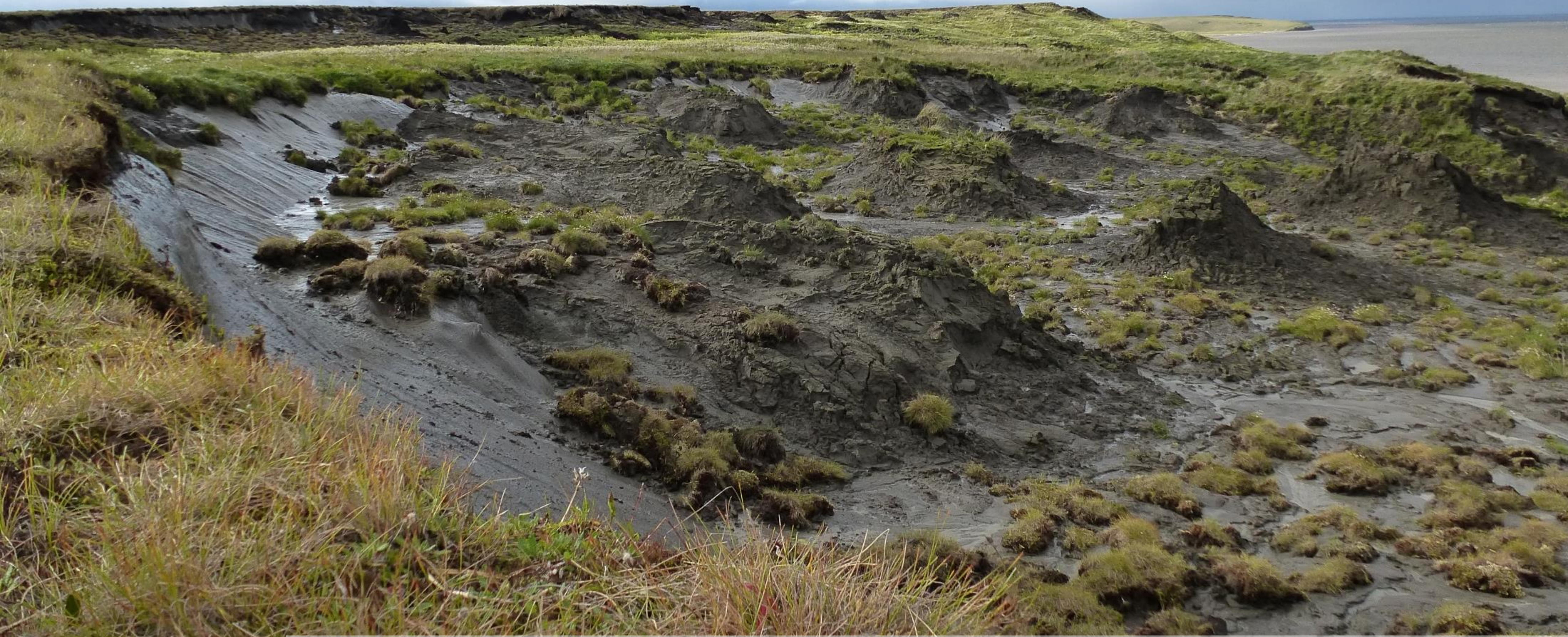
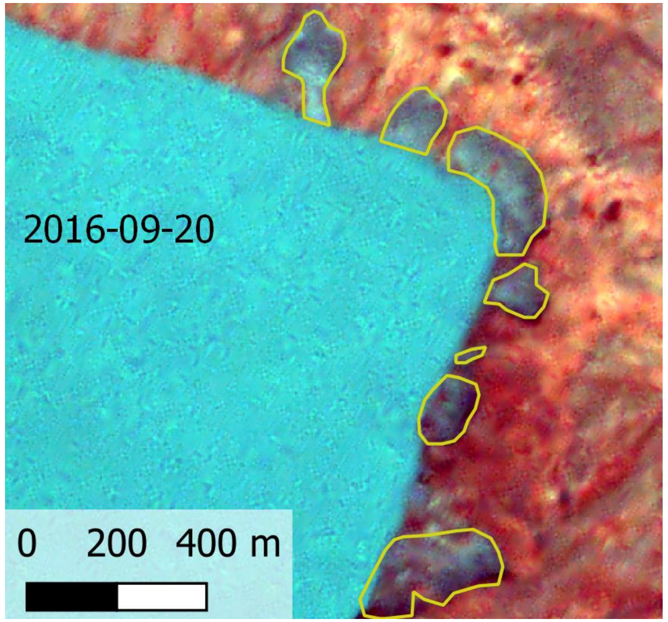
Deep Learning for mapping retrogressive thaw slumps across the Arctic

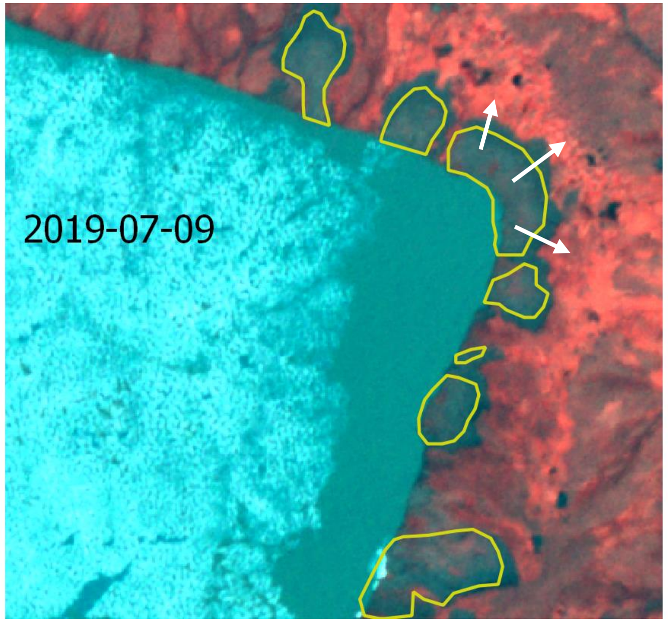


2022-05-19- International Circumpolar Remote Sensing Symposium (ICRSS)

