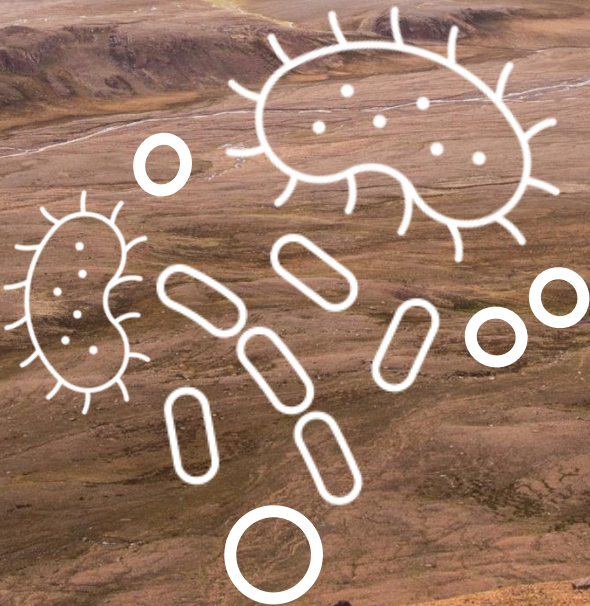


Relationship to
greenhouse gas
fluxes

Microbial ecology



Factors governing the structure
and function of microbial
communities

Cryosphere microbiomes in a warming world



Cryosphere






>25% surface of our planet

- Sea ice
- Ice sheets
- Arctic
- Alpine
- Antarctic
- Snow
- Glaciers
- Saline springs
- Permafrost



Cryosphere

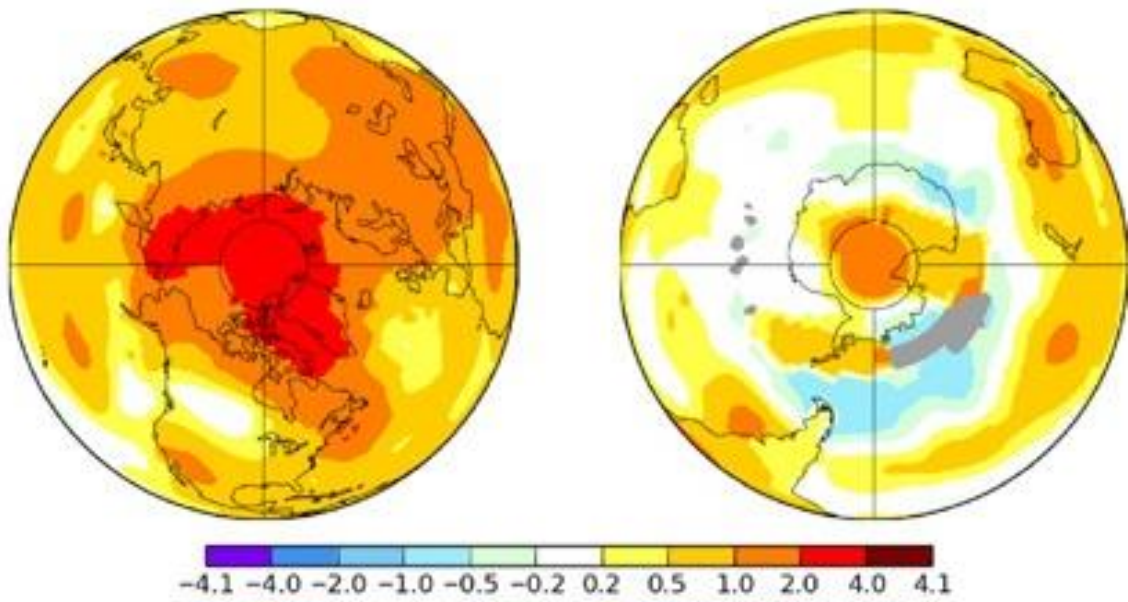
Challenges for Life

-  Sub-zero temperatures
-  Low water availability
-  Low nutrients
-  UV/gamma radiation
-  High salinity



Cryosphere Warming

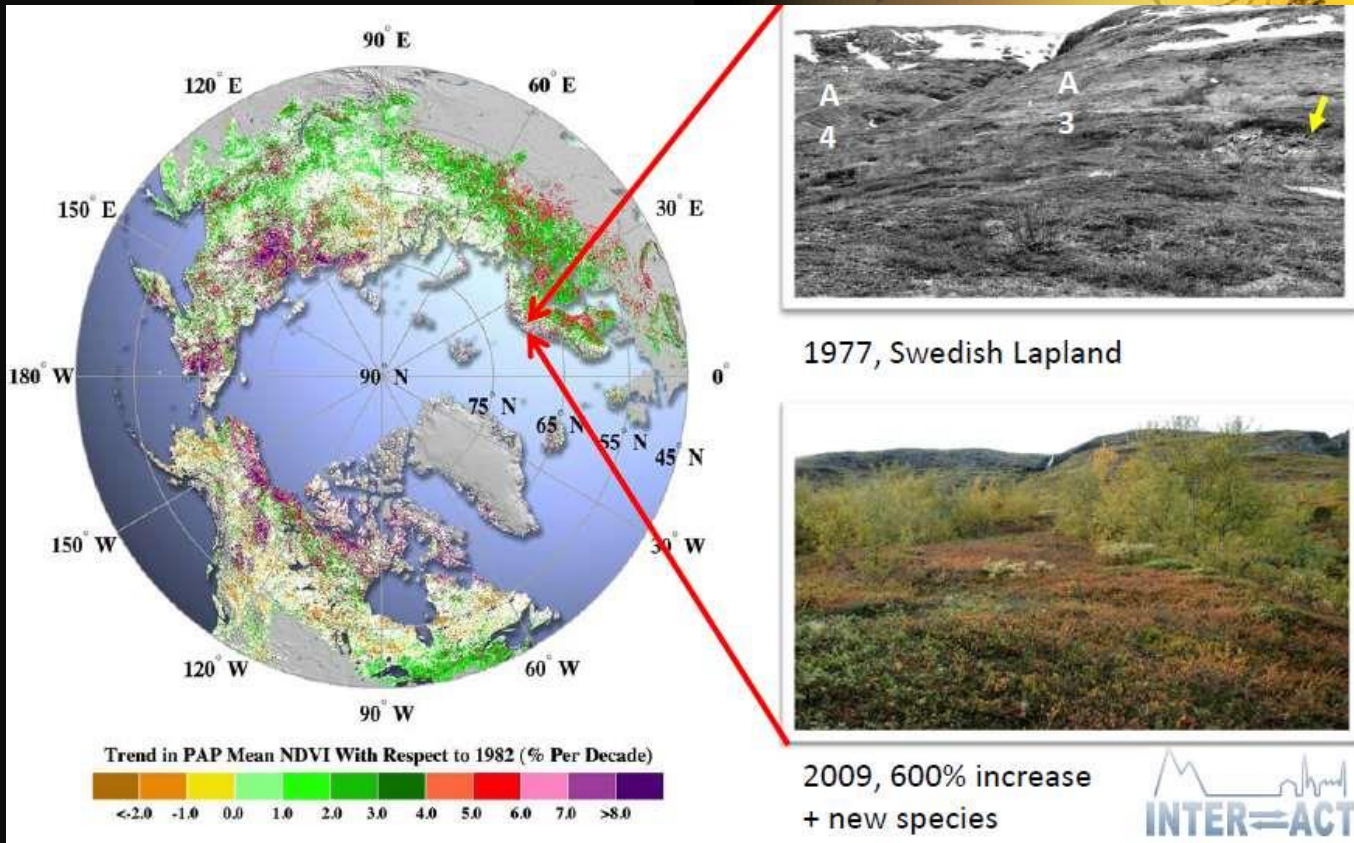
Annual J-D L-OTI (°C) Change 1986–2018



Loss of Sea Ice



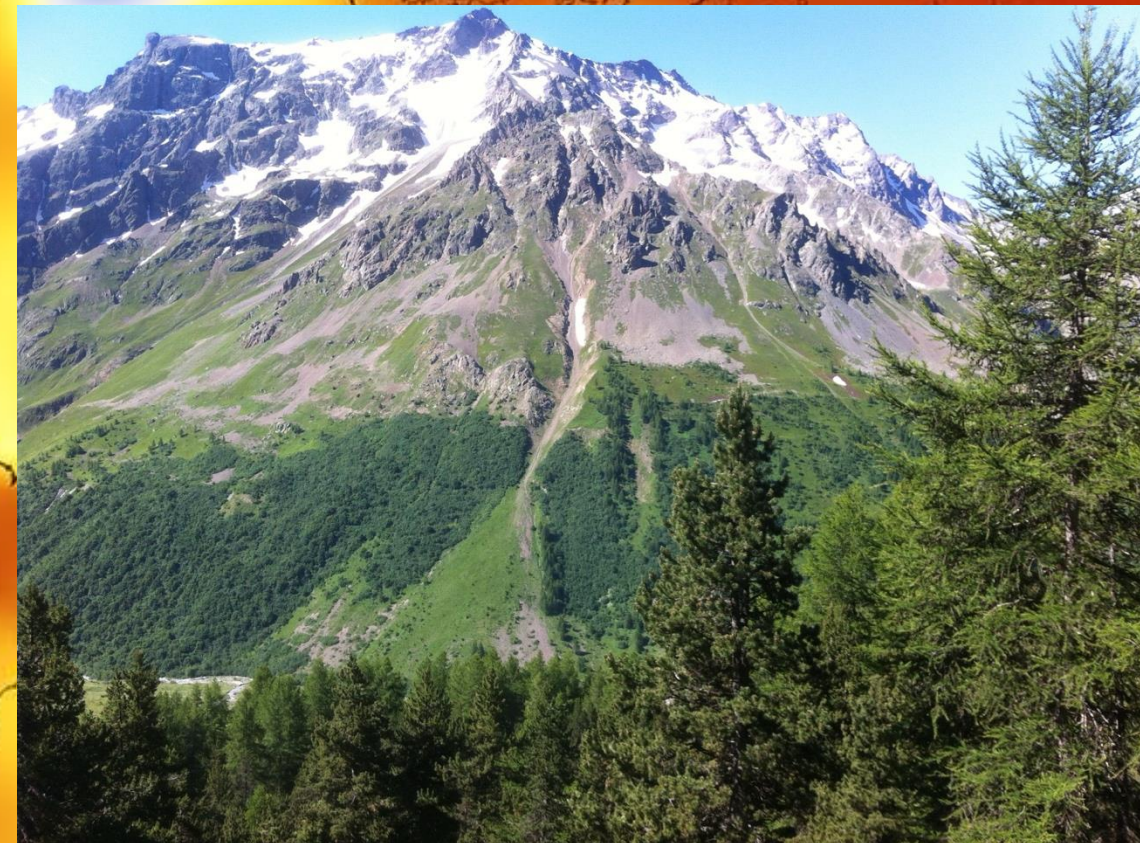
Arctic and Alpine “Greening”



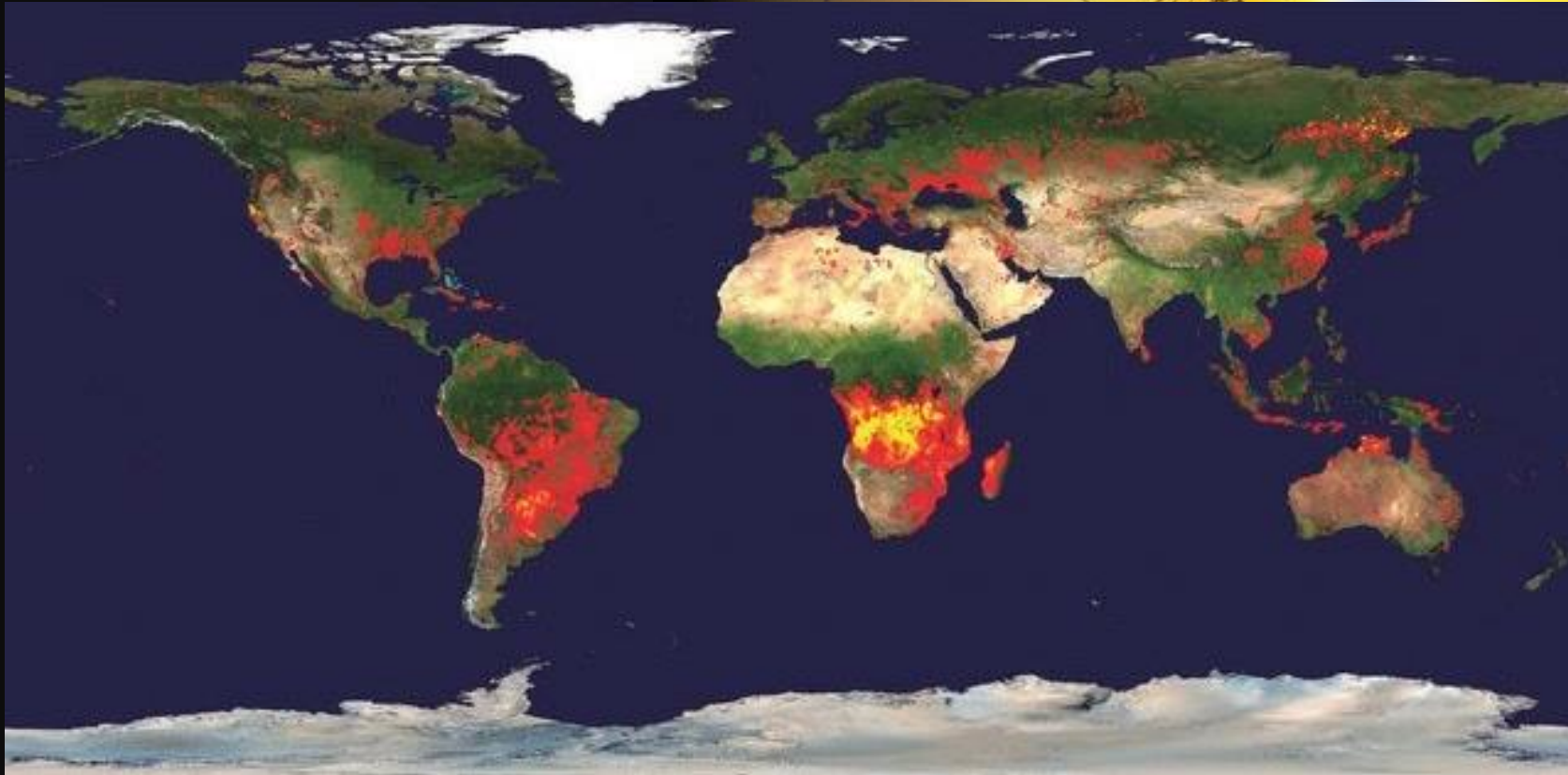
1977, Swedish Lapland



2009, 600% increase + new species

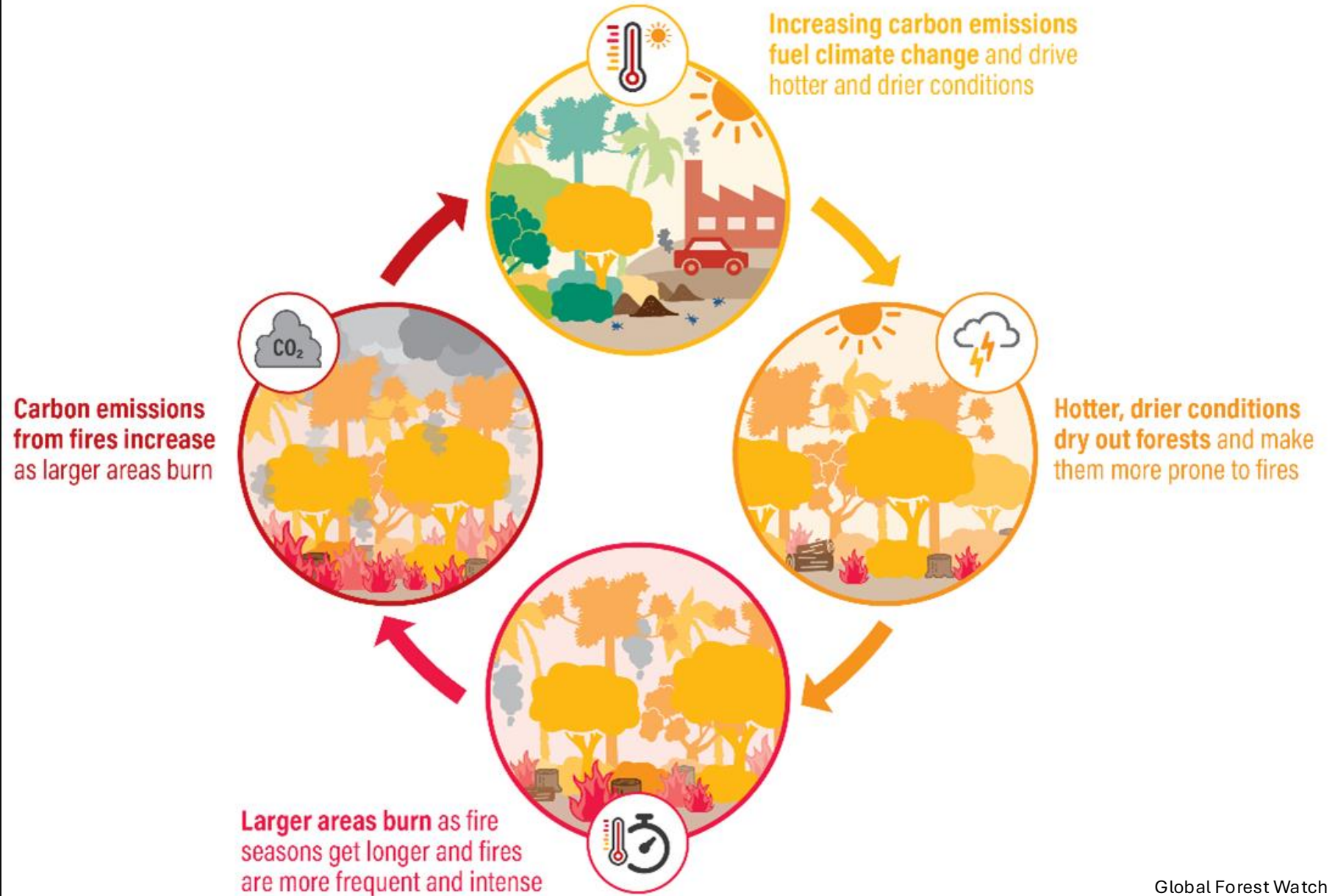


Forest fires



Fires and the Climate Feedback Loop

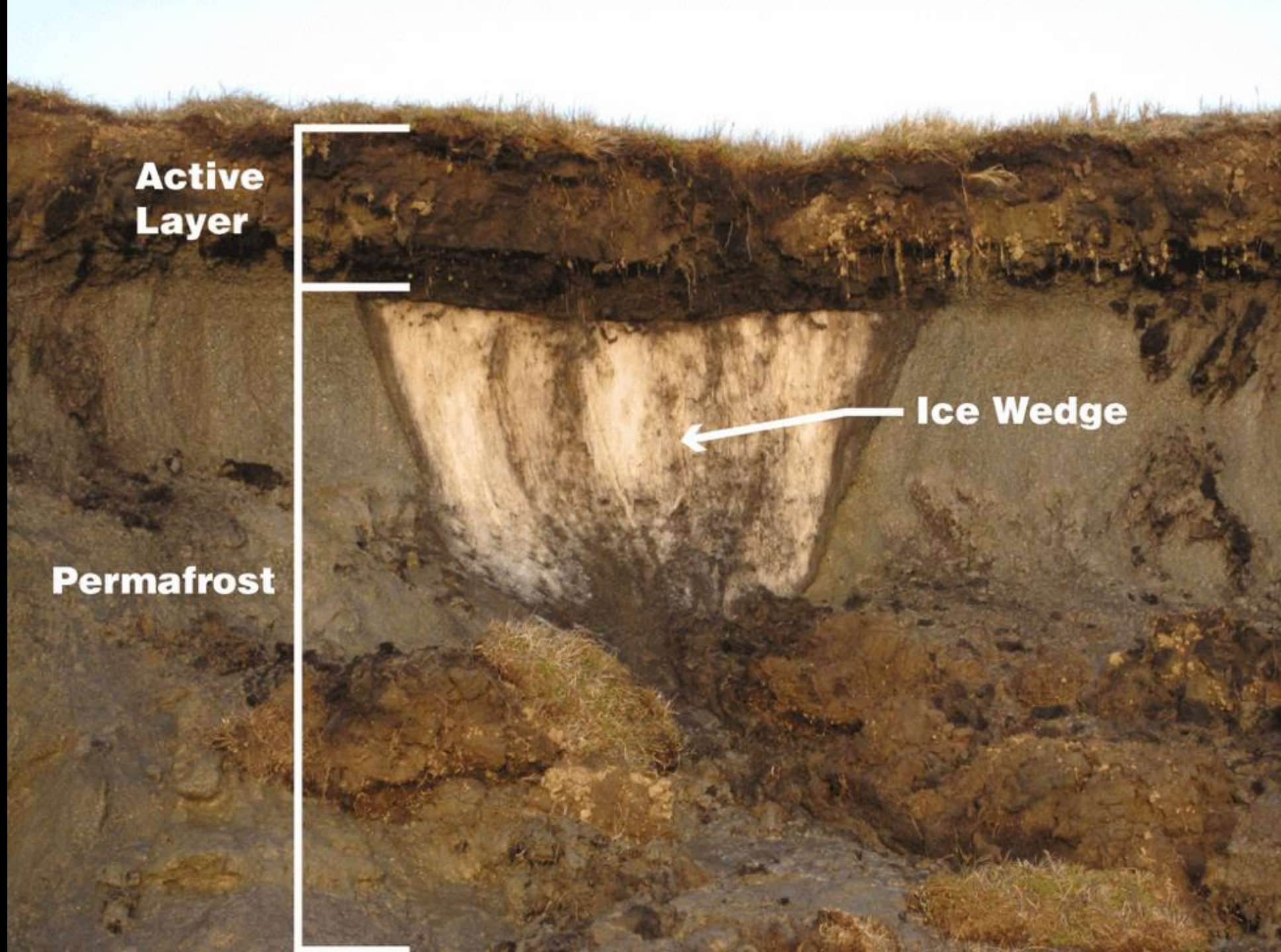
Forest fires



Permafrost

Permafrost: ground that has been frozen for at least two consecutive years (often for hundreds of thousands of years)

Active Layer: overlays permafrost, this layer thaws each summer and freezes again in winter.

