Glacial lake changes from cloud processing of optical satellite images

28.06.2021 Varya Bazilova

Image: National Geographic

Glacial lakes

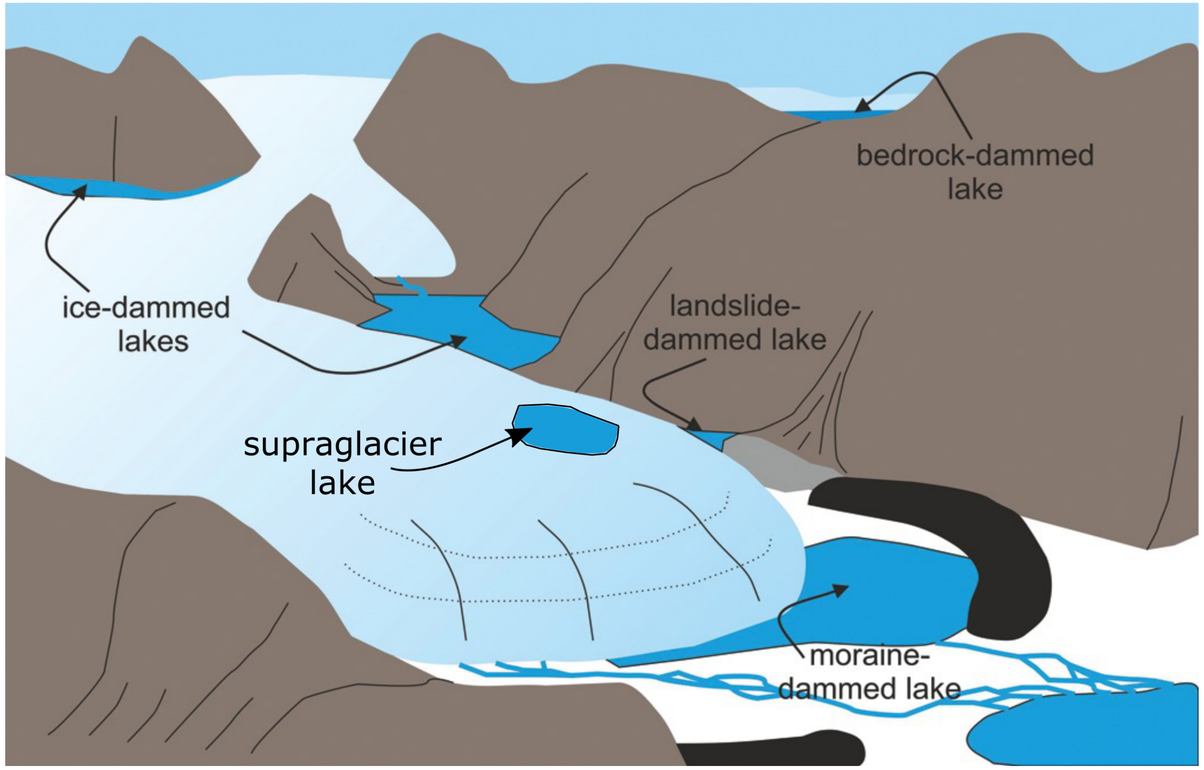
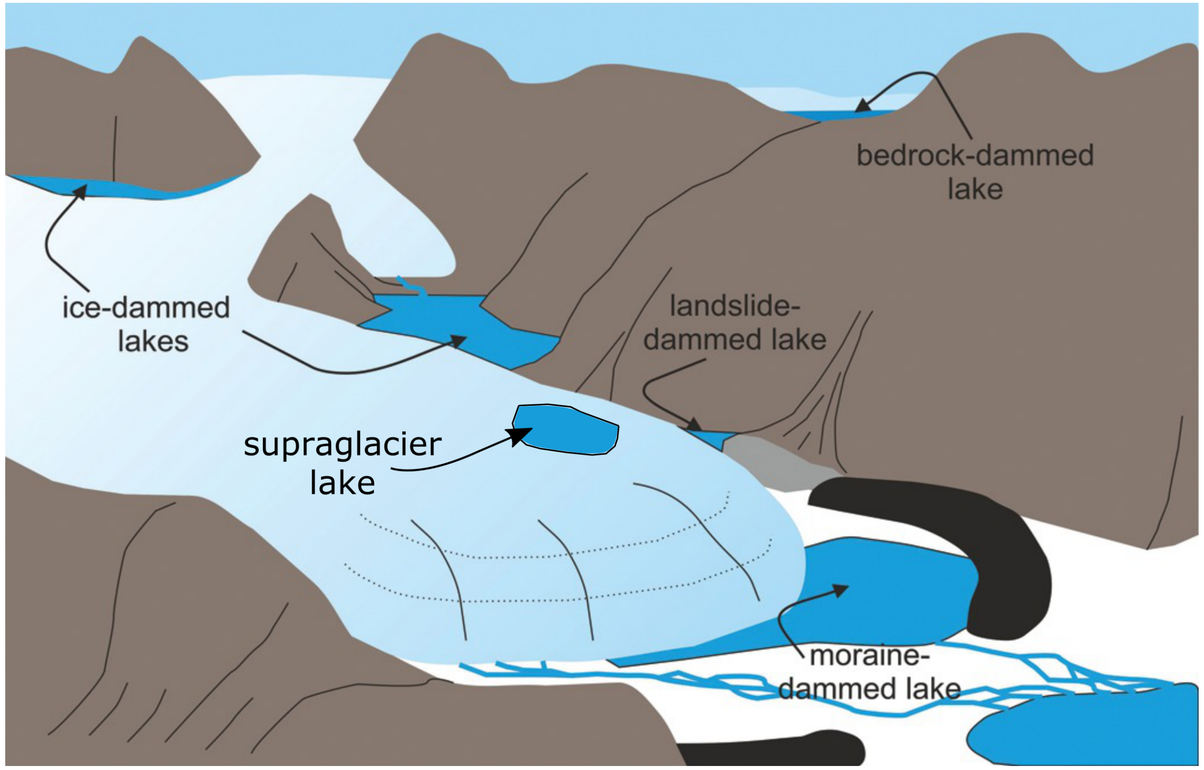


Image: modified after
(Tweed and Carrivick, 2015)

Glacial lakes



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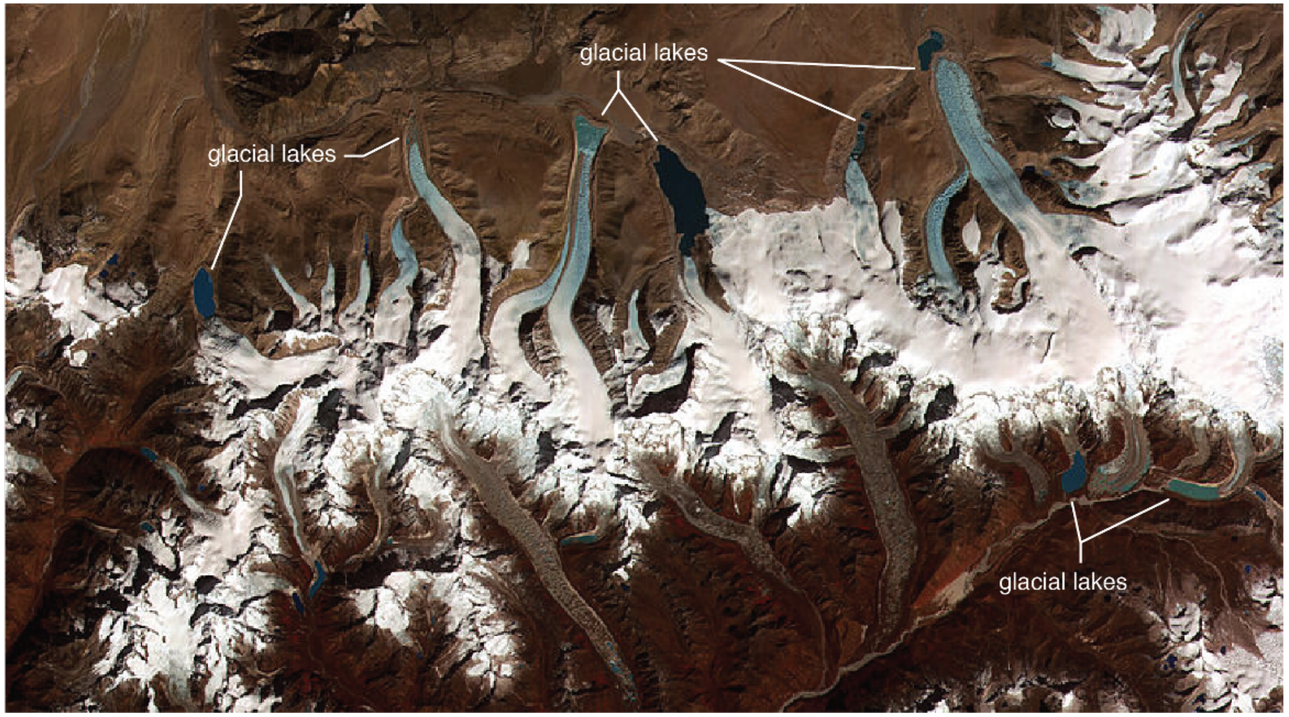

Image: NASA

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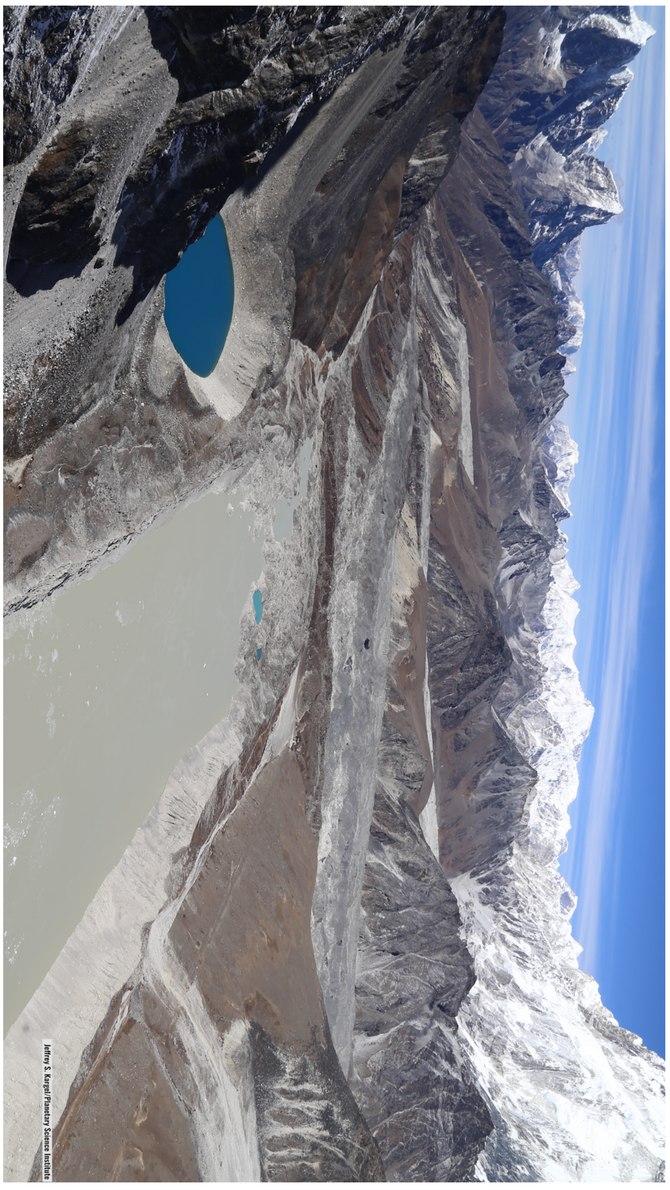


