ABoVE Modeling Working Group

Joshua B. Fisher (NASA/JPL; WG Lead)

Scott Goetz (WHRC), Daniel Hayes (U.Maine), Deborah Huntzinger (NAU), John Kimball (U.Montana), Chip Miller (NASA/JPL), Walt Oechel (SDSU), Brendan Rogers (WHRC), Kevin Schaefer (NSIDC), Christopher Schwalm (WHRC), Hank Shugart (U.Virginia), Jackie Shuman (U.Virginia)

ARCTIC BOREAL VULNERABILITY EXPERIMENT

NASA

Background

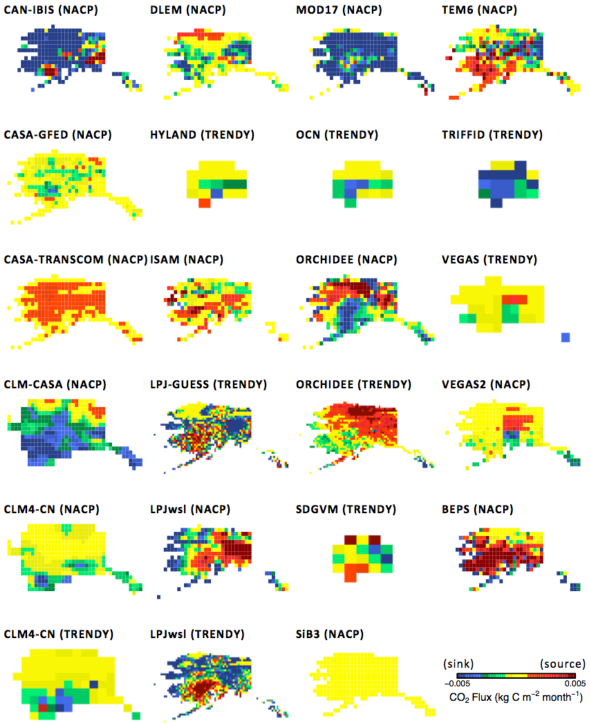
- The Arctic-Boreal Region (ABR) is warming and experiencing associated disturbances at a **much greater rate and magnitude** than is the rest of the planet;

AND…

- Because of the **sensitivity** of the cryosphere to warming, ABR ecosystem processes are highly **vulnerable** to change;

BUT…

- Current Earth System Models are **highly uncertain** in representing and predicting ABR ecosystem-climate feedbacks.

