Pacific Northwest NATIONAL LABORATORY

Integrated Coastal Modeling (ICoM) Overview

May 11, 2020

Ian Kraucunas
Principal Investigator

David Moulton
SBR Lead

U.S. DEPARTMENT OF ENERGY BATTELLE

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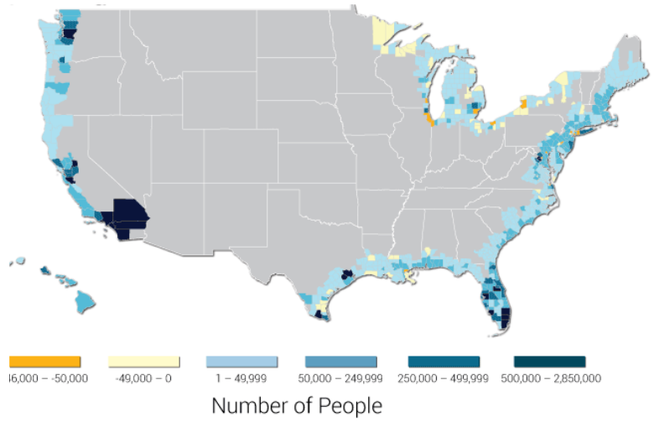
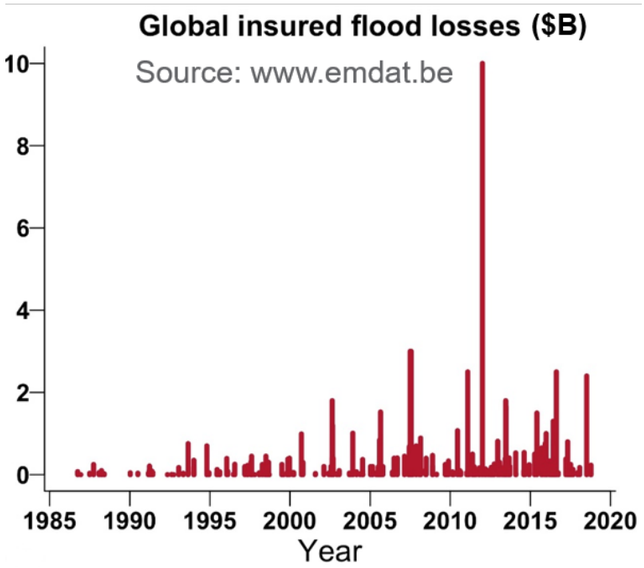
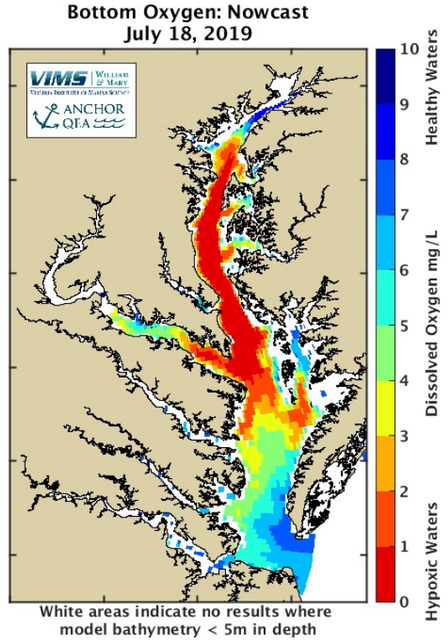
Why Integrated Coastal Modeling?

Population change in U.S. coastal watershed counties (1970–2010). Source: National Climate Assessment, 2014







Understanding how coastal environments and risks may evolve **over the next several decades** requires considering the co-evolution of many different human and natural systems, which necessitates an integrated modeling approach

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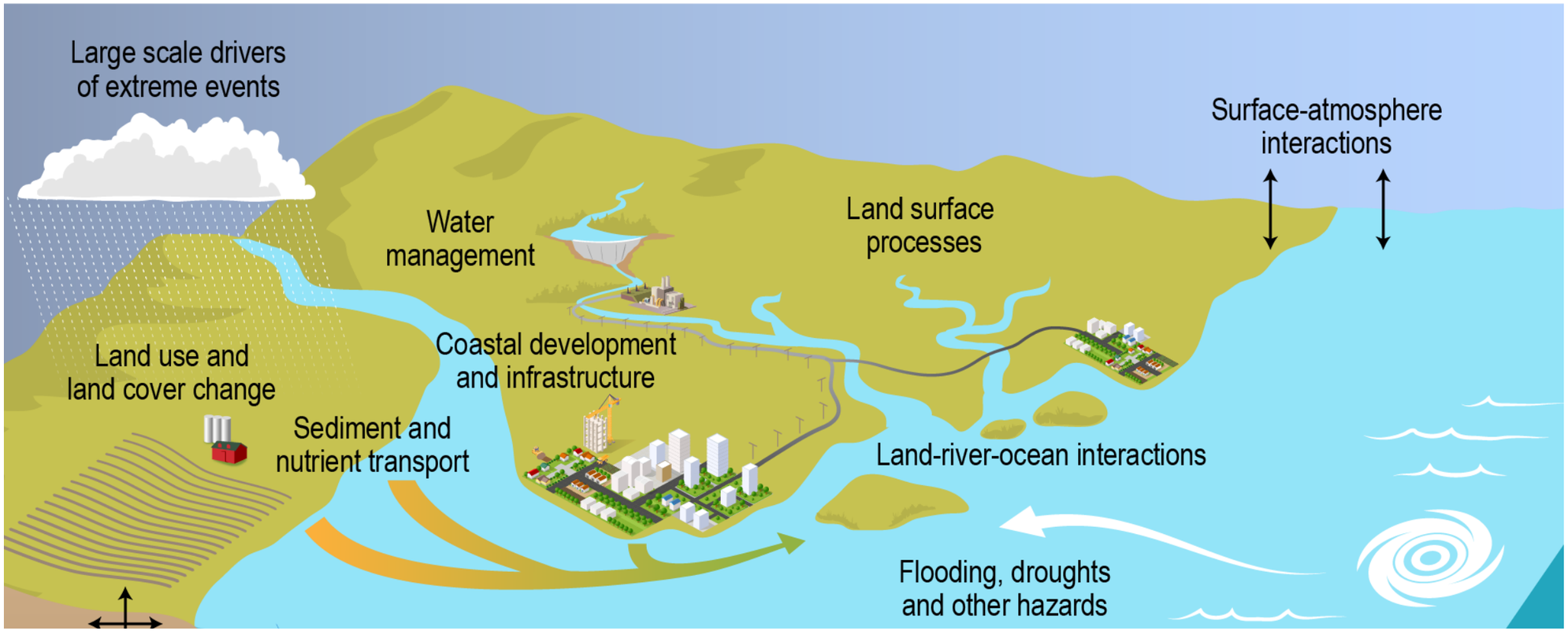
Overarching Science Questions for ICoM

- How do **interactions across different coastal systems and processes**, including the land–river–estuary–ocean continuum, atmosphere–surface–subsurface interactions, *and interplays between human activities and natural Earth system components*, influence coastal hazards?
- To what extent could **long-term changes in coastal environments**, including sea-level rise, human-development patterns, geomorphology, vegetative dynamics, biogeochemistry, and deliberate or autonomous adaptations alter the exposure, vulnerability, or resilience of coastal systems?
- How might **tipping points and shocks**, such as extreme weather, rapid technological or infrastructural changes, ecological shifts, and compound stressors, lead to significant impacts or major nonlinear changes in the co-evolving human and natural systems in coastal regions?

