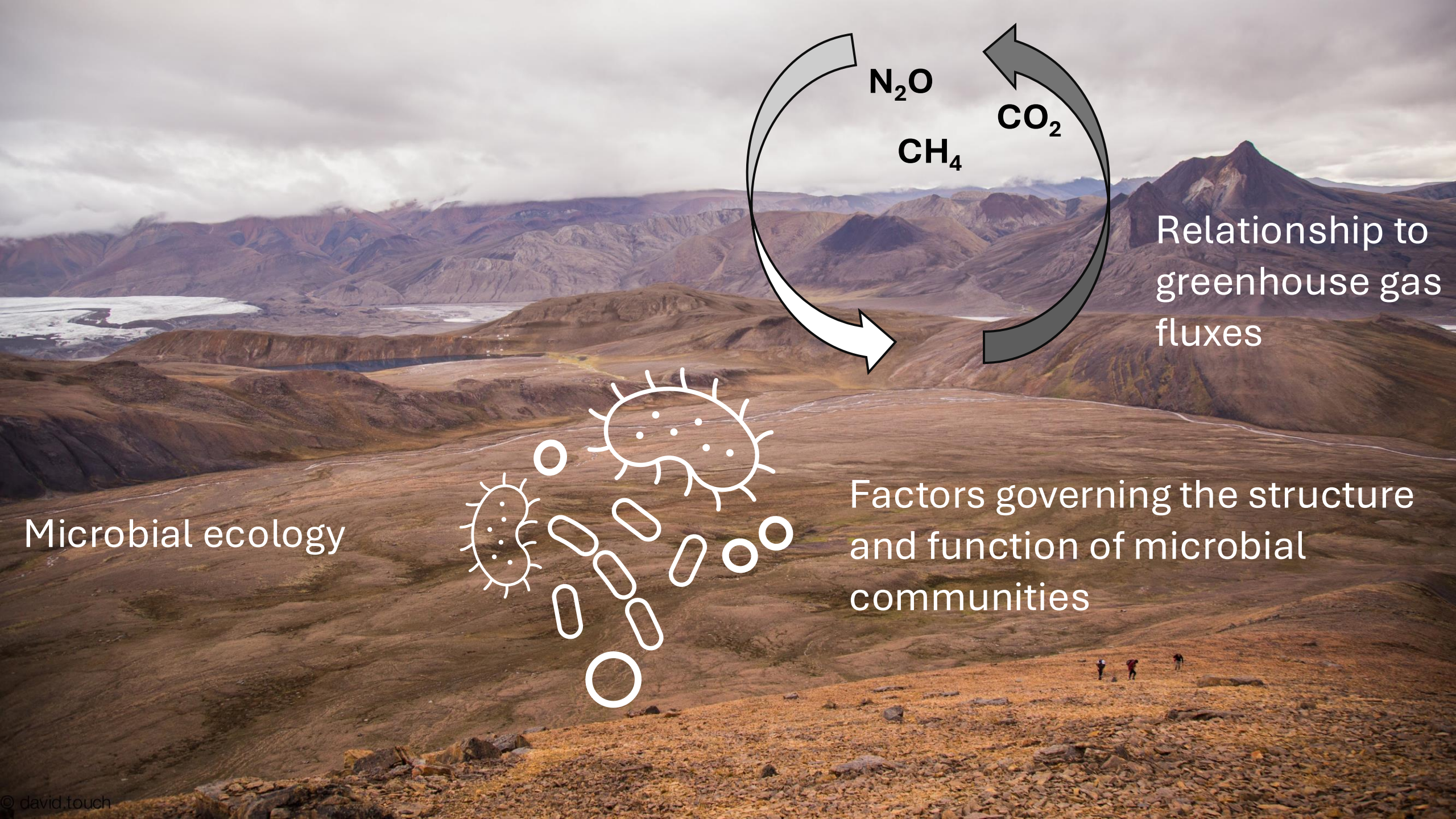


Relationship to greenhouse gas fluxes

Microbial ecology

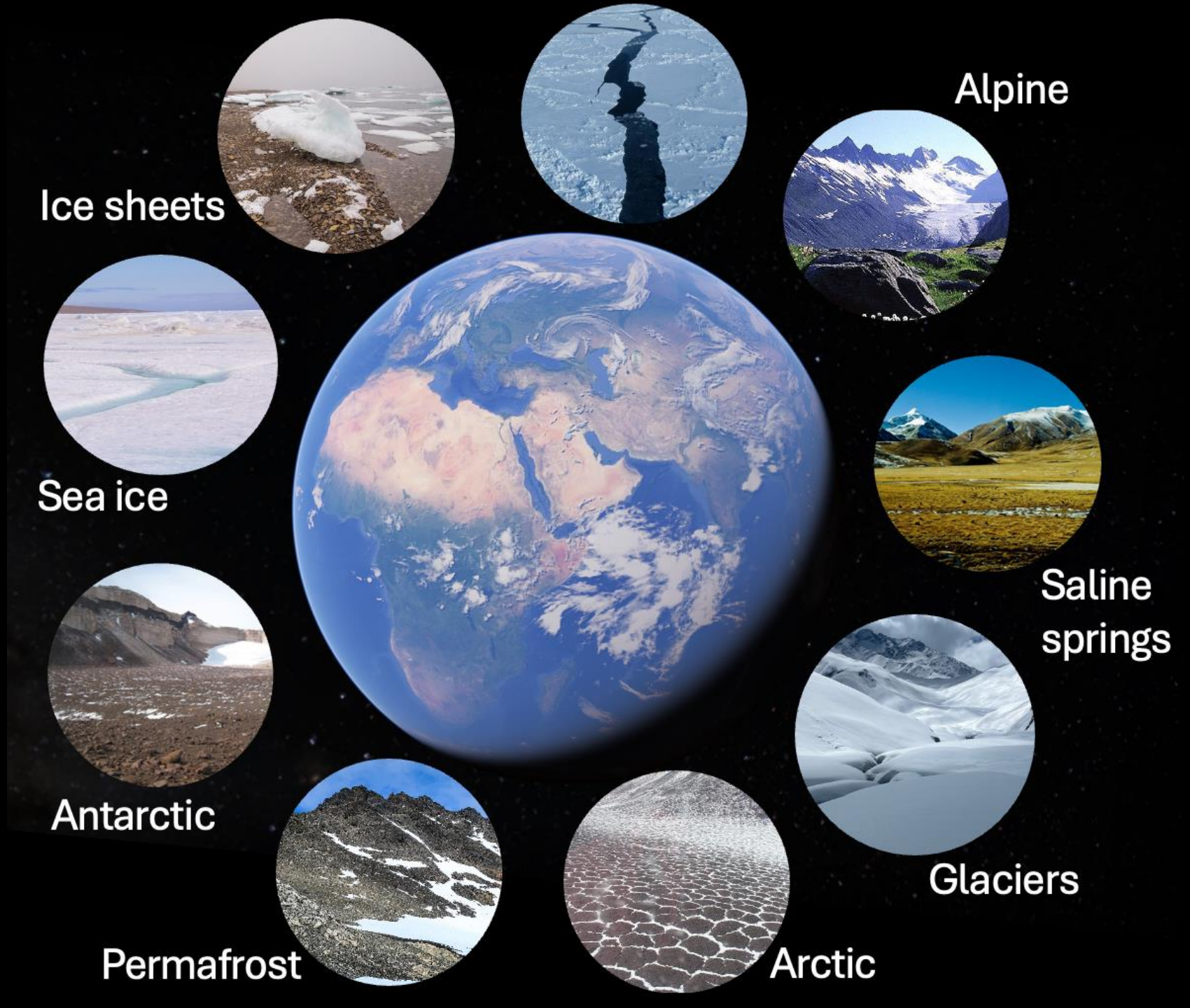
Factors governing the structure and function of microbial communities

© david.touch


Cryosphere microbiomes in
a warming world

Cryosphere

>25%
surface
of our planet

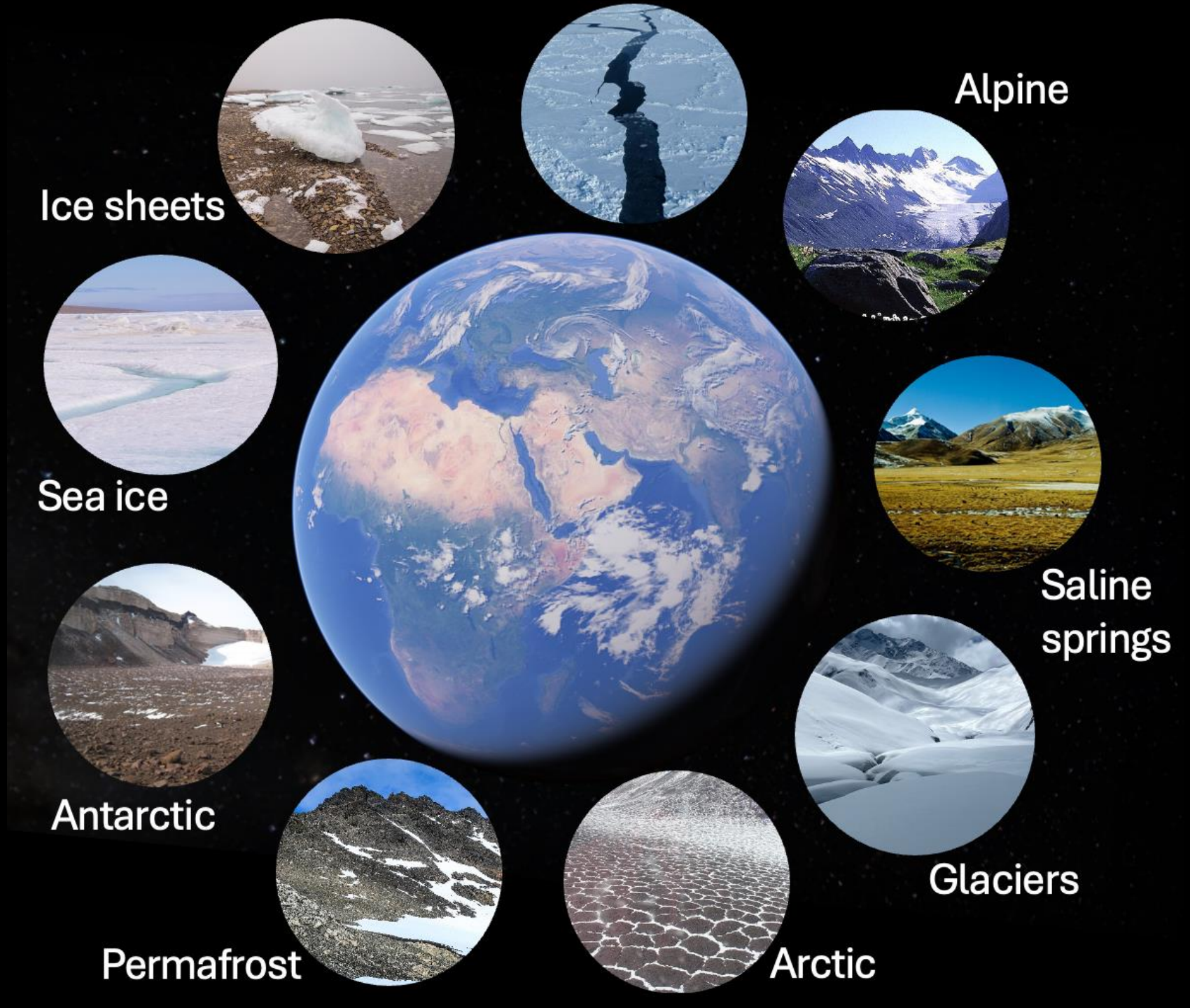


Ice caves??

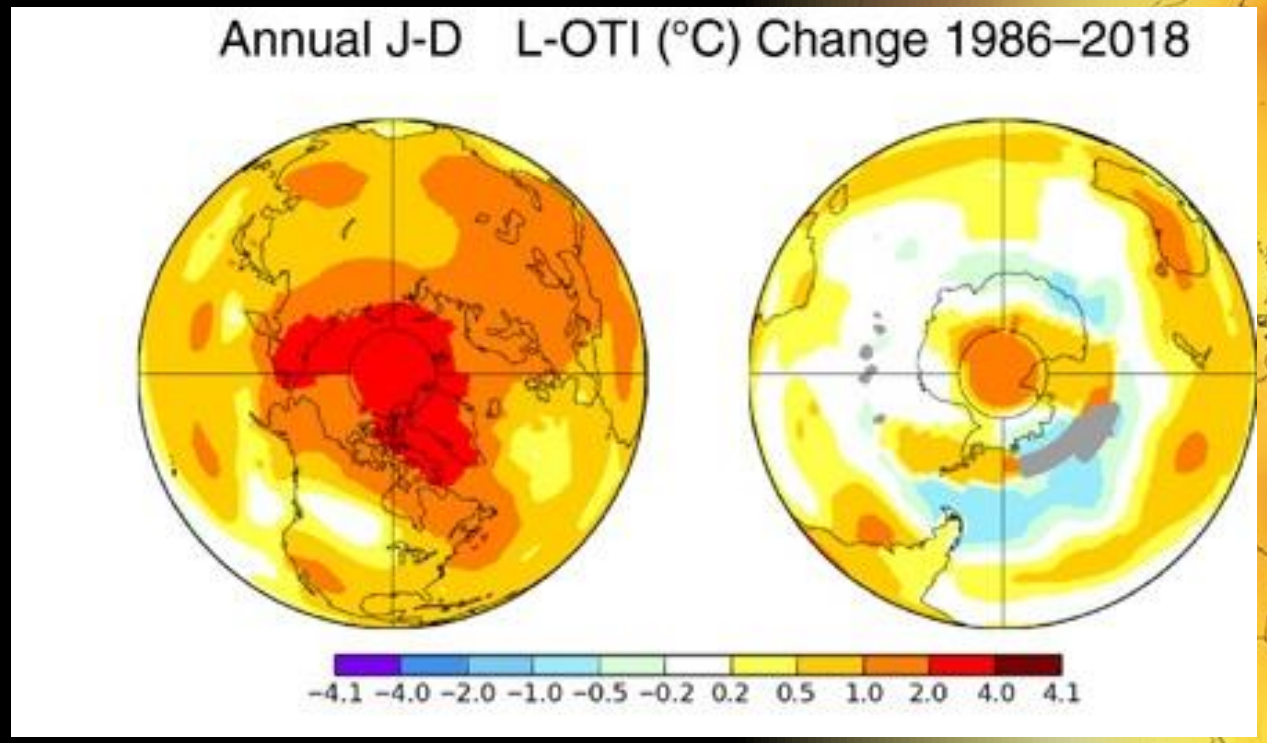
Cryosphere

Challenges for Life

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



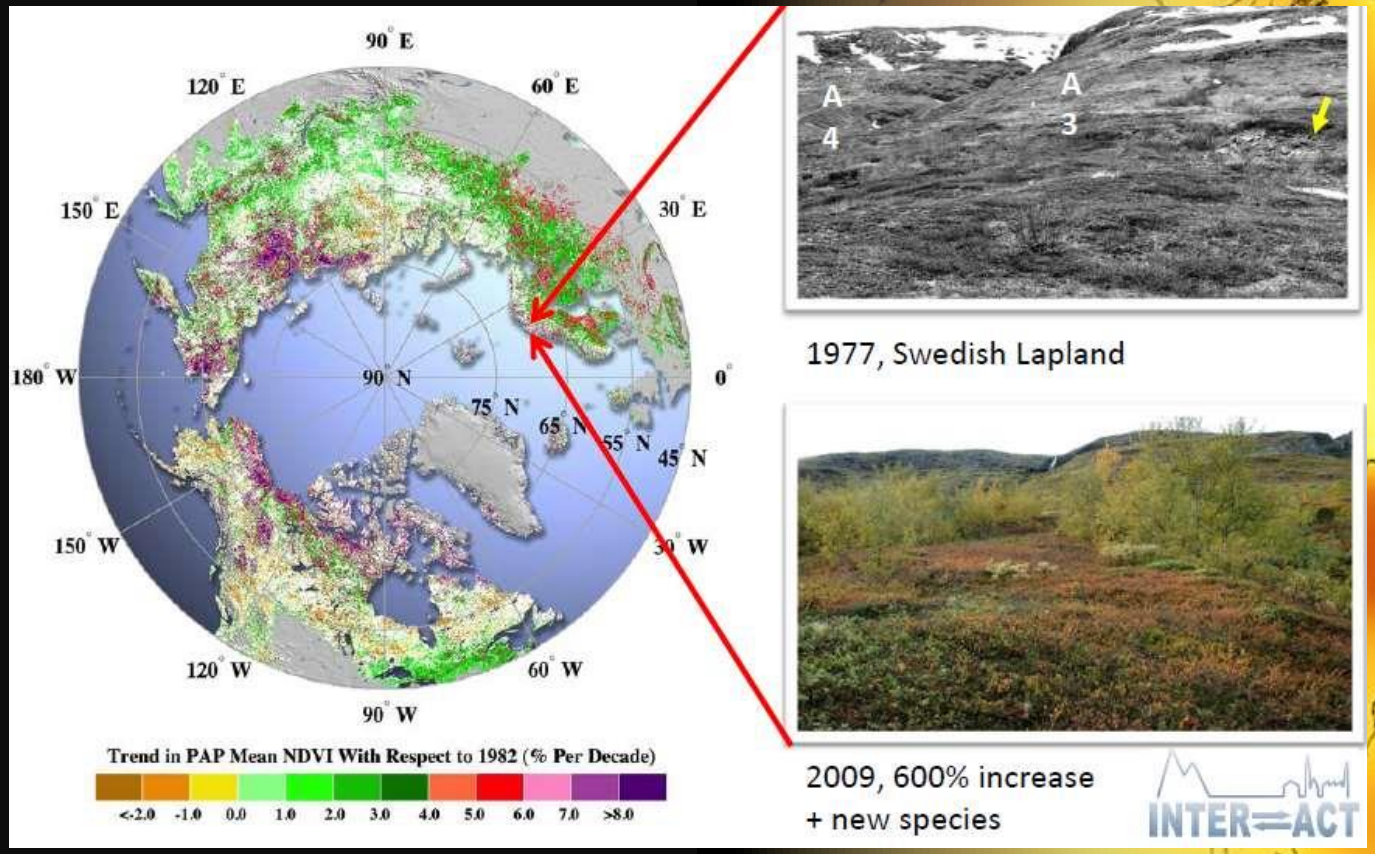
Cryosphere Warming



Post *et al.* 2019

Cryosphere Warming

Arctic and Alpine “Greening”

