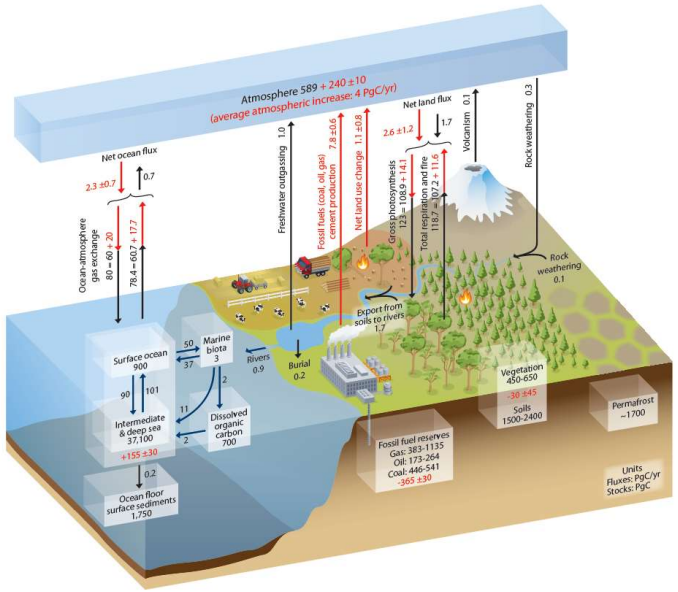
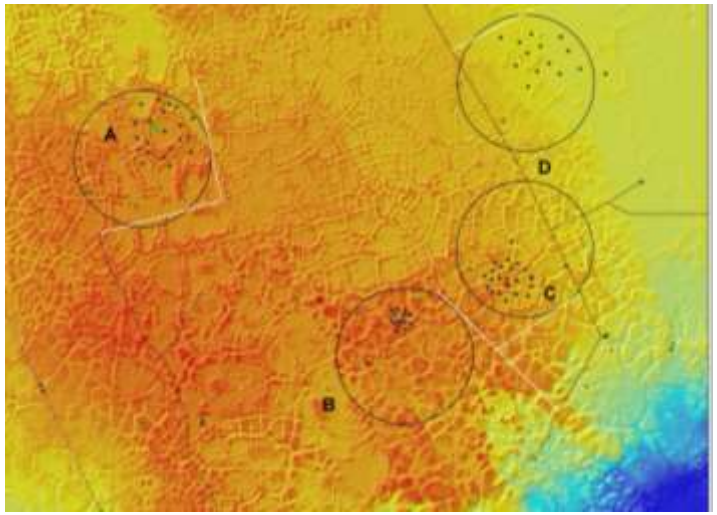
Migrating Knowledge Across Scales through Coupled Modeling and Process Studies



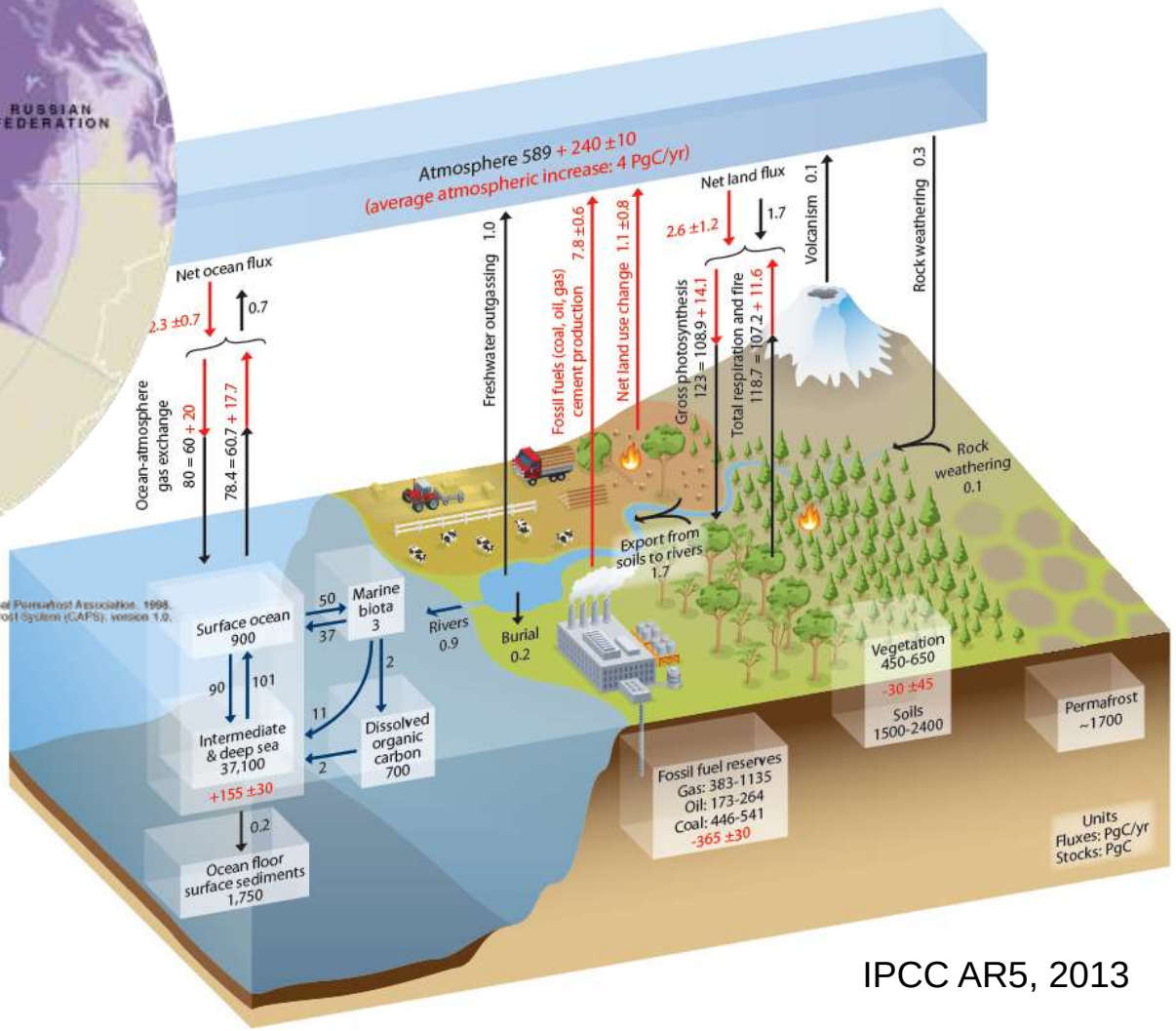
Next-Generation Ecosystem Experiments (NGEE Arctic) Project



Peter E. Thornton
Climate Change Science Institute
Oak Ridge National Laboratory

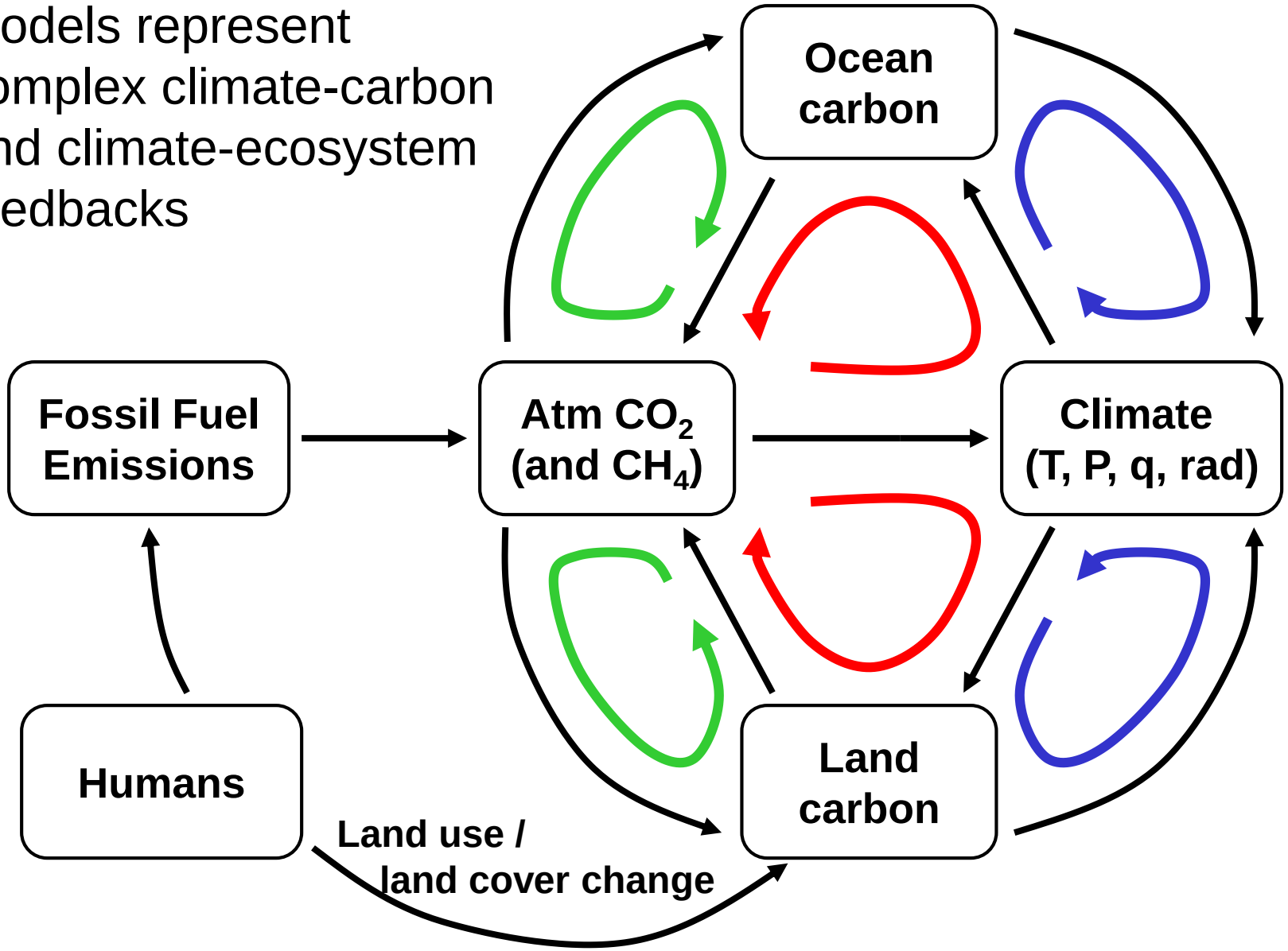
U.S. DEPARTMENT OF ENERGY · OAK RIDGE National Laboratory · Los Alamos NATIONAL LABORATORY · BERKELEY LAB · BROOKHAVEN NATIONAL LABORATORY · UAF UNIVERSITY OF ALASKA FAIRBANKS

- Permafrost contains ~1700 Pg carbon…
- Similar in size to fossil fuel reserves
- Situated in region that will experience maximum warming



