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Cryosphere and related hazards in High Mountain Asia in a changing climate

1–4 November 2022 | Almaty, Kazakhstan

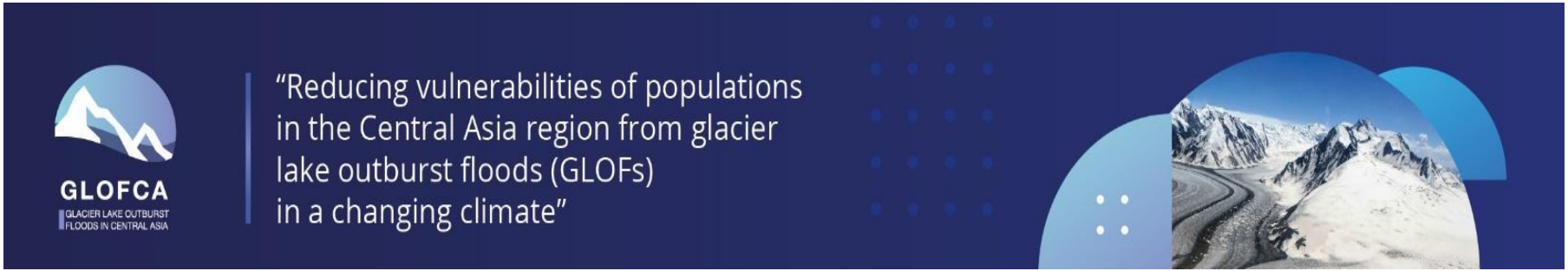
Presenter(s): Manu Tom, Post-Doctoral Researcher, University of Zürich, Switzerland

Date: 03 November 2022

A Toolbox for High-Frequency Mapping and Monitoring of Central Asian Glacial Lakes from Space

Motivation

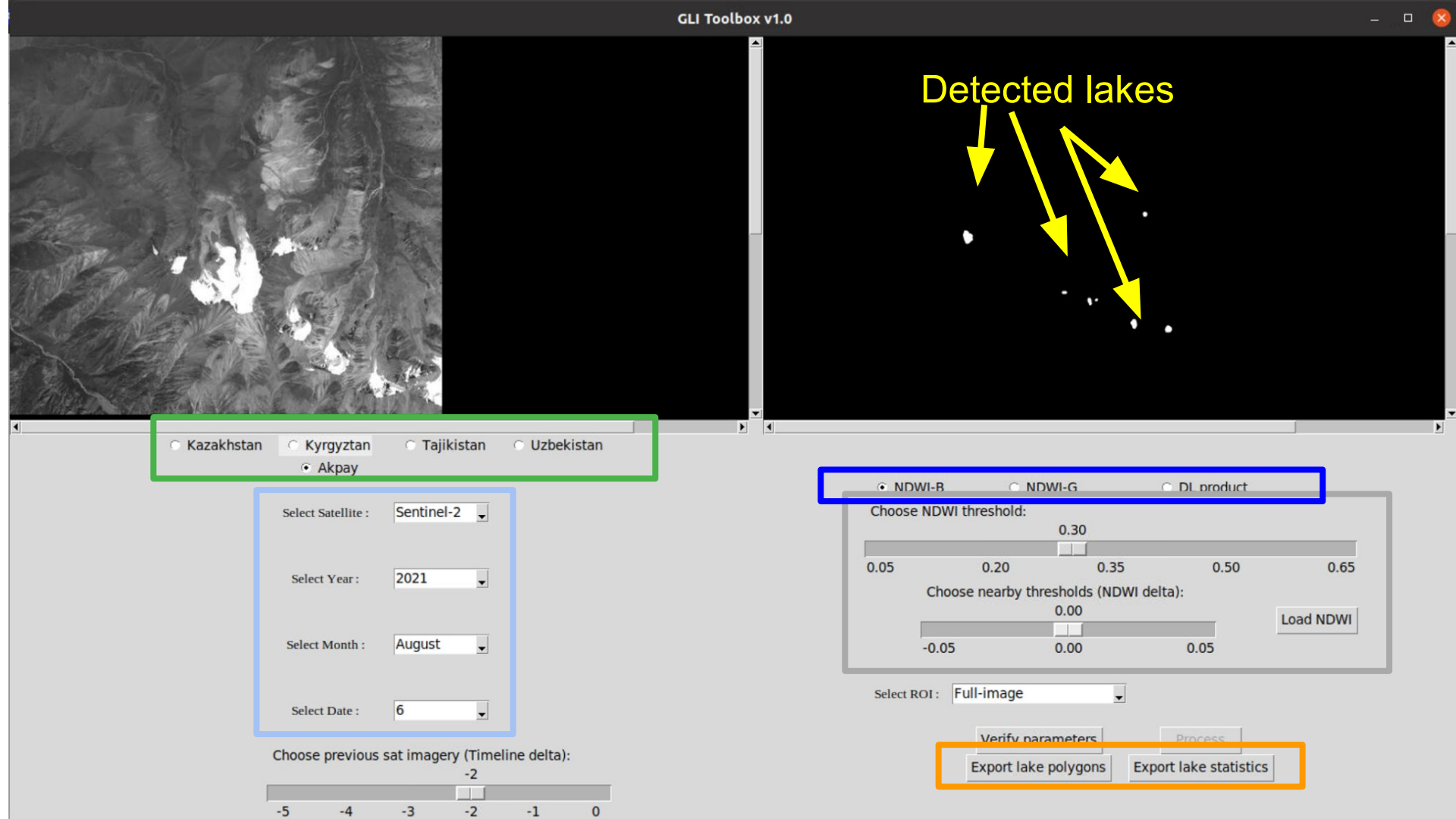
- Part of GLOFCA project (UNESCO Adaptation Fund)



Goal

NDWI: Normalised Difference Water Index
GSD: Ground Sampling Distance
SAR: Synthetic Aperture Radar

- Analytical *toolbox:*
  - for glacial lakes mapping and monitoring
    - spectral indices: NDWI-B, NDWI-G
    - Machine (deep) learning
  - using open source libraries/packages
    - Python (tkinter, rasterio etc.)
    - GDAL
  - with freely available Satellite data
    - Sentinel-2 (optical): 10m GSD
    - Sentinel-1 SAR: approx. 20m GSD