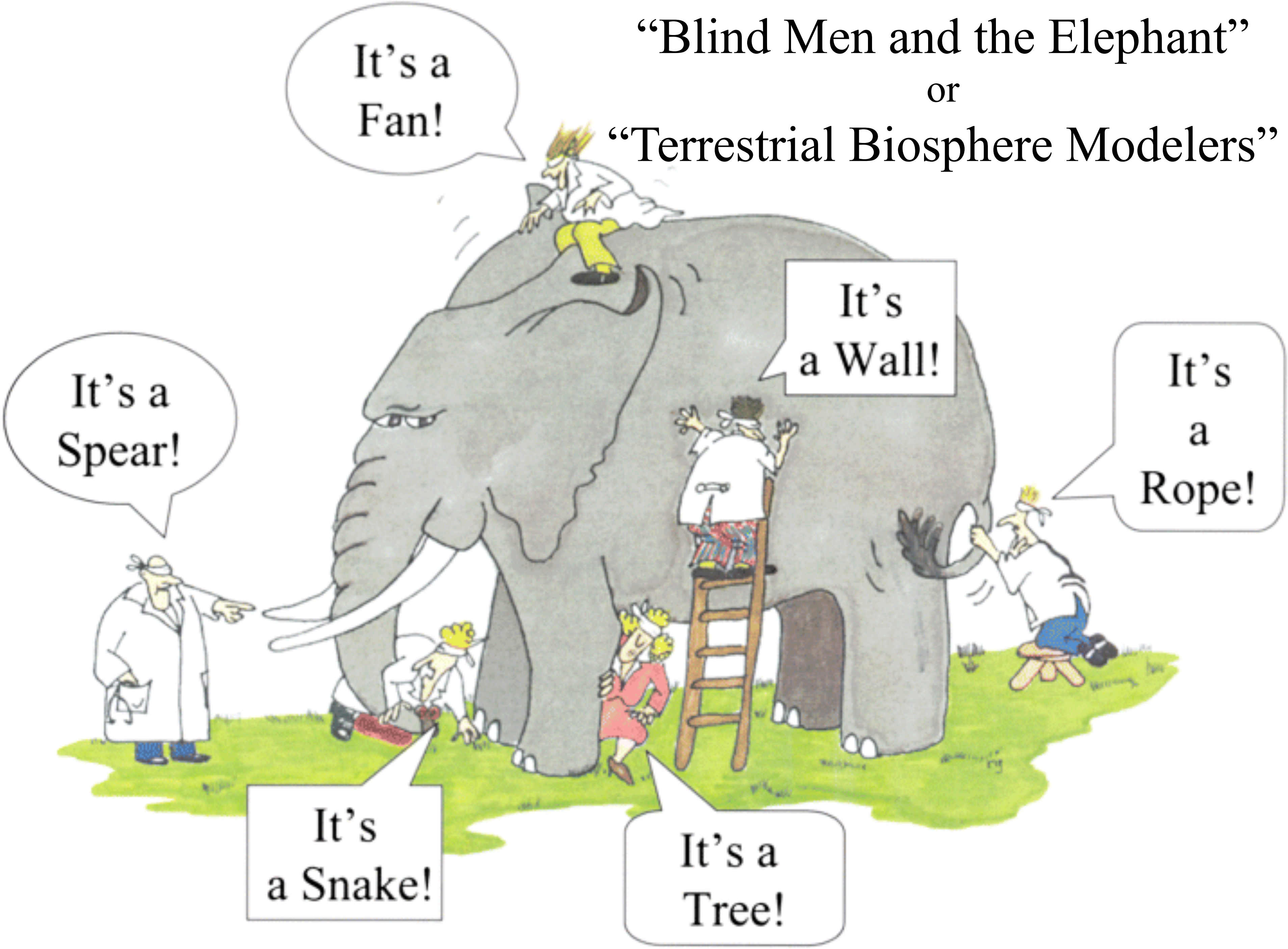


Fisher et al., 2014. Carbon cycle uncertainty in the Alaskan Arctic. *Biogeosciences* 11(15): 4271-4288.

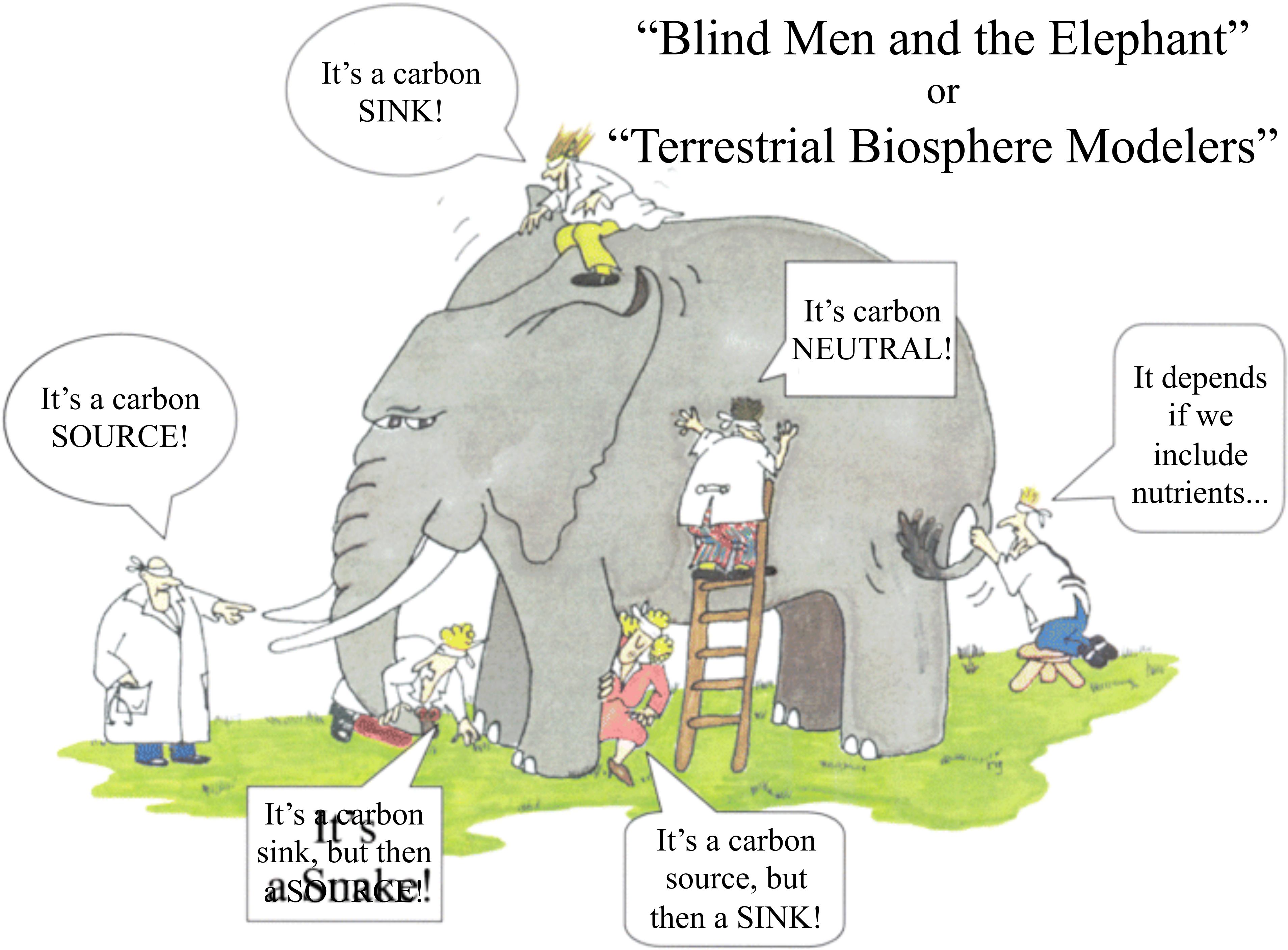
THEREFORE…

- We propose to **improve ABR model representation and confidence** by providing a framework for driving and evaluating biosphere models with ABoVE data.