Image: ICIMOD

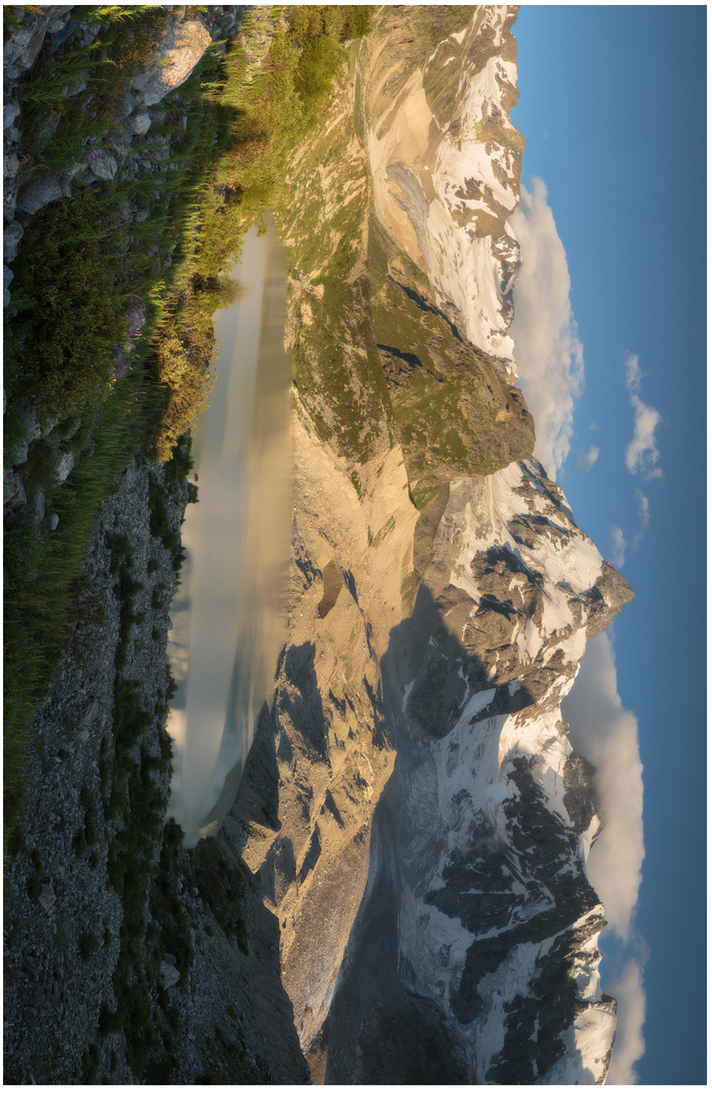
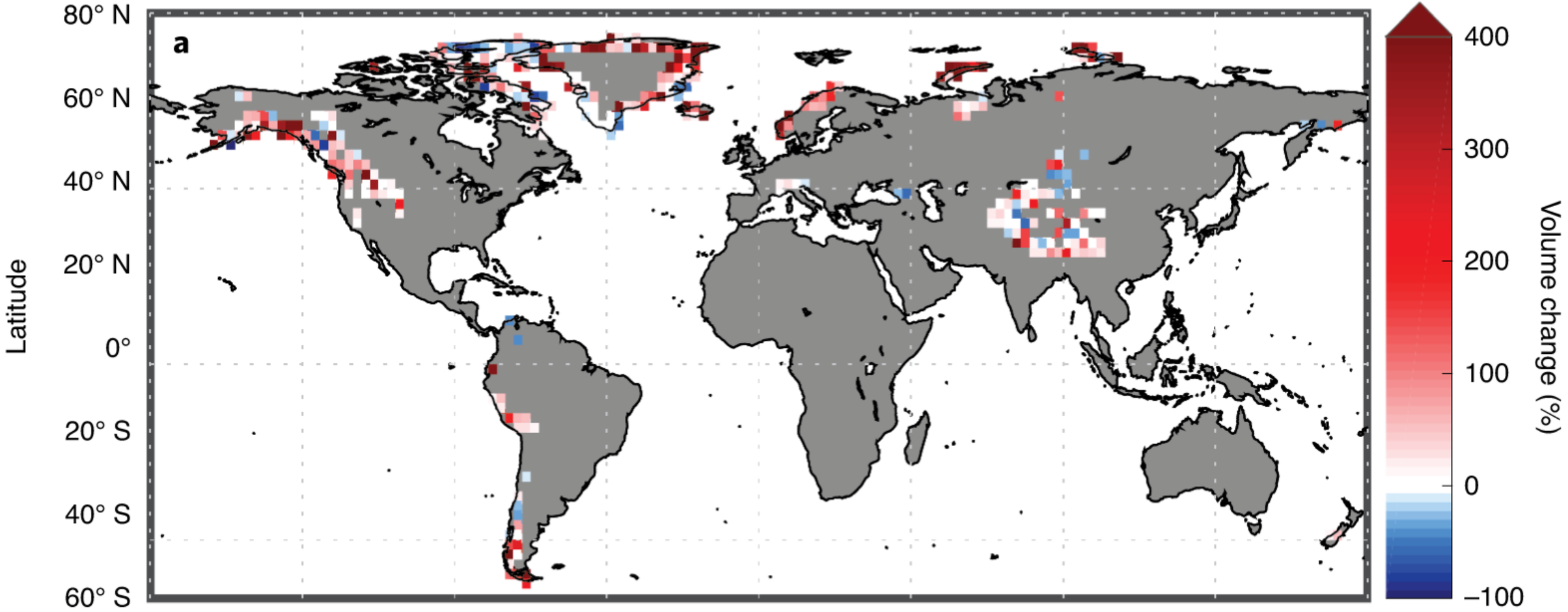


Image: Dmitry Monastirsky

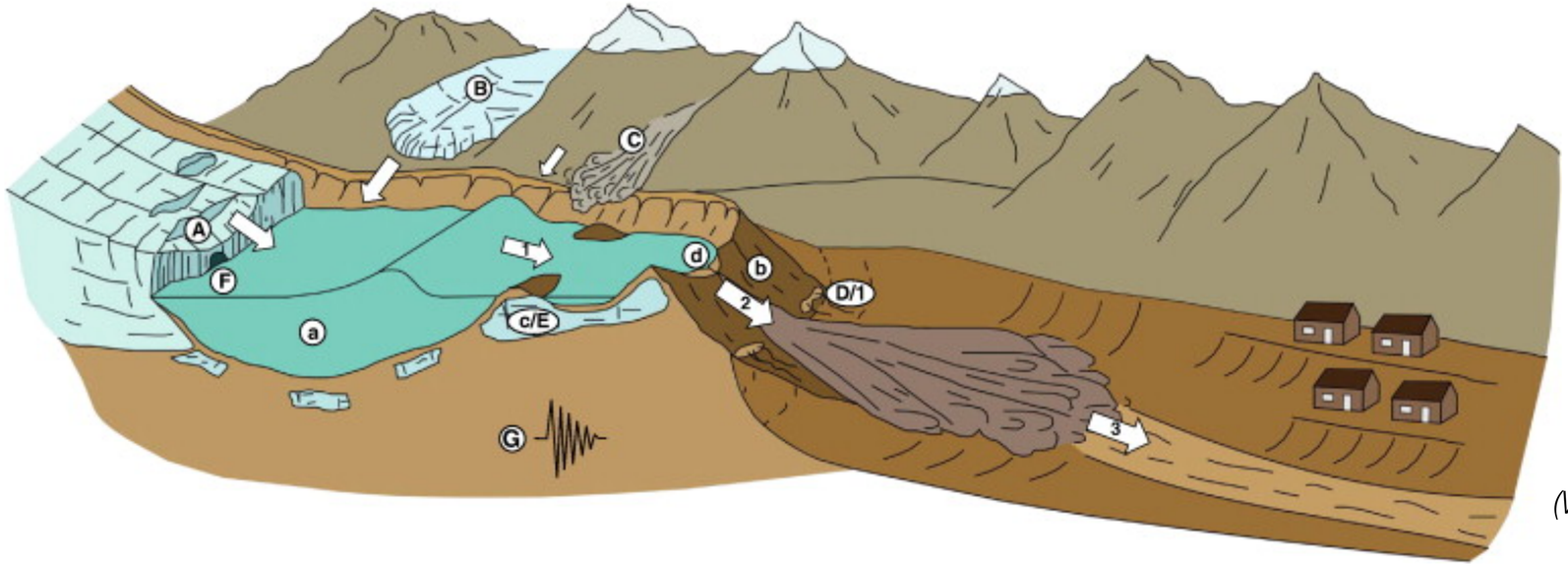
Image: swisseduc.ch

What do we know now?



(Shugar et al., 2020)

Glacial Lakes Outburst Floods (GLOFs)



(Westoby et al., 2014)

- Glacier outburst floods are sudden releases of large amounts of water from a glacier (Carrivick and Tweed, 2016)
- Dramatic increase in GLOF occurrence from 1930 to 1970, then a decline, therefore there is an increase of GLOFs is a delayed response to climate warming (Harrison et al., 2018)
- Existing GLOF inventories are incomplete and inconsistent