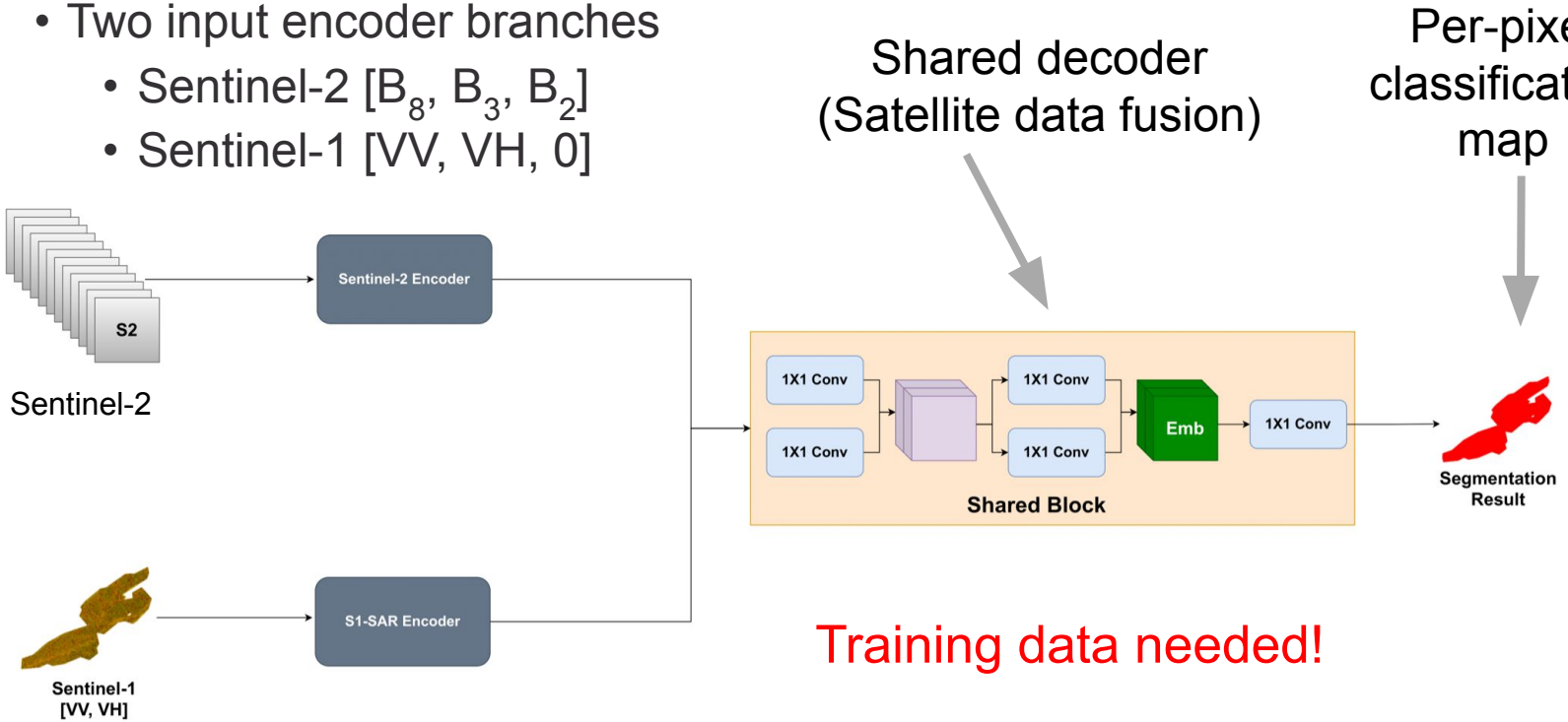

GLI Toolbox v1.0
Detected lakes
Kazakhstan
Kyrgyztan
Tajikistan
Uzbekistan
Akpay
Select Satellite :
Sentinel-2
Select Year :
2021
Select Month :
August
Select Date :
6
Choose previous sat imagery (Timeline delta):
-2
-5
-4
-3
-2
-1
0
NDWI-B
NDWI-G
DL product
Choose NDWI threshold:
0.30
0.05
0.20
0.35
0.50
0.65
Choose nearby thresholds (NDWI delta):
0.00
-0.05
0.00
0.05
Load NDWI
Select ROI :
Full-image
Verify parameters
Process
Export lake polygons
Export lake statistics

Water body mapping

Deep Learning (DL): CNN-backbone

- Encoder-Decoder architecture
  - Two input encoder branches
    - Sentinel-2 [B_8, B_3, B_2]
    - Sentinel-1 [VV, VH, 0]

CNN: Convolutional Neural Network



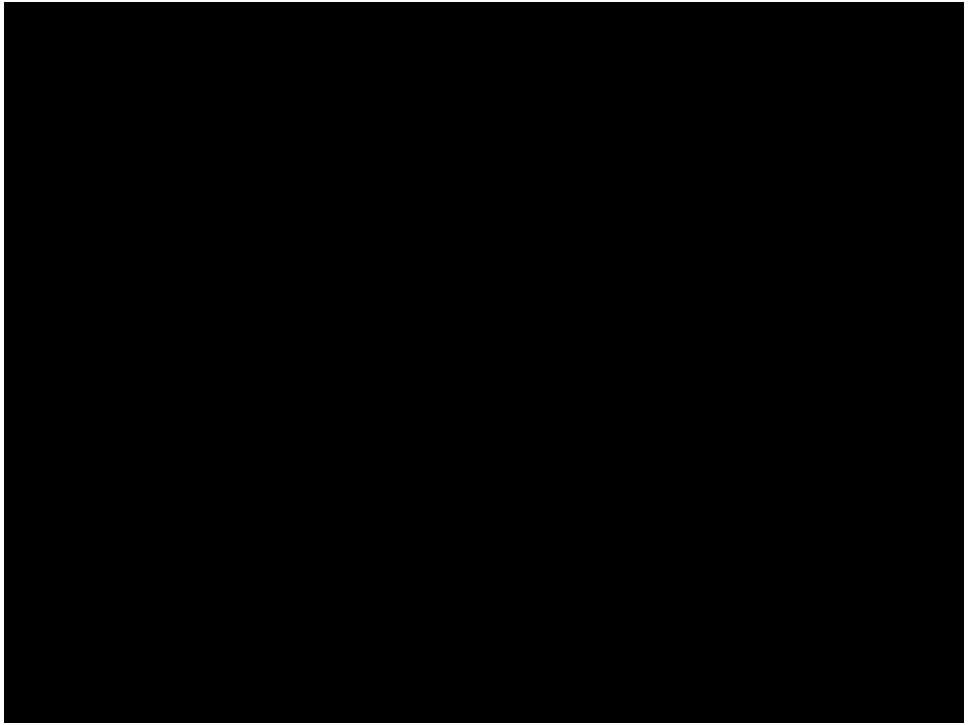
Training data needed!

Akpay GLOF (01 Aug 2021, Kyrgyzstan)

Jul 29, 2021

Aug 04, 2021

Akpay GLOF (03 Aug 2021, Kyrgyzstan)



Akpay GLOF (Satellite view, Sentinel-2)

Aug 16, 2020
(1 year before outburst)

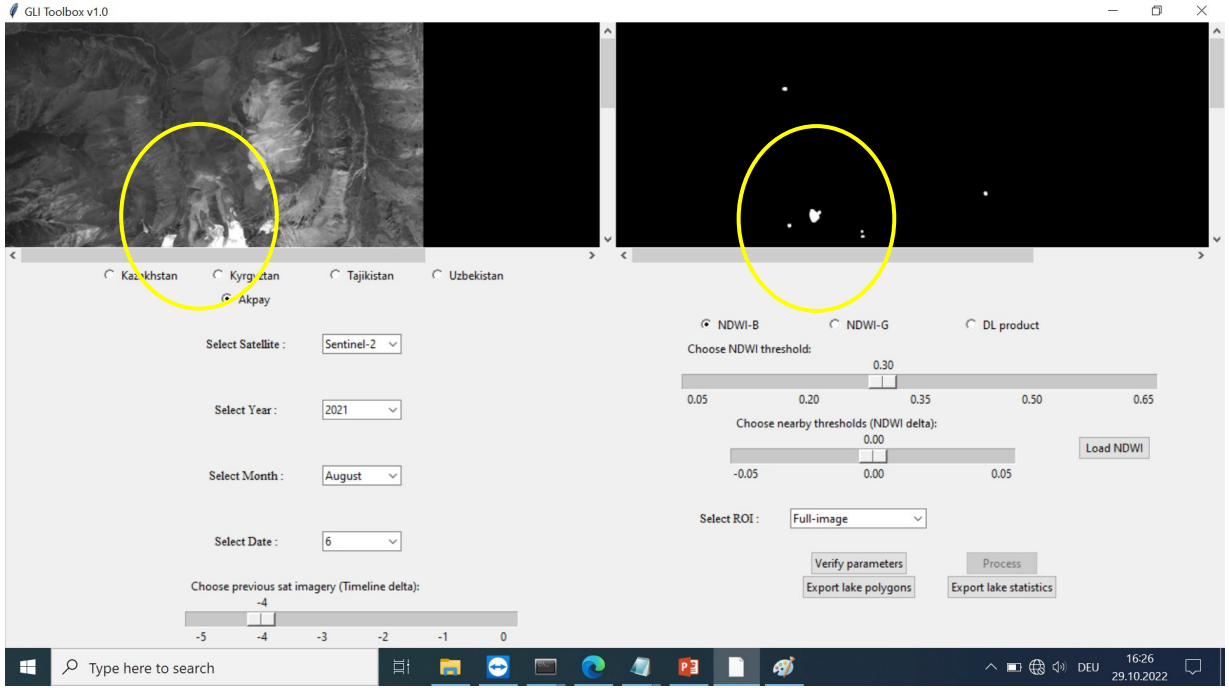
Aug 01, 2021
(few hours before outburst)

