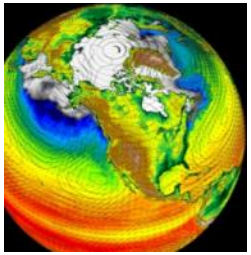
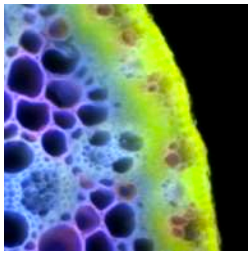
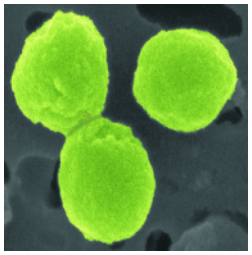


Community Modeling and Long-Term Predictions of the Integrated Water Cycle

September 24 – 26, 2012 Washington DC

L. Ruby Leung

2013 U.S. CLIVAR Summit, Annapolis, MD

Program sponsors: Renu Joseph, Bob Vallario, David Lesmes

U.S. DEPARTMENT OF ENERGY

Office of Science

Office of Biological and Environmental Research

Why Water?

- Water underlies and influences many important climate processes and feedbacks – a leading cause of uncertainty in projecting future climate

Water vapor and cloud feedback

Snow-albedo feedback

Aerosol-cloud interactions

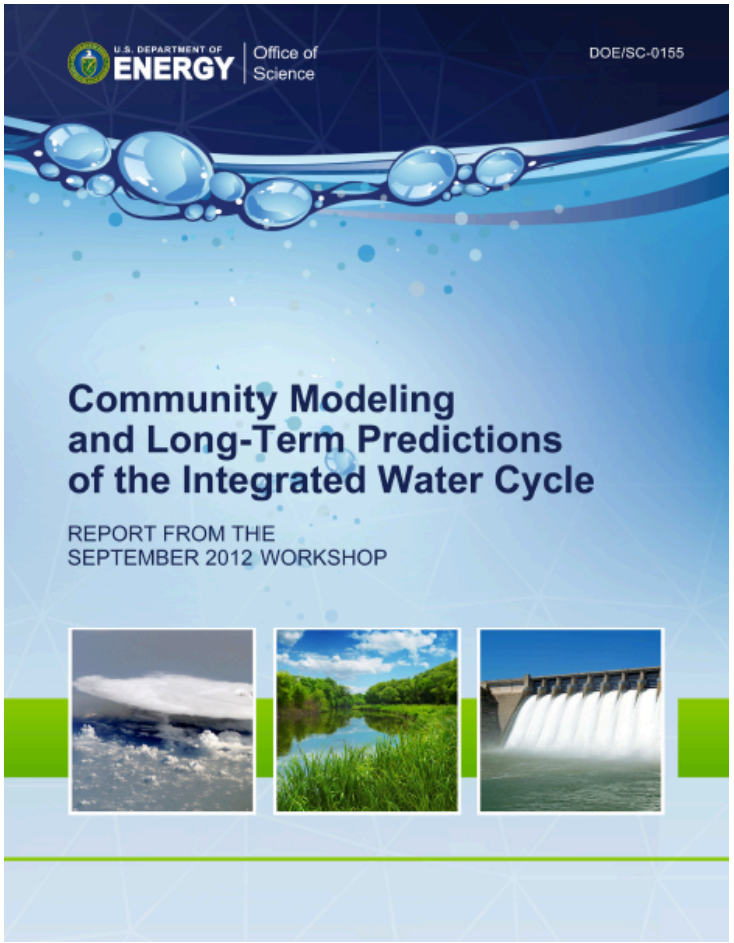
Carbon-water interactions

- Water is essential for energy systems, ecosystem services, and a wide range of life sustaining and other critical human activities

- Global and regional water cycles are influenced by natural processes as well as significant human components

