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Geomorphological controls on water and ecosystem processes in ice wedge polygon landscapes

Cathy Wilson

…and The NGEE-Arctic team

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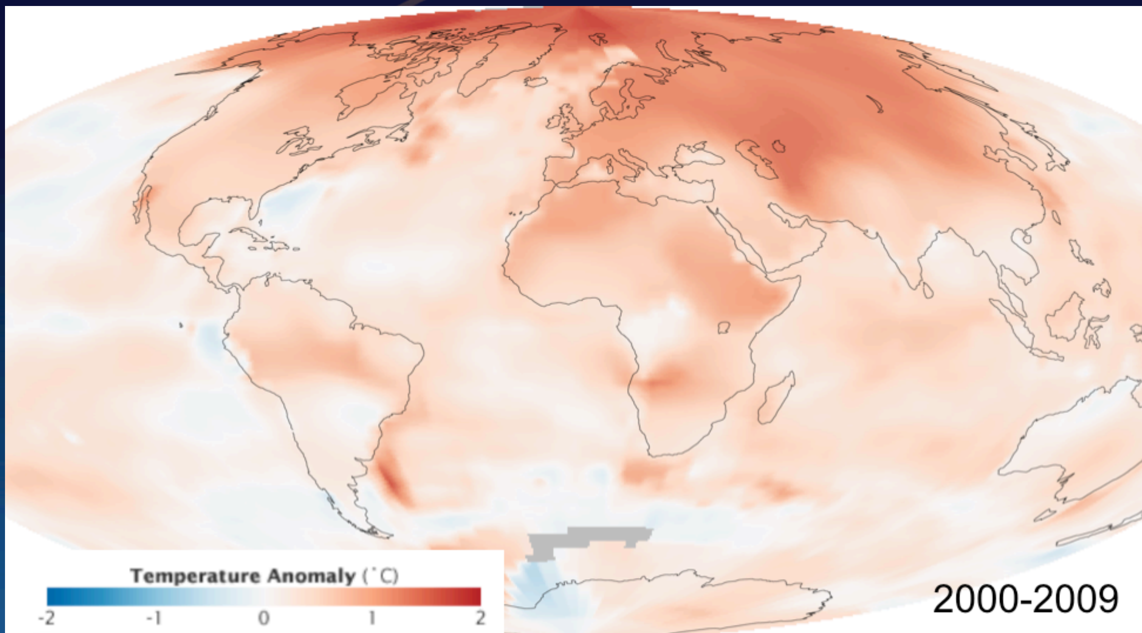
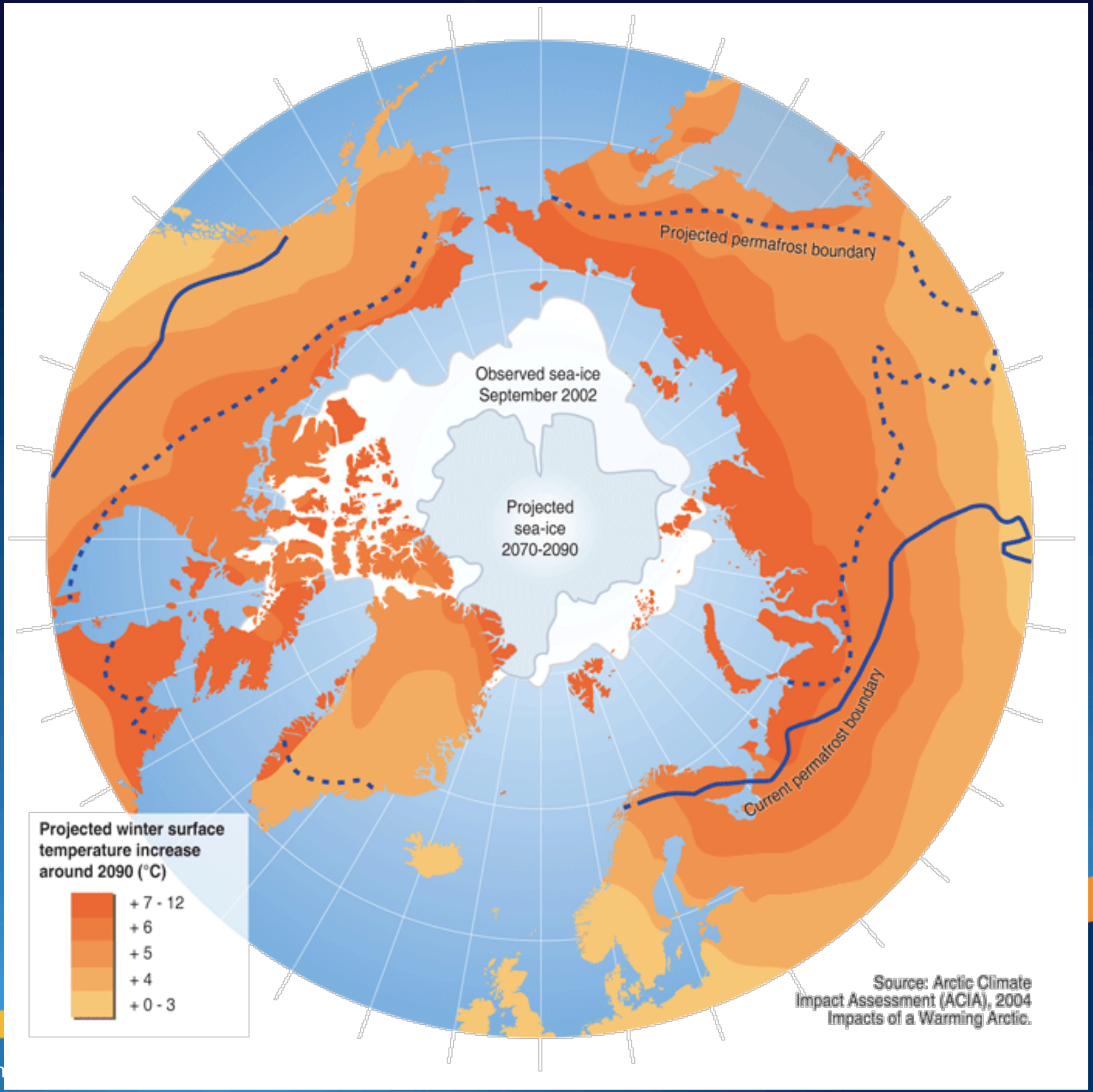
Rapid Arctic warming is driving dramatic changes across all systems

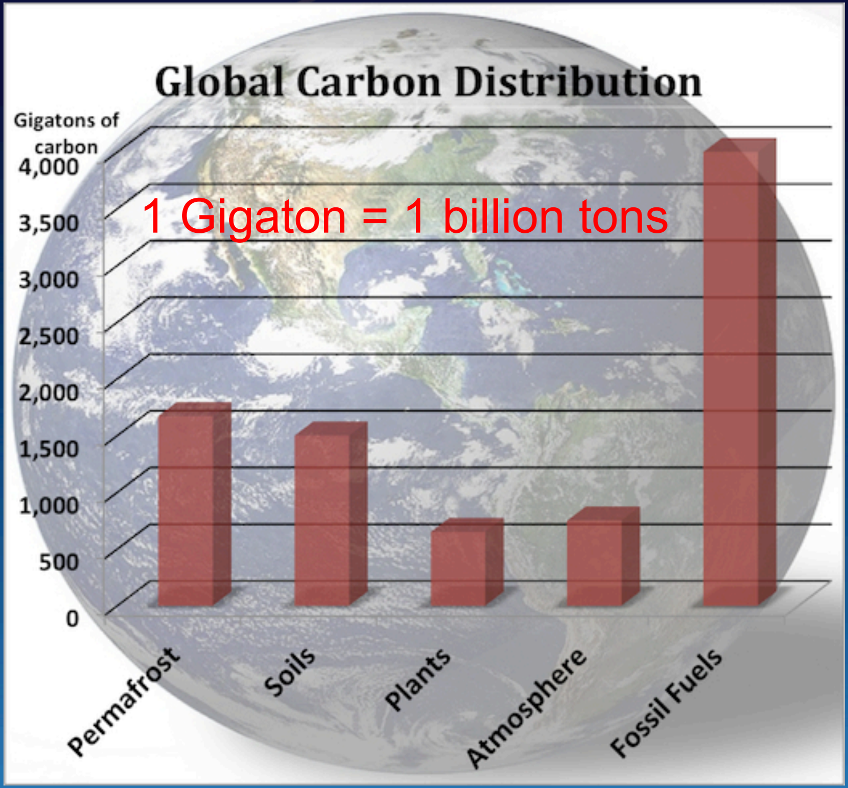


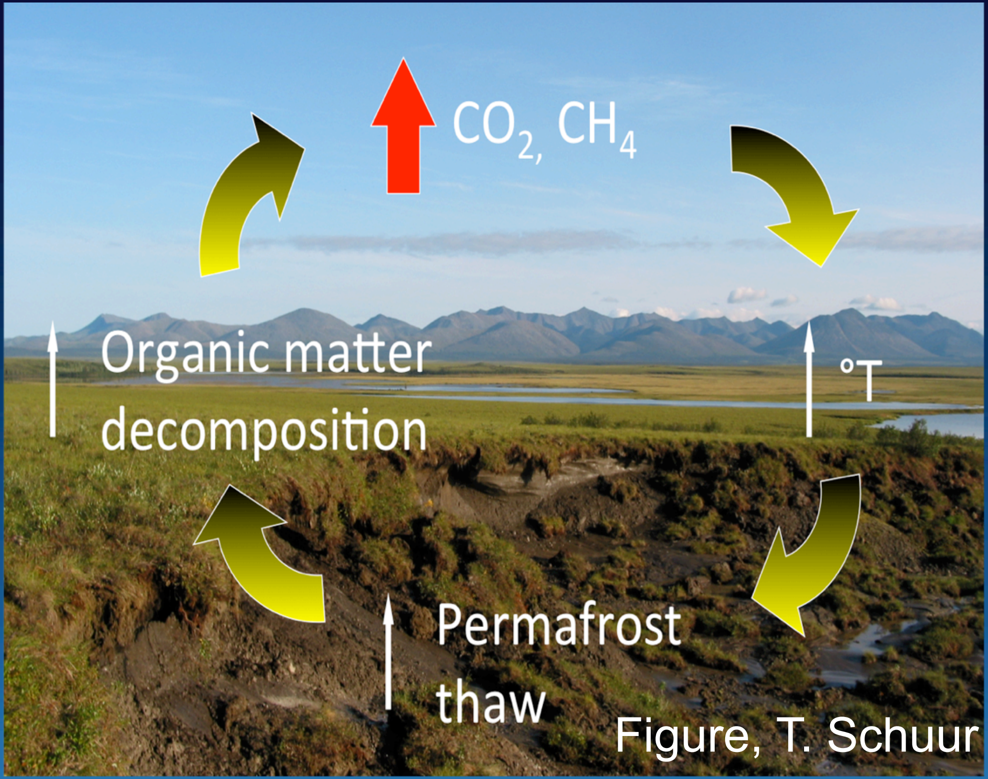
Permafrost covers about ¼ of the Northern hemisphere landmass