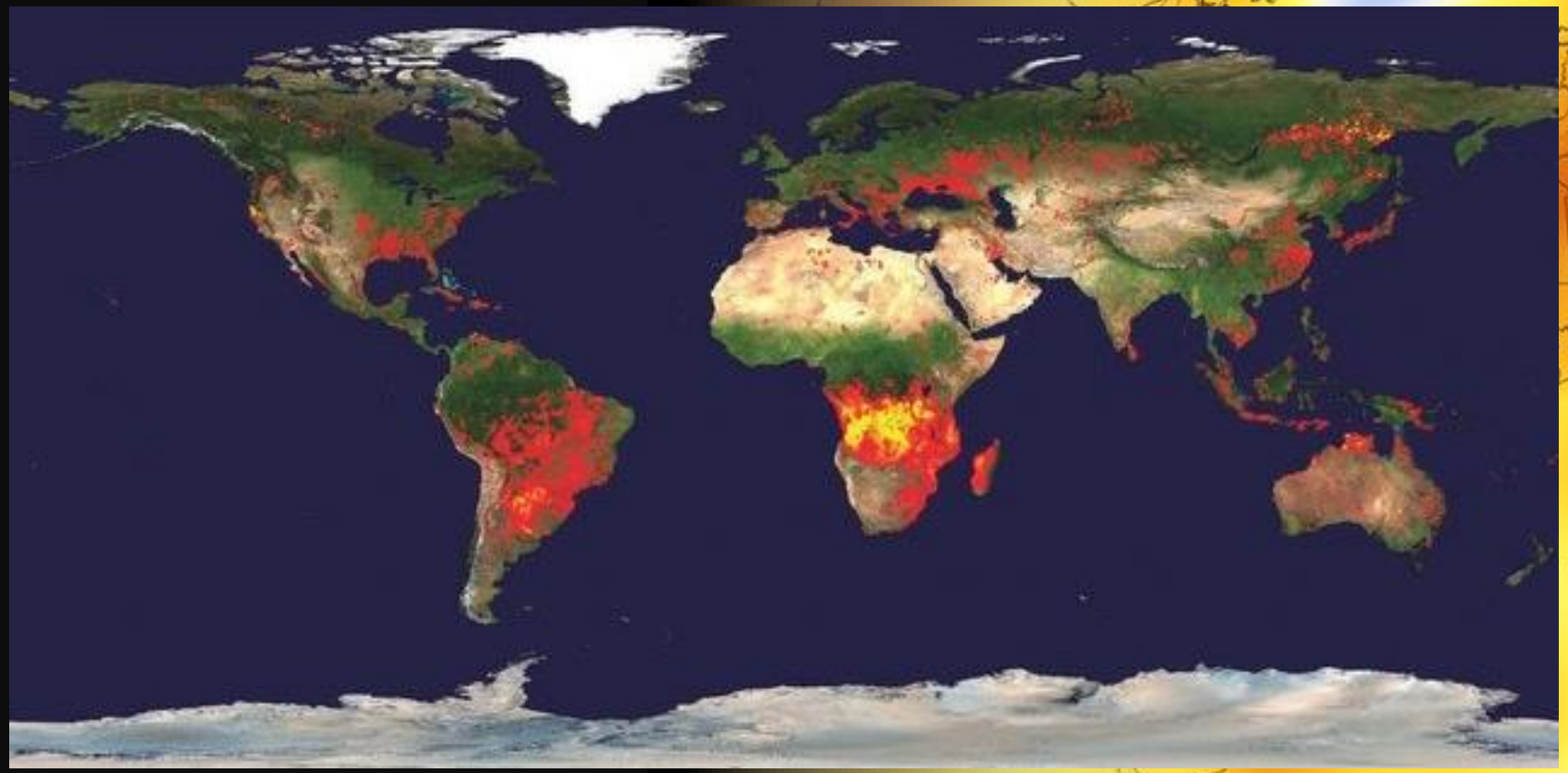


1977, Swedish Lapland

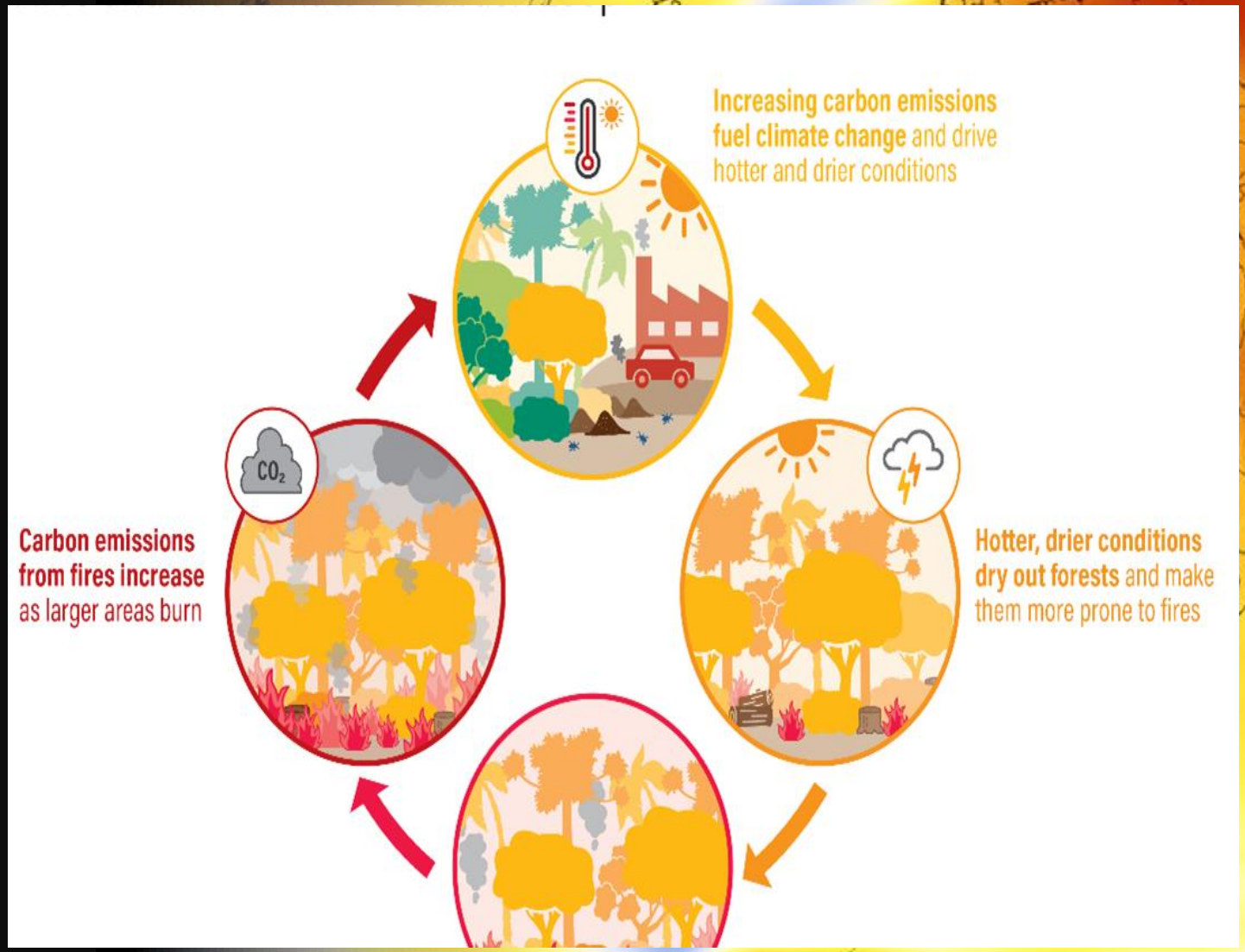
2009, 600% increase
+ new species

INTER=ACT

Cryosphere Warming



Cryosphere Warming



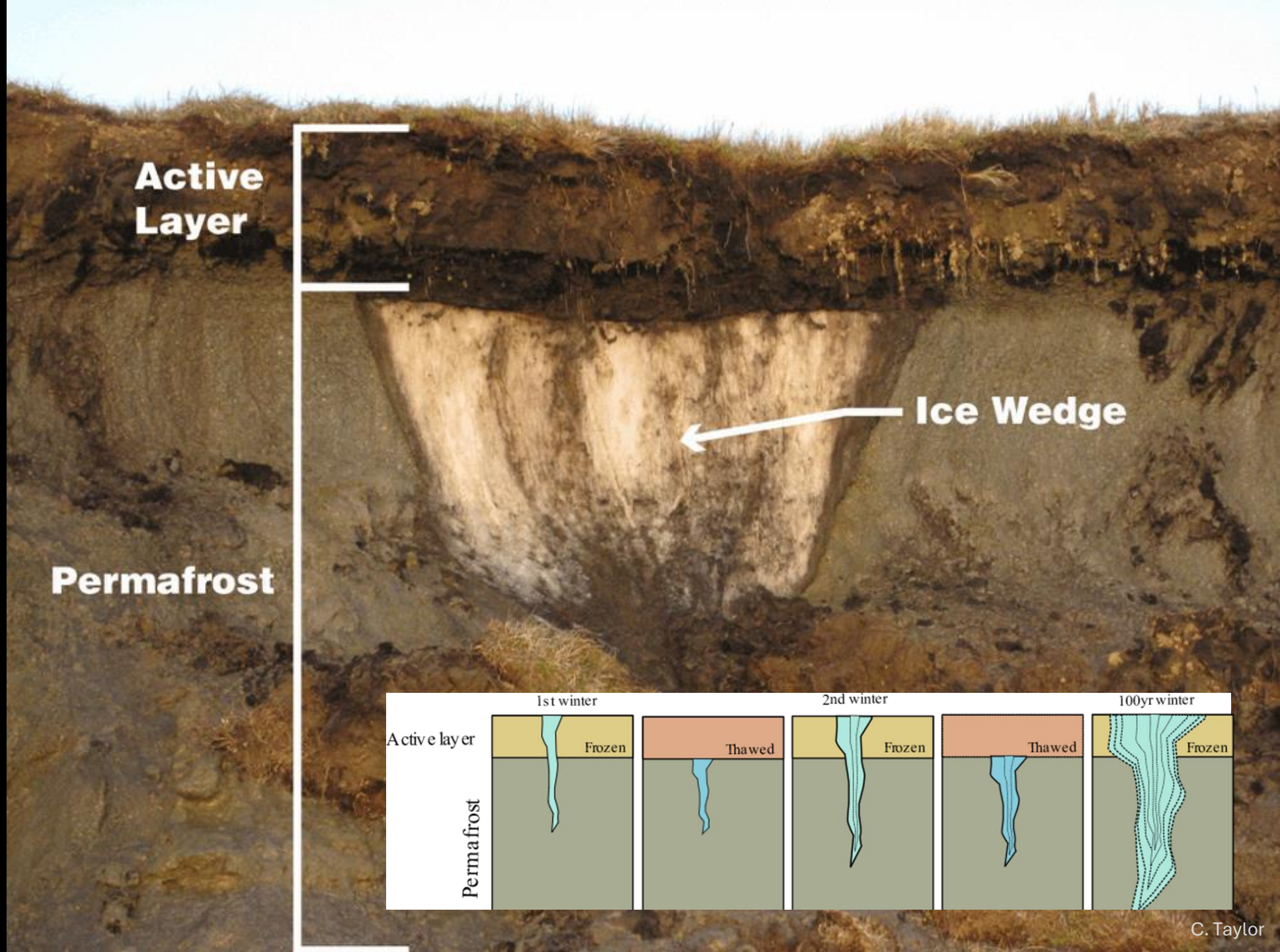
Global Forest Watch

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.

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

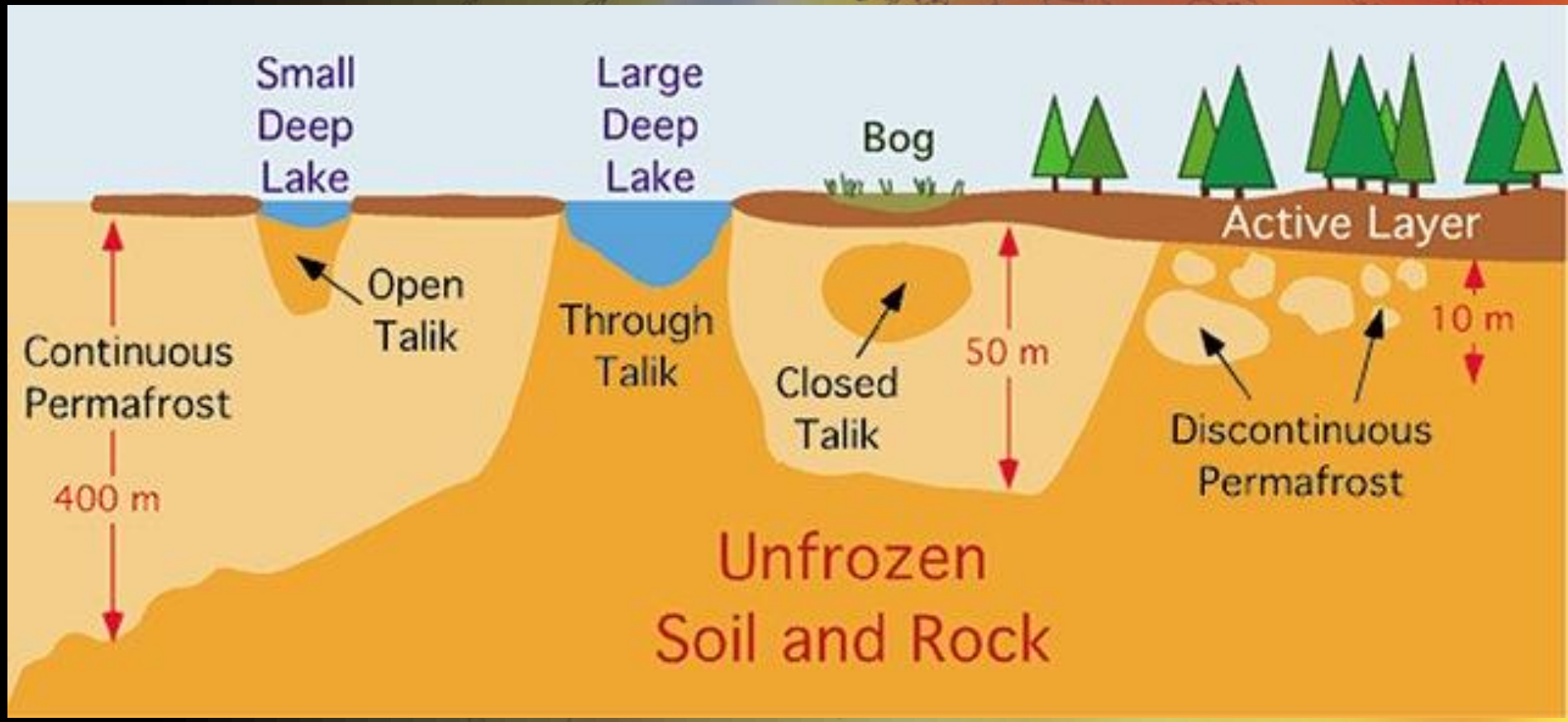


C. Taylor

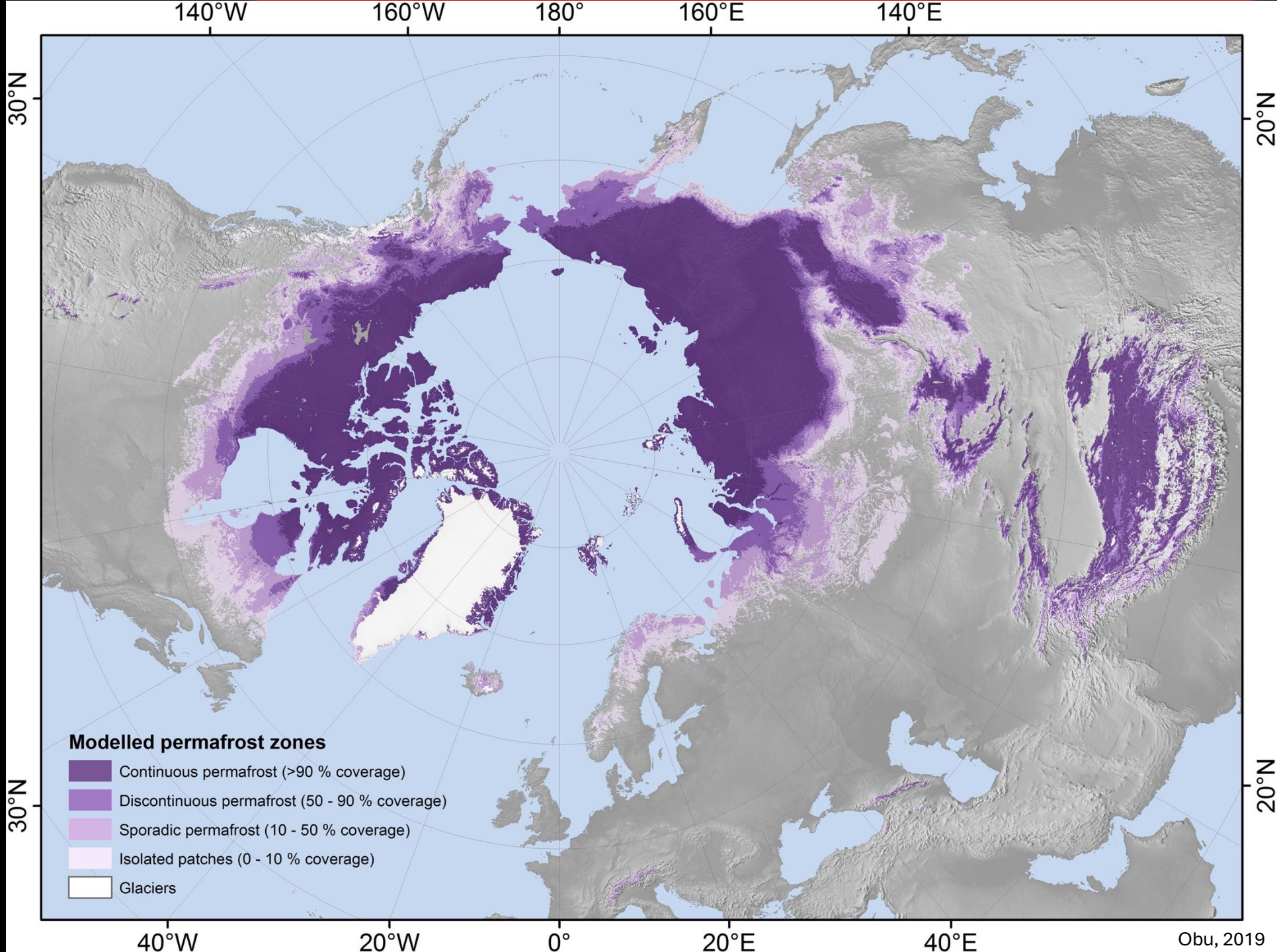
Permafrost

Continuous vs Discontinuous permafrost

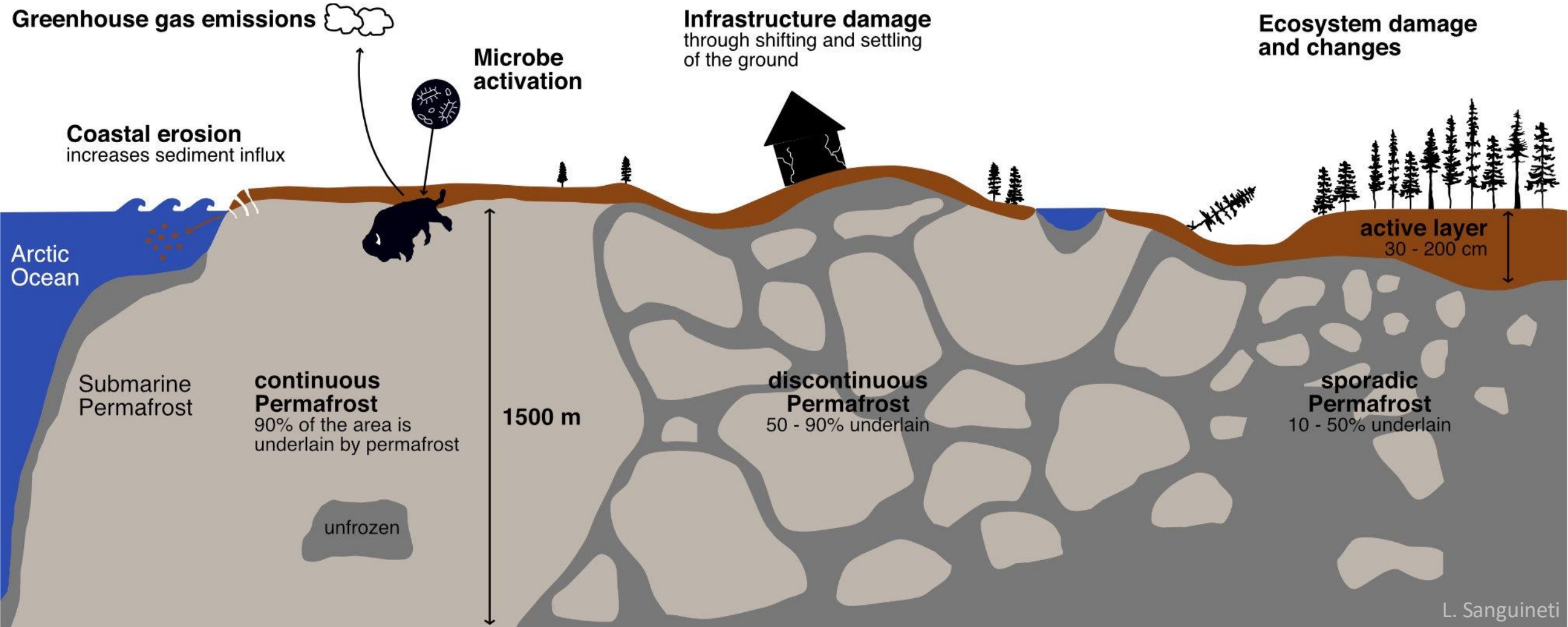
Talik: Portion of year-round unfrozen ground in a permafrost zone



Permafrost


140°W
160°W
180°
160°E
140°E
30°N
20°N
Modelled permafrost zones
Continuous permafrost (>90 % coverage)
Discontinuous permafrost (50 - 90 % coverage)
Sporadic permafrost (10 - 50 % coverage)
Isolated patches (0 - 10 % coverage)
Glaciers
40°W
20°W
0°
20°E
40°E
Obu, 2019

Permafrost thaw

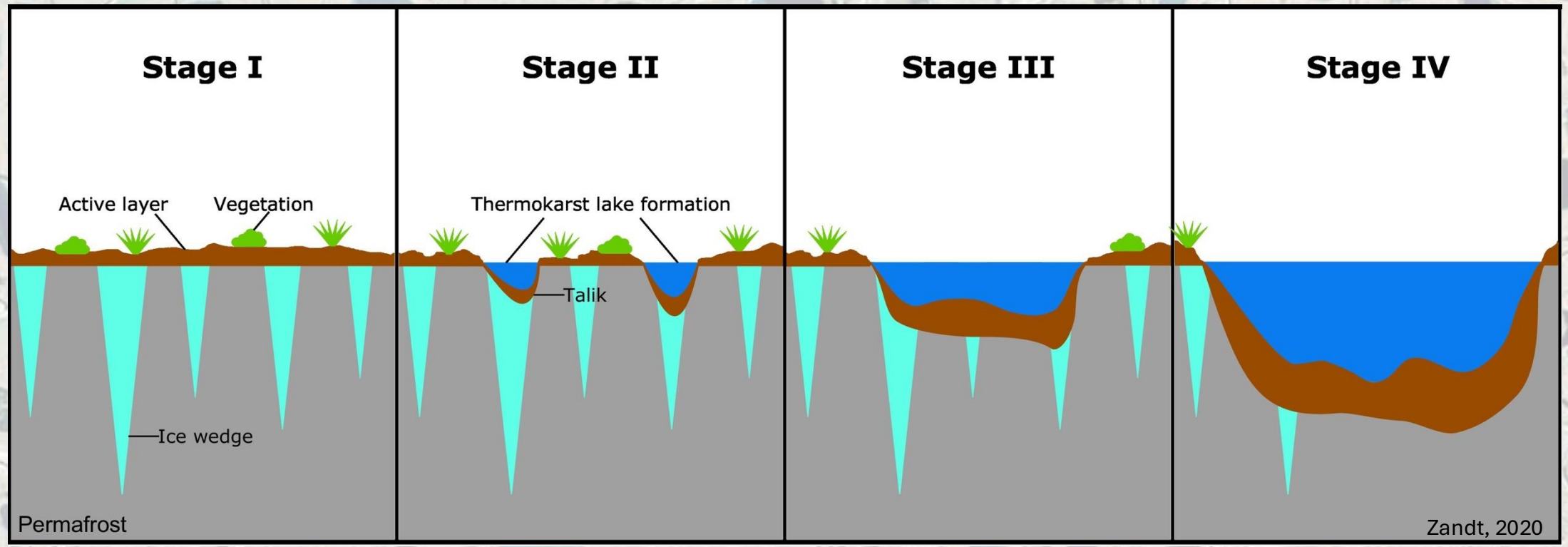


L. Sanguineti

Permafrost thaw

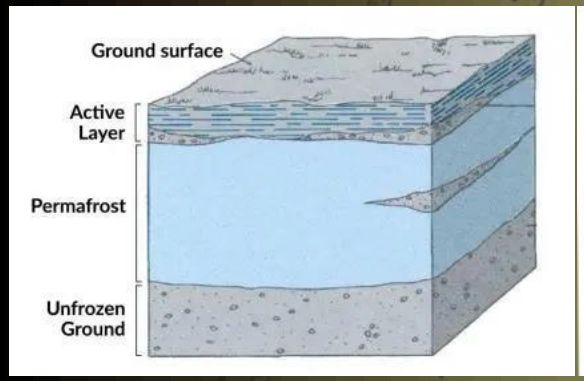
Abrupt thaw processes thermokarst lake formation in ice-rich continuous permafrost

