Research Experiences
for Undergraduates
National Science Foundation

Mountain Glacier Segmentation Method Using L*a*b* Color Space

Grace Stroh, Merril Storch

Eddie Robbins, Dr. R. White, and Dr. N. Nezamoddin

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Outline

- Introduction
- Image Processing
- Final Method
- Results
- Conclusions
- Q&A

Gorner Glacier
https://www.flickr.com/photos/120861725@N07/22485109480

Introduction

Franz Josef Glacier
https://www.flickr.com/photos/vjosullivan/33299673685

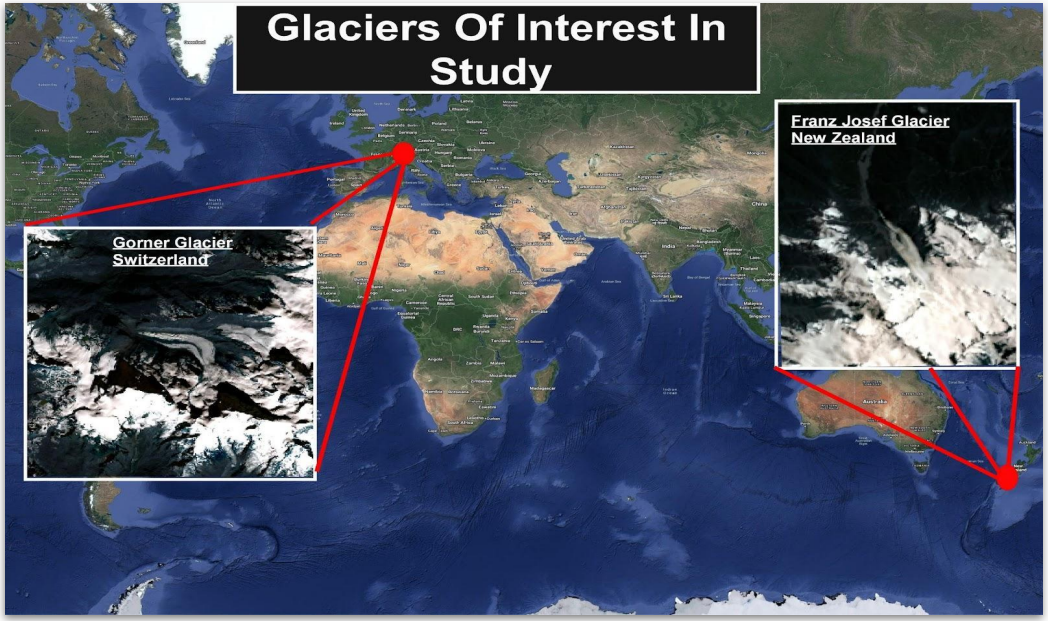
- Indicators of climate change
- Adverse effects of melting
  - Water security
  - Sea level rise
- Difficult to quantify variation
  - Physical impracticality
  - Debris/shadows
  - Up to 30% error [2]

Main Objectives

- Develop a glacier area image segmentation method.
- Quantify error with respect to a ground truth.

Introduction

- For both glaciers, we used
  - an Official GLIMS outline [4]
  - a Landsat satellite image [5,6]



Introduction

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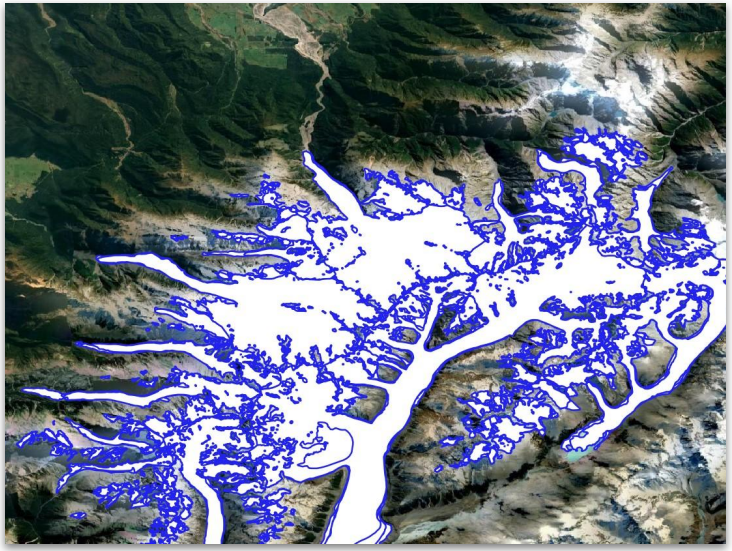

