4th Carbon from Space Workshop

Improving soil carbon estimates across the Arctic with satellite data

Annett Bartsch

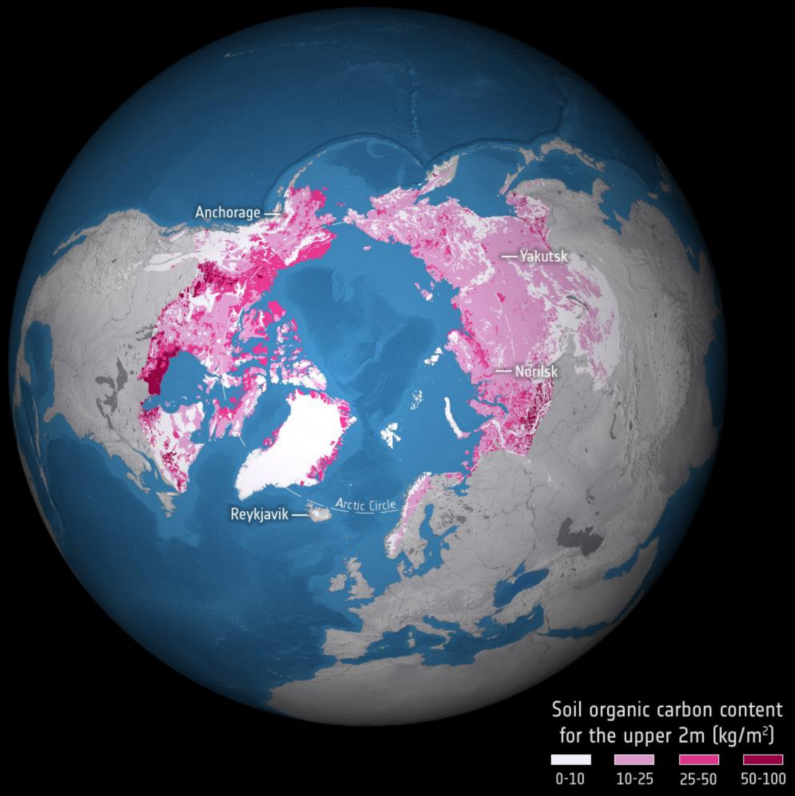
26.10.2022

Miner, K.R., Turetsky, M.R., Malina, E., Bartsch, A., Tamminen, J., McGuire A.D., Fix, A., Sweeney, C., Elder, C.D., Miller, C.E (2022). Permafrost carbon emissions in a changing Arctic. Nat Rev Earth Environ 3, 55–67

Key points

- Tundra fire and abrupt thaw events are increasingly driving the release of permafrost carbon into the atmosphere.
- Observational tools improve carbon flux estimates across scales, but scaling remains a major challenge.
- Satellite systems scheduled to come online by 2025 will provide high-frequency data and enable better monitoring of permafrost carbon emissions.
- Earth system models must include permafrost dynamics to enable accurate permafrost carbon feedback projections.

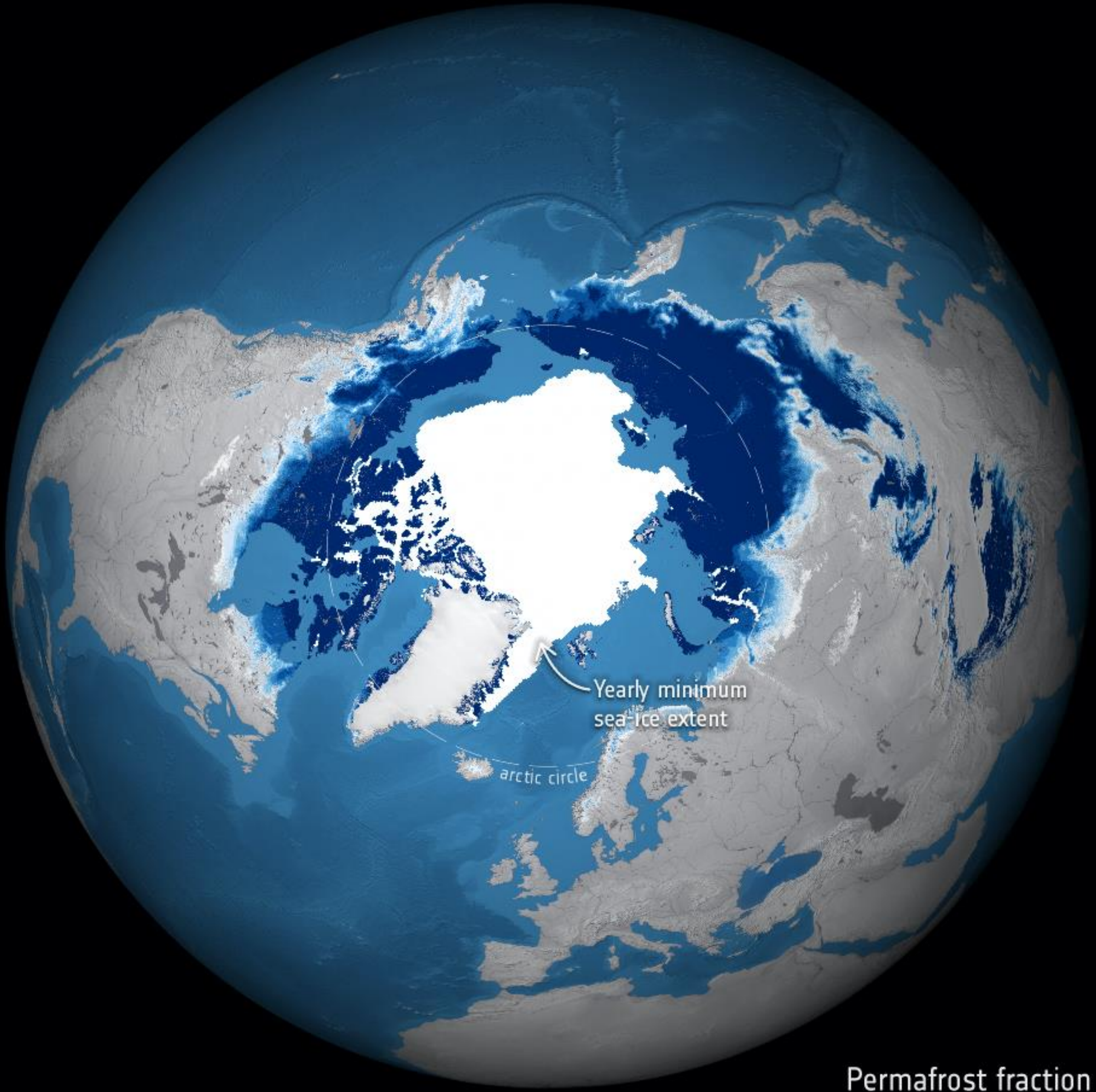
©ESA (data source: NCSCDv2, Hugelius et al., 2013)



Arctic permafrost stores nearly 1,700 billion tons of frozen and thawing carbon

1997

~25% of the Northern hemisphere is affected by permafrost



Continuous
Discontinuous
Sporadic
Isolated

Source: ESA, ESA/Permafrost Climate Change Initiative/NSIDC Sea Ice Index

Obu et al. (2020)

