

NGEE-Arctic: Multi-scale modeling for Arctic tundra



Presented by Peter Thornton for
the NGEE-Arctic Science Team

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U.S. DEPARTMENT OF
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Overview

- Dataset development for Barrow study sites
 - Physics coupling
 - Biogeochemistry coupling
 - Dynamic topography
-
- Drawn from presentations at the NGEE-Arctic All-Hands meeting, December 2013, San Francisco, with some recent updates

Dataset developments to support NGEA-Arctic modeling

A range of data sets are required to support the range of model development

Mesh Development

- ▶ Remote sensing based landscape characterization
- ▶ Delineation of landscape features
- ▶ Mesh generation

Initial and boundary conditions

- ▶ Metreological data
- ▶ Soil carbon/biomass

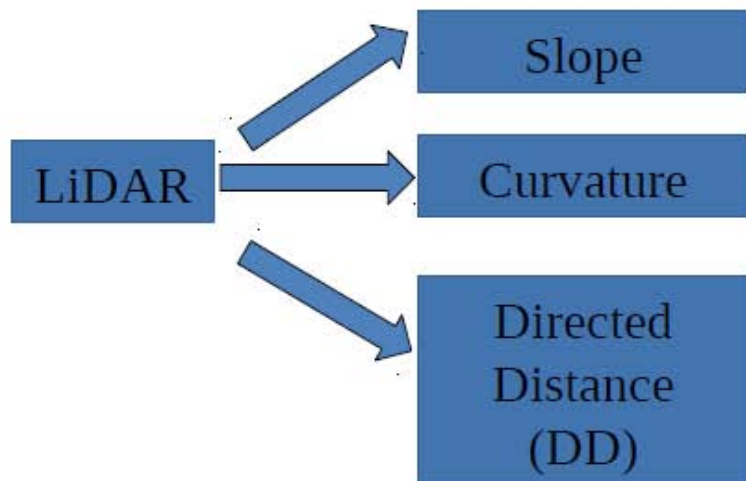
Model parameterization

- ▶ Soil hydraulic and thermal properties
- ▶ PFT parameterization
- ▶ Development of PFT maps

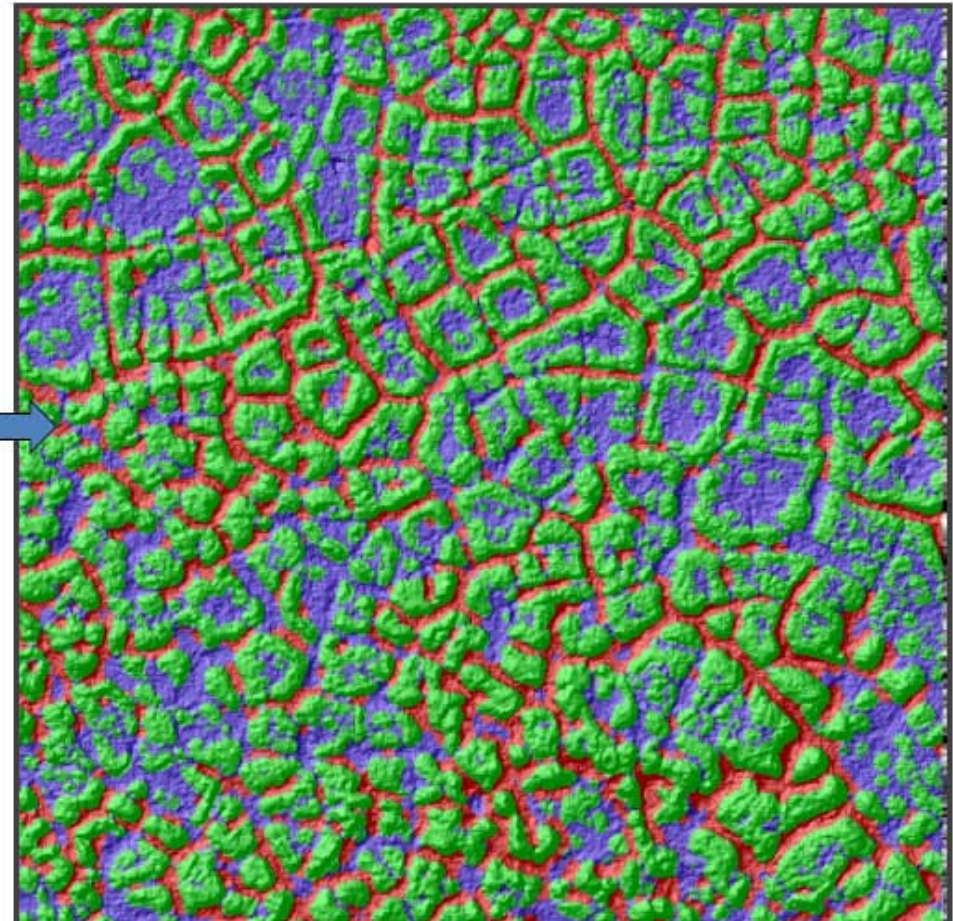
Validation and evaluation

- ▶ Active layer depth, subsurface temperatures
- ▶ Carbon flux measurements

Mapping Troughs, Rims, and Center Areas of Ice-Wedge Polygons



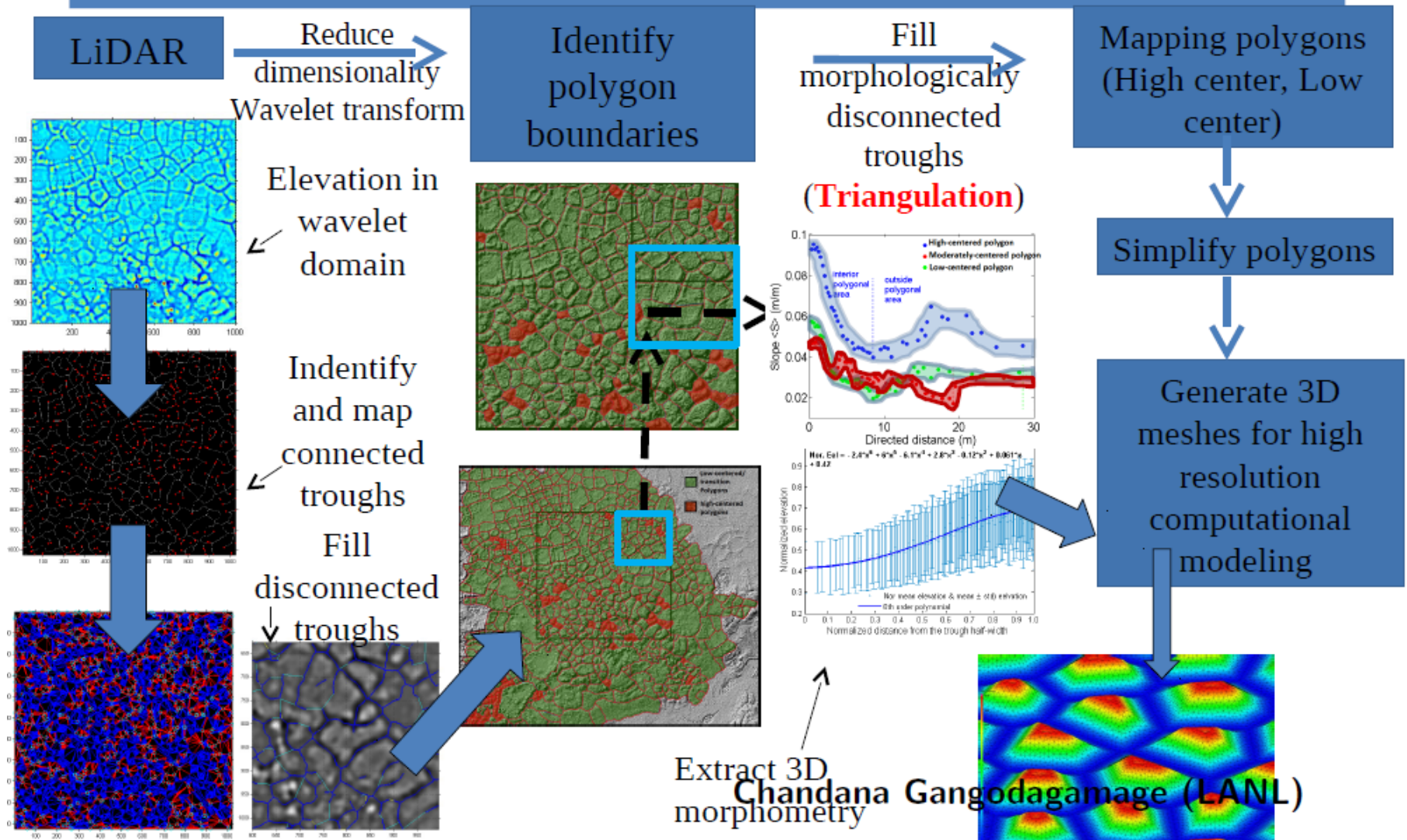
Optimize topographic attributes to classify micro topography



■ Troughs
■ Rims
■ Centers

Chandana Gangodagamage (LANL)

