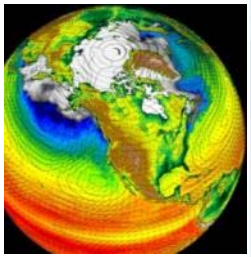
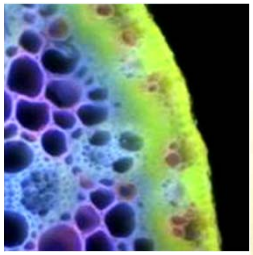
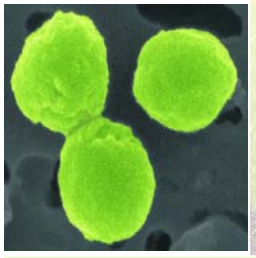


BERAC Briefing

2016 International Land Model Benchmarking (ILAMB) Workshop

May 16–18, 2016, Washington, DC, USA

October 27, 2016

Renu Joseph & Dorothy Koch

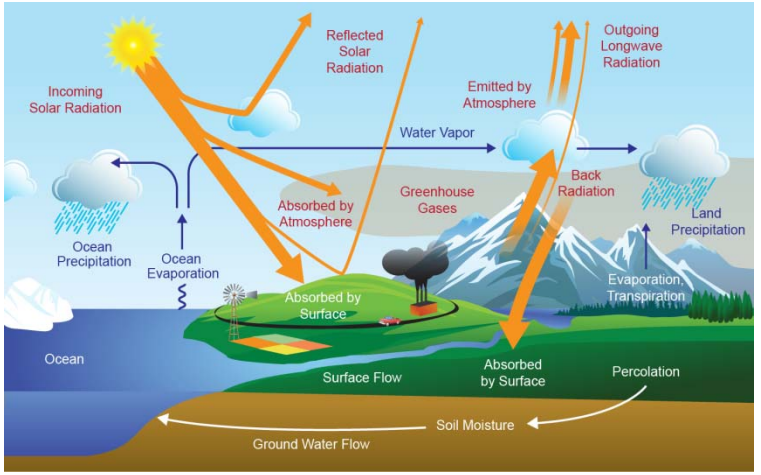
Workshop Co-Chairs: Forrest M. Hoffman, William J. Riley, James T. Randerson, Gretchen Keppel-Aleks, and David M. Lawrence

International Land Model Benchmarking (ILAMB)

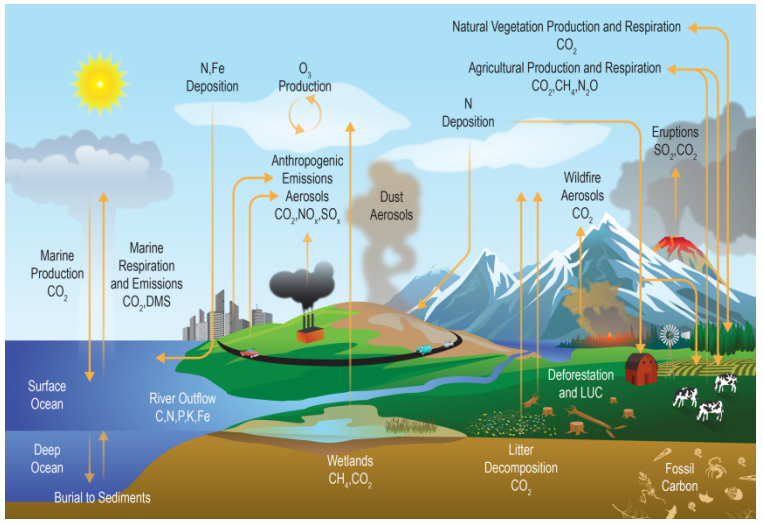
What is ILAMB?

A community coordination activity created to:

1. **Develop internationally accepted benchmarks** for land model performance by drawing upon collaborative expertise
2. **Promote the use of these benchmarks** for model intercomparison
3. **Strengthen linkages between experimental, remote sensing, and climate modeling communities** in the design of new model tests and new measurement programs
4. **Support the design and development of open source benchmarking tools**.



