Next-Generation Ecosystem Experiments (NGEE Arctic)

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

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Land/Biogeochemistry Working Groups Meeting
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Arctic terrestrial ecosystem processes play a critical role in prediction of future climate response to GHG forcing.

Recent assessment finds that Arctic processes make significant contributions to overall land ecosystem - climate feedbacks.

Figure: Arneth et al. 2010, Nature Geosci.
Current scaling approach for land component of climate prediction model (e.g. CLM4)

Best ESMs currently use quasi one dimensional approach, with assumption of linear scaling
Hypothesis: Linear scaling not a good assumption in Arctic tundra landscapes under warming scenario.

Typical GCM / ESM scales (1°x1°) ≈ 100km

Site scale (<1 m resolution)

Landscape scales (100 m to 10 km)
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 near-surface weather

**Spatial characteristics:**
- Domain: approx. 100m x 100m
- Resolution: ~10 cm (horiz), variable cm+ (vert)

**Temporal characteristics:**
- Domain: decades to century
- Resolution: sub-hourly
A nested scaling framework based on hydrology/geomorphology
Sub-grid representation of geomorphologically distinct landscape elements

**Geomorphological Types:**
- Lake
- Vegetated tundra
- Stream channel
- Barren fluvial plain
- Vegetated fluvial plain
- Vegetated “slopes”

15 km x 15 km

30 km x 30 km
Sub-grid representation of geomorphologically distinct landscape elements

**Geomorphological Types:**
- Lake
- Sunken-center polygon
- Raised-center polygon
- Rim (raised edge)
- Trough (sunken edge)
Automated mapping of geomorphological units on Arctic coastal plain

Up-scaling and down-scaling to achieve improved climate prediction
NGEE Organization & Approach

Model driven approach that recognizes the complex, hierarchical nature of the Arctic System

Process Integration

Scale Integration

Global / Regional

3-D Landscape

1-D Column

Hydro-Geomorphology

Soil Biogeochemistry

Plant Dynamics

(tasks)

(tasks)

(tasks)

(tasks)

(tasks)

(tasks)

Iterative and multi-scale experiments, observations and simulations
New approaches to parameterization and validation
Soil Biogeochemistry Challenge

GOAL: Develop a quantitative model of organic matter decomposition rates in high latitude soils as needed to improve predictions of CO$_2$, CH$_4$ and N$_2$O greenhouse gas feedbacks on changing Arctic ecosystems.

Northern soils and permafrost contain approximately 1700 Pg of organic carbon, 88% of which is sequestered in frozen soils (Tarnocai et al., 2009).
Example task: *Arctic Plant Functional Types*

- Develop improved representations of **plant functional types** that consider nitrogen and water acquisition strategies.
- Test **dynamic vegetation models with improved PFTs** against observed patterns across thermokarst gradients.

![Shrub, Sedge, Moss](images)
Implications for CLM

• Starting point: CLM4.x, ~10km grid
• Reconfigure and redeploy the current subgrid scheme
  – Landunits used to represent sub-grid basins (explicit topology for basins)
  – Columns used to represent sub-basin geomorphological units (statistical)
  – PFTs still represent multiple plant types within a geomorphologically consistent column
• Dynamic PFT and column weights, explicit sub-grid routing from landunits.
• Parameterizations developed from 3D models