Next-Generation Ecosystem Experiments (NGEE Arctic)

An integrated model-data activity focused on reduced uncertainty and improved climate prediction at regional to global scales

BER Town Hall Meeting
December 8, 2011

NGEE Arctic: Goals

Improve our understanding of the structure and function of terrestrial ecosystems in response to climate change:

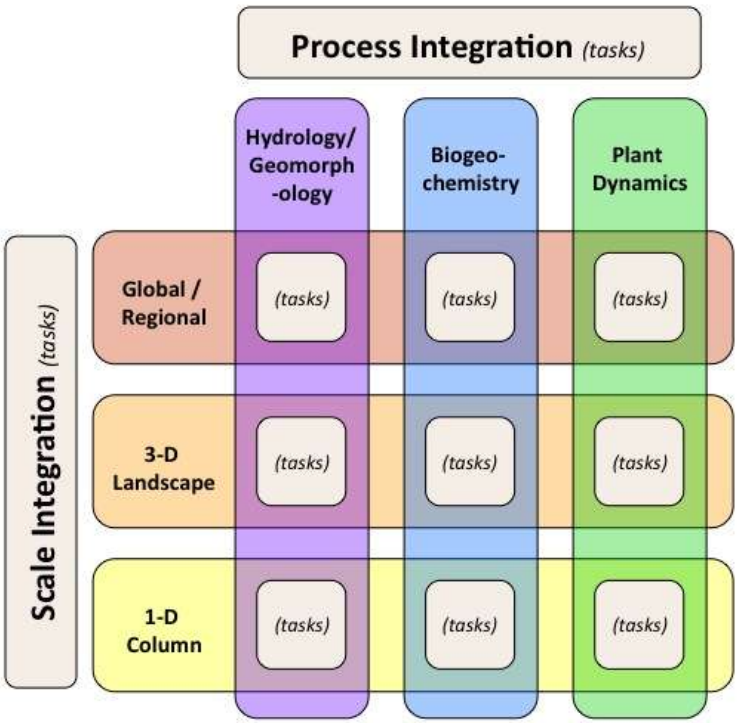
- **Geomorphology** (e.g., surface-subsurface interactions)
- **Hydrology** (e.g., vertical and lateral)
- **Biogeochemistry** (e.g., CN, CO_2 and CH_4)
- **Vegetation dynamics** (e.g., plant functional types)
- **Energy** (e.g., permafrost dynamics, albedo)

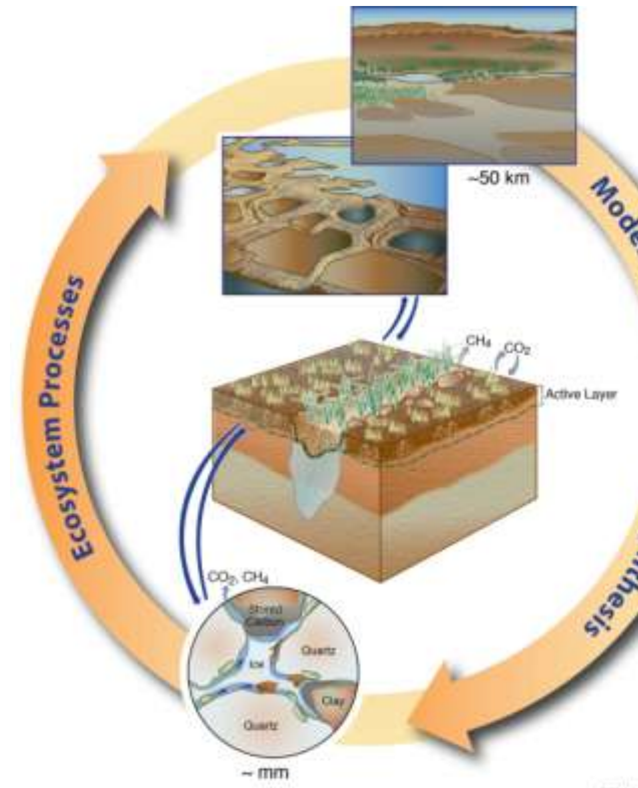
Incorporate into existing models (CLM 4.0) for improved prediction of carbon cycle processes and net energy balance feedbacks on Earth's climate, and

Develop a process-rich land model in which the evolution of Arctic ecosystems in a changing climate can be modeled at the scale of a high-resolution Earth System Model grid cell.