Original GLIMS Outline of New Zealand (Franz Josef)

Introduction

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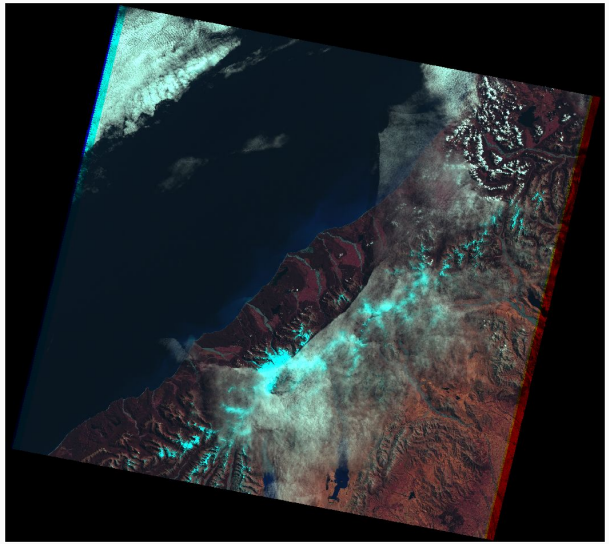
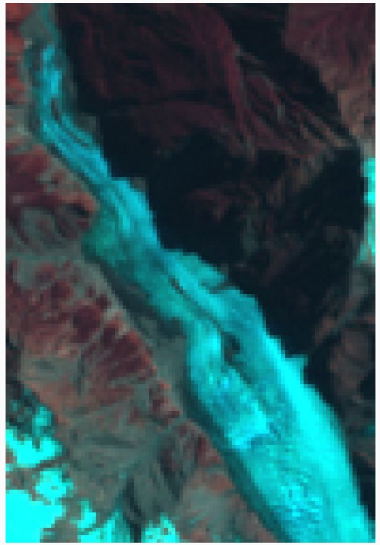
  - an Official GLIMS outline [4]
  - a Landsat satellite image [5,6]



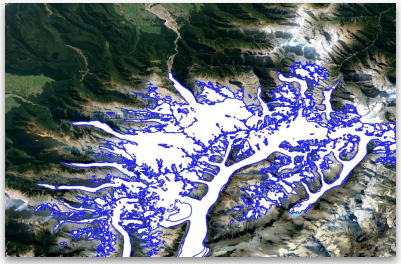
Original Landsat Image of New Zealand (Franz Josef)

