Automated detection of debris-covered glaciers using deep learning and object-based image analysis

A new, automated methodology for creating glacier inventories is explored. The method employs a convolutional neural network and object-based image analysis to identify debris-covered glaciers across the South-East Asia Himalaya region.

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1. Introduction

Debris–covered glaciers (DCG) are the most prevalent type of glacier across High Mountain Asia (HMA) (Nicholson *et al.*, 2018). HMA DCGs provide an important and reliable seasonal water source for the growing populations and water intensive economies downstream (Pritchard, 2019).

Loss of HMA glaciers and associated seasonal water supply could result in the destabilisation of downstream regions (Pritchard, 2019). HMA glaciers have been losing mass at an accelerating rate over the last 50 years (King *et al.*, 2020). However, in some cases, debris-cover can reduce the rate of glacial mass loss, subsequently increasing the longevity of the associated seasonal water supply.

To better understand DCGs response to climate change and the rate of melt, the accurate mapping of DCG boundaries, length and area are required (Ghosh *et al.*, 2014). Debris-cover complicates glacier mapping due to the spectral similarity between debris-cover and the surrounding slopes; significantly hindering the effectiveness of automated classification methods.

The current study aims to utilise the high potential of deep learning's application within remote sensing studies by developing an automated classification approach that employs a **Convolutional Neural Network** (CNN) and **Object-Based Image Analysis** (OBIA). This poster presents the deep learning methodology, and showcases unrefined preliminary results produced solely by the CNN.

2. Study area

South-East Asia Himalayas. The current study aims to classify and produce outlines for all the debris-covered glaciers in the Nepalese, Sikkim, and Bhutanese Himalayas. The South-East Asia Himalaya region contains DCGs with the most advanced debris-covered state of any region on Earth.

3. Datasets

The study uses freely available satellite and topographic datasets:

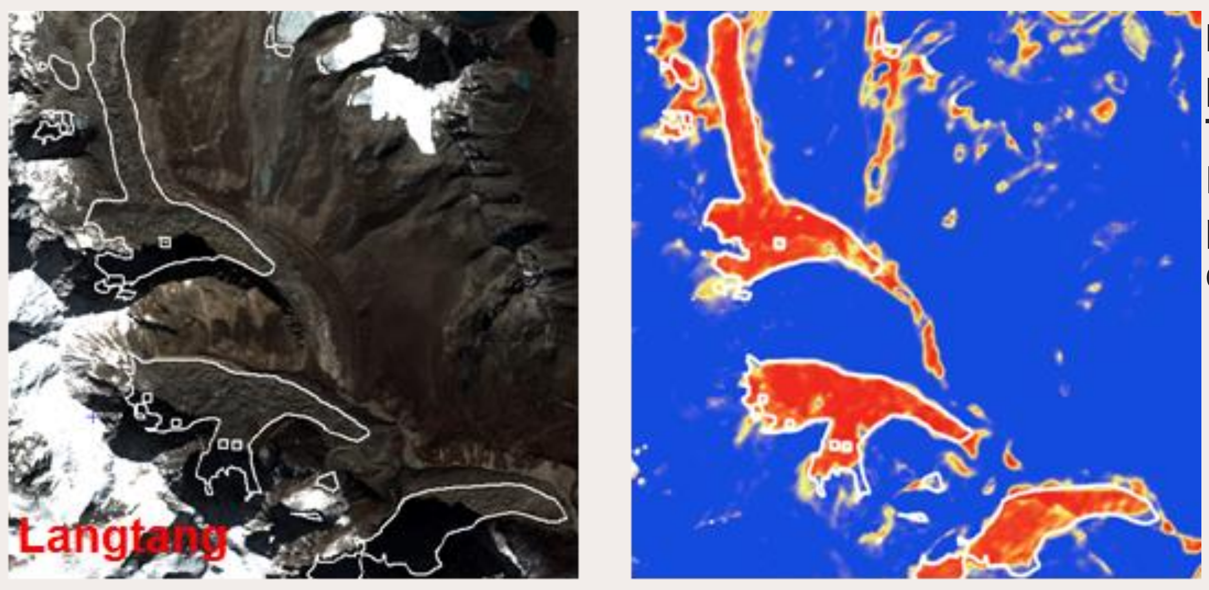
- Pansharpened **Sentinel-2** imagery provides ten 10 m res. multispectral bands.
- 6.5 m res. SAR coherence imagery derived from **Sentinel-1** interferometric imagery.
- **Landsat 8 ETM+** 100 m res. thermal imagery (TM10).
- 30 m res. **AWdD30** topographic data (DEM, Slope, Aspect, Hillshade, Planform curvature, Profile curvature).