permafrost cci

2019

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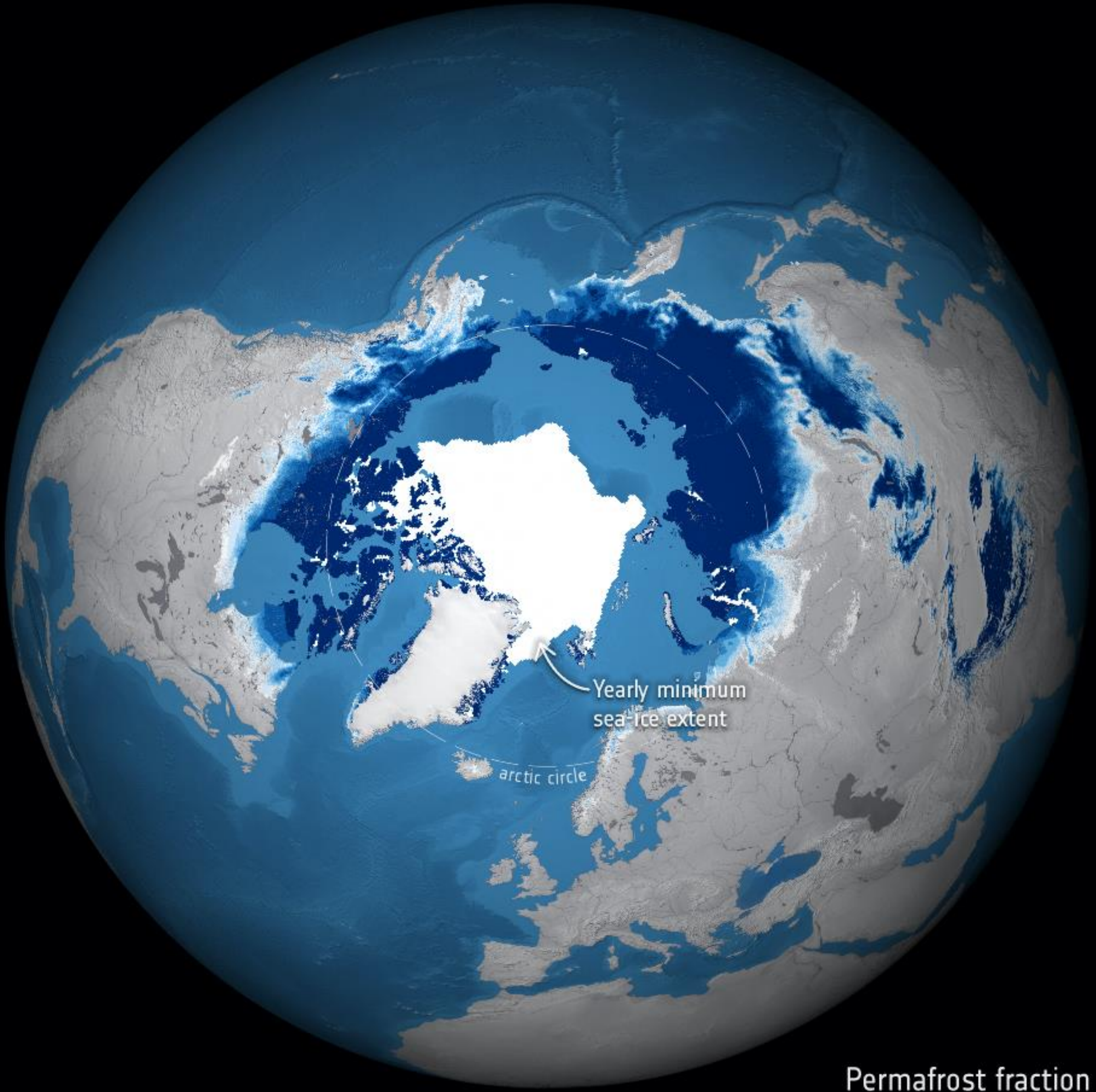
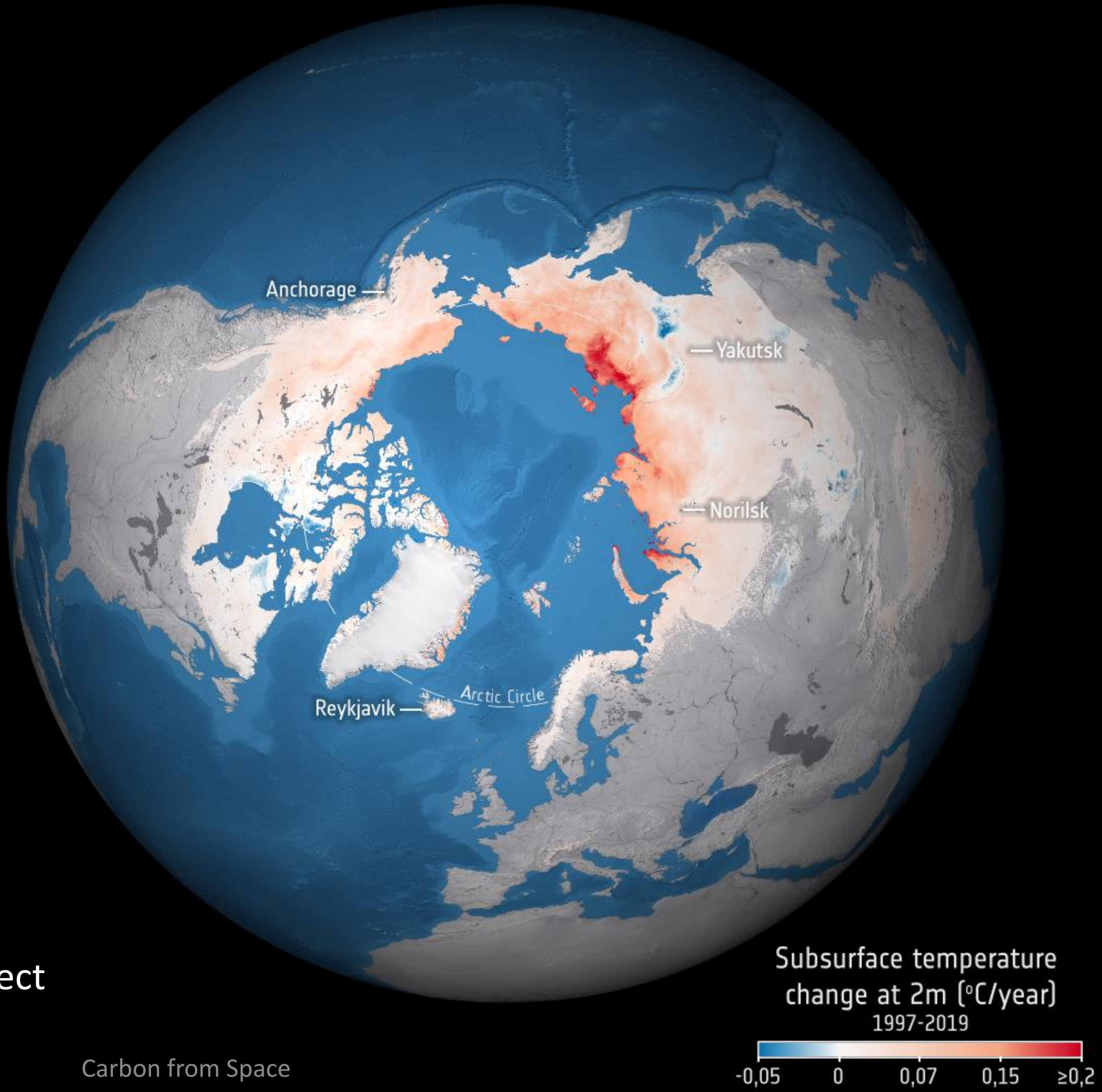


Continuous
Discontinuous
Sporadic
Isolated

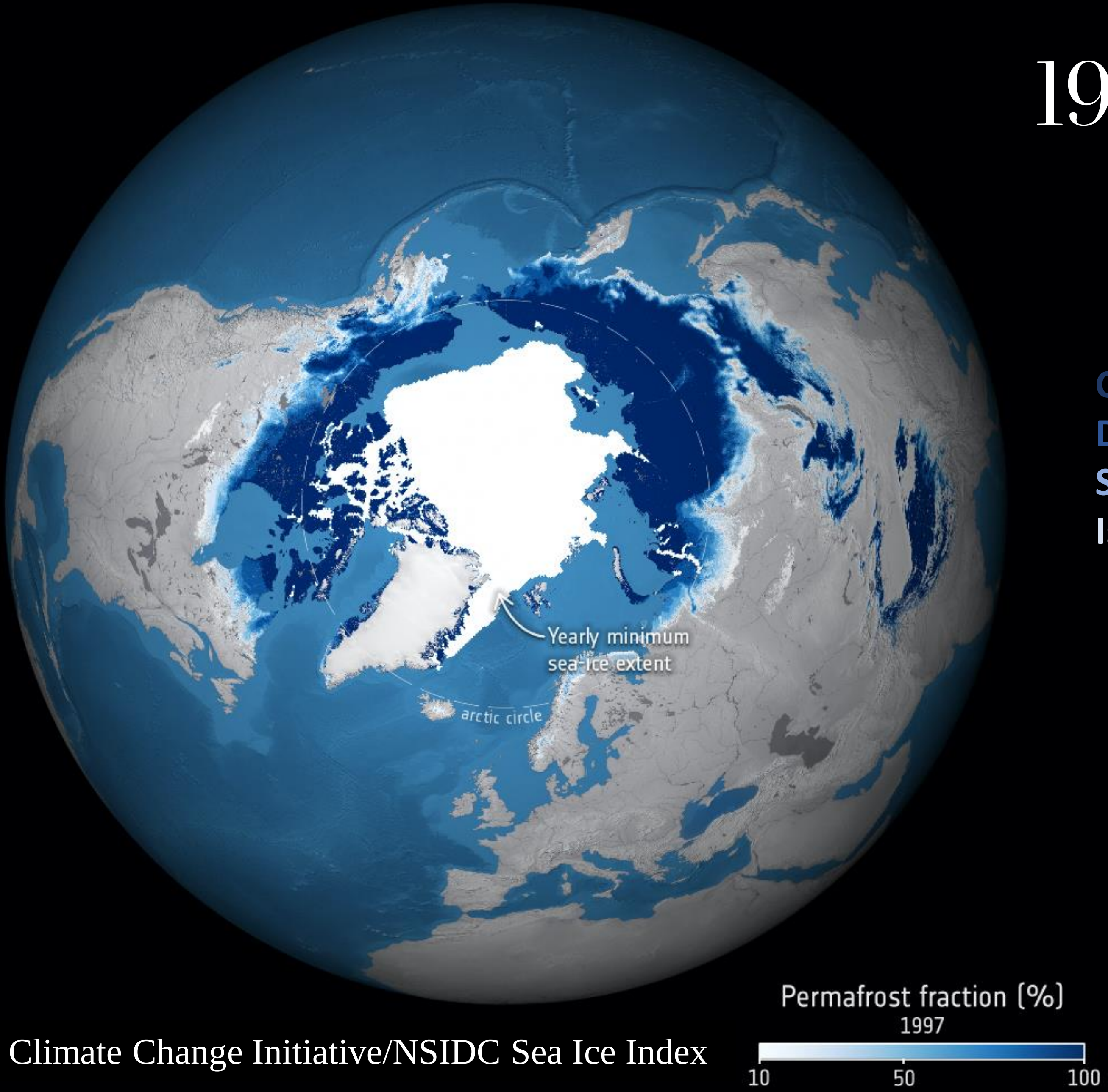
Permafrost fraction (%)
2019
10 50 100

Source: ESA, ESA/Permafrost Climate Change Initiative/NSIDC Sea Ice Index

Obu et al. (2020)