Energy and Water Cycles

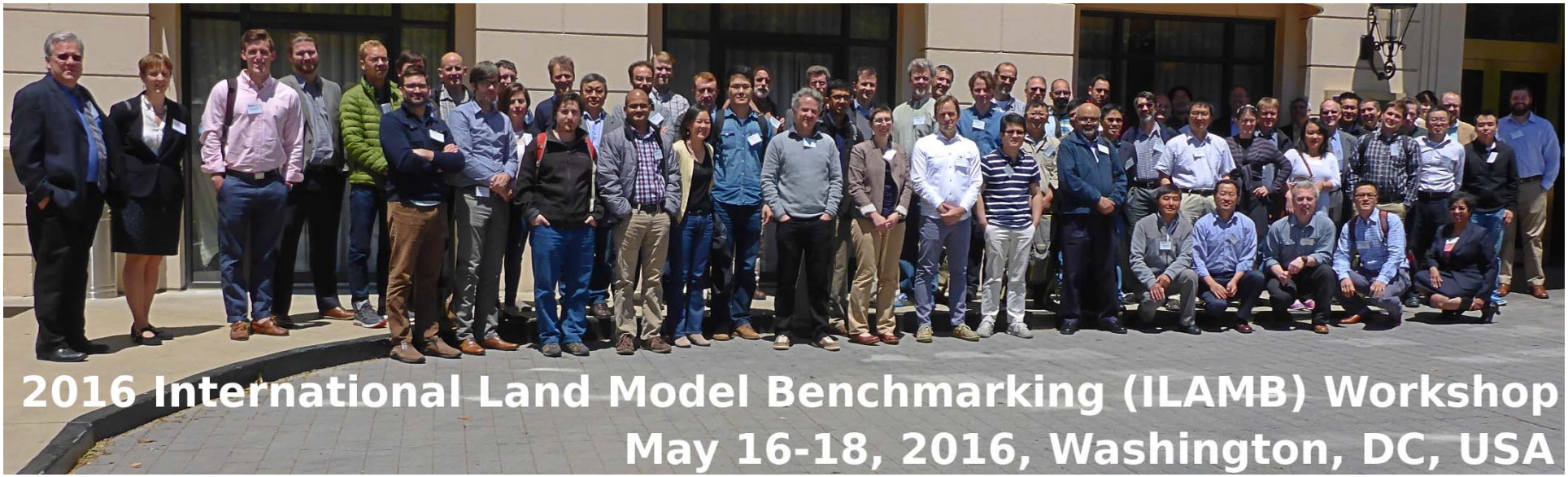


Carbon and Biogeochemical Cycles

Second US ILAMB Workshop, May 16–18, 2016

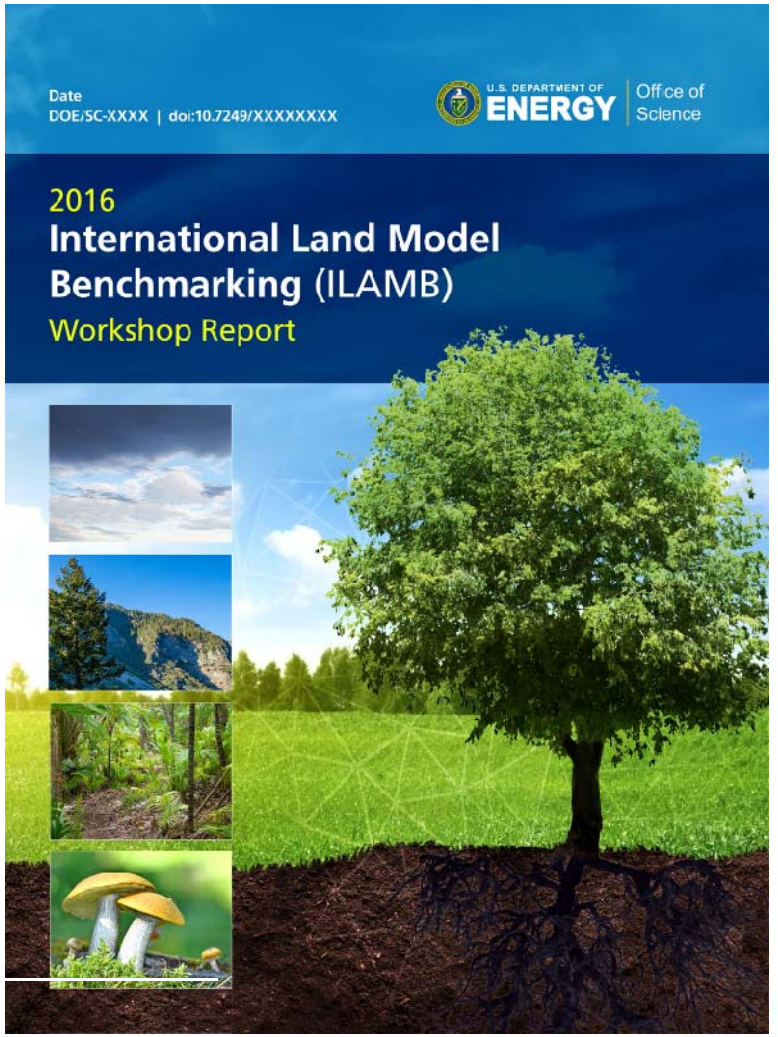
Goals of the workshop

- Understand benchmarking needs for model development and model analysis (including multi-model efforts)
- Engage the research community in defining scientific priorities for
  - Design of new metrics for model benchmarking
  - Model Intercomparison Project (MIP) evaluation needs
  - Model development, testbeds, and workflow practices
  - Observational data sets and needed measurements



Highlights of the Workshop

- **60+ participants** from Australia, Japan, China, Germany, Sweden, Netherlands, UK, and US
- **10 modeling centers** represented
- **~25 online attendees** at any time
- Report highlights
  - current state of the science
  - challenges and opportunities for benchmarking
  - model development needs
  - field and laboratory measurement priorities

