



# Monitoring of infrastructure across the Arctic with Sentinel-1 and -2

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HORIZON2020 NUNATARYUK (lead by AWI) brings together world-leading specialists in natural science and socio-economics to:

- develop quantitative understanding of the fluxes and fates of organic matter released from thawing coastal and subsea permafrost;
- **assess what risks are posed by thawing coastal permafrost, to infrastructure, indigenous and local communities and people's health, and from pollution;**
- use this understanding to estimate the long-term impacts of permafrost thaw on global climate and the economy.

➤ Infrastructure mapping within 100km buffer of Arctic coastline by **b·geos**





# Currently available records

- Global datasets of build-up areas
  - Not all Arctic settlements included, limitation to buildings
- Open Streep Map
  - Inconsistent information on settlements and infrastructure, many gaps across the Arctic, partially limited geometric accuracy, unknown timestamp
  - But currently most complete account, used in several studies
- Precise local accounts for some sites
  - Derived manually using aerial photographs and/or very high resolution satellite data as well as in-field GNSS observations



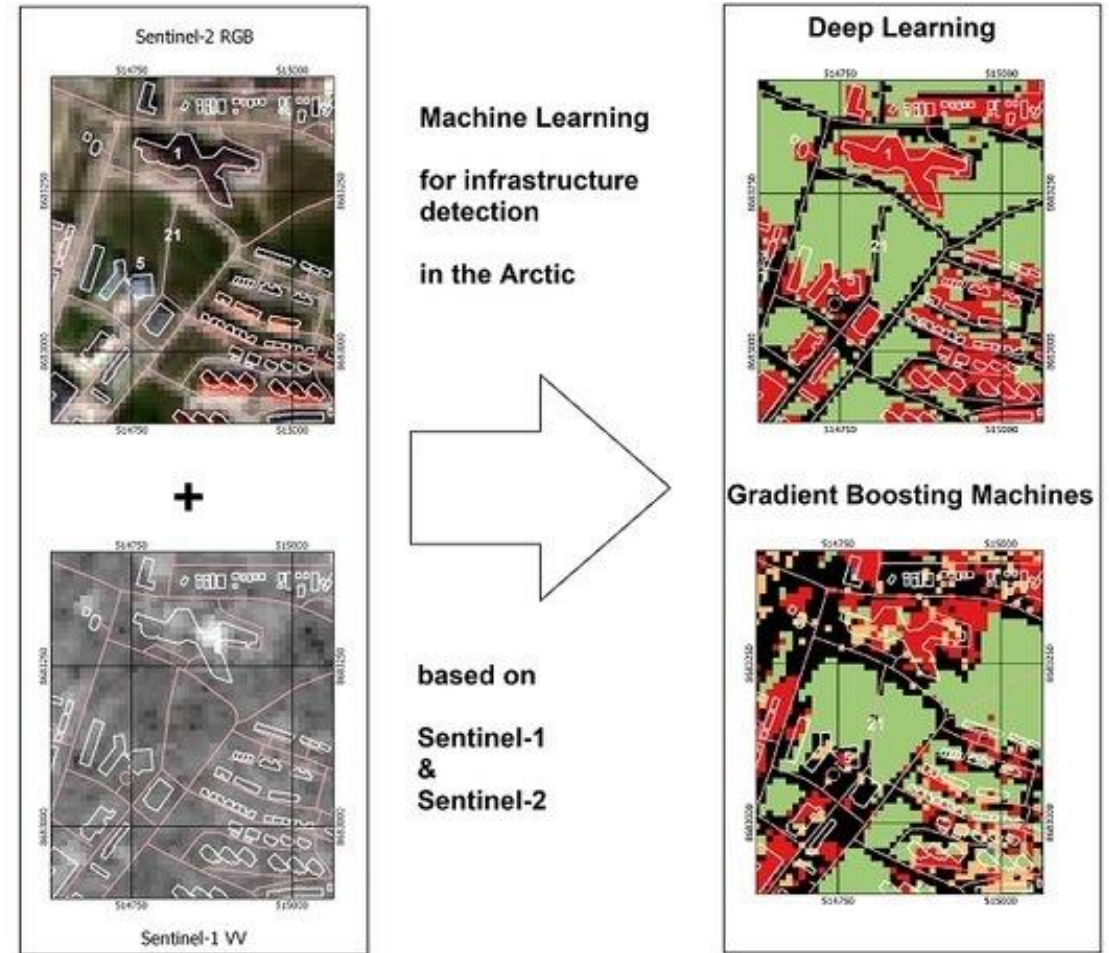
# What datasources could be used?