Overarching Science Question:

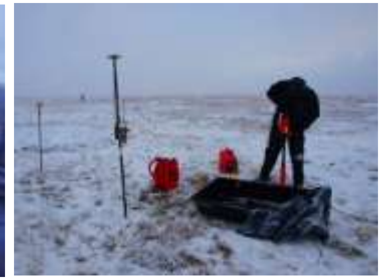
"How does permafrost degradation, and the associated changes in landscape evolution, hydrology, soil biogeochemical processes, and plant community succession, affect feedbacks to the climate system?"



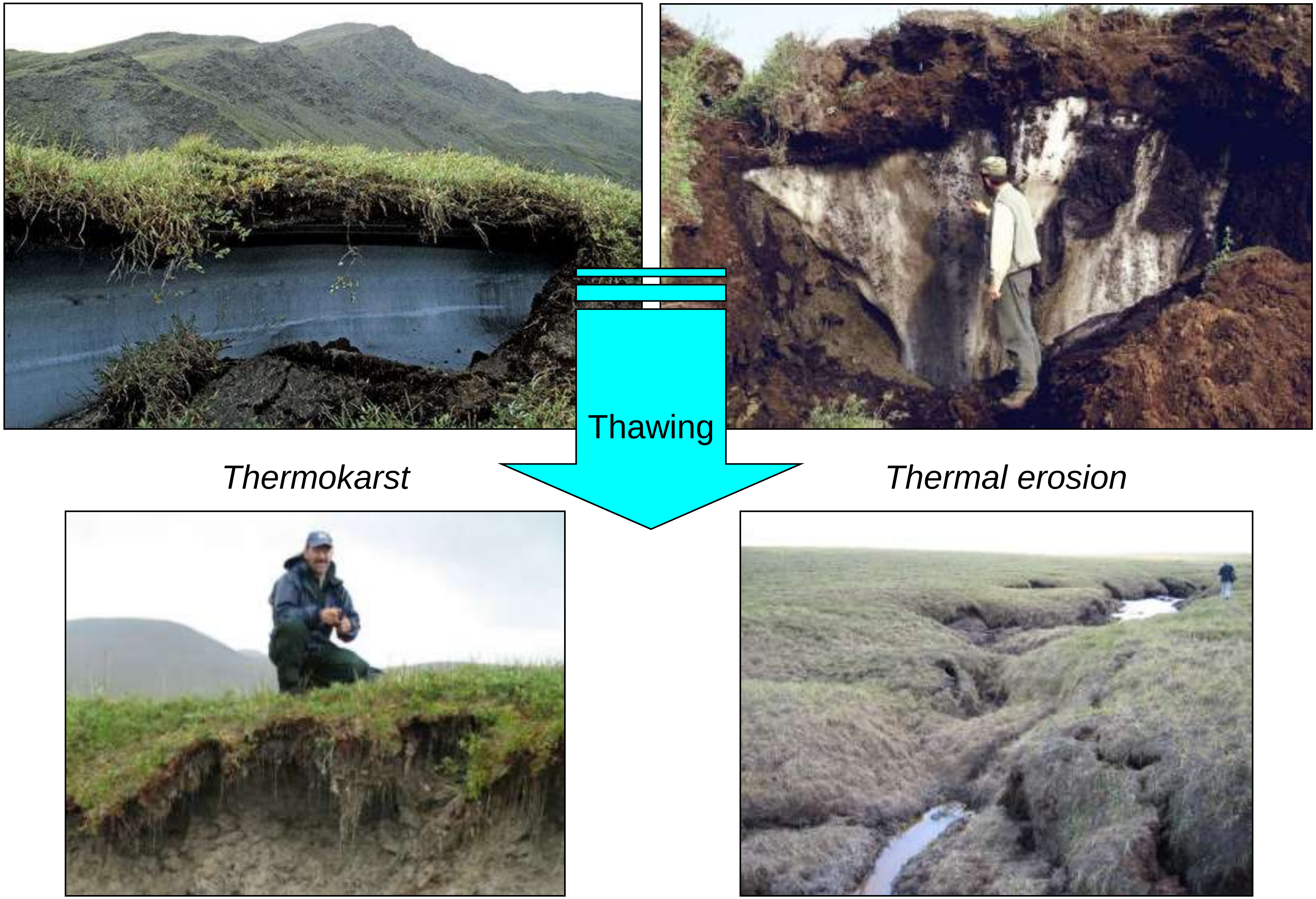


Model-driven approach that recognizes the complex and interconnected nature of Arctic surface and subsurface systems

