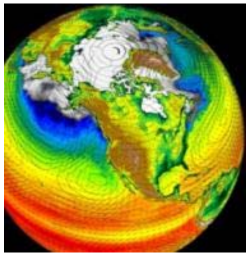
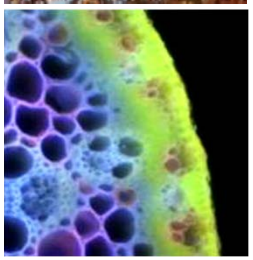
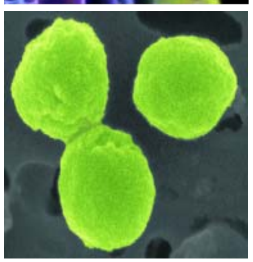


Trait Methods for Representing Ecosystem Change Workshop

BERAC Workshop Briefing
March 23, 2016

Daniel Stover, Ph.D. (TES)

Dorothy Koch, Ph.D. (ESM)

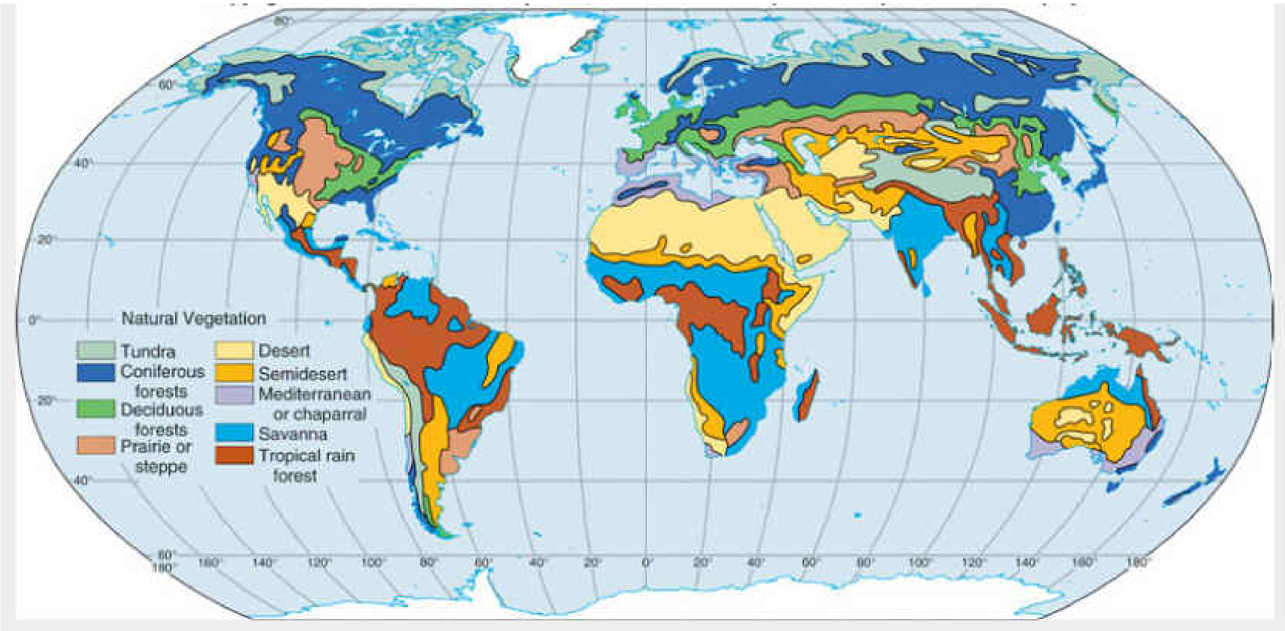
U.S. DEPARTMENT OF ENERGY

Office of Science

Office of Biological and Environmental Research

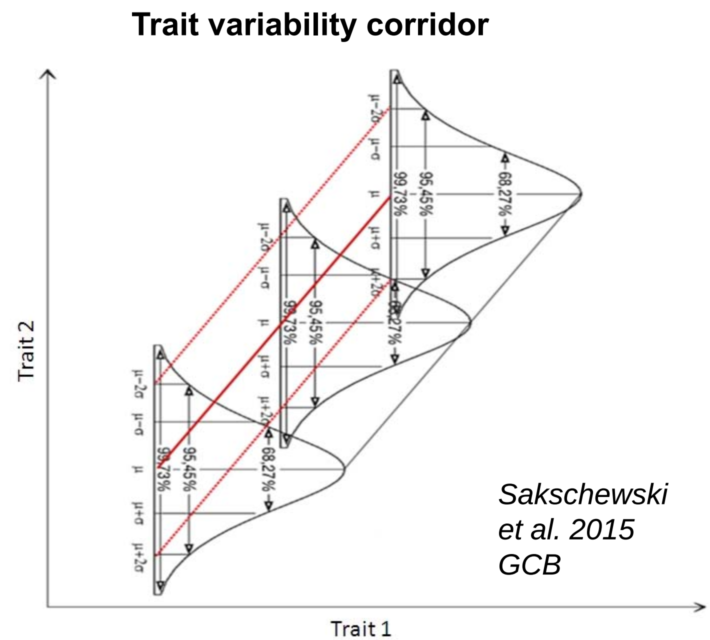
Justification

- Innovative modeling approaches are needed to improve our predictive understanding and representation of plant biological functions that interact with climate.
- Early generations of land models assumed a small number of Plant Functional "Types" (PFT's), defined based upon similar characteristics (e.g., growth form) and roles (e.g., photosynthetic pathway) in ecosystem function.