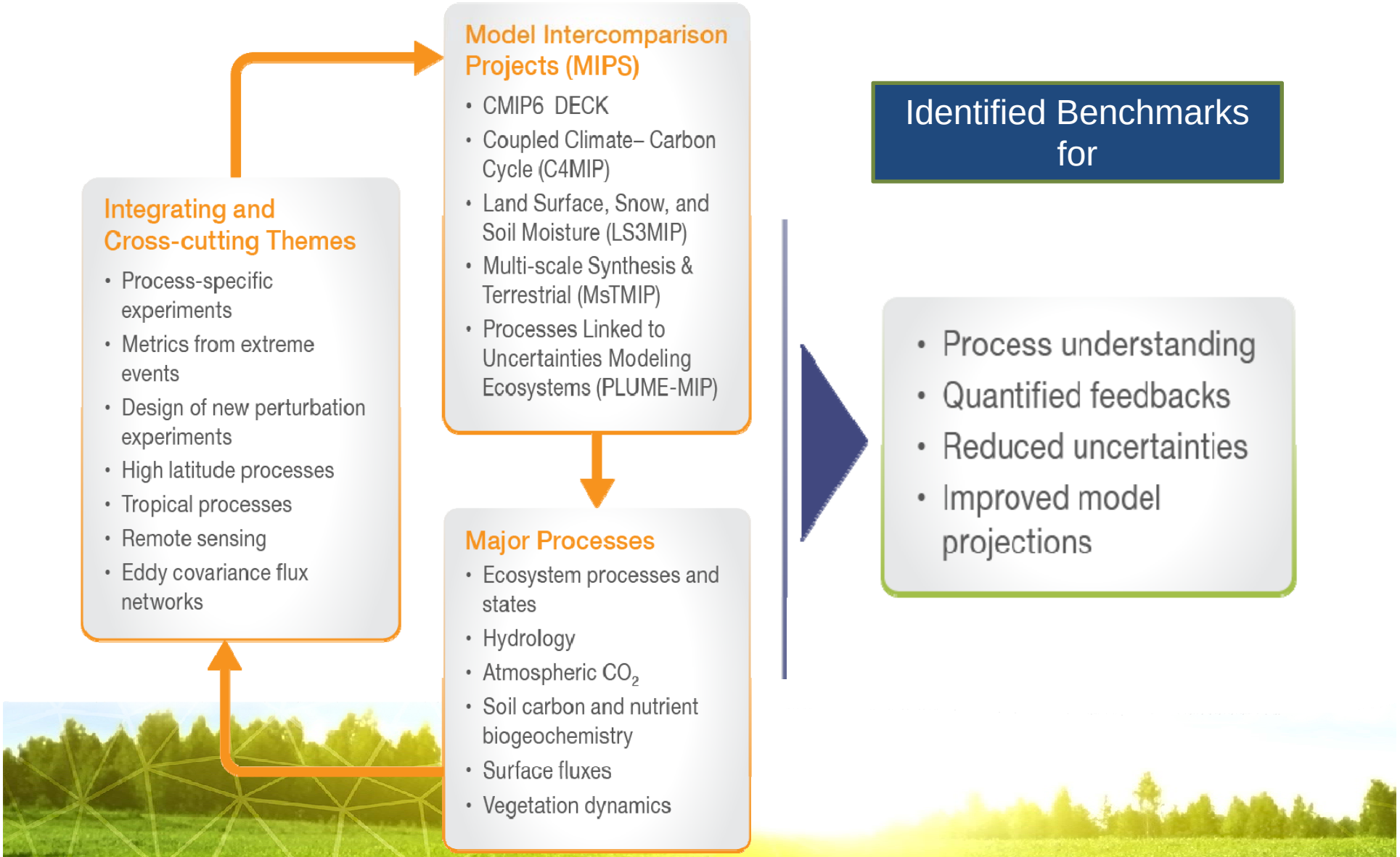


Hoffman, F. M., C. D. Koven, G. Keppel-Aleks, D. M. Lawrence, W. J. Riley, J. T. Randerson, A. Ahlström, G. Abramowitz, D. D. Baldocchi, M. Best, B. Bond-Lamberty, M. De Kauwe, A. S. Denning, A. Desai, V. Eyring, R. Fisher, P. J. Gleckler, M. Huang, G. Hugelius, A. K. Jain, N. Y. Kiang, H. Kim, R. D. Koster, S. V. Kumar, H. Li, Y. Luo, J. Mao, N. G. McDowell, U. Mishra, P. Moorcroft, G. S. H. Pau, D. M. Ricciuto, K. Schaefer, C. R. Schwalm, S. Serbin, E. Shevliakova, A. G. Slater, J. Tang, M. Williams, J. Xia, C. Xu, R. Joseph, and D. Koch (2016), *International Land Model Benchmarking (ILAMB) 