Akpay GLOF (Satellite view, Sentinel-2)

Aug 03, 2021
(after outburst)

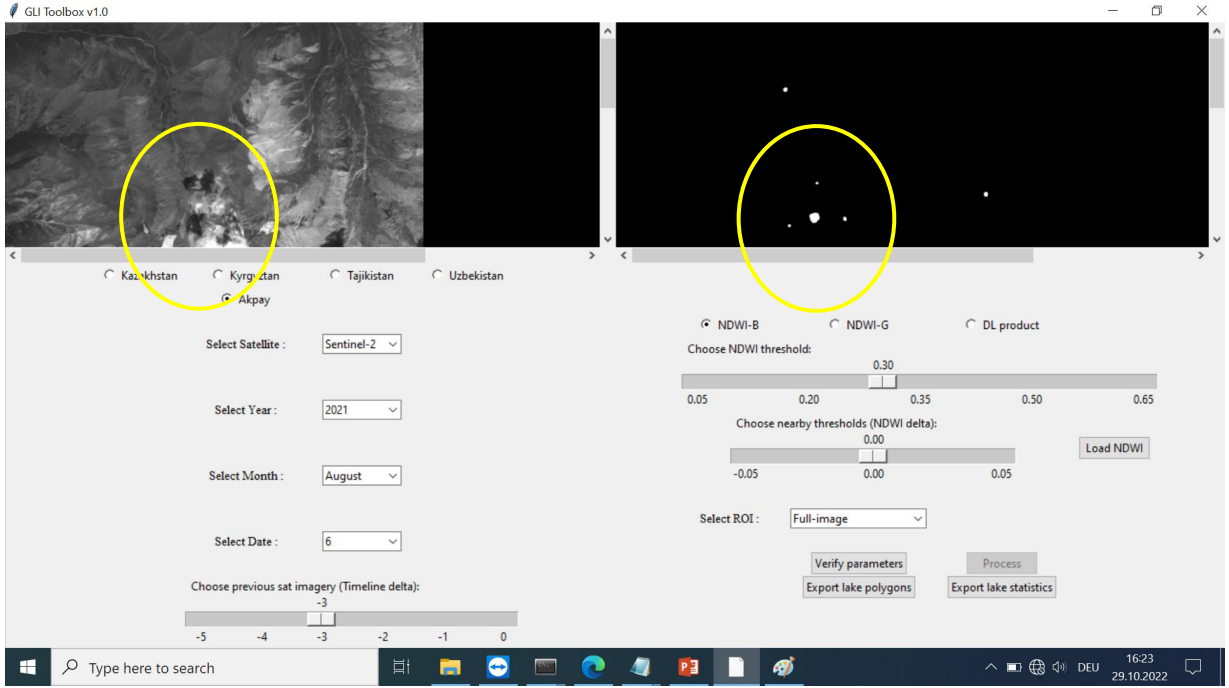
Aug 01, 2021
(few hours before outburst)

Akpay GLOF monitoring with Toolbox (Jul 27, 2021)



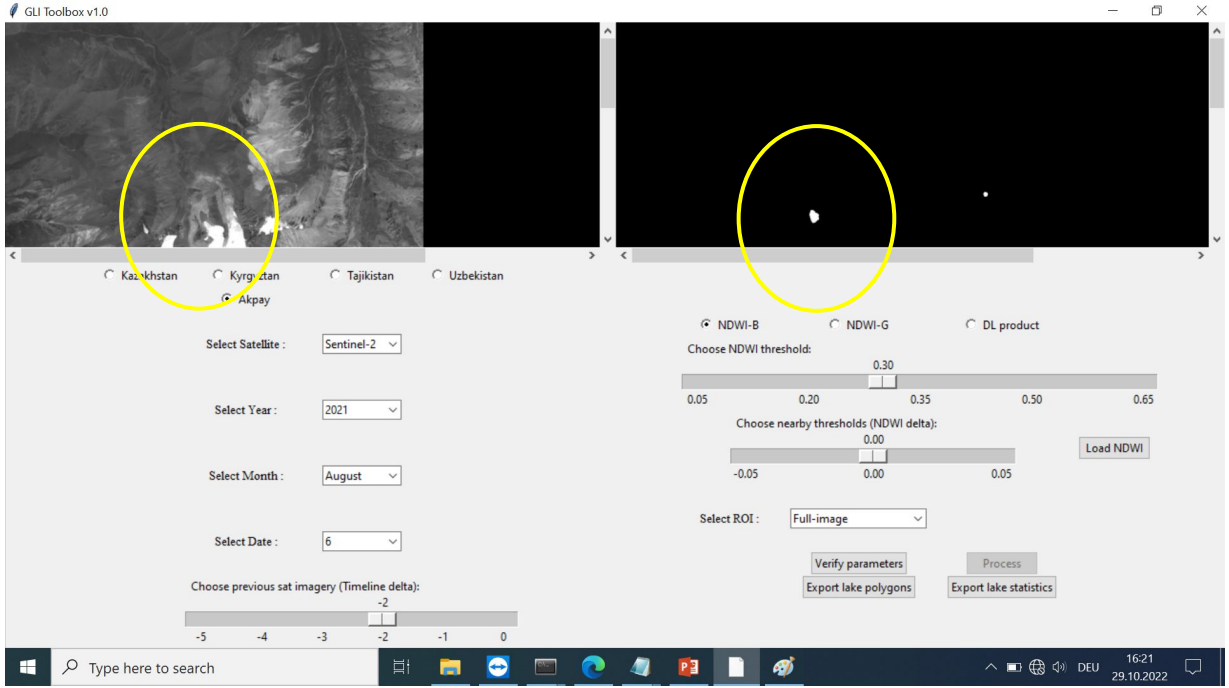
Lake = White, Background = Black

Akpay GLOF monitoring with Toolbox (Jul 29, 2021)