- However, these formulations do not permit dynamic plant changes in response to environment.



Justification

- Recently, “trait”-based approaches are used which allow for dynamically representing plant characteristics (e.g., size, permanence, water uptake and respiration, photosynthesis, etc.):
  - Empirical trait-environment relationships of PFT’s
  - Trait trade-offs and evolutionary rules applied to PFT’s
  - Abandon PFTs for optimality principles or empirical relationships to predict trait prevalence and vegetation
- There is no consensus on optimal strategies for trait-approaches.



Sakschewski et al. 2015 GCB

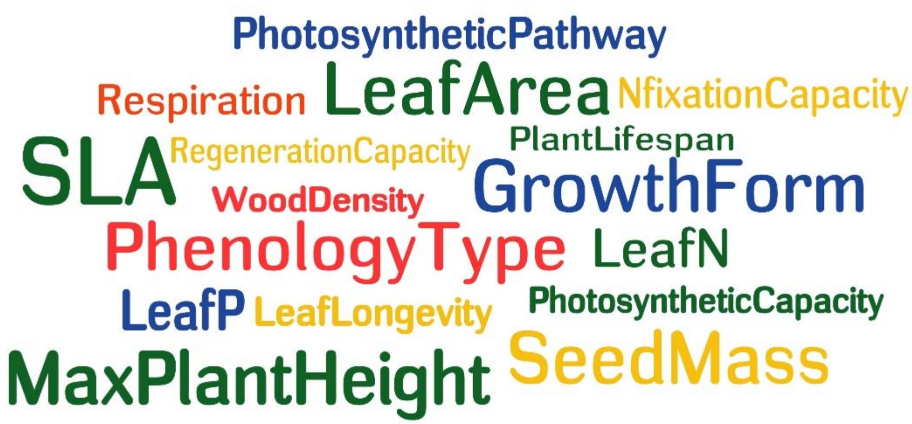
- The ACME and NGEE projects are among the pioneers seeking to use traits for representing ecosystem dynamics for global climate models