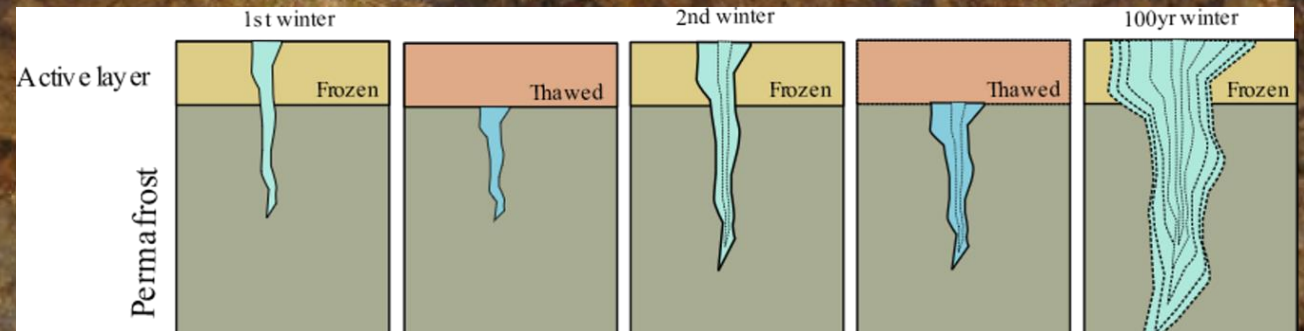
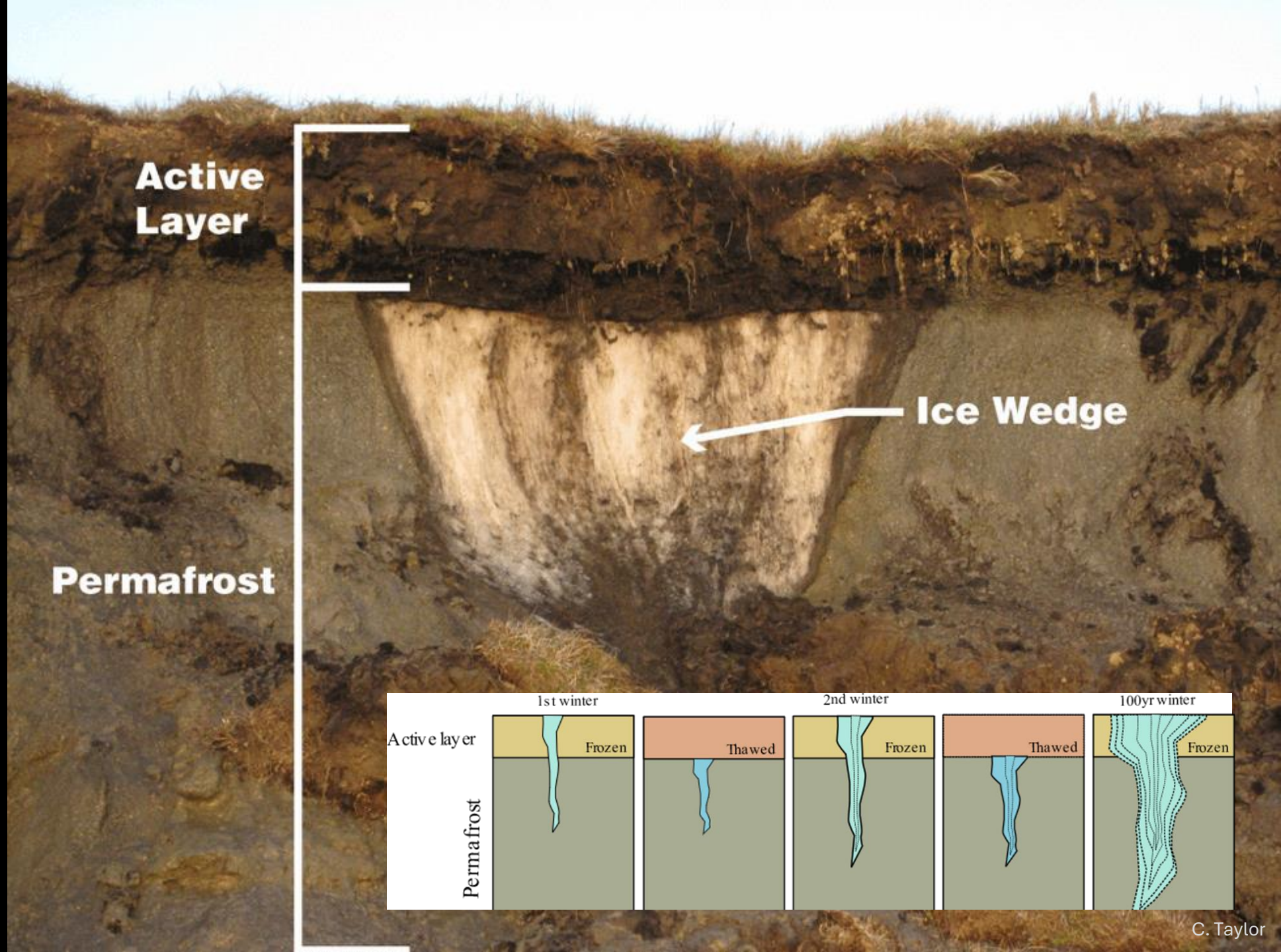


Permafrost

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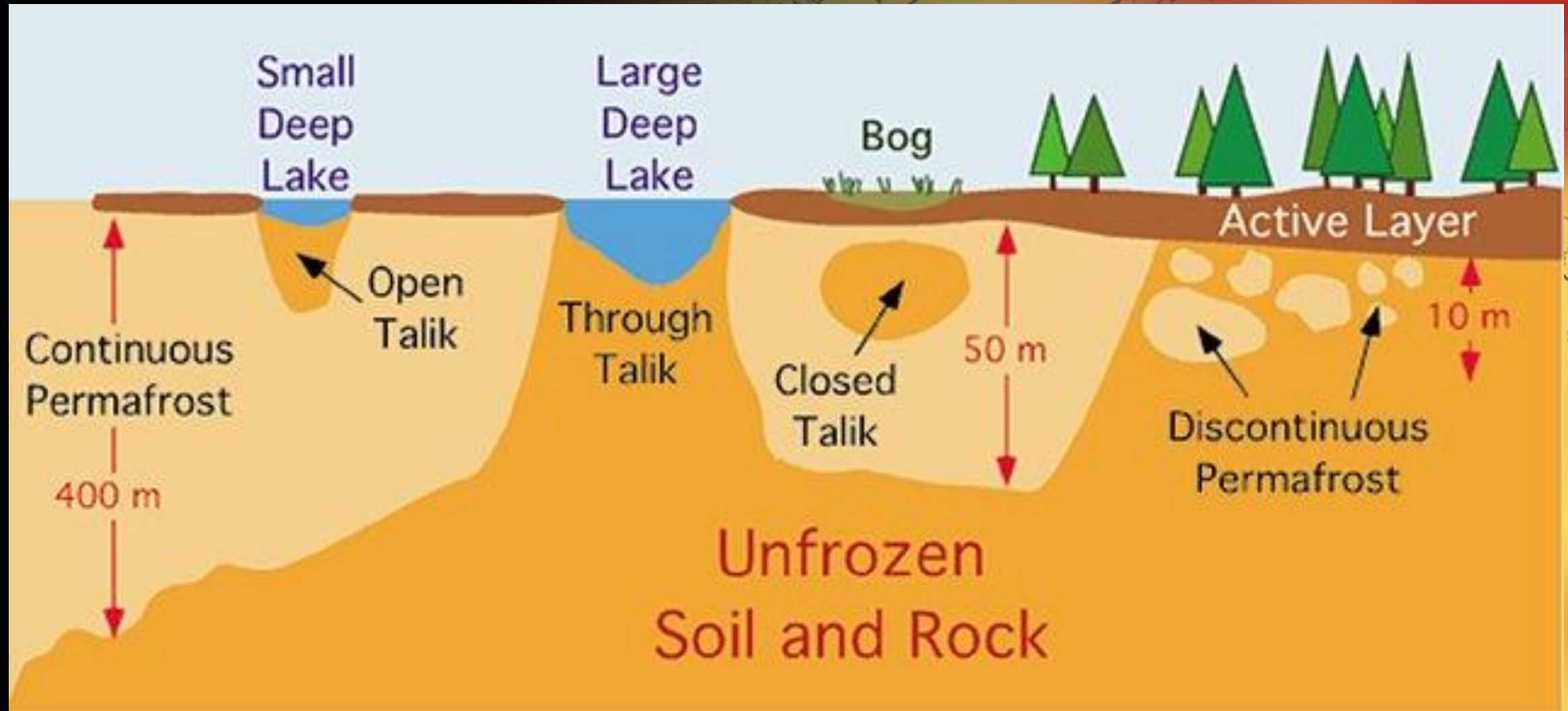
Ice Wedge: a crack in the ground formed by a narrow piece of ice and extends downwards into the ground.





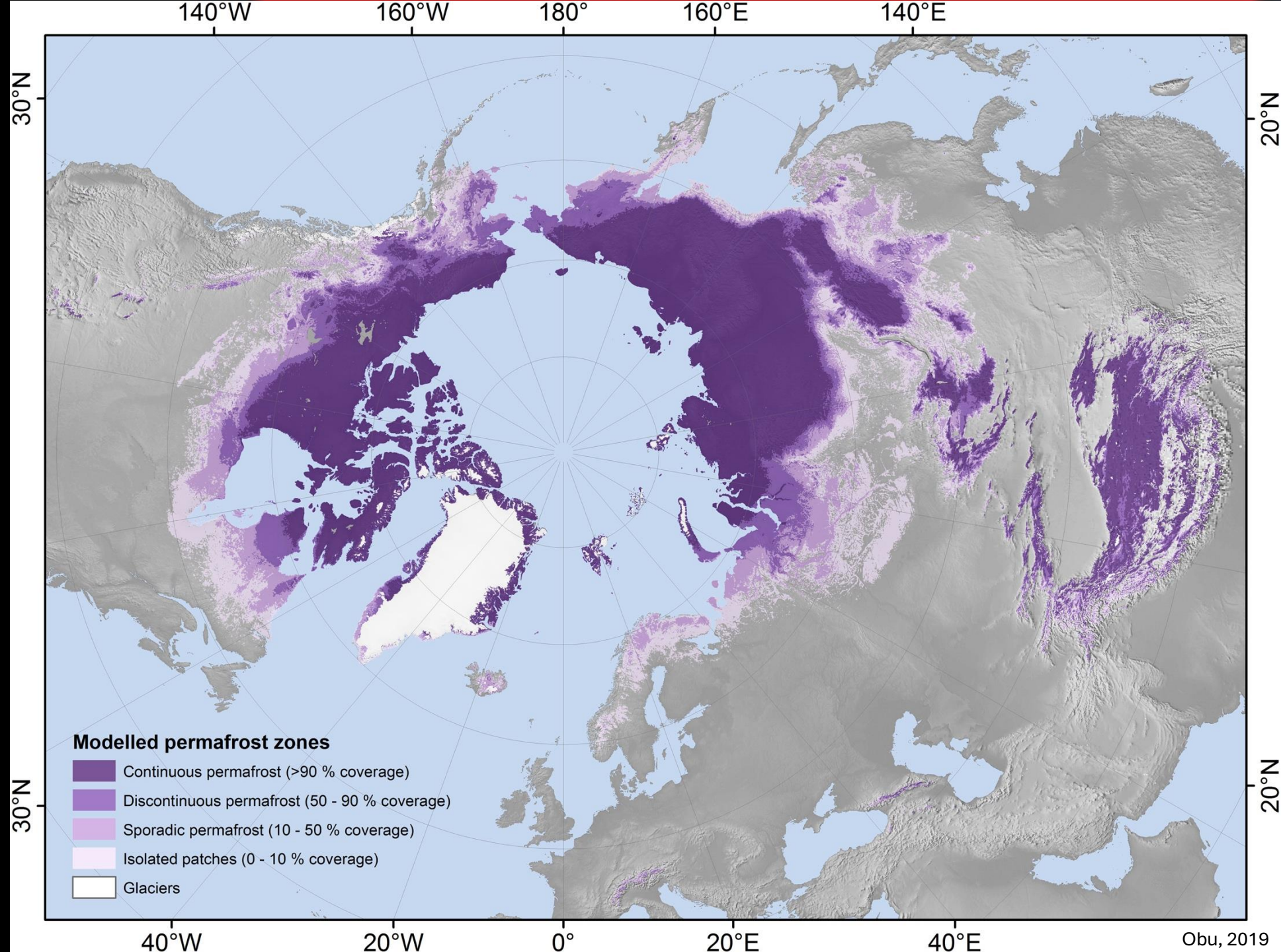


Permafrost

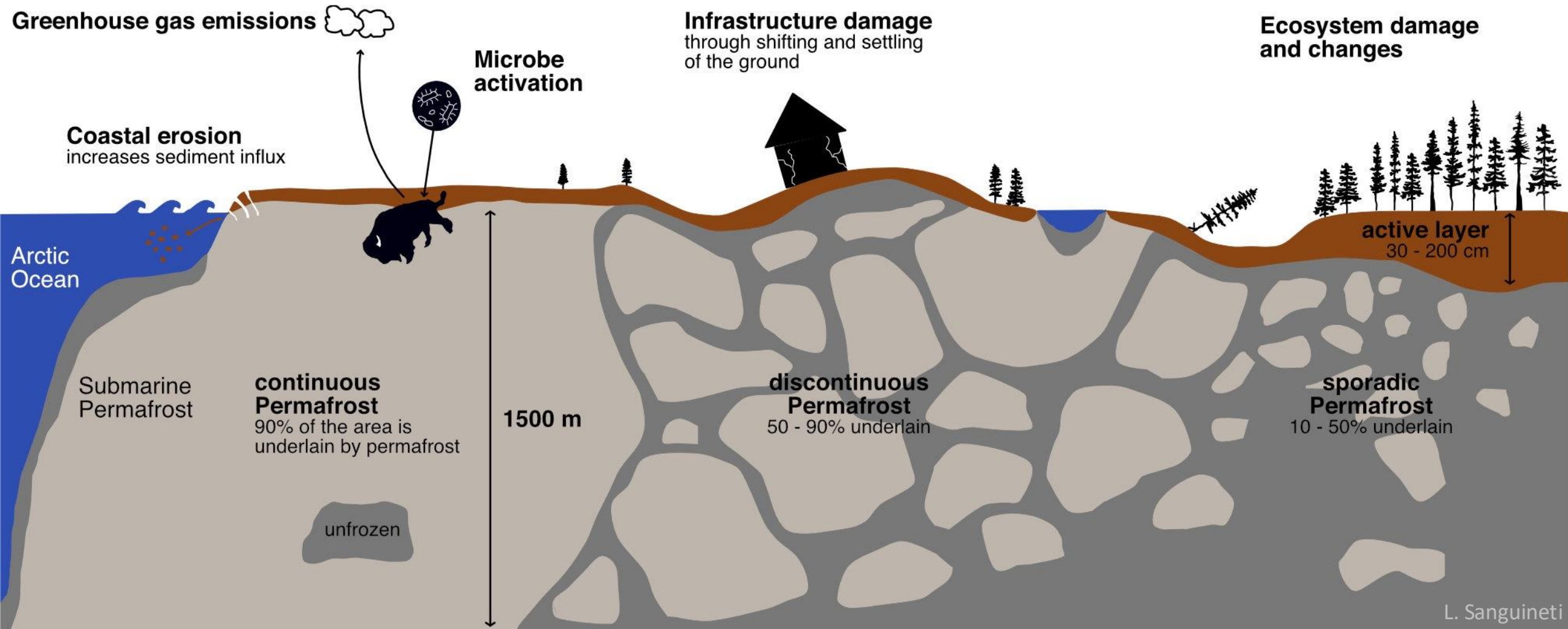


- Continuous vs Discontinuous permafrost
- Talik: Portion of year-round unfrozen ground in a permafrost zone

Permafrost



Permafrost thaw



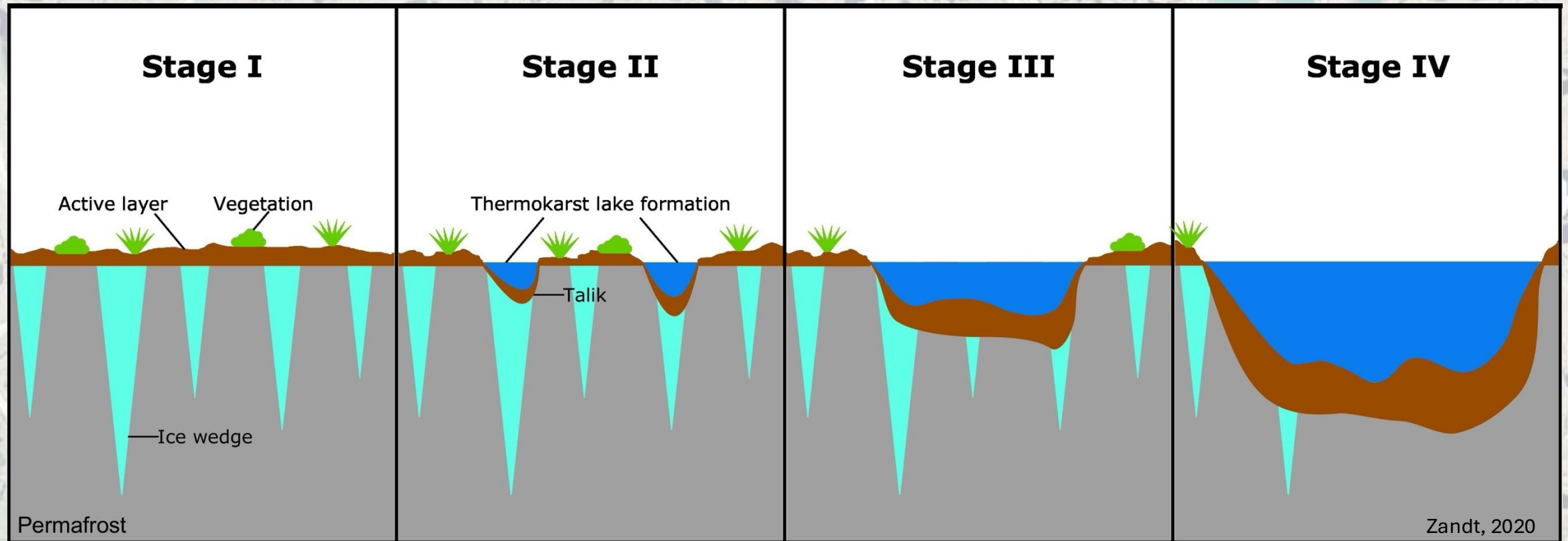


Permafrost thaw

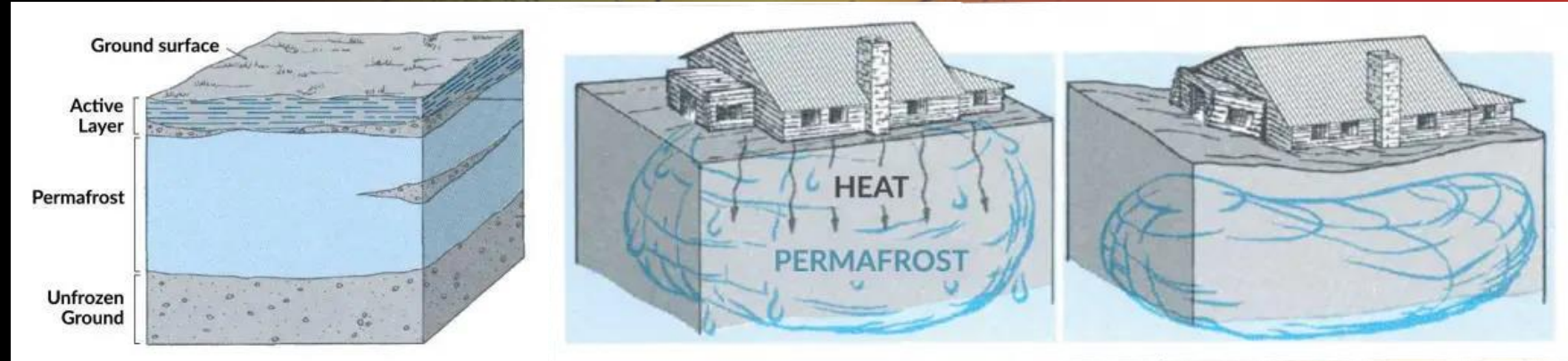
Abrupt thaw results in thermokarst lake formation in ice-rich continuous permafrost



M. Schwab



Permafrost thaw



Infrastructure damage





Permafrost thaw

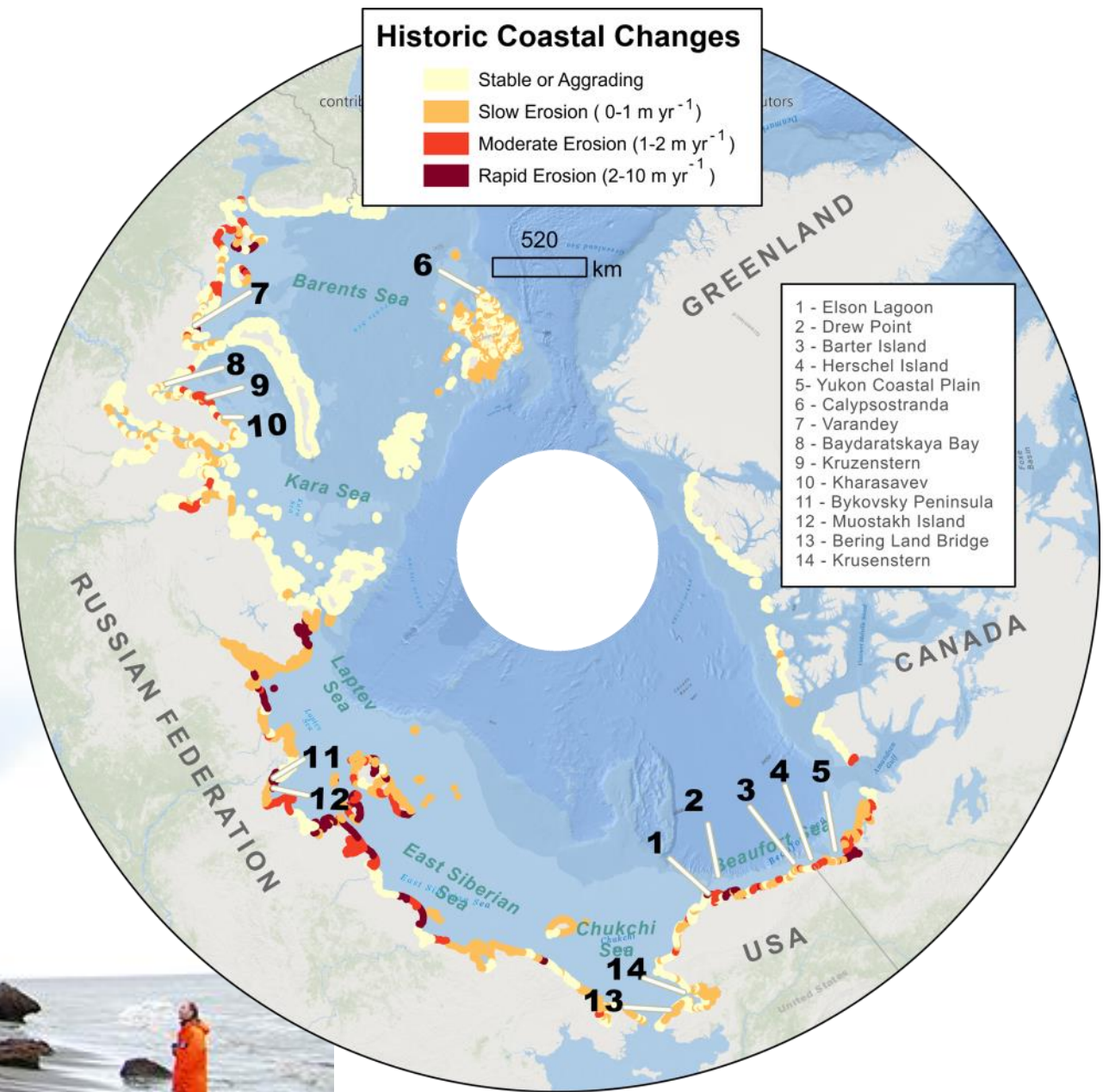
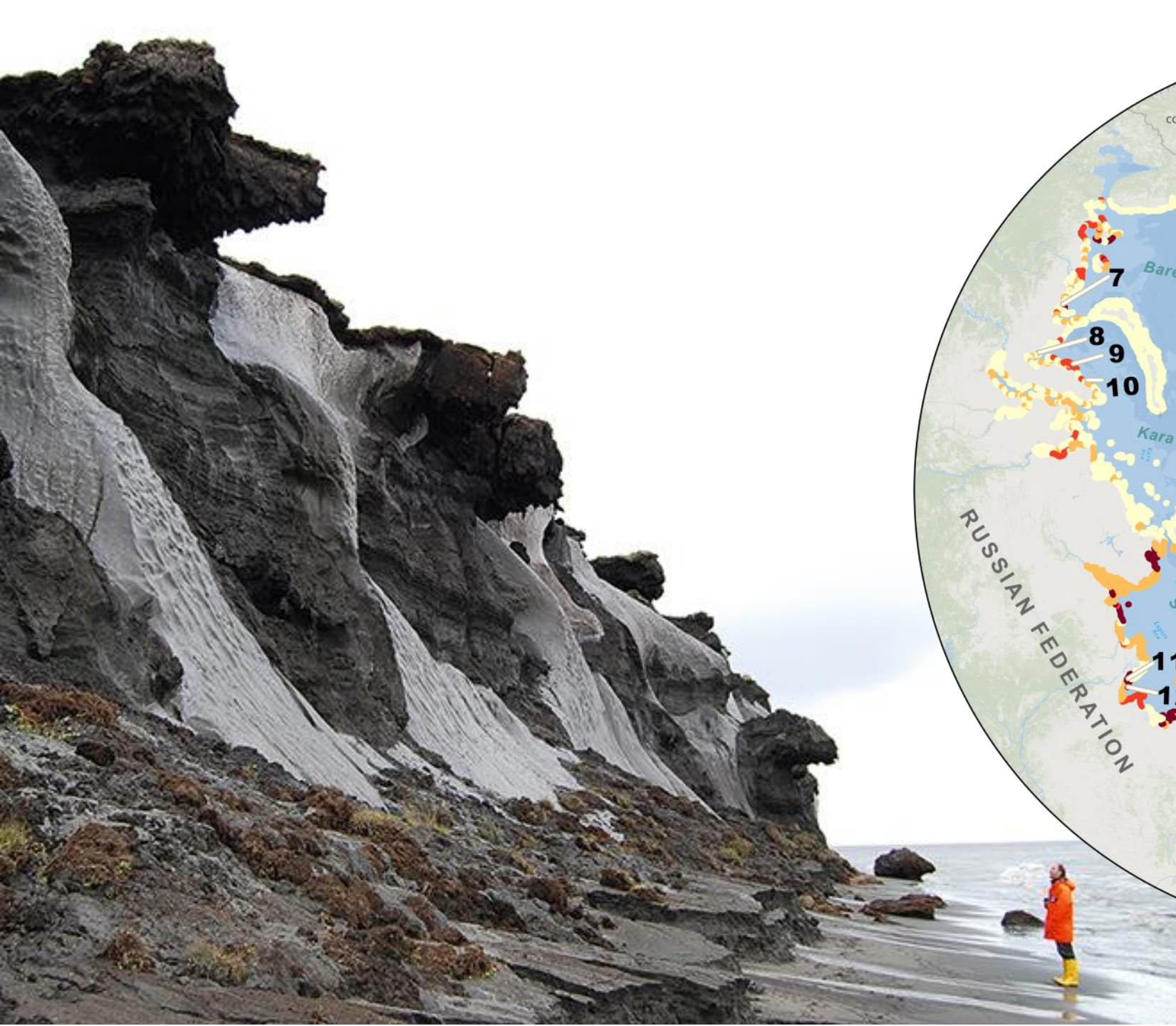


