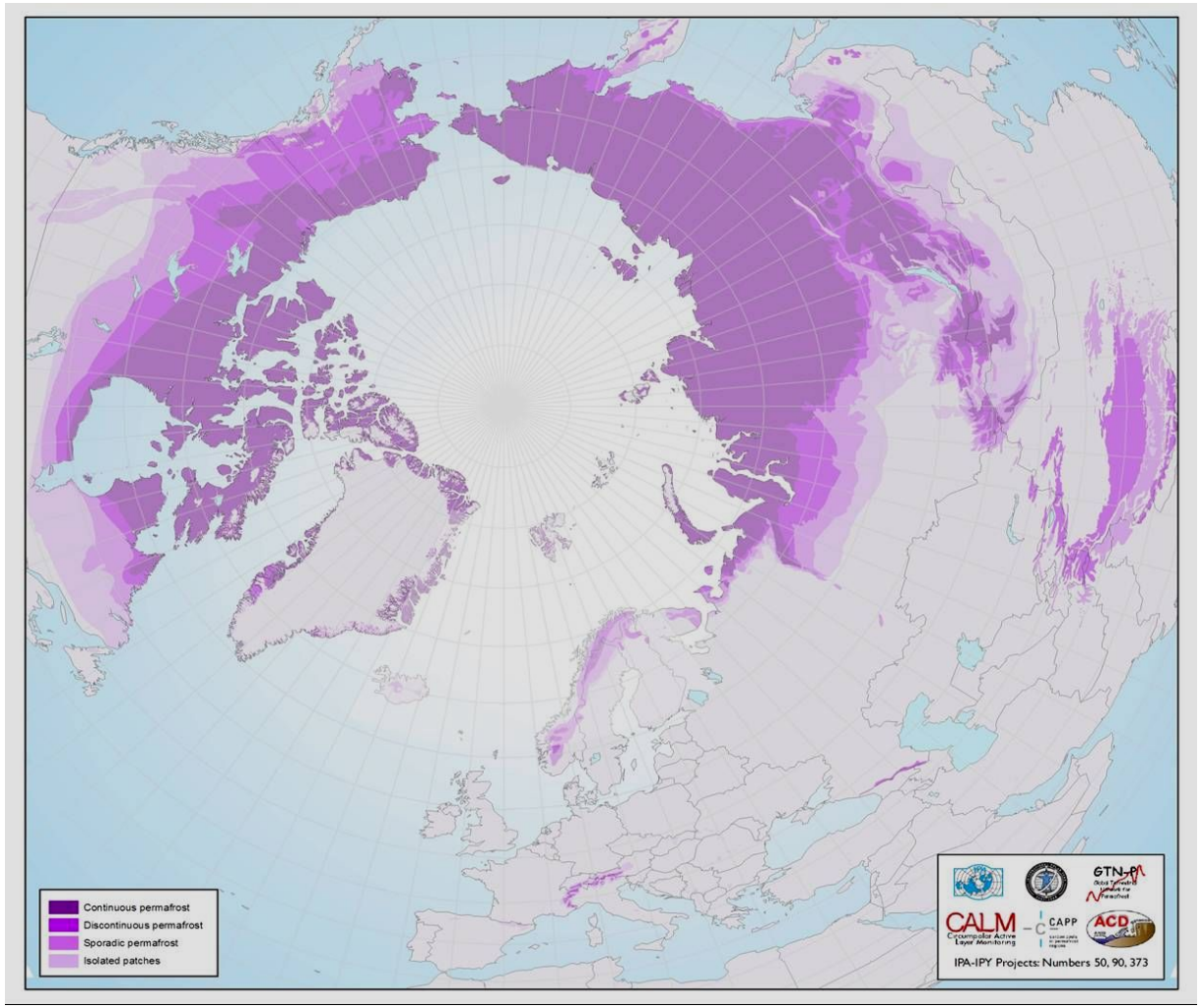
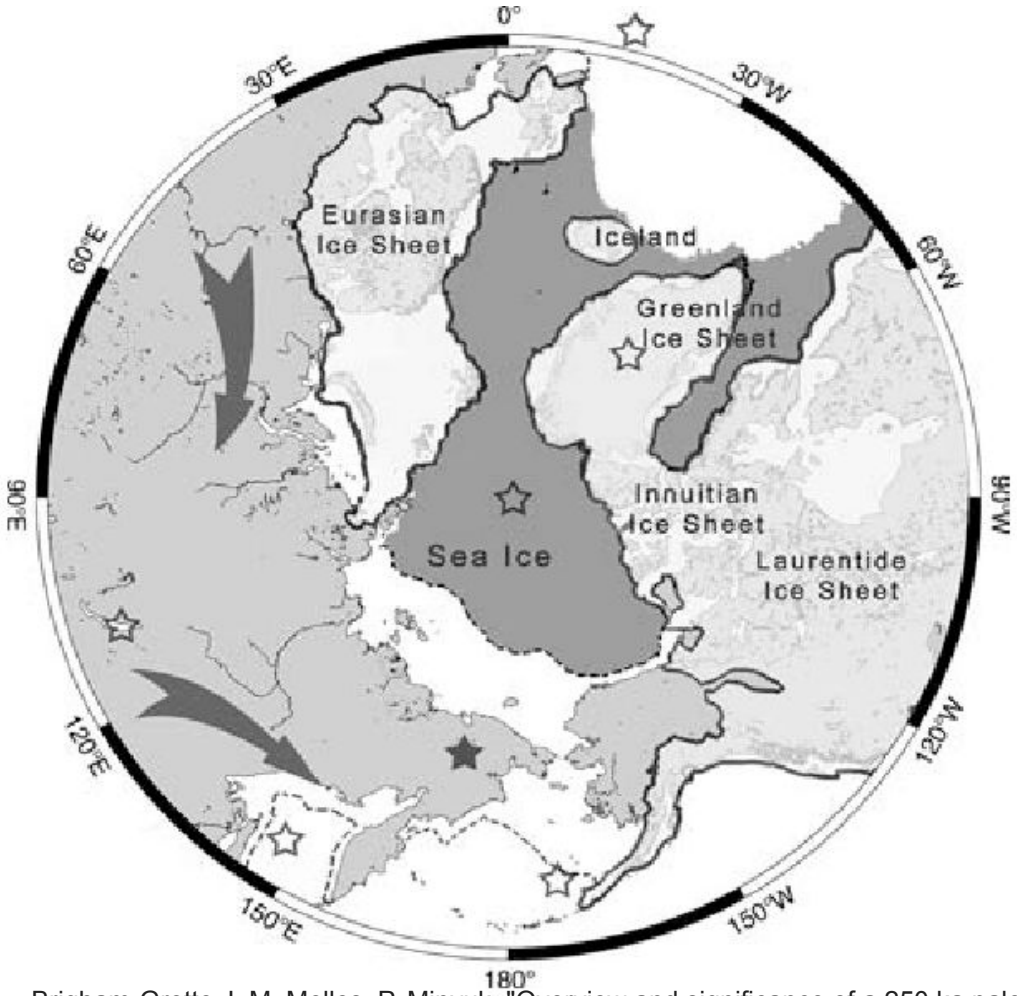
STATE and FATE of PERMAFROST in ALASKA

Permafrost Defenition

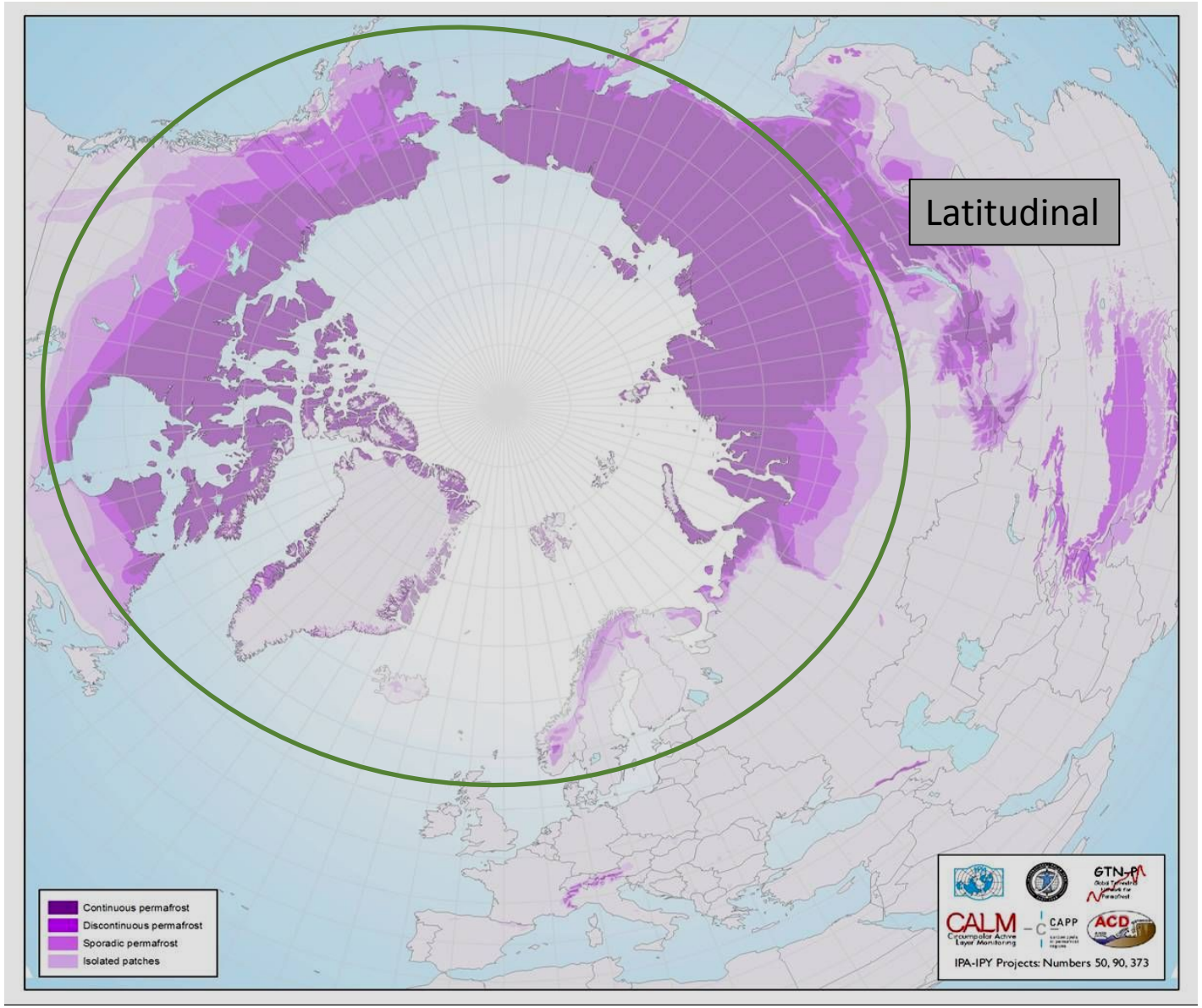
Ground (soil, rock, ice and organic matter) that remains at or below 0 °C for at least two consecutive years, for natural climatic reasons (van Everdingen, 1998).