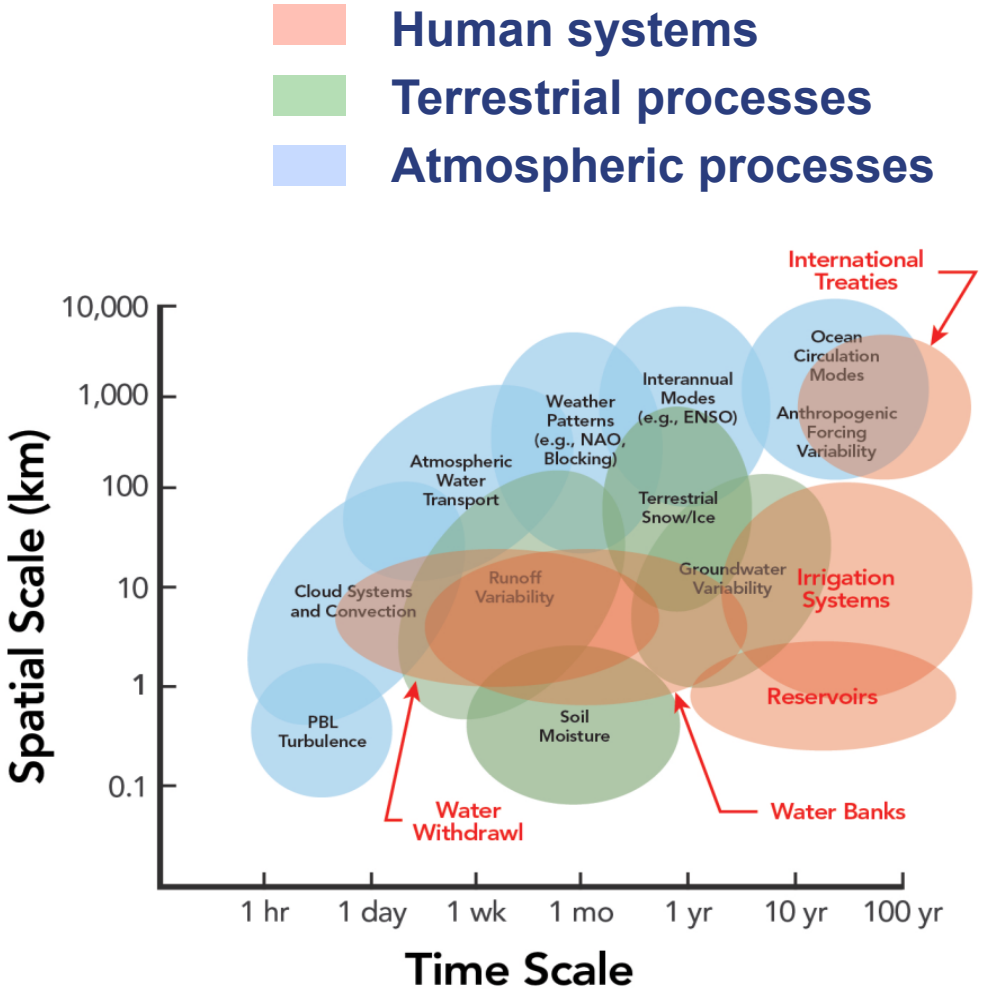
Workshop Goal

- Goal: Identify challenges of next generation human-earth system models for improving long-term predictions of the **regional-scale integrated water cycle**
- Co-chairs:
  - L. Ruby Leung, PNNL
  - Bill Collins, LBNL
  - Jay Famiglietti, UC Irvine
- ~ 80 invited participants including representatives from 8 agencies
