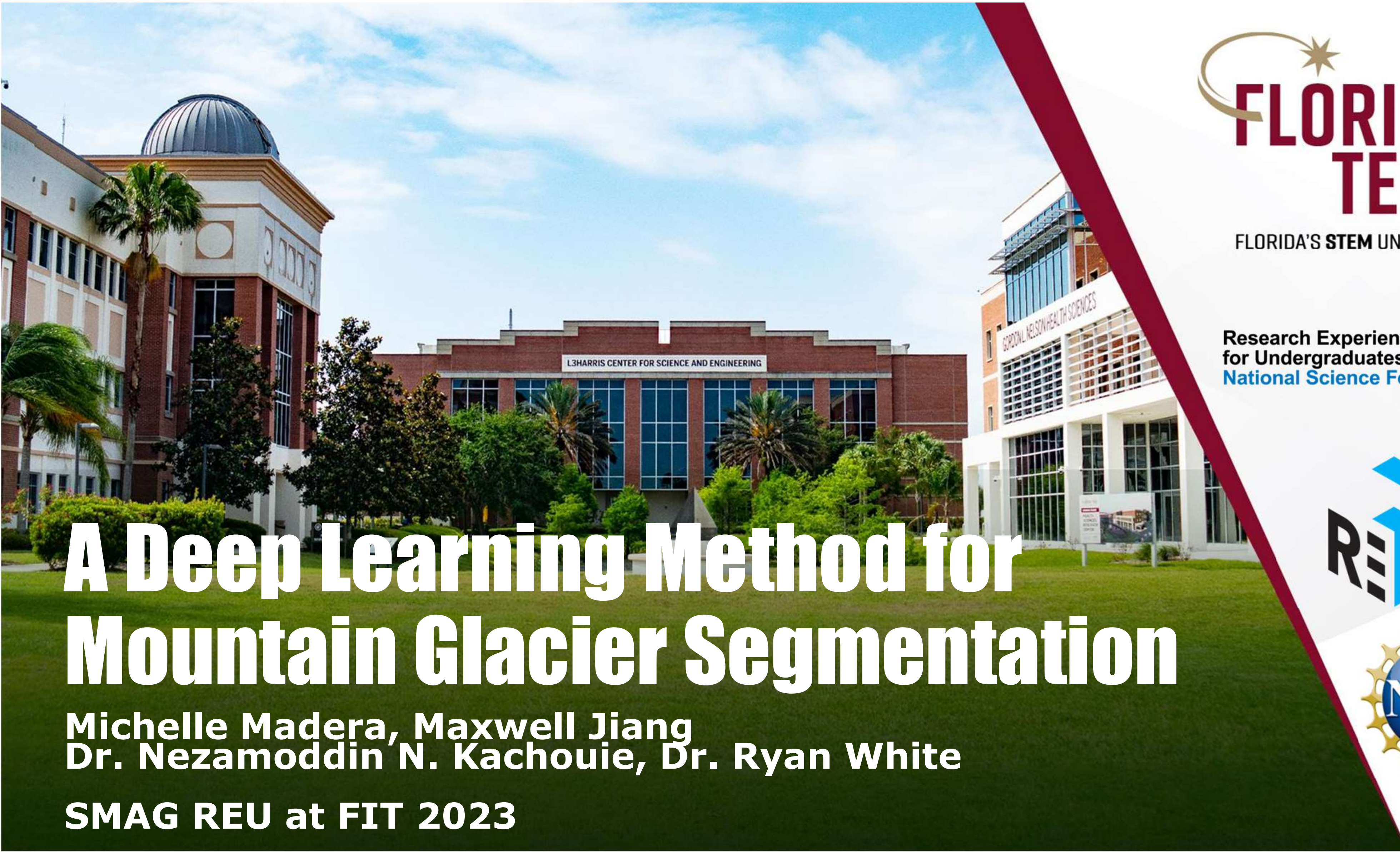

A Deep Learning Method for Mountain Glacier Segmentation

Michelle Madera, Maxwell Jiang
Dr. Nezamoddin N. Kachouie, Dr. Ryan White

SMAG REU at FIT 2023

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Research Experiences
for Undergraduates
National Science Foundation

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Introduction

[2]

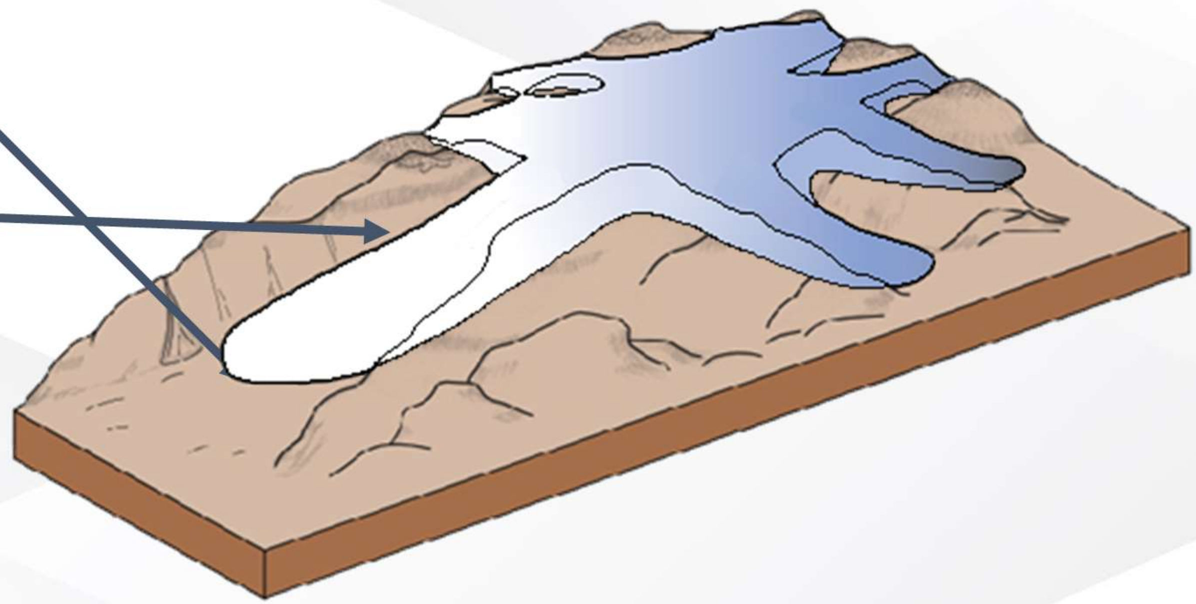
Problem Introduction

- ➢ Glaciers are key water resources
  - ○ ~1.9 billion people depend on glacial water (Smithsonian, 2021)
- ➢ Global warming threatens water security
- ➢ Glacial size updated infrequently

[3]

Glacier Size Metrics

- ➢ Terminus point
- ➢ Length
- ➢ Area
- ➢ Volume



Adapted from [4]

Segmentation Method for Glacial Area

- Over 200,000 glaciers in the world
  - Impractical to manually determine their areas

- Therefore autonomous approach needed

- This project intends to develop such a method

On Site vs. Remote

Summer Rupper and Mike Roberts preparing an ablation stake in the Himalayas
[5]

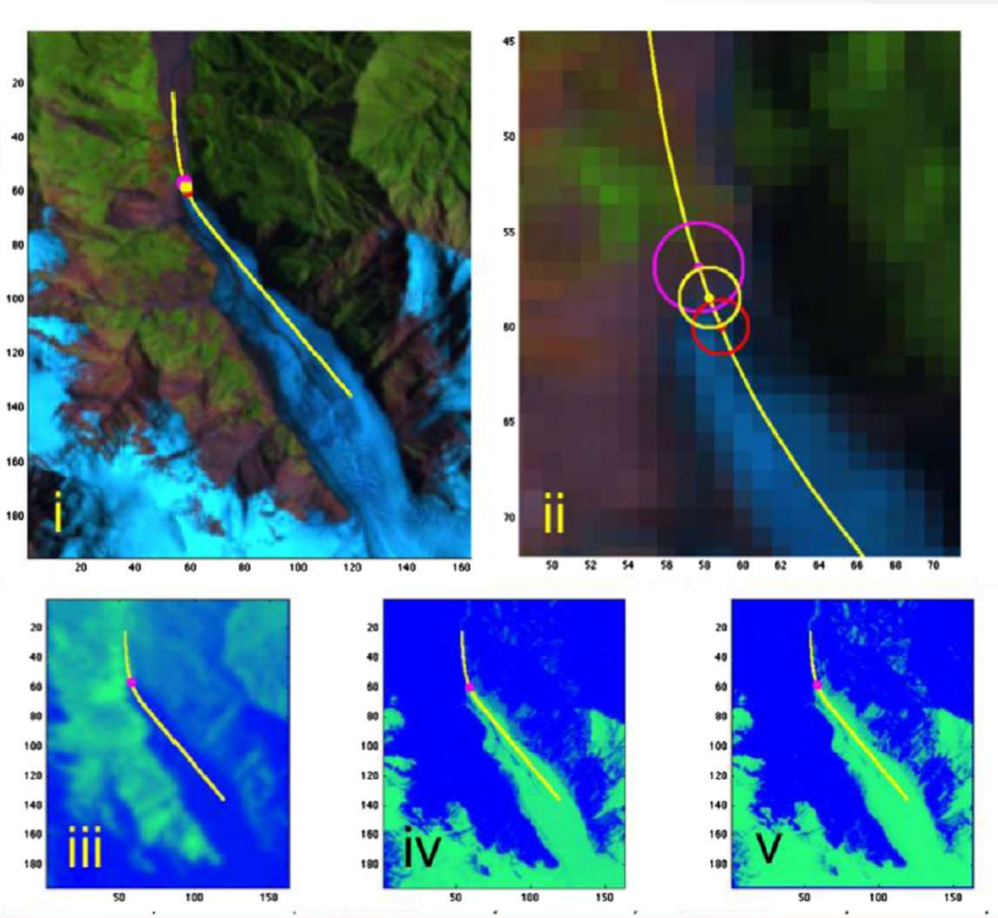
Adapted from USGS [6]

Focus Area

Adapted from [7]

[8]

Previous Attempts: Terminus Detection



- Not scalable for global
- Edge Detection

(Kachouie et al., 2012)

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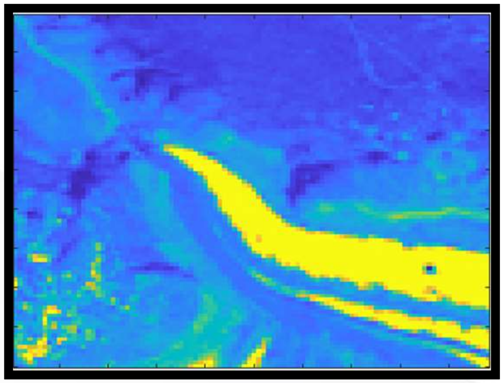
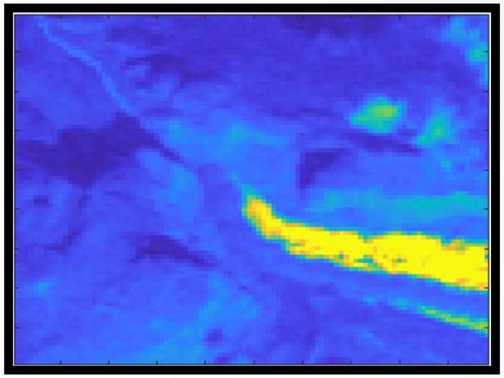
Previous Attempts: Simple Area Segmentation