Coastline erosion

thermal and mechanical drivers

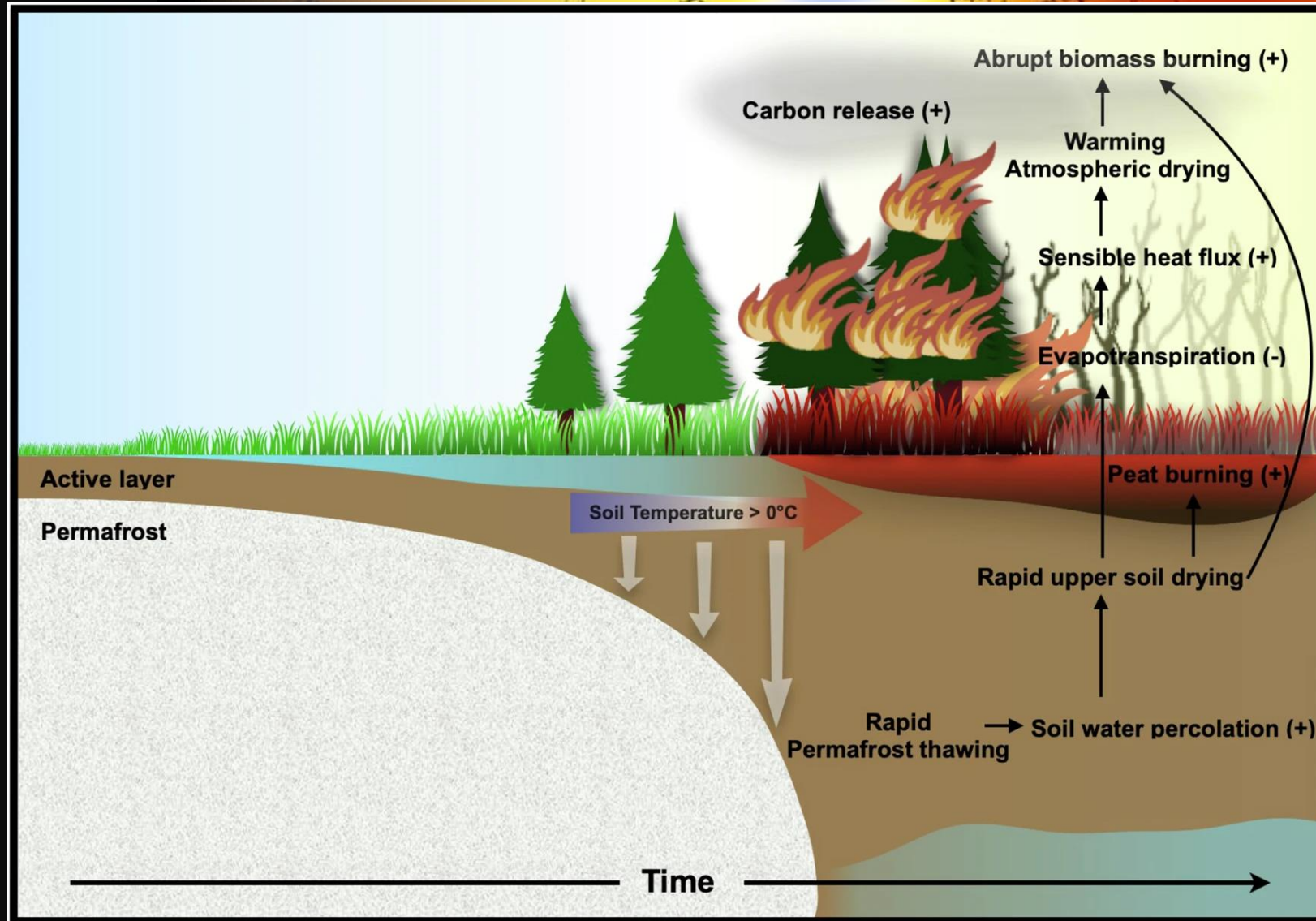
Coastal Erosion



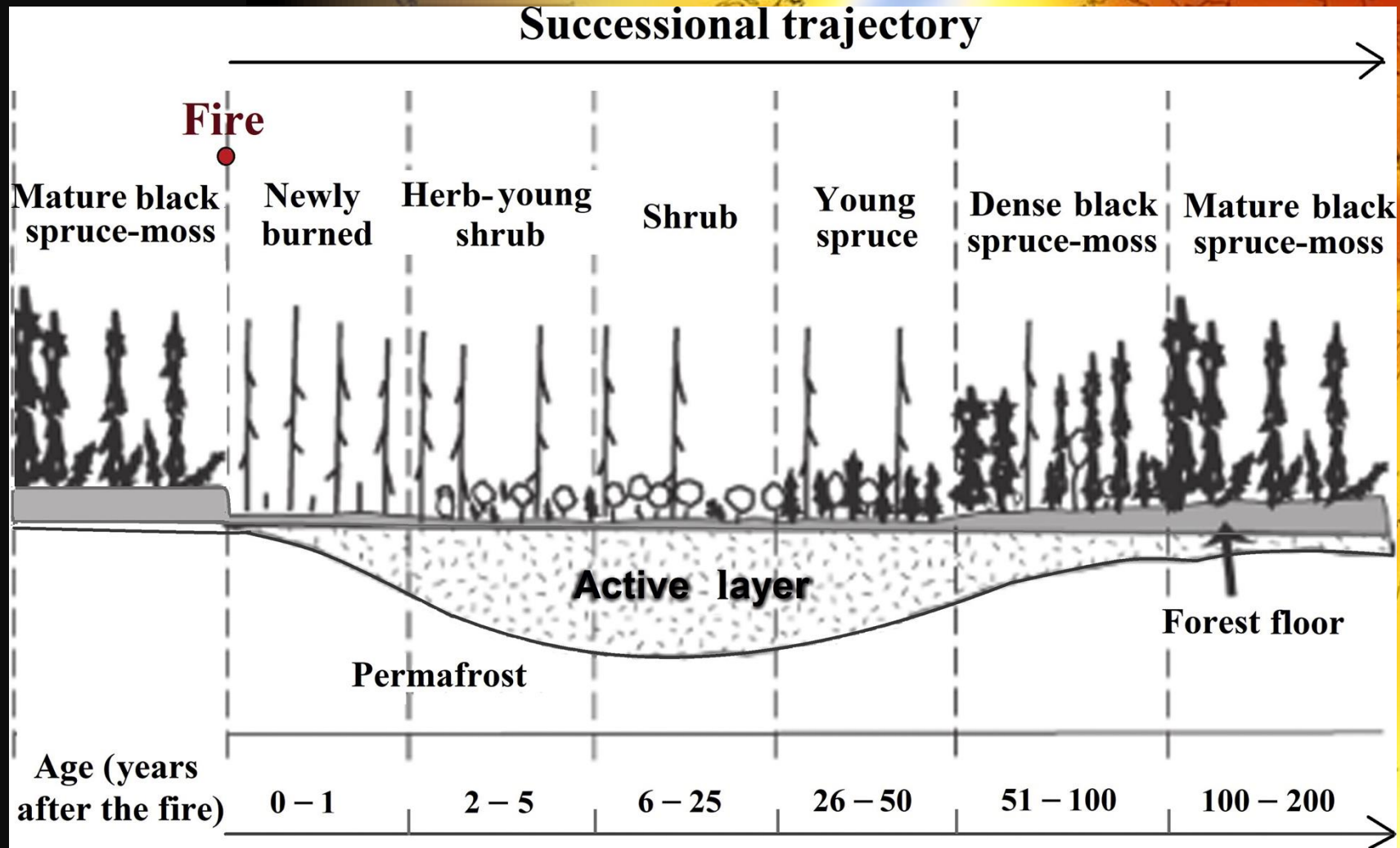




Permafrost x Forest Fires

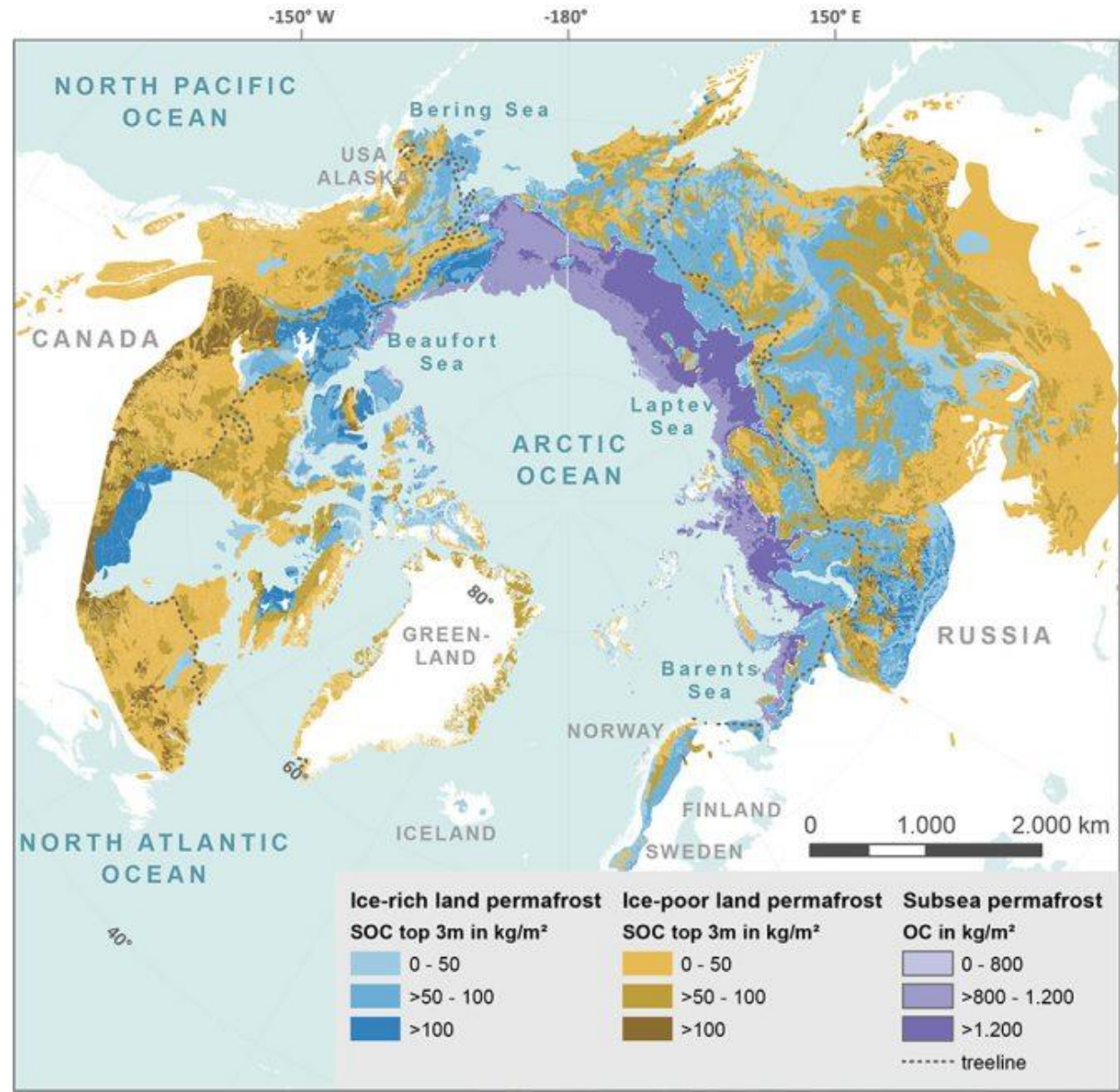


Permafrost x Forest Fires



Permafrost carbon stores

- estimated 1500000000000000 kg of carbon stored in permafrost (1,500 gigatonns)
- twice as much as the atmosphere contains



Permafrost carbon stores



Pleistocene:

- 2.58 million to 11,700 years ago
- Repeated glaciation events

Ancient DNA

Permafrost thaw positive feedback

Permafrost thaw

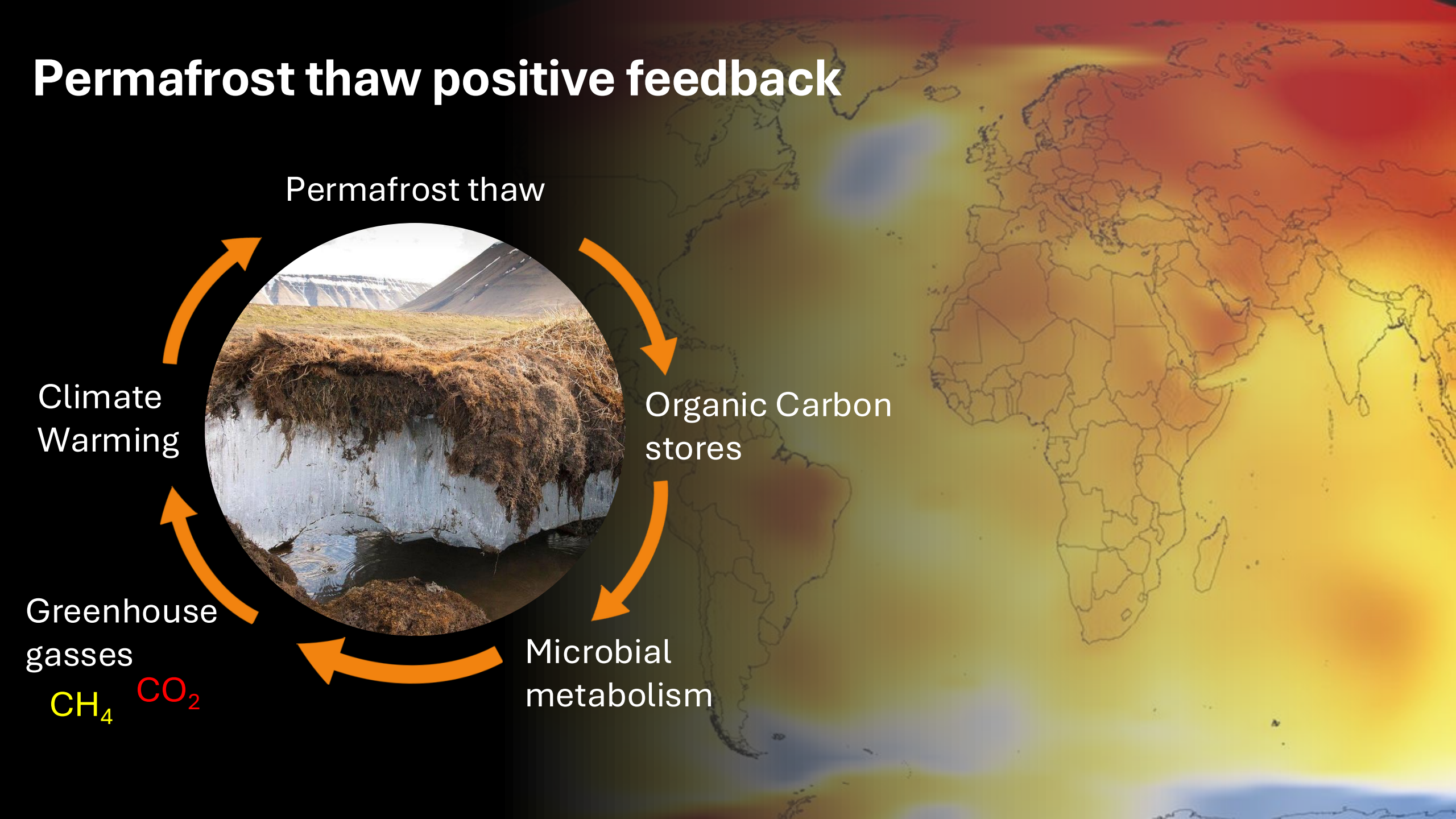


Climate Warming

Organic Carbon stores

Greenhouse gasses

Microbial metabolism



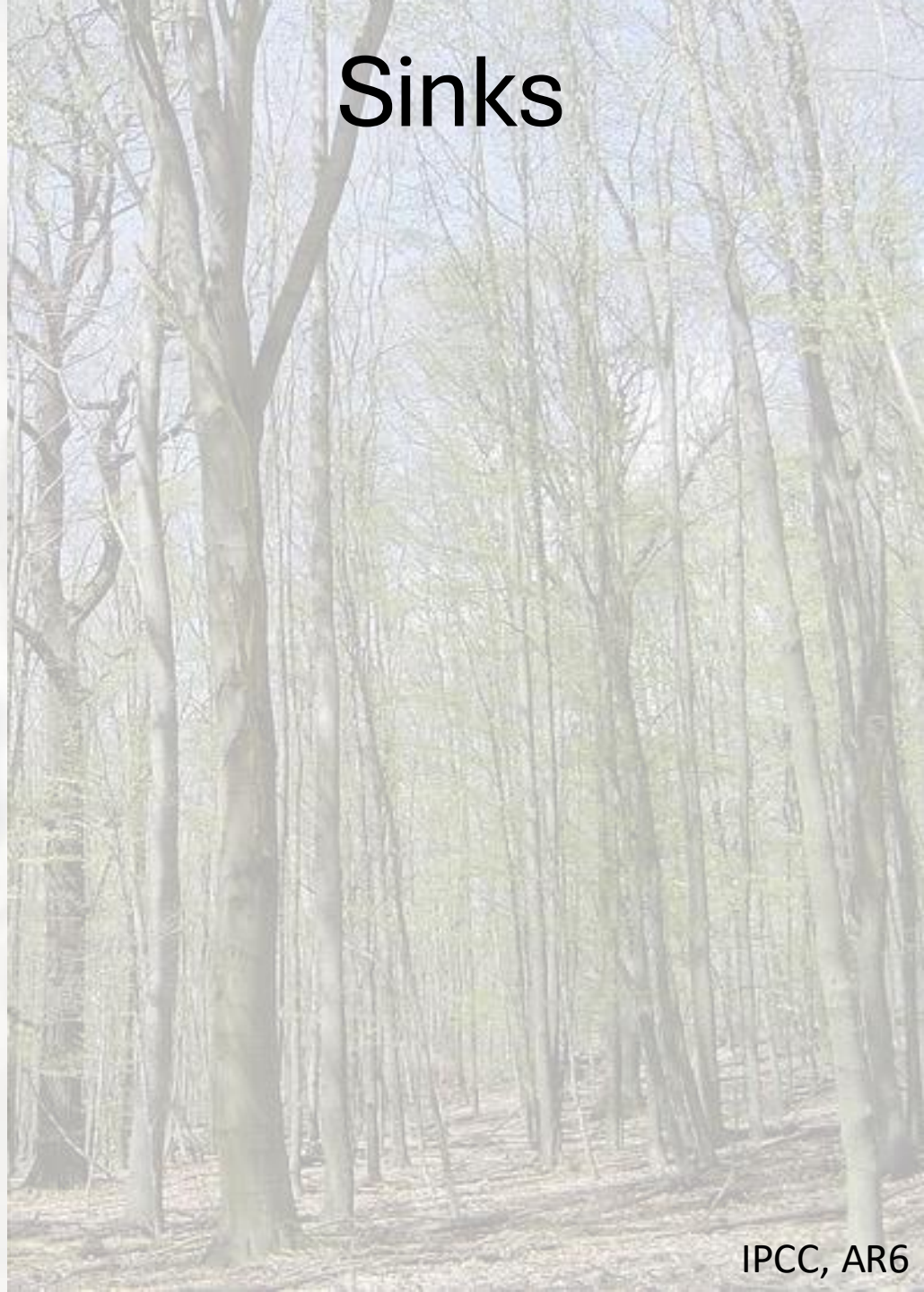
Atmospheric Methane

- Second most important anthropogenic GHG
- ~30X more global warming potential compared to CO₂
- Increase from ~700ppb during preindustrial times to ~1900ppb in 2019

Sources



Sinks



Sources

Anthropogenic



Sinks

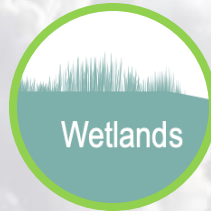


Sources

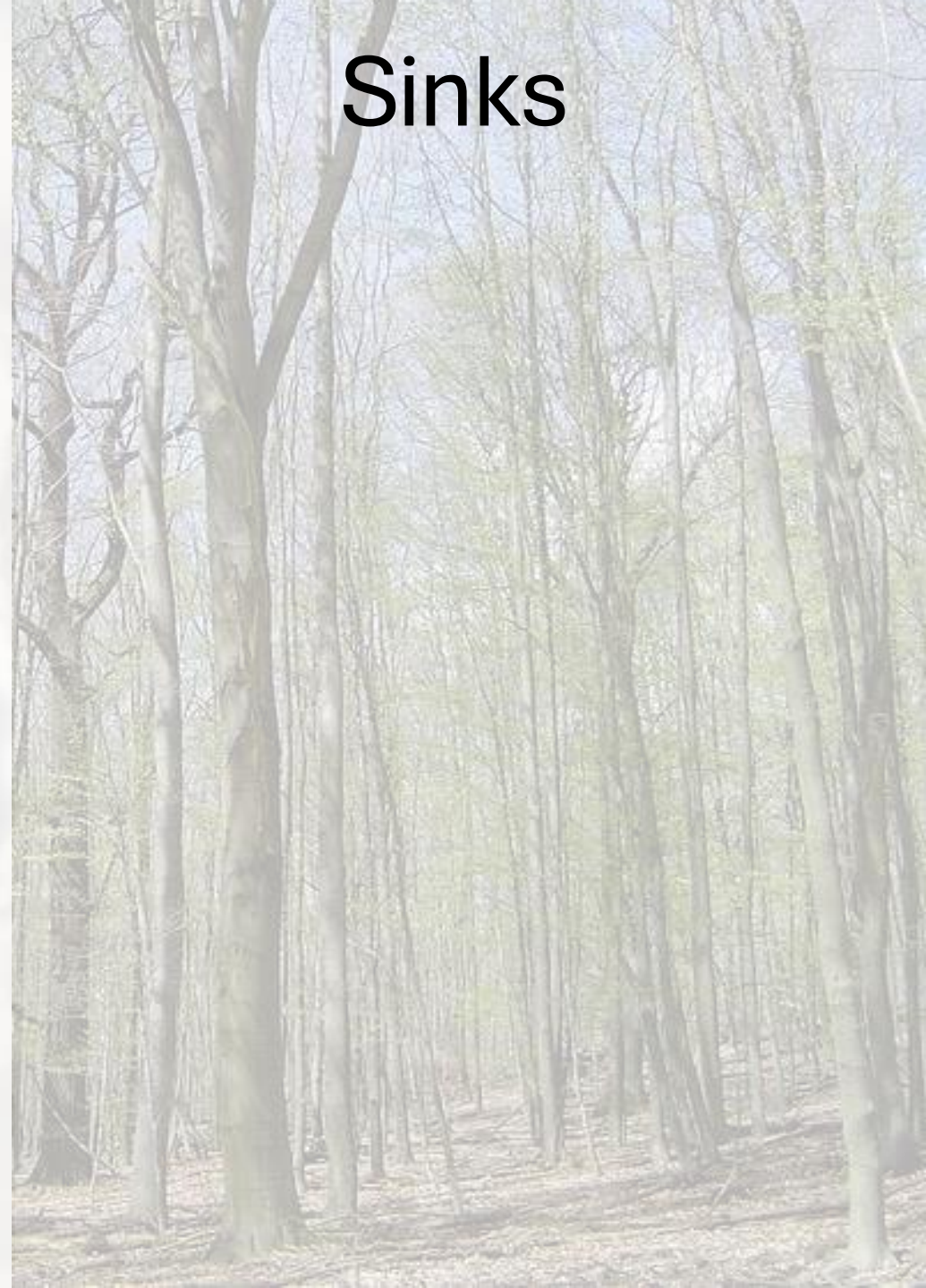
Anthropogenic



Natural



Sinks

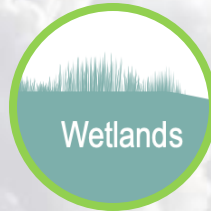


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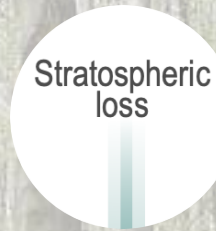
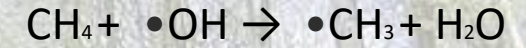
Anthropogenic



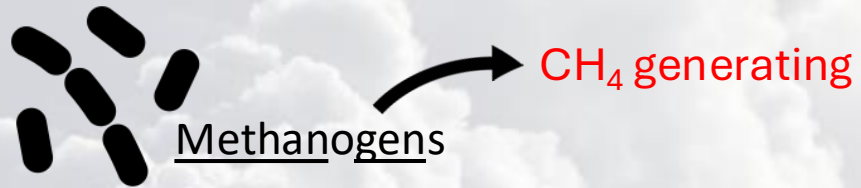
Natural



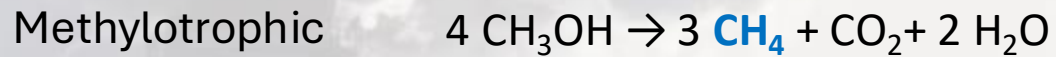
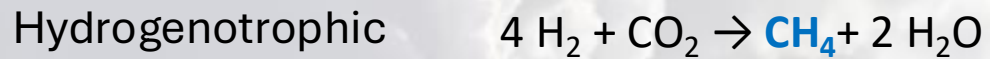
Sinks



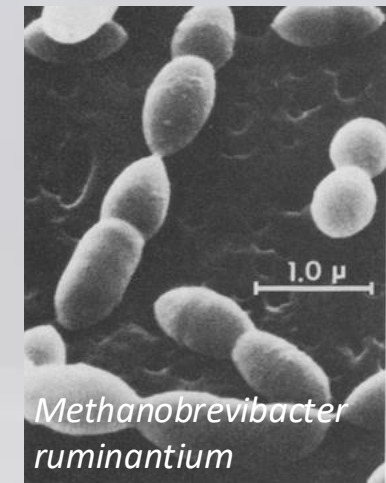
Sources



Anaerobic environments

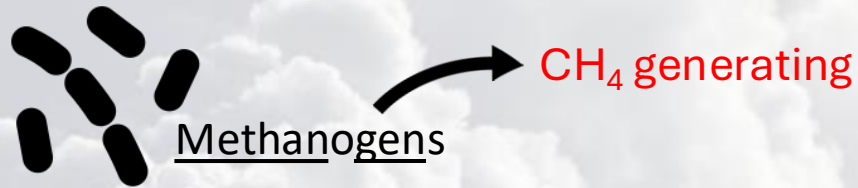


Sinks

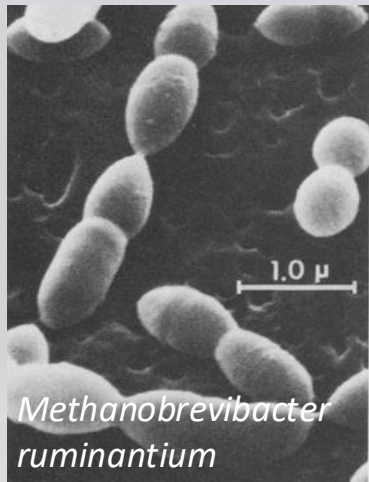
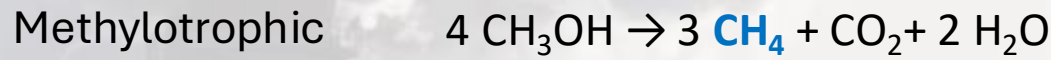
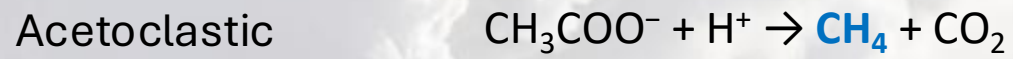
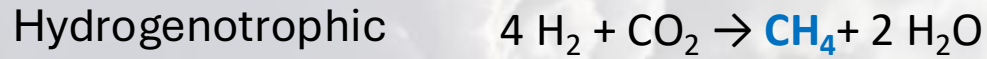


Methanobrevibacter ruminantium

Sources



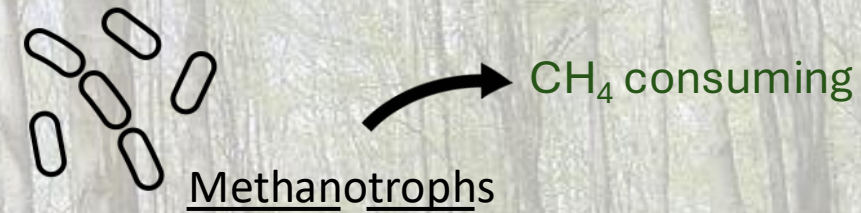
Anaerobic environments



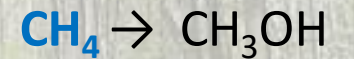
Methanobrevibacter ruminantium

Miller et al. 1986

Sinks



Aerobic environments



Methane oxidation & assimilation as a carbon source



Methylomonas sp.

