Machine Learning for Glacier Monitoring in the Hindu Kush Himalaya

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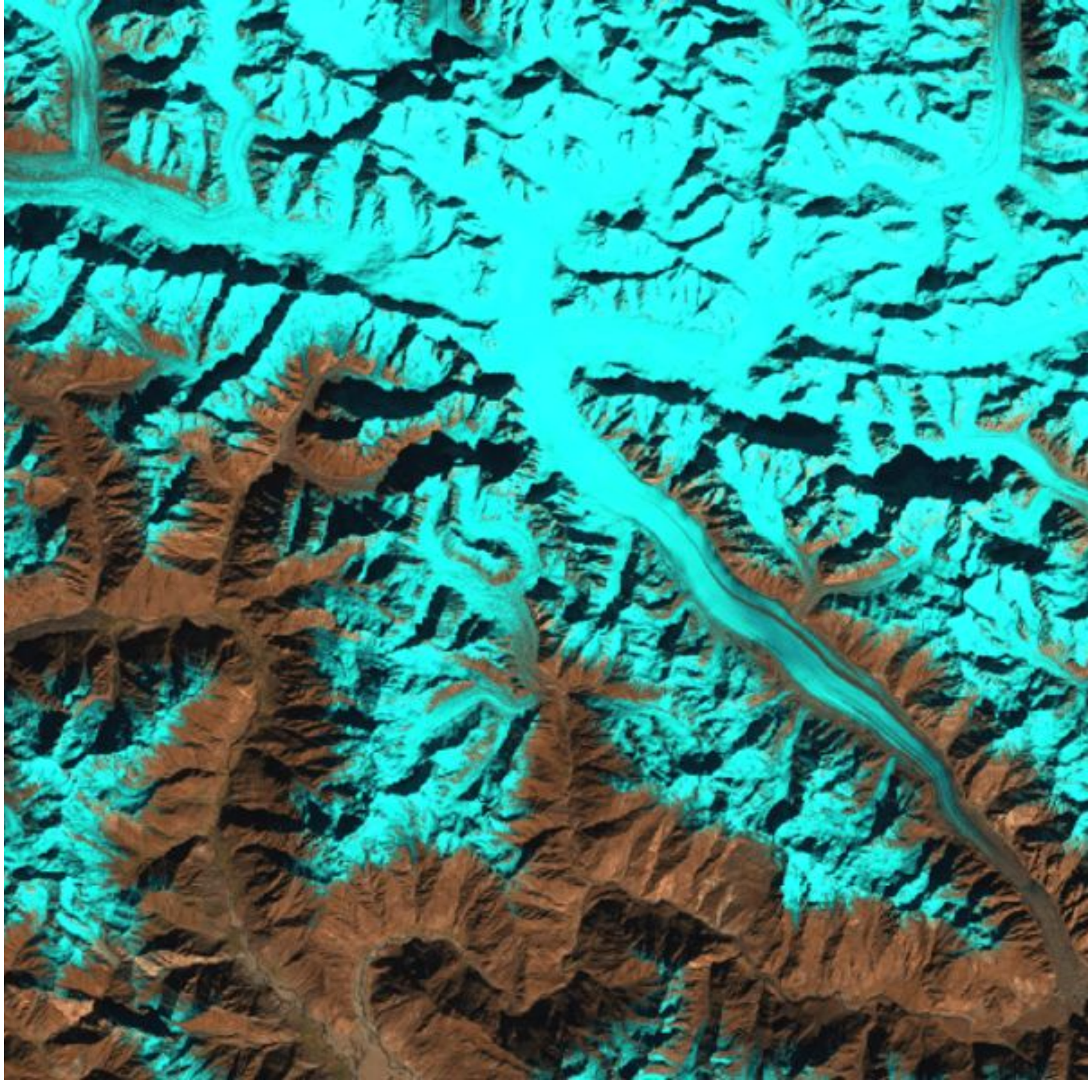
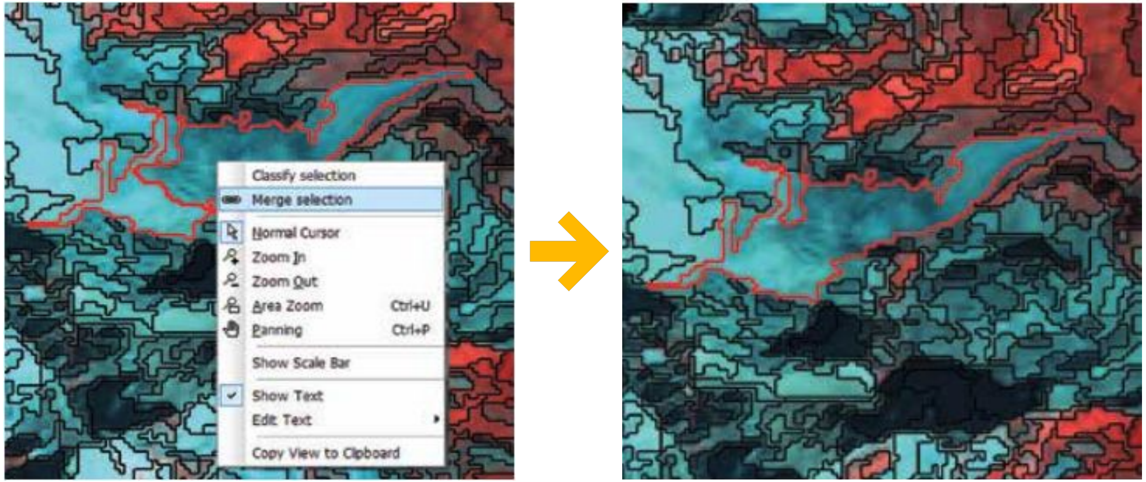