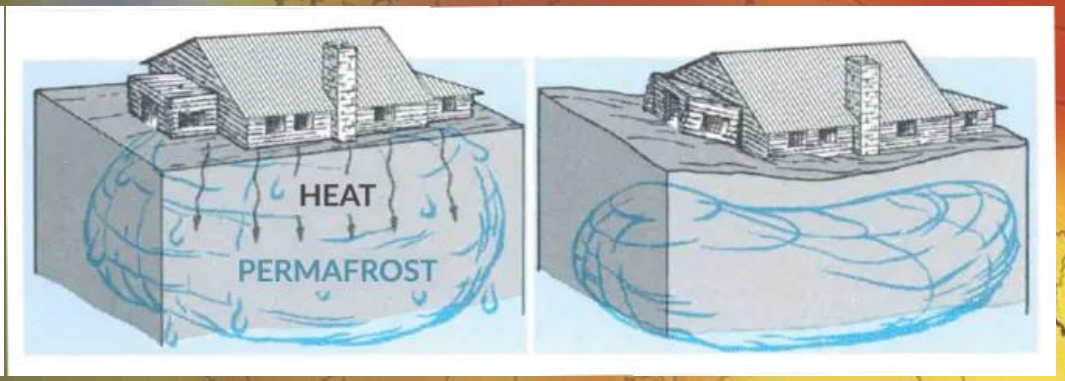
M. Schwab



Permafrost thaw

Infrastructure damage

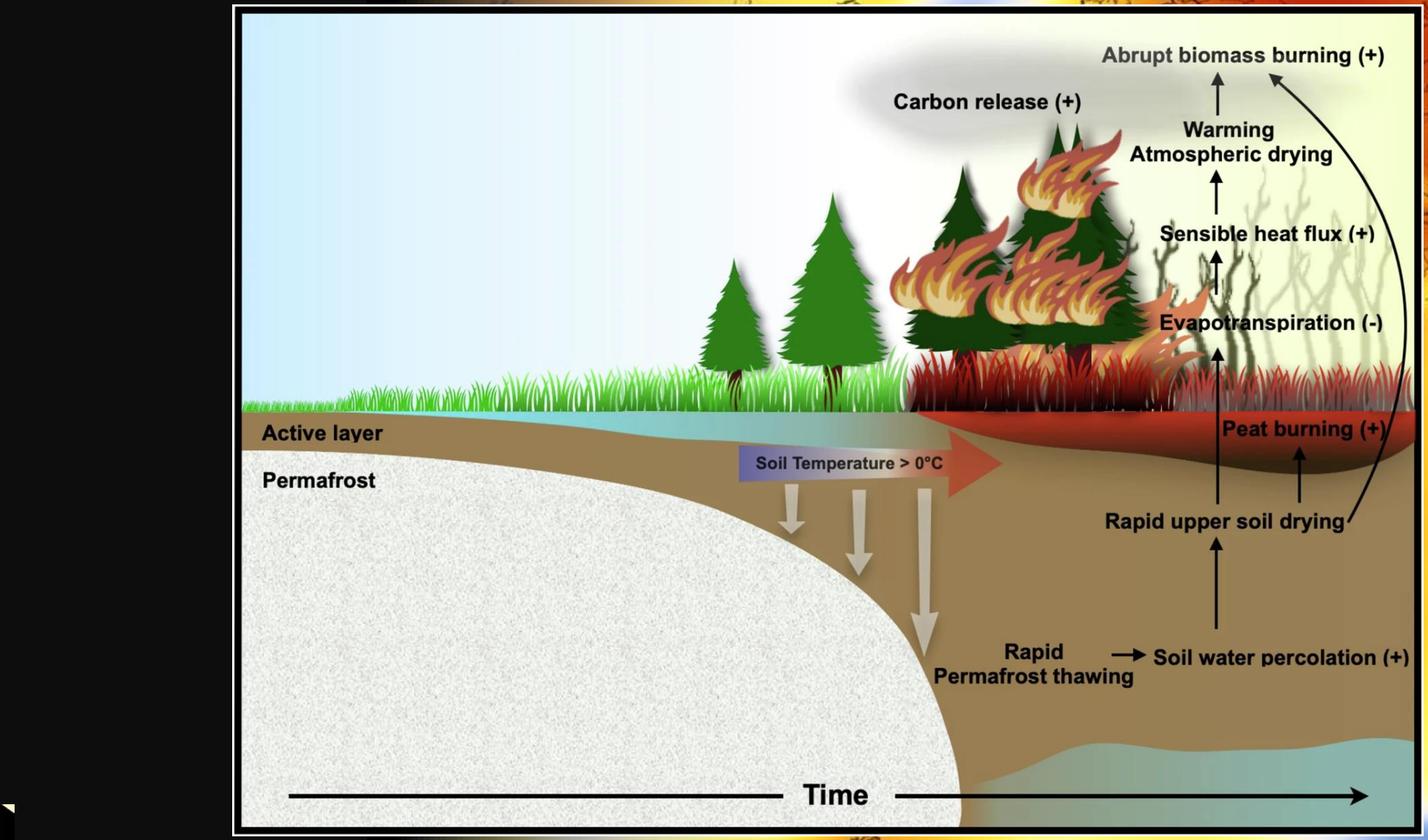




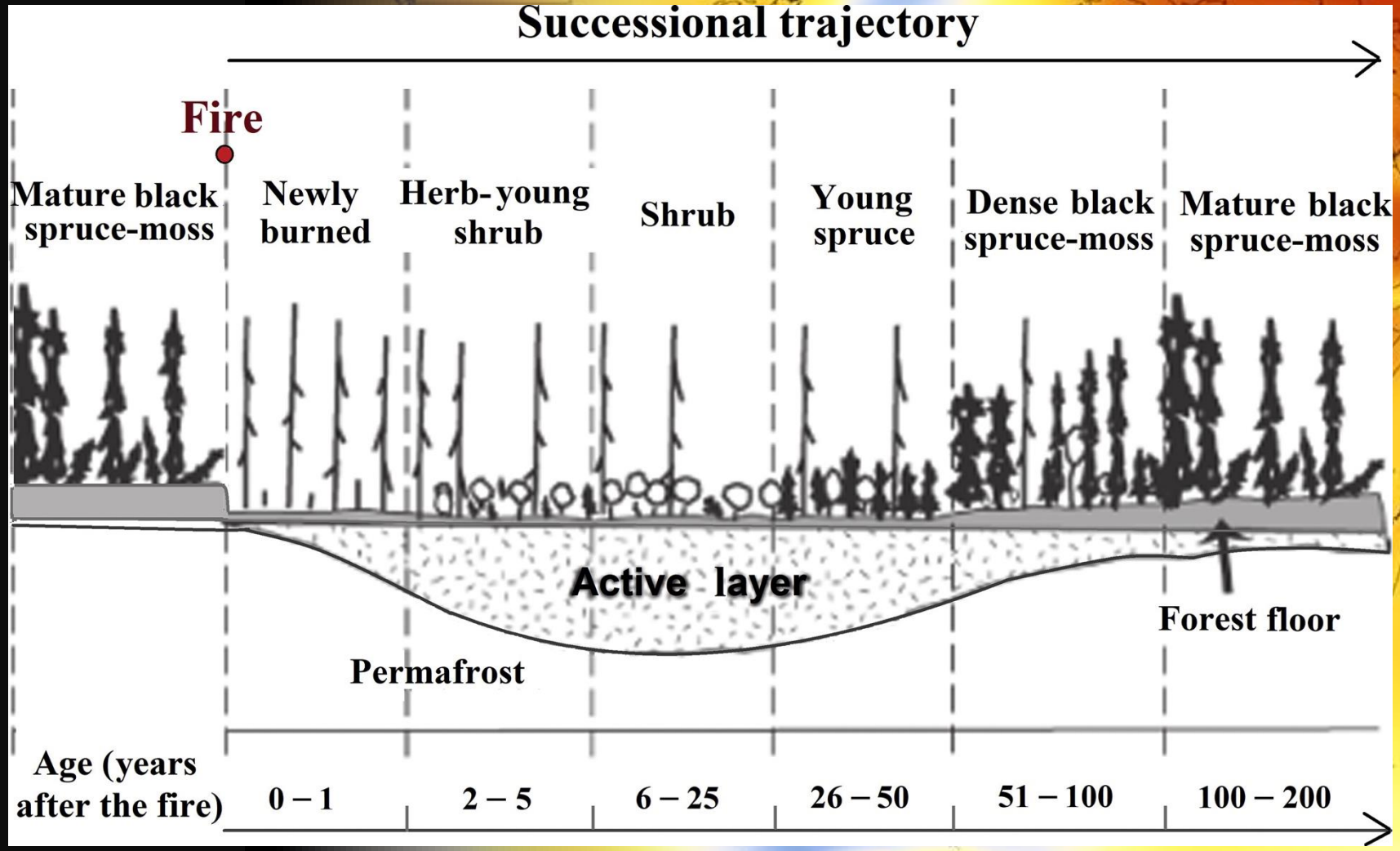
Permafrost thaw

Permafrost thaw

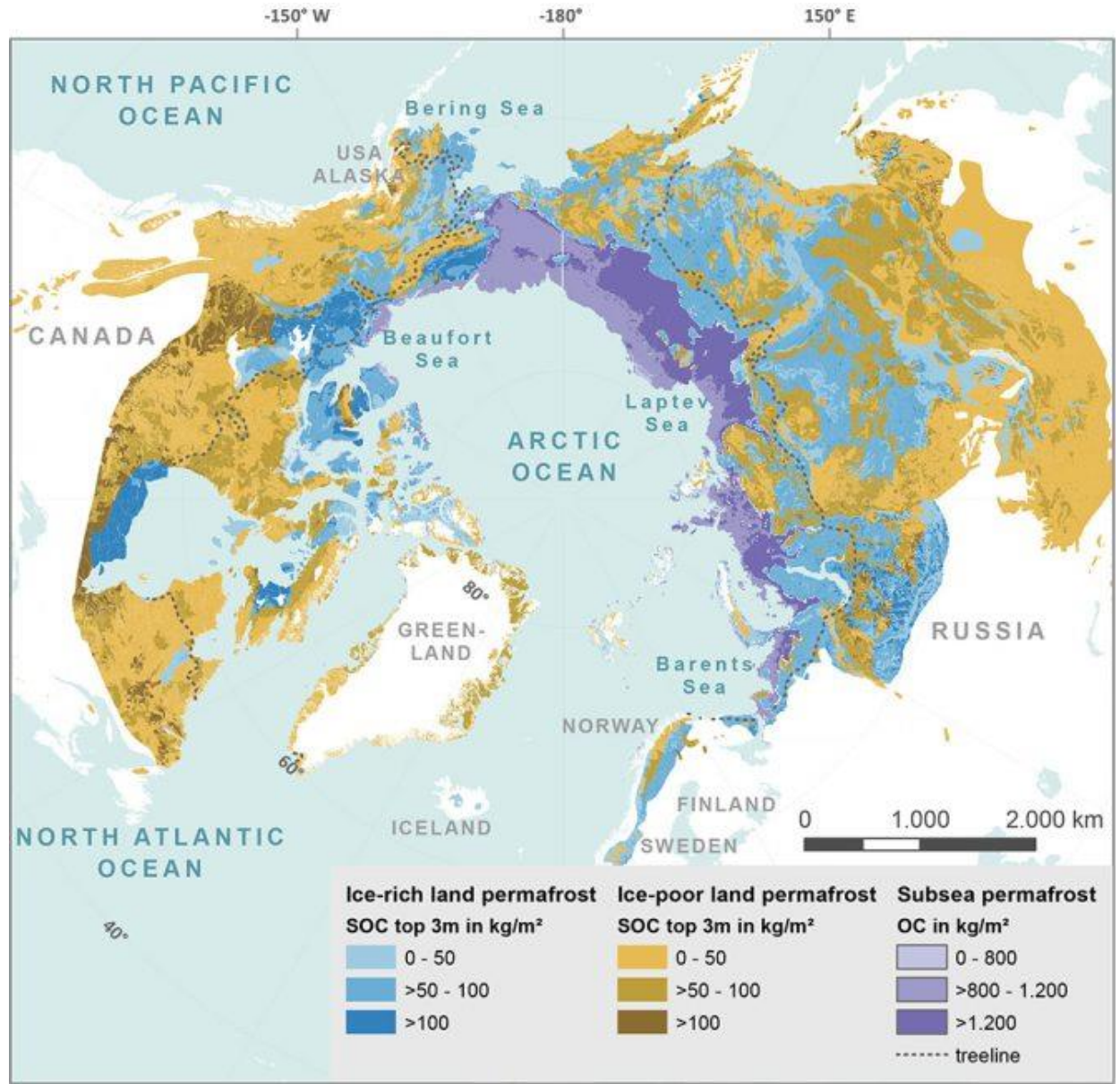
Permafrost x Forest Fires



Permafrost x Forest Fires



Permafrost carbon stores



Permafrost carbon stores

Pleistocene:

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

Kjær, 2022

Permafrost thaw positive feedback

Permafrost thaw

Organic Carbon stores

Microbial metabolism

Greenhouse gasses

CH_4 CO_2

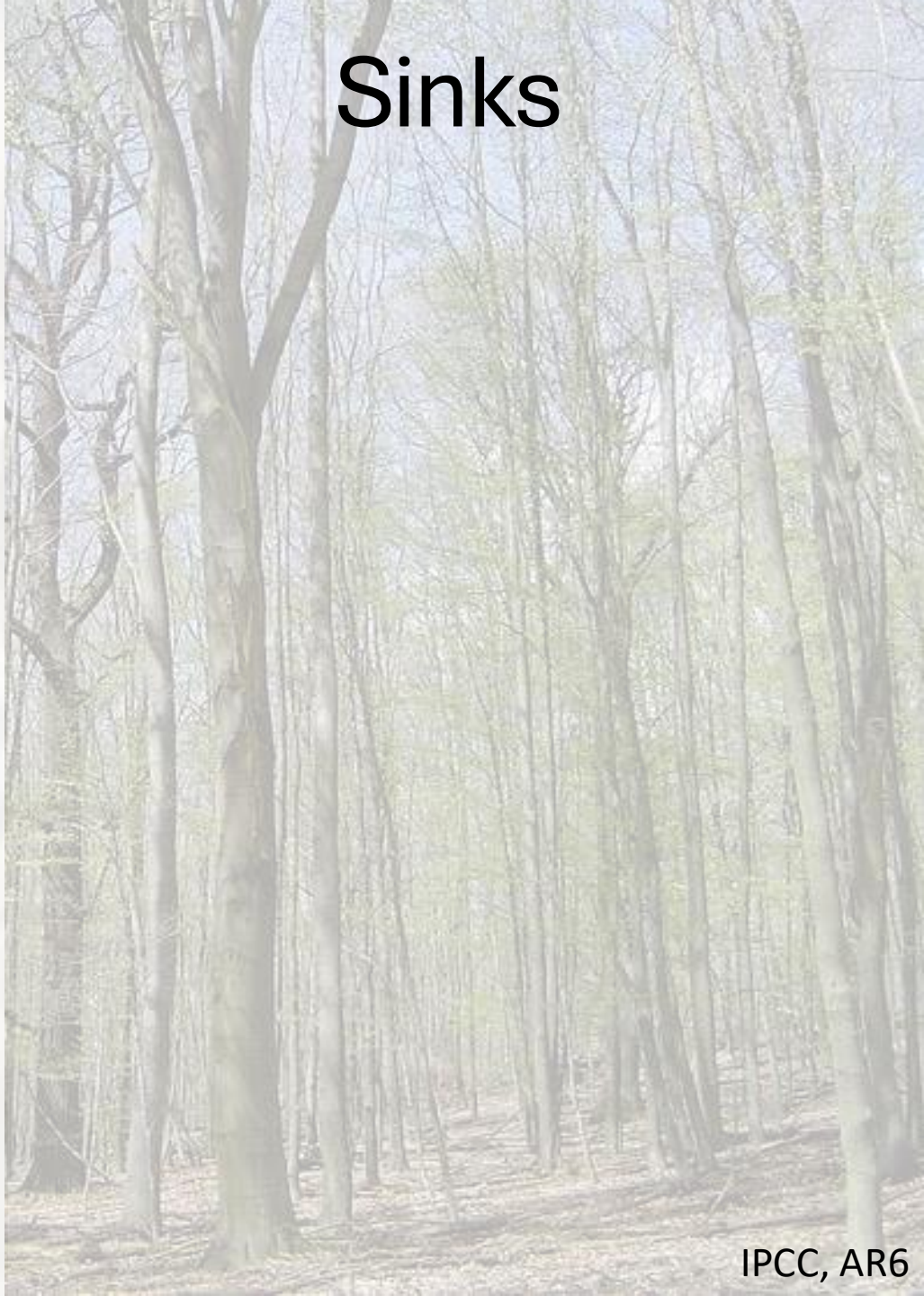
Climate Warming

Atmospheric Methane

- Second most important anthropogenic GHG
- ~30X more global warming potential compared to CO_2
- Increase from ~700ppb during preindustrial times to ~1900ppb in 2019

Sources

Sinks



IPCC, AR6

Sources

Anthropogenic

Biomass burning

Landfills and waste

Fossil fuels

Rice cultivation

Livestock

Sinks

Sources

Anthropogenic

Biomass burning

Landfills and waste

Fossil fuels

Rice cultivation

Livestock

Natural

Geological sources

Freshwaters

Wetlands

Termites

Sinks

Sources

Anthropogenic

Biomass burning

Landfills and waste

Fossil fuels

Rice cultivation

Livestock

Natural

Geological sources

Freshwaters

Wetlands

Termites

Sinks

Tropospheric hydroxyl loss

$CH_4 + \bullet OH \rightarrow \bullet CH_3 + H_2O$

Tropospheric chlorine loss

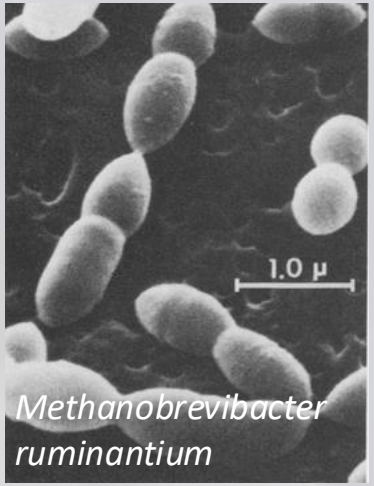
Stratospheric loss

Oxidation in soils

Sources

Methanogens → CH_4 generating

Anaerobic environments



Miller et al. 1986

Hydrogenotrophic $4\ H_2 + CO_2 \rightarrow \mathbf{CH_4} + 2\ H_2O$

Acetoclastic $CH_3COO^- + H^+ \rightarrow \mathbf{CH_4} + CO_2$

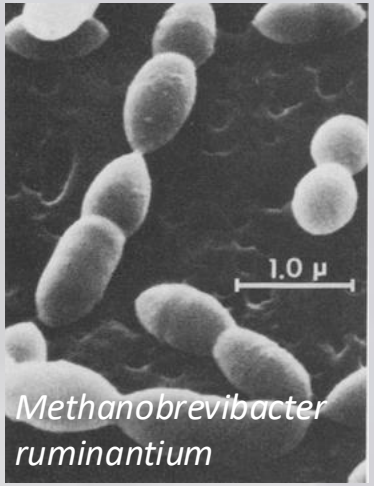
Methylotrophic $4\ CH_3OH \rightarrow 3\ \mathbf{CH_4} + CO_2 + 2\ H_2O$

Sinks

Sources

Methanogens → CH_4 generating

Anaerobic environments



Miller et al. 1986

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Methylotrophic $4\ CH_3OH \rightarrow 3\ \mathbf{CH_4} + CO_2 + 2\ H_2O$