- Culminated in an interagency panel discussion



What is the Integrated Water Cycle

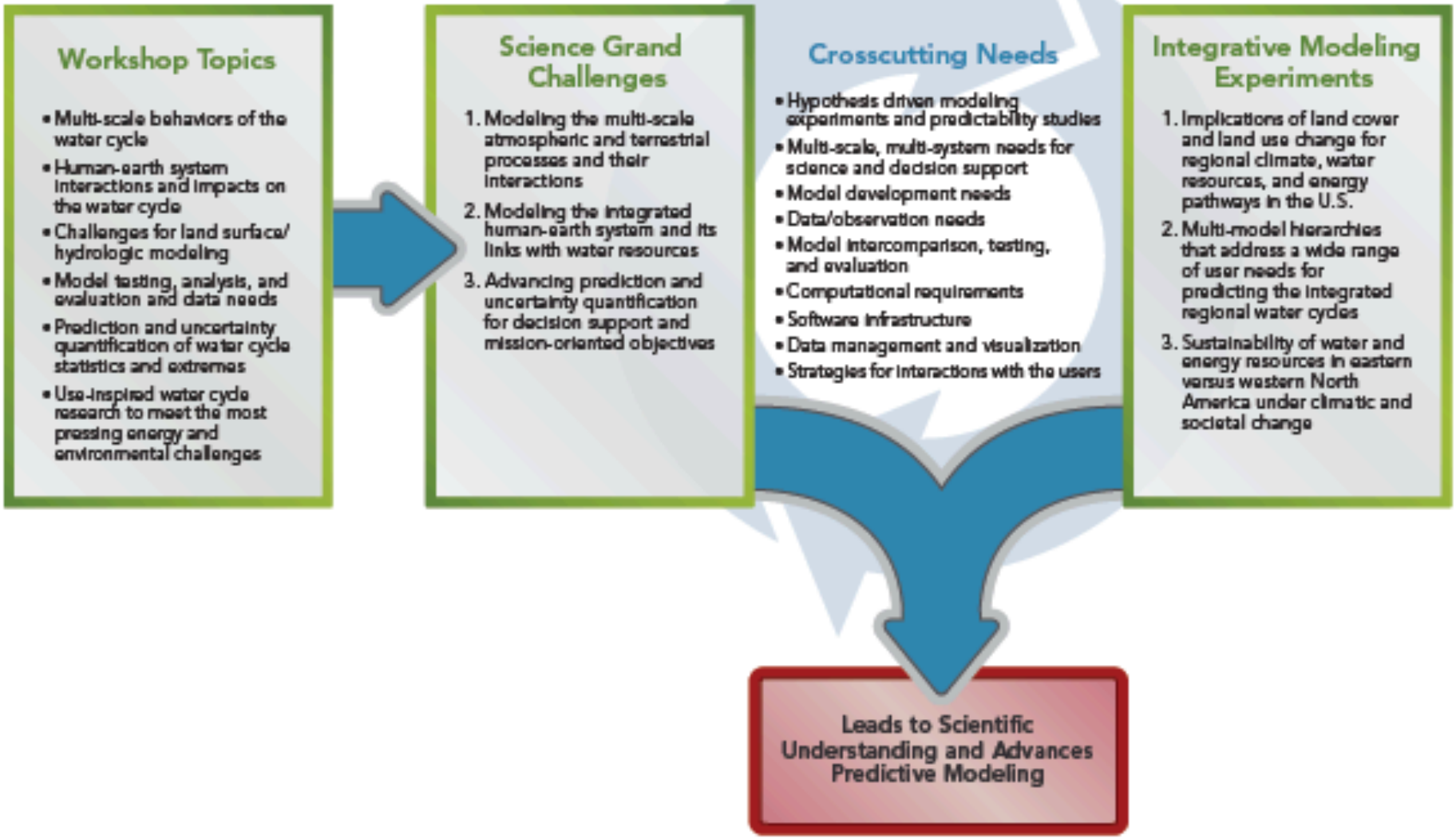
- The *integrated water cycle* consists of:
  - Natural Processes: Water budget involving natural terrestrial and atmospheric processes of the earth system
  - Human systems: Water budget involving human systems and human influences on the natural processes/system