Background and Motivation

- Glaciers in the Hindu Kush Himalaya (HKH) are ecologically and societally important, and are at risk due to climate change
- Monitoring changes is key for water resource and glacial hazard management
- The International Centre for Integrated Mountain Development (ICIMOD) curates a Regional Database System to support glacier monitoring of the HKH

Current Workflow

- Derive spatial data by semi-automatically annotating landsat images
  - Data are used by scientific and policy communities
- Labels are available dating back to 1990 and across the HKH



An example of hyperpixel editing in the current labeling workflow.

Problem Description

- Delineating glaciers is time consuming and challenging to scale
- Manual interventions are needed to account for cloud cover, variable snow conditions, and supra-glacial debris

Goal:

- To effectively demarcate the boundaries of glaciers at different time points
- Utilize machine learning to accelerate the mapping workflow

Problem Formulation

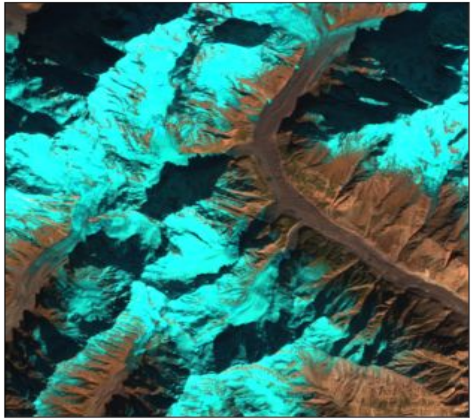
Given a training dataset, semantic segmentation methods learn to assign pixel-level labels Y over input images X