ICoM Focuses on Key Processes and Uncertainties



Our long-term vision is to deliver a robust predictive understanding of coastal evolution that accounts for the complex, multiscale interactions among physical, biological, and human systems

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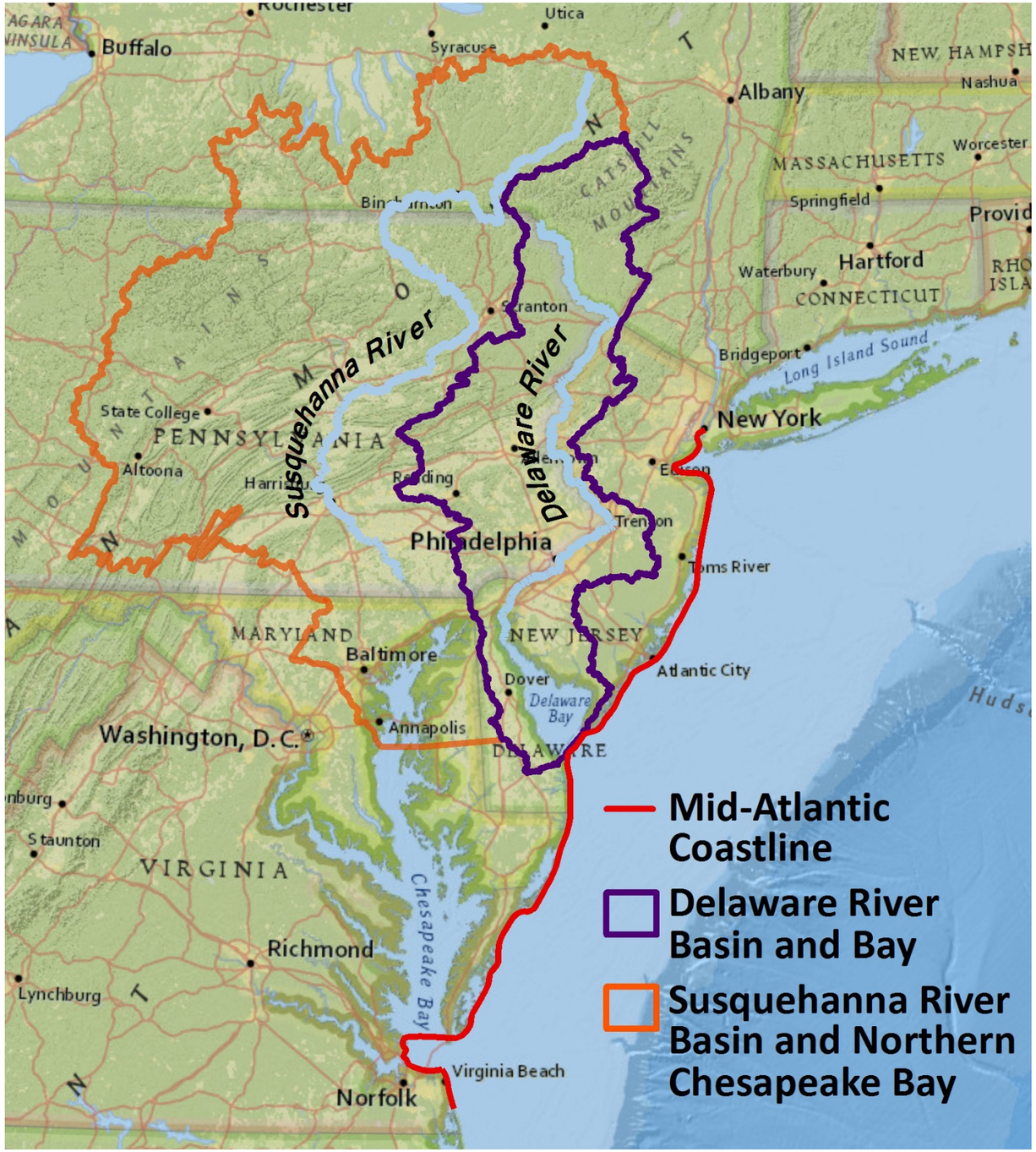
Mid-Atlantic Study Region

- Exposed to many different stresses and extremes
- Key uncertainties well aligned with DOE strategic goals
- Opportunities to compare and contrast systems
- Potential to leverage existing investments and capabilities
- Sets the stage for future research



ICoM Research Topics for FY 2020–2022

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	

DOE Program Areas

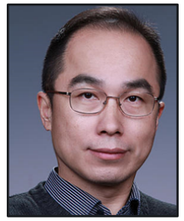
Improving Understanding of How Large-Scale Meteorological Patterns and Surface–Atmosphere Interactions Drive Mid-Atlantic Extreme Events

Regional and Global Modeling and Analysis (RGMA) Program Area

RGMA PI
Ruby Leung

Task Leads

Paul Ullrich



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Key Staff

Karthik Balaguru

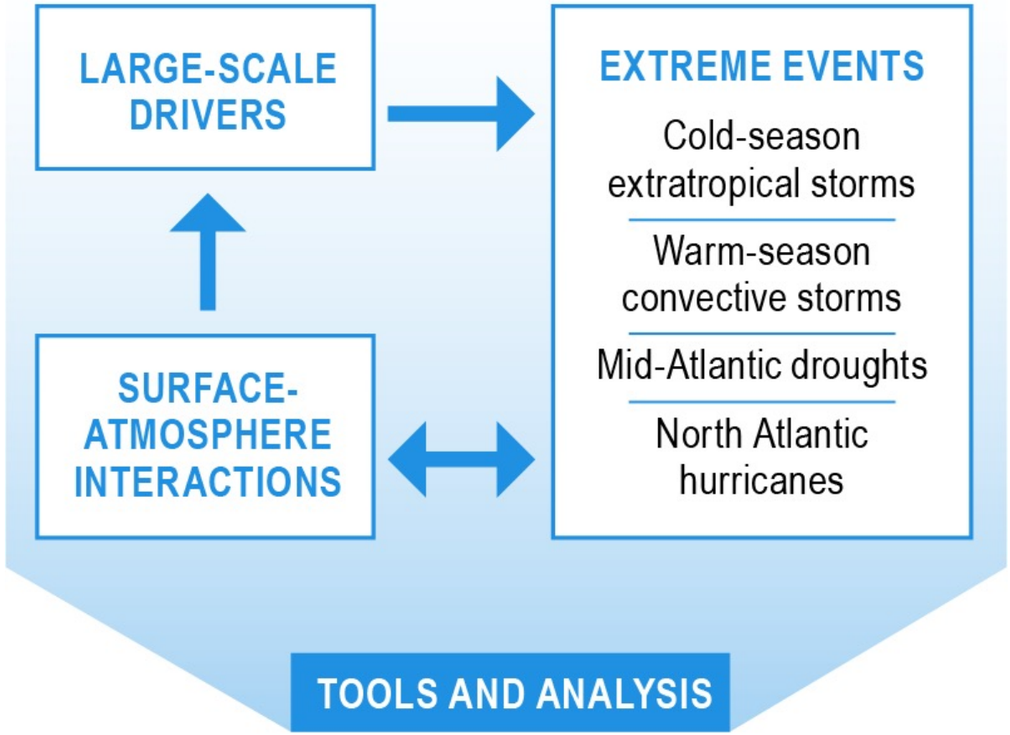
Laura Condon

Lu Dong

Reed Maxwell

Michael Wehner

Colin Zarcycki

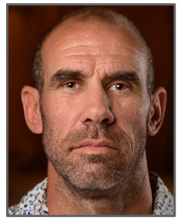


Coupling Infrastructure, Coastal Development, and Hazard Modeling/Emulation to Characterize Time-Evolving Risks and Resilience of Coastal Systems