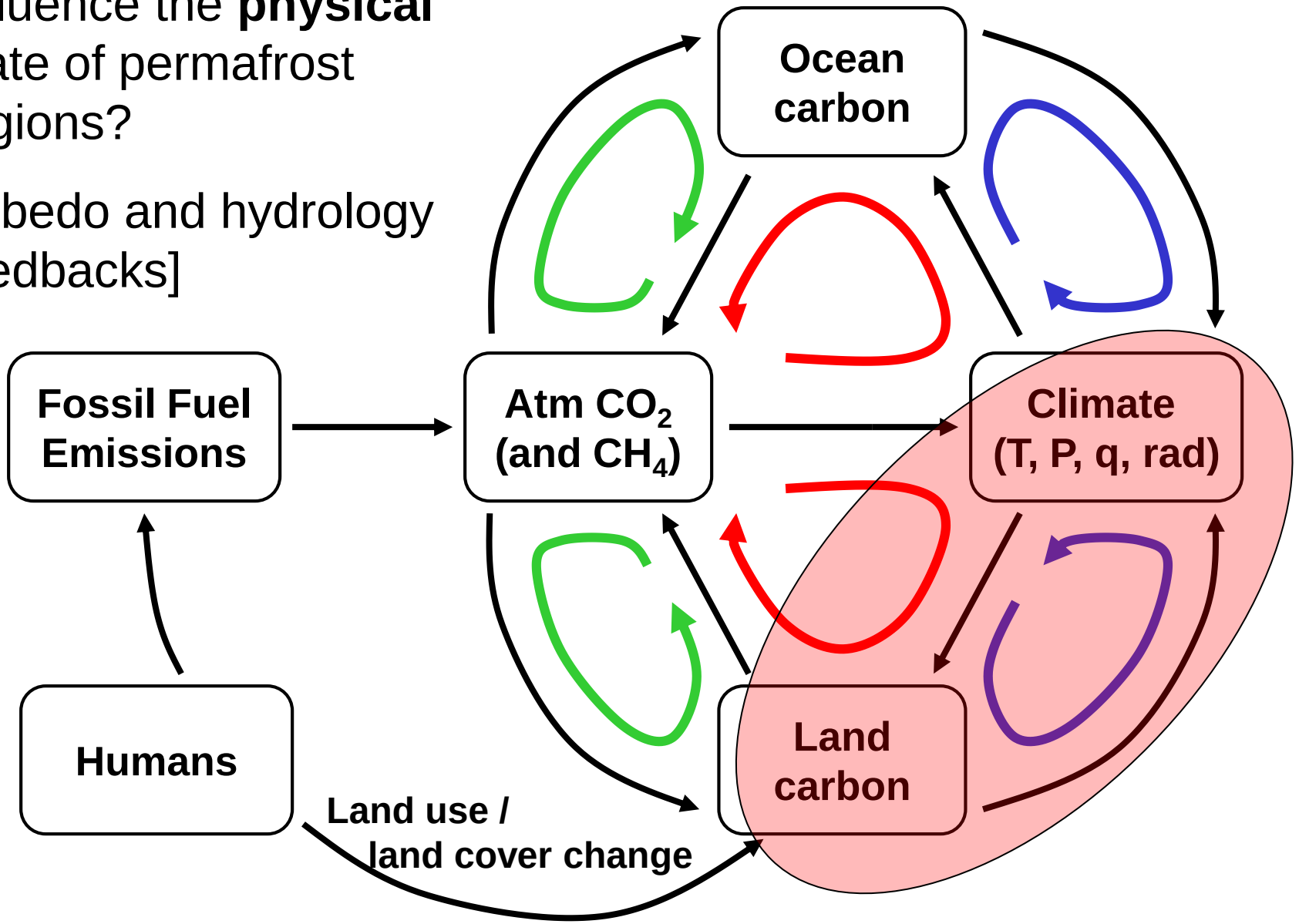
IPCC AR5, 2013

Current Earth System Models represent complex climate-carbon and climate-ecosystem feedbacks



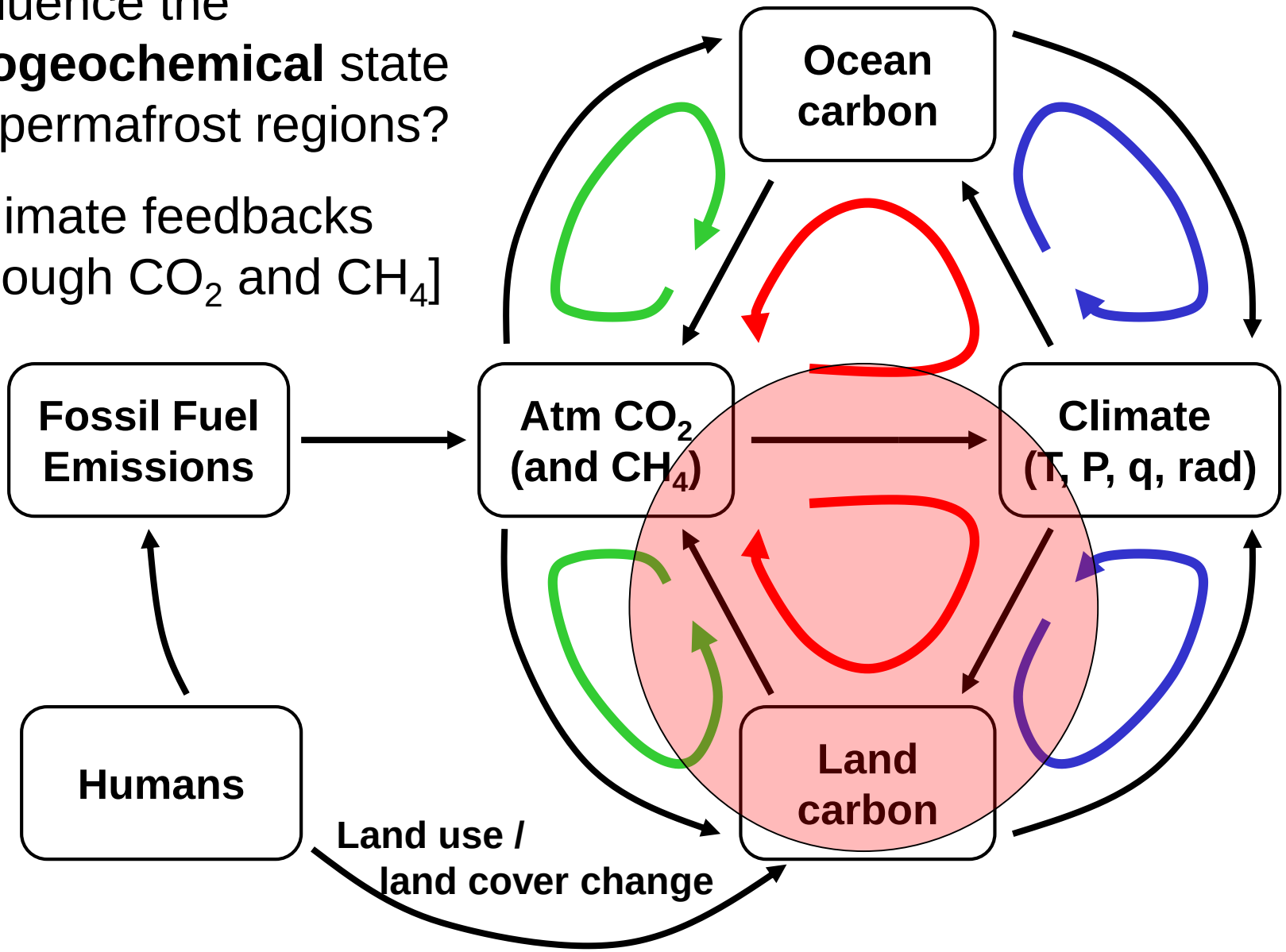
How does warming influence the **physical** state of permafrost regions?

[Albedo and hydrology feedbacks]



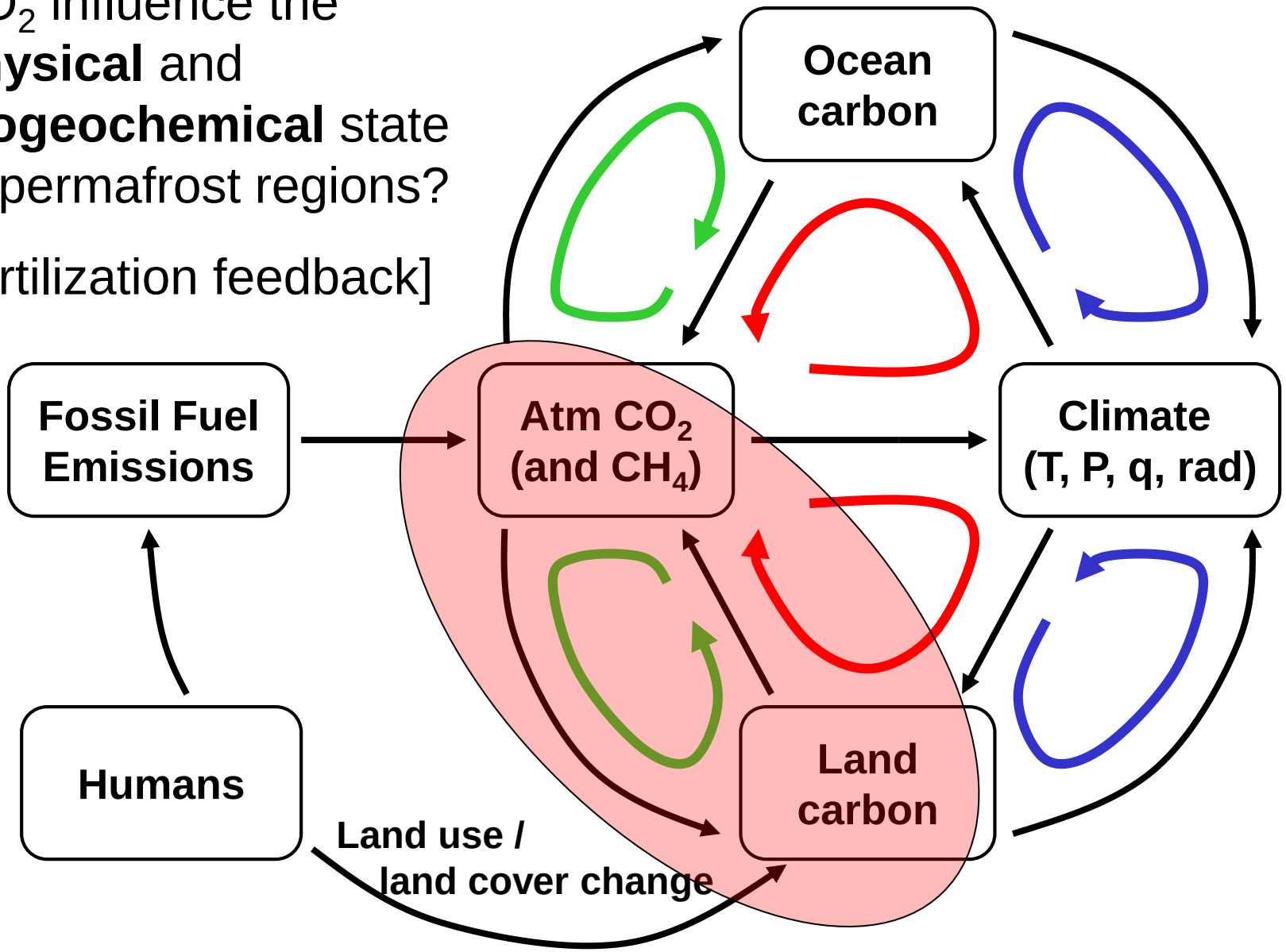
How does warming influence the **biogeochemical** state of permafrost regions?

[Climate feedbacks through CO_2 and CH_4]

