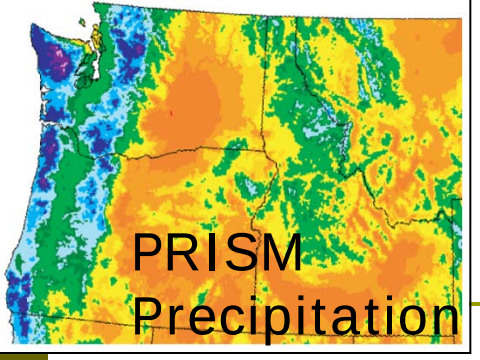
Regional-scale integrated modeling as a "Way and Means" towards sustainable land and water resource management

Jennifer C. Adam
Assistant Professor
Civil and Environmental Engineering
Washington State University

INL MWWI "Water Ways and Means", May 15, 2012



Columbia River Basin (CRB) and Water Resource Sustainability

- Multiple competing in and out-of-stream water uses: hydropower, flood control, fish flows, navigation, recreation; agricultural, municipal, industrial uses
- Trans-boundary water management
- Projected temperature and precipitation changes anticipated to exacerbate water quantity and quality problems
- Interdisciplinary teams required to address the grand challenge of CRB natural and agricultural resource sustainability
- Integrated modeling efforts are becoming a way to synthesize ongoing modeling and observational activities

