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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Cryosphere tipping elements, specifically permafrost abrupt thaw

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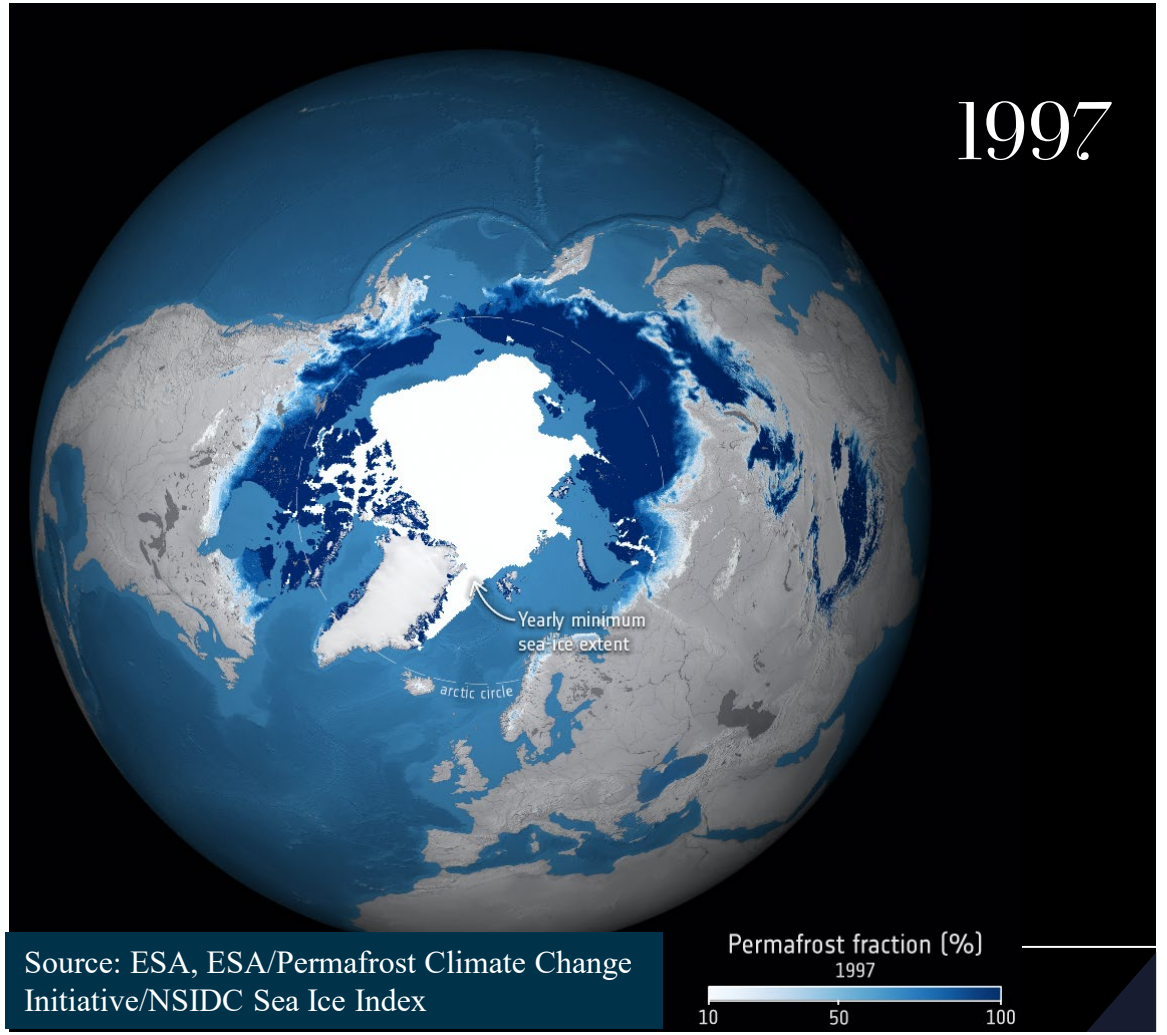
Tipping elements – Agora session, 25th of May 2022

Cryospheric tipping elements

- Arctic Sea ice loss
  - Decline in extent
  - also properties of interest (thickness, age …)
- Greenland ice sheet
  - Accelerating loss of ice
- West and East Antarctica ice sheets
  - Accelerating loss of ice