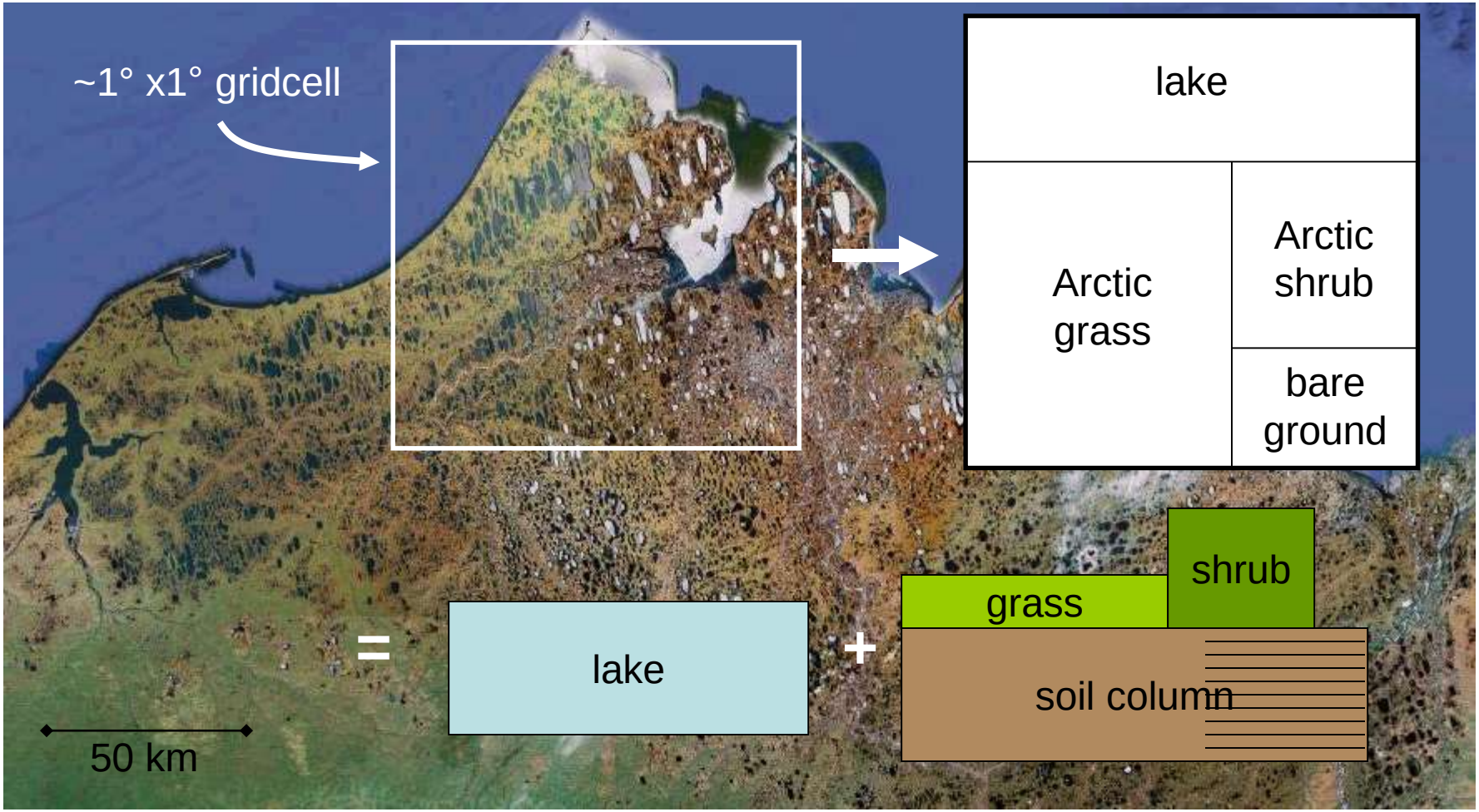


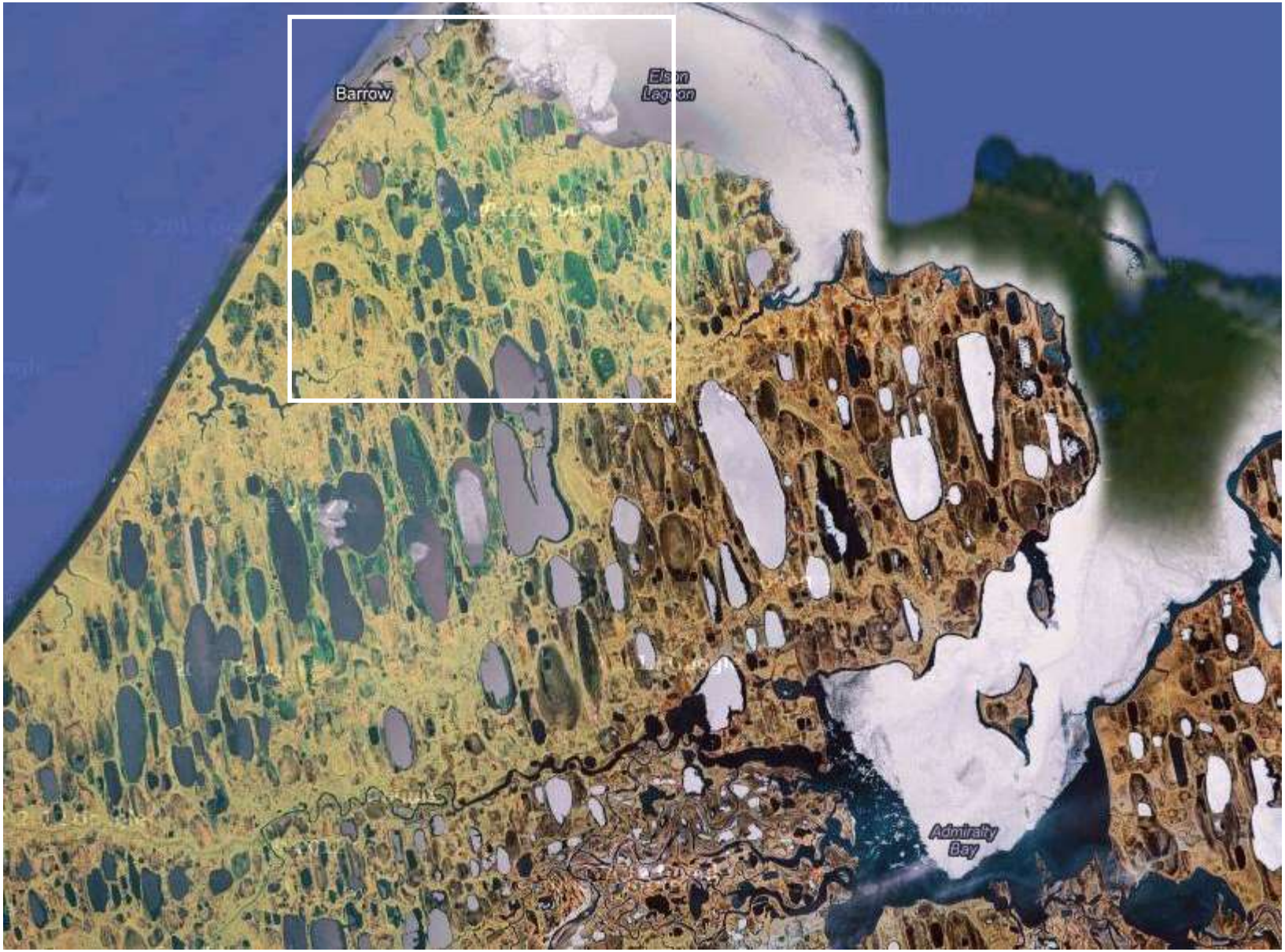
How does atmospheric CO_2 influence the **physical** and **biogeochemical** state of permafrost regions?

[fertilization feedback]

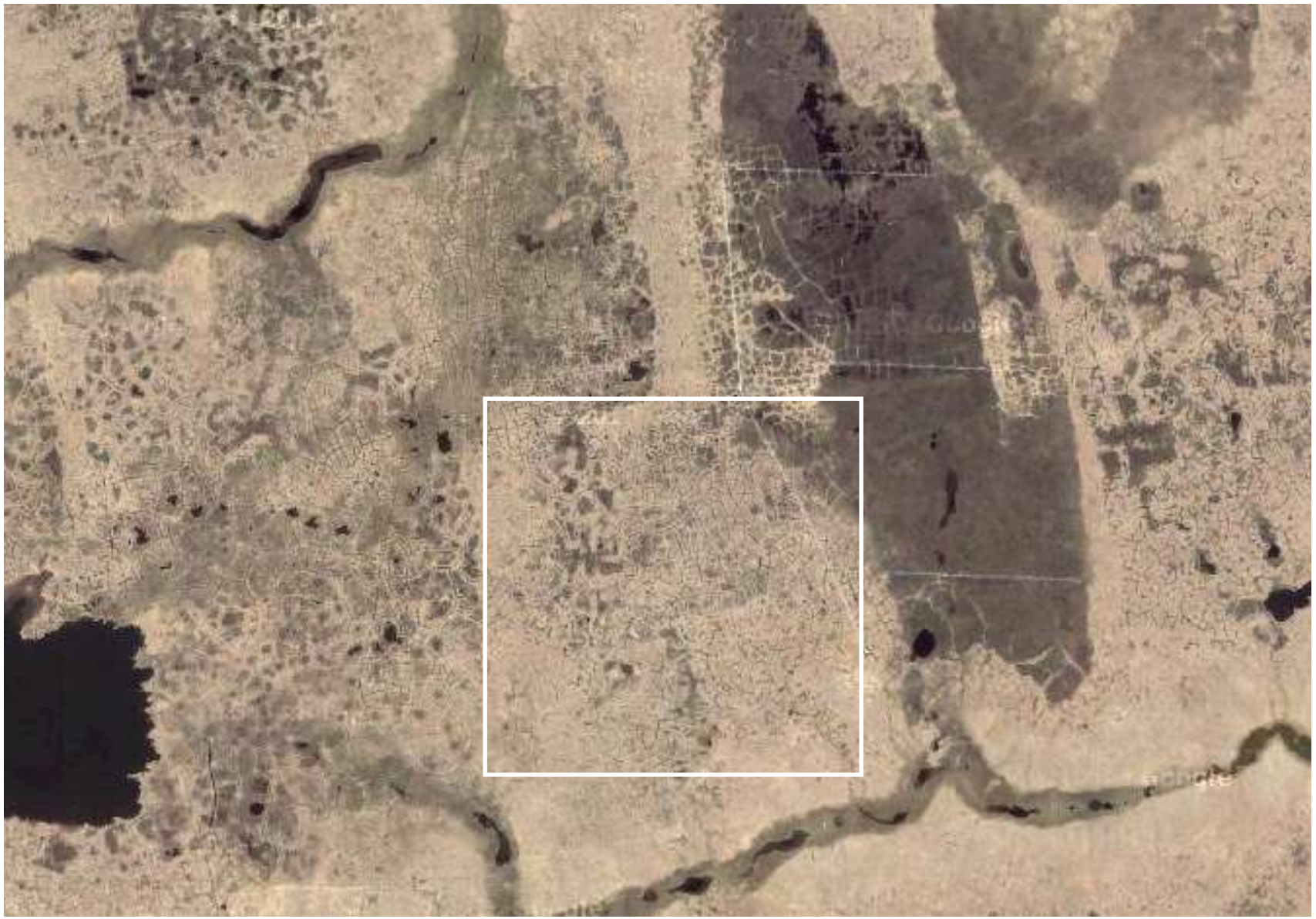


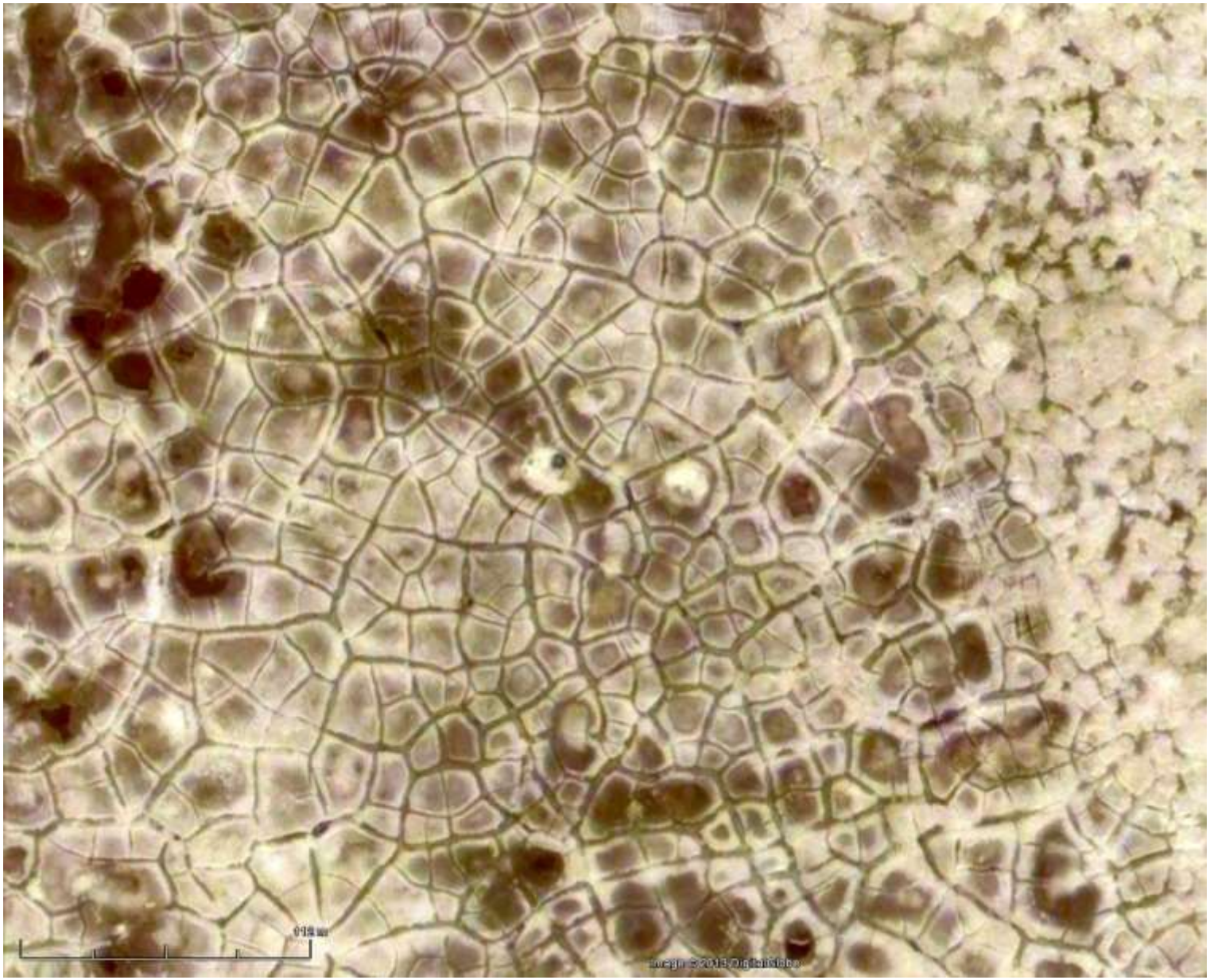
Current climate model treatment of a permafrost tundra landscape…