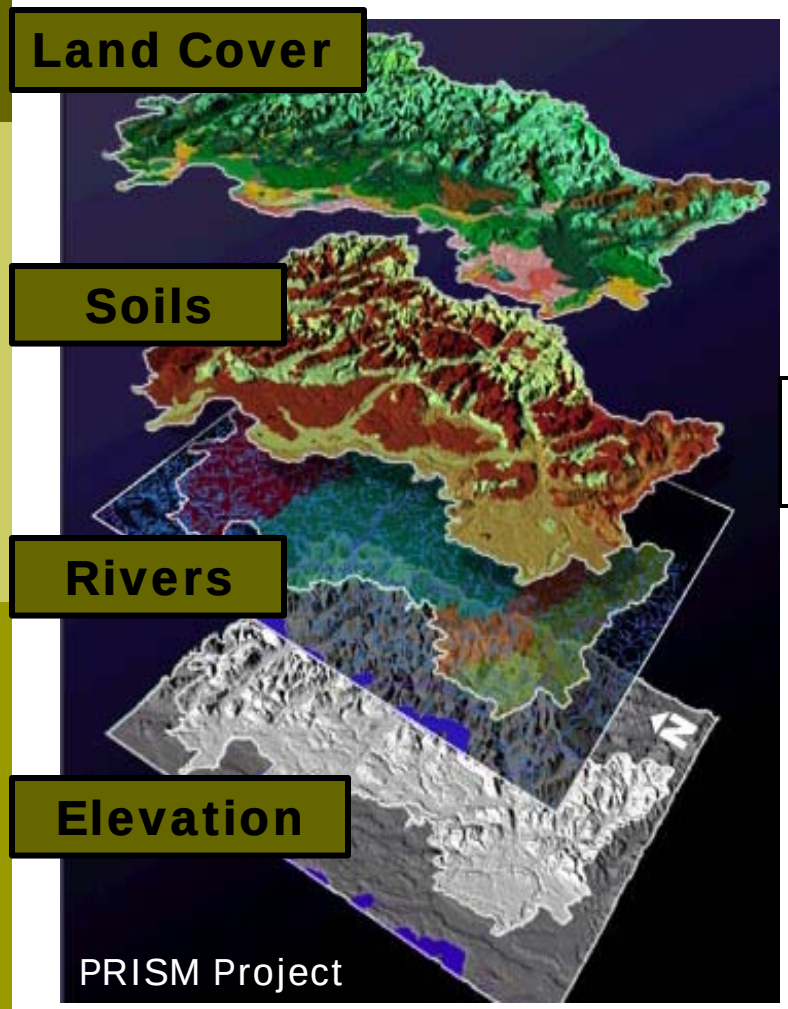
Objectives of this talk

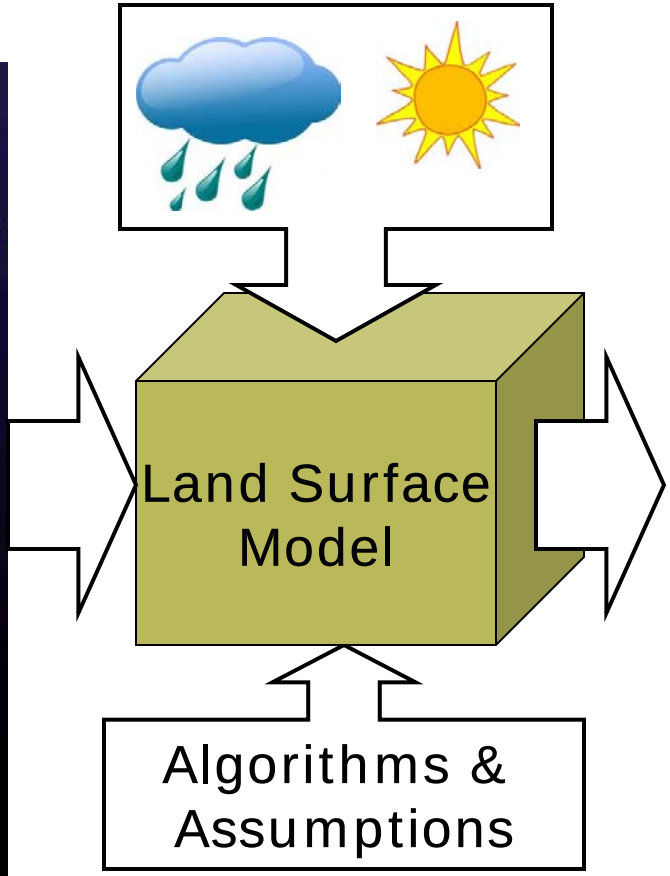
- Define “Integrated Modeling”
- Describe developing capacity for integrated modeling over the Pacific Northwest region
  - Columbia Basin Water Supply & Demand Forecast
  - Regional Earth System Modeling: BioEarth
  - Watershed Integrated System Dynamics Modeling: WISDM
- Identify future directions and avenues for collaboration

“Integrated Modeling” Defined

- “Integrated environmental modeling is a discipline of developing a system of models where models from two or more academic disciplines are integrated such that they behave like a unit to external stimuli.“ – Andy Soos, ENN

What is NOT an integrated model? Answer: a "Stand-Alone" Model



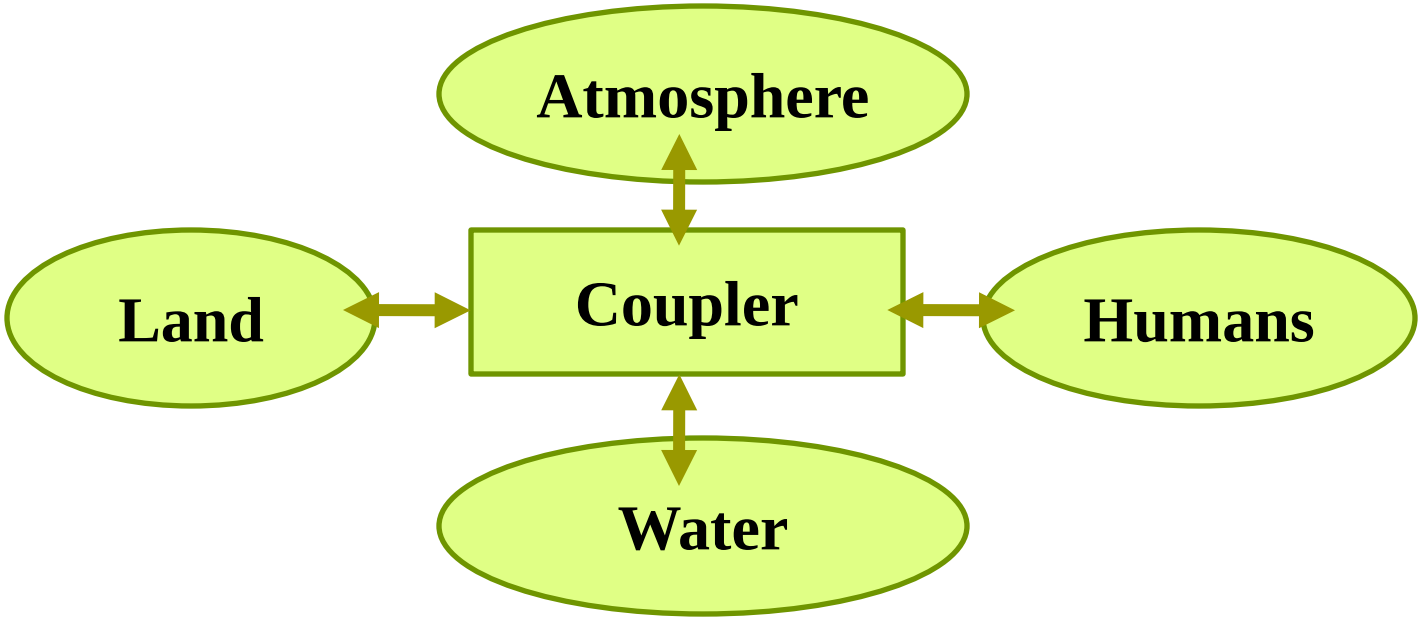


Streamflow
Evaporation
Transpiration
Snowpack
Soil Moisture
etc...

Represents a single or limited number of components of a system

What IS an integrated modeling system?

