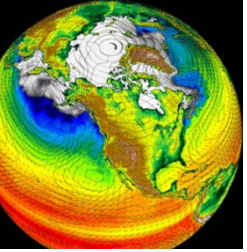
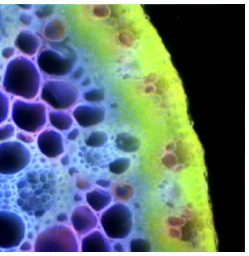
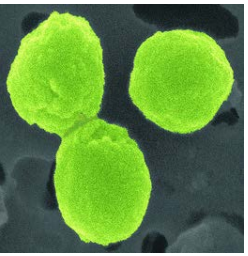


Multisector Dynamics (MSD)
and Complex, Adaptive Systems

Bob Vallario

U.S. Department of Energy
Office of Science
Office of Biological & Environmental Research
Climate and Environmental Sciences Division

Annual Meeting
November 2019

Program Goal

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

With relevance for:

- **energy sector and multisector analyses** (global, national, regional, and sub-regional);
- next-generation, **resilient infrastructure**;
- **geographic regions in transition**;
- economic development and **sustainability**;
- multi-stressor **risk and hazards analysis** and more…

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

Context

- Program Alignment

Atmospheric Science

- ★ Atmospheric Radiation Measurement User Facility
- Atmospheric System Research

Earth and Environmental Systems Modeling

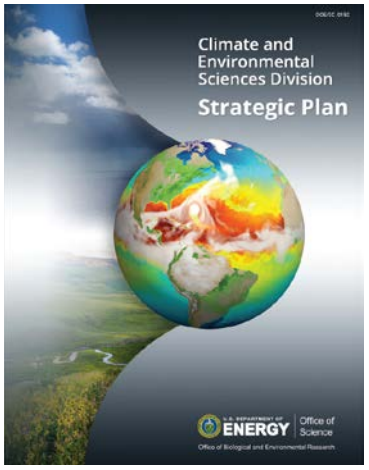
- Earth System Model Development
- Regional and Global Model Analysis
- Multisector Dynamics

Environmental System Science

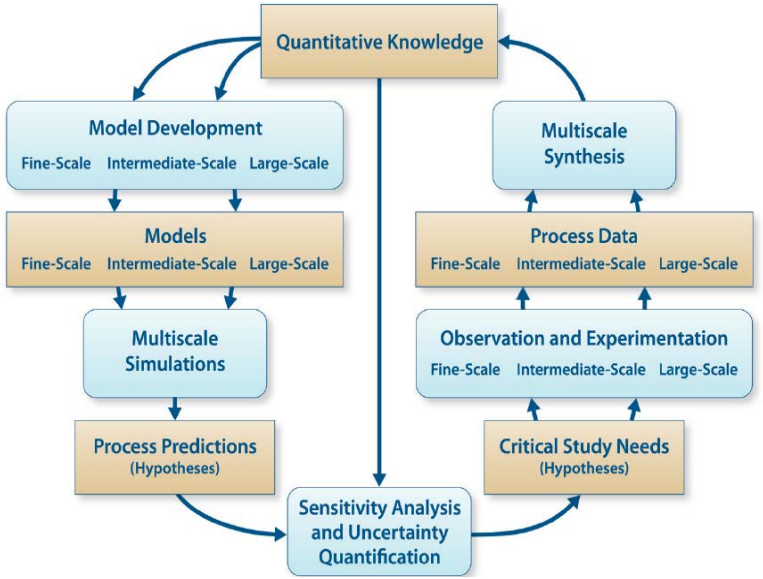
- Terrestrial Ecosystem Science
- Subsurface Biogeochemical Research
- ★ Environmental Molecular Sciences Laboratory

Data Management

- Strategic Plan Alignment



1. Integrated Water Cycle
2. Biogeochemistry
3. High Latitudes
4. Drivers & Response in the Earth System
5. Data-Model Integration