High uncertainty in predicted rates of loss of permafrost by 2100



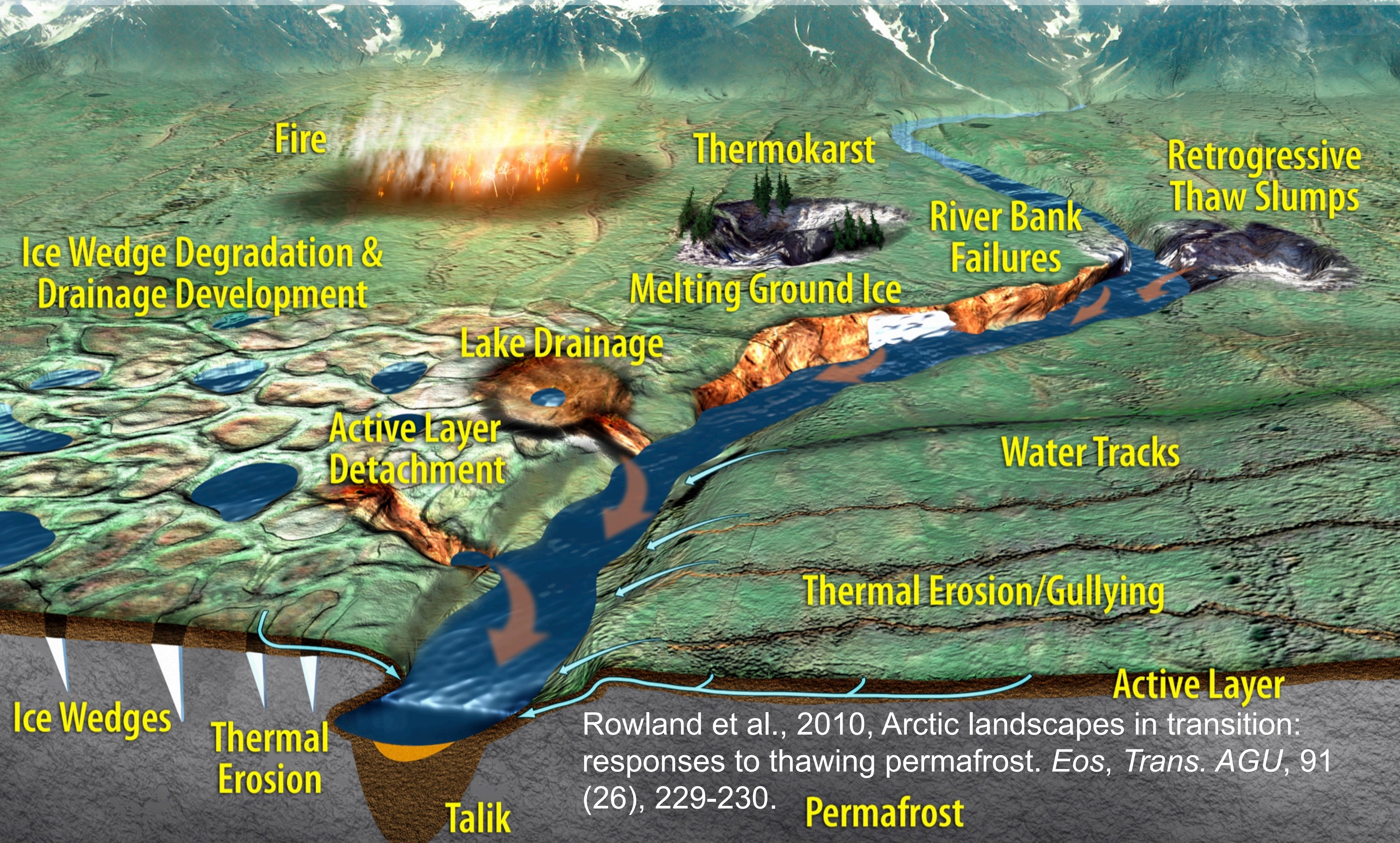
High uncertainty in fate of ~1700GT of permafrost carbon





How much? How fast? What form?

Warming is driving complex interactions and feedbacks between physical, chemical and ecological processes; this is poorly represented in predictive models



Rowland et al., 2010, Arctic landscapes in transition: responses to thawing permafrost. *Eos*, *Trans. AGU*, 91 (26), 229-230.

Next Generation Arctic Ecosystem Experiment, NGEE-Arctic Goal:

Build a process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy, 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.

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NGEE Arctic aims to improve prediction-through better representation of observed multi-scale structure and processes in Arctic tundra landscapes

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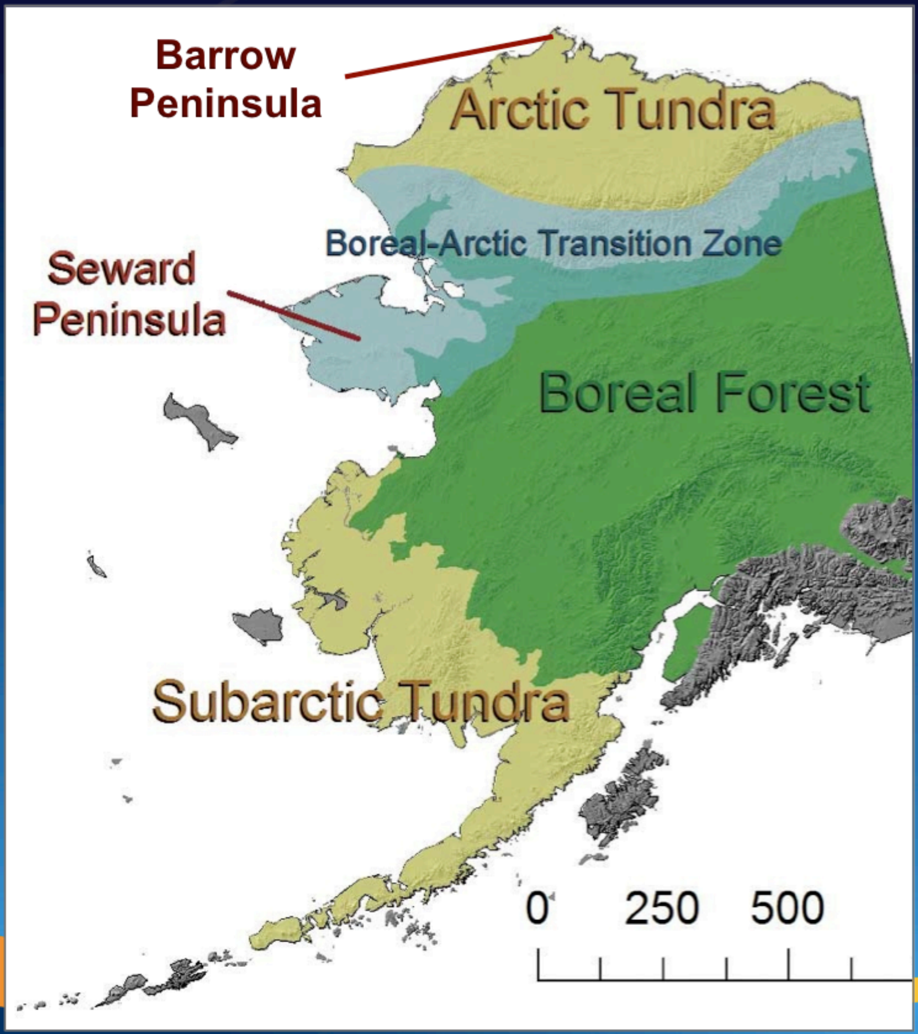

Develop the data and models to represent the complexity of Arctic land ecosystem processes and interactions, and predict Arctic evolution