X: Cropped Landsat image

- 10 channels from Landsat 7
- Add NDVI, NDSI, NDWI
- Add SRTM Elevation / Slope

Y: Pixel-level glacier labels

- Background
- Clean ice glacier
- Debris-covered glacier

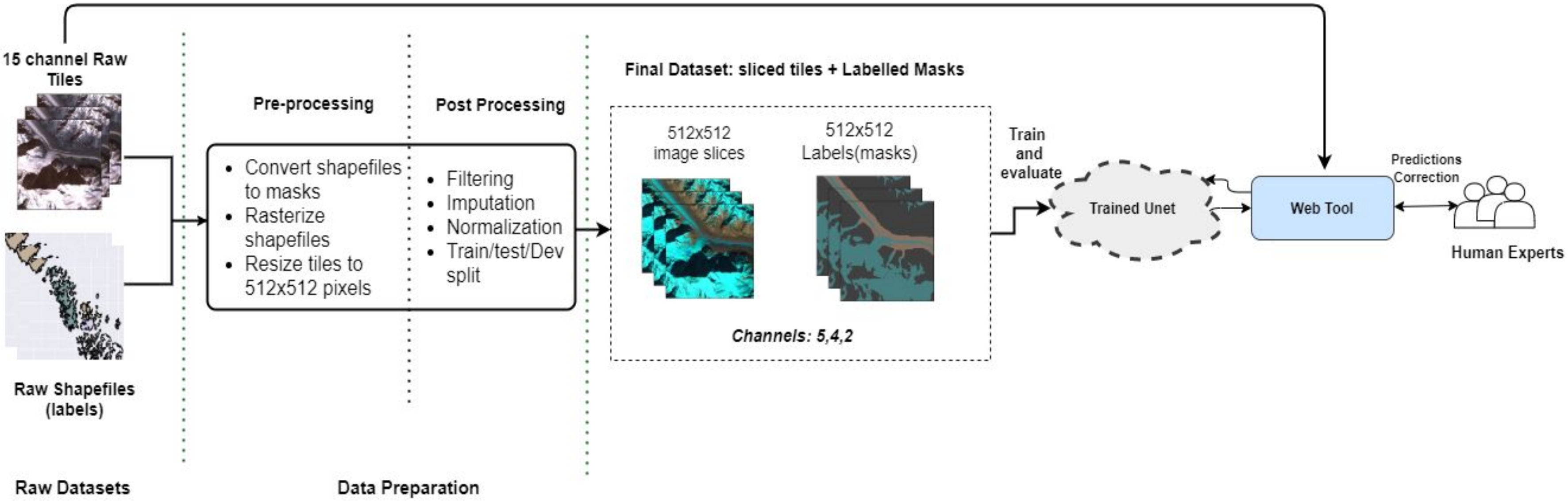


X: Input patch

Y: Glacier labels

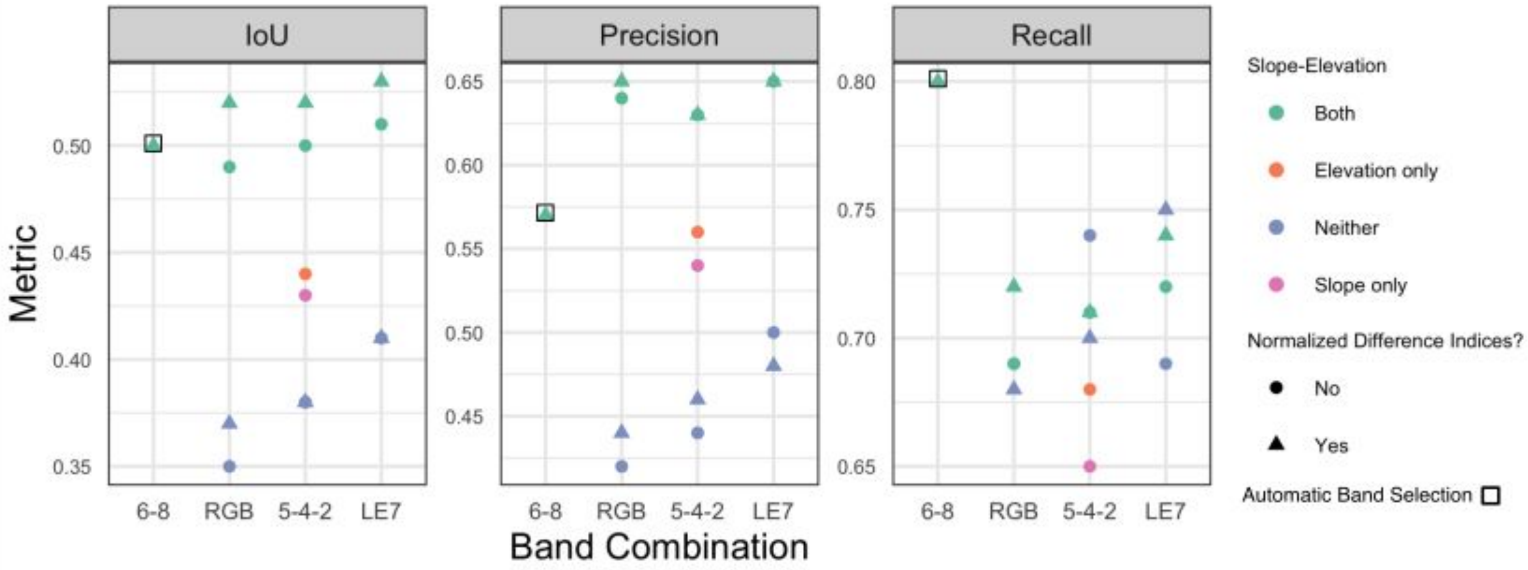
Our Approach

- Prepare data for modeling
- Train semantic segmentation
- Use web tool to incorporate feedback



