Integrated Assessment and Regional Climate Change

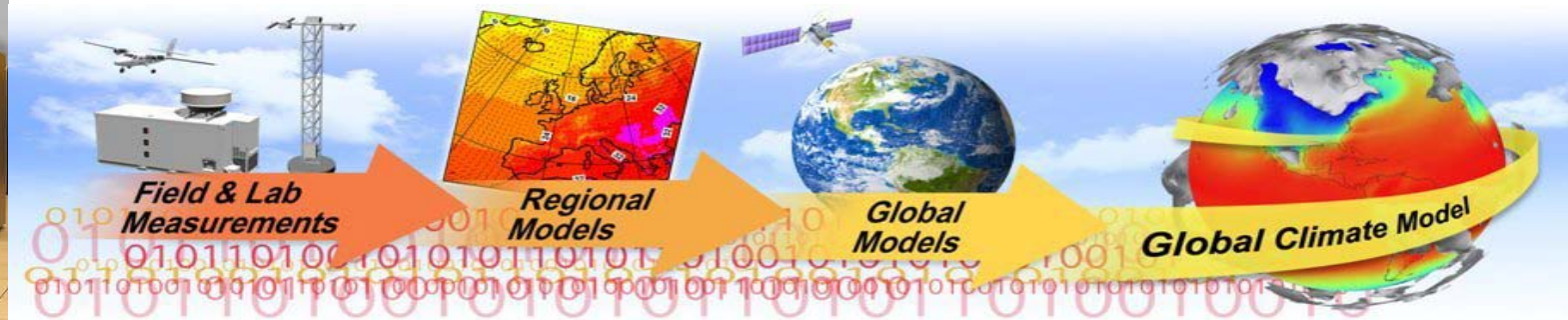
- *Enabling regional understanding of the impacts of climate change and the implications of human decisions*

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

Our Vision at PNNL

- Deliver breakthrough science to improve the prognostic capability of climate models and our understanding of system feedbacks and response
- We focus on understanding the critical interactions in the climate system that limit the predictive ability of models and insight on our climate
- Our research is conducted with integrated teams, from measurements to models to insights
  - Laboratory and field studies
  - Data analysis and synthesis, in the context of model needs
  - Process, regional and global models
  - Integrated earth system models (human and natural systems)

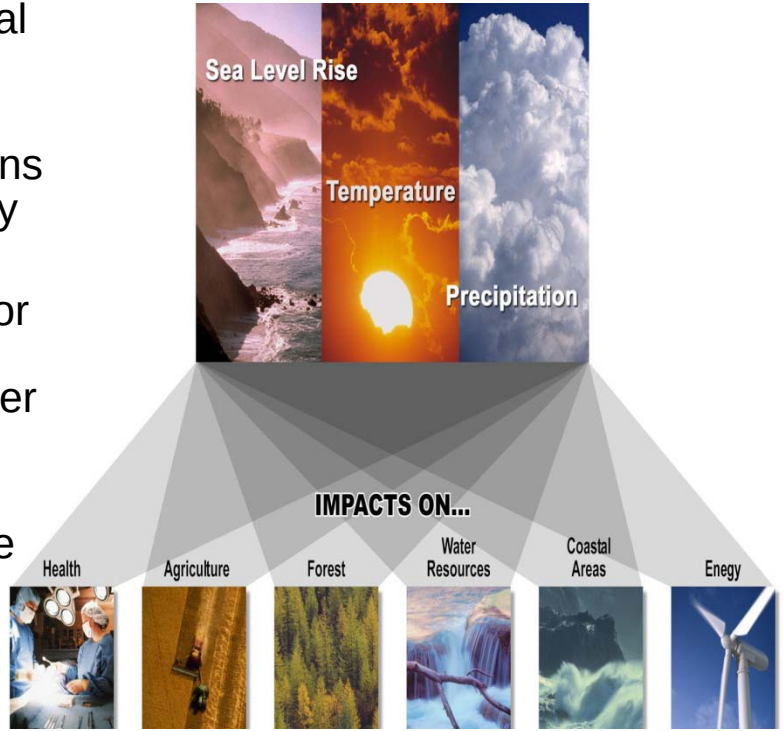


Understanding and integrating information at regional scales is increasingly important

- The need for modeling tools and credible regional insights into climate-human system impacts, interactions and feedbacks