Barrow
Admiralty Bay


Barrow
Ikroavik
Lake

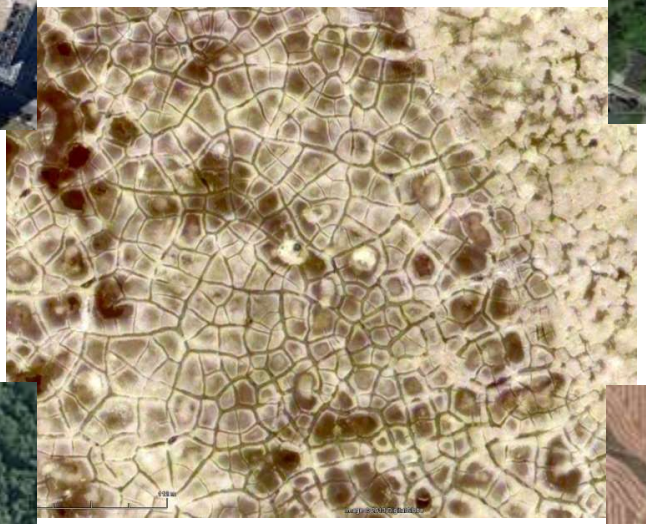




Trying to achieve a sense of scale…

Manhattan

Polygonal tundra near Barrow, AK

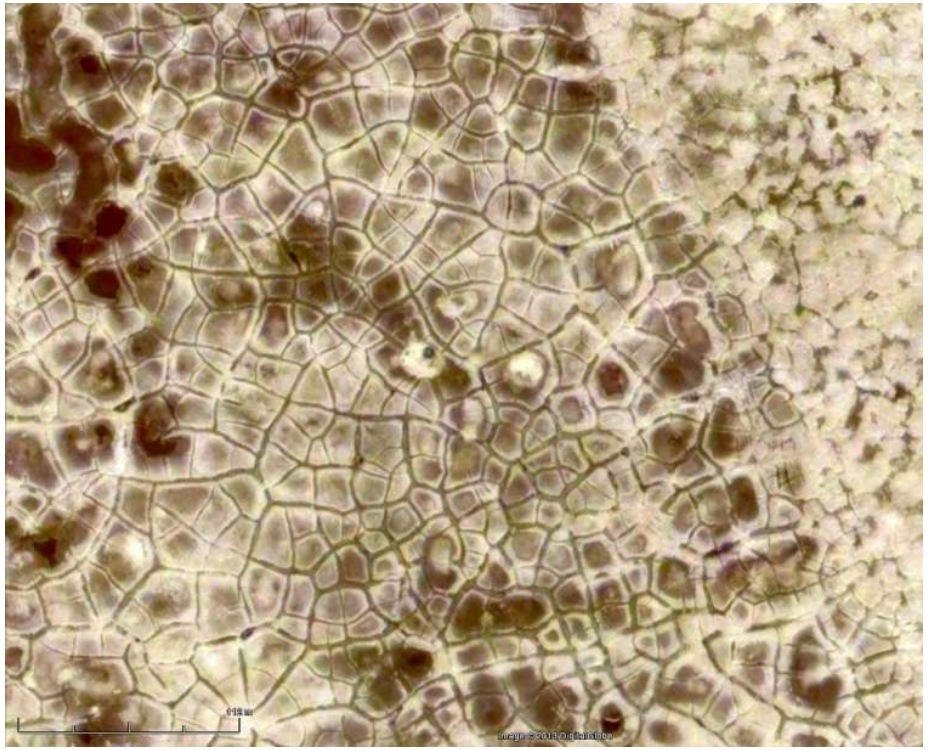


Suburban Knoxville

Amazon Basin

Ohio cropland

A serious scaling problem:



All the quantities of interest for the large-scale climate-prediction problem…

(Moisture, temperature, freeze/thaw state, albedo, vegetation distribution and dynamics, biogeochemical processes)

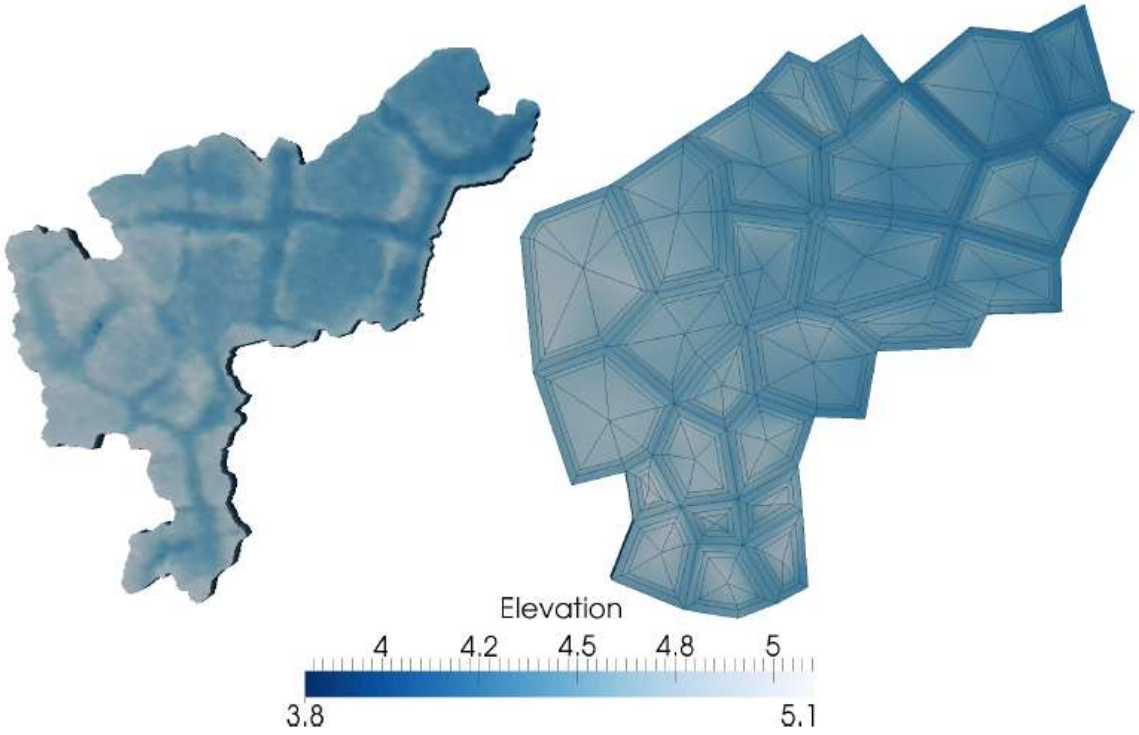
… appear to be strongly controlled by microtopographic variations

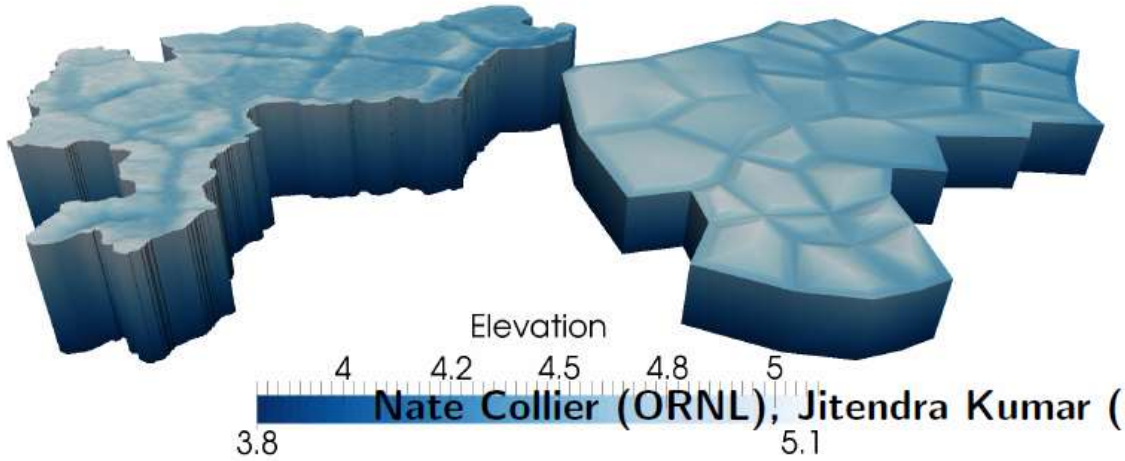
(horizontal scales of centimeters to meters).

A possible solution to the scaling problem:

- Develop explicit process-resolving models at appropriate scales
  - Inform with observations and experimentation
- Add relevant process representation in the climate-scale model
  - Provide parameterization “hooks”
- Use fine-scale models to parameterize coarser-scale models
  - Evaluate with independent observations

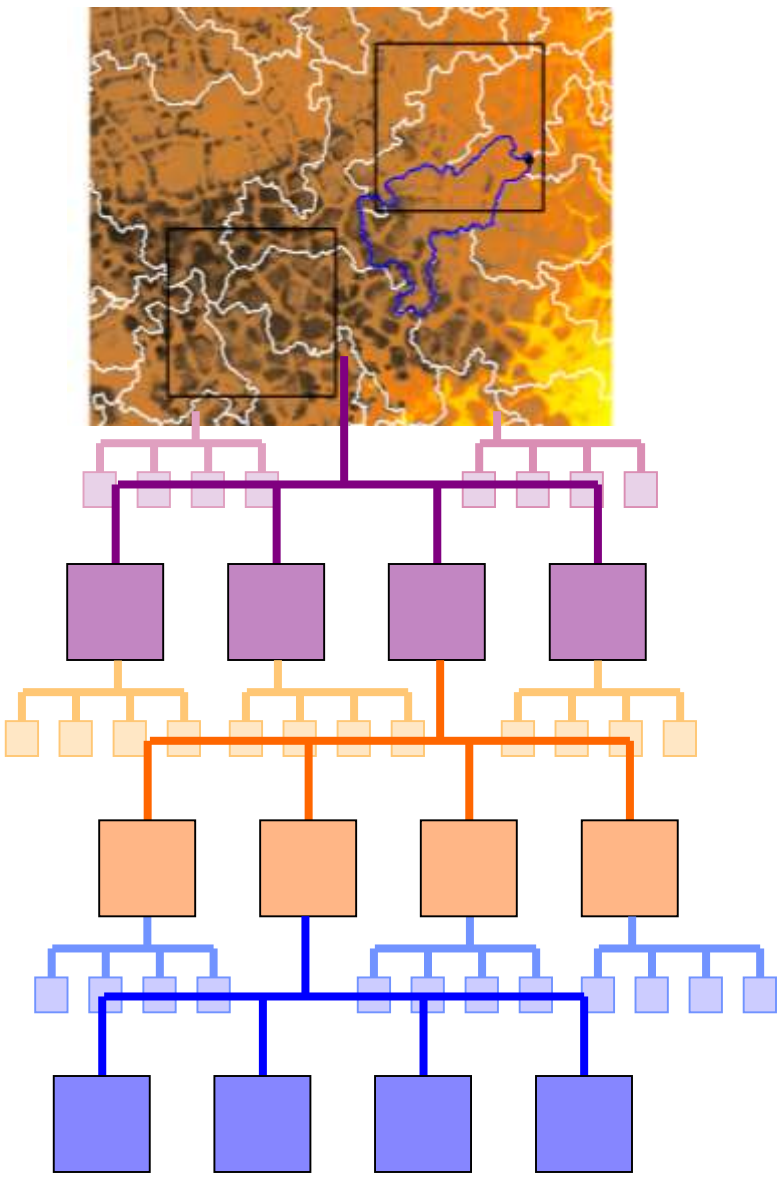
Fine and intermediate scale models: explicit process representation