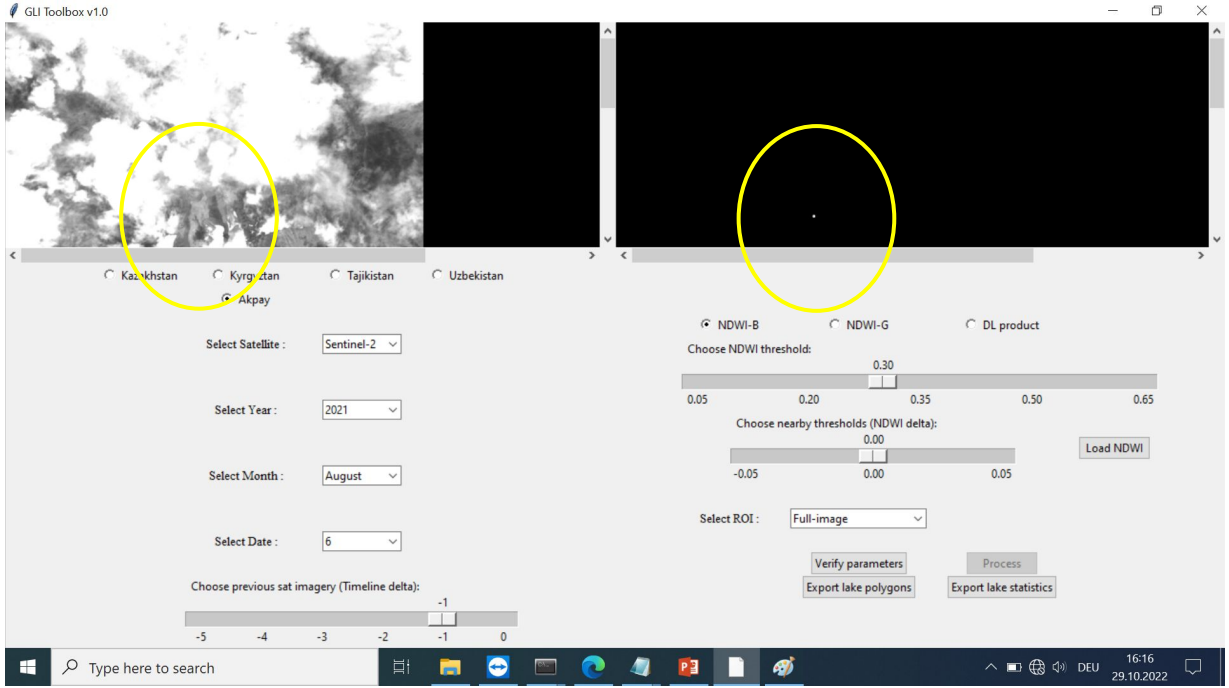
Lake = White, Background = Black

Akpay GLOF monitoring with Toolbox (Aug 1, 2021)



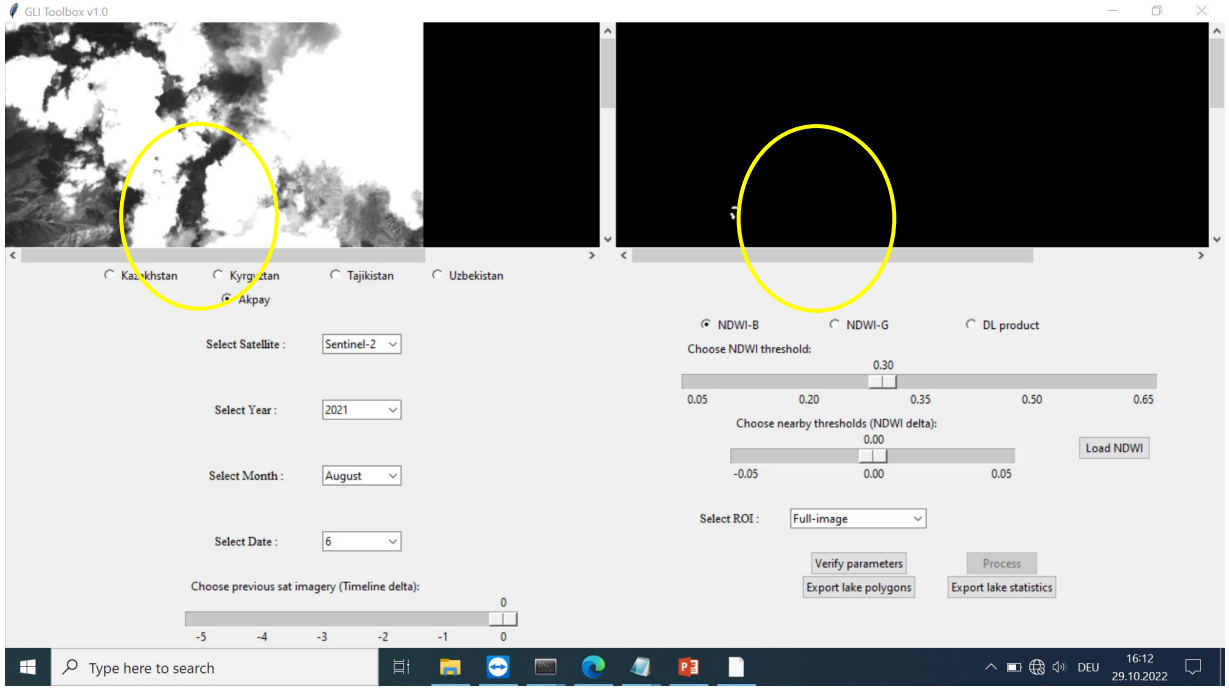
Lake = White, Background = Black

Akpay GLOF monitoring with Toolbox (Aug 3, 2021)



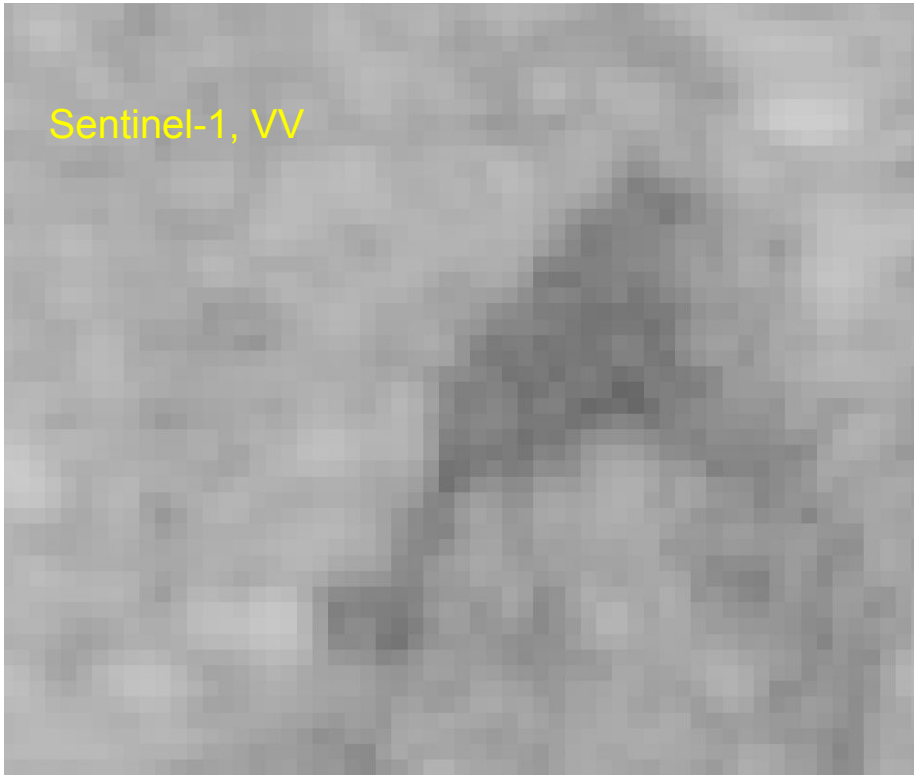
Lake = White, Background = Black

Akpay GLOF monitoring with Toolbox (Aug 6, 2021)

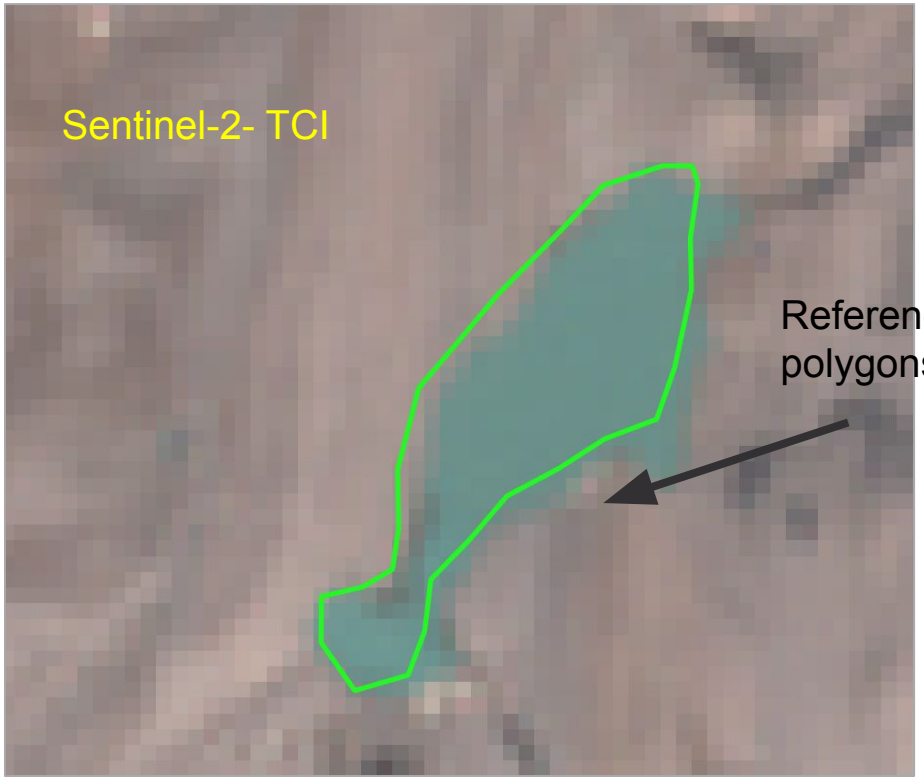


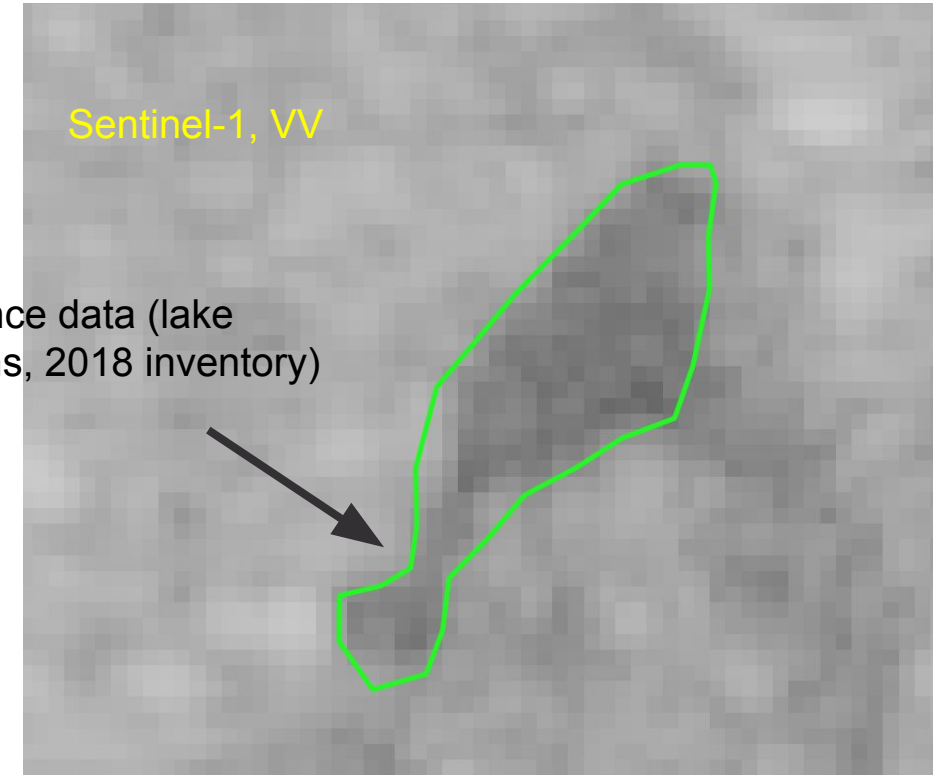
Lake = White, Background = Black

Toolbox case study: Adygene (Kyrgyzstan), Aug 01, 2021



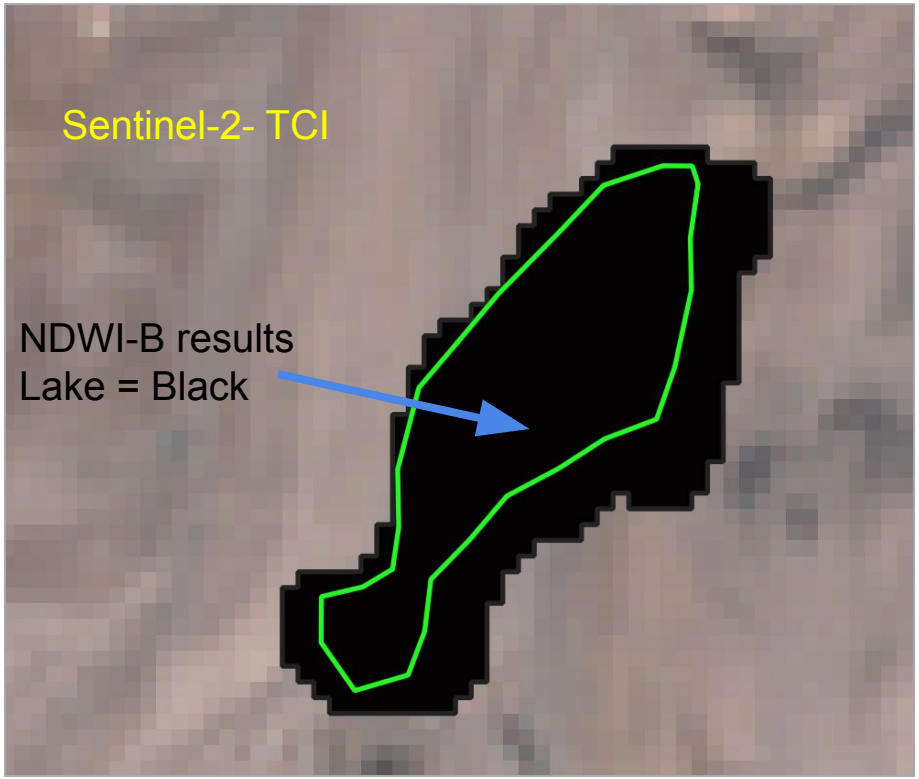
Toolbox case study: Adygene (Kyrgyzstan), Aug 01, 2021

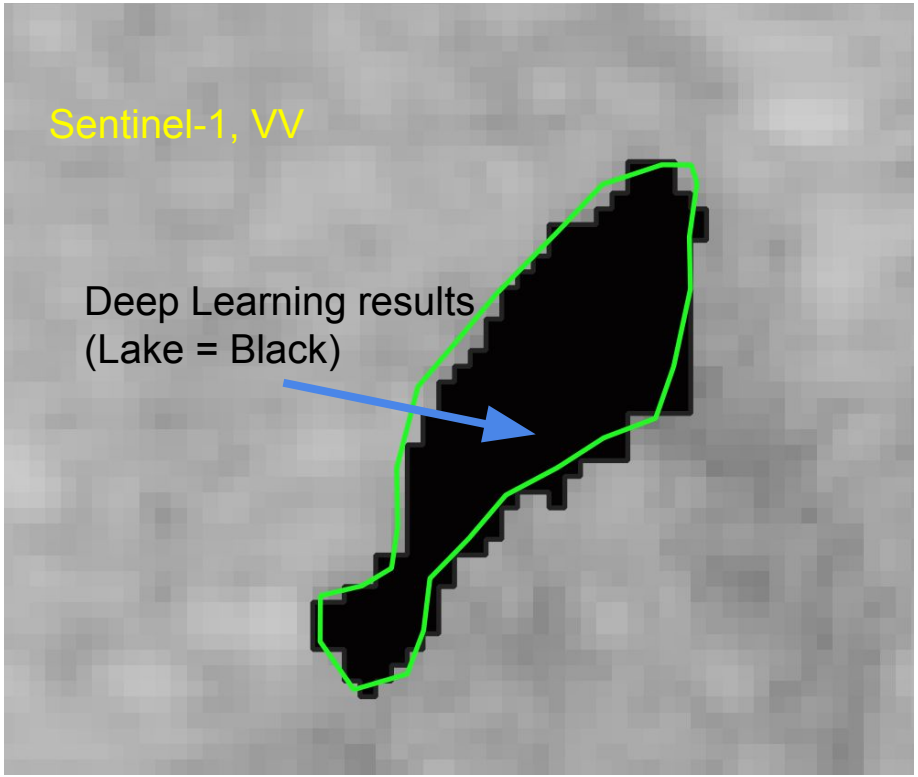




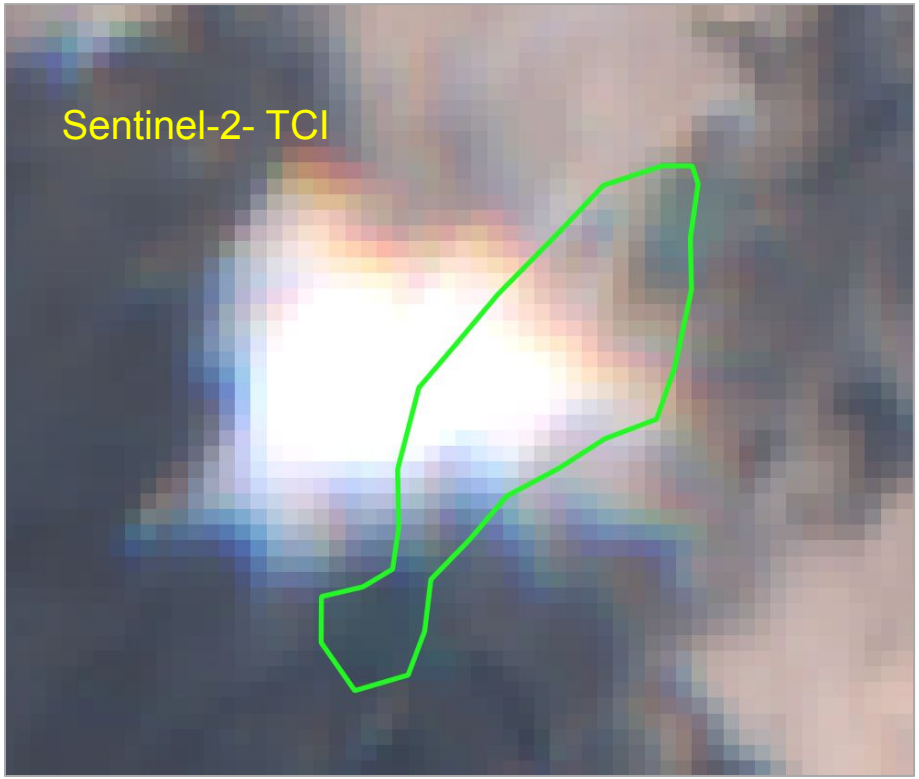
Reference data (lake polygons, 2018 inventory)

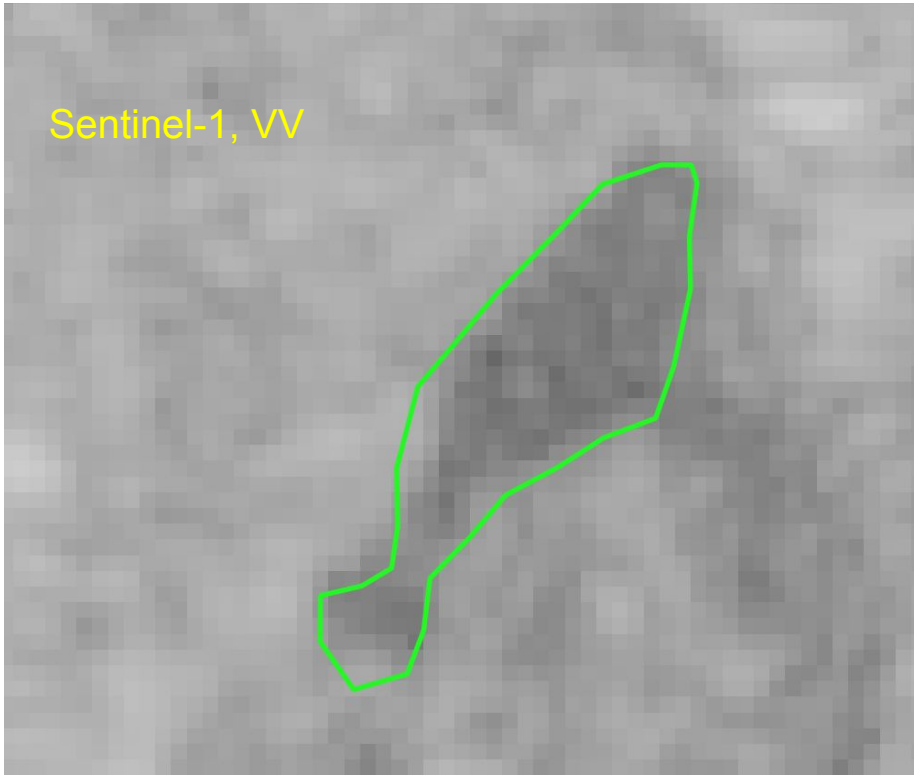
Toolbox case study: Adygene (Kyrgyzstan), Aug 01, 2021



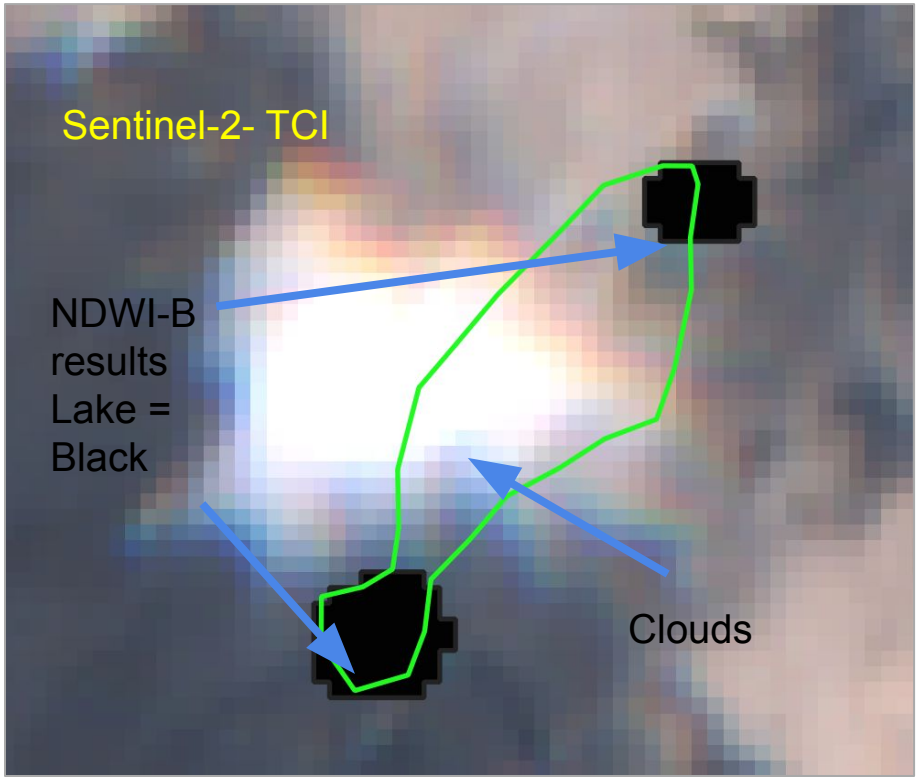


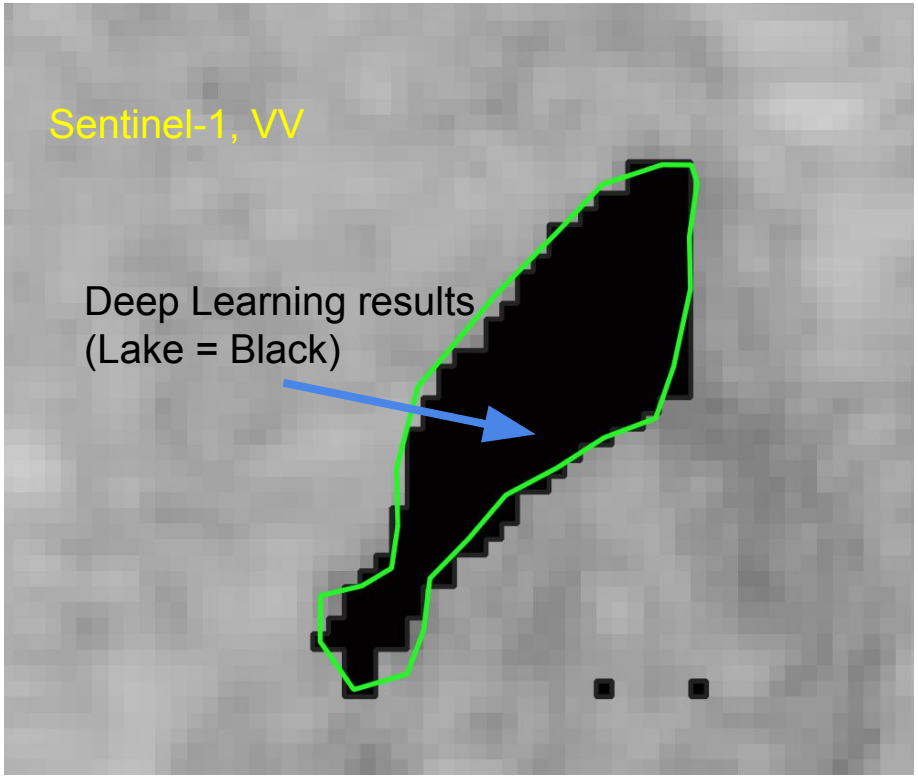
Toolbox case study: Adygene (Kyrgyzstan), Aug 13, 2021 (partly cloudy)





Toolbox case study: Adygene (Kyrgyzstan), Aug 13, 2021 (partly cloudy)





Toolbox case study: Adygene (Kyrgyzstan), Aug 03, 2021 (fully cloudy)

Sentinel-2- TCI

NDWI-B results:
No lake detected!

Toolbox features: summary

Incorporates 3 products:

- NDWI-B
- NDWI-G
- Deep Learning (DL)

NDWI: Normalised Difference Water Index
SAR: Synthetic Aperture Radar

Mapping/Monitoring frequency:

- Whenever Sentinel-1, Sentinel-2 (cloud-free) available

Output: glacial lake maps

- Lake polygons (geolocated, *shp* file vector)
- Lake statistics (number of lakes, per-lake area)

Geographical coverage:

- Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan

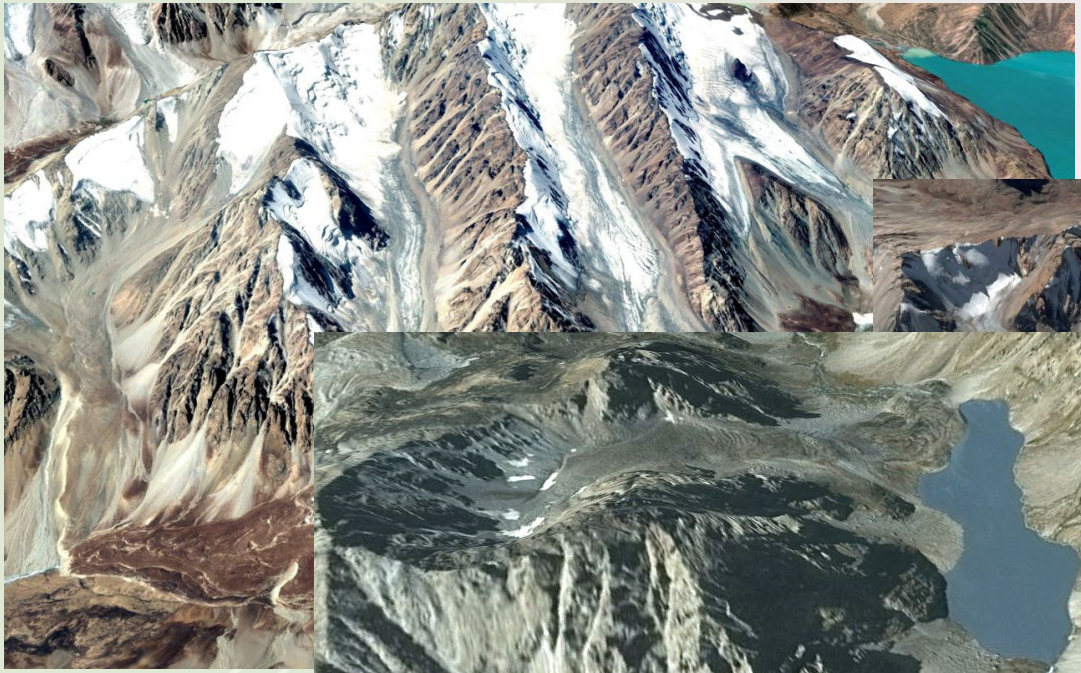
Outlook

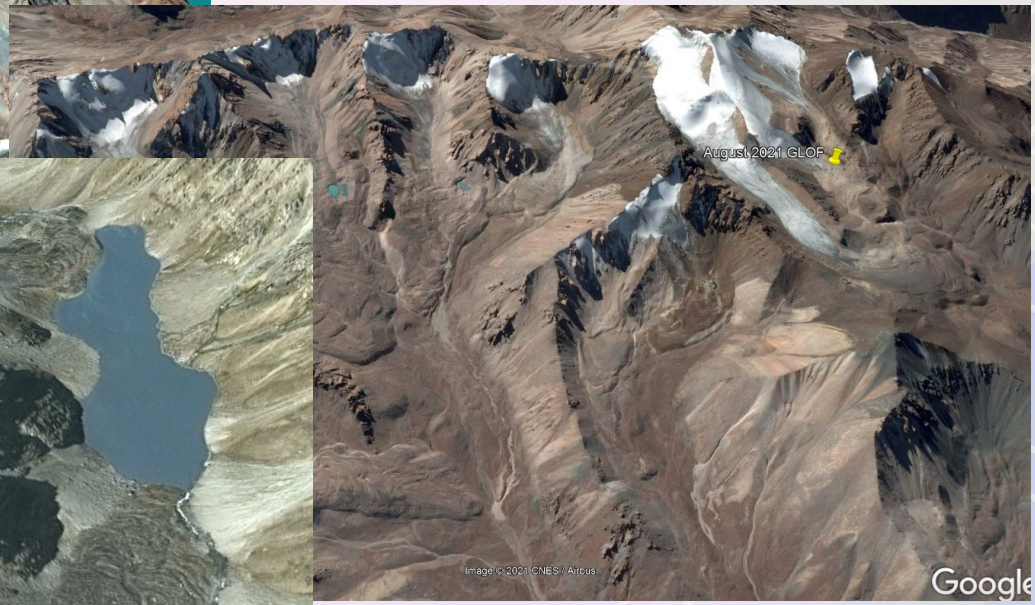
Sentinel2 deep learning results generation

Sentinel1-Sentinel2 results fusion (incl. Multi-temporal analysis)

Optimise toolbox (for execution speed)

Thank you





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Acknowledgements

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- Dr. Holger Frey
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- Prof. Dr. Christian Huggel
- Dr. Alessandro Cicoira
- Laura Niggli

Thanks to all **GLOFCA project** colleagues

Water body mapping

Normalised Difference Water Index (NDWI)

- **NDWI-B** (Huggel et al., 2002)
  - Derived from Sentinel-2:

$$(\varrho_{483} - \varrho_{865}) / (\varrho_{483} + \varrho_{865})$$

Huggel, C., Kääb, A., Haeberli, W., Teysseire, P., Paul, F., 2002. Remote sensing based assessment of hazards from glacier lake outbursts: a case study in the Swiss Alps. Can. Geotech. J. 39, 316–330. https://doi.org/10.1139/T01-099

Water body mapping

Normalised Difference Water Index (NDWI)

- **NDWI-G** (McFeeters, 1996)
  - Derived from Sentinel-2

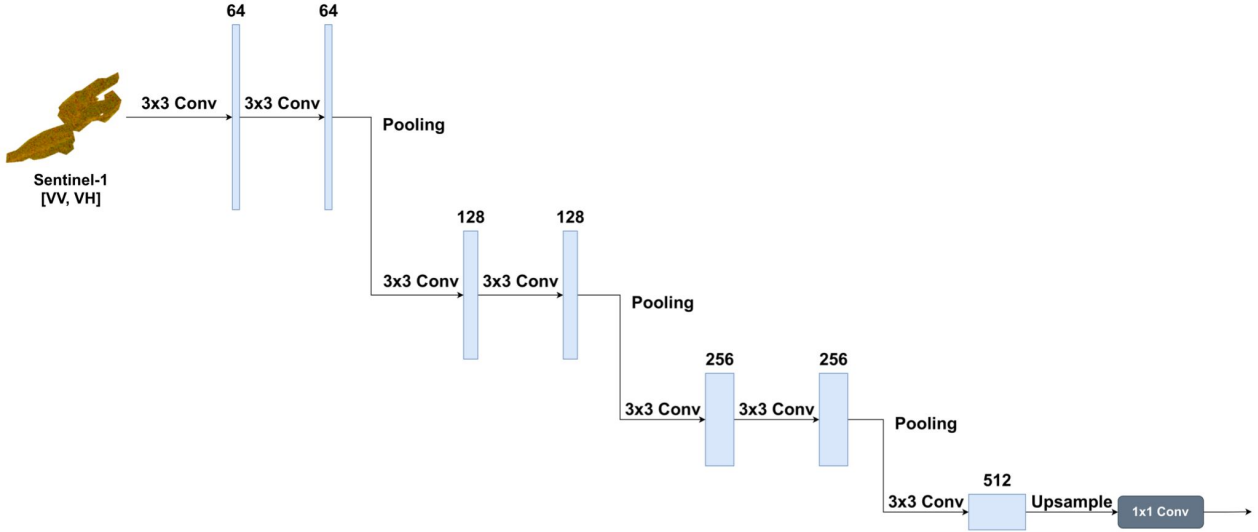
$$(\varrho_{560} - \varrho_{865}) / (\varrho_{560} + \varrho_{865})$$

S. K. McFEETERS (1996) The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features, International Journal of Remote Sensing, 17:7, 1425-1432, DOI: 10.1080/01431169608948714

Water body mapping

Deep Learning (DL)

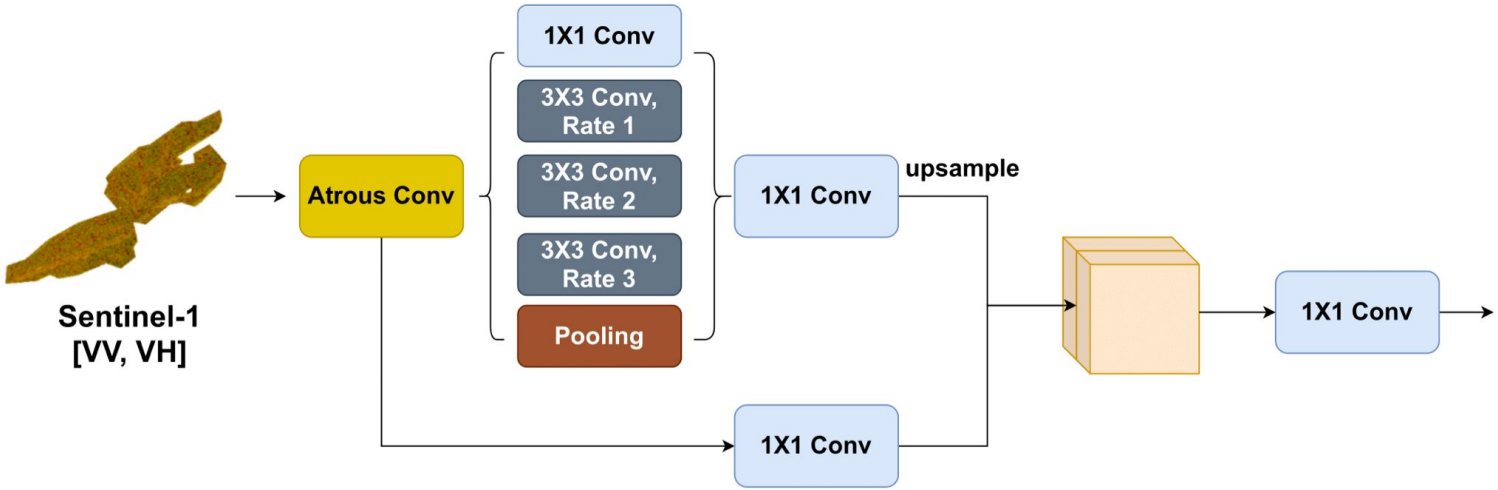
- Backbone: Convolutional Neural Network (CNN)
  - **uNet-style** encoder
    - approx 2.5 million parameters



Water body mapping

Deep Learning (DL)

- Backbone: Convolutional Neural Network (CNN)
  - **Deeplabv3+** encoder
    - Approx. 7.8 million parameters



Water body mapping

Deep Learning (DL)

- Reference data needed to train network parameters
  - Three steps:
    - Test-train-validation split of available dataset (with ground truth annotations)
    - Training a model (using ground truth/reference data) on the train dataset, validate the model on the validation dataset for choosing the right parameters
    - Test the performance of trained model on test dataset

Water body mapping

Deep Learning (DL)

- Steps for Central Asia
  - Train and validate a model on the Swiss glacial lakes dataset (655 lakes)
  - Fine-tune the trained model on data from Central Asia
  - Test on the date and region of interest to generate output maps