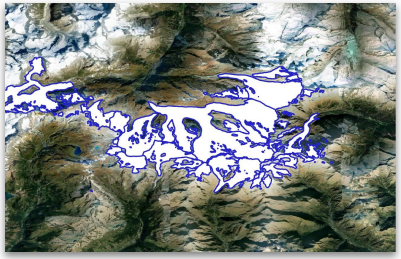


Cropped Landsat Image of Franz Josef

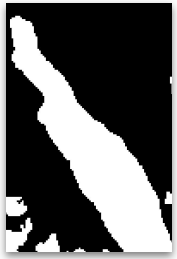
Pre-Processing GLIMS

1. Georeference

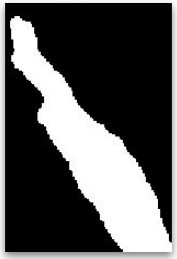


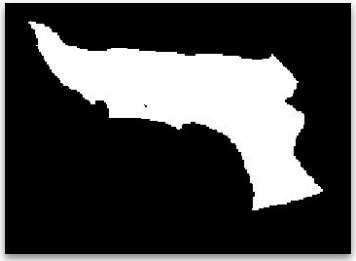


2. Crop and Align



3. Mask

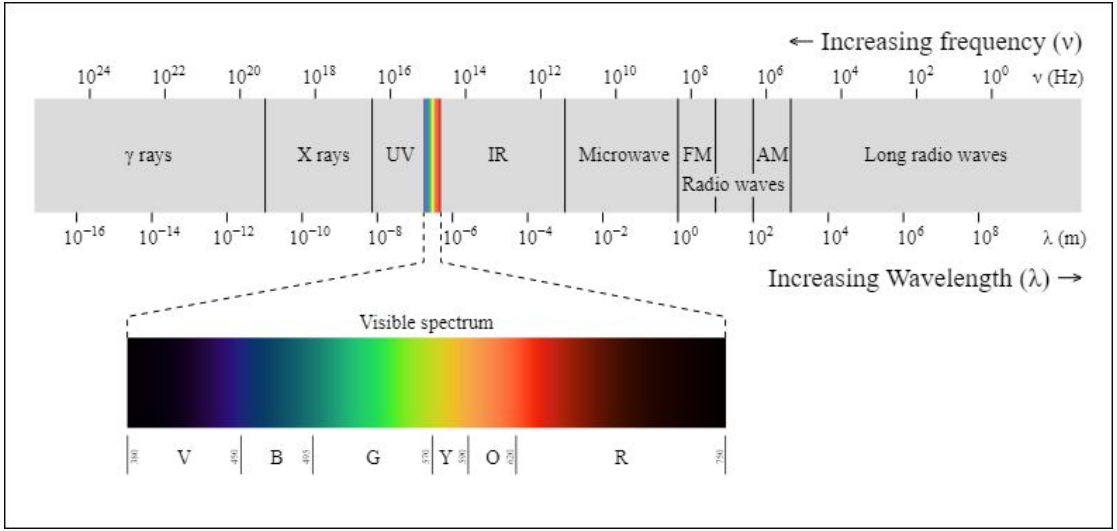




Landsat Bands

Band	Wavelength
Band 1 - blue	0.45-0.52
Band 2 - green	0.52-0.60
Band 3 - red	0.63-0.69
Band 4 - Near Infrared	0.77-0.90
Band 5 - Short-wave Infrared	1.55-1.75
Band 6 - Thermal Infrared	10.40-12.50
Band 7 - Short-wave Infrared	2.09-2.35
Band 8 - Panchromatic (Landsat 7 only)	.52-.90

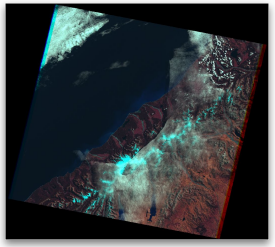
Landsat 4-5 and 7 Bands
https://www.usgs.gov/media/images/landsat-4-5-tm-and-landsat-7-etm-bands-and-their-uses