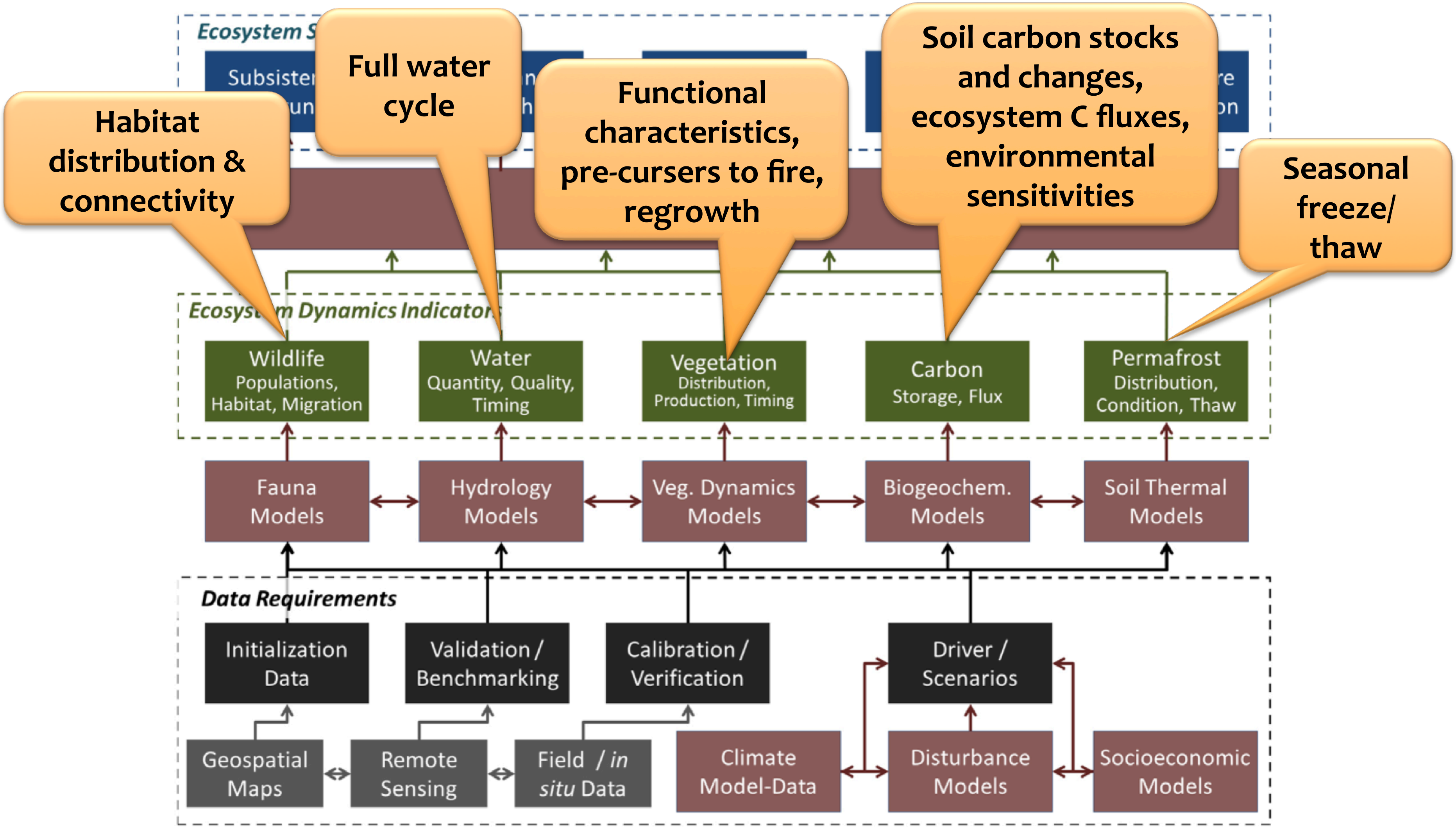
"Blind Men and the Elephant"
or
"Terrestrial Biosphere Modelers"



“Blind Men and the Elephant”
or
“Terrestrial Biosphere Modelers”



Science Questions



Science Questions

How is flora responding to changes in biotic and abiotic conditions, and what are the impacts on ecosystem structure and function?

TBMs are mature in representing floral changes to environmental conditions through structure and function, yet uncertainties remain large in the ABR. Models will be evaluated against remotely sensed structural and functional observations. A critical evaluation will assess decadal greening/browning and biome expansion/contraction. Individual-scale tree models target this question directly.

How is fauna responding to changes in biotic and abiotic conditions, and what are the impacts on ecosystem structure and function?

TBMs do not typically explicitly represent faunal characteristics; however, habitat distribution and connectivity are represented in TBMs, and the models will be evaluated for these characteristics.

What processes are contributing to changes in disturbance regimes and what are the impacts of these changes?

Fire (and, to a lesser extent, insects and pathogens) is included in many TBMs. While fire sparks are difficult to model in an exact sense (they are typically represented as probabilistic in prognostic models), the *pre-cursers* to fire and extent (fuel load, quality, distribution, moisture) and *regrowth dynamics* should be captured in models. TBMs will be evaluated in their representation of fire pre-cursers prior to remotely sensed fire observations and regrowth dynamics relative to vegetation remote sensing observations. Moreover, models will be evaluated for burned area/frequency over decadal temporal integration periods. Finally, burn severity, as linked to the pre-cursers, will be evaluated as a high quality burn severity dataset will be produced in ABoVE. While spatial data on wildfire occurrence, extent, and severity are readily available across Alaska and Canada, information on other important disturbances such as insects, pathogens, rapid thaw events (thermokarst) and land use change are not. As modeling representatives, we will engage with the ABoVE Science Team early in the campaign planning process to solicit existing and new data and research activities related to the more comprehensive suite of disturbance types from investigators working across the various Research Areas of the Domain.

How are the magnitudes, fates, and land-atmosphere exchanges of carbon pools responding to environmental change, and what are the biogeochemical mechanisms driving these changes?