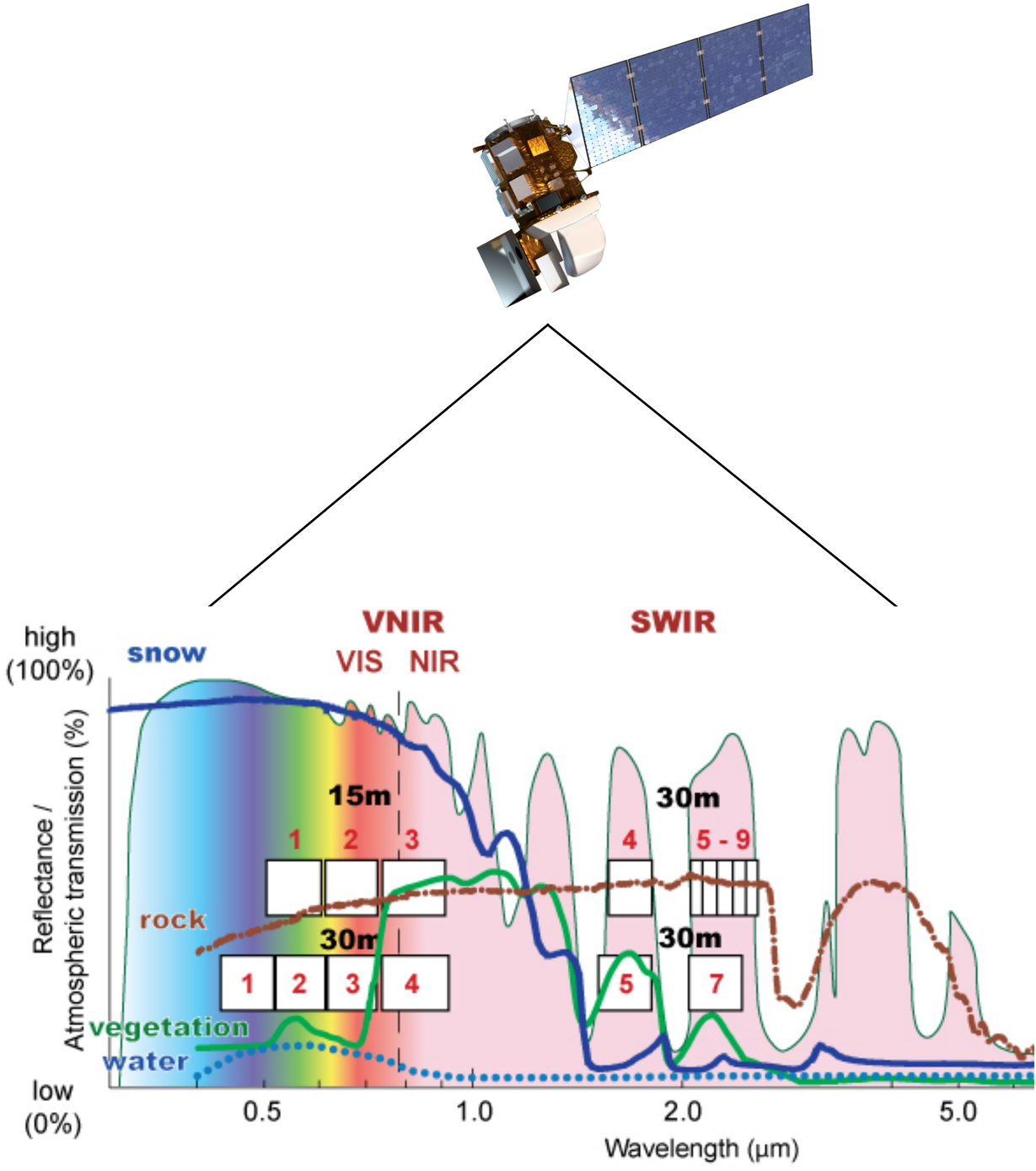
What is missing? and what is my research question?

- Is there a way to **make a complete inventory of lakes and find GLOFs** on a global scale?

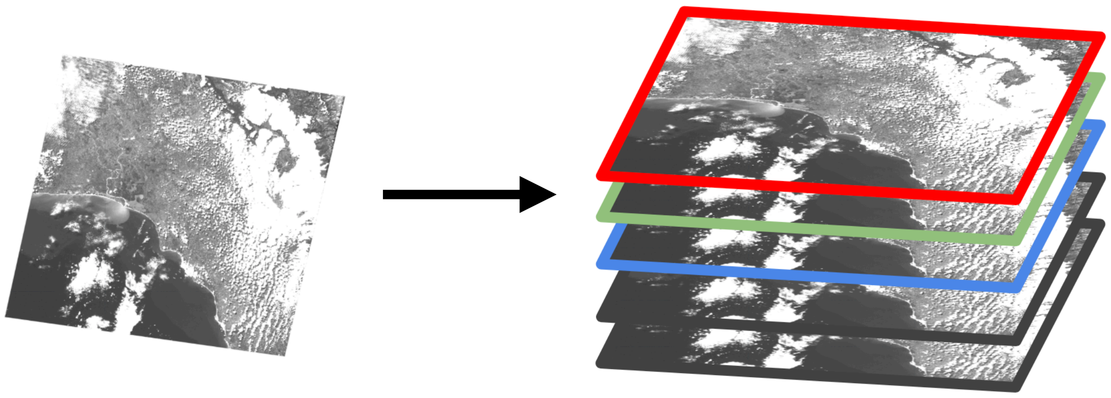
- Can I suggest a **method for water mapping using optical satellite images, that will be applicable to the glacier lakes?**

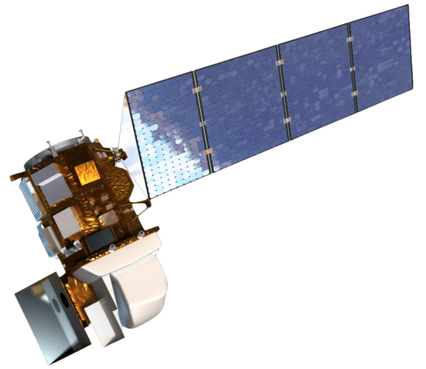
- **How can problems be avoided**, that are commonly associated with water mapping in high-mountain glaciated environments?