Hur et al. 2016

Permafrost thaw positive feedback

Permafrost thaw



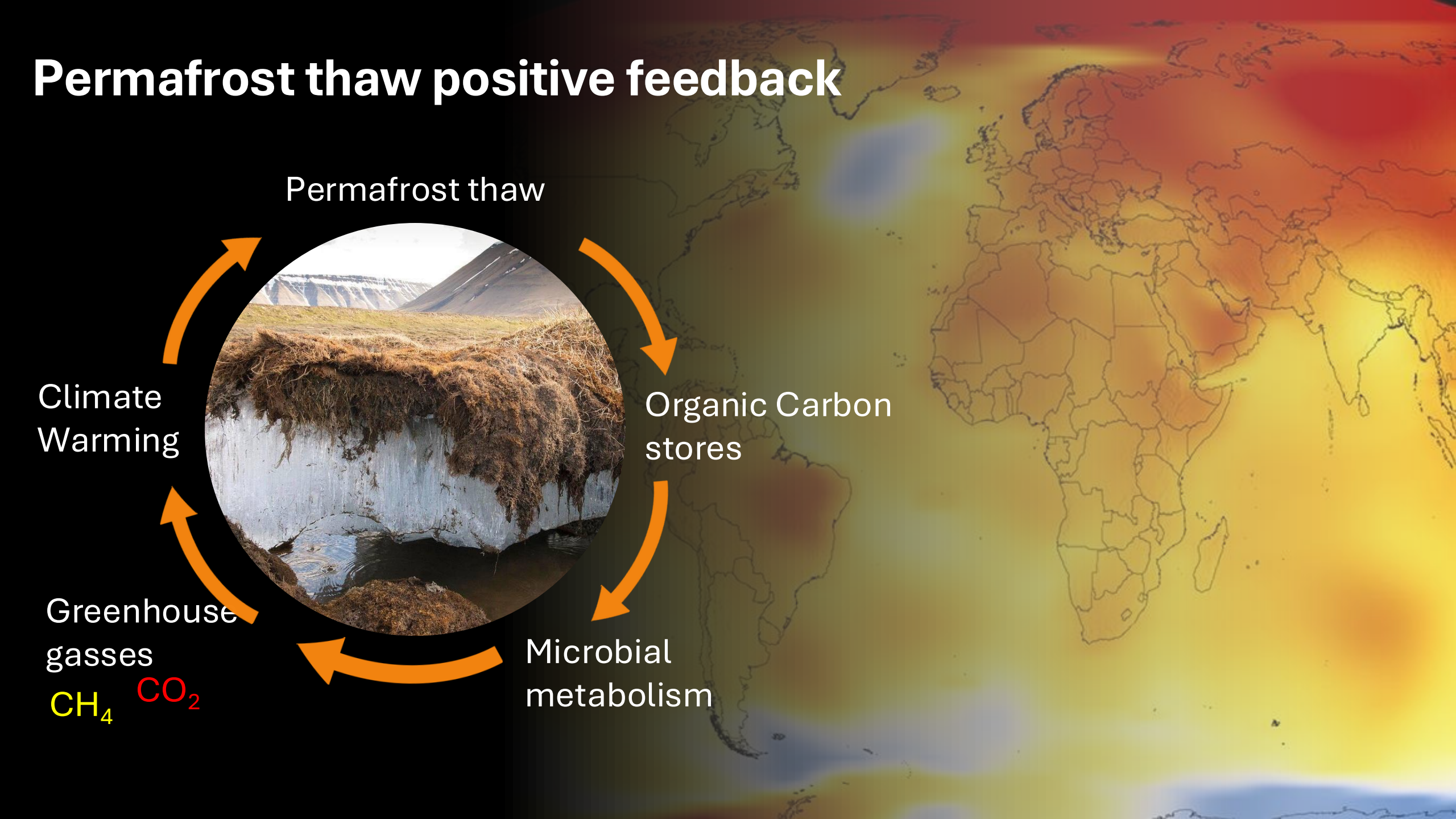
Climate Warming

Organic Carbon stores

Greenhouse gasses

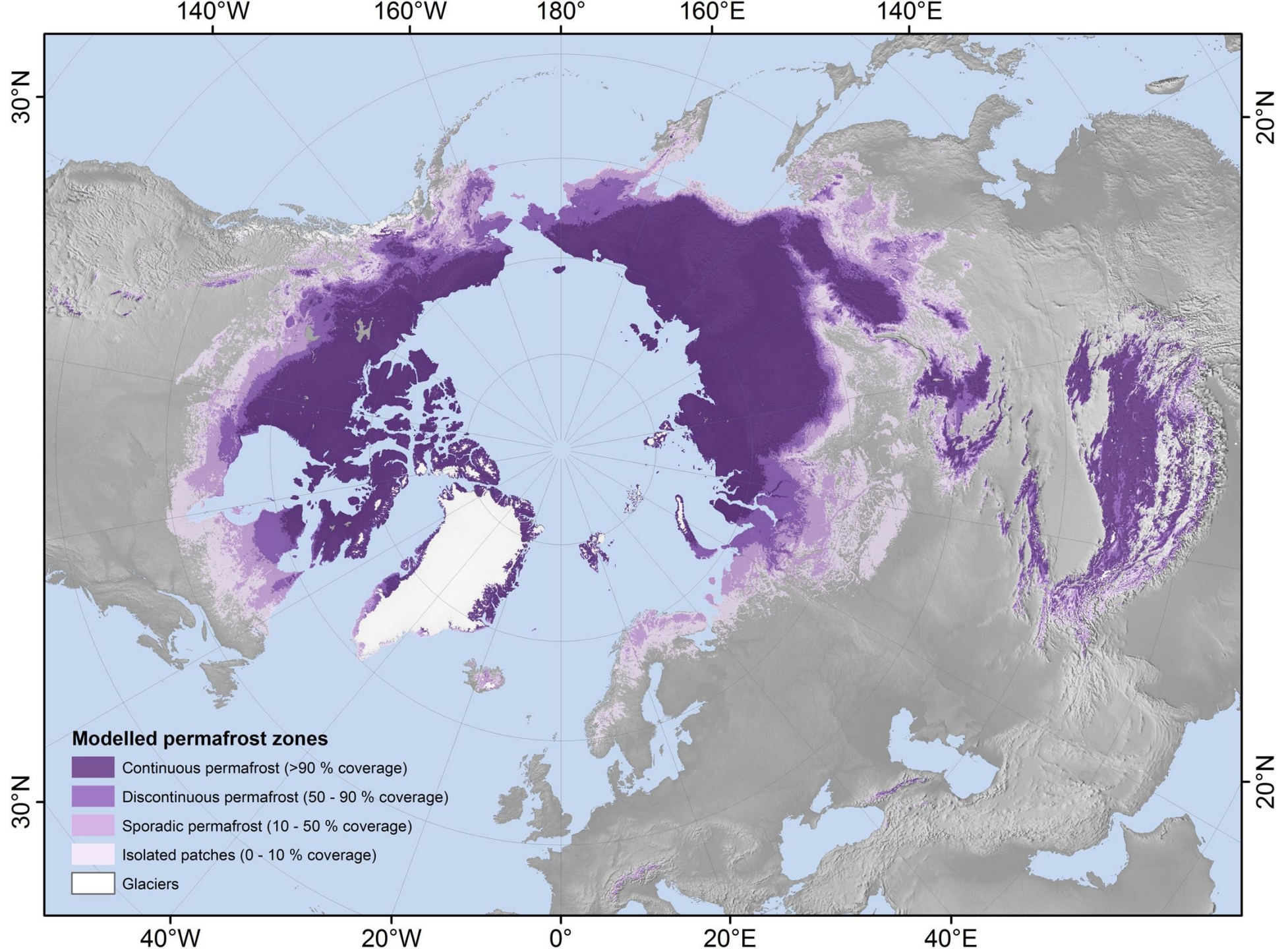
Microbial metabolism

CH_4 CO_2

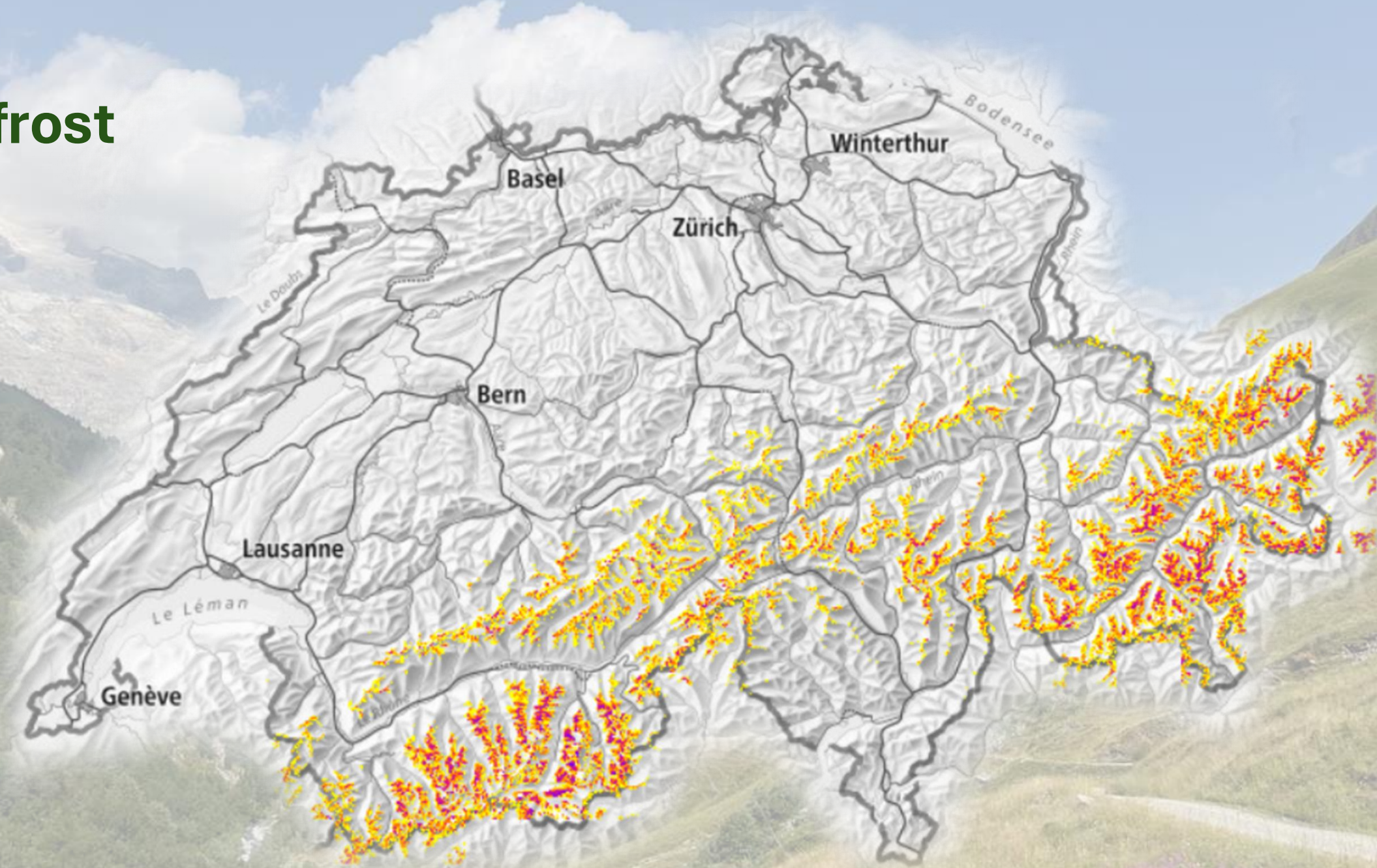




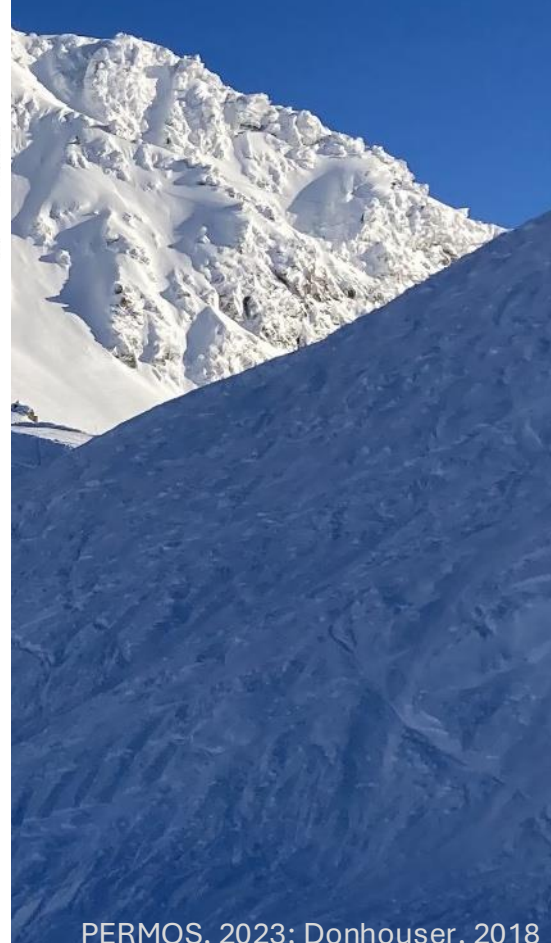
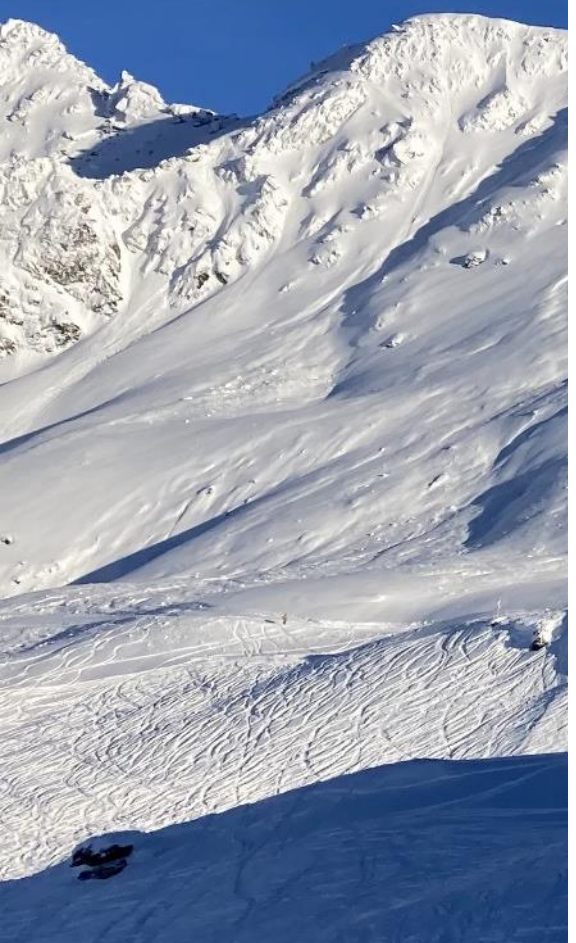
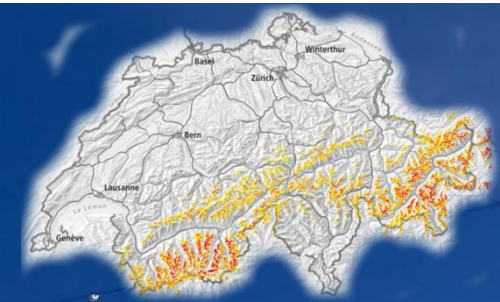
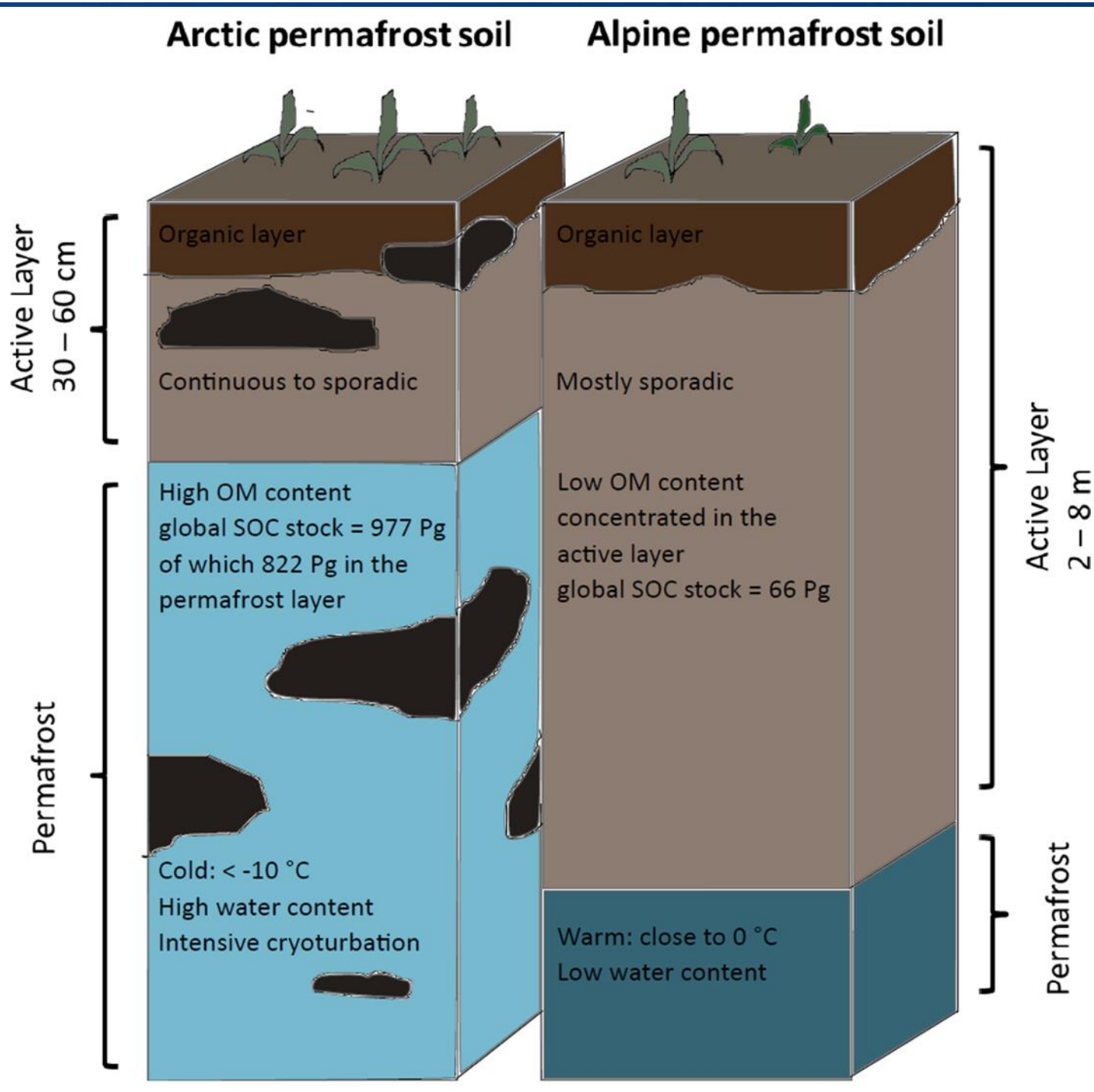




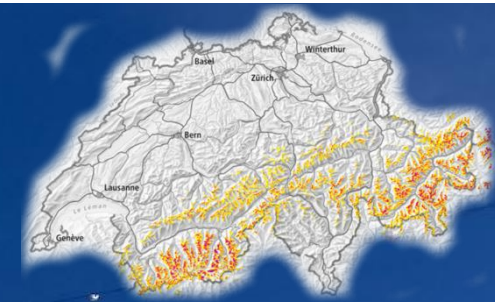
Alpine Permafrost



Alpine Permafrost



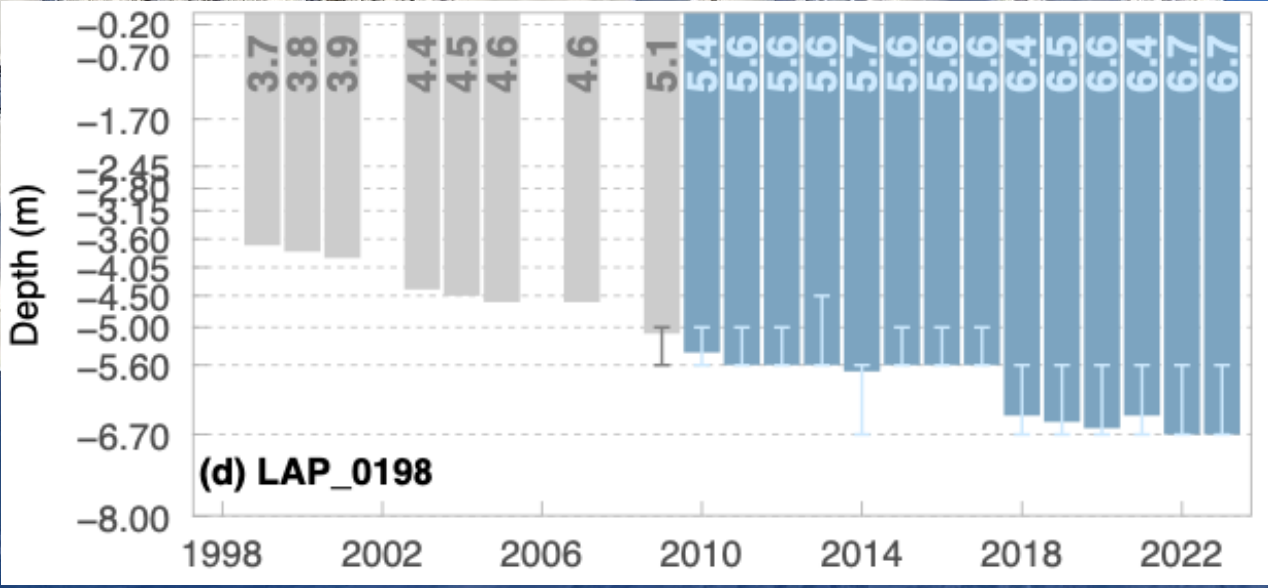
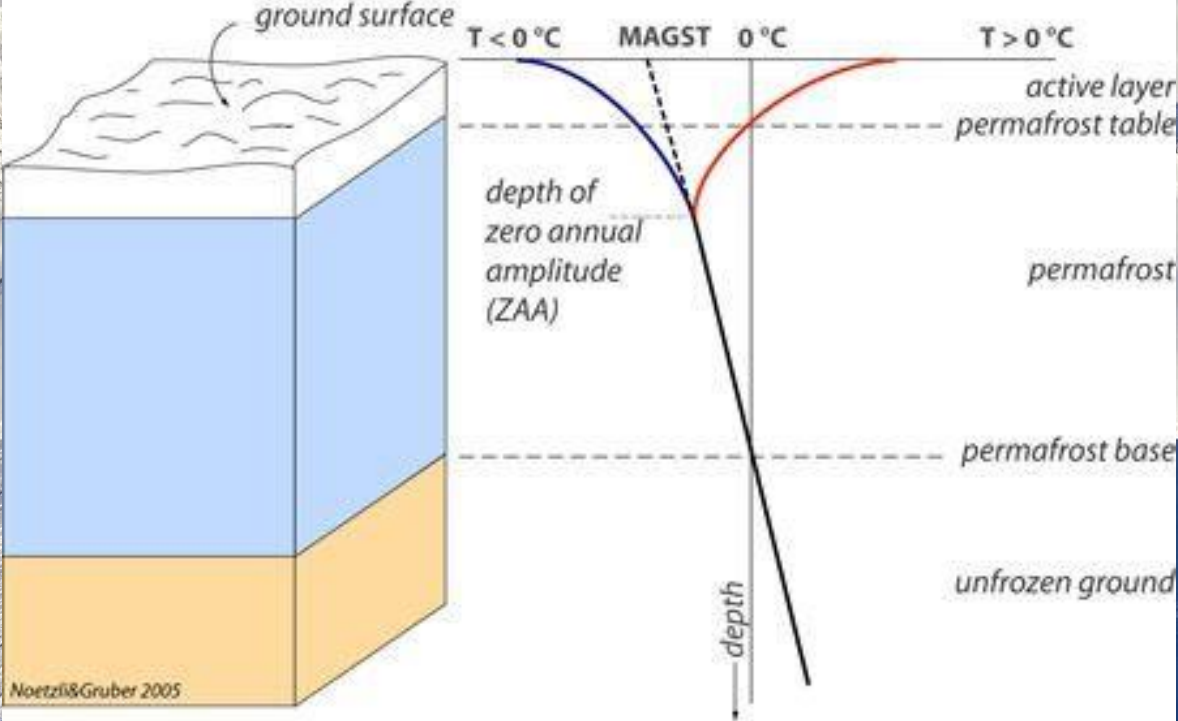
Alpine Permafrost