- Incorporates interactions between multiple components of a complex system, for example:



When to use Stand-Alone versus Integrated Models

- Stand-Alone Models:
  - Only needing to examine 1-way impacts
  - When “forcing” the model with observed data is better than “forcing” the model with outputs from another model (e.g., historical simulations)
- Integrated Models:
  - To explore 2-way effects or feedbacks between components of the system
  - To explore projected changes in a system when wanting to capture feedback effects, e.g., due to climate change

PROJECT #1

THE COLUMBIA BASIN WATER SUPPLY & DEMAND FORECAST

2009-2012, funding from Washington State Department of Ecology

WSU Team

- **Biological Systems Engineering**
  - Claudio Stöckle, Professor and Chair
  - Roger Nelson, Research Associate
  - Keyvan Malek, PhD Student
- **Center for Sustaining Agriculture and Natural Resources**
  - Chad Kruger, Director
  - Georgine Yorgey, Research Associate
  - Sylvia Kantor, Research Associate
- **Civil and Environmental Engineering / State of Washington Water Research Center**
  - Jennifer Adam, Assistant Professor
  - Michael Barber, Professor and Director of SWWRC
  - Kiran Chinnayakanahalli, Postdoctoral Associate (SWWRC)
  - Kirti Rajagopalan, PhD Student
  - Dana Pride, Web Designer (SWWRC)
  - Shifa Dinesh, PhD Student
  - Matt McDonald, MS Student
- **School of Economics**
  - Michael Brady, Assistant Professor
  - Jon Yoder, Associate Professor
  - Tom Marsh, Professor and Director of IMPACT Center

Background: Need for a Columbia Basin Water Supply & Demand Forecasting

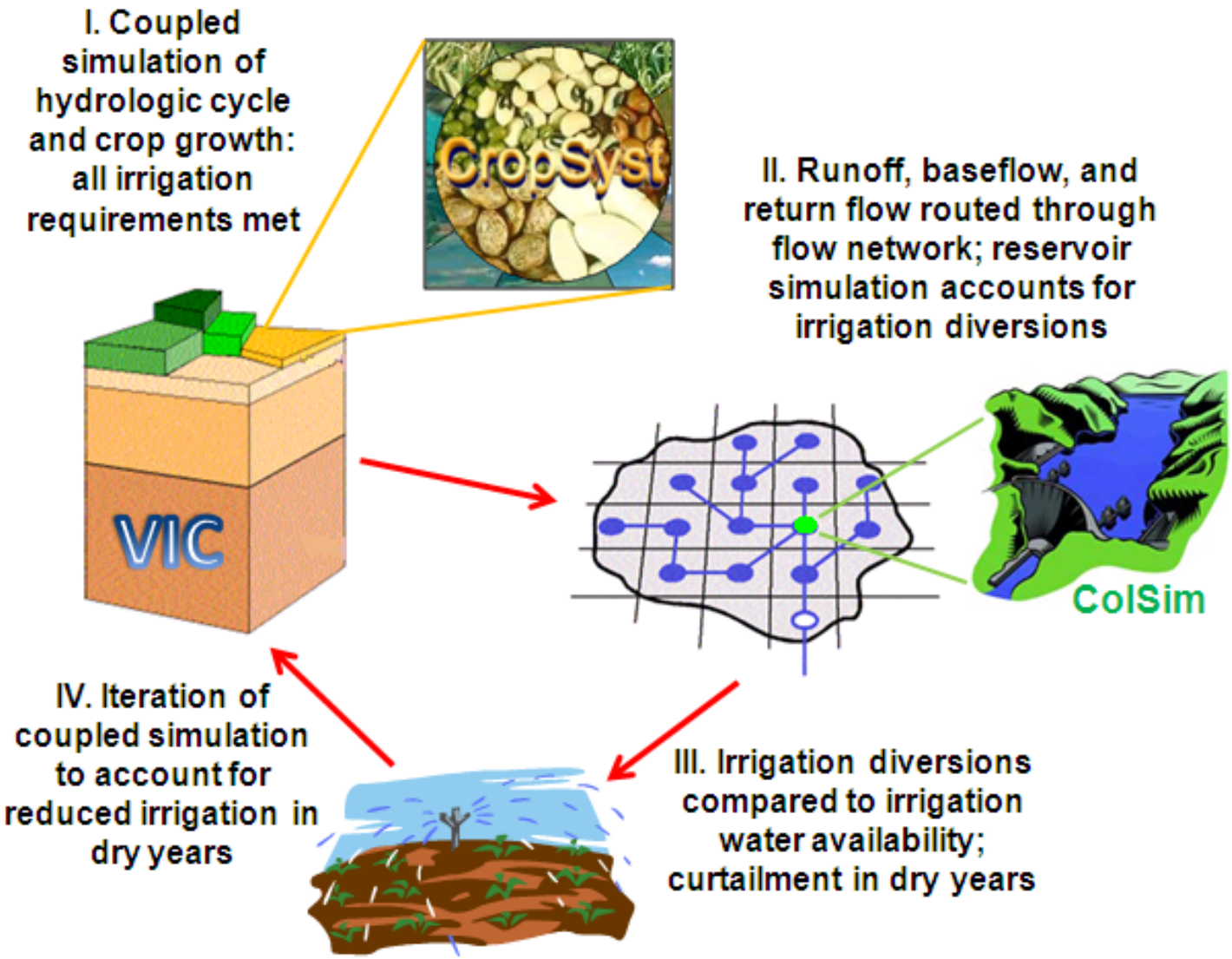
- Every 5 years, the Washington State Department of Ecology's office of the Columbia River (OCR) is required to submit a long-term water supply and demand forecast to the Legislature
- Washington State University (WSU) was assigned to develop the 2030s forecast for water supply and out-of-stream demand
- Changes in climate and water demand are expected to exacerbate the current complexity of managing the water resources of the basin
- The forecast helps improve understanding of where additional water supply is most critically needed, now and in the future