TBMs suffer in representing soil carbon pools well. We will evaluate with critical priority TBM ability to capture soil carbon stocks and changes, and environmental sensitivities leading to changes.

What processes are controlling changes in the distribution and properties of permafrost and what are the impacts of these changes?

Modeled soil thermal and hydraulic properties will be evaluated against the NASA MEaSUREs 25 km historical freeze/thaw product. Some of the uncertainty with respect to modeled permafrost is outside the control of model parameterization, instead lying in the uncertainty inherent in the forcing data (e.g., temperature, radiation). Nonetheless, models will be evaluated in their qualitative ability to represent seasonal dynamics of freeze/thaw.

What are the causes and consequences of changes in the hydrologic system, specifically the amount, temporal distribution, and discharge of surface and subsurface water?

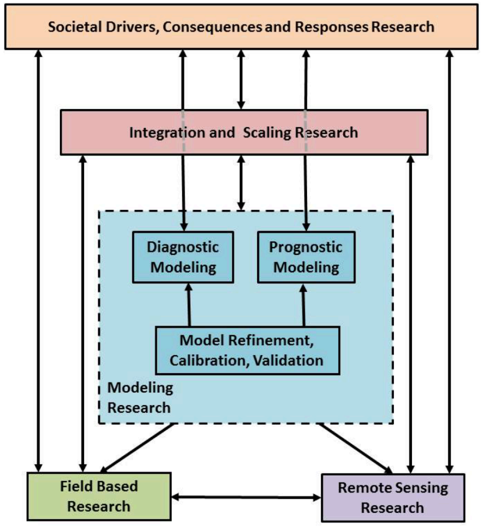
TBMs have fully coupled hydrological cycles, and can thus be evaluated directly against remotely sensed hydrological observations.

How are environmental changes affecting critical ecosystem services – natural and cultural resources, human health, infrastructure, and climate regulation – and how are human societies responding?

This question will not be directly addressed in the scope of this Working Group. In the final year, we will provide direction on how to address this goal from a modeling perspective in ABoVE Phase II.

Science Objectives

The overarching objective is to **evaluate and improve model performance of ABR ecosystem dynamics focusing on critical data gaps** in initializing, driving, and validating process-based simulations for the ABoVE domain.



Our Modeling Working Group coalesces a suite of modeling teams and model elements within field- and/or remote sensing-based teams within the ABoVE Science Team to provide a **meta-synthesis of TBM requirements for the ABoVE campaign data collection**.