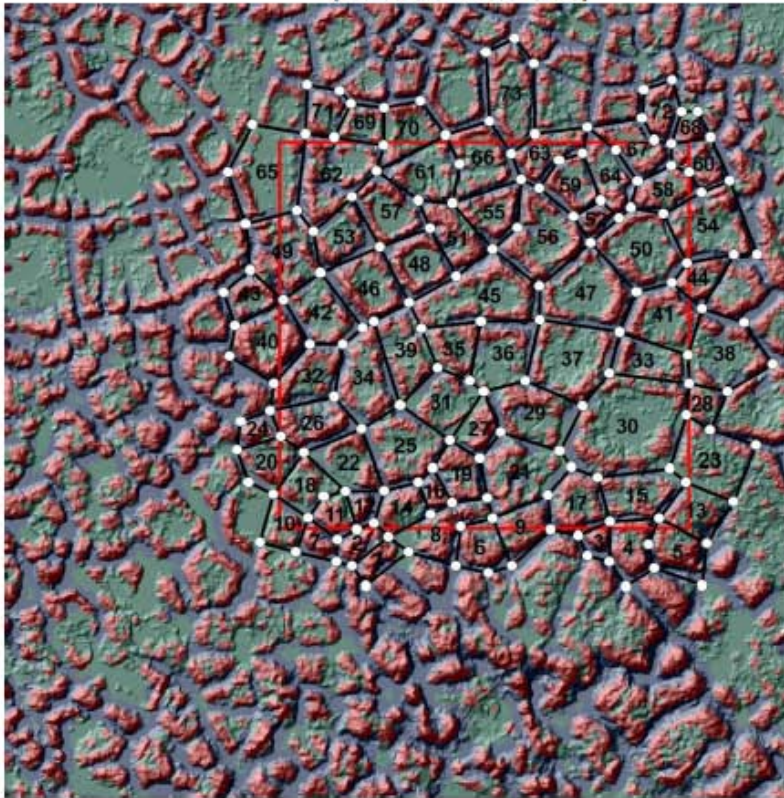
Mesh Generations for High Resolution Computational Modeling



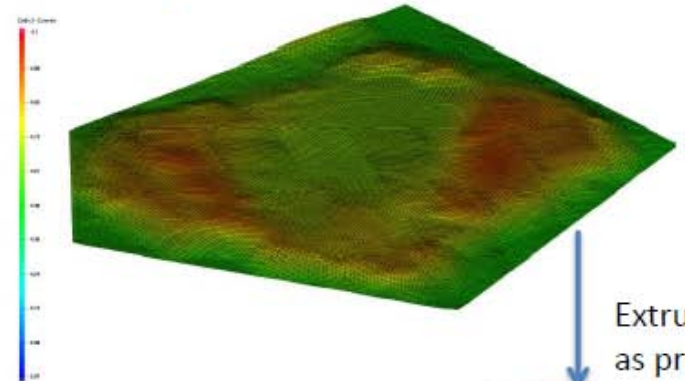
Fine-scale mesh development

meshing.lanl.gov/proj/arctic_ice_wedge_poly

Delineate polygons
(semi-automated)



Triangulate
on surface



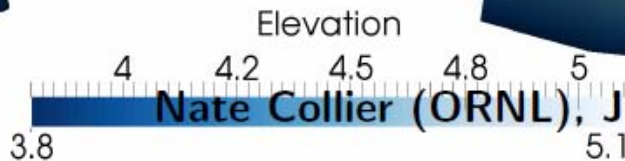
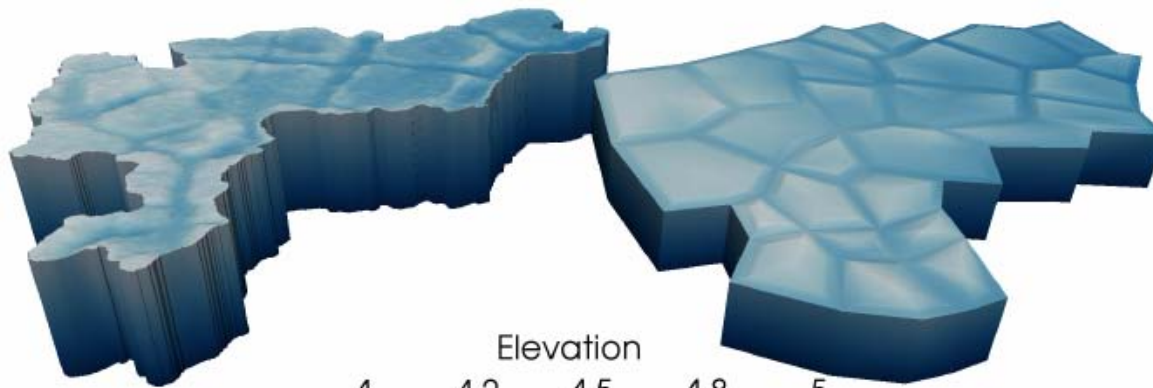
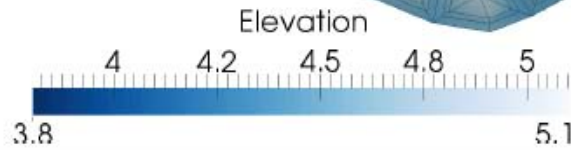
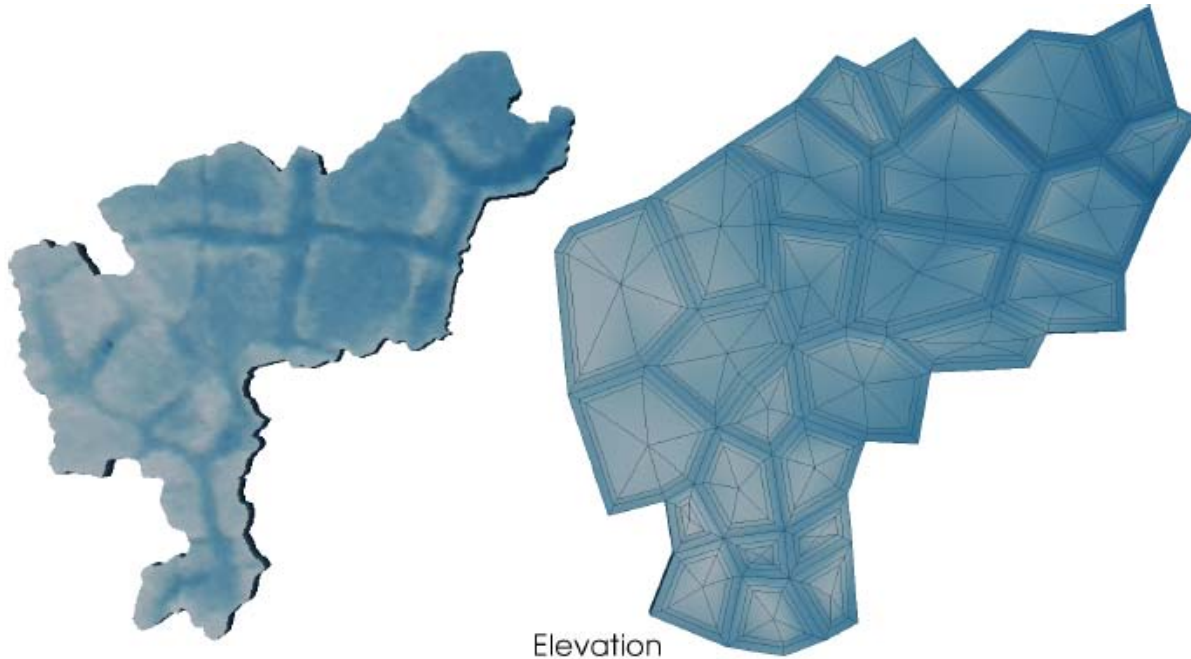
Extrude
as prisms



Scott Painter (LANL)

Lucia Short, Chandana Gangodagamage, Terry Miller,
Carl Gable, Scott Painter, Cathy Wilson

Intermediate scale grid development

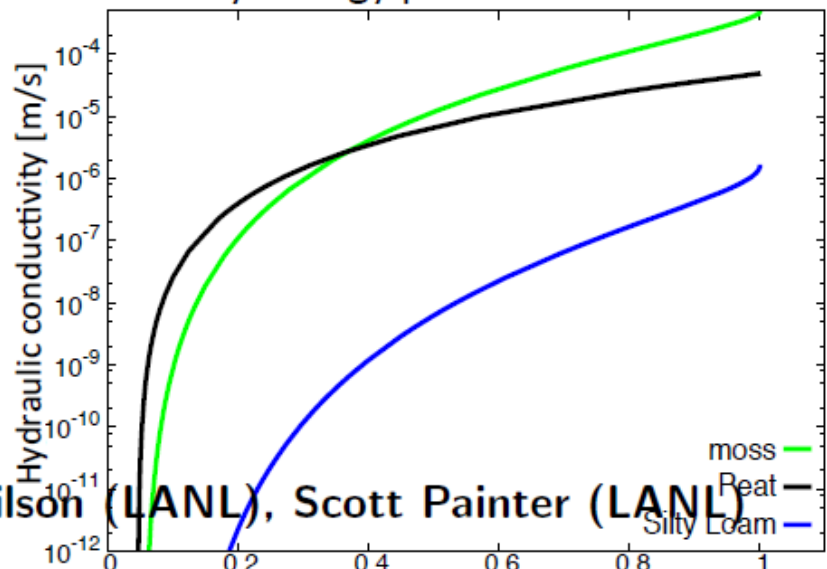
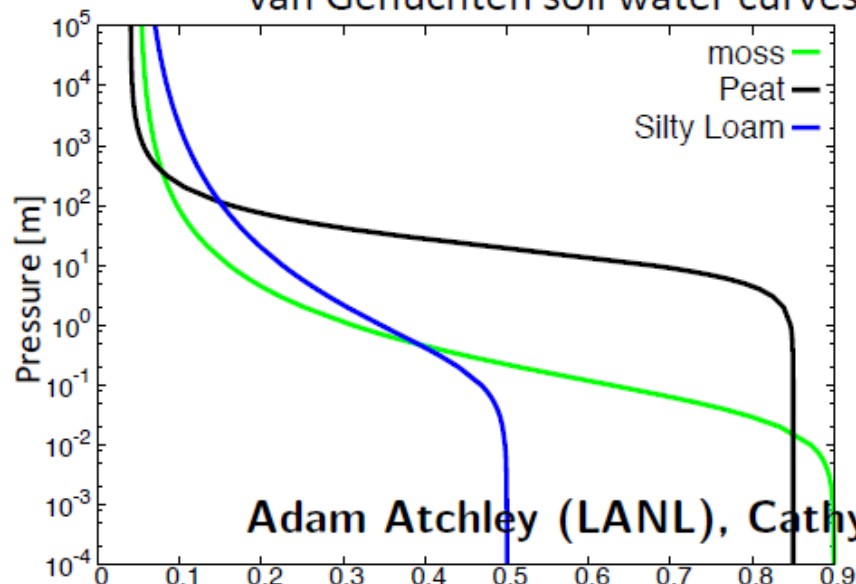