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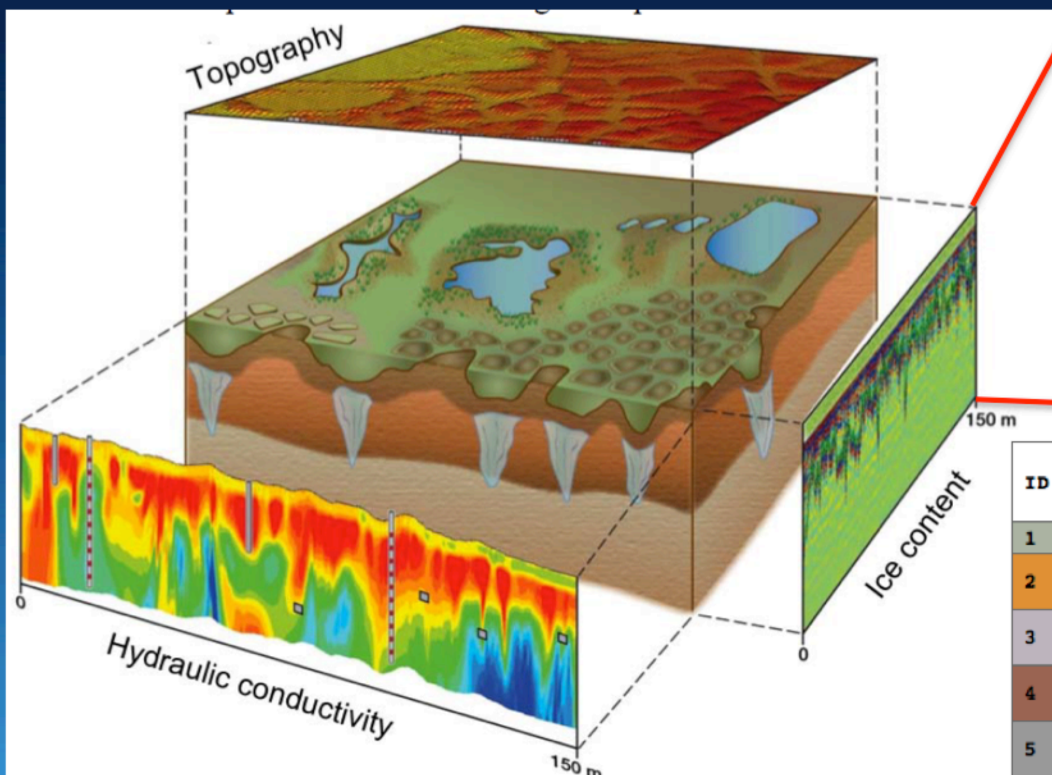
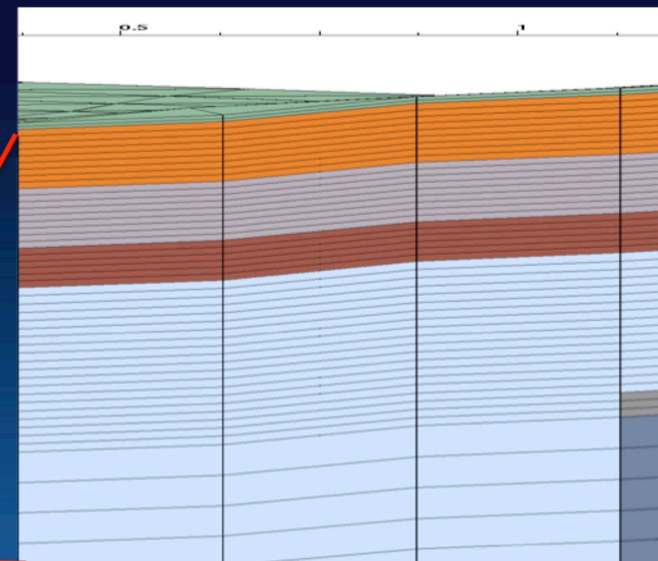
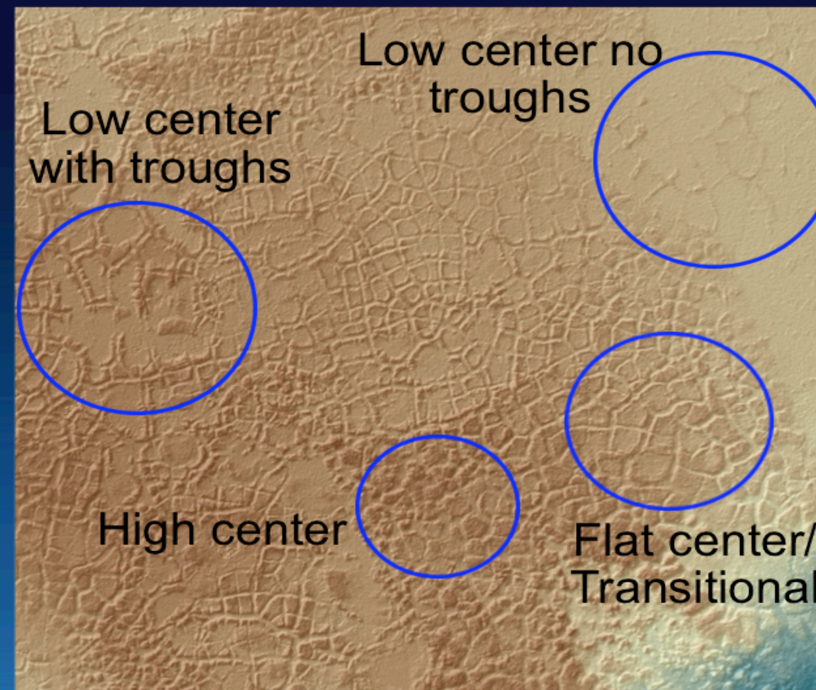




ID	Layer Name	Layer Thick	Layer Vertical Cells	Layer Volume	Min Top Elevation	Max Top Elevation
1	moss(top)	0.02	2 x .01	7.936425	4.50	4.99
2	upper organic	0.18	9 x .02	79.36425	4.48	4.97
3	upper mineral	0.18	9 x .02	71.42801	4.30	4.79
4	lower organic	0.12	6 x .02	47.61855	4.12	4.61
5	lower mineral	0.50	20 x .025	146.4469	4.00	4.49
6	deep mineral	2.2 - 4.8	50 x .09	1745.817	3.50	3.99
7/30	ice	0.00 – 2.3	variable	182.7924	4.49	4.00

NGEE Phase 1 site: Barrow AK

In Barrow DTLB’s and ice wedge polygons control the distribution of properties and processes in the landscape



~200 cores for subsurface property data for model initialization

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National Nuclear Security Administration

CT (x-ray Computed Tomography) scans of cores with measured hydrologic properties (LBNL)

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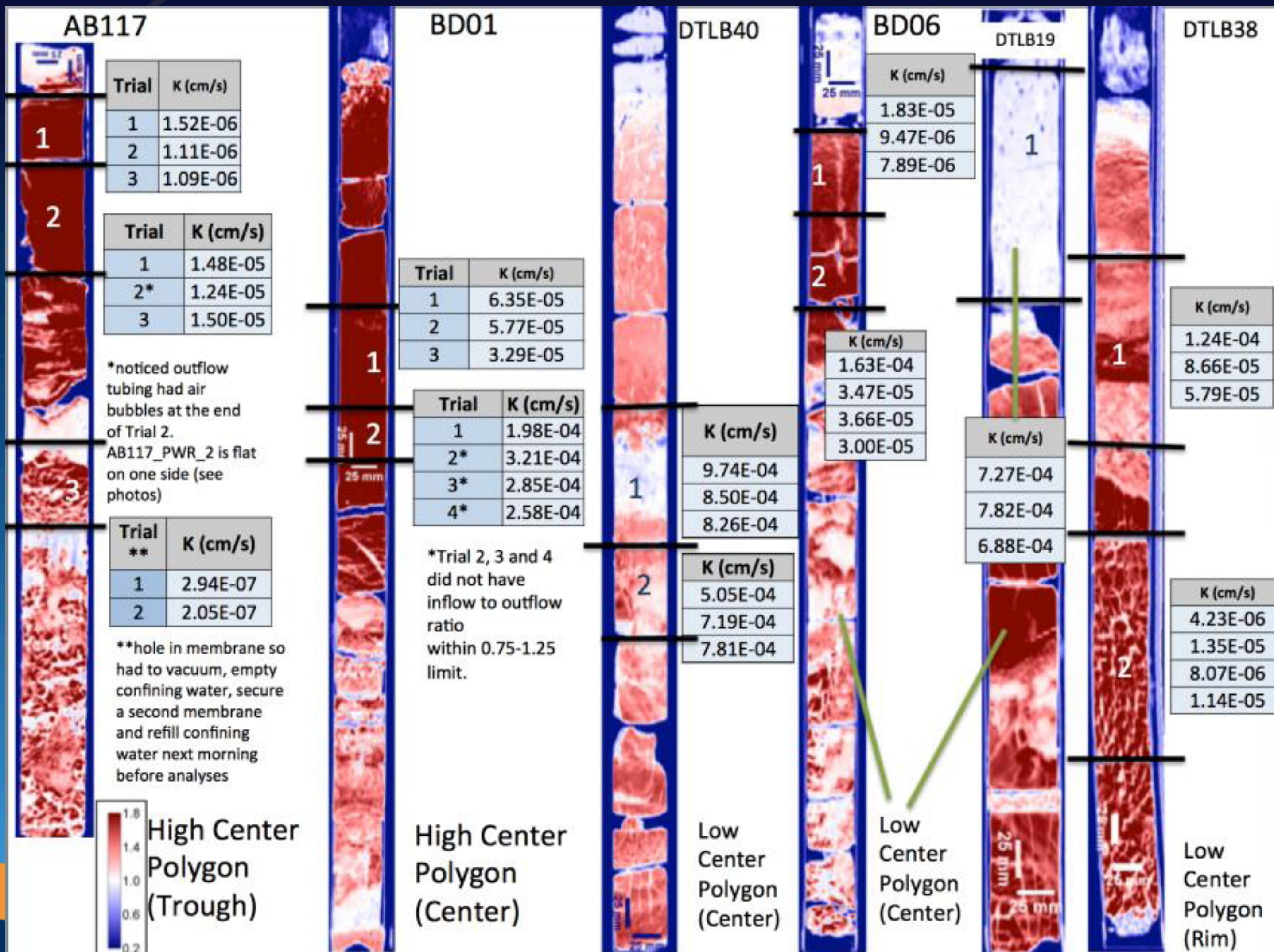


AB117

Trial	K (cm/s)
1	1.52E-06
2	1.11E-06
3	1.09E-06

Trial	K (cm/s)
1	1.48E-05
2*	1.24E-05
3	1.50E-05

Trial **	K (cm/s)
1	2.94E-07
2	2.05E-07

BD01

Trial	K (cm/s)
1	6.35E-05
2	5.77E-05
3	3.29E-05

Trial	K (cm/s)
1	1.98E-04
2*	3.21E-04
3*	2.85E-04
4*	2.58E-04

DTLB40

K (cm/s)
9.74E-04
8.50E-04
8.26E-04

K (cm/s)
5.05E-04
7.19E-04
7.81E-04

BD06

K (cm/s)
1.83E-05
9.47E-06
7.89E-06

K (cm/s)
1.63E-04
3.47E-05
3.66E-05
3.00E-05

DTLB19

K (cm/s)
7.27E-04
7.82E-04
6.88E-04

DTLB38

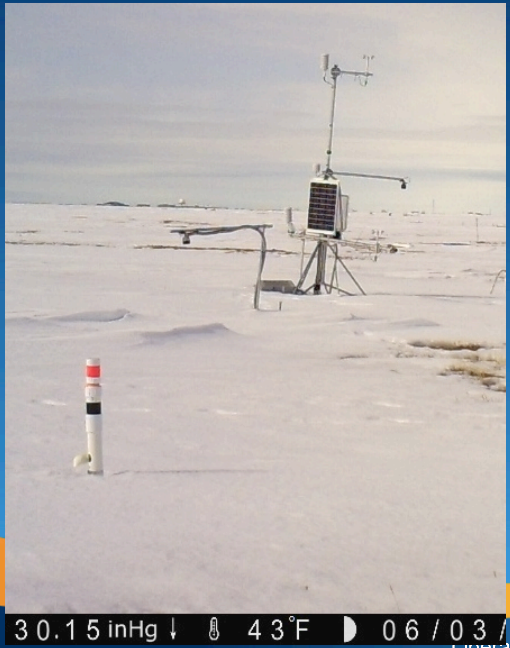
K (cm/s)
1.24E-04
8.66E-05
5.79E-05

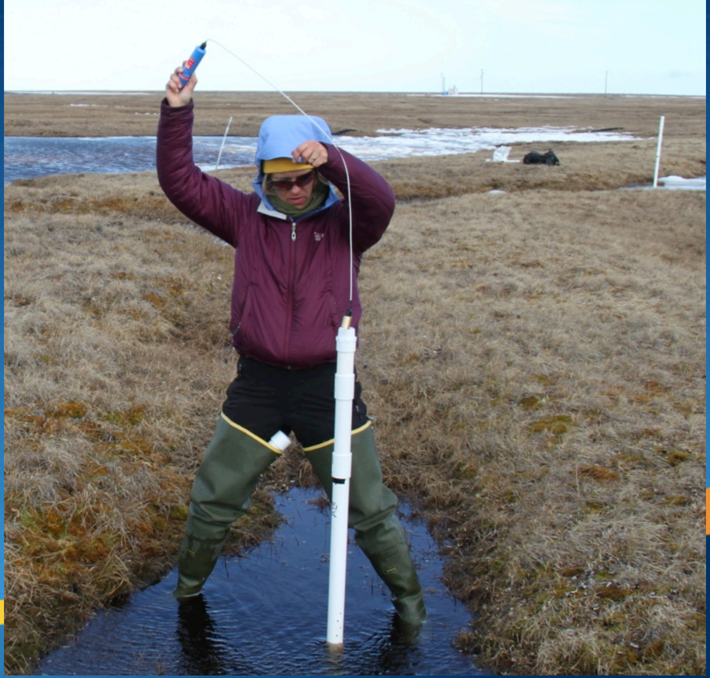
K (cm/s)
4.23E-06
1.35E-05
8.07E-06
1.14E-05