Modeling Capabilities Developed

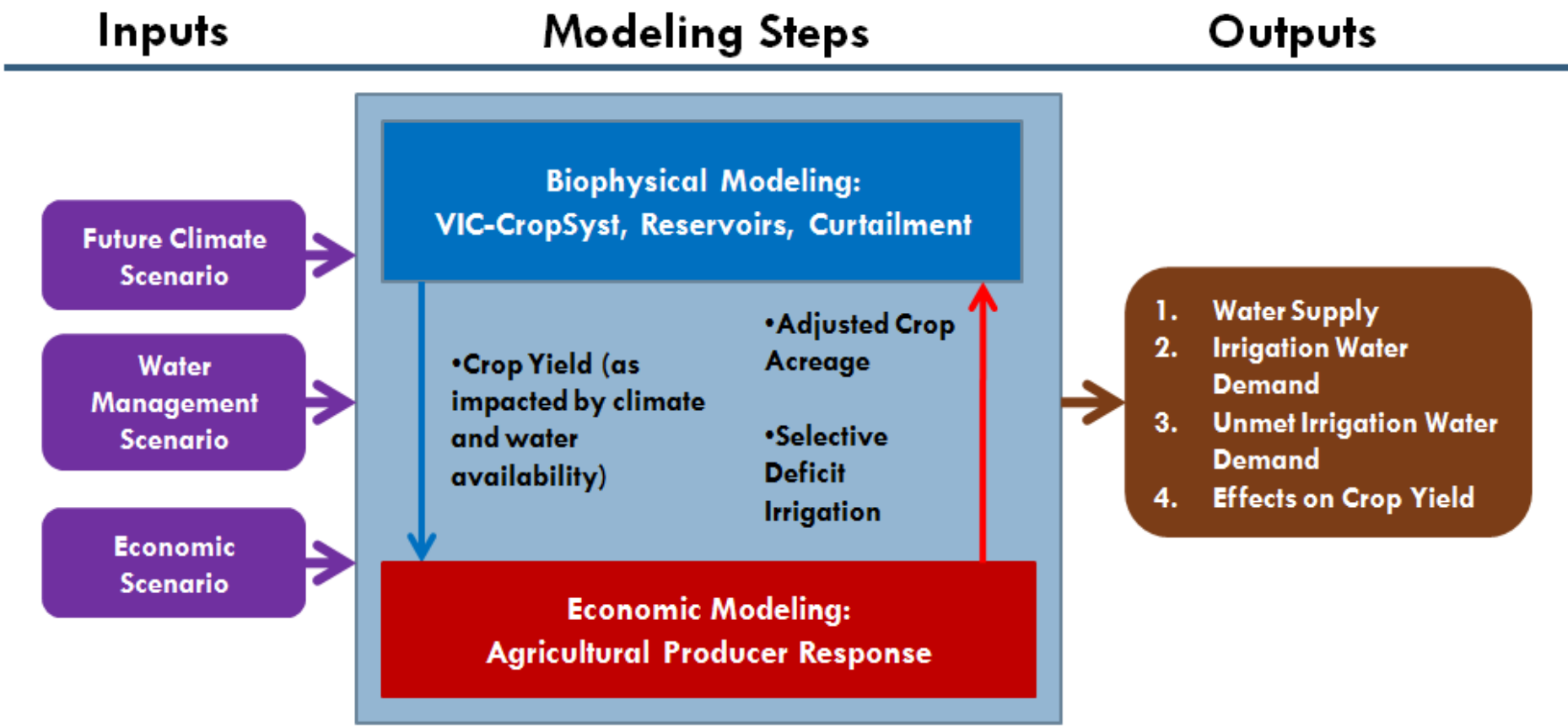
- Started with tools developed at the University of Washington Climate Impacts Group (UW CIG), and added:

1. Integrated surface hydrology and crop systems modeling
2. Inclusion of water management
   1. Reservoirs
   2. Curtailment
3. Interaction between biophysical and economic decision making models