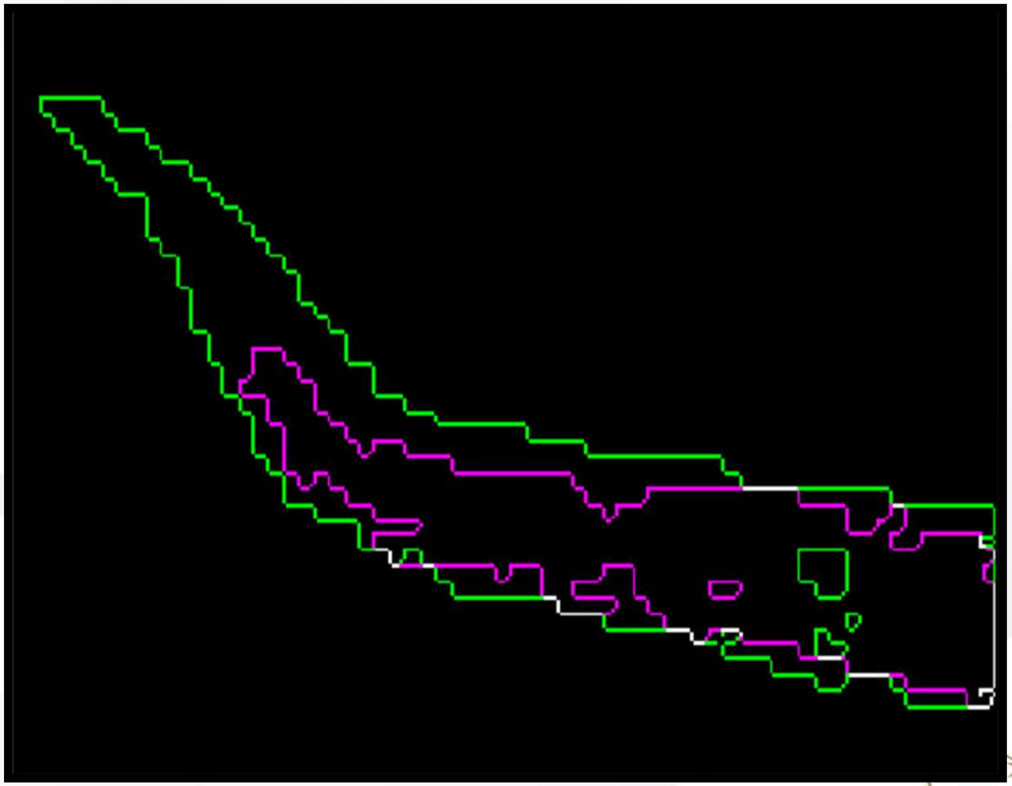
- Classification of each pixel
- Manual determination of threshold between glacier & non glacier
  - Non-scalable
- Inconsistent results

(Kachouie et al., 2012)

Classification and Segmentation

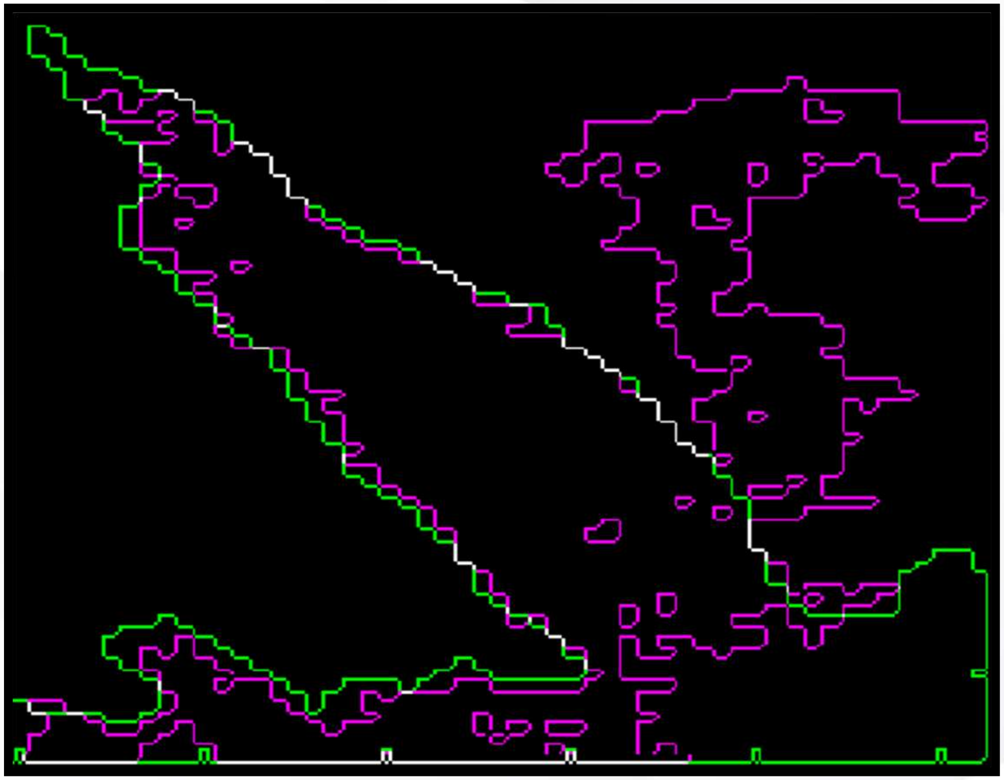






(Kachouie et al., 2012)

Typical Segmentation



(Kachouie et al., 2012)

Purpose of Study

- ➢ To build upon insights provided from prior techniques and the 1-D profile
- ➢ Understand glacial variation as it impacts communities
- ➢ Develop a segmentation method to quantify variation

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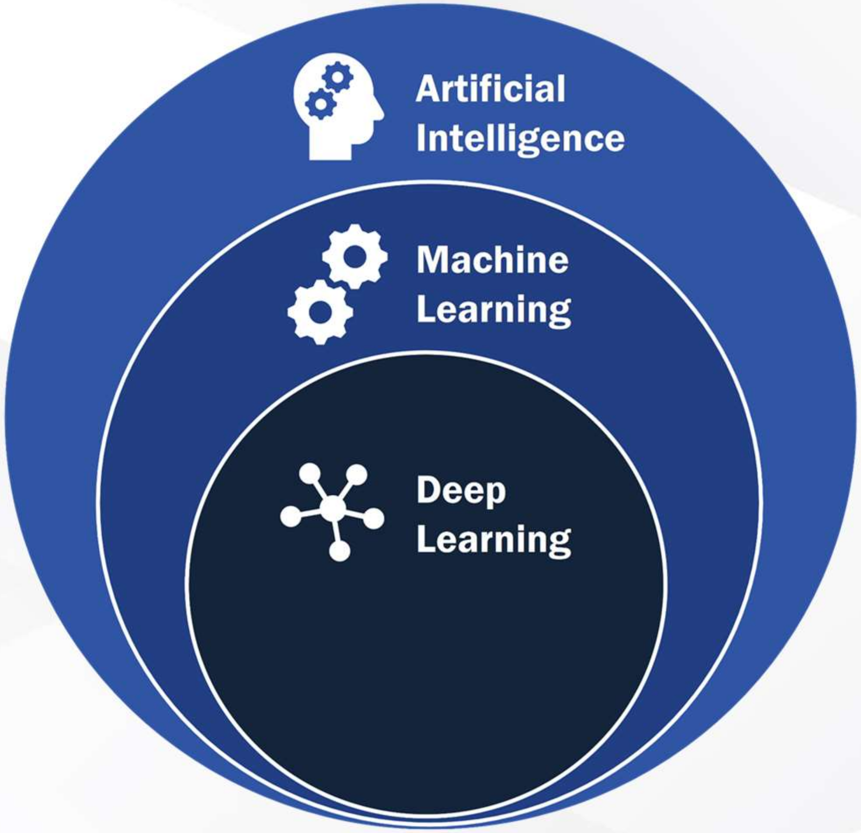
Research Questions

How to quantify the Southern Alps of New Zealand's mountain glacier variations based on Landsat satellite imagery through image processing techniques?

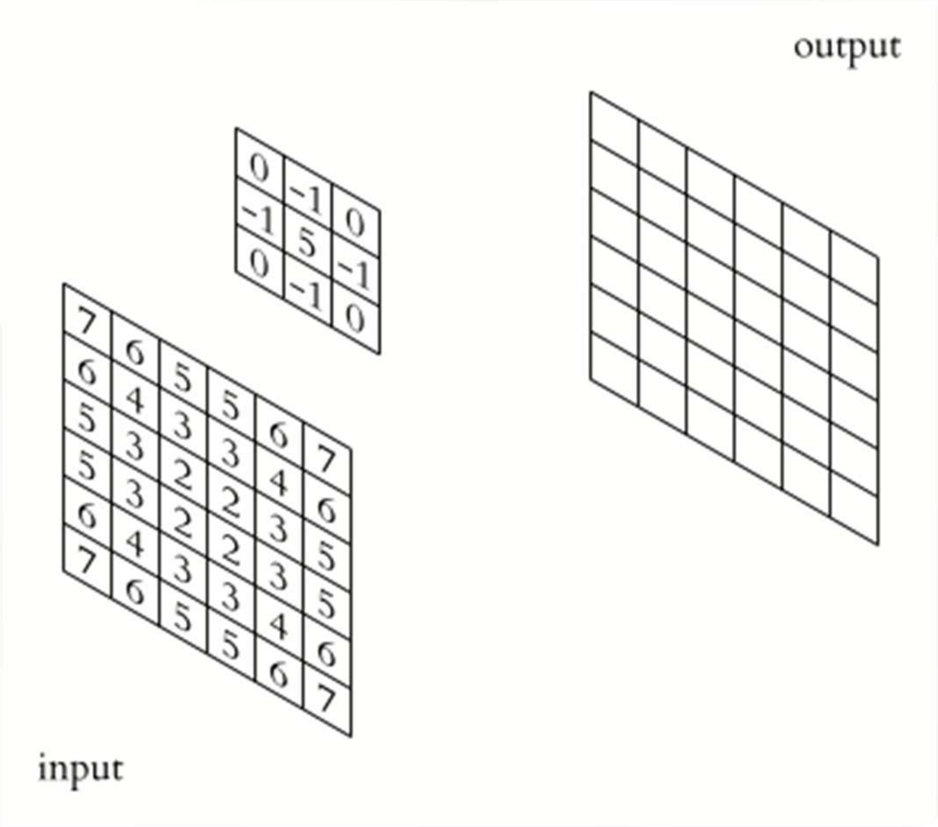
Investigate the correlations between glacier variations and climate factors.