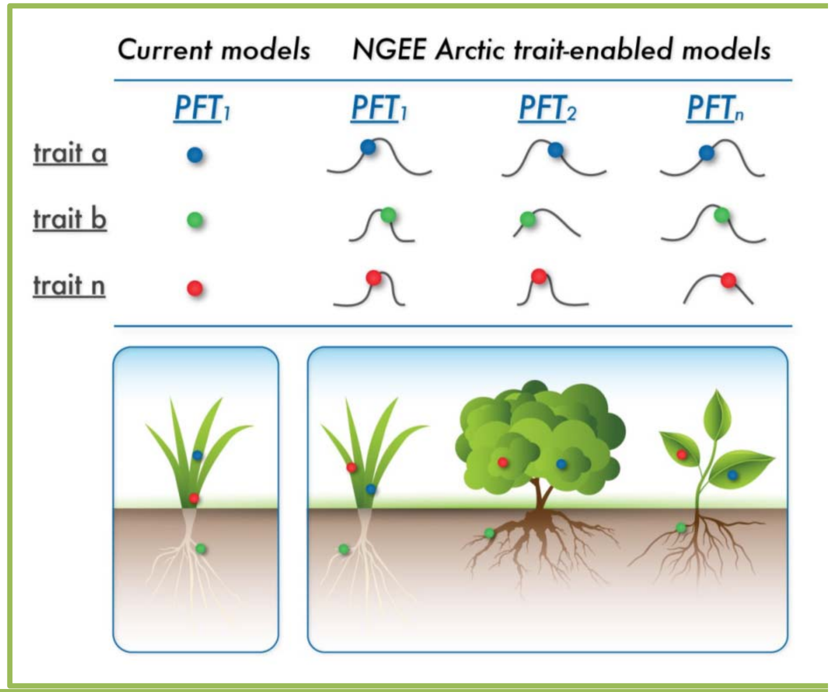
Workshop Objectives

- To advance a community discussion on trait-based methodologies used to represent ecosystem change in land systems and climate models, including:
  - Conceptual understanding of traits (what are they? why do they matter?)
  - Current and future model treatment of plant traits
  - Data availability for model parameterization and validation
  - Consequences for output of ESMs
- Engage the modeling and empirical communities to share current thinking and approaches to this issue.
- Help inform optimal strategies and approaches for field, theory and land modeling, specifically in the Next Generation Ecosystem Experiments (NGEE) in the Arctic and in the Tropics, as well as the Accelerated Climate Model for Energy (ACME).

Logistics

- Two-day workshop (Nov 17-18, 2015) in Rockville, MD
- Workshop Chairs:
  - Colleen Iversen and Peter Thornton (ORNL)
  - Lara Kueppers and Charlie Koven (LBNL)
  - Peter Reich (University of Minnesota)
- 36 US and international attendees representing a mix of approaches from academic and DOE Labs





Participants

Participant	Institution
Arindam Banerjee	Univ. of Minnesota
Ethan Butler	Univ. of Minnesota
Ming Chen	Univ. of Minnesota
Brad Christoffersen	LANL
Mike Dietze	Boston Univ.
Ray Dybzinski	Princeton Univ.
Eugenie Euskirchen	Univ. of Alaska, Fairbanks
Rosie Fisher	NCAR
Habacuc Flores	Univ. of Minnesota
Bill Hoffman	North Carolina State Univ.
Jens Kattge	Mac Plank Inst.
Jeremey Lichstein	Univ. of Florida
Yiqi Luo	Univ. of Oklahoma
Luke McCormack	Univ. of Minnesota
David Medvigy	Princeton Univ.

Participant	Institution
Isla Myer-Smith	Univ. of Edinburgh
Rich Norby	ORNL
Ryan Pavlick	NASA-JPL
Adam Pellegrini	Princeton Univ.
Ben Poulter	Montana State Univ.
Dan Ricciutto	ORNL
Sahajpal Ritvik	Univ. of Maryland
Alistair Rogers	BNL
Elena Shevlakova	Princeton Univ.
Ben Turner	Smithsonian Inst.
Maria Uriarte	Columbia Univ.
Dave Weston	ORNL
Joe Wright	Smithsonian Inst.
Kirk Wythers	Univ. of Minnesota
Chonggang Xu	LANL

Breakout Groups

1. **Plant functional traits and trait tradeoffs across species, PFTs, and biomes**
   - Re-visit the development and key findings of functional trait ecology, and what we know about the strengths and weaknesses of trait-based approaches.
2. **How plant traits are represented in models today, and novel approaches to representing dynamic plant traits in the next-generation of models**
   - Discuss modeling strategies, how they differ from each other and from classic dynamic vegetation models.
3. **Datasets to inform dynamic plant trait models**
   - Discuss observations and experimental data (above- and belowground) needed to fill gaps in our current understanding and model representation of plant functional traits.
4. **Consequences of including dynamic plant traits in Earth system models**
   - Address the availability of datasets at the global scale to initialize models with dynamic plant traits, the availability and interpretation of forcings, and the development of simulation experiments that help to assess the influence of dynamic trait representation on climate prediction in terms of system feedbacks and metrics of simulation fidelity.

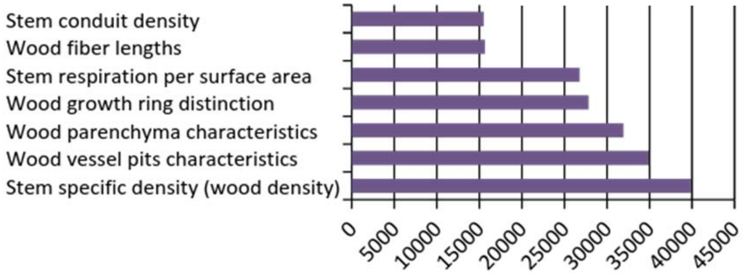
Common Themes and Outcomes: Theory

- The definition of “trait” varied among communities.
- Need to assess the trait mechanisms and the associated trade-offs:
  - biophysical based trade-off (e.g. allocation to two different tissue types)
  - Those with benefits but countervailing costs (e.g. higher photosynthetic rate comes higher respiration cost)
  - those possible in theory but don’t make ecological sense (i.e. they are selected against) (e.g. by sequestering N in vacuoles, plants probably could build very high N leaves with low photosynthetic rates, but these don’t show up in trait-trait relationships, probably because it is selected against).
- Require a better understanding of which traits are conserved vs. responsive to a changing environment.
- Need to understand and represent both trait correlations driven by physical constraints and those reflecting strategic plant trade-offs.

