COMPASS Overview

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COMPASS
Coastal Observations, Mechanisms, and Predictions
Across Systems and Scales

Coastal regions are facing a wide range of changes and challenges

- Climate warming
- Regional hydrology
- Extreme weather events
- Ecosystem shifts (e.g., invasive species)
- Land use and land cover change
- Shoreline evolution
- Air and water pollution
- Water quality (e.g., harmful algal blooms)
- Aging infrastructure
- Energy system changes
- Transportation impacts

We have identified key knowledge gaps in coastal systems that DOE is well positioned to address

- Mechanistic understanding of fundamental processes governing carbon and nutrient cycling in coastal systems

- Coupling of processes in predictive frameworks across scales

- Enhanced representation of land–lake–atmosphere interactions

- Enhanced representation of nutrient removal and transport in watershed models

- Representation of coastal processes in Earth system models
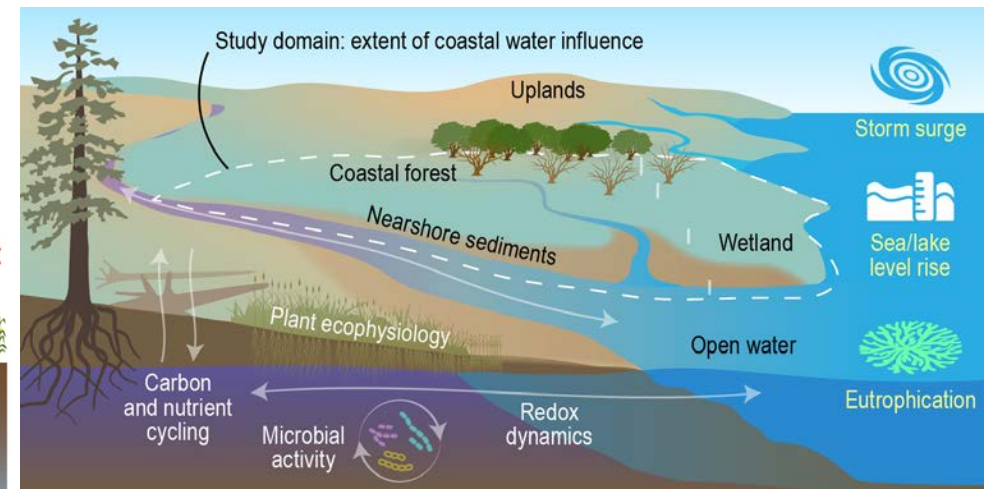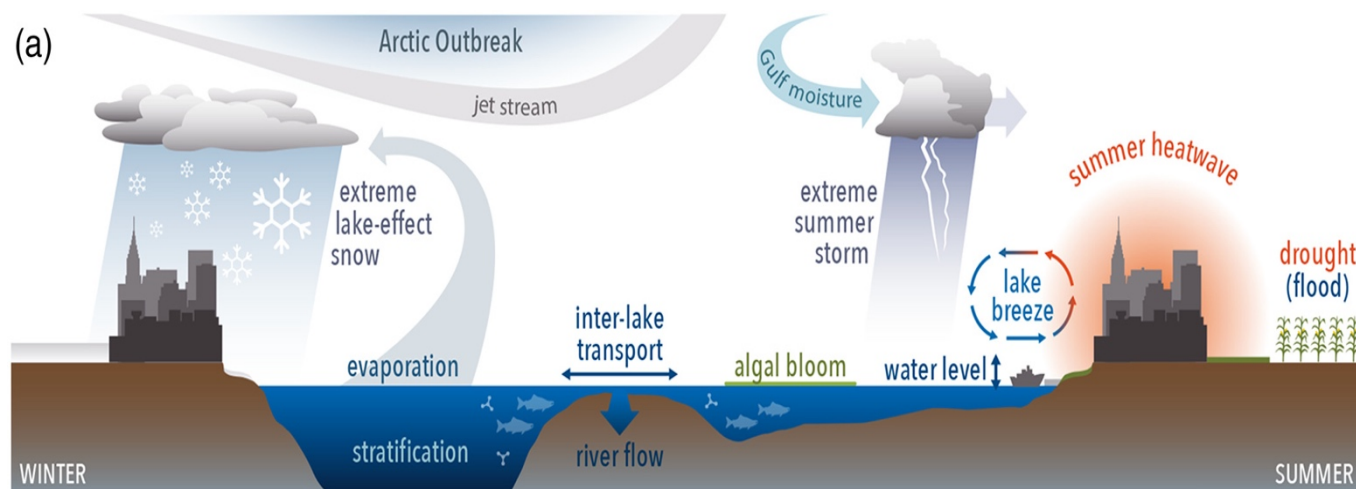
From Sharma et al., 2018