A Deep Learning Approach



[9]

Convolutional Neural Networks

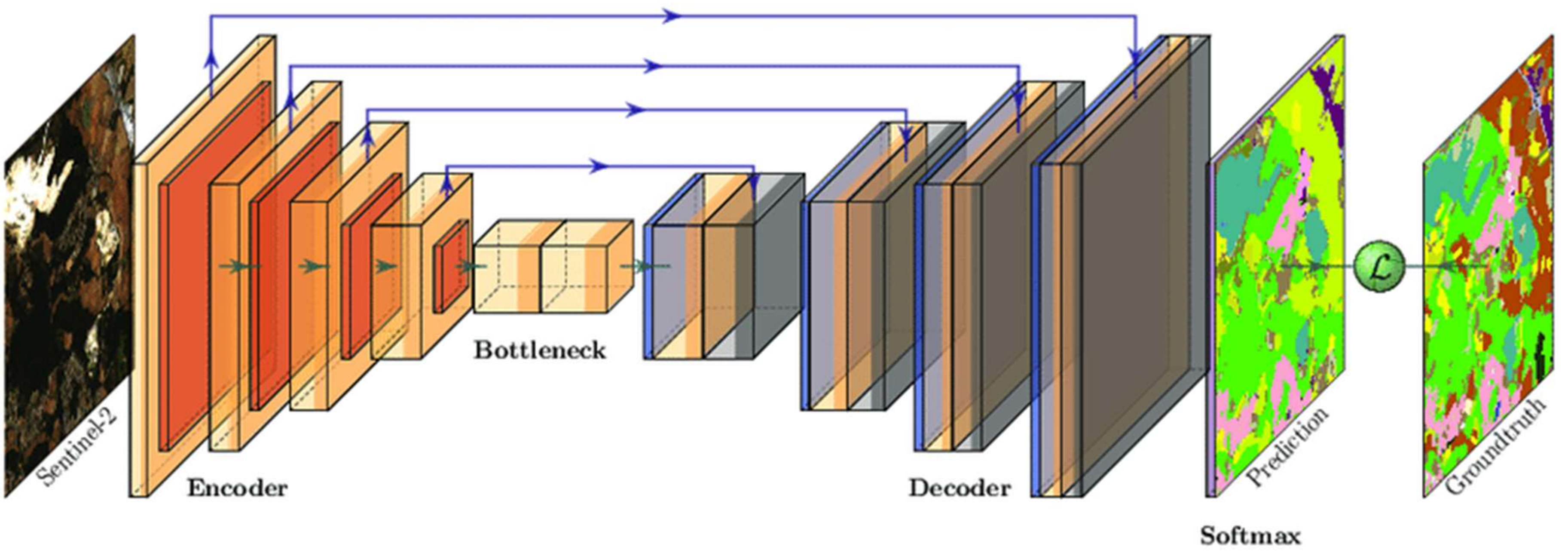


[10]

Relevant Studies

[2]

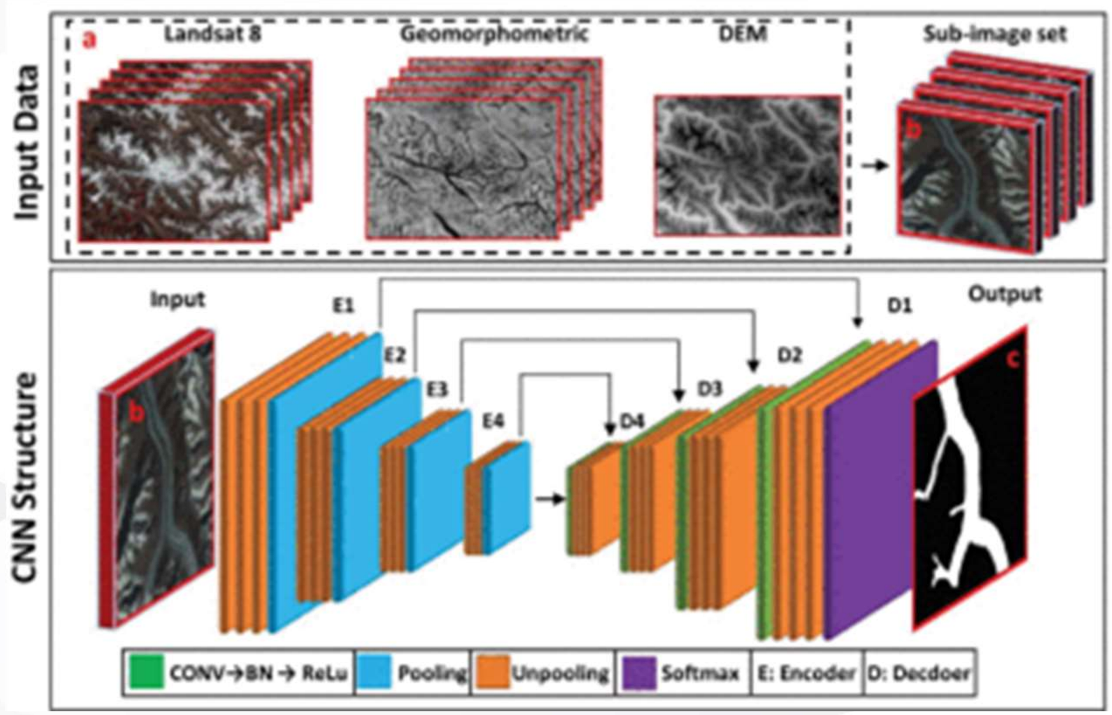
Relevant Technique: U-Net



[11]

Relevant Studies: GlacierNet

- ➢ 11 Landsat bands as inputs
- ➢ Nepal Himalaya and Karakoram study area



(Xie et al., 2020)

Methodology

[2]

Project Overview & Tools

Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → Model Application → Area Analysis

QGIS [12]

TensorFlow [14]

[13]

Keras
Simple. Flexible. Powerful. [15]

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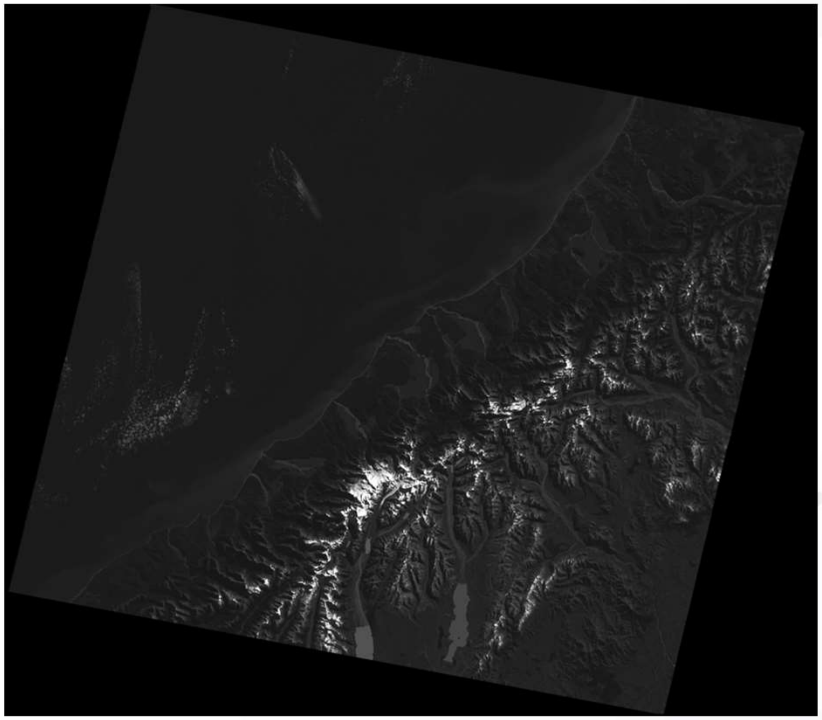
Data Description: Landsat Satellite Imagery

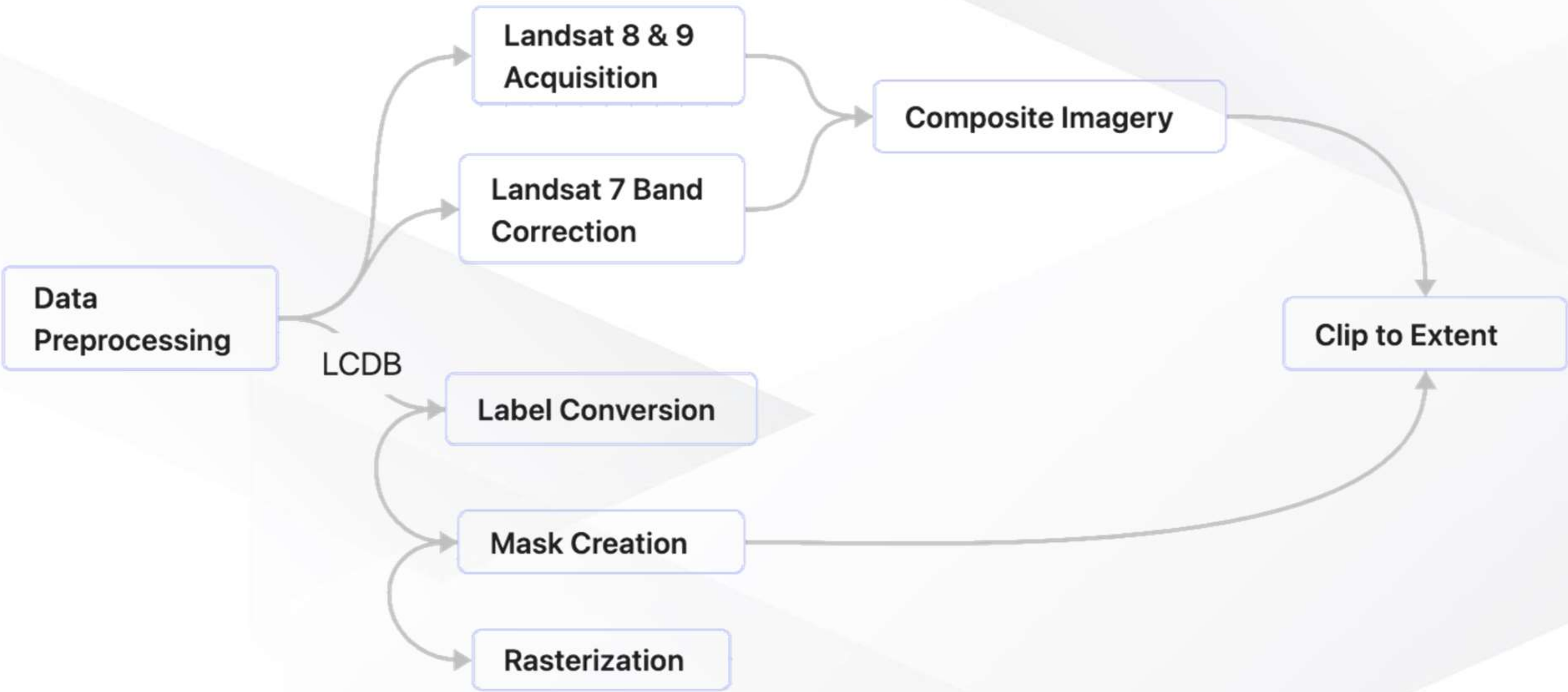


Landsat 7 courtesy of USGS [6]

