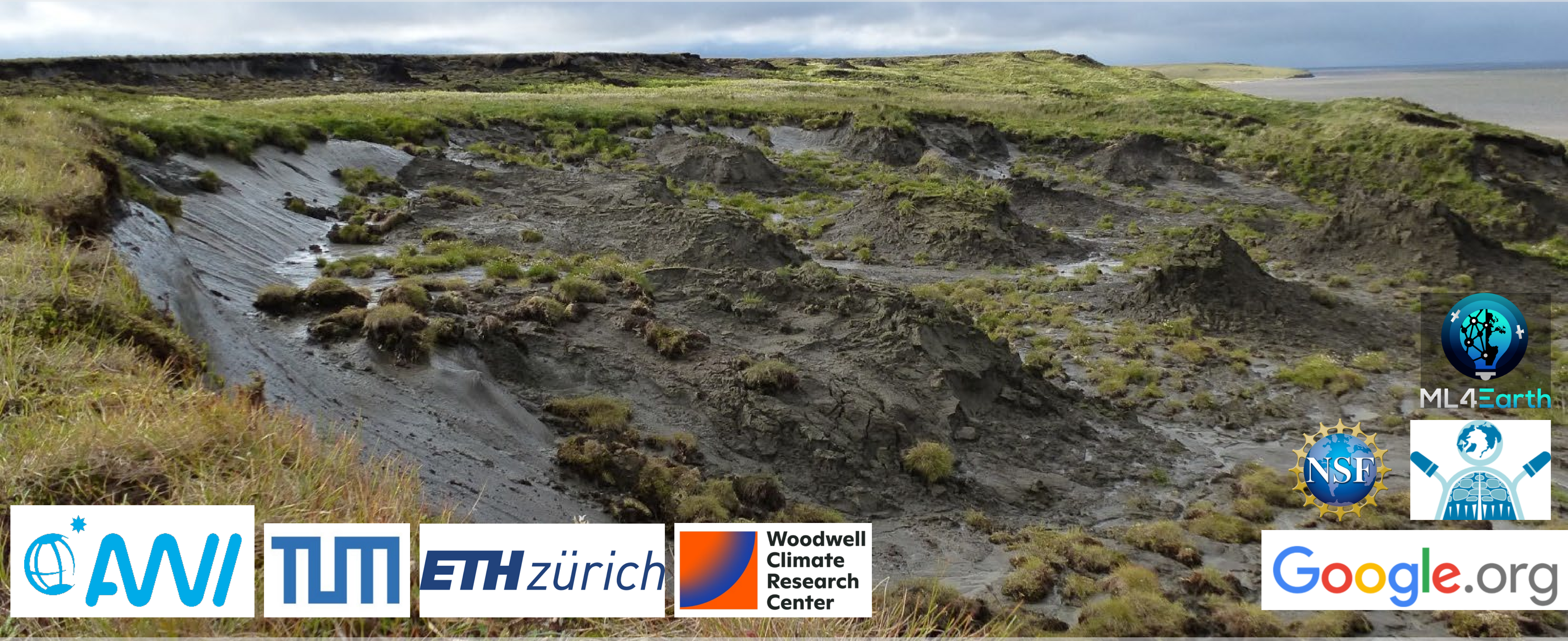
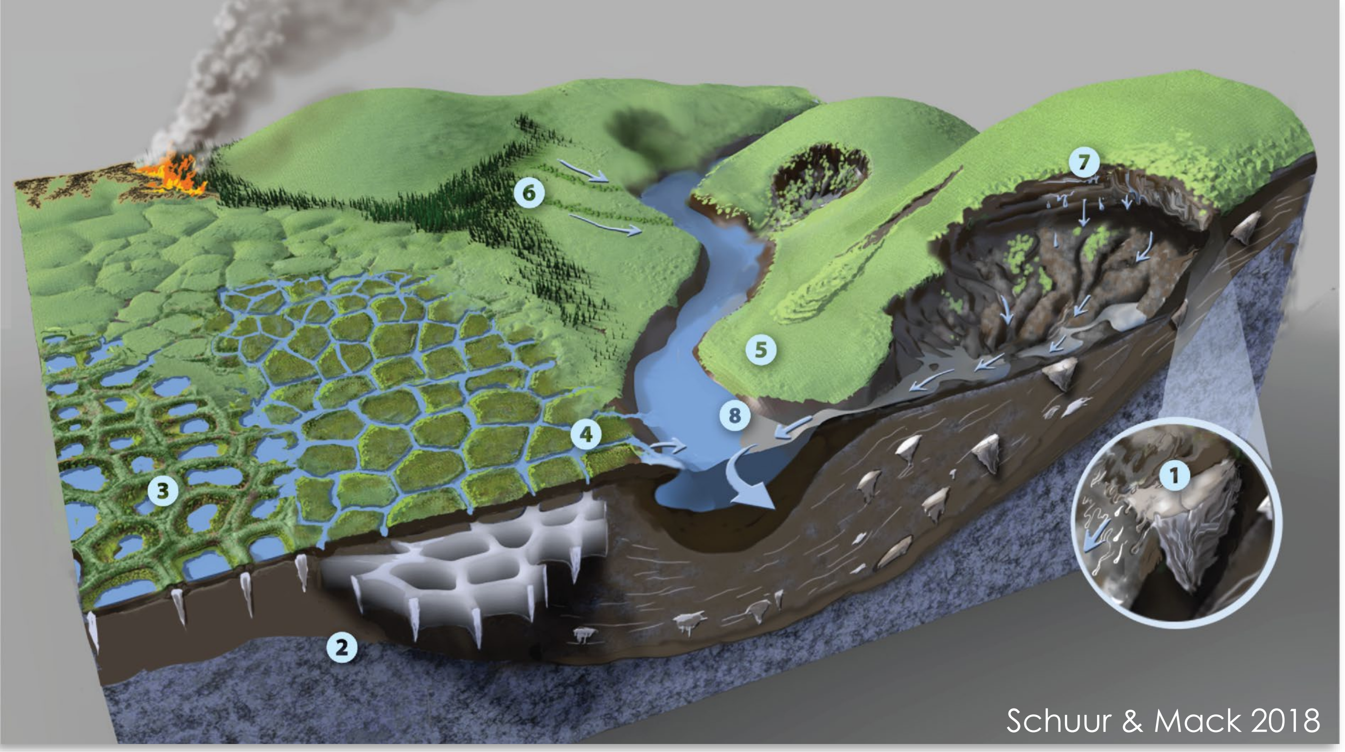
Using Deep Learning to Advance Global Monitoring of Retrogressive Thaw Slumps at High Spatio-Temporal Resolution