Properties and Processes are Important

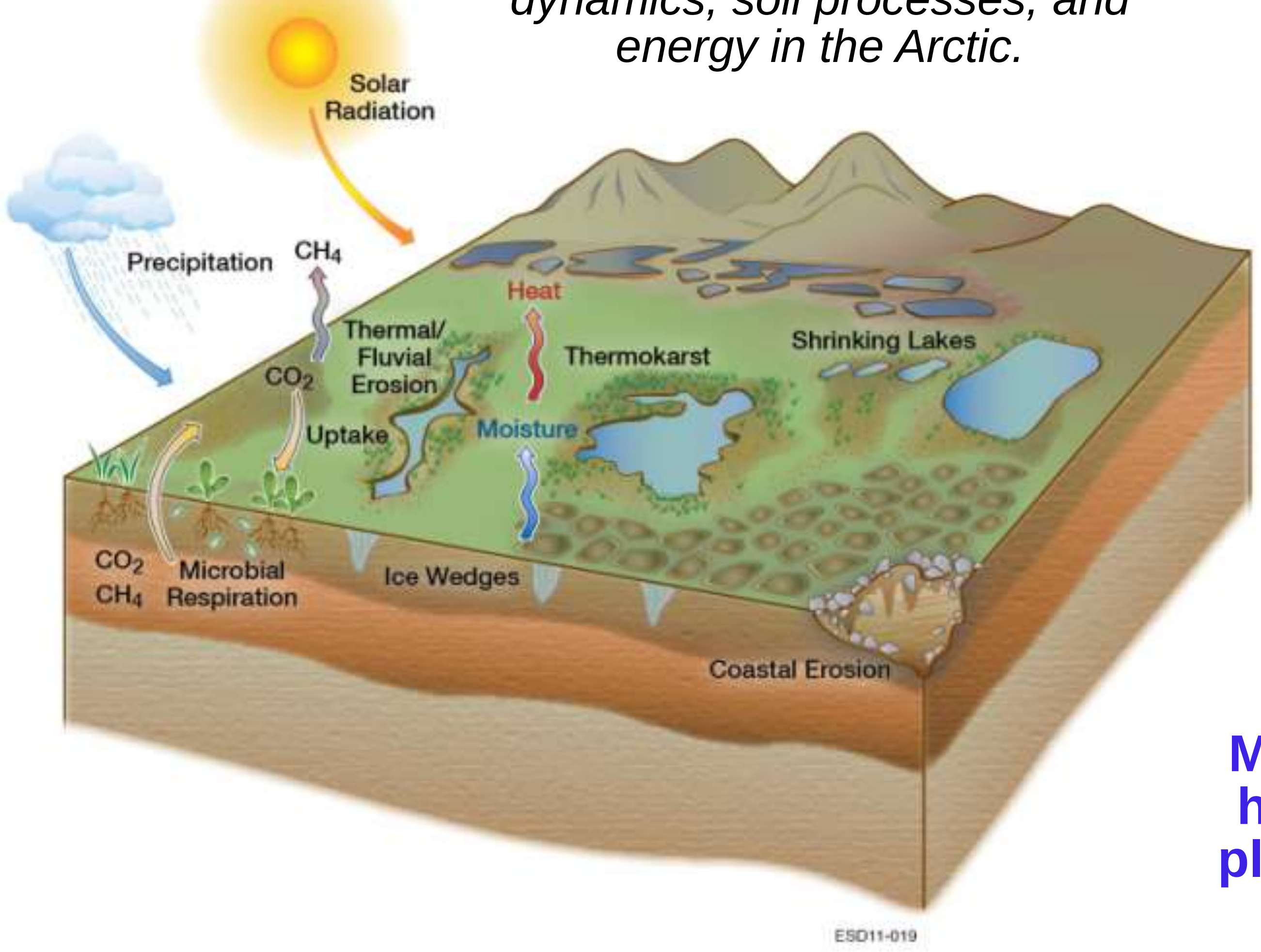


Surface-subsurface interactions and the consequences for landscape evolution.



Landscapes in transition

...integrates hydrology, vegetation dynamics, soil processes, and energy in the Arctic.



Must understand mechanisms that underlie the processes that control carbon and energy transfer in the biosphere.

Must also understand how those processes play out in a changing landscape.

Hydrology and Geomorphology

Rationale: Improving climate change prediction in high-latitude systems requires an accurate understanding of permafrost dynamics along with geomorphic processes that control hydrology and underpin ecosystem, soil biogeochemistry, and land-atmosphere interactions.

Question: Does permafrost degradation lead to a predictable progression of landscape change, characterized by thermokarst development, increased heterogeneity in soil moisture and surface water distribution, and eventual large-scale drying of the landscape?

Task 1: Assess mechanical properties of permafrost and freeze-thaw deformation of soils; lateral and vertical flux of water.

Task 2: Quantify active layer thickness and depth of water table; preferential flow paths; characterize lateral flow patterns.

Task 3: Characterize surface topography and watershed-scale hydrologic fluxes and stocks; conduct high-resolution surveys of surface micro-topography.

Vegetation Dynamics

Rationale: Increasing dominance of shrubs over smaller statured tundra vegetation creates feedbacks to climate through changes in net energy balance and C fluxes; mechanisms uncertain.