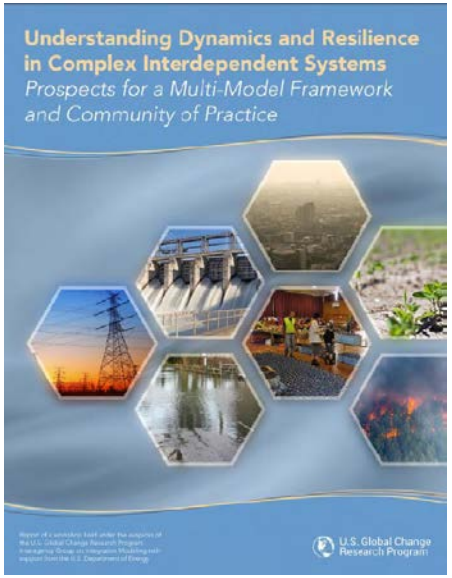


History

- **1990s-2009** - pioneering work focused on the contributions of anthropogenic and natural forcings in climate system evolution under a broad range of development scenarios.

- **2009-2016** - a notable pivot with focus on human and natural systems responses to climate (impacts, adaptations, vulnerabilities), including feedbacks, aligned with a 2009 community workshop report.

- **2016 – present** - a significant transition to the present focus on Multisector Dynamics, catalyzed by a DOE sponsored interagency workshop and report on *dynamics and resilience in complex, adaptive systems*.



Major scientific questions/challenges

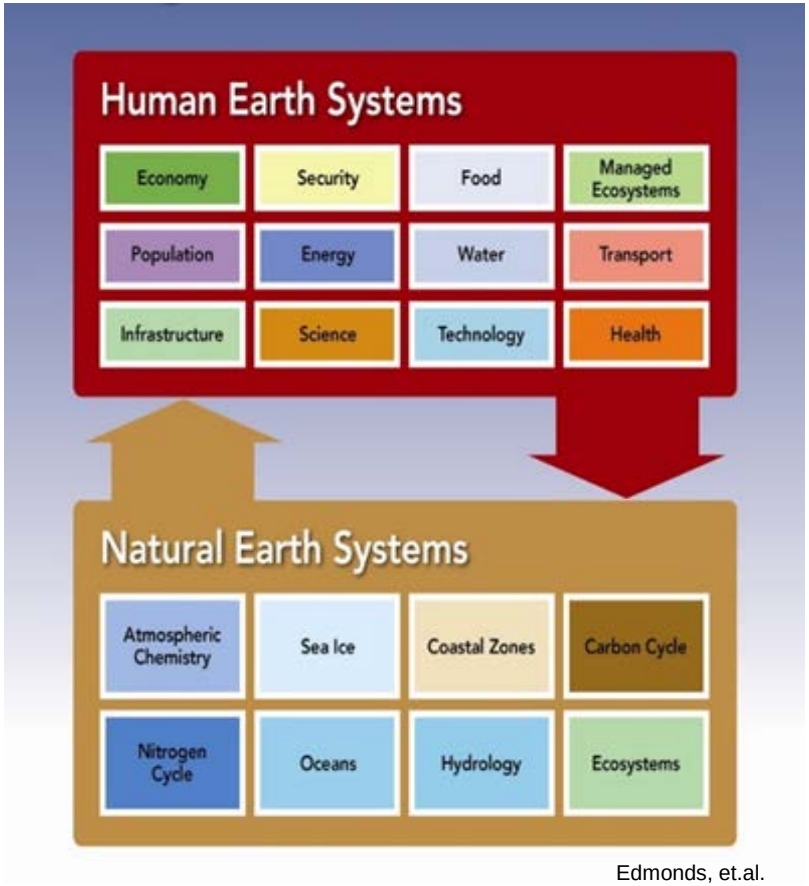
1. **Forces and Patterns.** What combination of factors, varying by geographies, contribute most significantly to ***patterns of development in transregional, regional, and sub-regional landscape evolutions***, including interactions and interdependencies among natural and built environments and human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

2. **Stabilities and Instabilities.** What are the characteristics of interacting natural and built environments and human processes that lead to ***stabilities*** **and** ***instabilities*** across systems, sectors, and scales, and what roles do strong interdependencies, feedbacks, and compounding influences and stressors play?