MultiSector Dynamics (MSD) Program Area

MSD PI
Dave Judi

Task Leads



Brent Daniel

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Klaus Keller

Key Staff

Russell Bent

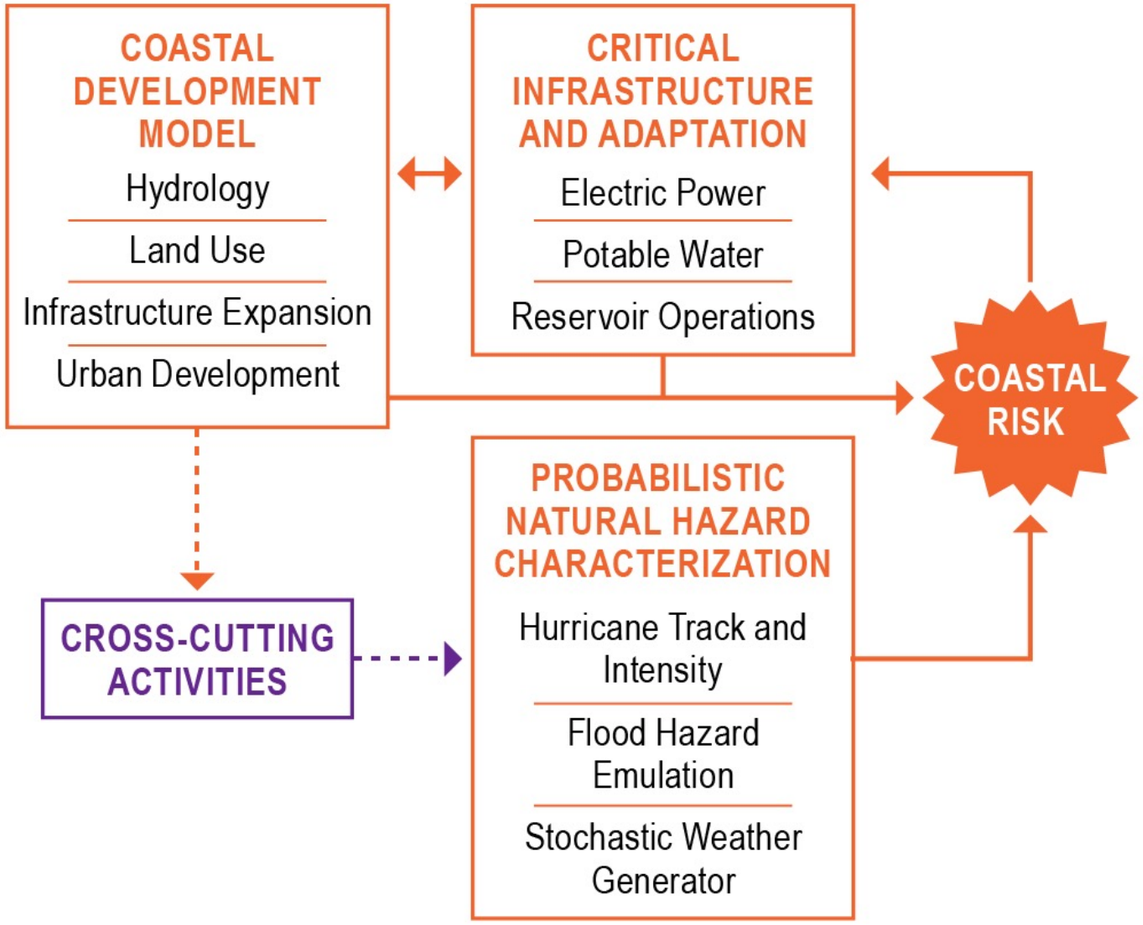
Patrick Reed

Vivek Srikrishnan

Nathan Urban

Stephanie Waldhoff

Jim Yoon



Extending the Energy Exascale Earth System Model (E3SM) to Better Resolve Human-Land-River-Ocean Interactions and Corresponding Fluxes

Earth System Model Development (ESMD) Program Area

ESMD PI
Phil Wolfram

Task Leads

Zeli Tan

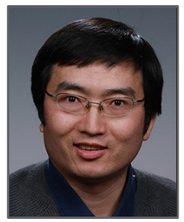
Tian Zhou

Gautam Bisht

Key Staff

Brian Arbic

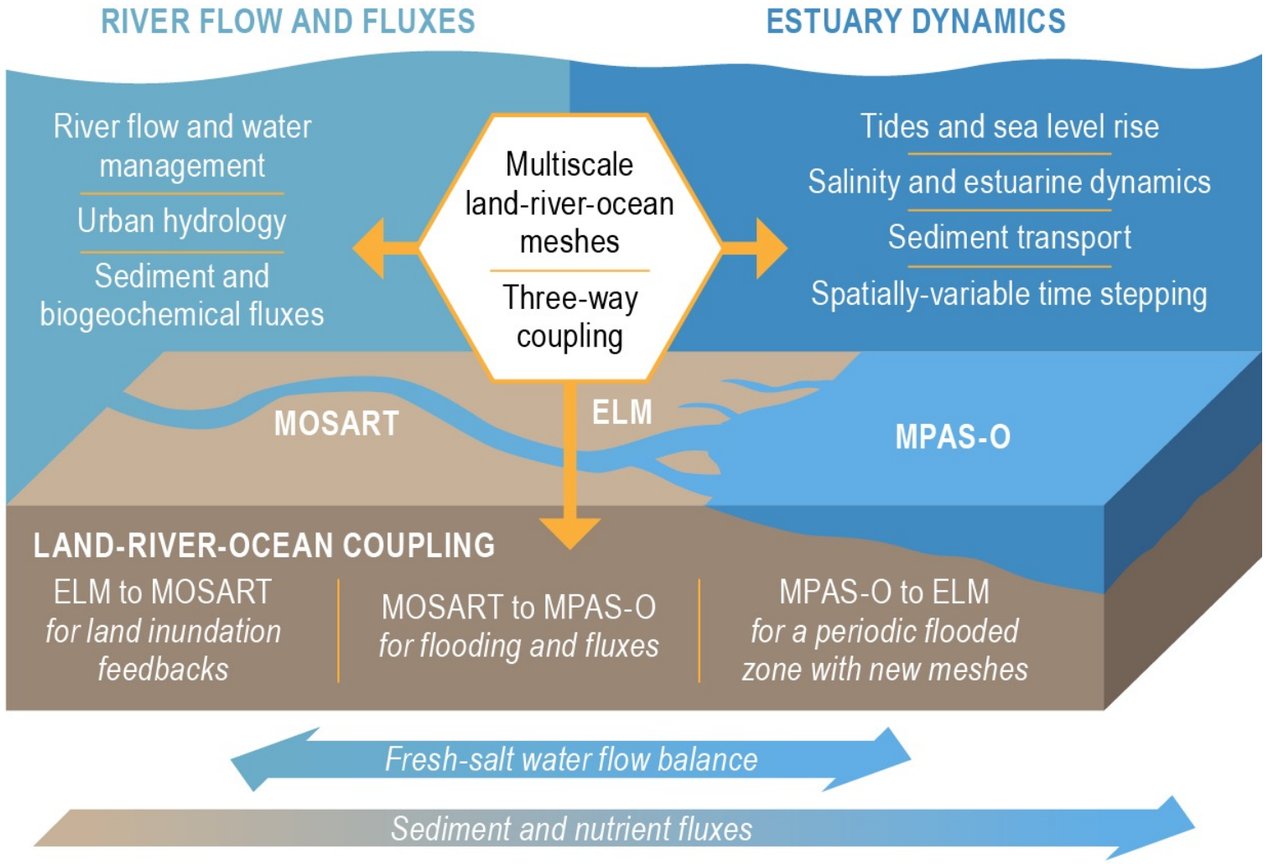
Darren Engwirda



Hong-Yi Li

Mark Petersen

Andrew Roberts

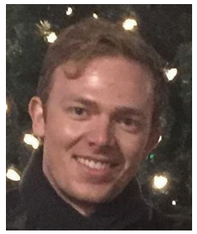


Characterizing Subsurface Hydrological Response and its Interaction with Surface Water during Storms and Droughts

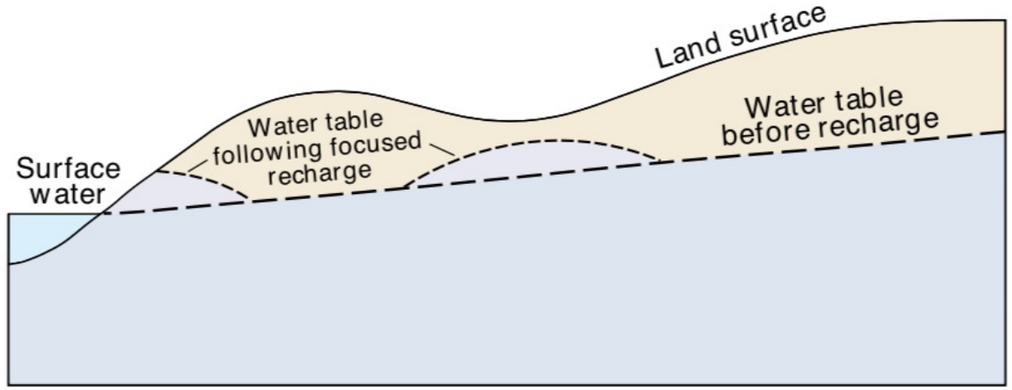
Subsurface Biogeochemistry Research (SBR) Program Area

SBR PI and Task Lead
David Moulton

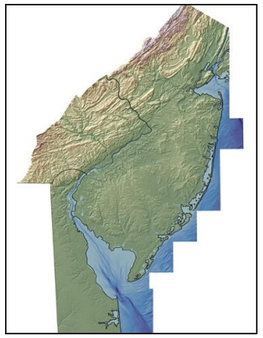
ATS Modeling
Yu Zhang



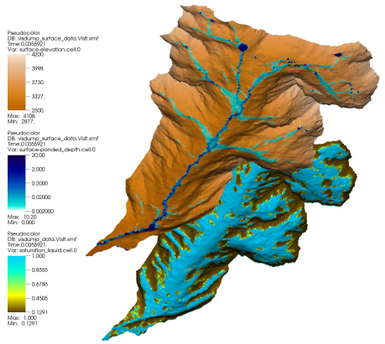
Meshing/Setup
Daniel Livingston



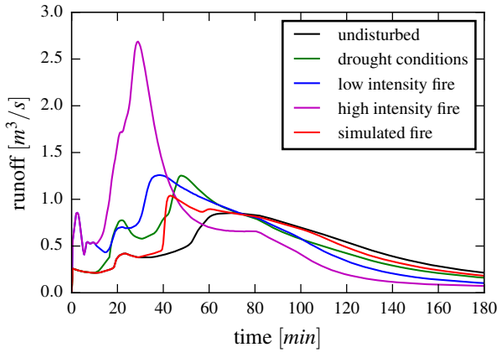
Ground Water and Surface Water: A single resource, USGS Survey Circular 1139, 1998.