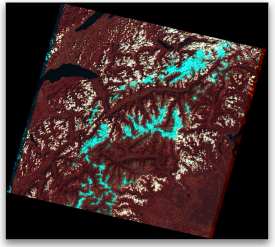


Electromagnetic Spectrum
https://commons.wikimedia.org/wiki/File:EM_spectrum.svg

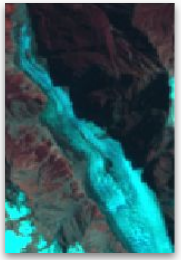
Pre-Processing Landsat

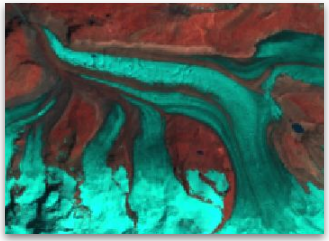
1. Convert to False Color



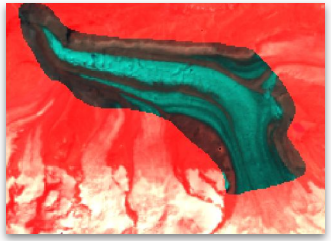


2. Crop and Align

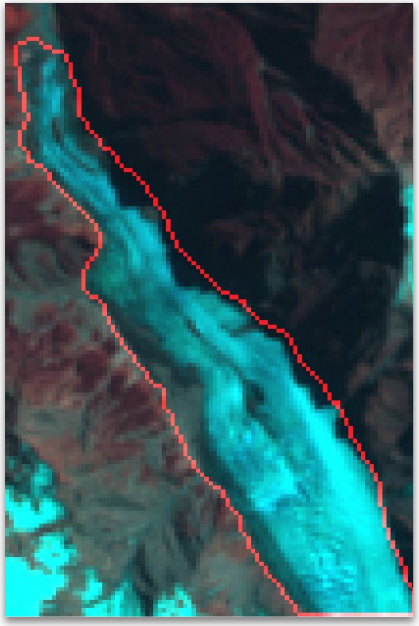




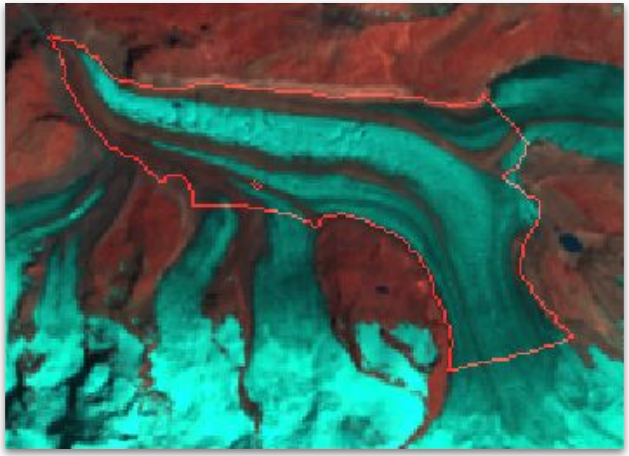
3. Mask



GLIMS Outline On Image



Franz Josef (Shadows within GLIMS)



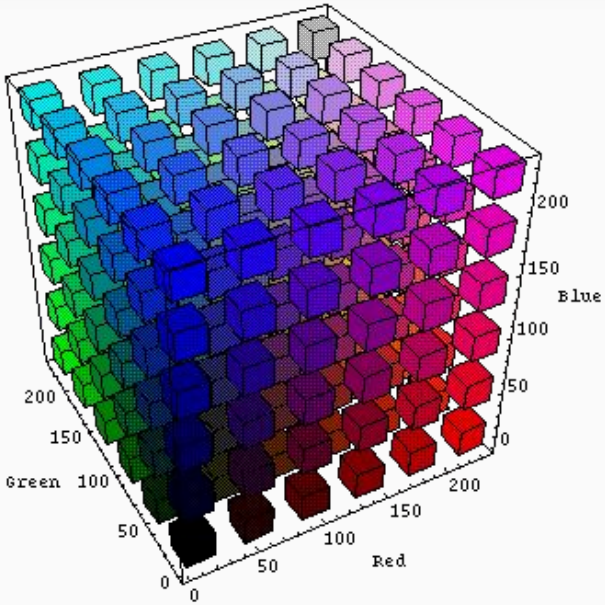
Gorner (Debris within GLIMS)

Image Processing

Gorner Glacier
https://cdn.pixabay.com/photo/2020/05/05/13/36/gorner-glacier-5133145___480.jpg

Image processing

- Pixel Values
- Equations/Functions
- MATLAB
- Color Spaces
- Binary Images



RGB Colorspace
https://engineering.purdue.edu/~abe305/HTMLS/rgbspace.htm

Image Processing

- Attempts
  - Edge Detection
  - Region Growing
  - Freehand Outline
- Drawbacks:
  - Manual
  - Inconsistent