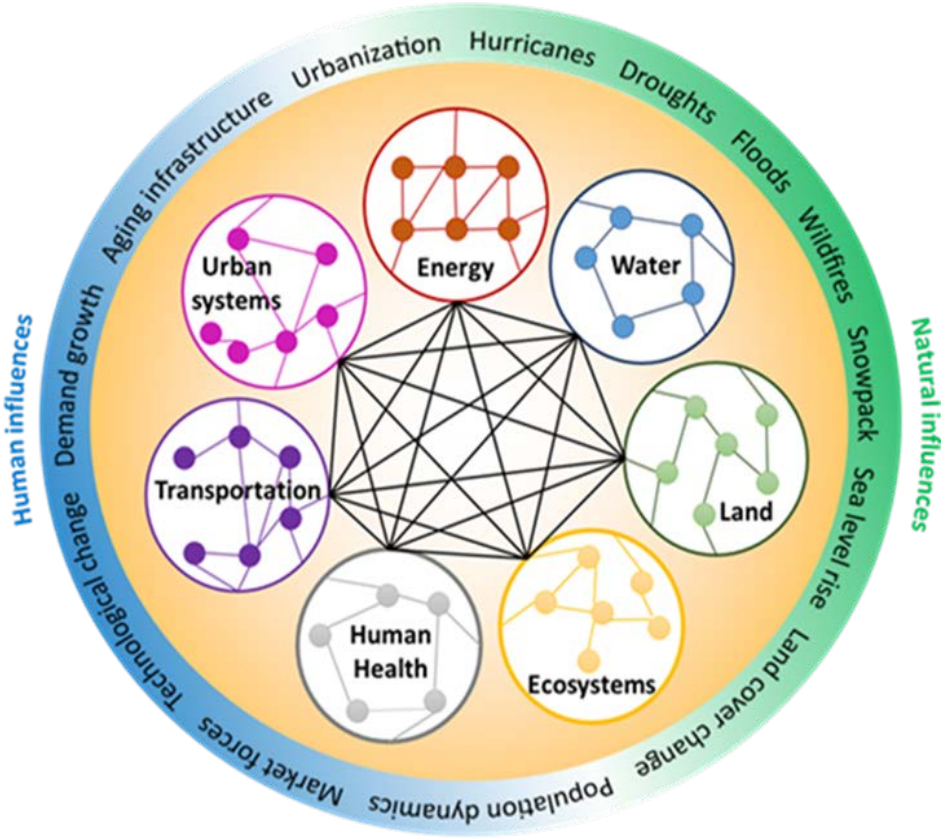
3. **Foresight**. How might development patterns, stabilities, instabilities, and ***systems resilience*** evolve within multisector, multi-scale landscapes as a result of ***future forces, stressors, and disturbances…*** and what pathways, characteristics, and risk profiles may emerge from ***both gradual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

Most notable change ….

Global/Regional ⟷ **Regional/Sub-regional**



Edmonds, et.al.



Hejazi, et.al.