We need models and tools that support decision-making at a variety of scales

- **Climate models** that simulate potential climate change and impacts at global, regional & local levels
- **Models** for evaluating mitigation options for economic and technological feasibility and impact
- **Modeling and analysis framework** for understanding effects of energy choices on food security, economic systems, other sectors, and on climate change
- **System models and analysis tools** that enable regional/local climate change projections for managing risk, planning and adaptation

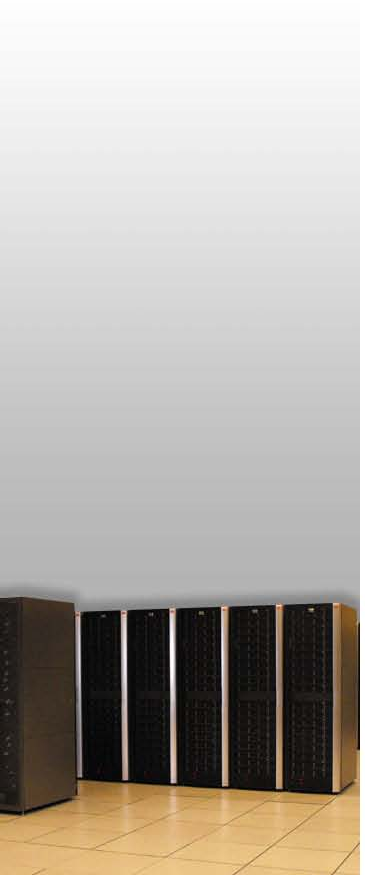


Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Challenges for Regional Modeling

- **Needs** by decision, research and policy community to provide integrative analyses
- **Regional Issues** are complex weave of energy, agriculture, socio-economics **and** climate
- **Consequences and Tradeoffs** to understand the regional specificities and interactions of land use, energy technologies and natural resource management
- **Consistency with global framework** yet not being ultimately dependent on any global framework.

Investing in solutions: Integrated Regional Earth System Model Initiative



- The **iRESM** initiative will:
  - Develop the science base and infrastructure to support a new generation of coupled Earth system models to
    - improve attribution and prediction of regional climate, and
    - provide predictions of impacts affecting adaptive capacities and vulnerabilities of environmental and human systems.
  - Do cross-cutting research focused on understanding the interactions among the climate, human, and environmental systems, and societal responses to climate change.
  - Strengthen research on adaptation, mitigation, and vulnerability.

iRESM: Addressing questions of decision makers

- What are the regional characteristics and opportunities for mitigation and adaptation strategies?
- How do changes in mean climate and climate variability affect adaptation and mitigation strategies?
- What are the interactions between management decisions and natural processes that contribute to rapid or nonlinear changes in the environment?
- How will adaptation and mitigation strategies interact in the next few decades?

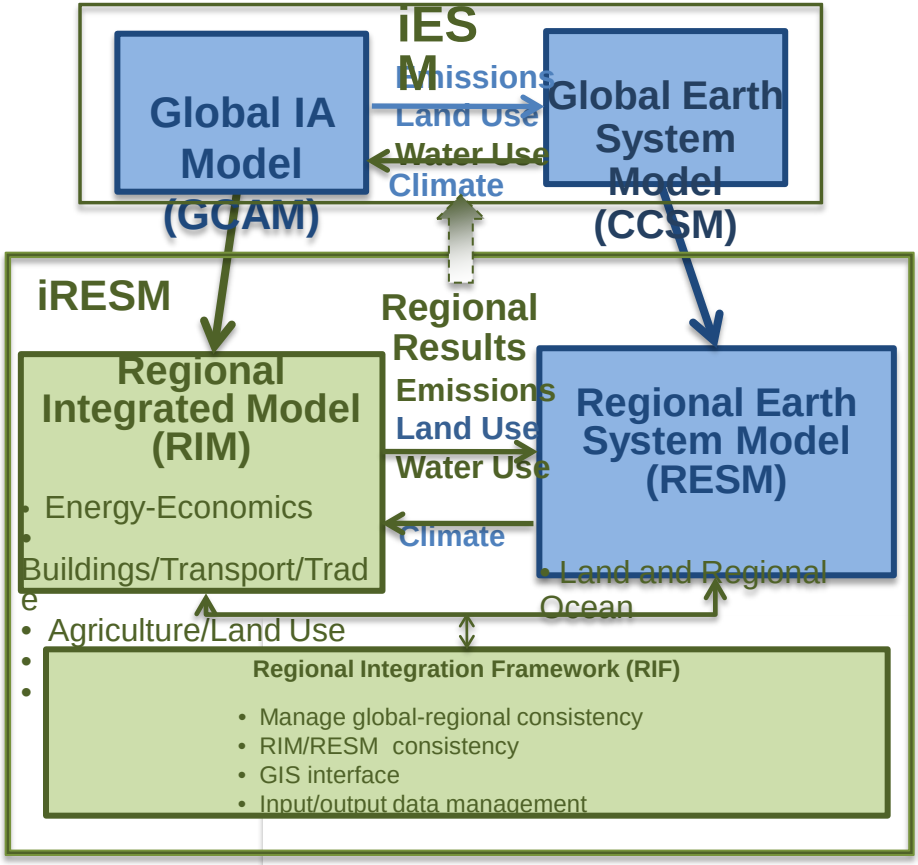
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Model Structure