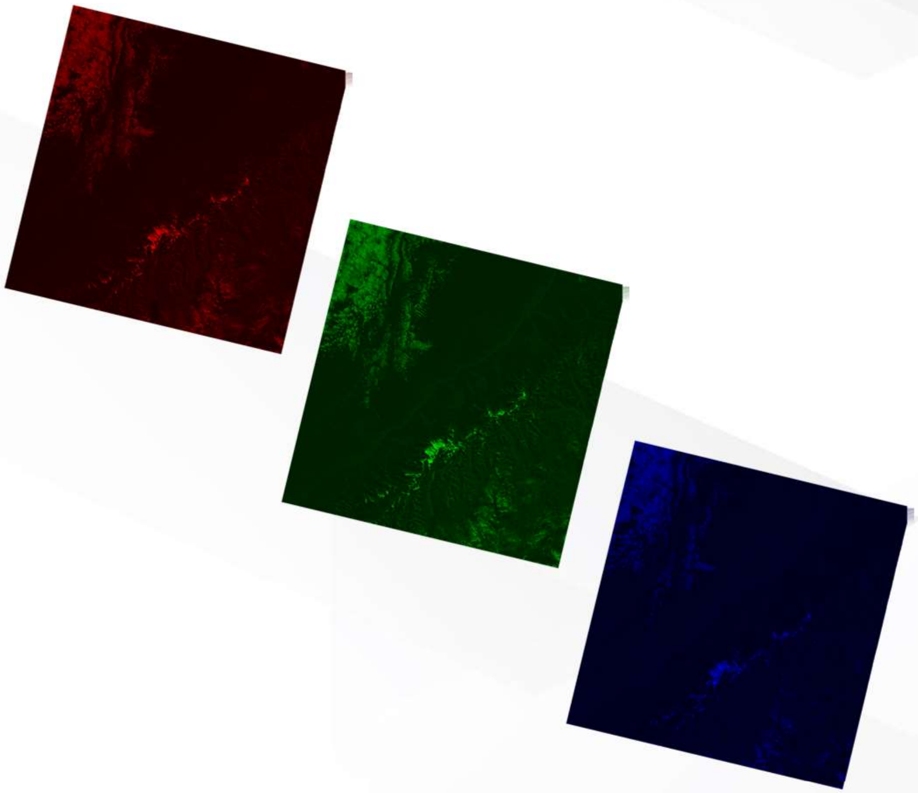
Band 2 Landsat 7 image from April 2011

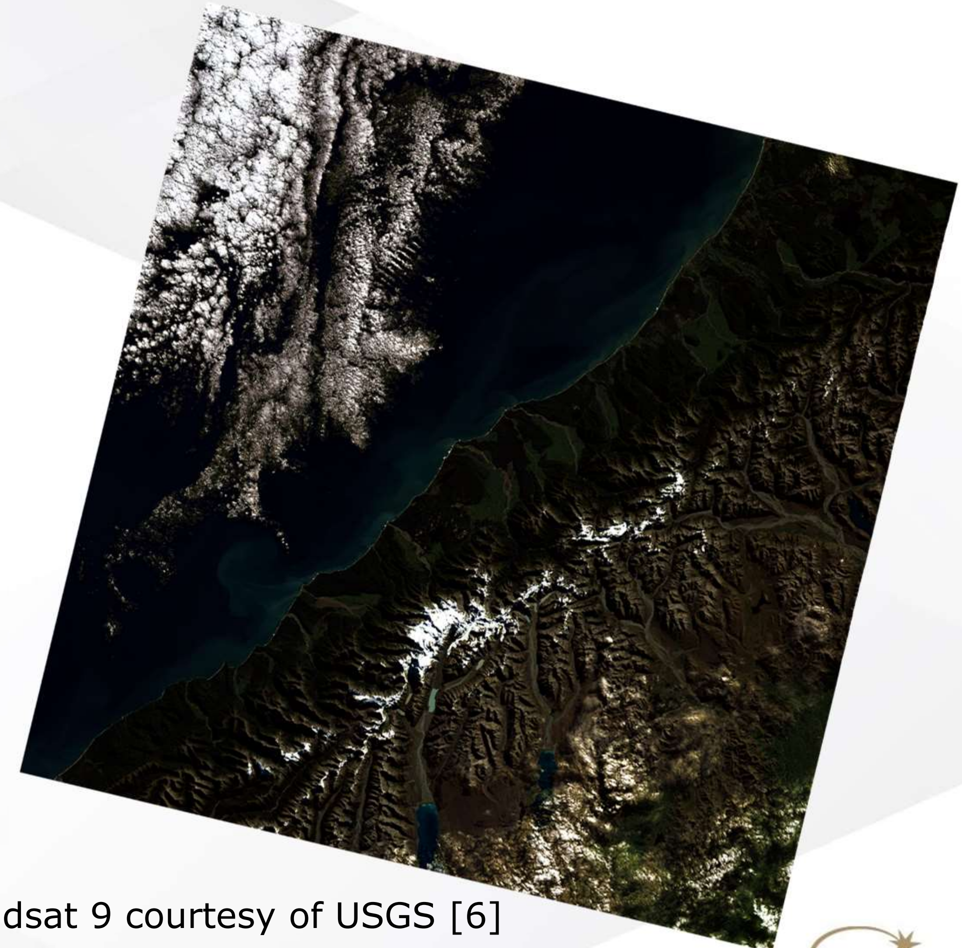
Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → Model Application → Area Analysis

Preprocessing Methods



Compositing Image

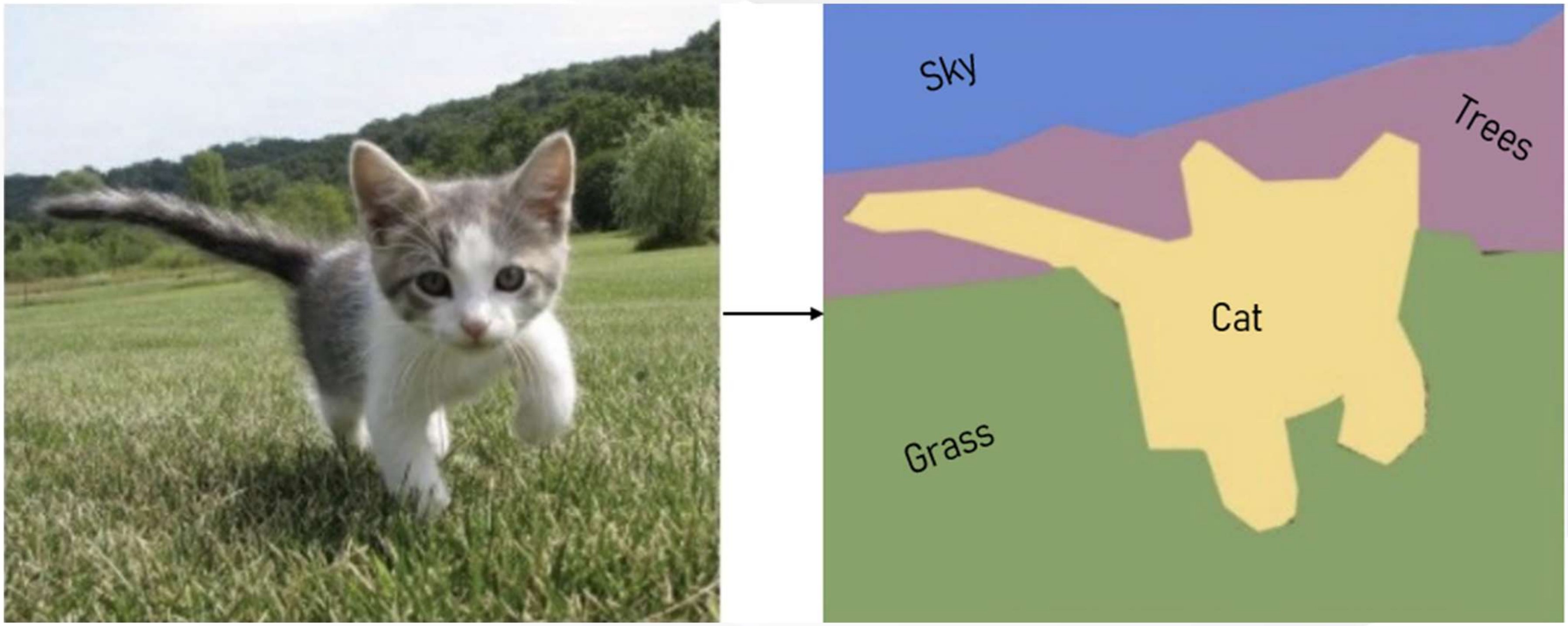




Landsat 9 courtesy of USGS [6]

Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → Model Application → Area Analysis

Semantic Segmentation



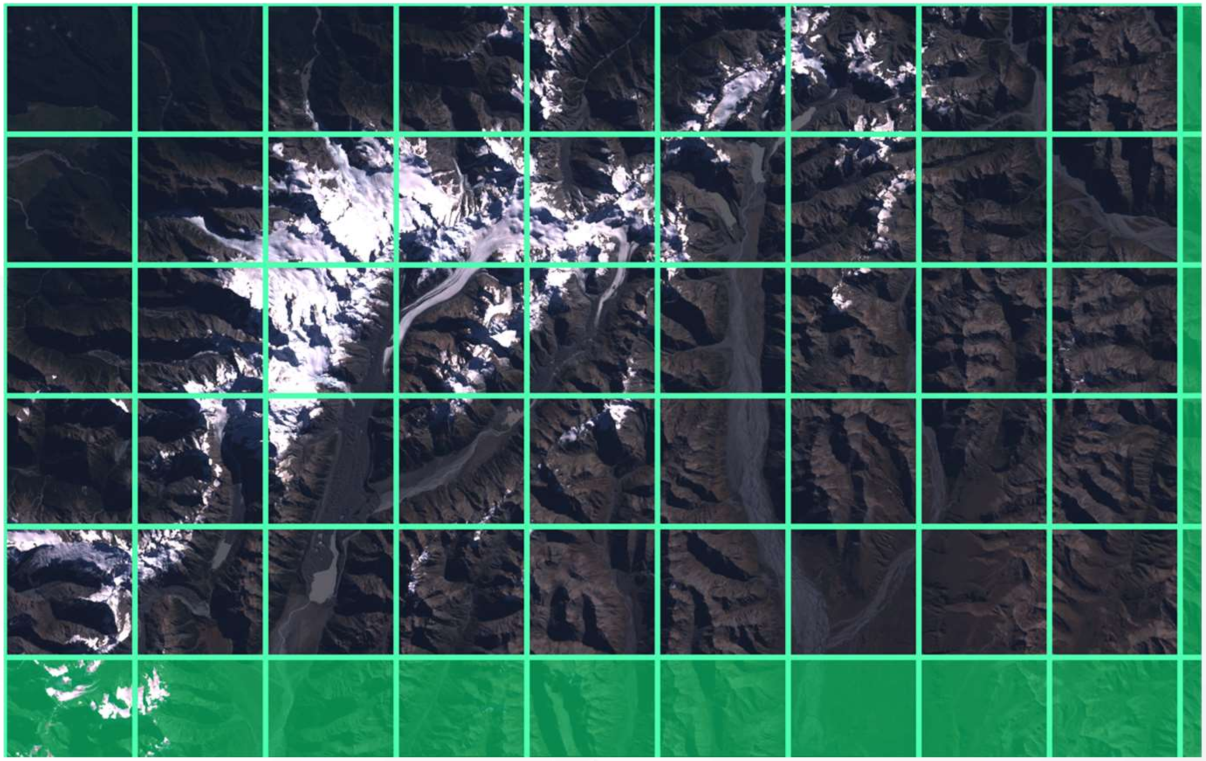
[16]