- Landsat (30m) popular for Arctic landcover mapping (e.g. review in Bartsch et al. 2016, RS), but settlements and infrastructure rarely mapped
    - Spatial resolution largely insufficient (e.g. Kumpula et al. 2012)
  - Sentinel-1 and Sentinel-2 provide now data at 10 m resolution
- Aim: Consistent account of human presence based on Sentinel-1 and Sentinel-2 across the Arctic

# Approach

- Two machine learning methods are applied
  - Gradient boosting machines (GMB)
  - Deep Learning (DL)
  
- Fusion of results

Bartsch, Pointer, Ingeman-Nielsen & Lu (2020), RS

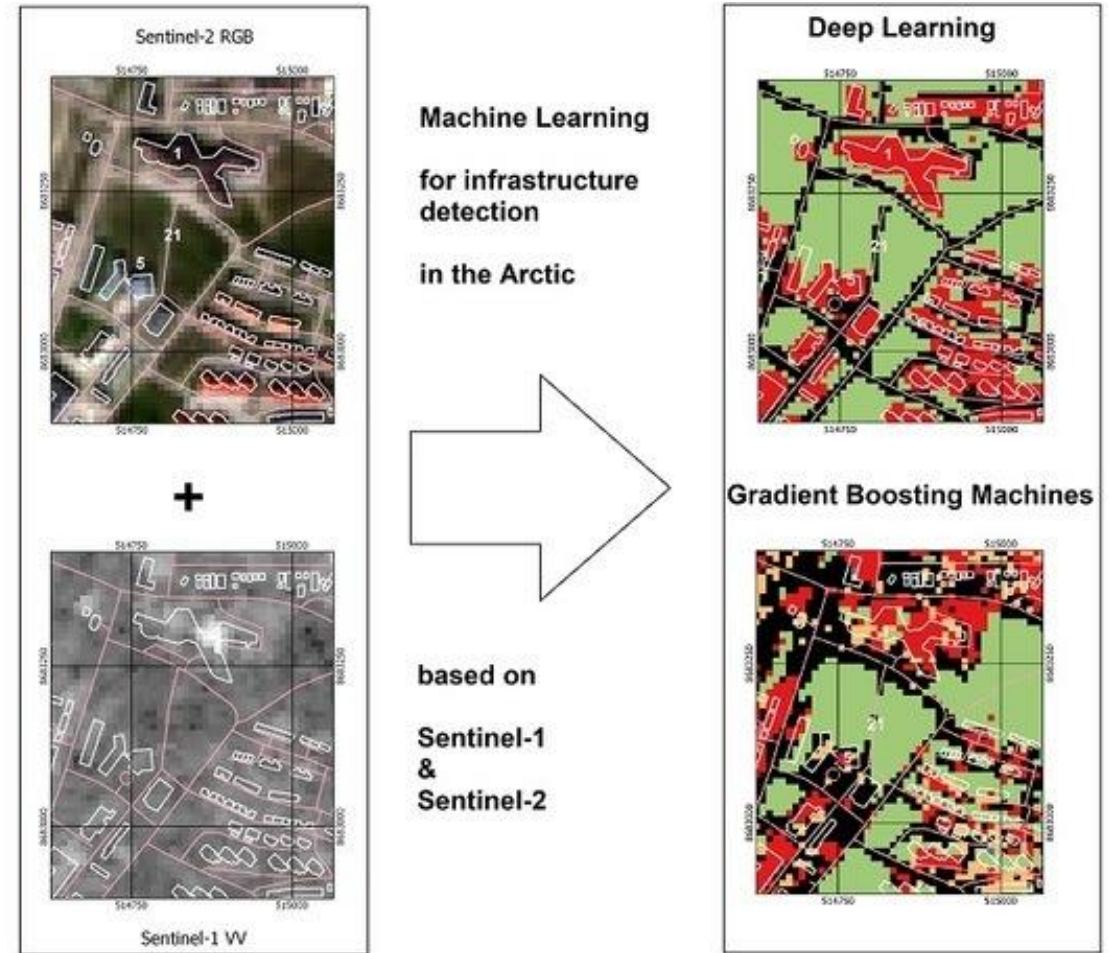


(2016-2018)

# Approach

- Provides
  - Buildings
  - Roads
  - Other human impacted area
- GBM also includes
  - Vegetated areas
  - water