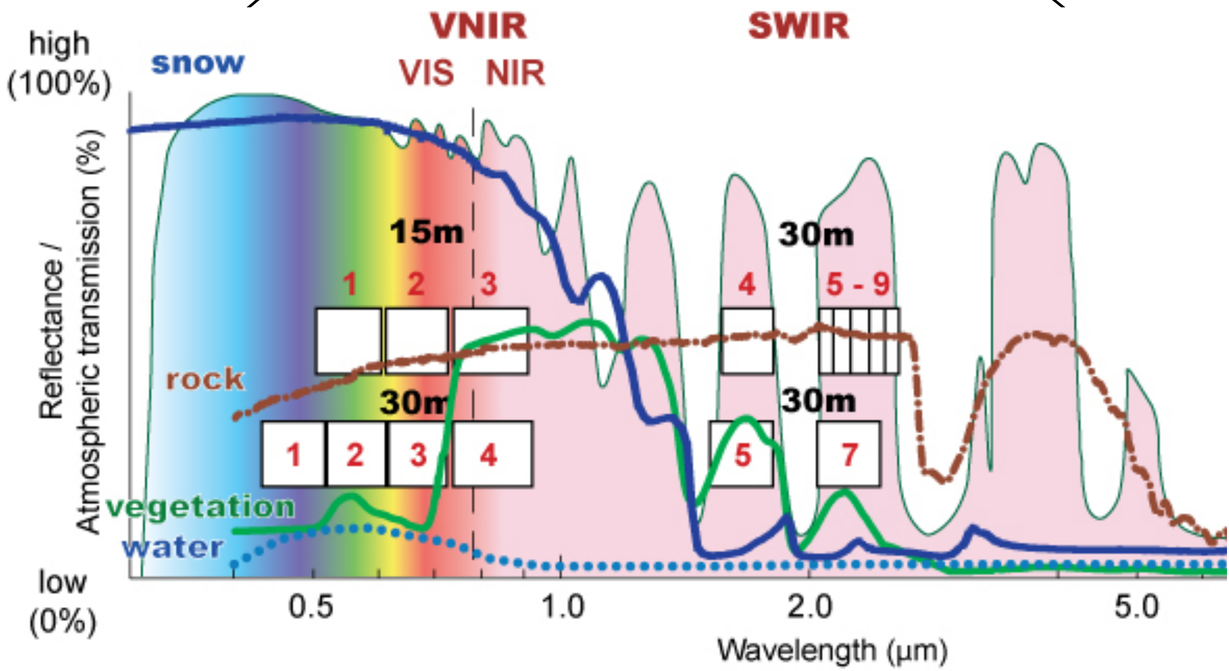
Data and tools



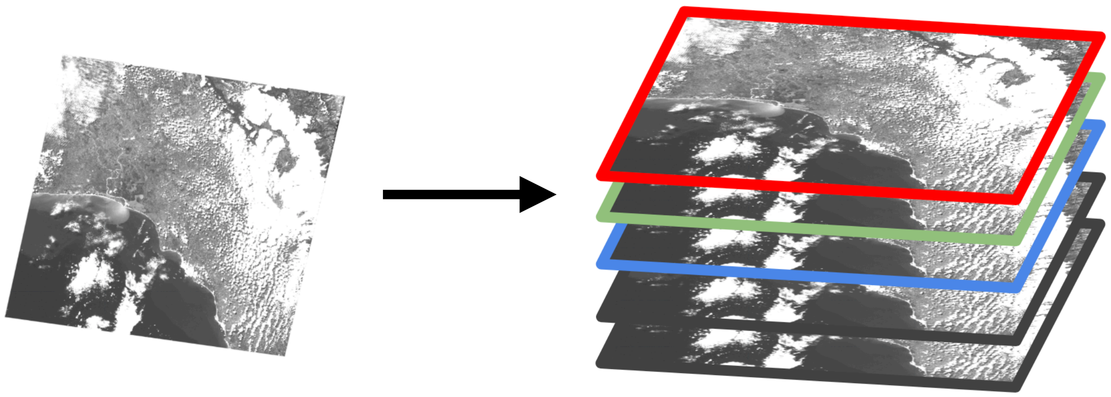
Data and tools







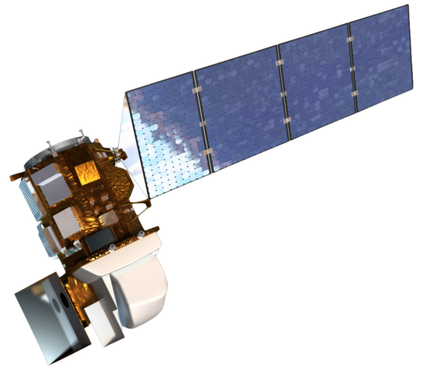
Data and tools

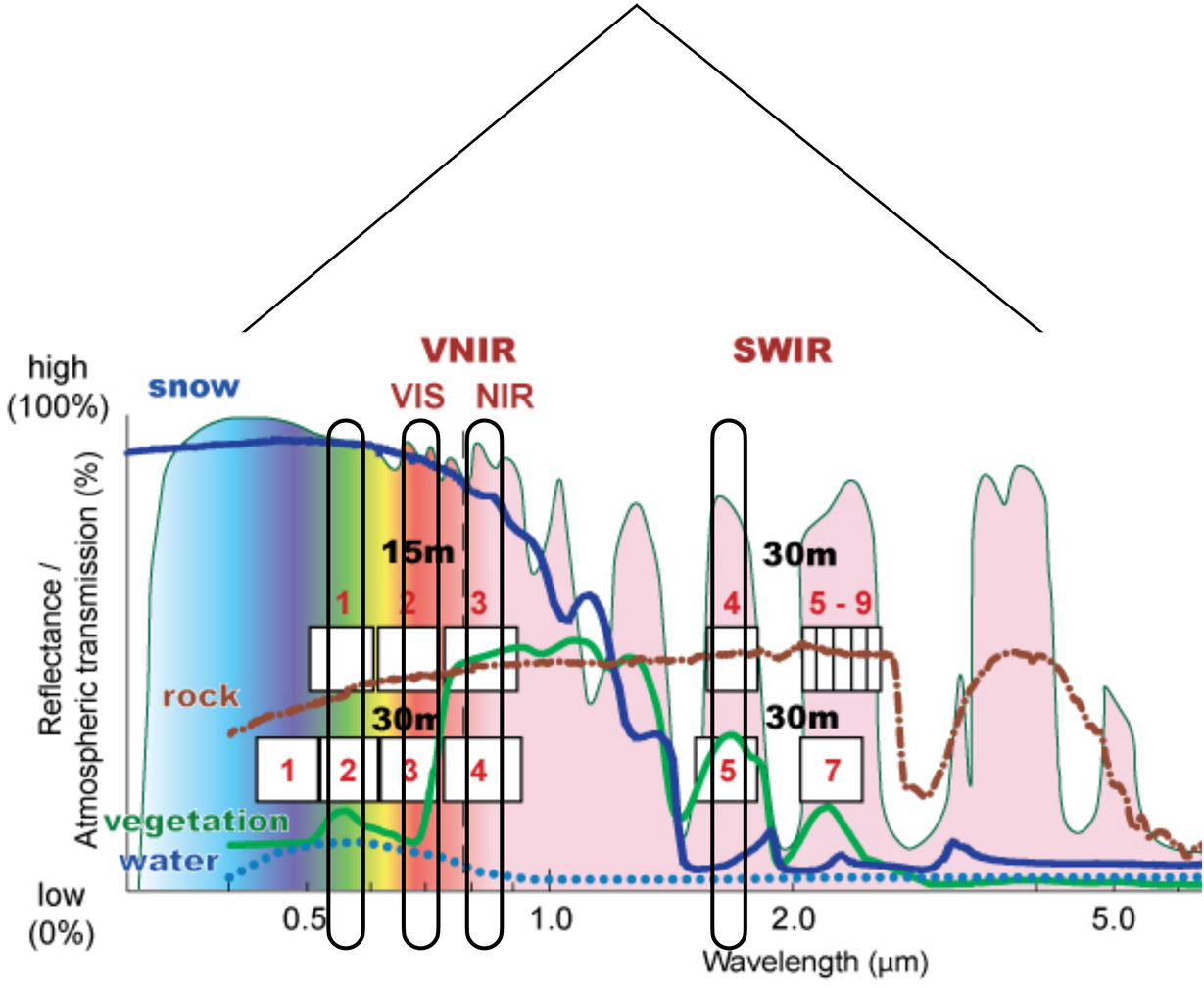


$$NDVI = \frac{(Xnir - Xred)}{(Xnir + Xred)} \qquad R_{vegetation} = \frac{Xnir}{Xred}$$

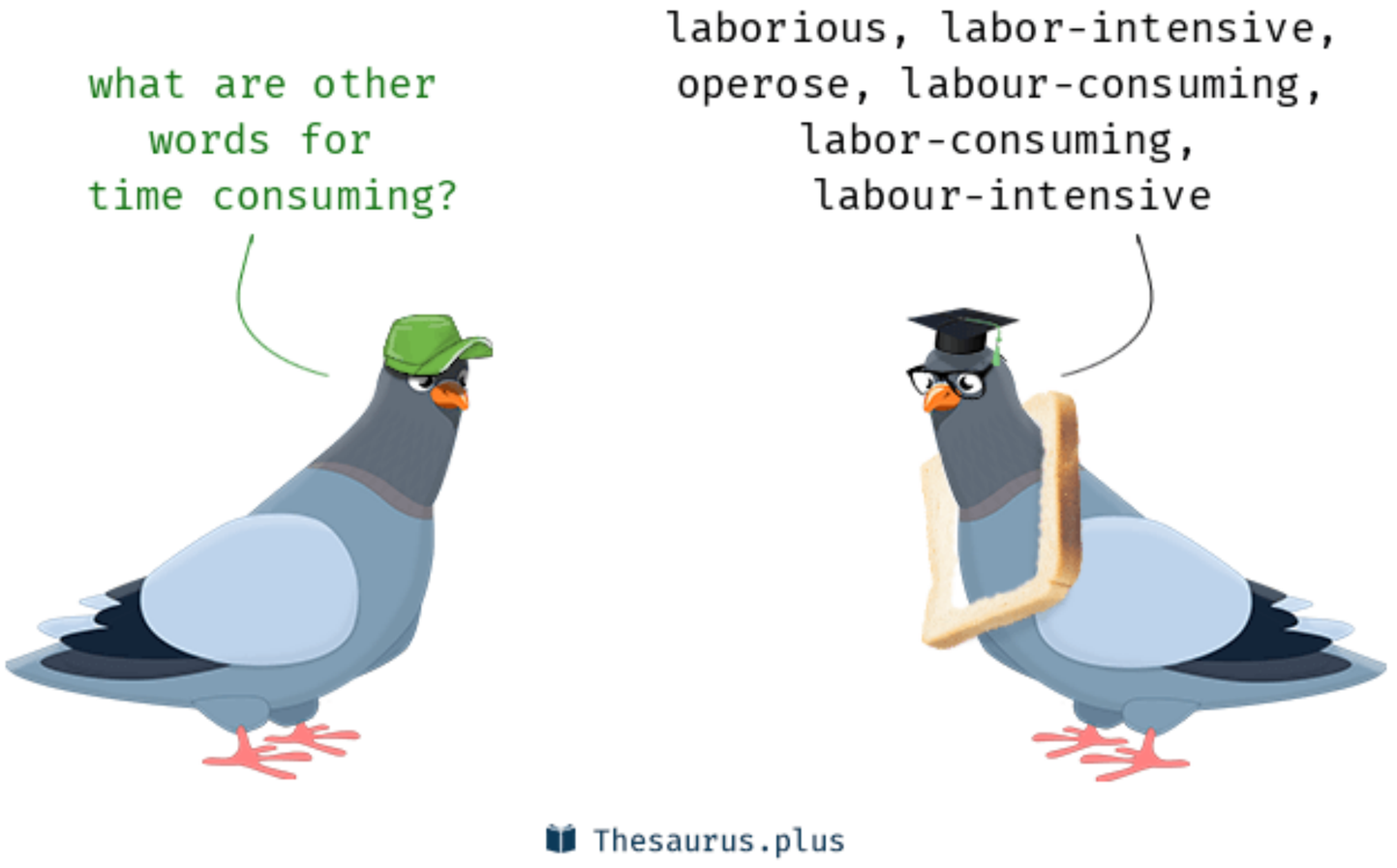
$$NDWI = \frac{(Xgreen - Xnir)}{(Xgreen + Xnir)} \qquad R_{water} = \frac{Xgreen}{Xnir}$$

$$NDSI = \frac{(Xgreen - Xswir)}{(Xgreen + Xswir)} \qquad R_{snow} = \frac{Xgreen}{Xswir}$$





Problems with “traditional” satellite image processing



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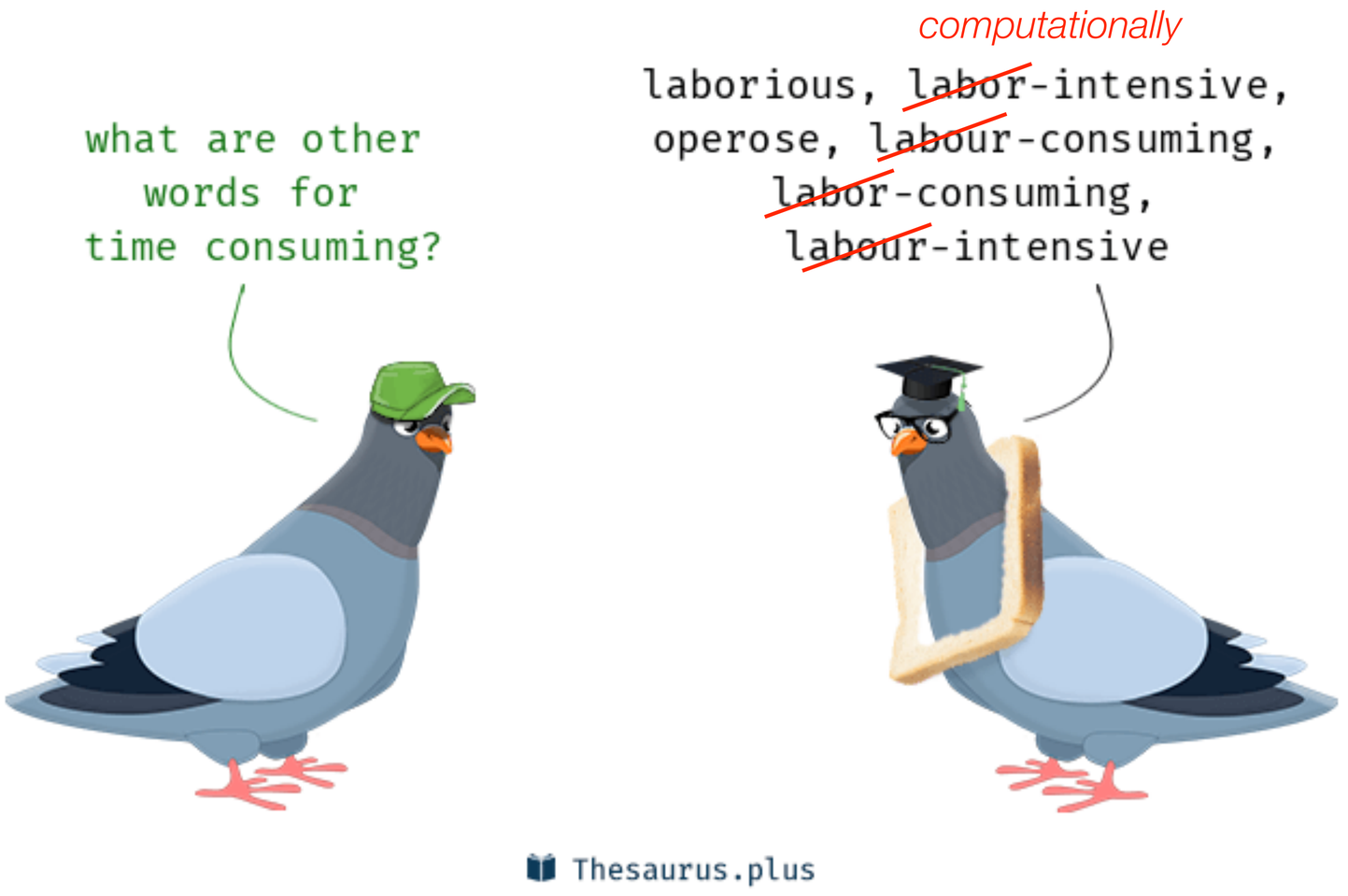


Google Earth Engine

Search places and datasets...

Scripts | Docs | Assets

Filter methods...