Long term: seasonal – decadal – century

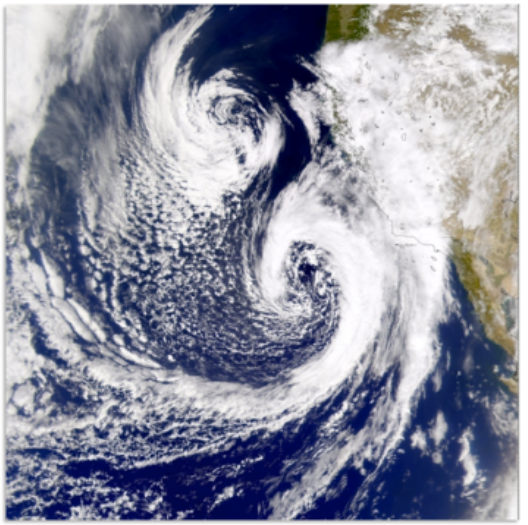
Workshop Outcome

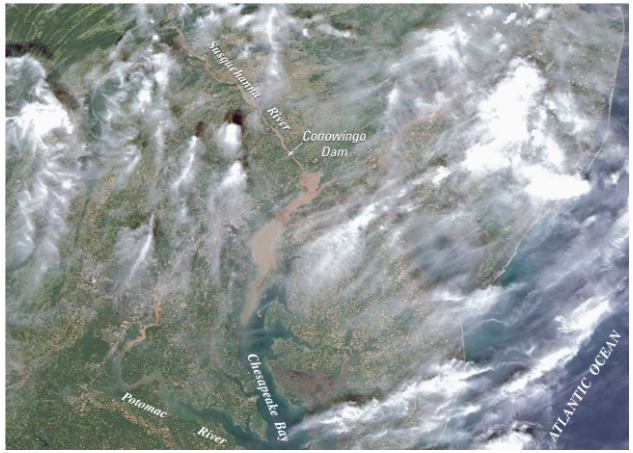
DOE and Research Community



Science Grand Challenge 1

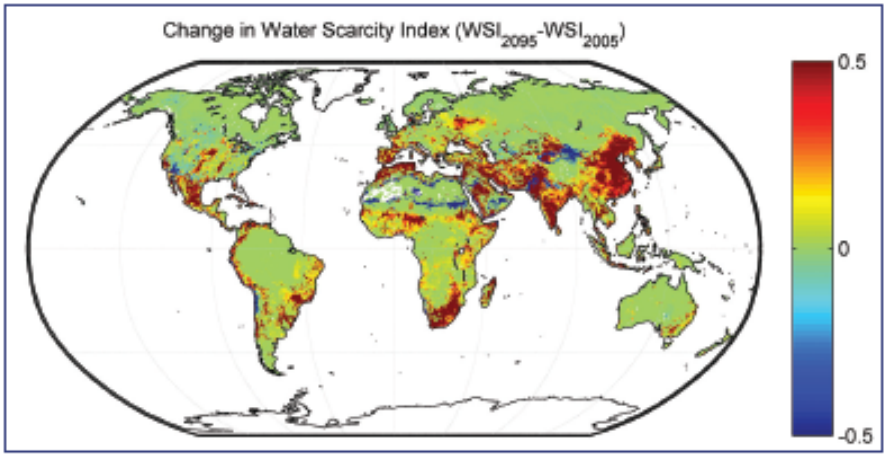
- **Modeling the multi-scale atmospheric and terrestrial processes and their interactions**
  - Understanding the scaling and scale interactions of atmospheric and terrestrial processes
  - Representing the multi-scale processes and the interactions across systems in earth system models
  - Model testbed, evaluation, and data needs





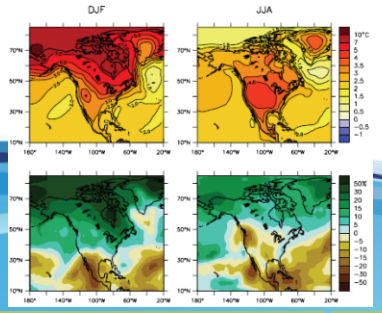
Science Grand Challenge 2

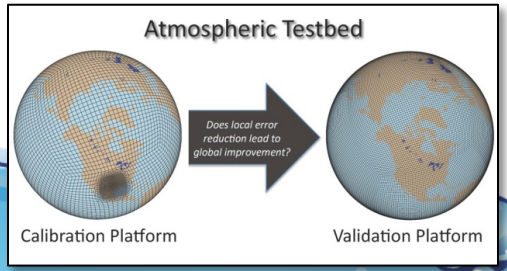
- **Modeling the integrated human-Earth system and its links with water resources**
  - Understanding the roles of human systems at different spatial and temporal scales in the coupled system
  - Representing the wide range of human-Earth system interactions across scales
  - Model testbed, evaluation, and data needs
  - Advancing understanding of the role of human-Earth interactions in water cycle changes

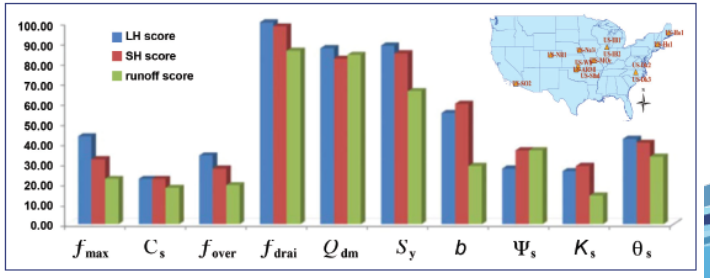


Science Grand Challenge 3

- **Advancing prediction and uncertainty quantification for decision support and mission-oriented objectives**
  - Advancing model predictions
    - Quantitative evaluation of prediction skill derived from different factors
    - Develop and maintain a hierarchy of models to support global and regional analysis
  - Developing uncertainty quantification, metrics, and observations
  - Developing a team approach to use-inspired research





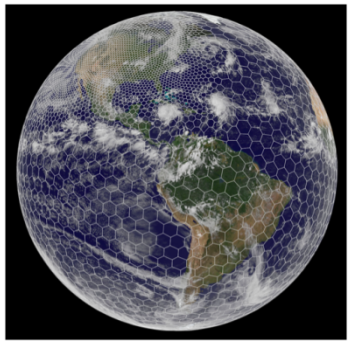


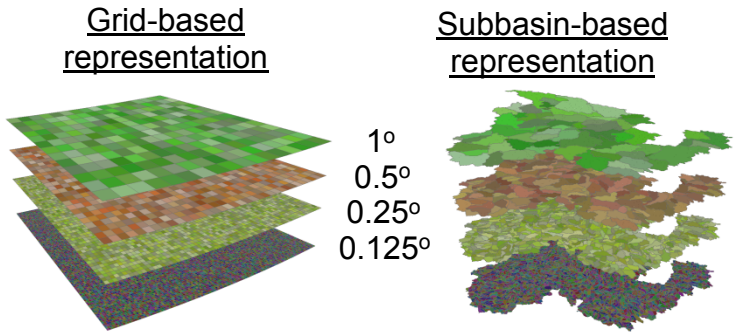
Integrative Modeling Experiment 1

- **Implications of land cover and land use change for regional climate, water resources, and energy pathways in the U.S.**
  - Impacts of changes in irrigation and land cover/land use on local to global climate
  - Effects of climate change and its socio-economic responses on irrigation practices and land cover/land use under various policy scenarios
  - Effects of droughts on irrigation investments and feedback onto climate and water resource availability