- Permafrost
  - Thawing: decline in extent, loss at the ‚top' (deeper seasonal thaw) and mobilisation of carbon through abrupt thaw



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

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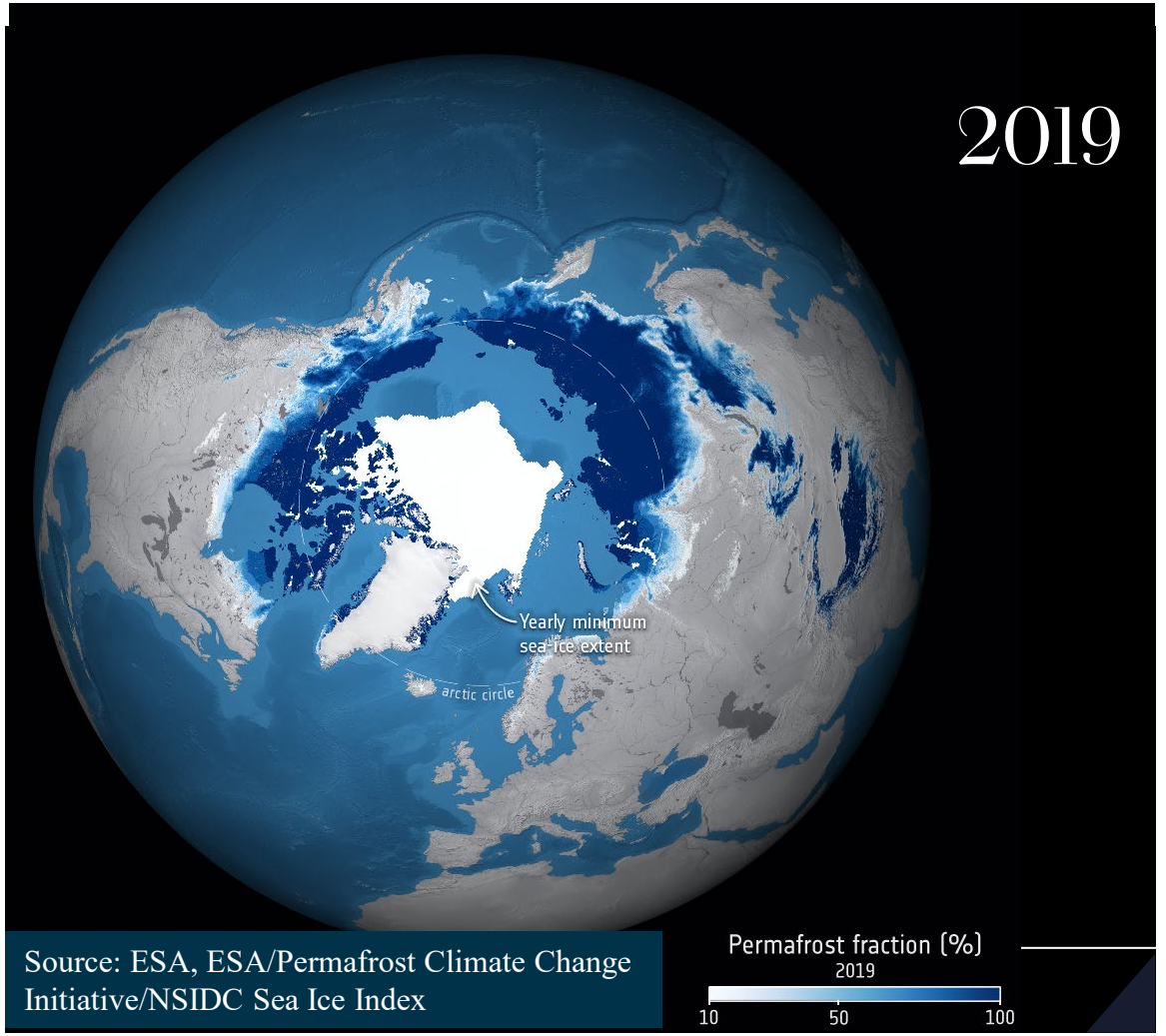