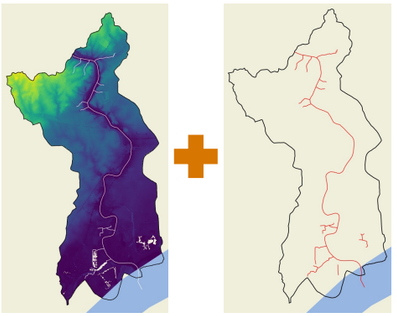
Model setup



Model spin-up



Simulate/analyze responses



Explore impact of coupling

Evaluating Different Modeling Techniques and Elucidating the Role of Coastal Development in Driving Natural System Changes

Cross-Cutting Research Area

Cross-Cutting Lead
Ian Kraucunas

Cross-Cutting Task Leads


Dave Judi


Phil Wolfram

Coordinating Program Area Leads

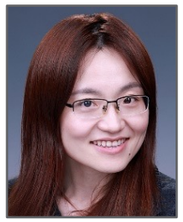

Ruby Leung


David Moulton

Key Staff


Karthik Balaguru

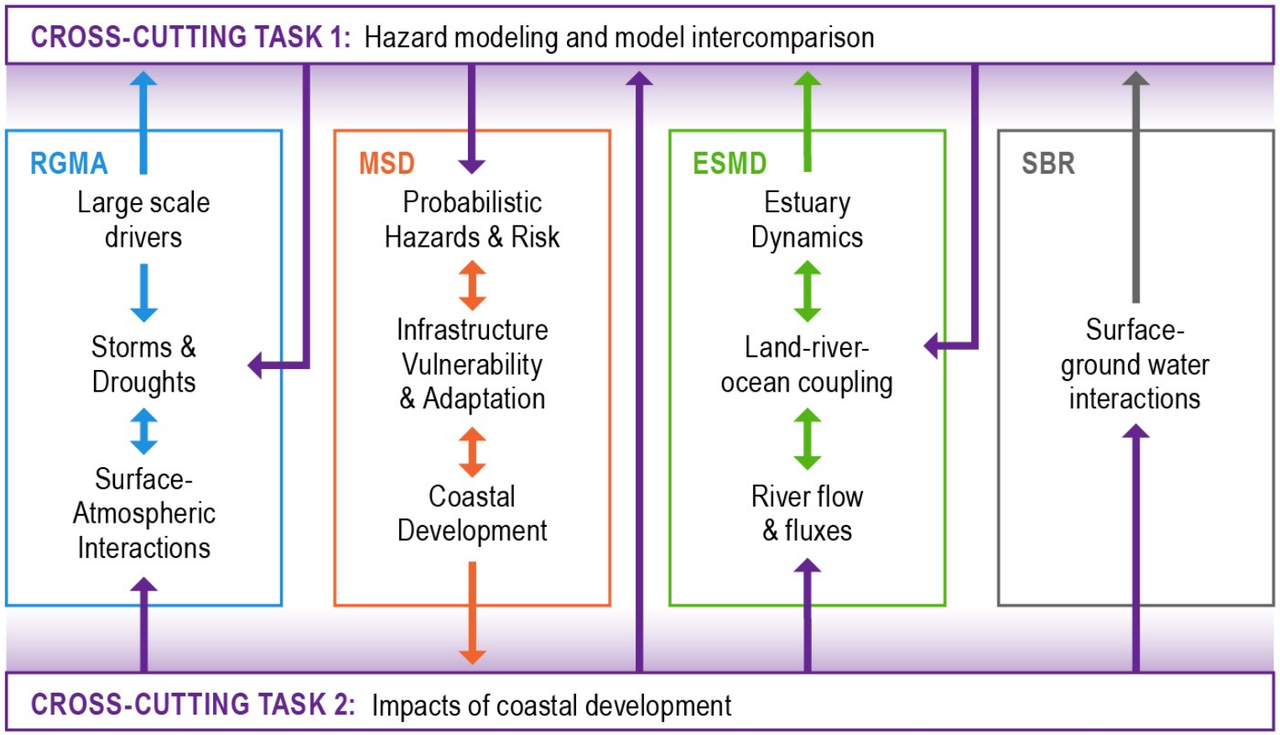

Shuyi Chen


Ning Sun


Zhaoqing Wang


Mark Wigmosta


Michael Wehner



ICoM Will Leverage and/or Collaborate With Many Other Activities Inside and Outside DOE

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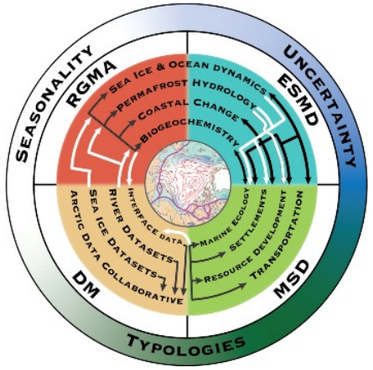
E3SM Energy Exascale Earth System Model

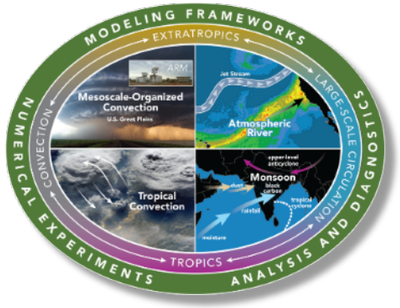


IM3 INTEGRATED MULTISECTOR MULTISCALE MODELING

IDEAS Watersheds

HYPERFACETS

NEW COASTAL ACTIVITY



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RUTGERS Institute of Earth, Ocean, and Atmospheric Sciences

USGS

Delaware River Basin Commission
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UNITED STATES OF AMERICA

NSF

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

U.S. Department of Homeland Security

NASA

Key ICoM Outcomes for FY 2020–2022

New Insights

- Factors controlling mid-Atlantic extremes and how they might change in the future
- Time-evolving risks and resilience of co-evolving human and natural systems
- Role of groundwater in regional flooding, including antecedent conditions and lateral flows
- The role of coastal development in driving regional hydrological, biogeochemical, and atmospheric changes
- Relative strengths of different coastal modeling approaches

New/Enhanced Capabilities

- Regionally refined global-to-coastal-scale Earth system model
- Model of coastal development patterns
- Endogenous adaptation in coastal infrastructure systems
- Integrated hydrologic models for the Delaware and Susquehanna basins
- High-resolution simulations of mid-Atlantic flooding, droughts, and hypoxia
- Metrics for land surface processes

Potential Future Work (and/or Partnership Opportunities with Other Projects & Programs)

Additional Stresses

- Coastal erosion, floodwater scouring
- Acidification, saltwater intrusion
- Ice storms, ice dams, etc.
- Compound stresses

Additional Impacts

- Compromised infrastructure due to saltwater intrusion, erosion, and wave impacts
- Salinity-induced ecosystem mortality and impacts on biogeochemistry

Additional System Dynamics

- Vegetative dynamics
- Ecogeomorphology
- Additional infrastructure systems (e.g., transportation)

Additional Geographic Contexts

- Use tools and lessons learned from the mid-Atlantic in other regions
- Establish typologies of coastal systems
- Identify data gaps/observational needs