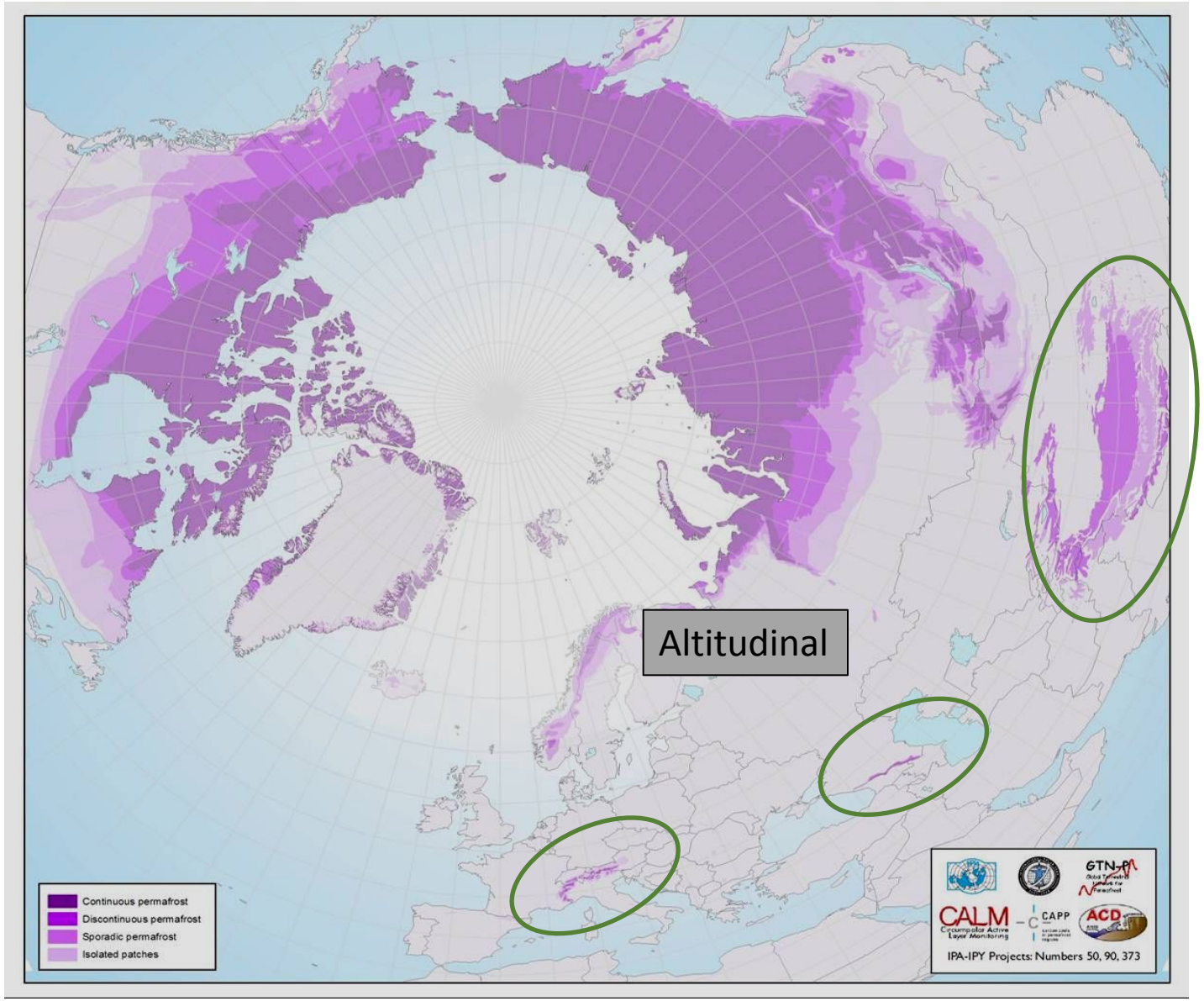


http://ipa.arcticportal.org



Brigham-Grette J, M. Melles, P. Minyuk. "Overview and significance of a 250 ka paleoclimate record from El'gygytgyn Crater Lake, NE Russia." *Journal of Paleolimnology* 37.1 (2007): 1-16.


Latitudinal
Continuous permafrost
Discontinuous permafrost
Sporadic permafrost
Isolated patches
CALM
Circumpolar Active Layer Monitoring
CAPP
ACD
GTN-P
IPA-IPY Projects: Numbers 50, 90, 373


Altitudinal
Continuous permafrost
Discontinuous permafrost
Sporadic permafrost
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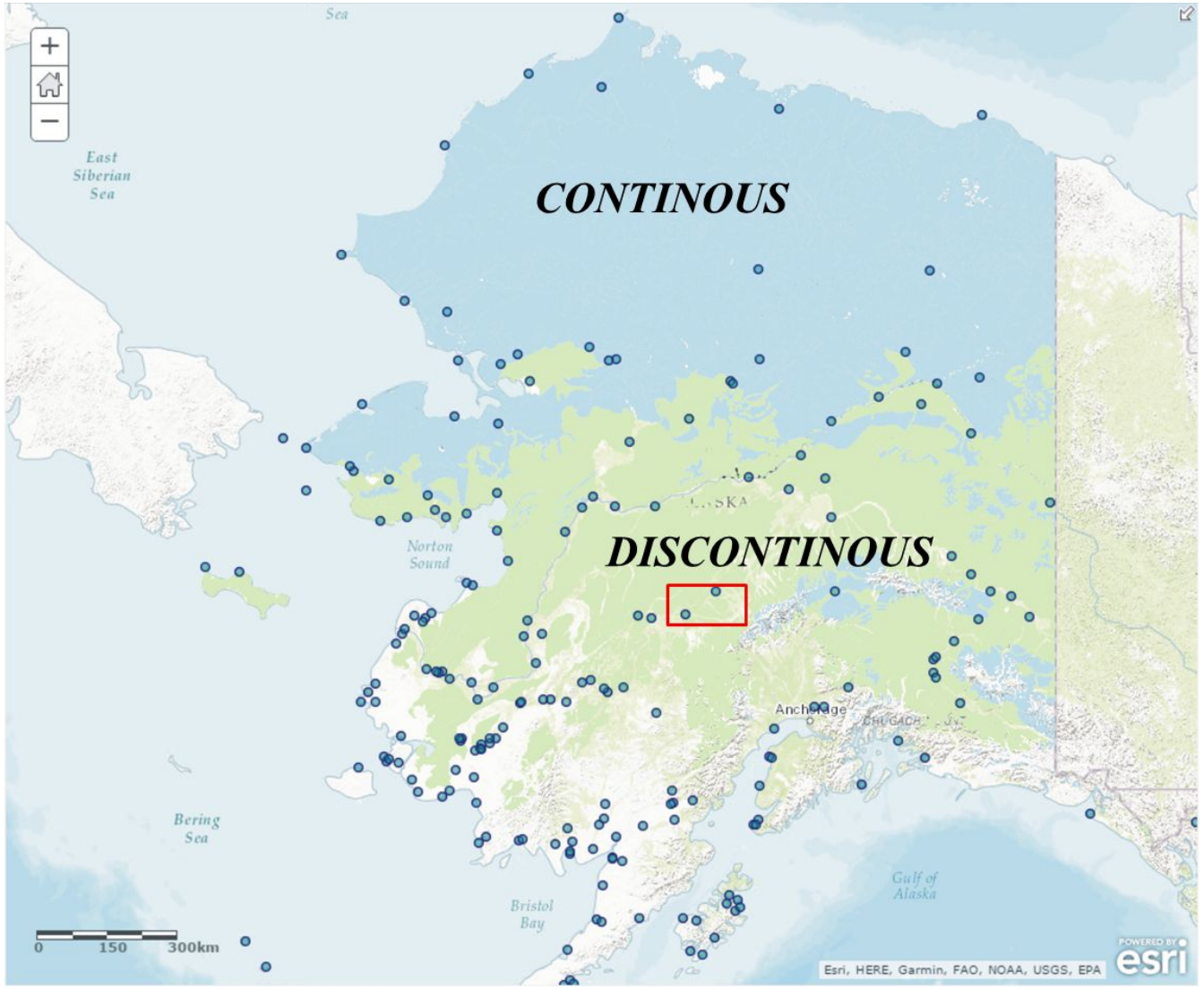
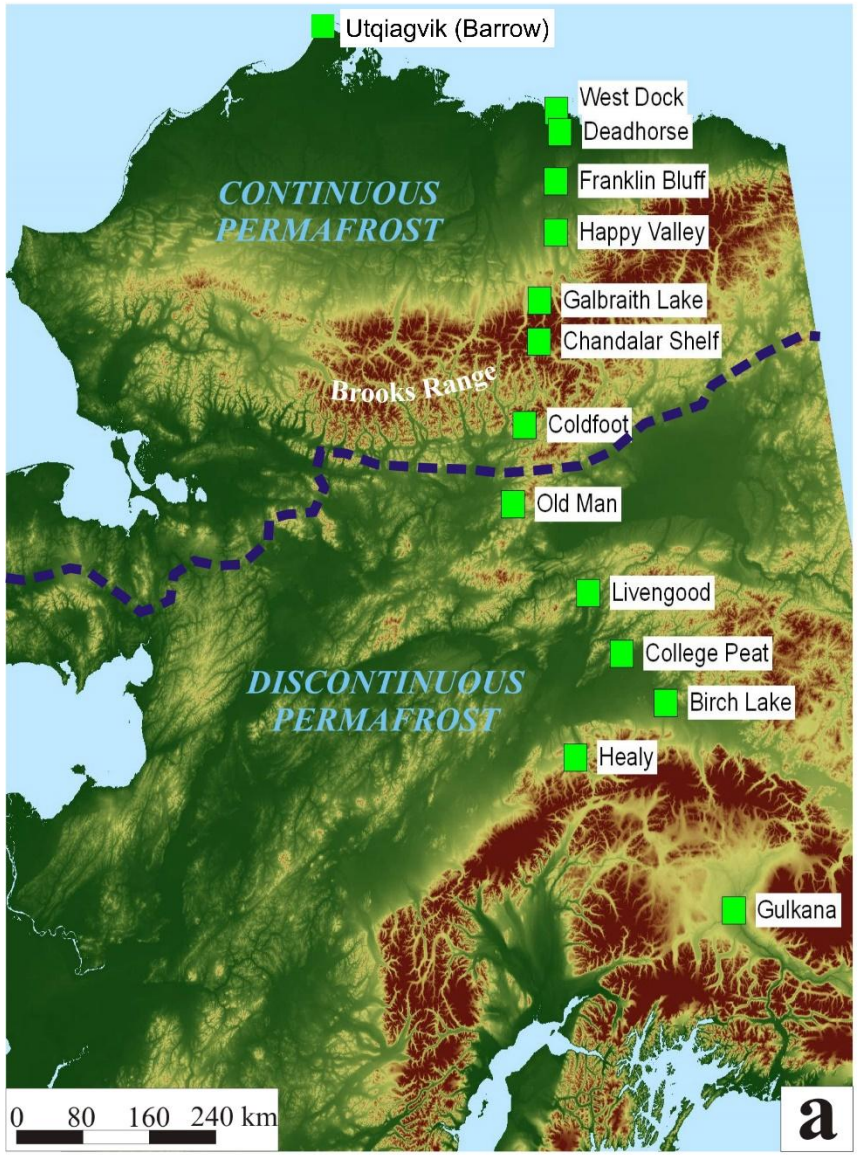
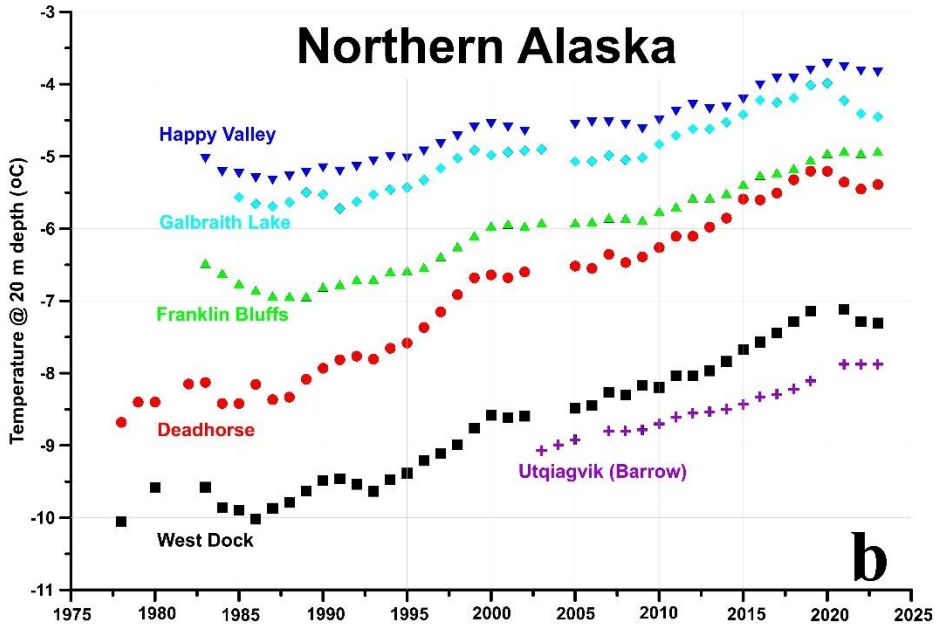
CALM
Circumpolar Active Layer Monitoring
CAPP
ACD
GTN-P
IPA-IPY Projects: Numbers 50, 90, 373