Nate Collier (ORNL), Jitendra Kumar (ORNL)

Climate-scale model: process representation through parameterized sub-grid heterogeneity



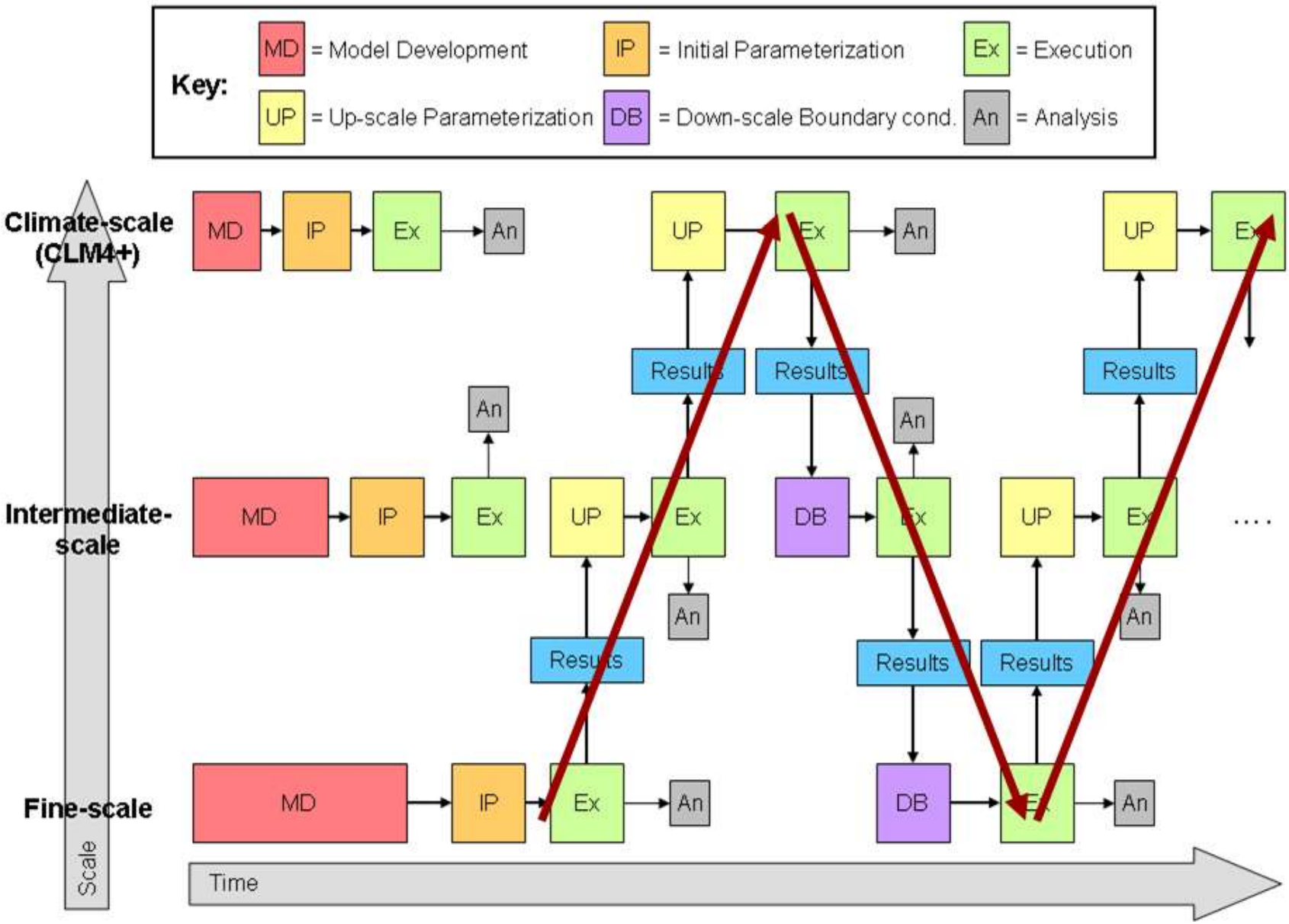
Gridcells: approximately 10 km x 10 km

Landunits: sub-grid basins

Soil columns: groups of similar polygons

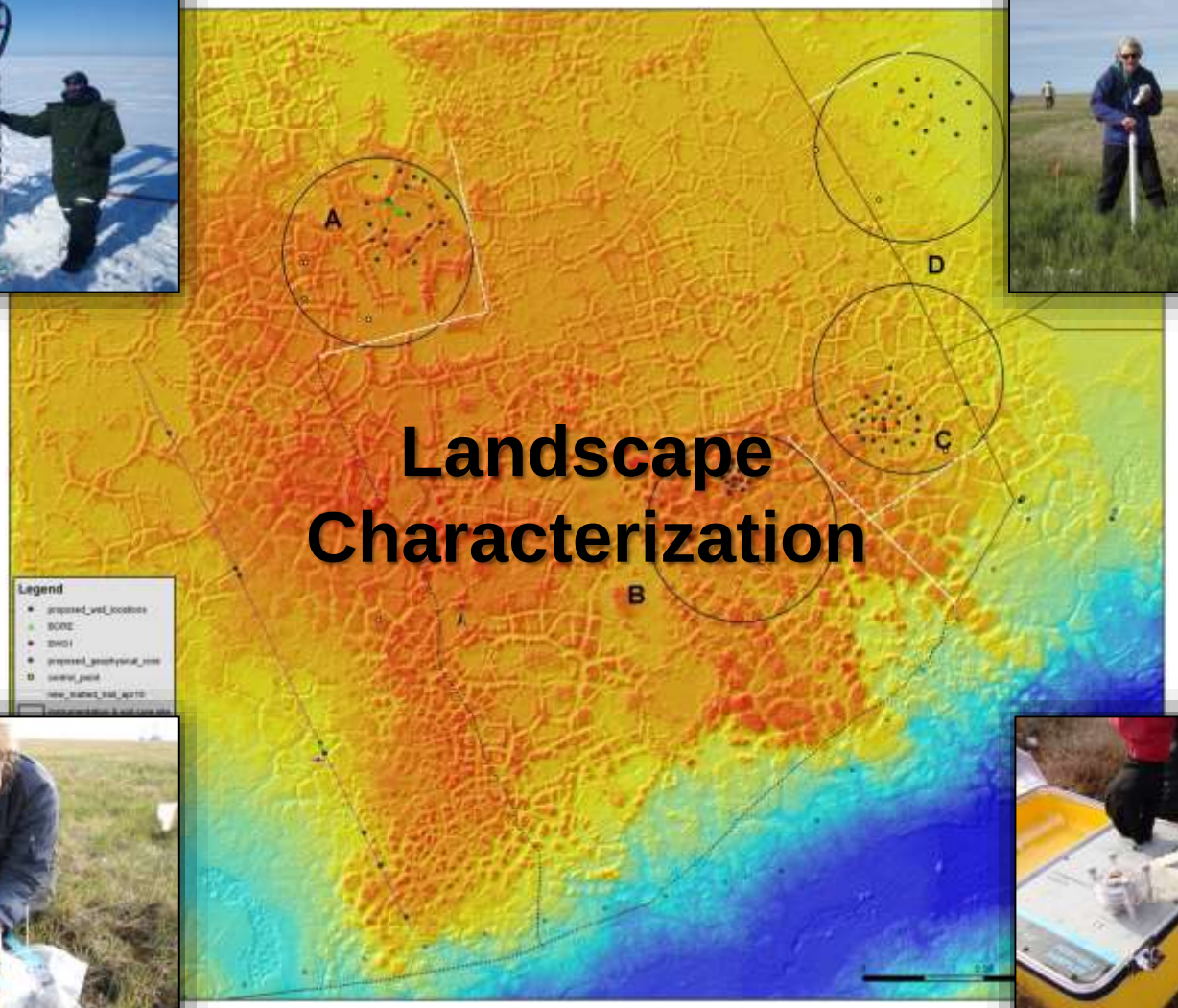
Plant Functional Types: Multiple types on each column (competing)