Integrative Modeling Experiment 2

- **Multi-model hierarchies to address a wide range of user needs for predicting the regional integrated water cycle**
  - Limitations on predictive skill and predictability in the space and time scales of the end use applications
  - Critical trade-offs among model resolution, complexity, and fidelity for decision making
  - Reconcile predictions from completely different representations of the underlying system dynamics
  - Quantify uncertainty across a hierarchy of models with different complexities





Integrative Modeling Experiment 3

- **Sustainability of water and energy resources in eastern vs western North America under climatic and societal changes**
  - Effects of climate change and projected human footprints on water and energy supplies in different parts of NA
  - New modeling capabilities to represent the fully integrated dynamic regional climate-water-energy system
  - Contrast the vulnerability and adaptability between the snow fed water cycle of western NA and the less seasonal precipitation regimes of eastern NA, each with their own profiles of human influence

East vs west power plant water withdrawal

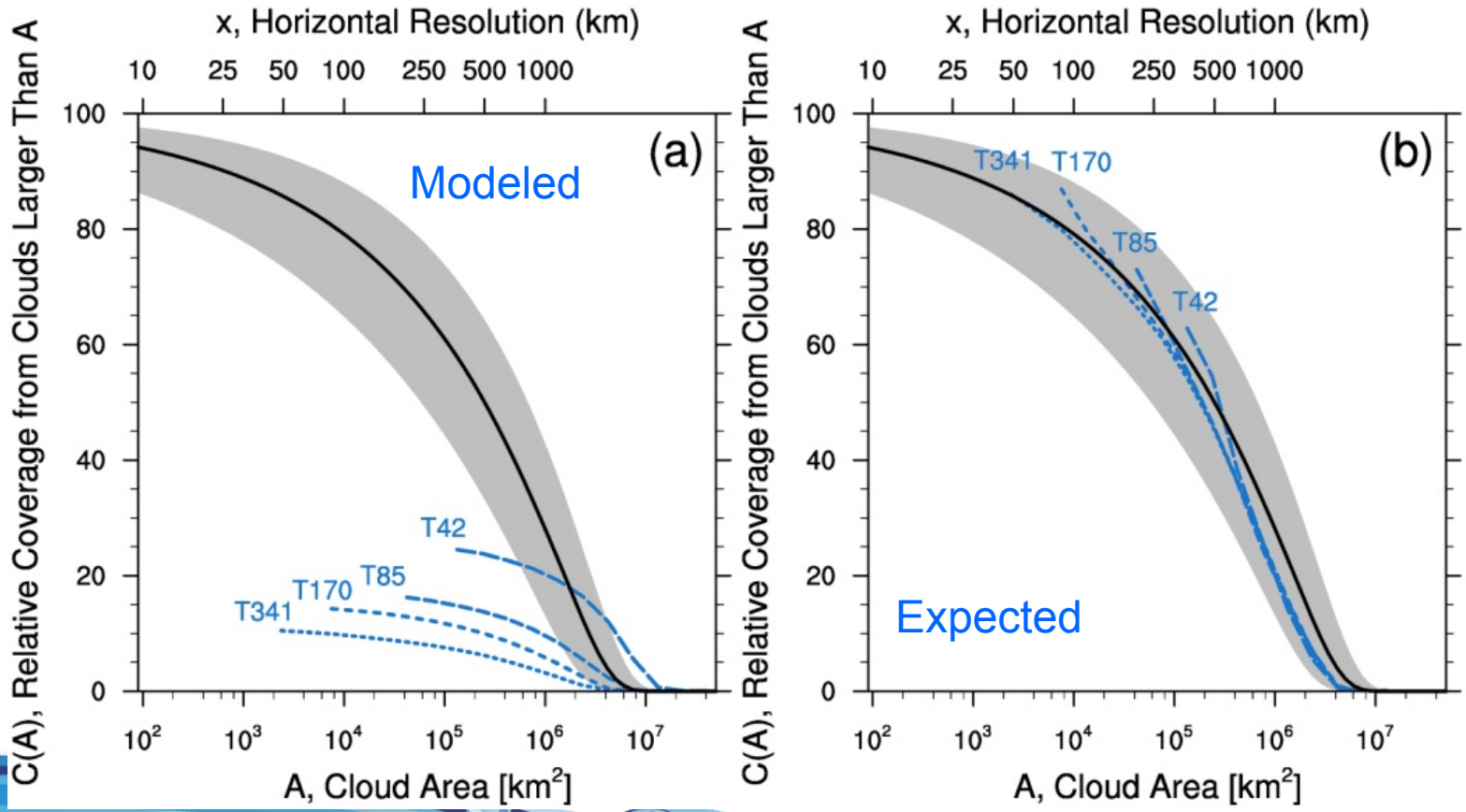
Opportunities for Interagency Collaborations: Water Cycle Extreme