2024-06-17 – 12th International Conference on Permafrost

Ingmar Nitze, K Heidler, K Maier, S Barth, N Nesterova, E Schütt, J Küpper, T Hölzer, A Liljedahl, G Grosse



Schuur & Mack 2018


Oblique aerial image of a large RTS on the Peel Plateau, NW Canada, July 2023, Photo I.Nitze

Retrogressive Thaw Slumps

- Disturbance in permafrost
- Indicator of degradation
- Impact on multiple systems

Status

- Good knowledge regionally
- Limited knowledge pan-arctic
- A lot of progress lately

Goals

- AI/DL based RTS detection
- Freely accessible data and code
- Panarctic RTS Monitoring

Data and Workflow

Data

- PlanetScope (3m) + NDVI
- ArcticDEM (rel. Elevation, Slope)
- Landsat Trends

Model

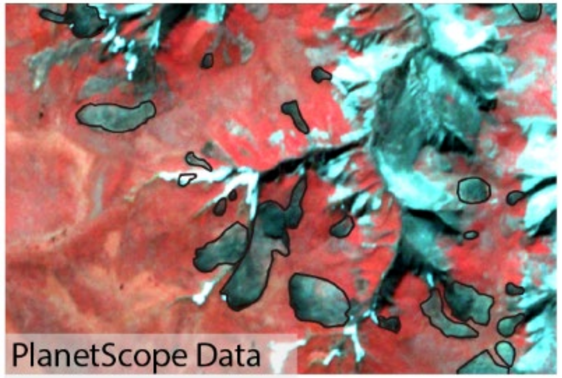
- DL Models (Unet++)
- Image segmentation

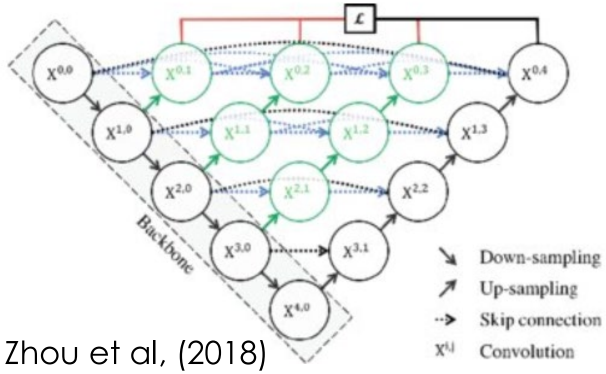
Postprocessing

- Model ensemble
- Threshold optimization

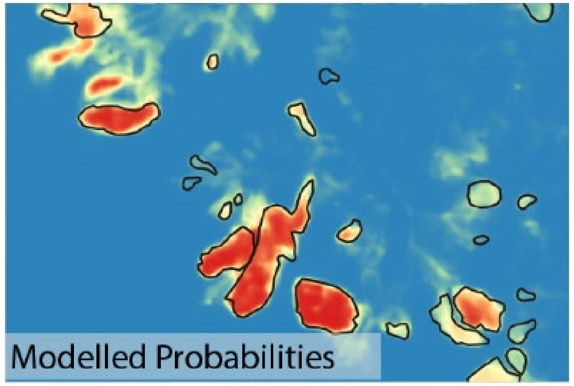
Output

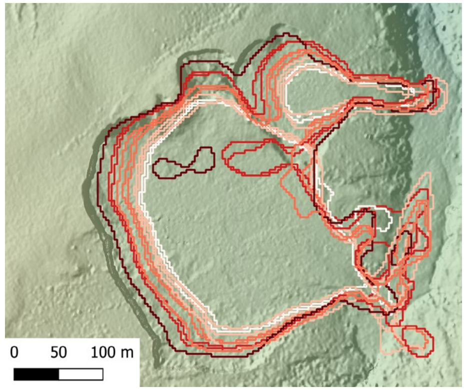
- Vectors of RTS footprints
- Rich metadata