Bartsch, Pointer, Ingeman-Nielsen & Lu (2020), RS

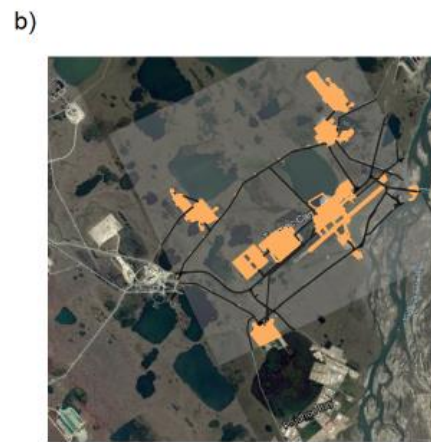
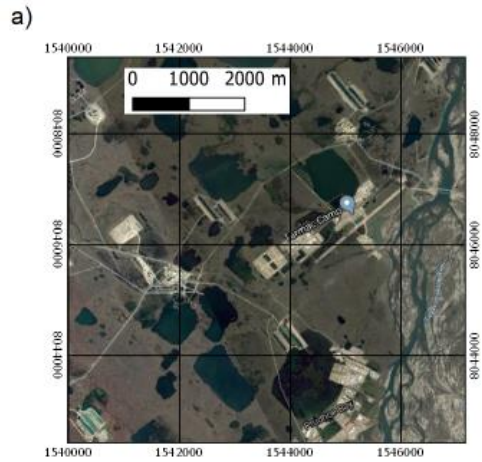


(2016-2018)

Central Longyearbyen, Svalbard

# Example Prudhoe Bay, Alaska

Google Hybrid  
background map

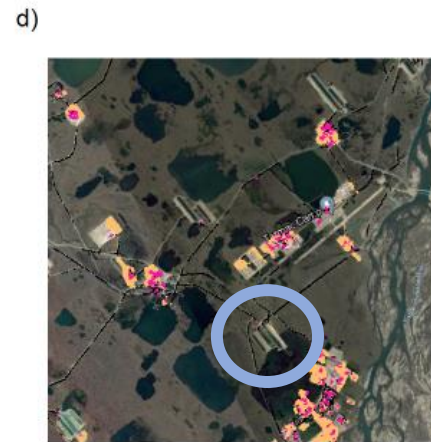


high-resolution validation dataset  
(area C of the work in Reynolds et al. 2014)

Gradient Boost  
Machine  
classification result



Gradient Boost Machine  
■ Roads  
■ Buildings and artificial objects  
■ Other human impacted area



Deep Learning  
■ Roads  
■ Buildings  
■ Other human impacted area

Deep Learning result

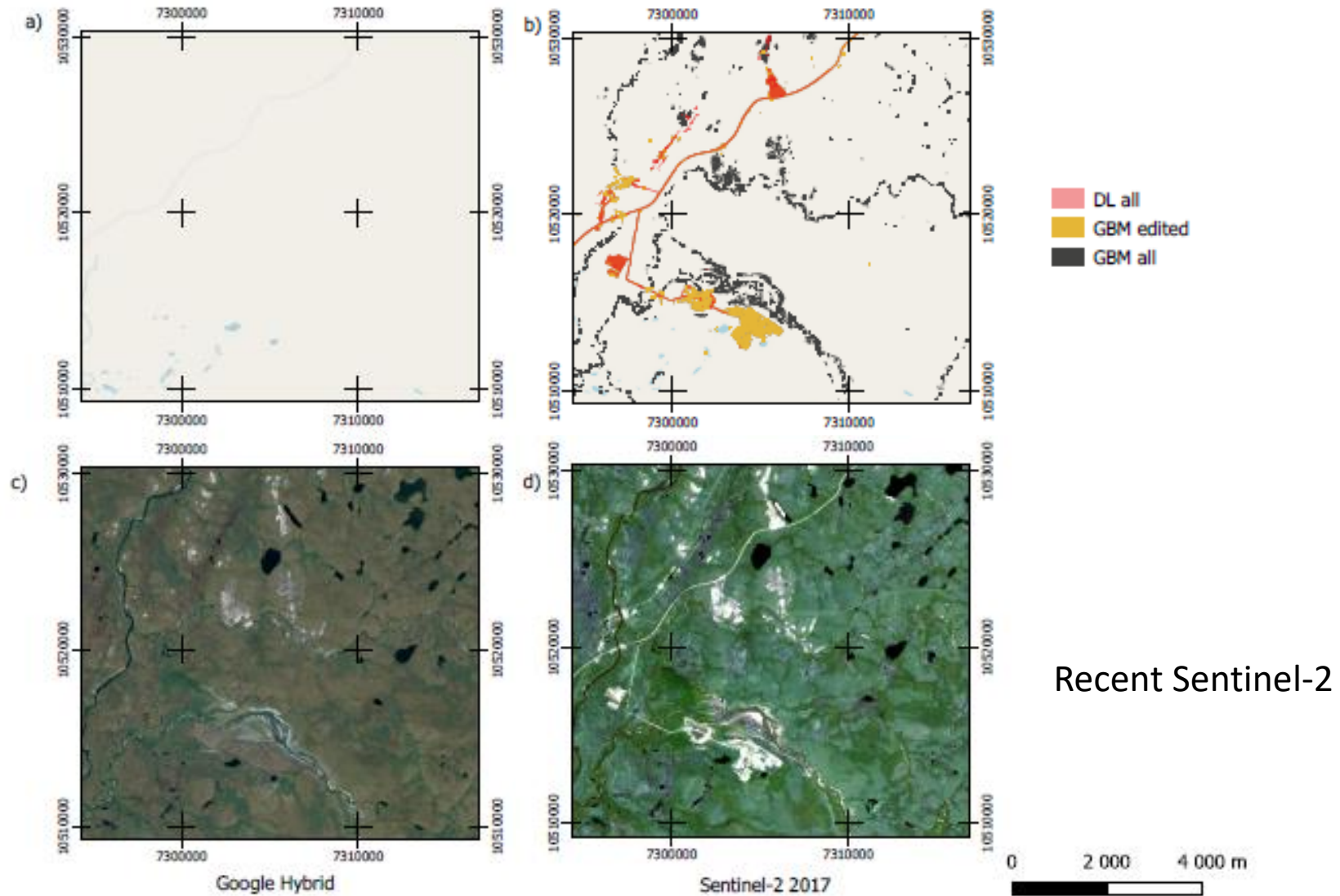
Bartsch, Pointer, Ingeman-Nielsen & Lu (2020), PS