Next Steps

- Advance water cycle modeling in CESM, most notably enhancing capabilities in CLM and coupling with CAM, IAM, and ocean and ice components
- Topics will selectively be included in future solicitations
  - DOE
  - Other agencies
- Interagency Working Groups
  - USGCRP Interagency Group on Integrative Modeling (IGIM) and National Climate Assessment (NCA)

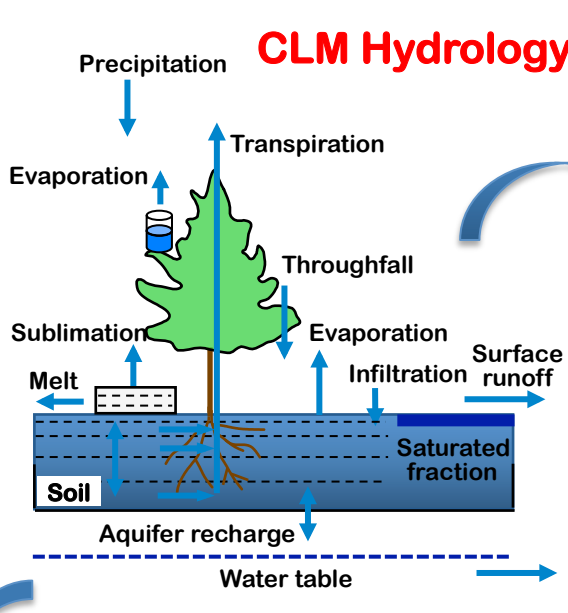
Cloud scaling behaviors as a model metrics

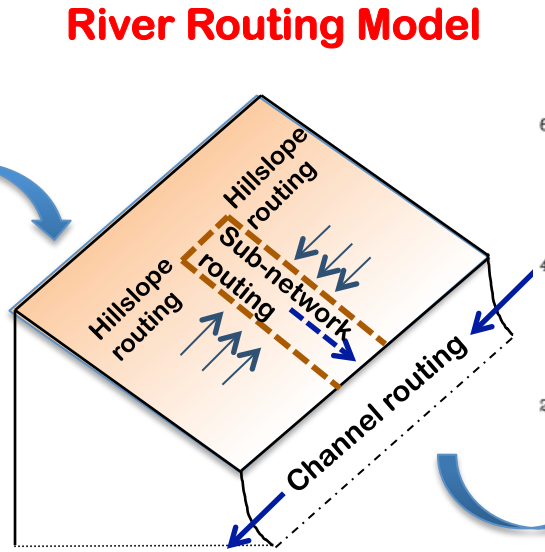
- Aqua-planet simulations show reducing cloud cover with increasing resolution

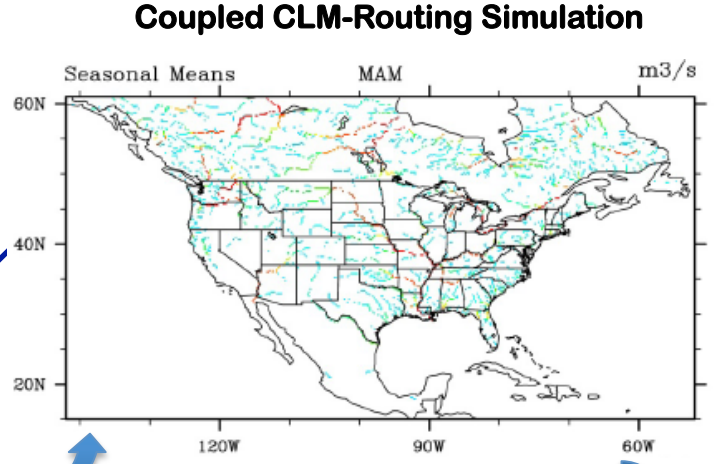


CLM coupled with river routing and water management

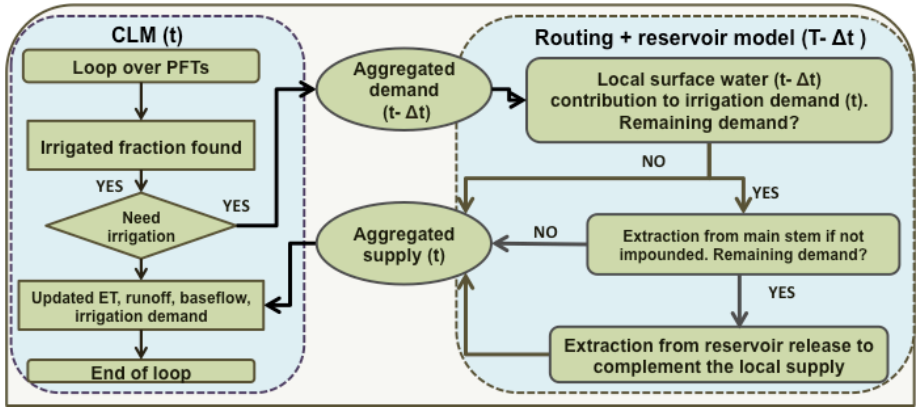
- Improve and add new capabilities in Community Land Model (CLM) to represent hydrology and human – water cycle interactions at multiple time and space scales