I.Nitze, K.Heidler, S.Barth, G.Grosse

Retrogressive Thaw Slumps

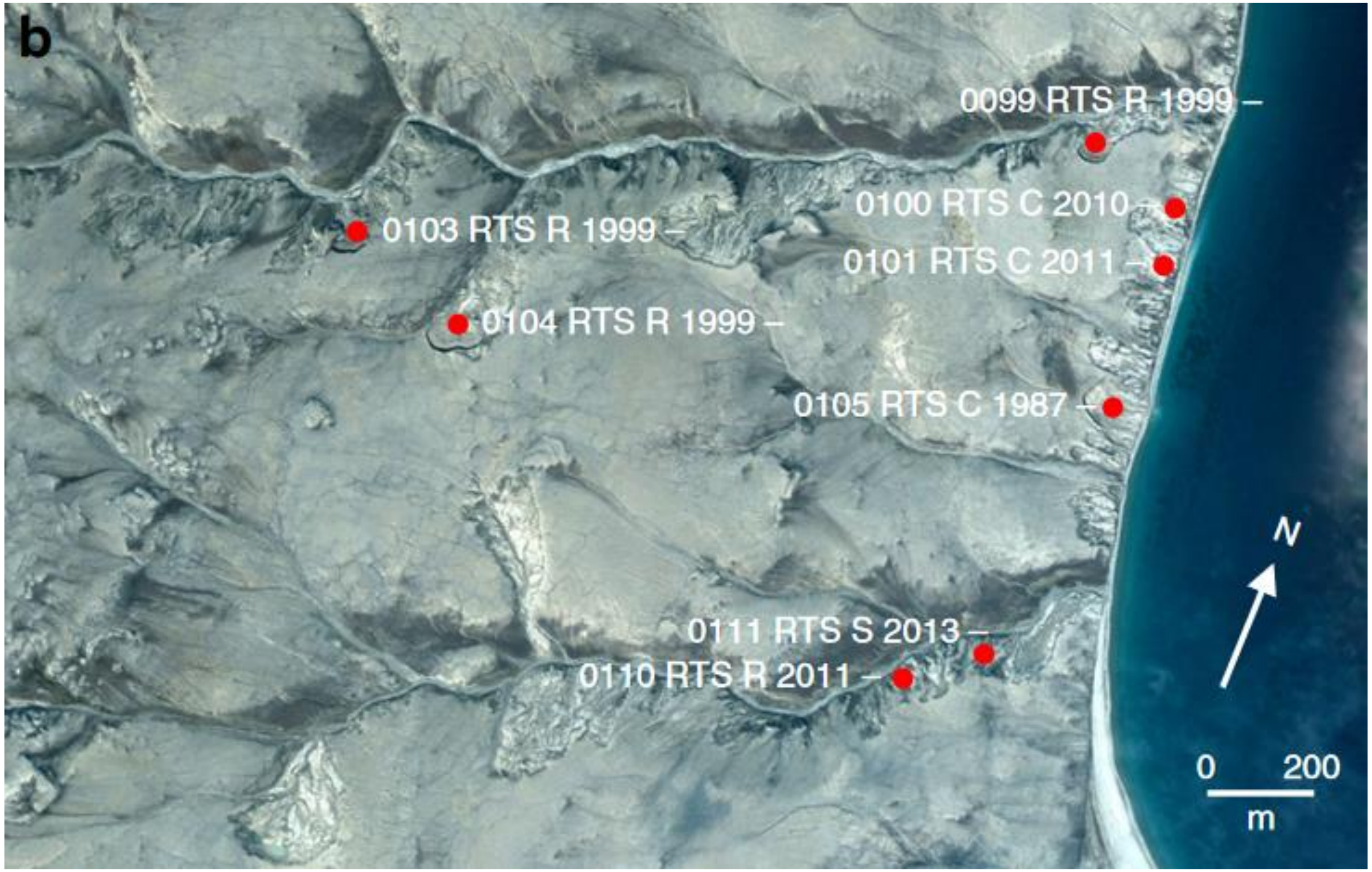


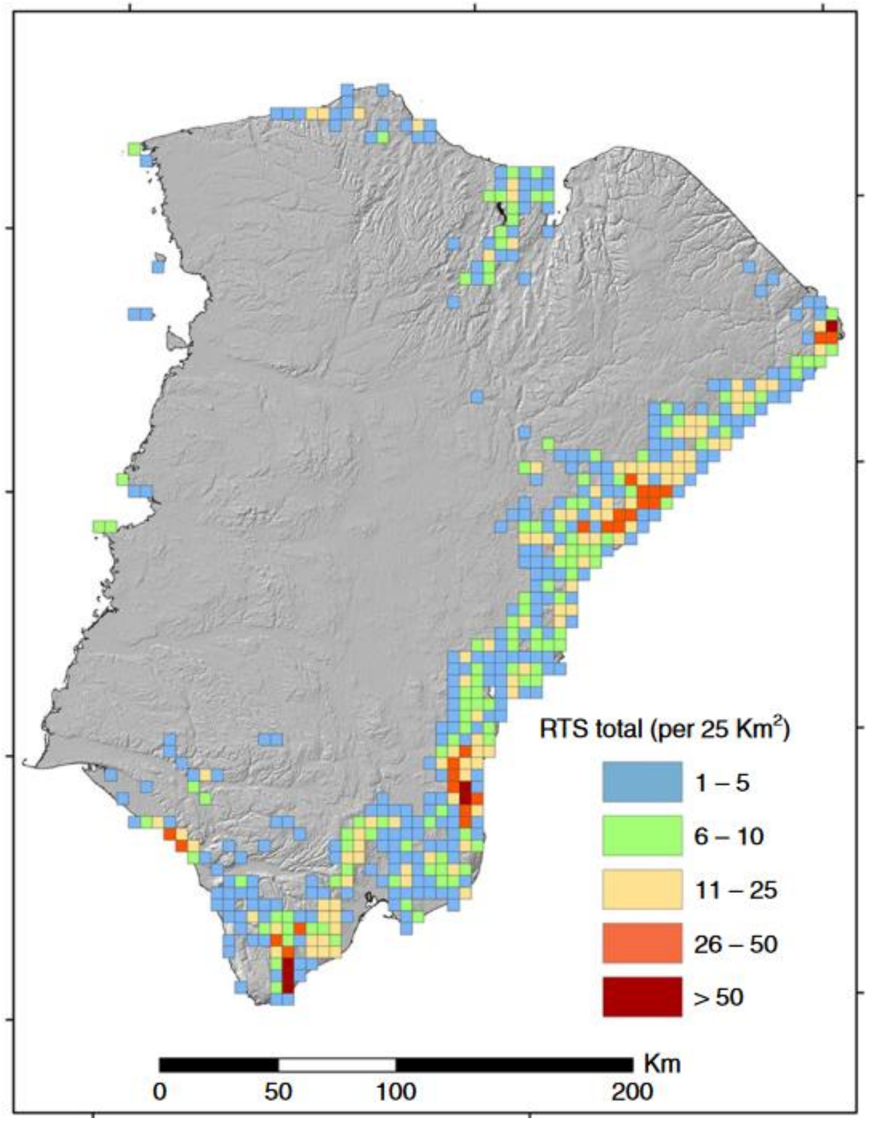


- Erosion
- Dynamic
- Progressive/Polycyclic
- Small (m^2-<1km^2)
- Often undetected
- Clustered Distribution