# Example Siberia

Bartsch, Pointer, Ingeman-Nielsen & Lu (2020), RS

OpenStreetmap  
(also background in  
(b))

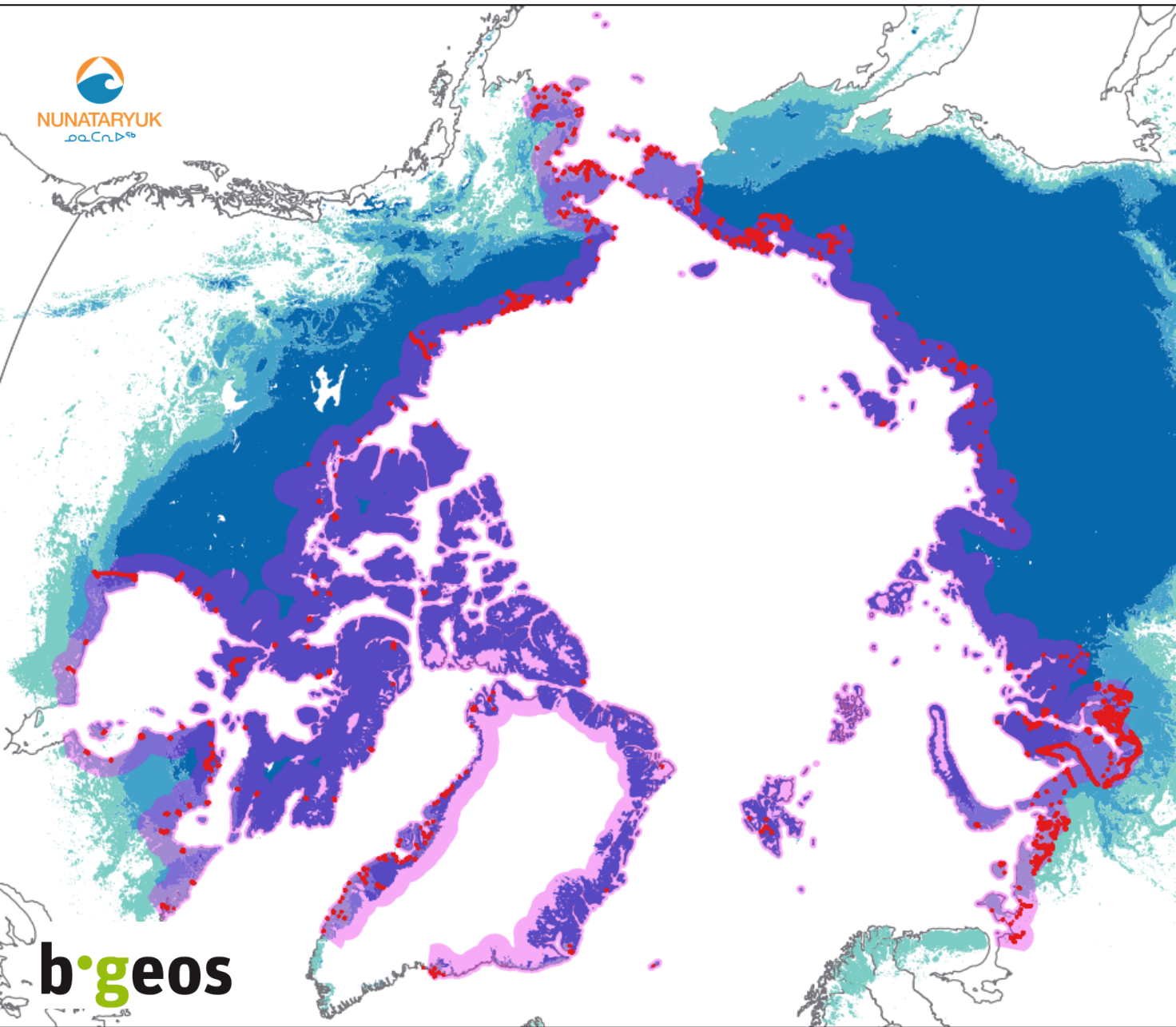


Google Hybrid

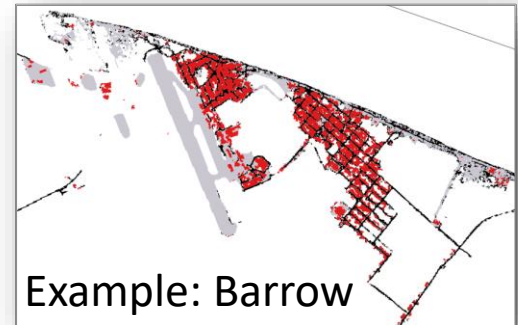
Recent Sentinel-2