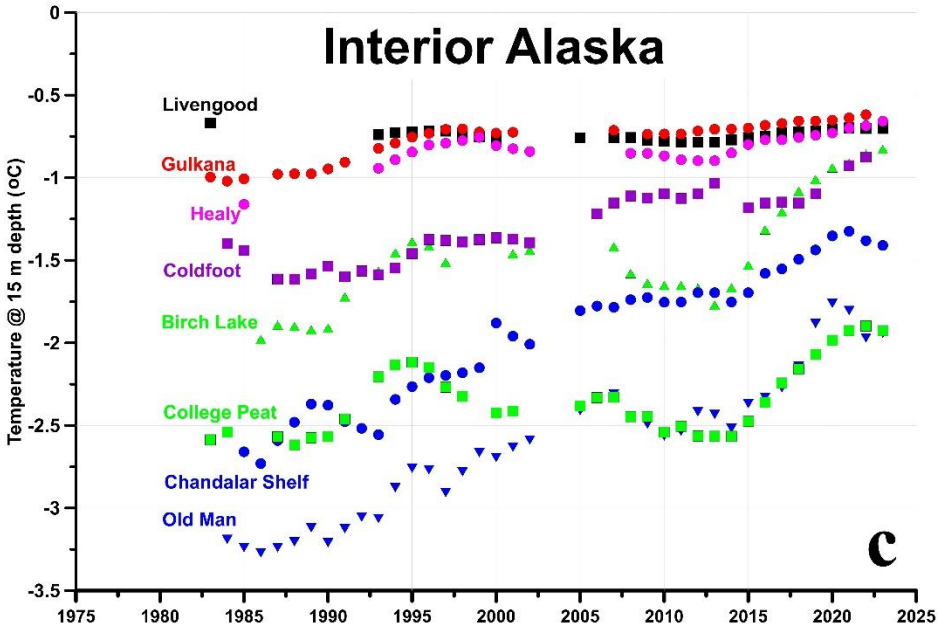
PERMAFROST ON ALASKA

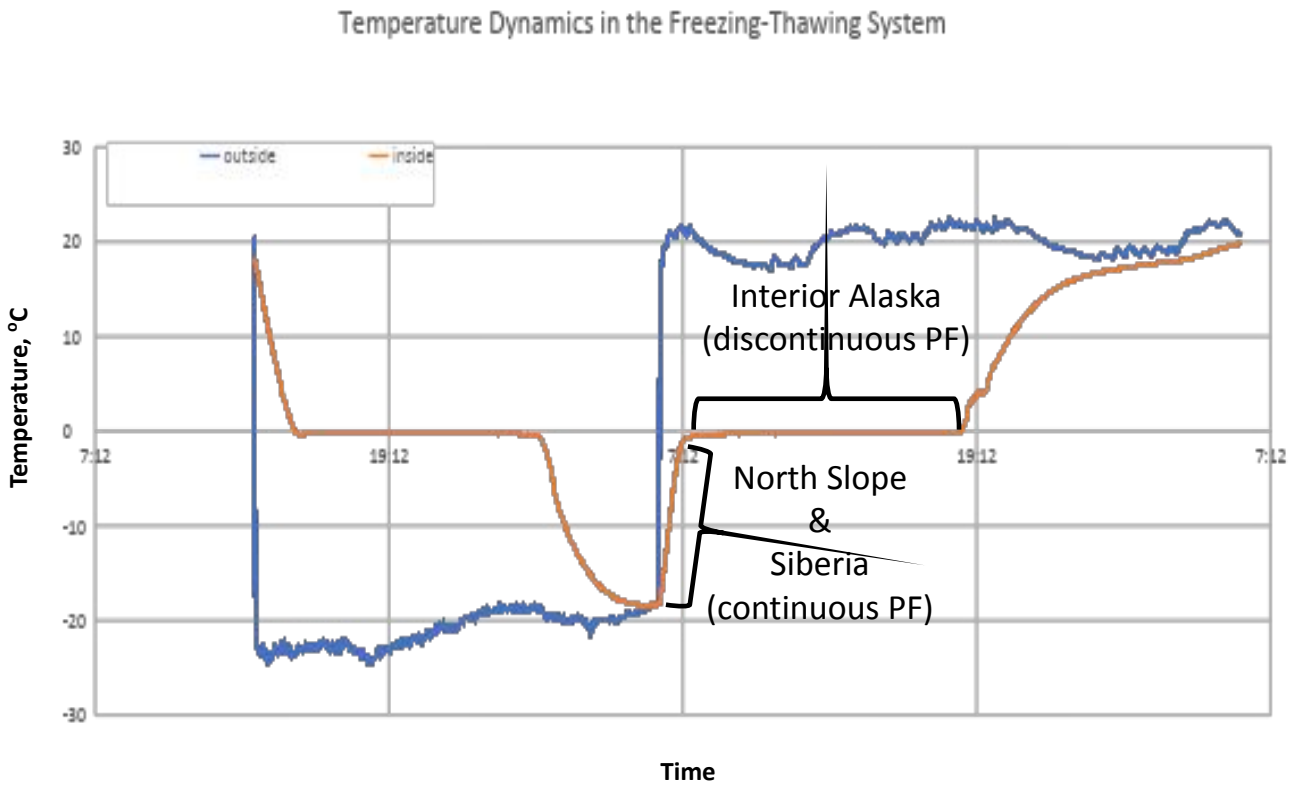


Permafrost underlies ~80% of Alaska (Jorgenson et al. 2008). Permafrost distribution can be classified as continuous (>90% of land area underlain by permafrost), discontinuous (90% – 50%),sporadic (50% – 10%), or isolated (<10%) (Ferrians 1965).


Utqiagvik (Barrow)
West Dock
Deadhorse
Franklin Bluff
Happy Valley
Galbraith Lake
Chandalar Shelf
Brooks Range
Coldfoot
Old Man
Livengood
College Peat
Birch Lake
Healy
Gulkana
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
0 80 160 240 km
a


Northern Alaska
Temperature @ 20 m depth (oC)
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
Utqiagvik (Barrow)
West Dock
b


Interior Alaska
Temperature @ 15 m depth (oC)
Livengood
Gulkana
Healy
Coldfoot
Birch Lake
College Peat
Chandalar Shelf
Old Man
c


Temperature Dynamics in the Freezing-Thawing System
outside
inside
30
20
10
0
-10
-20
-30
7:12
19:12
7:12
19:12
7:12
Temperature, °C
Time
Interior Alaska
(discontinuous PF)
North Slope
&
Siberia
(continuous PF)

COOL YOUR DRINKS WITHOUT DILUTING THEM!