Anchorage
Yakutsk
Norilsk
Reykjavik
Arctic Circle
Subsurface temperature change at 2m (°C/year)
1997-2019
-0,05
0
0,07
0,15
≥0,2

~25% of the Northern hemisphere is affected by permafrost



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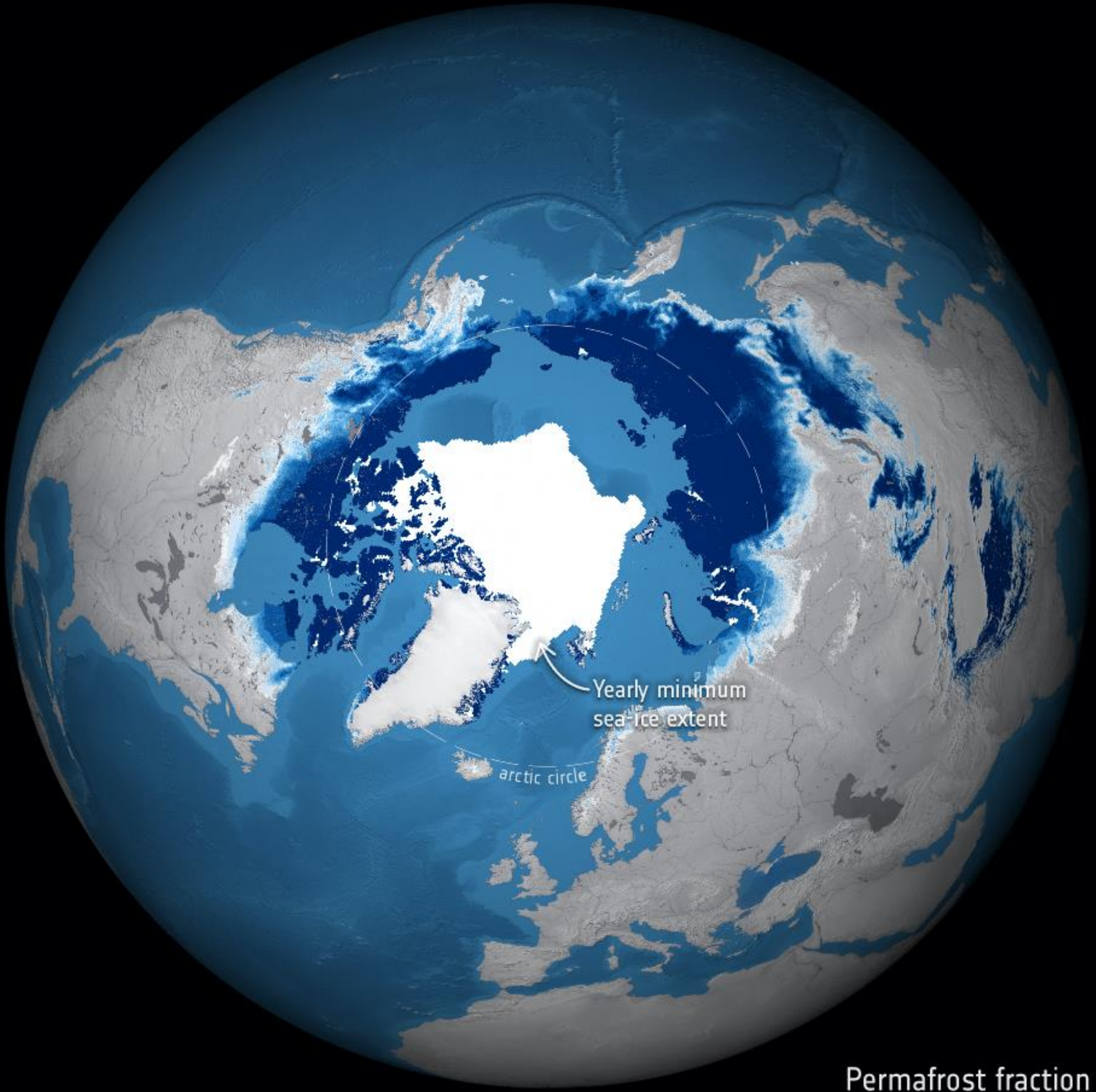

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Permafrost fraction [%]
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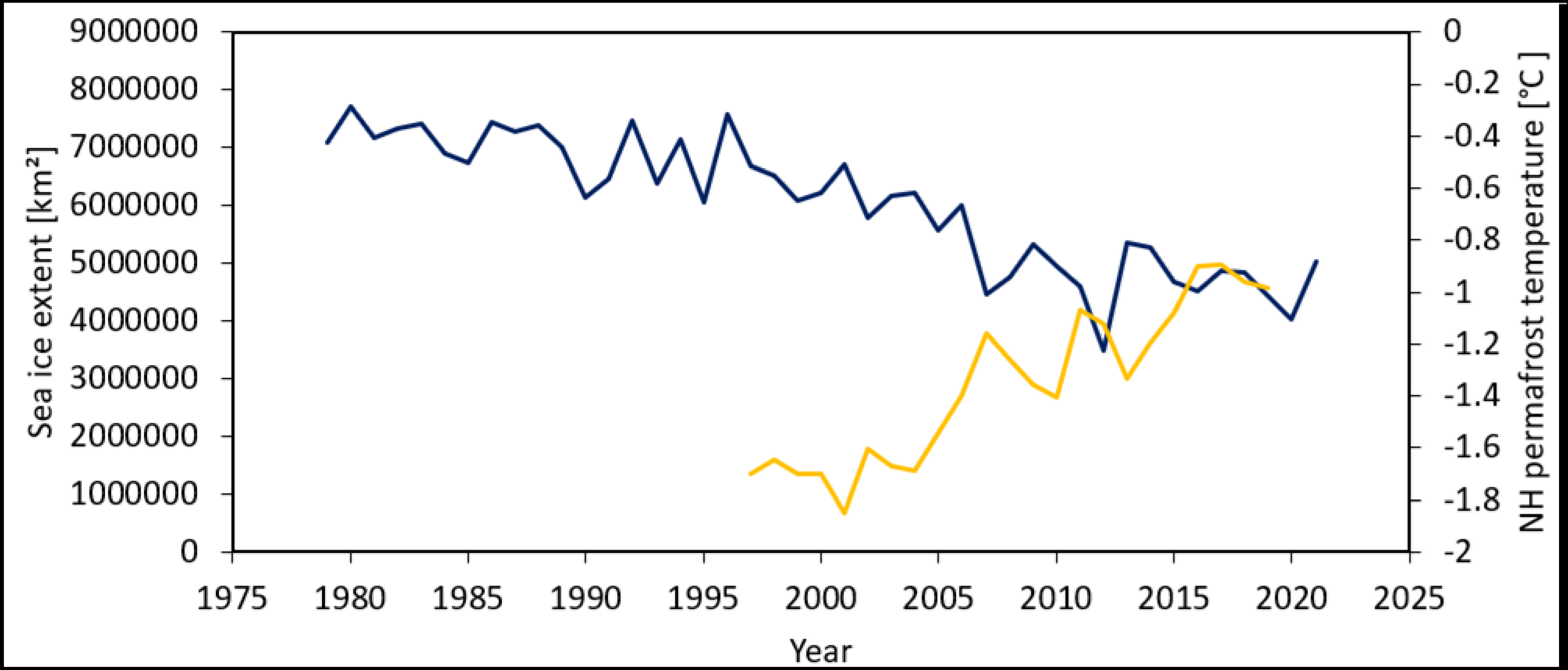
Source: ESA, ESA/Permafrost Climate Change Initiative/NSIDC Sea Ice Index

Obu et al. (2020)

Climate change impacts in the Arctic – satellite retrievals



September sea ice extent – source: seaiceportal.de

2 m depth ground temperature – derived based on Obu et al. 2021 (CEDA archieve)