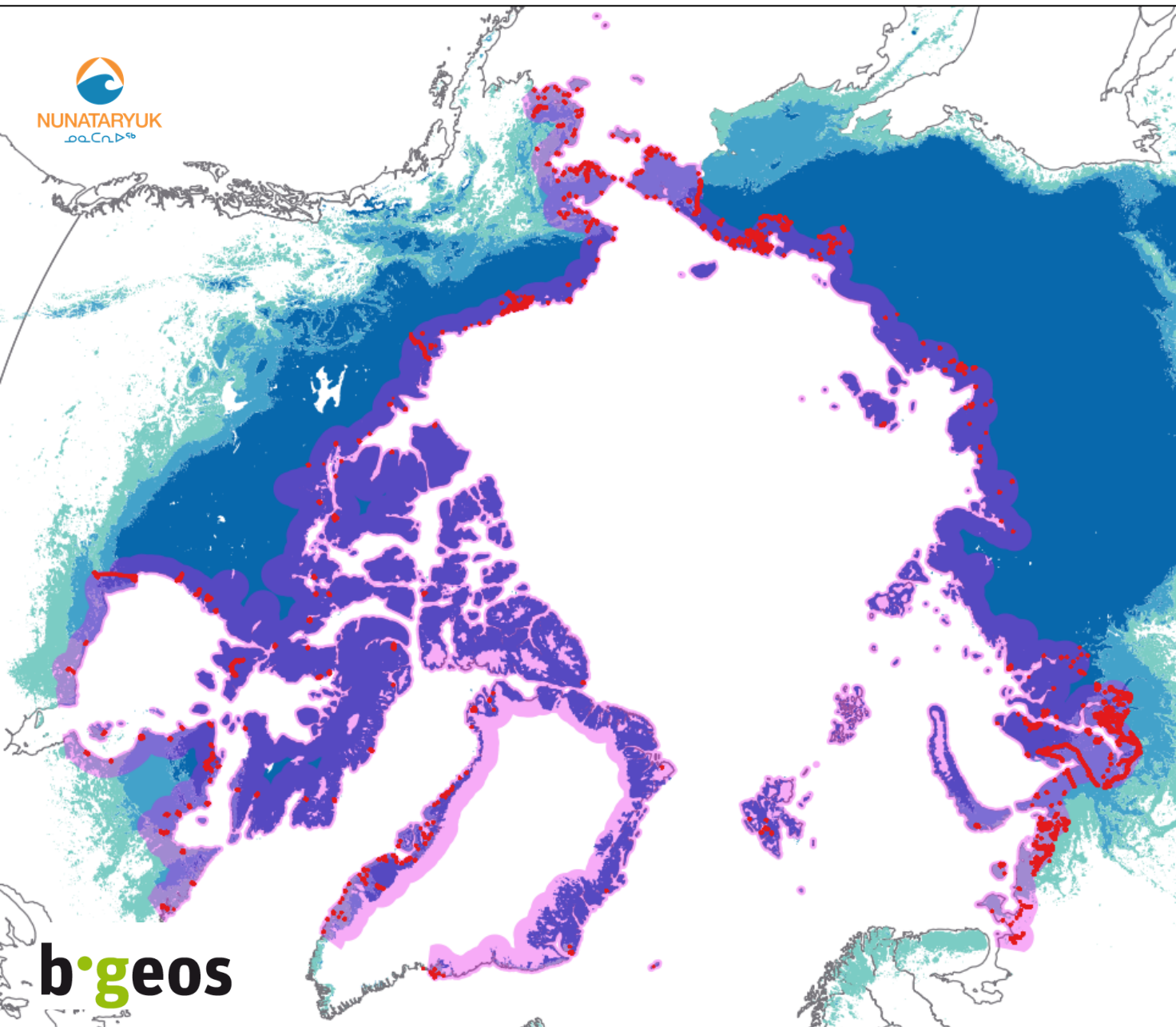




- Three final classes:
  - Buildings and other constructions (bridges etc)
  - Roads and rail tracks
  - Other human impacted area (gravel pads, air strips open pit mines etc)