Sinks

Methanotrophs → CH_4 consuming

Aerobic environments

Hur et al. 2016

$\mathbf{CH_4} \rightarrow CH_3OH$

Methane oxidation & assimilation as a carbon source

Permafrost thaw positive feedback

Permafrost thaw

Organic Carbon stores

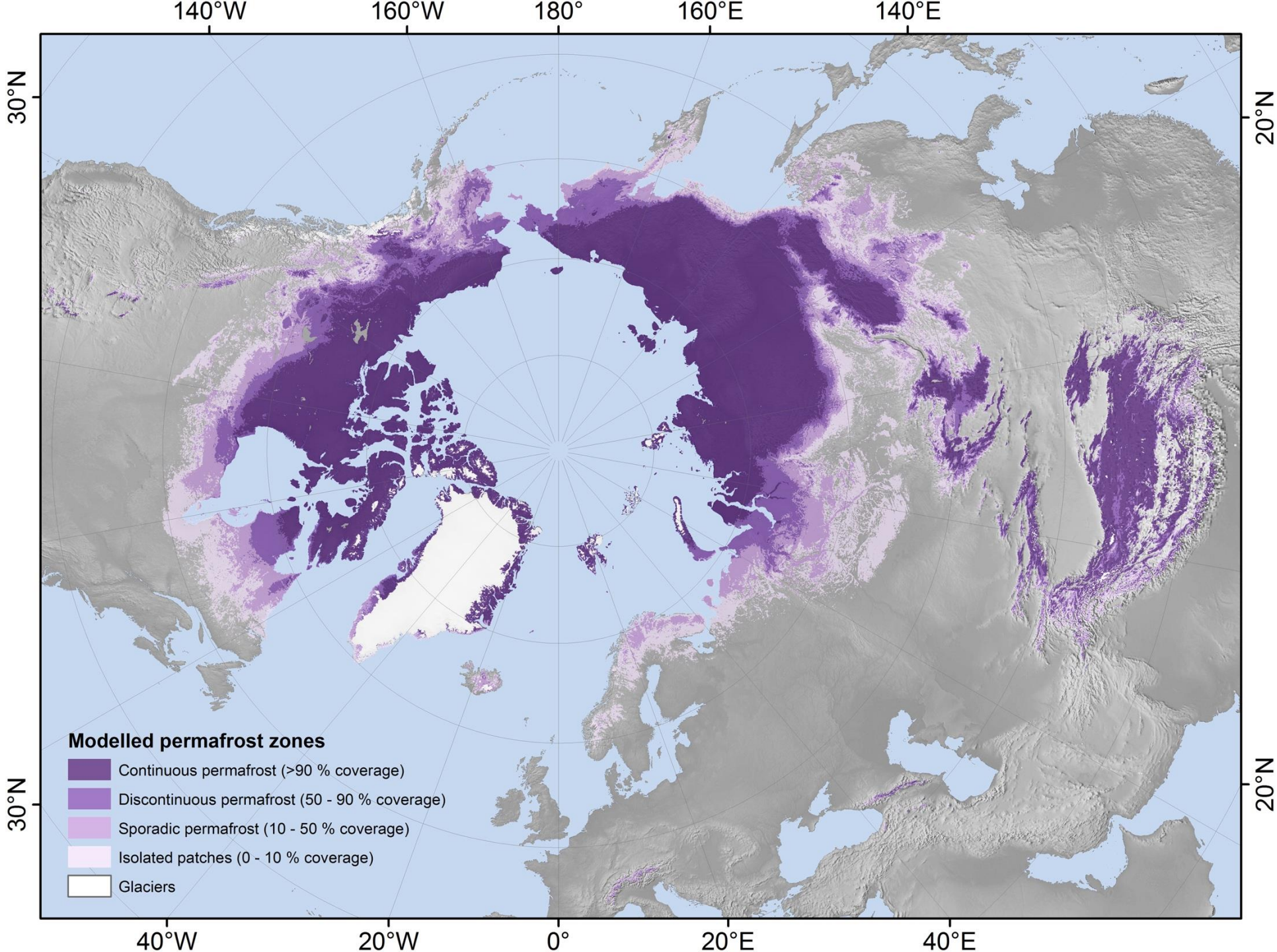
Microbial metabolism

Greenhouse gasses

CH_4 CO_2

Climate Warming

M. Schwab


140°W
160°W
180°
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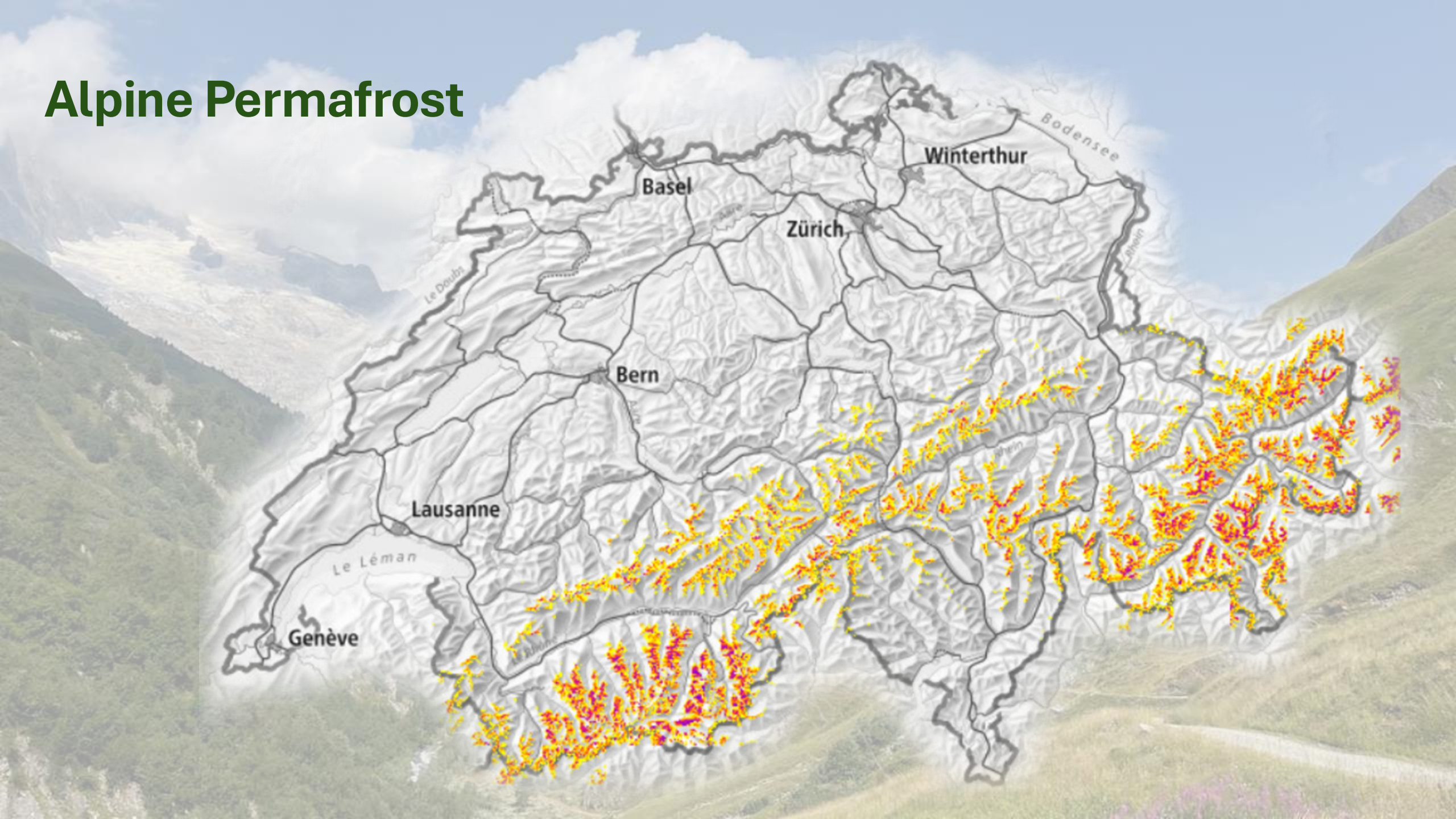
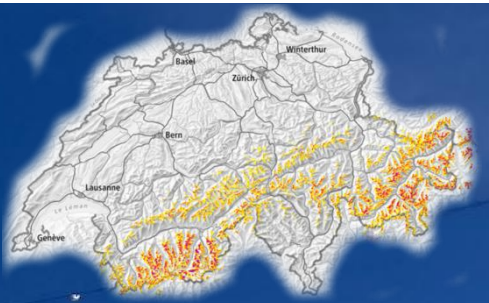
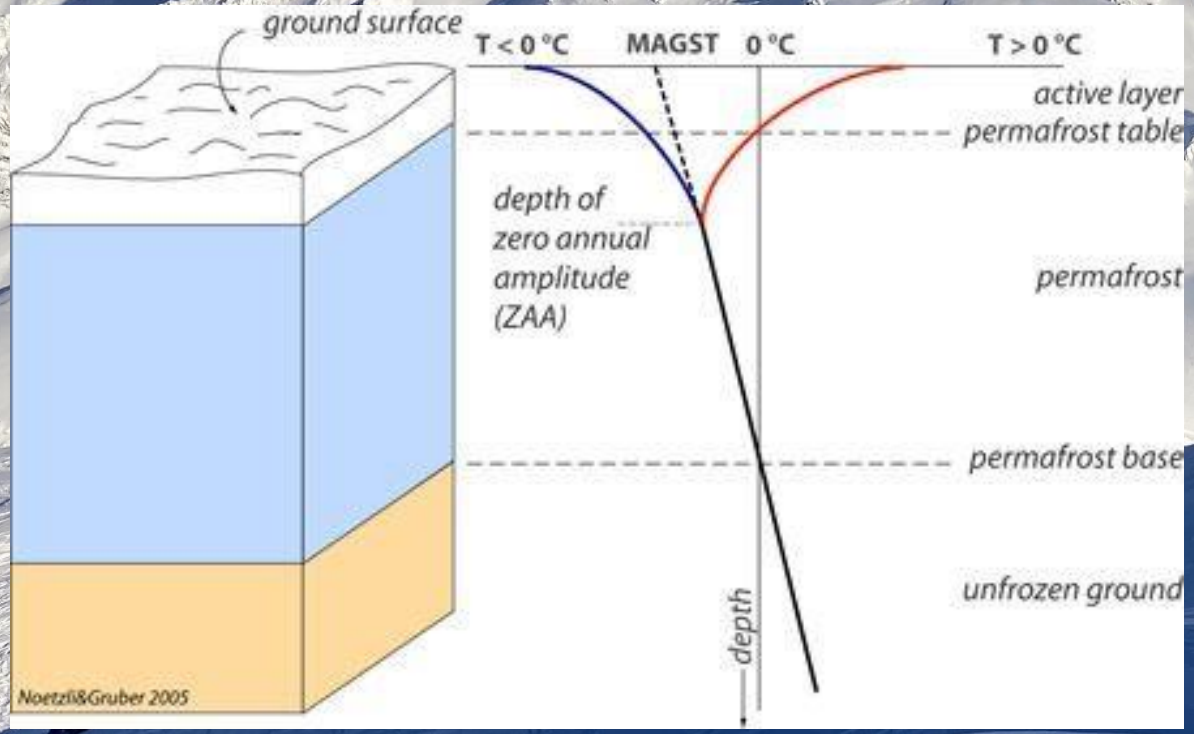
Modelled permafrost zones
Continuous permafrost (>90 % coverage)
Discontinuous permafrost (50 - 90 % coverage)
Sporadic permafrost (10 - 50 % coverage)
Isolated patches (0 - 10 % coverage)
Glaciers
40°W
20°W
0°
20°E
40°E

