Deep Learning for Monitoring Permafrost Disturbances

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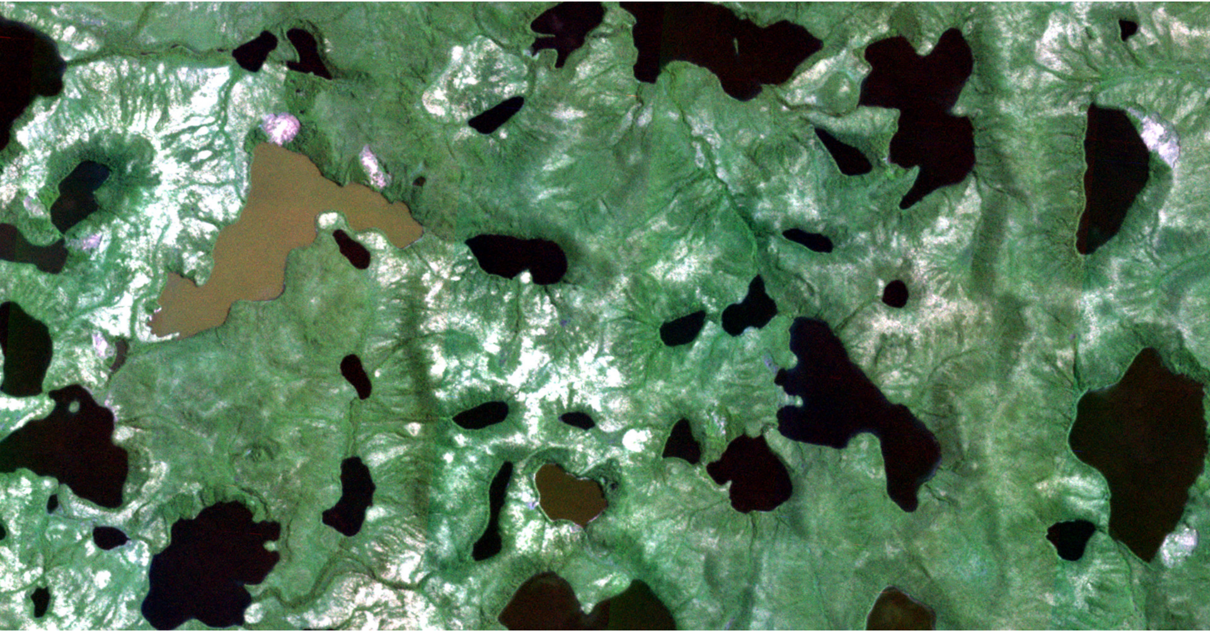
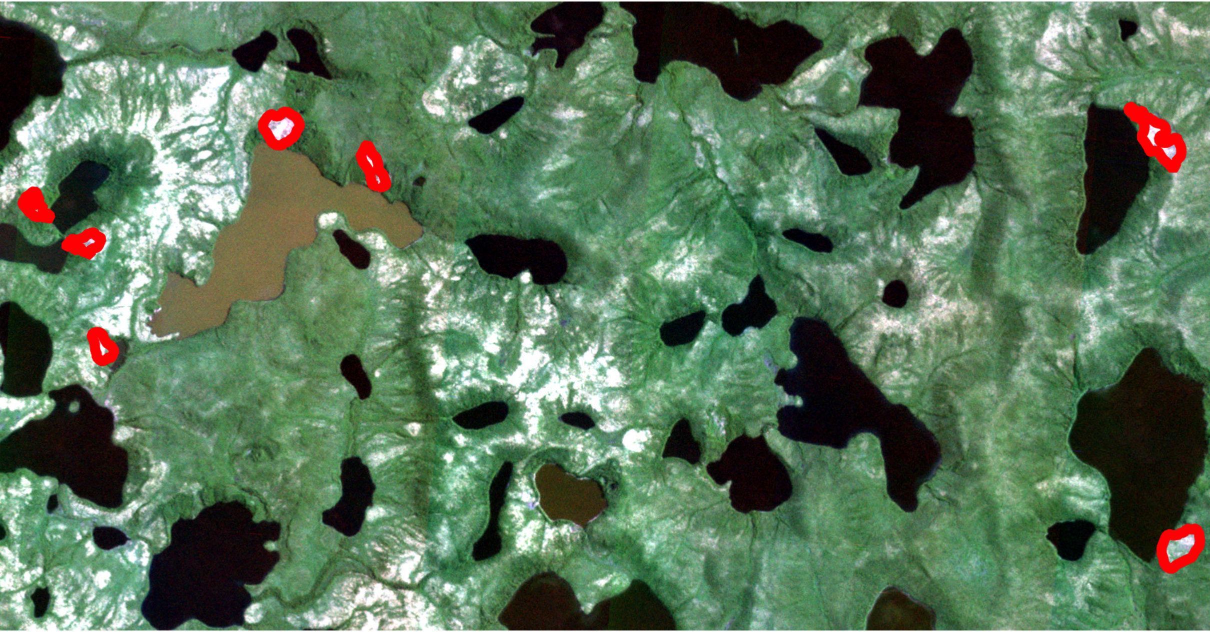
DLR

Retrogressive Thaw Slumps (RTS)

- Dynamic soil erosion from thawing
- Small: Few m^2 up to $1km^2$
- Often undetected





Remote Sensing of RTS

Challenges

- Sparsity of Targets
- Vast Areas to Monitor
- No Strict Definitions for RTS outlines

Study Sites

Study Sites

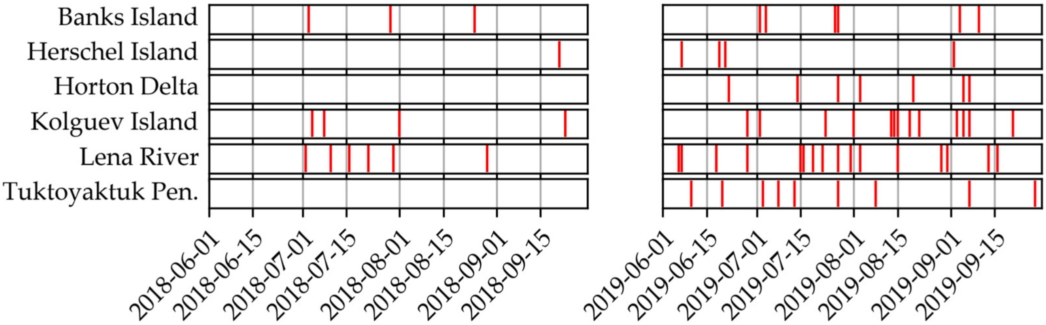

Banks Island
Herschel Island
Horton Delta
Tuktoyaktuk Peninsula
Kolguev Island
Lena River

Dataset Creation

Manual Digitization

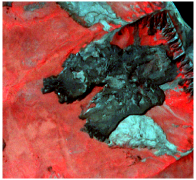
- PlanetScope as main data source
- Imagery from 175 PlanetScope scenes
- More than 2100 RTS digitized.

Temporal Distribution



Auxiliary Data

Planet Imagery



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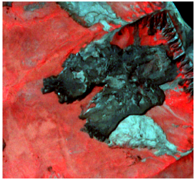
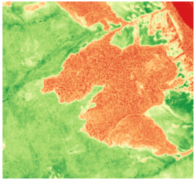


NDVI



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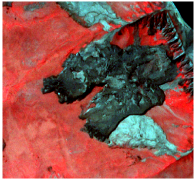
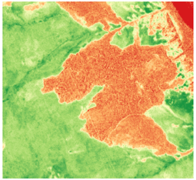
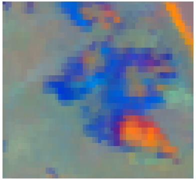


NDVI



Landsat TS



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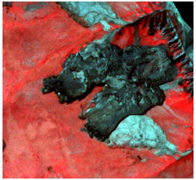

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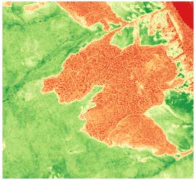

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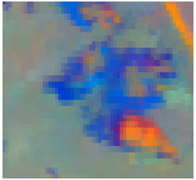
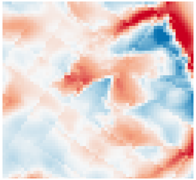
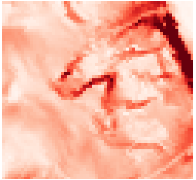


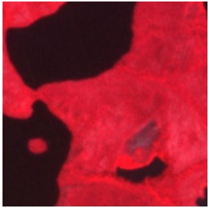
Elevation



Slope



Segmentation for RTS mapping



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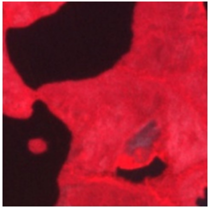

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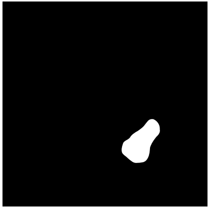

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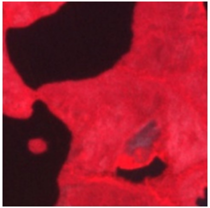

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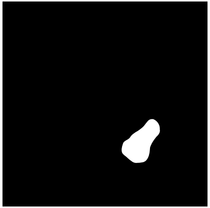
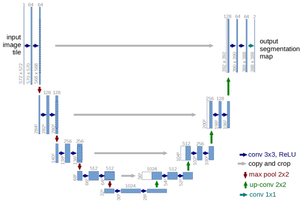


Approach

- Pixel-wise predictions
  - 0: Background
  - 1: RTS
- Use Semantic Segmentation models

Models

UNet [1]



Models

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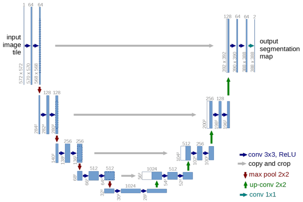
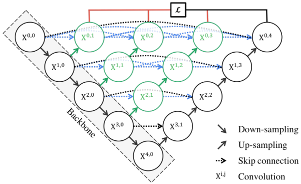


UNet++ [2]



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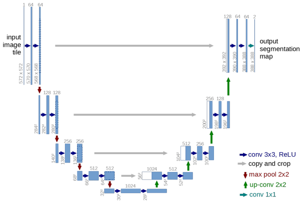

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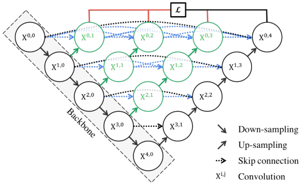
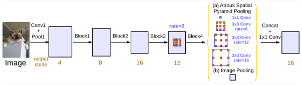


DeepLab v3 [3]



Training Protocol

Preprocessing

1. Rasterize target vectors
2. Stack input data
   - PlanetScope
   - NDVI
   - Landsat Trends
   - Elevation
   - Slope
3. Cut data into tiles

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Dense Training

Use all available training tiles.

Sparse Training

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Full Training

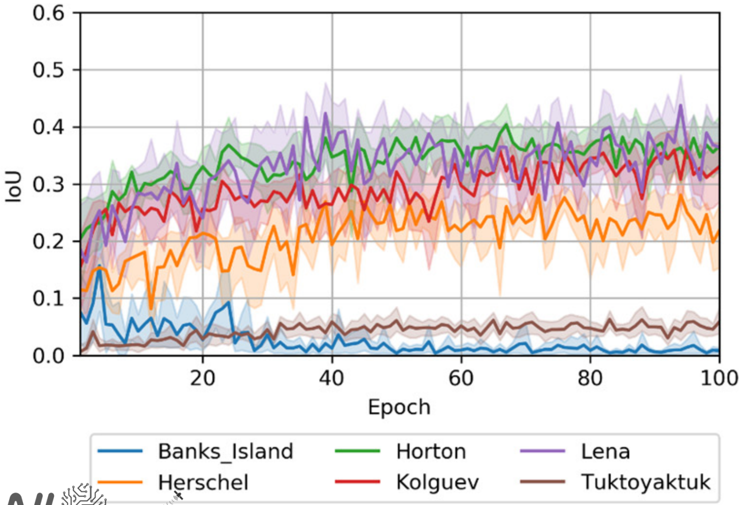
Sparse Training followed by Dense Training.

Evaluation Protocol

Spatial Leave-One-Out Cross Validation

- Train using data from 5 study sites.
- Evaluate performance on the 6th study site.

Results


0.6
0.5
0.4
0.3
0.2
0.1
0.0
IoU
20
40
60
80
100
Epoch
Banks_Island
Herschel
Horton
Kolguev
Lena
Tuktoyaktuk

Numerical Results

Study Site
Banks Island
Herschel Island
Horton Delta
Kolguev Island
Lena River
Tuktoyaktuk Peninsula

Numerical Results

Study Site	Best Model
Banks Island	UNet++
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Numerical Results

Study Site	Best Model	Top IoU
Banks Island	UNet++	0.39
Herschel Island	DeepLab v3	0.39
Horton Delta	UNet++	0.55
Kolguev Island	UNet++	0.48
Lena River	UNet++	0.58
Tuktoyaktuk Peninsula	UNet++	0.15

Numerical Results

Study Site	Best Model	Top IoU	90% IoU
Banks Island	UNet++	0.39	0.08
Herschel Island	DeepLab v3	0.39	0.32
Horton Delta	UNet++	0.55	0.51
Kolguev Island	UNet++	0.48	0.43
Lena River	UNet++	0.58	0.50
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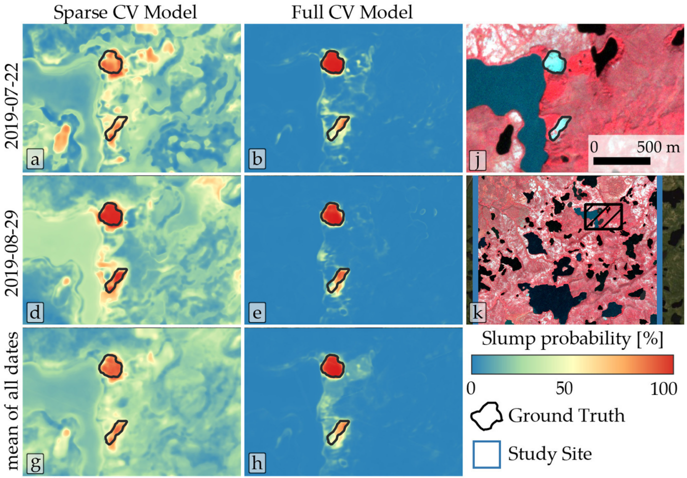
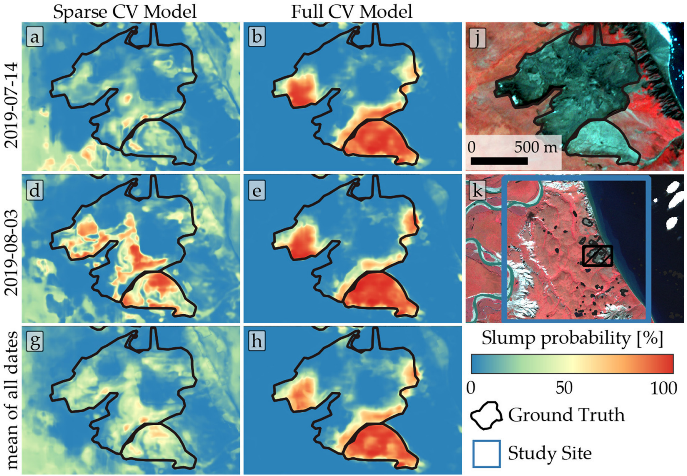
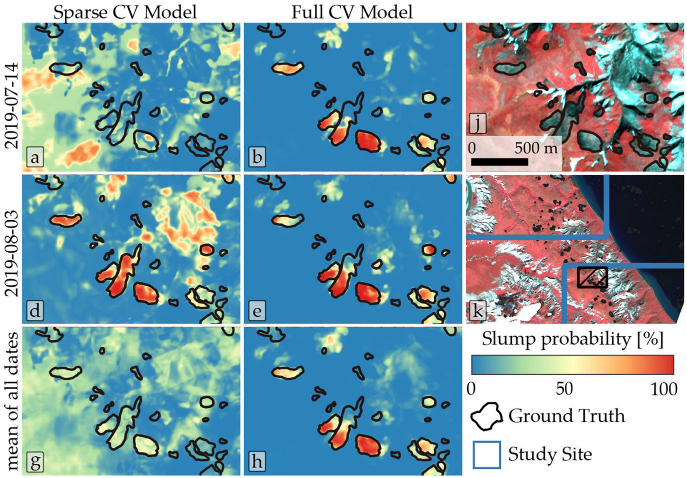
Results – Lena River



Results – Horton Delta



Results – Horton Delta



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Conclusion

- Deep Learning is strong tool for RTS detection
- Spatial variability of RTS is large
- A larger dataset (in development) will likely lead to better results

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Code

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

References i

[1] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. "U-Net: Convolutional Networks for Biomedical Image Segmentation". In: *Proc. Int. Conf. Med. Image Comput. Comput.-Assist. Intervent. (MICCAI)*. Ed. by Nassir Navab et al. Oct. 2015, pp. 234–241.

[2] Zongwei Zhou et al. "UNet++: Redesigning Skip Connections to Exploit Multiscale Features in Image Segmentation". Jan. 28, 2020. arXiv: `1912.05074 [cs, eess]`.

[3] Liang-Chieh Chen et al. "Rethinking Atrous Convolution for Semantic Image Segmentation". Dec. 5, 2017. arXiv: `1706.05587 [cs]`.