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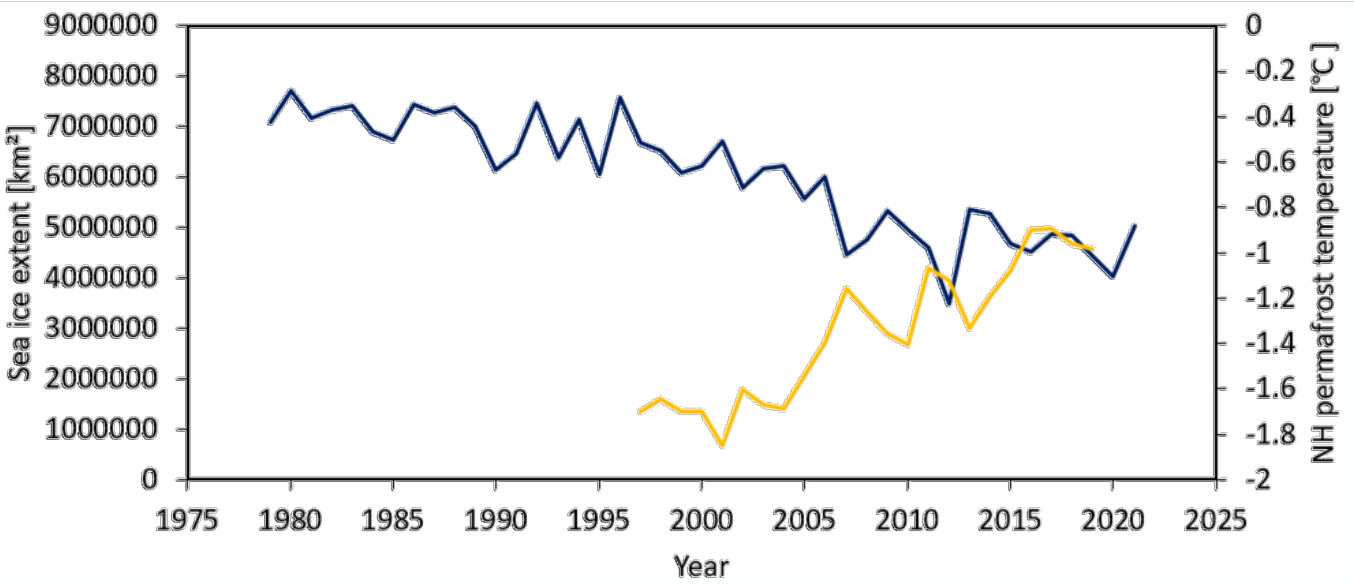
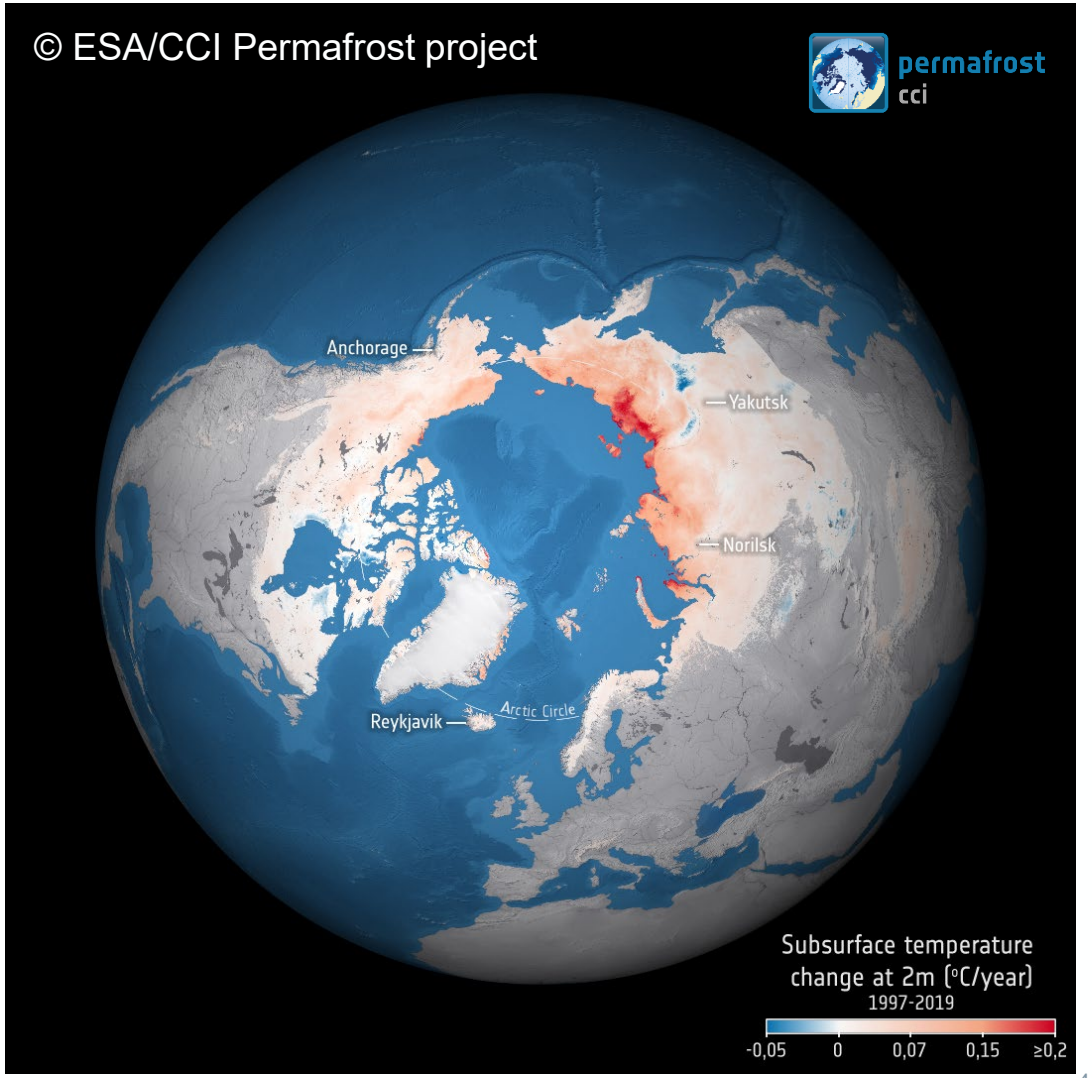
Sea ice extent and ground temperature