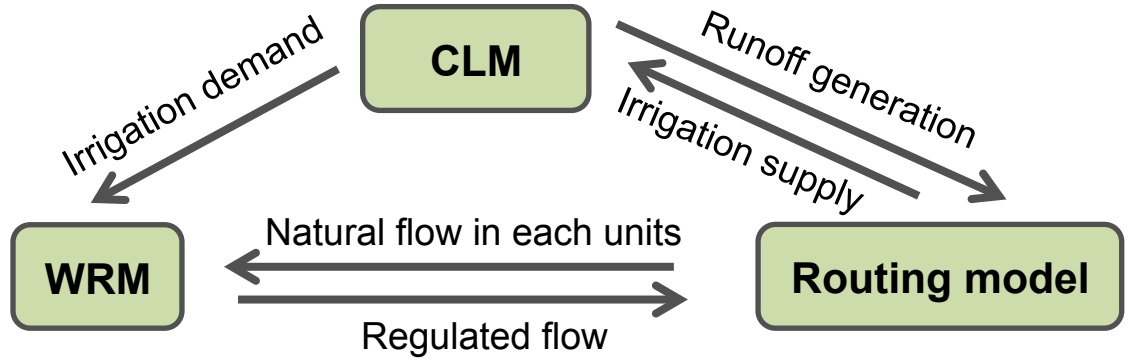
Irrigation water demand

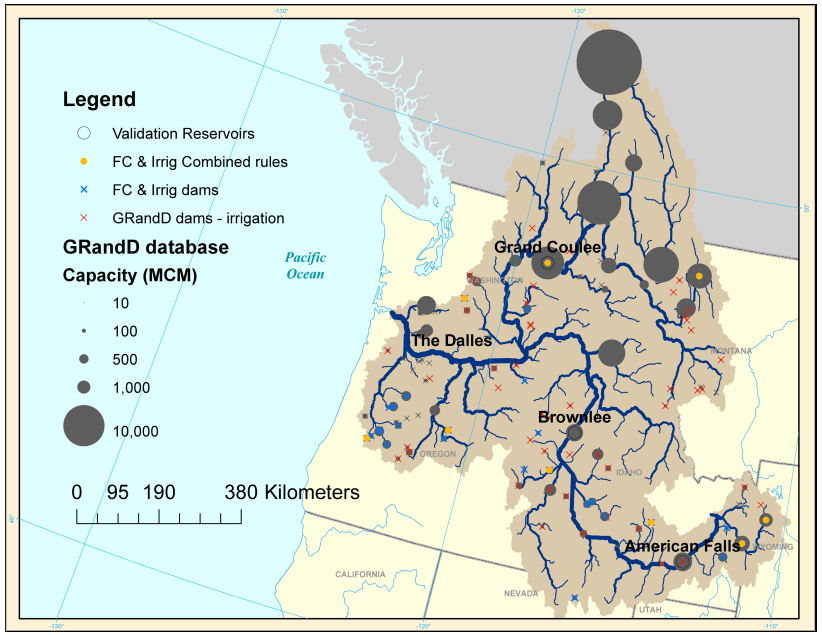


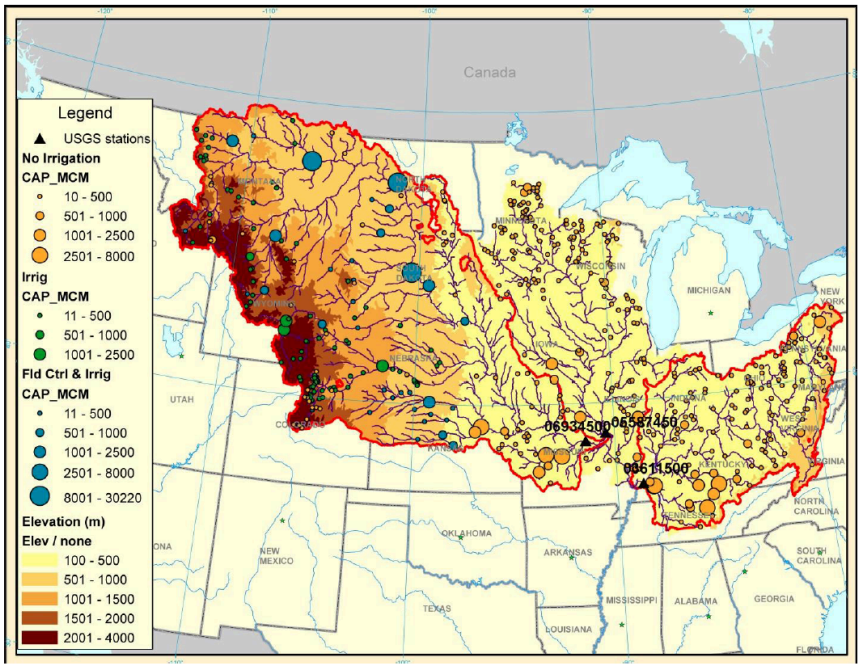
Reservoir operations

Water management model

- Designed for full coupling in an earth system models
  - Assume no knowledge of future inflow; use generic operating rules