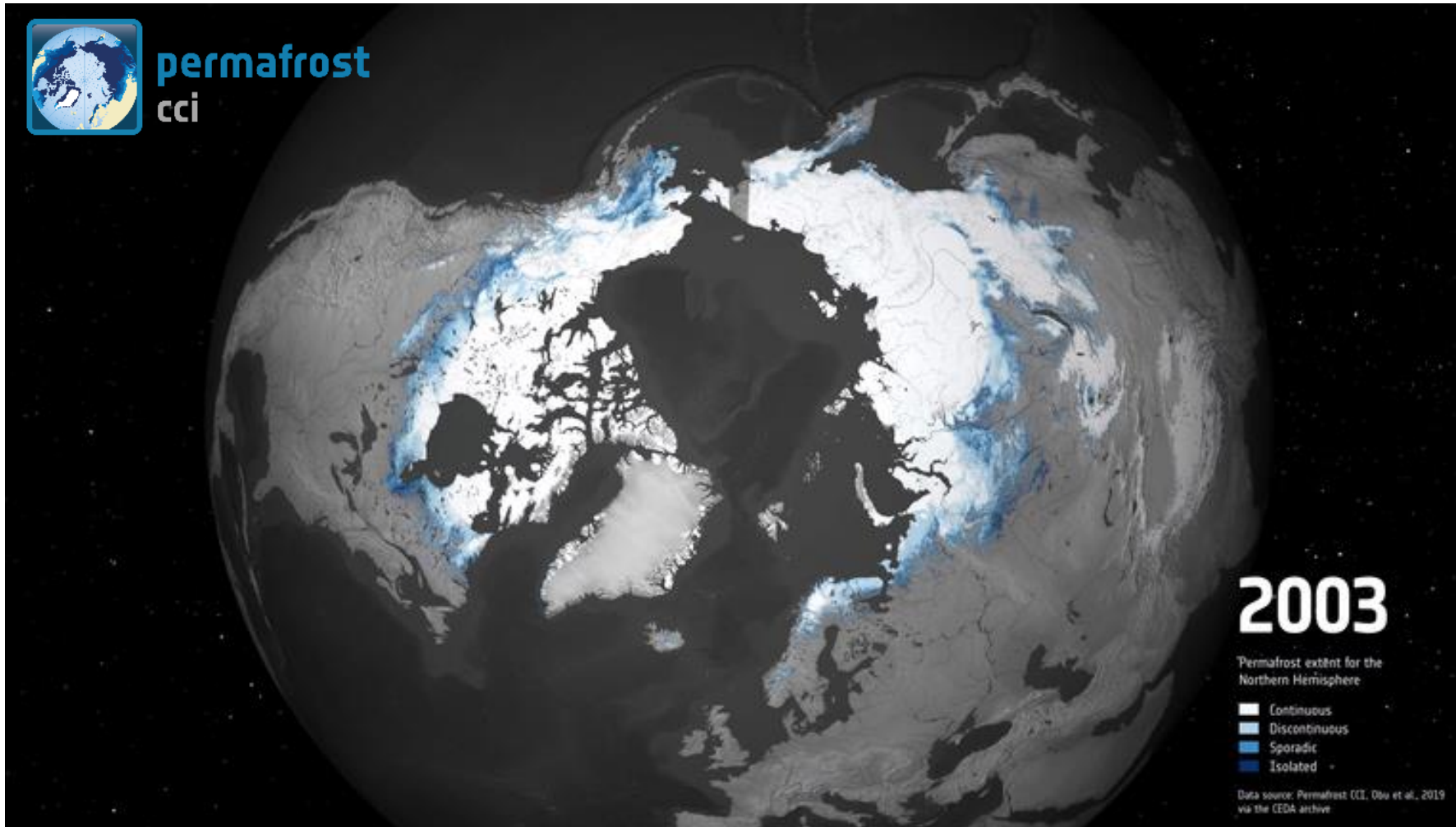


- Within 100 km buffer from coast (Nunataryuk focus area)
- None-permafrost area settlements not included



- Added value through combination with other datasets
- Combination with e.g. ESA CCI+ Permafrost records

# Novel datasets available from Permafrost\_cci



Permafrost extent from Permafrost\_cci (based on 2m ground temperatures 2003-2017; modelled using MODIS LST)

**New dataset just published 1997-2018**

<https://climate.esa.int/en/projects/permafrost/>

Download via CEDA  
Includes:

- Ground temperatures
- Active layer thickness
- Permafrost extent

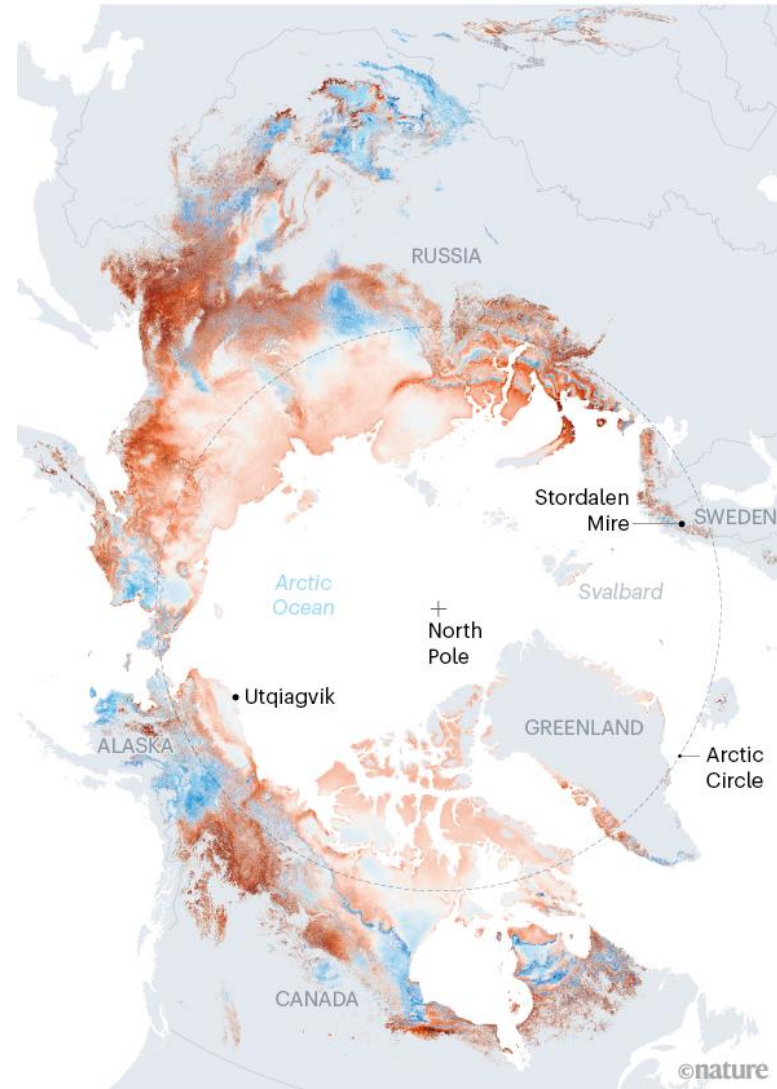
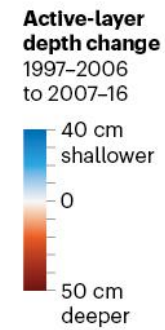
## Novel datasets available from Permafrost\_cci



- Active layer thickness used e.g. in this weeks news feature in Nature
- [How microbes in permafrost could trigger a massive carbon bomb \(nature.com\)](#)

## 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.



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# Active layer thickness also of interest related to infrastructure, e.g. the Norilsk tank break last year

Rajendran et al. 2021  
(scientific reports) –  
conclusion no ALT trend  
(data from CALM site  
(~20km?) east of Norilsk)