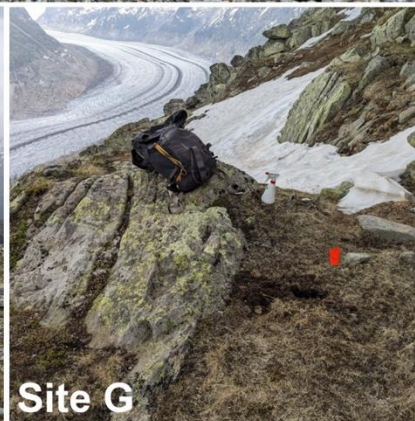
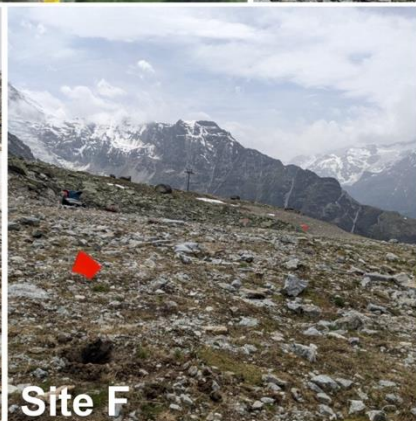
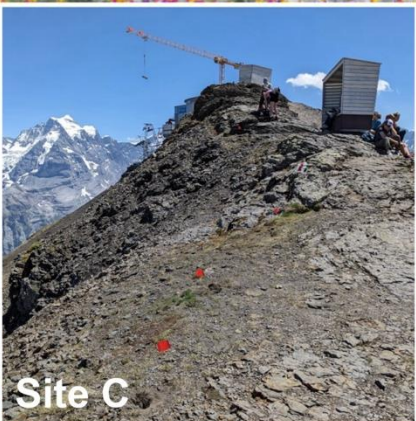
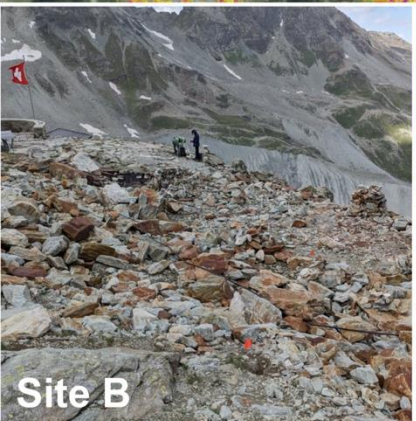
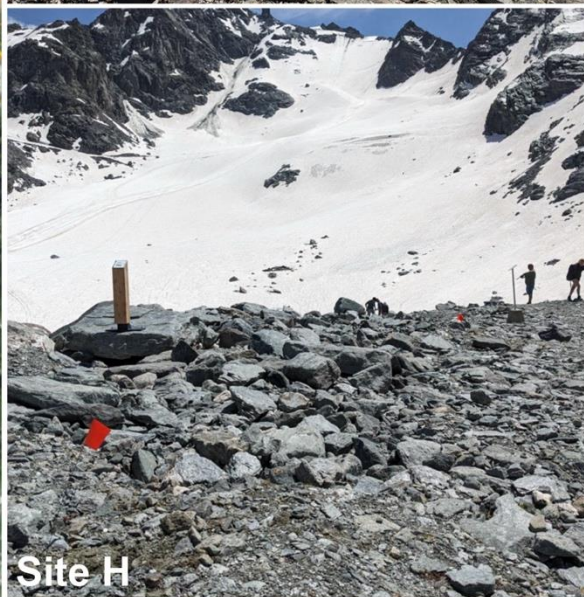
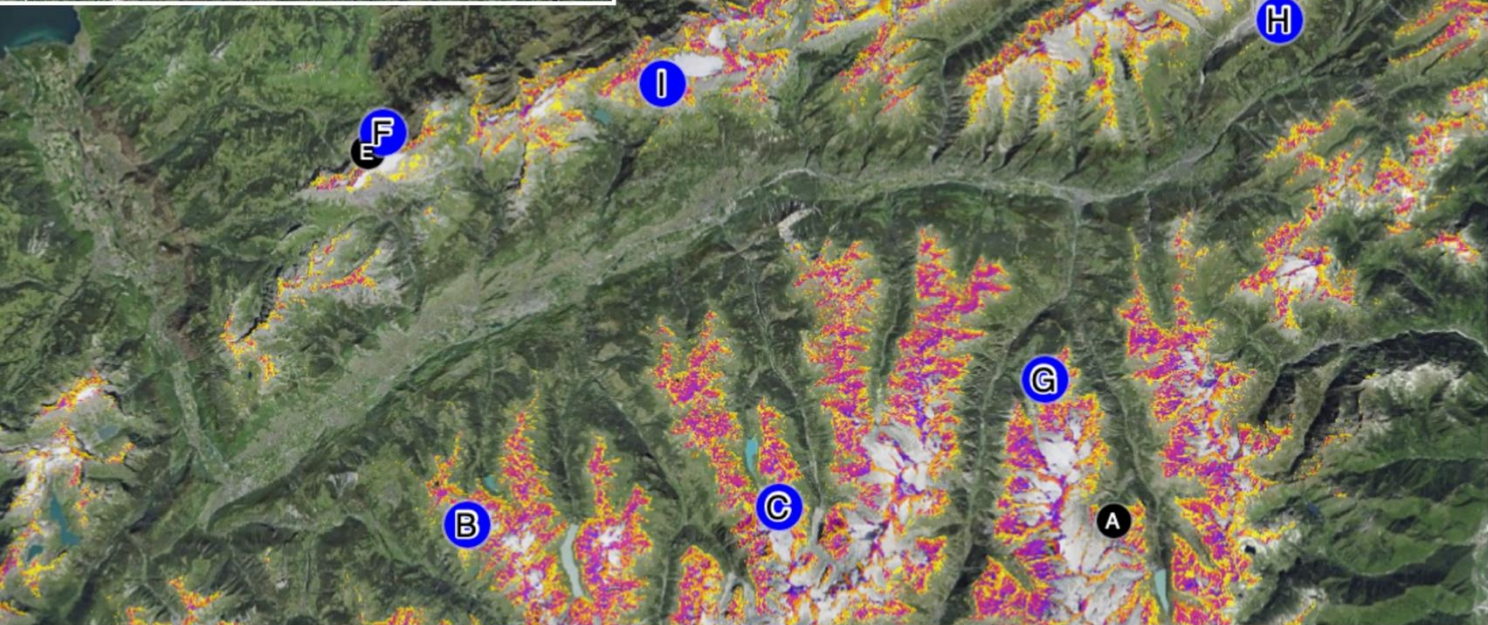
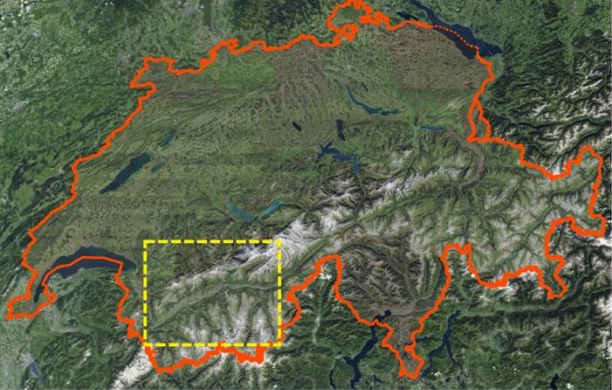
Mont Gelé



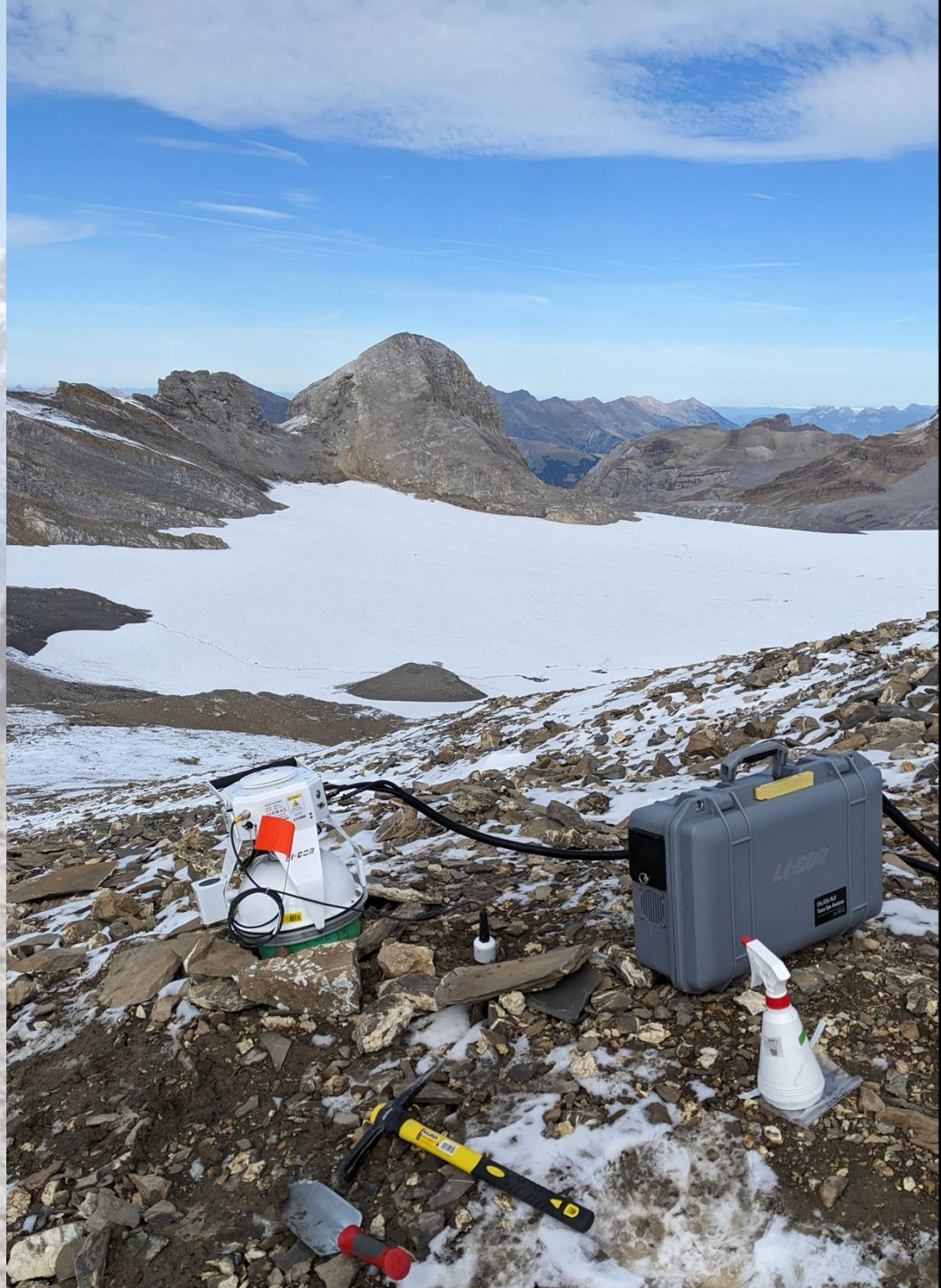
Alpine Permafrost

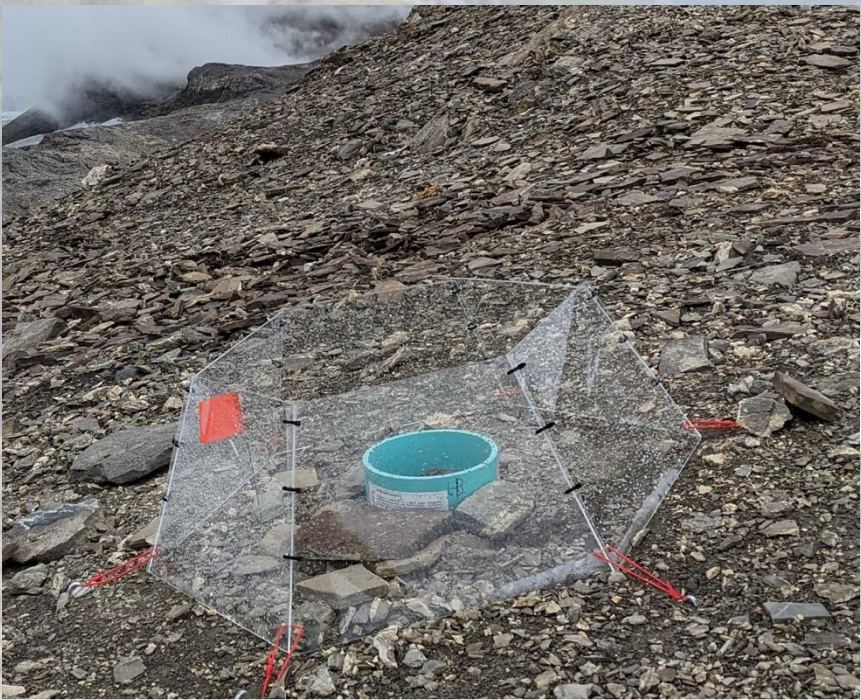






Plaine Morte





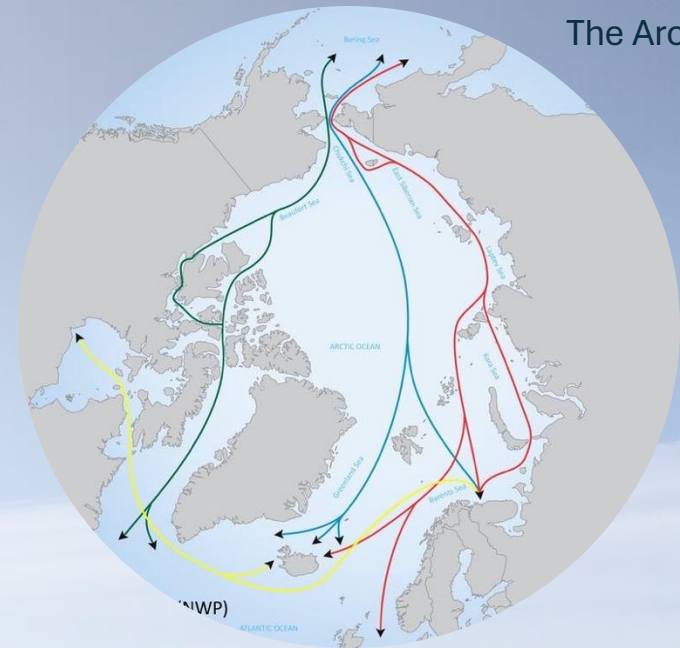


Sea Ice Loss

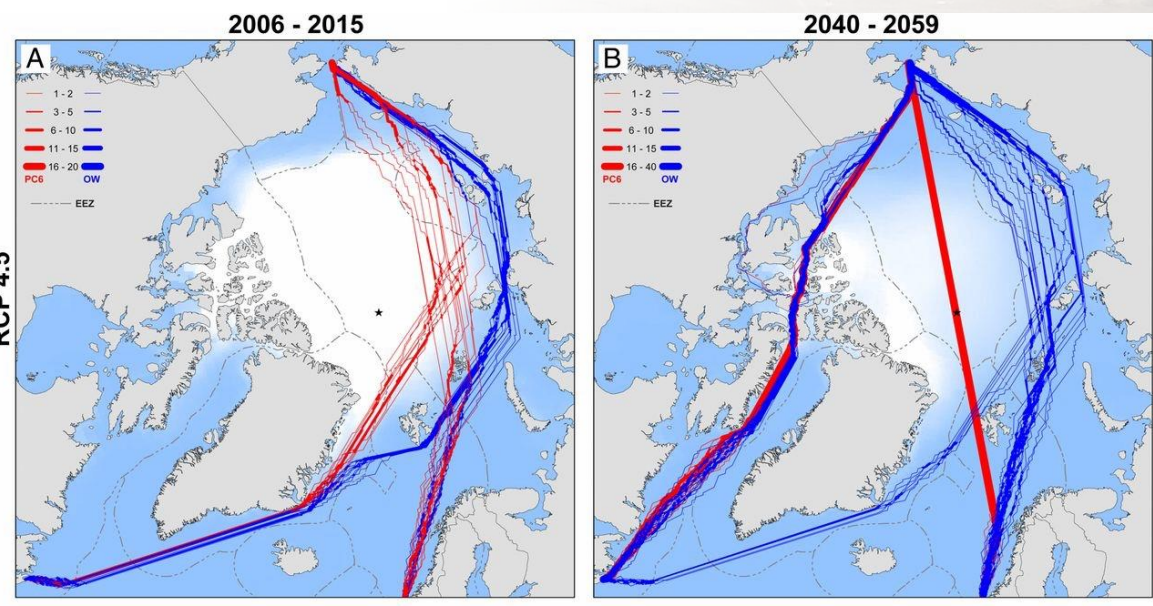


Sea Ice Loss

- Increased shipping activity in the Arctic ocean
- oil prospecting
- commercial and private boat traffic



Increased risk of oil spills and fuel contamination



Smith et al. 2013



Exxon Valdez oil spill - 1989

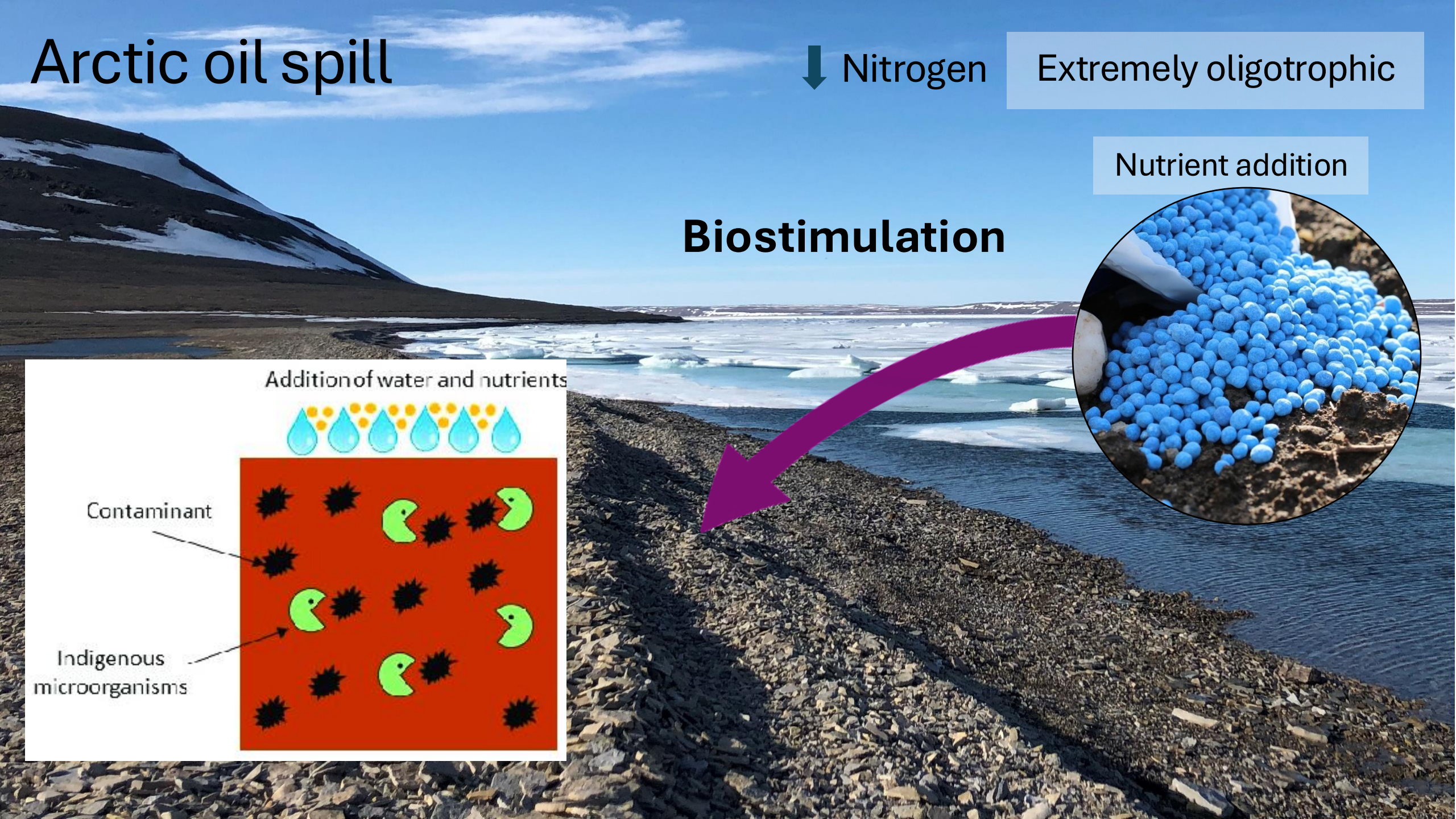
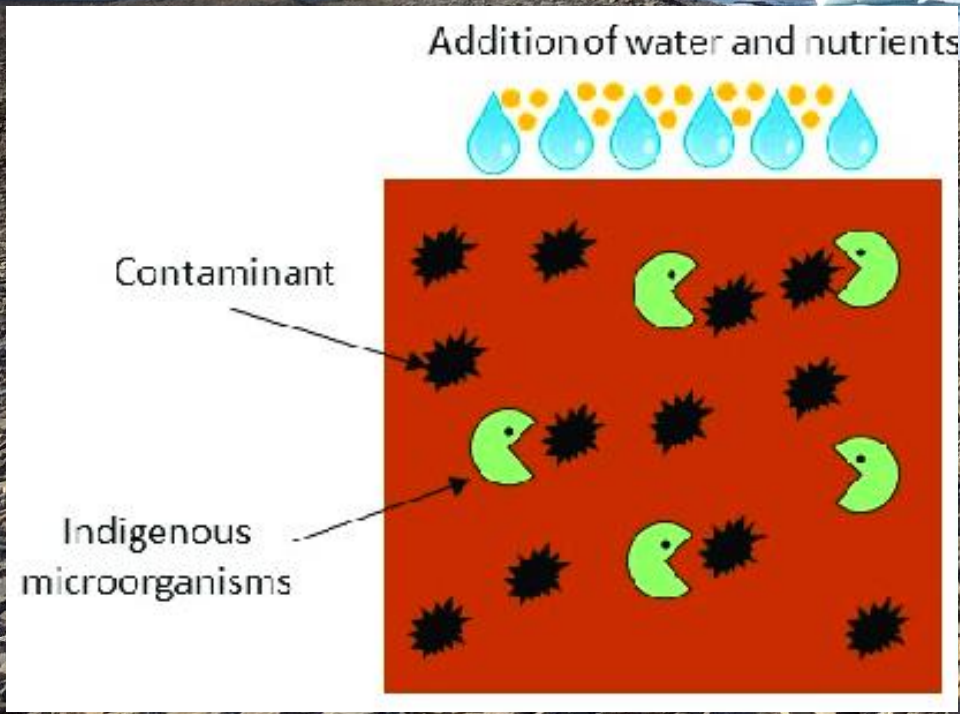
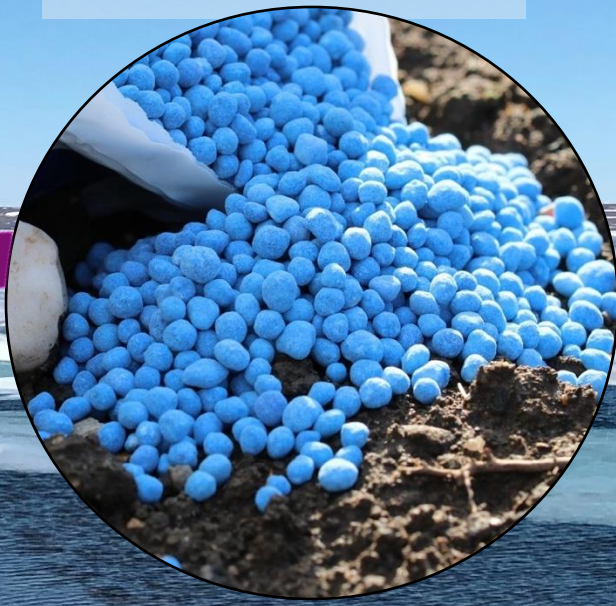
Arctic oil spill