Two study regions offer complementary and contrasting characteristics

Mid Atlantic region

Great Lakes region

Saline to freshwater tidal, sea level rise

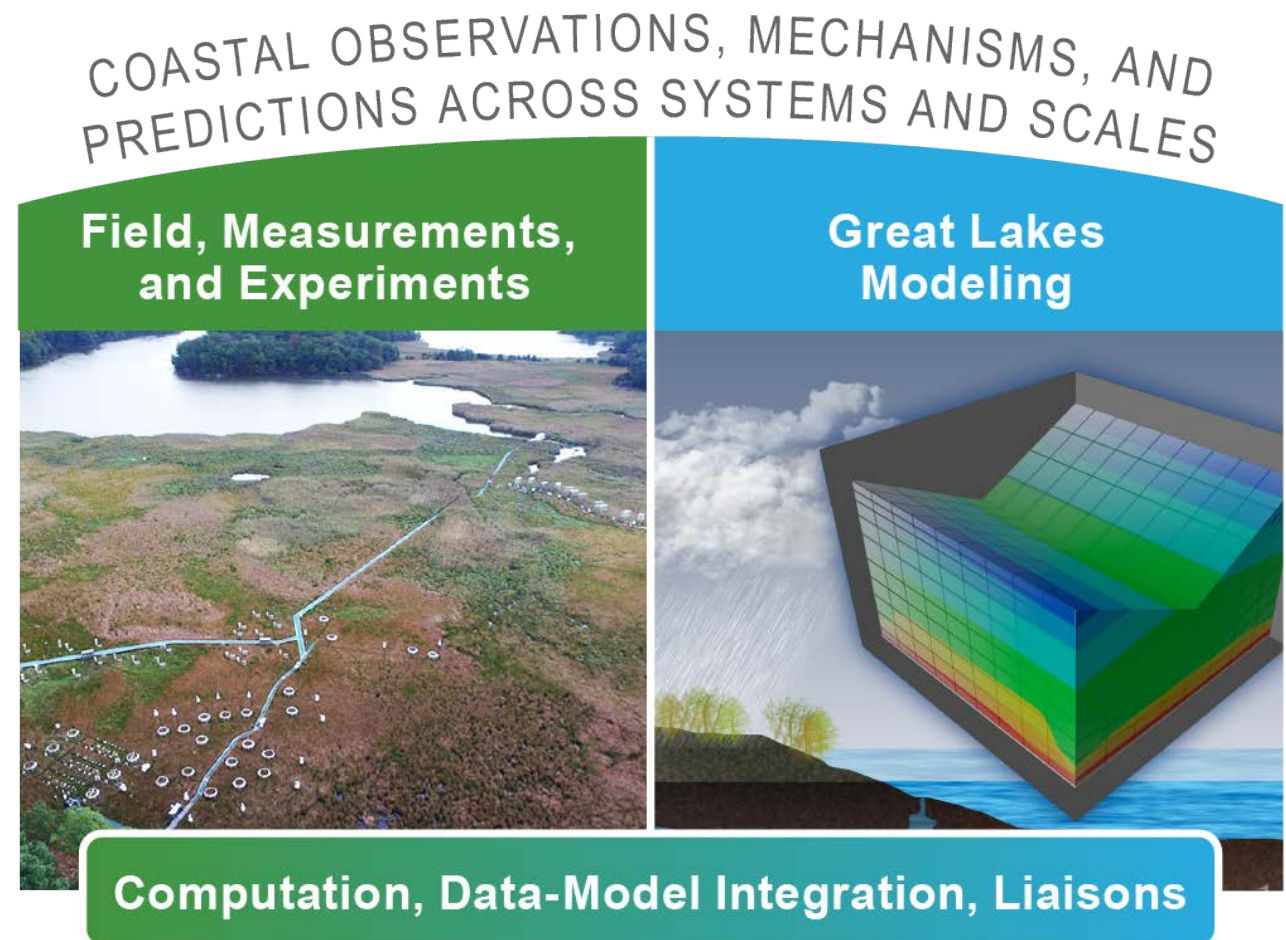Largest freshwater lake system, annual ice

Heavily modified by humans, experiencing natural system change, home to existing research that can be leveraged

COMPASS aims to dramatically enhance predictive understanding of coastal systems, including their response to short- and long-term changes

Two pilot studies, one focused on measurements and one focused on modeling

Cross-cutting capabilities, including new computational resources for DOE coastal science and liaisons to other projects

COASTAL OBSERVATIONS, MECHANISMS, AND PREDICTIONS ACROSS SYSTEMS AND SCALES

Field, Measurements, and Experiments

Great Lakes Modeling

Computation, Data-Model Integration, Liaisons

DOE PM: Dan Stover, ESS   **DOE PM: Renu Joseph, EESM**

COMPASS aims to dramatically enhance predictive understanding of coastal systems, including their response to short- and long-term changes

Overarching science questions	What multiscale mechanisms govern coastal systems at different spatial and temporal scales?	How do coastal systems respond to natural and anthropogenic influences?	Can we generalize new process knowledge and predictive skill across the diversity of coastal systems?

	FIELD, MEASUREMENTS, AND EXPERIMENTS	**ModEx**	**GREAT LAKES MODELING**
Pilot study science questions	What key ecological, biogeochemical, and hydrologic mechanisms control coastal zone structure, function, and evolution? How do these mechanisms interact across multiple scales, and what process interactions are most important to improve predictive models?		How do precipitation, runoff, and air temperature in the Great Lakes Region interact with lake water balance, thermal structure, and circulation to govern regional climate changes and extremes? How do managed drainage practices, legacy nutrient stores, and an intensified hydrologic cycle affect the nutrient removal capacity of soils and riparian corridors in the Maumee River Basin?

Foundational resources	Computing/data management • Liaisons • Data–model integration

| COMPASS OUTCOMES	**ESTABLISH** a network of sites across diverse coastal systems	**DEVELOP** hierarchical, process-rich models	**IMPROVE** coastal system representation in E3SM	**REDUCE** uncertainty in future model projections

A multidisciplinary team brings expertise and proven experience for achieving our goals

