IM3 Overview

July 16, 2019
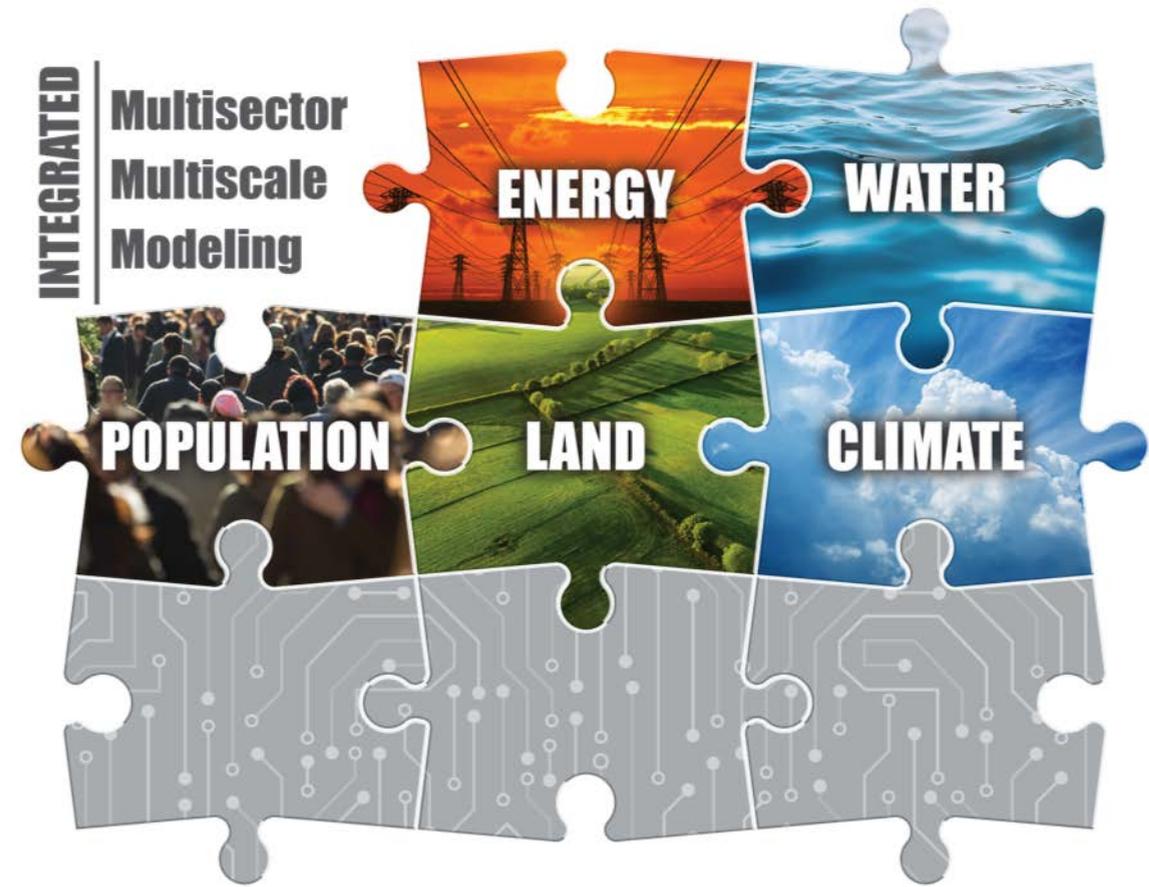
Jennie Rice

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IM3 Interim PI

INTEGRATED Multisector Multiscale Modeling

ENERGY

WATER

POPULATION

LAND

CLIMATE

IM3 Collaborators:

BERKELEY LAB

NREL — NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

Sandia National Laboratories

BOISE STATE

LEHIGH UNIVERSITY

UNIVERSITY of DENVER

BOSTON UNIVERSITY

COLORADO SCHOOL OF MINES — EARTH ▲ ENERGY ▲ ENVIRONMENT

Cornell University

UNIVERSITY of HOUSTON

IM3 Long-Term Goals

Develop flexible and extensible coupled modeling capabilities that capture the dynamic multiscale interactions among energy, water, land, socioeconomics, critical infrastructure, and other sectors.

Use these capabilities to **study the vulnerability and resilience of coupled human and natural systems** from local to continental scales due to short-term shocks, long-term stresses, and feedbacks associated with human decision-making.