Lowest Threshold

Highest Threshold

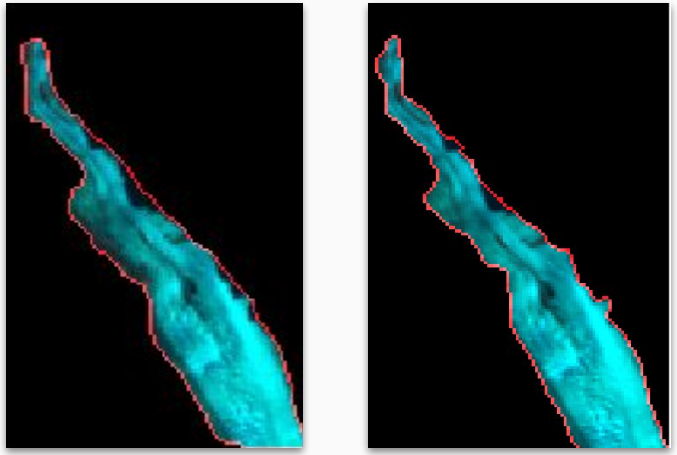
20 Iterations

40 Iterations

60 Iterations

Image Processing

- Attempts
  - Edge Detection
  - Region Growing
  - Freehand Outline
- Drawbacks:
  - Manual
  - Inconsistent



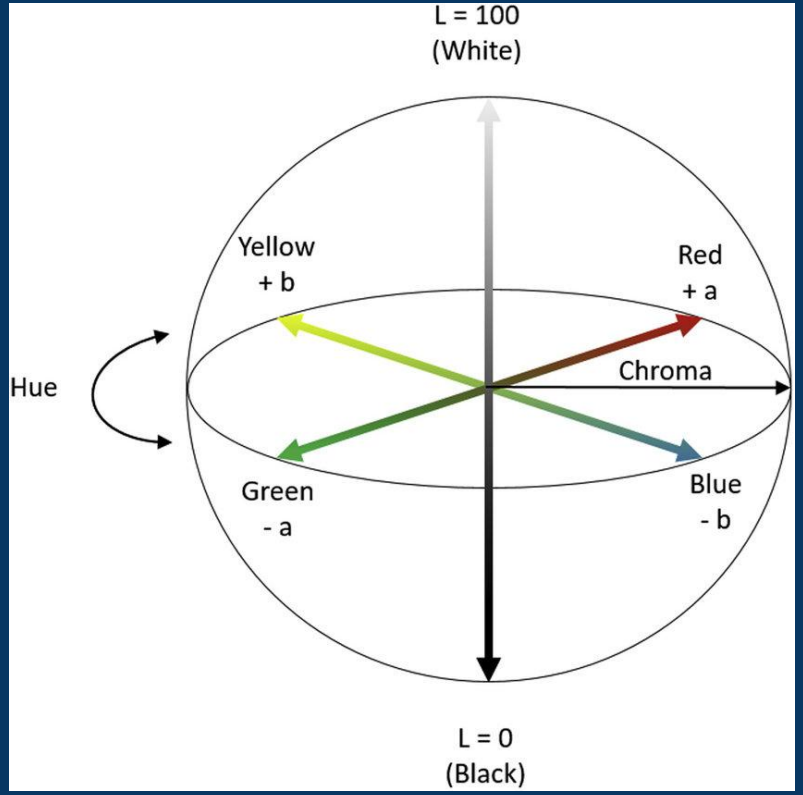
Hand-drawn Masks of Franz Josef

Final Method

L*a*b* Color Space

Franz Josef Glacier
https://www.getyourguide.com/franz-josef-glacier-ka-roimata-o-hine-hukatere-l93428/extreme-sports-adrenaline-tc85/