New Zealand Classification

Adapted from (Manaaki Whenau, 2021)

Adapted from [6]

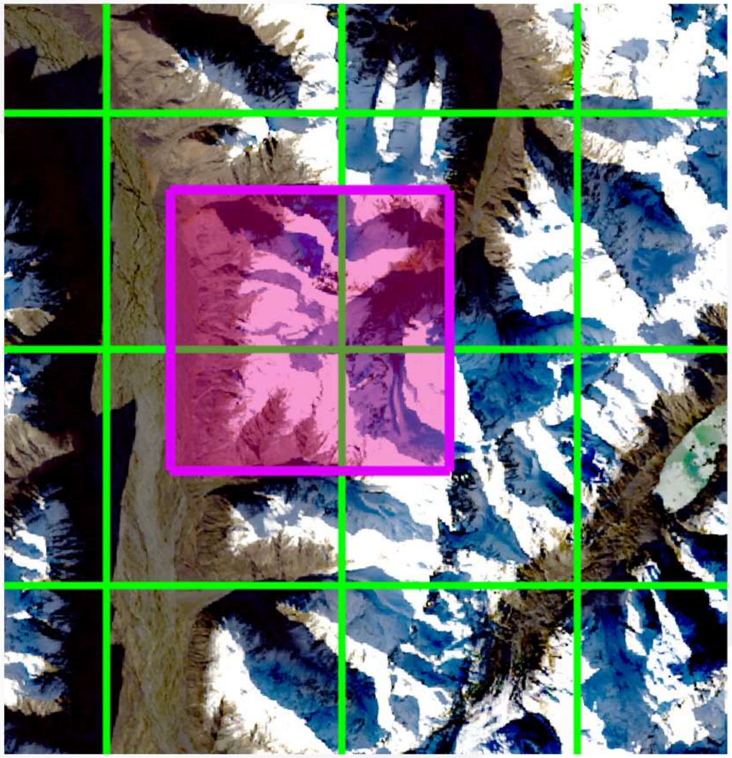
Data Preprocessing



Landsat Satellite Imagery → Data Collection → **Data Preprocessing** → Model Training → Model Evaluation → Model Application → Area Analysis

Data Augmentation: Random Patching

- ➢ Image split into 256 x 256 px patches
  - ○ Created patches 256 px apart in a grid
- ➢ Can take patches off the grid to increase dataset size
  - ○ Added 2.5x more patches



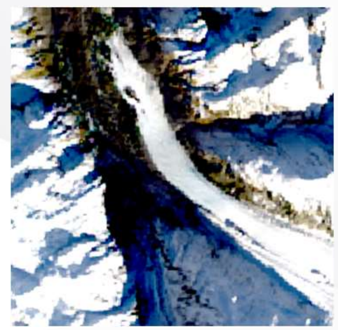
Patching Pattern

Landsat Satellite Imagery → **Data Preprocessing** → Model Training → Model Evaluation → Model Application → Area Analysis

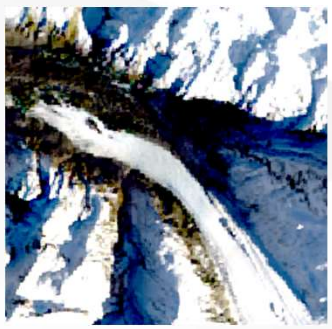
Data Augmentation: Random Flip or Rotate

Normal

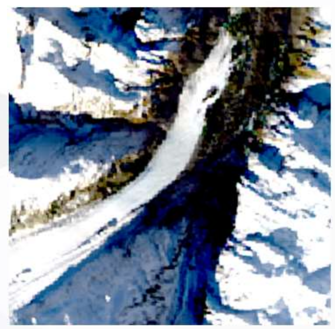
Horizontal Flip



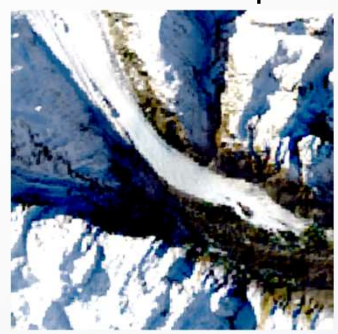
Vertical Flip



90° CW



180°



90° CCW

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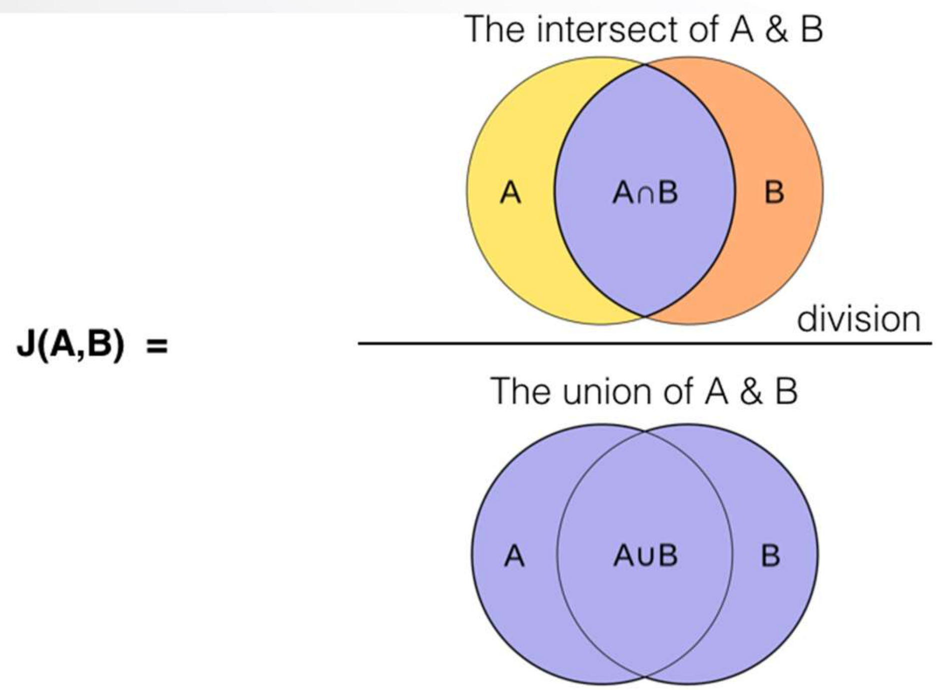
Jaccard Index/IoU

The Jaccard Index/Intersection over Union

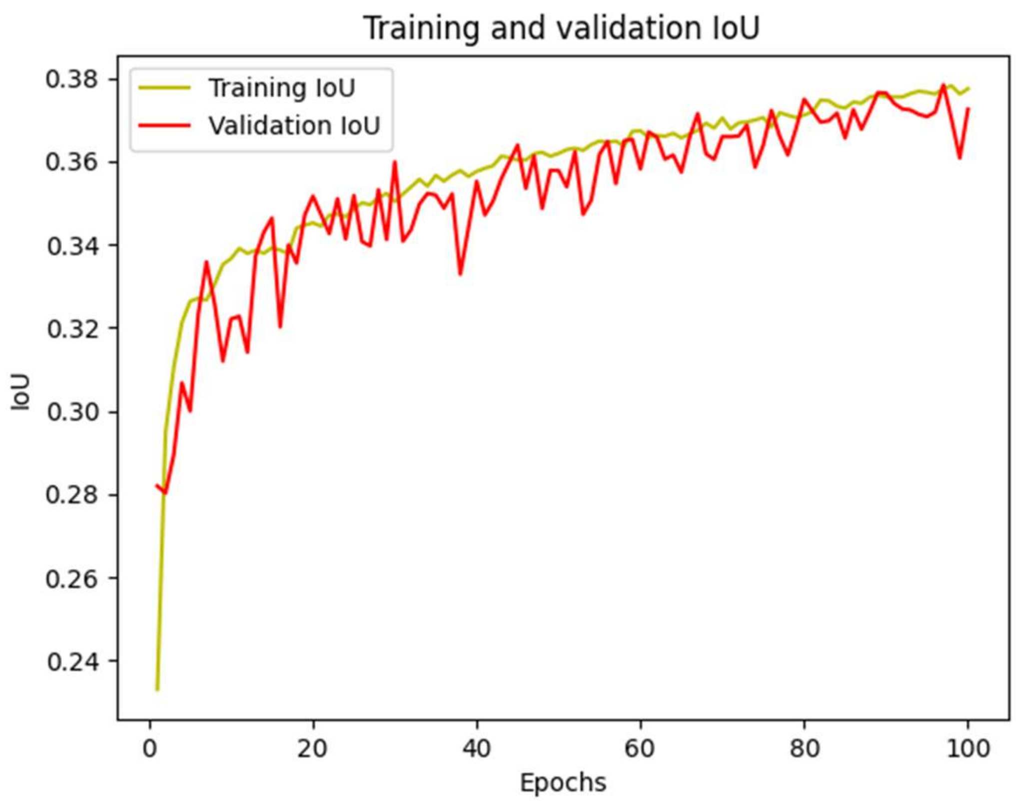
- ➢ Measures the similarity between two datasets



[17]

[3]