↓ Nitrogen

Extremely oligotrophic

Nutrient addition

Biostimulation



Arctic fuel spill



Arctic fuel spill

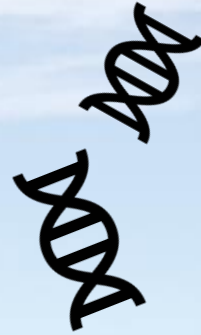


No Oil

Oil

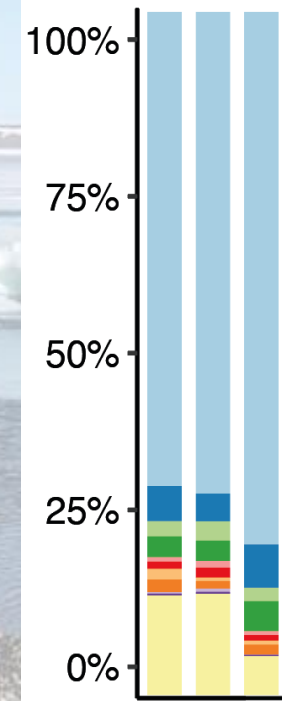
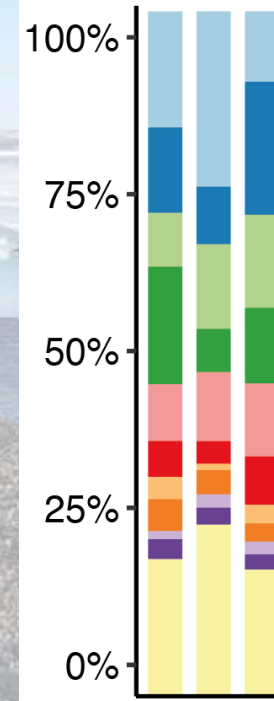
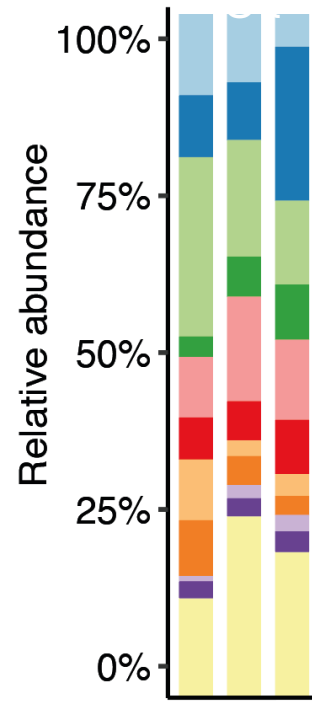
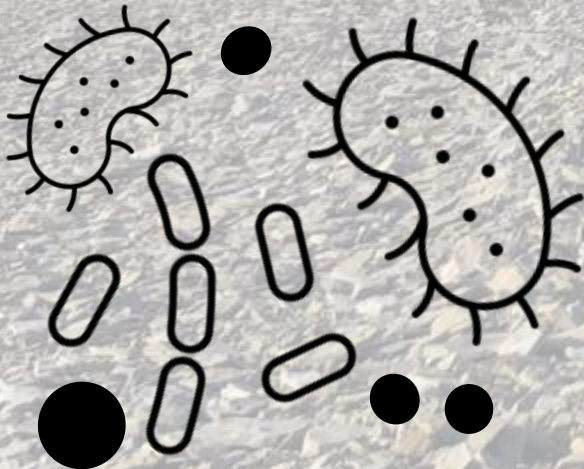
Oil+ Fertilizer

Arctic fuel spill



Large scale population changes and loss of biodiversity

Increase in species with hydrocarbon degradation ability

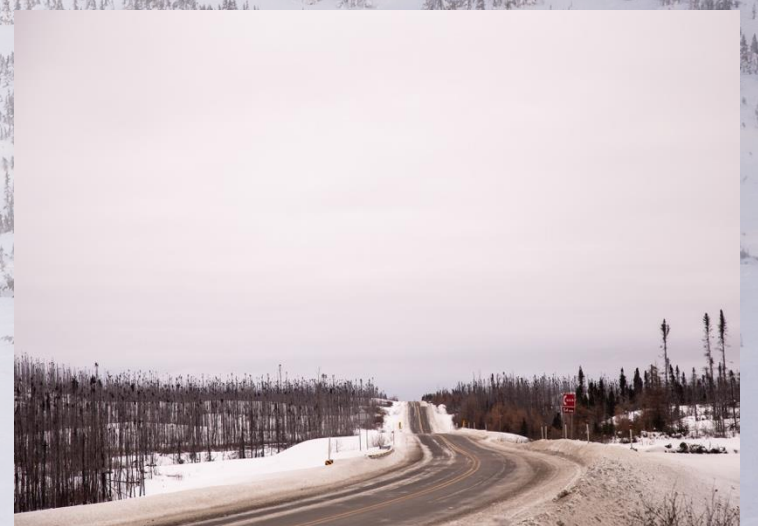
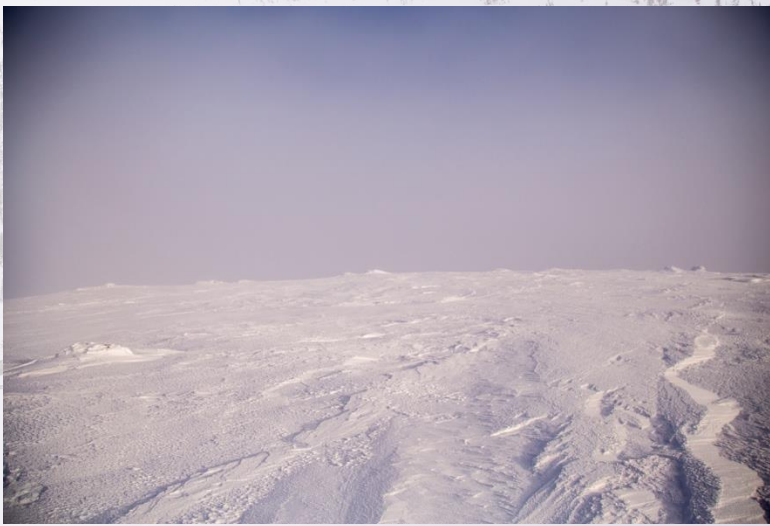


Oil degradation

Snow Landscapes

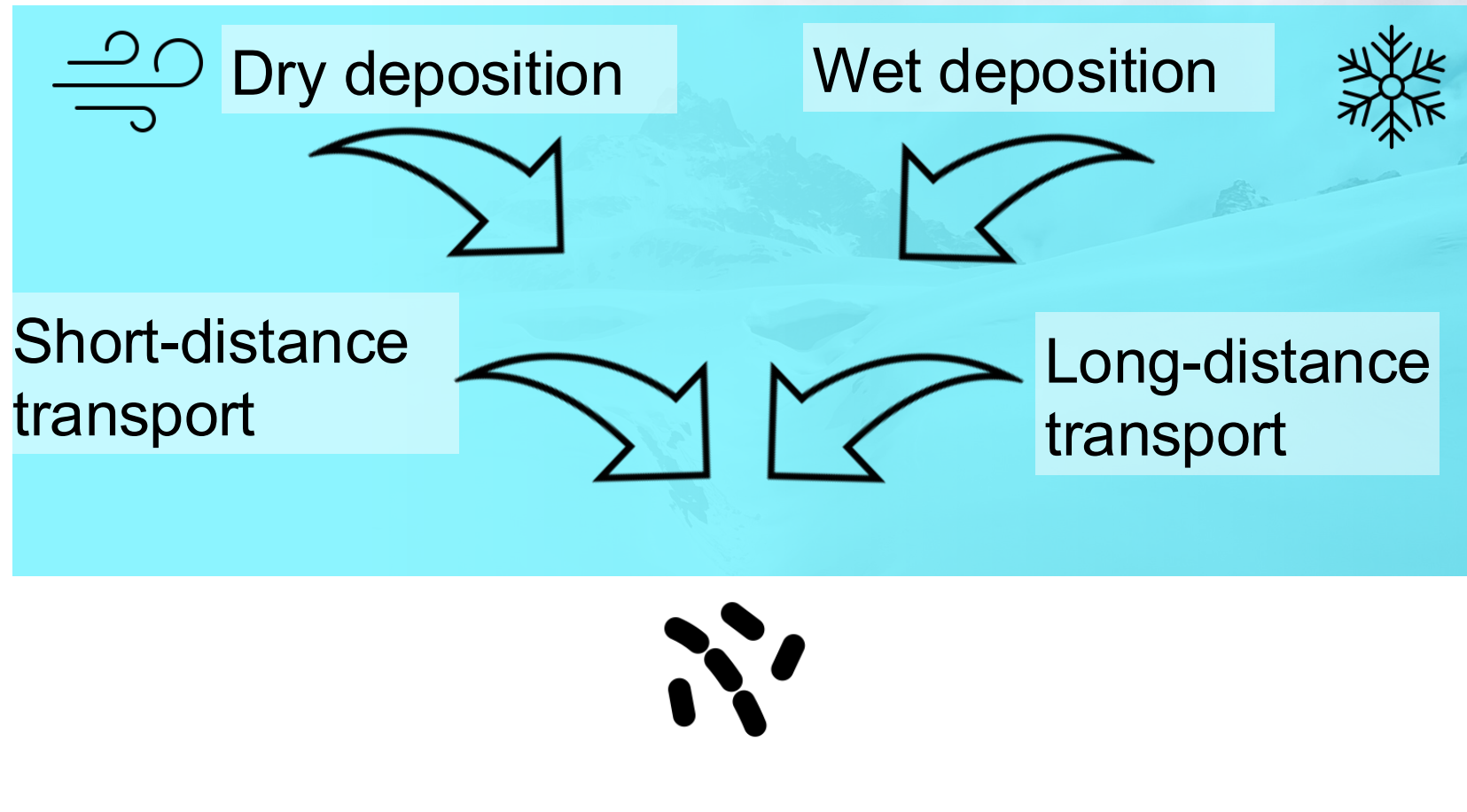


Snow is a Microbial Habitat

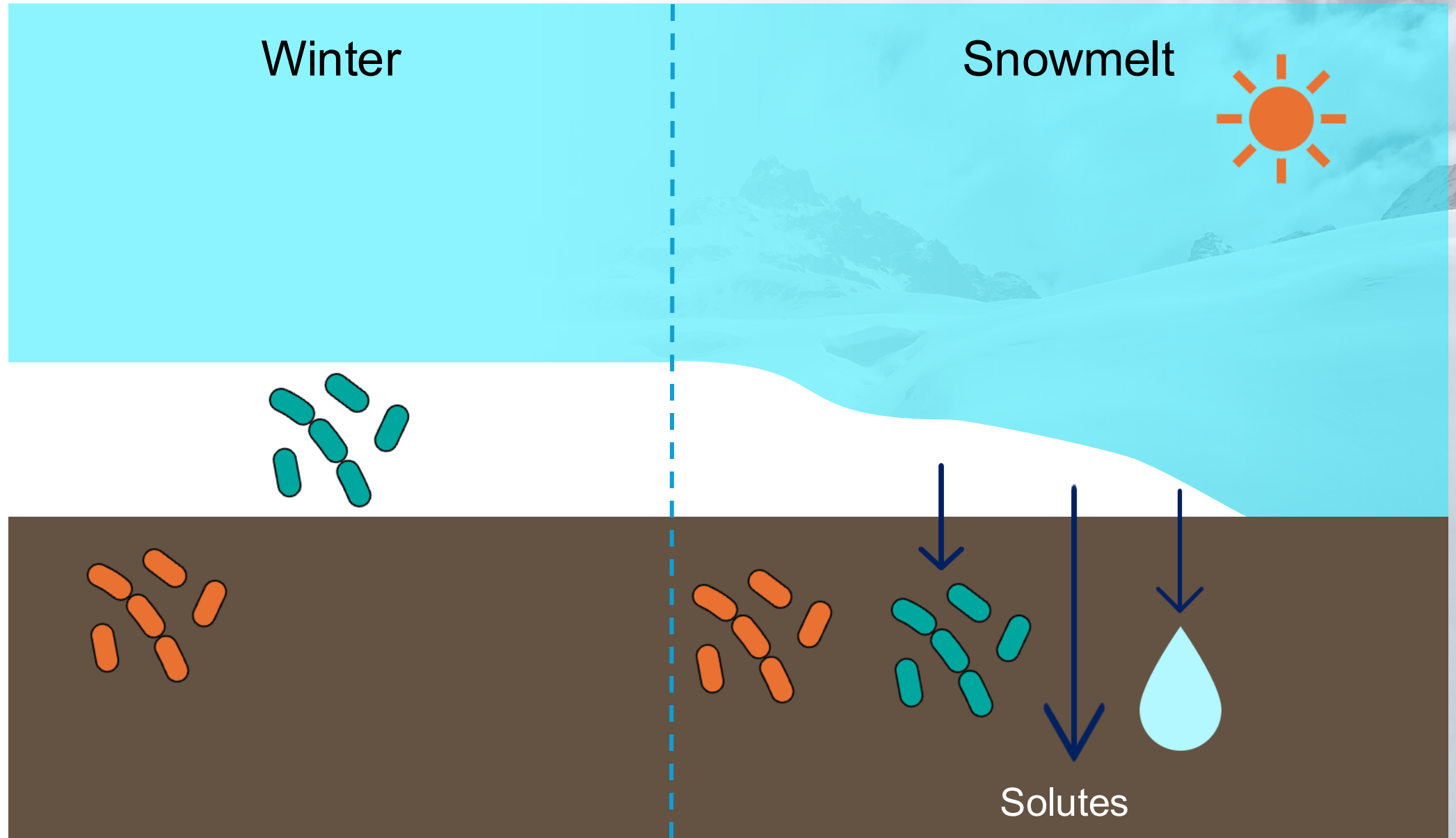


© david.touch

Snow inhabiting organisms

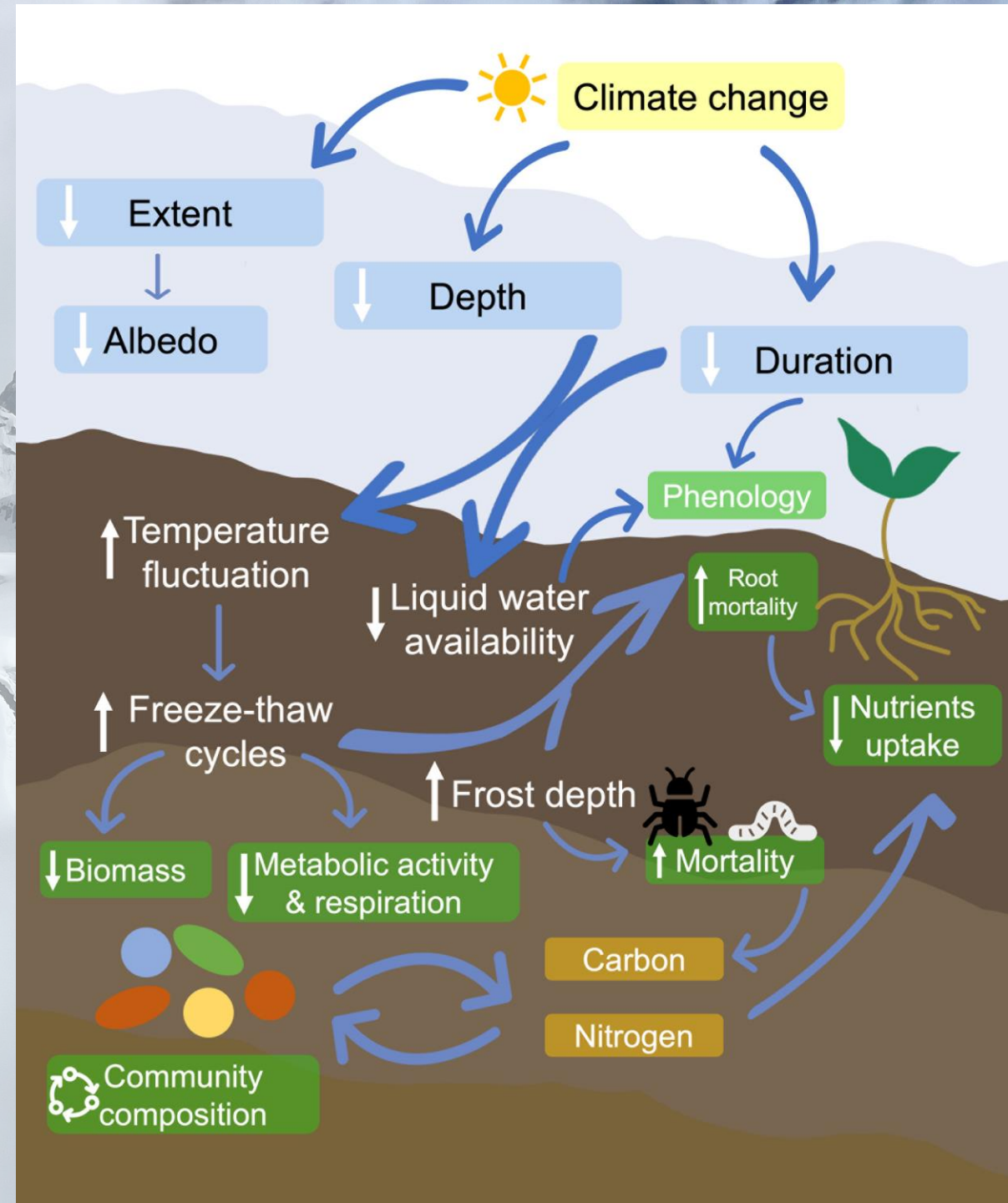


Soil and snow interplay



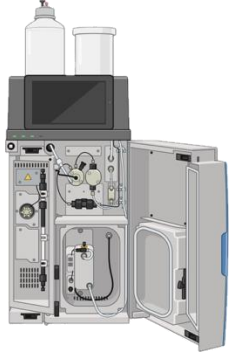
Reduction of Snow Cover and Depth in Alpine Ecosystems

- Reduced albedo
- Loss of snow insulation
- Loss of native local biodiversity
- Reduced soil microbial buffering capacity





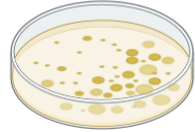




IC*
measurements

Chemical
composition

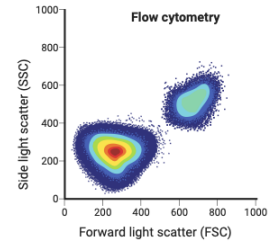
What is the chemistry?



CFU
enumeration

Culturable
microorganisms

How many microorganisms are
there?



Flow
cytometry

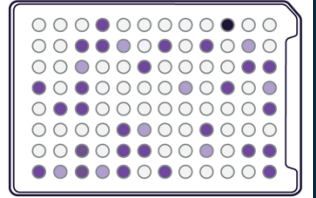
Bacterial
abundance



Sequencing

Community
structure and
function

Who are they?

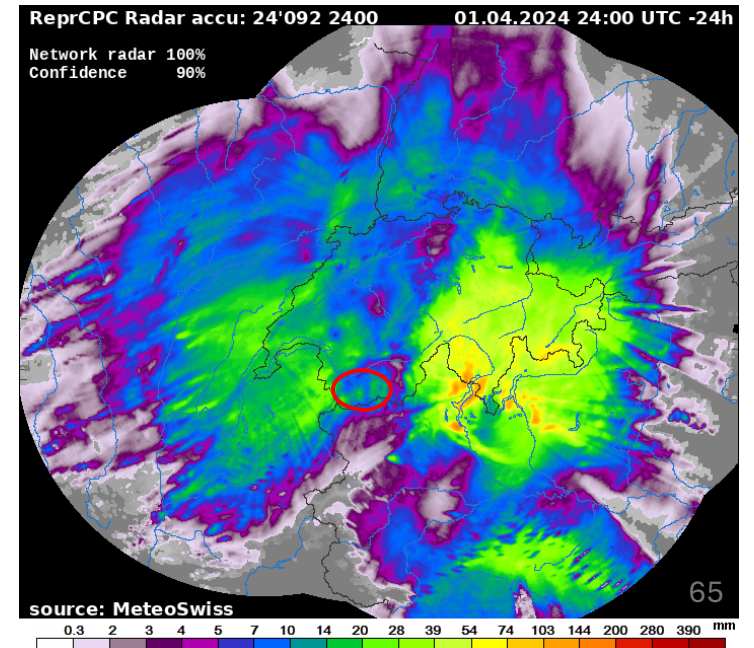
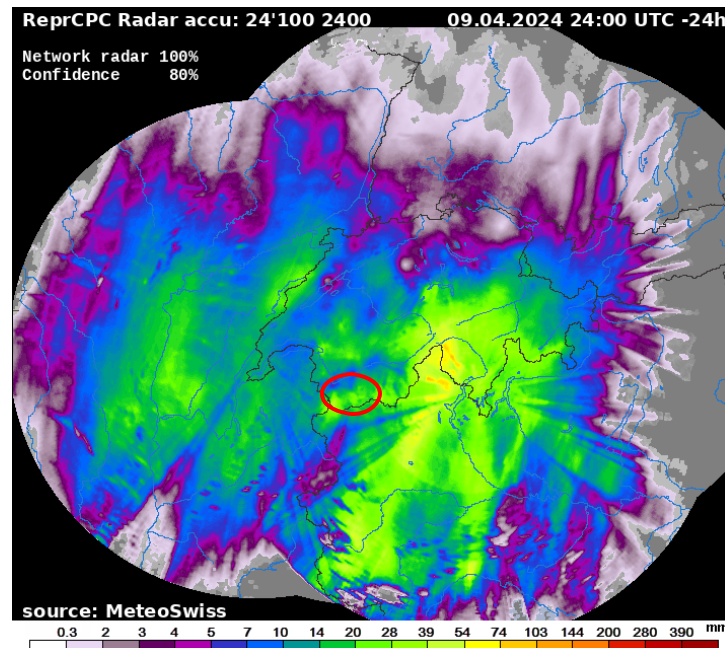
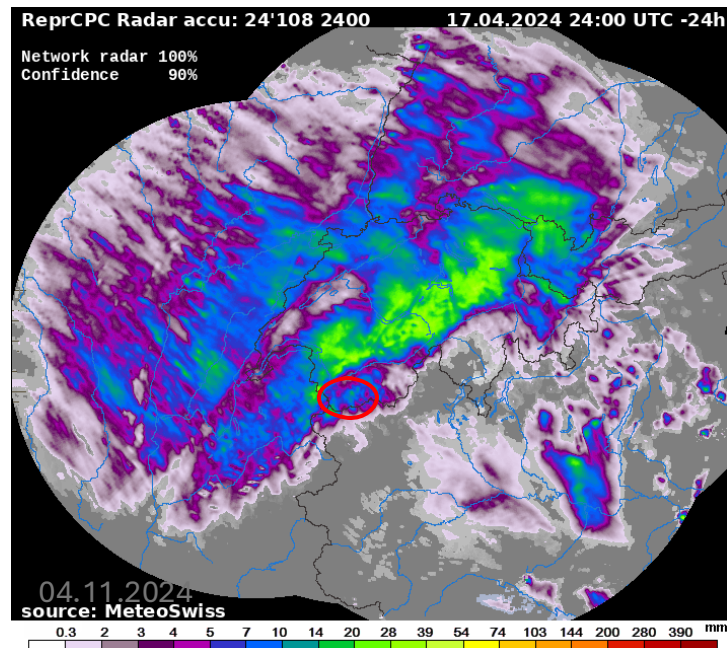
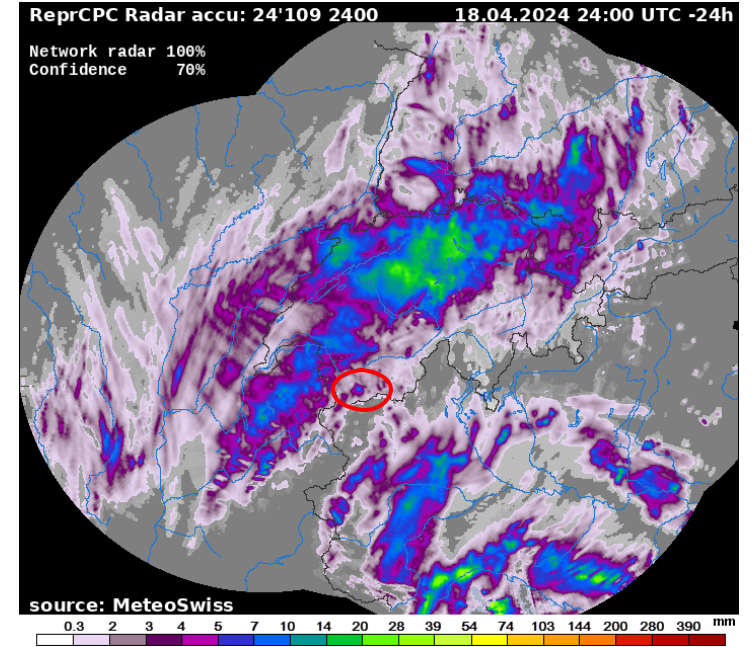
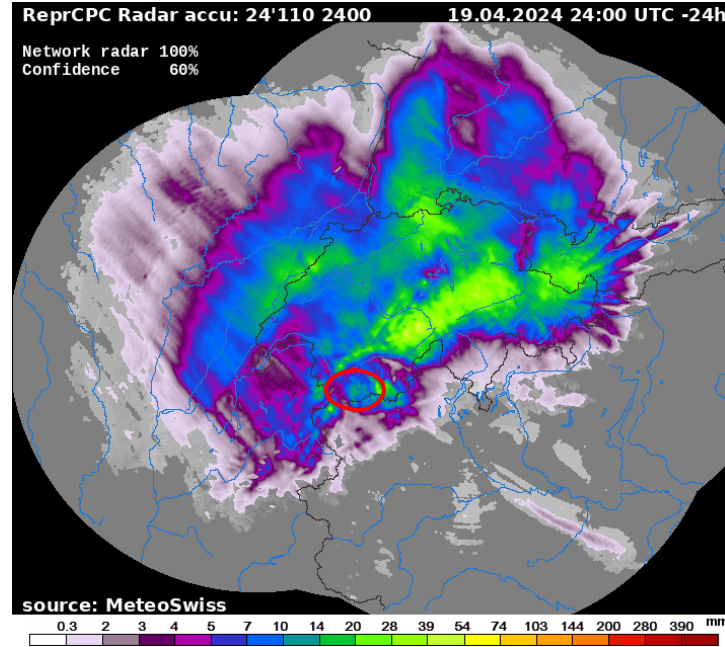
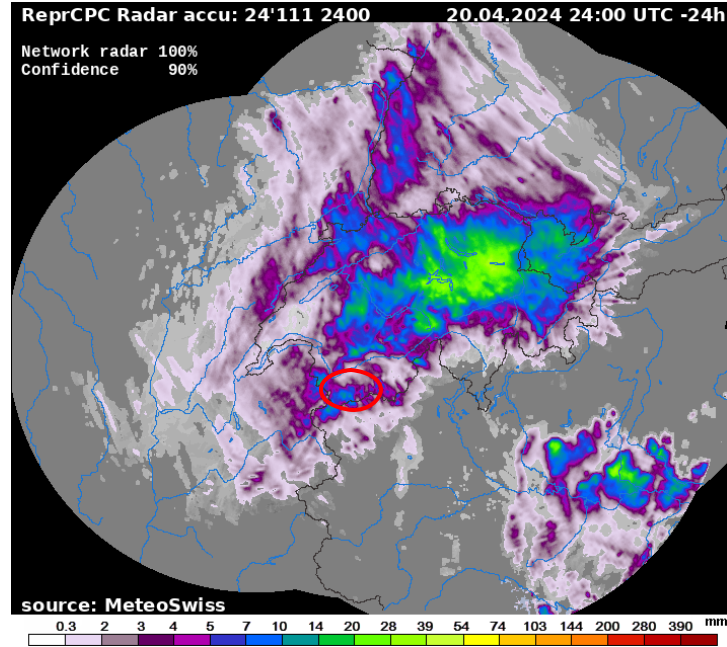