NNSA National Nuclear Security Administration

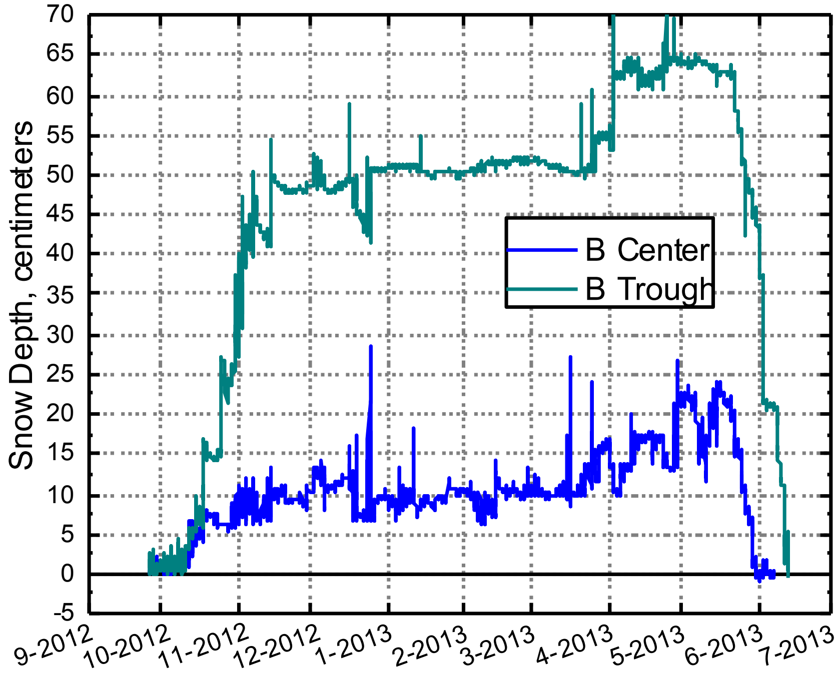
Landscape controls on thermal-hydrology

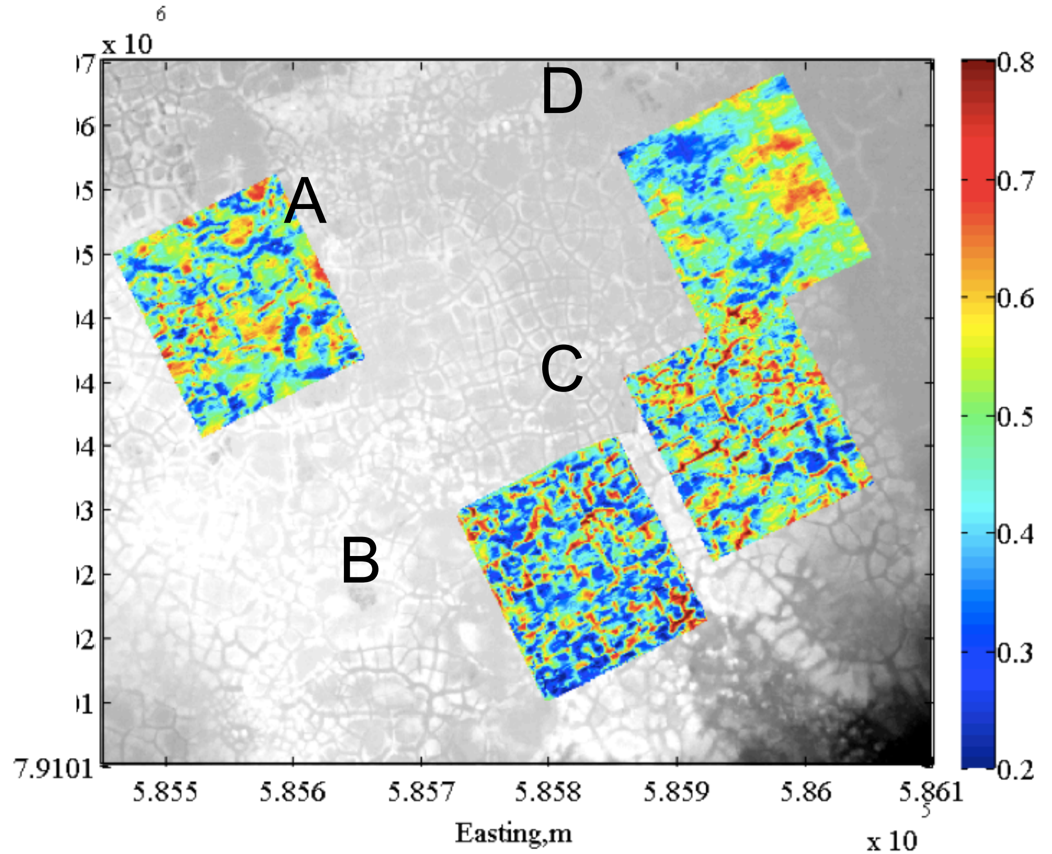
- Snow depth, melt, runoff
- Water levels
- Precipitation
- Soil temperatures and heat flux



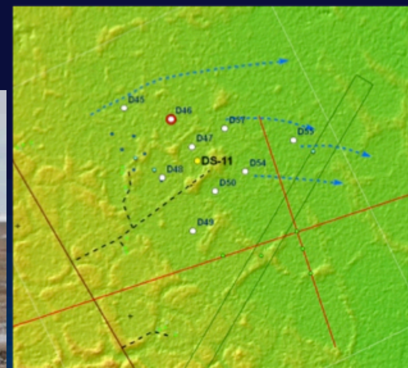


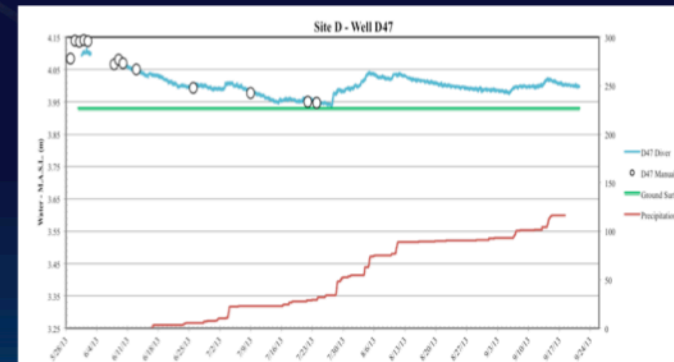
Micro-topography controls snow depth distribution, subsurface temperature and spring inundation (UAF, LANL, LBNL)

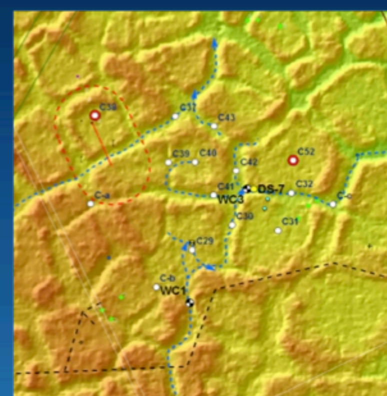


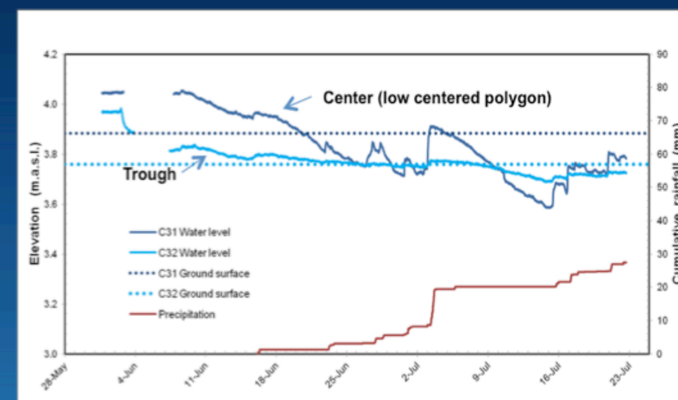


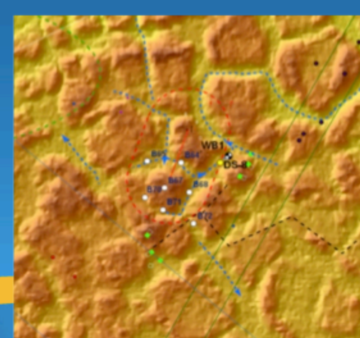
Strong differences in hydrologic response between polygon types