Nate Collier (ORNL), Jitendra Kumar (ORNL)

Recommended arctic soil thermal-hydrology parameters

Notation/Units	Moss	Moss-Range	Peat	Peat-Range	Mineral (Silty Loam)	Mineral-Range
Perm [m ²]	5×10^{-11}	$1.9 \times 10^{-10} - 2.4 \times 10^{-12}$	5×10^{-12}	$1.2 \times 10^{-9} - 1.6 \times 10^{-14}$	2×10^{-13}	$2.7 \times 10^{-14} - 2.6 \times 10^{-11}$
Porosity [-]	0.9	0.88 - 0.95	0.85	0.7 - 0.93	0.5	0.2 - 0.75
Alpha [1/Pa]	2.3×10^{-3}	$1 \times 10^{-5} - 2.35 \times 10^{-3}$	8.2×10^{-6}	$3.1 \times 10^{-7} - 1.2 \times 10^{-3}$	5.5×10^{-4}	$2.9 \times 10^{-4} - 1 \times 10^{-3}$
n [-]	1.38	1.3 - 2.82	1.9	1.3 - 1.9	1.24	1.24 - 1.3
Residual Sat [-]	0.056	0.022 - 0.20	0.047	0.043 - 0.26	0.1	0.1 - 0.33
K _{dry} [W/m K]	0.07	0.007 - 0.3	0.07	0.05 - 0.38	0.29	0.2 - 1.6
K _{unfrozen Sat} [W/m K]	0.57	0.5 - 5.9	0.67	0.43 - 2.9	1	0.96 - 3.1
K _{frozen Sat} [W/m K]	2.1	0.81 - 2.8	2.1	0.81 - 2.3	1.8	1.31 - 2.8
$\alpha_{T,uf}$ [-]	0.5	--	0.5	--	0.5	--
$\alpha_{T,f}$ [-]	1	--	1	--	1	--

van Genuchten soil water curves → from arctic hydrology parameters



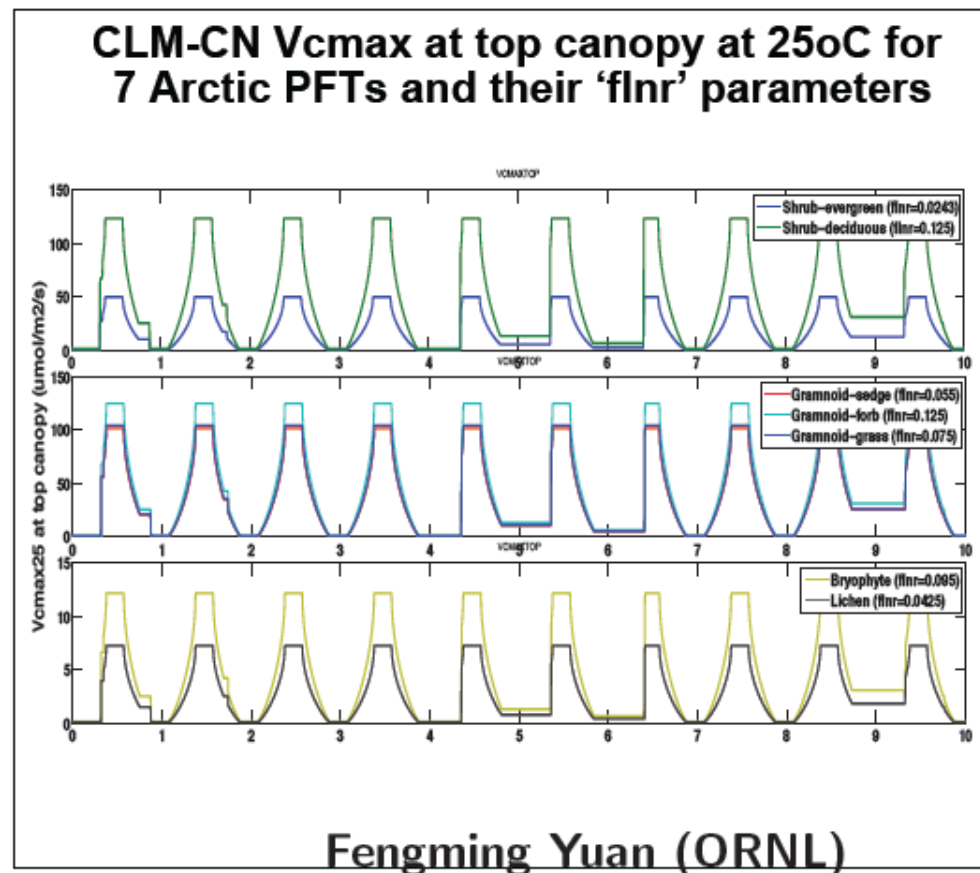
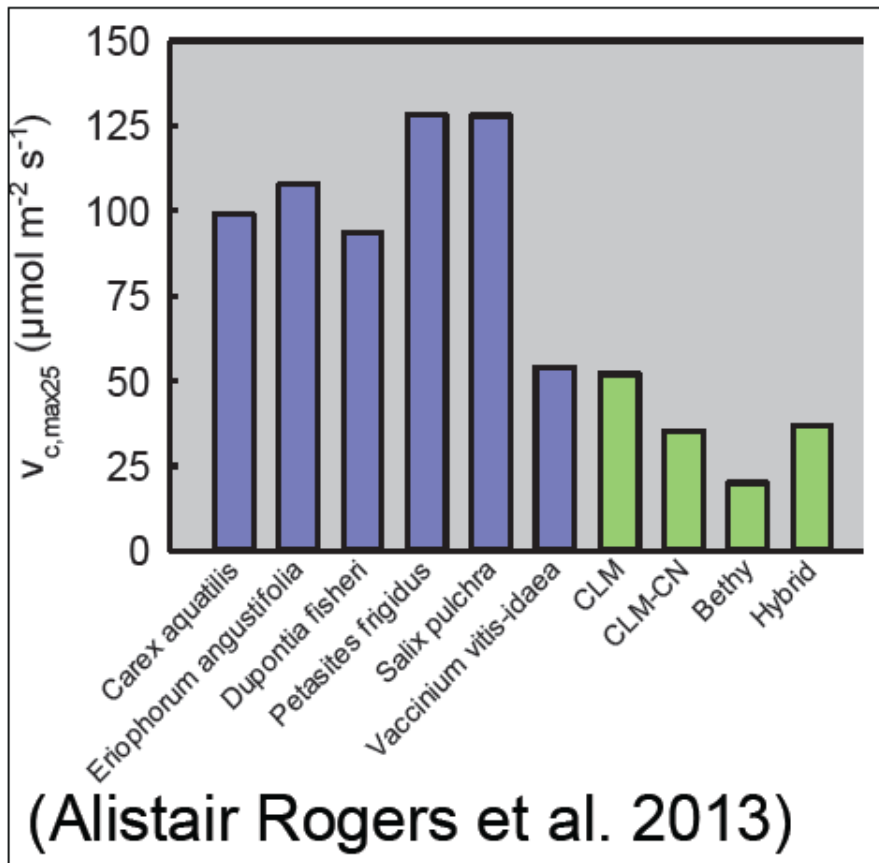
Parameterizing New PFTs for Arctic Tundra

- $V_{c,max}$ parameterized via 'flnr':

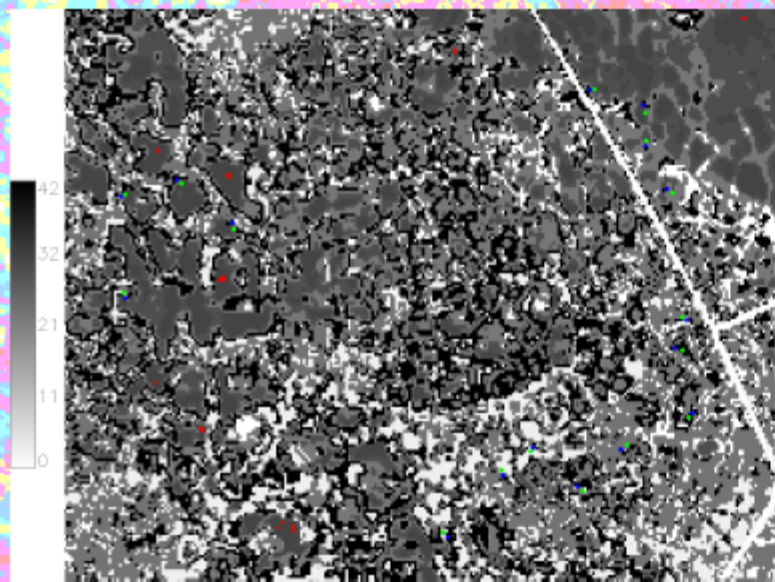
Vasculars: Alistair Rogers et al., 2013;

Moss: Williams and Flanagan, 1998. *PCE* 21: 555-564;

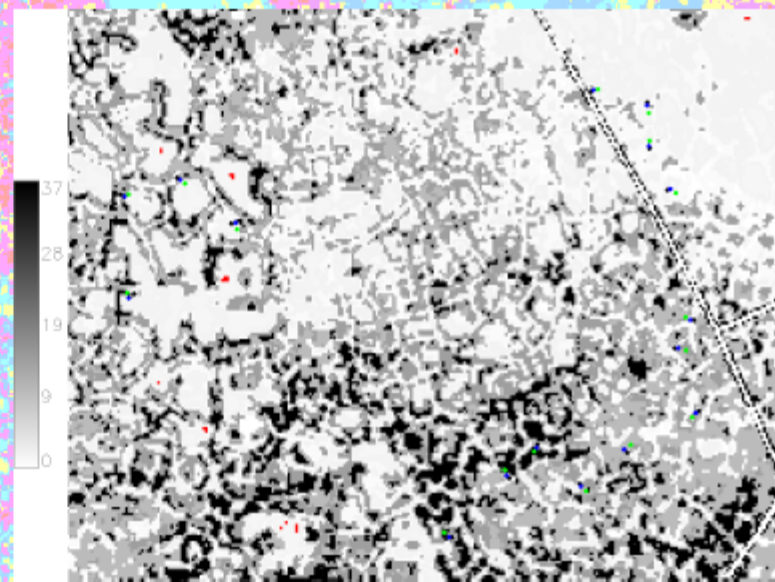
Lichen: Nash et al. 1983. *Oecologia* 58: 52-56)