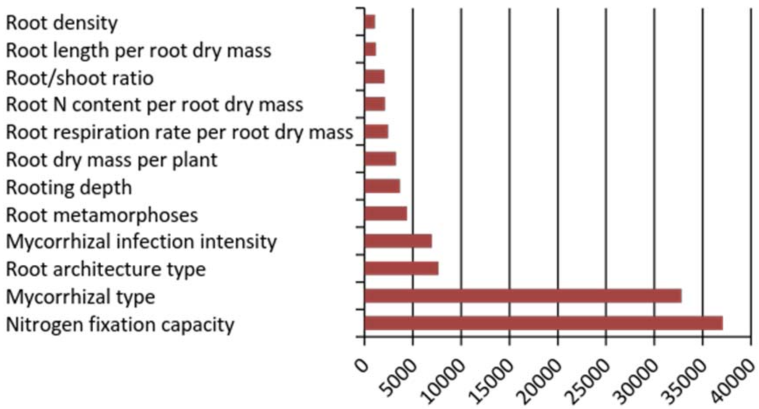
Common Themes and Outcomes: Data

- Numerous gaps in the data available to inform new models.
  - Data are sparse for belowground traits relevant to plant water and nutrient acquisition
  - Data are sparse for undersampled but climatically important regions, such as biome transition zones and tropical forests, where trait diversity is highest.
  - Manipulative experiments (e.g., FACE, SPRUCE, nutrient network, etc.) provide a good insight on tradeoffs

Stem traits



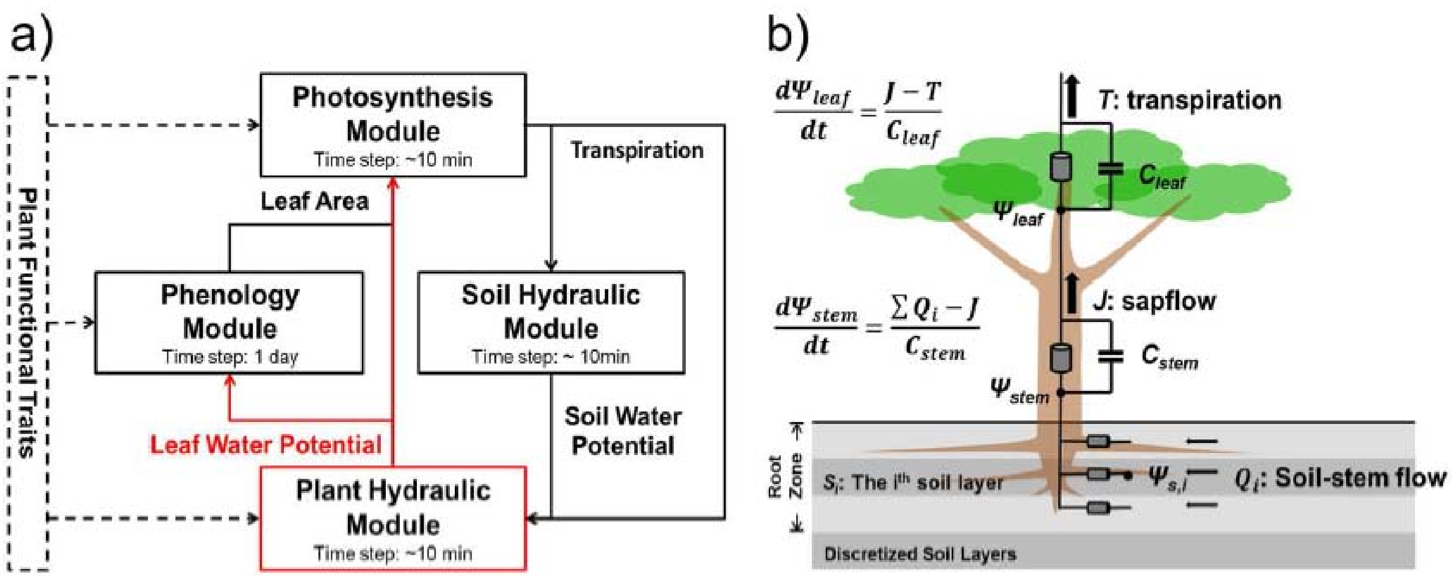
Root traits



- Apply the tools of "big data" to assemble and interpret trait observations for the modeling community.