Modeling Approaches: Models

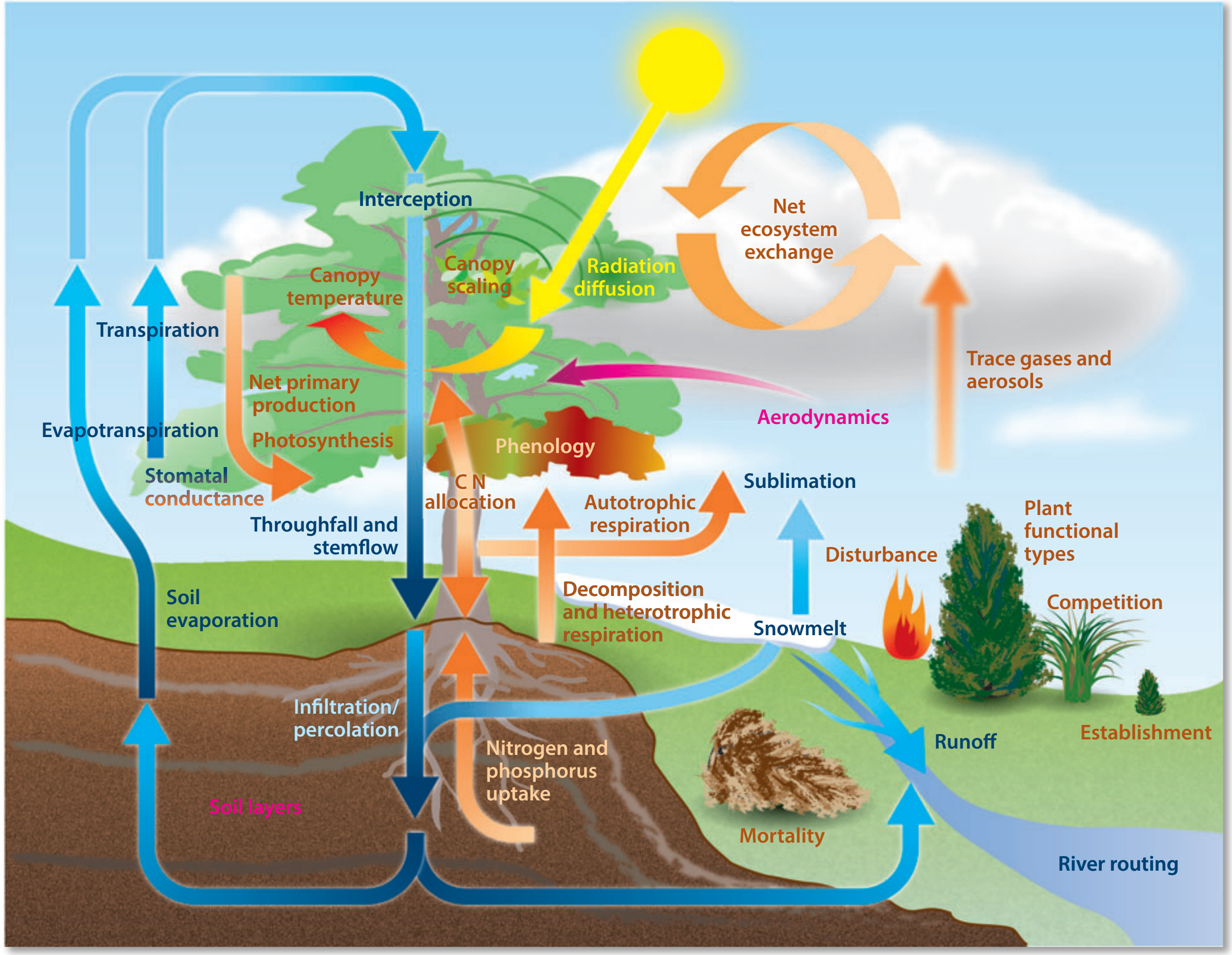


Figure 2

The terrestrial biosphere as represented in terrestrial biosphere models.

Fisher et al., 2014. Modeling the terrestrial biosphere. *Annual Review of Environment and Resources* 39: 91-123.

Modeling Approaches: Models

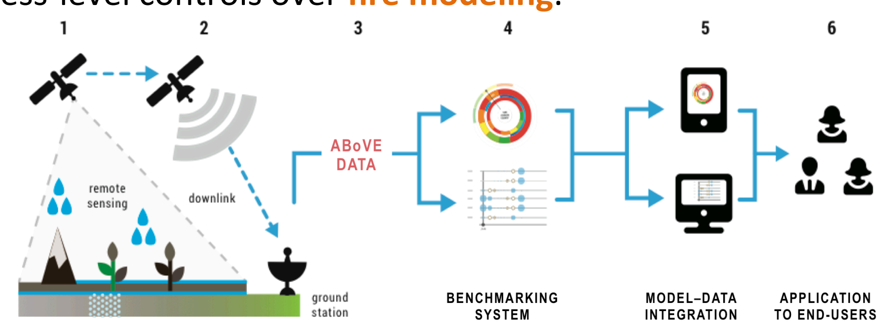
Model	Collaborator(s)	Selected Reference
aDVGM2	Simon Scheiter, Senckenberg Gesellschaft für Naturforschung, Germany	[*Scheiter and Higgins*, 2009]
Biome-BGC	Weile Wang, NASA Ames, USA	[*Thornton et al.*, 2002]
CABLE	Yiqi Luo, Oklahoma University, USA	[*Wang et al.*, 2010]
CLASS-CTEM	Altaf Arain, McMaster University, Canada	[*Huang et al.*, 2011]
CLM4	Charles Koven, LBNL, USA	[*Koven et al.*, 2015]
CLM4-VIC	Maoyi Huang, PNNL, USA	[*Li et al.*, 2011]
DLEM	Hanqin Tian, Auburn University, USA	[*Tian et al.*, 2014]
DVM-DOS-TEM	Hélène Genet, University of Alaska Fairbanks, USA	[*Euskirchen et al.*, 2009]
ecosys	Robert Grant, University of Alberta, Canada	[*Grant et al.*, 2009]
GTEC	Dan Ricciuto, ORNL, USA	[*Ricciuto et al.*, 2011]
Hyland	Joshua Fisher, NASA JPL, USA	[*Levy et al.*, 2004]
ISAM	Atul Jain, University of Illinois at Urbana-Champaign, USA	[*Jain and Yang*, 2005]
JeDI	Ryan Pavlick, NASA JPL, USA	[*Pavlick et al.*, 2013]
JULES	Anna Harper, University of Exeter, UK	[*Best et al.*, 2011]
LPJ-GUESS	Ben Smith & Paul Miller, Lund University, Sweden	[*Smith et al.*, 2001]
LPJ-wsl	Ben Poulter, Montana State University, USA	[*Sitch et al.*, 2003]
MC2	Dominique Bachelet, Conservation Biology Institute, USA	[*Peterman et al.*, 2014]
Noah-MP	Zong-Liang Yang, University of Texas, USA	[*Niu et al.*, 2011]
ORCHIDEE	Philippe Ciais, LSCE, France	[*Krinner et al.*, 2005]
SiB3	Ian Baker & Katherine Haynes, Colorado State University, USA	[*Baker et al.*, 2008]
SiB4	Ian Baker & Katherine Haynes, Colorado State University, USA	[*Baker et al.*, 2008]
SiBCASA	Kevin Schaefer, NSIDC, USA	[*Schaefer et al.*, 2008]
SSiB	Yongkang Xue, UCLA, USA	[*Xue et al.*, 1991]
TECO	Yiqi Luo, Oklahoma University, USA	[*Zhou and Luo*, 2008]
TEM6	Daniel Hayes, University of Maine, USA	[*Hayes et al.*, 2011]
TRIPLEX-GHG	Changhui Peng, University of Quebec at Montreal, Canada	[*Peng et al.*, 2013]
VEGAS2.2	Ning Zeng, University of Maryland, USA	[*Zeng et al.*, 2005]
VISIT	Akihiko Ito, National Institute for Environmental Studies, Japan	[*Ito*, 2010]