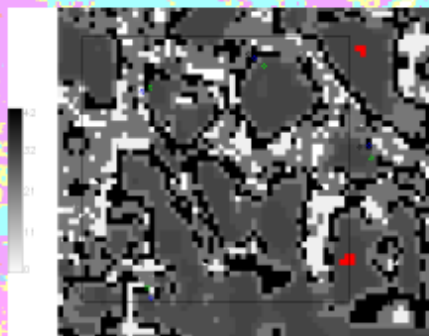
- ▶ Landscape classification using multi-spectral remote sensing data from Worldview 2
- ▶ Field data on vegetation/PFT distribution from $1\text{m} \times 1\text{m}$ plots at NGE sites in Barrow
- ▶ Upscaling of point data to the landscape
- ▶ Development of PFT distribution maps for the BEO at 2m resolution



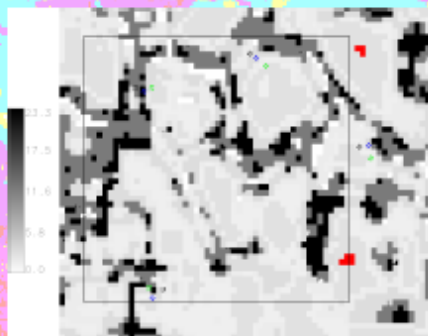
(a) Wet tundra graminoid



(b) Lichen



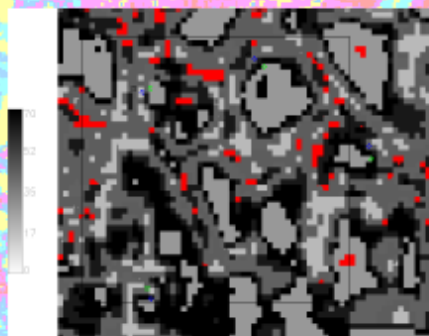
(c) Wet tundra graminoid



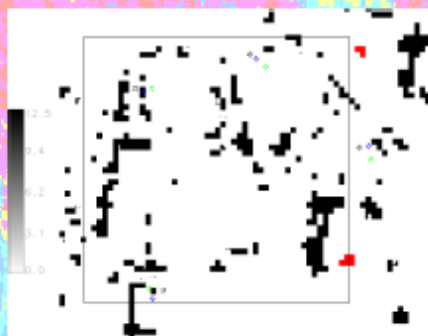
(d) Dry tundra graminoid



(e) Lichen



(f) Moss



(g) Evergreen



(h) Deciduous



(i) Forb

Meteorological data sets for initial and boundary conditions

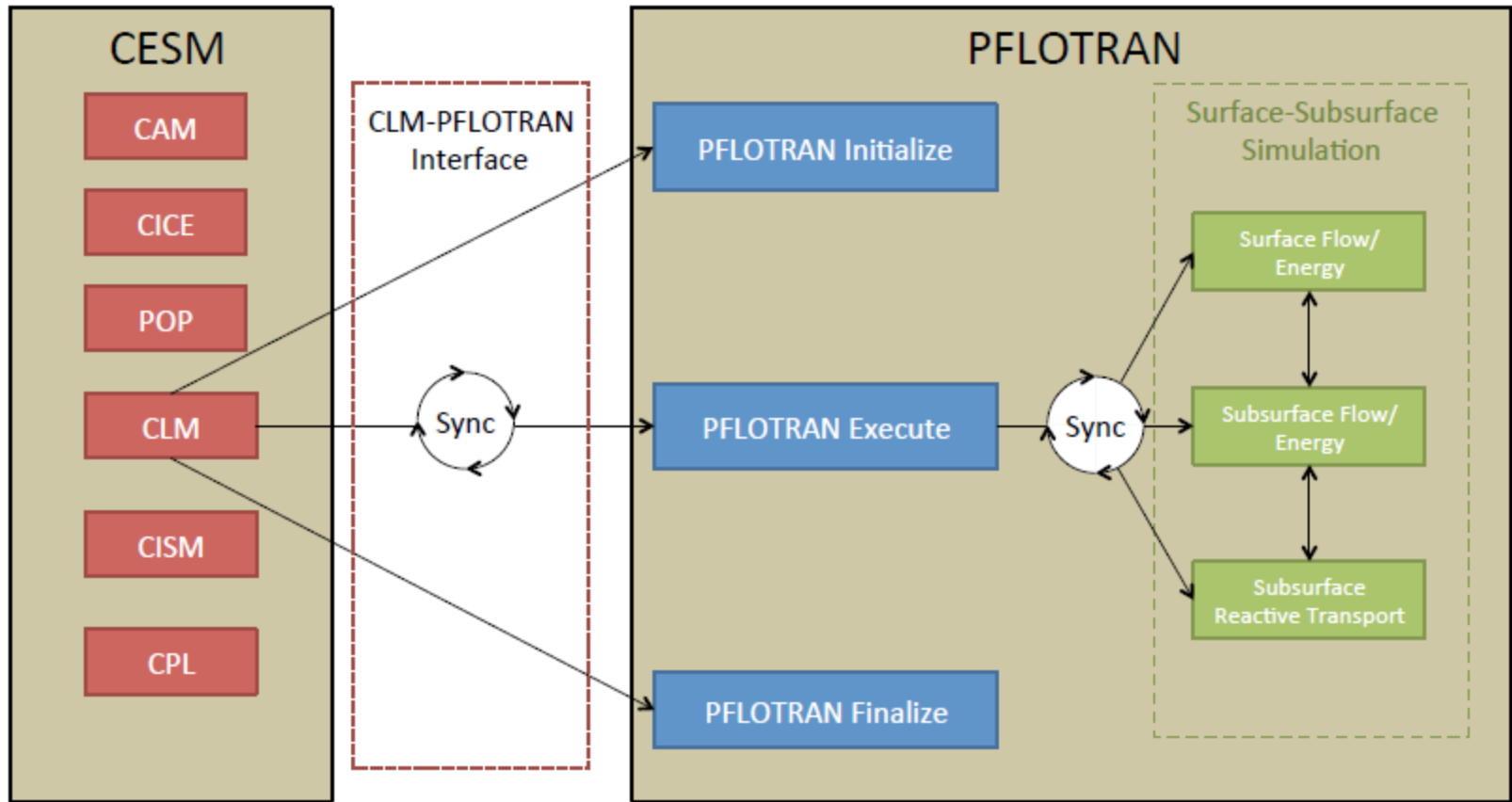
Meteorological data sets are required to provide initial and boundary conditions for simulations at all scales. These data sets are being compiled from a range of sources to support NGEE–Arctic modeling.

- ▶ Subsurface temperature and active layer depths (Circumpolar Active Layer Monitoring Network)
- ▶ Radiation data (NOAA Earth System Research Laboratory, Global Monitoring Division)
- ▶ Meteorological data (NOAA Earth System Research Laboratory, Global Monitoring Division, NCDC/NOAA)
- ▶ Flux data (latent heat, CO_2 etc.) (ARM, NGEE–Arctic)

These data sets are being processed into appropriate formats for use by simulation models (CLM, PFLOTRAN etc.) by members of the modeling team.

**Jitendra Kumar, Xiaofeng Xu, Fengming Yuan (ORNL),
Gautam Bisht (LBNL)**

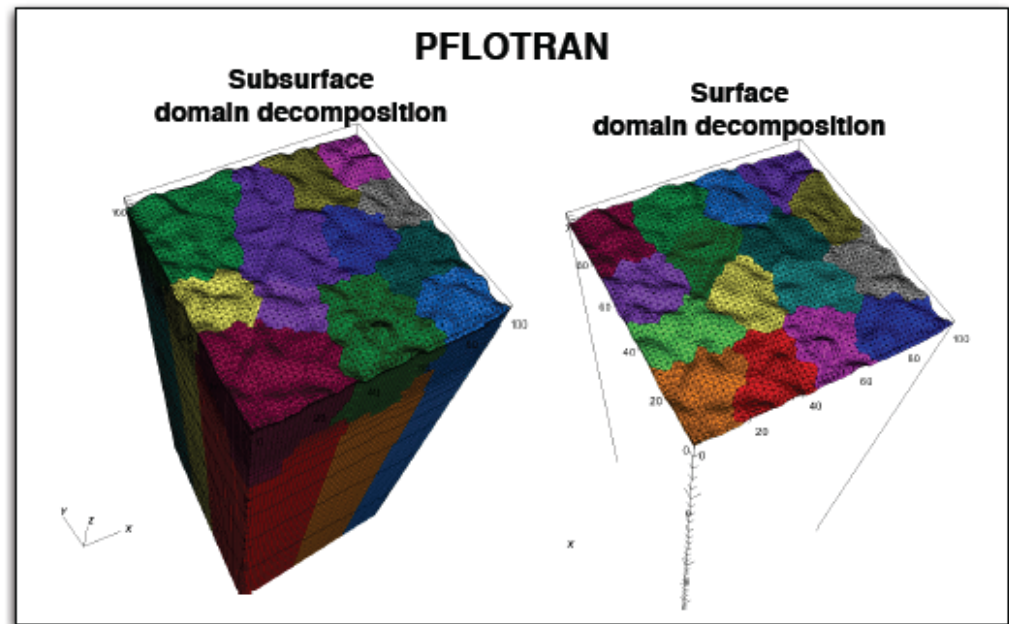
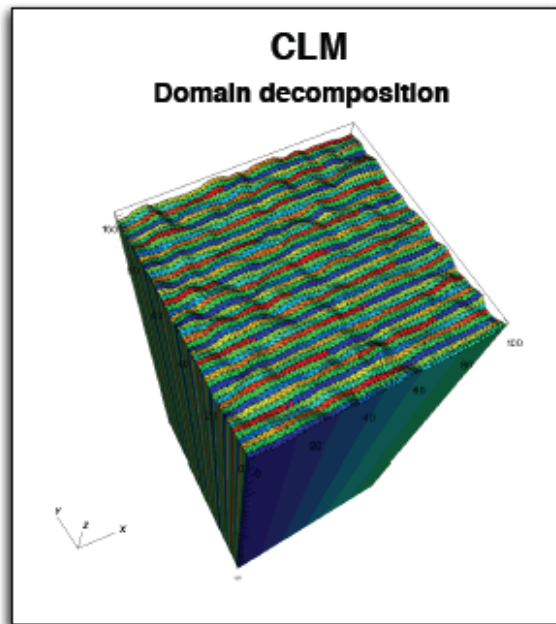
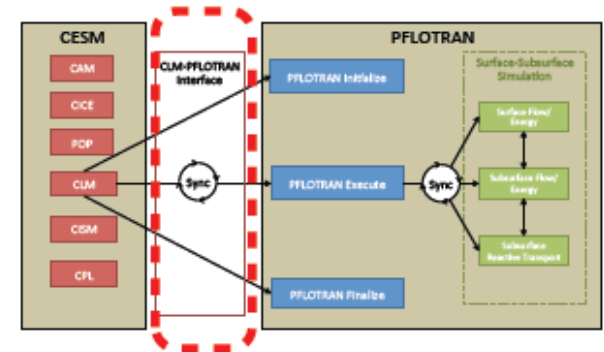
CLM-PFLOTRAN: Coupling overview