IOU New Zealand Classification Trained



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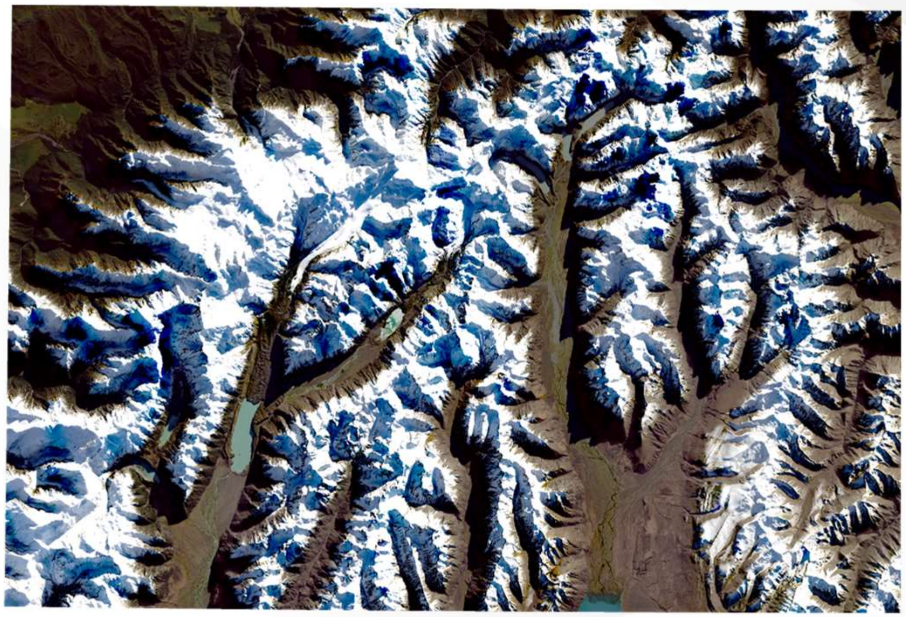
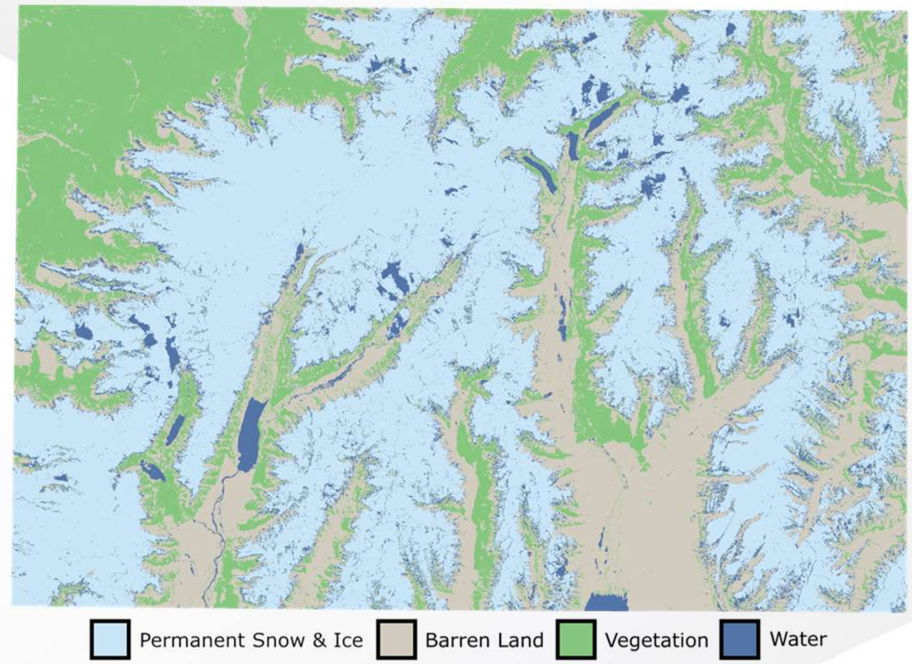
Land Cover Label Generation



Original Cropped Landsat Scene

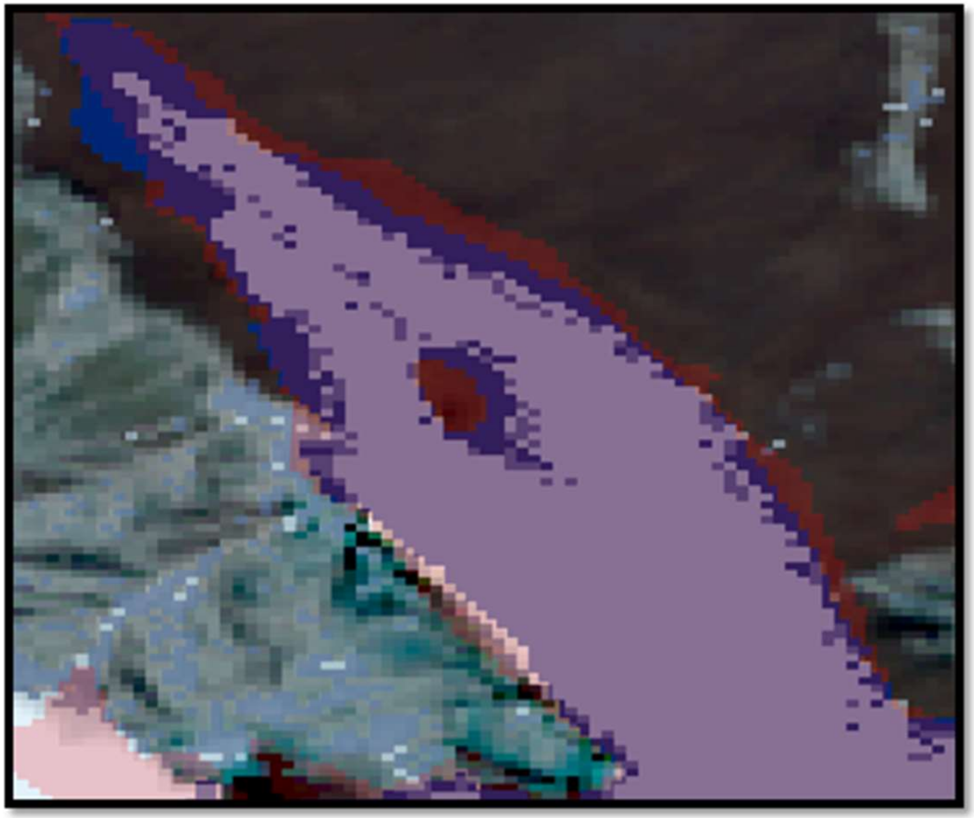
Adapted from [5]



Annotated Ground Truth

Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → Model Application → Area Analysis

Comparison of Various Truths



- New Zealand Land Cover in Red
- New Annotation in Lilac
- GLIMS in Blue
  - Collection of expert derived outlines

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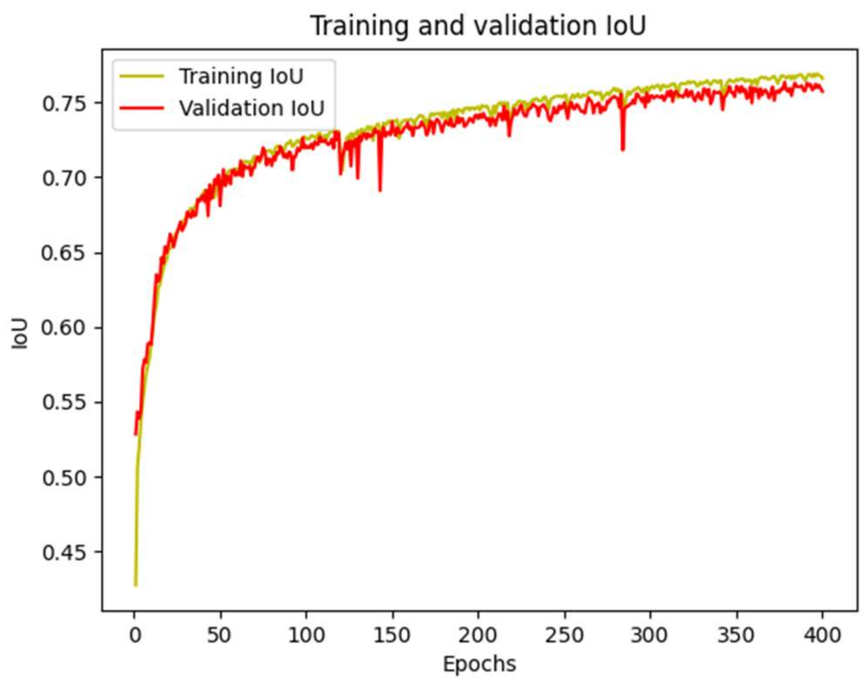
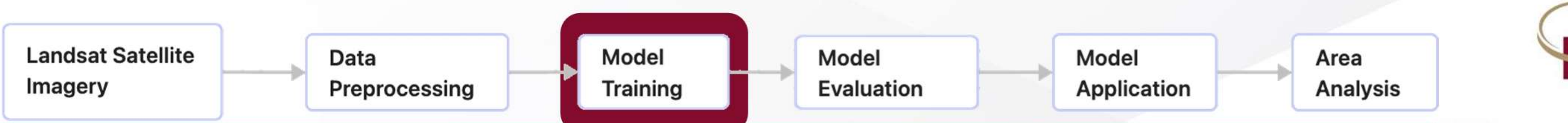
IOU Annotated Ground Truth



Model Modifications/Improvements

- ➢ Added two convolutional layers (for a total of 11) to improve validation accuracy
- ➢ Reduced learning rate upon long period of no improvement
- ➢ Used VGG16 convolution layers as encoder
    - ○ Jaccard Coefficient improved from 0.8 to 0.85



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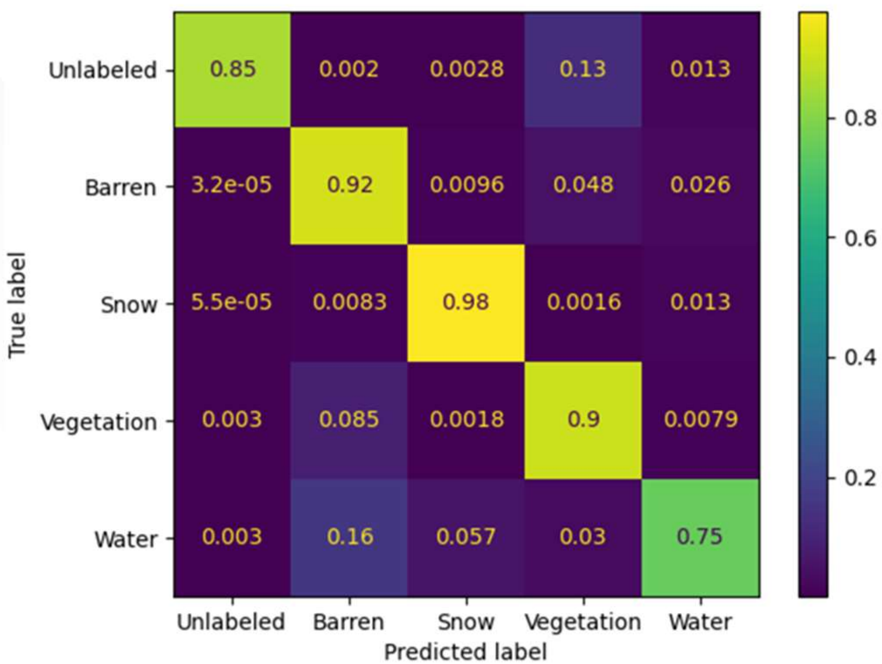
Results

[2]

Model Accuracy



Confusion matrix of trained model

- Model performs well on snow
- Shadowed ice often confused as water on the label which lead to misclassification