September sea ice extent – source: seaiceportal.de

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

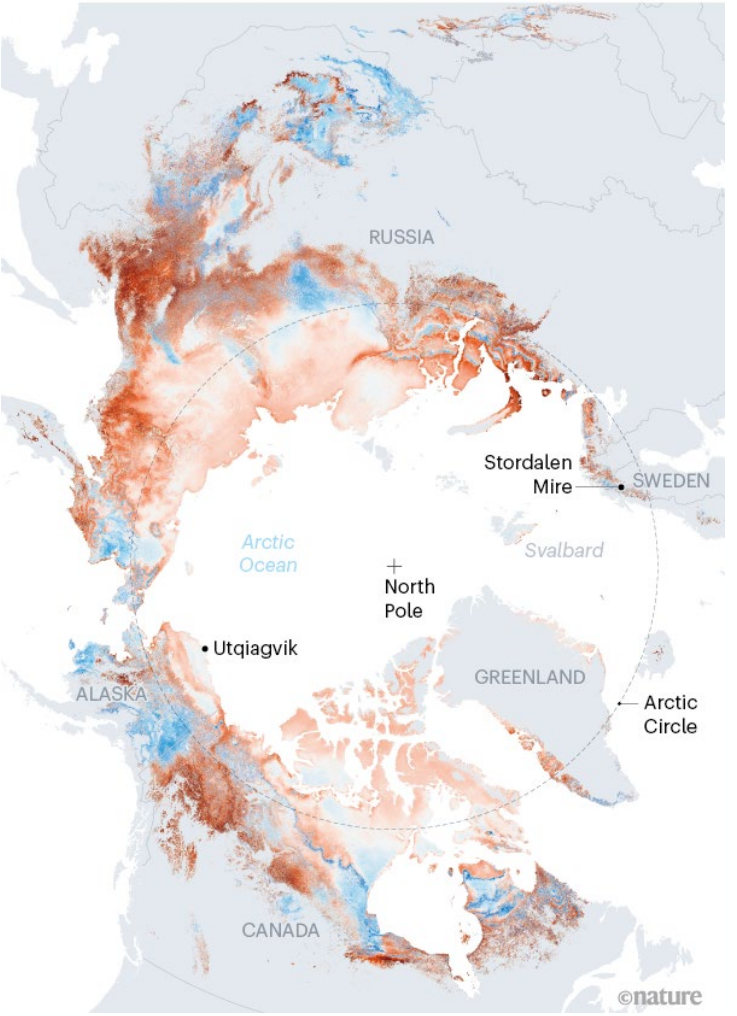
No direct observation of ground temperature from space! CryoGrid model using Landsurface temperature as input