Integrated Hydrology, Cropping Systems, and Water Management



Interactions with Economic Modeling



Results

- A small increase of around **3.0 (±1.2)%** in average annual supplies by 2030 compared to historical (1977-2006)
- Unregulated surface water supply at Bonneville will

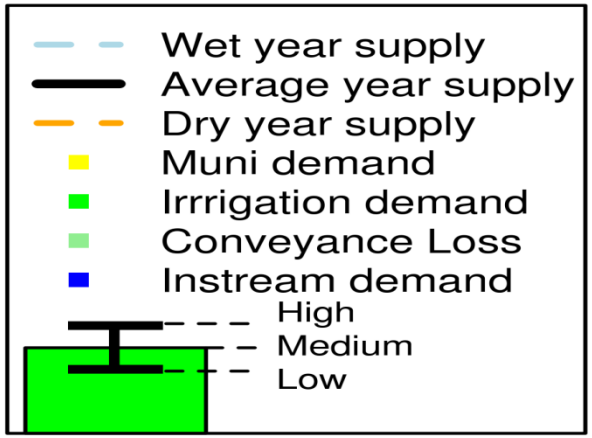
  ↓ **14.3 (±1.2)%** between June and October

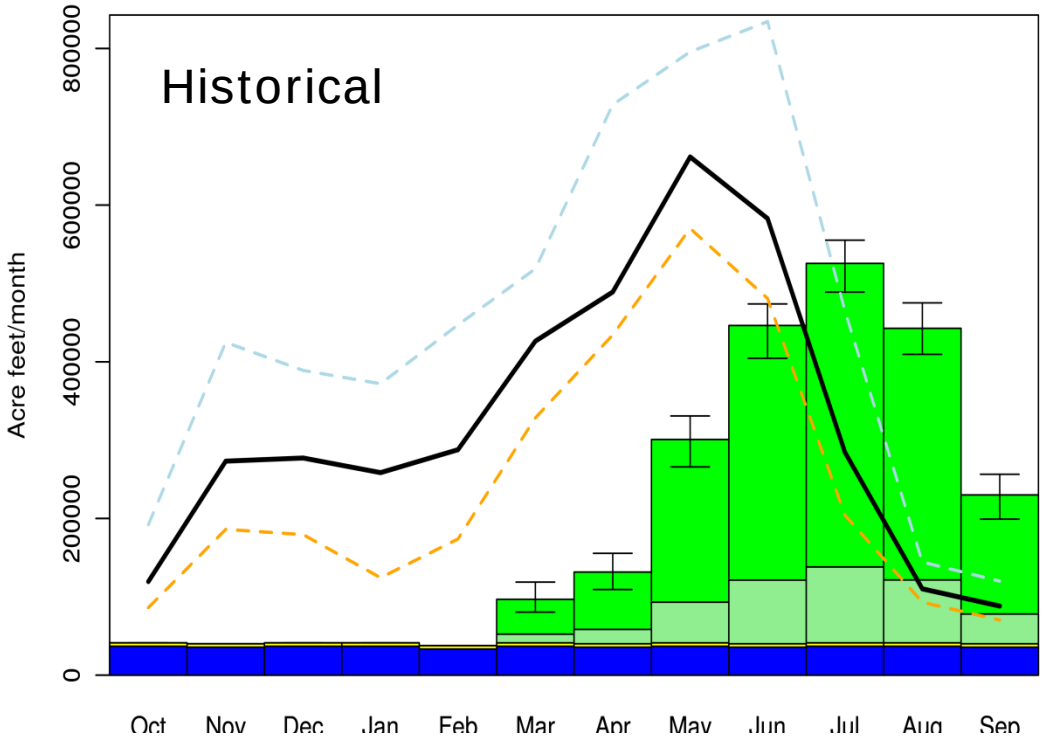
  ↑ **17.5 (±1.9)%** between November and May