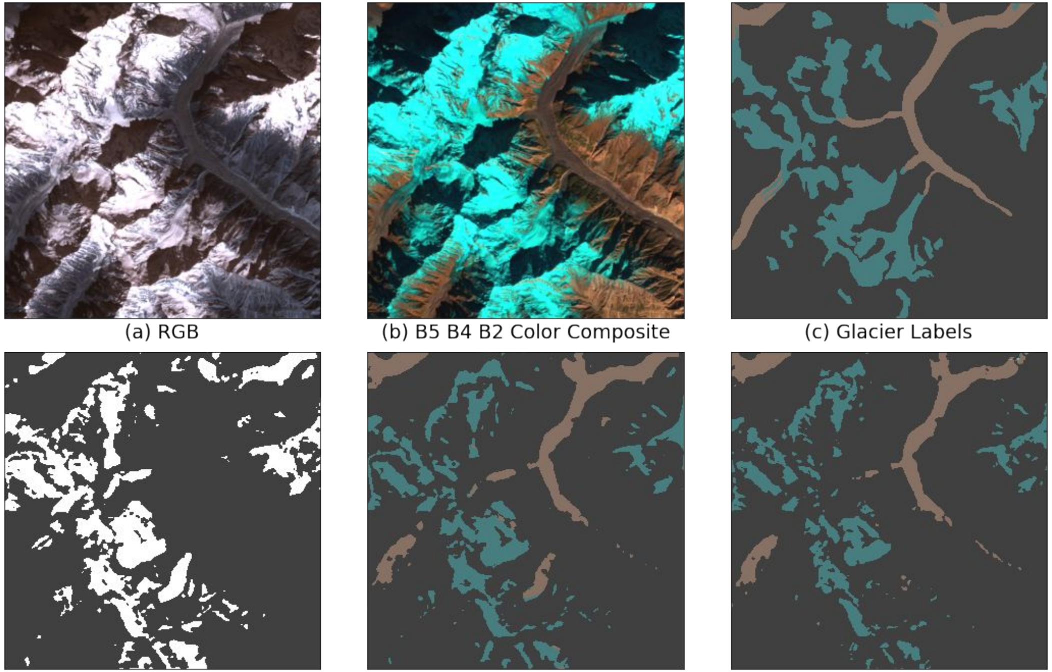
Challenges and Takeaways: Band Selection

- Best performance per subset of bands.
- Importance of domain knowledge vs. automatic selection.



Challenges and Takeaways: Error Analysis and Debris Discovery

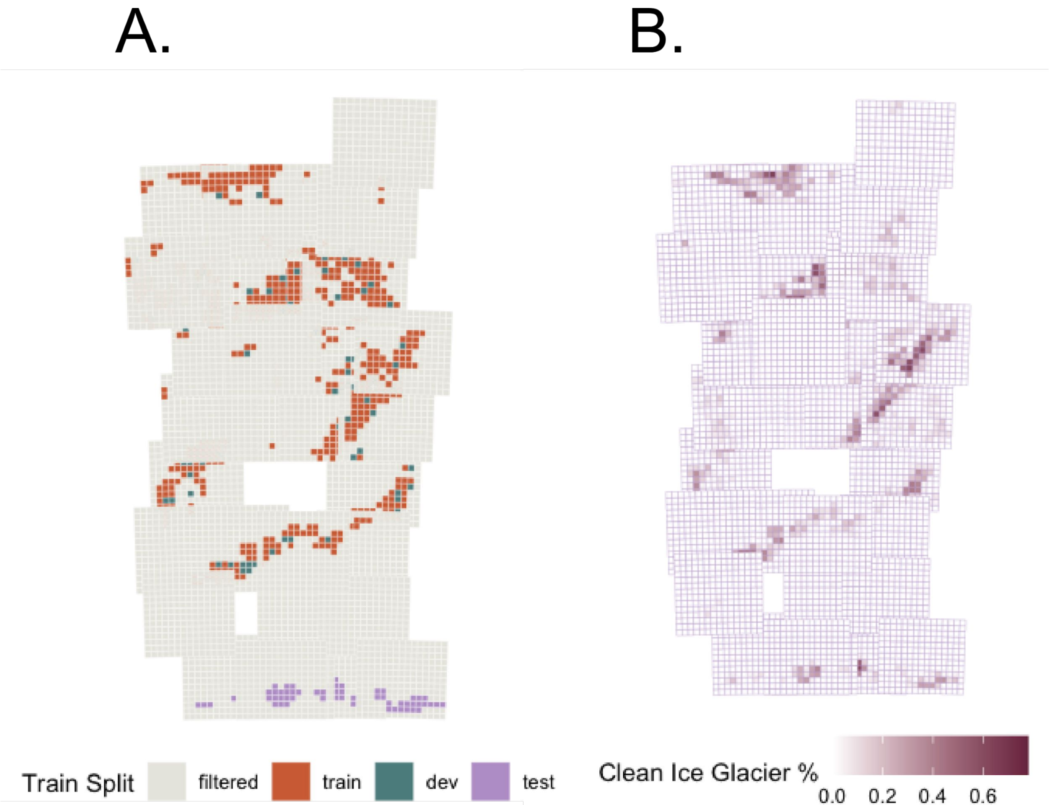
- We have compared segmenting glaciers vs. differentiating segmentation of clear ice glaciers and debris-covered ones.
- Same overall performance with small amount of debris-covered data.
- The gap increases when we have more debris data. (Up to 16% difference when evaluating for area of more than 10% coverage of debris)