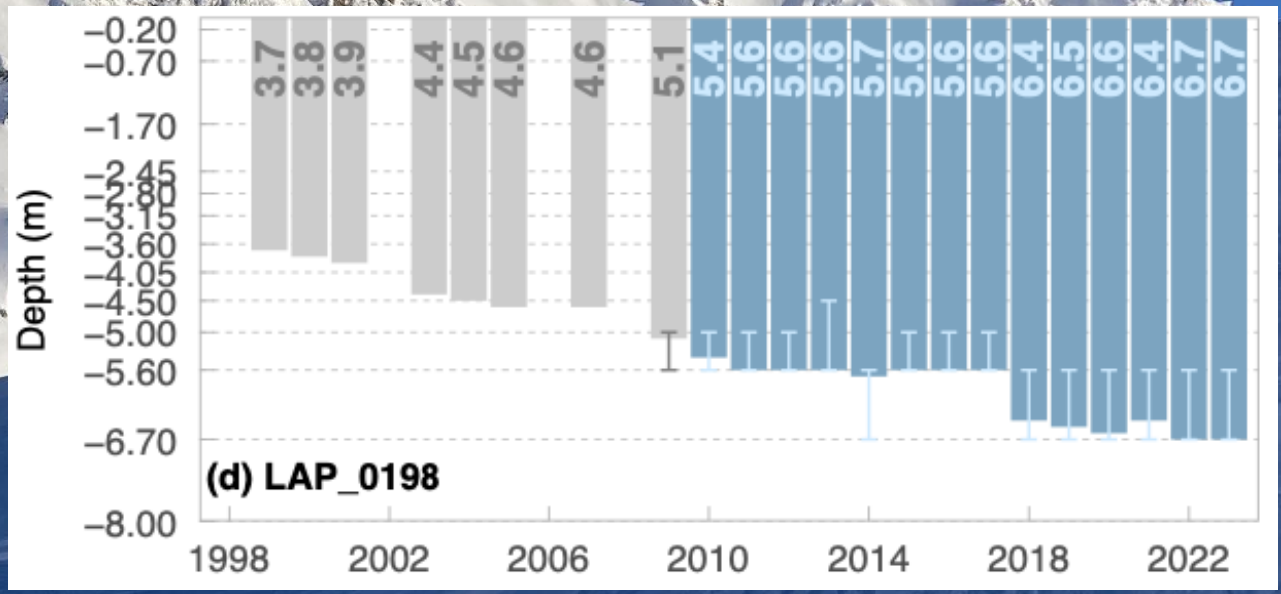
Alpine Permafrost



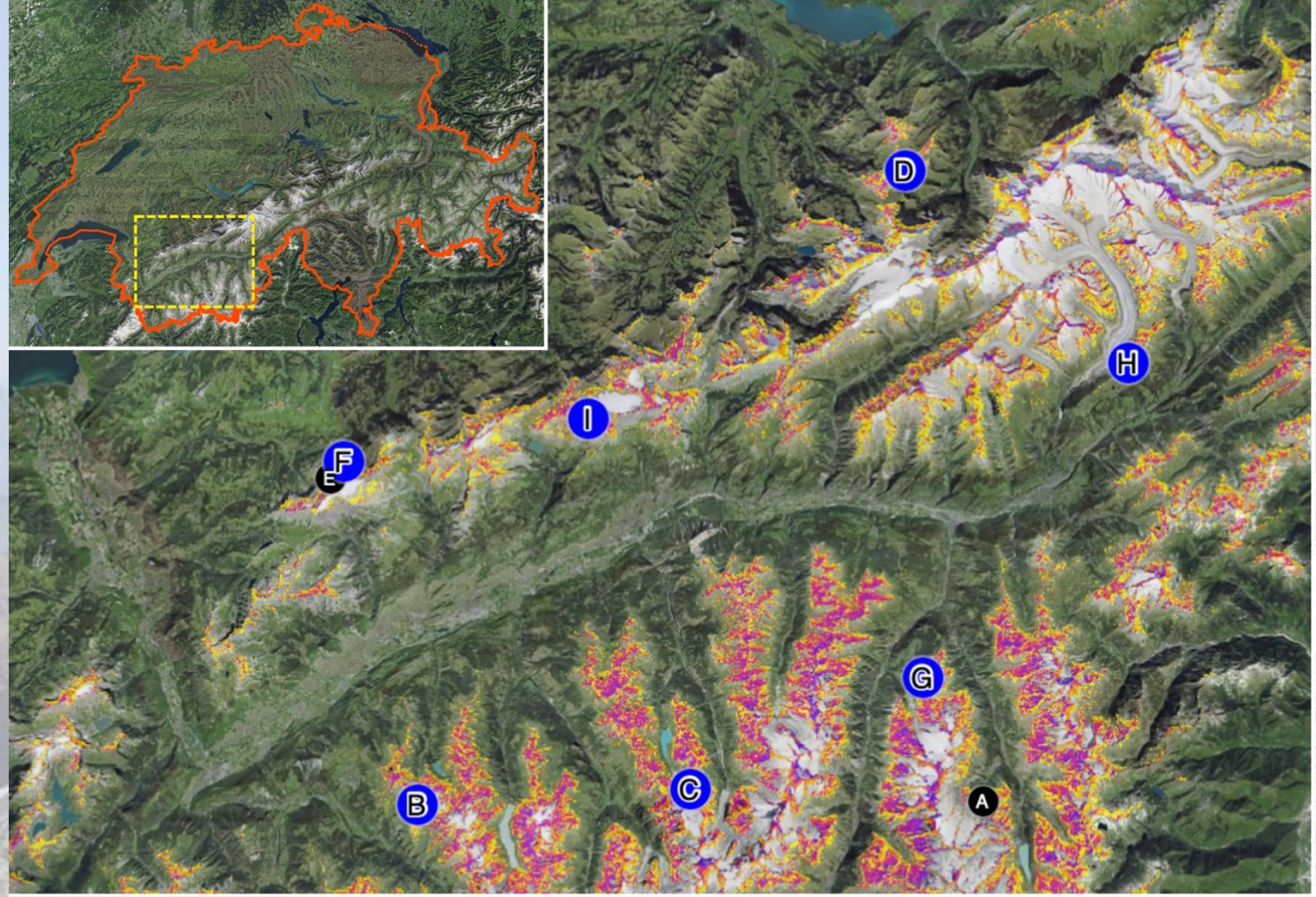
Alpine Permafrost



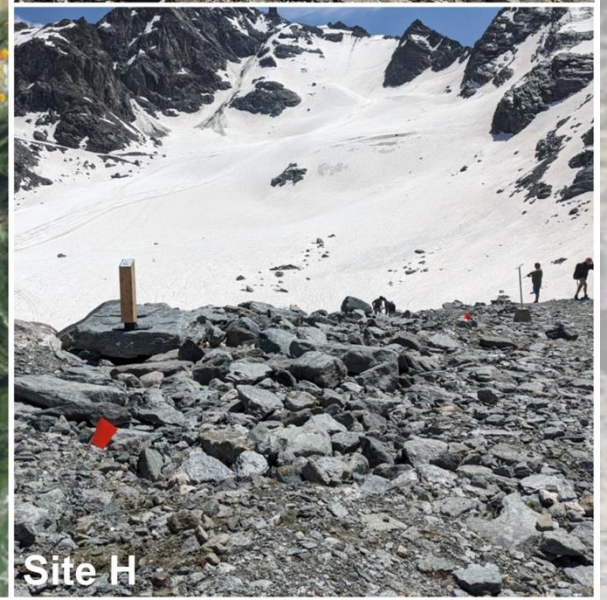




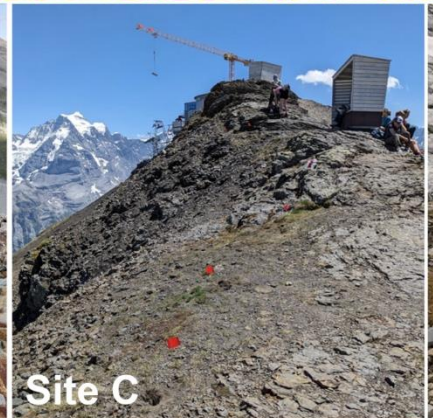
PERMOS, 2023

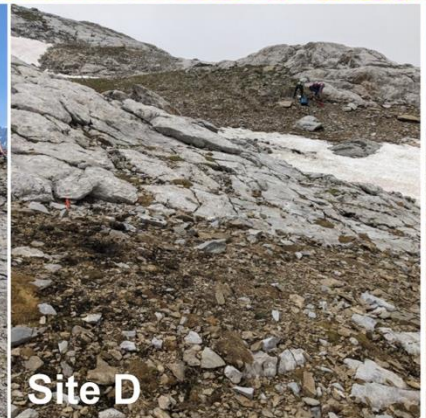

D
H
I
F
E
G
B
C
A

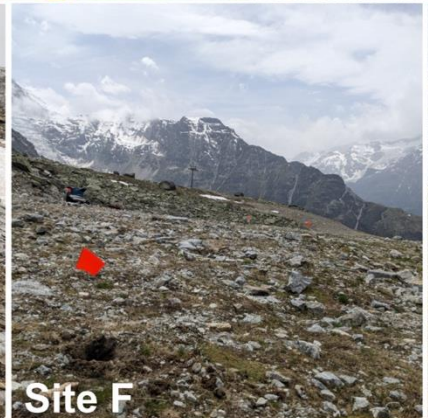

Site I

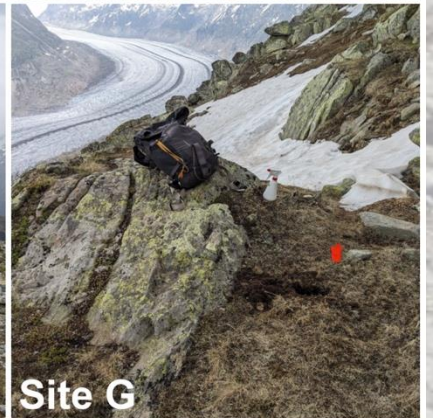

Site H


Site B

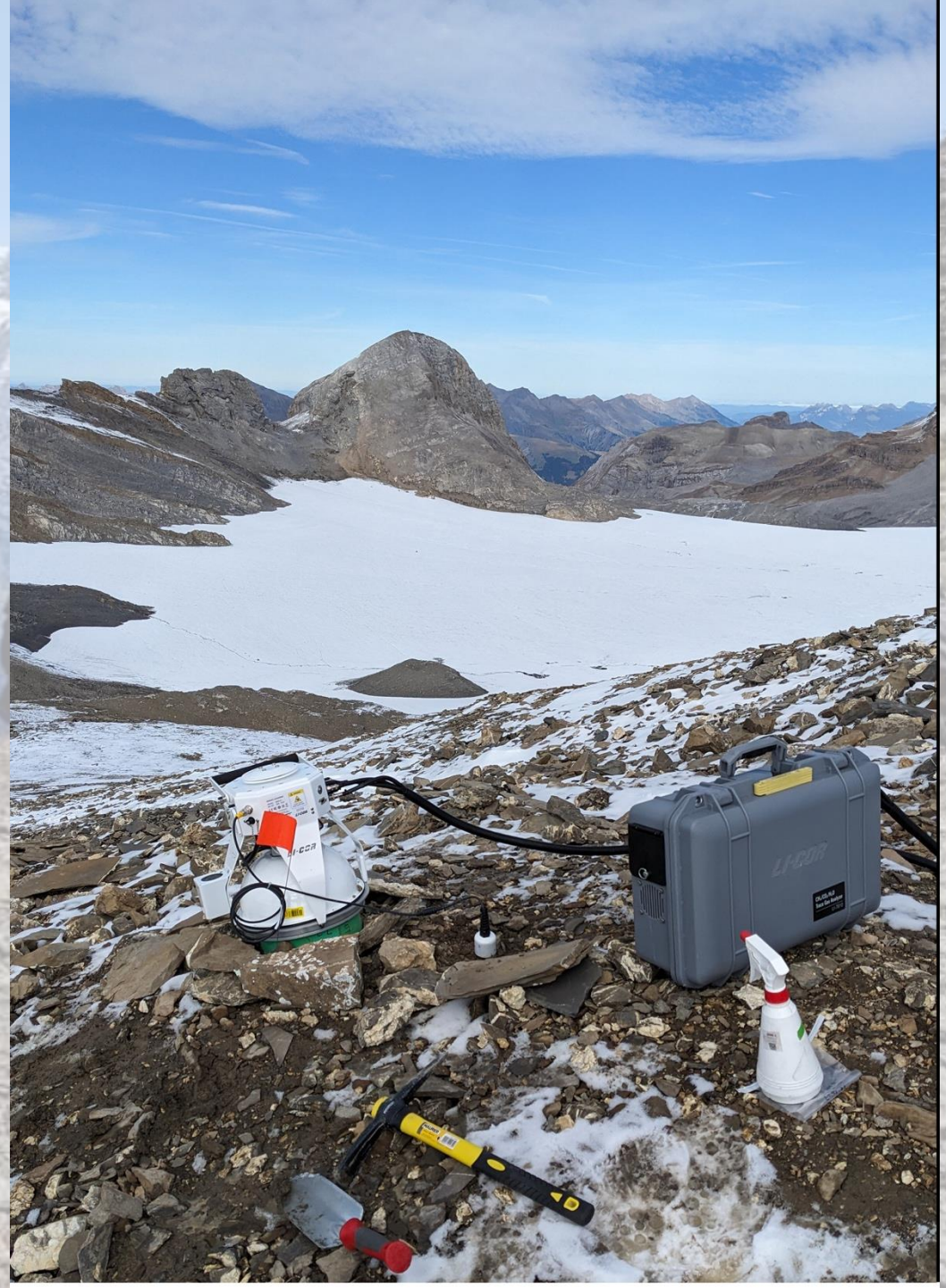

Site C

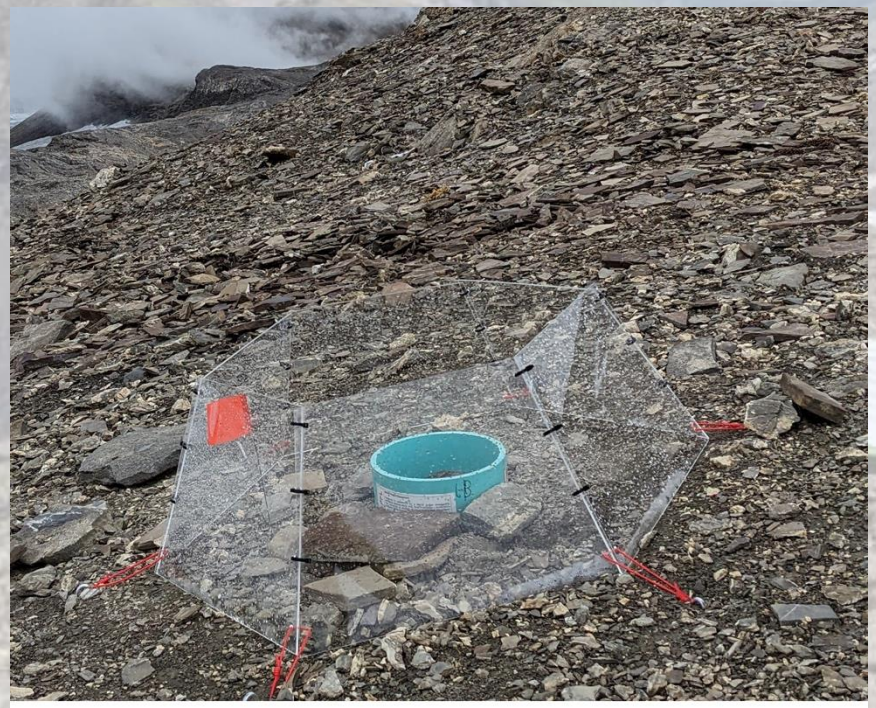

Site D


Site F

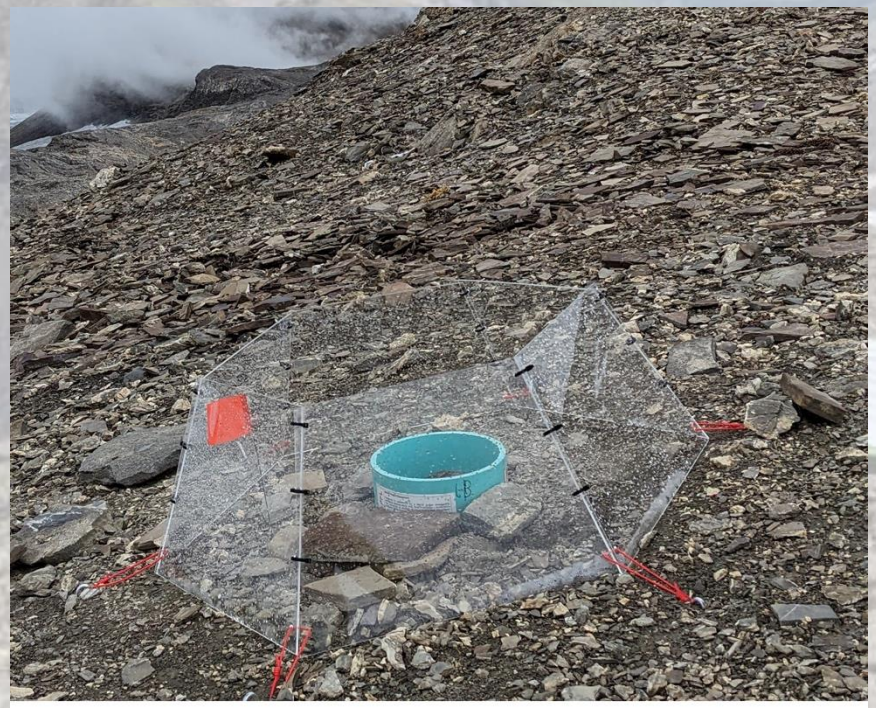

Site G

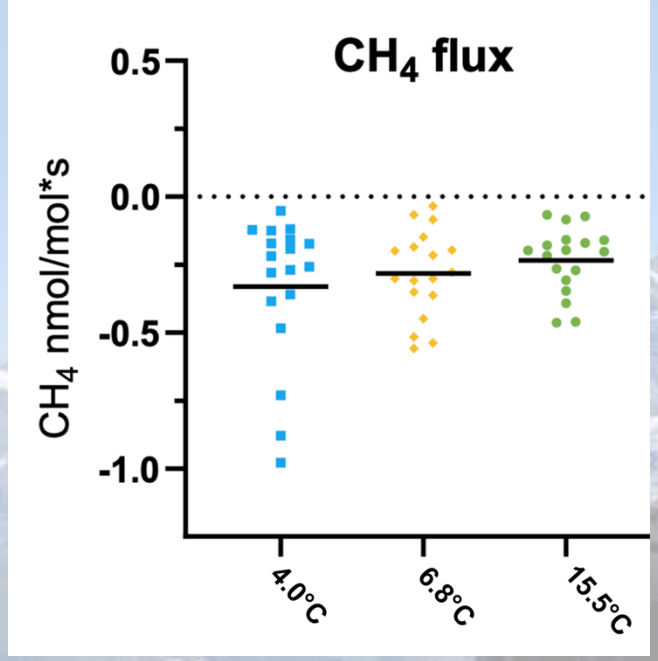
Plaine Morte

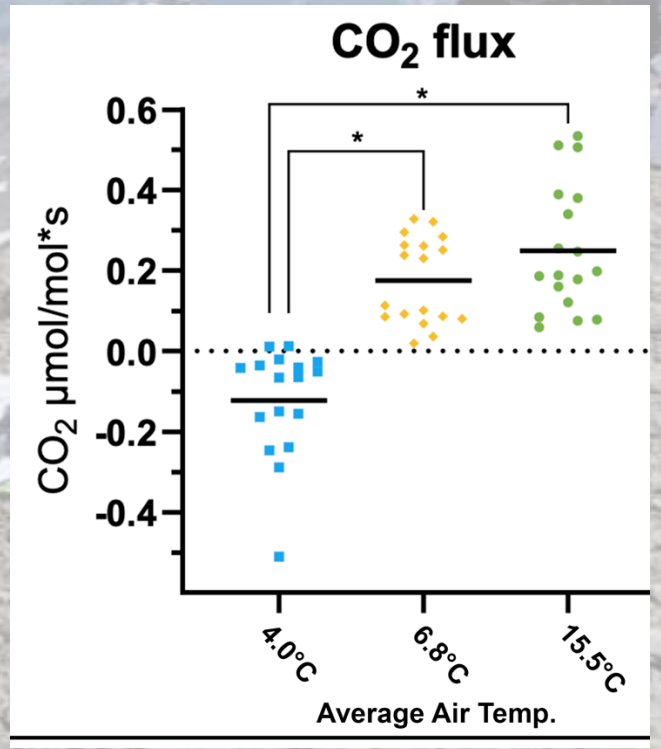





EPFL



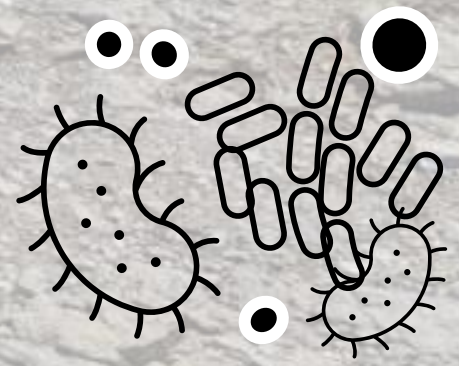


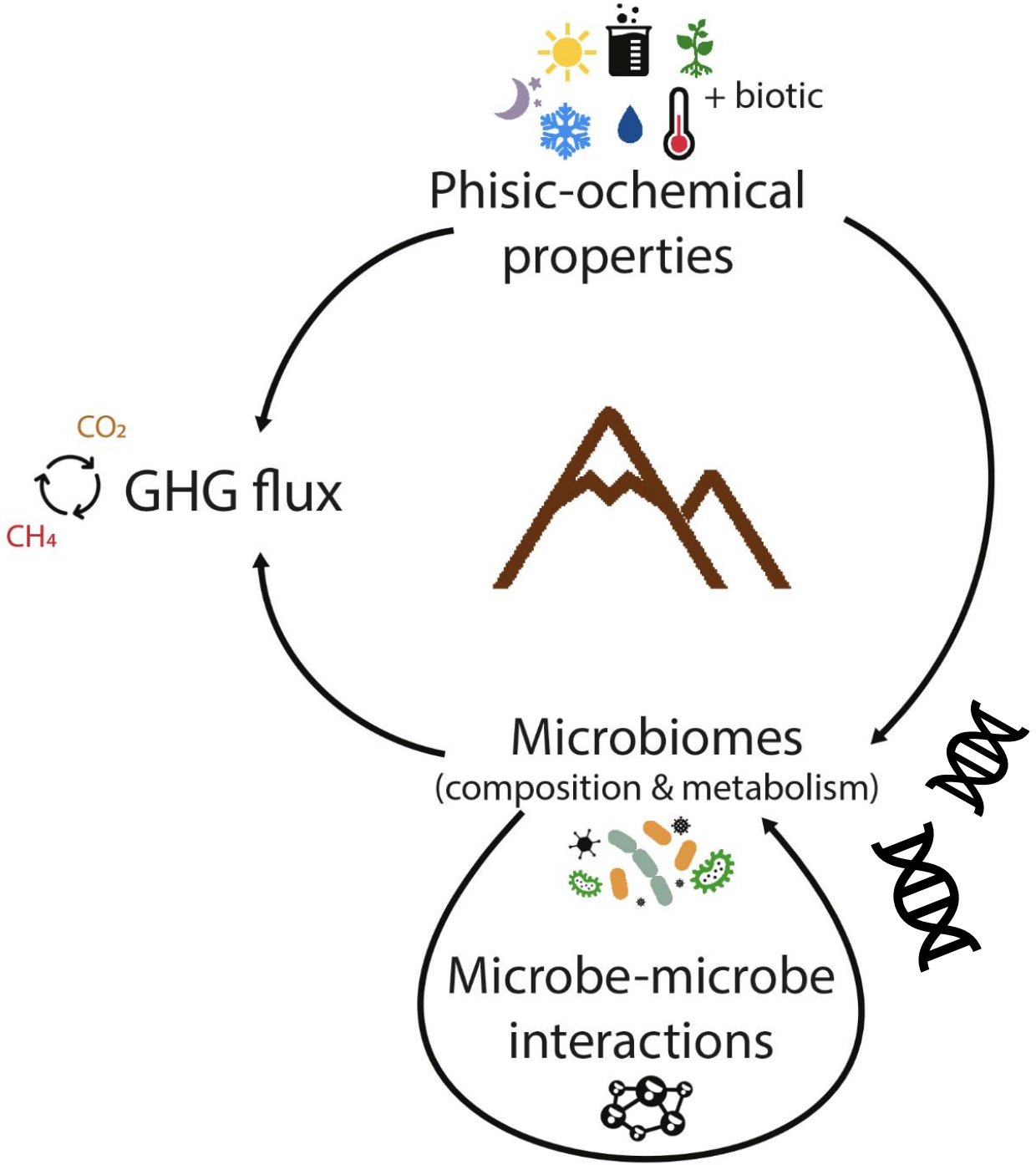


Permafrost zones in the Alps act as sinks of CH^4

$CH_4 \rightarrow CH_3OH$
Methanotrophs

Warmer temperature stimulates microbial metabolism



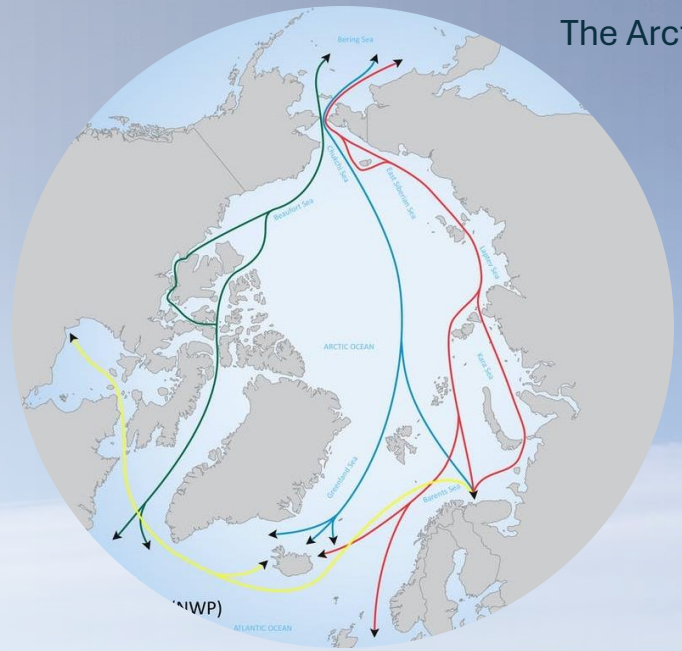

+ biotic
Phisic-ochemical properties
CO2
GHG flux
CH4
Microbiomes
(composition & metabolism)
Microbe-microbe interactions

Sea Ice Loss

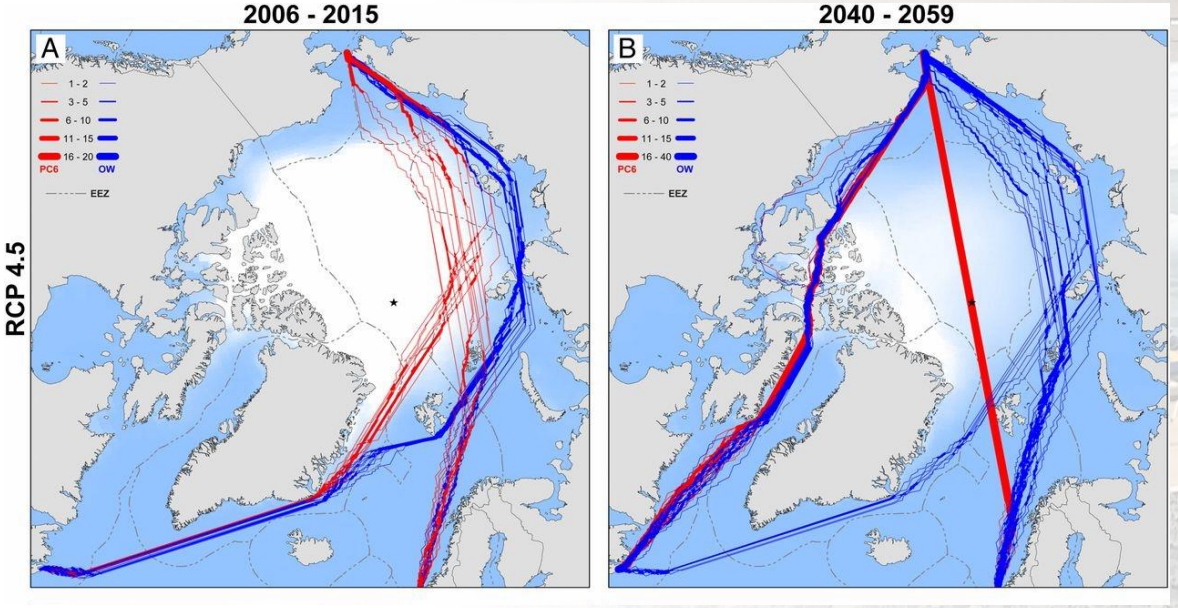
Sea Ice Loss

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

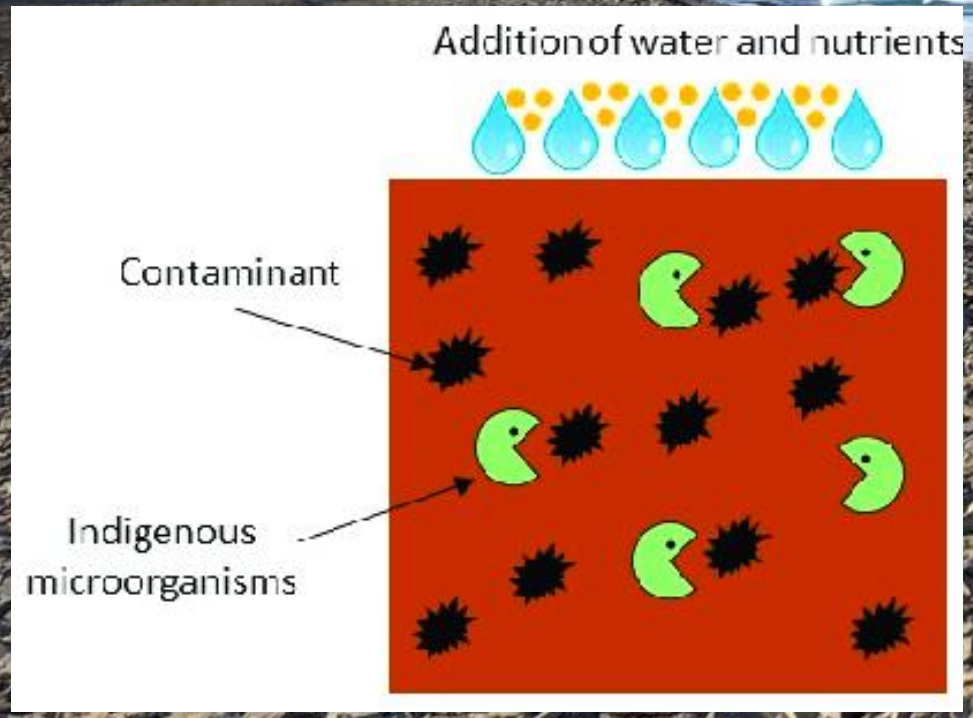
Arctic oil spill

⬇ Nitrogen

Extremely oligotrophic

Nutrient addition

Biostimulation



Arctic fuel spill

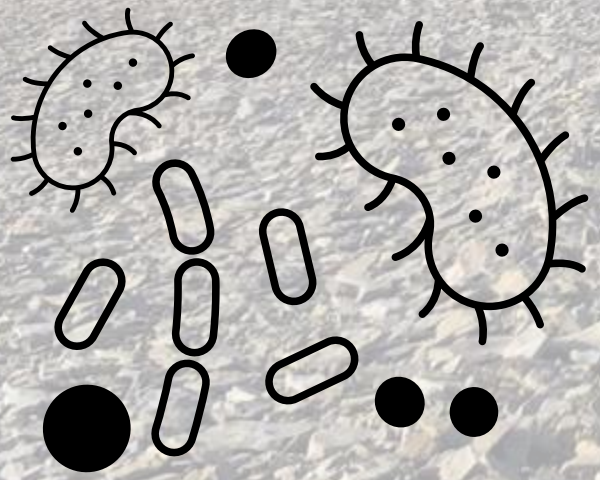
Arctic fuel spill

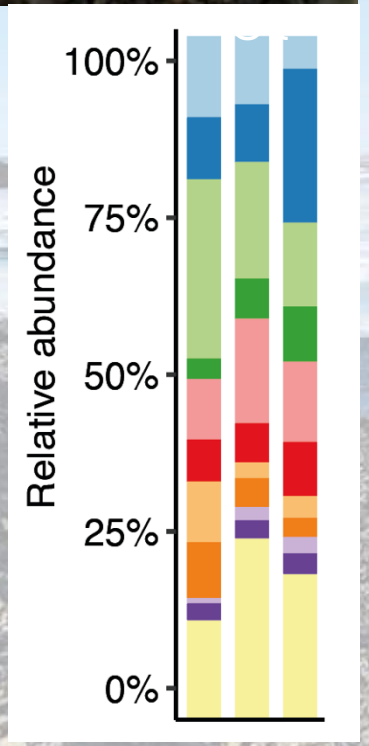
No Oil Oil Oil+ Fertilizer
MAP & S200

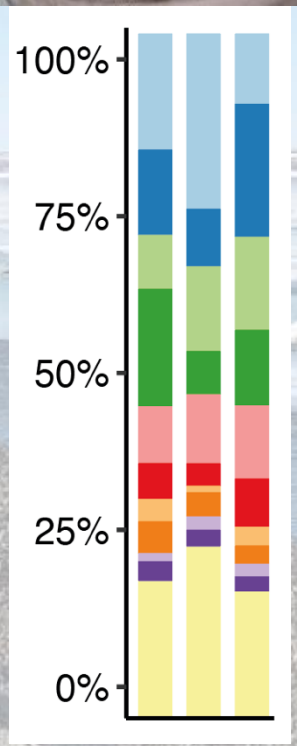
Arctic fuel spill

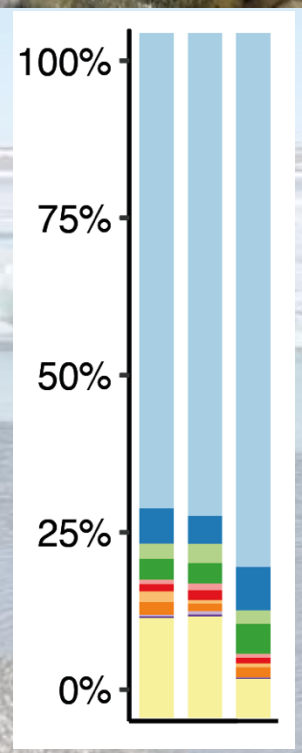
Large scale population changes and loss of biodiversity

Increase in species with hydrocarbon degradation ability









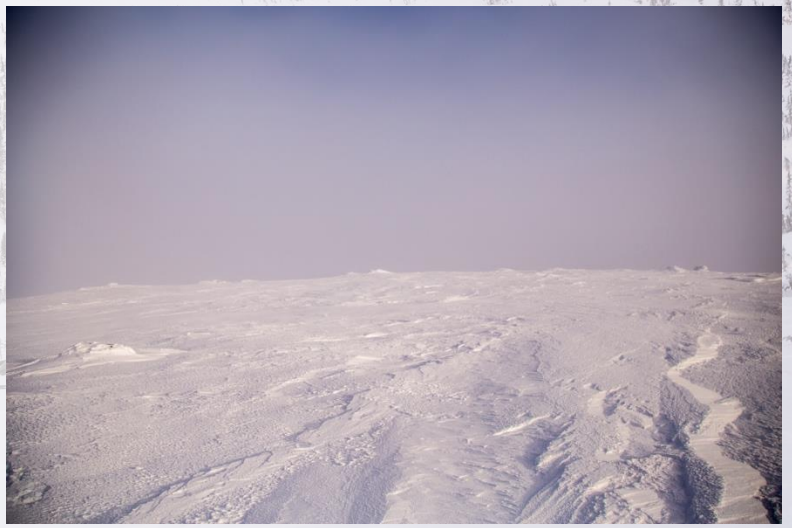
Chitinophagales
Xanthomonadales
Granulosicoccales
Flavobacteriales
Burkholderiales
Sphingomonadales