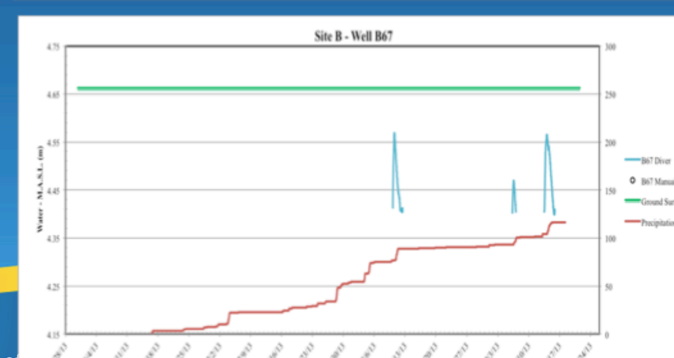




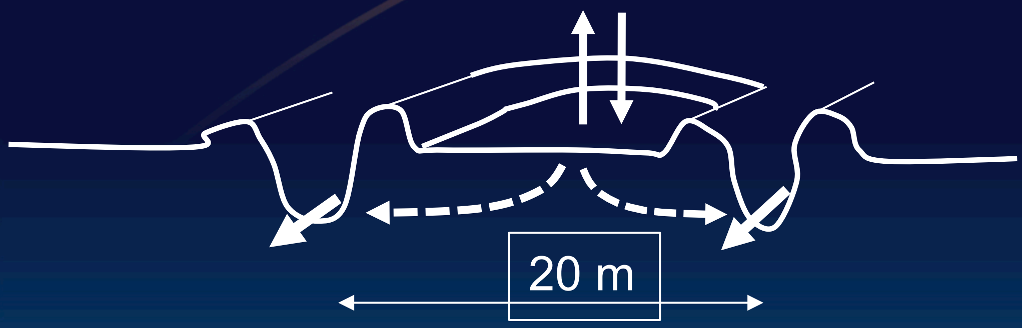


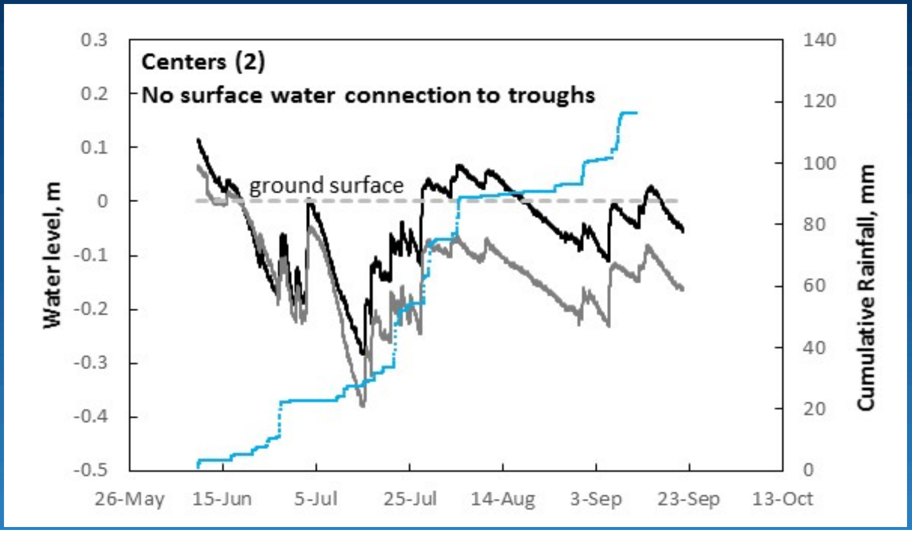


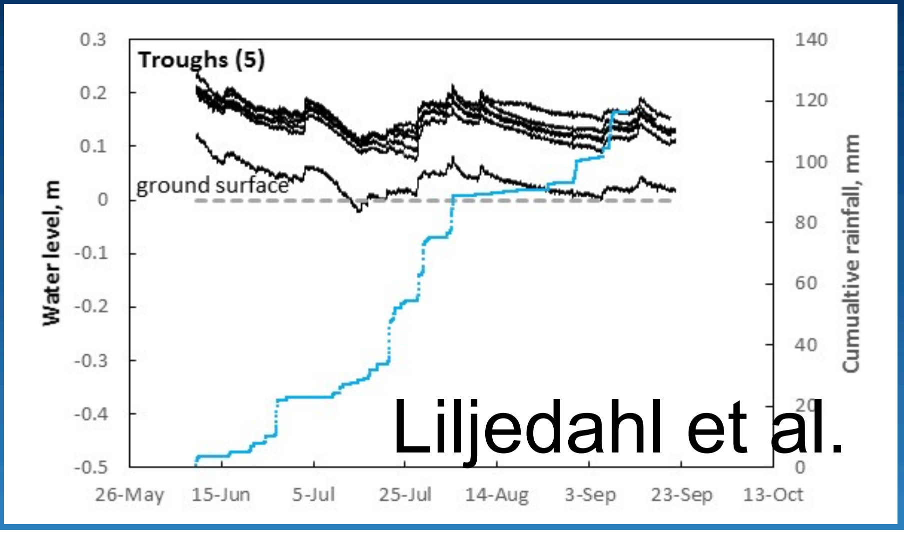




Lateral connectivity controls water levels in polygon troughs and centers (UAF, LANL)

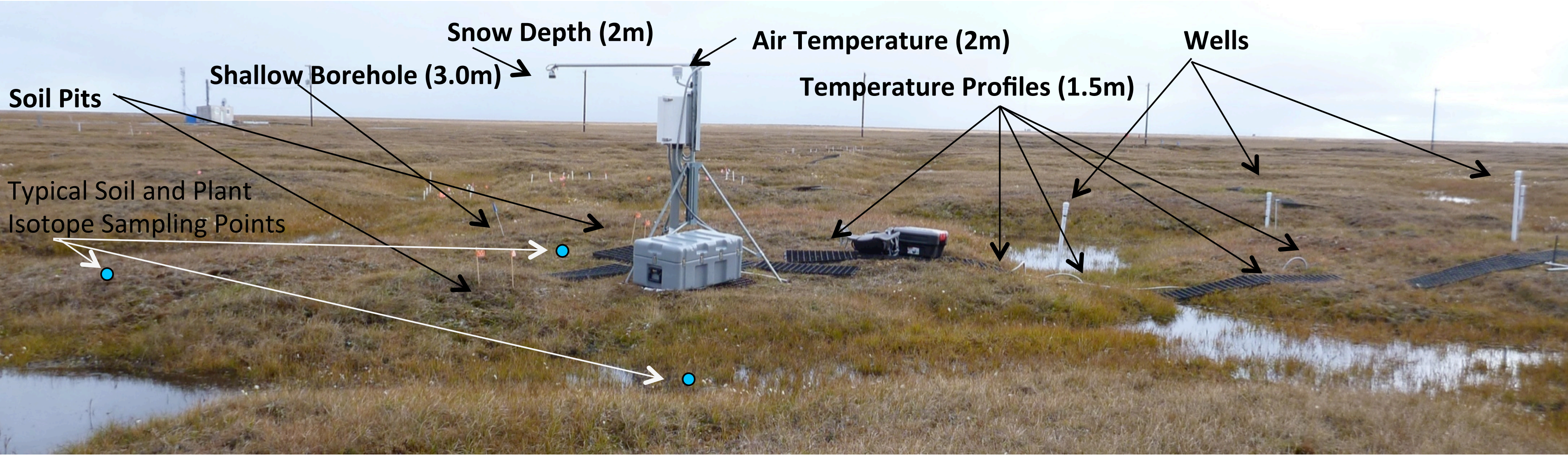


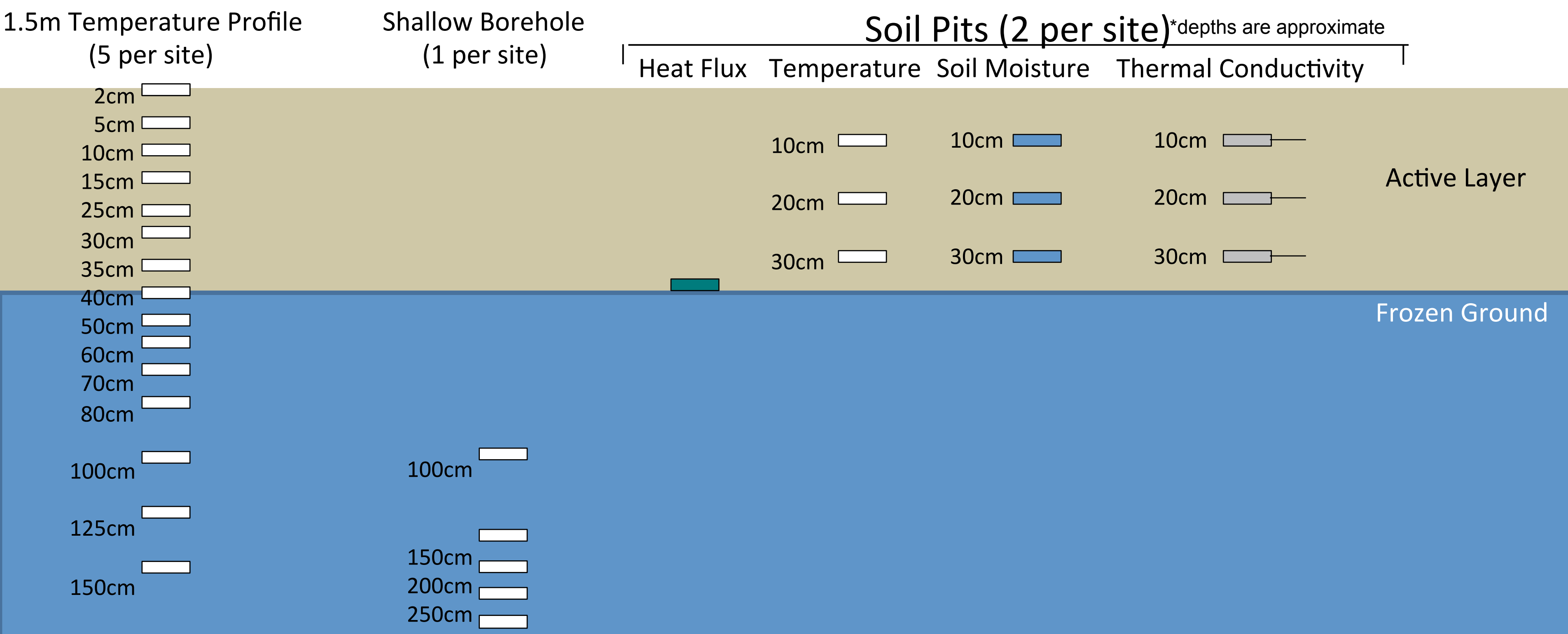




Liljedahl et al.