- ▶ PFLOTRAN is an external physics library called by CESM.
- ▶ CESM namelist variable turns PFLOTRAN on/off.

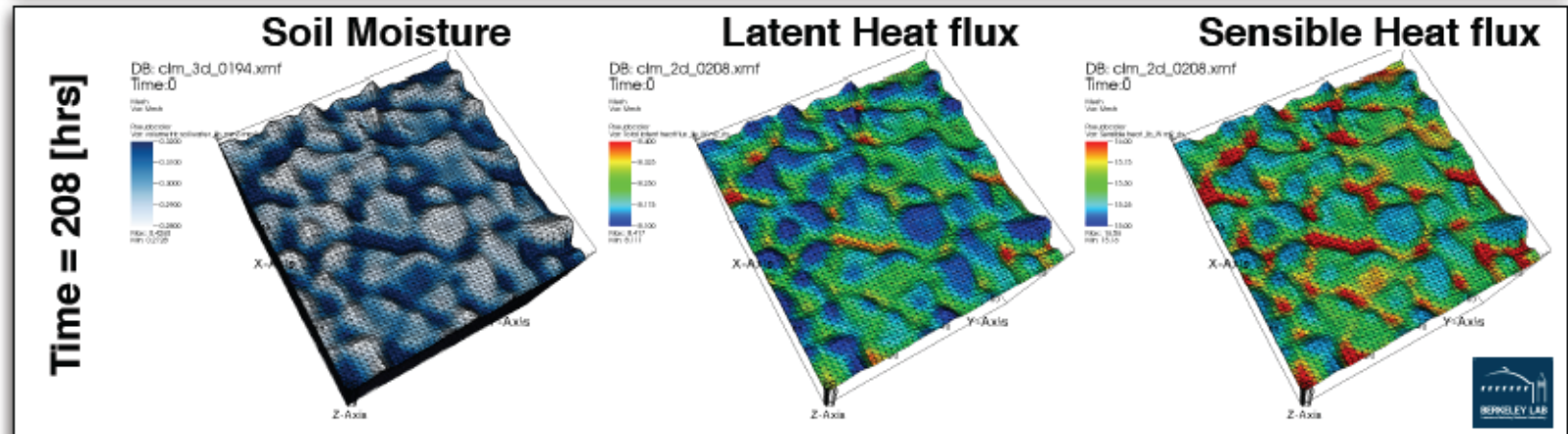
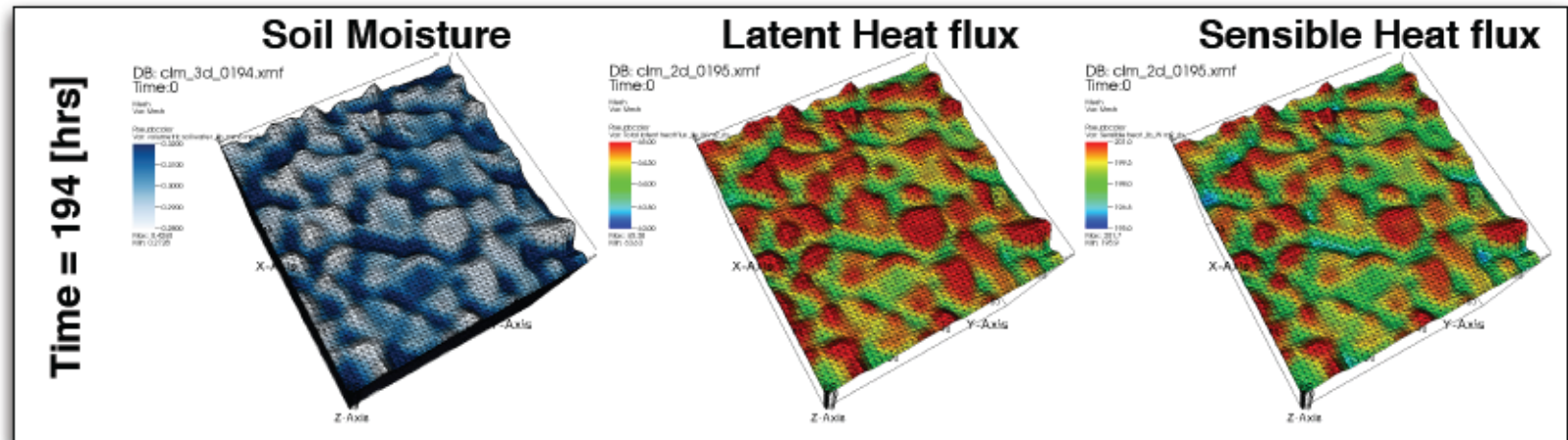
CLM-PFLOTRAN: Model interface

1. Accommodates different domain decomposition for the two models.
2. Data is transferred between two model grids using ESMF mapping files.



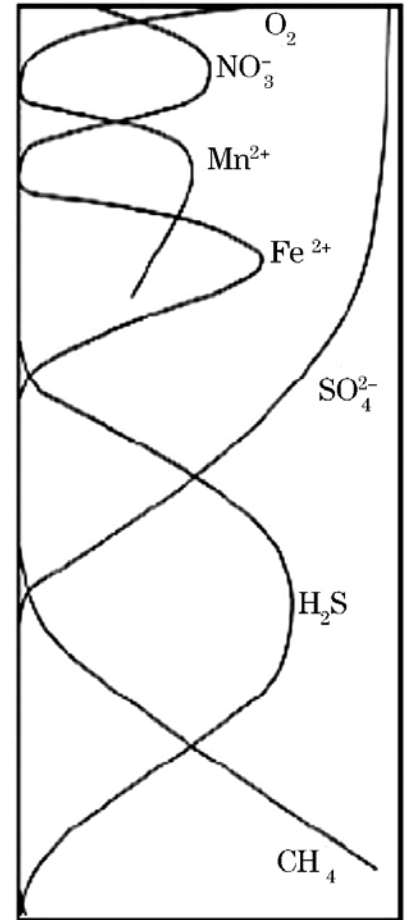
CLM-PFLOTRAN: Preliminary Results

- ▶ Hydrologically coupled CLM – PFLOTRAN ([subsurface](#)) simulation.
- ▶ Ngee Site B Domain:
 - ▶ Horizontal extent is 100 [m] with $dx=dy=2$ [m].
 - ▶ Vertical: 10 soil layers with exponentially varying thickness.



CLM-PFLOTRAN Biogeochemistry

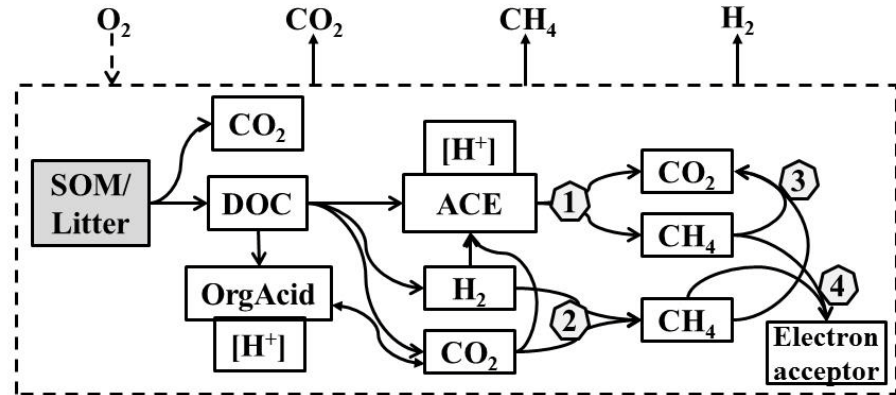
- Litter/SOM decomposition
 - CLM-CN, CENTURY, CLM45 (O_2)
 - Microbial / enzymatic processes, P
 - DOMs, particulate transport
- Nitrification/Denitrification
 - CENTURY, CLM45, ...
- O_2
 - O_2 diffusion, advection, aerenchyma transport, consumption
- CH_4
 - Production, oxidation, diffusion, aerenchyma transport, bubbling/air-water phase transport