Pseudomonadales

Oil degradation

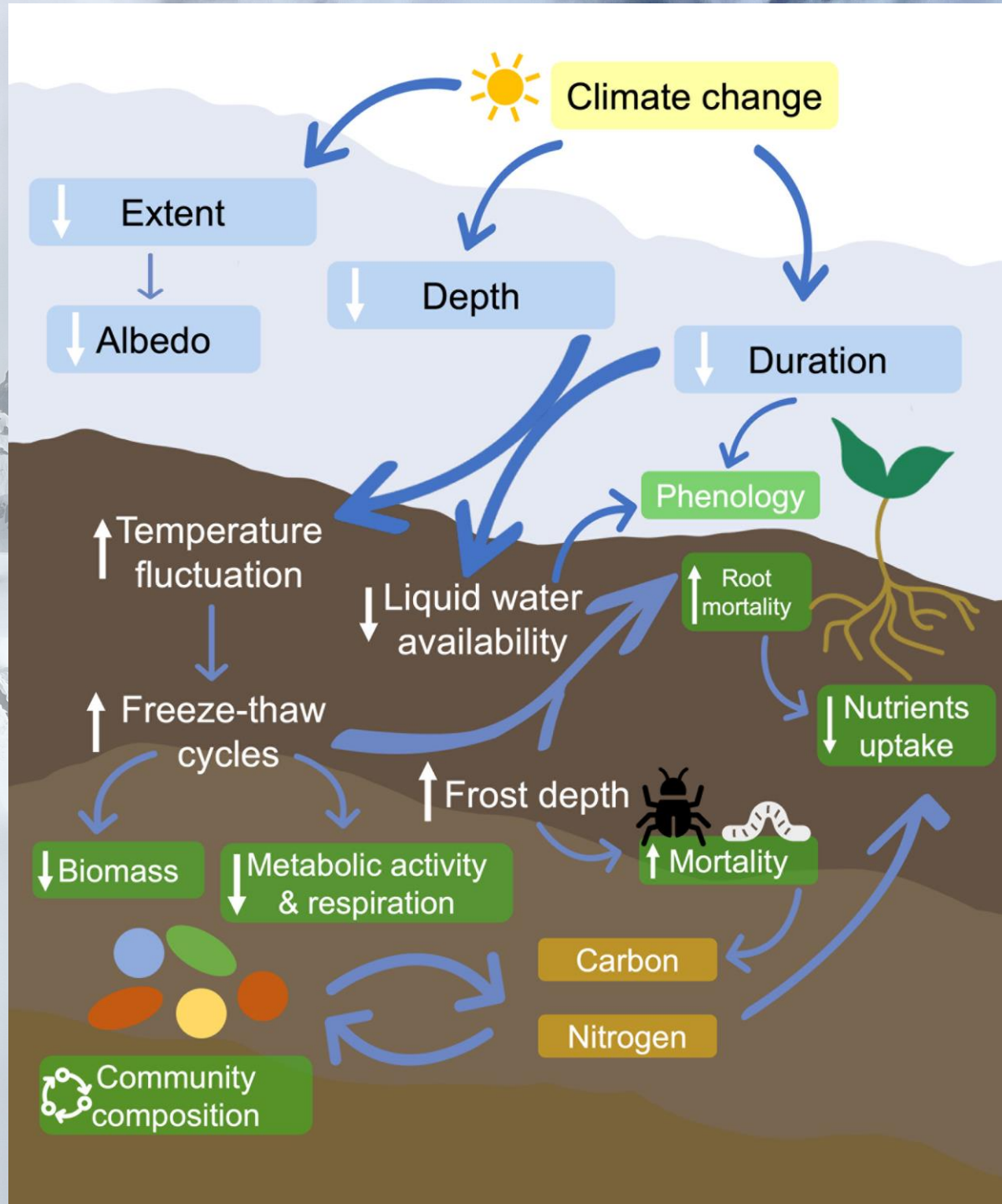
Snow Landscapes

Snow is a Microbial Habitat

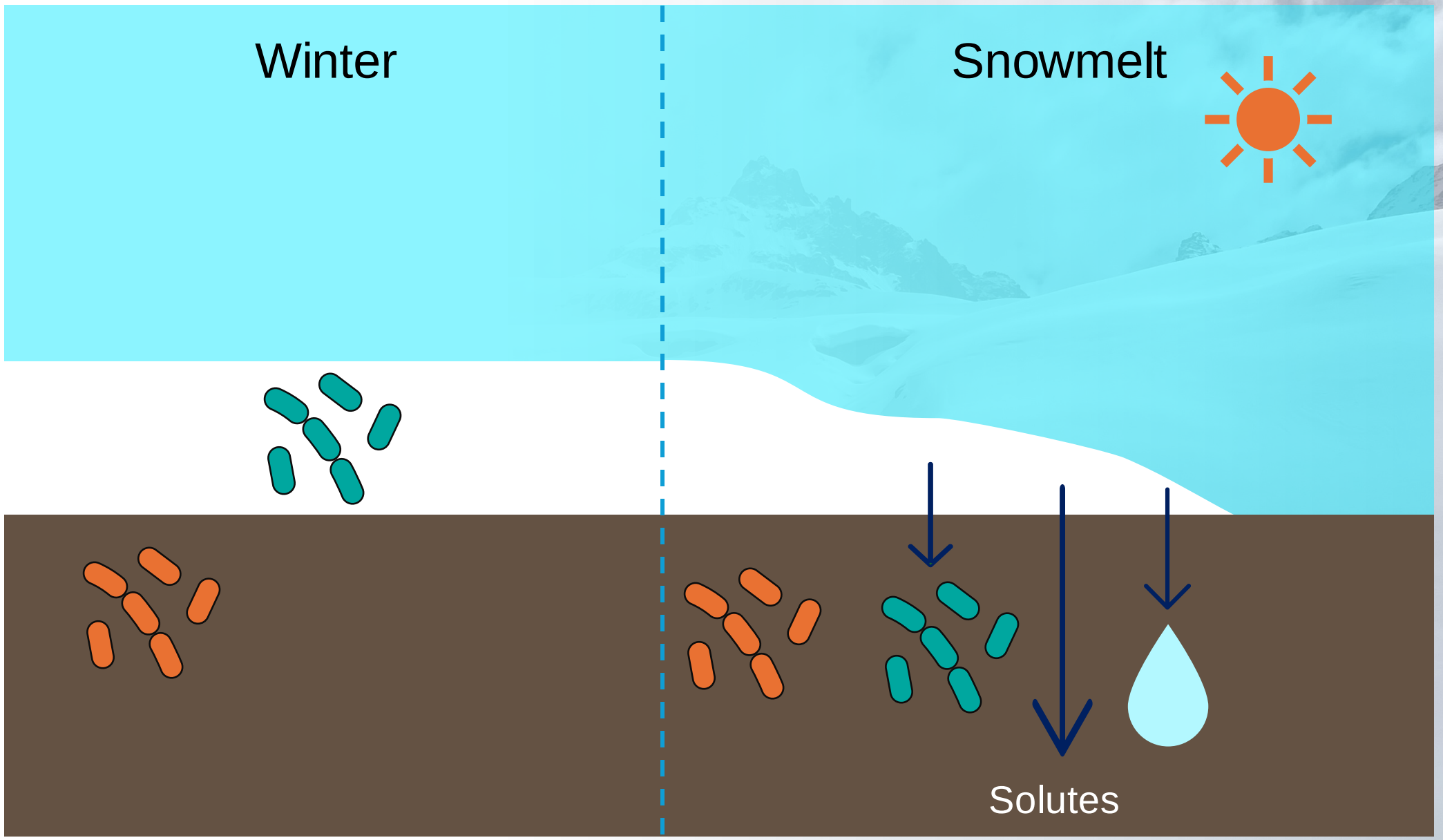


Reduction of Snow Cover and Depth in Alpine Ecosystems

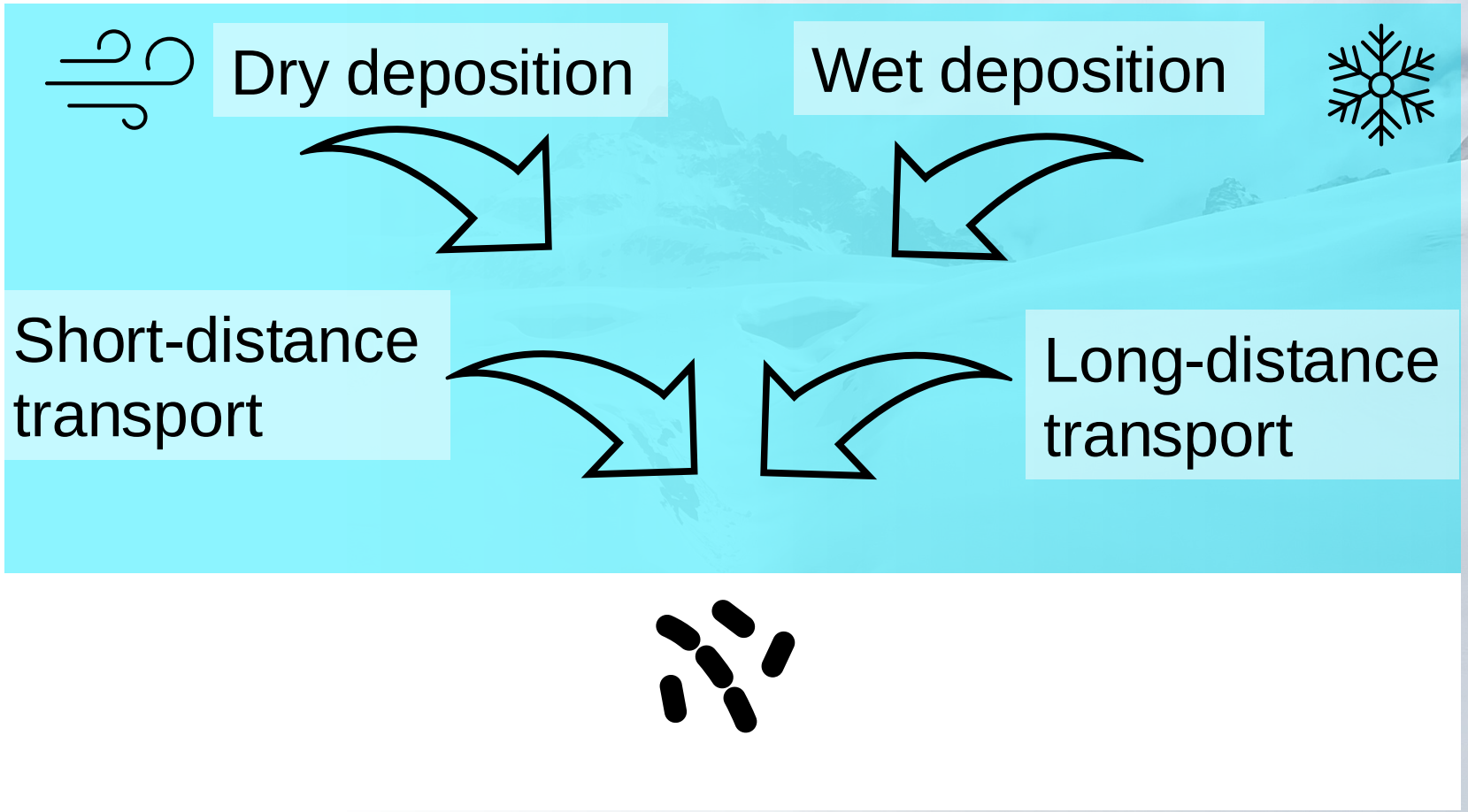
- Reduced albedo
- Loss of snow insulation
- Loss of native local biodiversity
- Reduced soil microbial buffering capacity

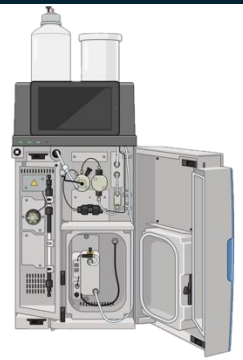


Soil and snow interplay



Snow inhabiting organisms

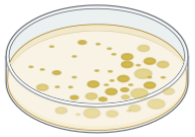




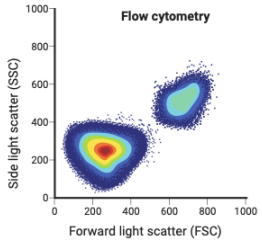
IC* measurements

Chemical composition

What is the chemisty?



CFU enumeration



Flow cytometry

Culturable microorganisms

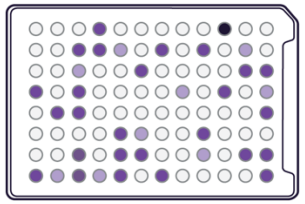
Bacterial abundance

How many microorganisms are there?

Sequencing

Community structure and function

Who are they?

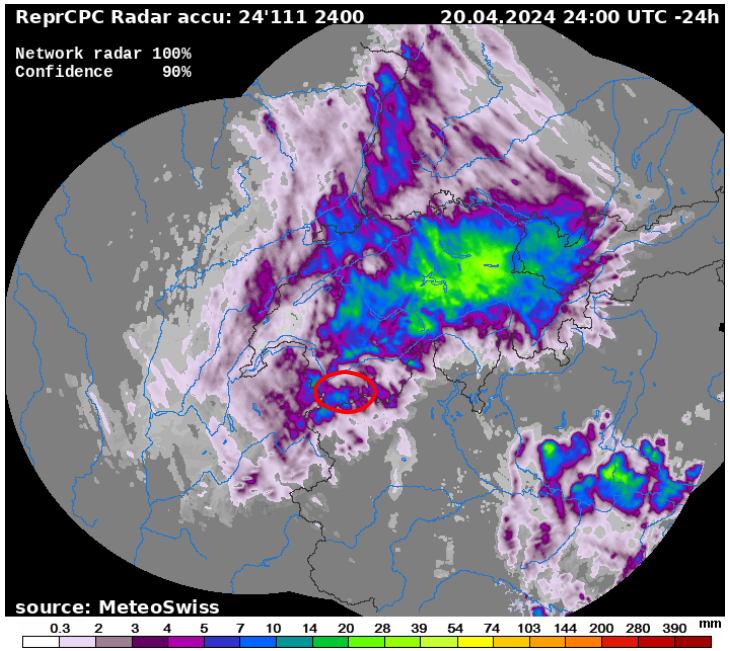


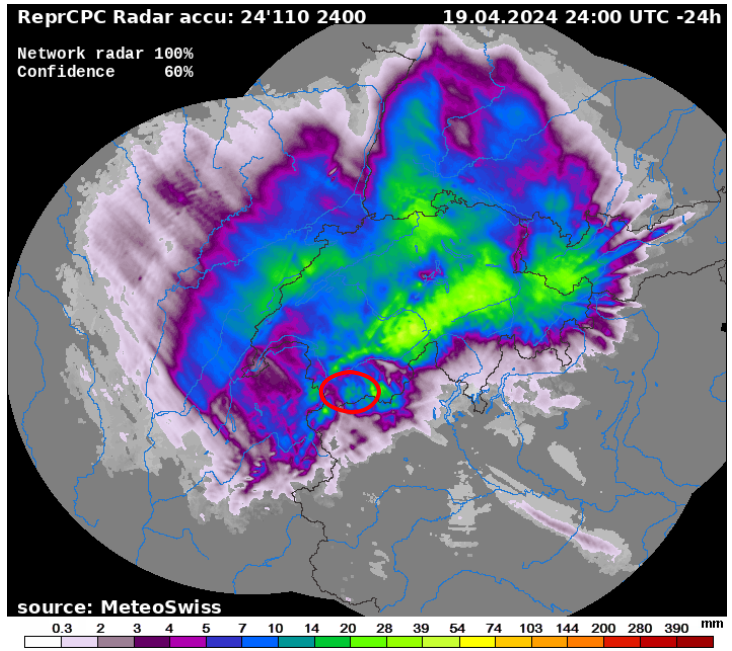
Biolog Ecoplate

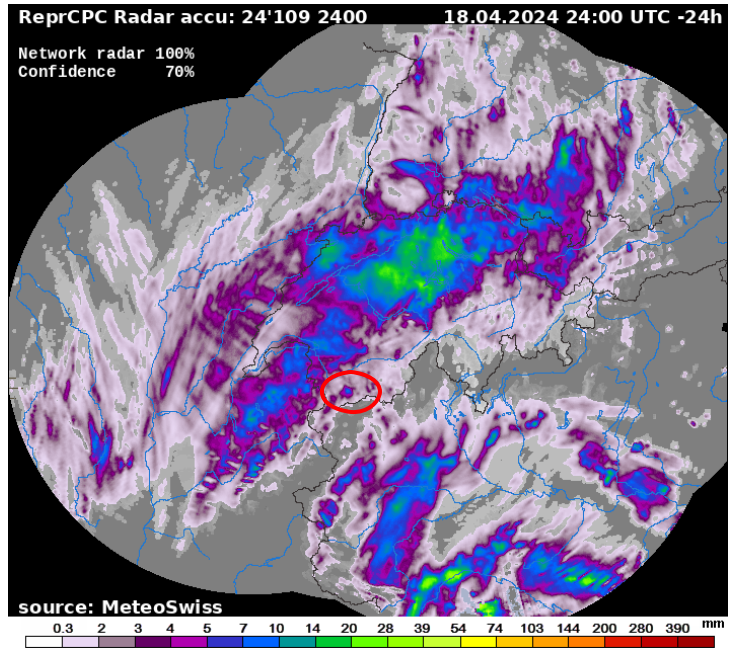
Community activity

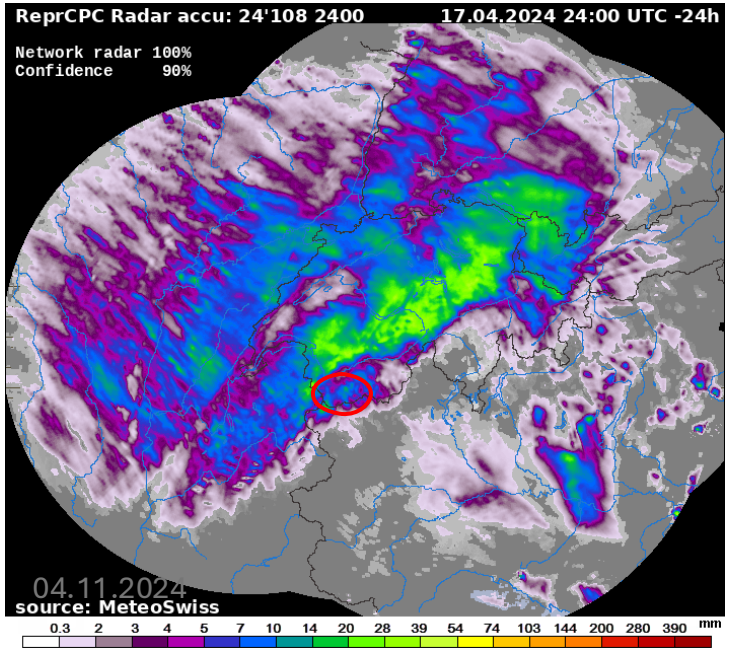
What are they doing?

Meteodata


ReprCPC Radar accu: 24'111 2400
20.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 90%
source: MeteoSwiss
0.3 2 3 4 5 7 10 14 20 28 39 54 74 103 144 200 280 390 mm


ReprCPC Radar accu: 24'110 2400
19.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 60%
source: MeteoSwiss
0.3 2 3 4 5 7 10 14 20 28 39 54 74 103 144 200 280 390 mm


ReprCPC Radar accu: 24'109 2400
18.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 70%
source: MeteoSwiss
0.3 2 3 4 5 7 10 14 20 28 39 54 74 103 144 200 280 390 mm


ReprCPC Radar accu: 24'108 2400
17.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 90%
source: MeteoSwiss
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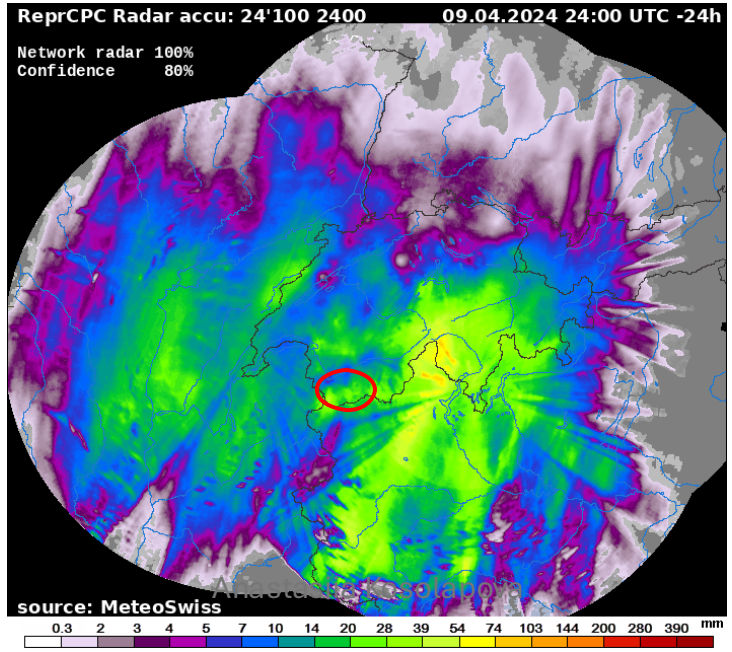
ReprCPC Radar accu: 24'100 2400
09.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 80%
source: MeteoSwiss
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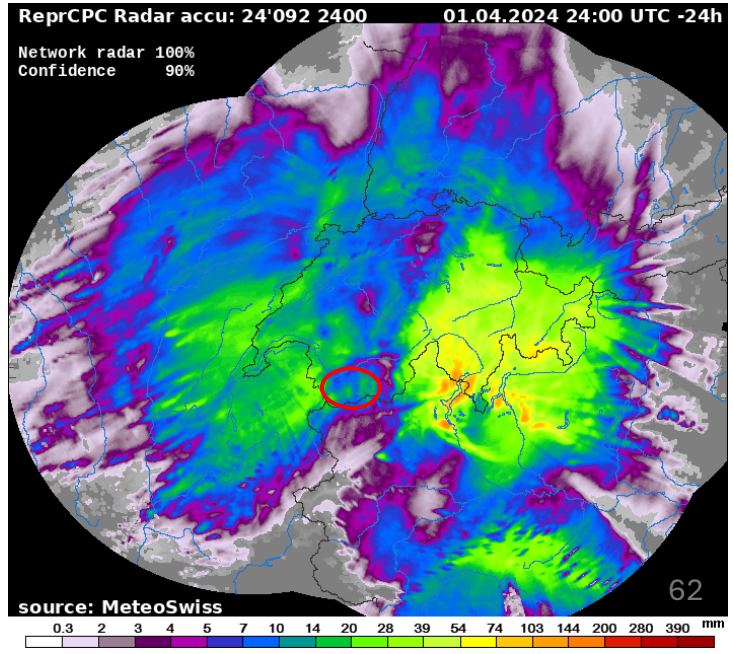
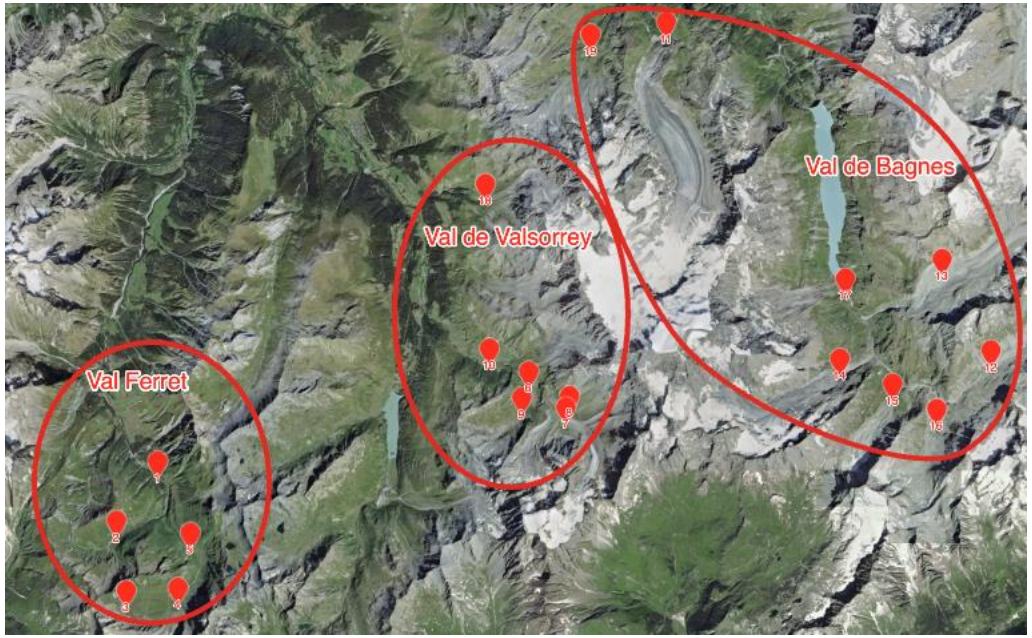
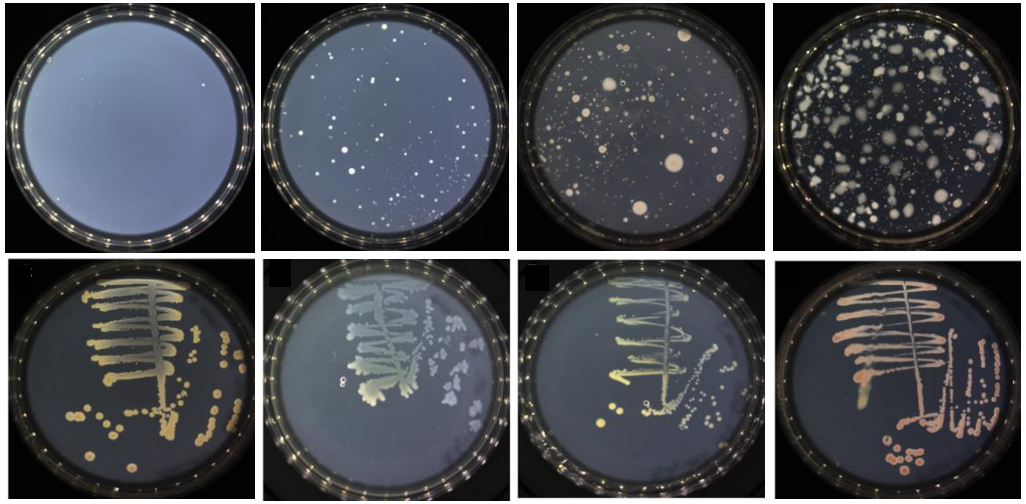
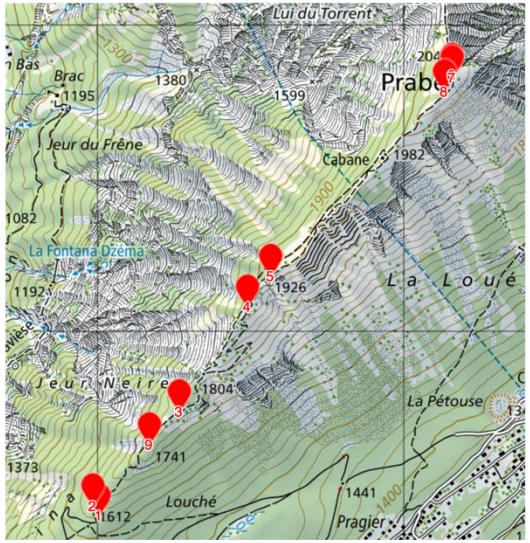

ReprCPC Radar accu: 24'092 2400
01.04.2024 24:00 UTC -24h
Network radar 100%
Confidence 90%
source: MeteoSwiss
0.3 2 3 4 5 7 10 14 20 28 39 54 74 103 144 200 280 390 mm