Volumetric heat capacity of granite is 1896 kJ/(m^3*^{o}K);
Size of one cube is 8 cm^3, so 4 of them – 32cm^3, or 32*$10^{-6}m^3$;
How much heat does it take to warm up these four cubes cooled to the temperature of -4^{o}C to the temperature of 20^{o}C?

$Q=1896*(20-(-4))*32*10^{-6}$ =1.46 kJ

Is it a lot?

It is equivalent to the heat required to cool down the glass of water (250 ml) by the 1.4^{o}C

How about ice cubes?

Volumetric heat capacity of ice is 2100 kJ/(m^3*°K); water – 4190kJ/(m^3*°K). Latent heat of melting ice is $3.4*10^5$ kJ/(m^3)

$$Q=2100*4*32*10^{-6} +4190*20*32*10^{-6}*0.9 +3.4*10^5*32*10^{-6} =35.28 \text{ kJ}$$

Is that a lot?

It is equivalent to the heat required to cool down the glass of water (250 ml) by the **33.7ºC**!

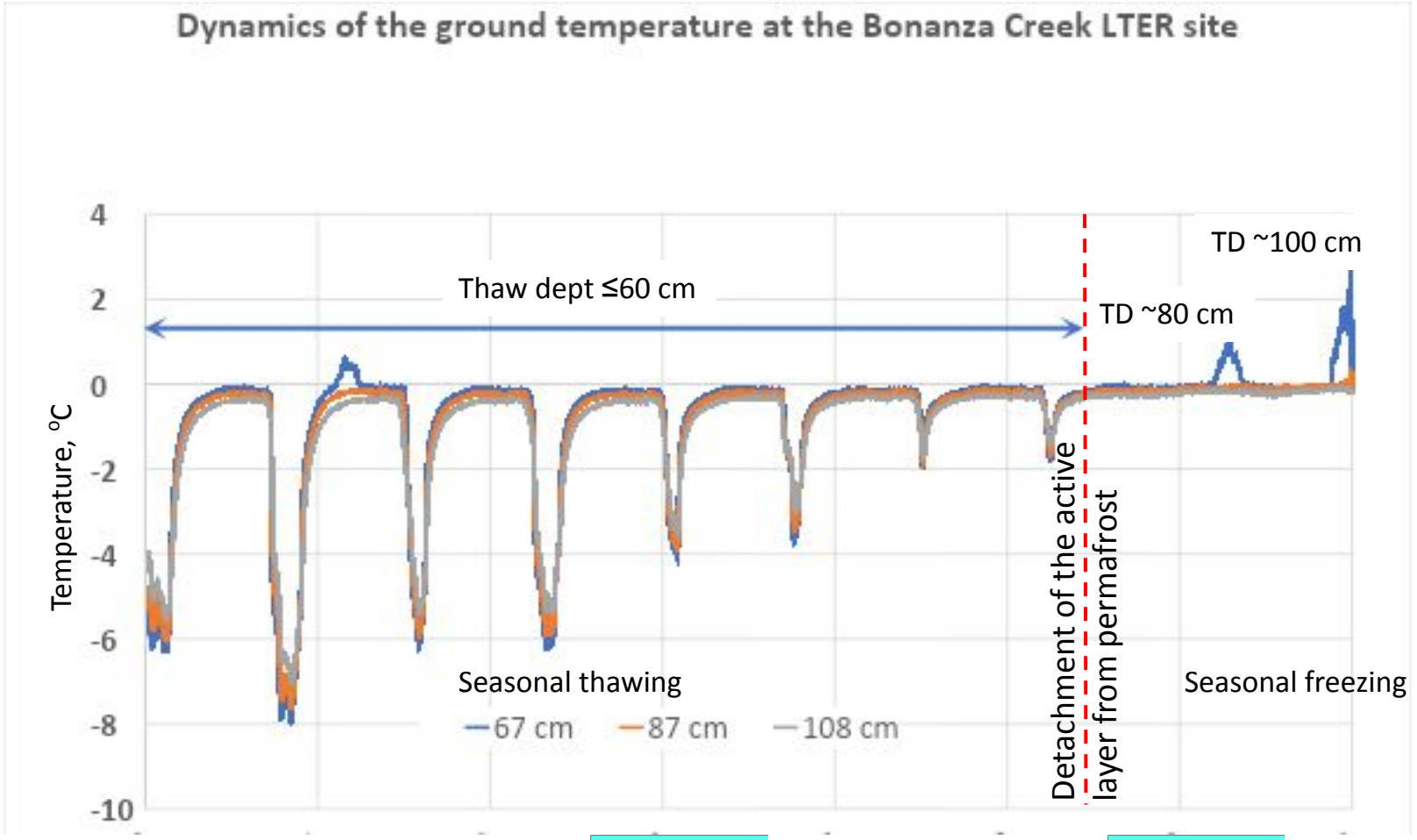
Are you still thinking it is possible to
COOL YOUR DRINKS WITHOUT DILUTING THEM?

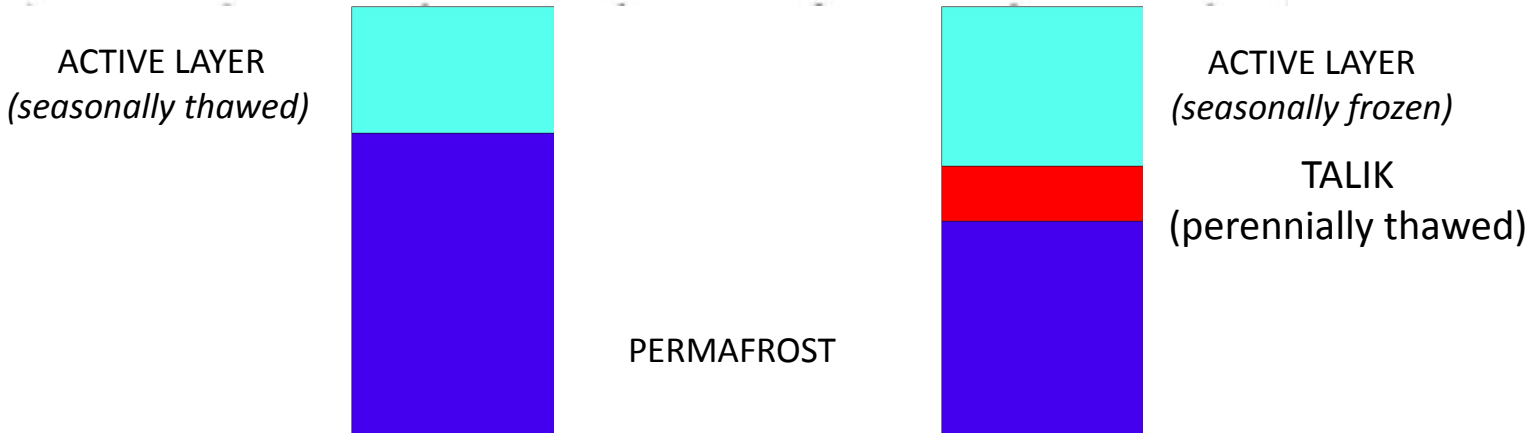
TWO POSSIBLE PATHWAYS OF PERMAFROST DEGRADATION:

IC≈P

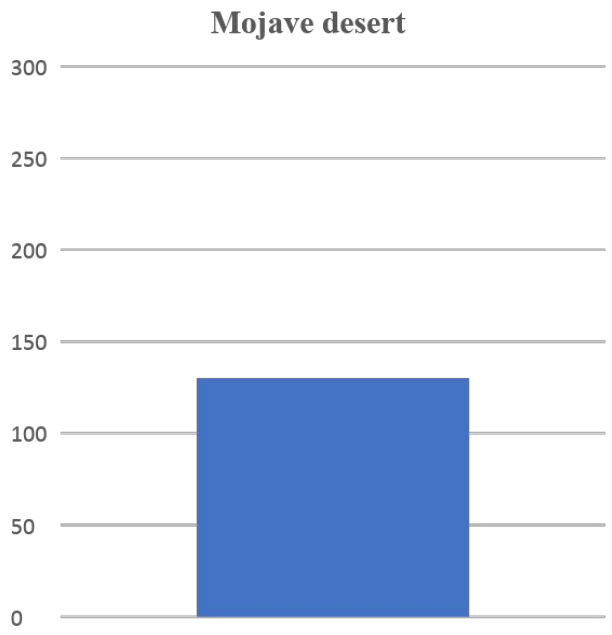
Formation of ***talik***, i.e. unfrozen layer between an active layer and permafrost.