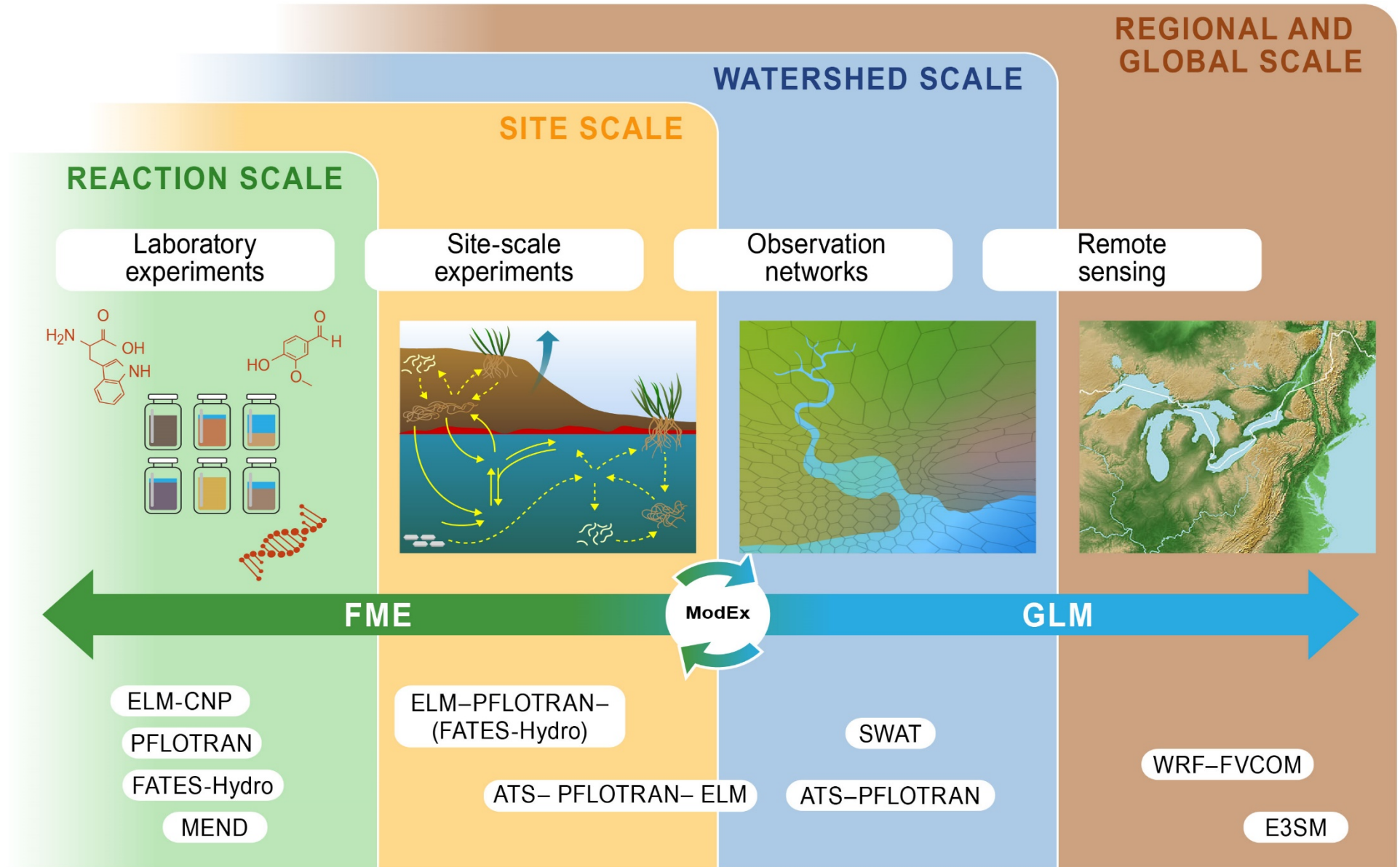**Field, Measurements, and Experiments**

**COMPASS project management and cross project scientists**

Great Lakes Modeling
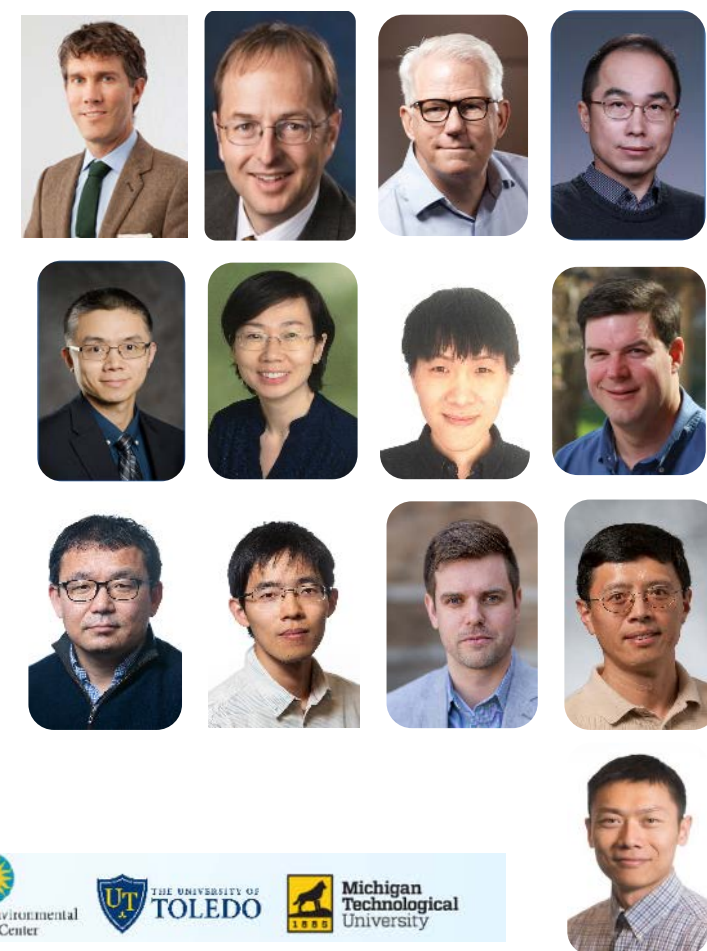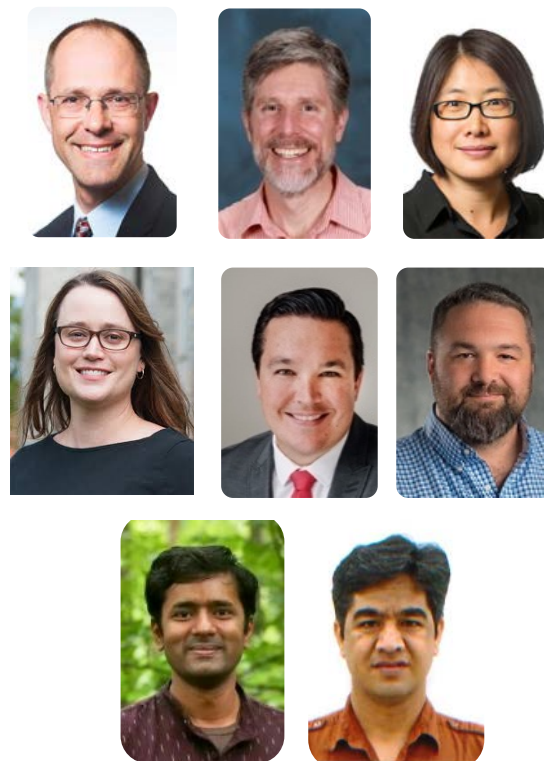
Our two pilot studies span reaction to regional scales and are linked through ModEx

COMPASS-FME (Field, Measurements, Experiments) focuses on the transformations and fluxes of carbon and nutrients across reaction to site scales

Science Questions:

1. What are the fundamental mechanisms that control the structure, function, and evolution of coastal terrestrial–aquatic interfaces?