Permafrost & Carbon

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.



Active-layer depth change
1997–2006
to 2007–16

40 cm shallower

0

50 cm deeper

derived based on Obu et al. 2018 (CEDA archive)

permafrost cci

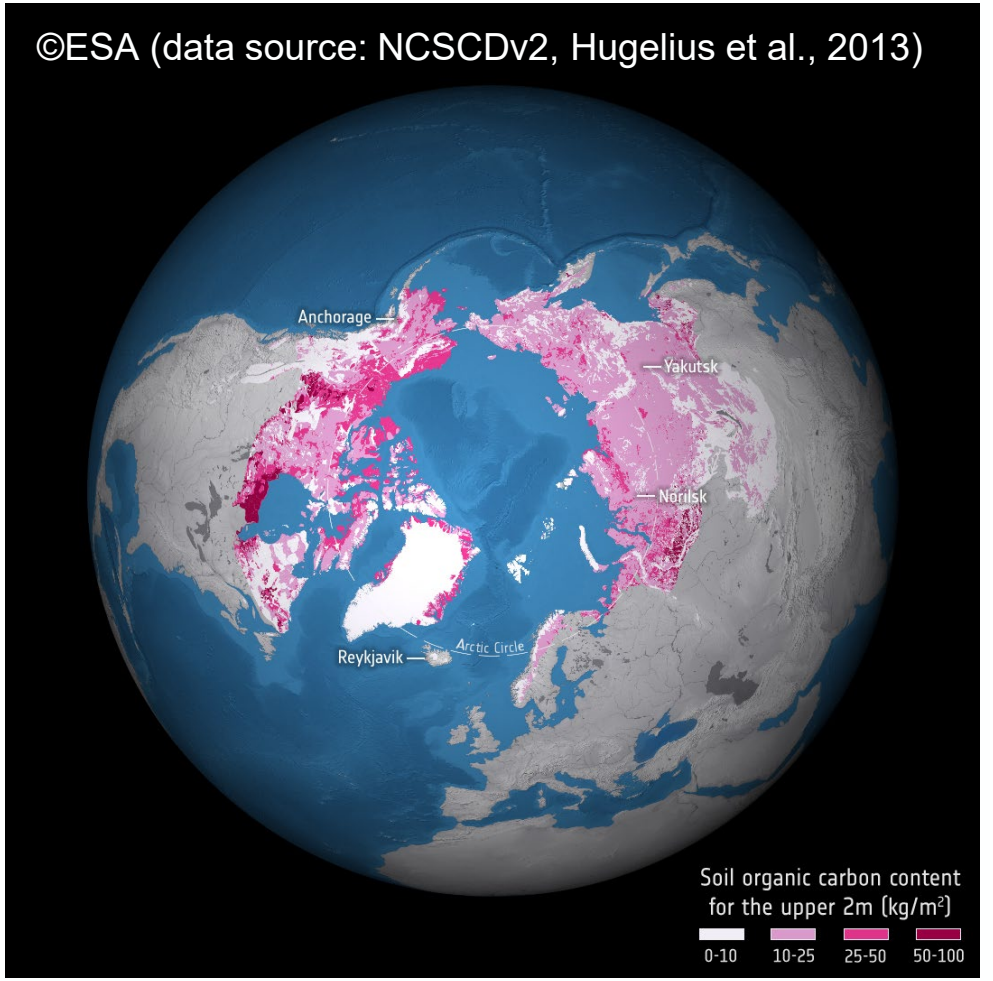
Monique Brouillette (2021): How microbes in permafrost could trigger a massive carbon bomb Genomics studies are helping to reveal how bacteria and archaea influence one of Earth's largest carbon stores as it begins to thaw. News Feature. Nature 591, 360-362 (2021), doi: https://doi.org/10.1038/d41586-021-00659-y