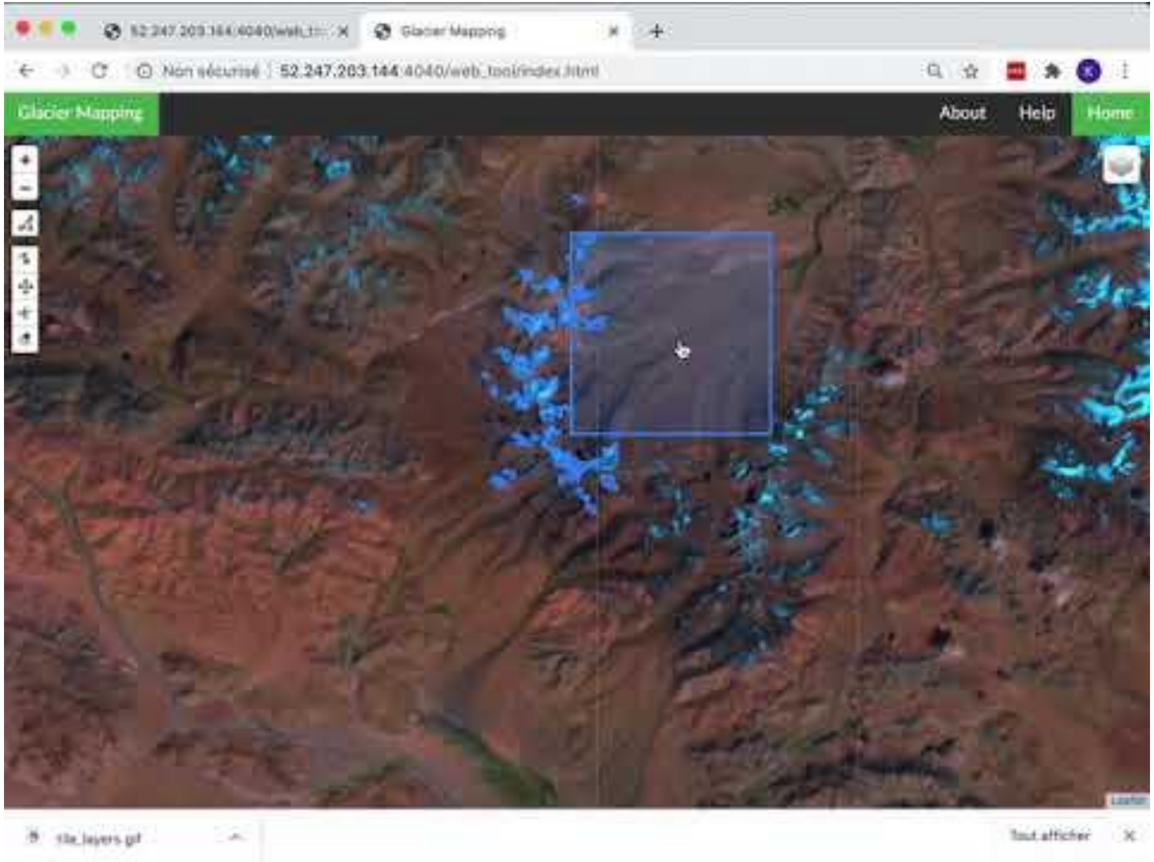
(a) RGB (b) B5 B4 B2 Color Composite (c) Glacier Labels (d) Mask of Binary Class IoU = 0.37 (e) Mask of Multiple Classes IoU = 0.44 (f) Mask of Combined Two Models IoU = 0.41

Challenges and Takeaways: Generalization to New Areas

- How is the model is going to work in other geographic areas?
- No performance difference is shown when restricting testing geographically.
- There study area might be homogenous.