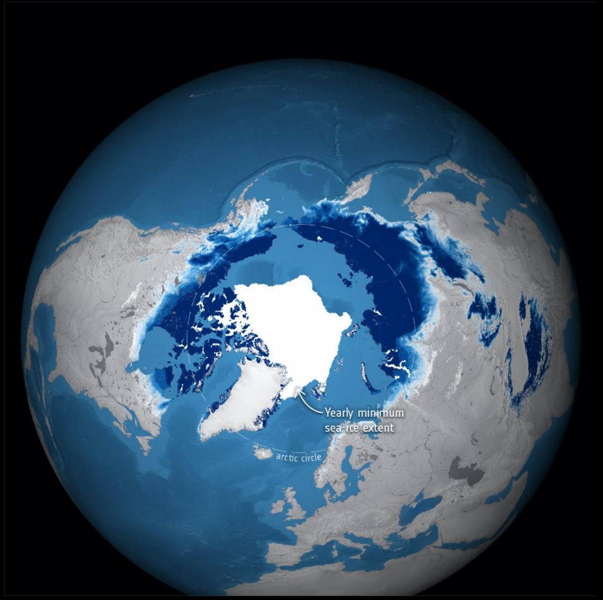
permafrost cci

1 km, Landsurface temperature, snow, landcover

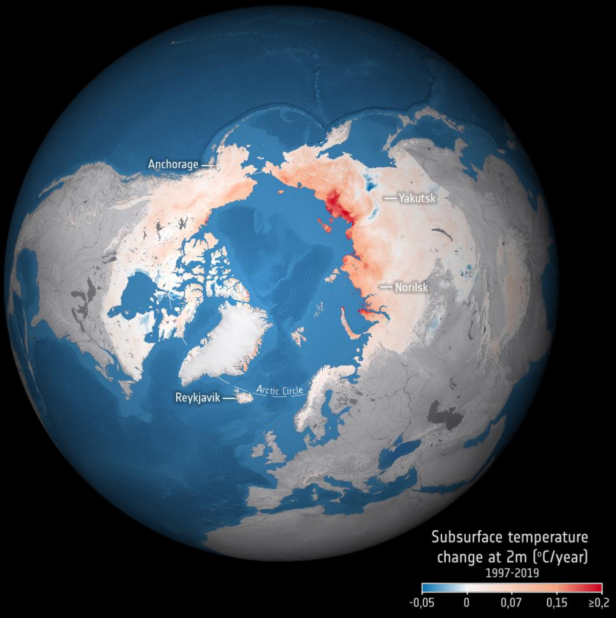
climate.esa.int/en/projects/permafrost/
www.globpermafrost.info

permafrost cci

Permafrost extent



Ground temperature



Active layer thickness

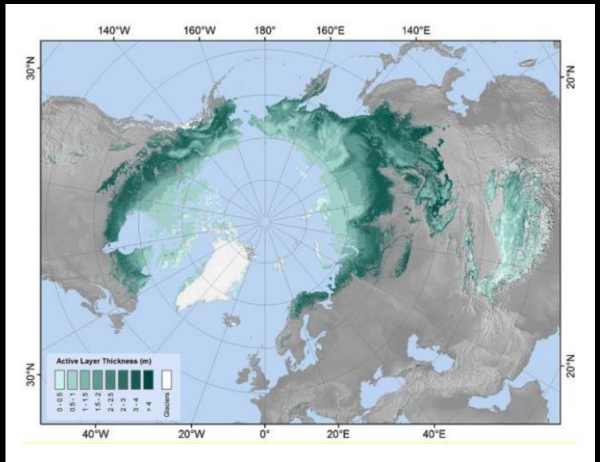
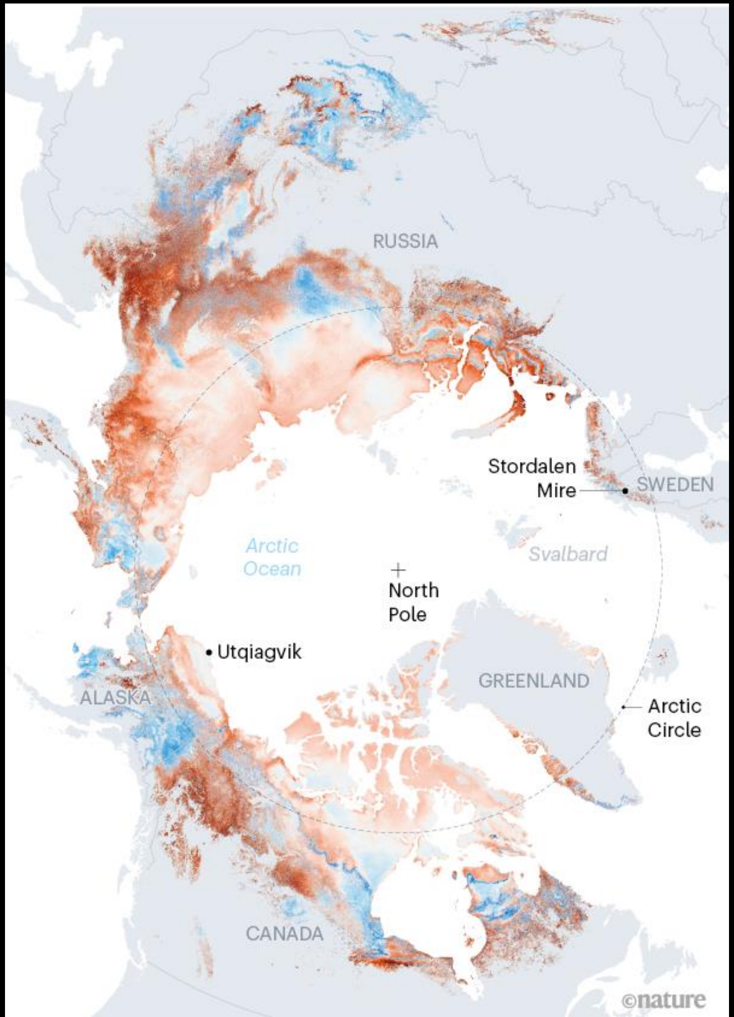


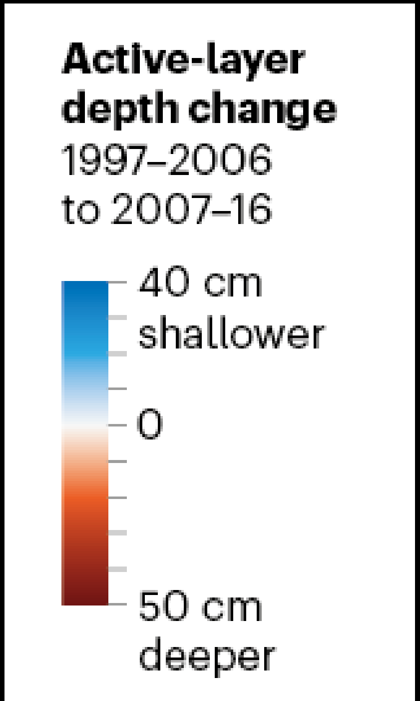
Figure 2: Example of Active Layer Thickness for 2015

CCI Permafrostt

THE BIG THAW

Scientists can track the loss of permafrost using satellite data. The active layer, the soil that thaws and refreezes seasonally, deepened by an average of 2.5 cm across the Northern Hemisphere during 2007–16 compared with the previous decade. For about 5% of the area, the active layer has deepened by more than 30 cm. The deepening active layer destabilizes the landscape and makes more carbon available to microbes in the soil.