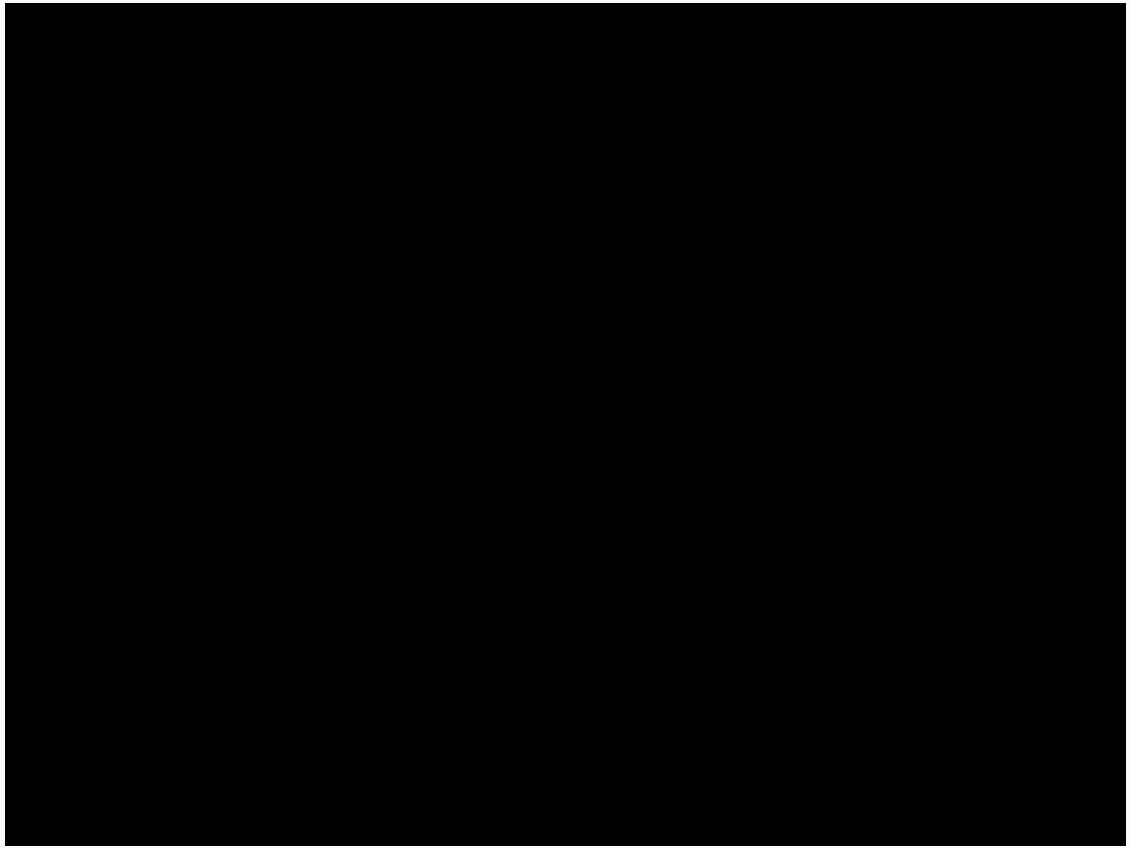
L*a*b* Color Space



L*a*b* Color Space Diagram [8]

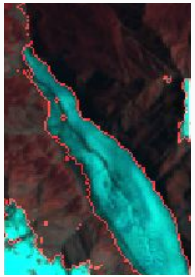
Methods (L*a*b* Color Space)