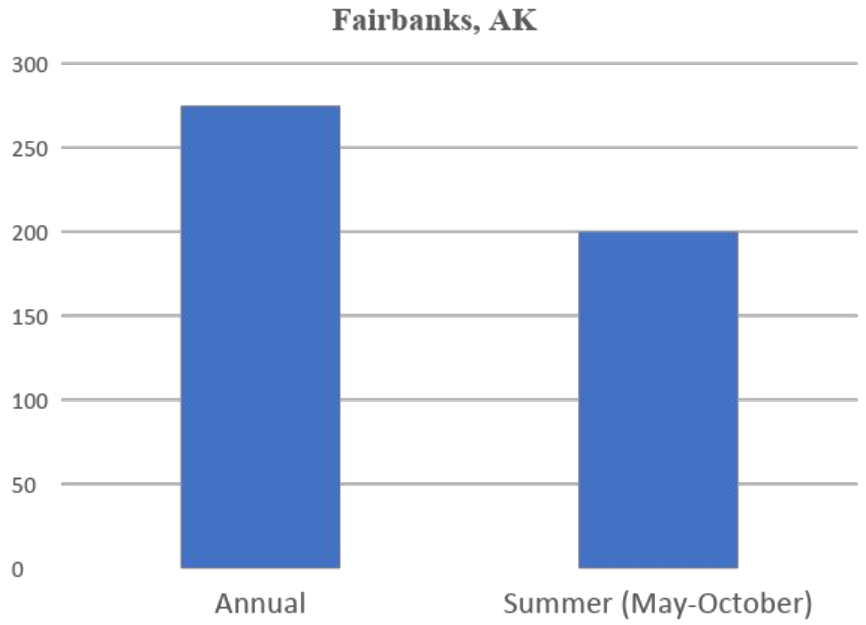
"Dry" scenario

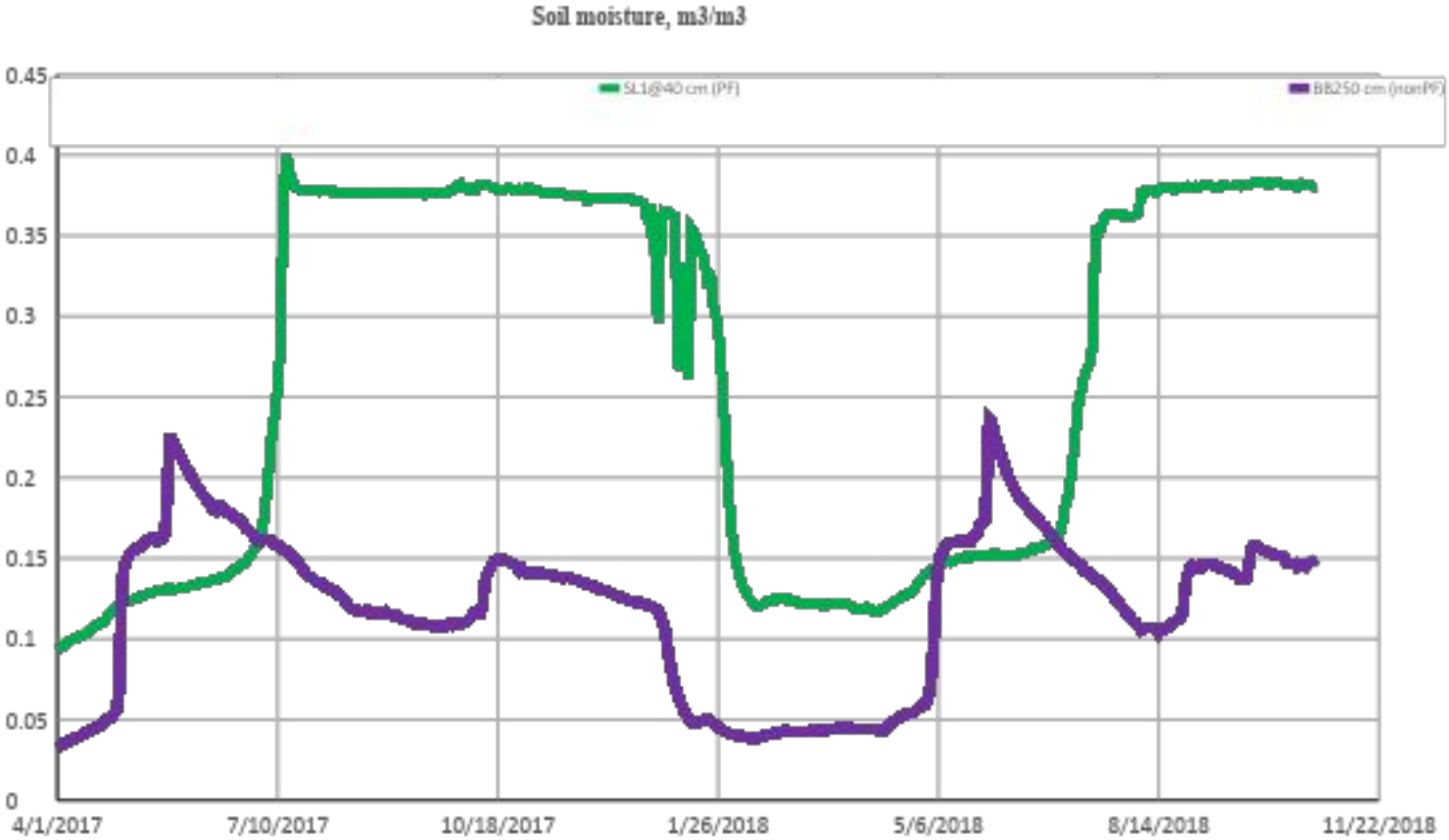

Dynamics of the ground temperature at the Bonanza Creek LTER site
Temperature, °C
4
2
0
-2
-4
-6
-8
-10
Thaw dept ≤60 cm
TD ~80 cm
TD ~100 cm
Detachment of the active layer from permafrost
Seasonal thawing
Seasonal freezing
67 cm
87 cm
108 cm


ACTIVE LAYER
(seasonally thawed)
PERMAFROST
ACTIVE LAYER
(seasonally frozen)
TALIK
(perennially thawed)

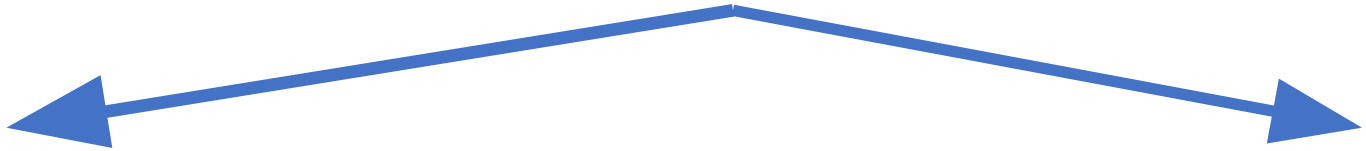
Amount of precipitation, mm






Soil moisture, m3/m3
SL1@40 cm (PF)
BB250 cm (nonPF)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
4/1/2017
7/10/2017
10/18/2017
1/26/2018
5/6/2018
8/14/2018
11/22/2018

TWO POSSIBLE PATHWAYS OF PERMAFROST DEGRADATION:



IC≈P

Formation of ***talik***, i.e. unfrozen layer between an active layer and permafrost.

"Dry" scenario

IC>P

Thermokarst, i.e. ground surface subsidence due to melting of ground ice.

"Wet" scenario

PEOPLE'S CONCERNS

HEALTH

FOOD SECURITY

INFRASTRUCTURE AND TRANSPORTATION

Houses or roads damage, formation of sink holes or new wetlands due to melting of ground ice!

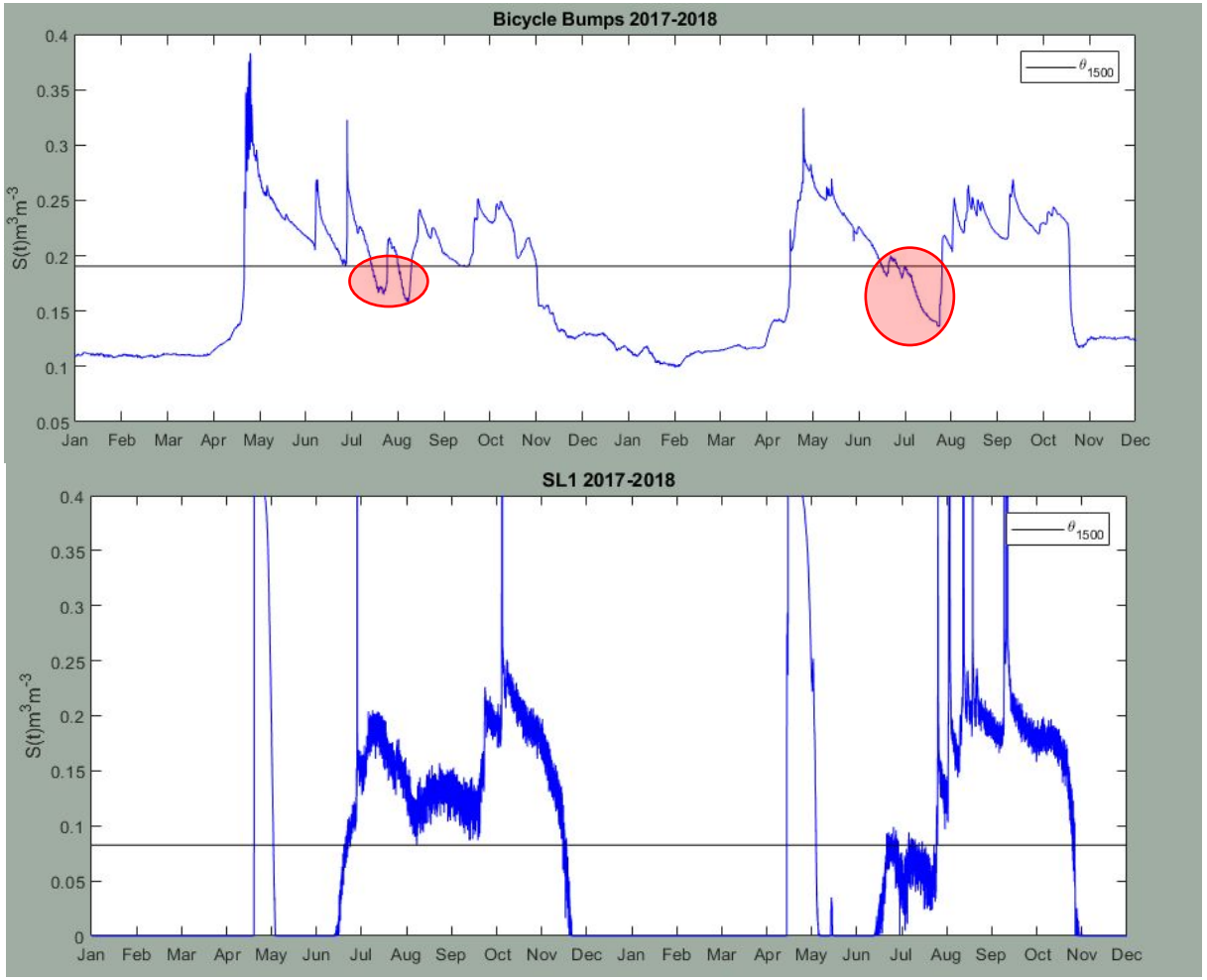
Societal Impacts of Permafrost Degradation

Photo provided by the Fairbanks DOT office

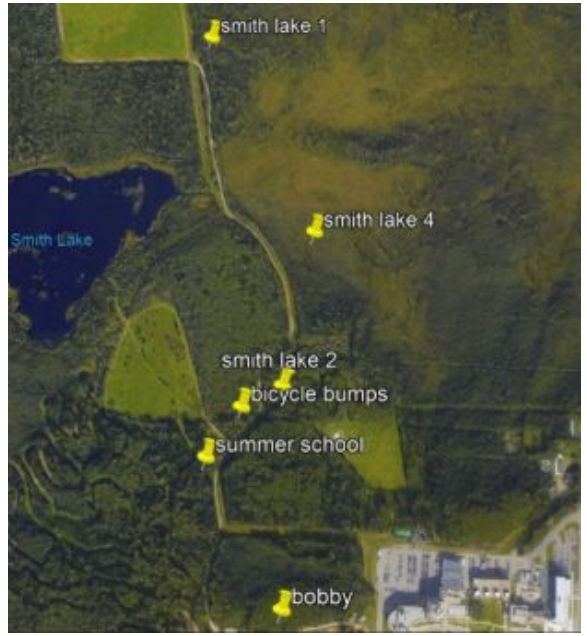
PEOPLE'S CONCERNS

HEALTH	
FOOD SECURITY	Decreasing of berry productivity or changes in wildlife behavior due to environmental changes associated with permafrost degradation. Problems with usage of permafrost cellers!
INFRASTRUCTURE AND TRANSPORTATION	Houses or roads damage, formation of sink holes or new wetlands due to melting of ground ice!