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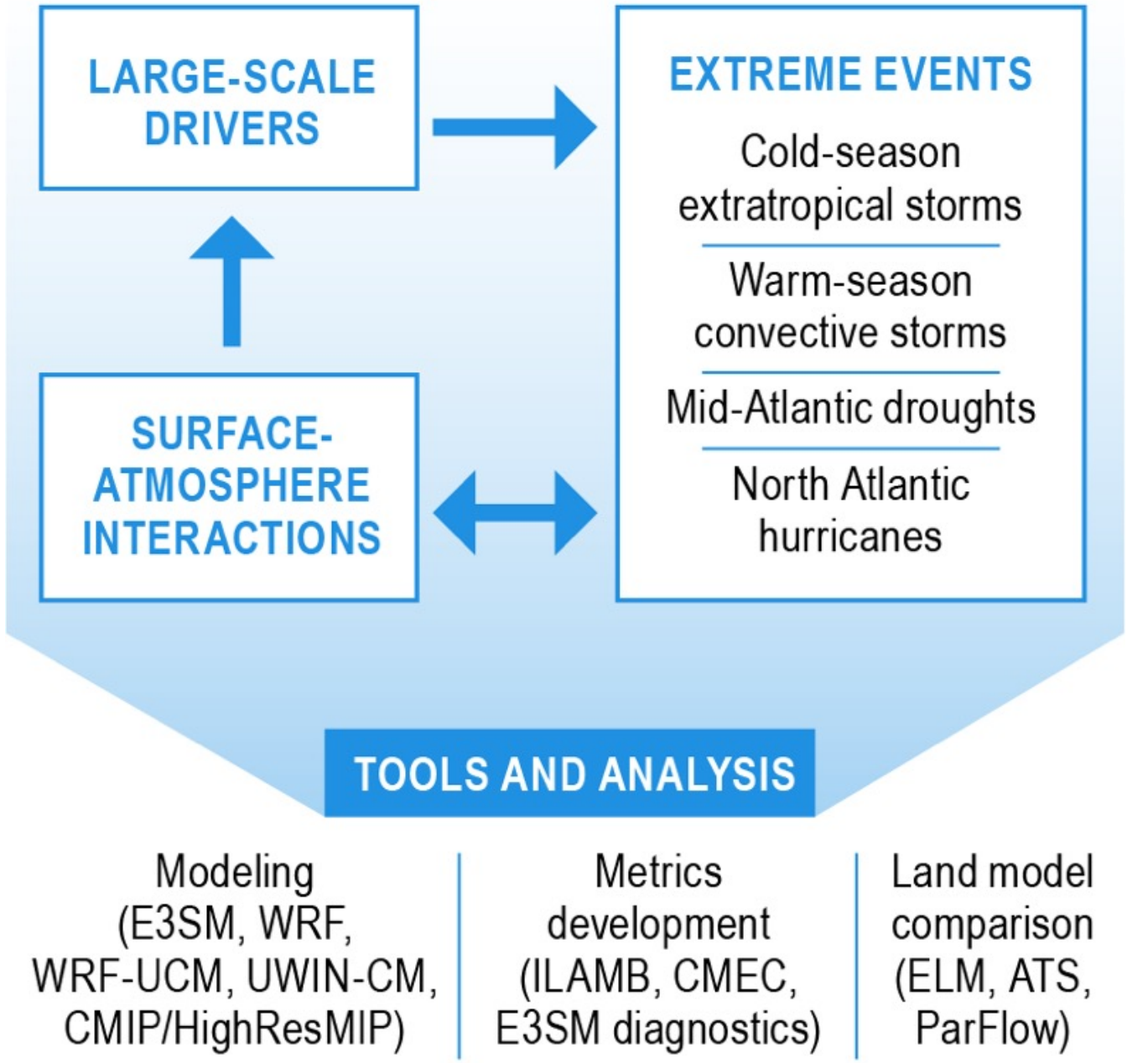
Thank you

Improving understanding of how large-scale patterns and surface-atmosphere interactions drive mid-Atlantic extreme events

Regional and Global Modeling and Analysis Program Area (PI: Ruby Leung, PNNL)

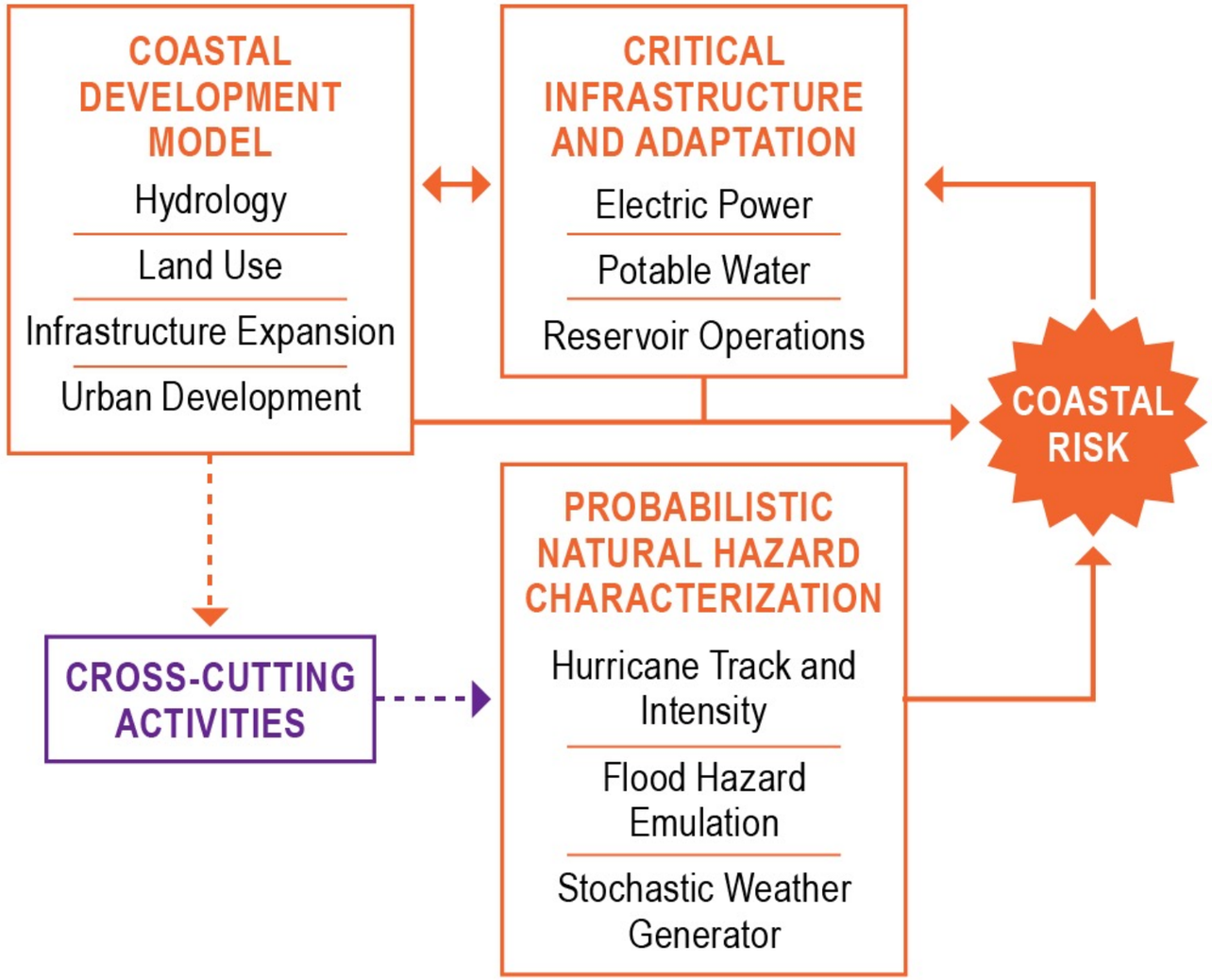
- What are the large-scale drivers of extreme events affecting winter storms and droughts in the Susquehanna and Delaware basins in different seasons?
- What are the roles of surface–atmosphere interactions on hurricanes and summer convective storms in the complex environment of the mid-Atlantic region?