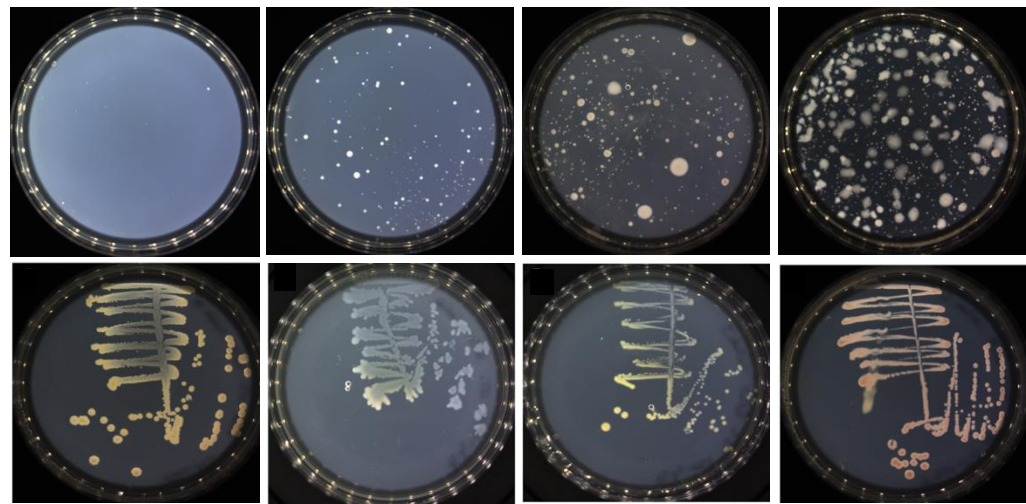
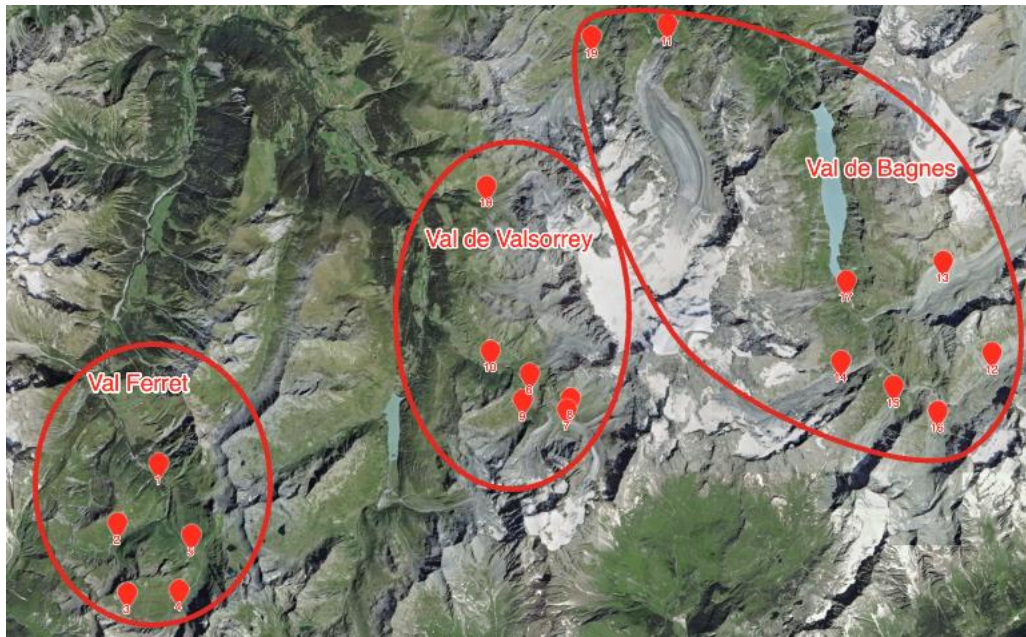
Biolog
Ecoplate

Community
activity

What are they
doing?

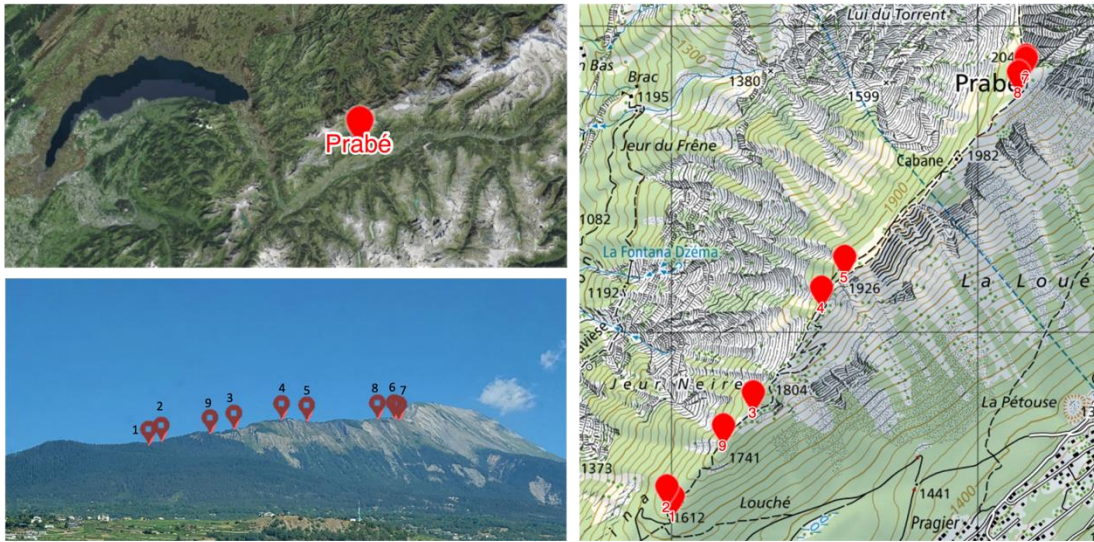
Meteodata: where did the snow come from?





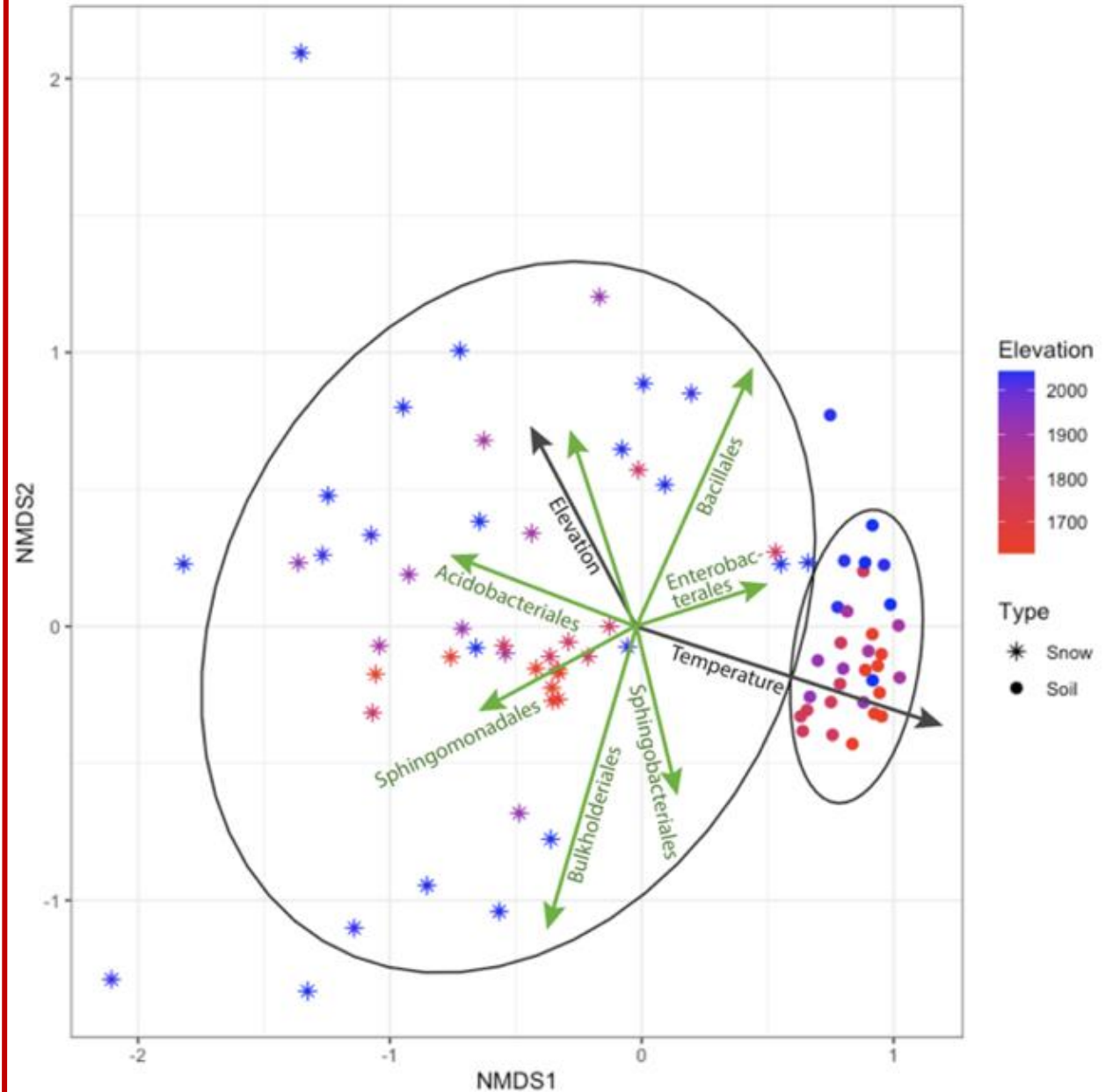
Focus on local snow microbial biodiversity and biogeographic distributions of species in neighbouring valleys

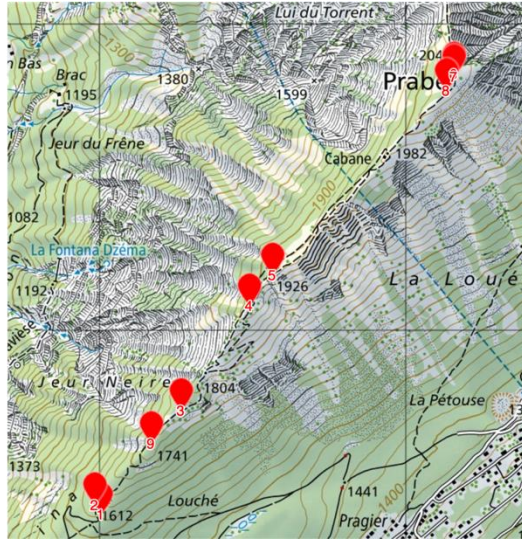




1629 m.a.s.l. Elevation 2036 m.a.s.l.
 Forest Vegetation gradient Grassland

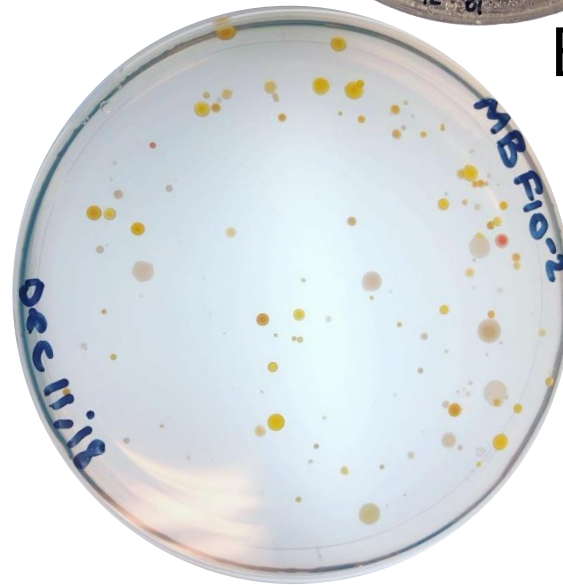
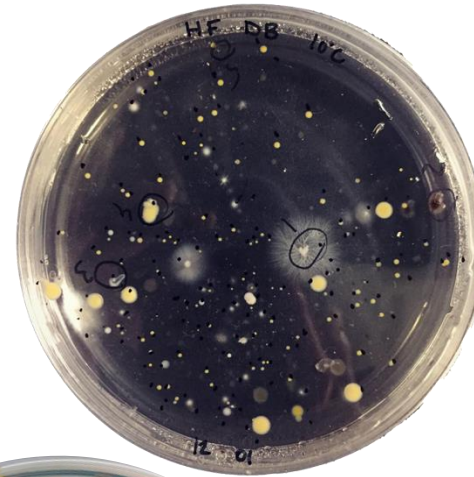
Monitor soil temperature, snow depth, and snow chemistry/microbiology across altitudinal gradients to understand their impacts on soil biodiversity





1629 m.a.s.l. Elevation 2036 m.a.s.l.
 Forest Vegetation gradient Grassland

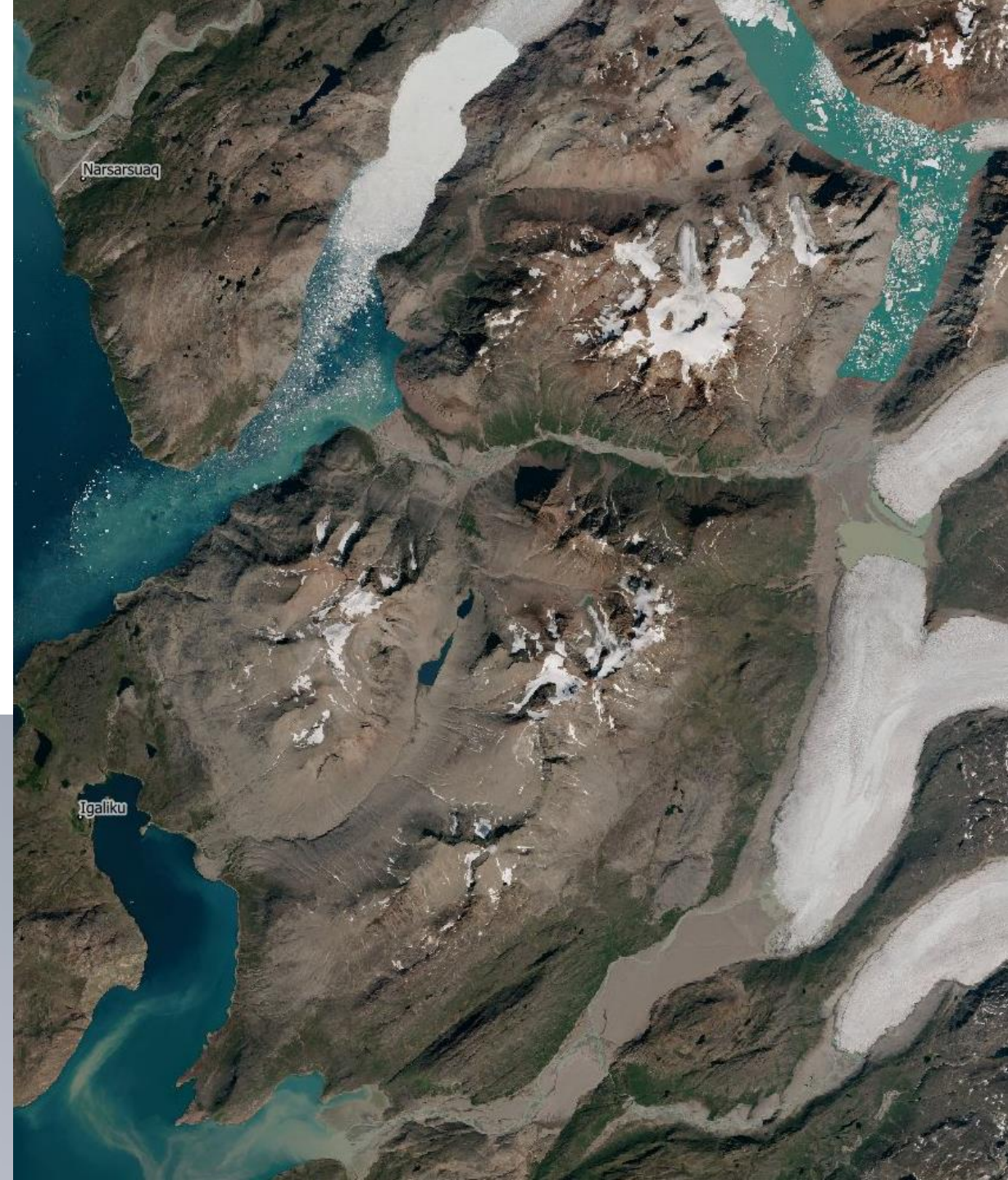
Lichen species

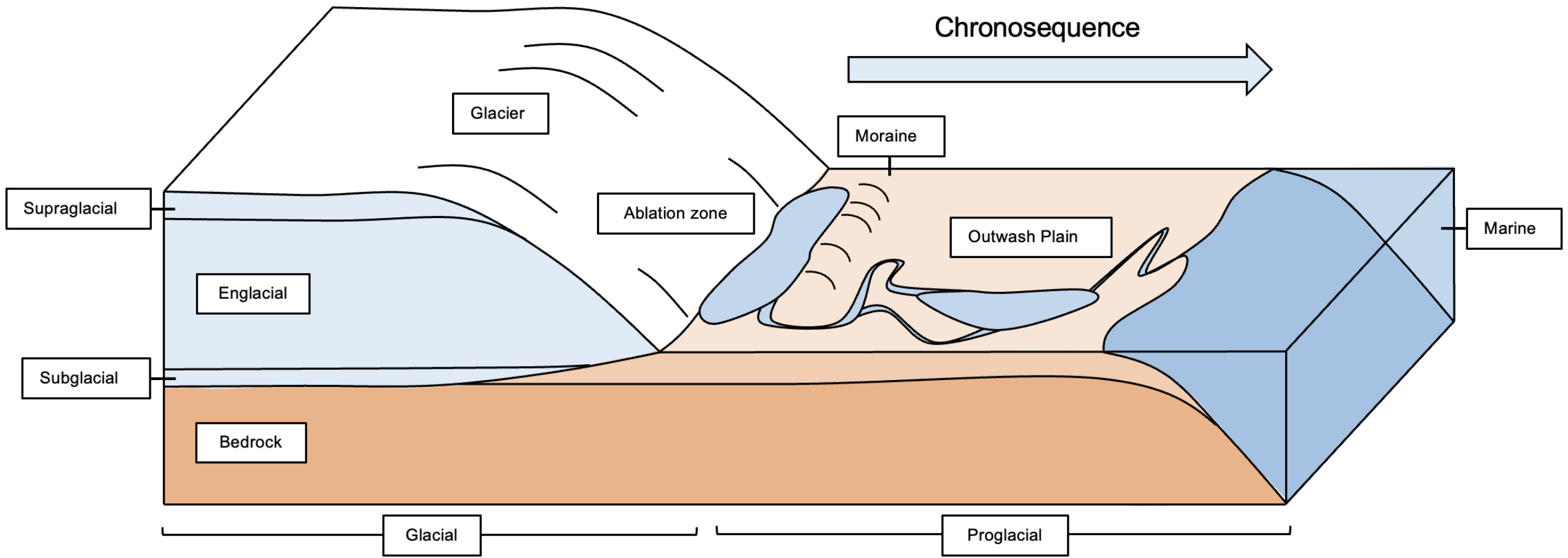
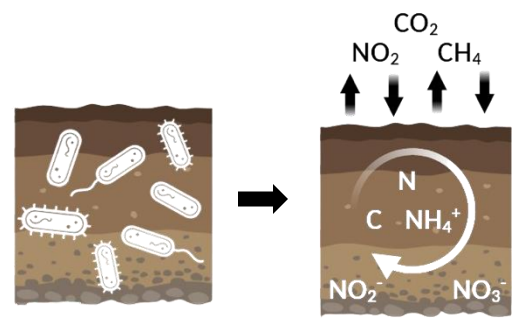


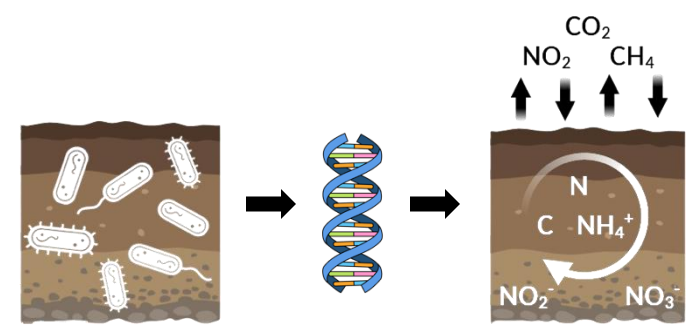
Bacteria
Fungi
Algae

Monitor soil temperature, snow depth, and snow chemistry/microbiology across altitudinal gradients to understand their impacts on soil biodiversity

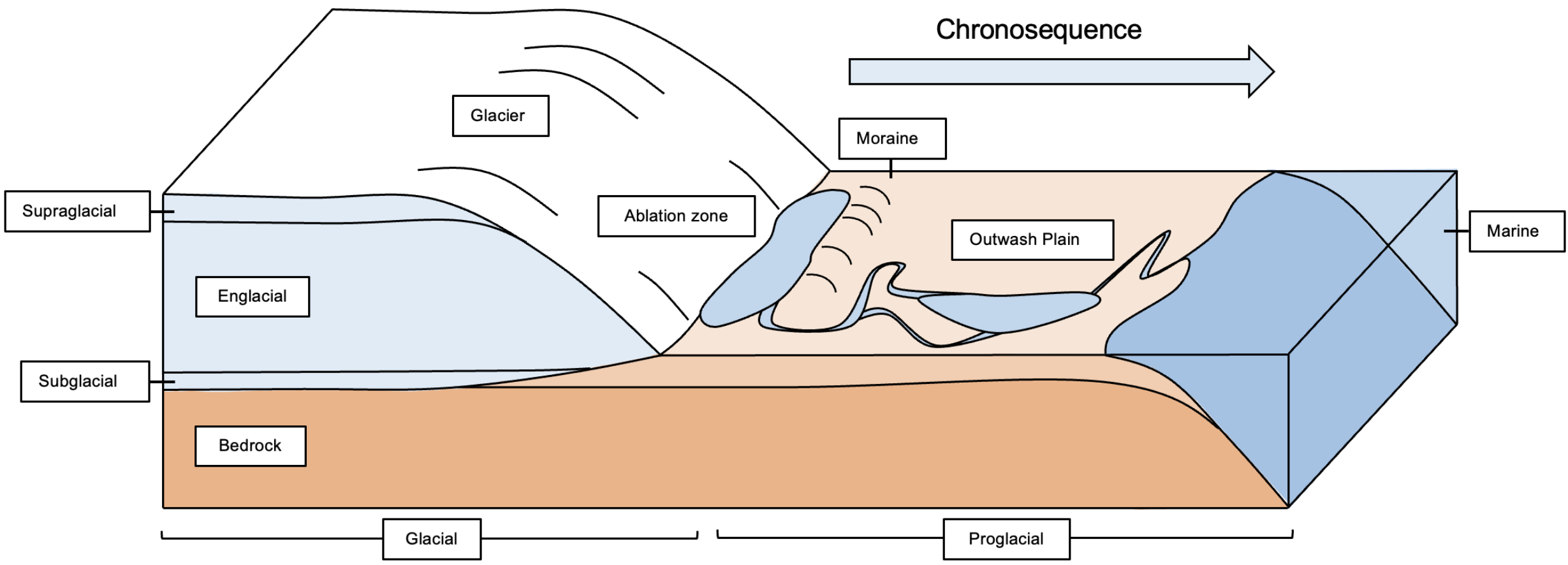
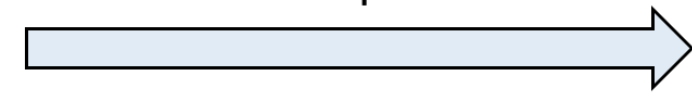
Glacial Outwash Plains