- ee.Algorithms
- ee.Array
- ee.Blob
- ee.Classifier
- ee.Clusterer
- ee.ConfusionMatrix

time_series_canny_grad_etc — Get Link | Save | Run | Reset | Apps

```
// ------------------ IMPORT DATA ------------------

// import collection, filter, map functions

var l5 = ee.ImageCollection("LANDSAT/LT05/C01/T1_SR").select(l57_bands, l57_names).filterBounds(caucasus)
var l7 = ee.ImageCollection("LANDSAT/LE07/C01/T1_SR").select(l57_bands, l57_names).filterBounds(caucasus)
var l8 = ee.ImageCollection("LANDSAT/LC08/C01/T1_SR").select(l8_bands, l8_names)  .filterBounds(caucasus)


var l5collection = l5
                  // errors:
```

Inspector | Console | Tasks

List (33 elements) JSON

- 0: Image (51 bands)
- 1: Image (51 bands)
- 2: Image (51 bands)
- 3: Image (51 bands)
- 4: Image (51 bands)
- 5: Image (51 bands)
- 6: Image (51 bands)
- 7: Image (51 bands)
- 8: Image (51 bands)

Geometry Imports

Layers

- lakes - points
- !! water_final_mask caucasus
- display polygon
- !! blue_min
- !! NDSI_min
- !! water_ratio_max
- !! veg_ratio_min
- veg_ratio, water_ratio, NDSI
- ind (year)
- image (year)
- slope - mean

Map | Satellite

Nevinnomyssk Невинномысск
Budyonnovsk Буденновск
Neftekumsk Нефтекумск
Zelenokumsk Зеленокумск
Cherkessk Черкесск
Pyatigorsk Пятигорск
Kizlyar Кизлярский
Makhachkala Махачкала
Buynaksk Буйнакск
Kaspiysk Каспийск
Shetpe Шетпе
Zhanaozen Жаңаөзен
Senek Сенек
Bekdash
Poti ფოთი
Batumi ბათუმი
Hopa
Artvin
Ardahan
Trabzon
Rize
Giresun
Gümüşhane
Kars
Ganja
E60
E692
E70
-33

Google

Map data ©2021 Google | 50 km | Terms of Use | Report a map error

Results

I. Method

1. Detecting lake-changes from individual satellite images
2. Time-series: image stacking for annual resolution

II. Application

Regional-scale glacial lake inventory of glacial lakes

(Caucasus mountains as an example)

1. Detecting lake-changes from satellite images

Make time-series of images

↓

Map water on every image:
classify pixels based on thresholding

↓

Sum time-series of «water» layer:
count, how many times pixel is
classified as water

1. Detecting lake-changes from satellite images

Make time-series of images

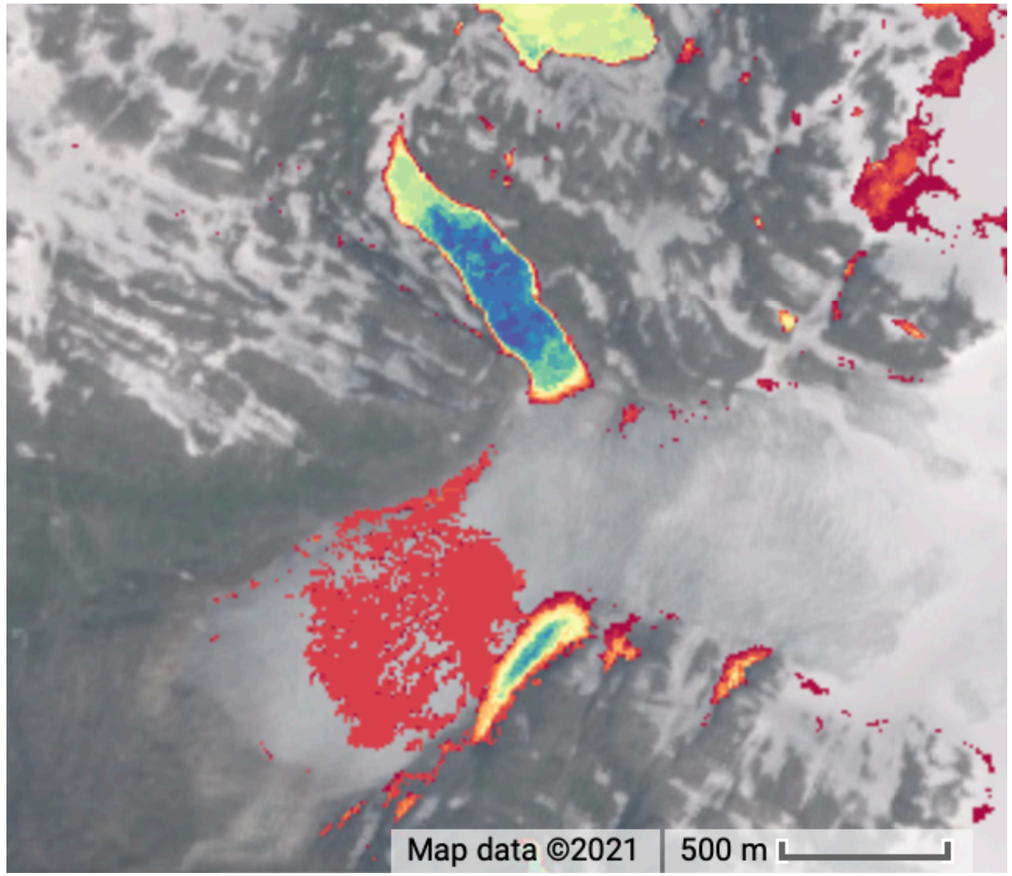
↓

Map water on every image:
classify pixels based on thresholding

↓

Sum time-series of «water» layer:
count, how many times pixel is
classified as water

Dammevatnet, Norway:
drains annually



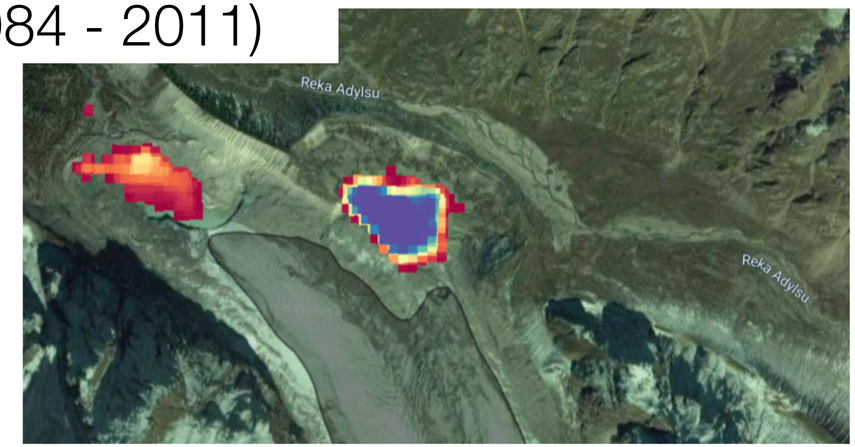
low high

water occurrence/frequency

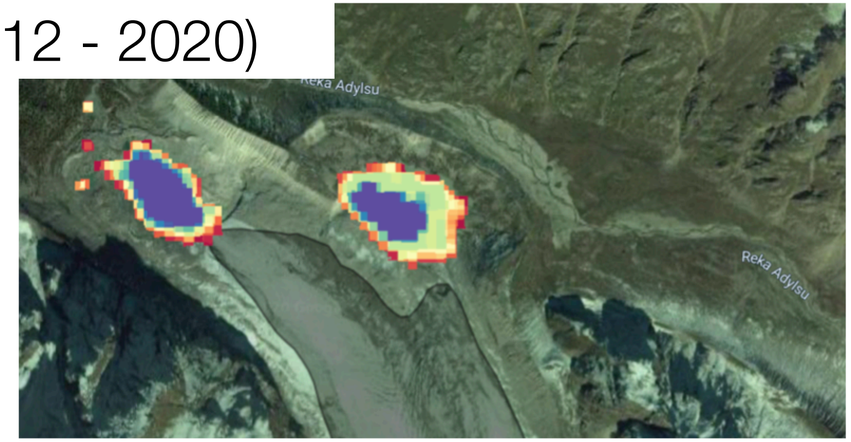
1. Detecting lake-changes from satellite images

Bashkara, Caucasus: bursted out on 1.9.2017

Data: Landsat 5
(1984 - 2011)



Data: Landsat 8
(2012 - 2020)



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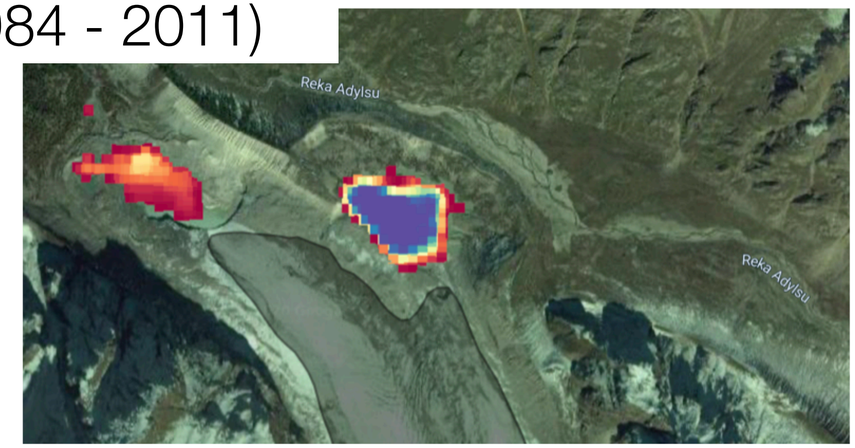
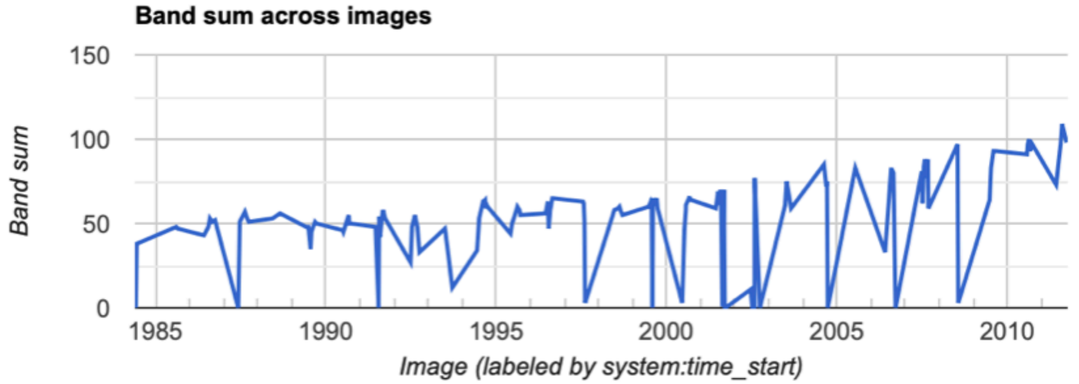
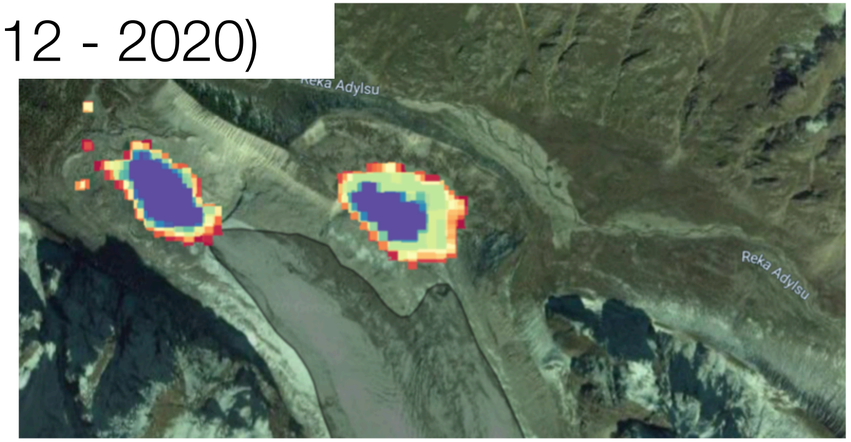