EFFECT OF PERMAFROST ON SOIL MOISTURE



2018			
Site	Mean SM - JJAS	Wilting point, Θ_{1500}	Difference
Bicycle bumps (no permafrost)	.157	.191	-.034
Smith Lake 1 (permafrost)	.117	.083	.034



“We used to have frozen meat and blubber in summertime, but they’re not frozen no more.”

Joe Towksjhea - Elder

Impact: thawing cellars

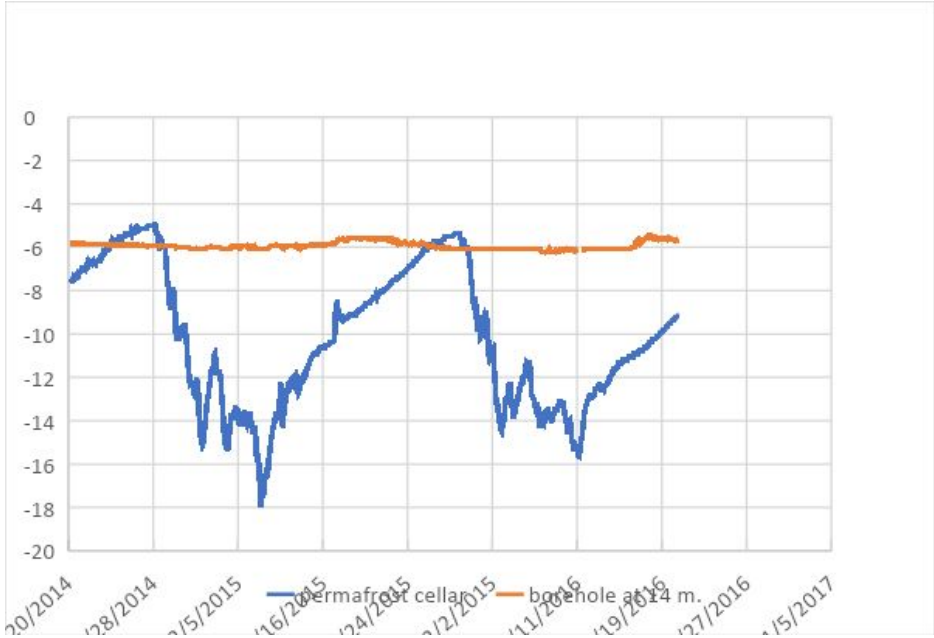
Effect: food insecurity

Adaptation: permafrost surveillance, adaptive design

FOOD SECURITY (PERMAFROST CELLARS)

Permafrost/ice cellars are traditional way for food storage in Arctic communities.

Warmest temperature within such cellars corresponds to the mean annual ground temperature. Thus permafrost warming will affect people's abilities to store food.

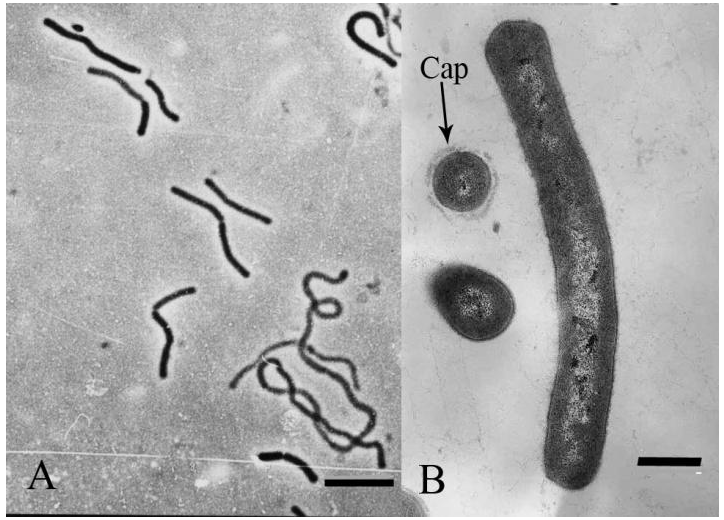


PEOPLE'S CONCERNS

HEALTH	Possible contamination of water sources with chemical compounds or pathogenic microbes realized from thawing permafrost!
FOOD SECURITY	Decreasing of berry productivity or changes in wildlife behavior due to environmental changes associated with permafrost degradation. Problems with usage of permafrost cellers!
INFRASTRUCTURE AND TRANSPORTATION	Houses or roads damage, formation of sink holes or new wetlands due to melting of ground ice!

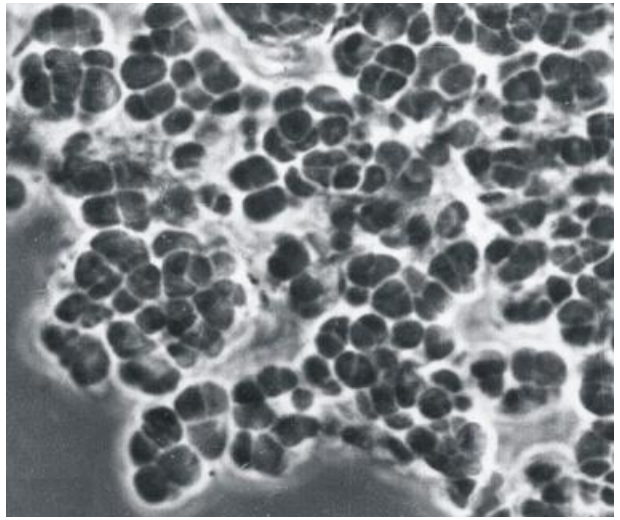
PROCARIOTS ISOLATED FROM ARCTIC PERMAFROST

BACTERIA



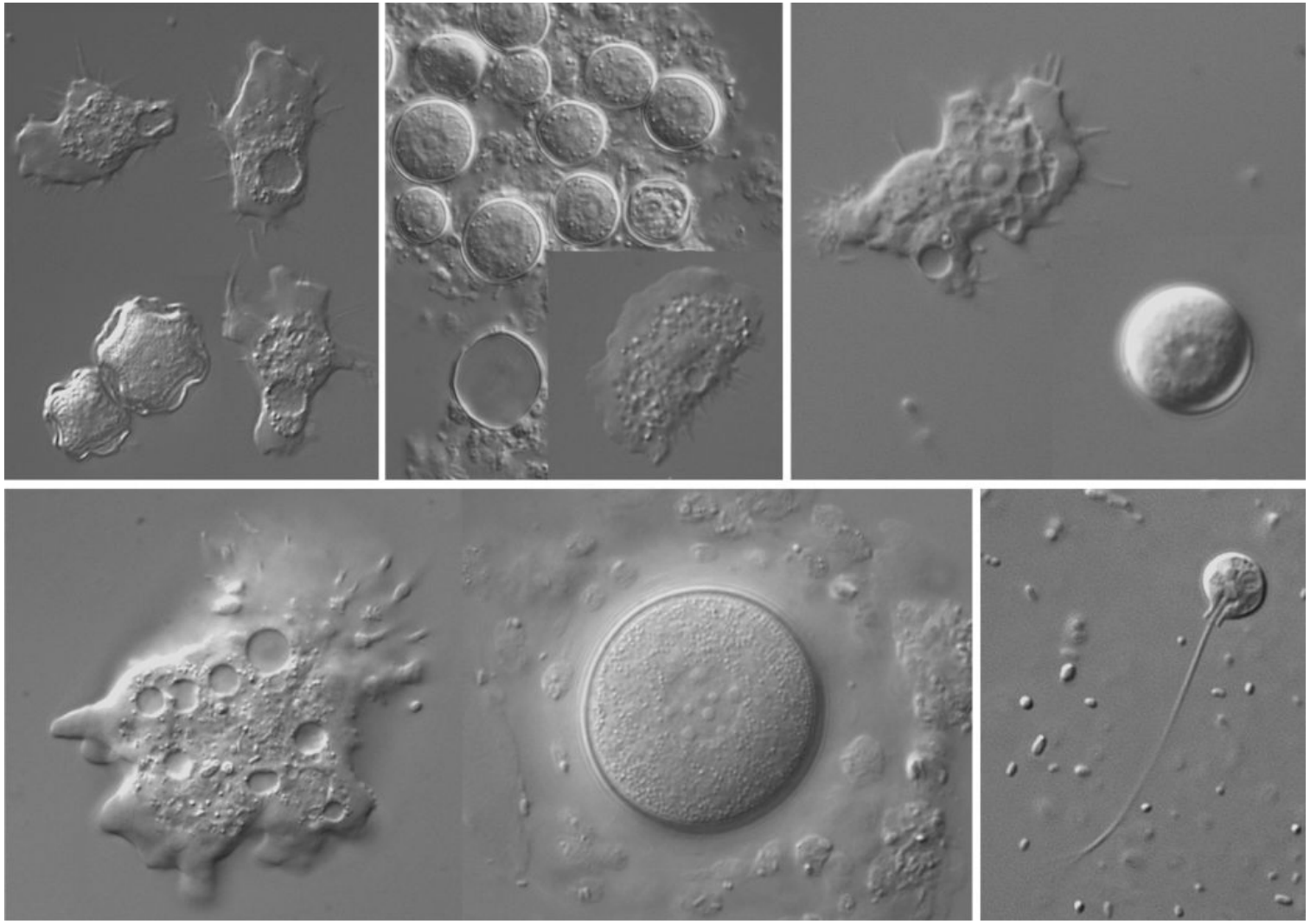
Methanobacterium veterum sp. nov.
(Krivushin et al., 2010)