Step 1: Manual Threshold Adjustment

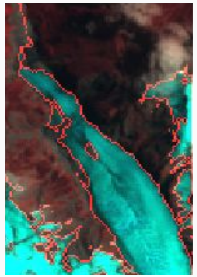


Same Threshold Over Time

Franz Josef
a* value = -7.501



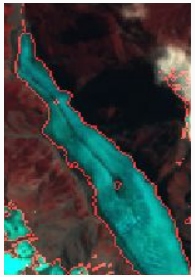
Jan 1990



Dec 2003

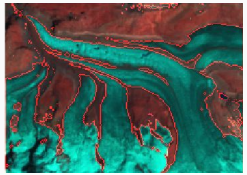
Feb 2007

Jan 2008

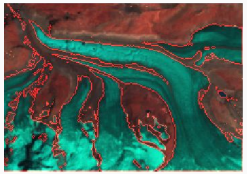


Jan 2010

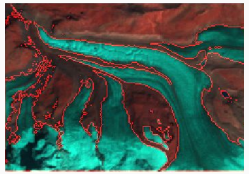
Gorner
a* value = 8.5150



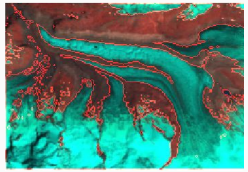
July 1990



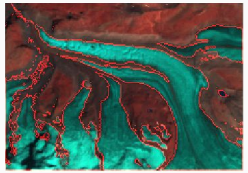
July 2003



Aug 2006



June 2008



July 2010

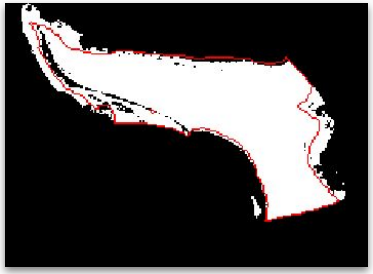
Methods (L*a*b* Color Space)

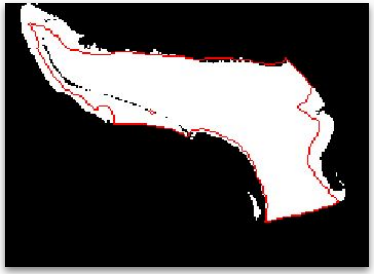
Step 2: Automatic a* Channel Threshold Iteration

Original Threshold Results

Segmentation Closest to GLIMS

Segmentation After Too Many Iterations

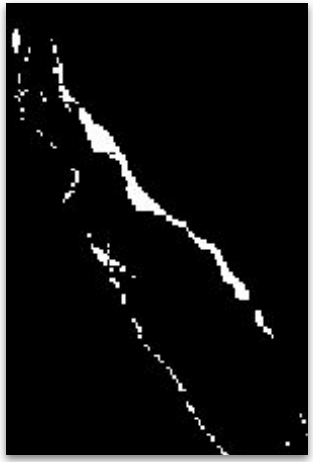




Methods (L*a*b* Color Space)