2016 Workshop Report*, DOE/SC-XXXX, U.S. Department of Energy, Office of Science, Germantown, Maryland, USA, XXX pp., doi:10.7249/XXXXXXX.

Crowdsourcing and Social Media at the Workshop

- Videoconferencing used for all plenary sessions
- All slides and meeting notes crowdsourced in Google Slides and Google Docs
- Twitter used for ideas, comments & questions
- White papers written and reviewed through crowdsourcing
- Technology reduced gender, racial, and cultural imbalances and travel costs and emissions

White Paper Synthesis and Workshop Outcomes



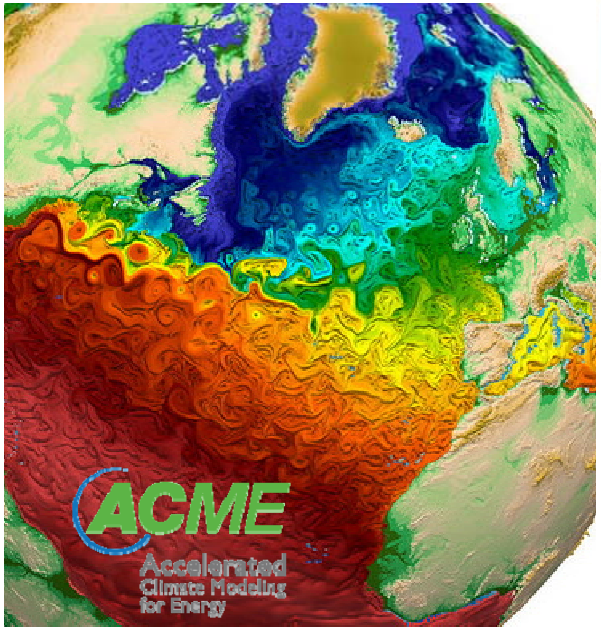
Benchmarking Challenges for Model Development