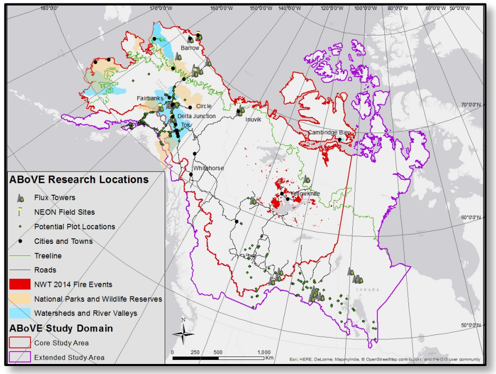
Modeling Approach: Detailed

Foundational [Y1]	Structural [Y2]	Synthesis [Y3]
Initial evaluations	Framework construction: data assembly & org.	Simulation benchmarking
Identify & prioritize process uncertainties	**Model–data integration & refinement**	**Evaluate model progress**
Identify & prioritize data gaps	Model simulation	**Develop ABoVE modeling for Phase II**

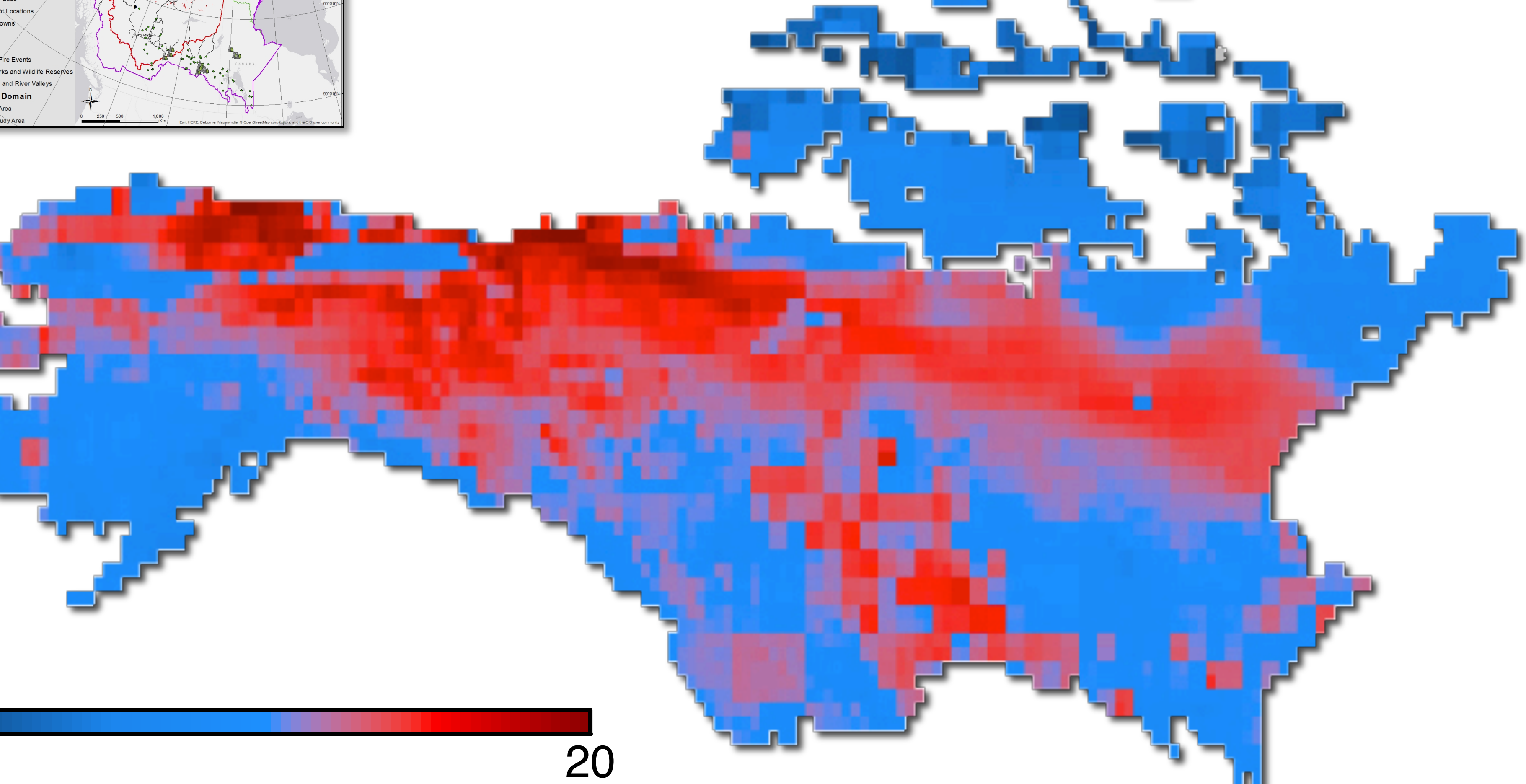
ABoVE modeling activities also include model analyses and developments focused on **targeted variables or ecosystem dynamics**:

- **Tree-level modeling** of forest productivity and demographics will address how mixed species stands are responding to climate and environment specifically trends in boreal tree mortality, as well as potential range expansion across the ABoVE domain. Analysis of species-scale models will help unify common trends that can be incorporated into PFT-based TBMs.
- We will use a satellite data-driven **carbon model** to evaluate CO_2 and CH_4 fluxes and **Light-use efficiency modeling**.
- ABoVE is investigating process-level controls over **fire modeling**.