Coupling Infrastructure, Coastal Development, and Hazard Modeling to Characterize Time-Evolving Risks and Resilience

MultiSector Dynamics Program Area (PI: Dave Judi, PNNL)

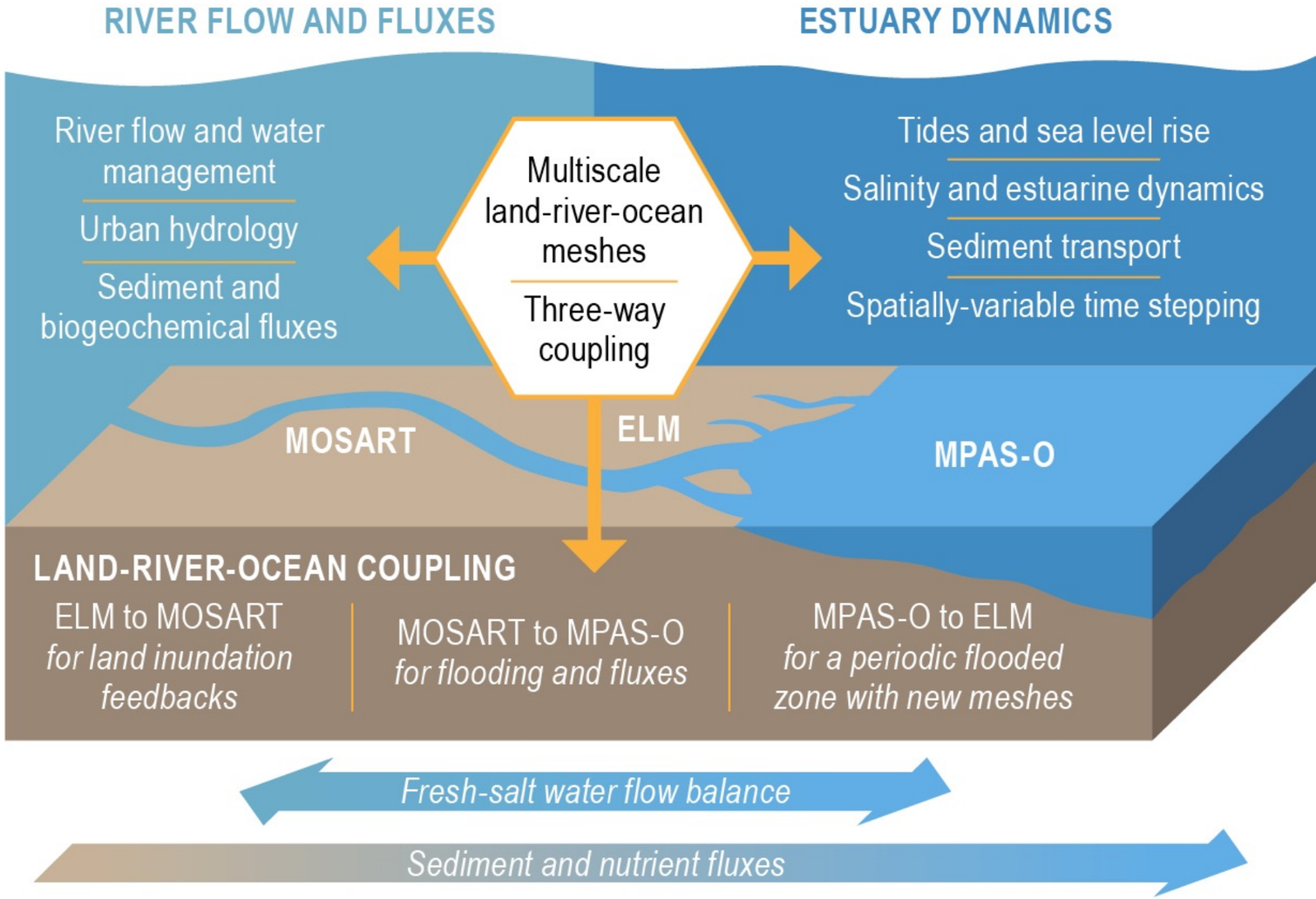
- How might time-evolving stressors in the natural system affect risks to human systems in coastal regions?
- How might coastal development patterns and critical infrastructure management influence flooding and drought in coastal regions?
- How can adaptation strategies influence co-evolving human and natural systems in coastal regions to reduce risk or enhance resilience?



Extending the Energy Exascale Earth System Model (E3SM) to Better Resolve Human-Land-River-Ocean Interactions and Corresponding Fluxes

Earth System Model Development Program Area (PI: Phil Wolfram, LANL)

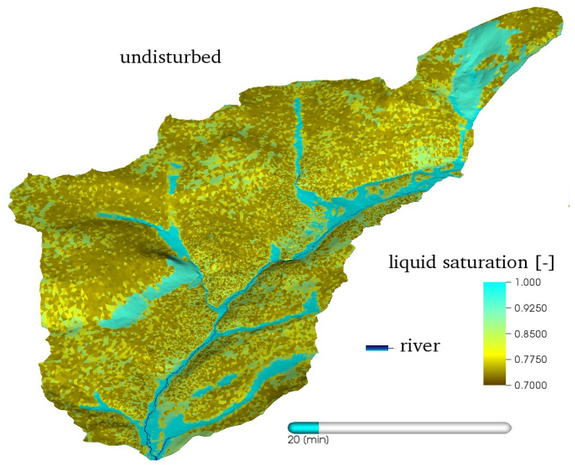
- What is the sensitivity of coastal flooding to human and natural changes?
- What are the interactions between processes and controls of coastal salinity, a key driver of coastal biogeochemistry?
- What controls the coastal fate and transport of nutrients and sediment in terms of timing and spatial distribution?



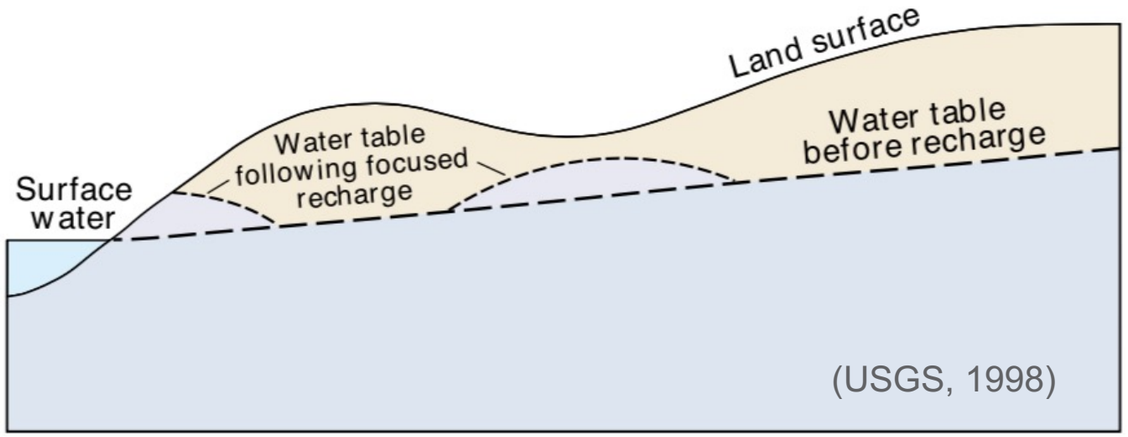
Characterizing Subsurface Hydrological Response and its Interaction with Surface Water during Storms and Droughts

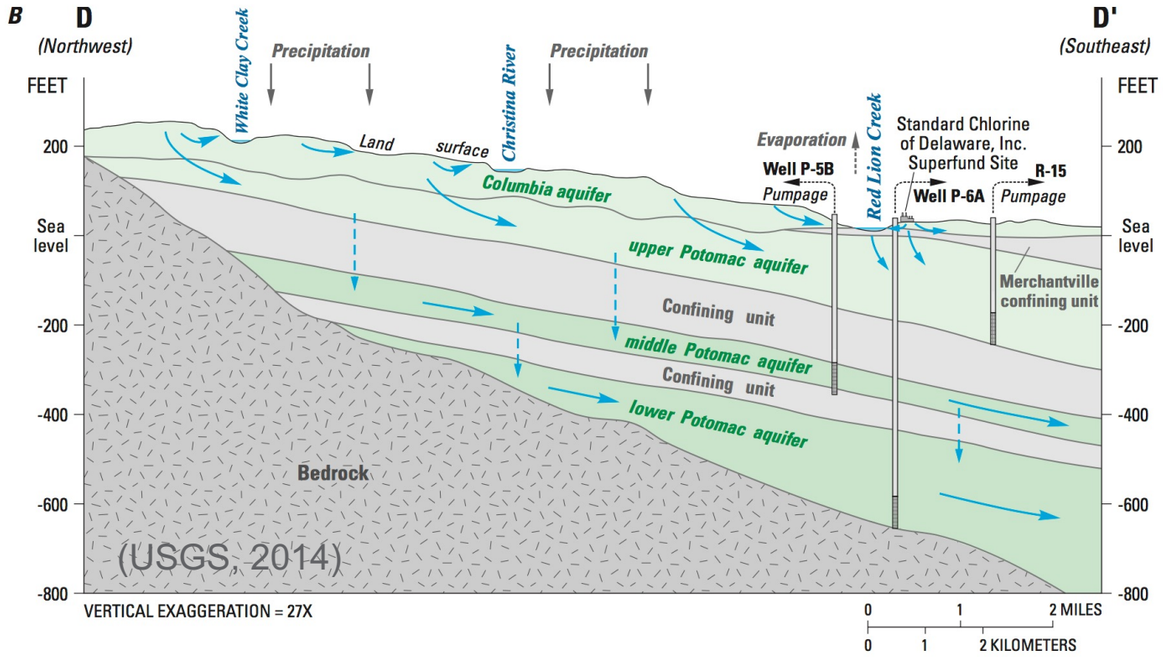
Subsurface Biogeochemistry Research Program Area (PI: David Moulton, LANL)

- How does the antecedent state of the hydrologic system (e.g., soil moisture, ground water elevation, snowpack) and its integrated response to extreme weather events impact flooding in the mid-Atlantic coastal zone?