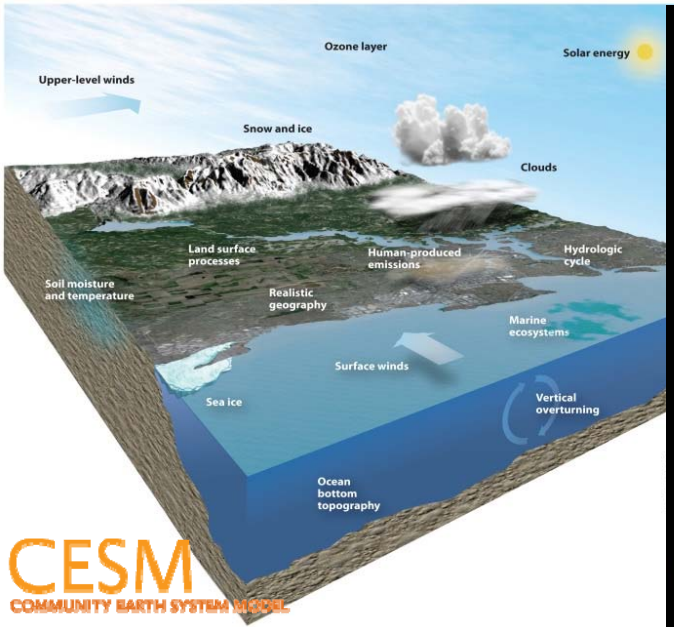
Developing metrics that make appropriate use of observational data remains **a scientific challenge** because of

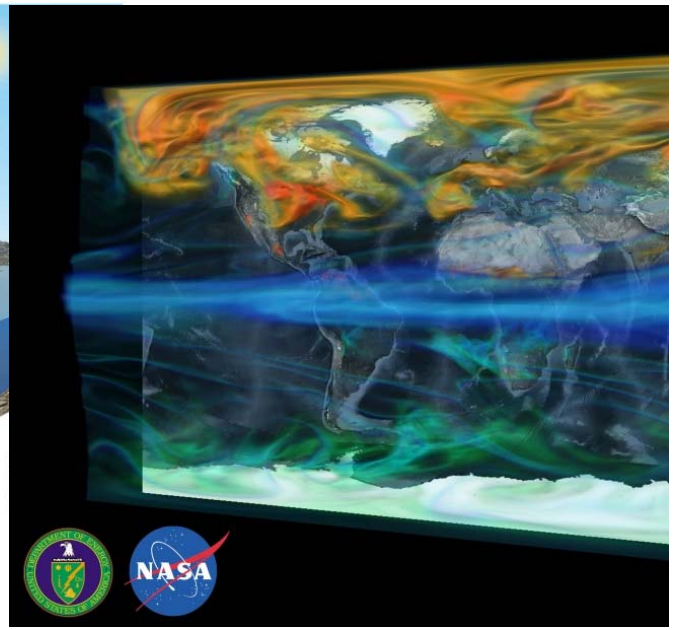
- **spatial and temporal mismatch** between models and measurements,
- **poorly characterized uncertainties** in observational data products,
- **biases** in reanalysis and forcing data,
- **model simplifications**, and structural and parametric **uncertainties**

Model testing requires

- Ability to test **alternate model formulations and develop in-situ diagnostics**
- **Land Model Testbed (LMT) capability** should be incorporated into routine model development testing (e.g., nightly/weekly automated testing)