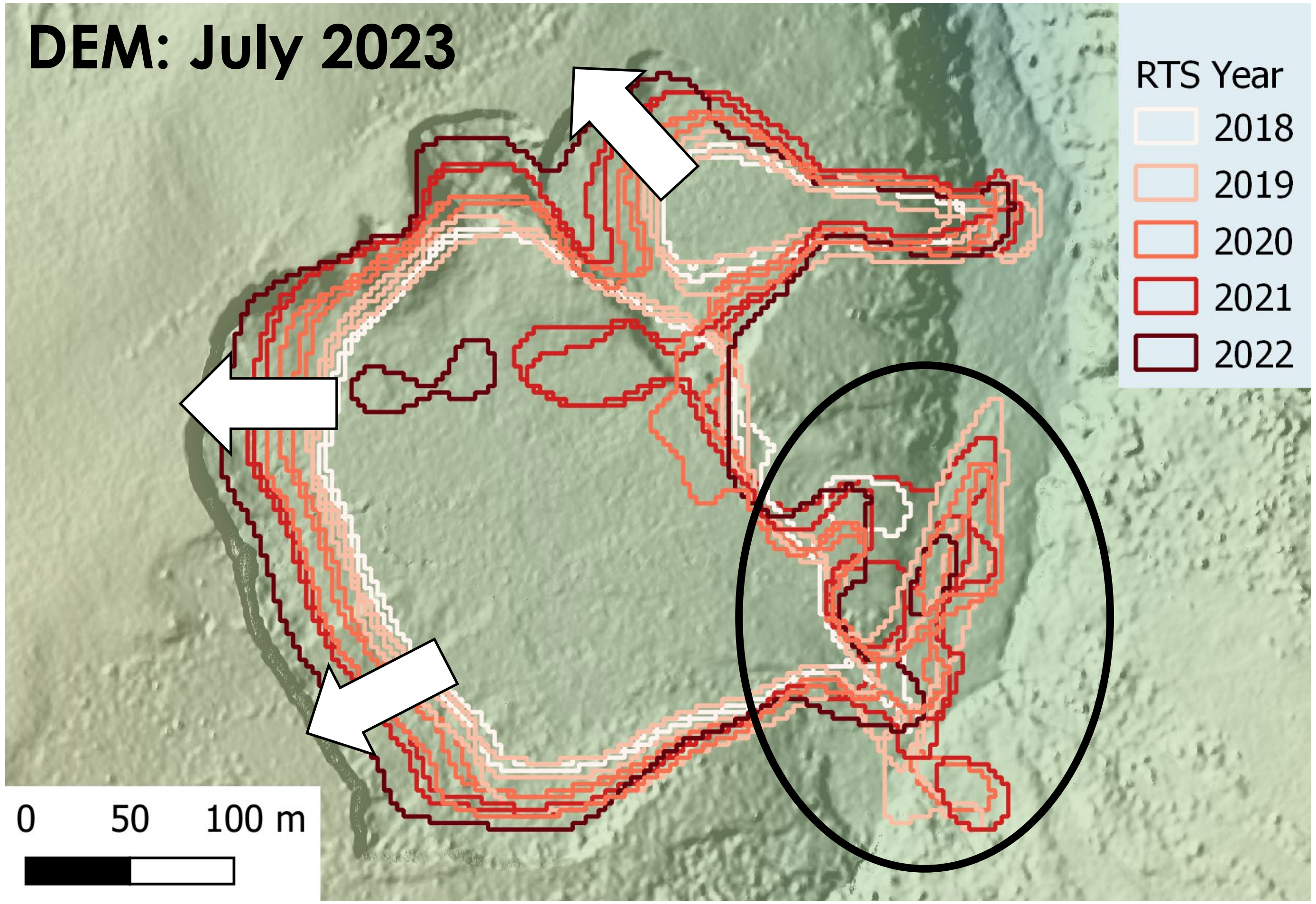
Zhou et al, (2018)





- Processing based on Nitze et al., 2021

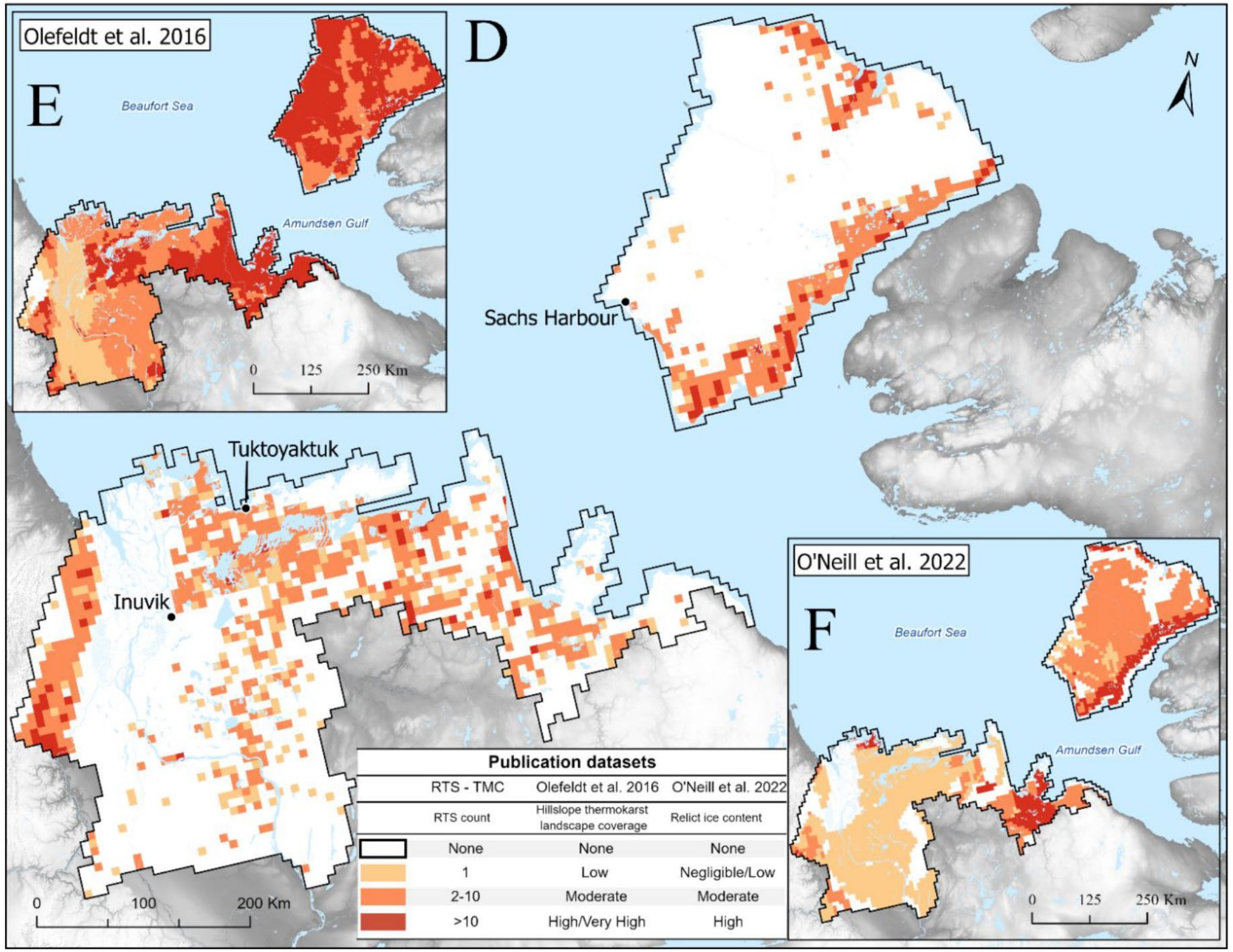
Results

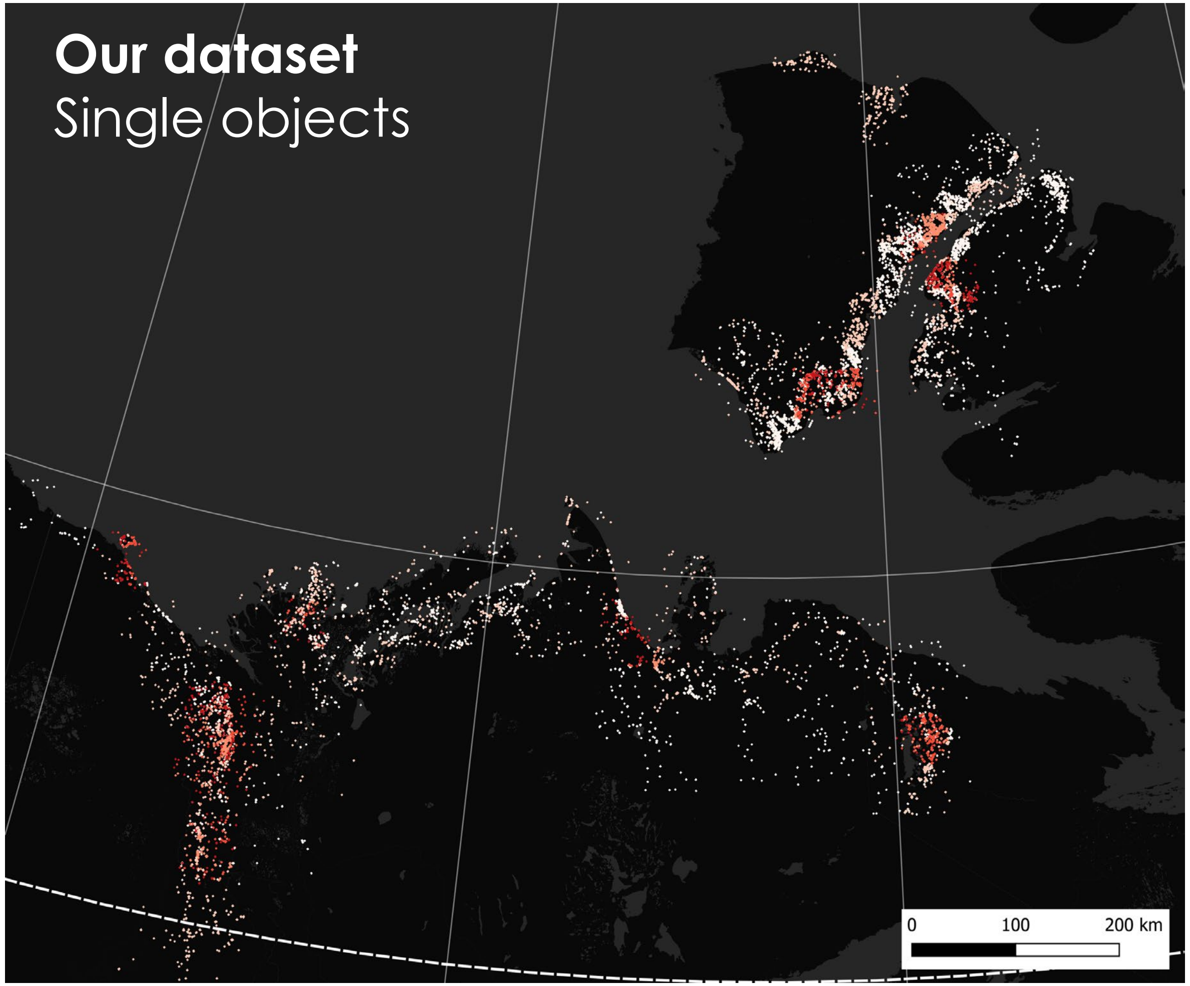


Automatically extracted RTS footprints, overlaid over SfM DSM of a large RTS on the Peel Plateau

- Timeseries of individual observations
- Many regions 2021-2023
  - Min once per year
- Focus sites with dense time-series

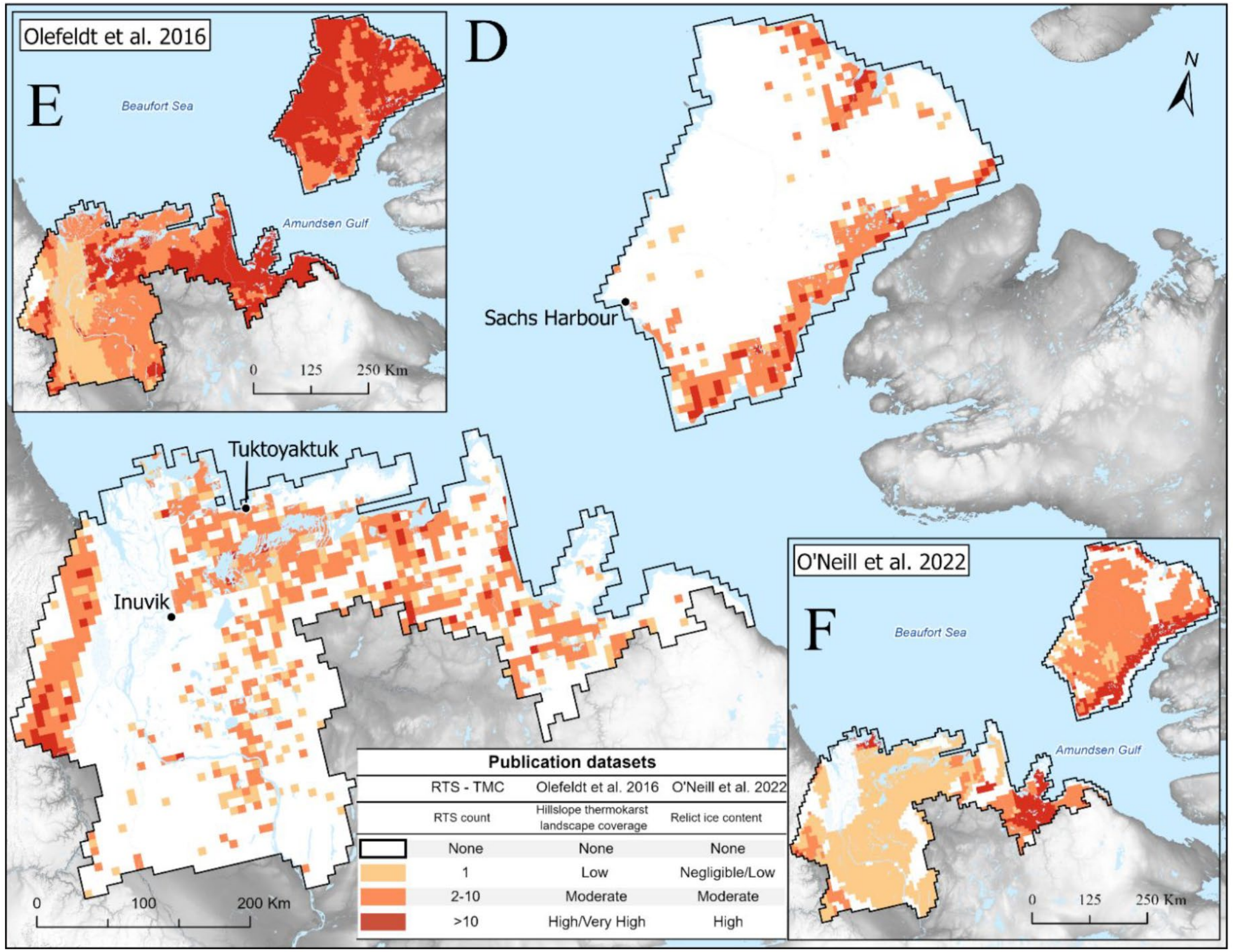
Visuals and validation



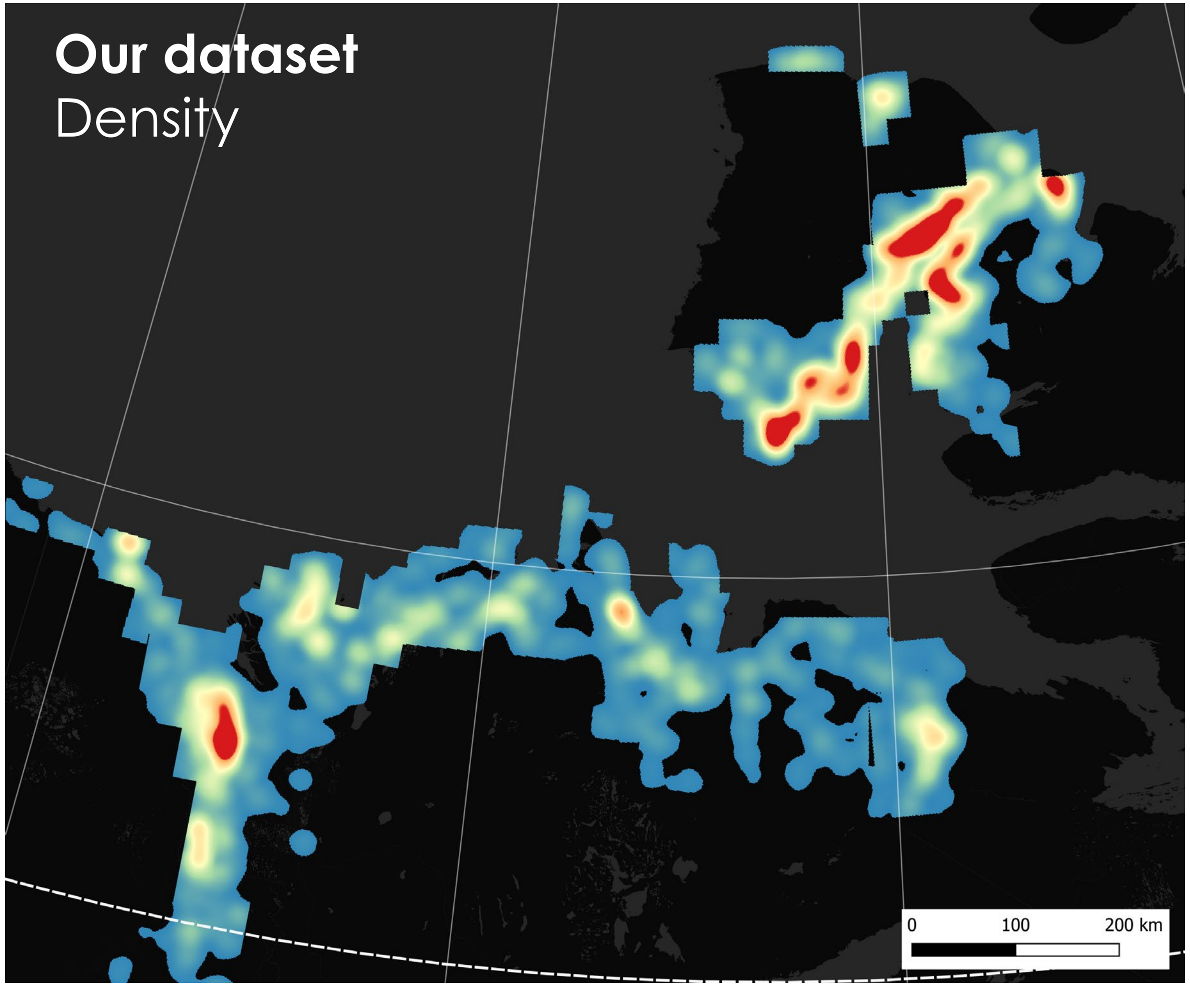


Adapted from Kokelj, 2023

Visuals and validation

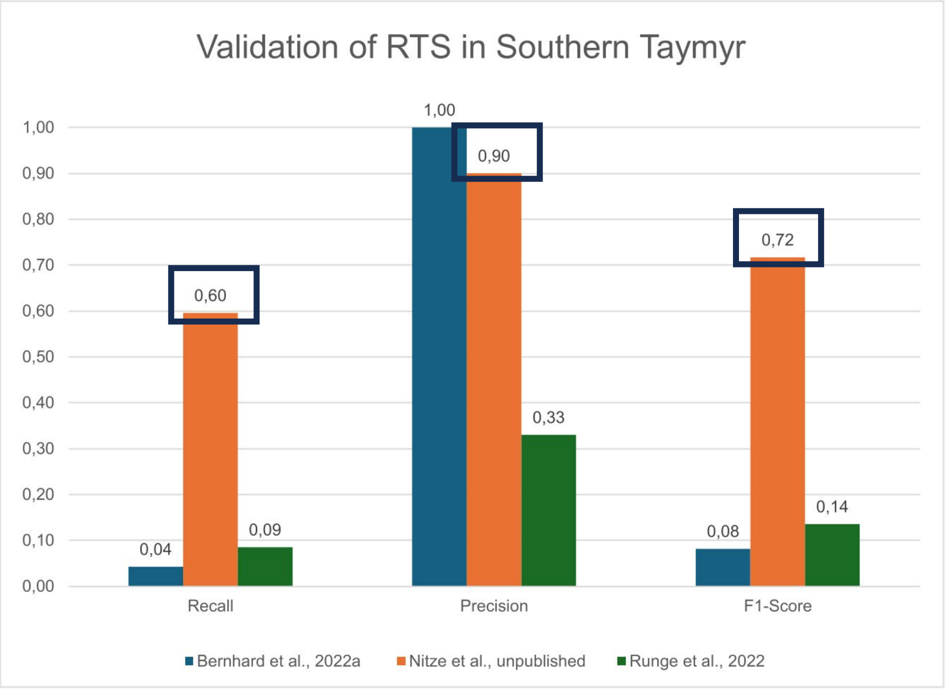


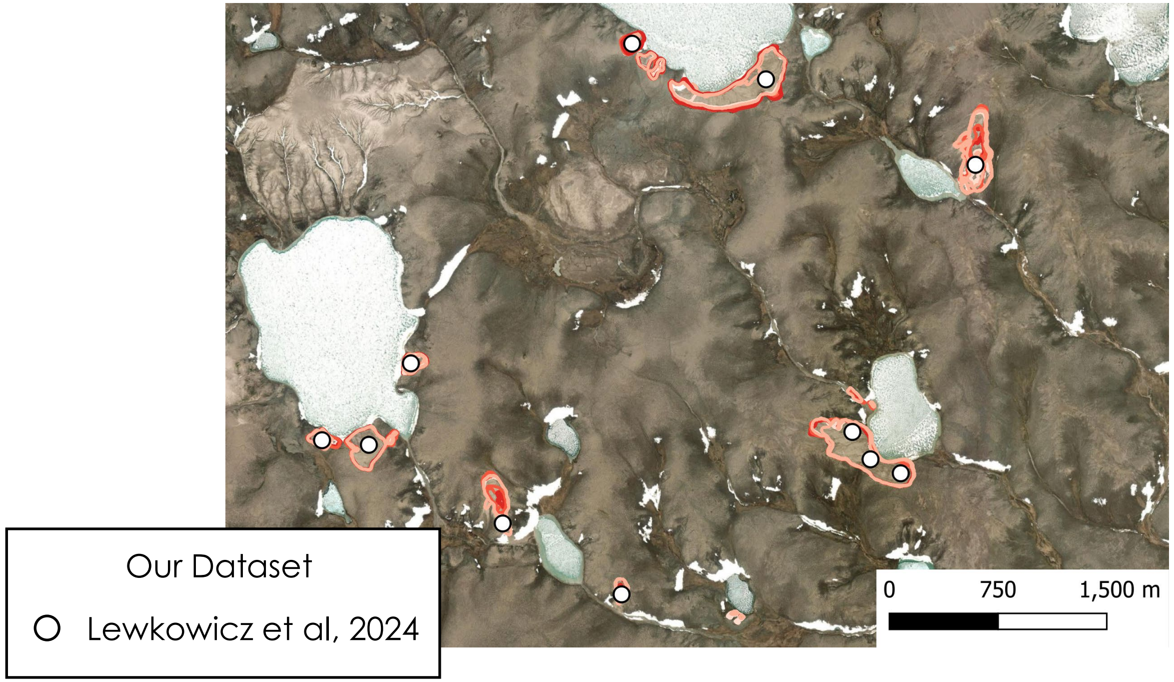
Adapted from Kokelj, 2023



Validation

- Validation in Siberia shows good results > than other datasets (F1=0.72)
- More ongoing tests and fine-tuning
- Good match with other datasets, too





Data Coverage

Complete coverage 2021-2023

Incomplete coverage 2021-2023

In the making

Self supervised learning

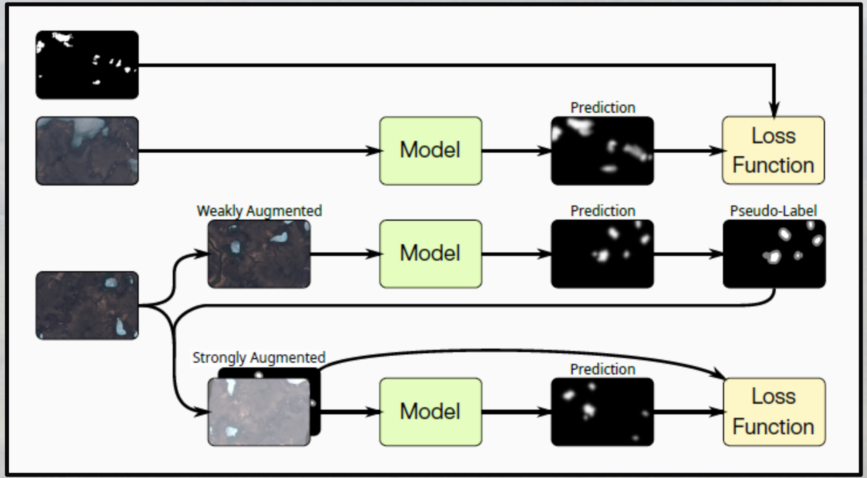
- Less training data required

Additional Data Sources

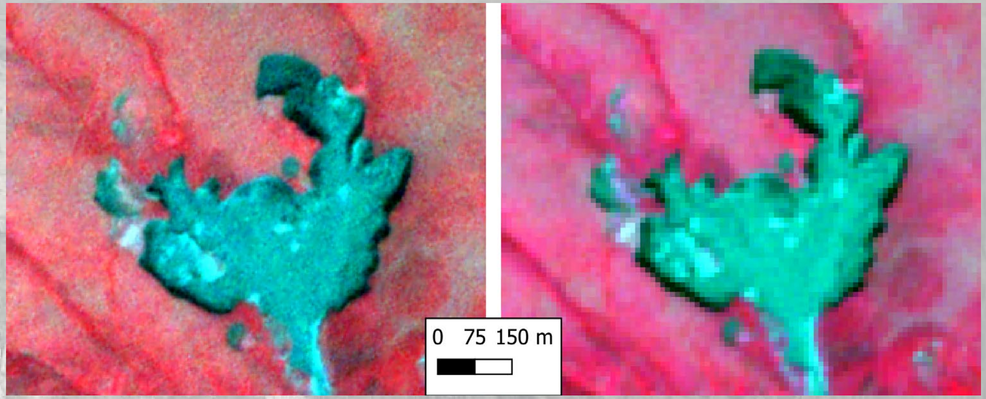
- Sentinel-2 → free data
- Panarctic extent
- Monitoring
- Super-resolution

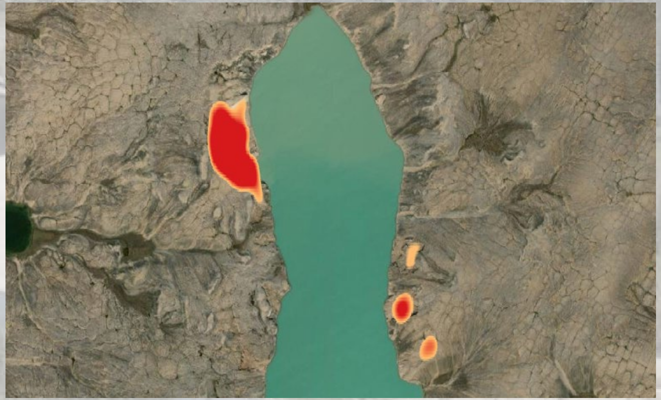
Volumetric Changes

- RTS are 3D features !!!



Heidler, et al., in revision





Take home

- EO based panarctic RTS monitoring
- Good results in many regions
- Data will be released soon

Data: happy to share, I'd love to get some feedback

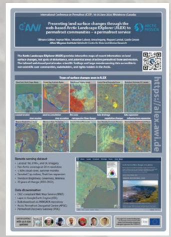
Contact: ingmar.nitze@awi.de

Github: https://github.com/initze/

Code: https://github.com/initze/thaw-slump-segmentation

Training Labels: https://github.com/initze/ML_training_labels

ID 505
Wed Posters
alex.awi.de



Thank You

References:

Heidler, K., Nitze, I., Grosse, G., & Zhu, X. X. (2024). PixelDINO: Semi-Supervised Semantic Segmentation for Detecting Permafrost Disturbances (arXiv:2401.09271). arXiv. http://arxiv.org/abs/2401.09271

Kokelj, S. V., Gingras-Hill, T., Daly, S. V., Morse, P., Wolfe, S., Rudy, A. C. A., Van Der Sluijs, J., Weiss, N., O'Neill, B., Baltzer, J., Lantz, T. C., Gibson, C., Cazon, D., Fraser, R. H., Froese, D. G., Giff, G., Klengenberg, C., Lamoureux, S. F., Quinton, W., … Young, J. (2023). The Northwest Territories Thermokarst Mapping Collective: A northern-driven mapping collaborative toward understanding the effects of permafrost thaw. Arctic Science, AS-2023-0009. https://doi.org/10.1139/AS-2023-0009

Lewkowicz, A.G. 2024. Retrogressive thaw slump activity and related lake colour change in five areas of the western Canadian Arctic, v. 1.0 (1984-2018). Nordicana D128, doi: 10.5885/45888XD-C644C19F4F414D58

Nitze, I., Heidler, K., Barth, S., & Grosse, G. (2021). Developing and Testing a Deep Learning Approach for Mapping Retrogressive Thaw Slumps. Remote Sensing, 13(21). https://doi.org/10.3390/rs13214294

Obu, J., Westermann, S., Bartsch, A., Berdnikov, N., Christiansen, H. H., Dashtseren, A., Delaloye, R., Elberling, B., Etzelmüller, B., Kholodov, A., Khomutov, A., Kääb, A., Leibman, M. O., Lewkowicz, A. G., Panda, S. K., Romanovsky, V., Way, R. G., Westergaard-Nielsen, A., Wu, T., … Zou, D. (2019). Northern Hemisphere permafrost map based on TTOP modelling for 2000–2016 at 1 km2 scale. Earth-Science Reviews, 193, 299–316. https://doi.org/10.1016/j.earscirev.2019.04.023

Schuur, E. A. G., & Mack, M. C. (2018). Ecological Response to Permafrost Thaw and Consequences for Local and Global Ecosystem Services. Annual Review of Ecology, Evolution, and Systematics, 49(1), 279–301. https://doi.org/10.1146/annurev-ecolsys-121415-032349

Zhou, Z., Rahman Siddiquee, M. M., Tajbakhsh, N., & Liang, J. (2018). UNet++: A Nested U-Net Architecture for Medical Image Segmentation. In D. Stoyanov, Z. Taylor, G. Carneiro, T. Syeda-Mahmood, A. Martel, L. Maier-Hein, J. M. R. S. Tavares, A. Bradley, J. P. Papa, V. Belagiannis, J. C. Nascimento, Z. Lu, S. Conjeti, M. Moradi, H. Greenspan, & A. Madabhushi (Eds.), Deep Learning in Medical Image Analysis and Multimodal Learning for Clinical Decision Support (Vol. 11045, pp. 3–11). Springer International Publishing. https://doi.org/10.1007/978-3-030-00889-5_1