Process knowledge migration through iterative scaling

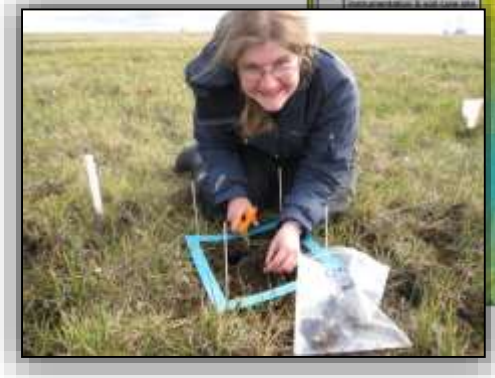


Geophysics

Hydrology



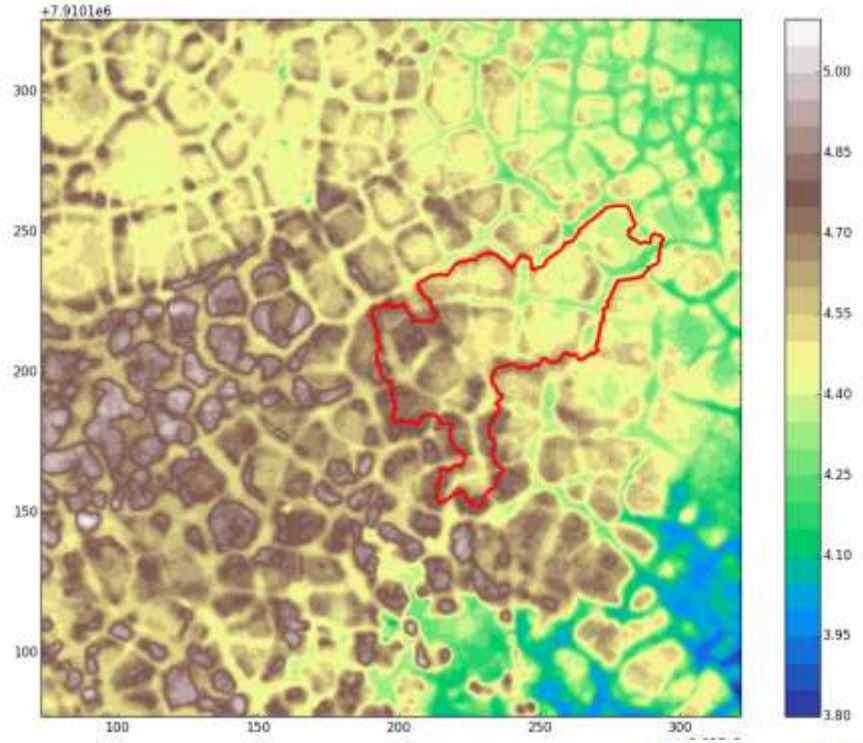
Landscape Characterization

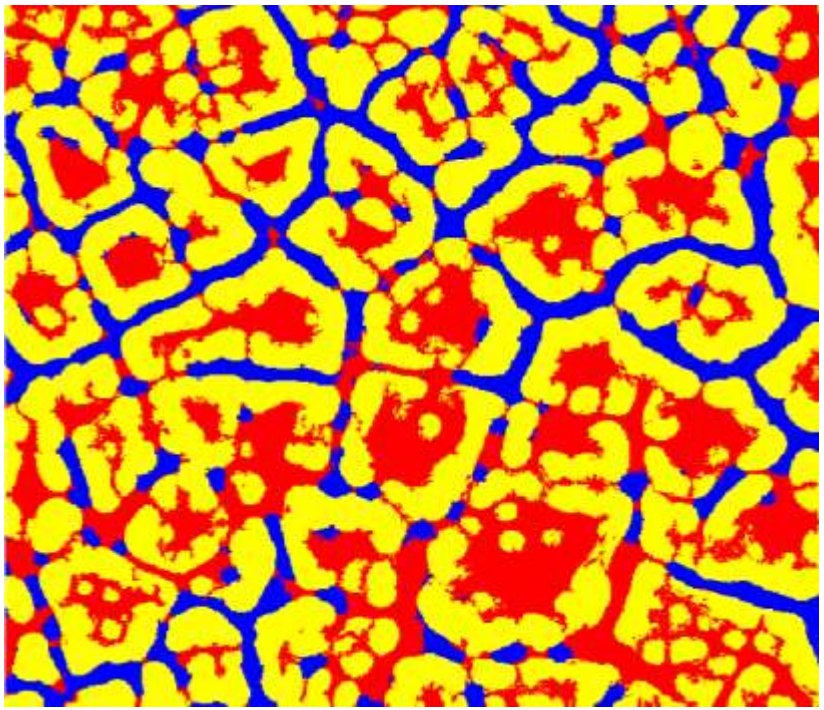


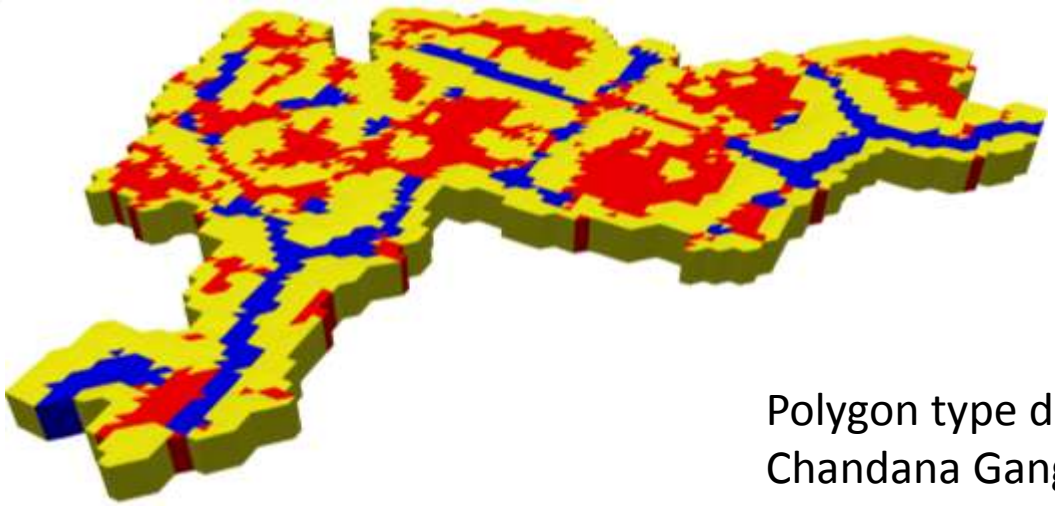
Vegetation

Biogeochemistry

Characterizing the modeling domain

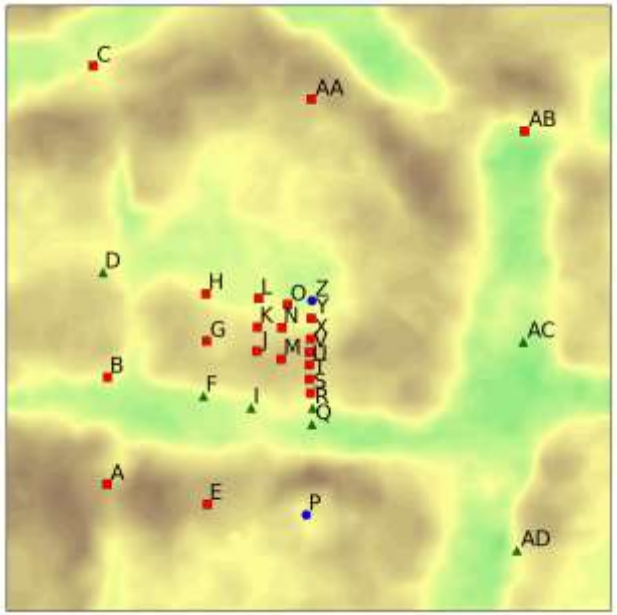




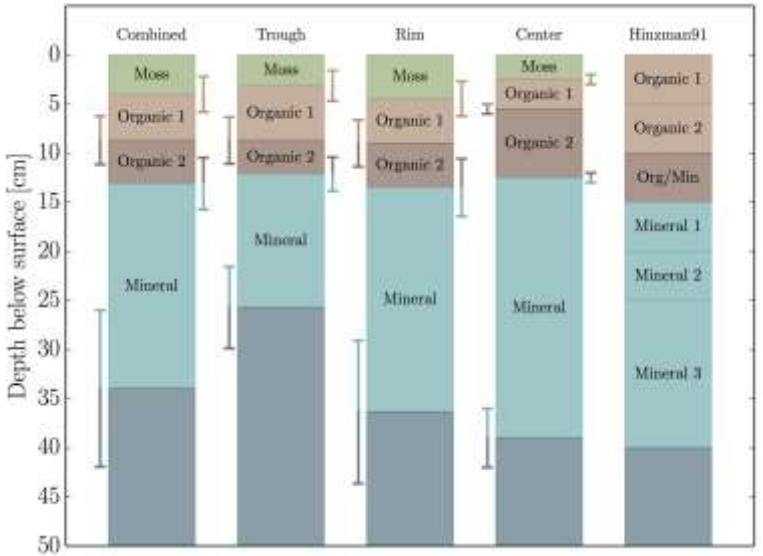


Polygon type delineation:
Chandana Gangodagamage, LANL

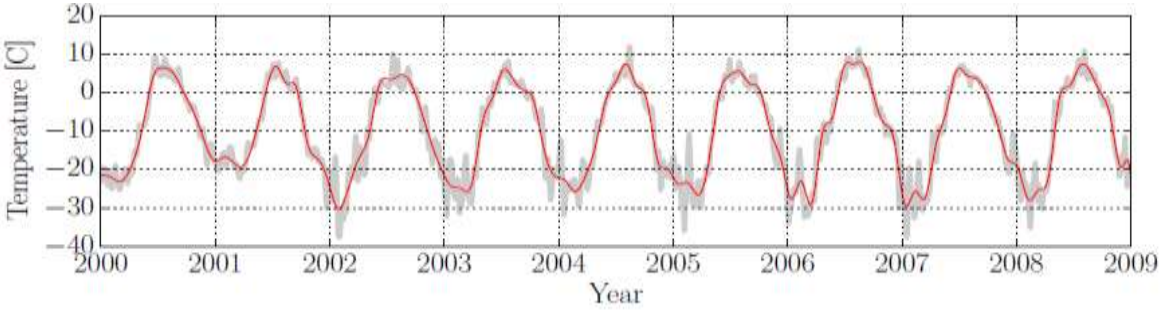
Characterizing the modeling domain



Intensive field measurements are translated to modeling domain characteristics



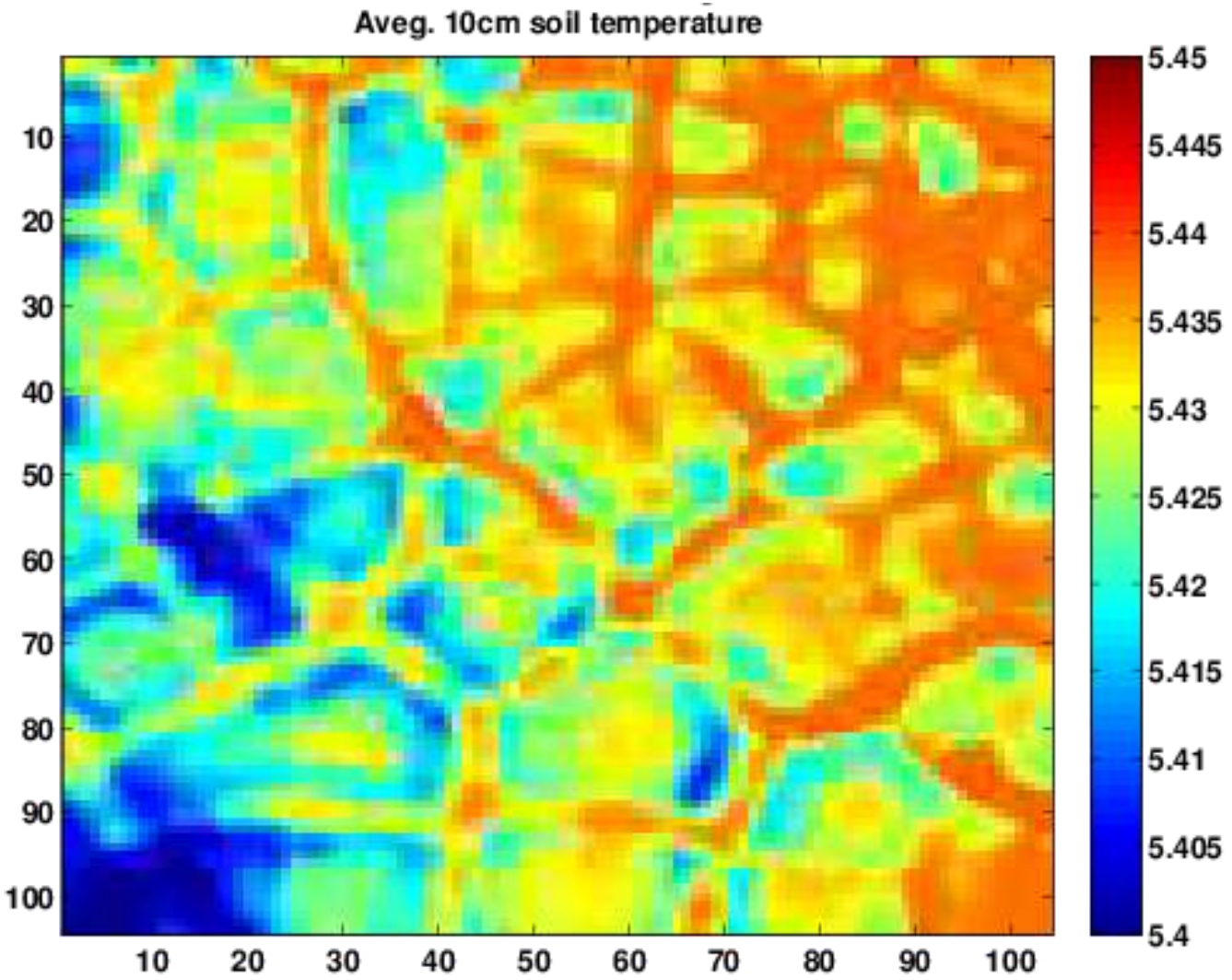
Surface weather observations drive multi-scale models



Soils data from Larry Hinzman and Anna Lilljedahl, UAF

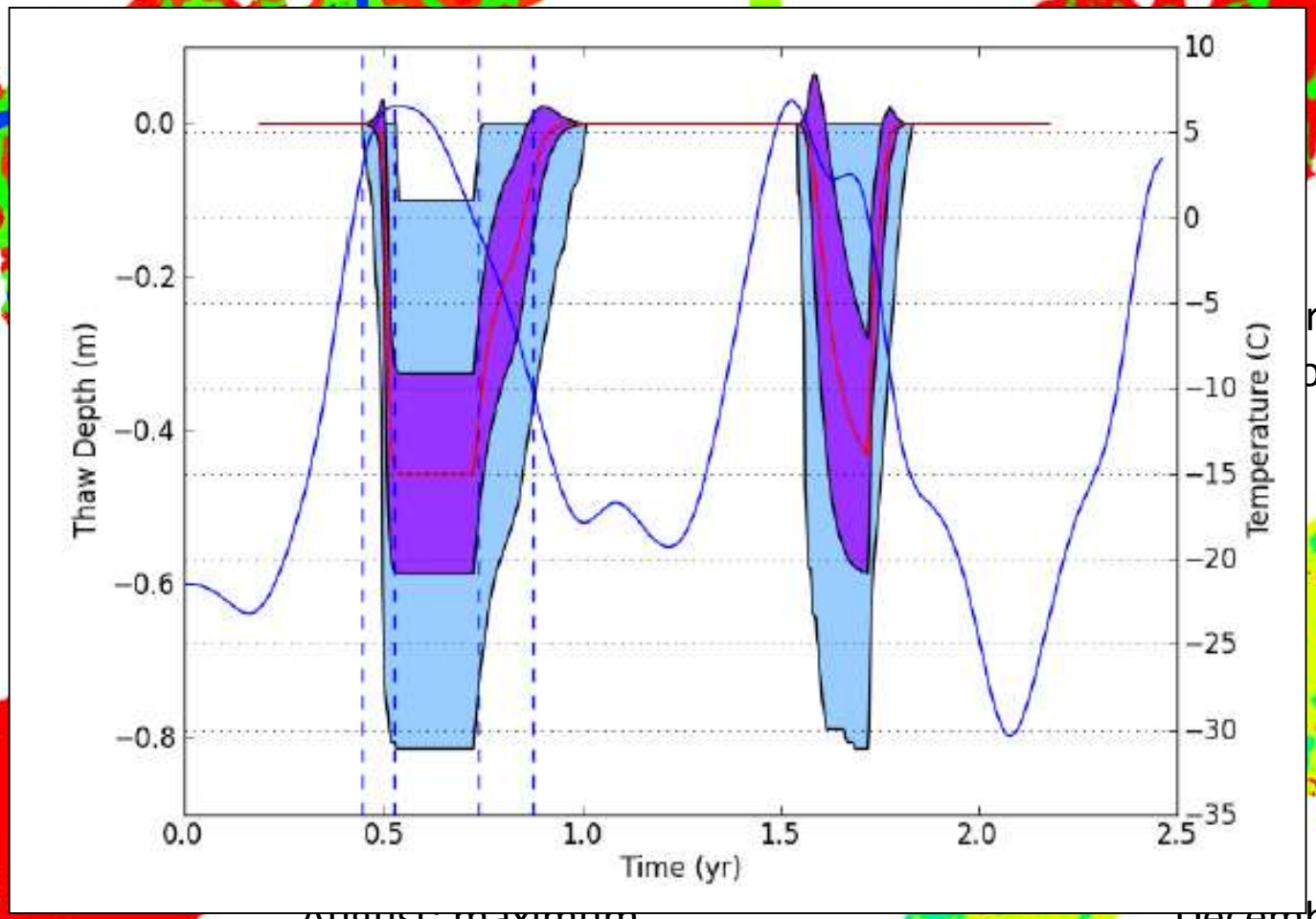
Atmospheric data source: ARM

Soil temperature simulations over gridded domains (Site C, August)