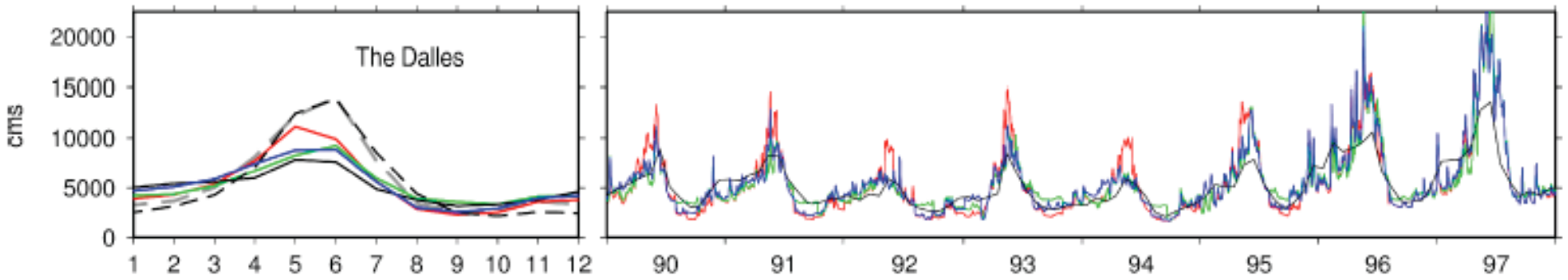


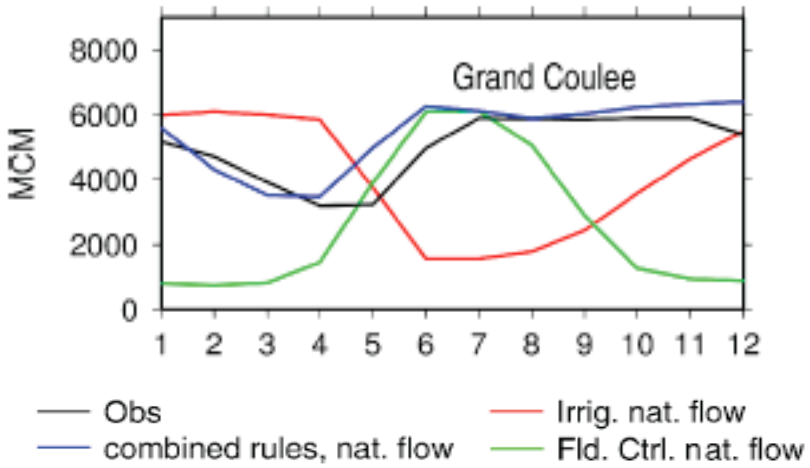


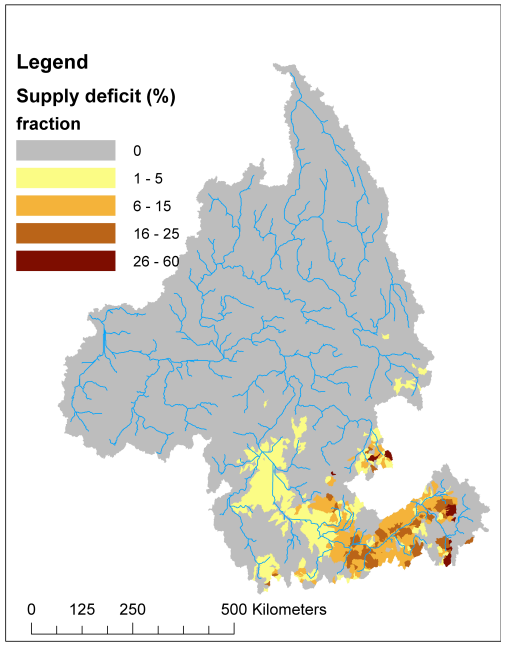


Natural and regulated flow

Combining flood control and irrigation objectives in operating rules best capture the observed regulated flow in the Columbia river basin







- Reservoir storage is only reproduced using operating rules that combine flood control and irrigation priorities

Modeling energy, land use, and water in an integrated assessment model

Components of the Global Change Assessment Model (GCAM)