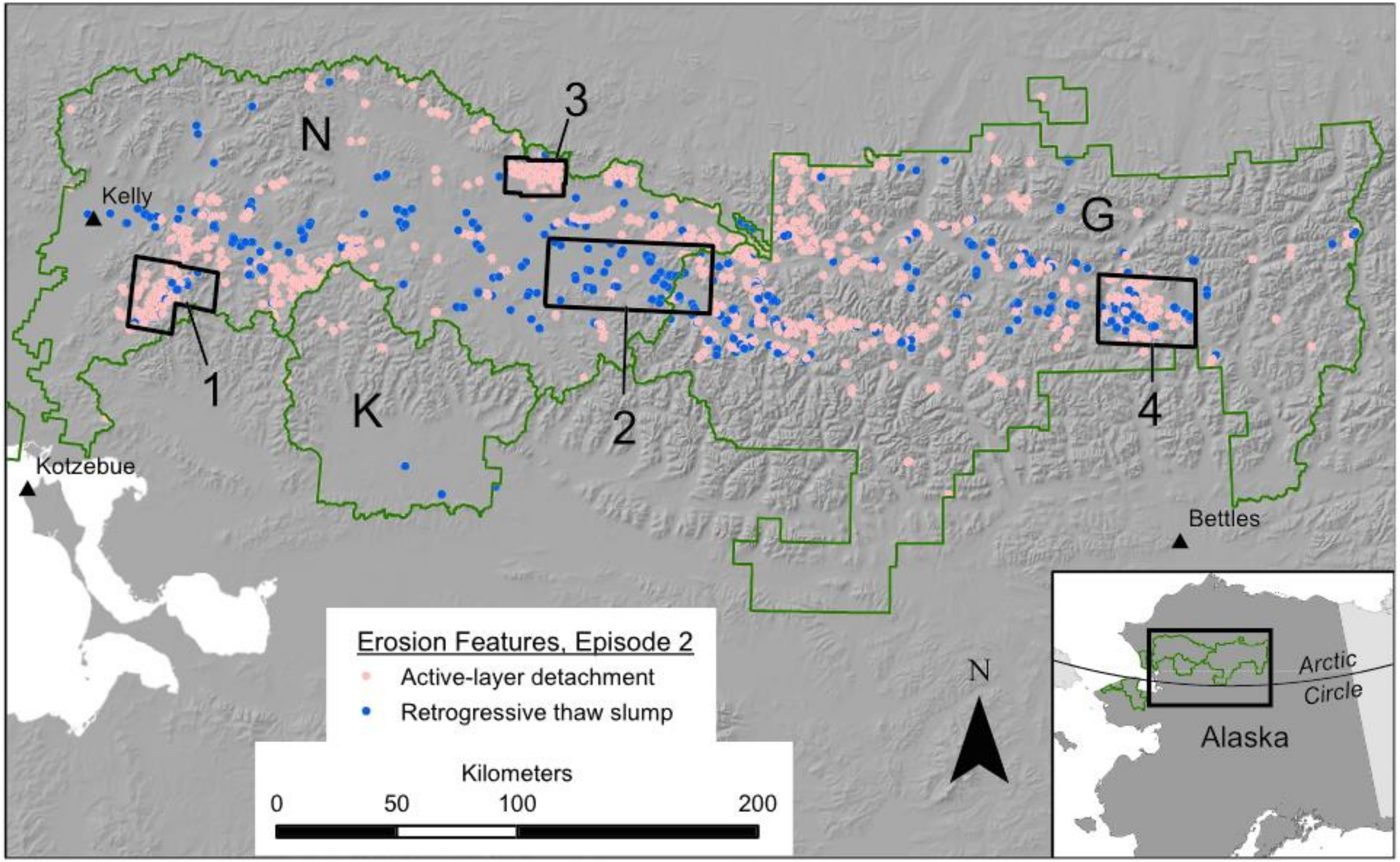
Segmentation Problem

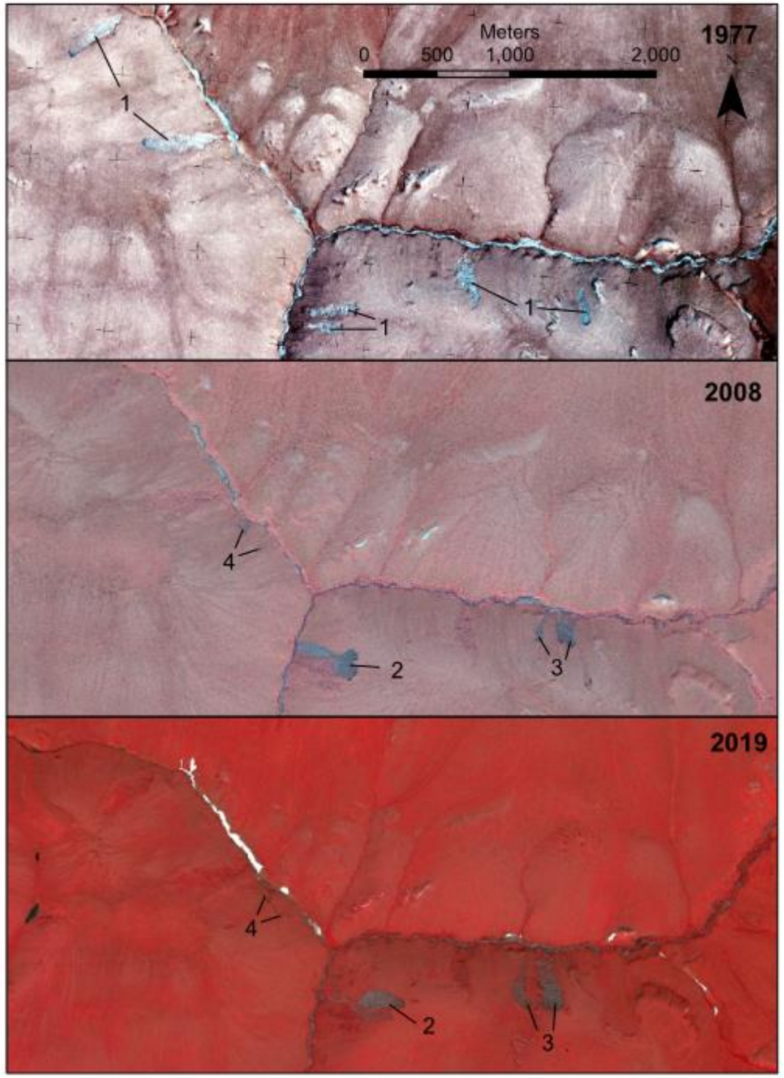
Manual RTS mapping



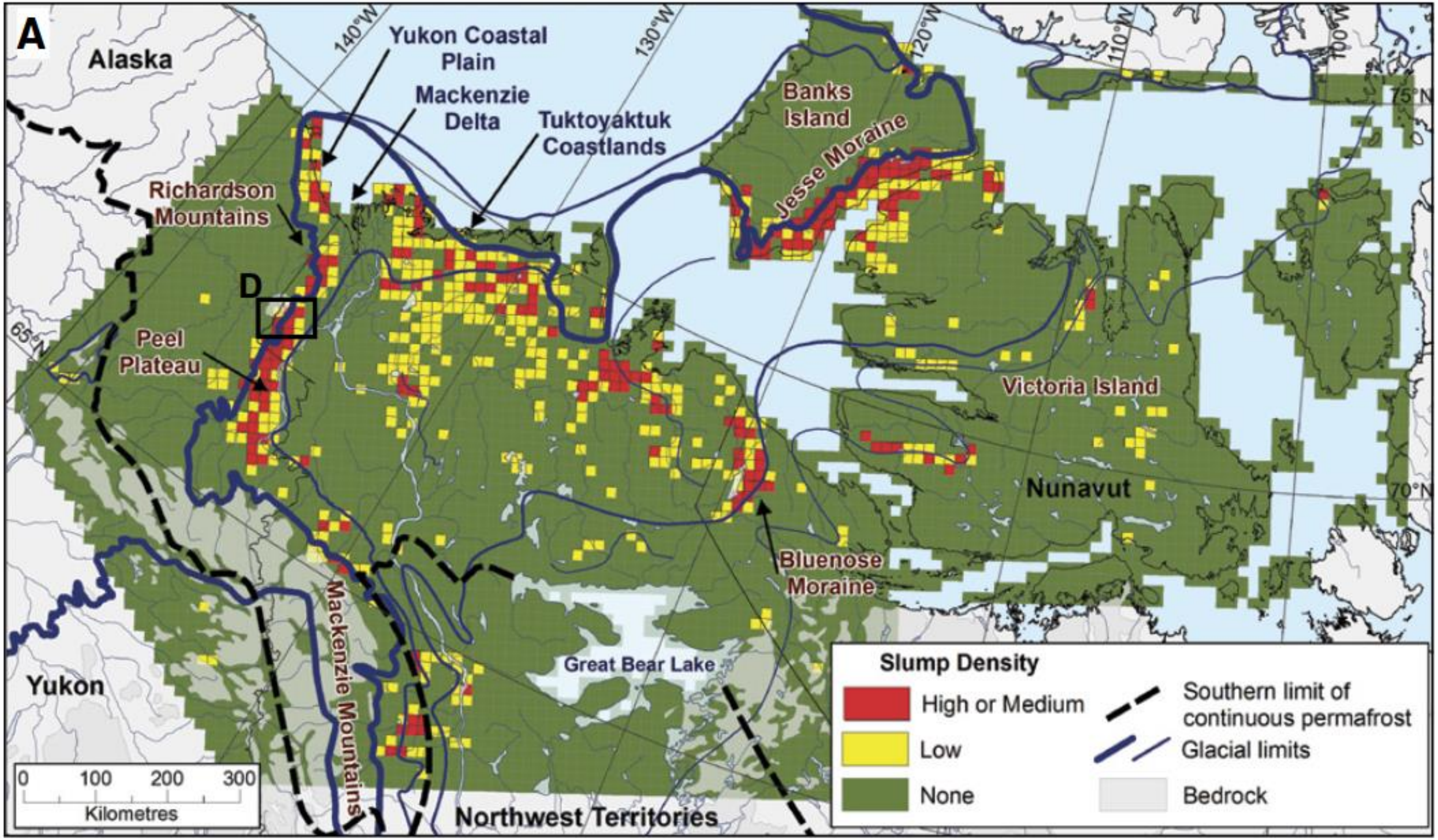


Lewkowicz and Way, 2019



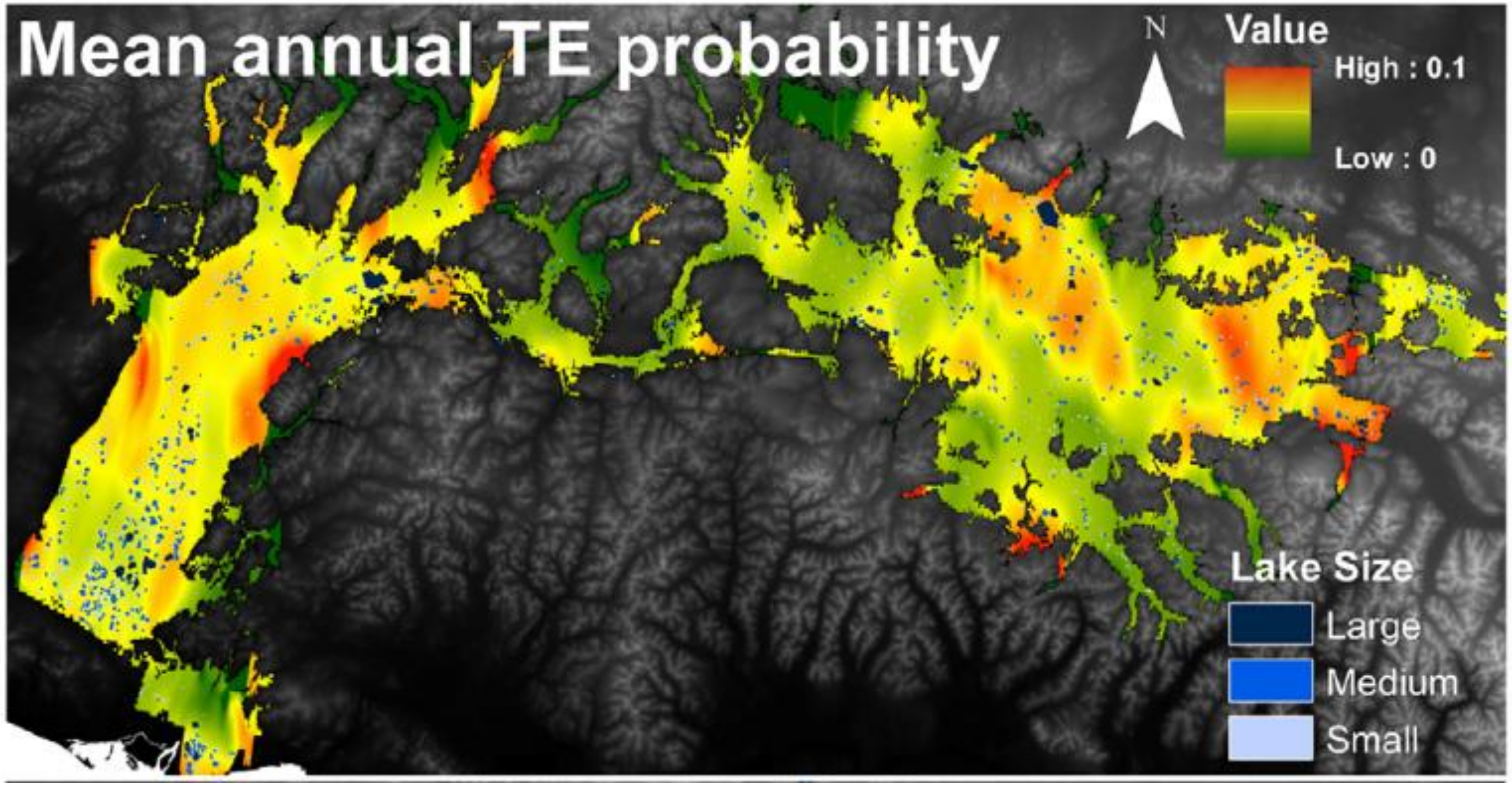


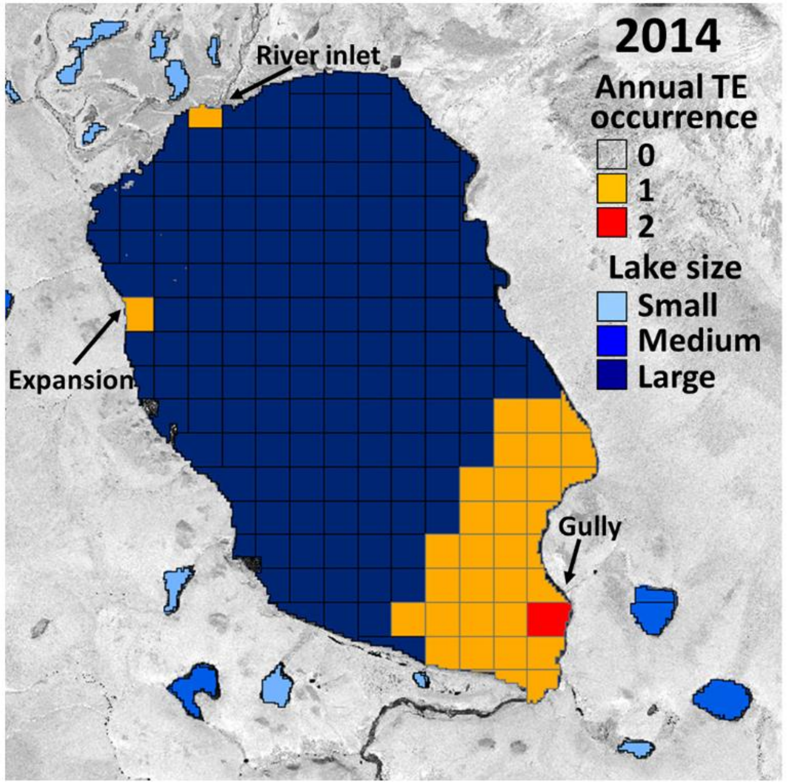
Swanson 2021



Kokelj et al., 2017

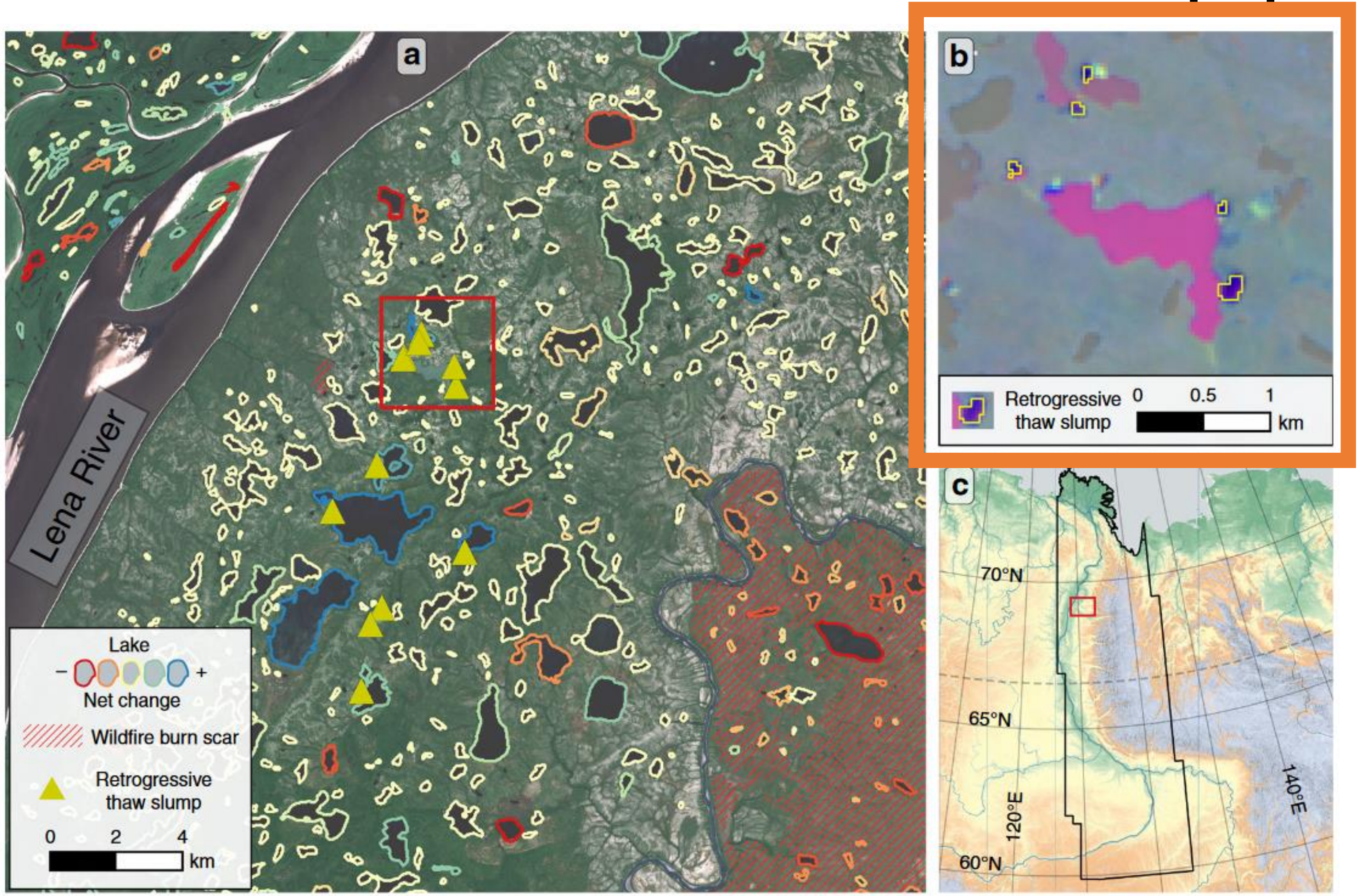
More automated approaches