4. Methodology

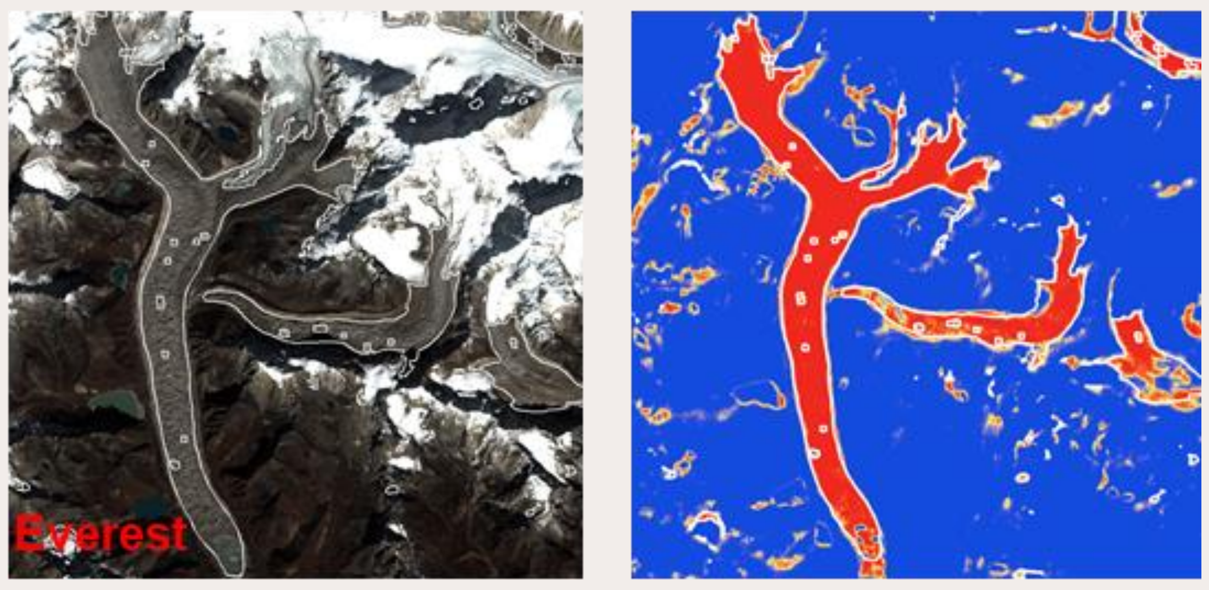
The automated approach was conducted within the eCognition Developer 9.5 software. **Sample points** were created for each prevalent land-cover class in the study region (clean ice/snow, glacial lakes, DCGs, vegetation, stable slope, clouds, and shadows). A 20 m buffer was created around the sample points and used to produce **weighted sample points**. A **6-layer CNN** was created (see base of poster), trained (using the weighted sample points), and applied to the study region to produce a probability heatmap.