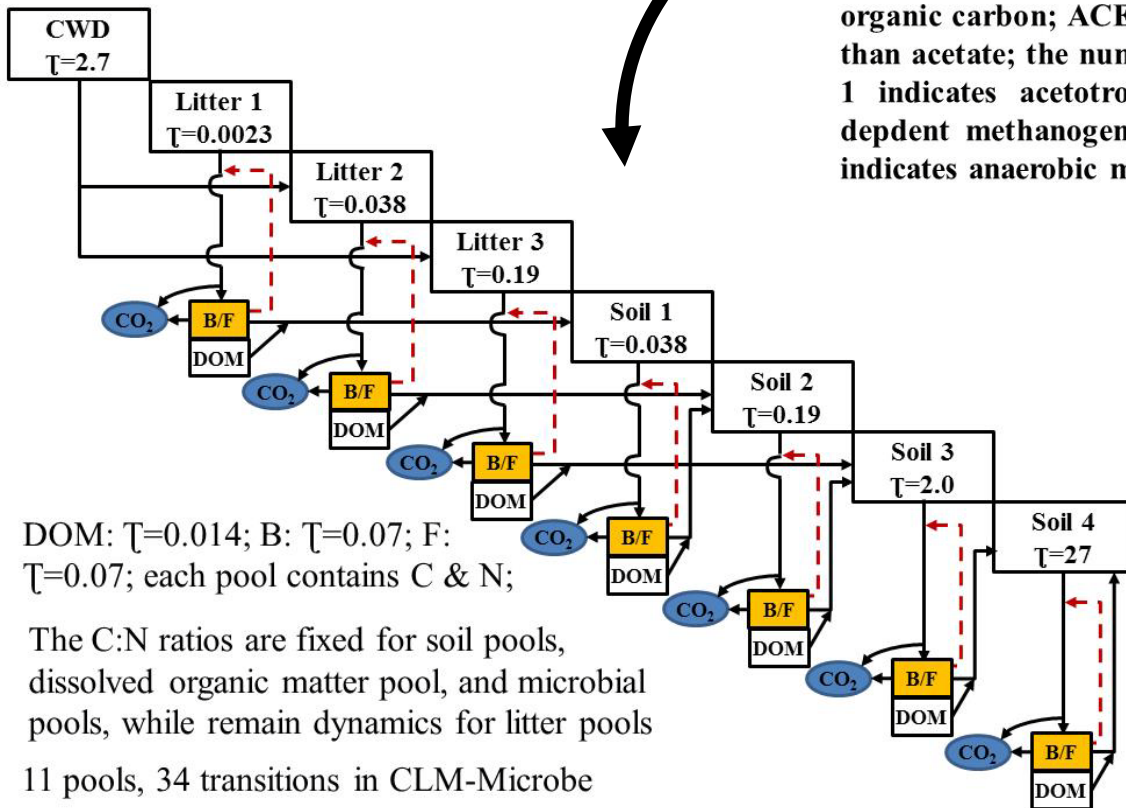
Green = developed
Blue = in development
Red = to be developed

➤ CLM-CN+ coupling with PFLOTRAN

Updated BGC reaction network and methane module in CLM-Microbe



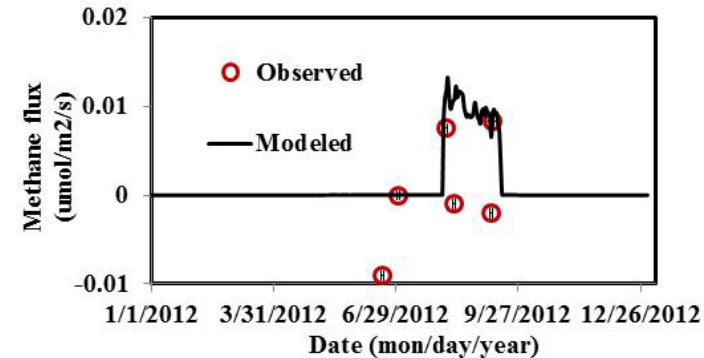
SOM/Litter: Soil organic matter and/or litter; DOC: Dissolved organic carbon; ACE: acetic acid; OrgAcid: Organic acid other than acetate; the numbers indicate microbial functional groups: 1 indicates acetotrophic methanogens; 2 indicates H_2 - CO_2 -dependent methanogens; 3 indicates aerobic methanotrophs; 4 indicates anaerobic methanotrophs



DOM: $\tau=0.014$; B: $\tau=0.07$; F: $\tau=0.07$; each pool contains C & N;

The C:N ratios are fixed for soil pools, dissolved organic matter pool, and microbial pools, while remain dynamics for litter pools