Domain

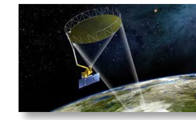


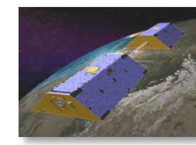
Multimodel std. dev TotSoilCarb
(2003; kg C m^{-2})

Spaceborne & Airborne Remote Sensing

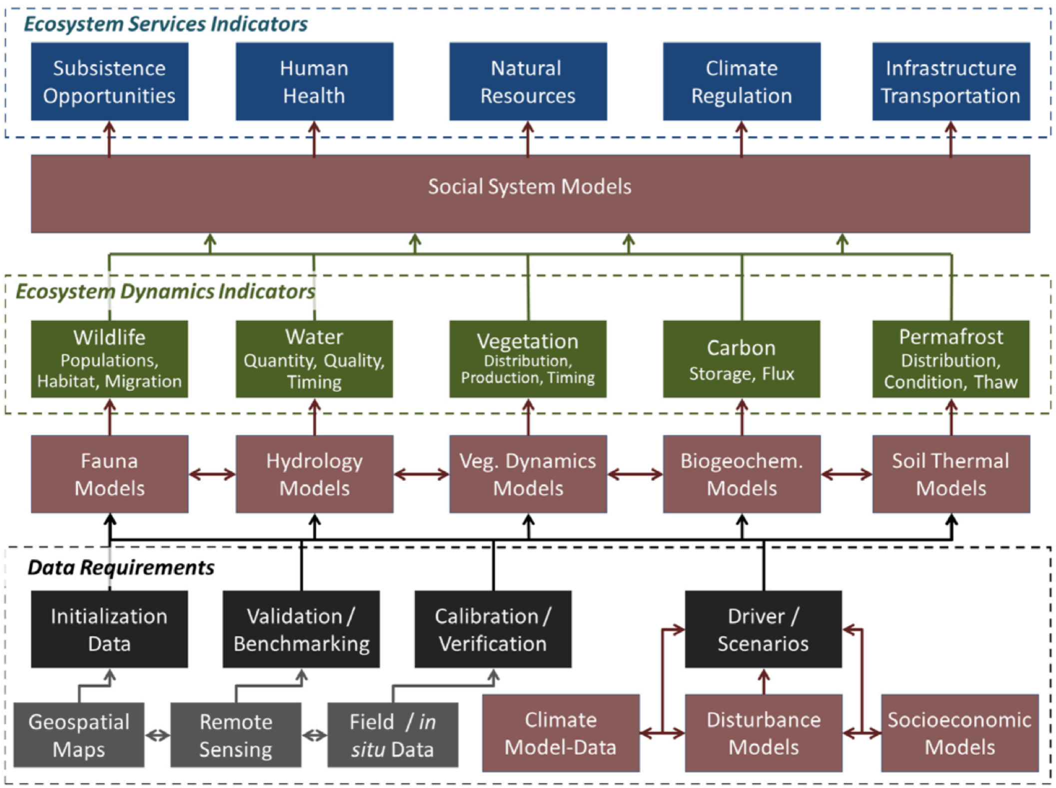
Table 1. Benchmarking data to be used in our project spans the full range of Indicators for ABoVE ecosystem dynamics.

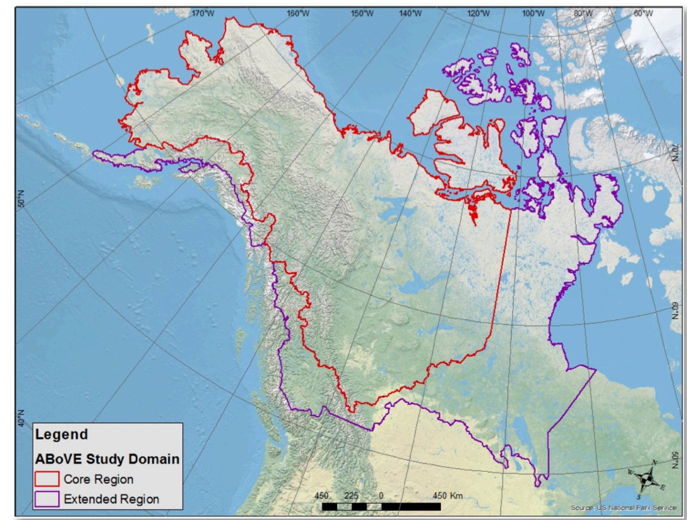
Variable	Dataset	Coverage
Carbon Dynamics		
NDVI, EVI, LAI, fAPAR, NPP	MODIS	Global; weekly; 2002-2013
Soil Carbon Stocks / Depth	Pedons	Regional; static; 100 km
Soil Carbon Residence Time	Incubations	Local; static; 1 m
CO_2 fluxes	AmeriFlux, MPI-BGC	Local/global; hourly; 1 km
CO_2, CH_4 concentration	CARVE, GOSAT, OCO-2/3, SCIAMACHY	Regional/global; weekly; 1-3 km
Biomass	ICESat/GLAS, G-LiHT, GEDI, CFS	Regional/global; static; 0.25-1 km
Canopy height	ICESat/GLAS, G-LiHT, GEDI	Regional/global; static; 1 km
Water Dynamics		
Soil moisture	SMAP, SMOS, ISMN	Local/regional/global; <weekly; 3-9 km
Evapotranspiration	MODIS, ECOSTRESS	Regional/global; <weekly; 0.05-1 km
Total Water Column	GRACE	Global; monthly; >100 km
Snow characteristics	NASCN, NOAA Snow Cover, MODIS	Regional/local; weekly-annually; 1 km
Energy Dynamics		
Soil, surface temperature	GTN-P, BOREAS, MODIS	Local/regional/global; weekly-static; 1 km
Freeze/thaw	SMAP	Regional/global; <weekly; 3 km
Active layer depth	InSAR, CALM/GTN-P	Regional; static; 1 m
Albedo	MODIS, VIIRS	Global; weekly; 1 km
Fire counts, burnt area	MODIS	Global; weekly; 1 km
Net radiation	MODIS	Global; weekly; 1 km