Explore how different model configurations, levels of complexity, multi-model coupling strategies, and spatial and temporal **resolutions influence simulation fidelity and the propagation of uncertainties**.

Aligned with CESD:

"Synthesize new process knowledge and innovative computational methods advancing next-generation, integrated models of the human-Earth system."

… and with MSD:

"Reveal key insights into the long-term, complex interactions of human and natural systems and their implications."

IM3 Science Questions and Approach

- What key factors and processes govern multisector interactions, and what levels of spatial, temporal, and process resolution are needed to account for them?

- How could short-term shocks and long-term trends interact to drive changes in the vulnerability and resilience of natural systems and human infrastructure across the United States?

- What key design elements, technical innovations, and features are needed to underpin the development of flexible, extensible, and robust multisector, multiscale modeling approaches?

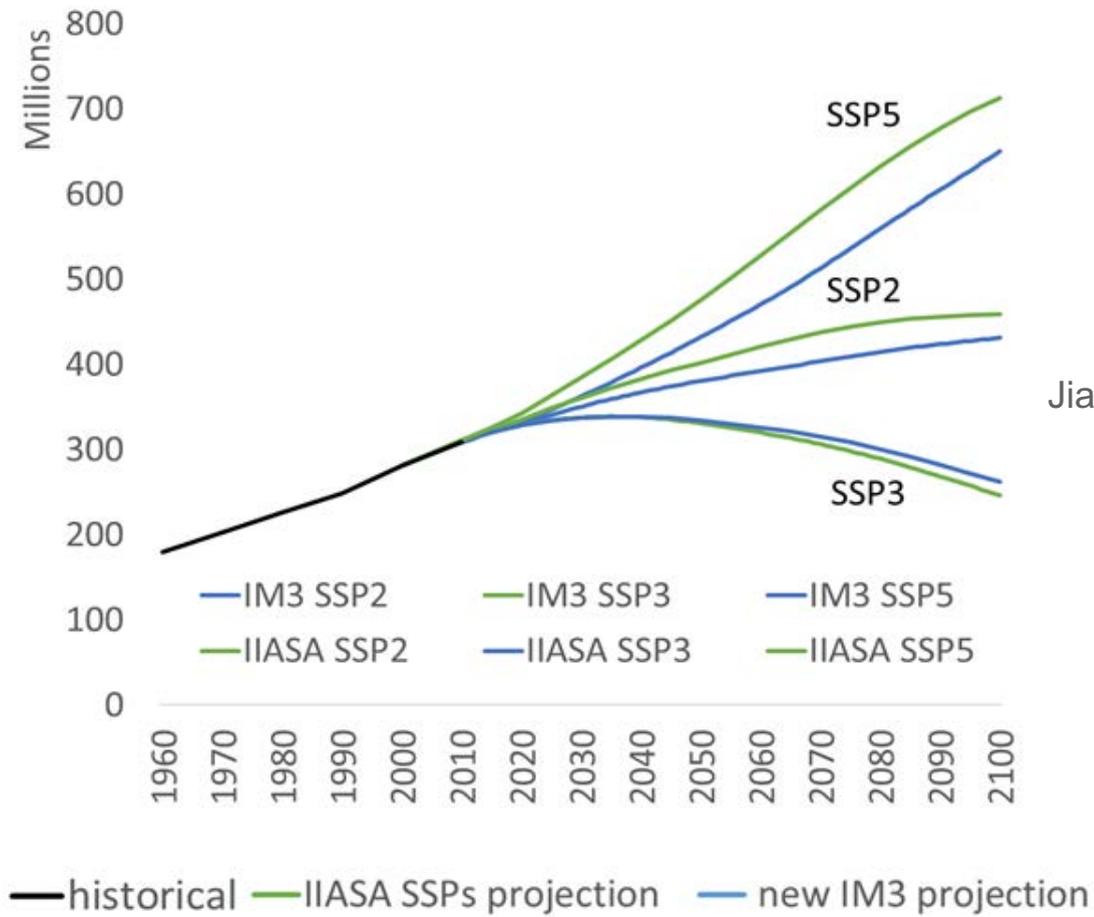Coupling process-based models at high-resolution to build system of systems
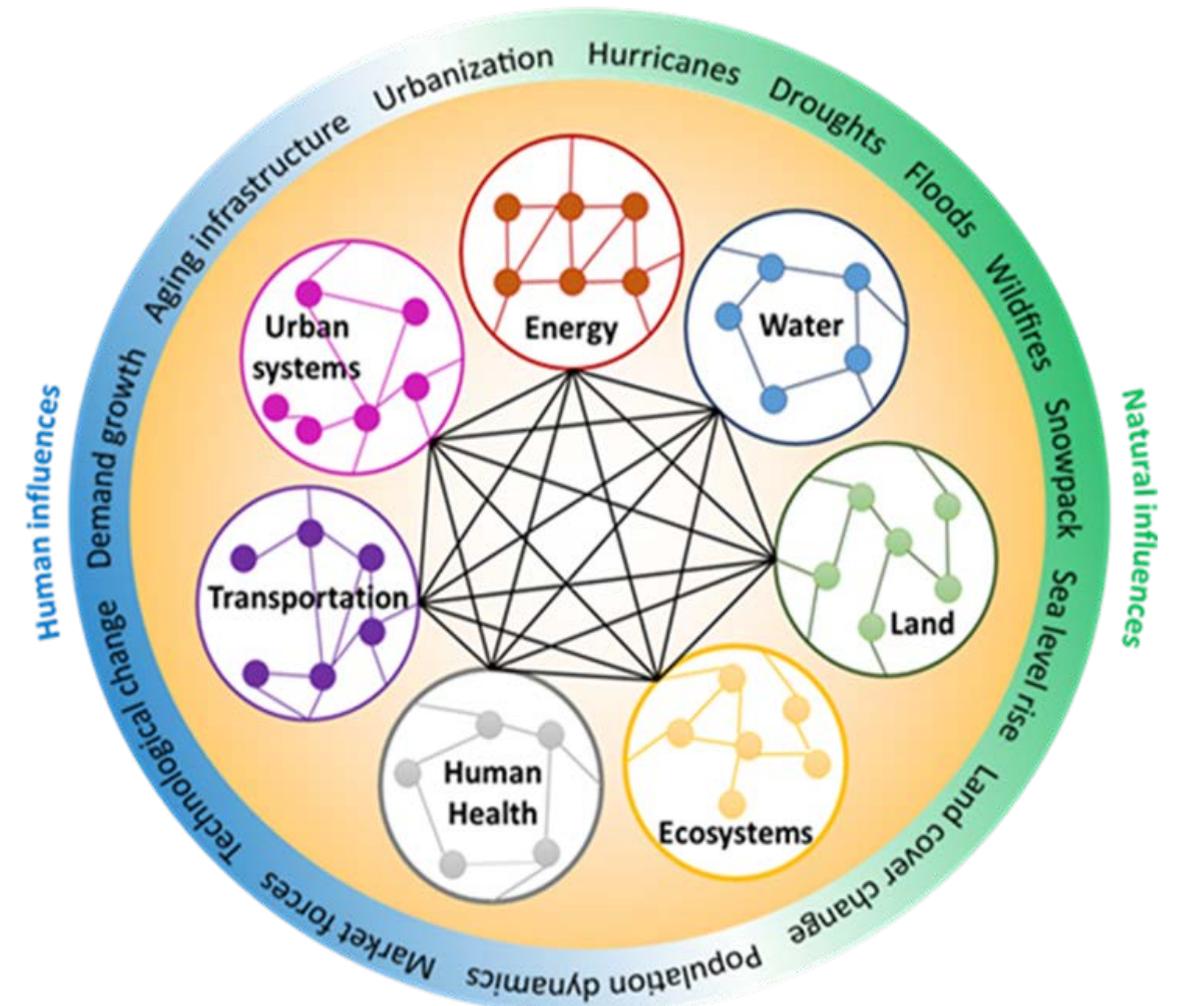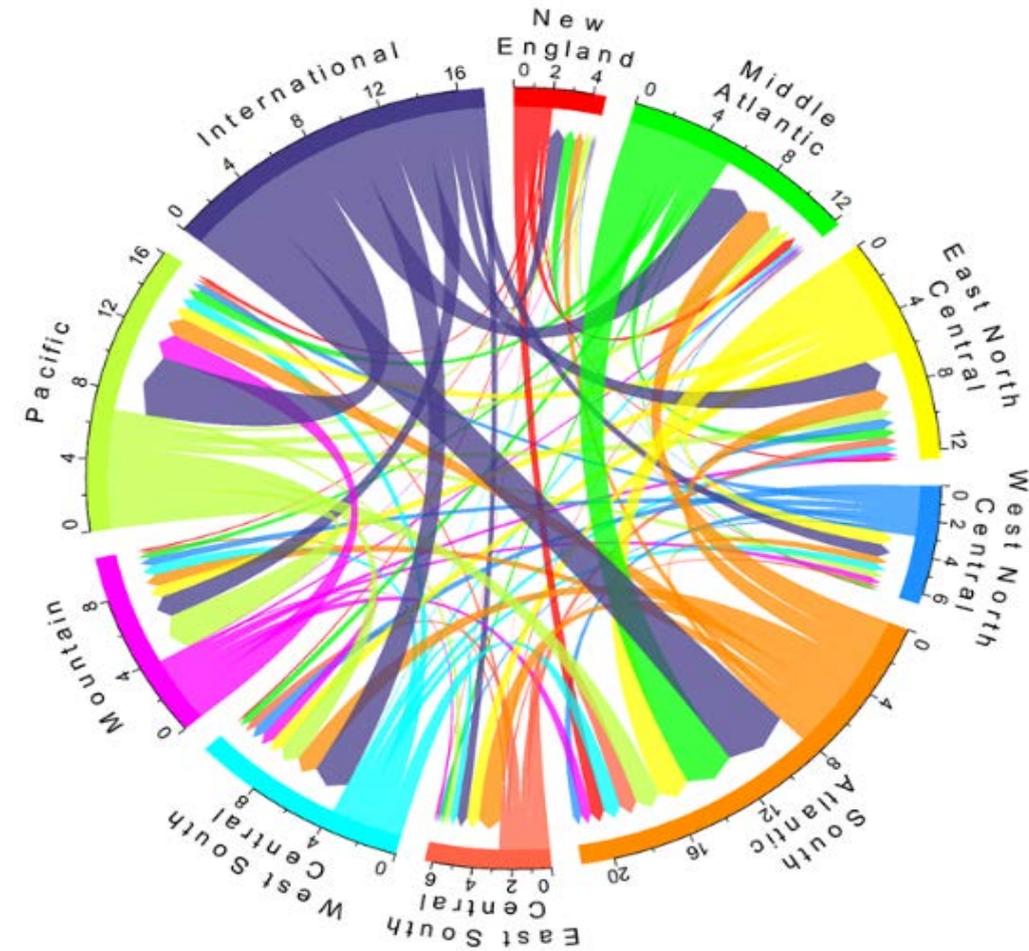
Current IM3 Research Areas