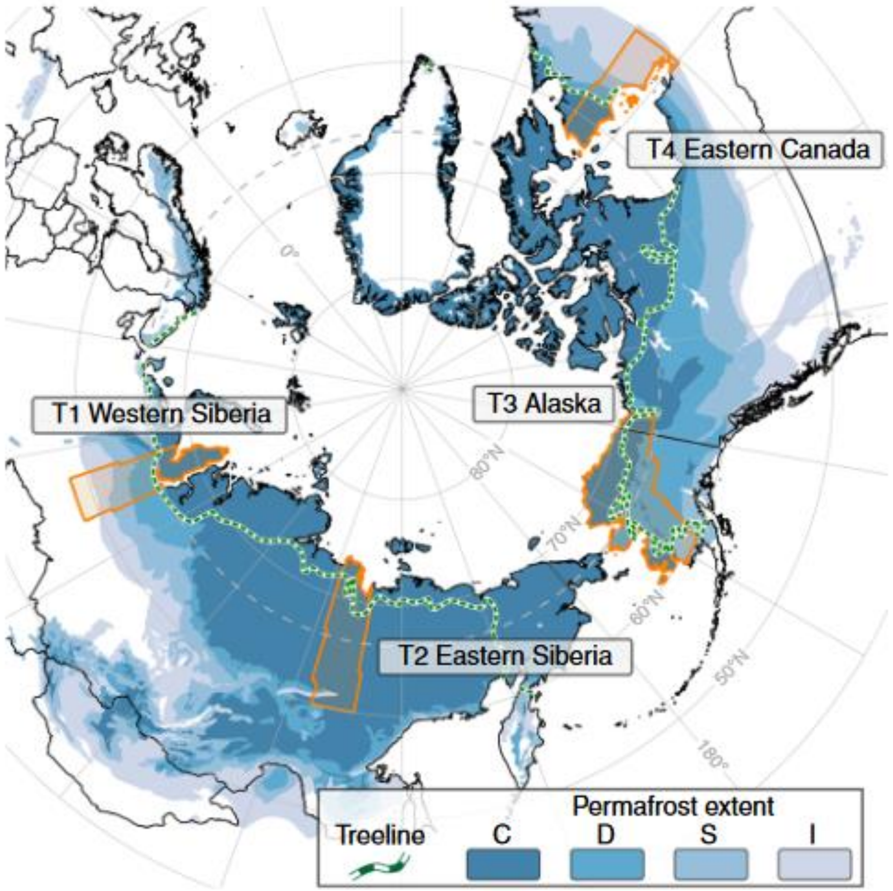




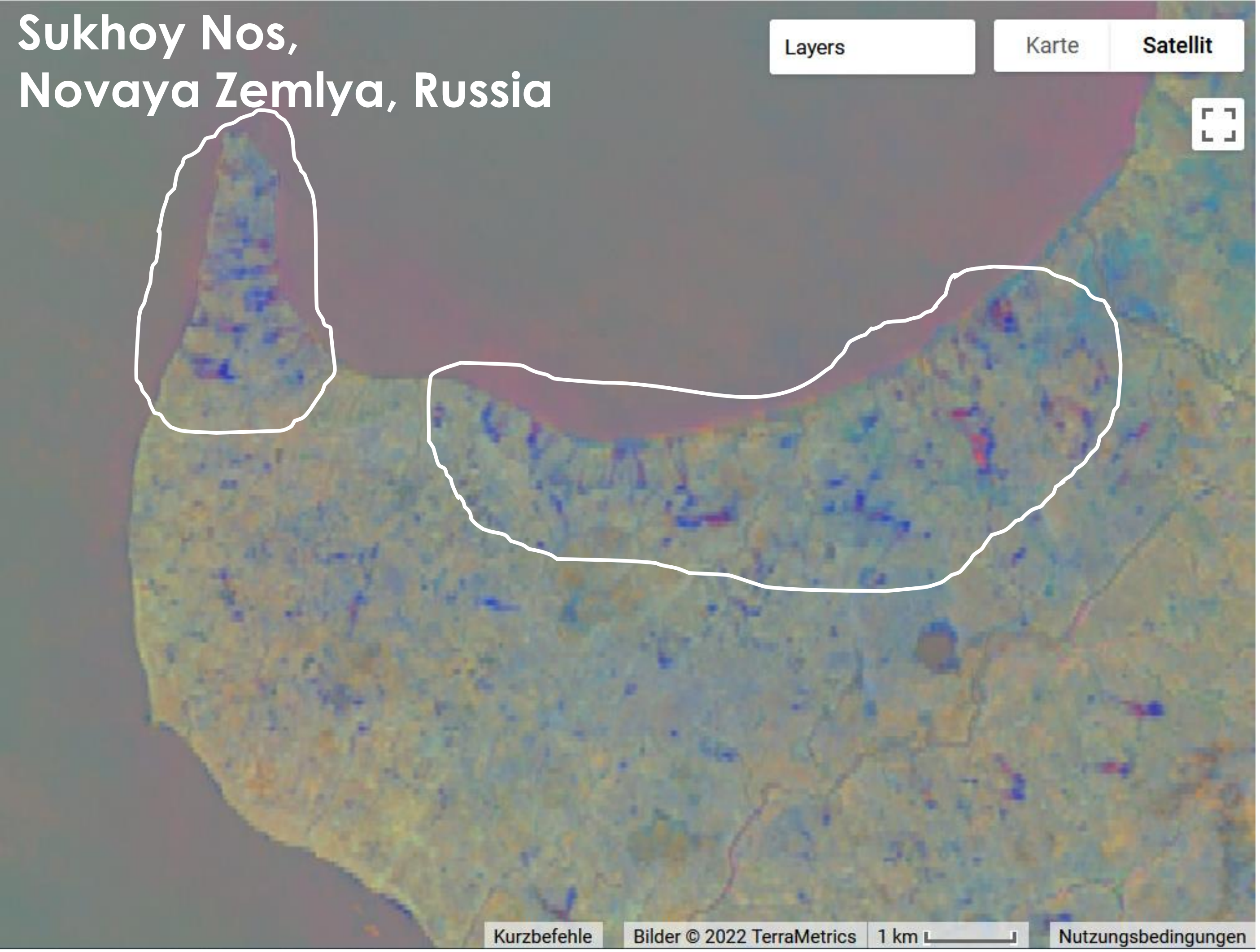
Lara et al., 2019

More automated approaches





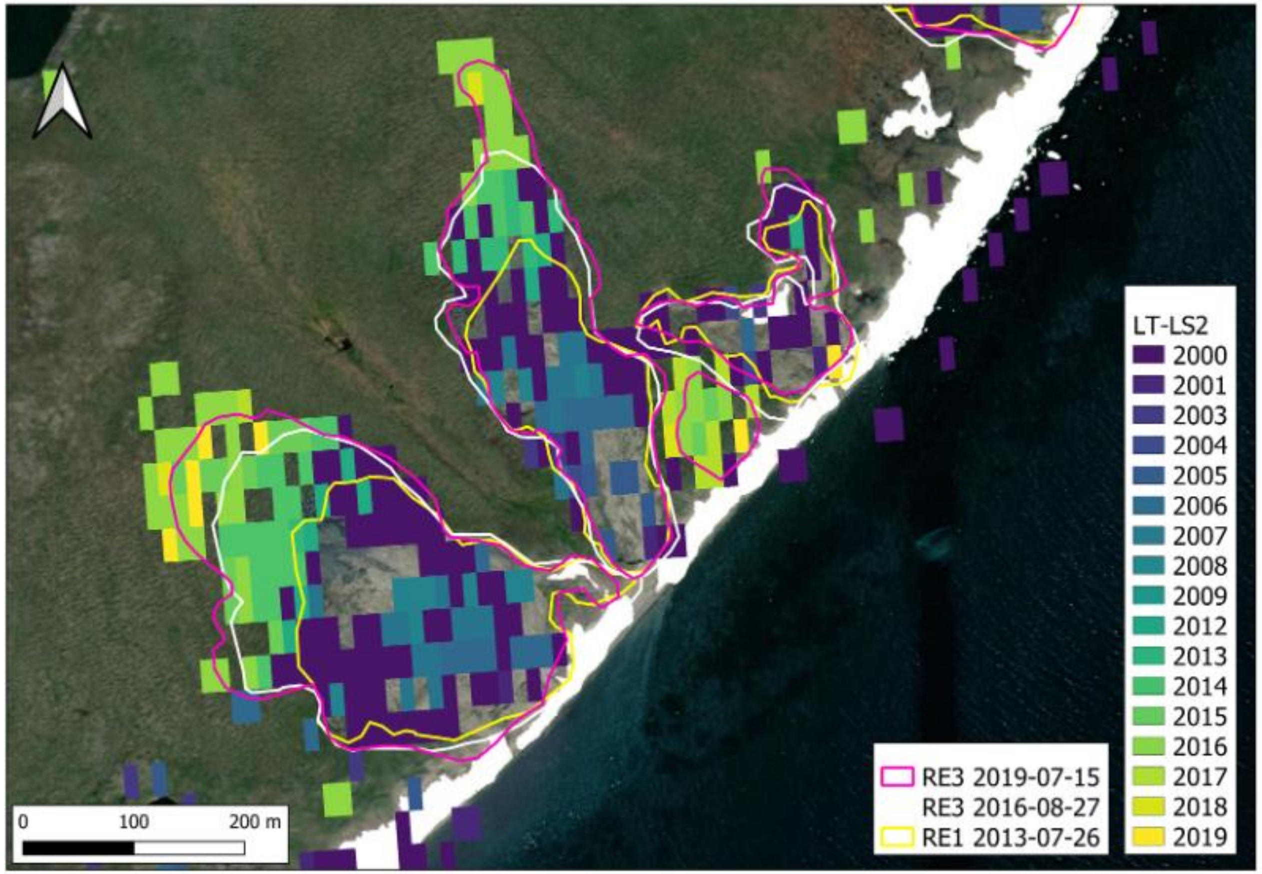
Nitze et al., 2018

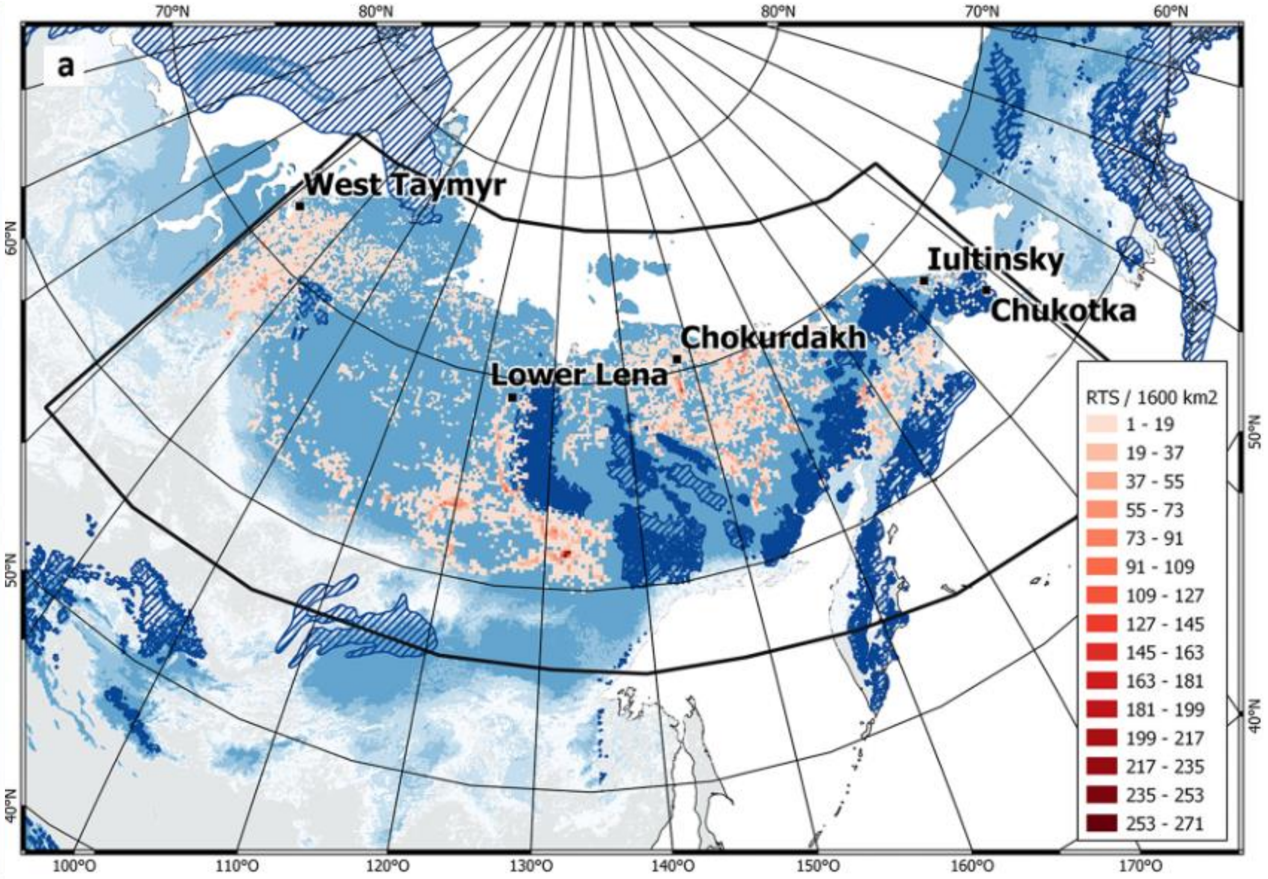


Explore by yourself !

https://ingmarnitze.users.earthengine.app/view/hotspottcvisapp

More automated approaches





Runge et al, 2022

Scale and Automation

Spatial Scale	Automation	Spatial Resolution	Accuracy
Local to regional	Low	Very High	😀
Pan-arctic/ continental	High	Moderate	🤔

Scale and Automation

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Local to regional	Low	Very High	😀
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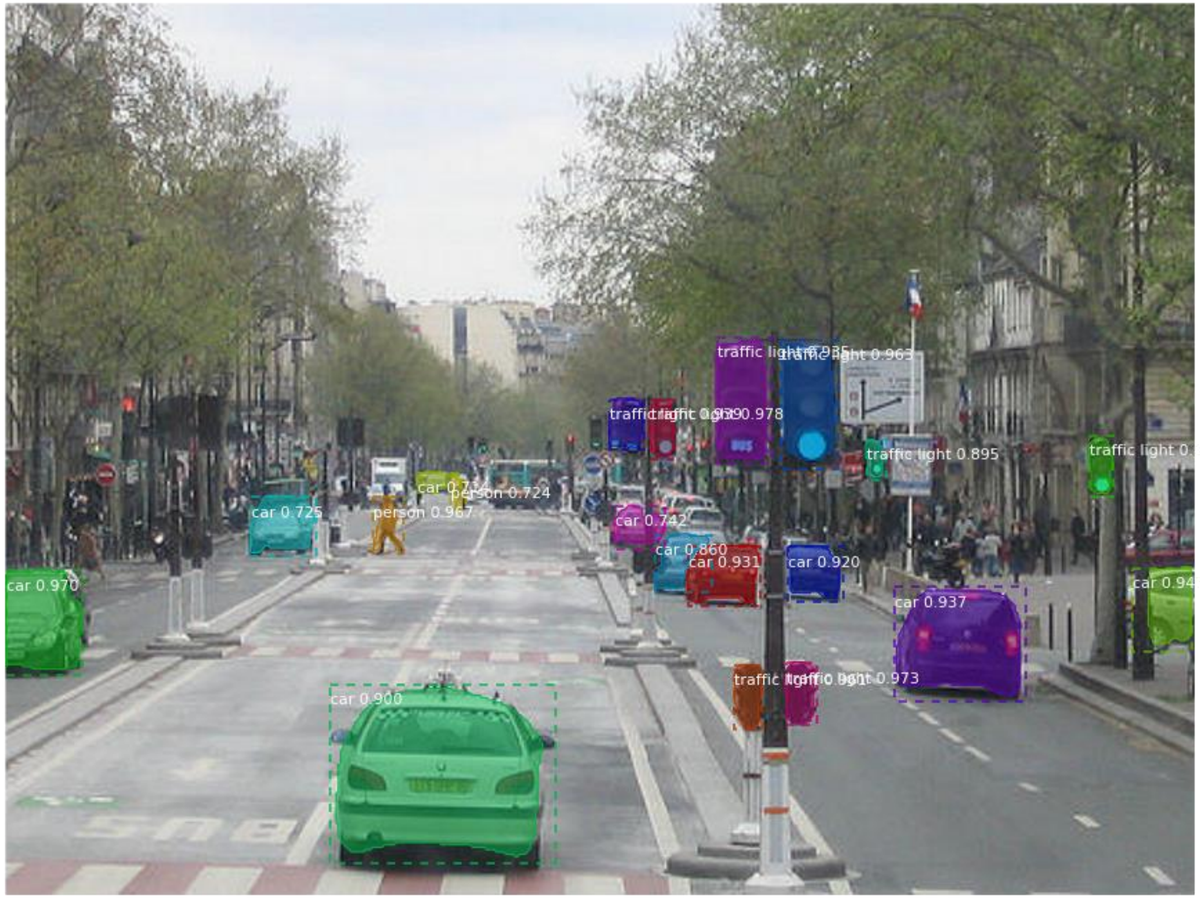
More Data

Better/more suitable Data

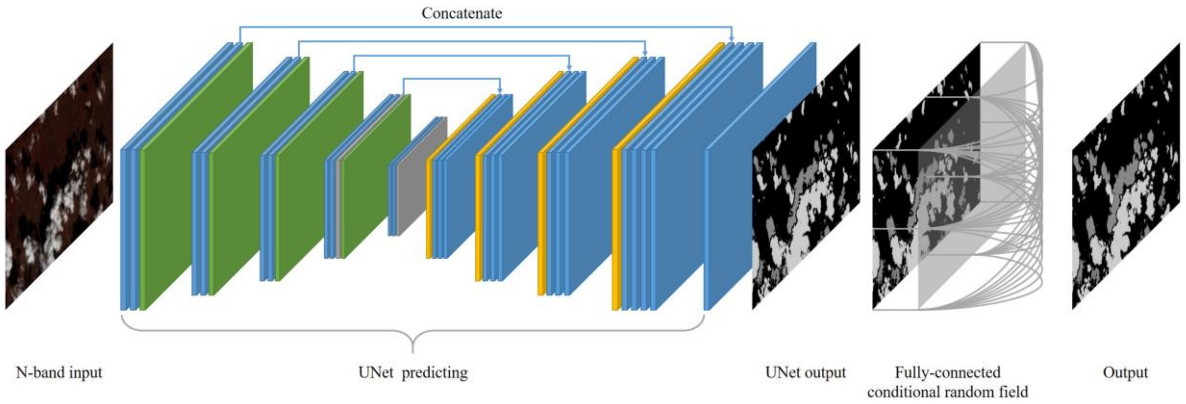
New Detection Techniques

Processing Capabilities

Deep Learning and Image Segmentation



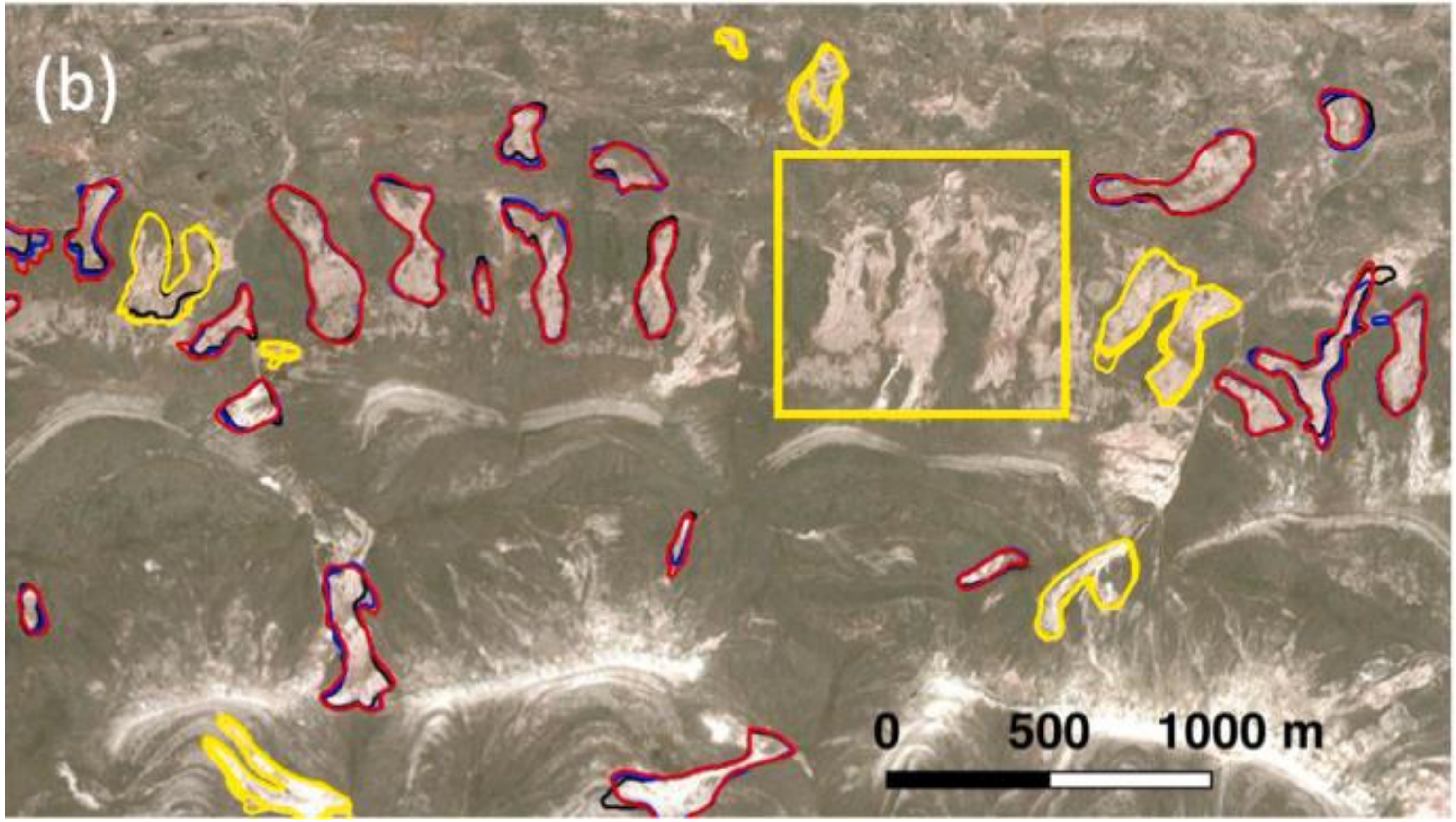
K.Majek.



Jiao et al., 2020

- Image segmentation
- Takes spatial context into account
- Computationally intensive (GPU)

Deep Learning for Object Segmentation



Only few permafrost deep learning studies

Even fewer for Thaw Slumps

Currently focussed on Tibetan Plateau

Huang et al., 2021

DL Model Framework

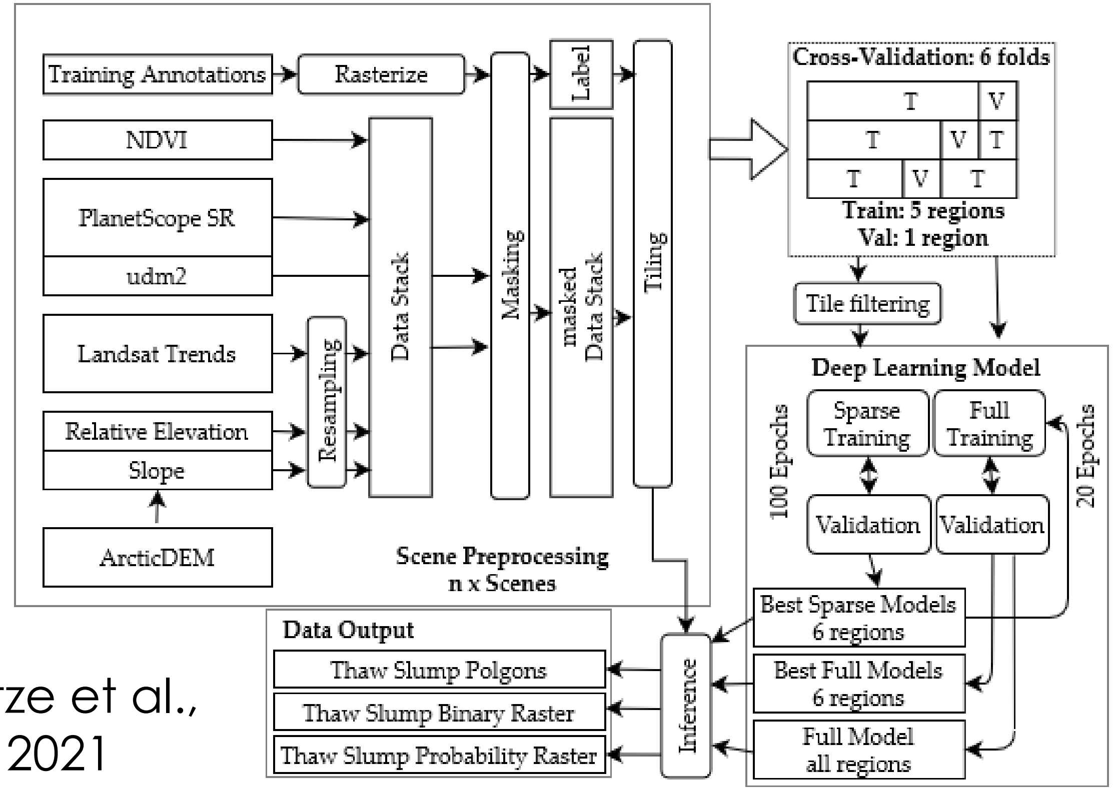
Input data → DL model → RTS footprints

PyTorch

Automated Processing
- Flexible configuration with yaml files
- Target can be any object

Flexible Model Architecture
- Segmentation architecture
- Encoder/backbone network
- Loss functions

Data Augmentation Pipeline



Nitze et al., 2021

Data

1. Planet SR Scenes (2018-2021) – 3m SR
- Multispectral (B-G-R-Nir) (A)
- NDVI (B)

2. Landsat Trends
- TCB, TCG, TCW (C)

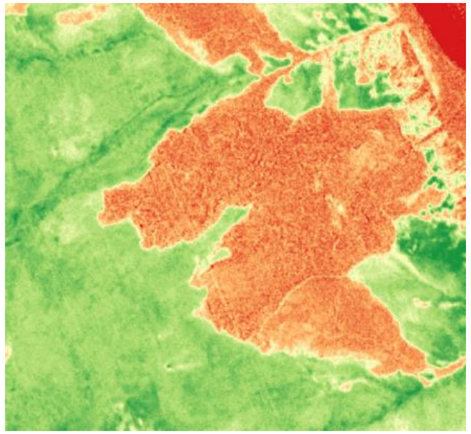
3. ArcticDEM
- Relative (detrended) elevation (D)
- Slope (E)

4. Training Data (polygons) n=2182
- How to delineate RTS?

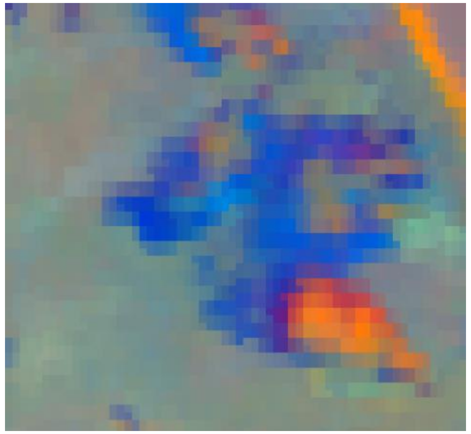
Output
- Raster (binary + probability)
- Vector (footprint)

A

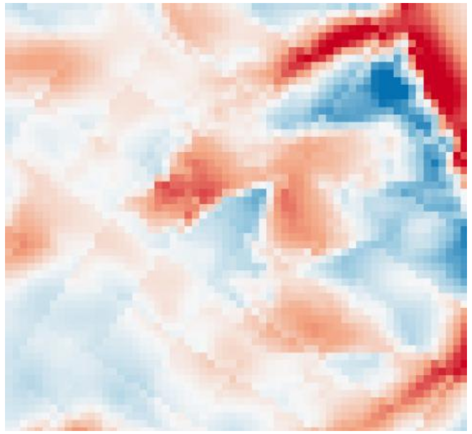
B



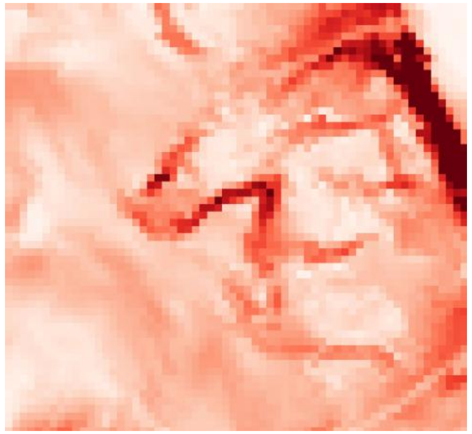
C

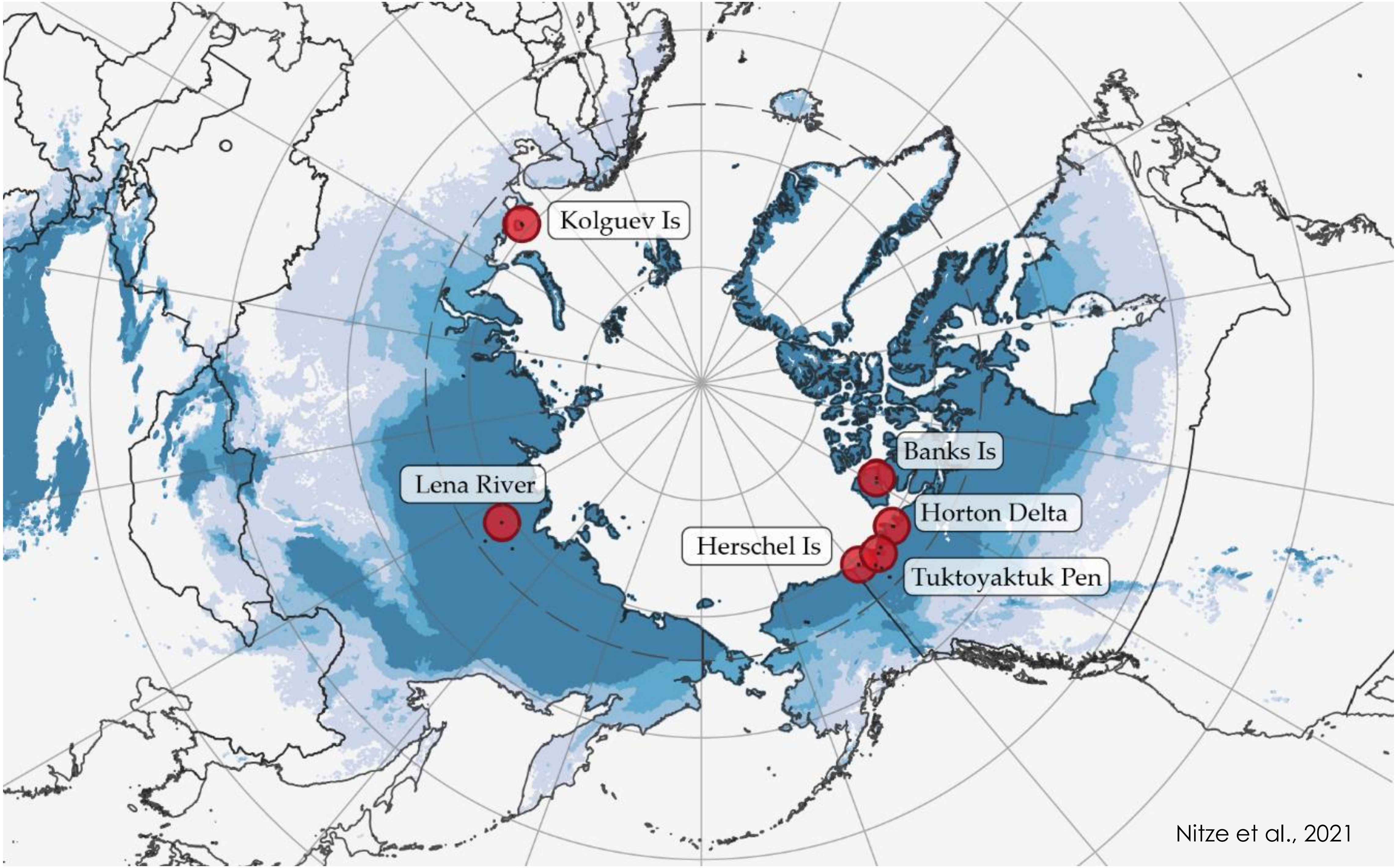


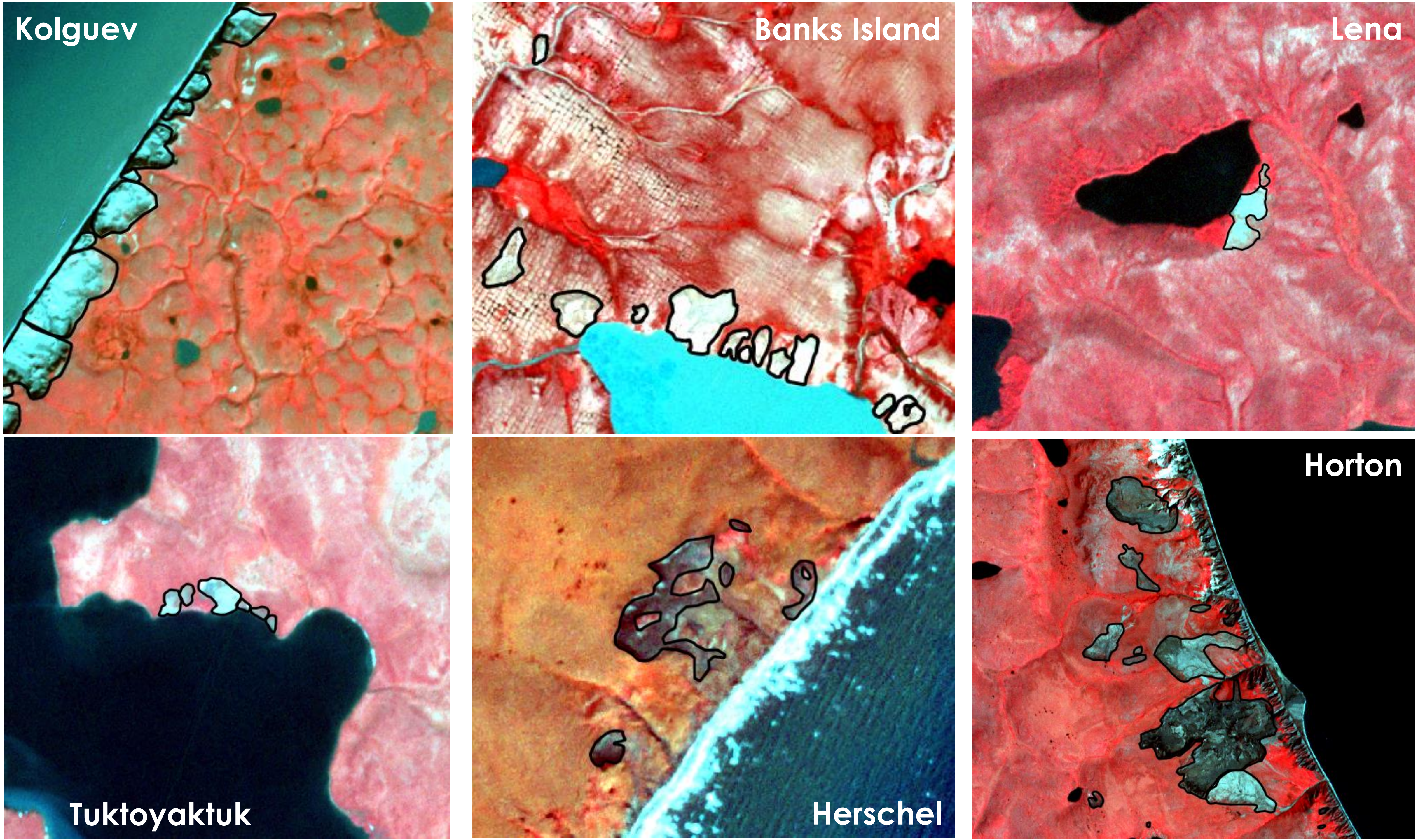
D

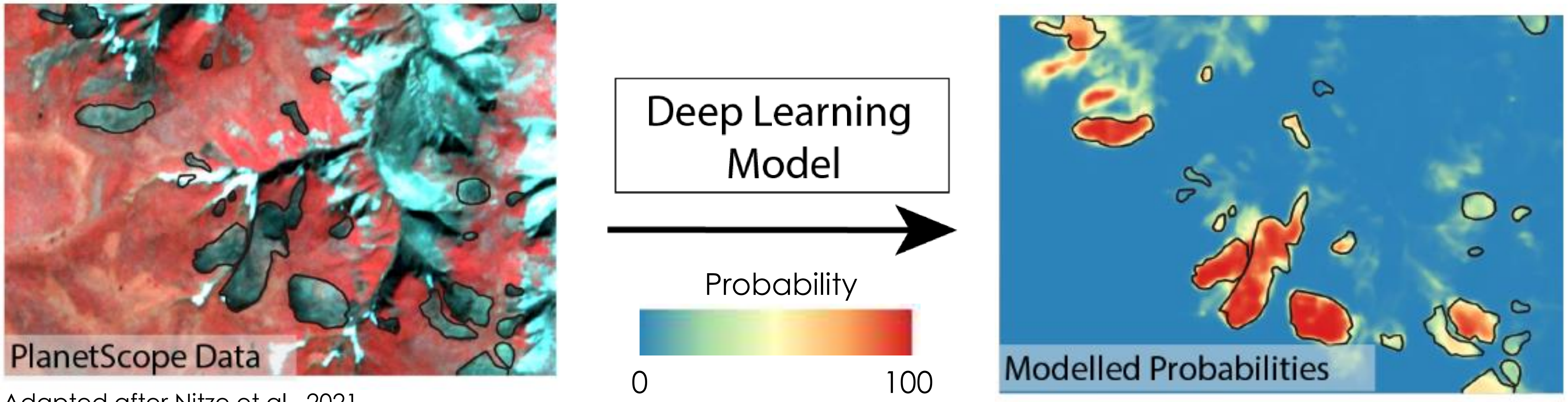


E

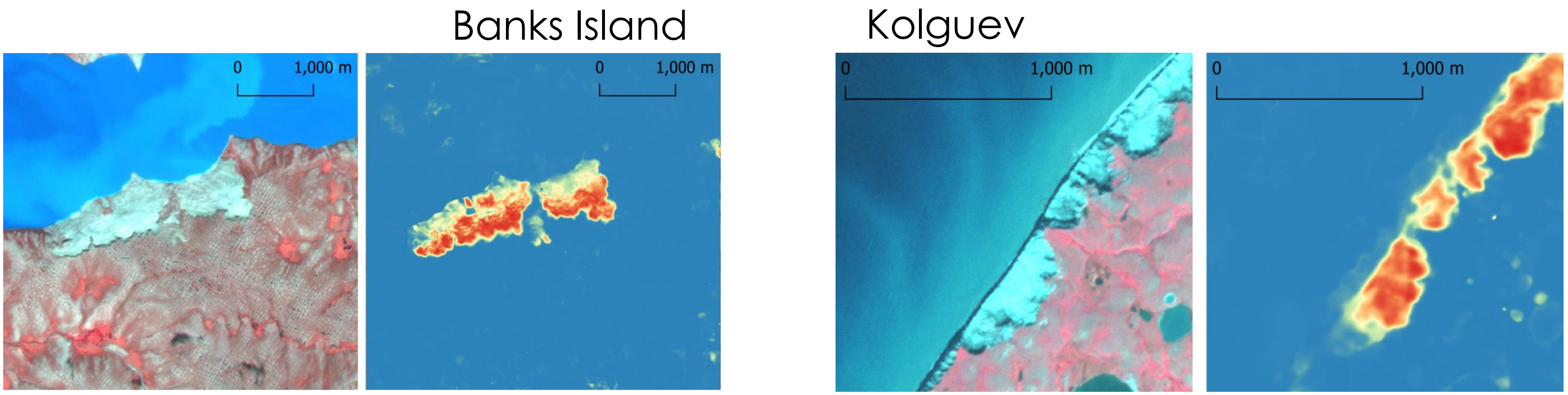



Kolguev Is
Banks Is
Lena River
Horton Delta
Herschel Is
Tuktoyaktuk Pen
Nitze et al., 2021


Kolguev
Banks Island
Lena
Tuktoyaktuk
Herschel
Horton



Adapted after Nitze et al., 2021
(Remote Sensing)



Key Results

Good model performance for 3 sites (Horton, Lena, Kolguev)
High variability between regions

Consistently best architecture: Unet++

Training data quite limited
More and better standardized data across the Arctic required

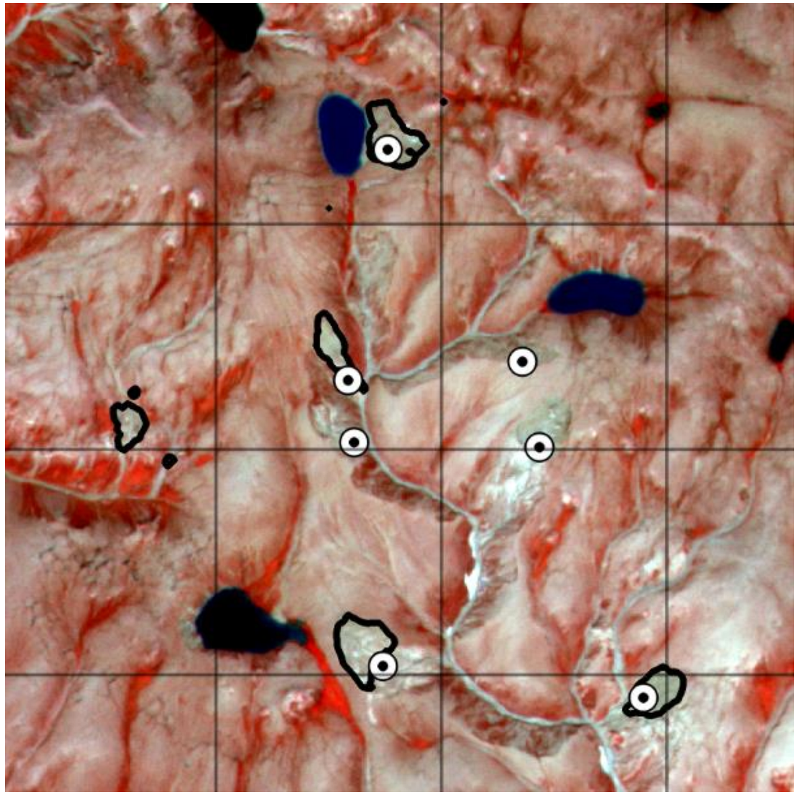
Adapted after Nitze et al., 2021
(Remote Sensing)

Inference + Scaling

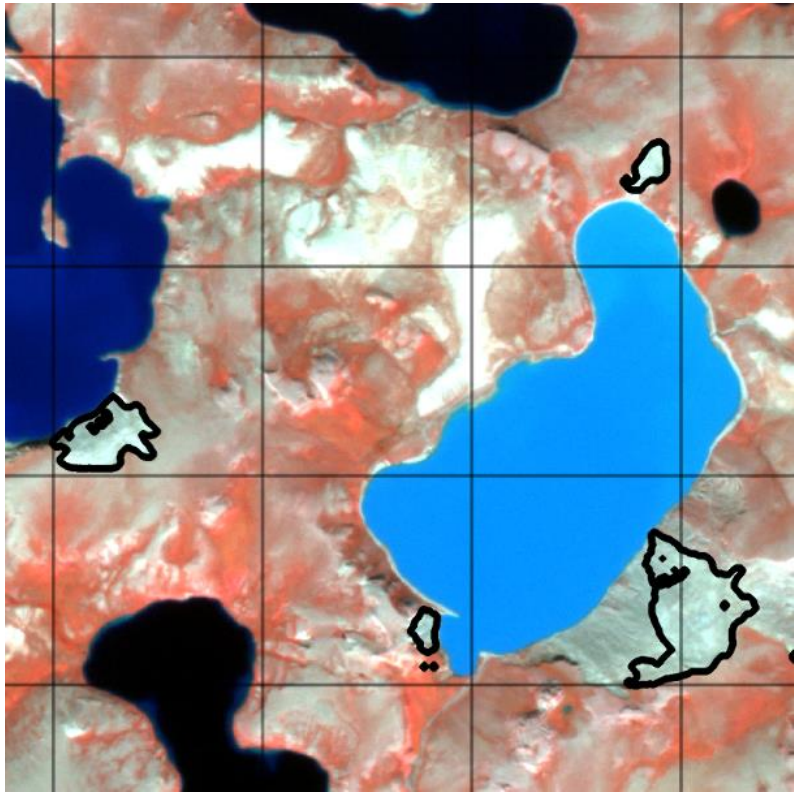
The good ones !

Not so good

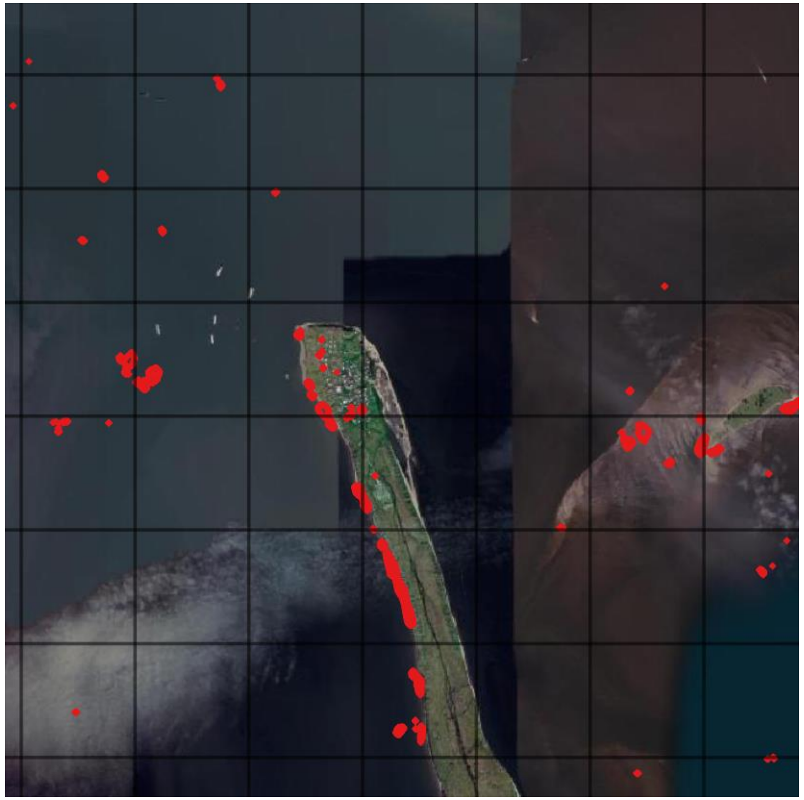
Banks Island, Canada



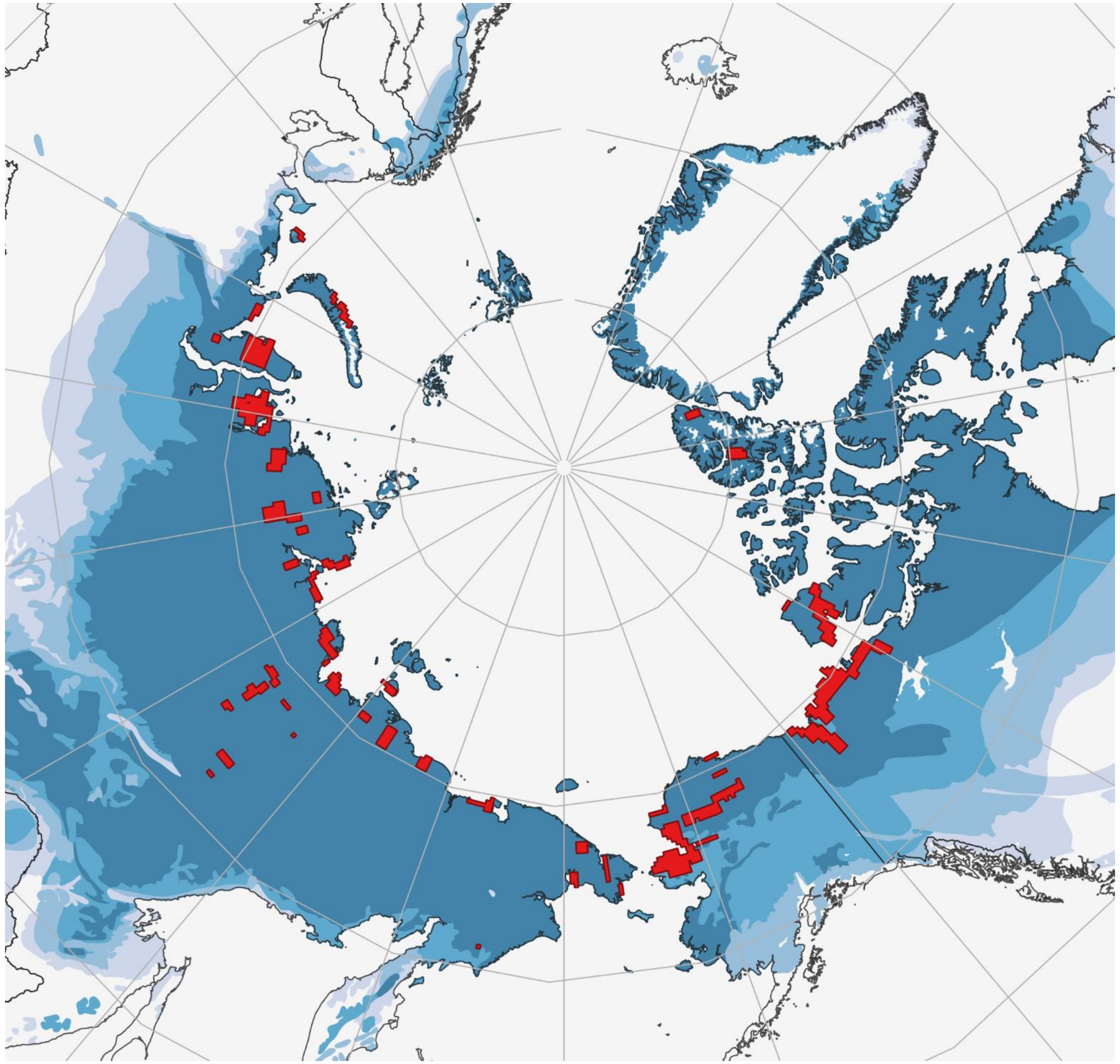
Bluenose Moraine, Canada



Bykovsky Peninsula, Russia



Spatial Expansion + Operationalization



Current data footprint

Requirements

- Improved (automated) data ordering
- More sophisticated (raster) data management (3k scenes atm)
- Operationalization (Auto-processing)
- More training data
    - RTSInAction Group

Summary

- Automated configurable DL workflow to map RTS
- Planet input data + other *free* data sources
- Good results but variable transferability

- More + standardized training data required
- Upscaling next step
- Continuous monitoring and model improvement

Thank You

Contact: ingmar.nitze@awi.de

Github repo code: https://github.com/initze/thaw-slump-segmentation

Github repo data: https://github.com/initze/DL_RTS_Paper

Twitter: @i_nitze, @Permafrost_RS

Landsat Trend App: https://ingmarnitze.users.earthengine.app/view/hotspottcvisapp

References

Nitze, I., Heidler, K., Barth, S., & Grosse, G. (2021). Developing and testing a deep learning approach for mapping retrogressive thaw slumps. Remote Sensing. https://doi.org/10.3390/rs13214294