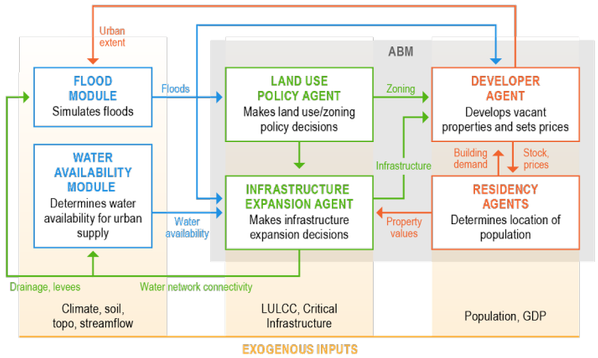


Advanced Terrestrial Simulator (ATS) – results courtesy of Ethan Coon, ORNL



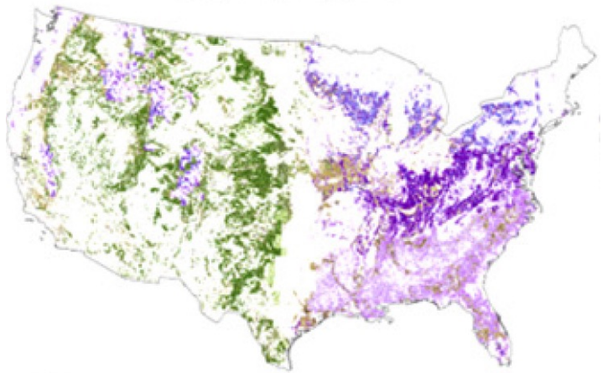


Cross-Cutting Activities will Leverage Multiple Tools to Evaluate the Influence of Coastal Development and LULCC on Storms, Flooding, Droughts, and Hypoxia (more on this tomorrow)

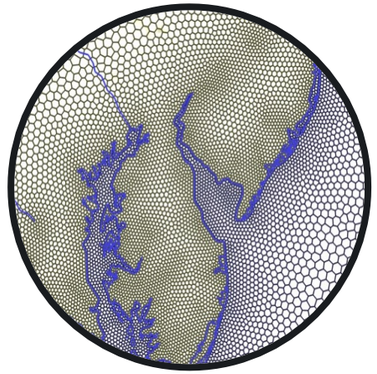


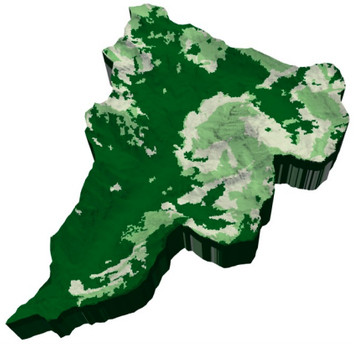
Coastal Development Model (MSD)

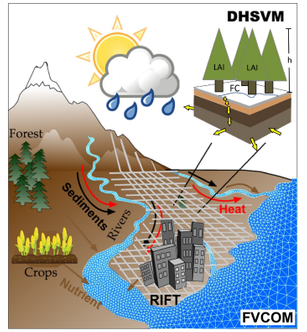
Impact on droughts and convection (WRF-UCM & WRF ensembles)



Demeter LULCC Downscaling Tool

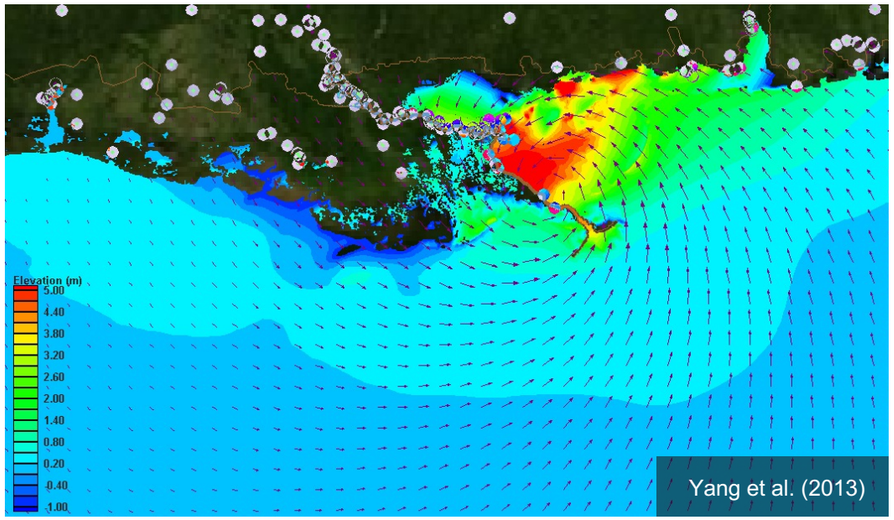




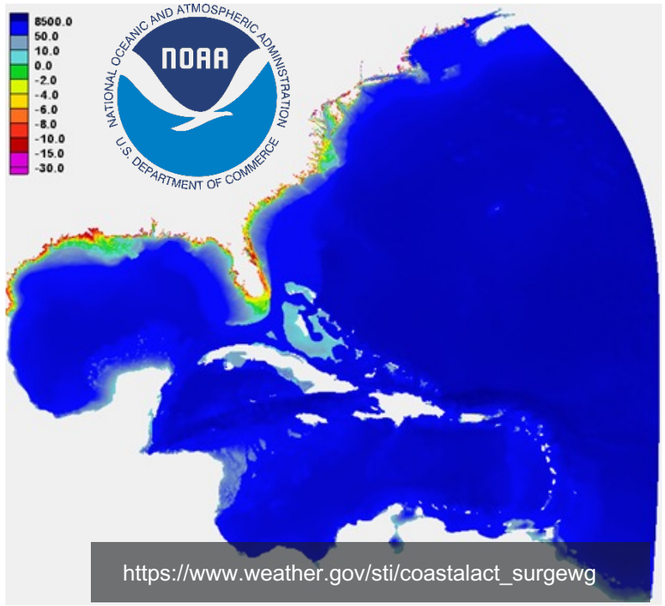


Impact of on flooding and droughts (E3SM, ATS, DHSVM-FVCOM-RIFT)

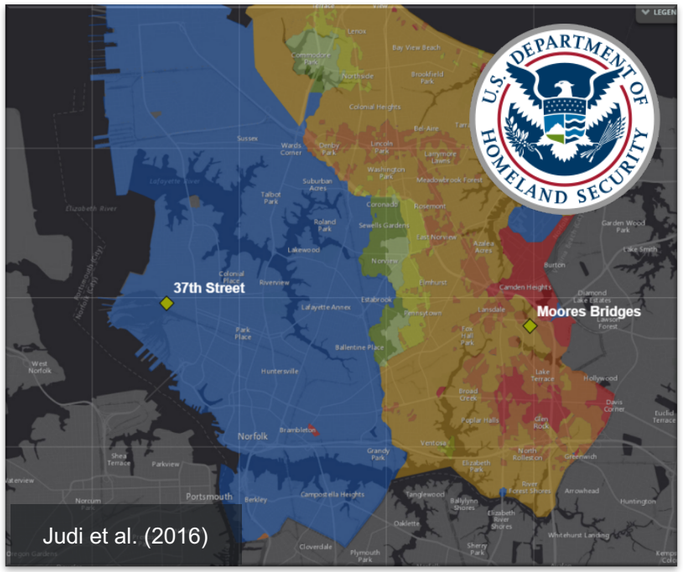
Emerging Capabilities Provide a Strong Foundation for Studying Coastal Processes and Dynamics