National Lab SFAs/ and Projects and University Collaborative Agreements

1. Integrated Multi-sector, Multi-scale Modeling (IM3)

2. Integrated Human Earth Systems Dynamics (IHESD)

3. Integrated Coastal Modeling (ICOM)*

4. Interdisciplinary Research for Arctic Coastal Environments (InteRFACE)*

5. Program on Coupled Human Earth Systems (PCHES)

6. Integrated Global Systems Modeling (IGSM)

7. HyperFACETS*

* Collaborative program funding

Pacific Northwest NATIONAL LABORATORY
SFA PI: Jennie Rice

Pacific Northwest NATIONAL LABORATORY
SFA PI: Mohamad Hejazi

Pacific Northwest NATIONAL LABORATORY
PI: Ian Kraucunas

Los Alamos NATIONAL LABORATORY
PI: Joel Rowland

Stanford University
CA PI: John Weyant/Karen Fisher-Vanden/Rob Nicholas

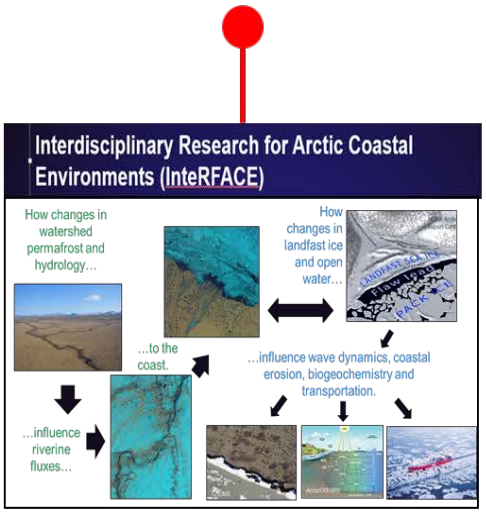
Massachusetts Institute of Technology
CA PI: Ron Prinn /John Reilly

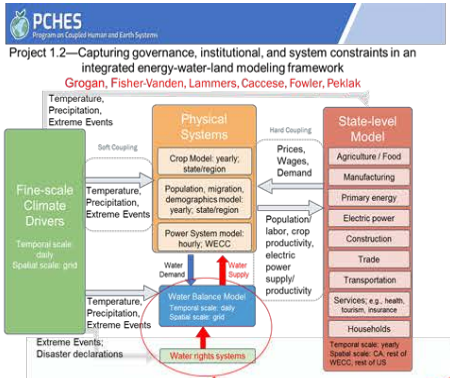
UCDAVIS UNIVERSITY OF CALIFORNIA
CA PI: Paul Ullrich

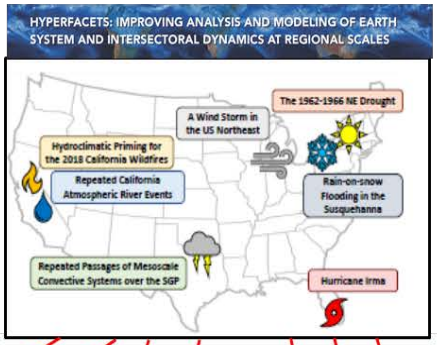
Partners (examples):

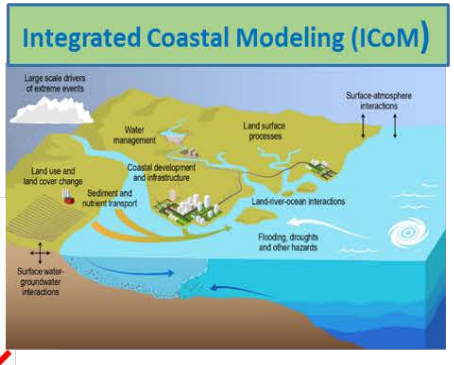
NREL
Sandia National Laboratories
Berkeley Lab
University of Maryland
UCAR
Cornell University
PennState
Boston University
Texas A&M University
Utah State University
Stony Brook University
UCLA
Purdue University
University of Delaware
University of New Hampshire
The University of Utah
Iowa State University