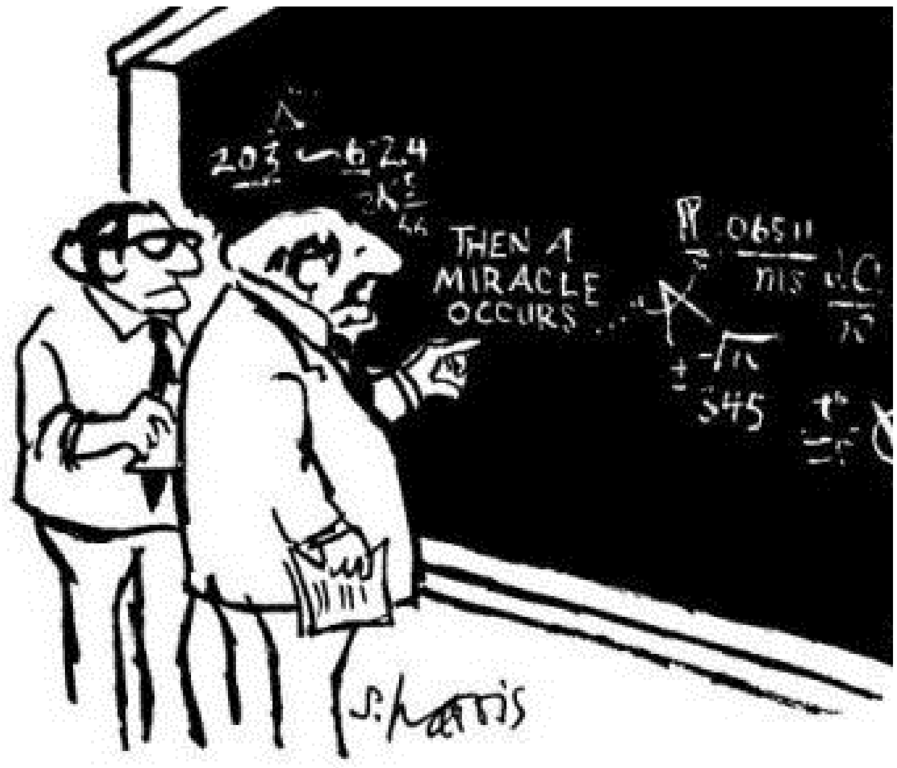
Common Themes and Outcomes: modeling

- Pursuing multiple distinct modeling approaches will yield more rapid advances than a single approach at this early stage.
- Analytically tractable models and ensembles of stochastic models both may be required to understand the emergent behavior and variability of real ecosystems.
  - How will life history/disturbance/competition be captured, especially during model spin up?



Remaining Challenges

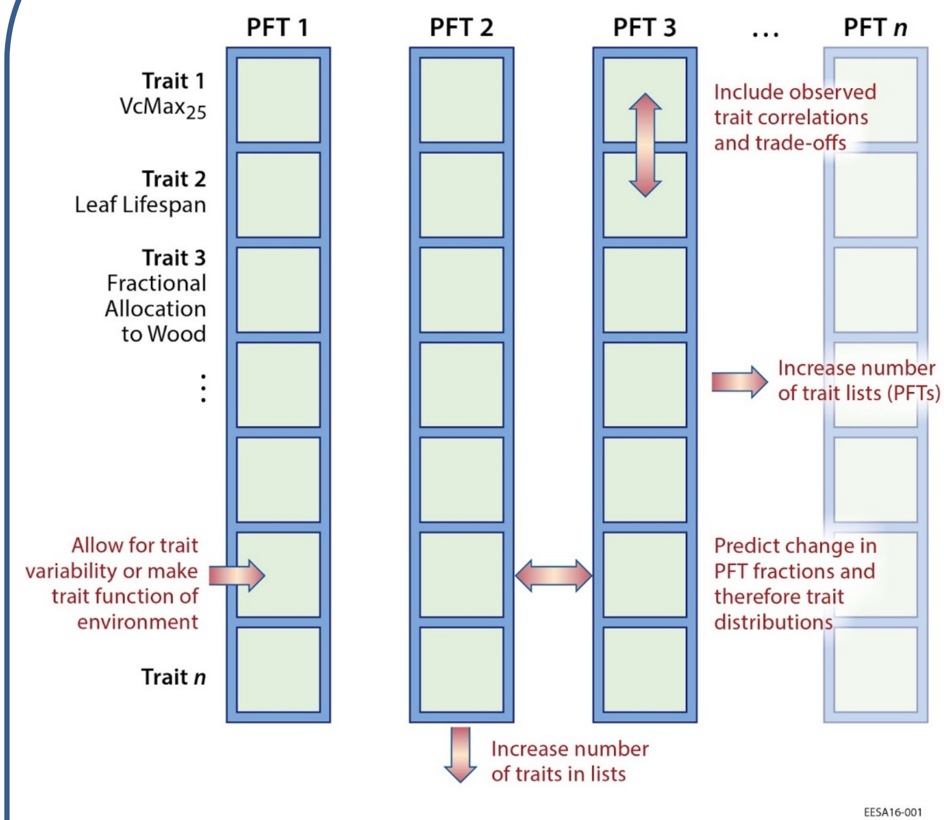
- What are key traits for climate change?
- What are optimal methods to appropriately represent these climate factors (e.g. carbon, energy fluxes)?
- Are there innovative methods to identify an optimal trait-framework?
- At what point and in what manner does it make sense to incorporate further "trait" complexity into global models?