Chronosequence





Narsarsuaq



Narsarsuaq

South Greenland

Soil, sediment, and water

Gas flux measurements

- *In situ* gas analysis of CO₂ and CH₄

Environmental measurements

- temperatures, soil moisture, chemistry

Microbial data

- abundance and metagenomics





Waterlogged sediments





Dry baren sediments

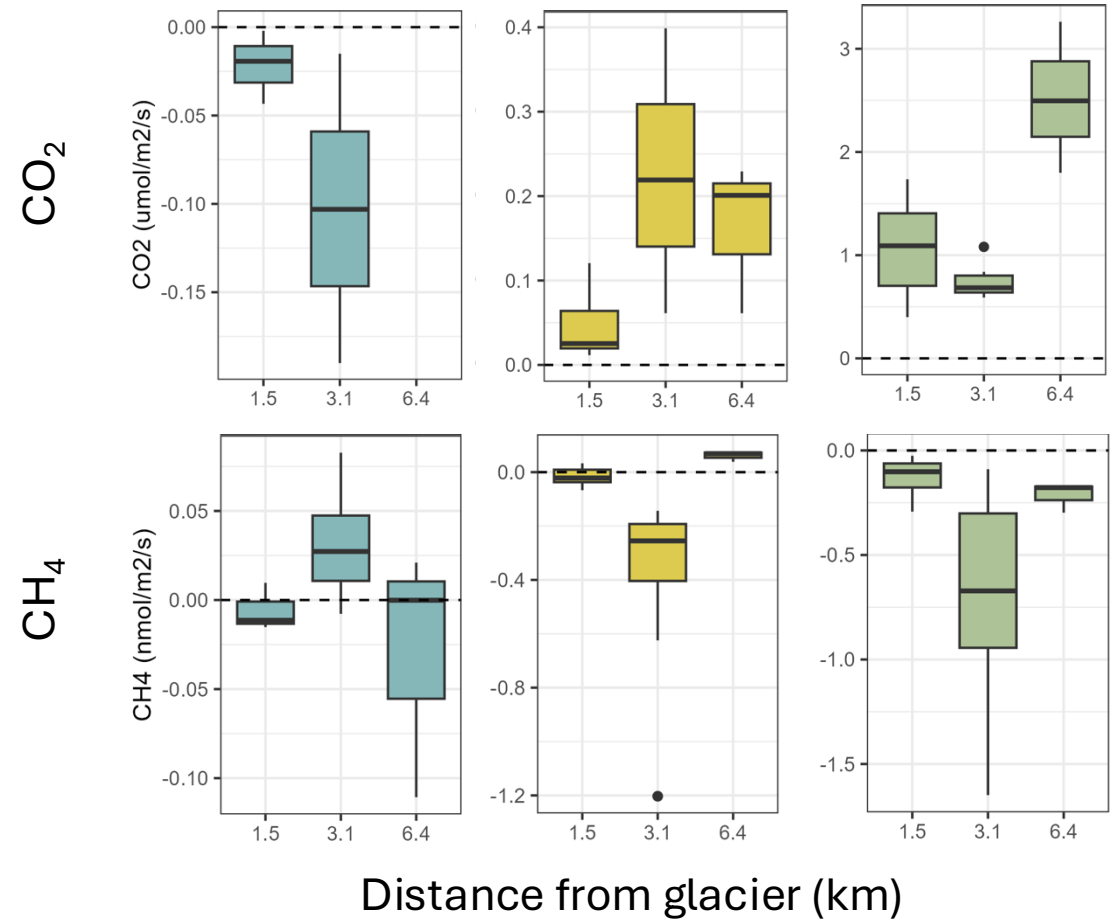




Vegetated soils

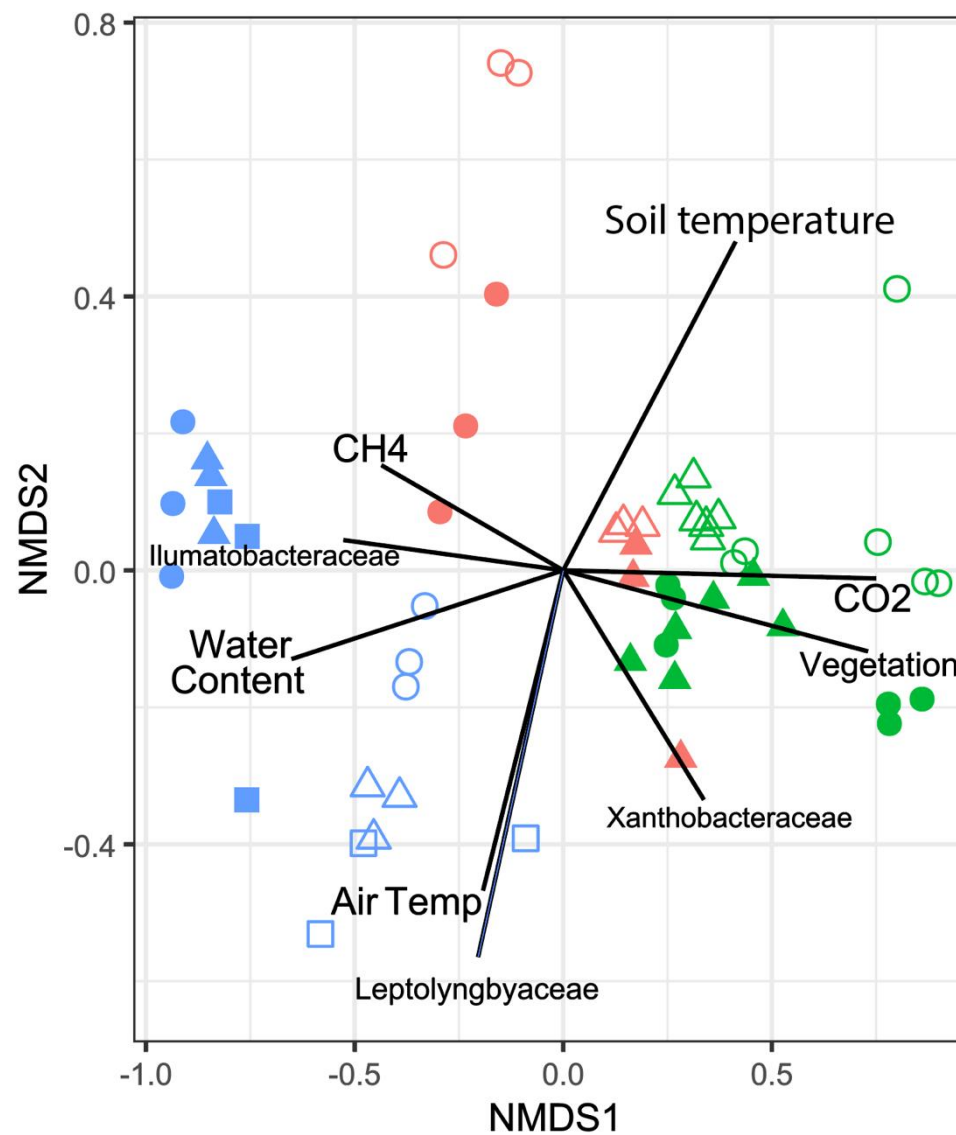


Gas Fluxes



Microbial Drivers

- Baren soil
- Vegetated soil
- Water saturated

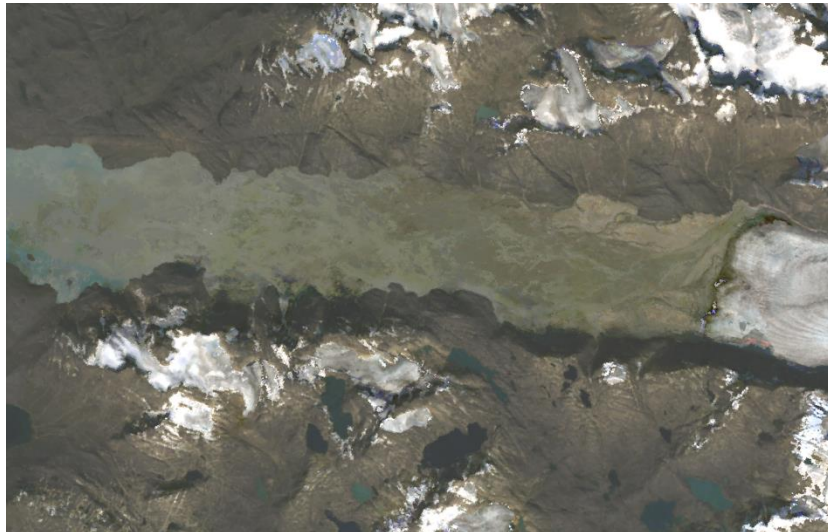
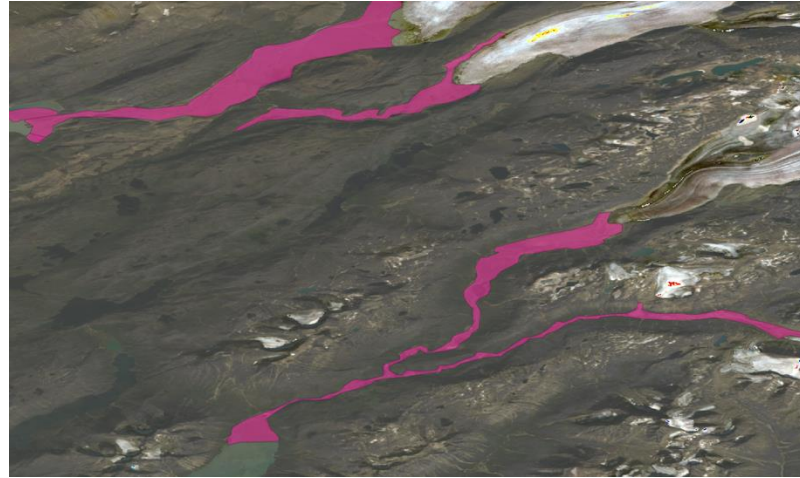
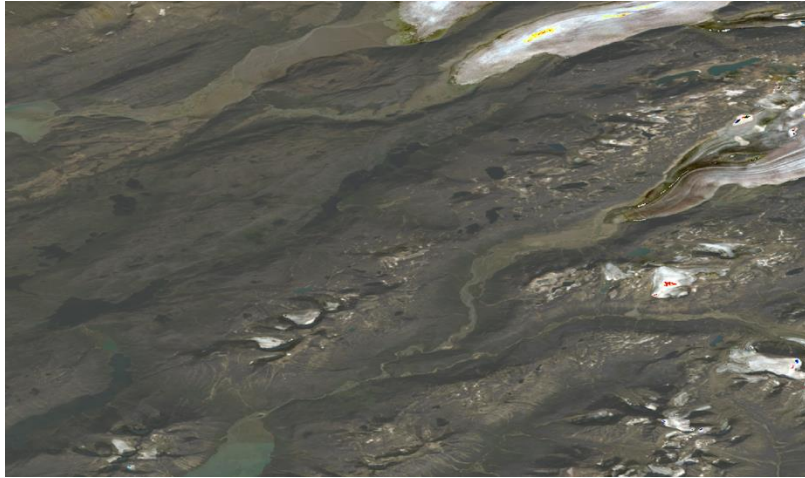


Upscaling: Mapping Greenland outwash plains

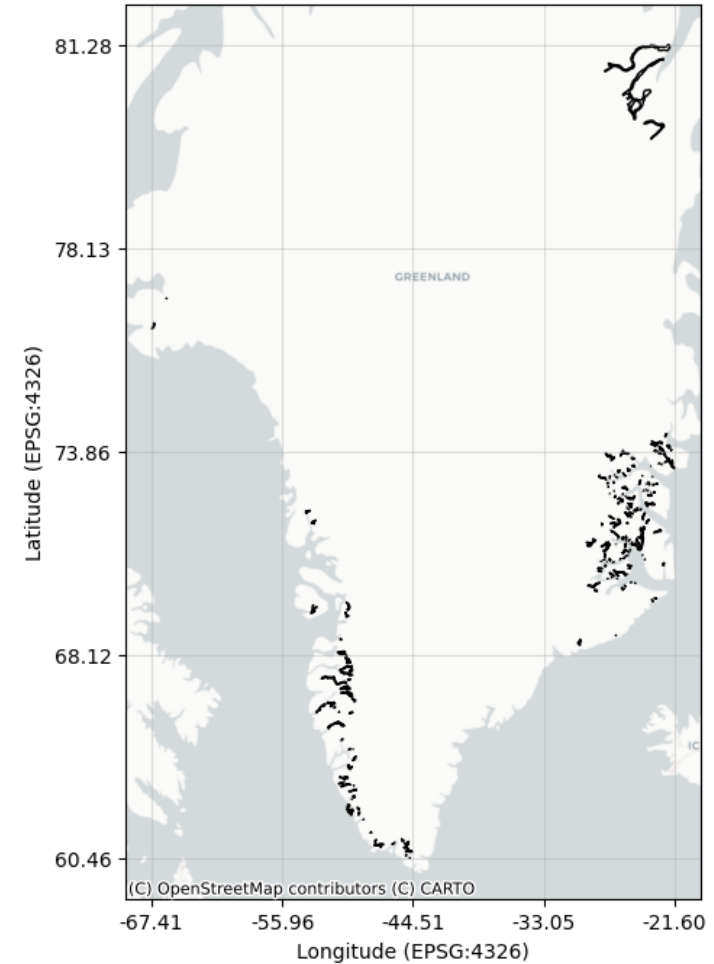
~4000 km²

Summer 2023

Outwash plains annotations

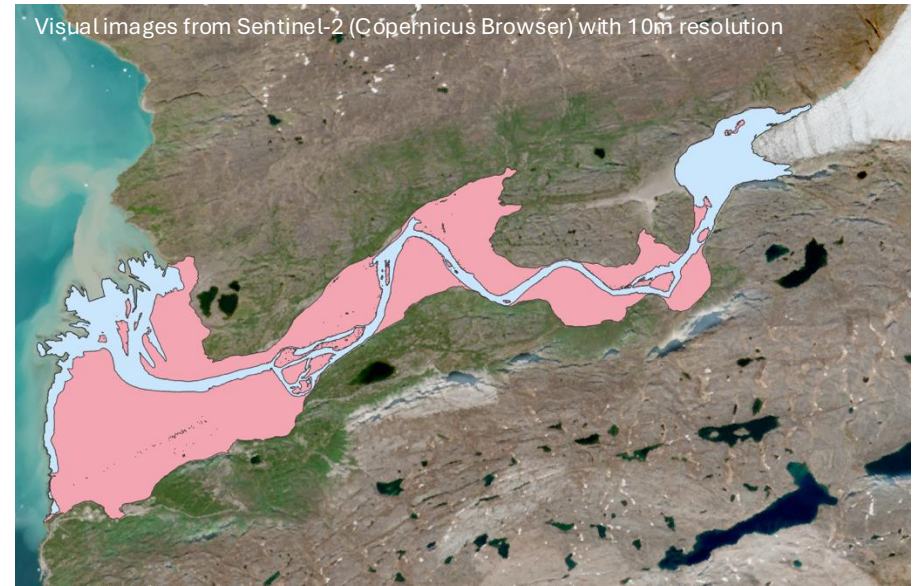


Geographic distribution



Satellite Indices

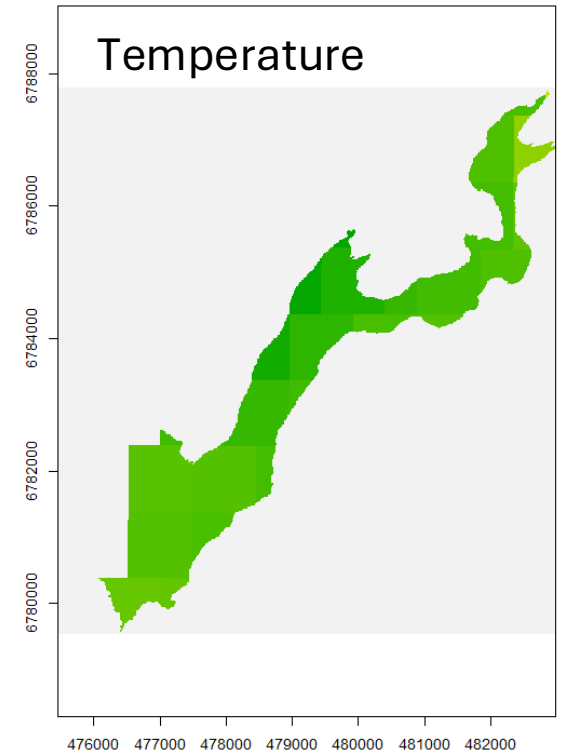
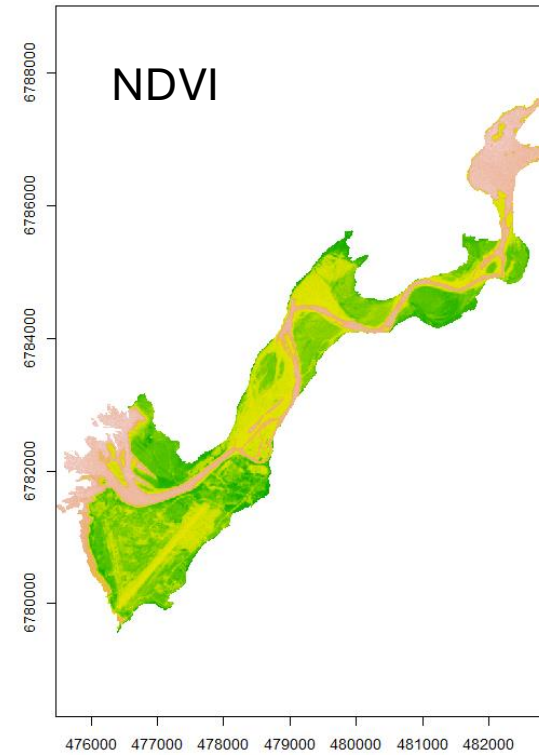
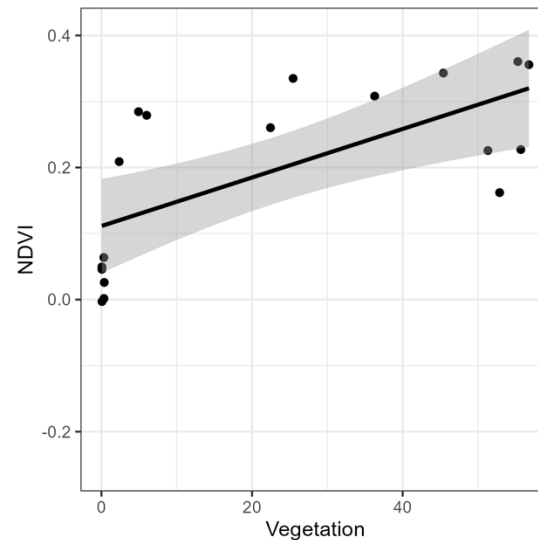
- Spectral indices calculated from satellite imagery
 - vegetation index (NDVI)
 - soil surface temperature
 - elevation
 - water content
- Satellite data was correlated with ground truth measurements



ground truth

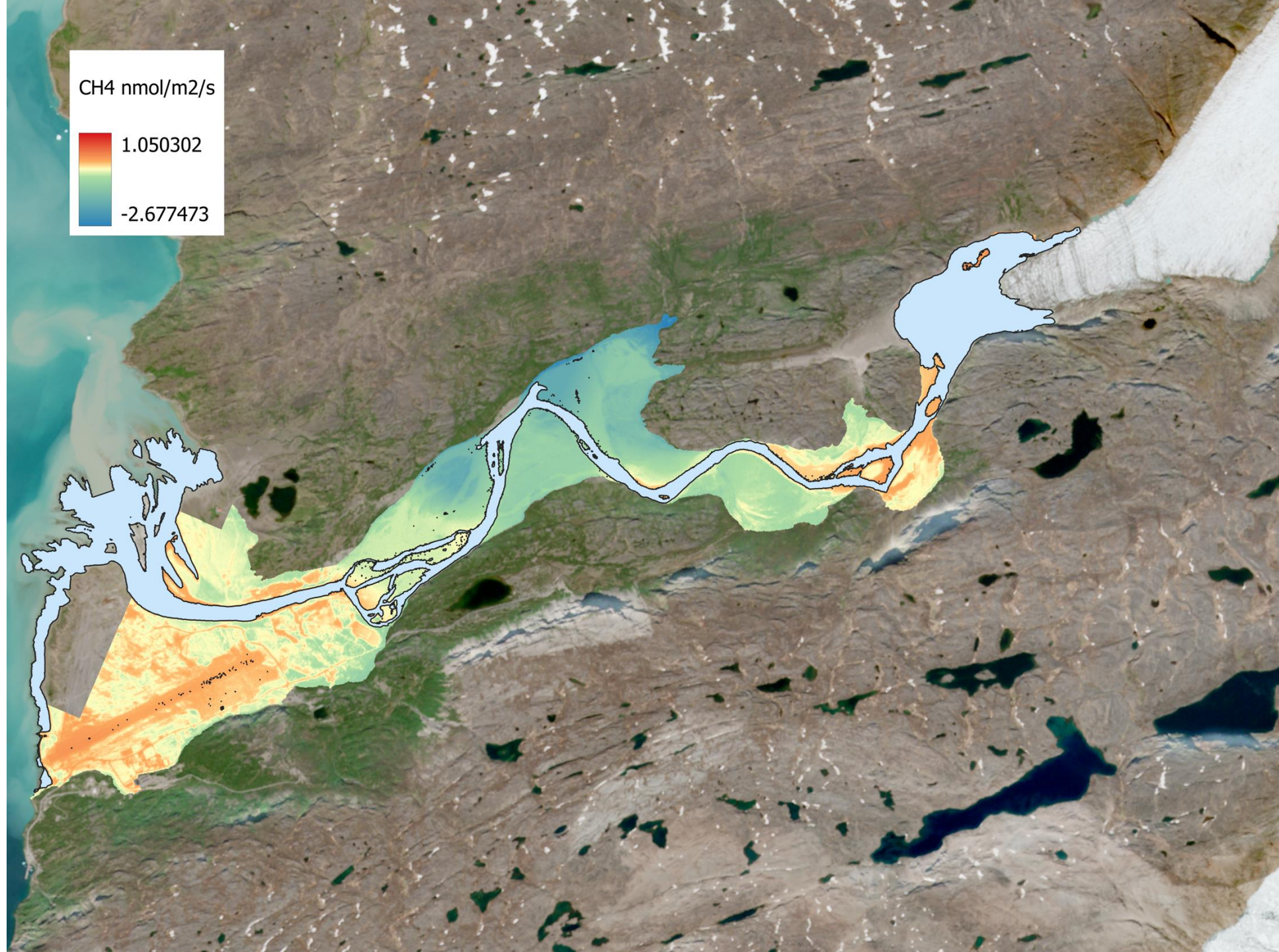


satellite

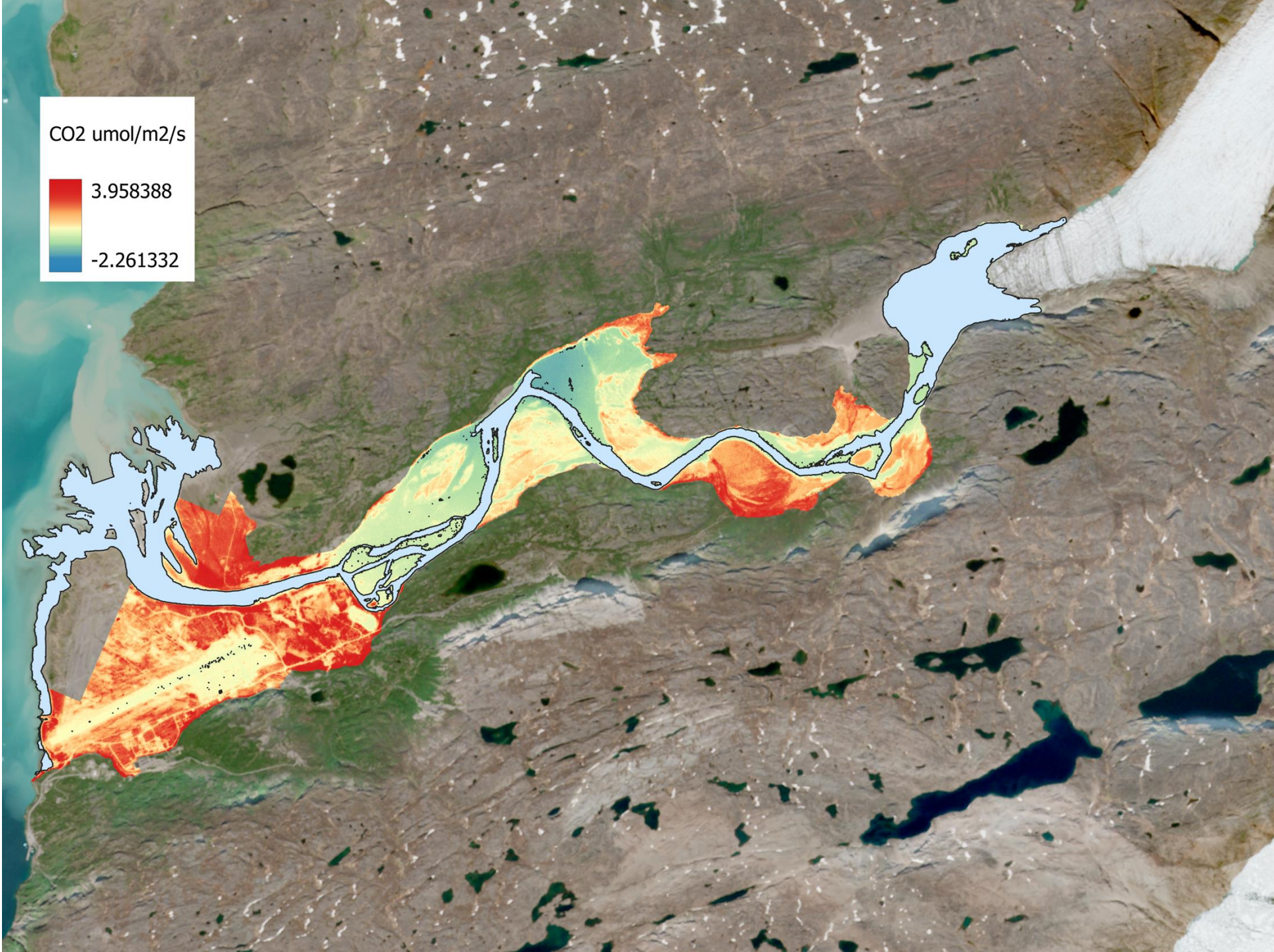
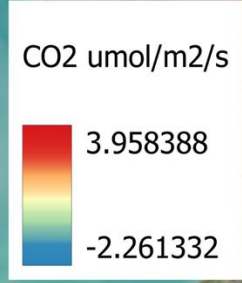


CH₄ Upscaling

Predicted net flux:
-316.5 nmol CH₄/h



CO₂ Upscaling



Predicted net flux:
627 umol CO₂/hr

Thank you for listening