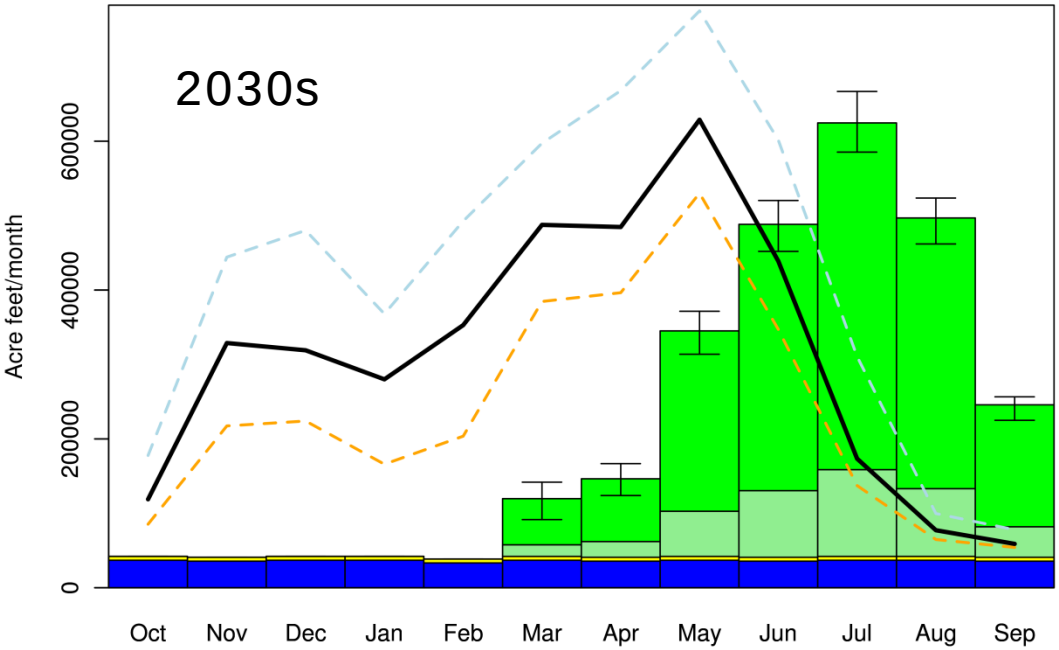
- The irrigation demand under 2030s climate was roughly 2% above modeled historic levels under average flow conditions
- Most severe impacts for specific watersheds

Example Watershed:

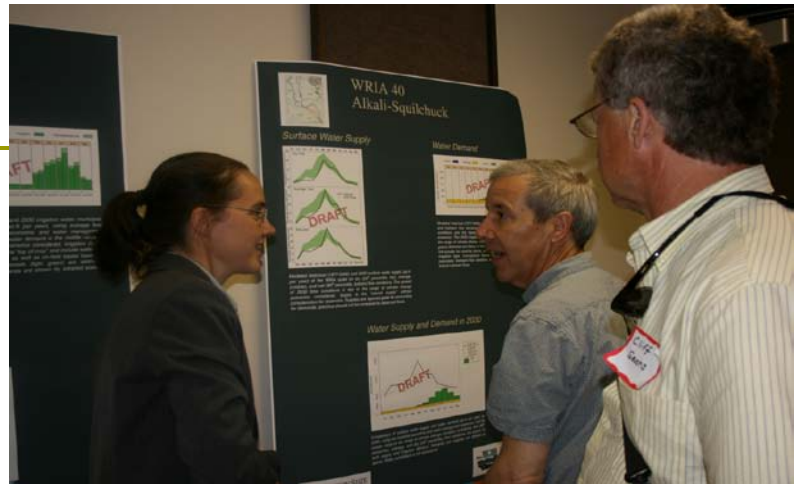
Yakima Regulated Supply and Demand







Review and Stakeholder Interaction Process



- National Review Panel
- Regional Review Panel
- OCR Policy Advisory Group
- 30-Day Public Comment Period
- Public stakeholder workshops (Tri-Cities, Wenatchee, and Spokane) in Sep 2011
  - Increase awareness
  - Seek feedback with improvement in modeling component, presentation of results, and description of results