Question: Does permafrost degradation and thermokarst formation promote increased availability of N within ecosystems, and if so, what is its role in driving plant competition, community composition, and transitions in the arctic landscape?

Task 1: Rates of microbial mineralization of organic compounds to ammonium and nitrate will be assessed; as will preferential uptake of N forms by plants.

Task 2: Nitrogen allocation within plants will be determined and related to photosynthesis; improved descriptions of plant functional types will be developed for inclusion into models.

Task 3: Leaf- and canopy-scale N concentrations determined by optical properties obtained through aircraft imaging spectroscopy; optical signatures evaluated for regional-scale prediction of GPP; variation analyzed in relationship to landscape patterns.

Biogeochemistry

Rationale: A predictive understanding of C transformation is needed, but does not yet exist given uncertainty in the biological and chemical reaction rates that are imposed by temperature and water.

Question 1: What is the primary variable that governs organic C degradation and the contribution of CO_2 or CH_4 to greenhouse gas emissions?

Question 2: Does organic C chemistry and geochemical interactions control microbial degradation in thawed permafrost?

Task 1: Fundamental controls on CO_2 and CH_4 fluxes from permafrost soils with an emphasis on depth-dependent processes; methane oxidation associated with microbial community structure.

Task 2: Soil water and redox potentials measured via lysimeters and groundwater wells; ^{14}C to determine age of organic C and advanced imaging to assess chemical structure.

Task 3: Conduct tower- and chamber-based CO_2 and CH_4 flux determinations.