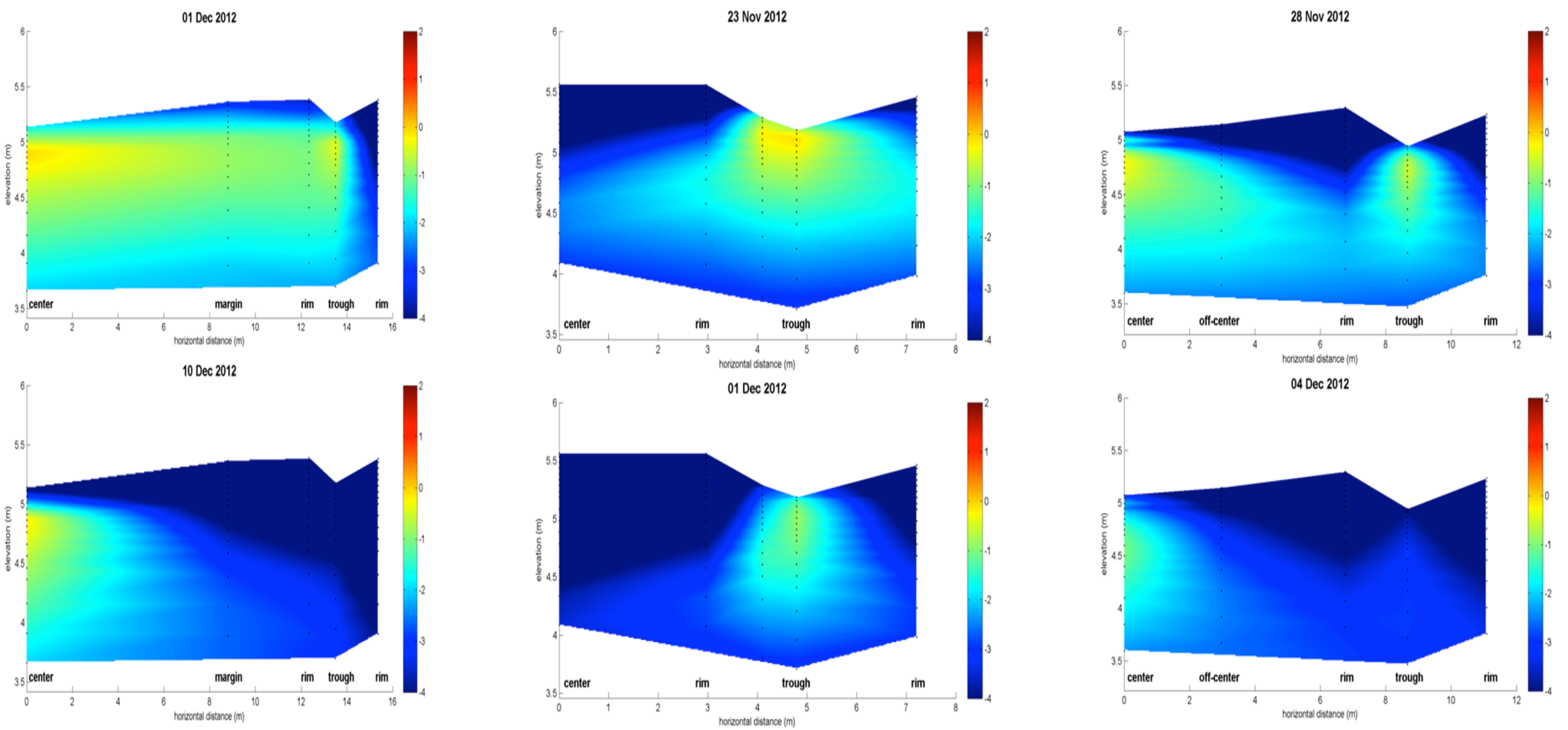
UAF soil temperature measurements





Thermal response varies by polygon type and polygon feature (December freeze-up)

Site A **Site B** **Site C**



Micro-topography controls vegetation, ET and biogeochemistry

Wet sedge
Carex aquatilis

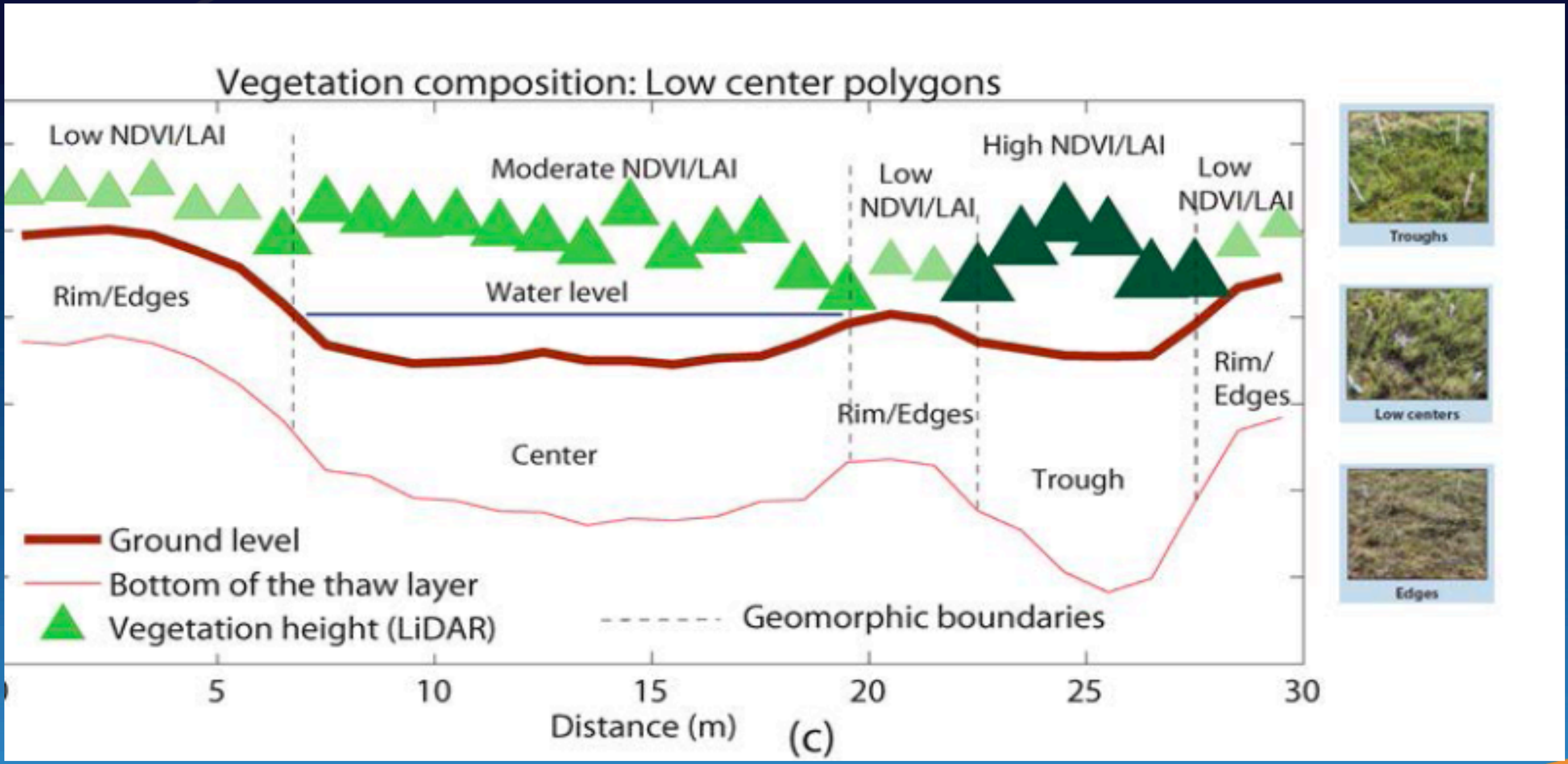
Grass *Poa arctica*

Dwarf shrub
Salix pulchra

Lichen
Dactylina arctica

Moss
Sphagnum sp.

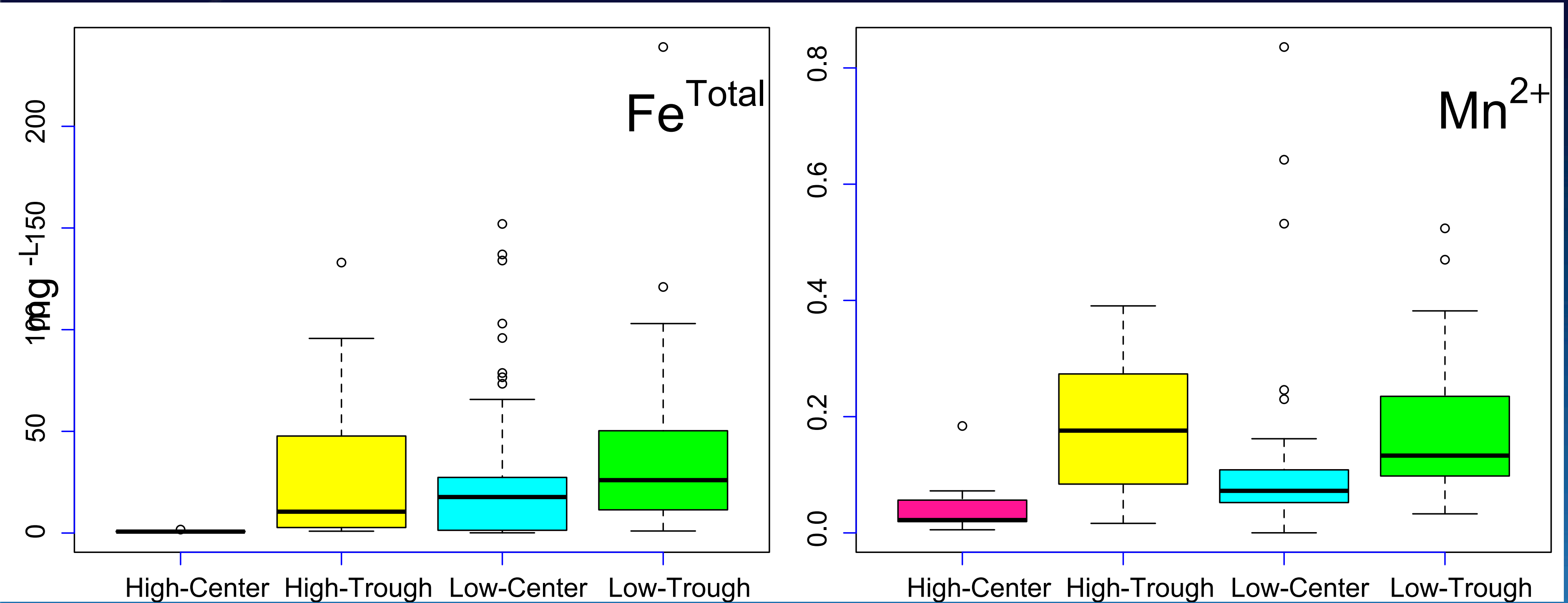
Vegetation varies by polygon feature (Victoria Sloan et al. Univ. Bristol, ORNL)