ARCHAEA

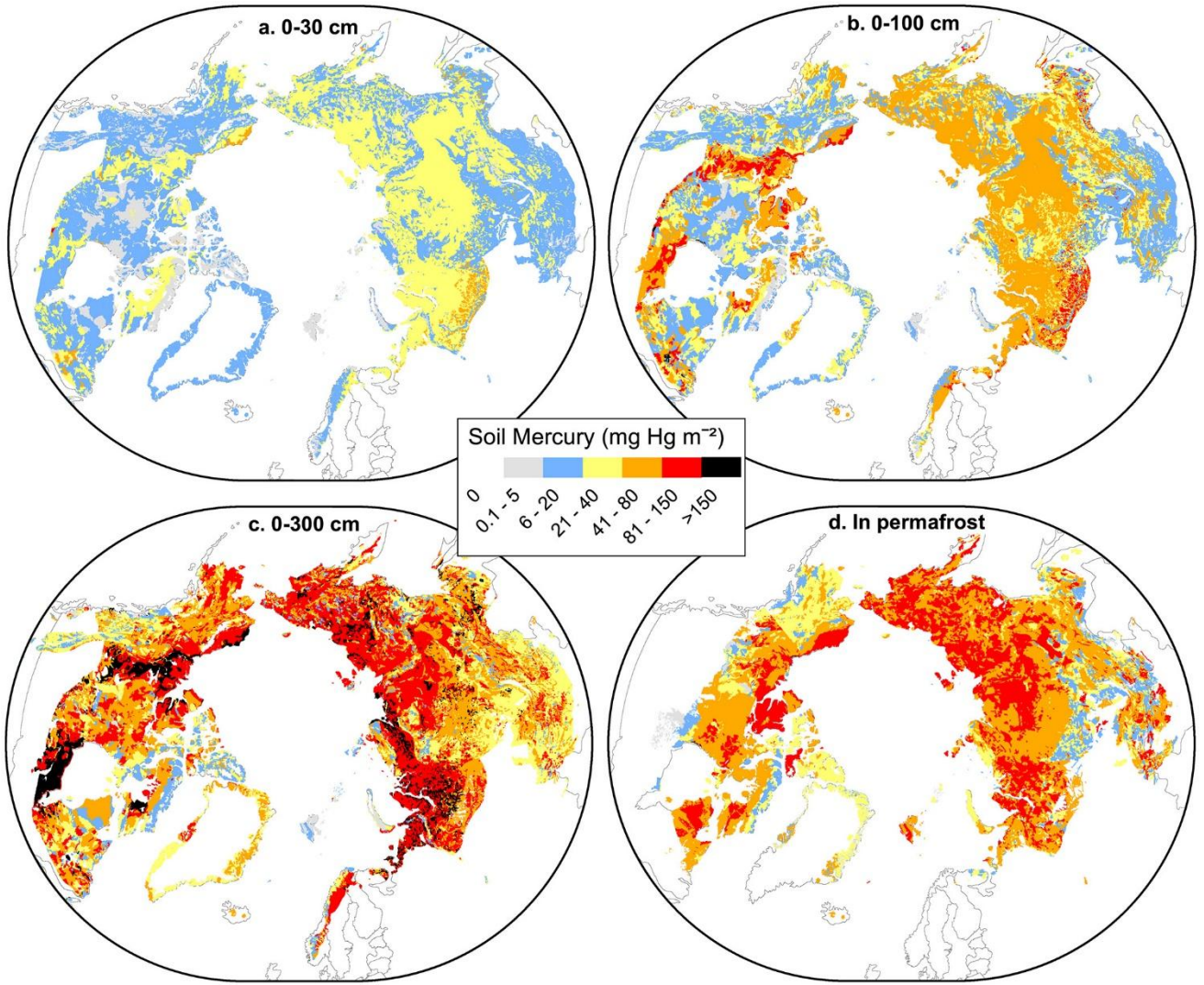


Methanosarcina mazei
(Rivkina et al., 2007)

EUCARIOTES (PROTISTA) ISOLATED FROM ARCTIC PERMAFROST



Organisms of the phylum Amoebozoa, extracted from the permafrost; trophozoites and cysts, DIC: (a) *Acanthamoeba castellanii*, strain SCL_am8; (b) *Flamella* sp., strain CL_flam1; (c, d) *Filamoeba* sp.: (c) strain SCL_148; (d) strain SCL_1410; (e) *Phalansterium* sp., strain SCL_phalan1. Scale bar, 10 µm. **(Shatilovich & Rivkina, 2015)**

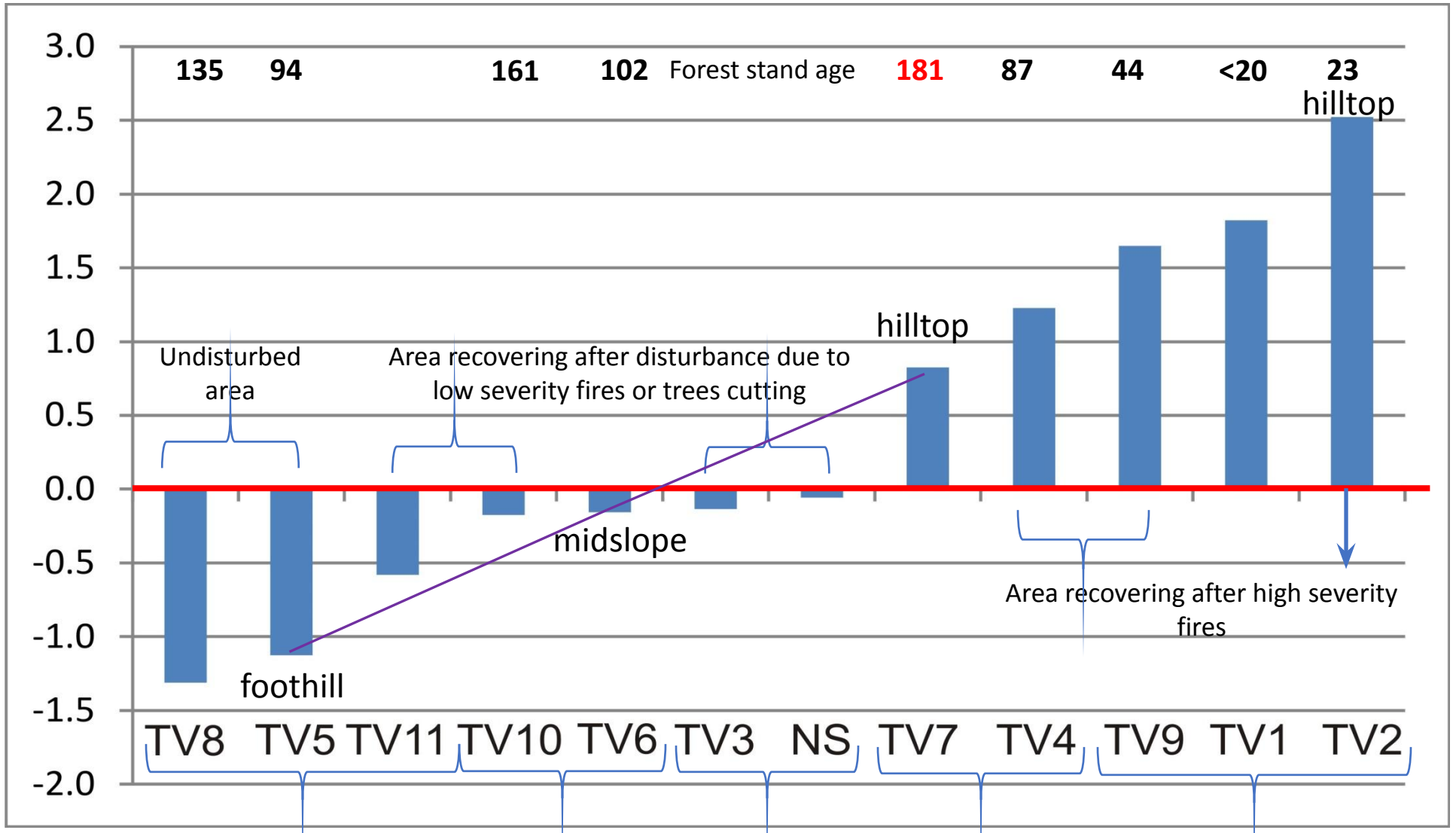


Maps of Hg (mg Hg m^{-2}) in Northern Hemisphere permafrost zones. Four soil layers: 0–30 cm, 0–100 cm, 0–300 cm, and permafrost derived by multiplying maps of carbon from Hugelius, Tarnocai, et al. (2013) and Hugelius et al. (2014) by the median $R_{Hg:C}$. The permafrost map represents the Hg bound to frozen organic matter below the ALD and above 300 cm depth. The relative uncertainty is