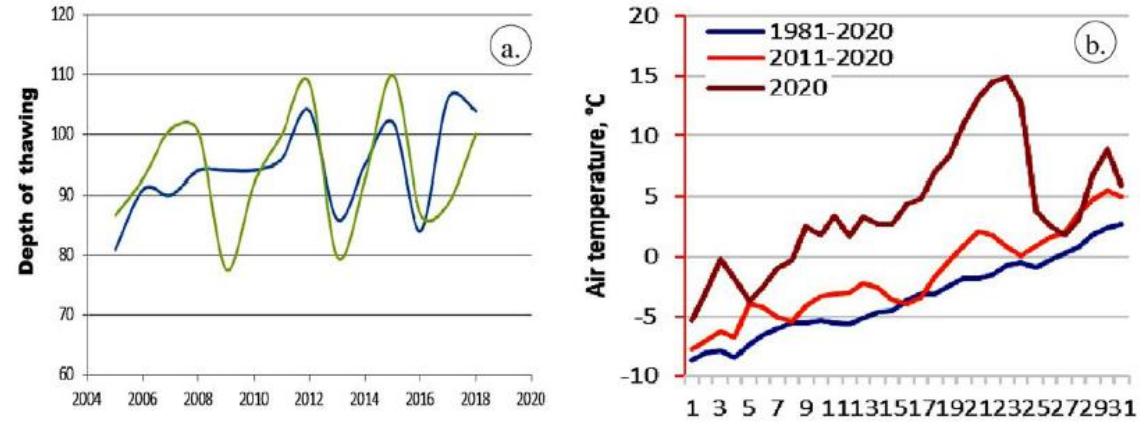
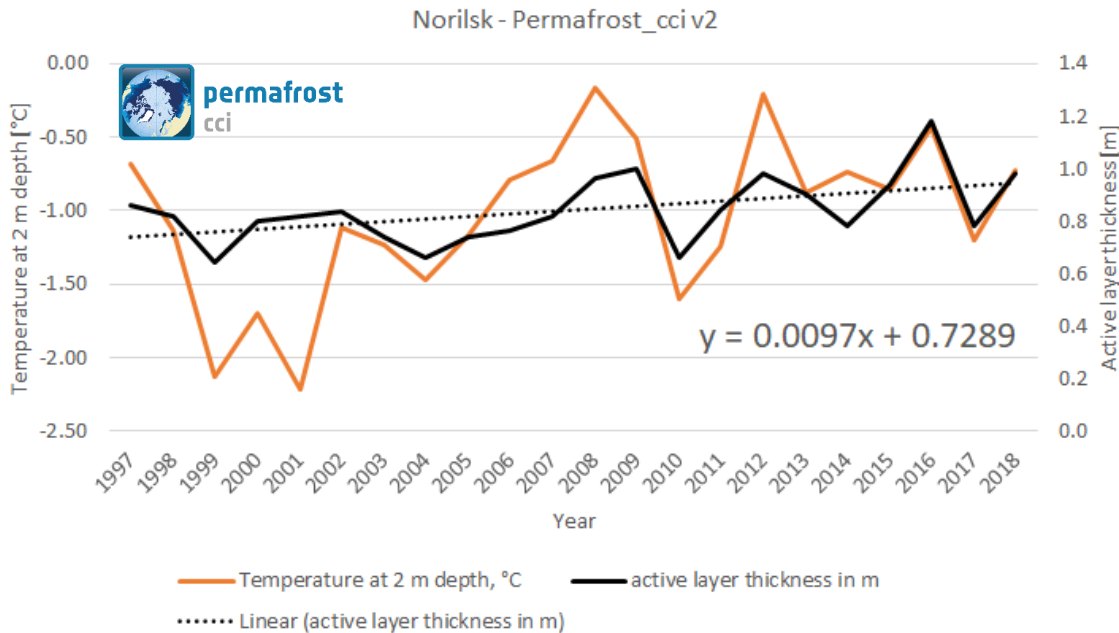


Figure 10. (a) Comparison of the calculated (green) and observed (blue) variations in the depth of seasonal thawing in Talnakh in the 2005–2019 period, (b) Mean daily air temperatures in May in Norilsk averaged over the periods 1981–2020, 2011–2020 and in 2020 [https://www2.gwu.edu/~calm/data/north.htm].



Data source: Obu, J.; Westermann, S.; Barboux, C.; Bartsch, A.; Delaloye, R.; Grosse, G.; Heim, B.; Hugelius, G.; Irrgang, A.; Käab, A.M.; Kroisleitner, C.; Matthes, H.; Nitze, I.; Pellet, C.; Seifert, F.M.; Strozzi, T.; Wegmüller, U.; Wieczorek, M.; Wiesmann, A. (2020): ESA Permafrost Climate Change Initiative (Permafrost\_cci): Permafrost Climate Research Data Package v1. Centre for Environmental Data Analysis.

<http://catalogue.ceda.ac.uk/uuid/1f88068e86304b0fbd34456115b6606f>



# RATIC Questions

*To what extent are you working with Arctic communities, government or industry in your research?*

- *HORIZON2020 Nunataryuk is an interdisciplinary project being in contact with communities across the Arctic, Canada, Greenland, Svalbard, Russia*
- *Cooperation mostly in other work packages (social science)*





# RATIC Questions

*How are you planning to disseminate your results, including "sharing back" your data and findings with Arctic communities and other stakeholders?*

- *Dataset will be published open access (PANGAEA)*
- *Online visualization platforms*
- *We will provide it to NSF Permafrost discovery Gateway*
- *Nunataryuk (GRID Arendal) develops an Atlas*





# RATIC Questions

*Thinking about best practices, what's one thing you have done or learned that could be transferable to other projects?*

- *Remote sensing: combining several approaches, target oriented*





# Summary

- Gradient boosting machines and Deep Learning have both advantages and disadvantages. Combined approach needed
- Pipelines itself cannot be captured but tracks along them
- Currently only three classes, but consistent mapping across the Arctic possible what allows for circumpolar permafrost thaw impact assessment



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