- **Population Dynamics** (PNNL, DU, CSM)
  - Spatially-distributed U.S. projections based on a dynamic population and migration model
  - Econometric model of climate impacts on migration
- **Land Use and Land Cover Change (LULCC)** (PNNL, BSU)
  - Downscaled, hi-res, non-stationary LULCC from global models feedback to regional models
  - Agent-based modeling (ABM) of LULCC decisions
- **Energy – Water Dynamics** (PNNL, NREL, Sandia, Cornell, Lehigh, UH)
  - Watershed-scale: runoff/routing/reservoir management; ABM for farmer irrigation decisions
  - Regional-scale: resolving hydropower in grid operations; water quantity and temperature impacts on thermoelectric plants; impacts of drought, heat waves, and fuel price variations; building energy demand; power plant siting; ABM
- **Urban Systems** (BU, LBNL, ORNL – new area in FY19)
  - Microclimates, heat islands, urban adaptation interactions; urban energy-water dynamics; urban-rural dynamics; outside speaker webinar series
- **Coupled Modeling Support Framework** (PNNL, NREL)
  - Software engineering and data management; open source licensing

# Key Inputs to State-Level U.S. Population Projections

Jiang et al., in prep

US national population size, historical and projected through 2100 according to the SSP projections carried out at the national level (green) and the projections carried out within IM3 at the state level (blue)

Current pattern of region-to-region migration within the US, and international in-migration, based on data from the American Community Survey. For each region (Census division), arrows into the region represent migration from other regions, while arrows out represent migration out of the region. Units are hundreds of thousands per year, averaged over 2007-2011.