Polygon type and features control geochemistry,

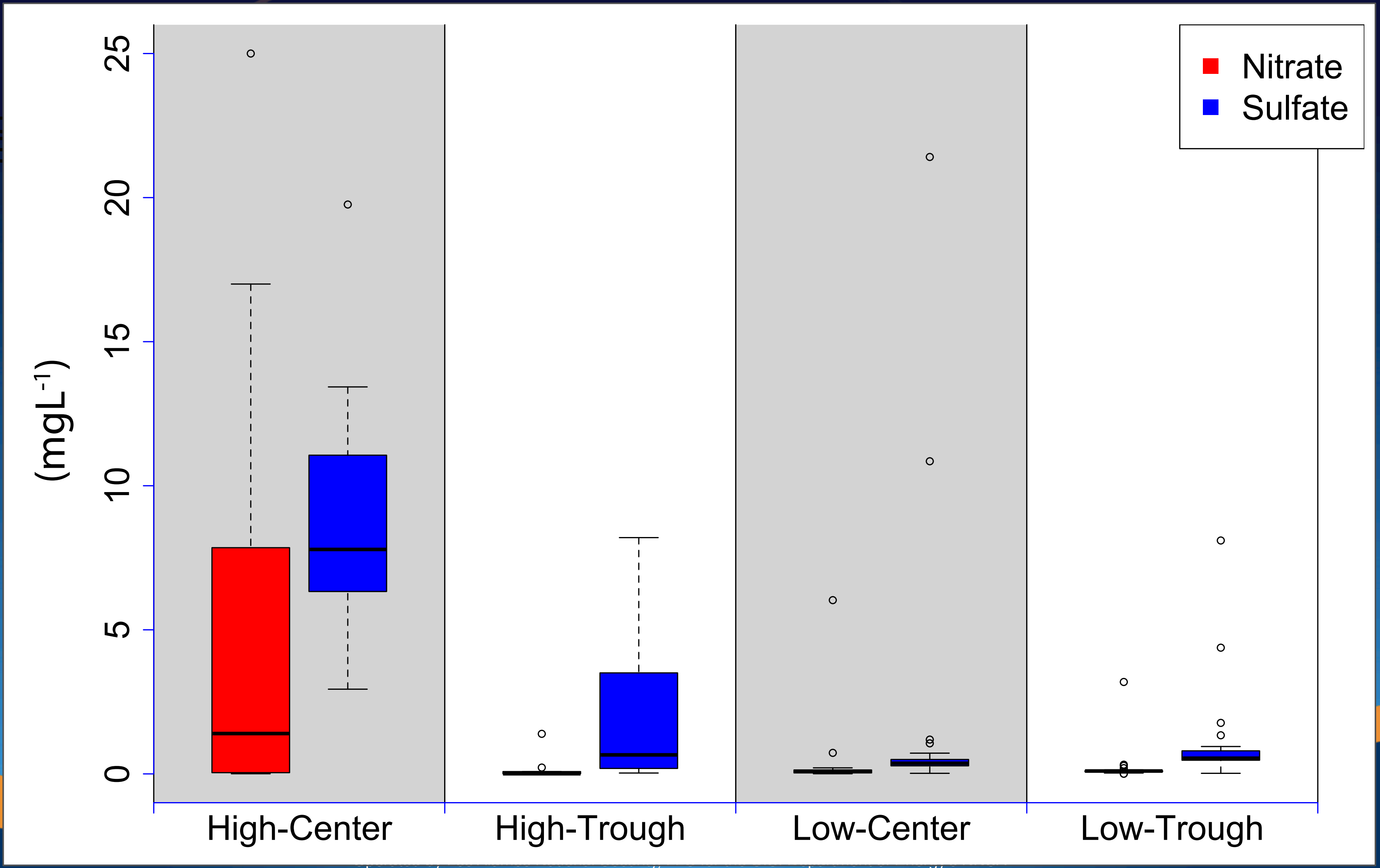
Newman et al. LANL, ORNL, LBNL

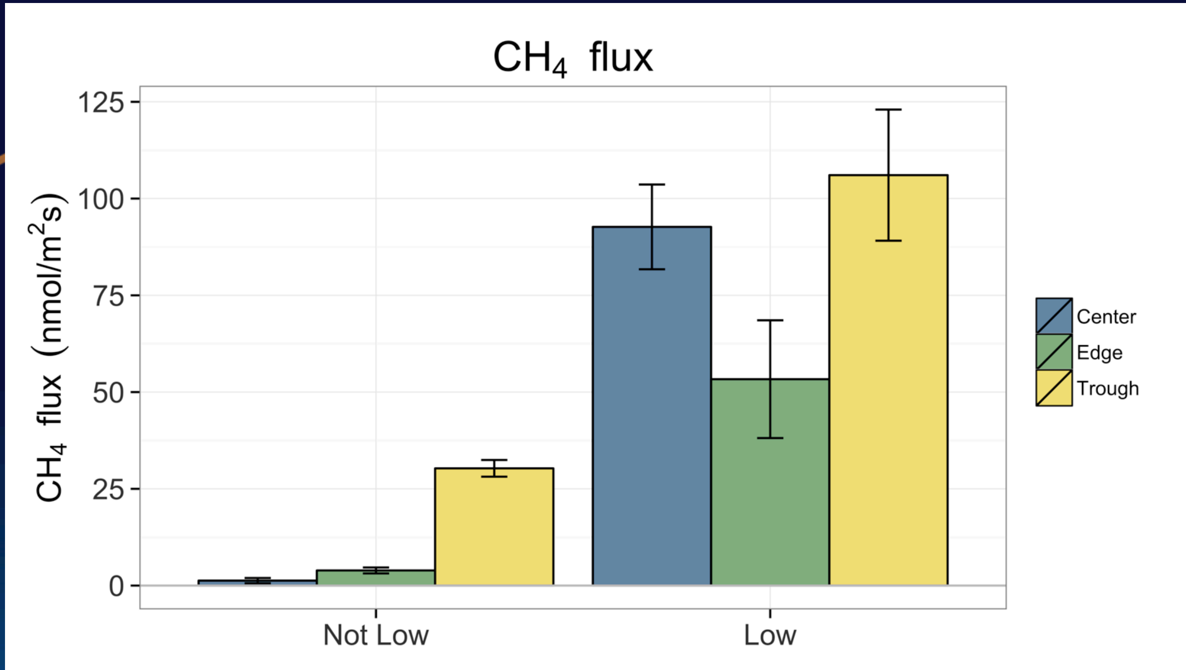
Redox indicators (Iron and Manganese)

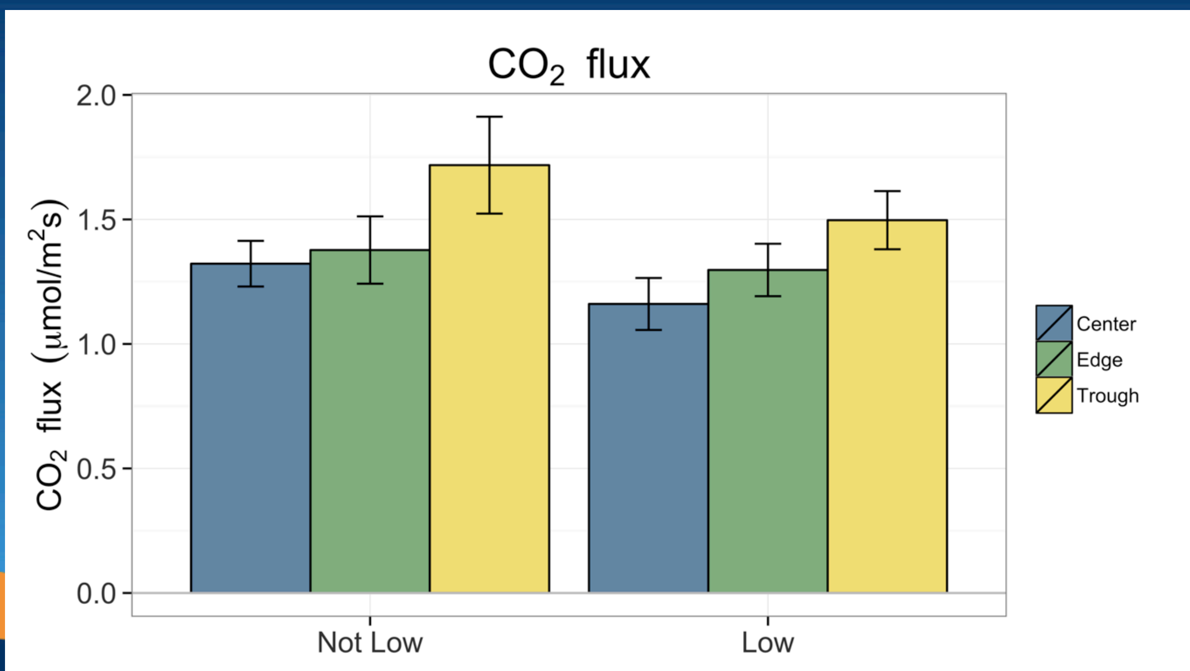


Most concentrated in Troughs
(High and Low Polygons)

Oxy-Anions (Sulfate, Nitrate) most concentrated in high-polygon centers



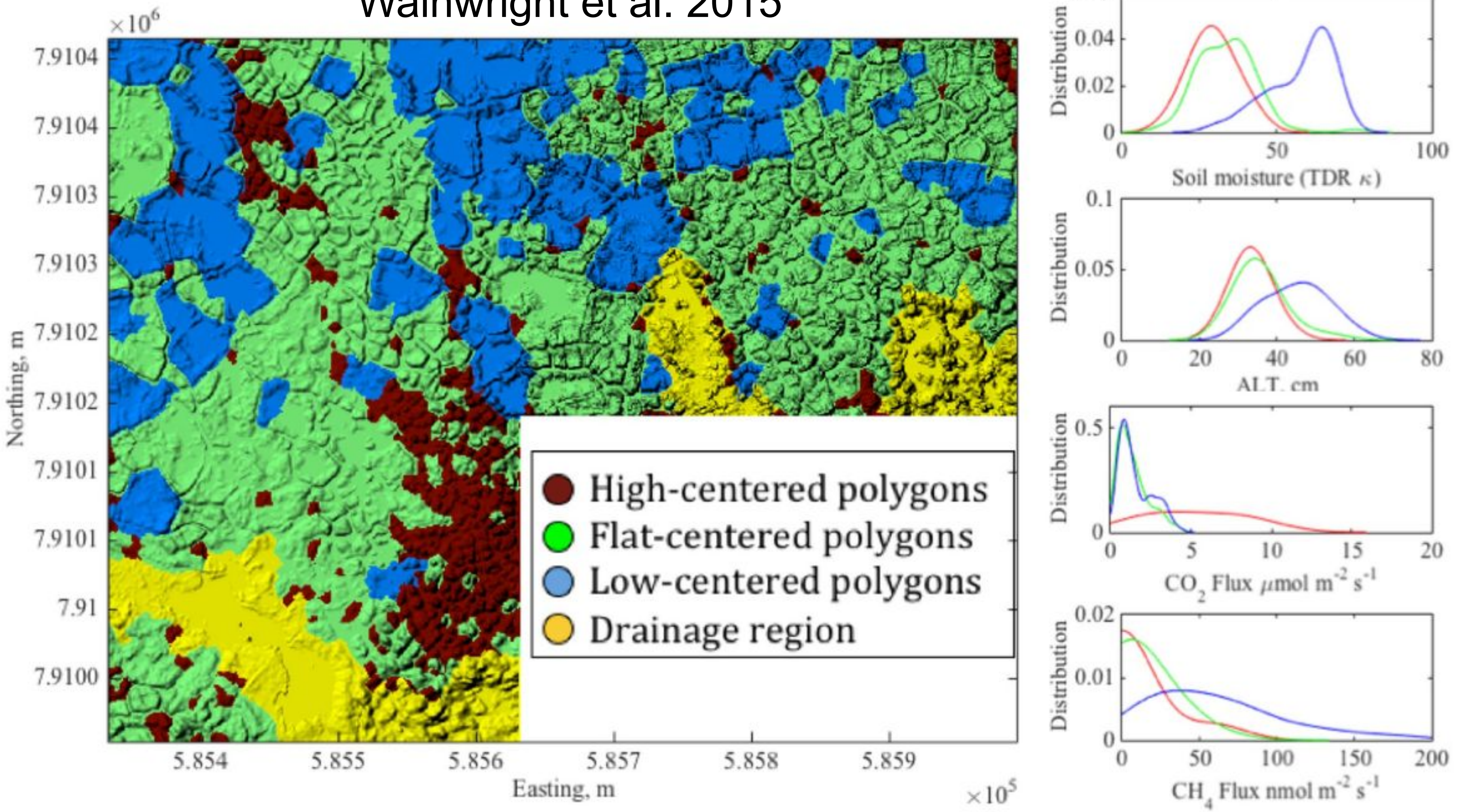




CH4 and CO2 primarily depends on soil moisture; High center and flat center polygons produce less CH4 and More CO2; Low center polygon troughs and centers produce the most CH4. Lydia Smith et al.