5. Results

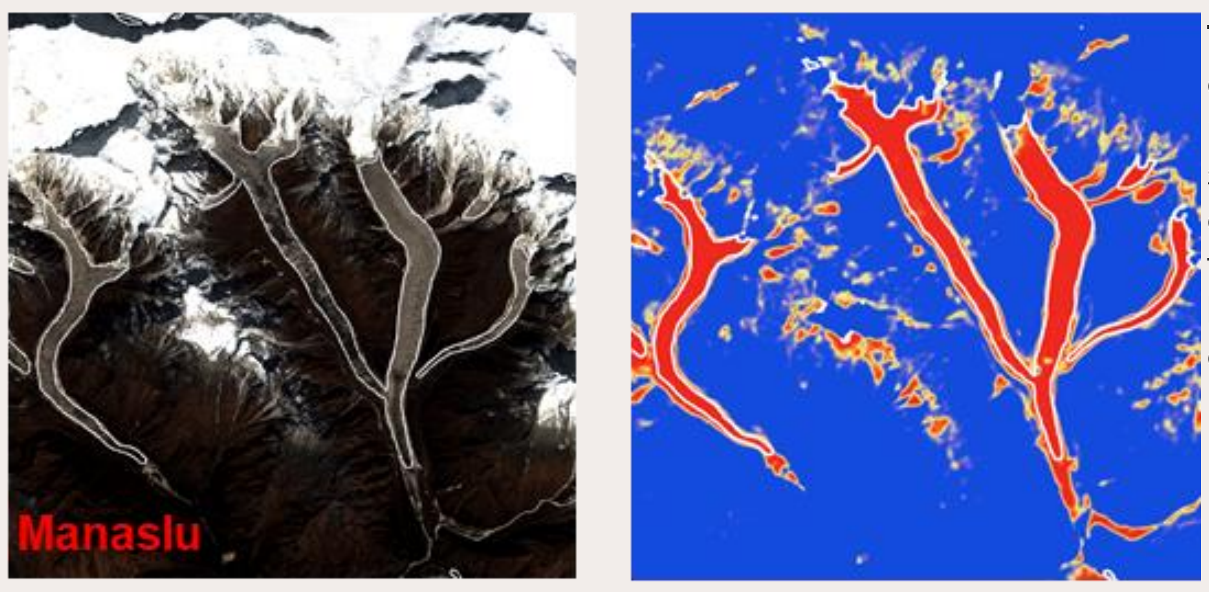
Heatmaps feature both incorrectly omitted and commissioned results. Commission occurs for features with similar textures (e.g. landslides).



Landslide in the north of image produces a false positive result. **Terminus** of the large northern DCG overestimated. **Glacial ponds** correctly identified and omitted from glacier area.



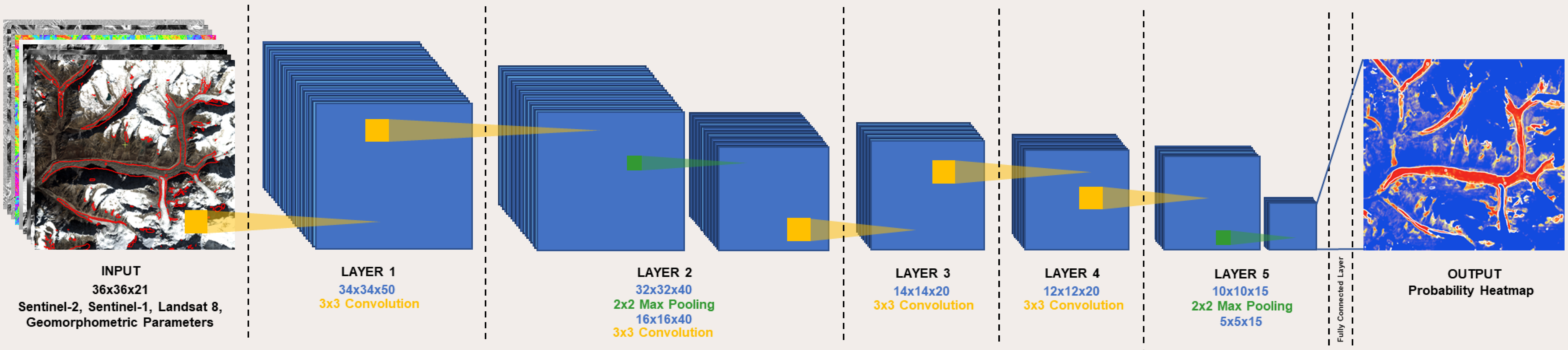
Glacial ponds correctly identified at terminus of large DCG. **Termini** of both large DCGs overestimated. False positives produced around **edges of glacial lakes** in the west.



Termini of all DCGs overestimated. False positives produced in **river channel** in the south east. **Landslides** along central mountain ridge produce false positives. **Lateral DCGs boundaries** have been overestimated.

6. What's next?

- OBIA refinement to remove false positives and false negatives.
- Application over entire study region.
- Accuracy assessment.



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