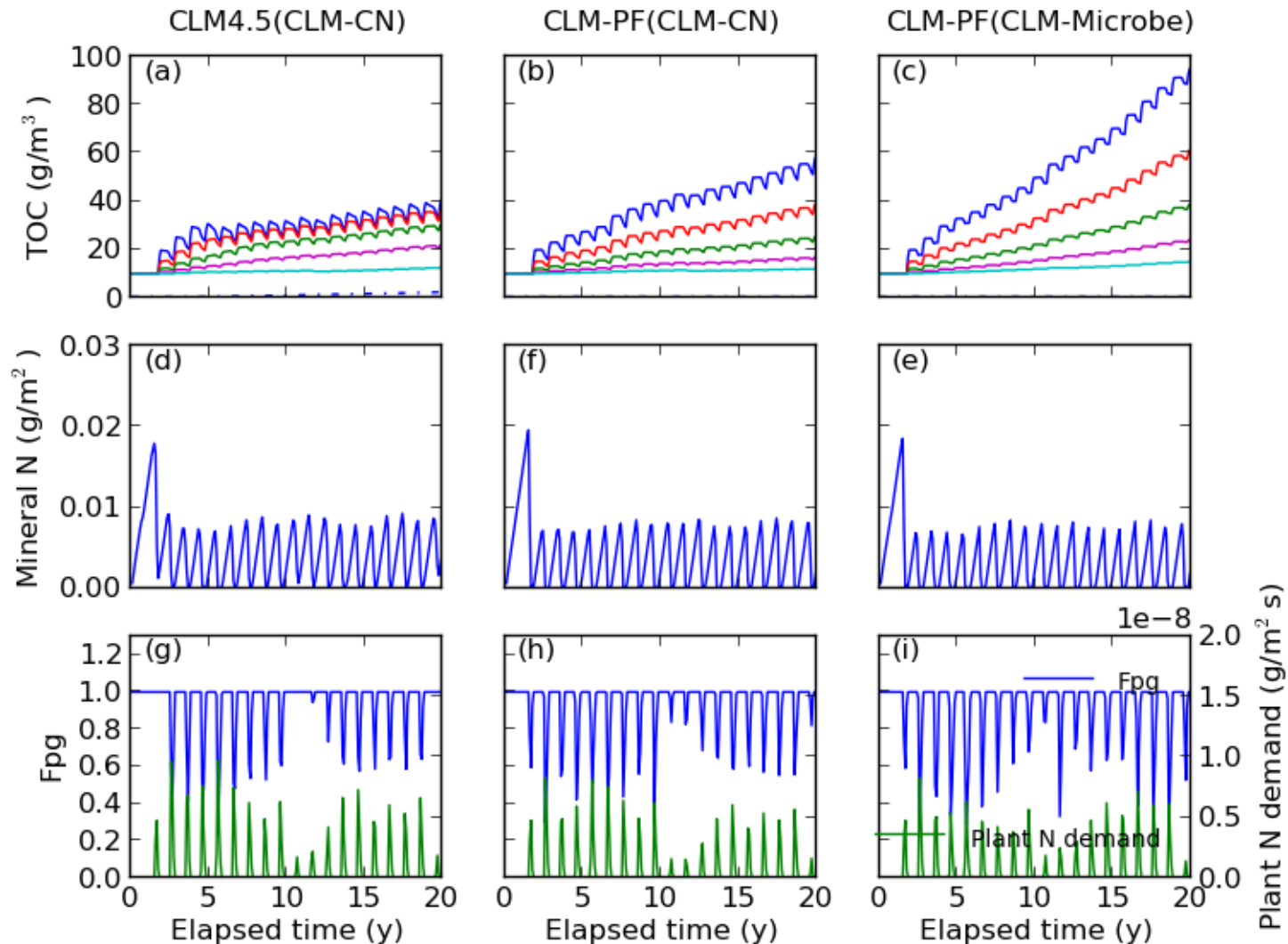
11 pools, 34 transitions in CLM-Microbe



Simulated CH_4 fluxes in Barrow, AK

Xiaofeng Xu, ORNL

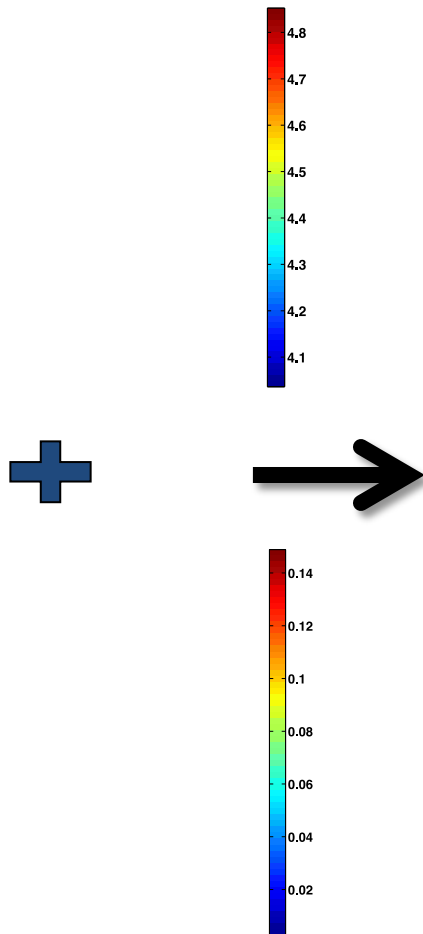
Preliminary Coupled Simulation Results



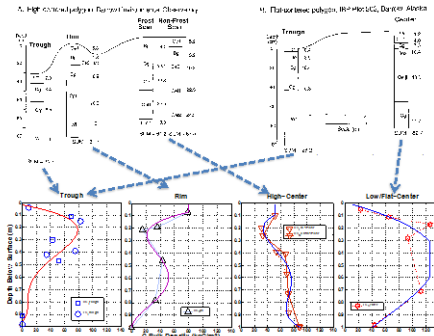
CLM-CN+ coupling with PFLOTRAN

Demo Simulations in Ngee Area C at Barrow, AK

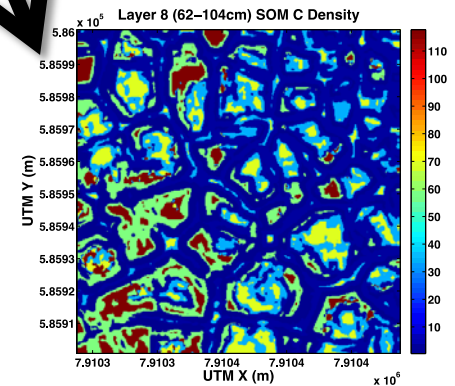
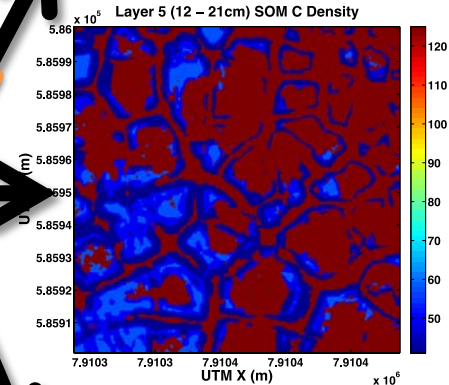
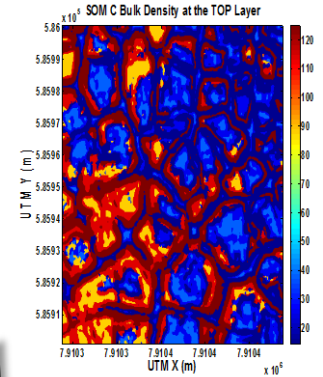
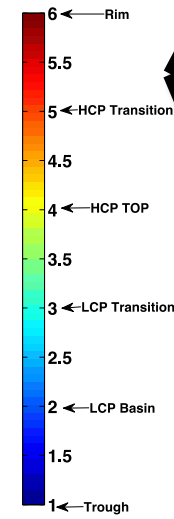
Area C landscape classification by elevation and standard deviation.



- Soil Organic Matter profiles associated with landscape positions.



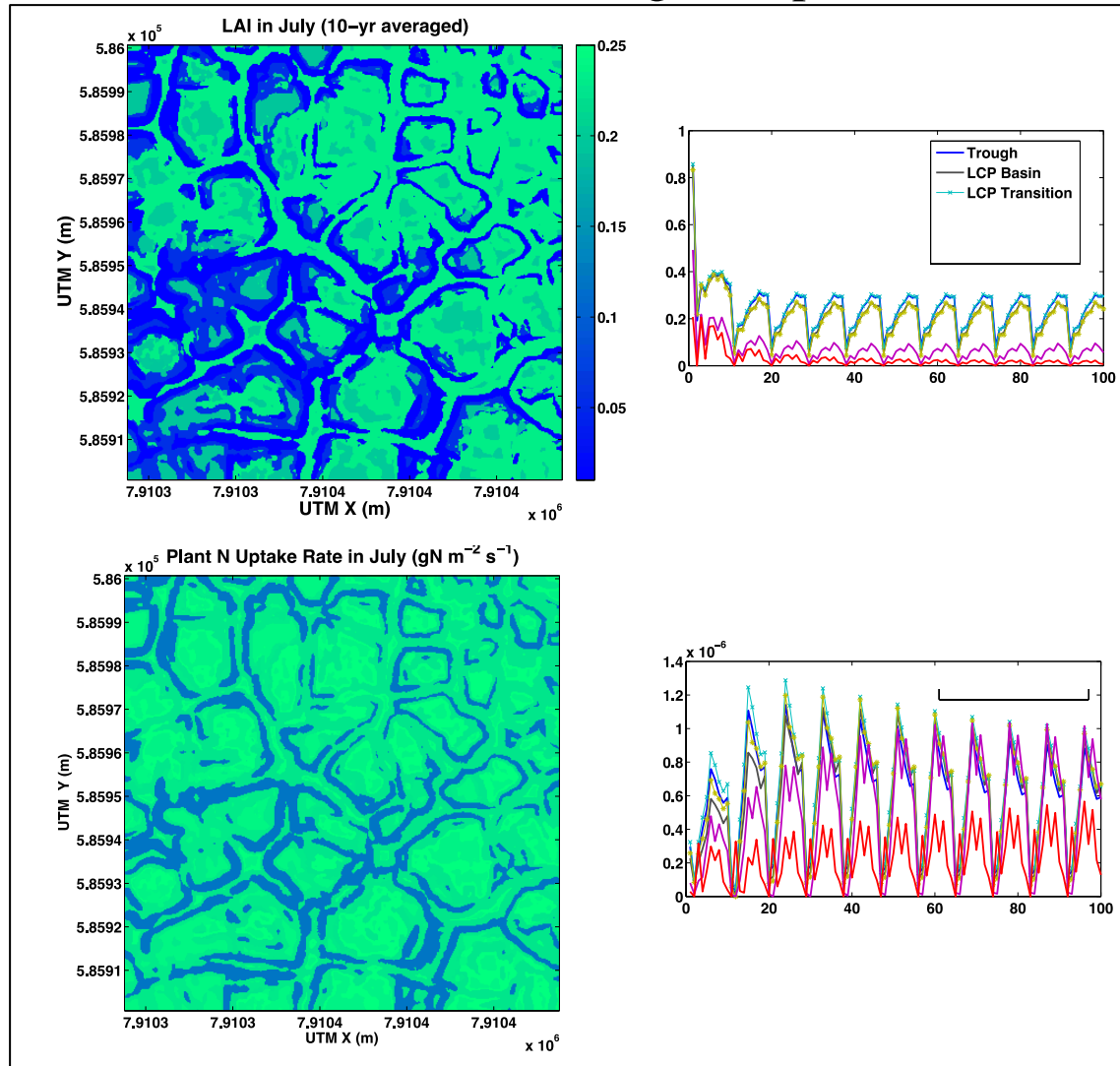
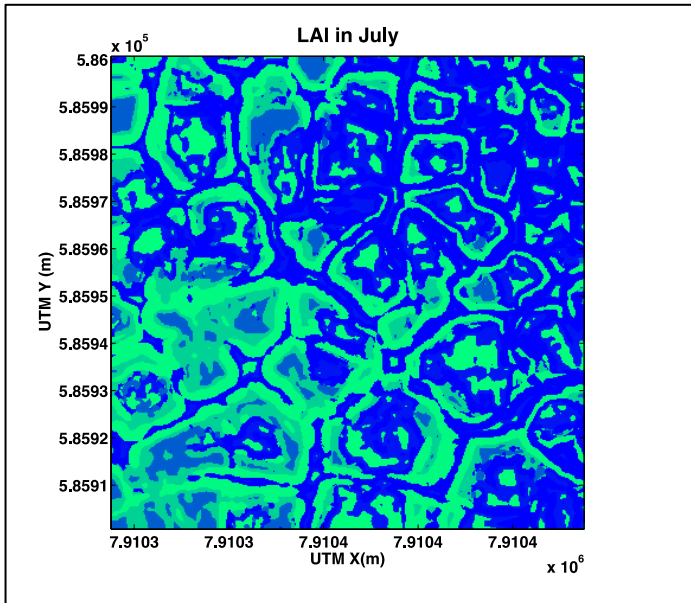
Graphs and Data Adapted from Fig. 3 in Bockheim et al. 1999 (SSSAJ)



CLM-CN+ coupling with PFLOTRAN

Demo Simulations in Ngee Area C at Barrow, AK

- CLM4.5-CN
- CLM4.5-CN-PFLOTRANbgc Coupled



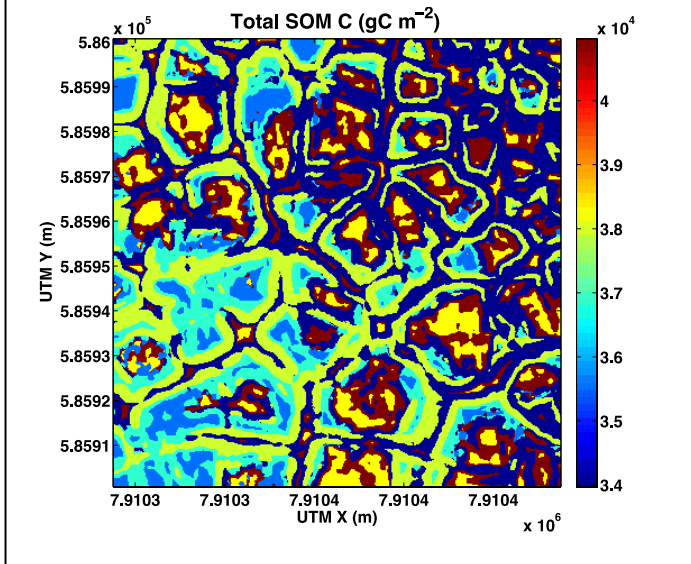
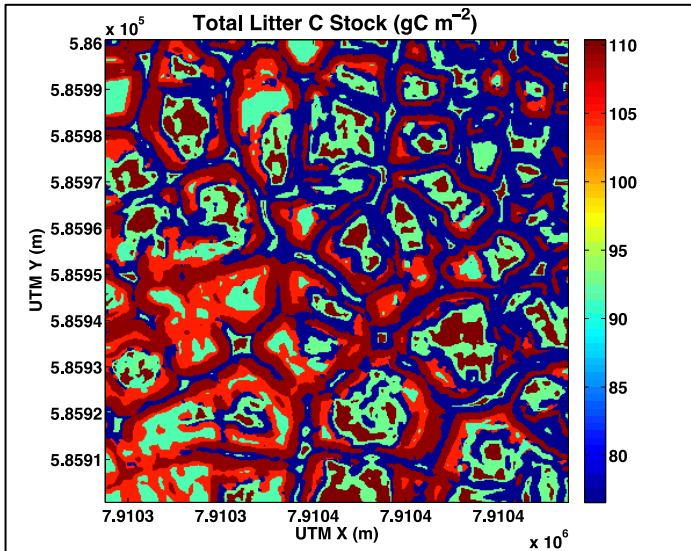
Notes on simulations settings:

- CLM4.5-CN accelerated spinup for 300 yrs at 40x40 grids (2.5 m res.);
- CLM4.5-CN spinup for 42 yrs at same resolution;
- CLM-PF bgc coupled run for 100 yrs (warm-start), for only 6 types of landscape positions.