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

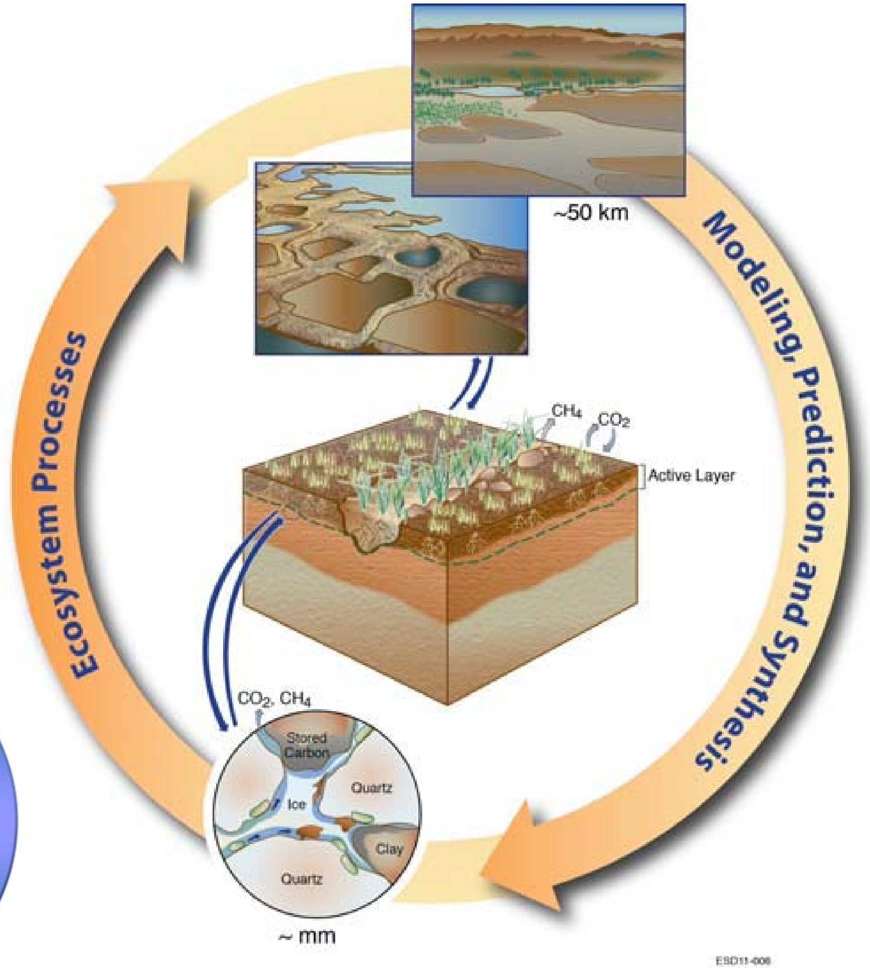
Next Steps

- Incorporate further trait observations important to well-understood processes, such as plant water stress, into ESMs
- Carefully target key opportunities to collect trait data on emerging model development areas, such as belowground processes
- Novel longer term objectives include representing dynamic trait filtering in response to environmental change.
- Convene a “working workshop” to develop new trait modeling approaches using well developed trait data; include modelers, theoreticians and observationalists



Earth system models define plant functional types (PFTs) as a list of values for the suite of plant traits that govern processes represented in the models. A variety of strategies (shown here with red arrows) have been proposed to better represent plant trait variation and dynamic responses of traits to global changes.