PROJECT #2

BIOEARTH: REGIONAL EARTH SYSTEM MODELING

BioEarth

Biosphere relevant earth system model

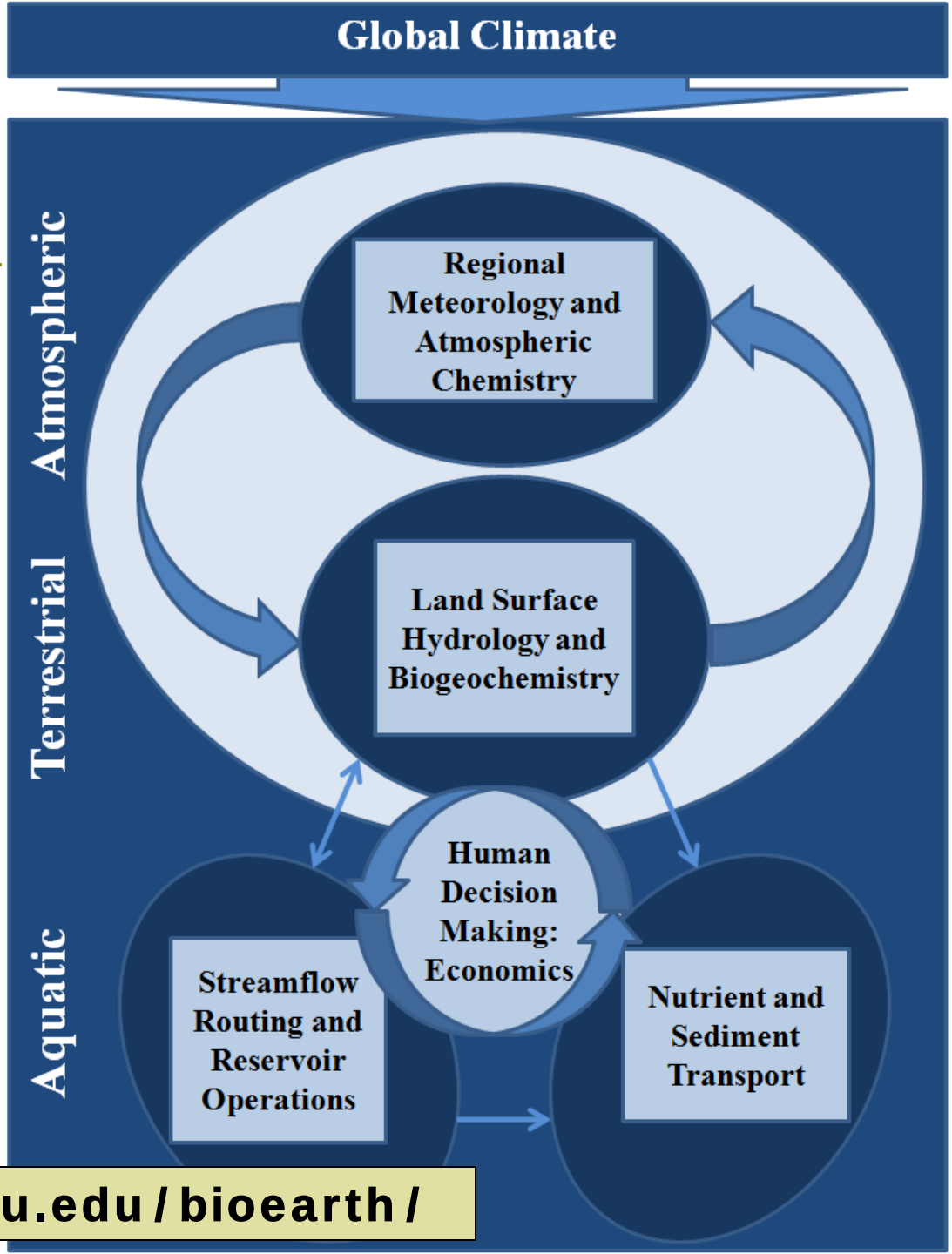
2011-2016, funding from U.S. Department of Agriculture

BioEarth Team

- Washington State University
  - Biological Sciences
  - Biological Systems Engineering
  - Center for Sustaining Agriculture and Natural Resources
  - Civil and Environmental Engineering
  - Communications
  - Computer Sciences
  - Earth and Environmental Sciences
  - Economics
  - Extension
  - Laboratory for Atmospheric Research
- Clark University, Communications
- National Center for Atmospheric Research
- Oregon State University, Economics
- Pacific Northwest National Lab, Atmospheric Sciences
- University of California Santa Barbara, Environmental Sciences

BioEarth

•***Overarching Goal:*** To improve the understanding of regional and decadal-scale C:N:H_2O interactions in context of global change to better inform decision makers involved in natural and agricultural resource management.



http://www.cereo.wsu.edu/bioearth/

BioEarth Features for Natural and Agricultural Resource Management

- Emphasis on adding detail to inform agricultural and natural resource use and management
  - Economics (macroeconomic drivers, regional dynamics, individual response)
  - Crop producer decisions, including modeling of crop growth and phenology
  - Forest management decisions, including modeling of biomass and succession
  - Water management, including modeling of reservoirs and curtailment
  - Nitrogen management, including modeling of coupled biogeochemical cycles
- Relevant outputs for decision making: air & water quality, water availability, crop & forest productivity, greenhouse gas emissions, carbon sequestration, hydropower potential, economic impacts

Communications Research Component

- *Question:* How does regular interaction between model developers and resource stakeholders influence the perceived relevance and utility of the model to decision-making?
- *Approach:* Environmental communication experts, researchers, and extension specialists will work together to simultaneously
  - develop mechanisms for frequent, regular, two-way, interactive communication between model developers and practitioners, and
  - perform surveys and interviews of both the stakeholders and the scientists to map the evolution of perceptions of utility and relevance of the model to decision-making.