2. How do these fundamental mechanisms interact across spatial scales, and what interactions are most important to improving predictive models?
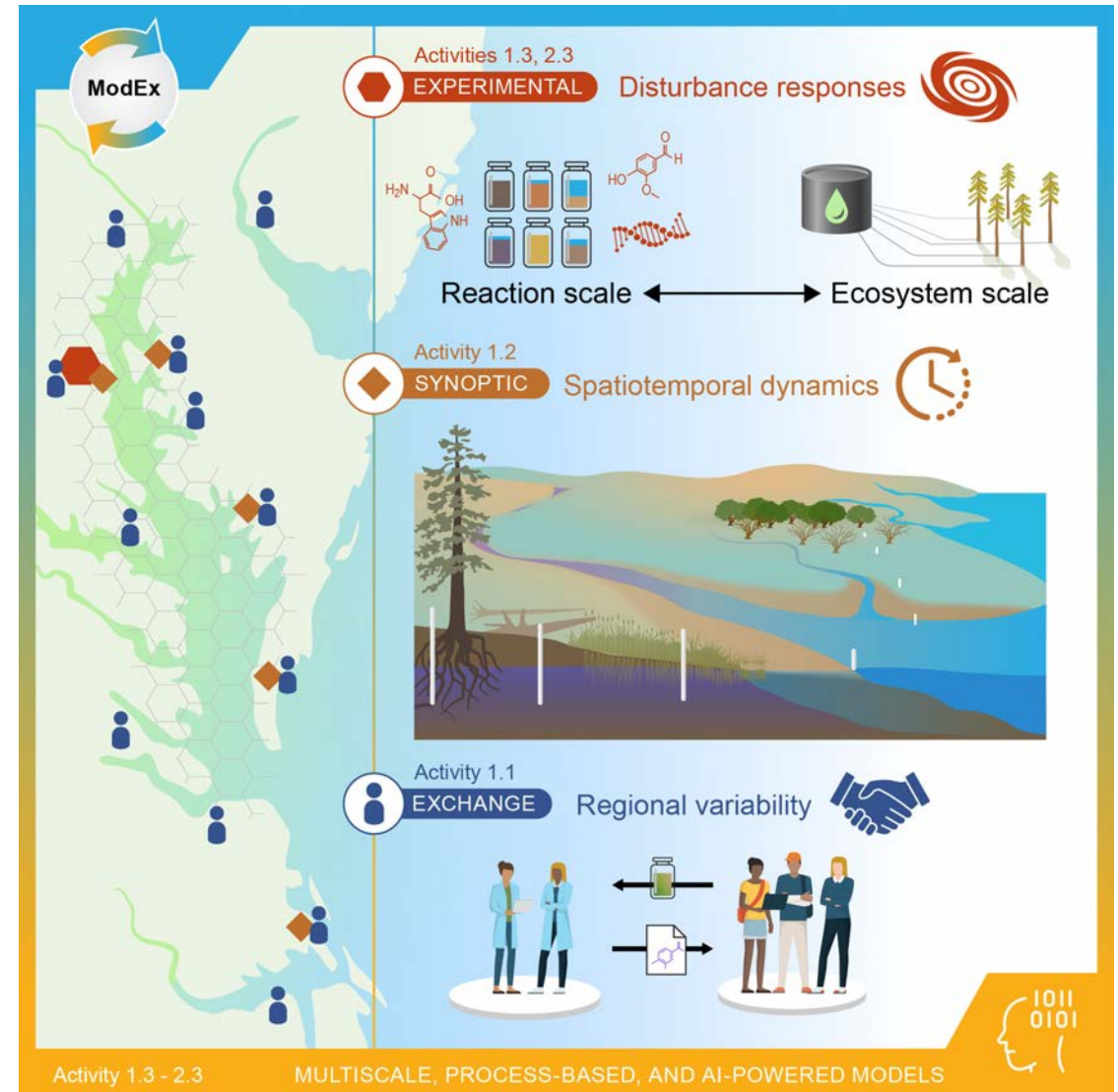
COMPASS-FME seeks a robust mechanistic understanding of coastal terrestrial–aquatic interfaces, with a focus on the transformations and fluxes of carbon and nutrients across reaction to site scales,

We will understand the interactions of soils, waters, and plants, as well as the emergent biogeochemistry to inform multiscale, hierarchical models at select sites in the Chesapeake Bay and Lake Erie regions
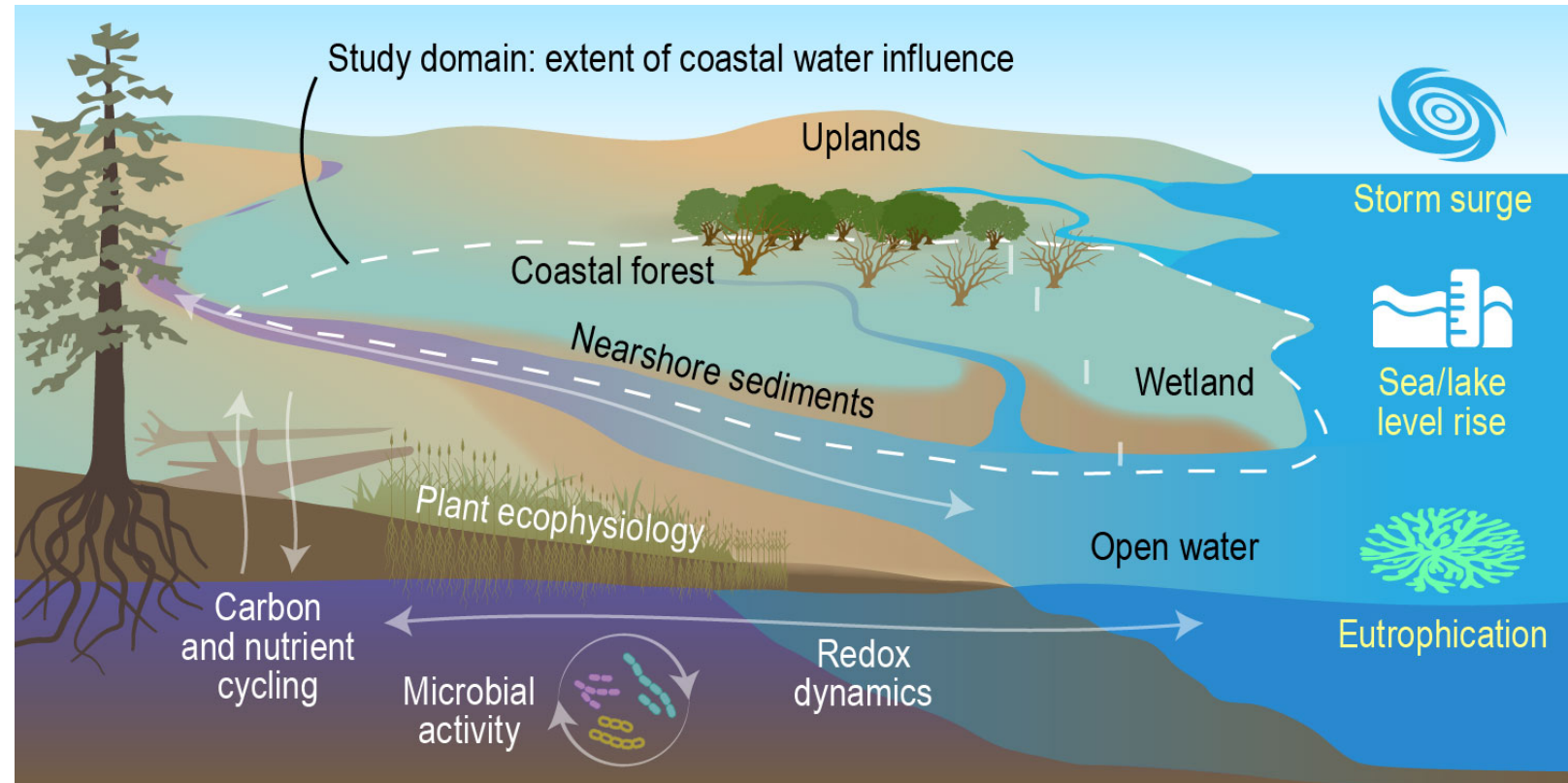
COMPASS-FME will leverage existing capabilities and data, including coordination with the ongoing ICoM project in the mid-Atlantic region