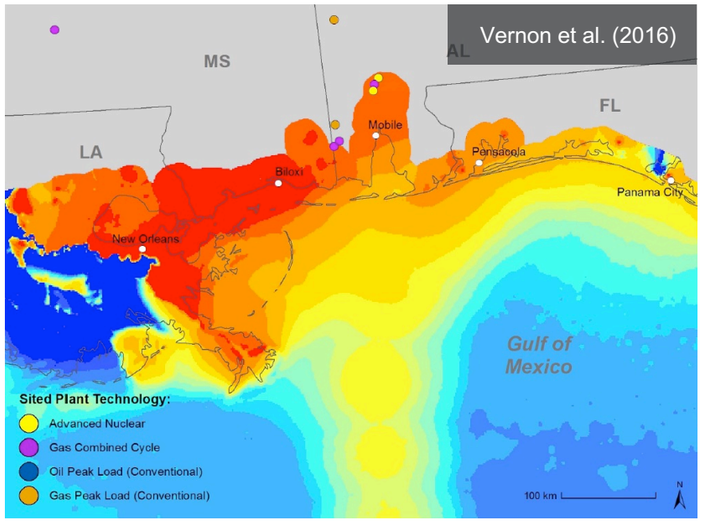
Yang et al. (2013)



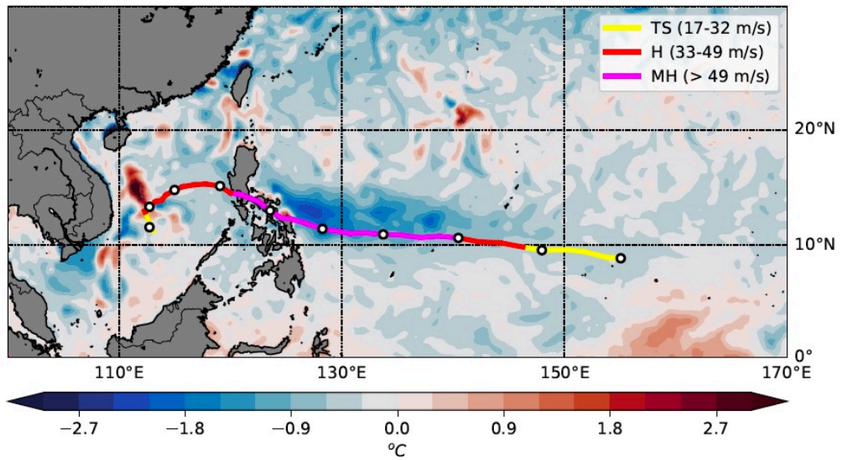
https://www.weather.gov/sti/coastalact_surgewg



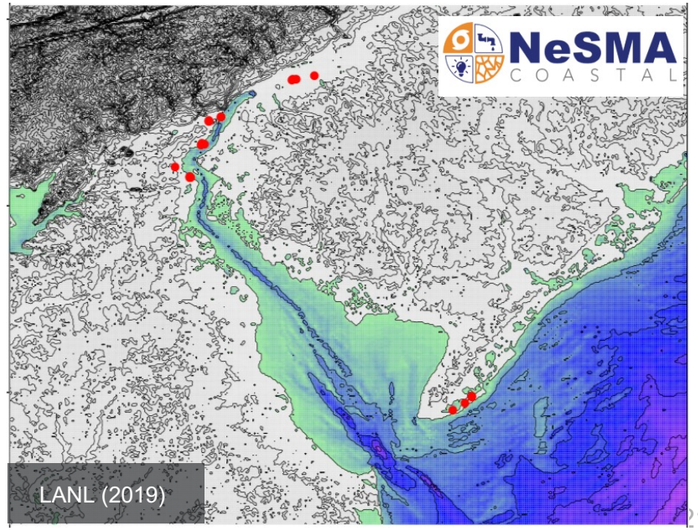
Judi et al. (2016)



Vernon et al. (2016)

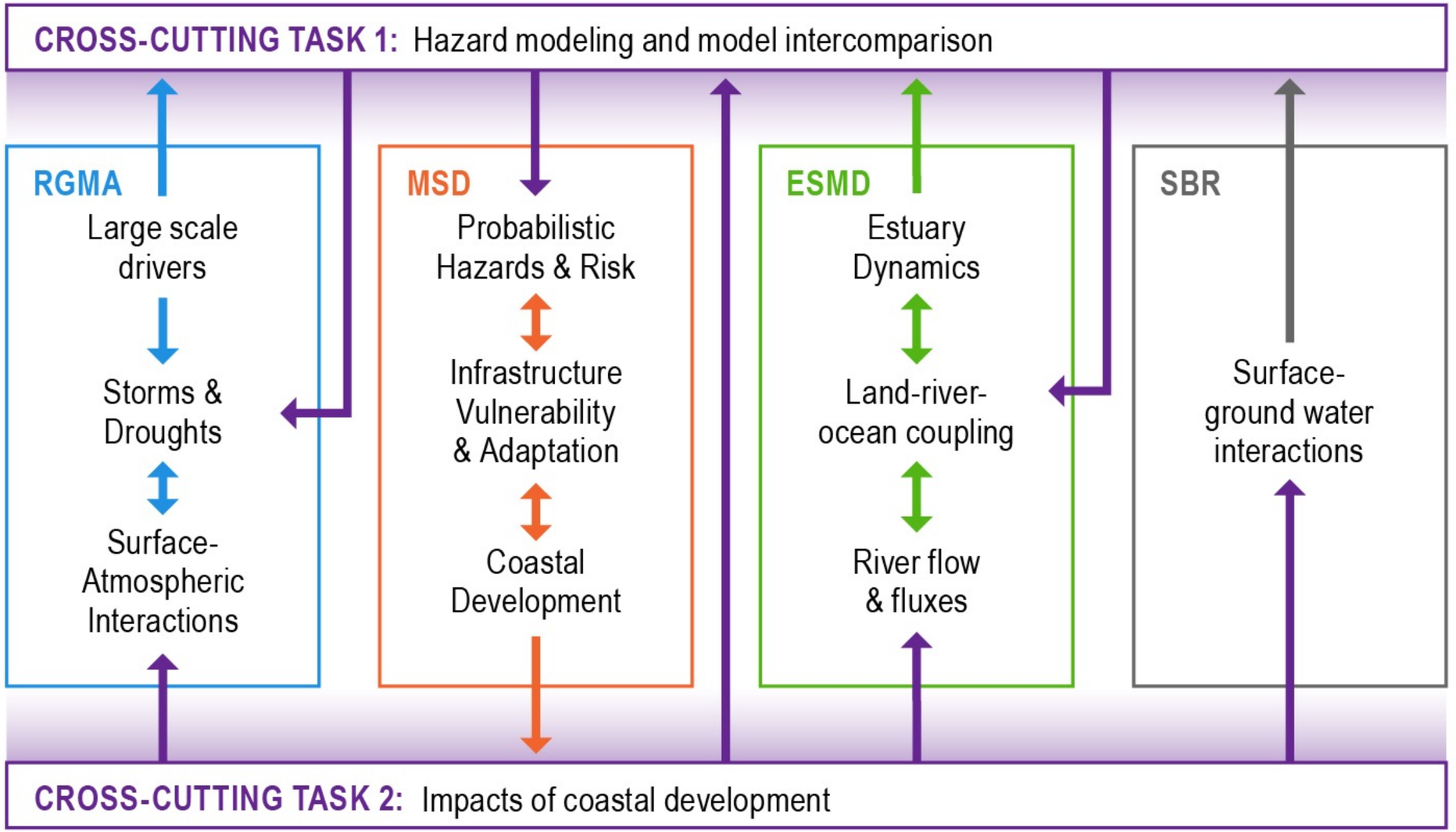


Ullrich and Zarzycki 2017; Balaguru et al. 2019



LANL (2019)

Cross-Cutting Research Topics in ICoM



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ICoM Modeling Capabilities

Model	RGMA	ESMD	MSD	SBR	Cross Cutting
Amanzi/ATS	X			X	X
CESM LENS	X				
CGwn-SCS-WaterModels-FastEcon			X		
CMIP6 DECK, HighResMIP, ScenarioMIP	X				X
FVCOM-DHSVM-RIFT			X		X
E3SM (ELM-MOSART-MPAS-O)	X	X			X
GCAM/GCAM-USA			X		
Hector, Demeter, Tethys, BRICK			X		
ParFlow	X				
SimWare			X		
UWIN-CM	X				X
WRF/WRF-UCM	X				X