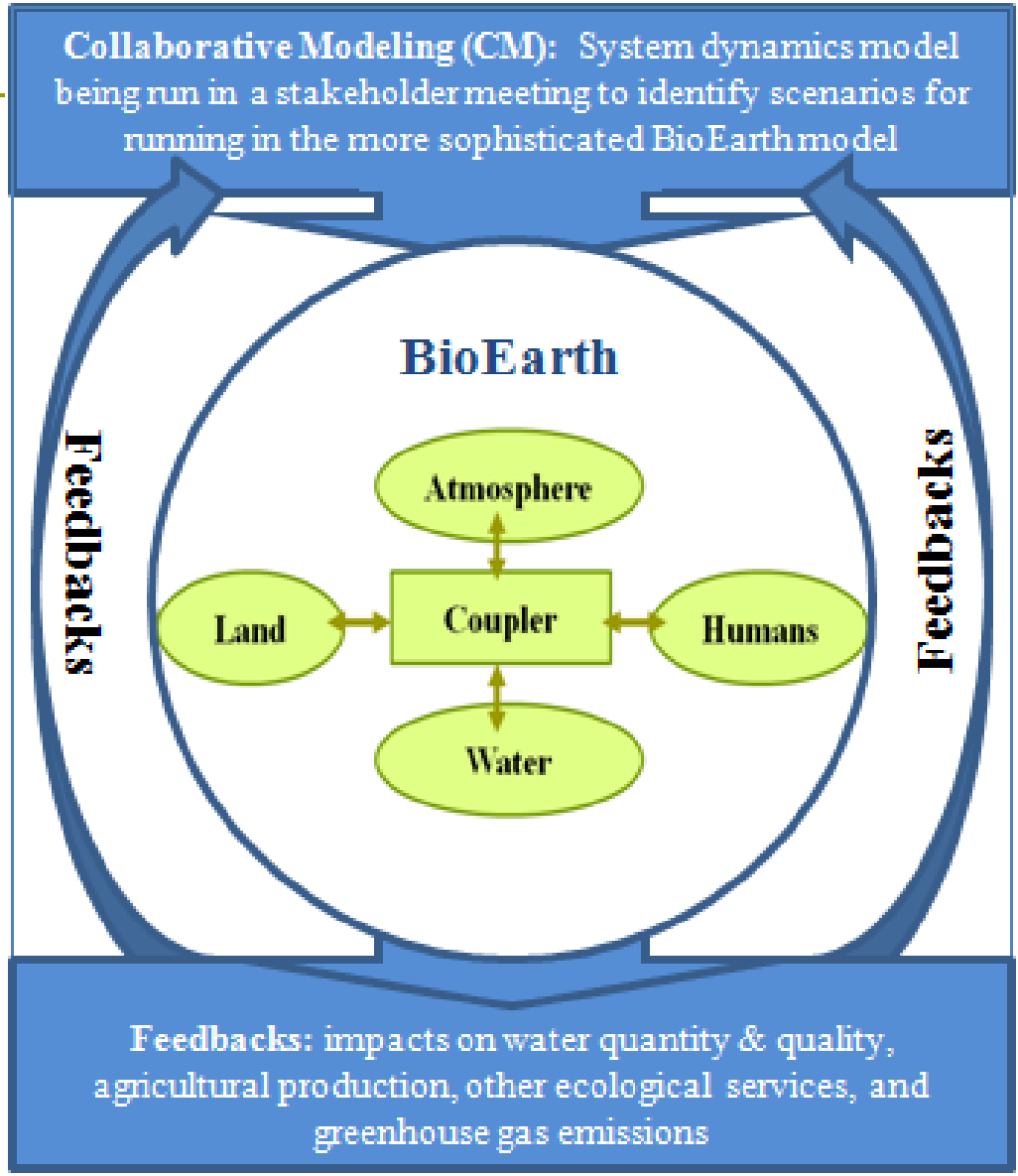
PROJECT #3

WATERSHED INTEGRATED SYSTEM DYNAMICS MODELING (WISDM)

2012-2016, WSU Lead: Cailin Huyck Orr

Stakeholder involvement in the WISDM Project

- *Question*: How are biophysical and social systems in the CRB likely to co-evolve to promote the sustainability of our agricultural and natural resources?
- *Approach*: Nested models
  - Use of system dynamics model for the Columbia, which can be run real-time in a stakeholder meeting to generate scenarios for adaptation of water users and regulatory institutions
  - Identified scenarios are later run in the BioEarth modeling framework to determine impacts
  - These impacts are used to improve the parameterizations in the system dynamics model and brought back to the stakeholders to generate better-informed scenarios



Future Directions and Avenues of Collaboration

- Improved integrated modeling of the extended Columbia River basin system, e.g.,
  - Better water management modeling outside of WA
  - Inclusion of groundwater dynamics and surface/ground interactions, e.g. in Upper Snake area
- Adaptation of tools for studying other research questions, such as the Water/Energy Nexus,
  - Expand collaboration network to include energy-focused participants
  - Optimization of reservoir management for multiple in and out-of-stream water demands
  - Investigation of Columbia River Treaty scenarios
- Broadening of stakeholder network outside of WA
  - Improve modeling assumptions and outputs
  - Increase awareness
- Progress towards global-scale integrated modeling

Conclusions

- Integrated modeling is one way to better holistically understand a complex system, particularly when a change is invoked upon it (e.g., climate change, increasing population, change in policy, etc…)
- These modeling frameworks are becoming more relevant as tools to improve natural resource management because they
  - Are becoming more sophisticated (capturing more processes)
  - Are becoming finer in space and in time
  - Can be used for investigating scenarios of policy or management strategies (e.g., to discover unintended consequences)
  - Are being improved through multiple ways of engaging with stakeholders
- Because these models are holistic and process-based, they can be adapted to a large variety of research questions, so <u>collaboration potential abounds</u>!

Thank you!

Wordle courtesy Liz Allen