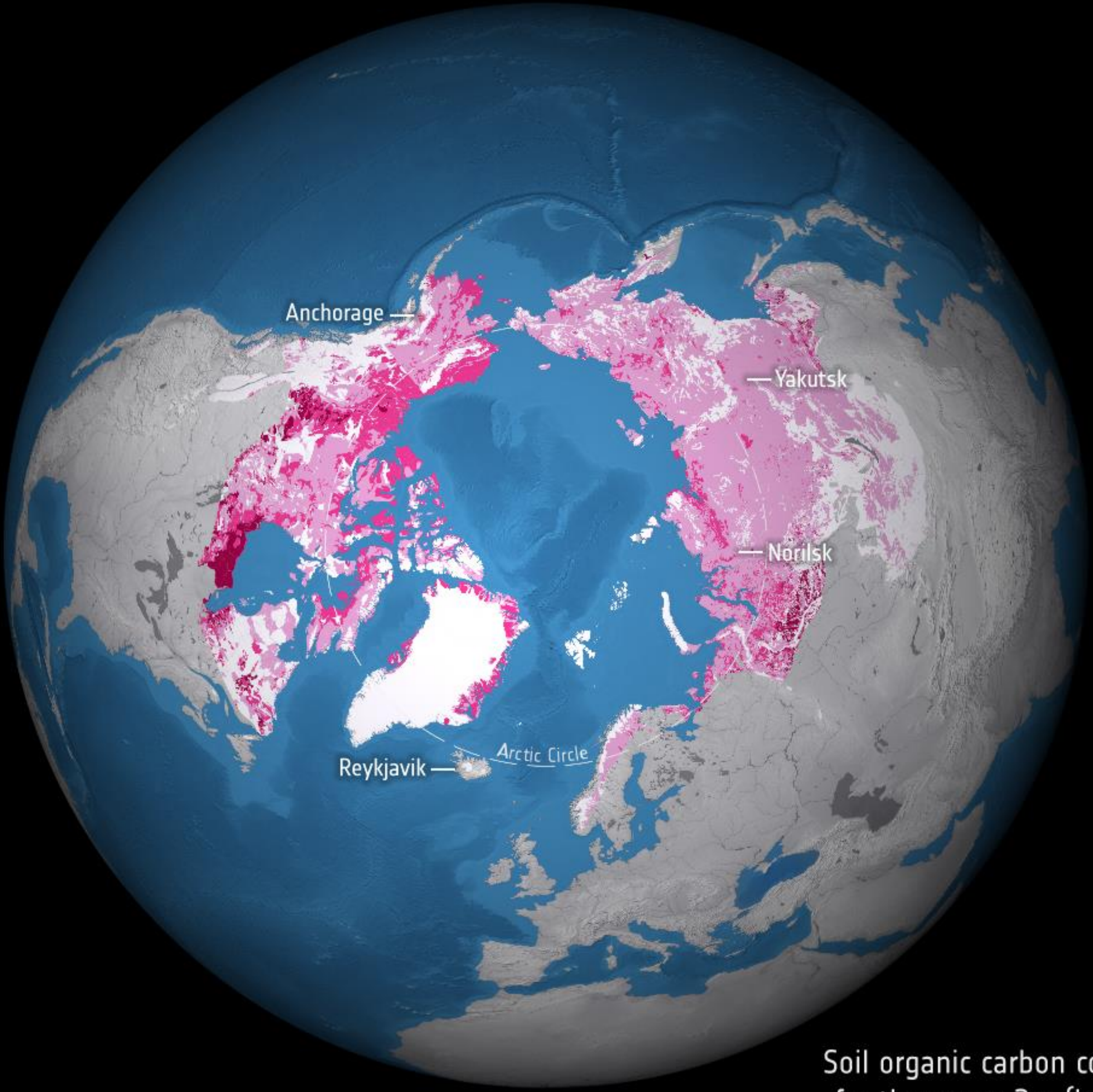




derived based on Obu et al. 2018 (CEDA archieve) permafrost cci

Monique Brouillette (2021): How microbes in permafrost could trigger a massive carbon bomb Genomics studies are helping to reveal how bacteria and archaea influence one of Earth's largest carbon stores as it begins to thaw. News Feature. Nature 591, 360-362 (2021), doi: https://doi.org/10.1038/d41586-021-00659-y

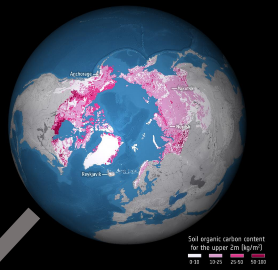
The Northern Circumpolar Soil Carbon Database version 2 (NCSCDv2) is a spatial dataset created for the purpose of quantifying storage of organic carbon in soils of the northern circumpolar permafrost region

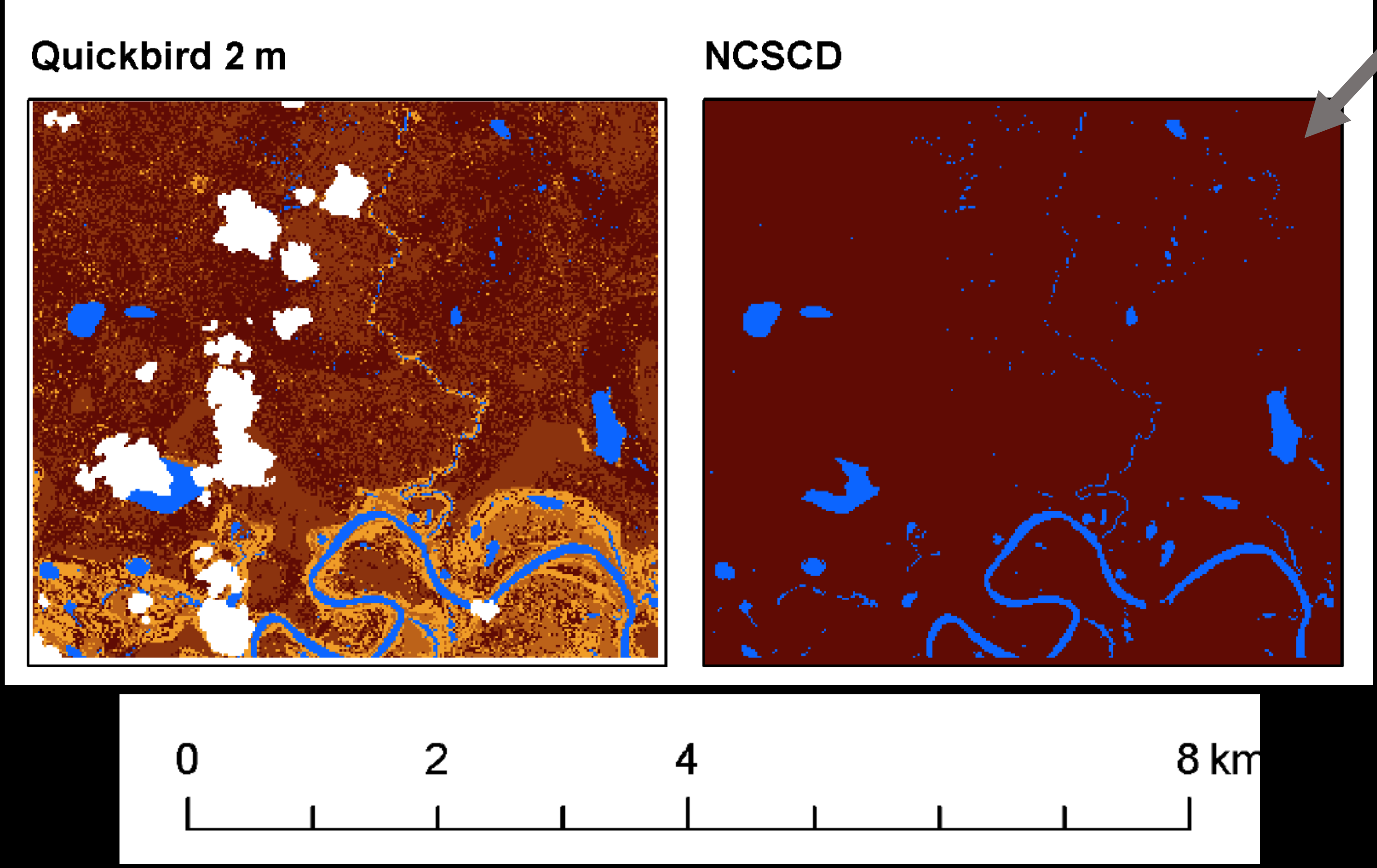


Landsurface information from satellites as proxy for soil organic carbon content?

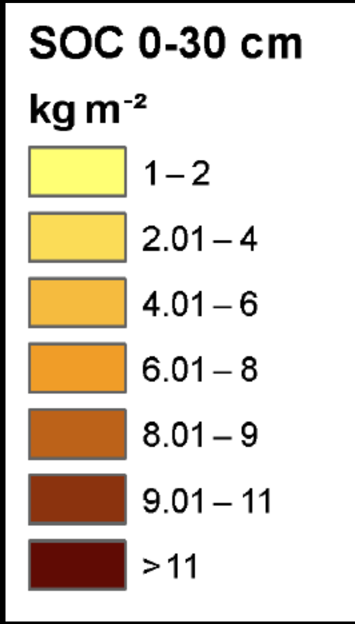
- Various studies explored landcover for upscaling on local to regional level in the past
- Challenge – very heterogeneous landscapes

Example – Kytalyk, eastern Siberia





- Quickbird analyses from Siewert et al. (2015), upscaling of in situ SOC data
- Figure from Bartsch et al. (2016)



Radar use? C-HH winter backscatter

Bartsch, A., Widhalm, B., Kuhry, P., Hugelius, G., Palmtag, J., and Siewert, M. B. (2016): Can C-band synthetic aperture radar be used to estimate soil organic carbon storage in tundra?, Biogeosciences, 13, 5453–5470