Modeling Land Use – Water System Interactions Improves Simulation Fidelity
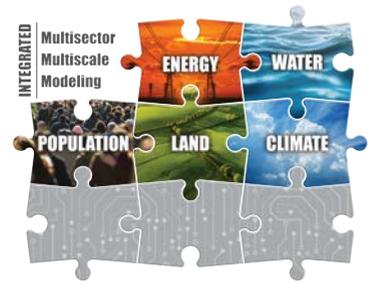
Approach

- Coupling of watershed model (SWAT) with model of reservoir operations (Riverware)

Results

- Improved representation of influence of reservoirs on seasonal flows

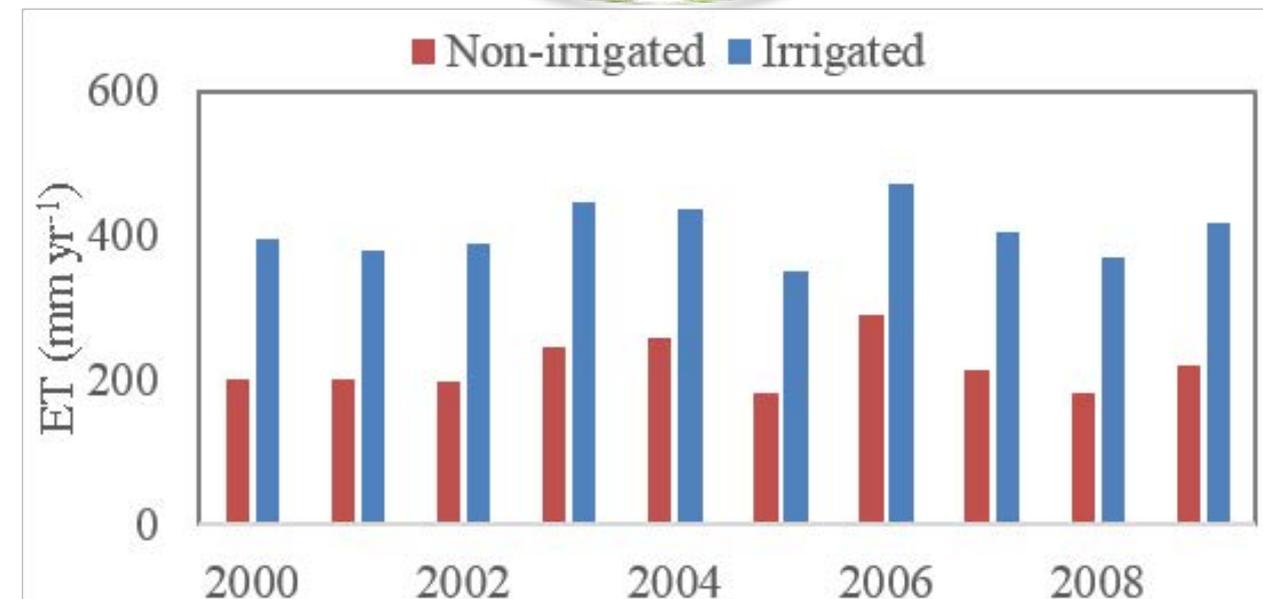- Irrigation results in doubling of surface evapotranspiration in the Yakima River basin.