Glacier Mapping Web Tool



Code & Dataset

Code:
https://github.com/krisrs1128/glacier_mapping

Data:
http://lila.science/datasets/hkh-glacier-mapping

LILA BC

Labeled Information Library of Alexandria: Biology and Conservation

Home Data Sets FAQ

HKH Glacier Mapping

Overview

The Hindu Kush Himalayas (HKH) glacier mapping dataset includes imagery of the Hindu Kush Himalayas (HKH) region, along with polygons indicating the locations of glaciers. This dataset is intended to facilitate the training of models that can identify glaciers in remotely-sensed imagery.

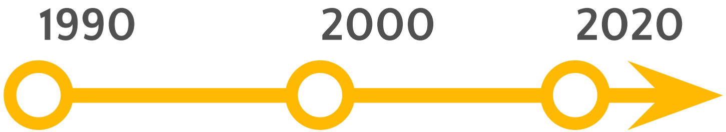
The HKH is also known as the world's "Third Pole", as it consists of one of the largest concentrations of snow and ice besides the two poles. It constitutes more than four million square kilometers of hills and mountains in the eight countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Glaciers within this region have been identified and classified by experts at the International Centre for Integrated Mountain Development (ICIMOD).

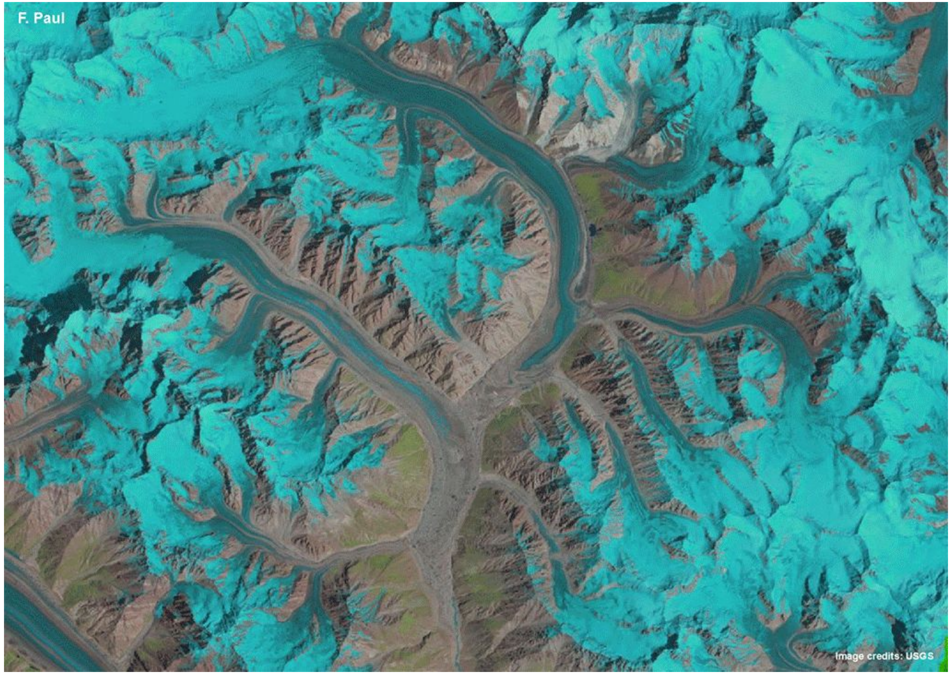
This dataset couples those annotated glacier locations with multispectral imagery from Landsat 7 [1] and digital elevation and slope data from SRTM [2]. Imagery are provided as thirty-five Landsat tiles and 14,190 extracted numpy patches. Labels are available as raw vector data in shapefile format and as multichannel numpy masks. Both the labels and the masks are cropped according to the borders of the HKH region.

Python code for training and testing machine learning models using PyTorch, as well as the source for a glacier mapping web tool, can be found in the accompanying GitHub repository:

Next Steps

- Formal comparison with semi-automated approach
- Use proposed approach for a glacier change analysis





Thank you.