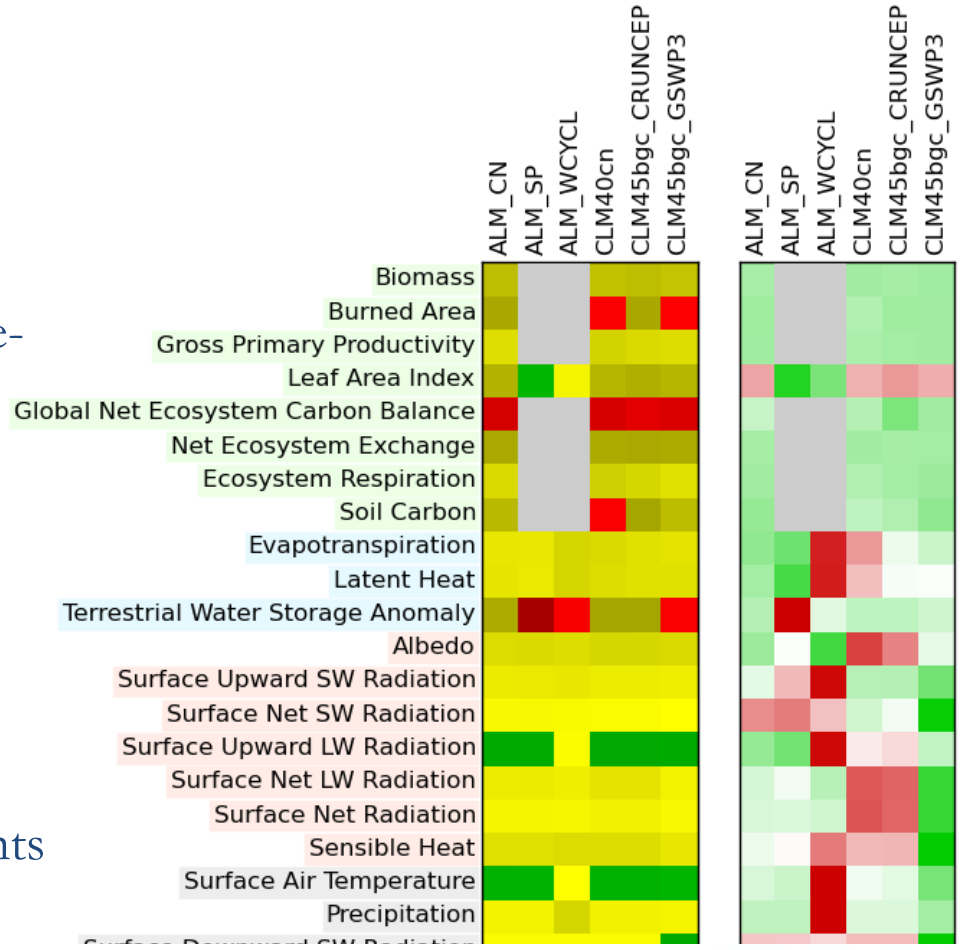






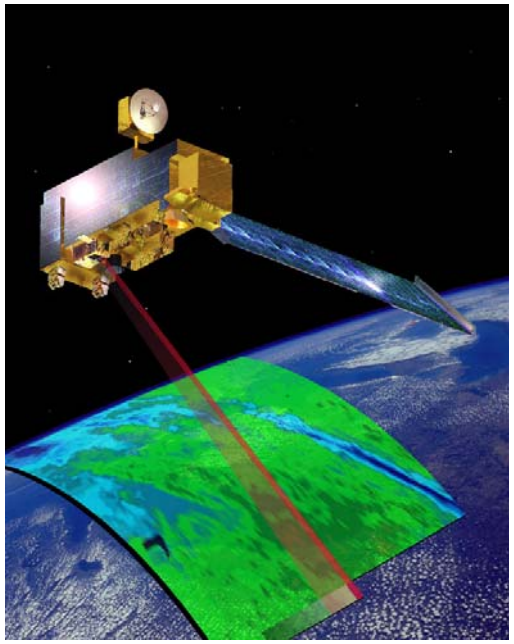
Benchmarking Approaches

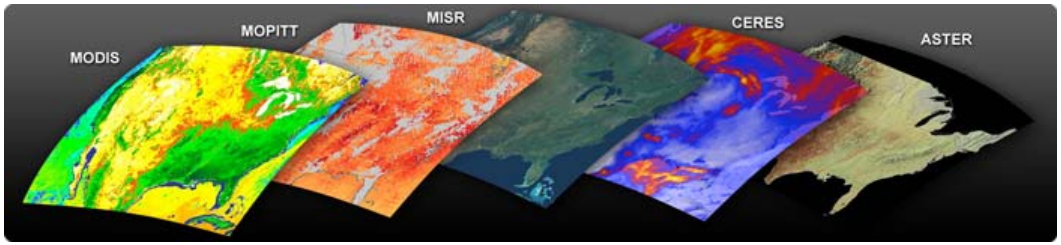
- Statistical comparisons (bias, root-mean-square error (RMSE), phase, amplitude, spatial distribution, Taylor diagrams and scores)
- **Functional response** metrics or variable-to-variable comparisons
- **Emergent constraints**
- Reduced complexity models and traceability analysis
- Formal **uncertainty quantification** methods
- Meta-analyses of perturbation experiments