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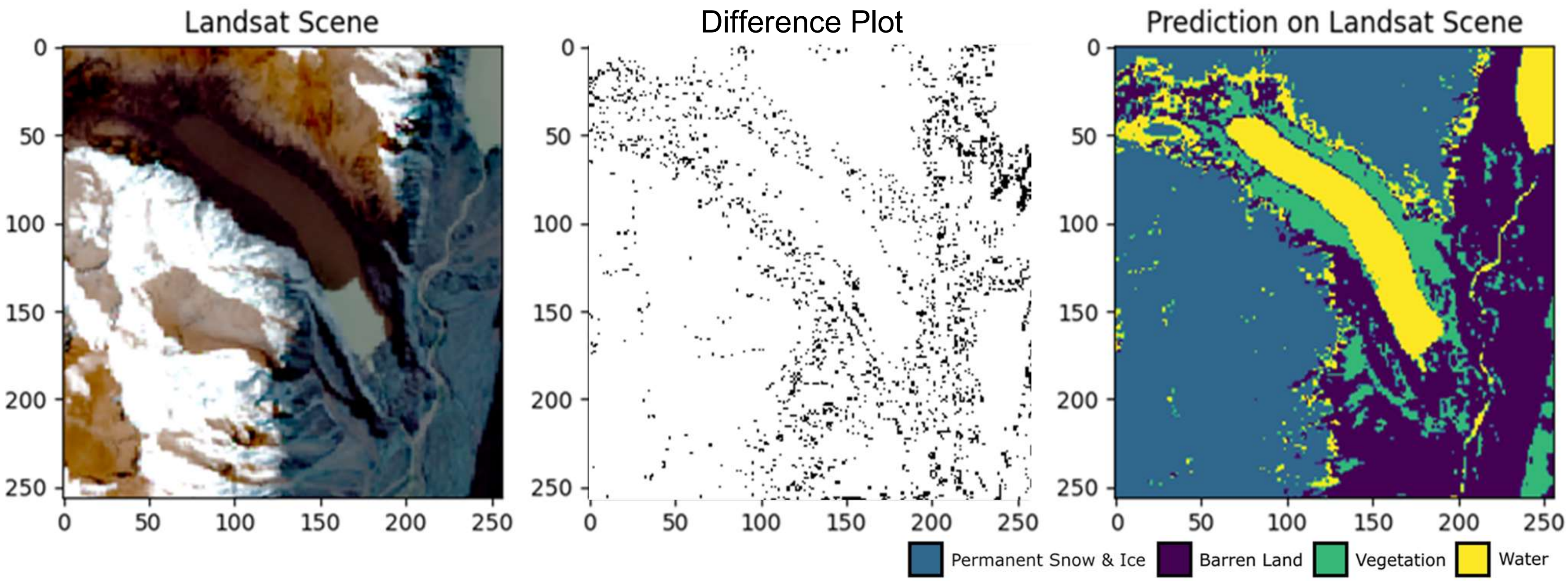
Model Accuracy Continued



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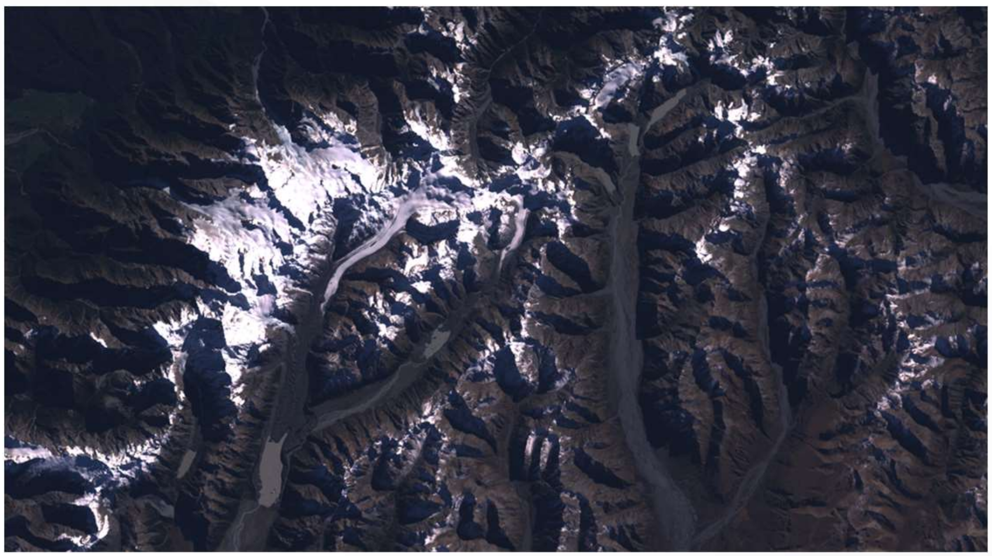
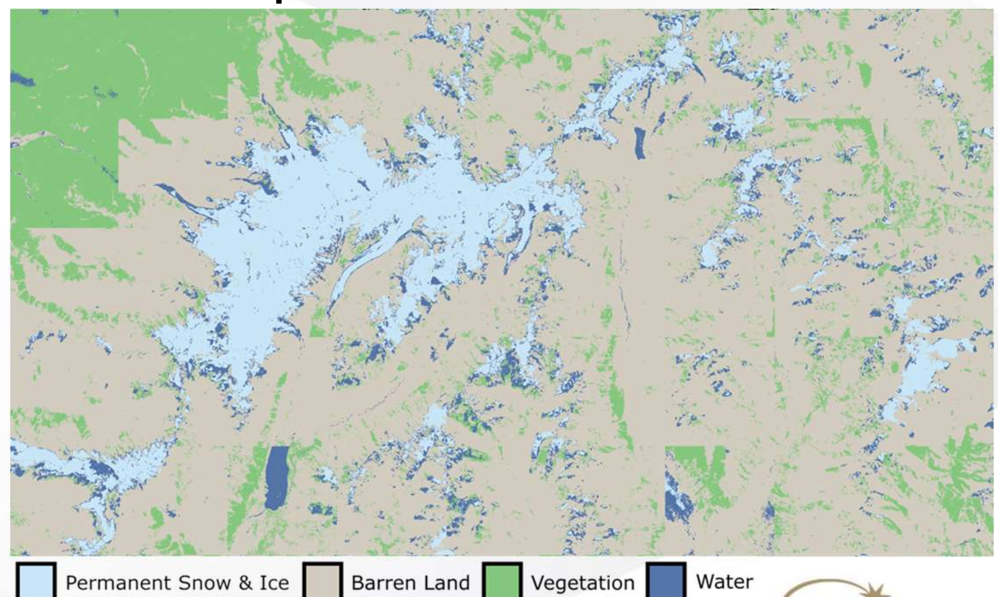
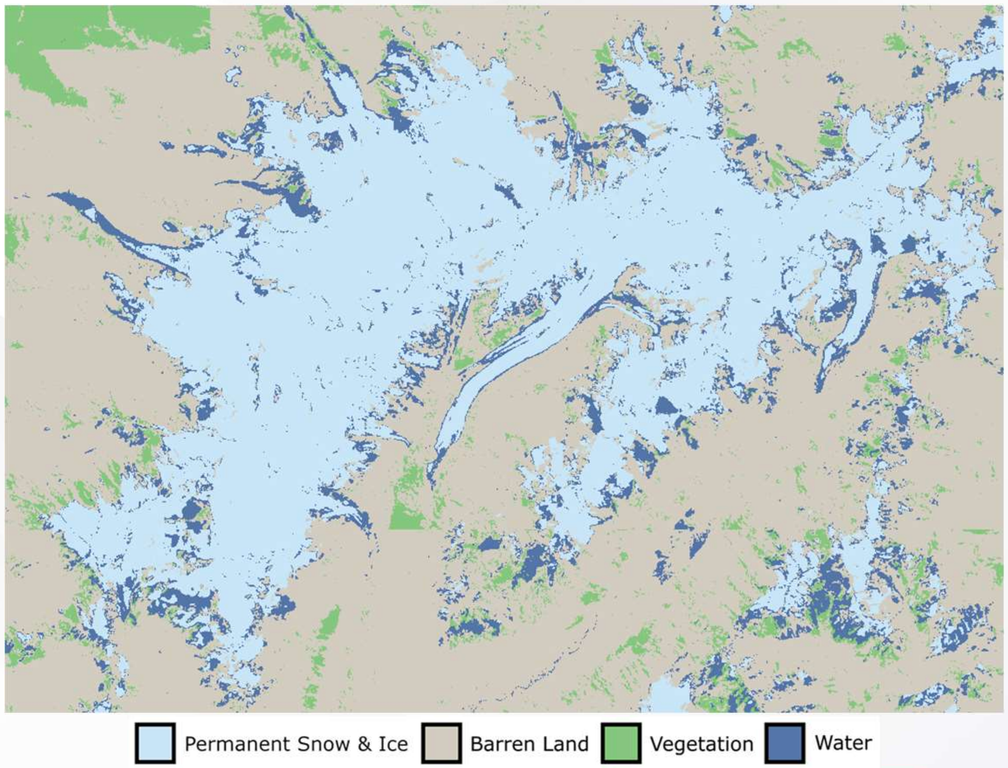
Model Accuracy Continued

- ➢ Complete scene prediction
- ➢ Combination of 256x256 patches





Model Accuracy Continued



Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → **Model Application** → Area Analysis

Conclusion

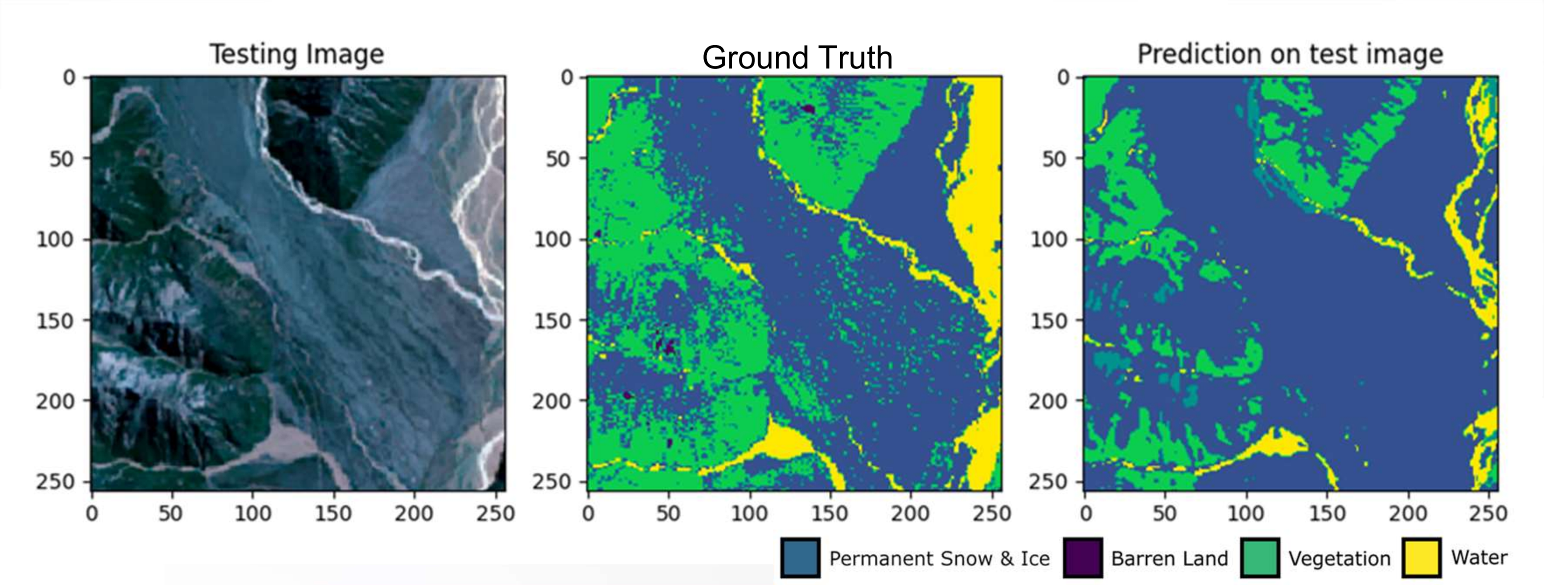
[2]