Energy

Rationale: Energy budgets are fundamental to climate feedbacks. Models must incorporate land-surface properties associated with changes in net energy balance due to vegetation dynamics and thawing permafrost.

Question: Will permafrost degradation result in a net positive feedback to the climate system through changes in albedo and energy exchange?

Task 1: Heat capacity and related thermal properties of permafrost; determination of ice fraction during freeze-thaw cycles; and multi-phase modeling in support of measurements.

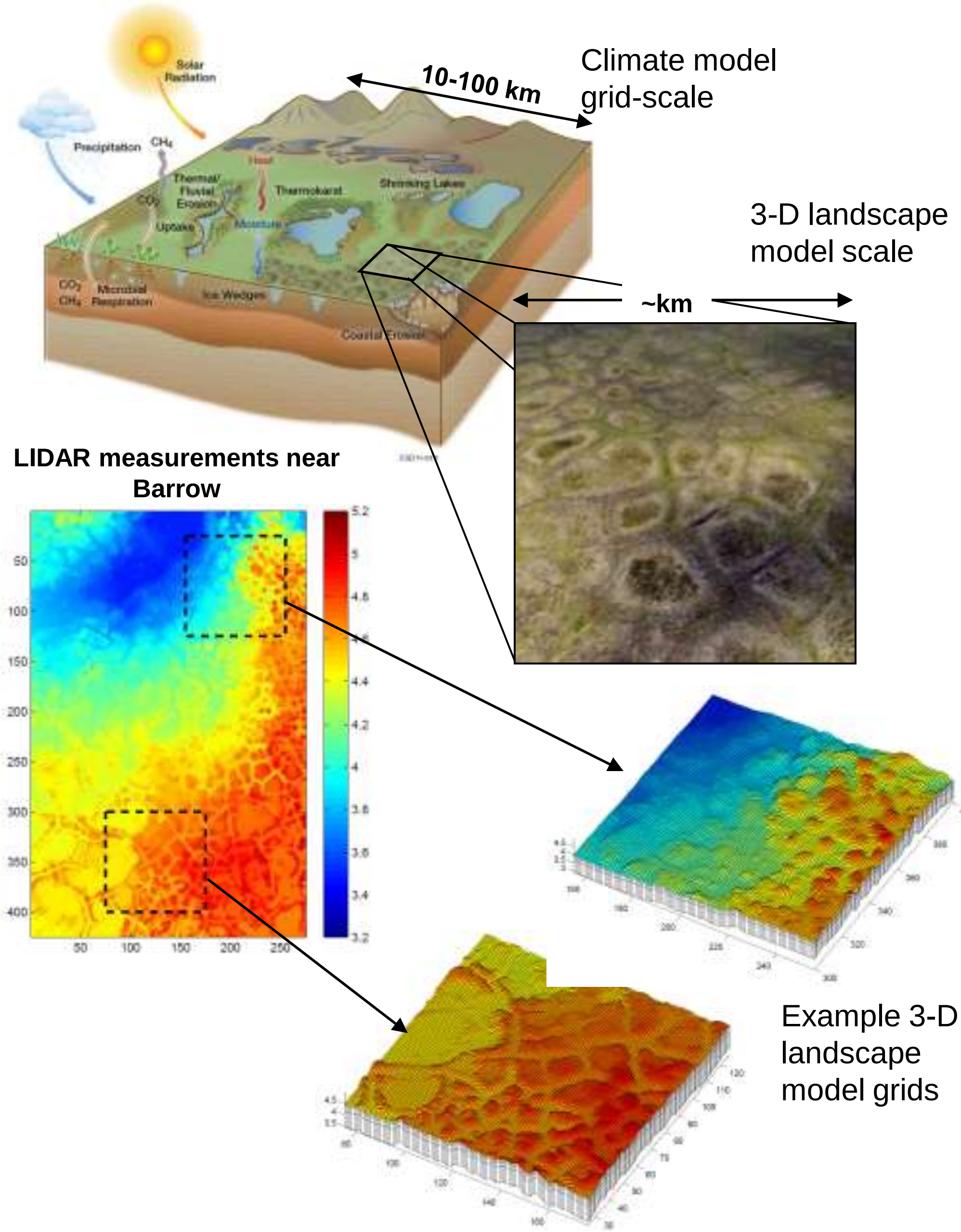
Task 2: Measure components of land-atmosphere energy fluxes (e.g., latent heat flux, sensible heat flux, shortwave radiation); albedo in relation to vegetation surveys and snow cover dynamics.