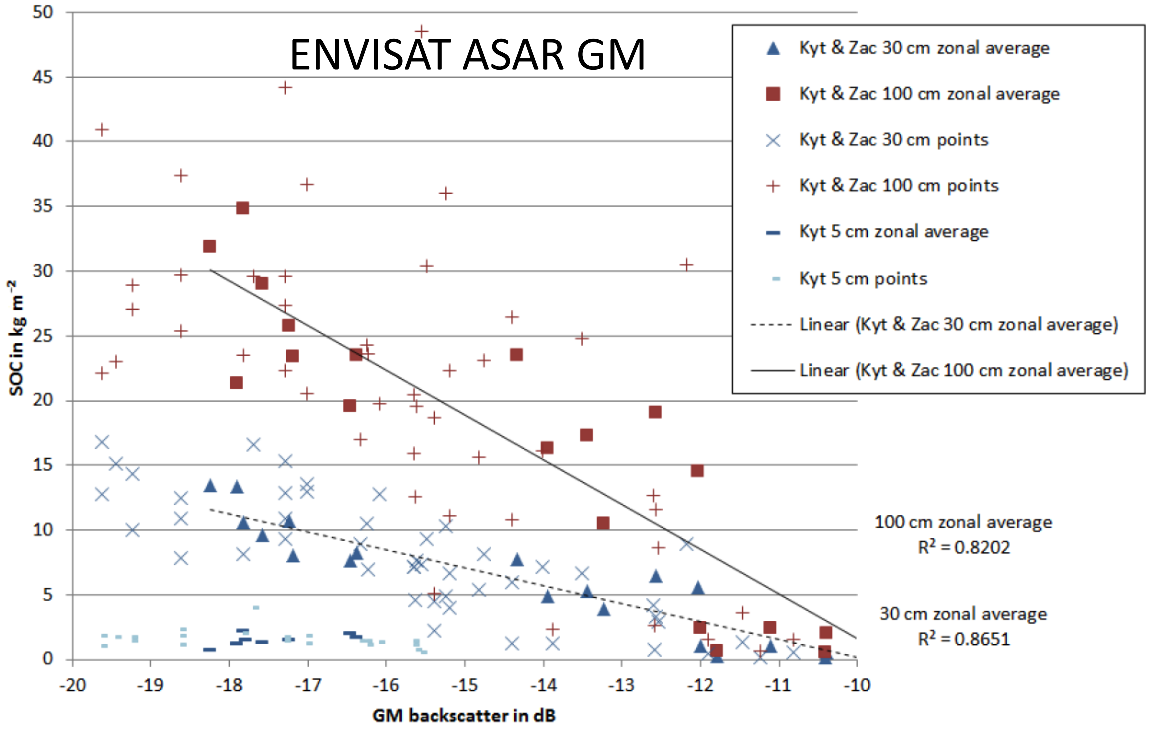
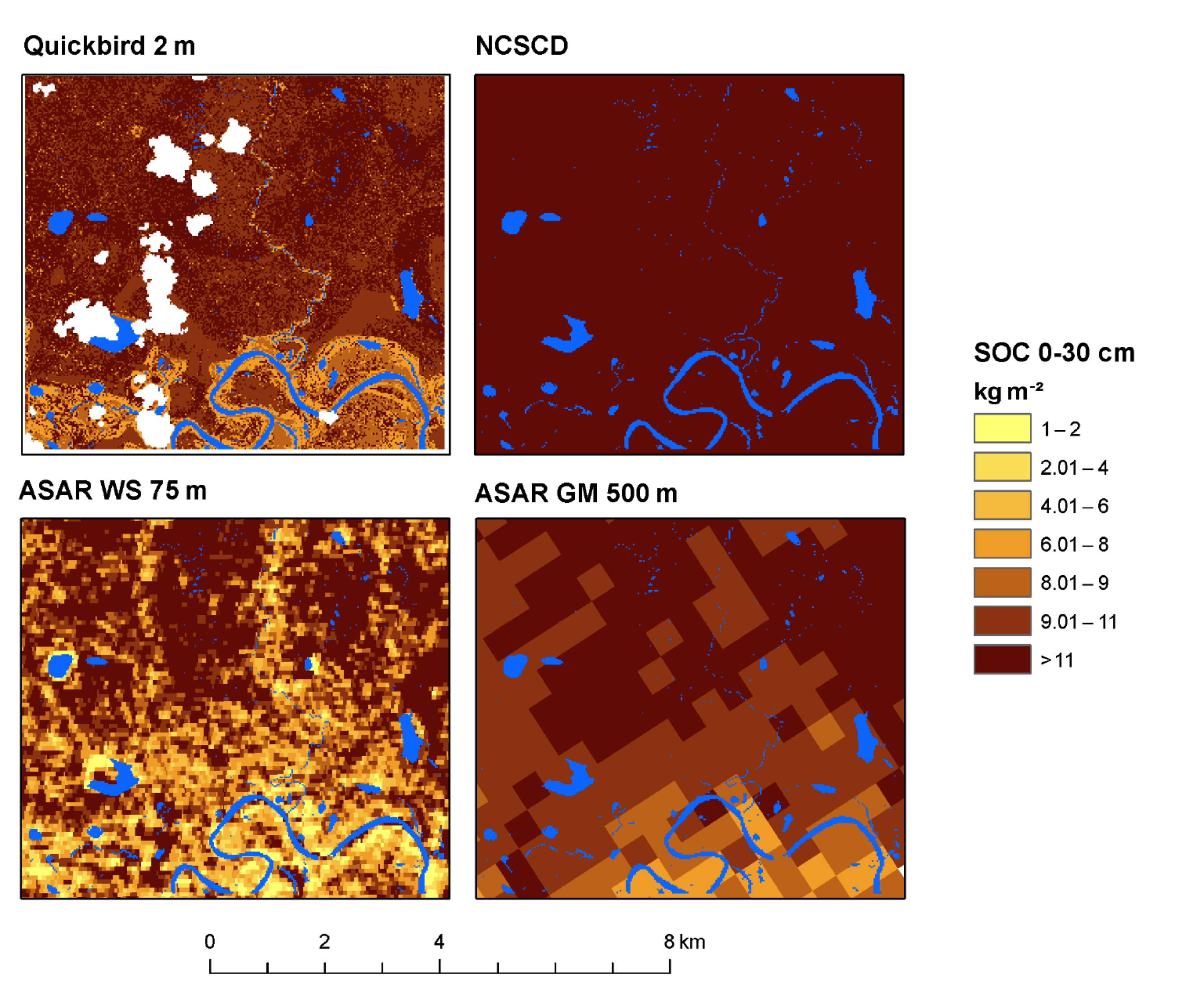
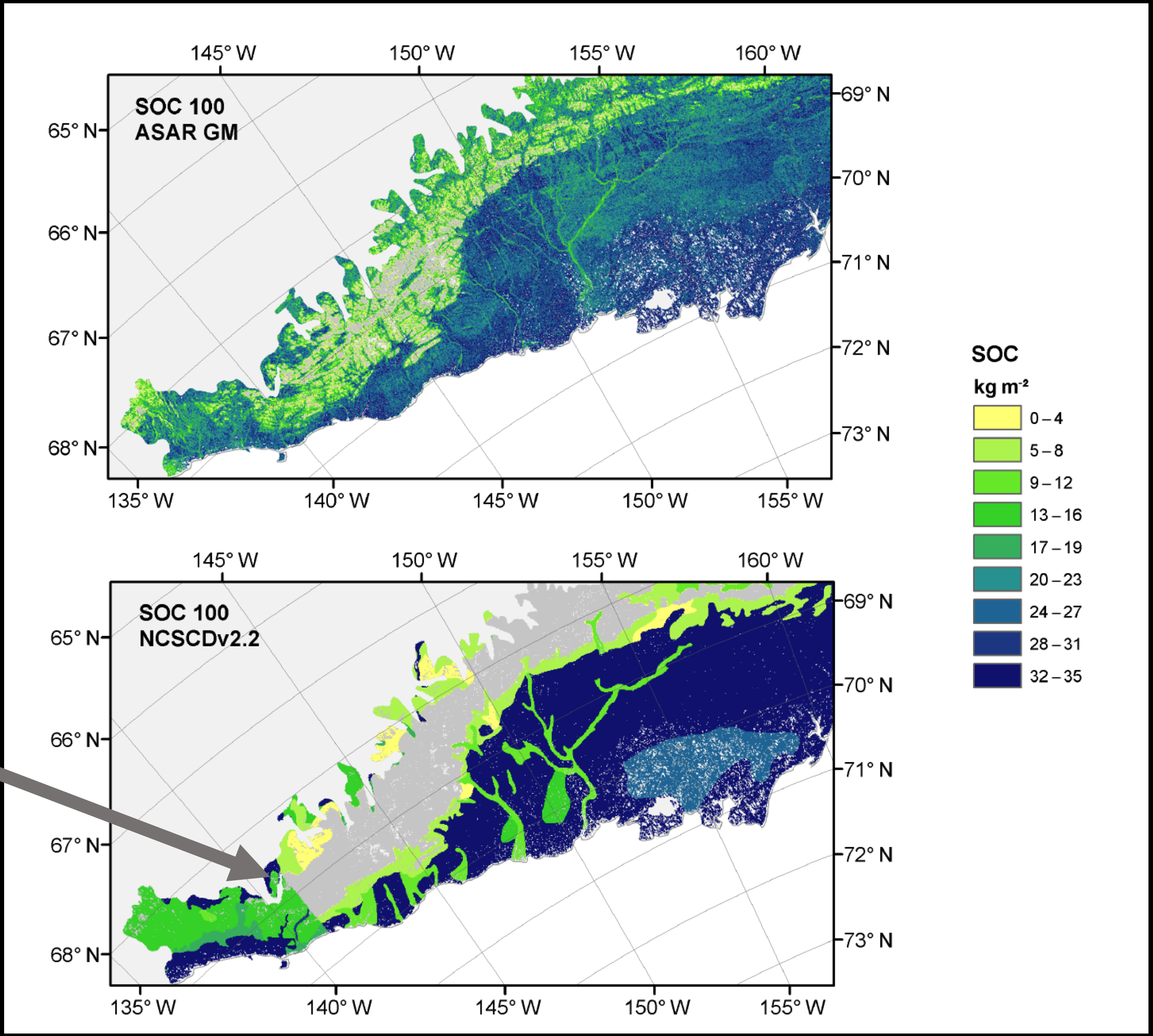


Figure 4. SOC from land cover classifications and pedon data (points) for all depths versus backscatter from ENVISAT ASAR GM, for Kytalik (Kyt) and Zackenberg (Zac). Five-centimetre data are only available for Kytalyk.