Qiu et al., 2018

Upstream Reservoir

Downstream Agriculture

Irrigation

Process-Based Modeling Reduces Uncertainty in Projections of Future Hydropower Generation
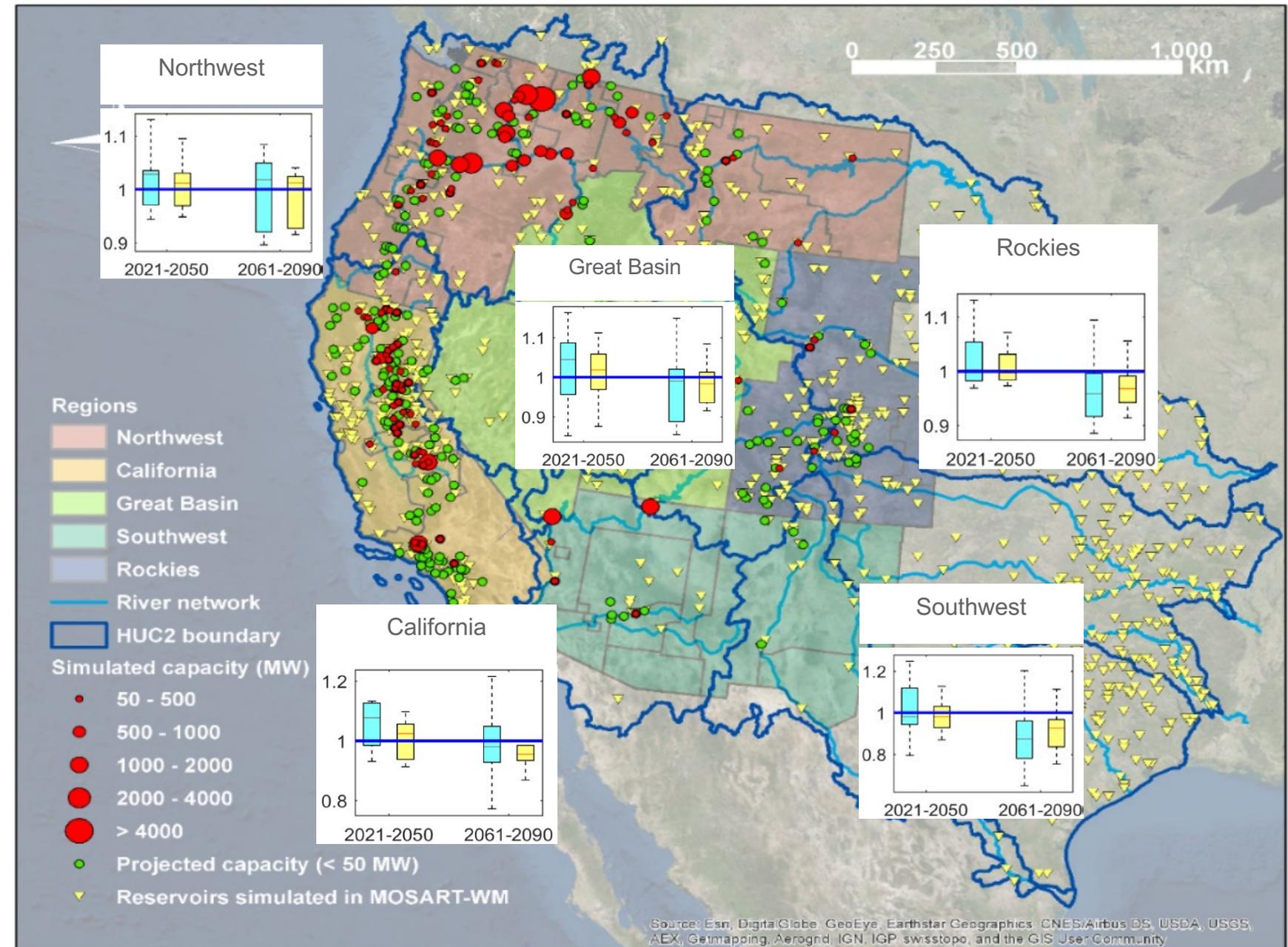
Approach

- Develop a new process-based hydropower module in MOSART-WM that accounts for both environmental regulations and operational requirements for the electric power grid
- Use a multiscale calibration approach to project hydropower generation for two different radiative forcing scenarios and 10 different downscaled Earth system models

Results

- Process-based modeling reduces uncertainty in future projections compared to regression-based model