FME Pilot Study Outcomes:

- A prototype **high-resolution coastal TAI module** with coupled processes important to coastal ecosystems

- Improved **knowledge of mechanisms** that control fluxes and transformations of carbon and nutrients across TAIs

- Improved **fine-scale representations** of these mechanisms in integrative models
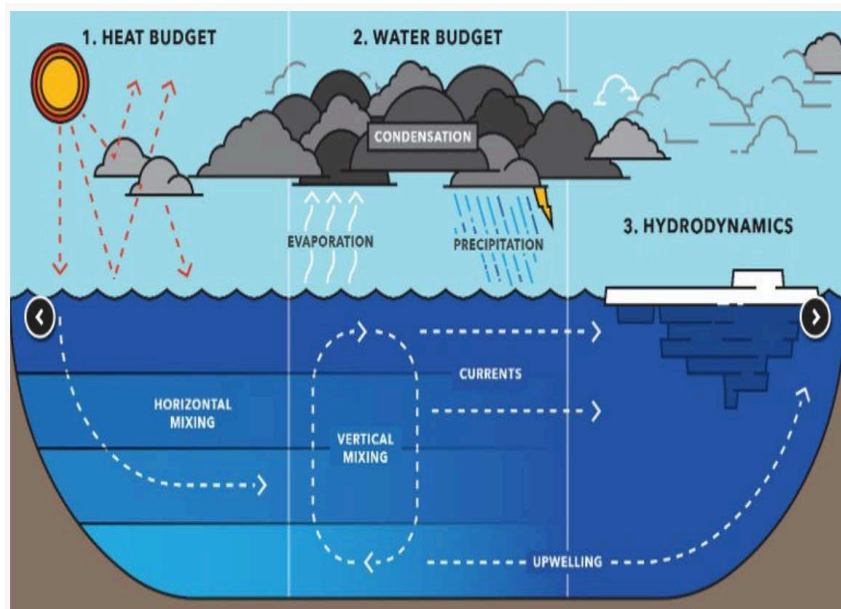
FME Future Work:

- Modeling disturbance impact
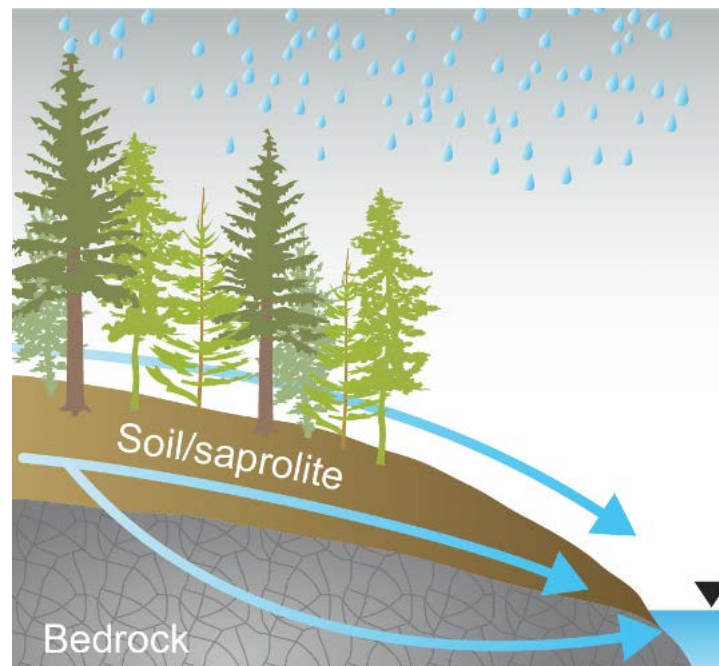- Research in new coastal regions

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COMPASS-GLM addresses three major knowledge gaps

How atmosphere–land–lake interactions affect regional climate and extreme events
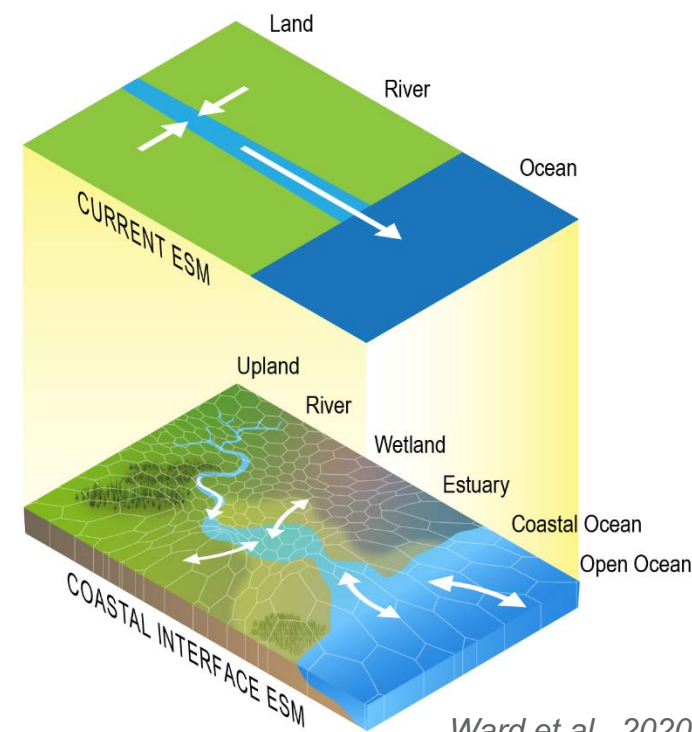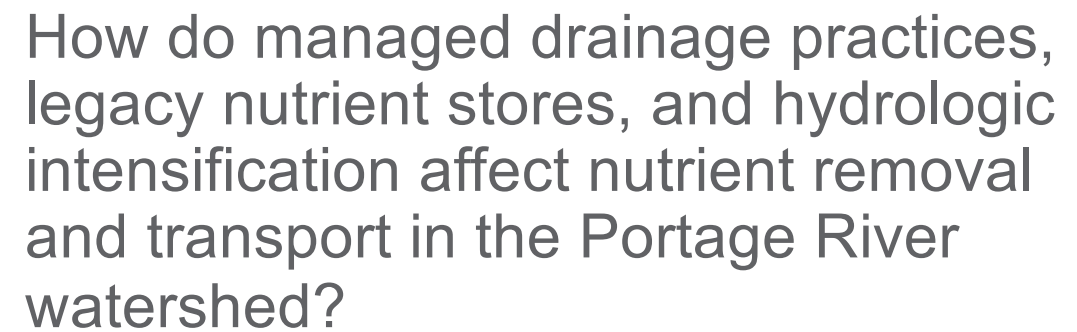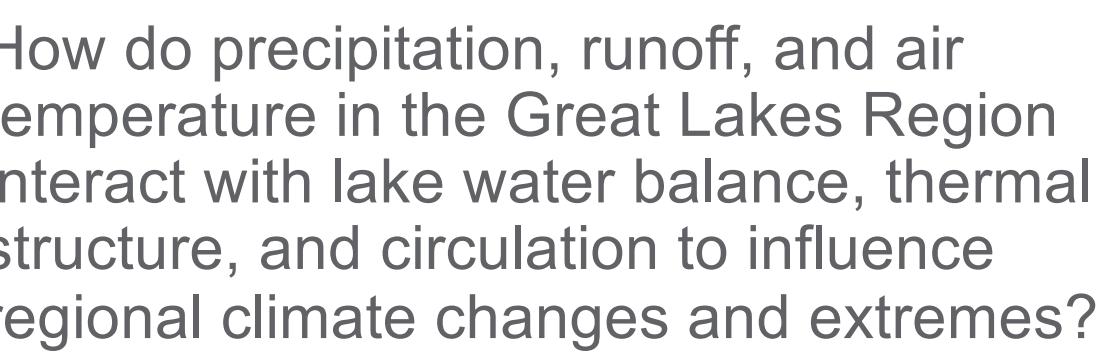
How specific watershed processes and features affect nutrient removal and transport