Task 3: Remote-sensing approaches to reflectance characteristics, skin surface temperature, and heat capacities using MODIS-class sensors; Quickbird satellite and it successor Worldview; and leverage investments of the ARM Program at Barrow.

3-D process-resolving Arctic tundra landscape simulator

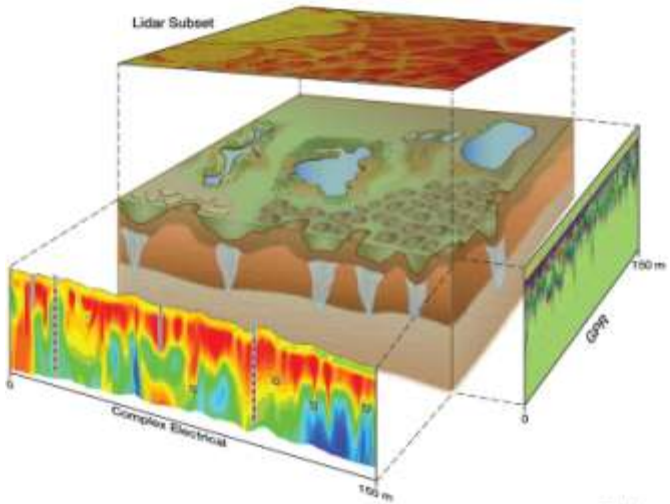
Process requirements

- Subsurface
  - Permafrost
  - Differential ice concentrations
  - Active layer
  - Biogeochemistry
- Surface
  - Deformable topography
  - Surface flow and dynamic flow paths
  - Snowpack dynamics
  - Vegetation dynamics
- Near-surface atmosphere
  - Canopy interactions with surface wind, humidity, temperature, and radiation balance
  - Influence of microtopography on snow dynamics, and shrub-snow interactions



Translation of information across scales or "scaling" is an important component of NGEE