Gautam Bisht, LBNL

Thermal-hydrology simulations over fine-scale domains



1

r: active layer
o freeze

August: maximum active layer depth

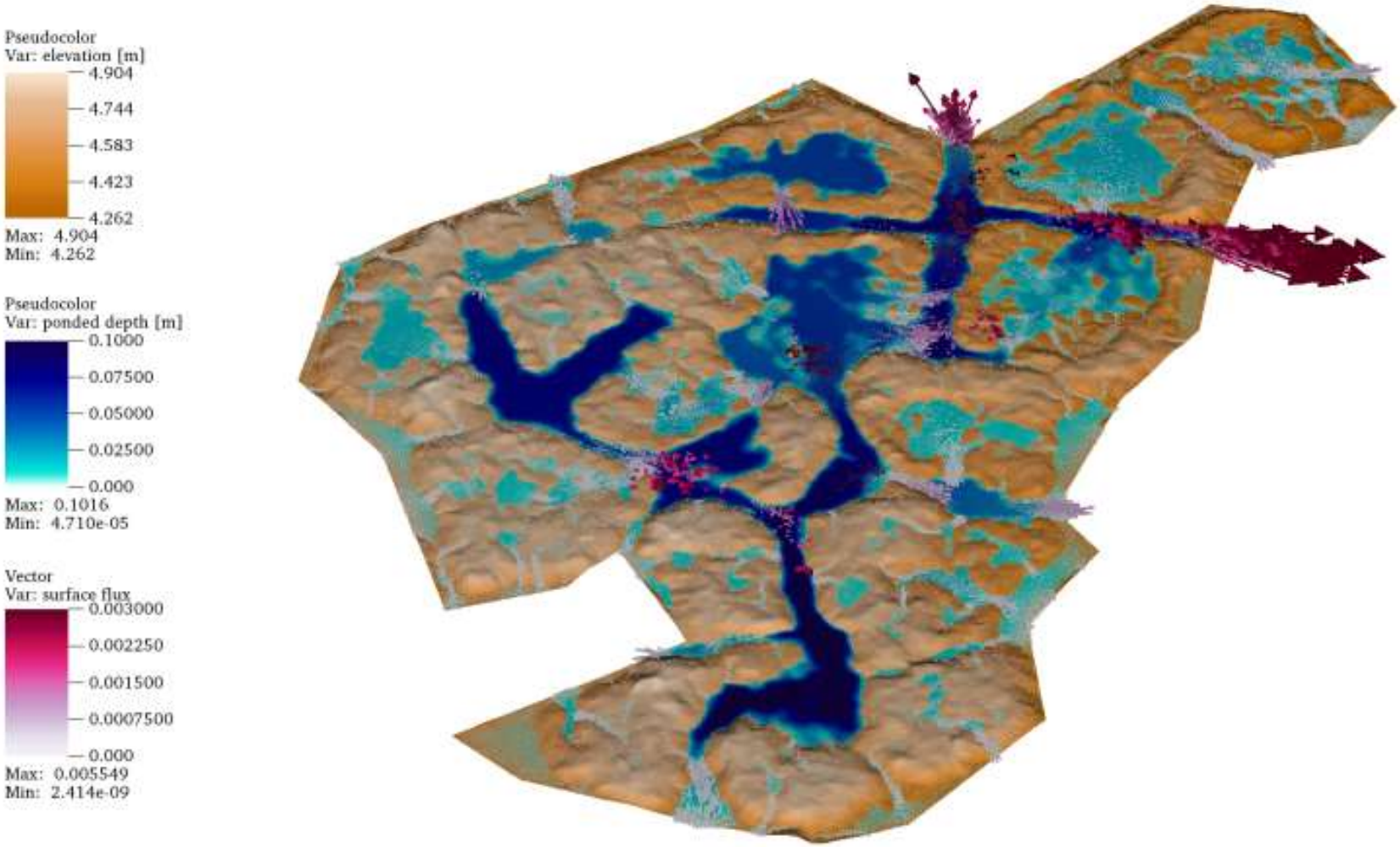
2

December: active layer nearly frozen

4

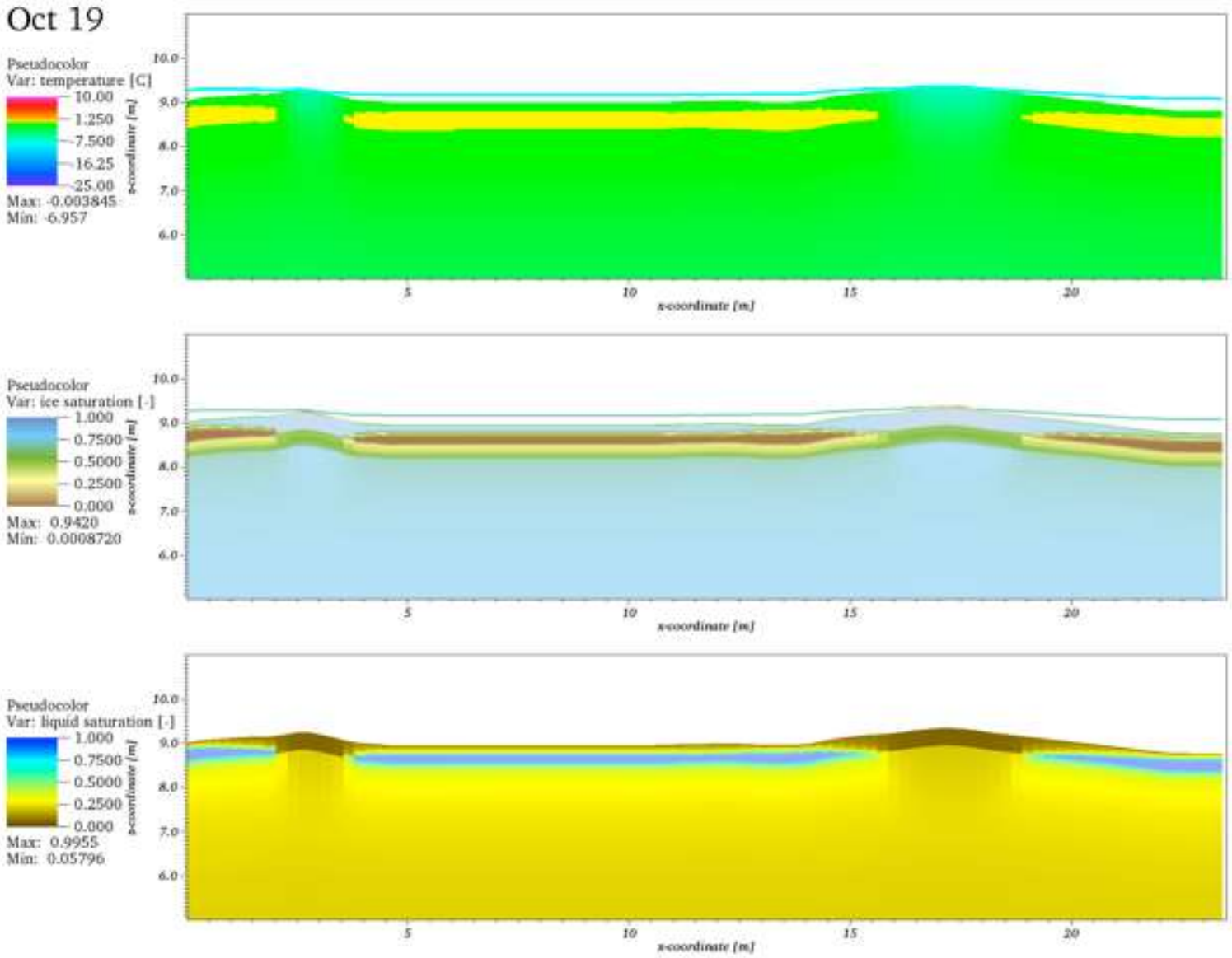
Jitu Kumar, Nathan Collier: ORNL

Surface flow simulation



Ethan Coon, Marcus Berndt,
Scott Painter (LANL LDRD-DR)

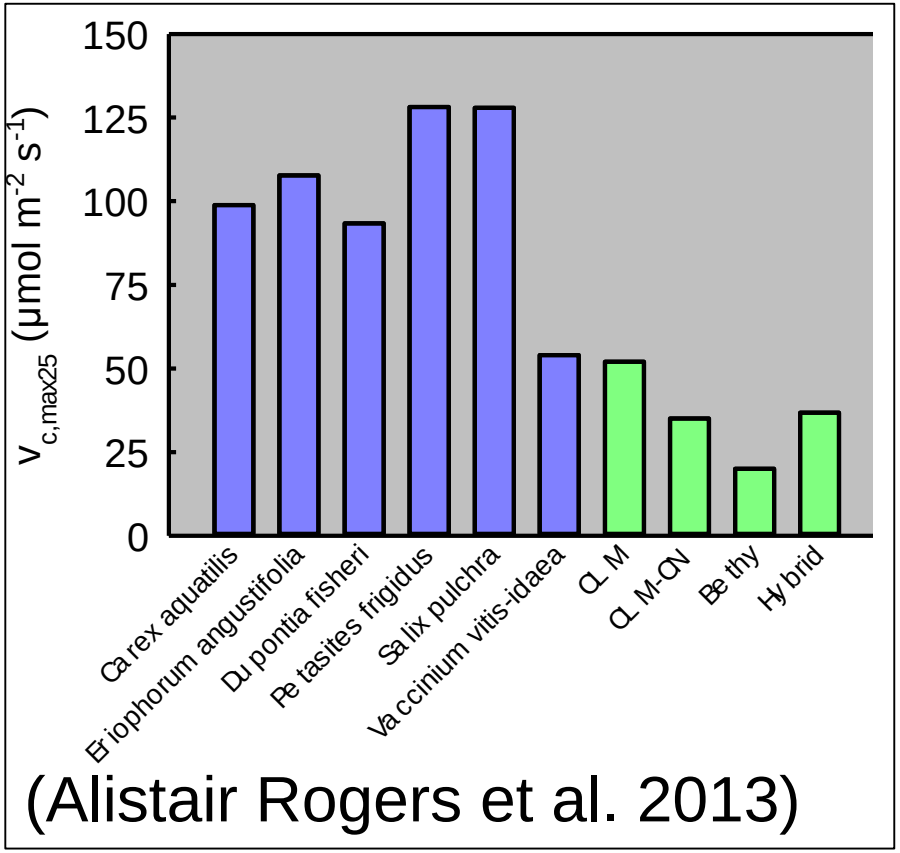
Fully coupled surface-subsurface thermal hydrology simulation