How to best represent coastal processes in E3SM and other ESMs


*MTU News, 2016*

Ward et al., 2020

COMPASS-GLM will enhance predictive understanding of freshwater coastal systems at regional to watershed scales

How do precipitation, runoff, and air temperature in the Great Lakes Region interact with lake water balance, thermal structure, and circulation to influence regional climate changes and extremes?

How do managed drainage practices, legacy nutrient stores, and hydrologic intensification affect nutrient removal and transport in the Portage River watershed?

COMPASS-GLM will enhance predictive understanding of freshwater coastal systems at regional to watershed scales
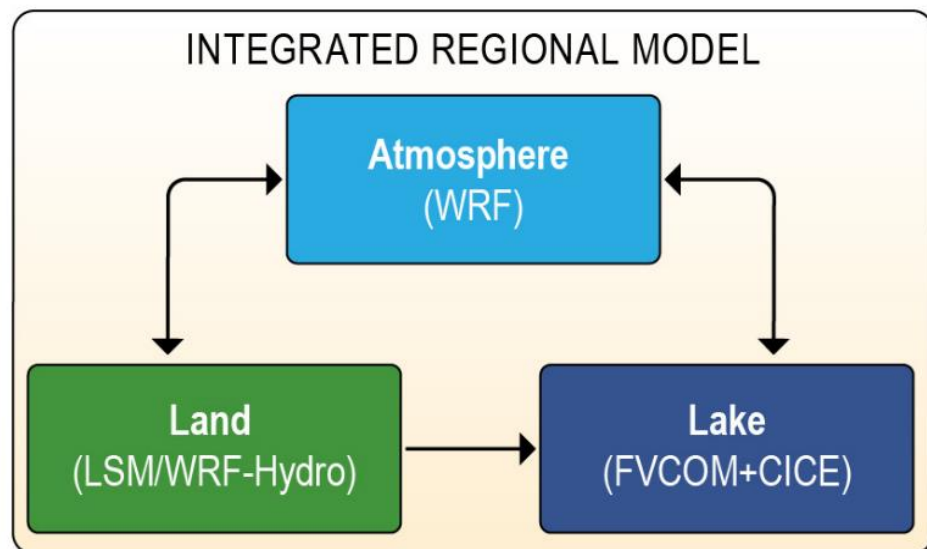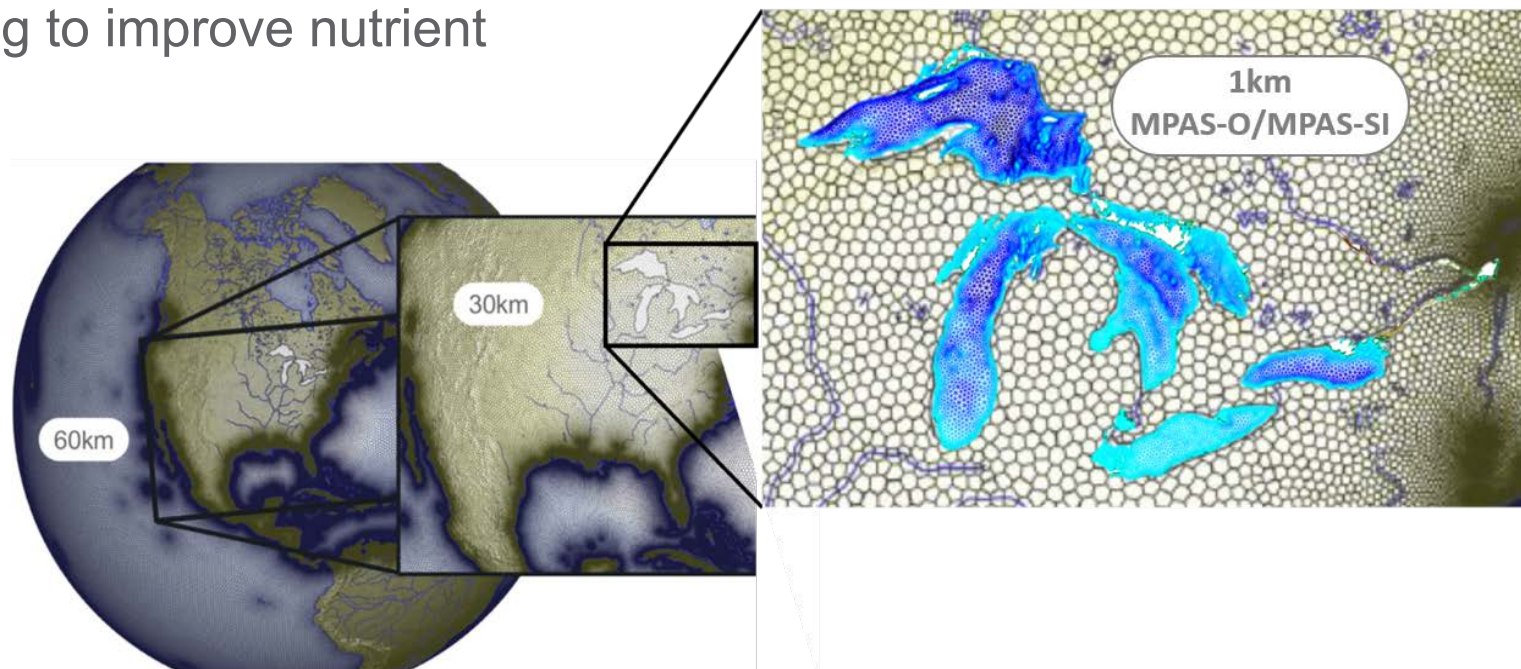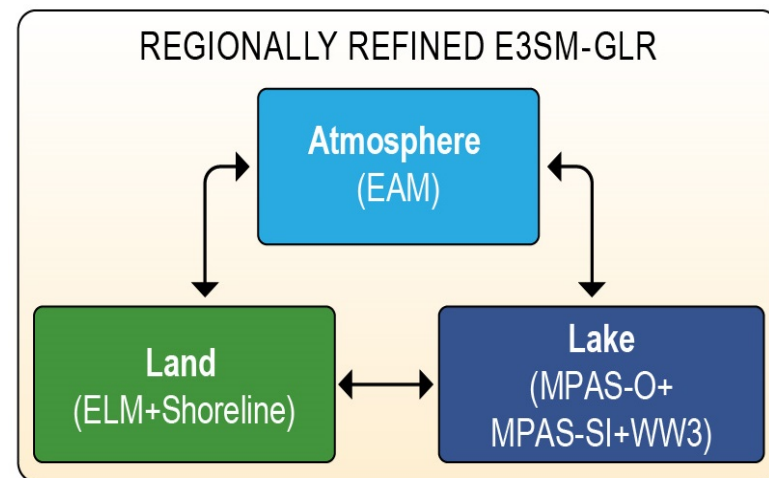