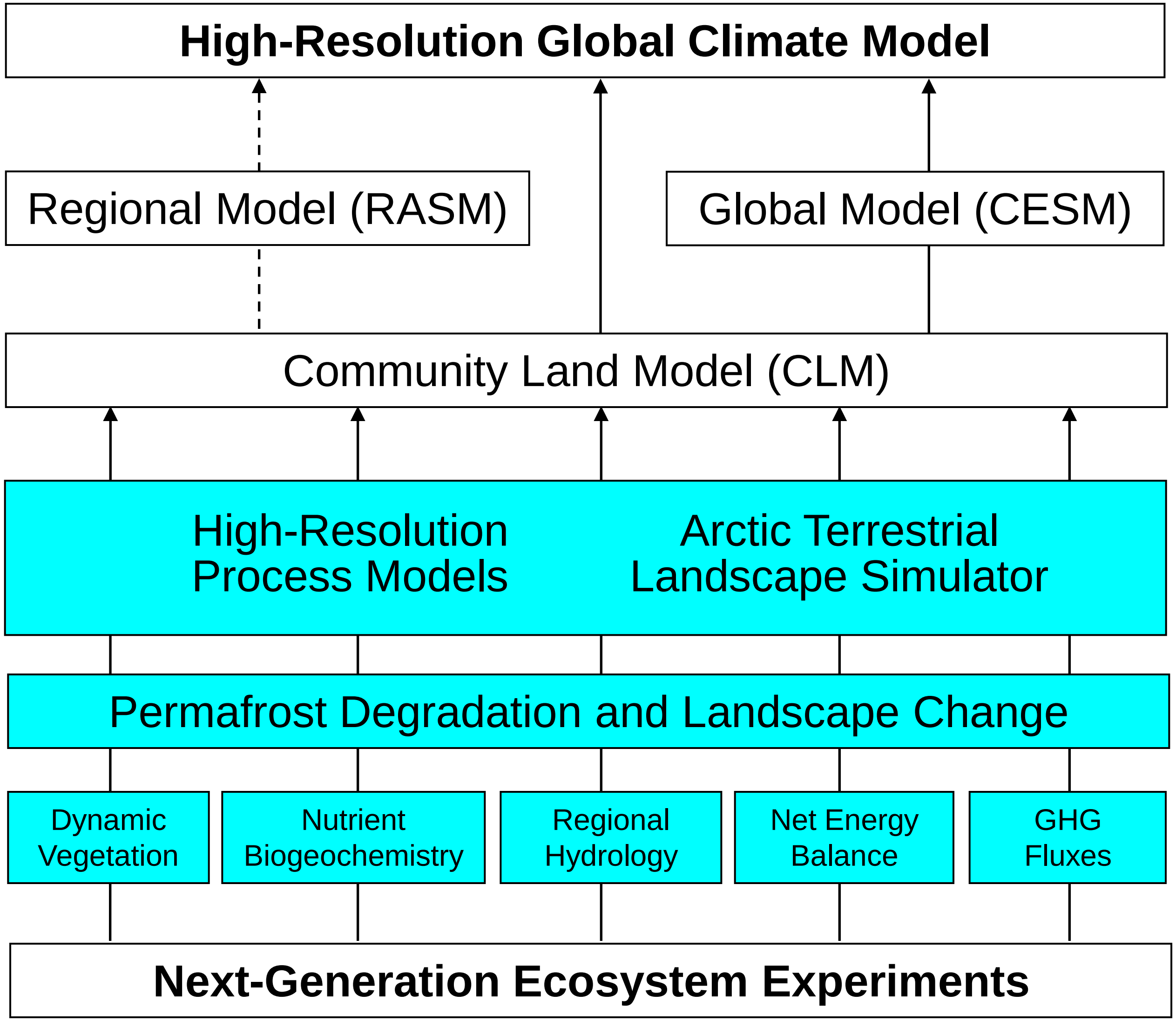
Process Scale



Landscape Scale

Regional and Global Scales

Extensive *versus* intensive sampling approach


High-Resolution Global Climate Model
Regional Model (RASM)
Global Model (CESM)
Community Land Model (CLM)
High-Resolution Process Models
Arctic Terrestrial Landscape Simulator
Permafrost Degradation and Landscape Change
Dynamic Vegetation
Nutrient Biogeochemistry
Regional Hydrology
Net Energy Balance
GHG Fluxes
Next-Generation Ecosystem Experiments

Opportunities to Become Engaged with NGEE:

- Leverage investments and facilitate continued scientific collaboration in Barrow, Alaska.
- Affiliate with other projects to understand Arctic ecosystems and feedbacks to climate (e.g., NEON, ABoVE, and CARVE).
- Encourage single PI interactions with NGEE investigators; future TES solicitations.
- Synthesis activities; workshops; facilitate model inter-comparisons.
- Share resources; make datasets available, permafrost samples, etc.

Next-Generation Ecosystem Experiments
(NGEE Arctic)

“Learn More” Session

December 8, Thursday 4:00 to 6:00pm
Marriott Marquis
Foothill F

Email: wullschlegsd@ornl.gov

Next-Generation Ecosystem Experiments (NGEE Arctic)

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Larry Hinzman	UAF
David Graham	ORNL
Susan Hubbard	LBNL
Liyuan Liang	ORNL
Richard Norby	ORNL
Bill Riley	LBNL
Alistair Rogers	BNL
Joel Rowland	LANL
Peter Thornton	ORNL
Margaret Torn	LBNL
Cathy Wilson	LANL

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