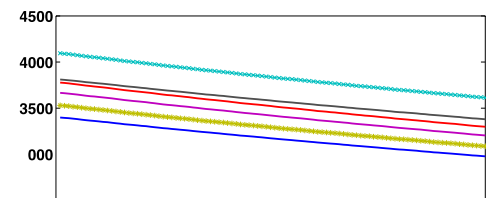
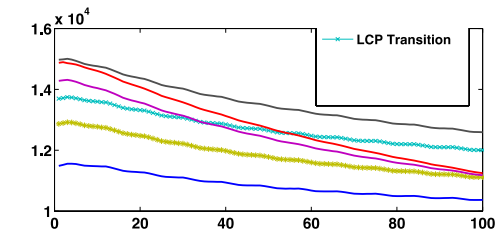
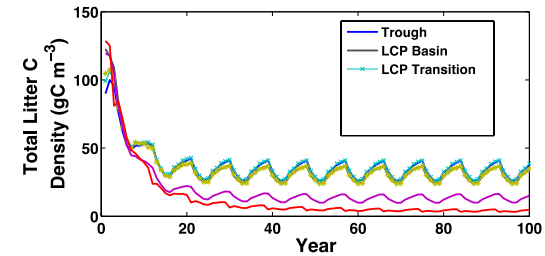
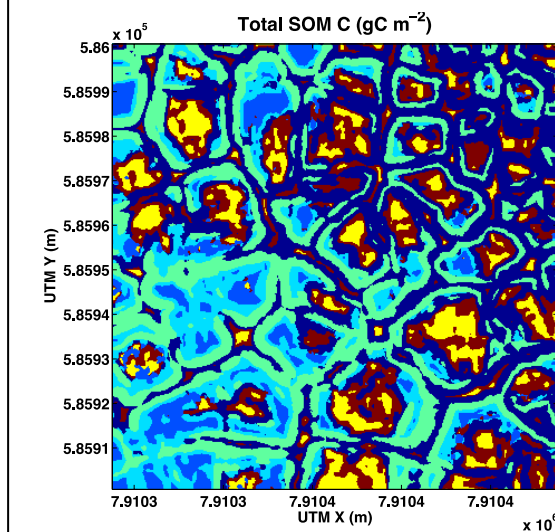
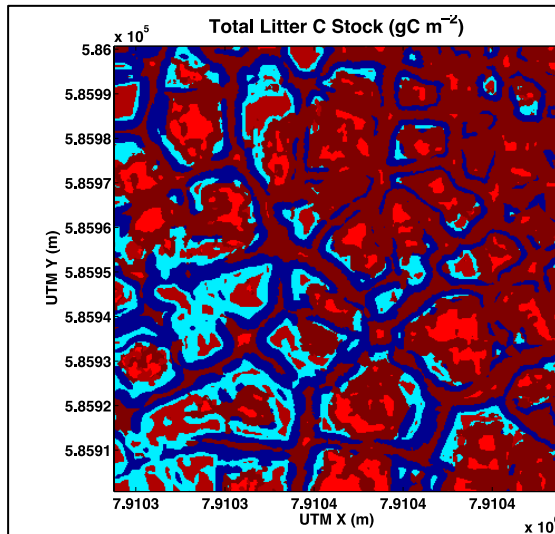
CLM-CN+ coupling with PFLOTRAN

Demo Simulations in Ngee Area C at Barrow, AK

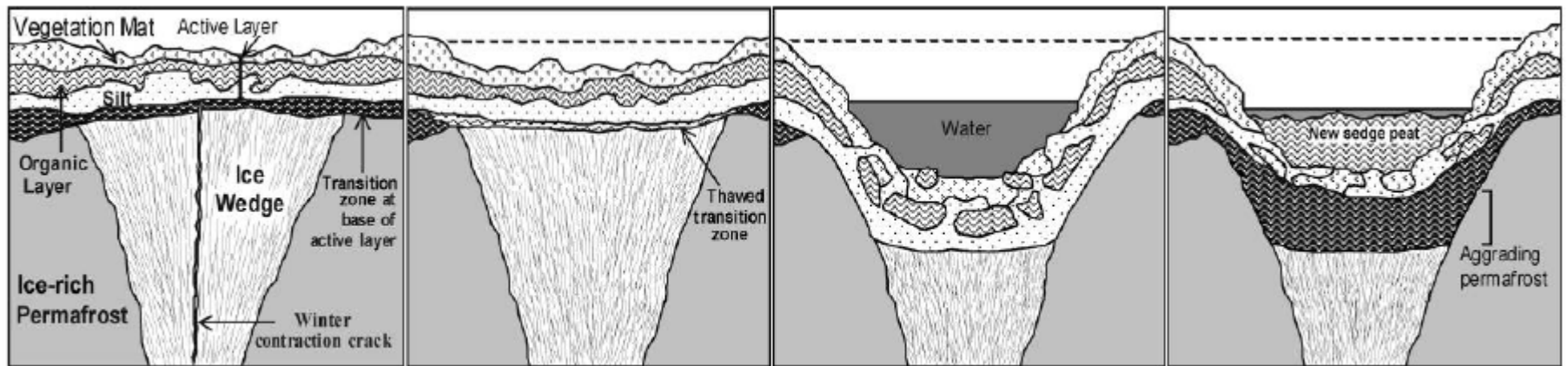
- CLM4.5-CN



- CLM4.5-CN-PFLOTRANbgc Coupled



Track 2: Dynamic topography

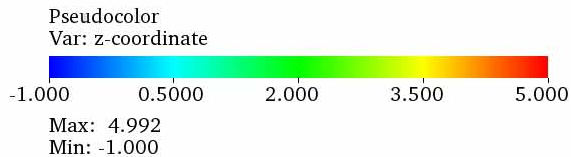
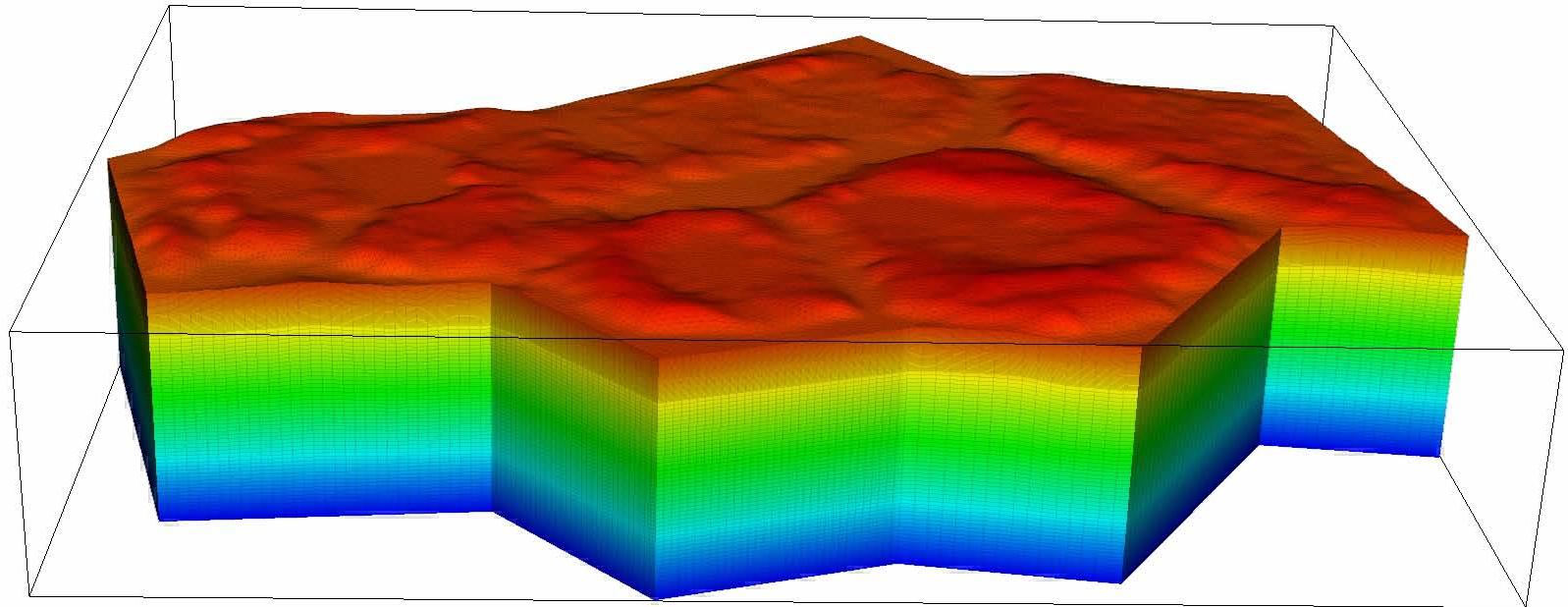


A **B** **C** **D**
Progressive Degradation



Jorgenson

Kinematic deformation, no hydrology



Scott Painter, Ethan Coon, David Moulton and the ATS Team (LANL)