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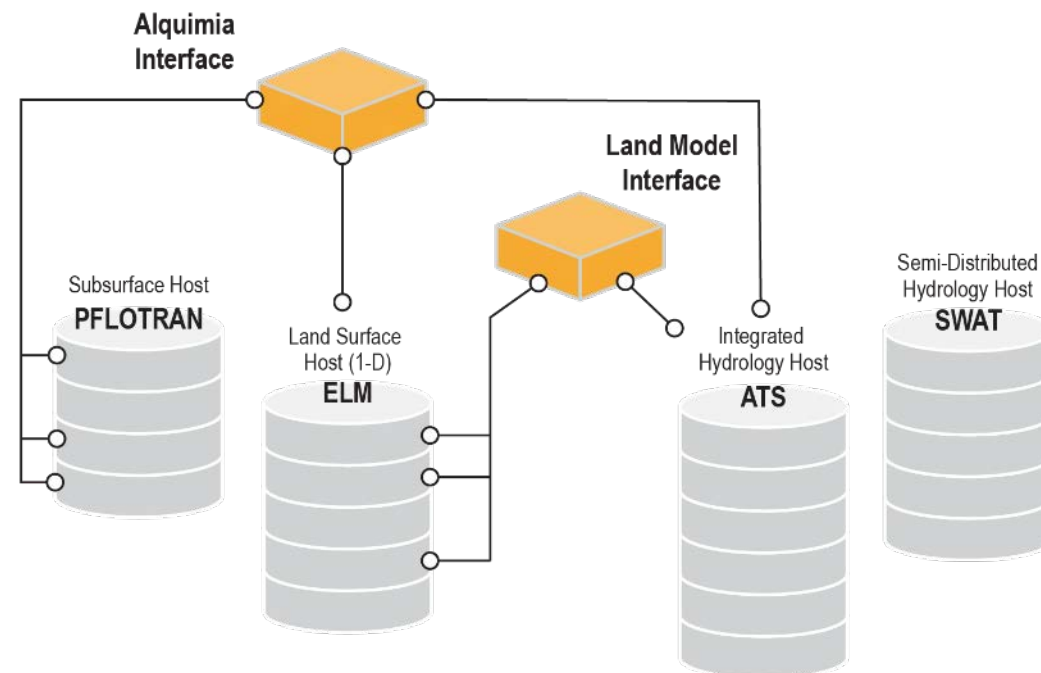
How do managed drainage practices, legacy nutrient stores, and hydrologic intensification affect nutrient removal and transport in the Portage River watershed?

Future work:
Extend E3SM to lake regional climate modeling

- Leverage regional grid refinement and other ongoing efforts
- Develop MPAS-O and Sea Ice modules for the Great Lakes at ~1 km resolution
- Improve ELM+MPAS-O coupling (ICoM) to resolve key freshwater coastal processes
- Improve ELM-ATS coupling to improve nutrient delivery to lake
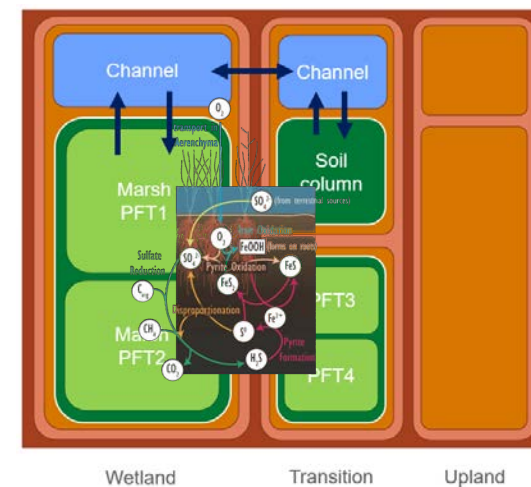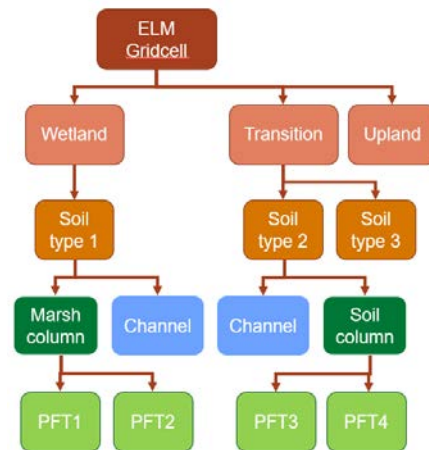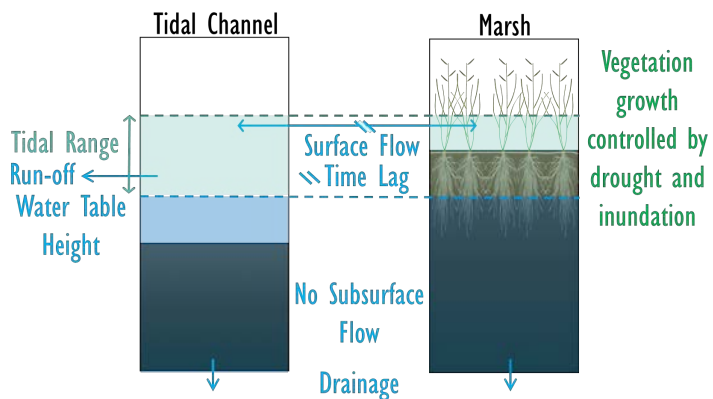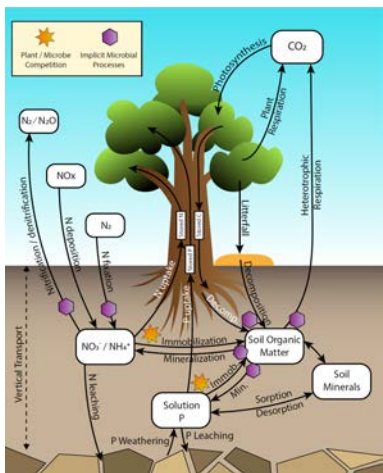- Regional- and watershed-scale modeling useful for guiding E3SM-GLR development