Permafrost & Carbon

- The key issue is the fate of carbon stored in permafrost
- Arctic permafrost stores nearly 1,700 billion metric tons of frozen and thawing carbon
- Anoxic conditions → Methane

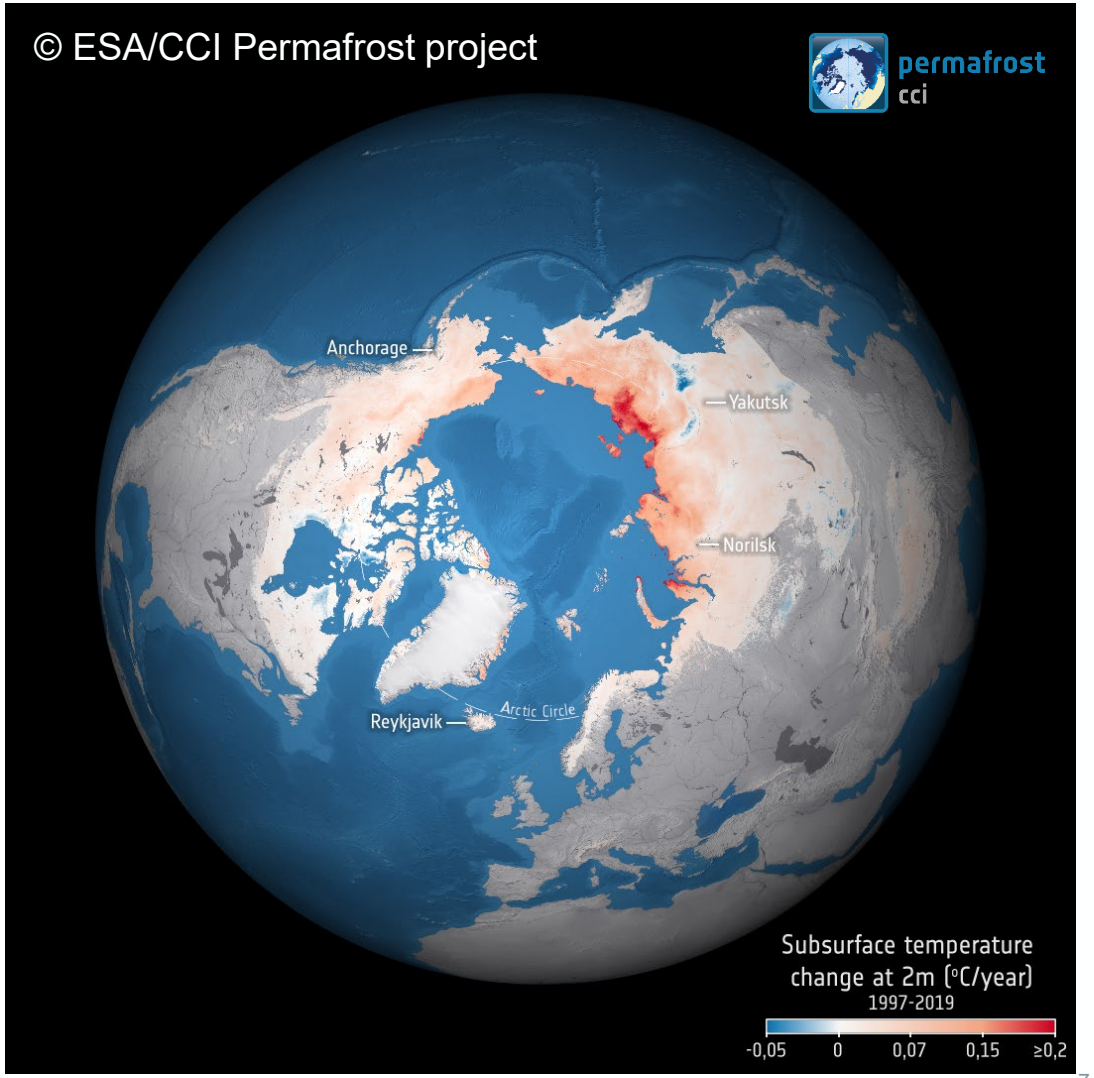
Abrupt thaw (Miner et al. 2022):