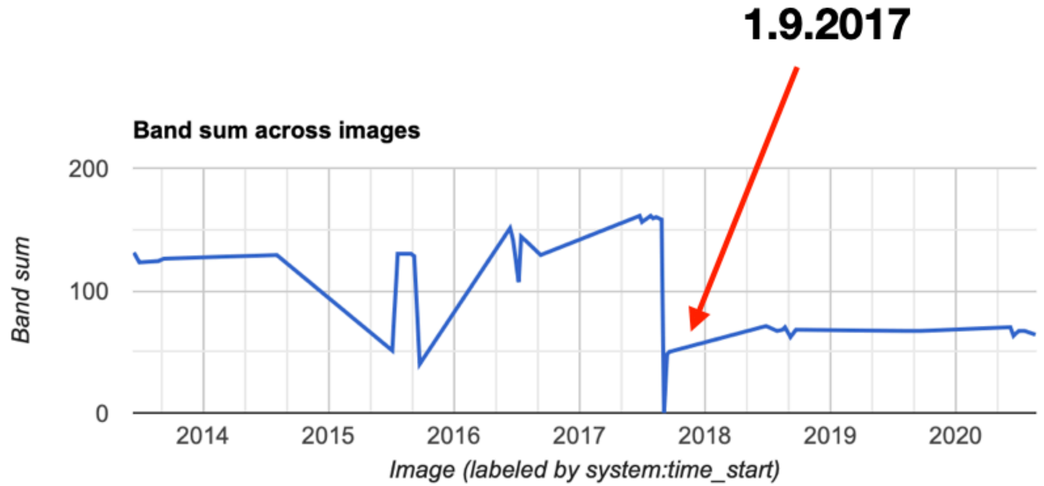
Landsat 5–7

Data: Landsat 8
(2012 - 2020)



low high

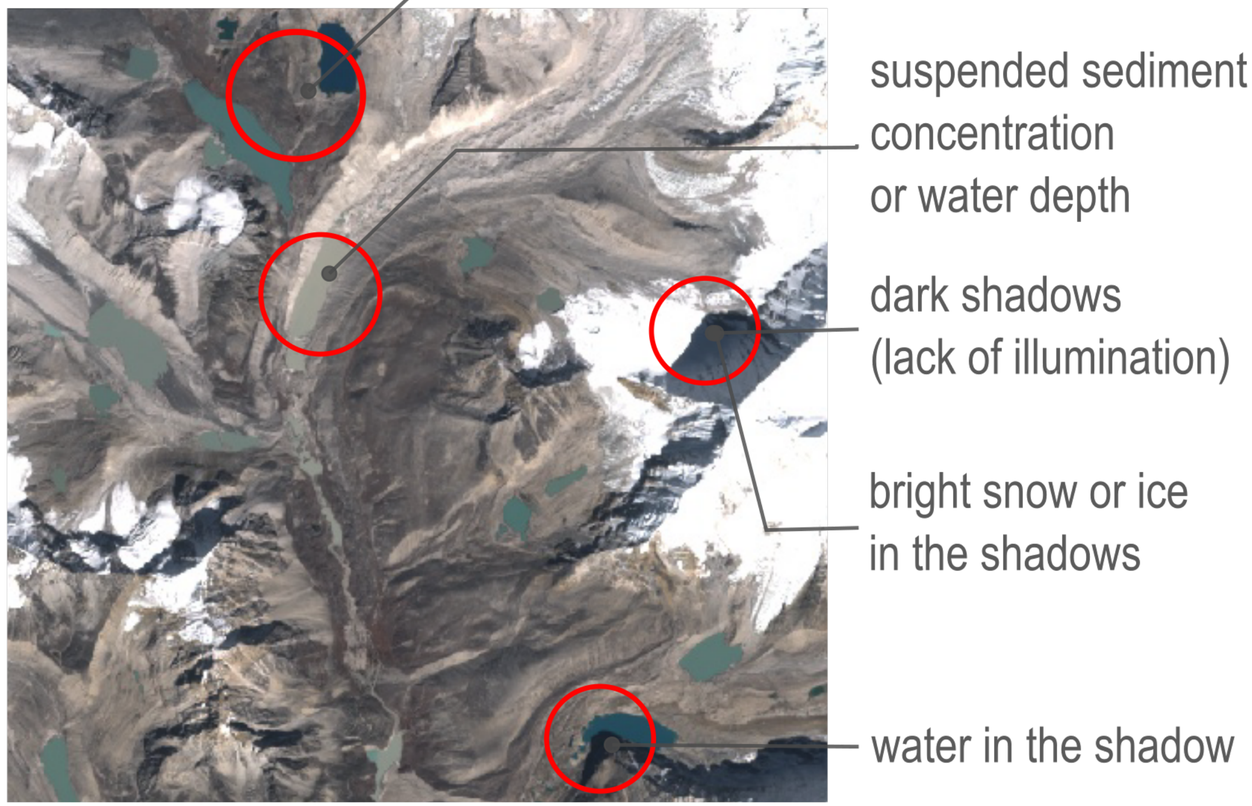
water occurrence/frequency



Landsat 8

1. Detecting lake-changes from satellite images

What are the problems?



Natural Color Composite

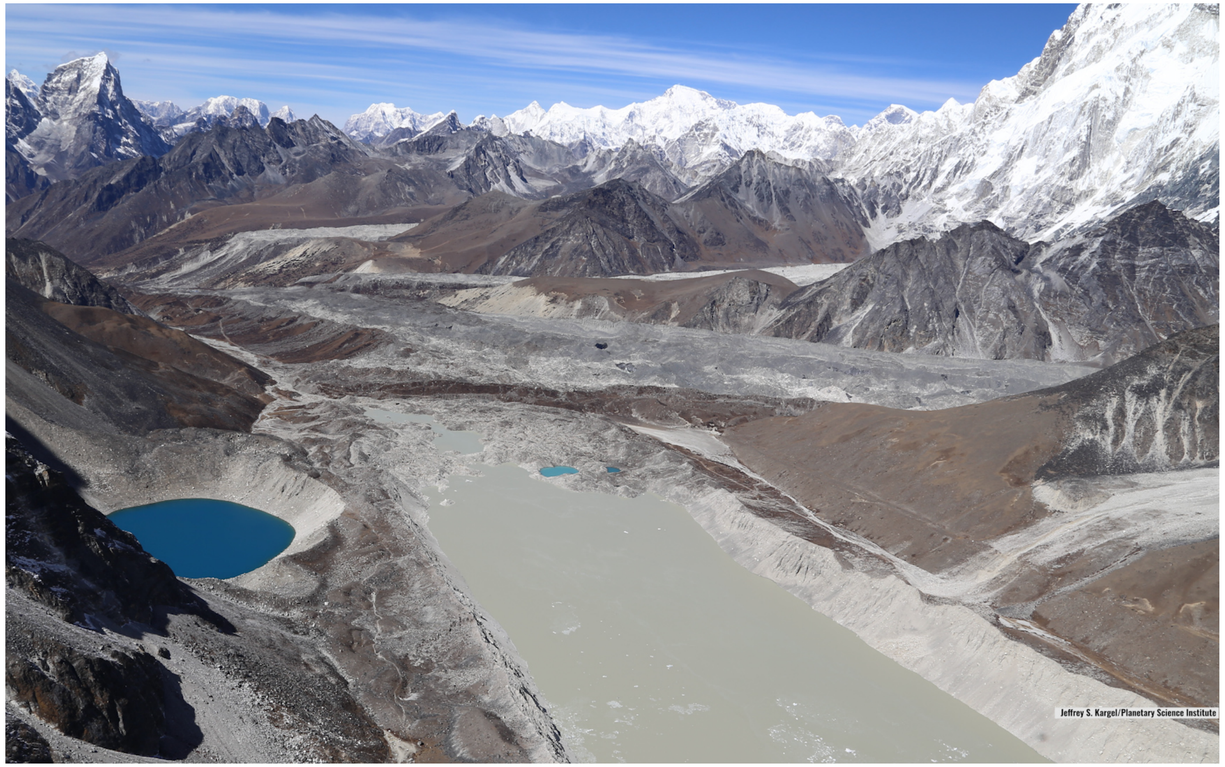
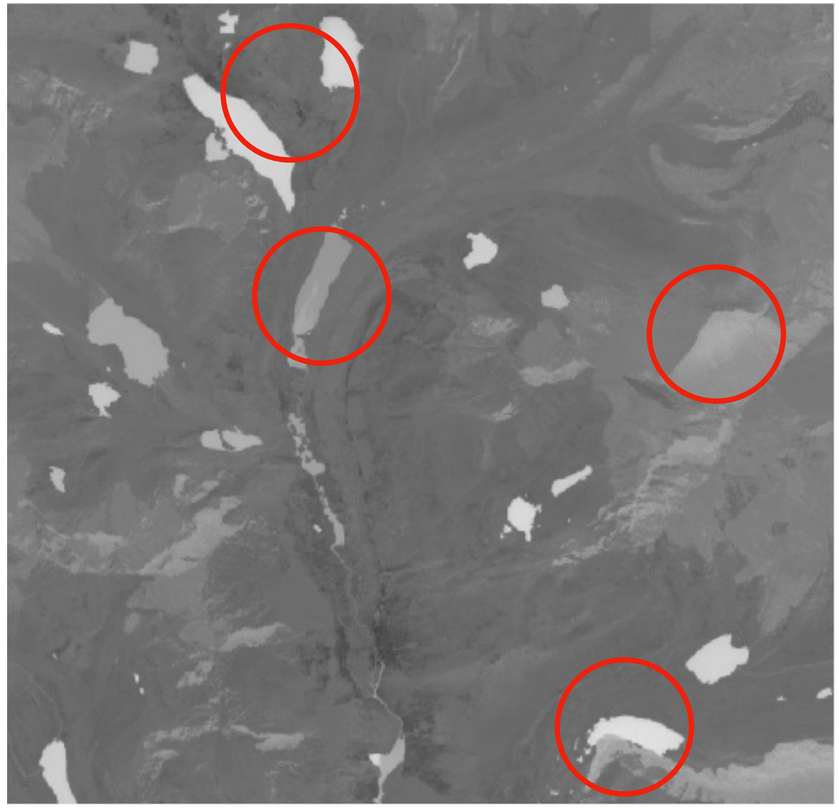