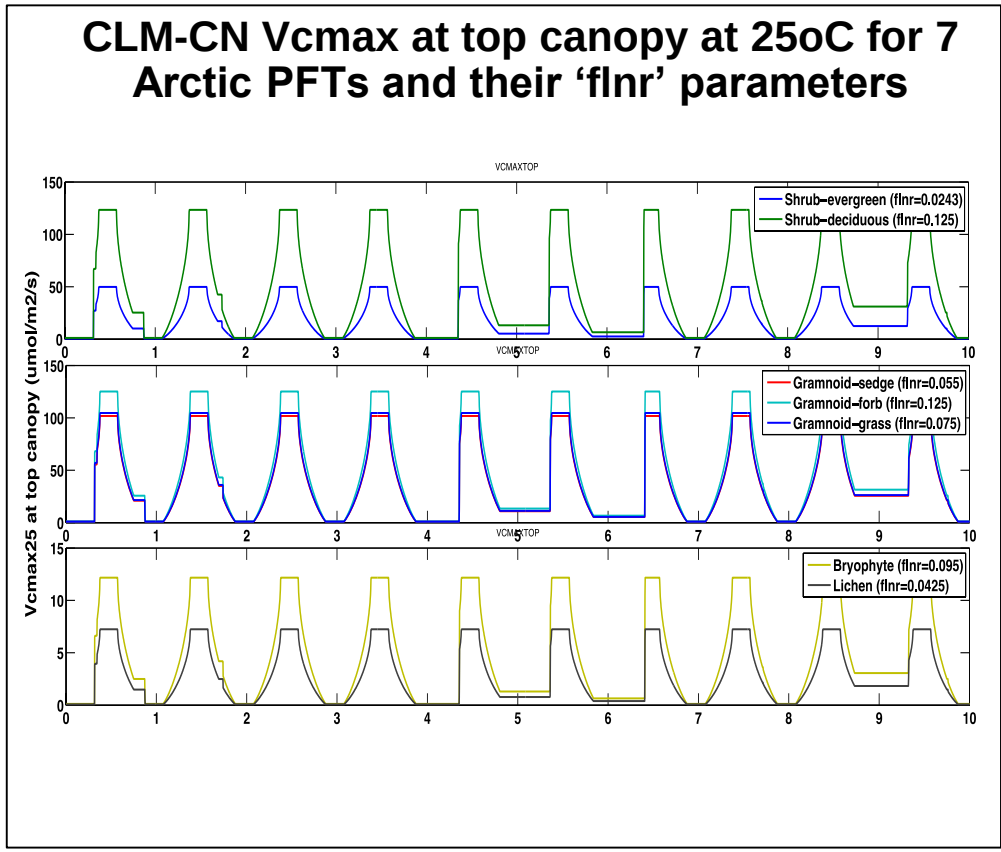
Ethan Coon, Adam Atchley, Scott Painter: LANL (LDRD-DR)

Parameterizing New PFTs for Arctic Tundra using intensive field observations

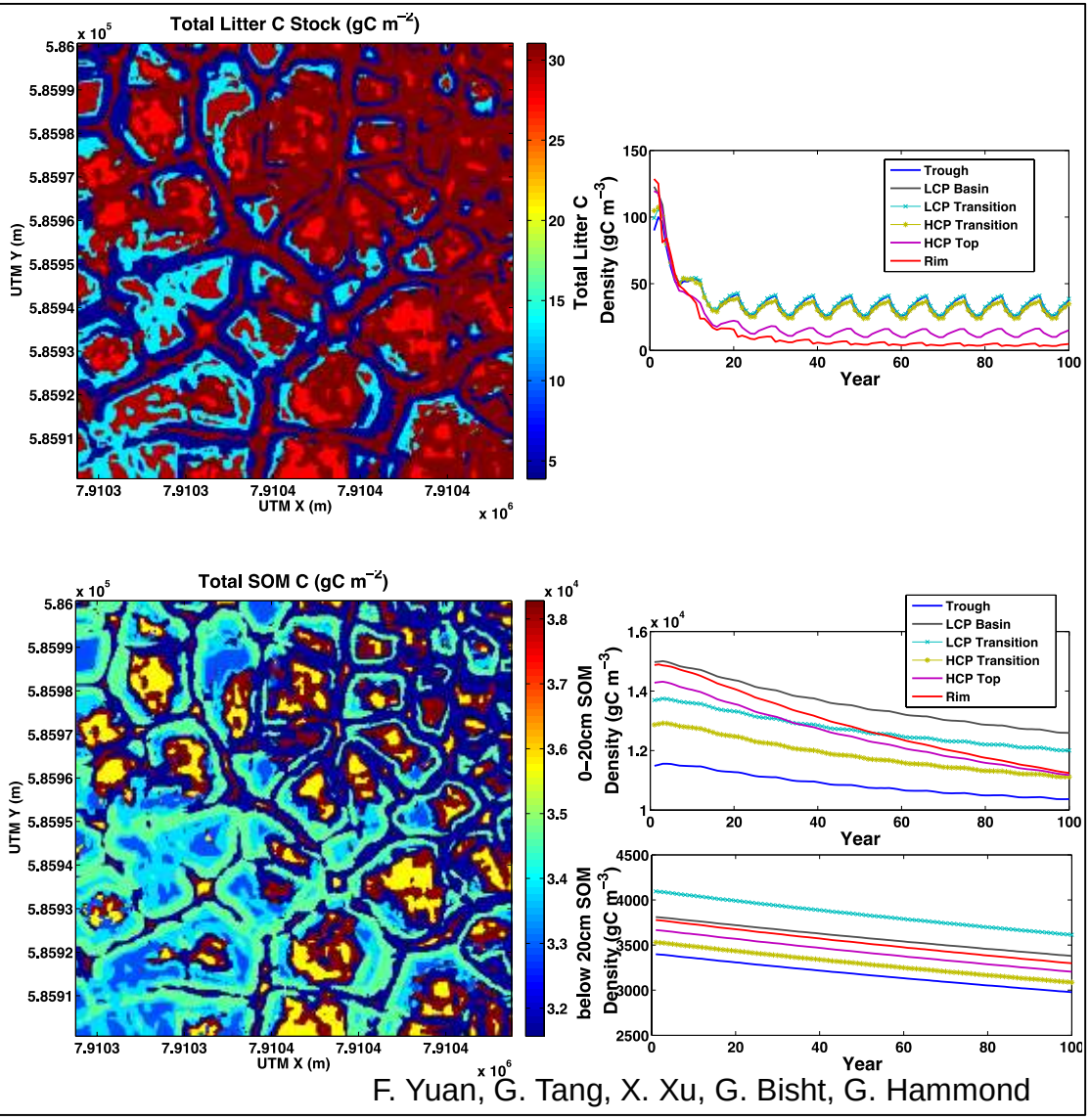
Field measurement (Vcmax) translated to model parameter
(fraction of leaf nitrogen in Rubisco, flnr)



(Alistair Rogers et al. 2013)



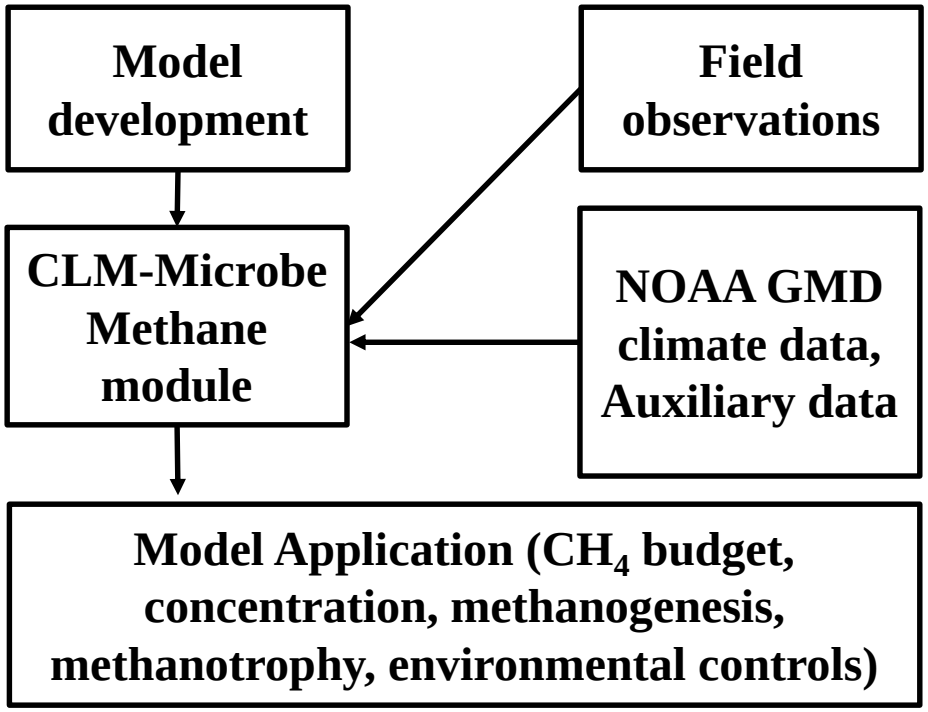
Coupled vegetation and soil biogeochemistry modeling

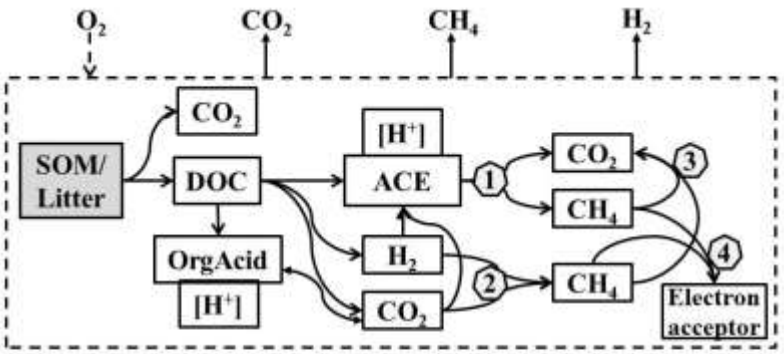


F. Yuan, G. Tang, X. Xu, G. Bisht, G. Hammond

A common modeling framework is being used for multi-scale simulation, reducing the loss of information in the up-scale migration of processes and parameterizations

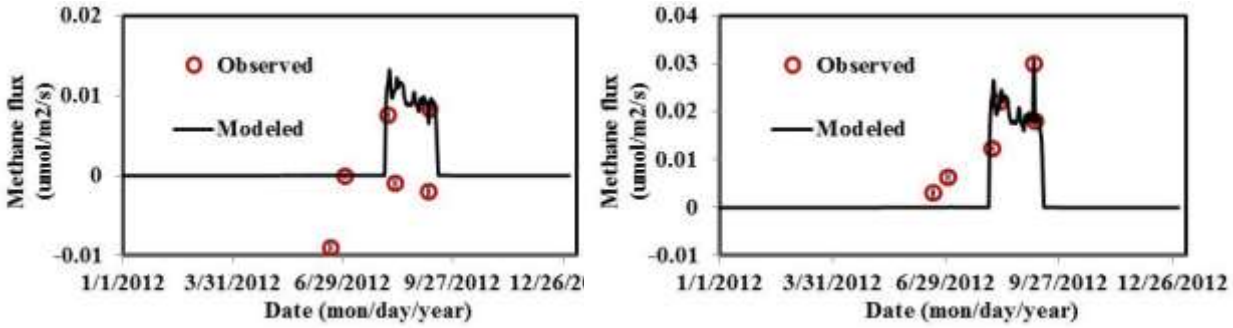
Example Data-Model Integration: Measuring and modeling CH_4 flux





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-depdent methanogens; 3 indicates aerobic methanotrophys; 4 indicates anaerobic methanotrophys

A Microbial Functional Group (MFG)-Based Methane Module



Modeled CH4 flux in Barrow, AK

X. Xu, ORNL (modeling)
M. Torn, LBNL (observations)

Next steps: Migrating NGEE-Arctic knowledge into global-scale models

- Observation-informed multi-scale modeling framework from NGEE-Arctic will be a core component of new land model development for next-generation, high-resolution Earth System Model
  - Nascent DOE project: Accelerated Climate Modeling for Energy

The Next-Generation Ecosystem Experiments (NGEE Arctic) project is supported by the Office of Biological and Environmental Research in the DOE Office of Science.

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Logistical Support Provided by: