Deep learning for mapping retrogressive thaw slumps and landslides across the Arctic permafrost domain

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Targets

Retrogressive Thaw Slumps

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

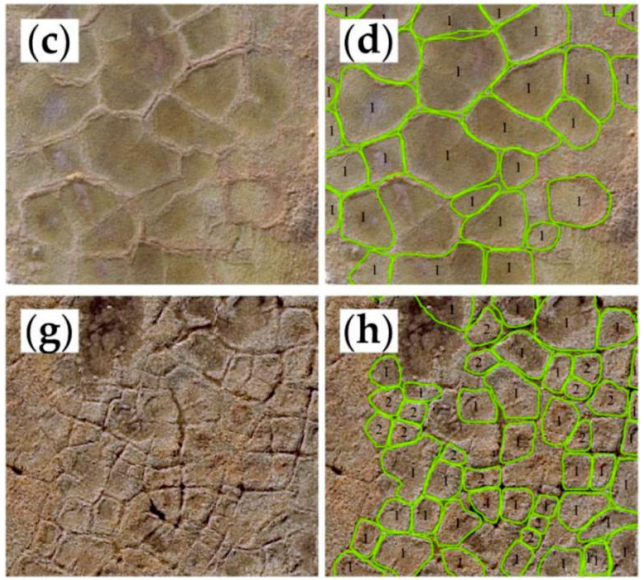
Segmentation Problem

Deep Learning for Object Segmentation

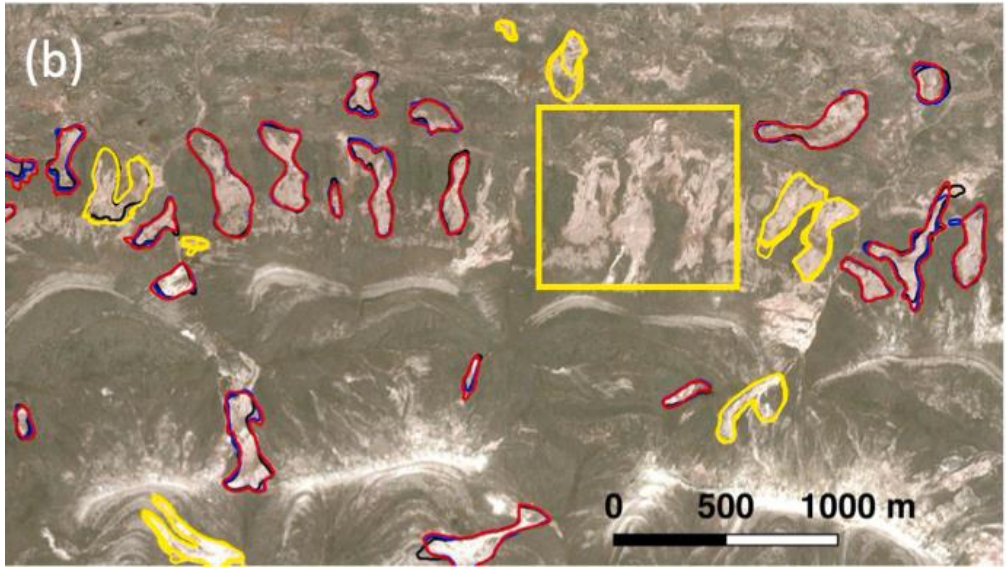
New Data + Techniques available !

Only few permafrost DL studies -> even fewer for Thaw Slumps

Mask R-CNN on a photo



Zhang et al., 2020 (+ other from Chandhi's group)



Huang et al., 2021

DL Model Framework

Input data → DL model → RTS footprints

PyTorch

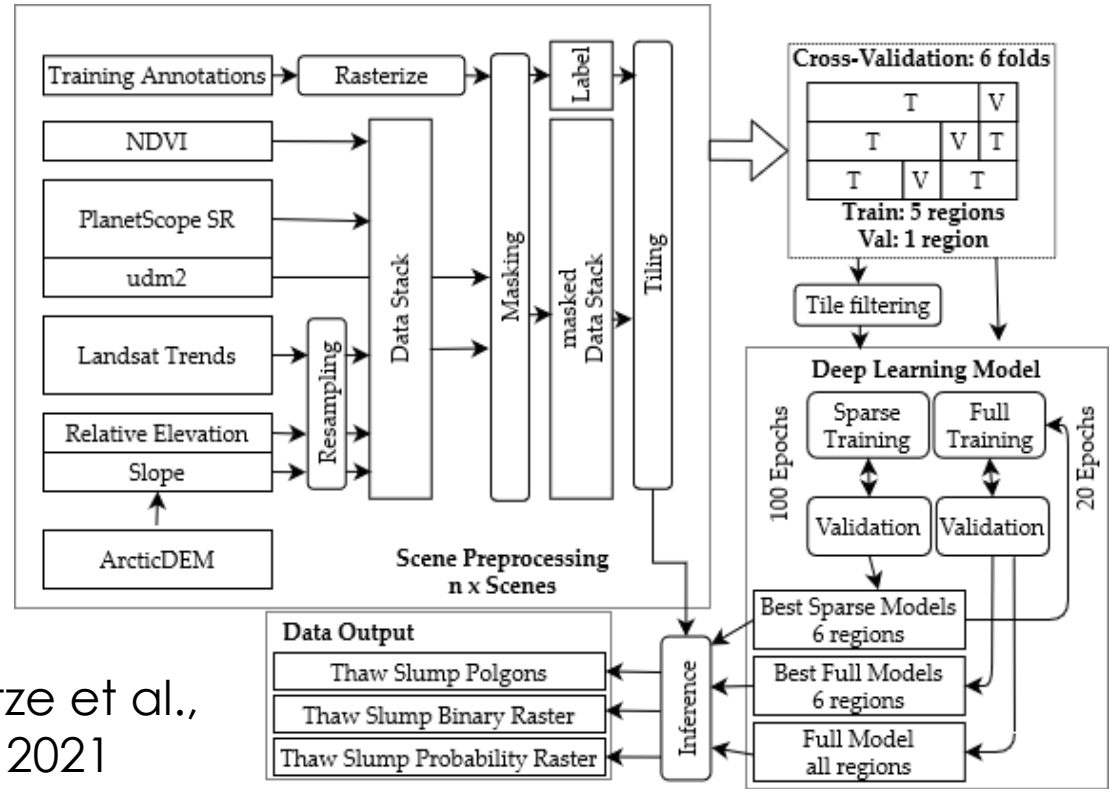
Automated Processing

- 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)

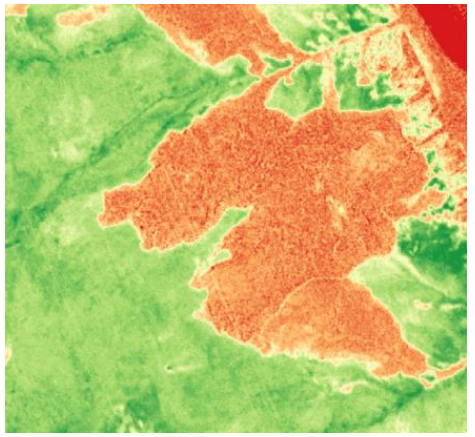
3. ArcticDEM
- Relative (detrended) elevation (D)
- Slope (E)

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

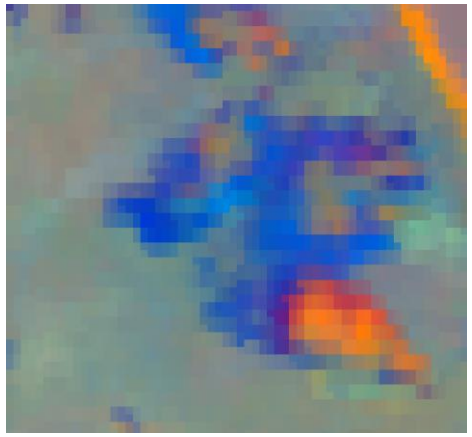
Output
- Raster (binary + probability)
- Vector (footprint)

A

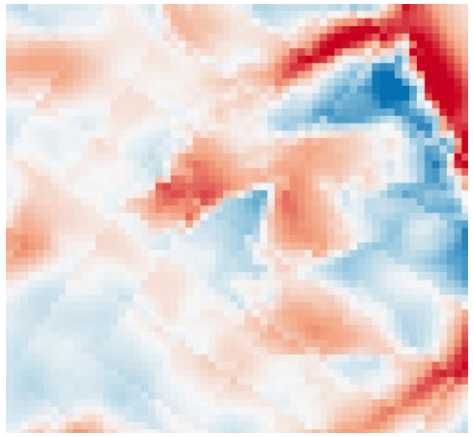
B



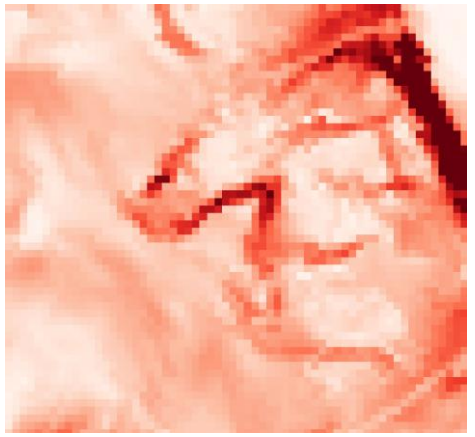
C

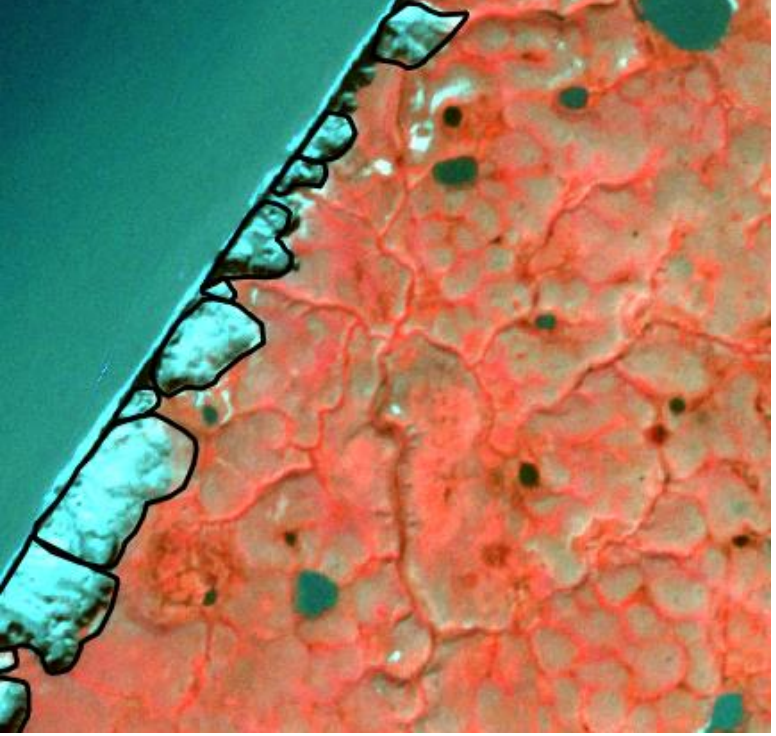


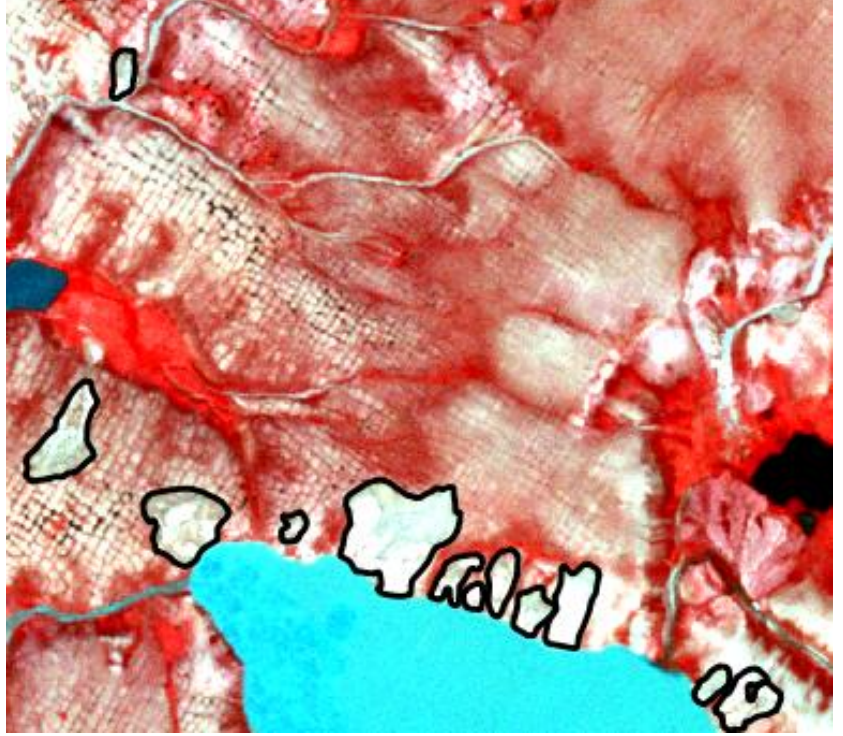
D

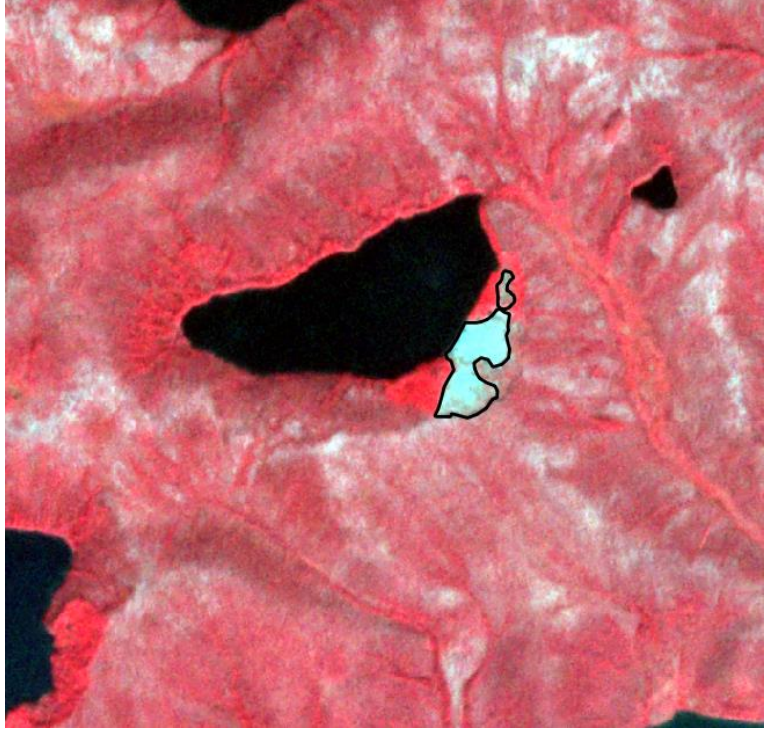


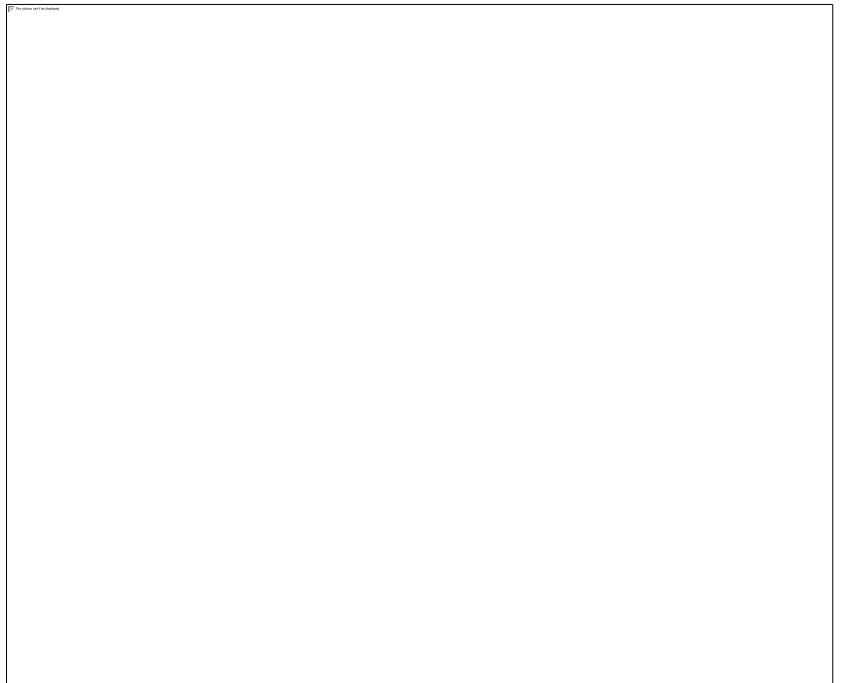
E

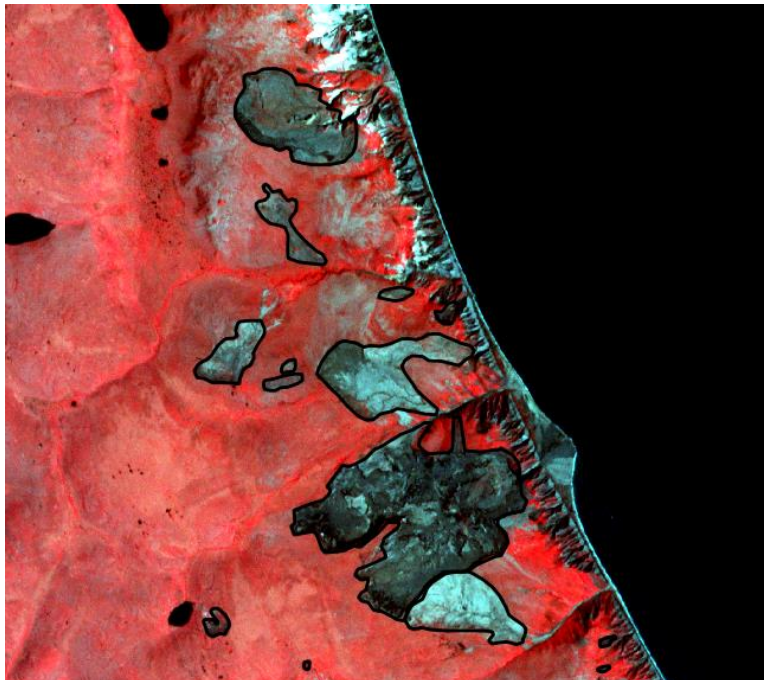


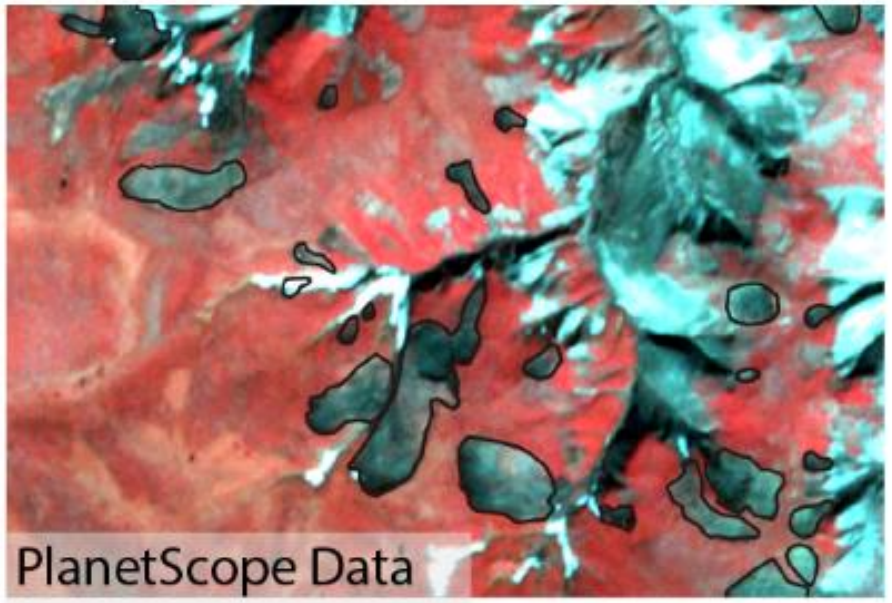




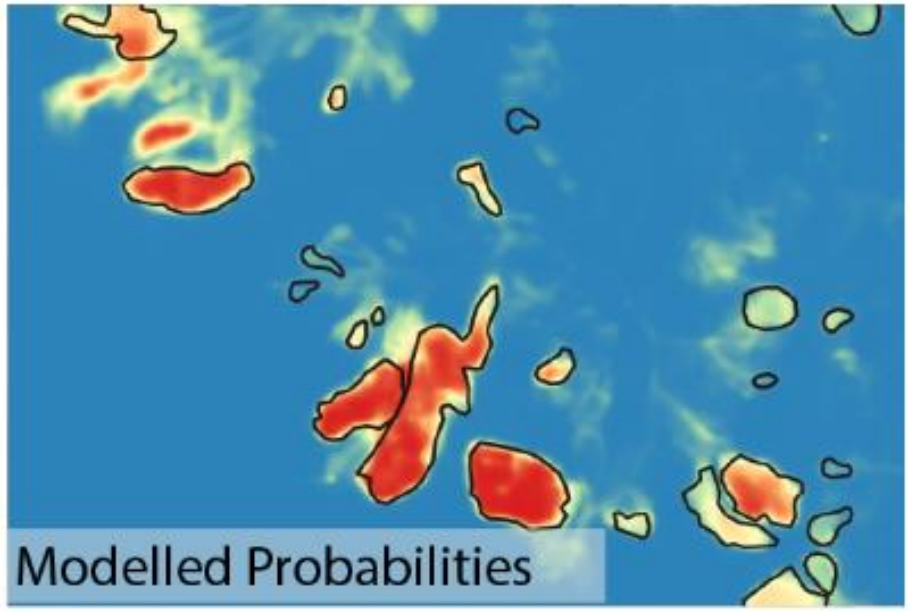


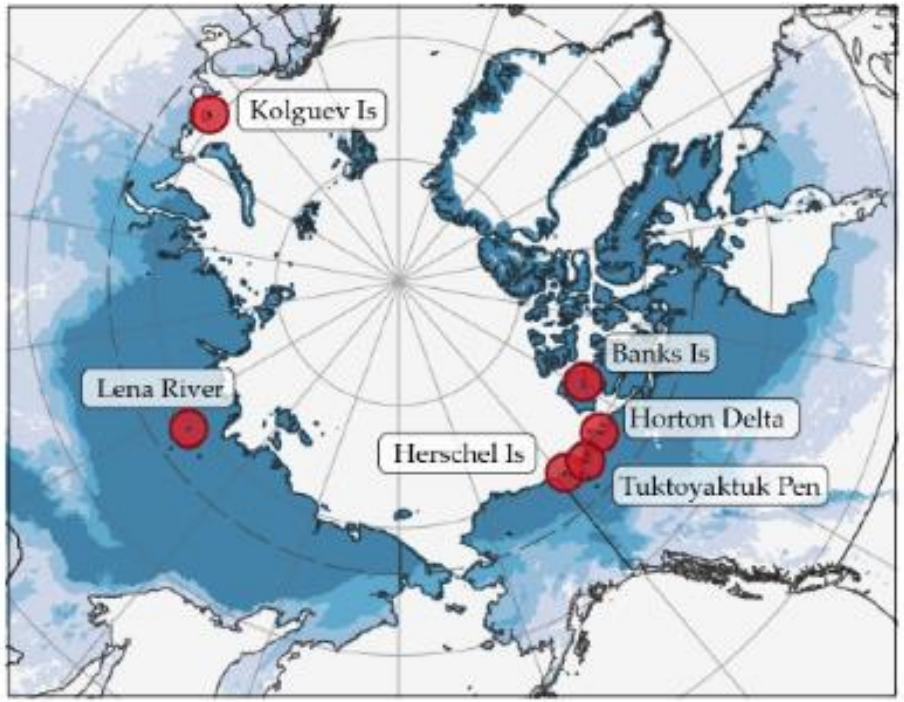






Deep Learning Model





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

Automated Segmentation

Model Selection
UNet, UNet++, DeepLabV3

Quantitative Assessment
OA, Kappa, F1, IoU, Precision, Recall

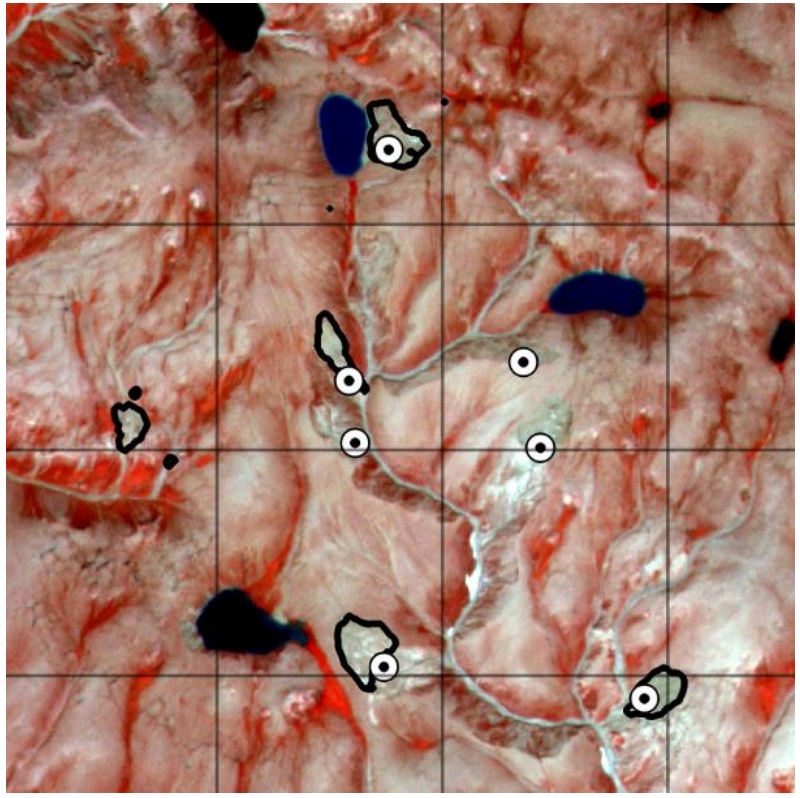
Regional Cross-Validation in six Arctic Regions
5 regions training; 1 validation

Results
- Good model performance in Horton, Lena, Kolguev
- Variable transferability
- Best model: UNet++
- Standardized pan-Arctic training data required for upscaling

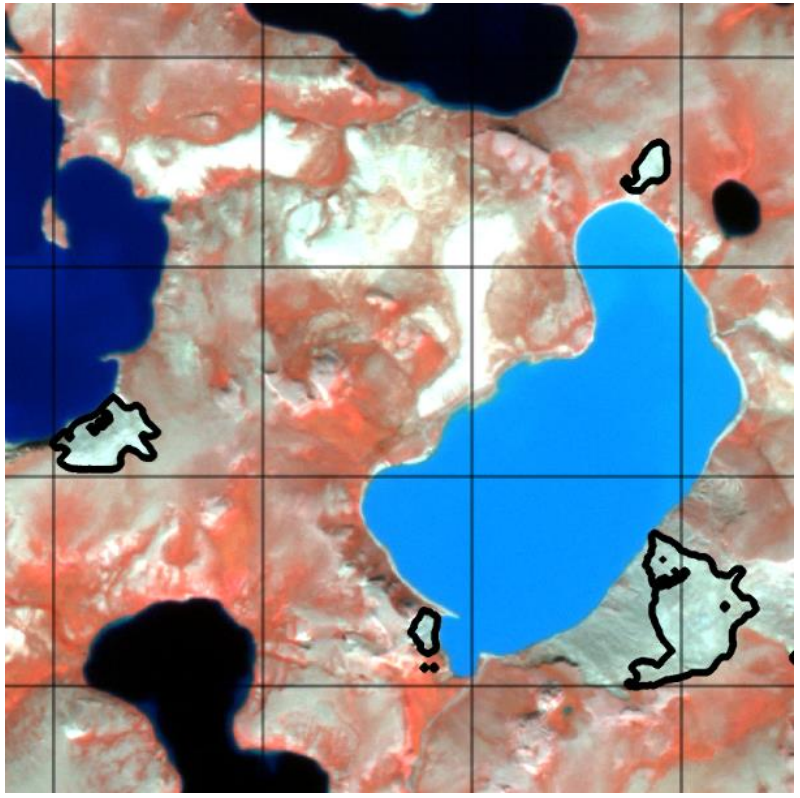
Inference + Scaling

The good ones !

Banks Island, Canada

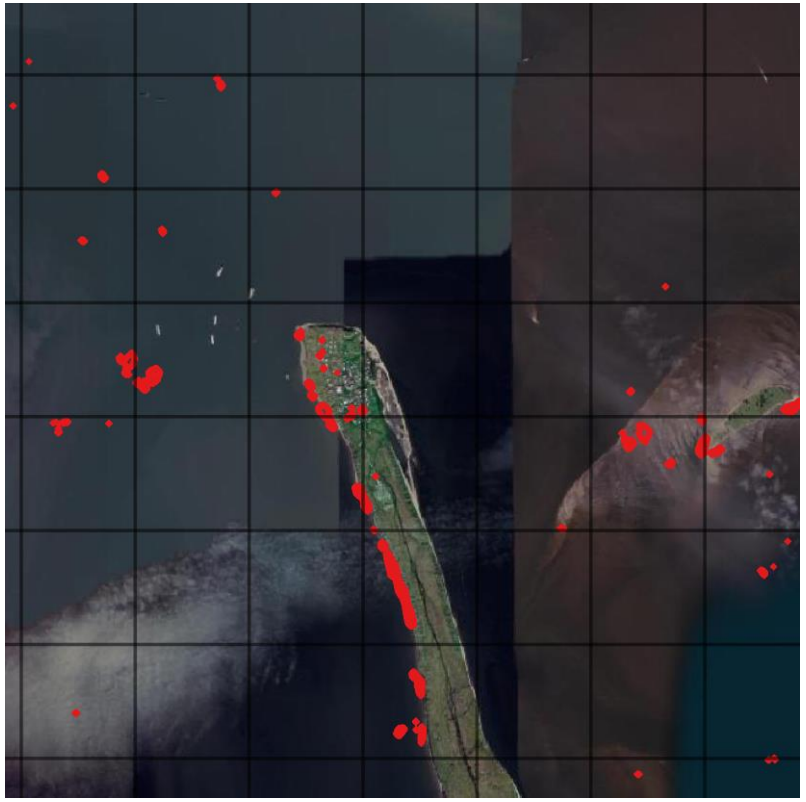


Bluenose Moraine, Canada

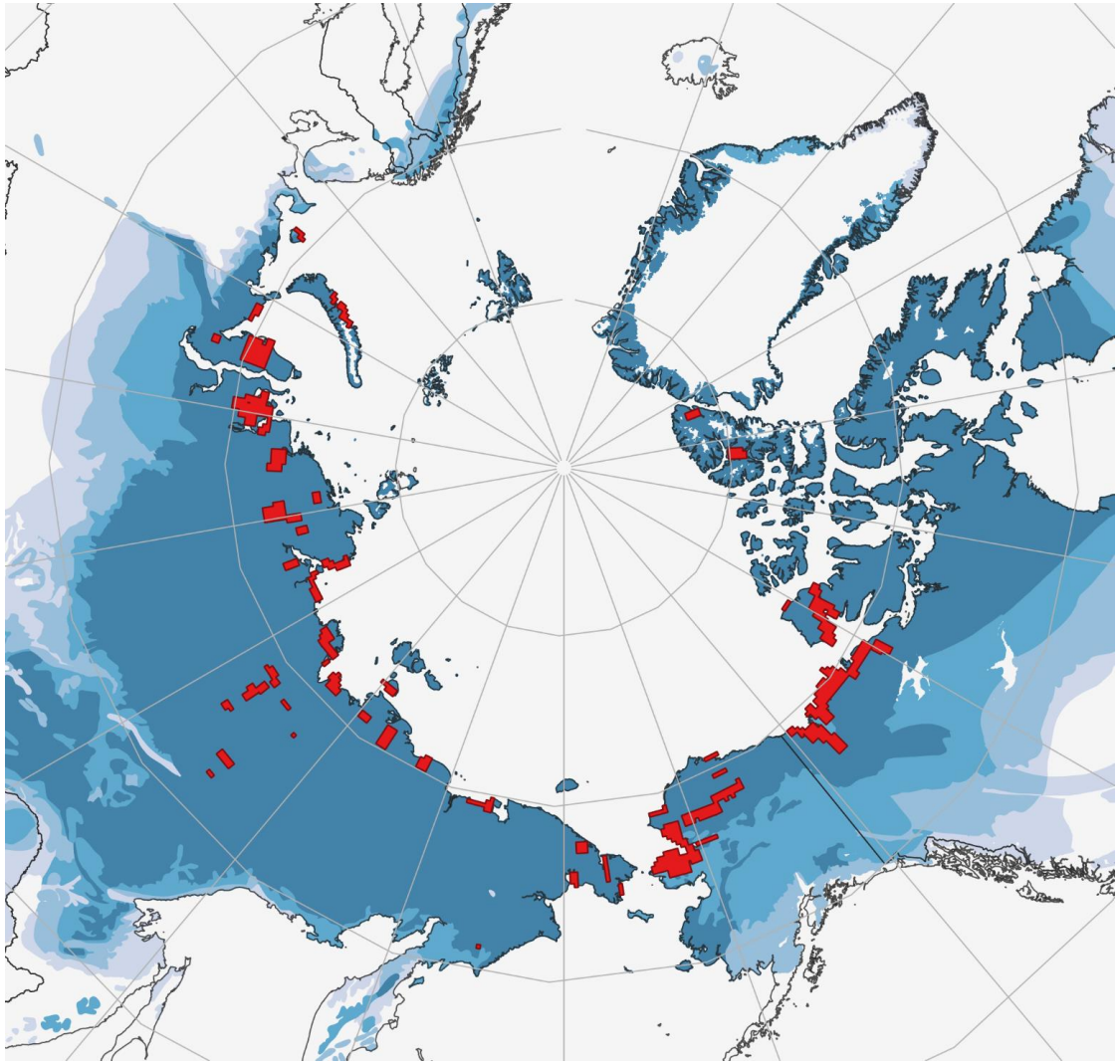


Not so good

Bykovsky Peninsula, Russia



Spatial Expansion + Operationalization



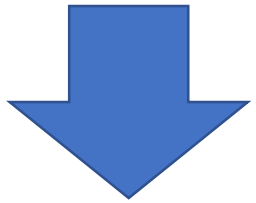
Current data footprint

Requirements

- Improved (automated) data ordering
- More sophisticated (raster) data management
- Operationalization
- 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

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