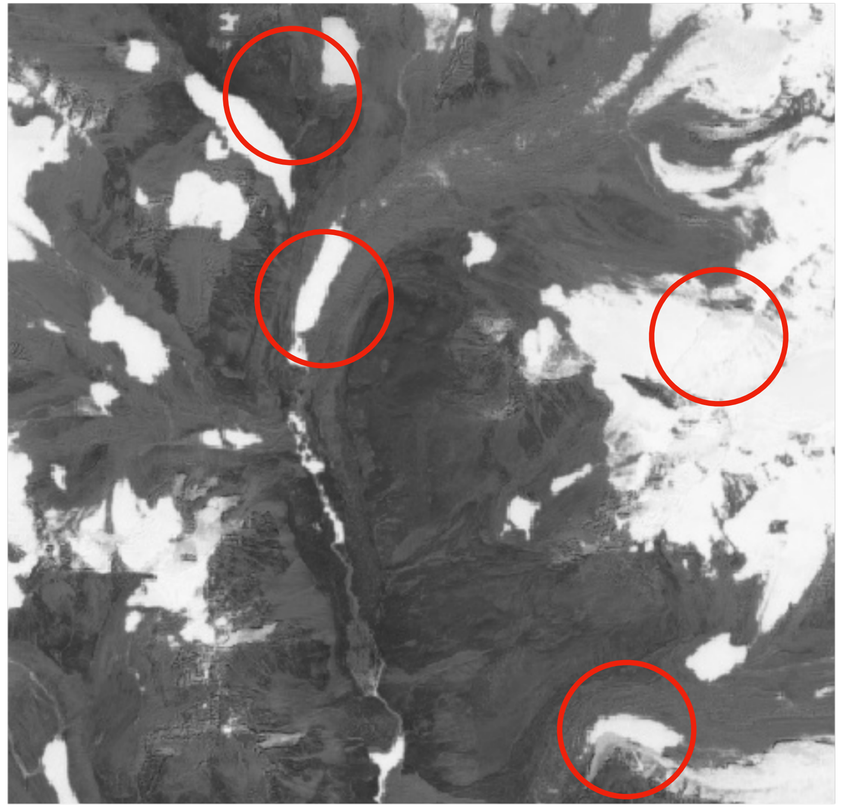
Image: NASA

1. Detecting lake-changes from satellite images

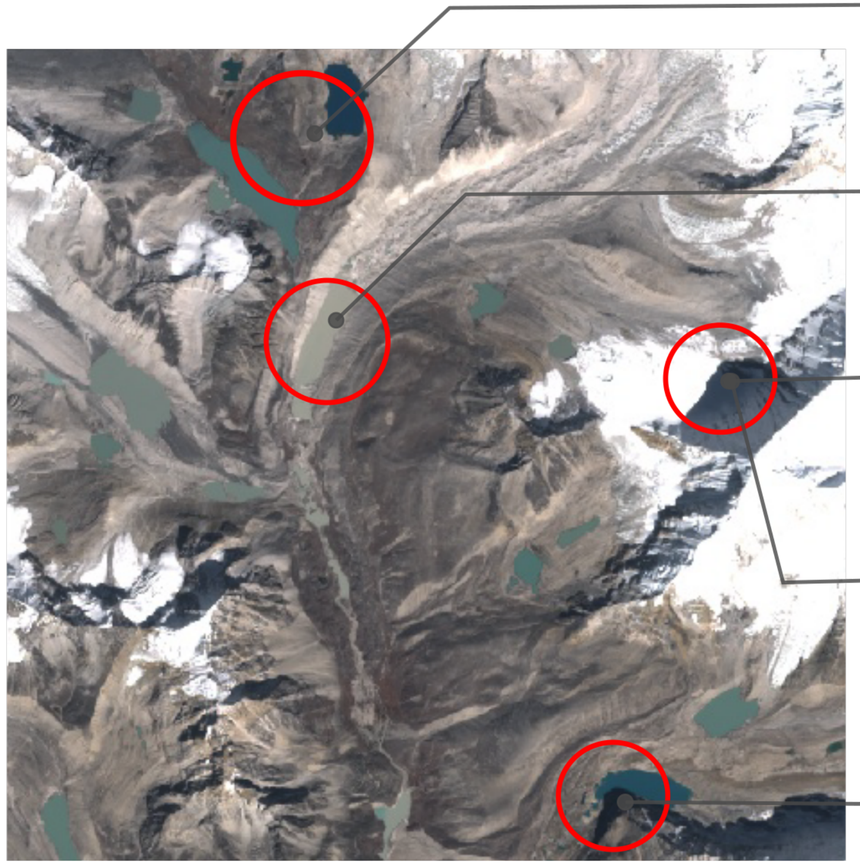
What are the problems?



NDWI

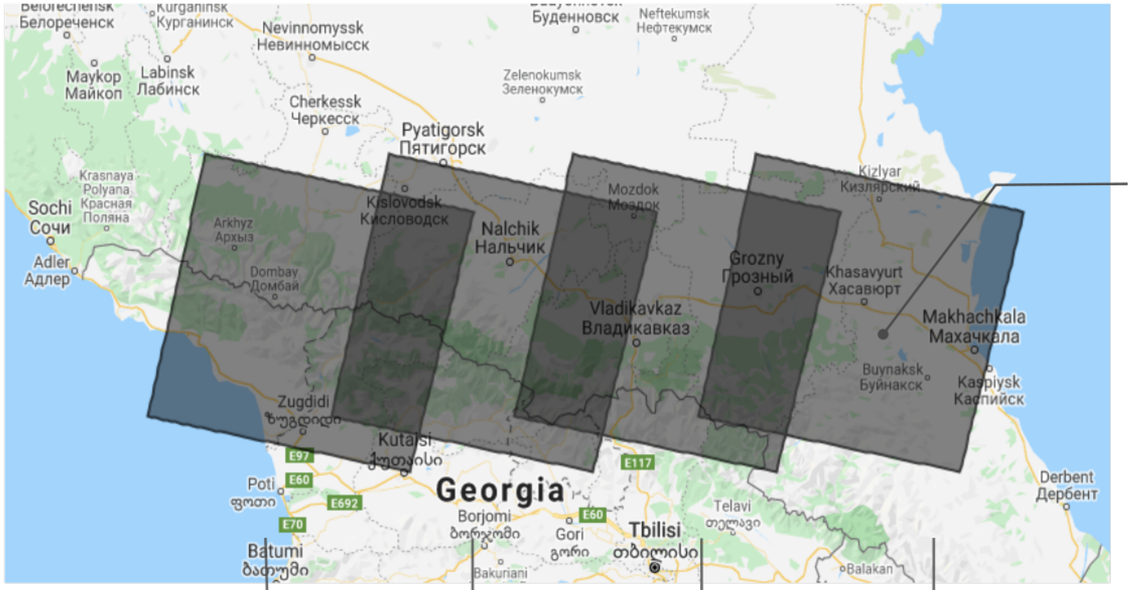


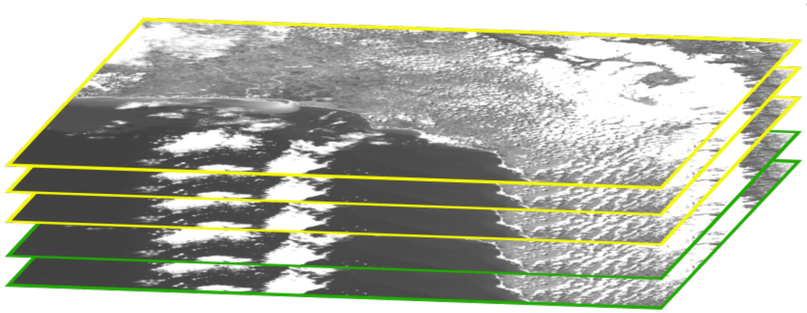
NDSI (mNDWI)



Natural Color Composite

2. Time-series: image stacking for annual resolution





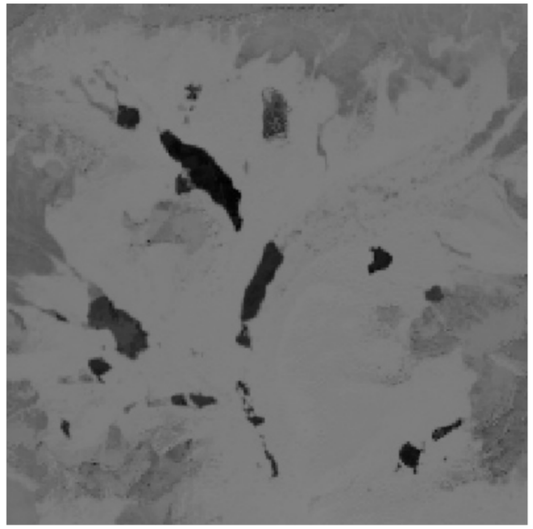
bands:
.min()
.max()
.median()

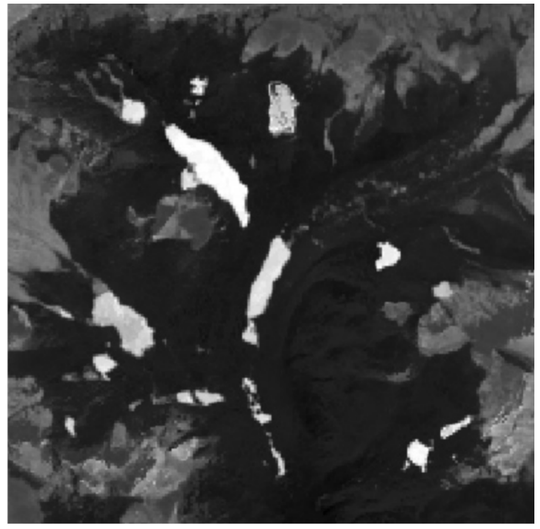
2. Time-series: image stacking for annual resolution