REGIONALLY REFINED E3SM-GLR

Atmosphere (EAM)

Land (ELM+Shoreline)

Lake (MPAS-O+ MPAS-SI+WW3)

1km MPAS-O/MPAS-SI

30km

60km

Example roadmap for COMPASS parameterization in E3SM

| Baseline Model: E3SM Land Model v2	COMPASS ModEx	New parameterization	Repository integration: ELMv3

COMPASS Liaison roles and responsibilities

- Take ownership of COMPASS deliverables that intersect with other projects
- Coordinate new code development and new data collection
- Track code and data repositories maintained by collaborating projects
- Provide periodic updates across COMPASS and related projects
- Organize annual multi-project collaboration events at COMPASS all-hands meetings
- Engage in key working meetings with collaborating projects

We will leverage and coordinate with other BER-funded projects
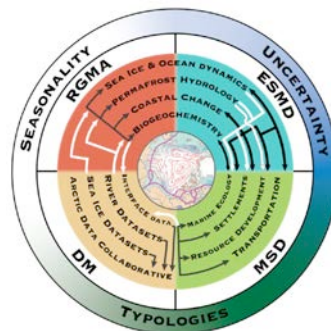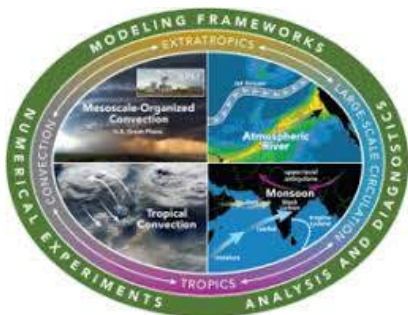
Examples:

- Similar components and regional experimental design to ICoM

- Leveraging the IDEAS-Watersheds software ecosystem and ExaSheds machine learning approaches

- ELM-ATS integration facilitates interactions with COMPASS-FME and sets the stage for longer-term integration with E3SM

- COMPASS is establishing technical liaisons with several other BER projects to facilitate model developing, leveraging, & coordination

COMPASS will also deliver a mid-scale, high-performance computing resource configured for coastal system science

- Shortage of mid-scale/production computing resources for BER scientists
  - NERSC allocations consistently a small percentage of proposed
- Received input from BER ESS Cyberinfrastructure Working Group, COMPASS and ICoM team members
  - Mechanistic parallel simulations on a modest number of cores (tens to thousands)
  - Ensembles of those simulations within SA/UQ and ML workflows
  - Data analytics and machine learning that can leverage GPGPUs
- Plan for 30% of allocations open to BER coastal science projects (allocation process still being worked out but probably something NERSC-like)
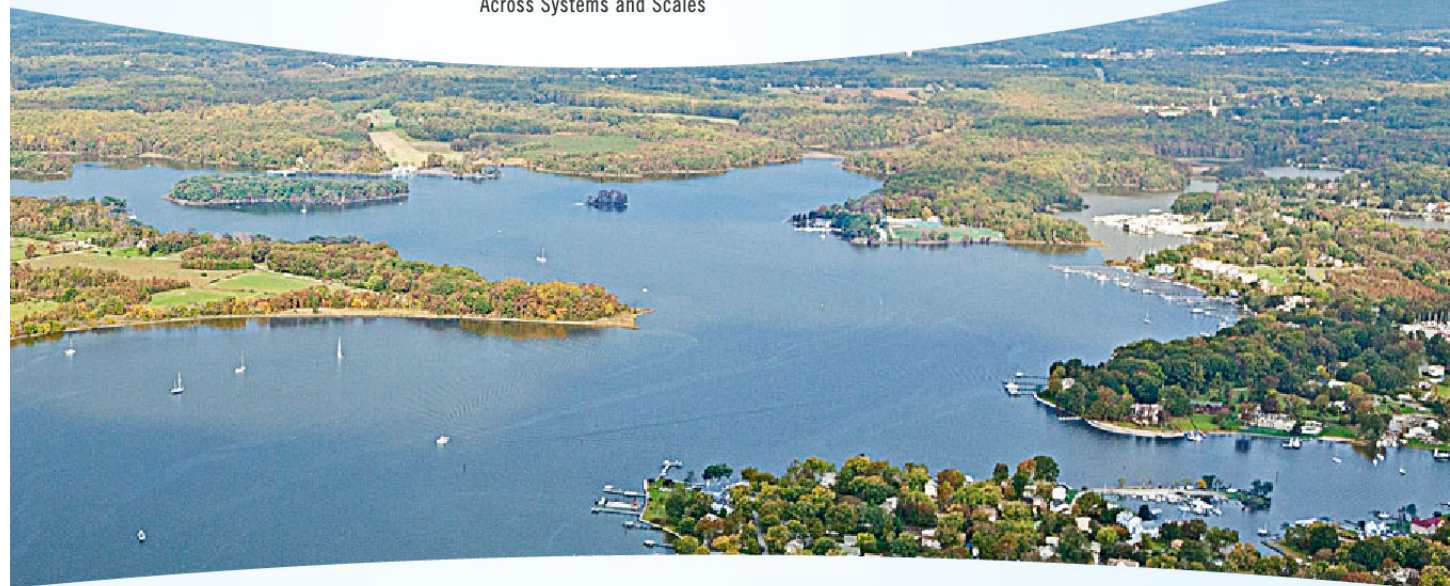- Bids are in, but timeline likely delayed due to global chip shortage

Thank you

Pacific Northwest
NATIONAL LABORATORY

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Across Systems and Scales

U.S. DEPARTMENT OF ENERGY   *BATTELLE*

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