- Rapid permafrost thaw that occurs on timescales of a few days to a few years
- can be triggered by climate warming or landscape disturbances, including wildfires or hydrological regime changes
- ‚Thermokarst'
  - Thaw slumps, thaw lakes …



Permafrost thaw – tipping point discussion

- Control: temperature
- Key impacts: release of methane and carbon dioxide, which lead to further warming at the global scale and therefore potentially further permafrost thawing
- Progression of thaw:
  - Lenton et al. (2008): Thaw expected to be ‘quasi-linear’
  - Schuur et al. (2015): gradual release of greenhouse gas emissions with permafrost thaw
- But
  - local abrupt thaw which is abundant
  - heat production caused by microbial decomposition of the soil (Bathiany et al. 2016) - rate induced tipping (Luke & Cox 2011) …
- ? Methane from permafrost affected sea floor



Permafrost & Carbon & Remote sensing

Remote sensing options & limitations (Swingedouw et al. 2020, Miner et al. 2022)

- Surface patterns of abrupt thaw and thermokarst, degradation
- Carbon release, top down – GHG concentrations
- Carbon release, bottom up – carbon rich soils and wetlands
- Improving model predictions through permafrost CDRs

Needed:

- Very high spatial resolution
- enhanced retrieval methods and new sensors
- landcover with matching thematic content
- High quality, long-term and spatial resolution LST, SWE and landcover

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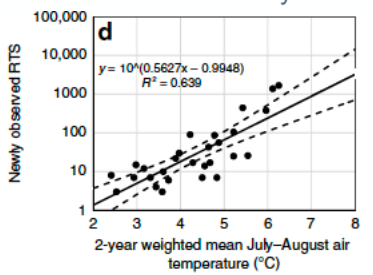
Landsat, Canada; Lewkowicz & Way 2019



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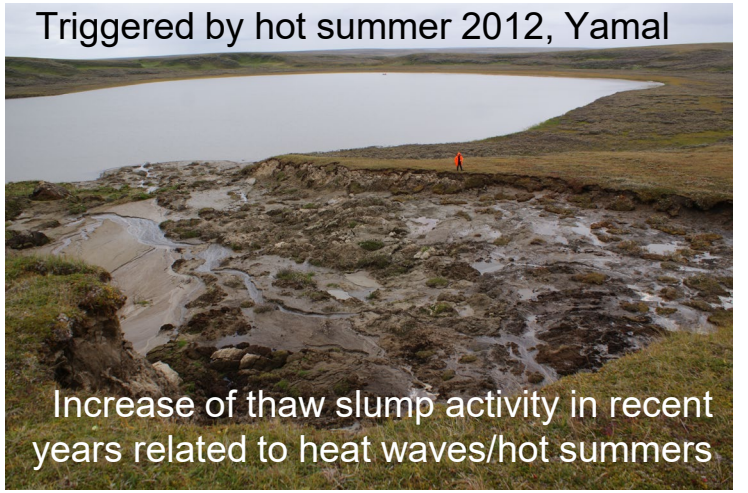
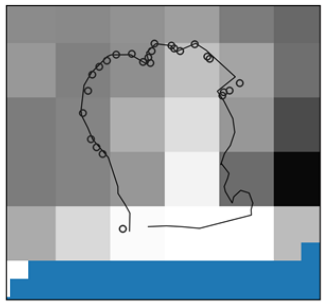


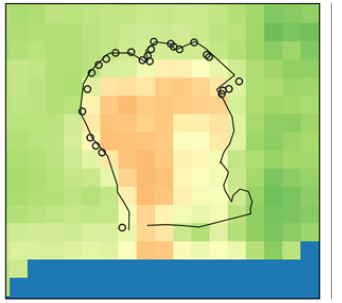
30m



Landsat NDVI trend (1999-2014)

0 50 100 m

10m



Sentinel-2 NDVI 2015

Lissak et al. 2020

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