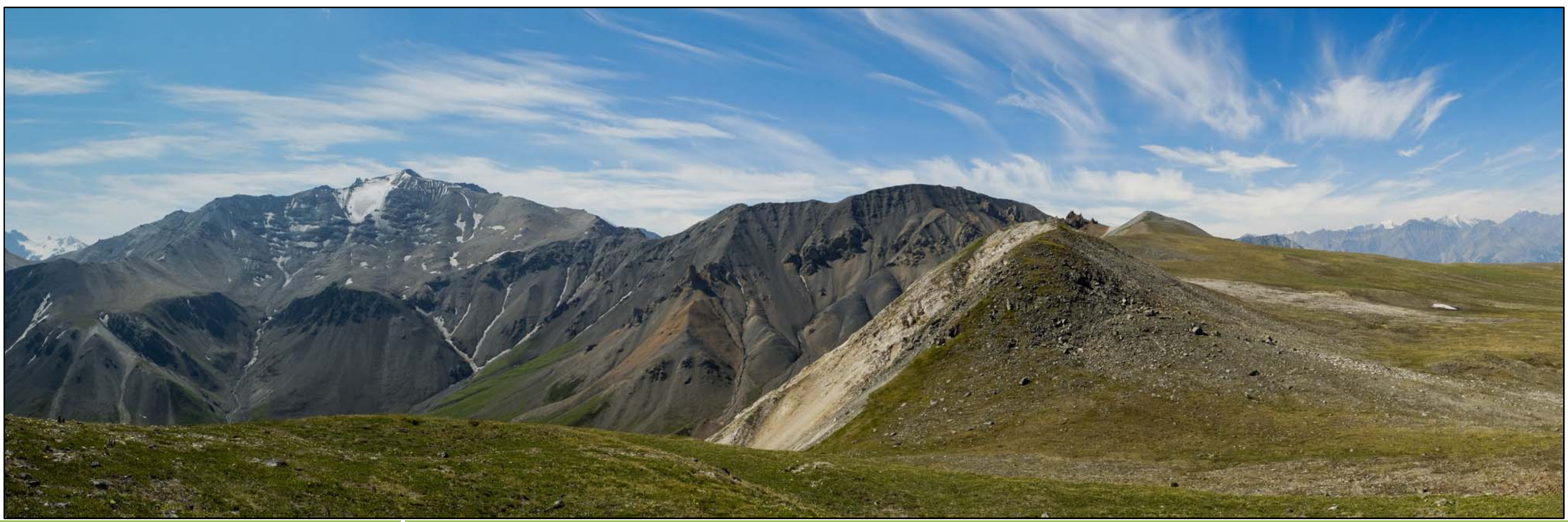
Engaging the Experimental and Modeling Communities

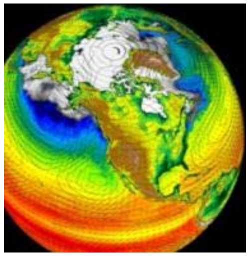


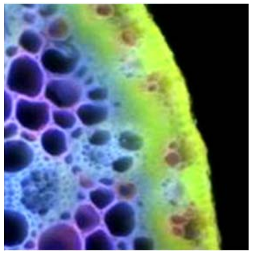
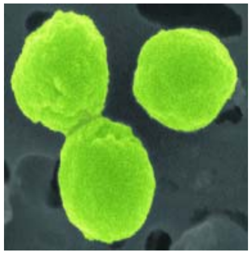
ACME
Accelerated Climate Modeling for Energy

Products

- EOS article (late March)
- Special Issue in New Phytologist *"Trait-based methods to represent ecosystem processes in land models and climate models"*
  - ~10 papers will be submitted in June
- Workshop executive summary due mid-April
- ACME-NGEE Collaboration Meeting