Zhou et al., 2018

Integrated E-W Modeling Shows Compound Impacts of Drought and Fuel Prices Vary by Region
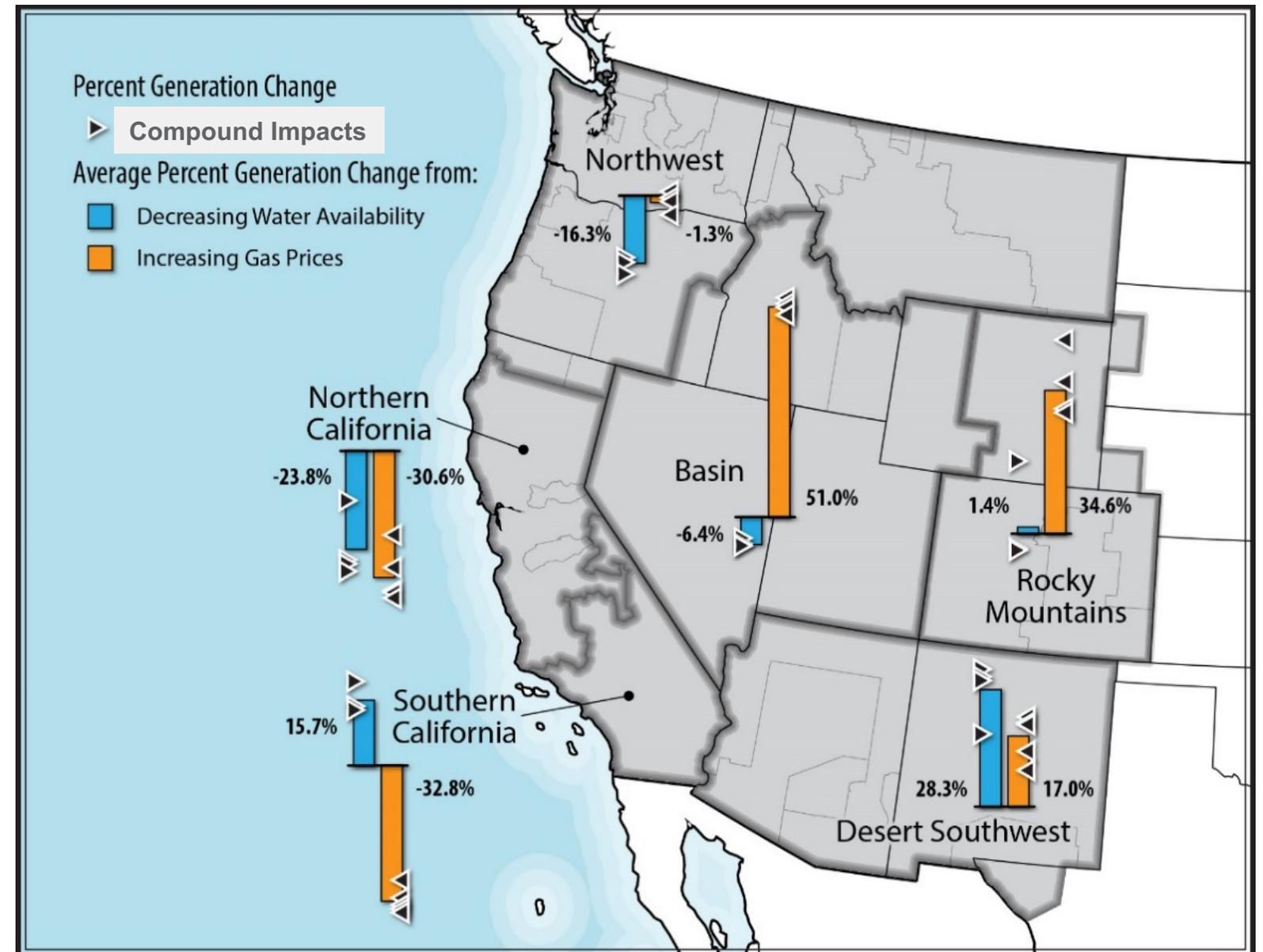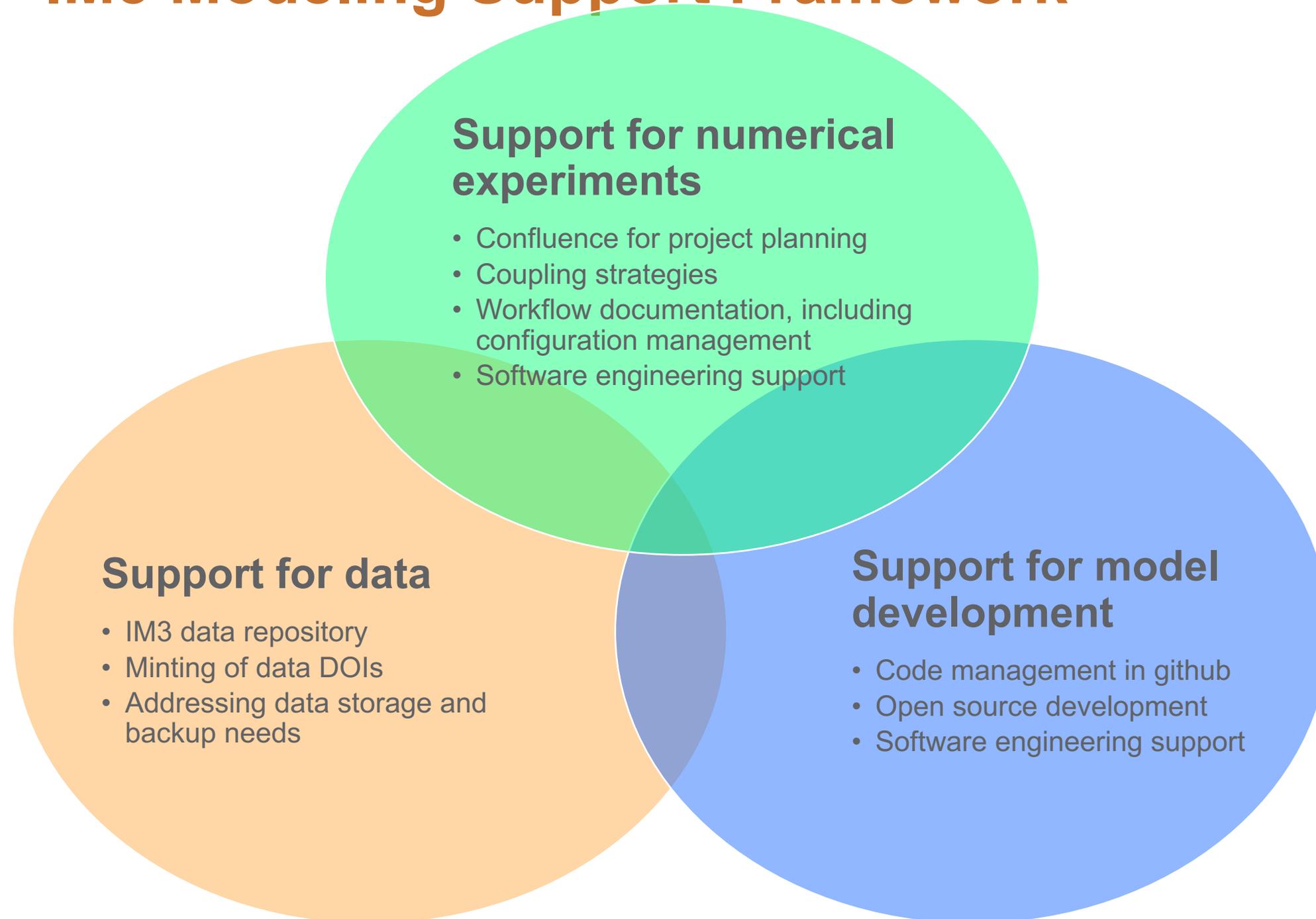
Approach