Takeaways

- ➢ Our method does not rely on hand-drawn segmentation
- ➢ Has the potential to be applied to any glacial region
- ➢ Demonstrates high performance on ice and snow classification
- ➢ 2-D profile provides deeper insights into glacial variation
- ➢ Consistent with previous CNN segmentation applications

Limitations

- ➢ Infeasible to have perfect labels
  - ○ Instrument error and labeling error
  - ○ No perfect ground truth available
- ➢ O
  - ○ E

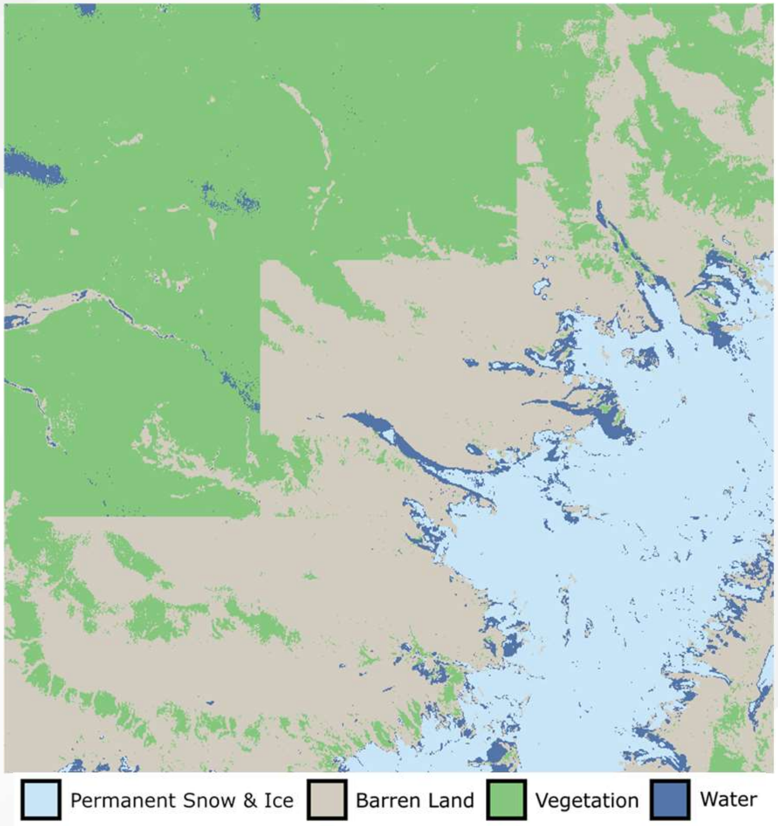


Next Steps: Project

- ➢ Determine method to measure glacial change with model
- ➢ Compile glacial areas through time
- ➢ Relate to climate factors

Next Steps: Model

- ➢ Make model more efficient
  - ○ Optimize current model width and depth
- ➢ Utilize more inputs
- ➢ Blurring patch borders



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Thank You! Questions?

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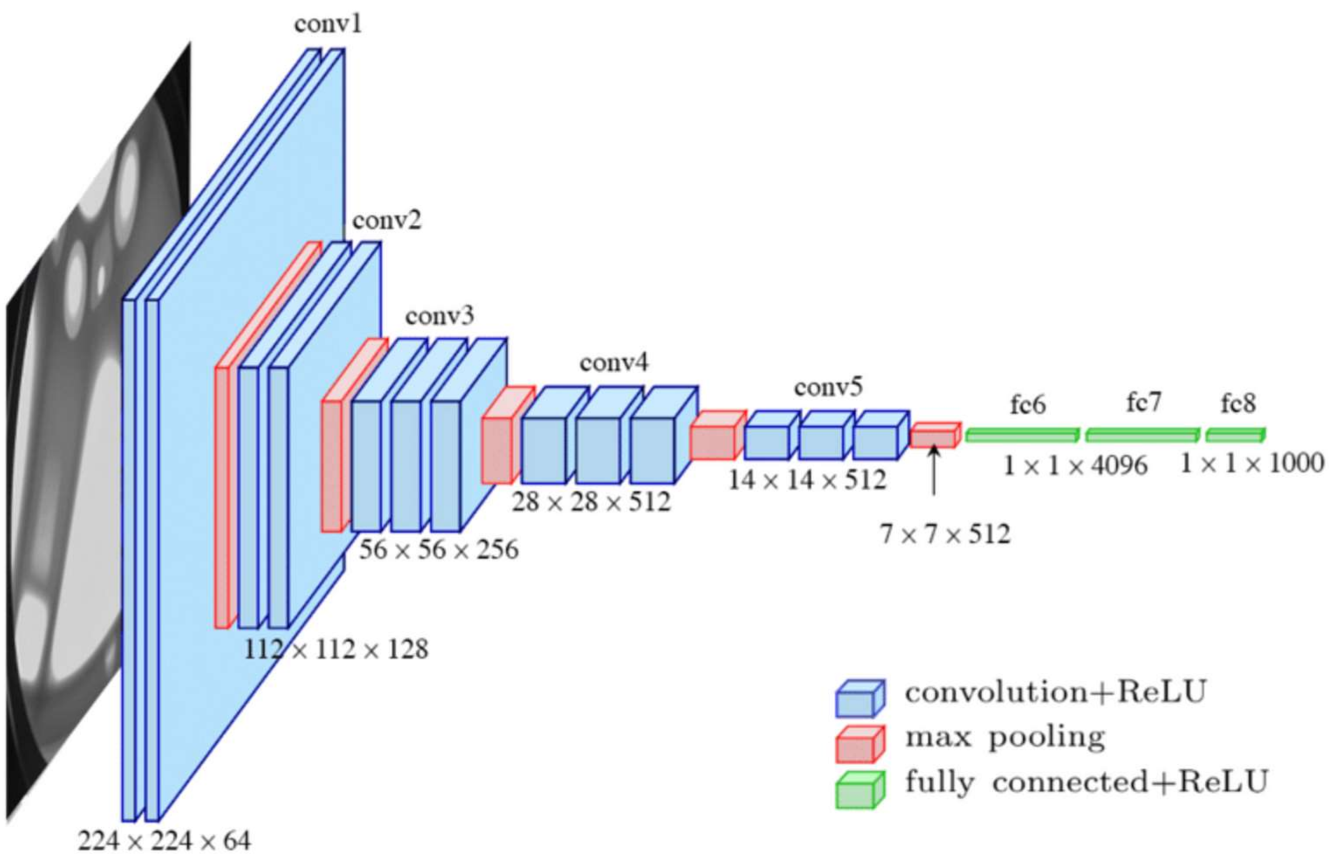
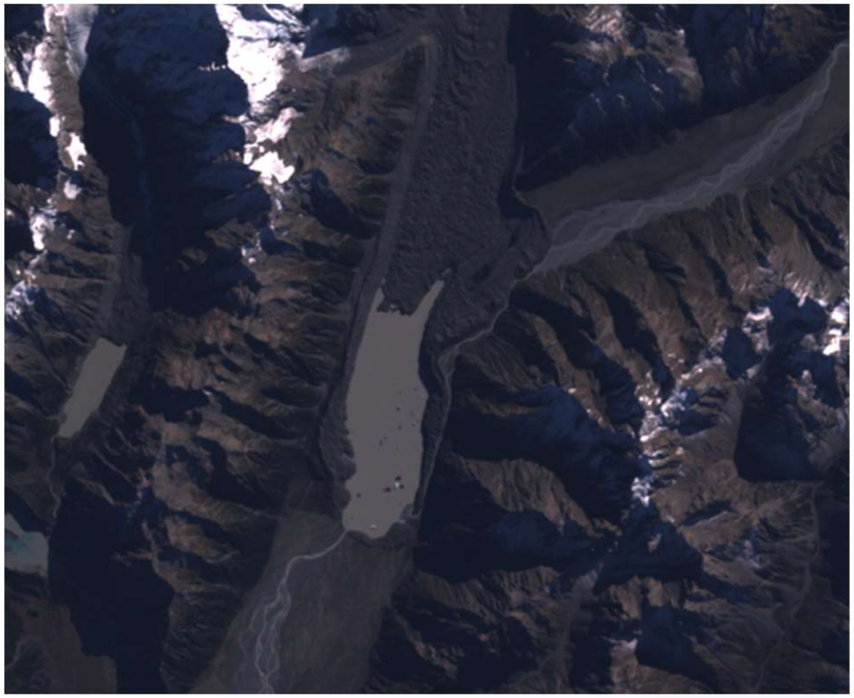
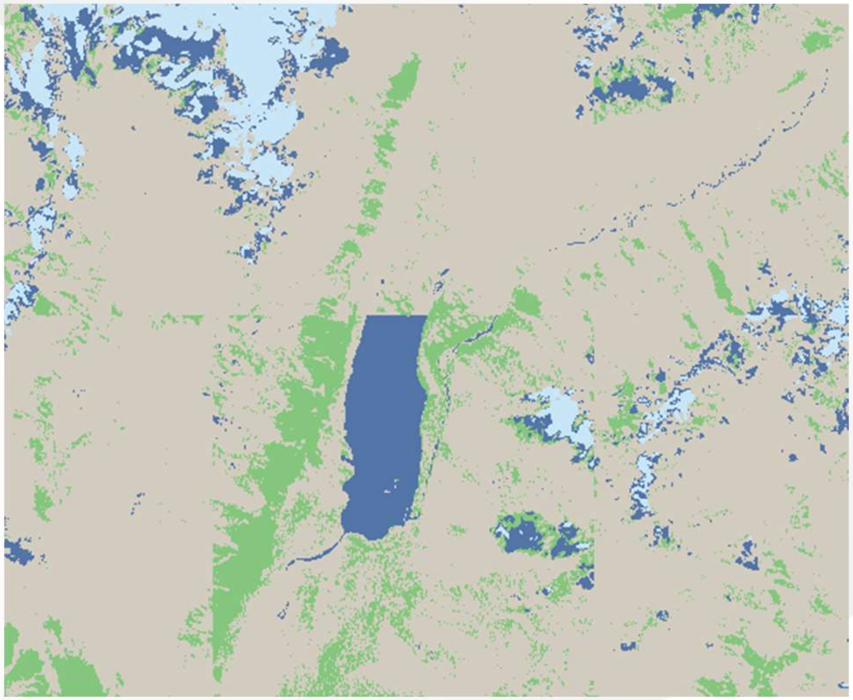
Supplementary: VGG



[18]

Model Accuracy Continued





Landsat Satellite Imagery → Data Preprocessing → Model Training → Model Evaluation → **Model Application** → Area Analysis

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