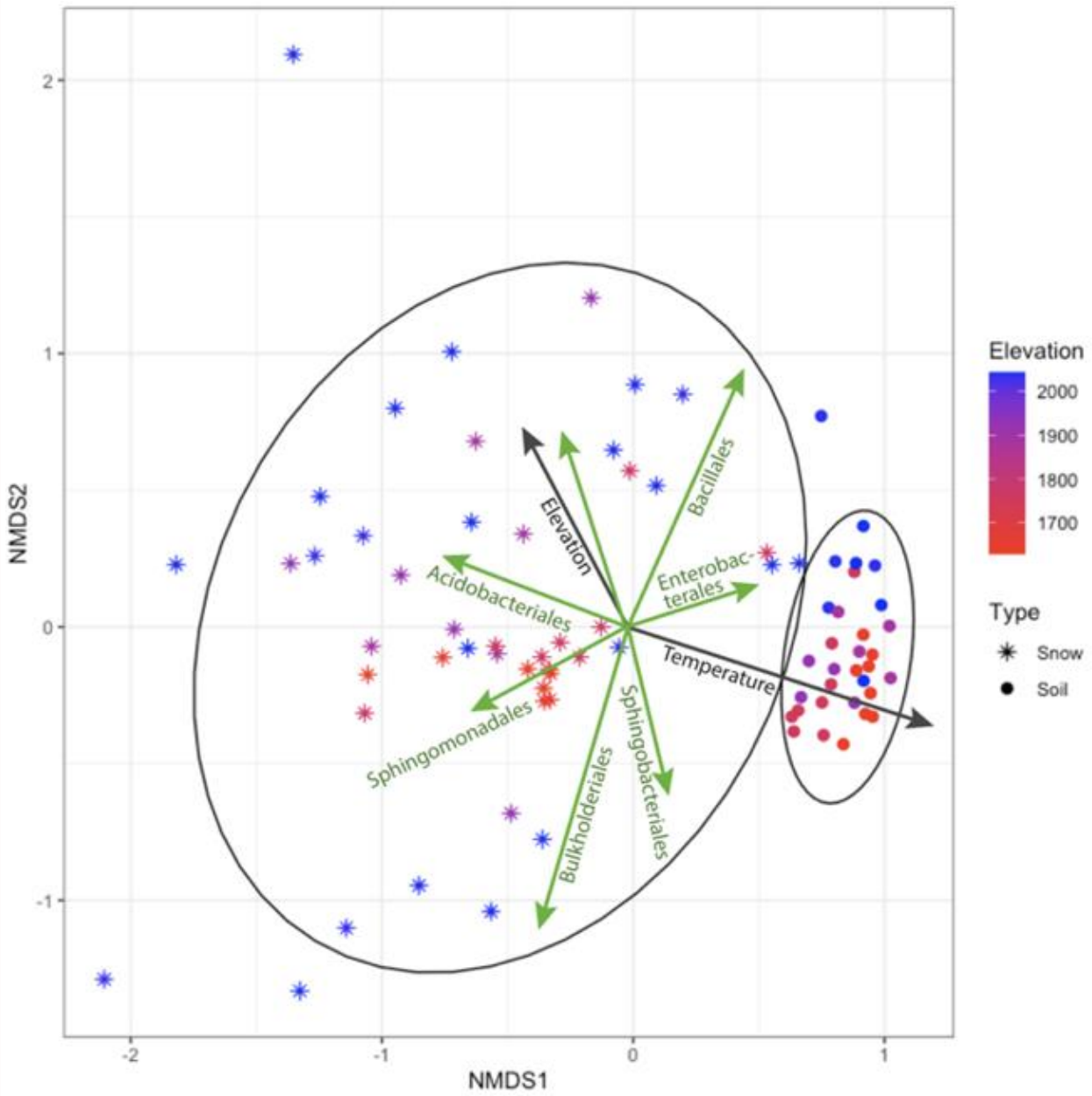


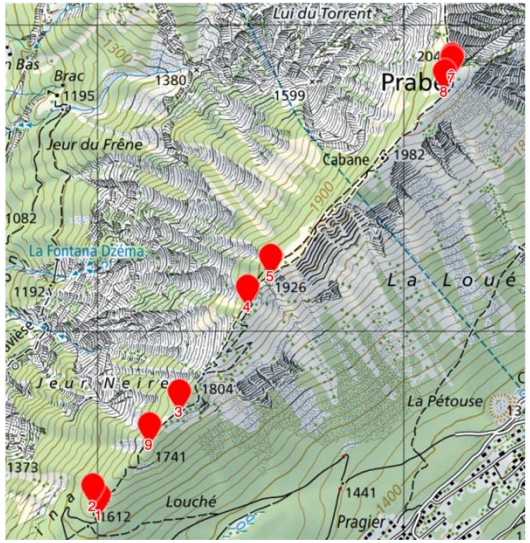


Focus on local snow microbial biodiversity and biogeographic distributions of species in neighbouring valleys



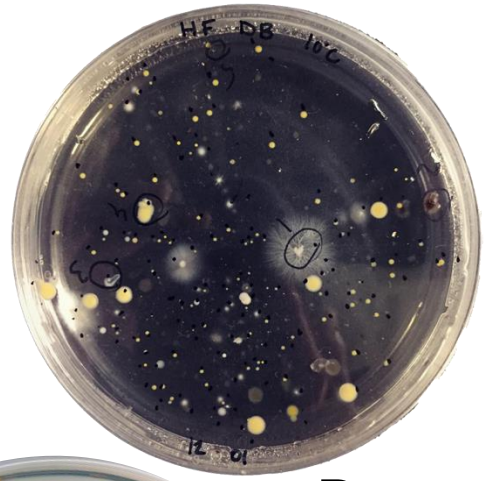
Monitor soil temperature, snow depth, and snow chemistry/microbiology across altitudinal gradients to understands their impacts on soil biodiversity

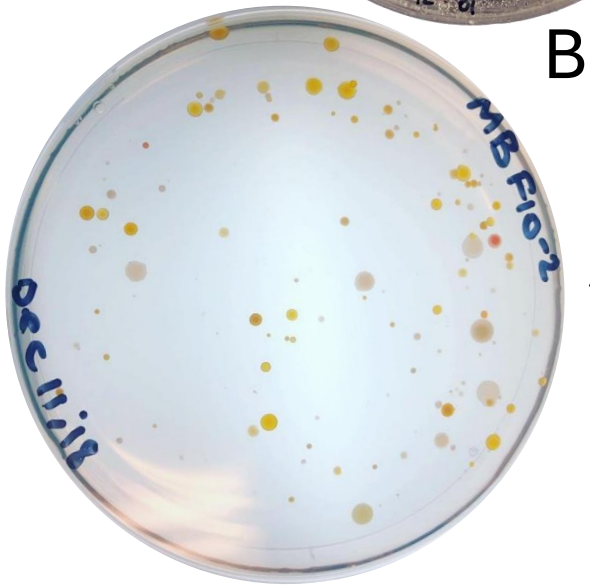




Monitor soil temperature, snow depth, and snow chemistry/microbiology across altitudinal gradients to understands their impacts on soil biodiversity

Lichen species



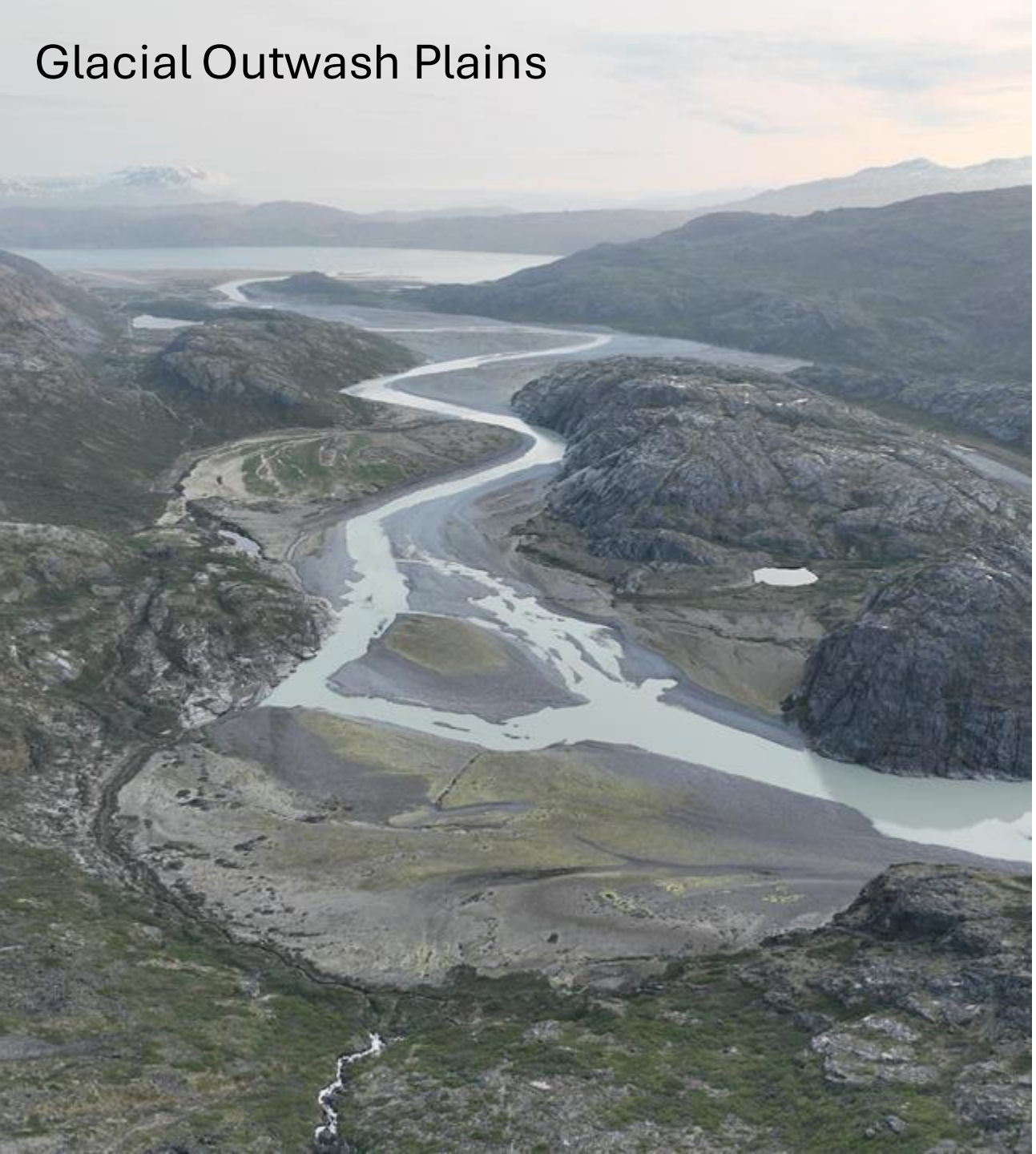


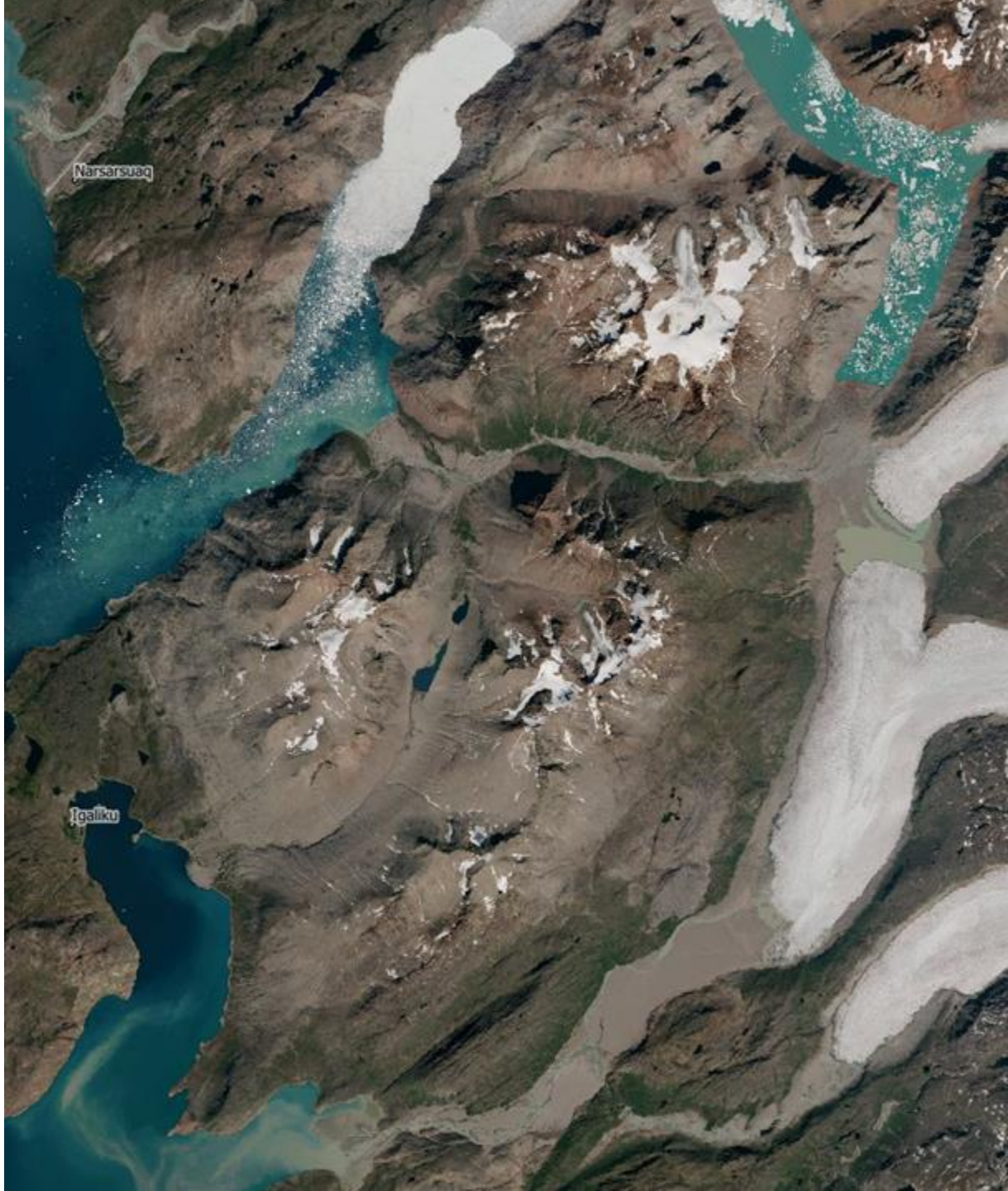
Bacteria

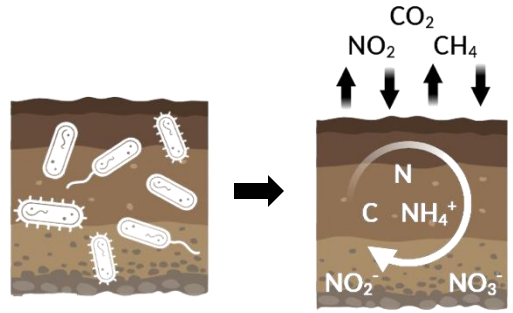
Fungi

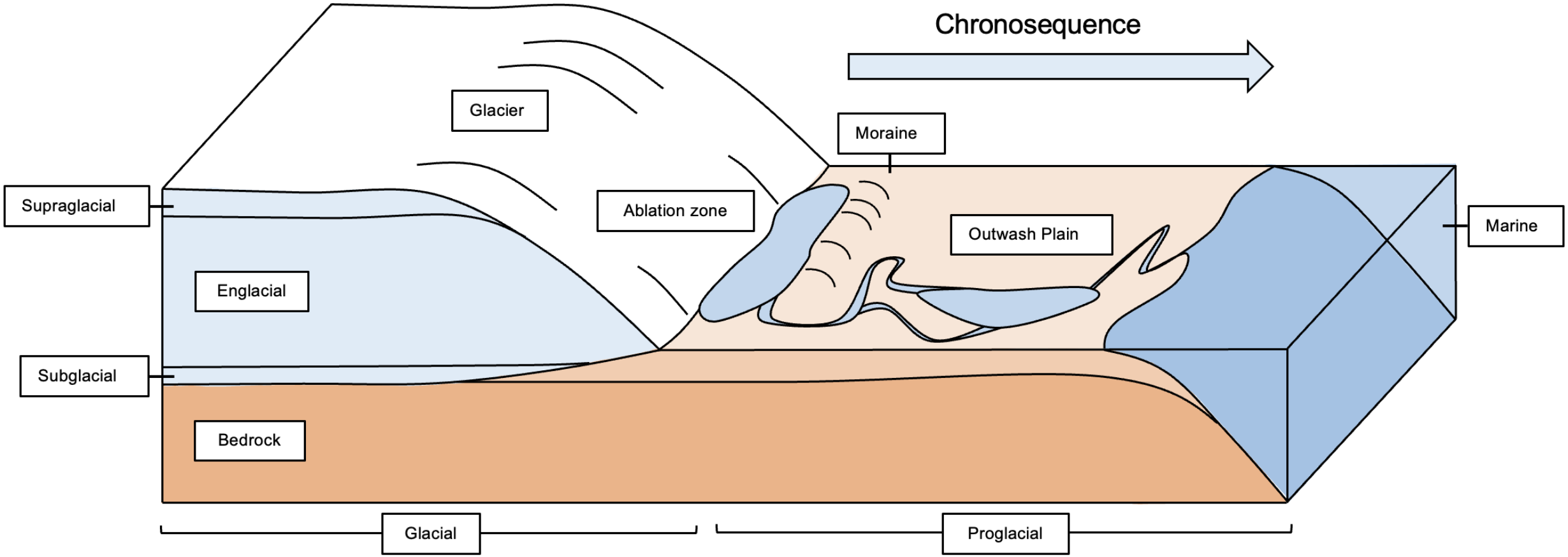
Algae

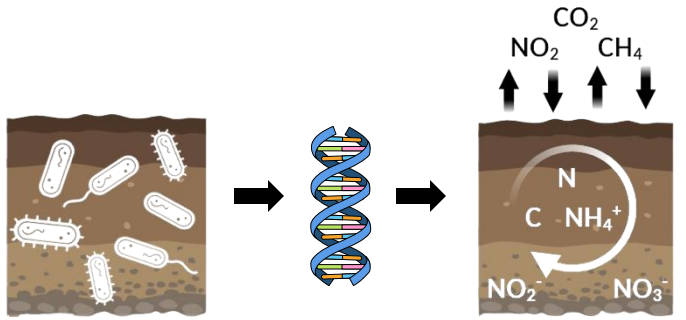
Glacial Outwash Plains






CO_2
NO_2
CH_4
N
C
NH_4^+
NO_2^-
NO_3^-


Chronosequence
Glacier
Moraine
Supraglacial
Ablation zone
Outwash Plain
Marine
Englacial
Subglacial
Bedrock
Glacial
Proglacial



Chronosequence

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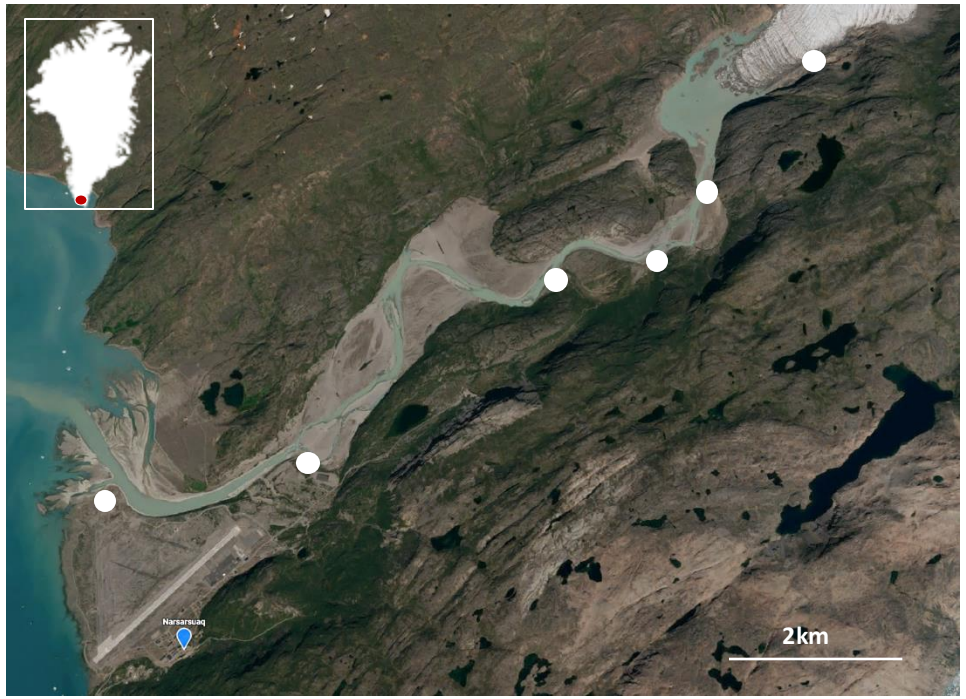
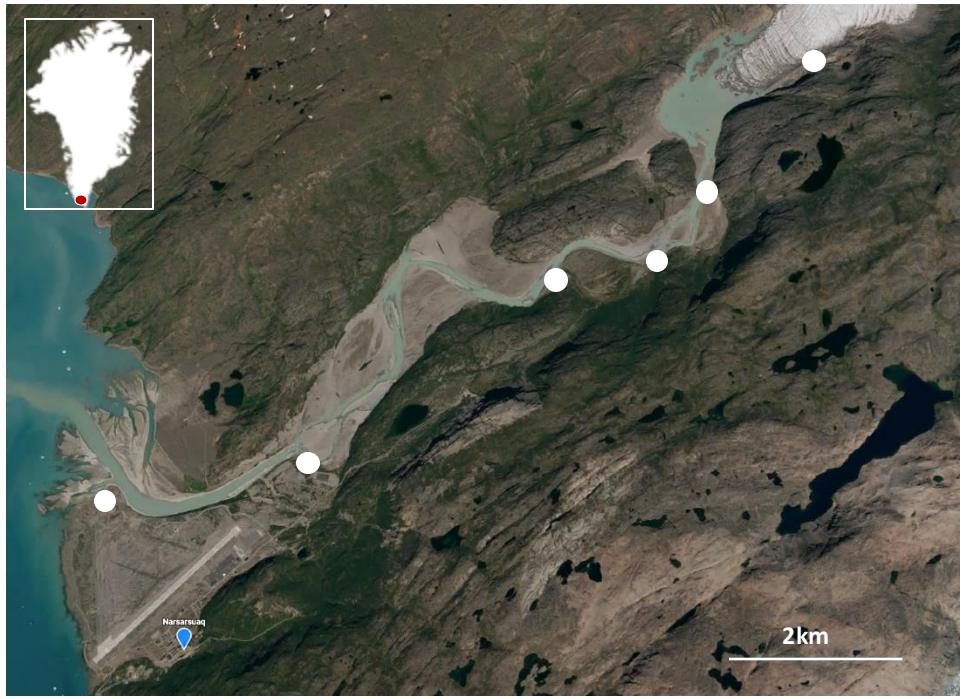