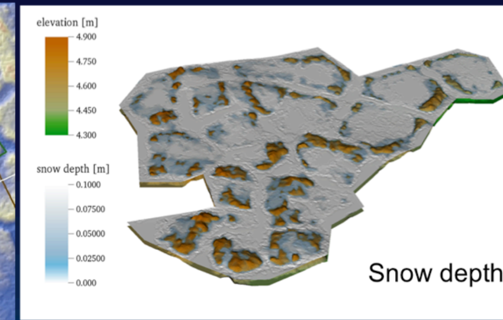
A major outcome of NGEE-Arctic Phase 1 is an integrated set of in situ and remotely sensed observations, that quantified the co-variation of terrestrial processes with map-able landscape units

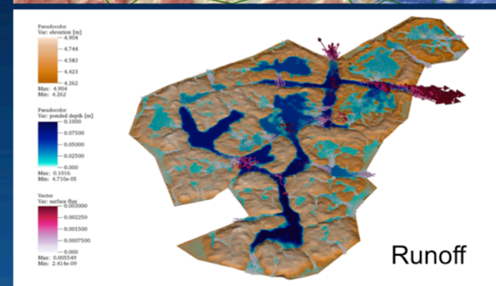
Wainwright et al. 2015

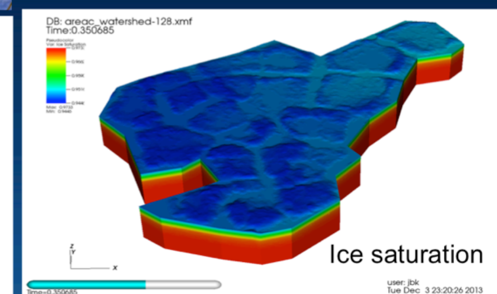


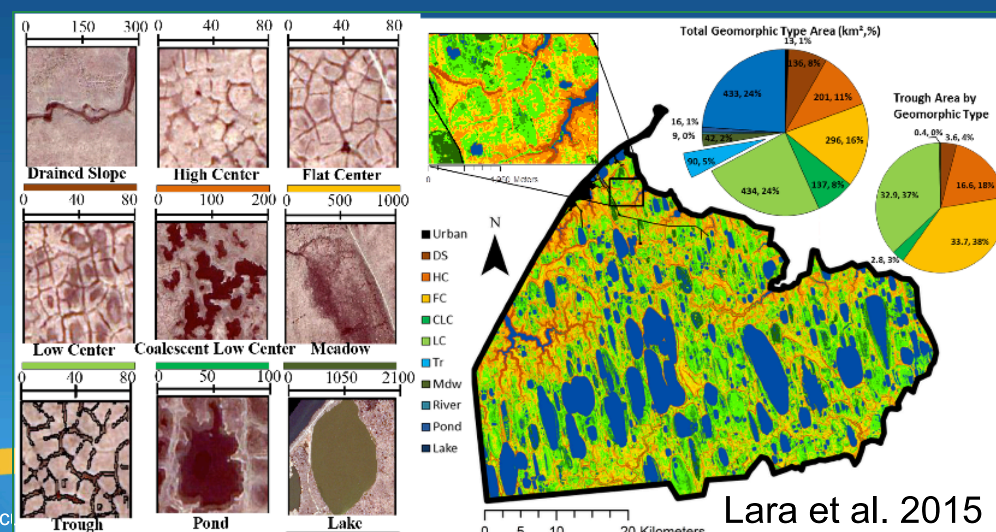
These observations informed fine to intermediate scale models used to:

- Improve understanding of critical thermal-hydrologic, geophysical and geochemical processes in space and time
- Demonstrate a path toward enhanced representation of heterogeneity
- Demonstrate scaling approaches from fine to global grid scale
- Show importance of representation of heterogeneity (Lara)





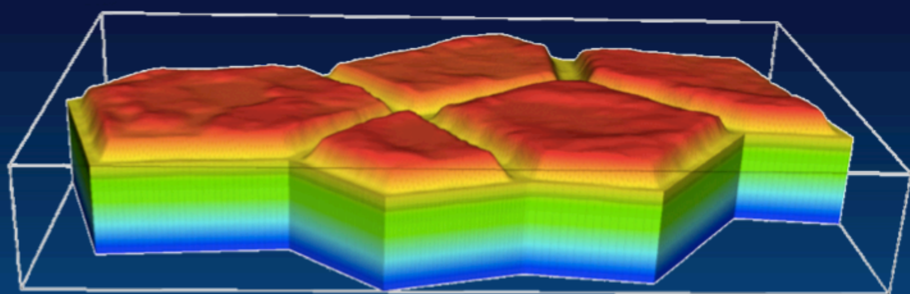




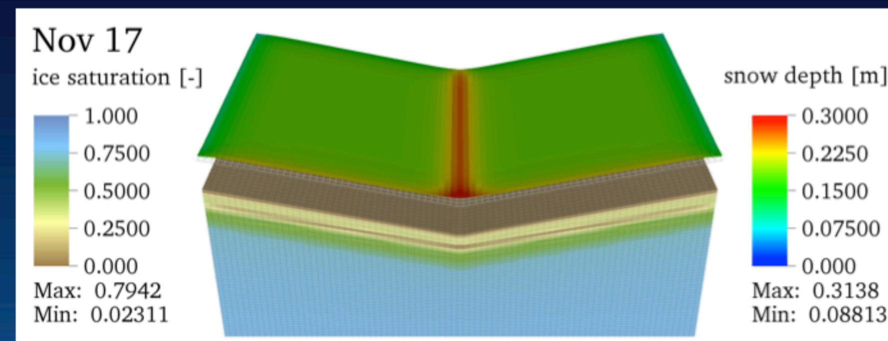
NGEE-Arctic Phase 2: Scaling up to predict climate impacts and feedbacks across the terrestrial Arctic

Inform parameterization of ESM grid cells for the Arctic Coastal Plain and the Seward Peninsula

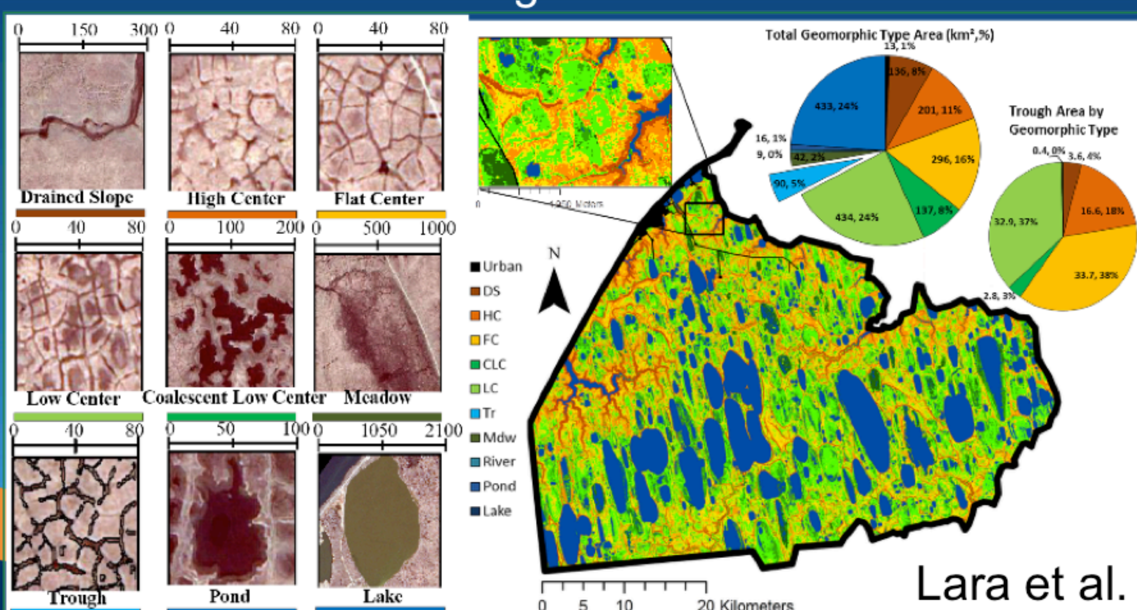
Polygon

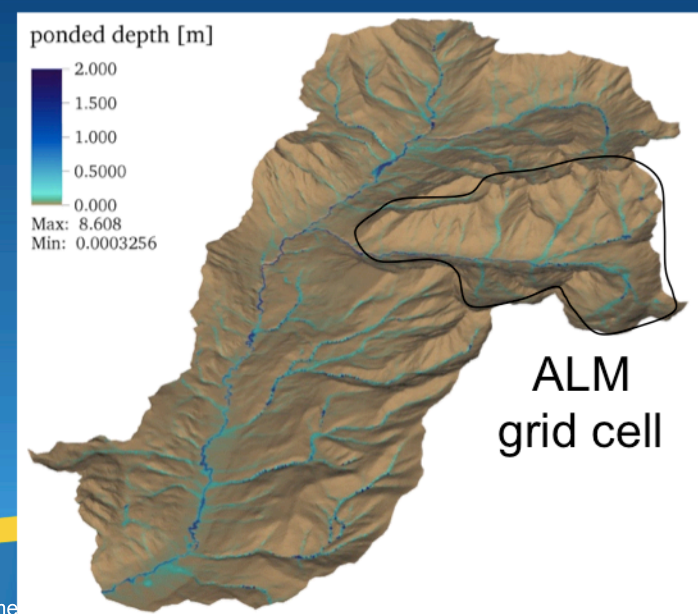


Hillslope



CLM grid cell





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Thank You!

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