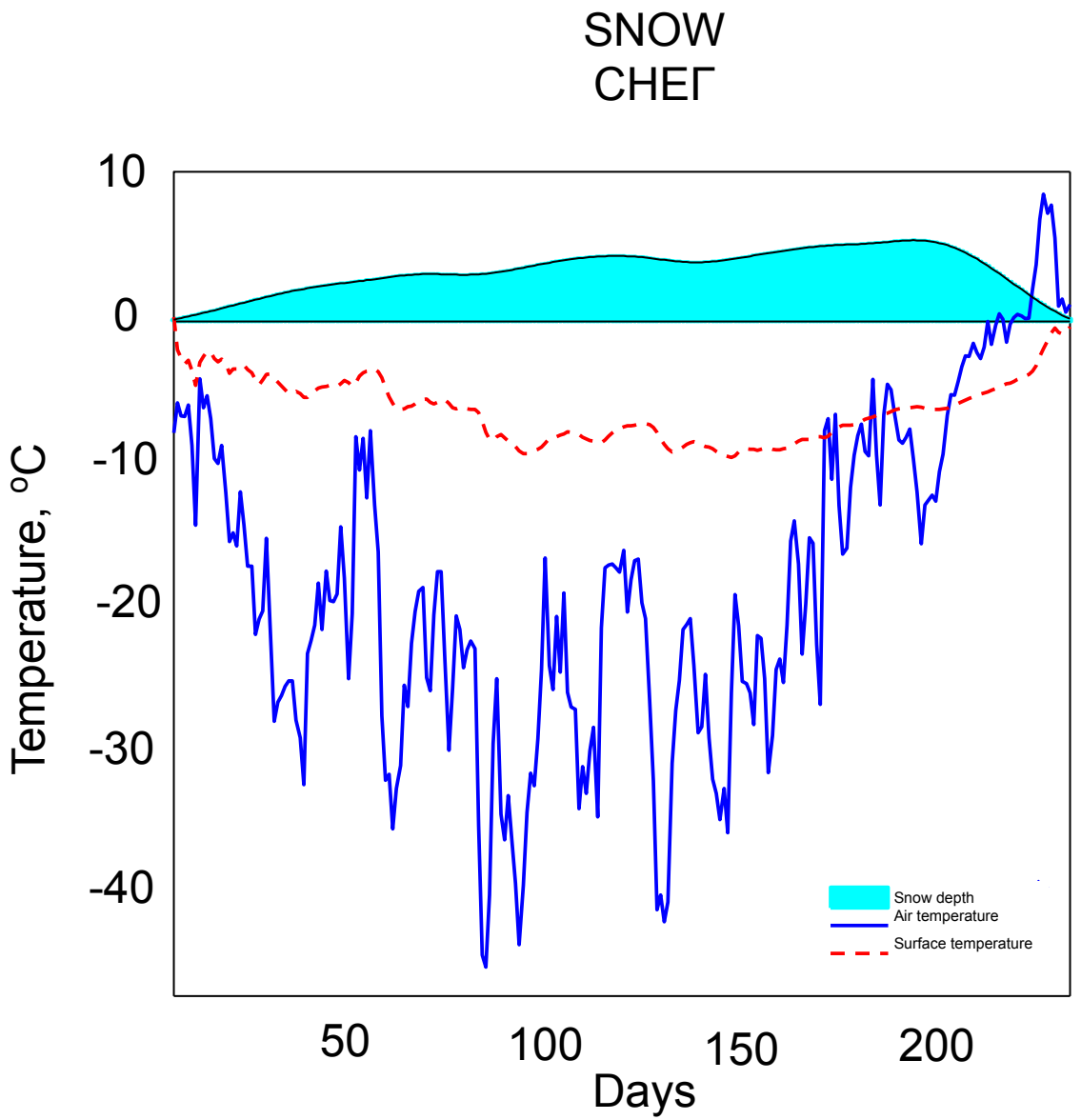
Schuster, Paul F., et al. "Atmospheric mercury deposition during the last 270 years: a glacial ice core record of natural and anthropogenic sources." Environmental science & technology 36.11 (2002): 2303-2310.

DOES THE LANDUSE ACTIVITY AFFECT PERMAFROST VULNERABILITY?

MEAN ANNUAL TEMPERATURE AT THE BOTTOM OF ACTIVE LAYER WITHIN DIFFERENT ECOTYPES IN 2016-2017

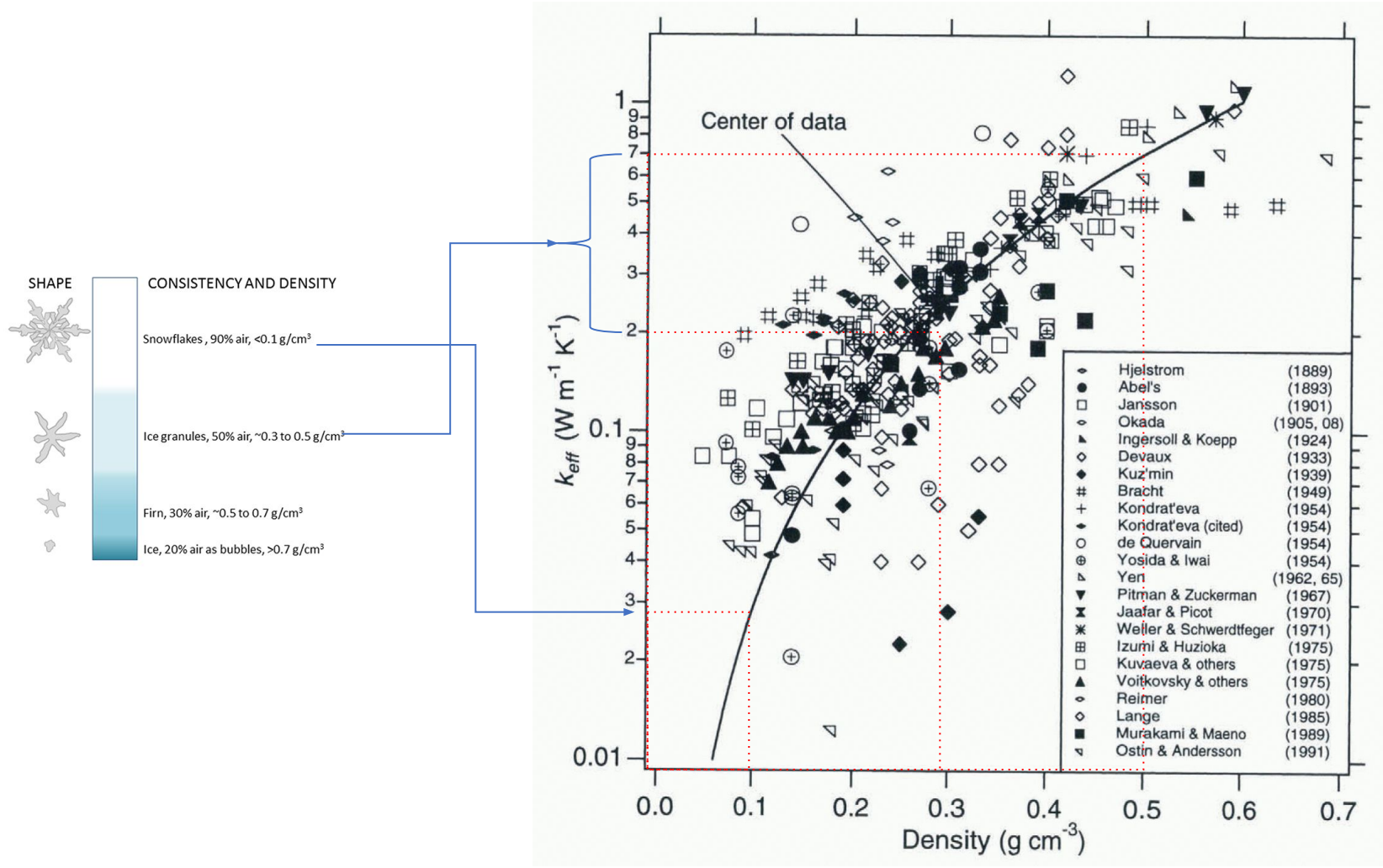


Can we do anything with it?



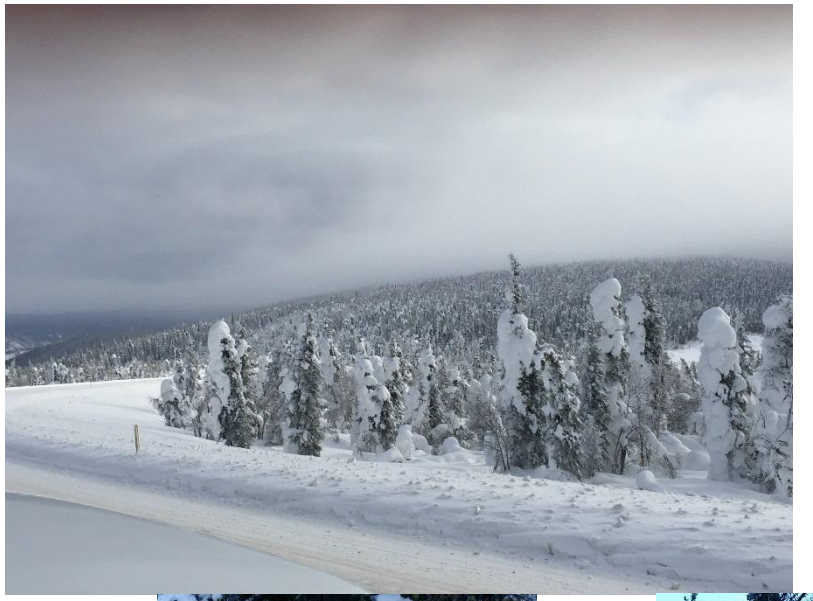
Time variations in snow thickness and ground surface temperatures.
Динамика толщины снежного покрова и температур воздуха и поверхности почвы.
(Jafarov et al., 2014)

SNOW
СНЕГ



Snow thermal conductivity vs density.
Зависимость теплопроводности снега от плотности.
(Sturm et al., 2017)

VEGETATION: SNOW REDISTRIBUTION
РАСТИТЕЛЬНОСТЬ: ПЕРЕРАСПРЕДЕЛЕНИЕ СНЕГА

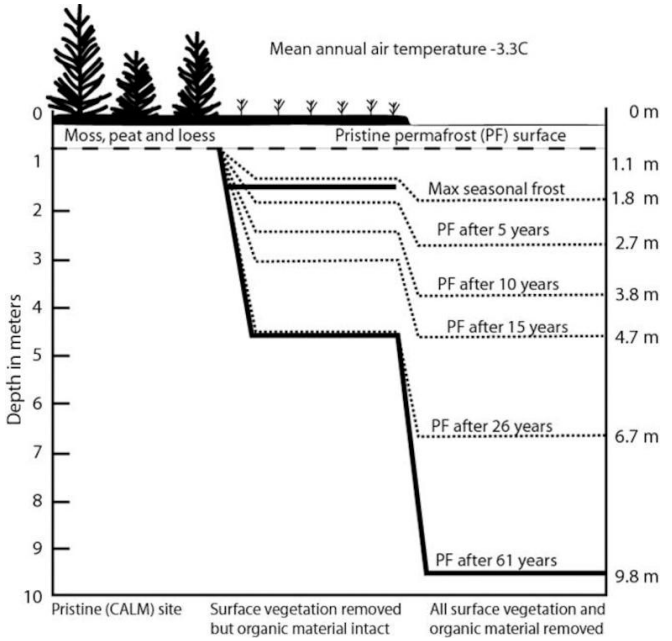


NATURE-BASED SOLUTIONS

Manipulation of the warming (snow cover), and cooling (soils and vegetation) factors such as compacting of can be used for naturally based solutions for protection of permafrost.

Planting of coniferous trees, control of shrubs expansion, amplification of succession of understory vegetation from vascular plants to moses as well as better planning of timber harvesting can also provide stabilization of permafrost.

Photo from the Pleistocene Park website
https://pleistocenepark.ru/



From Douglas et al., 2008