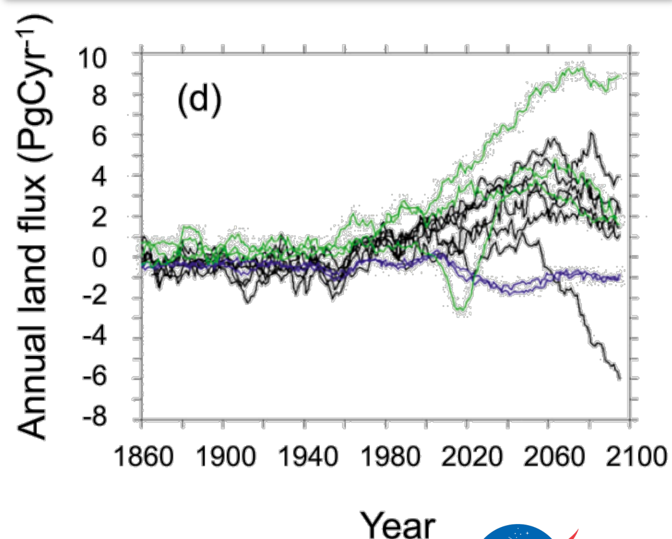




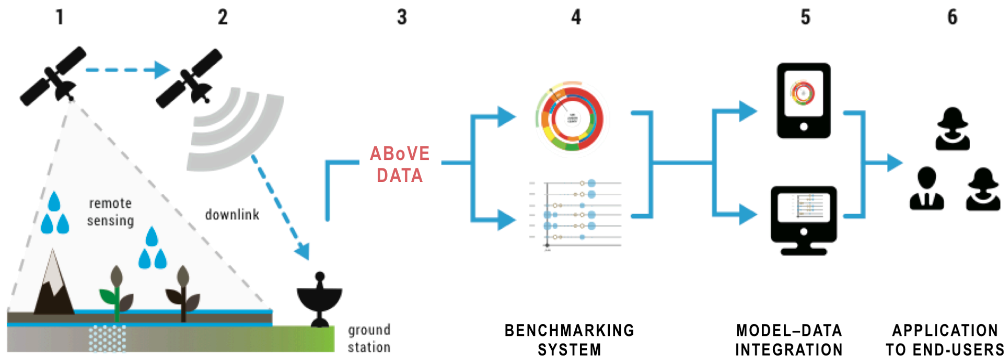
Geospatial Data Products







Other expected products / outcomes



- "**Lessons Learned**" report to guide preparations for ABoVE Phase II modeling research addressing **Ecosystem Services** objectives.
  - Direction and guidance for new and continued field and remote sensing data collections, model refinements and developments, and opportunities for integration across multiple modeling teams and other research activities within ABoVE.
  - In Year 3 we will begin to establish the links to the Ecosystem Services datasets and modeling requirements, following the foundation and setup we will establish throughout Phase I. **For example, this includes using permafrost projections to inform infrastructure decisions (e.g., roads, pipelines built on thawing permafrost).** The focus will be on engagement with interdisciplinary research teams toward a goal of science–data interoperability, including linking TBM frameworks with social systems to develop hypotheses related to ABoVE's Ecosystem Services Objectives.

Institutional Collaborations

Model	Collaborator(s)
aDVGM2	Simon Scheiter, Senckenberg Gesellschaft für Naturforschung, Germany
Biome-BGC	Weile Wang, NASA Ames, USA
CABLE	Yiqi Luo, Oklahoma University, USA
CLASS-CTEM	Altaf Arain, McMaster University, Canada
CLM4	Charles Koven, LBNL, USA
CLM4-VIC	Maoyi Huang, PNNL, USA
DLEM	Hanqin Tian, Auburn University, USA
DVM-DOS-TEM	Hélène Genet, University of Alaska Fairbanks, USA
ecosys	Robert Grant, University of Alberta, Canada
GTEC	Dan Ricciuto, ORNL, USA
Hyland	Joshua Fisher, NASA JPL, USA
ISAM	Atul Jain, University of Illinois at Urbana-Champaign, USA
JeDI	Ryan Pavlick, NASA JPL, USA
JULES	Anna Harper, University of Exeter, UK
LPJ-GUESS	Ben Smith & Paul Miller, Lund University, Sweden
LPJ-wsl	Ben Poulter, Montana State University, USA
MC2	Dominique Bachelet, Conservation Biology Institute, USA
Noah-MP	Zong-Liang Yang, University of Texas, USA
ORCHIDEE	Philippe Ciais, LSCE, France
SiB3	Ian Baker & Katherine Haynes, Colorado State University, USA
SiB4	Ian Baker & Katherine Haynes, Colorado State University, USA
SiBCASA	Kevin Schaefer, NSIDC, USA
SSiB	Yongkang Xue, UCLA, USA
TECO	Yiqi Luo, Oklahoma University, USA
TEM6	Daniel Hayes, University of Maine, USA
TRIPLEX-GHG	Changhui Peng, University of Quebec at Montreal, Canada
VEGAS2.2	Ning Zeng, University of Maryland, USA
VISIT	Akihiko Ito, National Institute for Environmental Studies, Japan

Institutional Collaborations?

Arctic Landscape Conservation Cooperative

Western Alaska LCC

Northwest Boreal
Landscape Conservation Cooperative

AK CSC
Alaska Climate Science Center

USGS
science for a changing world
Alaska Science Center

Institutional Collaborations?