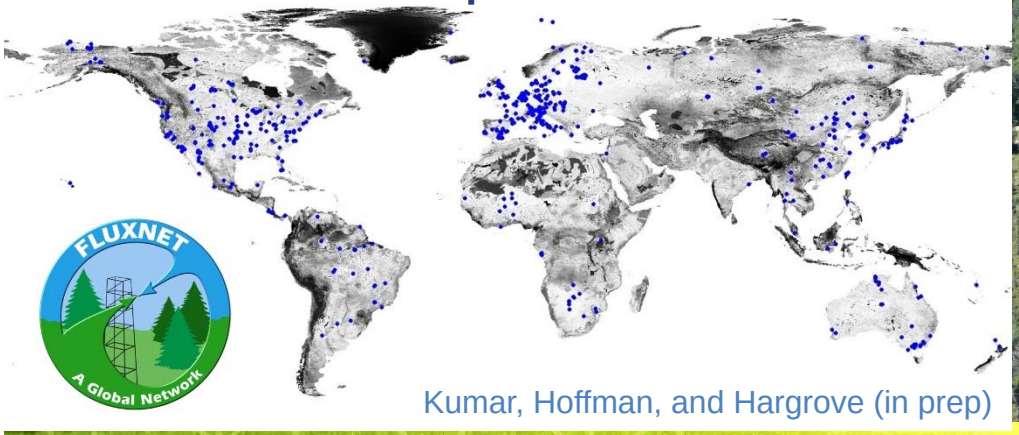
Benchmarking Challenges and Priorities

- **Super site benchmarks** for AmeriFlux and FLUXNET
- **Benchmarks for soil carbon** turnover, distribution, transport
- **Metrics for extreme events** & response of ecosystems
- **Data for vegetation** recruitment, growth, mortality, phenology, canopy structure
- Benchmarks for critical **high latitude & tropical ecosystems**
- Leverage **field projects & remote sensing methods**

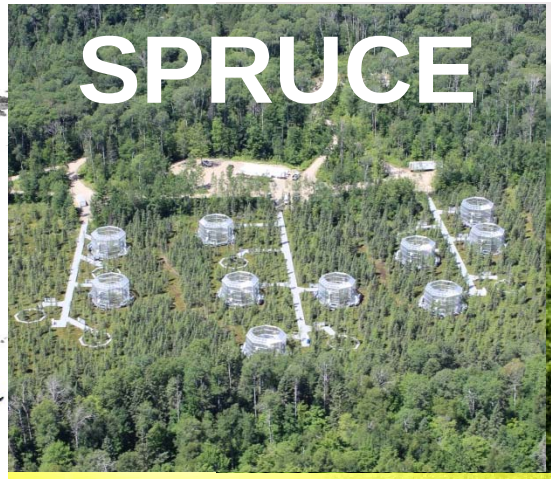




FLUXNET Representativeness



Kumar, Hoffman, and Hargrove (in prep)



Next Generation Benchmarking to Evaluate Models

Uncertainty Quantification (UQ) Frameworks

- Develop a hierarchy of approaches that integrate and report carbon cycle model diagnostics as a matrix of flows and turnover times to attribute responses to specific ecosystem components
- Apply Bayesian UQ approaches to identify model uncertainties
- Use UQ results to guide data collection activities and target process representation improvements

Computational Needs and Requirements

- Scalable algorithms and machine learning techniques should be developed for evaluating and benchmarking high resolution and long time series ESM results
- Scientific computing facilities should strike a balance between resources for compute-intensive vs. data-intensive applications as they plan expansion to exascale computing
- **Once developed, tools can be integrated with data repositories and archives**

Conclusion and Next Steps

- Successfully brought together the international community to identify scientific challenges for future research for model development and analysis
- To address specific benchmarking priorities, form small targeted working groups should be formed to research and publish
    - Super site benchmarks for AmeriFlux and FLUXNET
    - Benchmarks for soil carbon turnover, distribution, transport
    - Metrics for extreme events & response of ecosystems
    - Data for vegetation recruitment, growth, mortality, phenology, canopy structure
    - Benchmarks for critical high latitude & tropical ecosystems
    - Leverage field projects & remote sensing methods
- A top priority is supporting CMIP6 activities with additional ILAMB development for automated analysis and model–data intercomparison
- Support expanded use of Earth system models

Thank you!