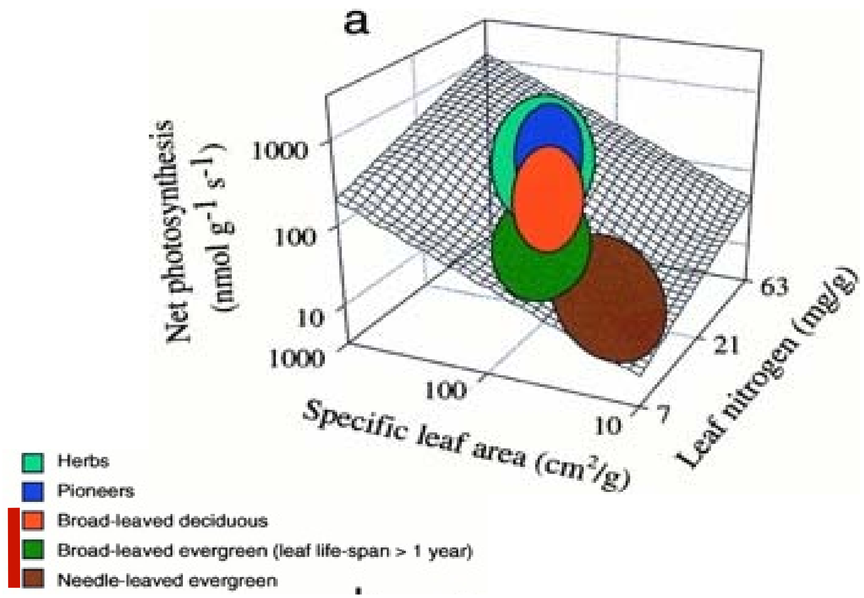




Questions?

Dan Stover (Daniel.Stover@science.doe.gov)

Dorothy Koch (Dorothy.Koch@science.doe.gov)

Backup Slides



Reich, PB, MB Walters & DS Ellsworth (1997) **From tropics to tundra: Global convergence in plant functioning.** Proc. Natl. Acad. Sci. USA 94, 13730-13734

Don’t turn to the Dark Side

Breakout 1

Plant functional traits and trait tradeoffs across species, PFTs, and biomes

- Re-visit the concept of traits, the development and key findings of functional trait ecology, and what we know to date about the strengths and weaknesses of a trait-based approach.
  - How general are relationships between suites of traits across spatial scales (within biomes, between biomes, along climate gradients), time, or organismal groups (individuals, species, populations, communities)? What is the relationship of these traits to growth and persistence?
  - Plant functional traits and their relationship to ecosystem processes (observations and models).
  - Match or mis-match? Are the traits we have data on the ones that we want? Are we missing key traits useful to ecosystem and land surface modeling?
  - If we wish to model system-scale processes, how do we deal with community means and variance? In essence, what trait metrics tell us the most about ecosystem-scale processes? How do quantitative descriptors of traits, such as mean, variance, skewness, and range affect ecosystem processes? In addition how does the composition of different trait mixtures, e.g. the structure of the distribution of a collection of traits, affect ecosystem processes?
  - How to best represent joint effects of traits and environmental responses (e.g. short- and long-term temperature response functions) in models?

Breakout 2

How plant traits are represented in models today, and novel approaches to representing dynamic plant traits in the next-generation of models

- Discuss these modeling strategies, how they differ from each other and from classic dynamic vegetation models.
  - The meaning, usefulness, and limitations of the PFT concept.
  - Approaches to maintaining coexistence and functional diversity in models.
  - Correlation vs competition approaches to representing dynamic plant traits.
  - How to best use trait database information to inform models?
  - Given sensitivity of existing models, what trait observations are highest priority?

Breakout 3

Datasets to inform dynamic plant trait models

- Discuss observations and experimental data (above- and belowground) needed to fill gaps in our current understanding and model representation of plant functional traits.
  - What are the availability of above- and belowground trait data for model parameterization across the globe?
  - How can we link above- and belowground trait data collection and interpretation?
  - How can we use statistical methodology to gap-fill data missing data?
  - What is the availability of data for model benchmarking or validation (remote-sensing, eddy flux) across the globe?
  - Where should the next-generation of measurements focus (e.g., in biomes underrepresented in current databases, measurement gaps identified by empiricists, processes that models find are highly-sensitive)?

Breakout 4

The consequences of including dynamic plant traits in Earth system models

- Address the availability of datasets at the global scale to initialize models with dynamic plant traits, the availability and interpretation of forcings, and the development of simulation experiments that help to assess the influence of dynamic trait representation on climate prediction in terms of both system feedbacks and metrics of simulation fidelity.
  - How will we initialize Earth system models with dynamic plant traits at the global scale? Do we understand the present-day distribution of traits and the factors that determine trait-climate-demography relationships well enough to initialize our models?
  - What is the role of trait diversity compared with better constraints on trait values?
  - How will dynamic trait models interact with land-use and land cover change forcings, increases in atmospheric CO_2, future nitrogen deposition, and future changes in climate?
  - How do we expect biogeochemistry-climate system feedbacks to be altered by the introduction of dynamic traits? Are there new types of feedbacks that the current approaches have not considered that will be introduced with dynamic plant trait models?
  - How do we evaluate the degree to which introduction of dynamic plant traits improves (or degrades) climate prediction skill for Earth system models?