- **Key Attributes:**
  - Modularity
  - Swap-ability
  - Flexibility
  - Integrated Regional Analyses

KEY

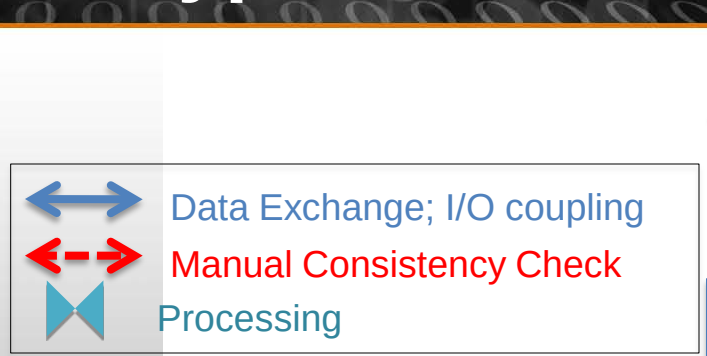
Blue = existing capability
Green = new capabilities

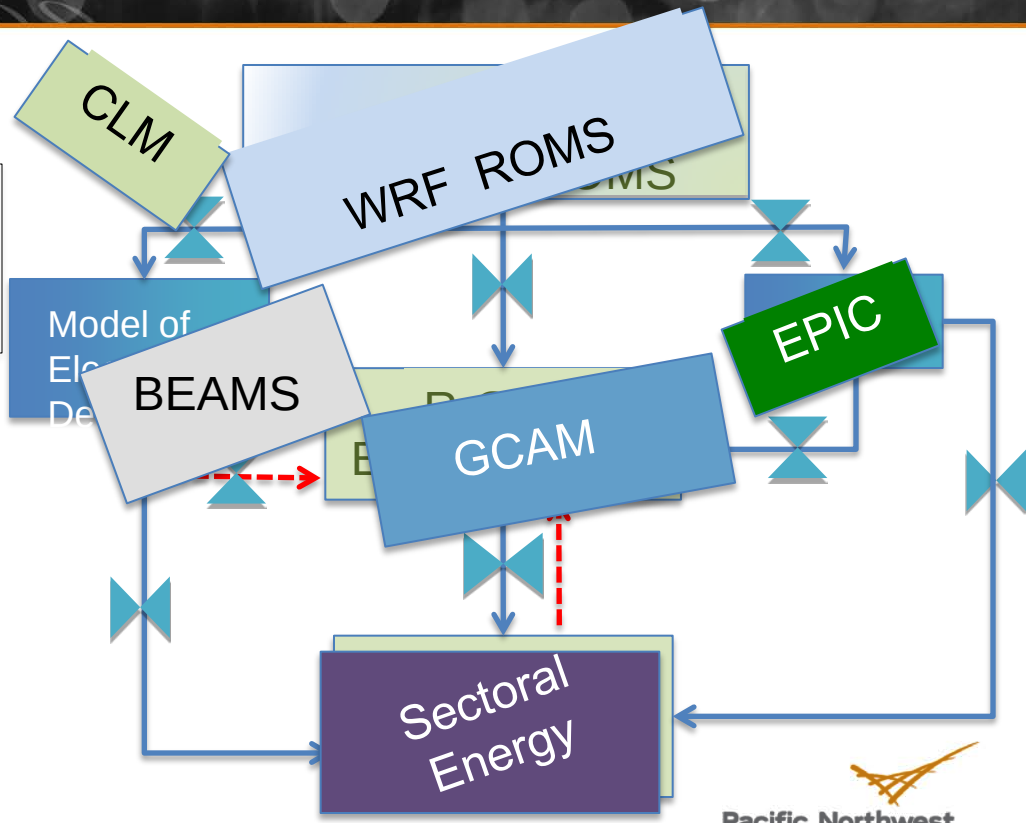


Computational Challenges

- Different simulation models, programming languages, implementation approaches and computational requirements
- Different temporal and geographical scales:
  - Hours to multi-year time steps
  - Geographic/GIS data-centric grids to political and organizational boundaries
- Consistent data coupling– temperature time series vs. heating degree days weighted by population density
- Integrating different scientific domains and semantics
- Integrating overlapping processes consistently across models