Bartsch, A., Widhalm, B., Kuhry, P., Hugelius, G., Palmtag, J., and Siewert, M. B. (2016): Can C-band synthetic aperture radar be used to estimate soil organic carbon storage in tundra?, Biogeosciences, 13, 5453–5470





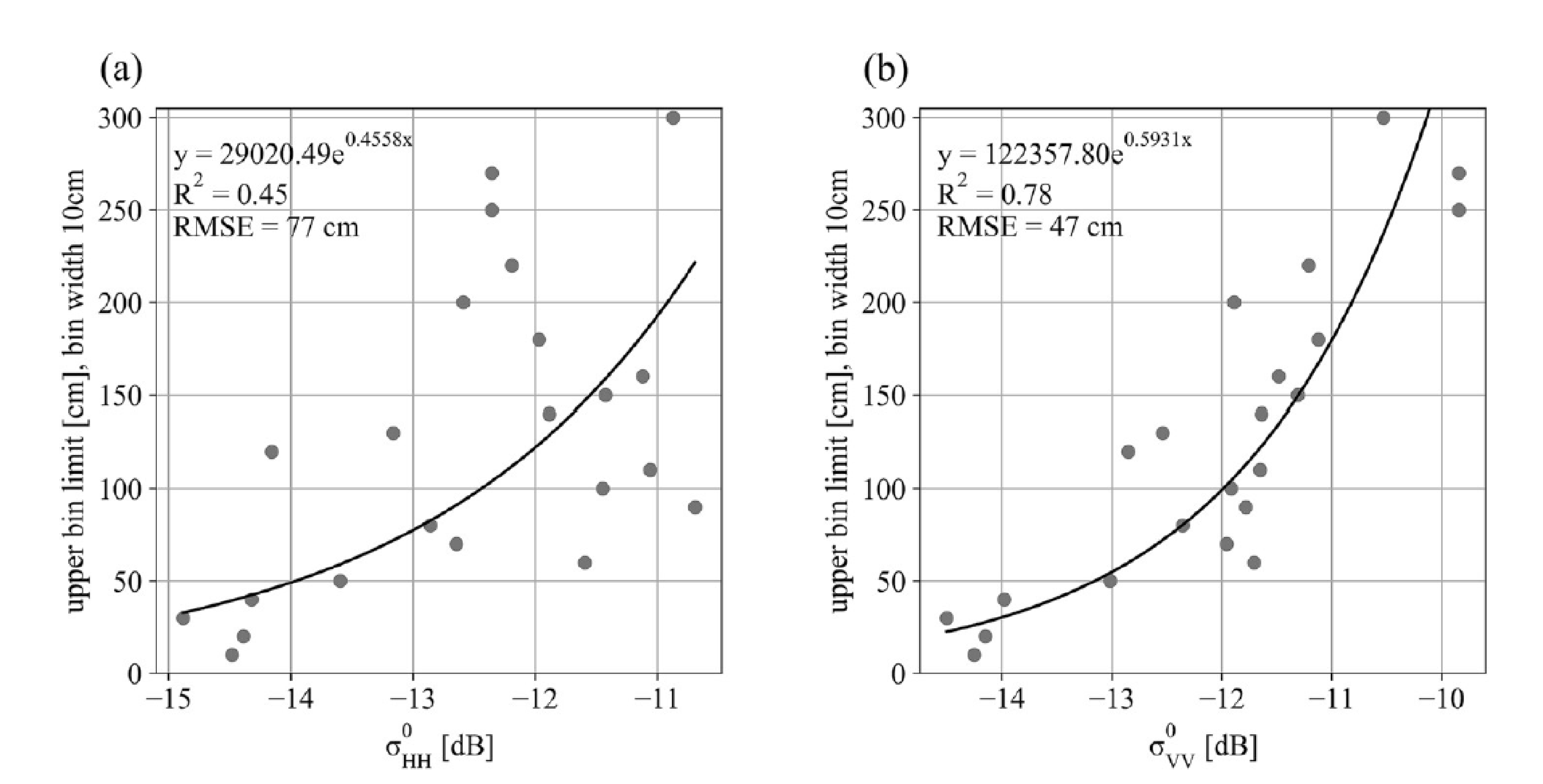
Alaska –
Canada border

N

Why does C-HH winter backscatter work better than C-VV?

Backscatter versus tundra vegetation height

C-HH represents soil surface
C-VV represents vegetation

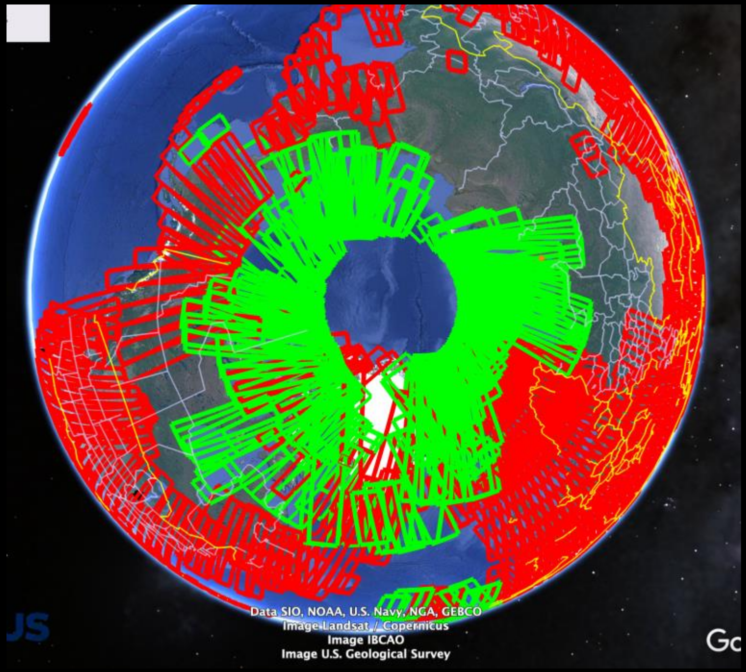


Bartsch A., B. Widhalm, M. Leibman, K. Ermokhina, T. Kumpula, A. Skarin, E.J. Wilcox, B.M. Jones, G. V. Frost, A. Höfler, G. Pointner (2020): Feasibility of tundra vegetation height retrieval from Sentinel-1 and Sentinel-2 data. Remote Sensing of Environment, Volume 237, 111515 DOI: 10.1016/j.rse.2019.111515

Can we make improved resolution maps with Sentinel-1?

- Currently NO
- In general, data are not acquired in HH over land
- Data are not acquired circumpolar over land

Situation without Sentinel-1B
→ Lack of data (red data type in figure below) for most Arctic permafrost regions
→ Time series for permafrost degradation monitoring currently interrupted

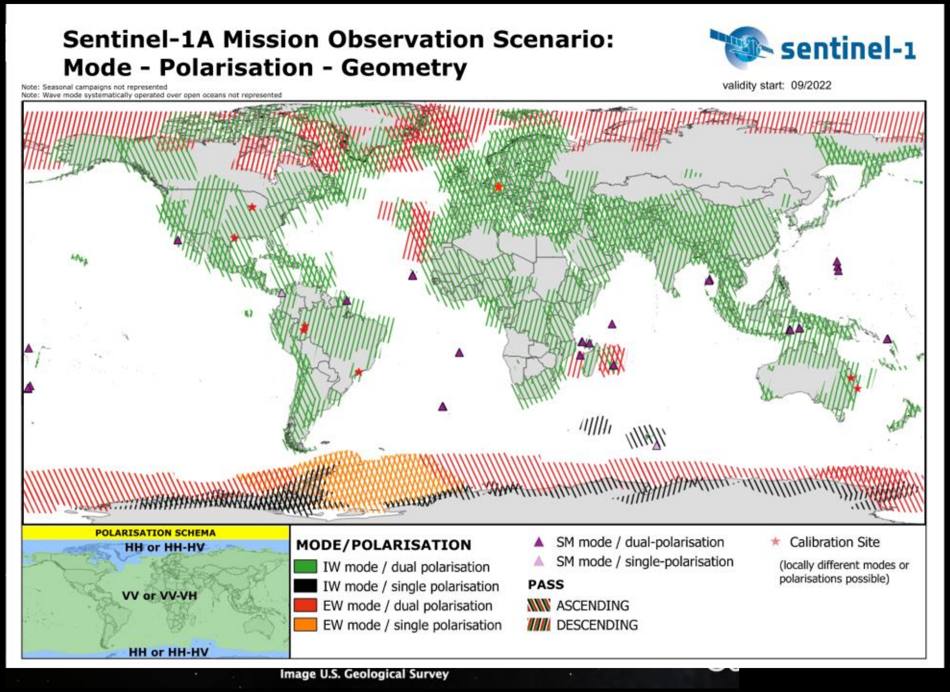


Can we make improved resolution maps with Sentinel-1?