Vegetation:
annual-min value

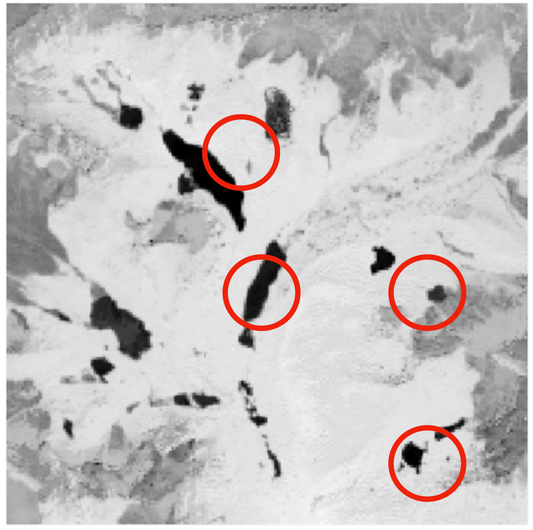
Water:
annual-max value

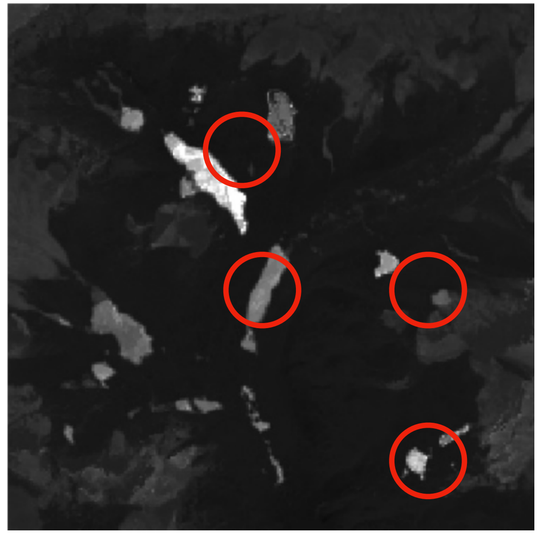
Normalized Difference

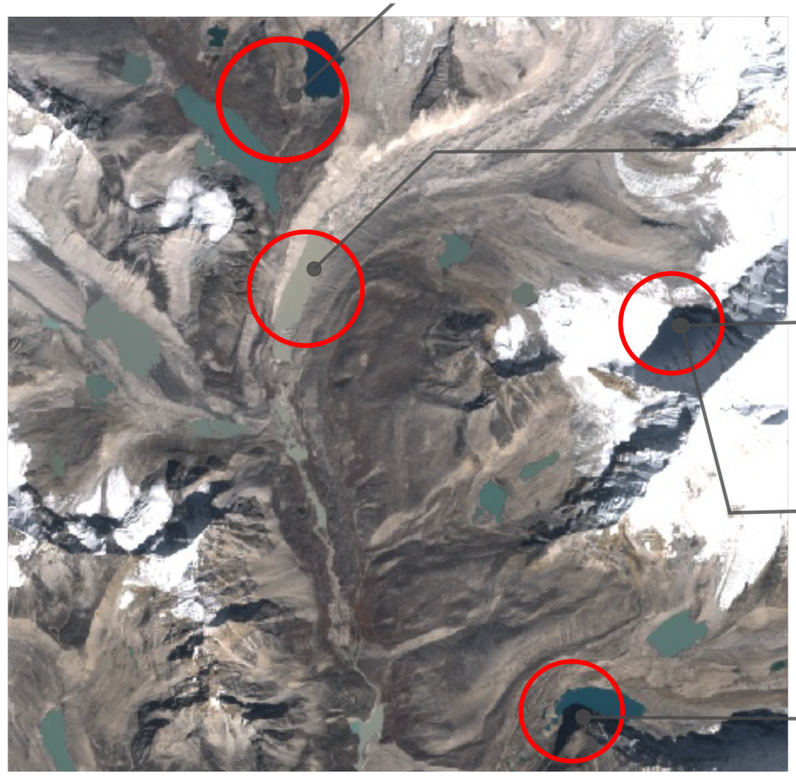




Band Ratio







Natural Color Composite

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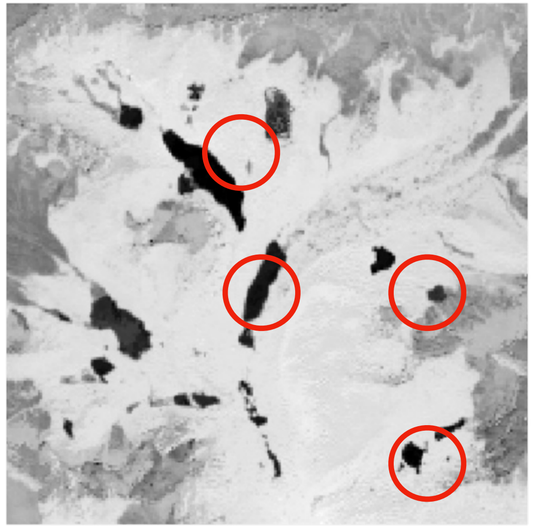
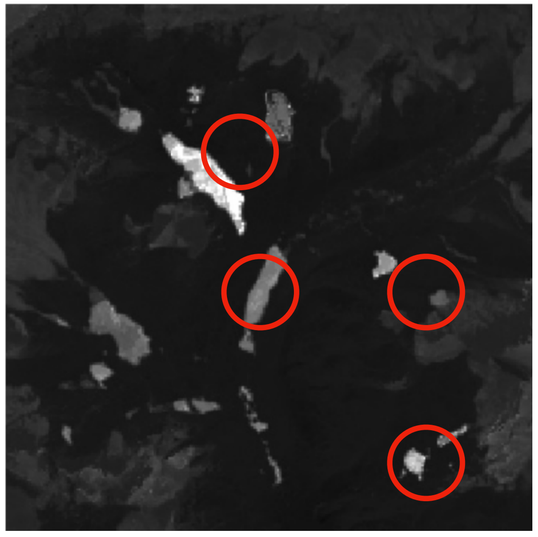
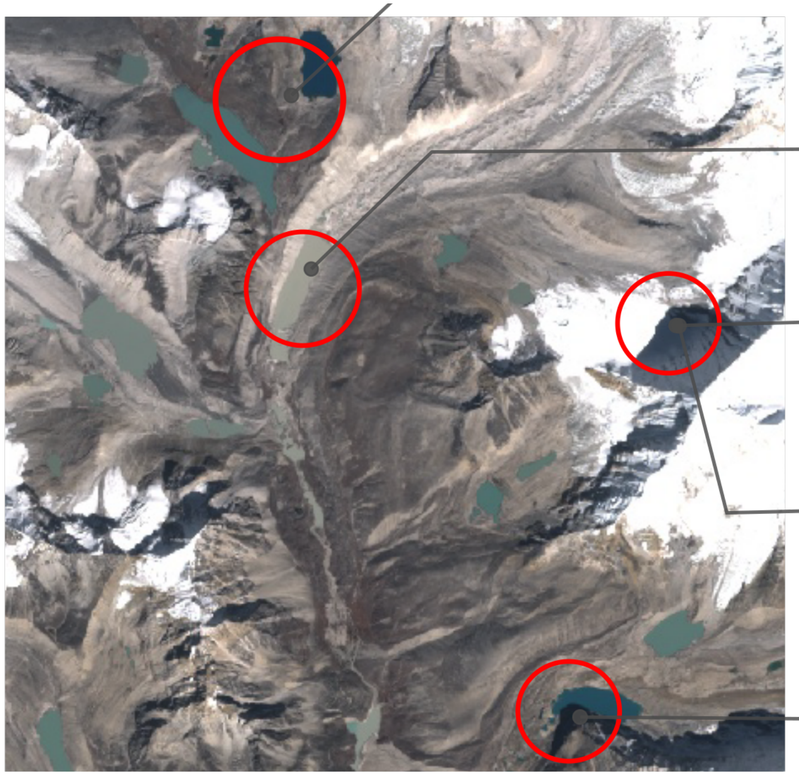






Natural Color Composite

Regional-scale glacial lake inventory in Caucasus mountains

What can we learn from glacial lake mapping?

«Stack» images to make annual time-series

↓

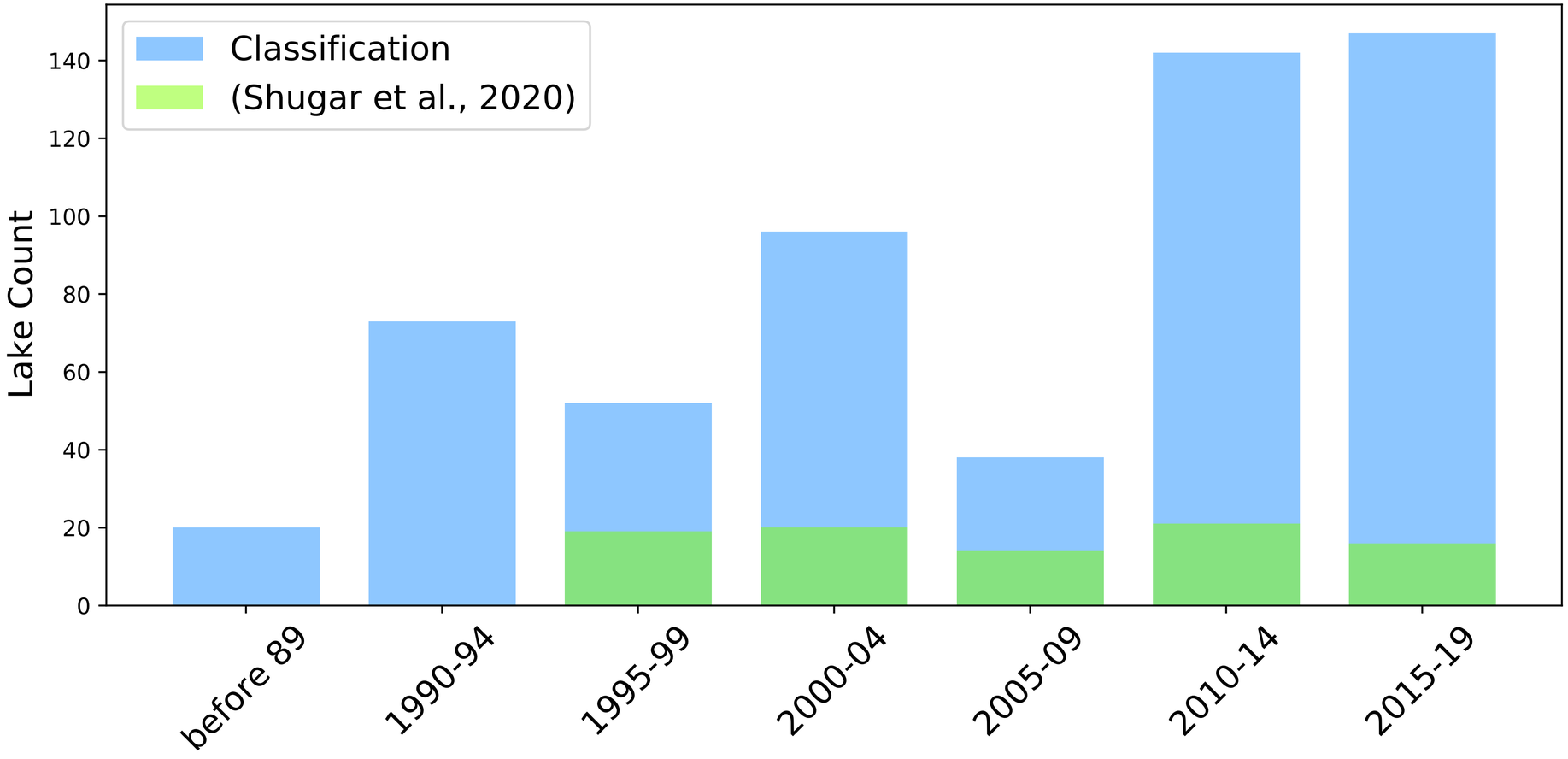
Map water on every image (annually):
classify pixels based on thresholding of
min-vegetation and max-water values

↓

Identify «lakes»: size threshold
make 5-year averaged mask

Regional-scale glacial lake inventory in Caucasus mountains

What can we learn from glacial lake mapping?



Conclusions

- Time-series of individual satellite images and water occurrence pattern can help to detect GLOFs
- Despite reduced temporal resolution, using the minimum and maximum reflection values of the stacked time-series of images allows to eliminate most problems, that are associated with optical satellite images for glacial lake mapping
- 2 band ratios prove to be enough for glacial lake mapping on the annual scale: maximum value of «water» and minimum value of «vegetation»
- The consistent and complete regional scale inventory of glacial lakes in Greater Caucasus shows, that the number of glacial lakes in the Greater Caucasus increased over the Landsat era (1984 - 2020)