- Coupling of VIC-MOSART-WM with PLEXOS
- Droughts identified from CMIP5-based simulations of 55-year historical record
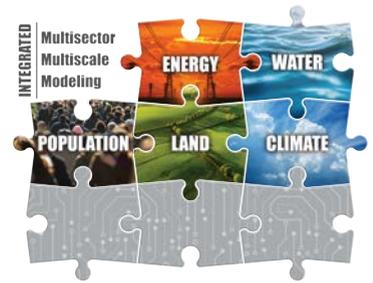
Results

- Water-related stresses can have the same magnitude of impacts on grid operations as natural gas price volatility
- Regional responses to simultaneous stresses can augment or offset stresses analyzed in isolation.

O'Connell et al., 2018

IM3 Modeling Support Framework

Support for numerical experiments

- Confluence for project planning
- Coupling strategies
- Workflow documentation, including configuration management
- Software engineering support

Support for data

- IM3 data repository
- Minting of data DOIs
- Addressing data storage and backup needs

Support for model development

- Code management in github
- Open source development
- Software engineering support

IM3 Future Directions

- FY20 research includes:
  - Additional publications based on FY17-19 research, including synthesizing research insights from FY17-19
  - Integrating the multiple ABM research threads
  - Continuing to develop uncertainty characterization methods for coupled, multi-sector models
  - Scoping work related to renewal proposal

- Preliminary directions for renewal proposal:
  - Organize research by science questions rather than by disciplines
  - Develop classification of coupled human-natural systems based on complexity theory/emergent properties to choose testbeds
  - Integrate urban systems and urban-rural gradients into multisector, multiscale research

- Continue to identify and expand collaborations with other researchers

Thank you