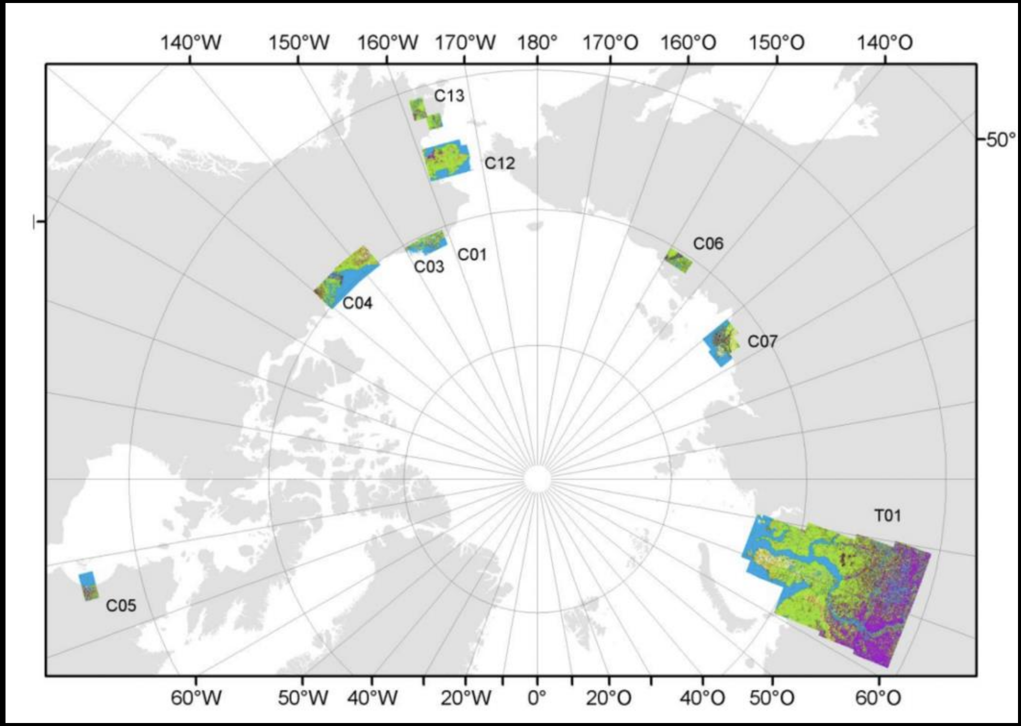
- Currently NO
- In general, data are not acquired in HH over land
- Data are not acquired circumpolar over land
- Alternative, but less precise: fusion of Sentinel-1 (VV)/2

-> classification

Situation without Sentinel-1B
→ Lack of data (red data type in figure below) for most Arctic permafrost regions
→ Time series for permafrost degradation monitoring currently interrupted

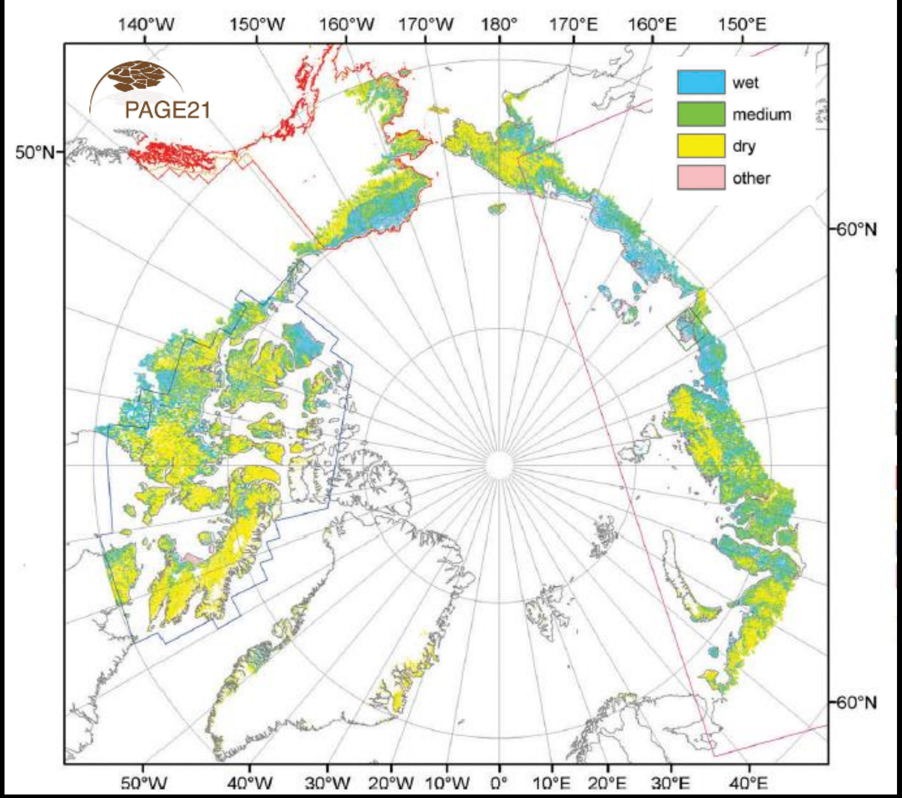


- Landcover prototypes developed in DUE GlobPermafrost
- Currently circumpolar implementation in CCI+ Permafrost for improvement of soil parameterization of the permafrost model (uses LST as input)



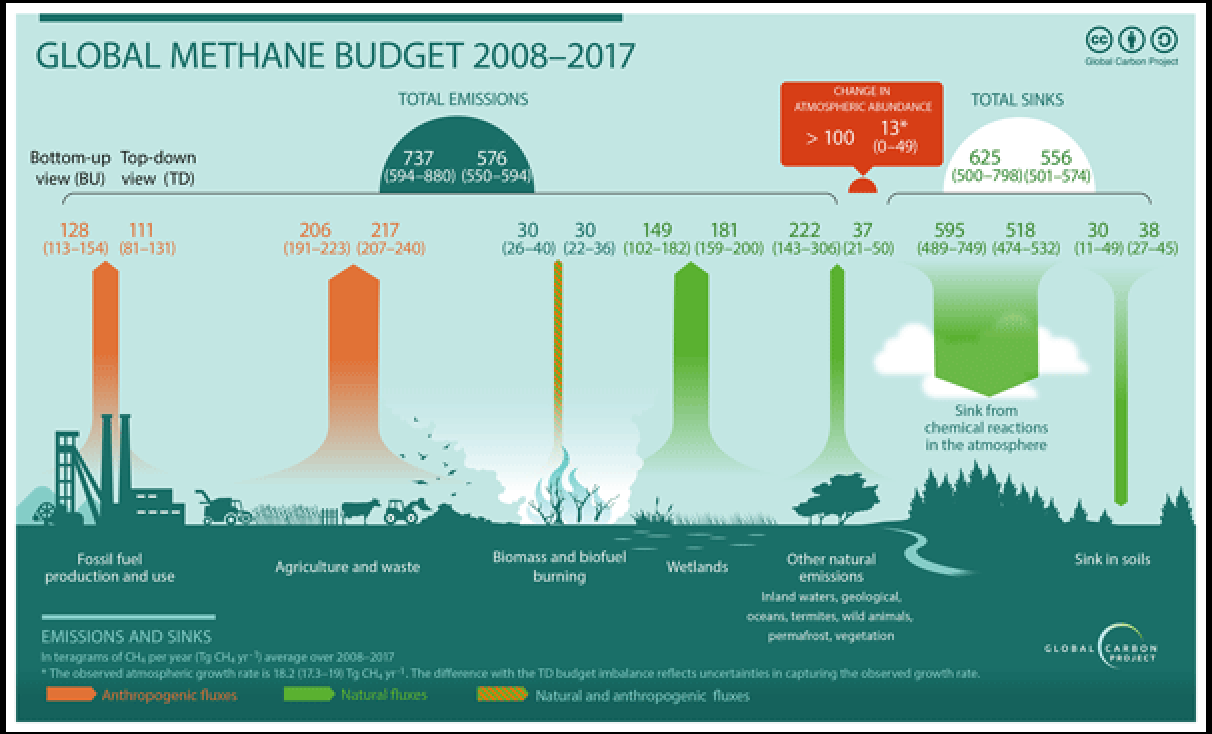
Note, surface roughness as seen with C-HH across the tundra also represents wetness levels

ENVISAT ASAR GM C-HH (500m)

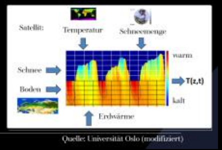


Widhalm et al. 2015, IJRS

Saunois, M. et al. (2020): The Global Methane Budget 2000–2017, Earth Syst. Sci. Data, 12, 1561–1623, https://doi.org/10.5194/essd-12-1561-2020, 2020



Also used for soil parameterization for Permafrost modelling based on landsurface temperature (Obu et al. 2019, GRL)



Knowledge gaps and priorities for next steps

- There is a lot of potential of SAR, but current acquisition strategies prevent consistent circumpolar retrieval
- Better use of L-band ? -> NISAR, ROSE-L
- Gradual and abrupt thaw to be treated separately in the climate tipping point assessment (MacKay et al. 2022)
  - Monitoring of abrupt thaw with high spatial and temporal resolution, consistent across the Arctic
- Benchmarking of wetland maps for upscaling of fluxes required -> AMPAC-Net

→ EUROPEAN SPACE AGENCY

eo science for society

Arctic Methane and Permafrost Challenge (AMPAC)

An ESA and NASA collaborative community initiative

ESA POLAR SCIENCE CLUSTER

EO SCIENCE FOR SOCIETY

AMPAC-Net

- Networking
- Gap analyses
- benchmarking

MethaneCamp

- Atmosphere

2022-2024

Further meetings this week

- Methane in the Arctic' community session at Carbon from Space: 26th of October 2022, 16:00-17:30 CEST
  - Ben Poulter - “Arctic wetlands and modeling methane emissions”
  - Johanna Tamminen - "Status of satellite observations of high latitude methane and validation needs"
  - Mathias Goeckede - "In situ observation of methane signals in the Arctic: current network status, and future challenges"
  - Chip Miller - "Satellite Monitoring of Arctic Methane and the Permafrost Carbon Feedback“
  - 30 min discussion

- **For more information go to www.ampac-net.info -> news**