A growing set of topics…and geographies…of interest

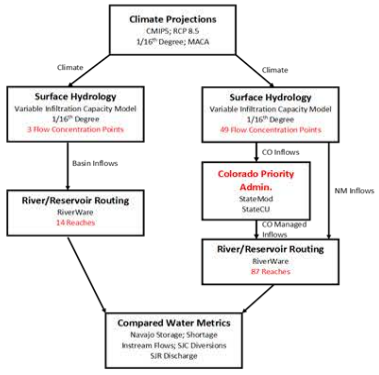


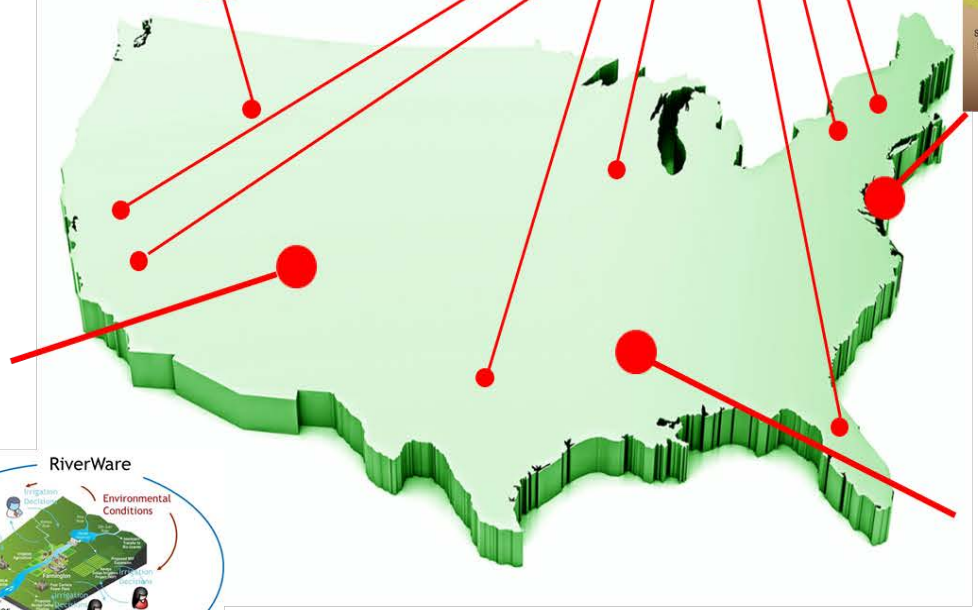






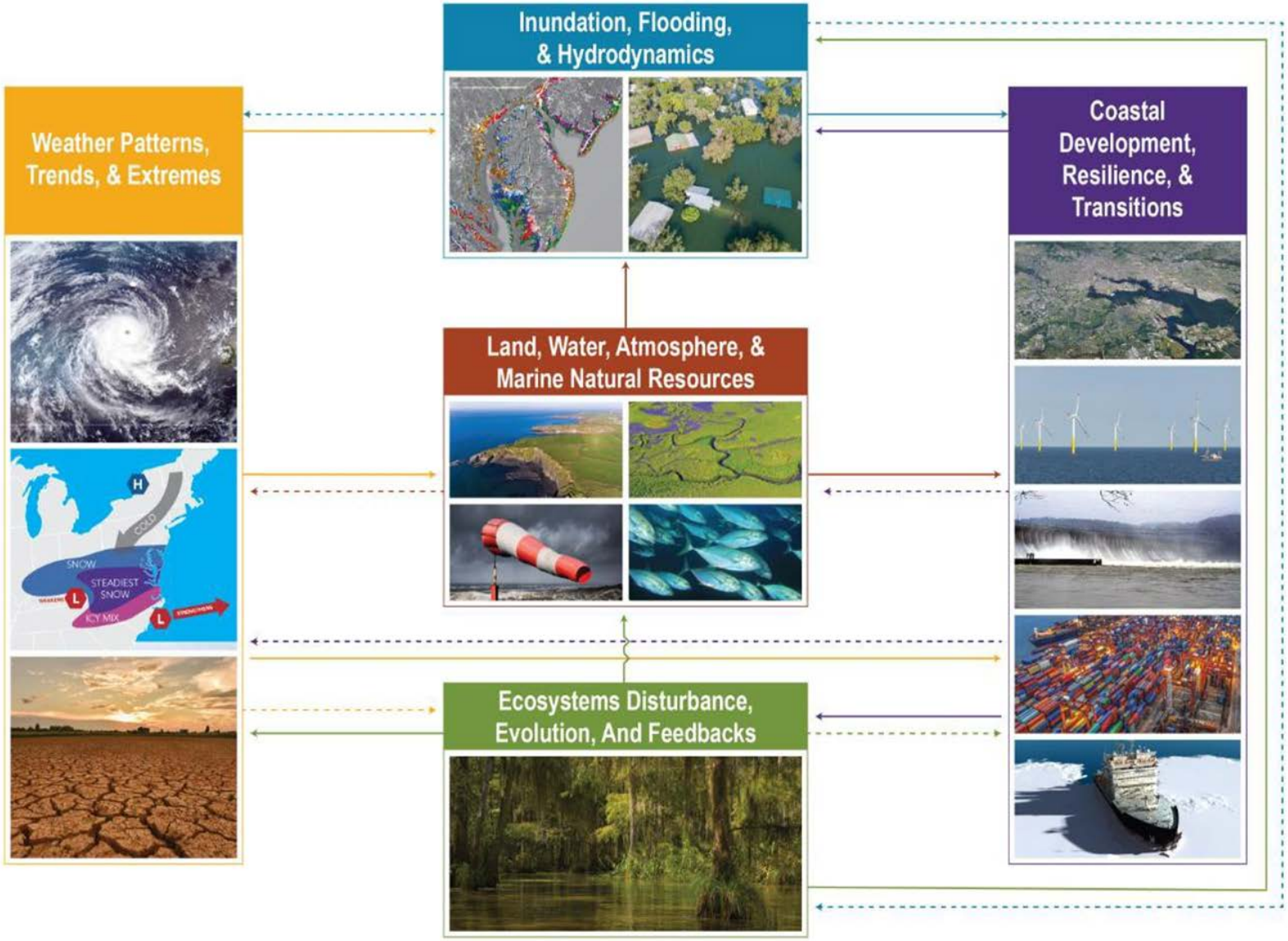
San Juan River Basin



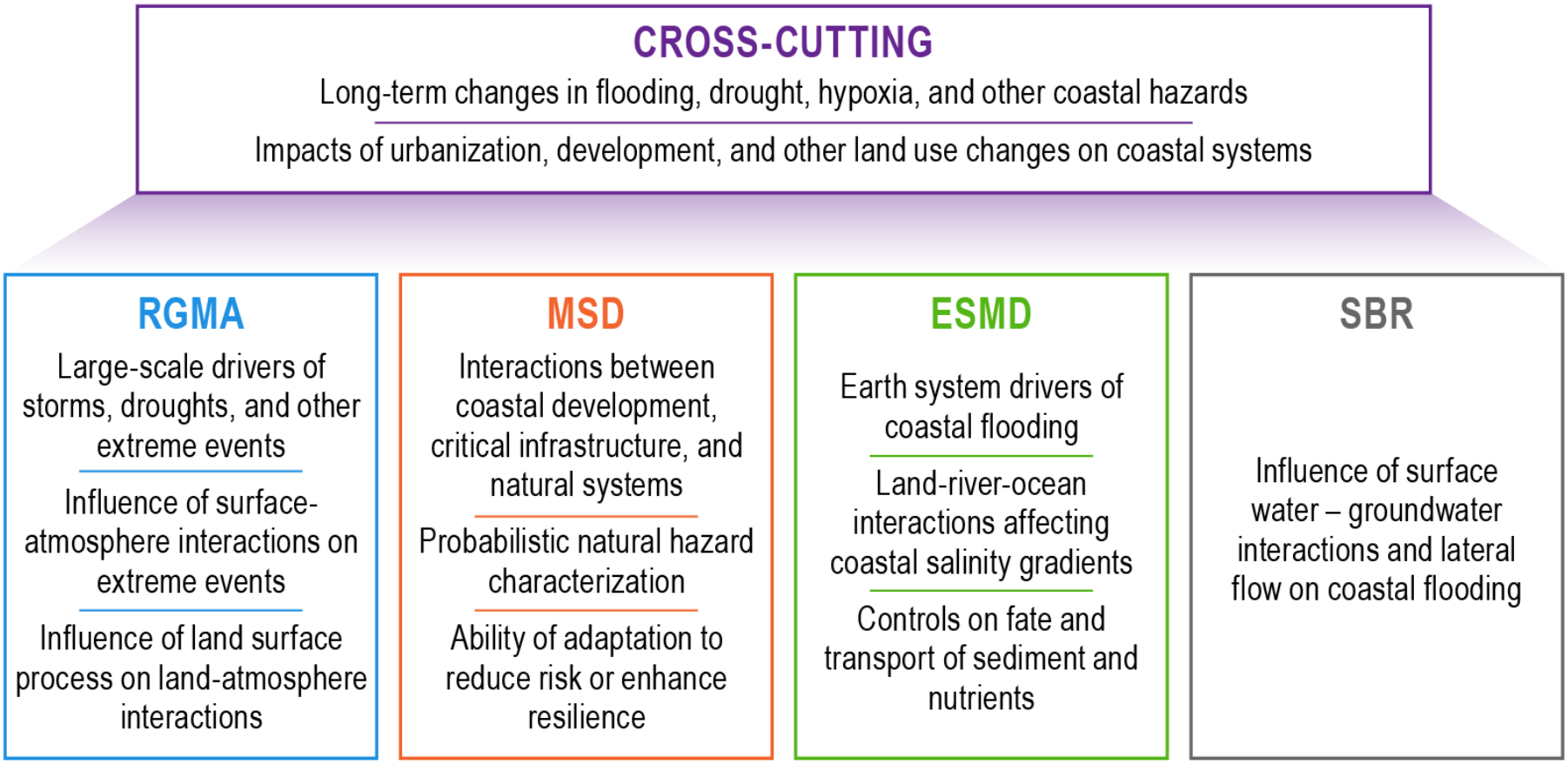


Sectoral Interactions, Stressors, and Tipping Points

And a growing set of “convergent” topics and communities

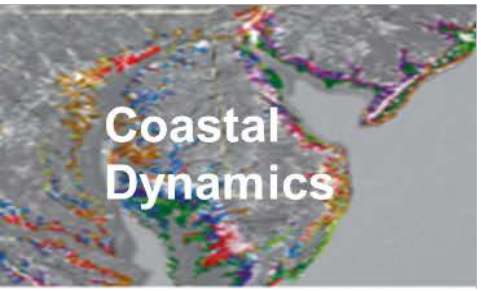


Exploring new approaches to managing convergence: ICoM example



Future directions

- **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, machine learning, etc.)
- **Scenario methods and development** with implications for uncertainty framing/analysis, complex storylines, modeling experiments, and more.
- **Model resolution and fit-for-purpose process details** across spatial and temporal scales (e.g., energy, water, land, economics, population, land use, technology
- **Significant coupled systems behaviors**, such as found among energy water and land systems, and non-linear responses, e.g., induced by extremes



Final thoughts

- **MSD community-of-practice**…a very big deal!
- **Teaming**…incentives for actions, not words
- **MSD – LIVE**…a community data/code repository, portal, and more
- **Interagency Integrated Hydro-Terrestrial Modeling (IHTM)** and three Priority Water Challenges
  - Hypoxia, Excess Nutrients and Harmful Algal Blooms
  - Water Availability in the Western United States
  - Extreme Water Hazards
- **Upcoming Town Halls** at American Geophysical Union (Coasts and Arctic) and one planned for AMS on integrative models
- **Major SFA renewal proposals** (and review) for IHESD…and IM3 underway.