Prototype of software architecture





- Models with multiple:
  - Time Steps
  - Spatial Domains
  - Run Times
  - Data Infrastructures
- One-way I/O coupling

Identifying the Common Threads across Models: Hydrology as an example

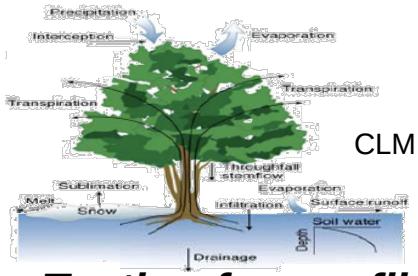
- Challenge – to develop a modeling framework that address interactions between climate, energy and land use through water supply, demand and management.
  - Address the multi-scale aspect of water by linking different models at various temporal and spatial scales (from watershed to regional/global)
  - To reconcile hydrologic modeling across different model components (e.g., EPIC, CLM, Energy Infrastructure)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Model Development: Water Supply, Demand and Testing

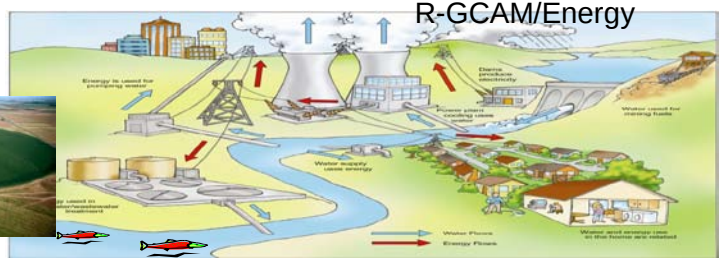
Supply

- CLM/D-CLM: Runoff & streamflow from precipitation, snowmelt
- Accounts for ecophysiological and biophysical fluxes



CLM → D-CLM

EPIC



R-GCAM/Energy

Testing for conflicts:

1. Utilize existing datasets to check for consistency before any kind of coordinated water management.

2. Compare irrigation and energy demand; EPIC and Energy (BEAMS, R-GCAM, Energy Infrastructure)

Demand

- R-GCAM: Uses water for electric power: distinguishes between consumption and withdrawal for each option
- Energy Infrastructure: uses water availability for siting and hyrdro operations
- EPIC/AgLU: regional agriculture for irrigated/dryland crop systems

Regional Criteria and Selection

- Pilot Study for iRESM
- Criteria:
  - Multiple energy sectors production and consumption
  - Land use e.g., biofuels versus agriculture
  - Strong links to existing science
  - Availability of high quality data

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Uncertainty Analysis and Stakeholder Engagement

- Uncertainty in climate
- Uncertainty in technologies
- Uncertainty in economics
- Future: uncertainty in ecosystems

(AP Photo/Charles Rex Arbogast)

Photo courtesy of Array Technologies

ARRA Enhanced Computing Project for Integrated Assessment

- New supercomputing capacity dedicated to Integrated Assessment through ARRA funds will make a huge difference
- Routine interactive runs can be performed that include both global and regional technological, ecological, and climate detail
- Routine ensemble runs of integrated IAM and iESM will be performed for quantitative exploration of uncertainties
- Expansion of community-modeling efforts to take advantage of broad expertise in many different disciplines, including ecosystems and social science, required for progress

Outcomes from this initiative will transform our ability to project climate change and its impacts

- Regional integrated assessment and climate models
  - Ability to provide high resolution climate change scenarios, including extreme events, and analysis of uncertainty
  - Ability to evaluate energy options, such as biofuels, and their links with/impacts on natural resource use and climate
  - Incorporation of earth system and human processes in a regional modeling framework
- More quantitative tools to support policy and investment decisions
- International leadership roles in research on climate, energy, land use, and resource management
  - Strategic partnerships with energy providers and investors
  - Long-term collaborations with leading institutions
- Leadership in connecting the best available climate science to decision makers and stakeholders

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Discussion