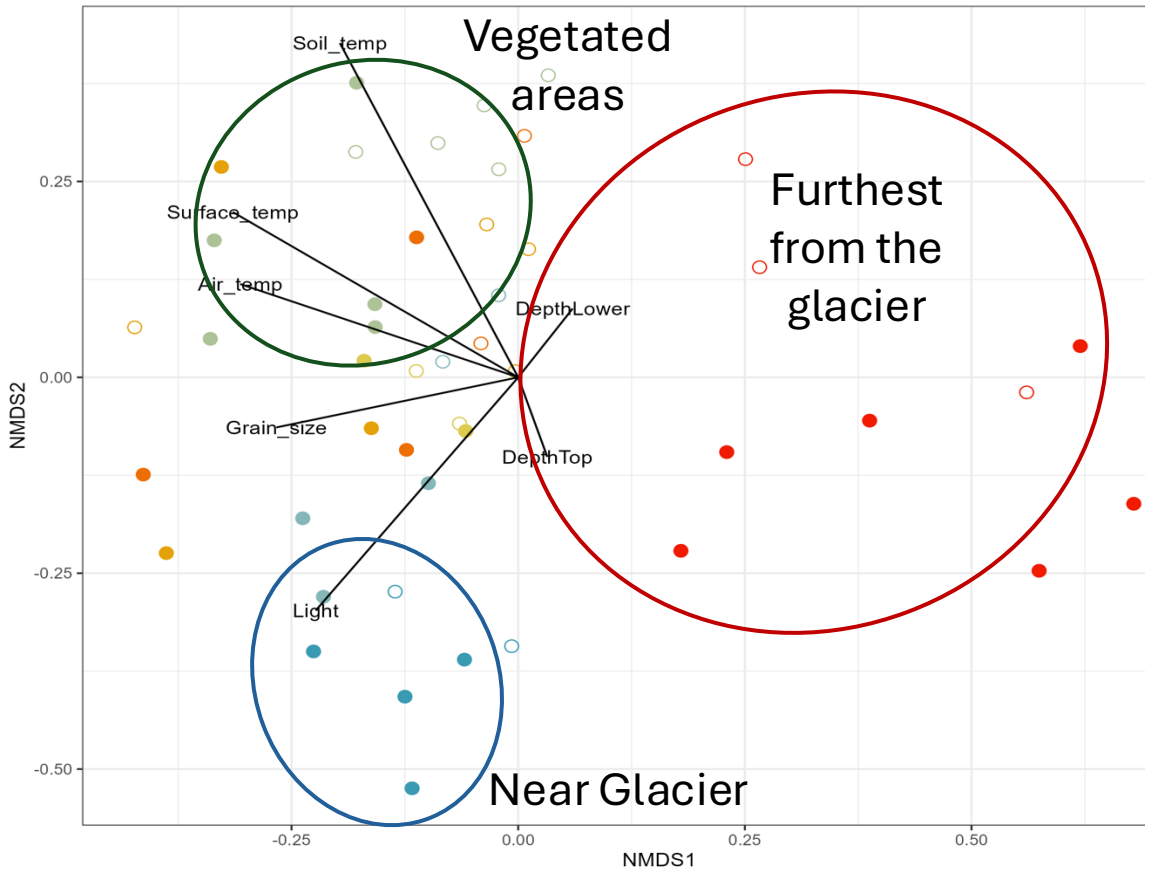
Dry bare sediments

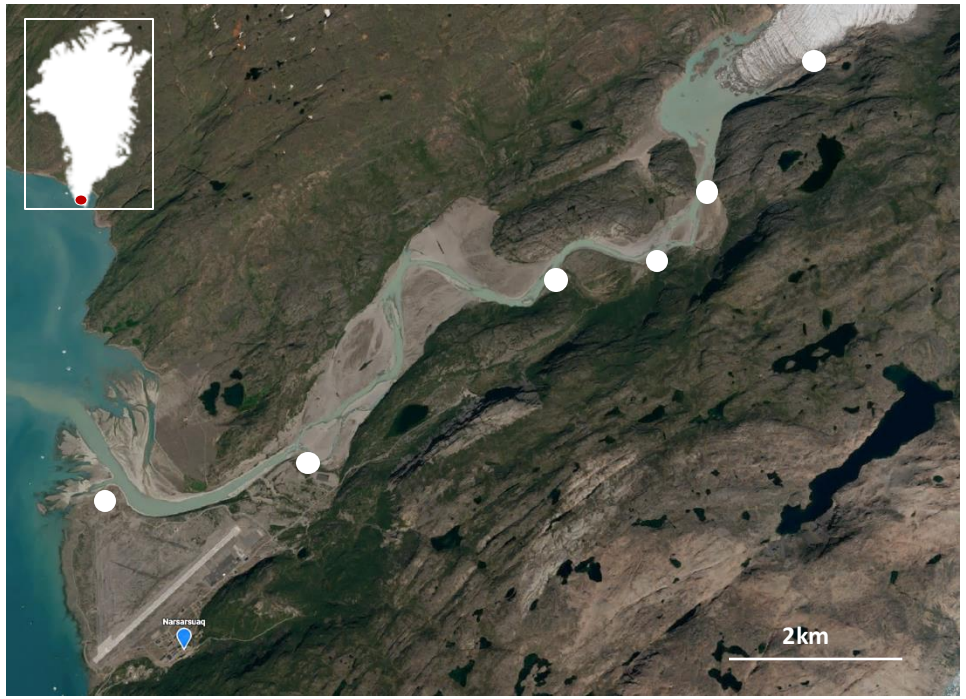
Vegetated “soils”

Waterlogged sediments



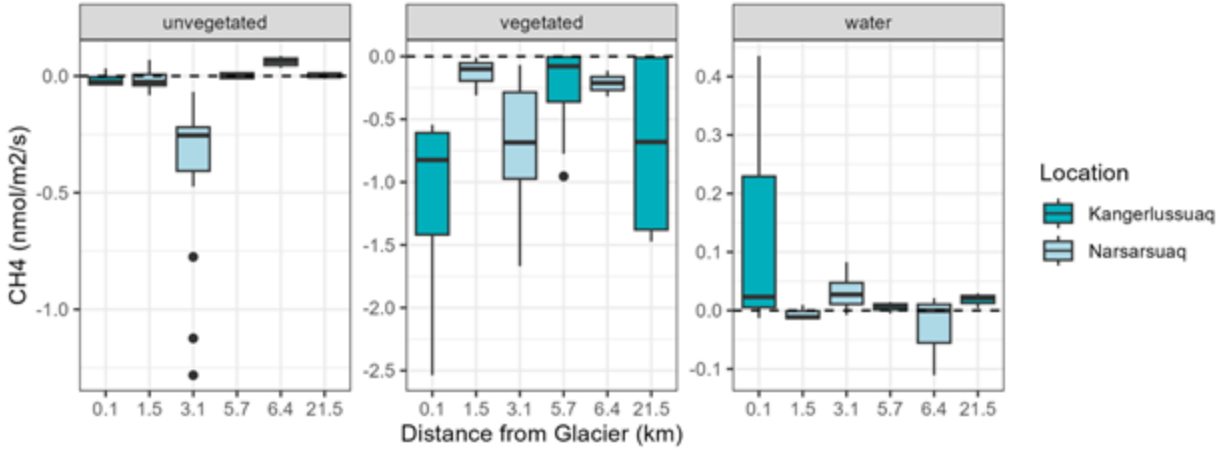
Microbiome drivers



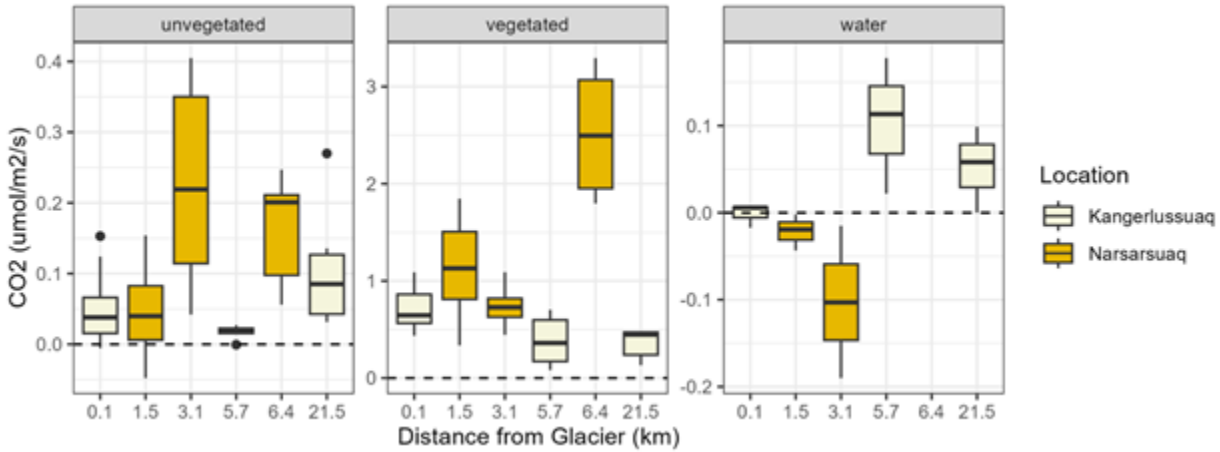


Gas Fluxes

CH_4



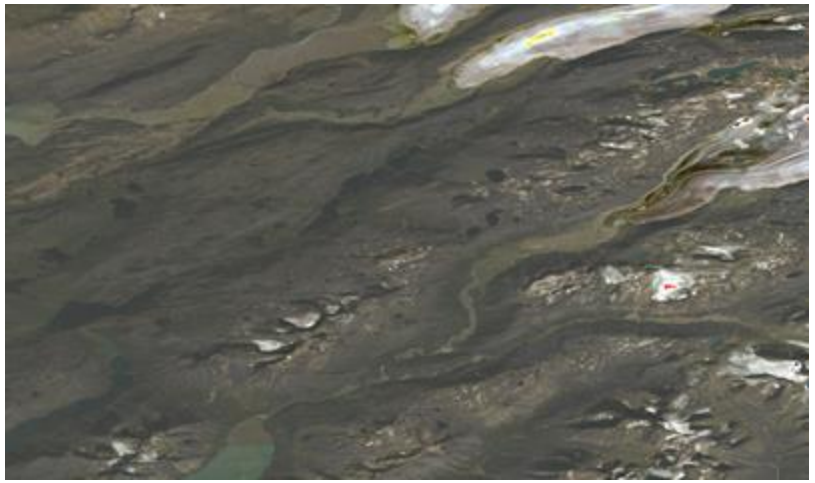
CO_2



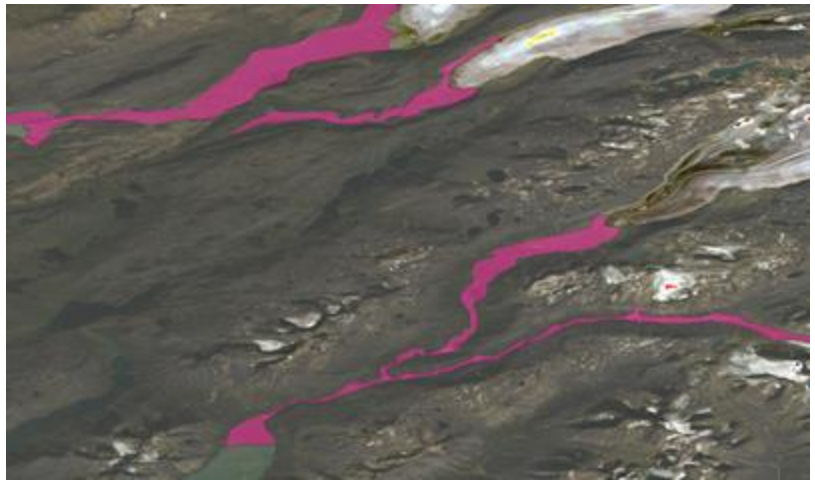
Upscaling: Mapping Greenland outwash plains

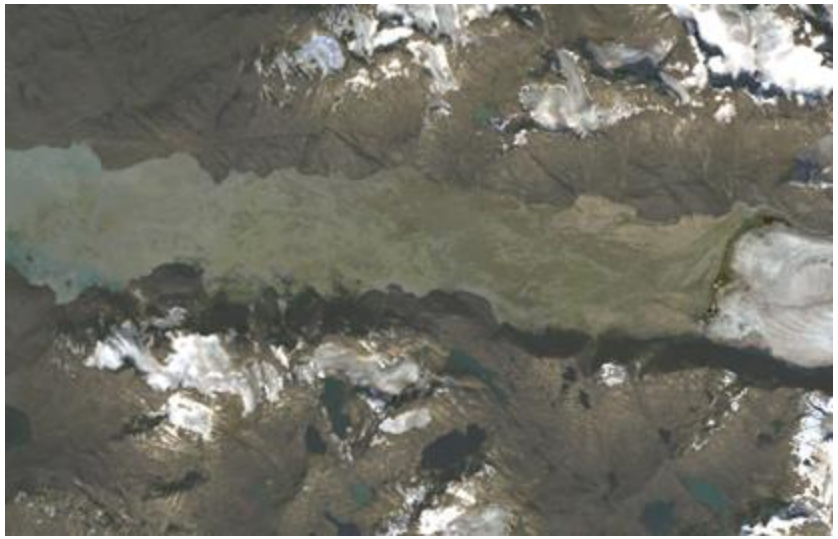
~4000 km²

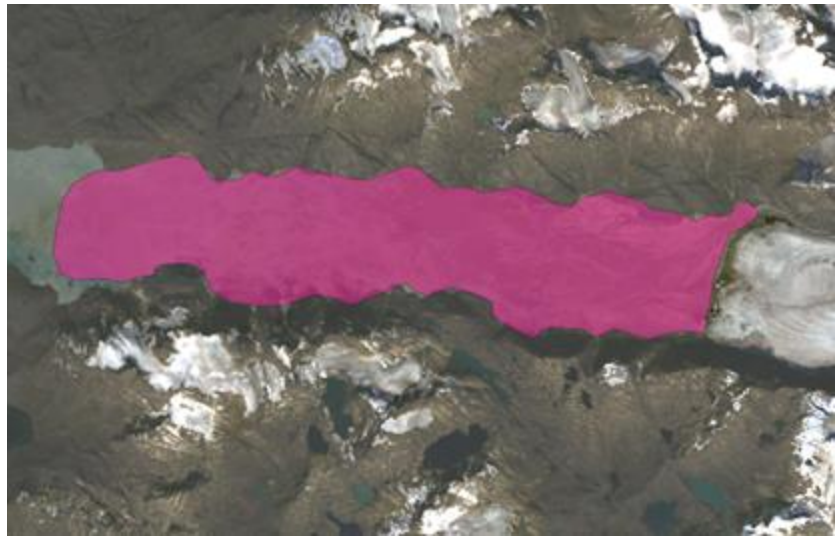
Summer 2023



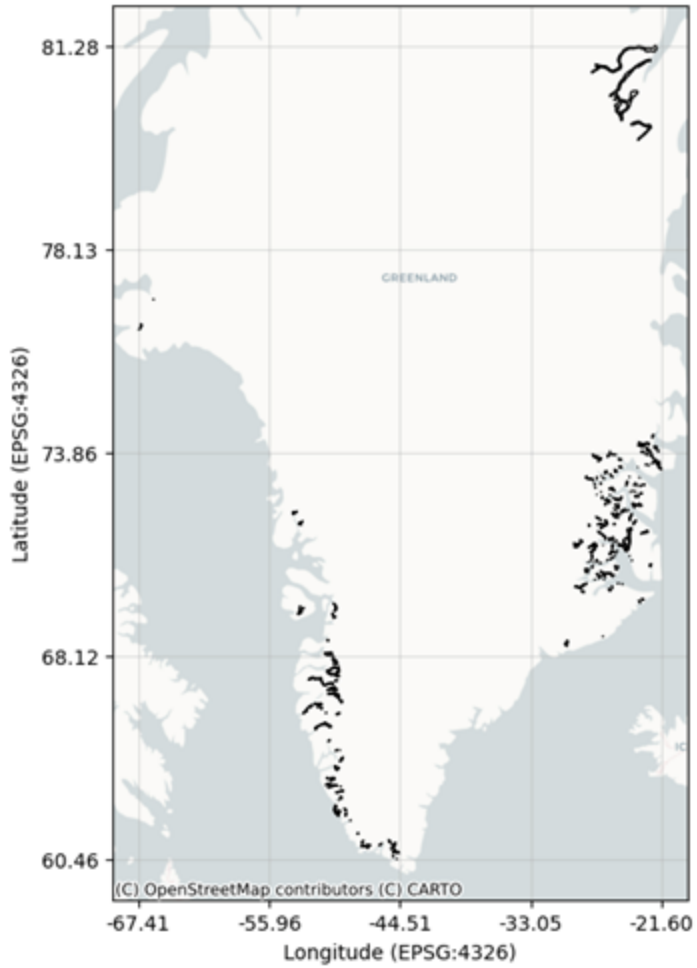
Outwash plains annotations



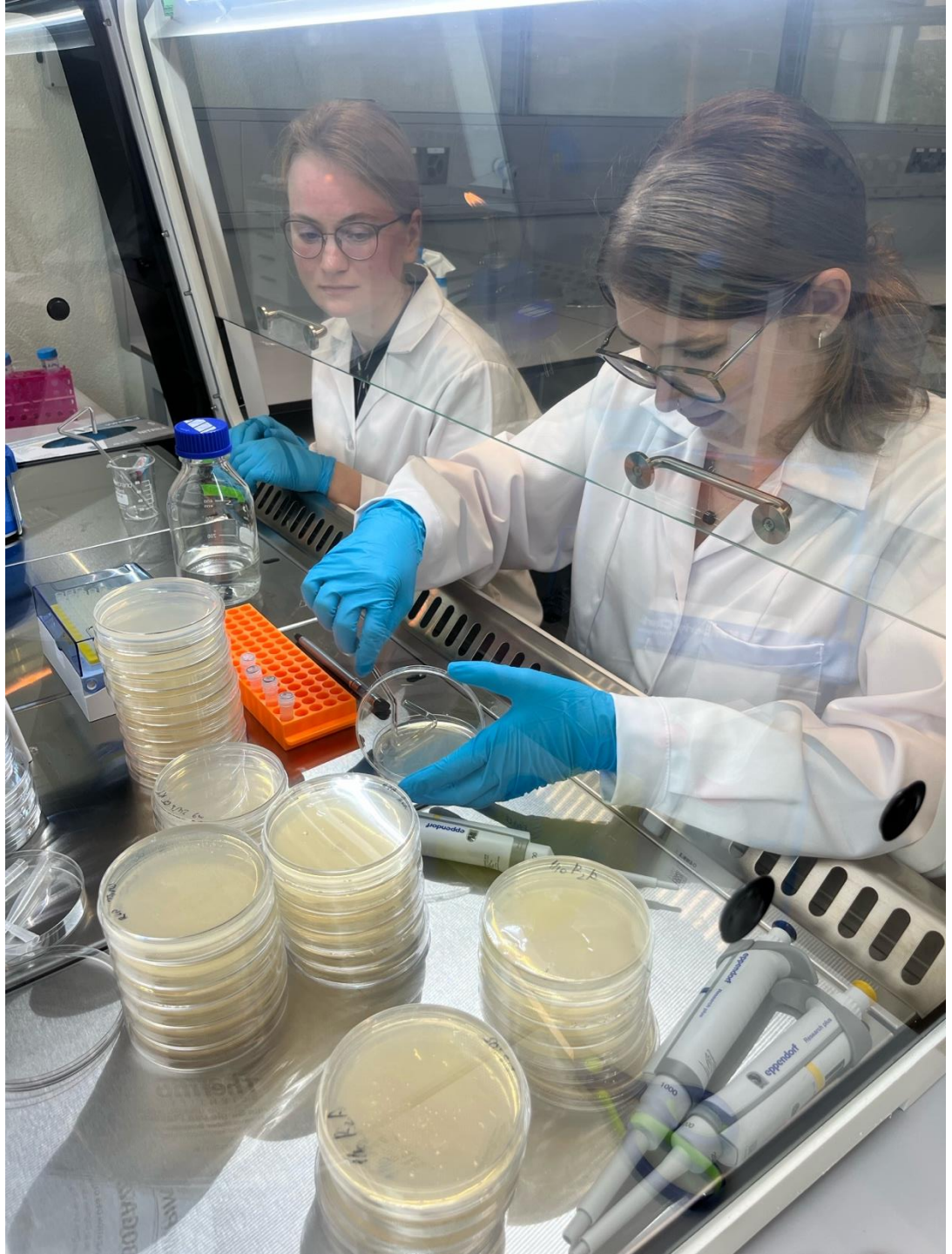




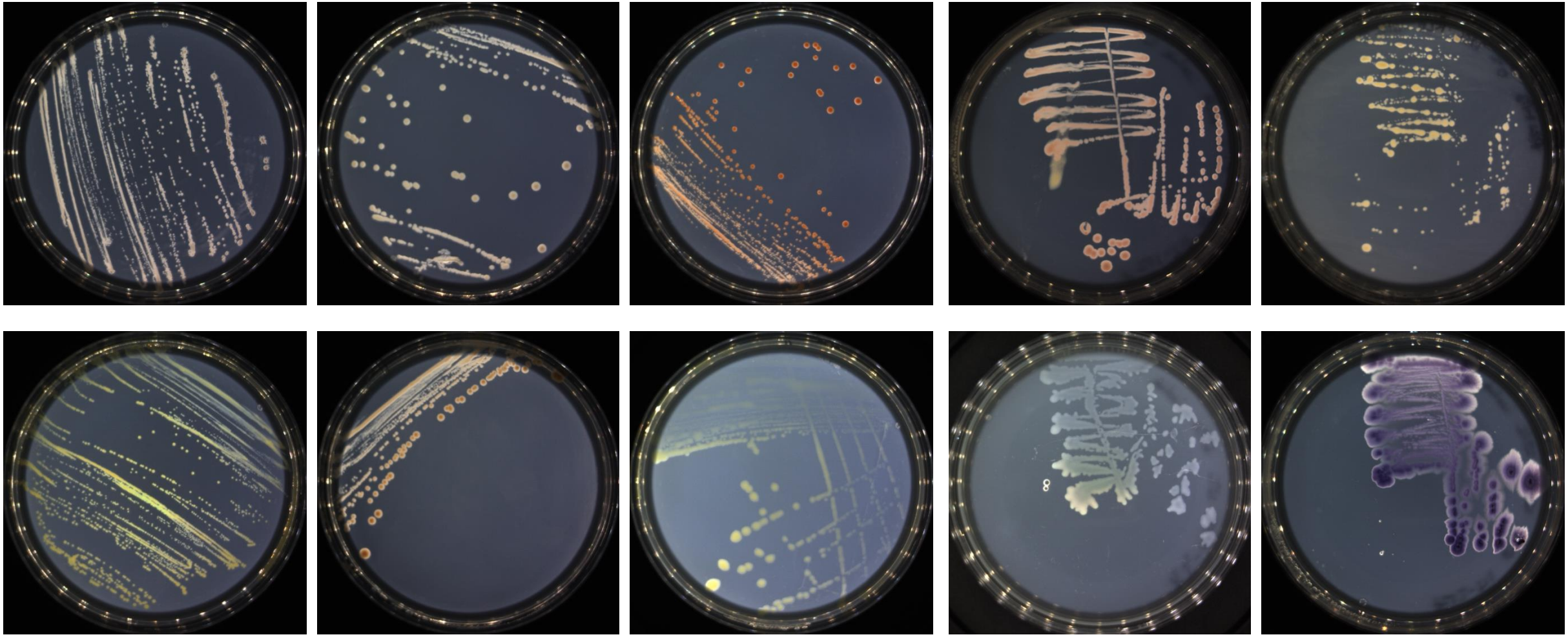
Geographic distribution



Cryo^2-biobank



Cryo^2-biobank



- Strains of bacteria and fungi isolated from cryosphere envronments are deposited in glycerol at -80°C