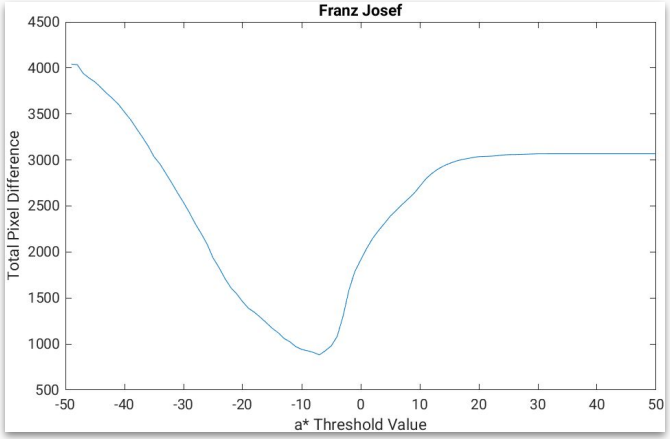
Step 2b: Selecting Minimum Error

Segmentation - GLIMS



GLIMS - Segmentation

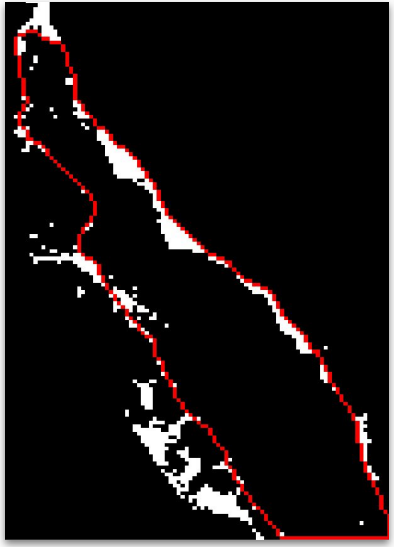
Total Error



Total Error vs Threshold Value

Results

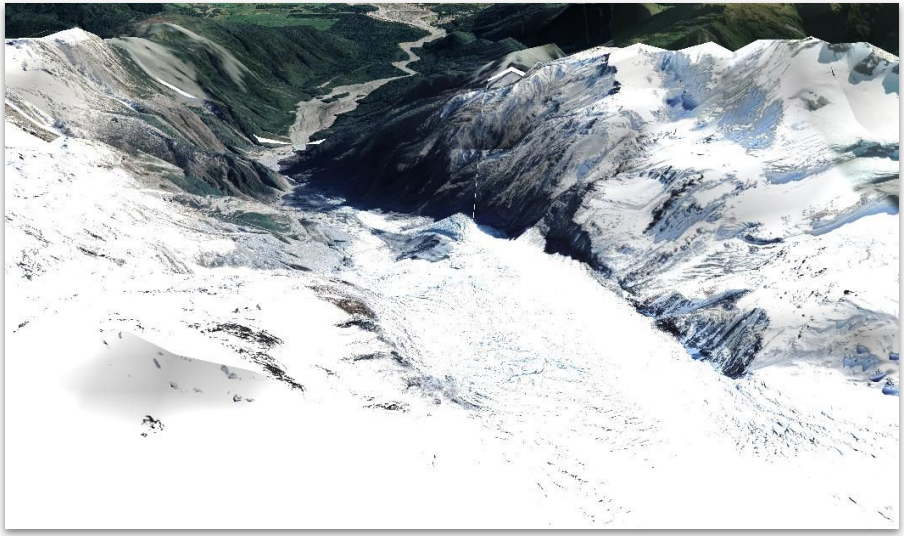
Franz Josef GLIMS Outline Over Error
(21.71% error)



Gorner GLIMS Outline Over Error
(19.87% error)

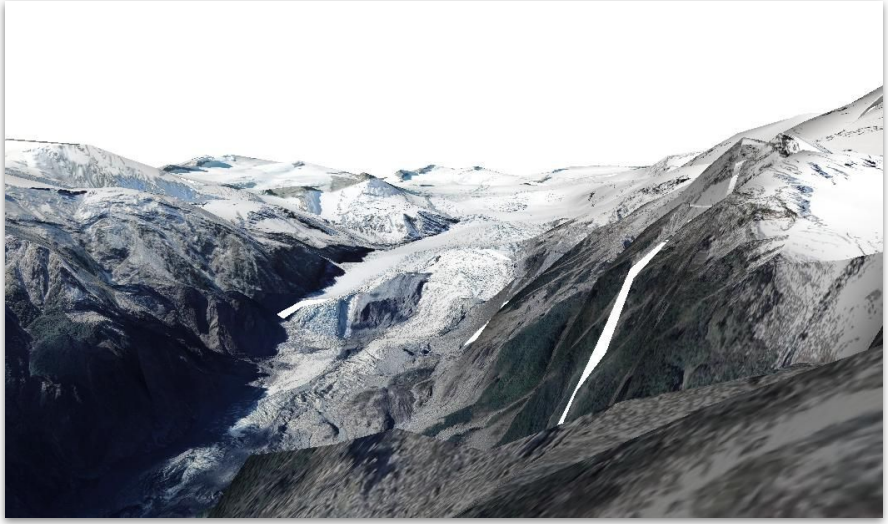
Conclusions

1. It is difficult to differentiate mountain and debris-covered ice.
2. Debris-covered glaciers require “more complex processing” [2].
3. L*a*b* segments visible ice well.



3D merge of Sentinel 2 images with DTED and GLIMS

Future Goals



3D merge of Sentinel 2 images with DTED and GLIMS

- Merge with DEMs
- Quantify error with respect to visible ice
- Apply best L*a*b* threshold to a collection of images

References

(1) Kachouie, N.N., et al. Localization of mountain glacier termini in Landsat multi-spectral images. Pattern Recognition Lett. (2012)

(2) Paul, F., Barrand, N., Baumann, S., Berthier, E., Bolch, T., Casey, K., . . . Winsvold, S. (2013). On the accuracy of glacier outlines derived from remote-sensing data. *Annals of Glaciology, 54*(63), 171-182. doi:10.3189/2013AoG63A296

(3) Bolch, Tobias; Kamp, Ulrich (2005). *Glacier mapping in high mountains using DEMs, Landsat and ASTER data.* In: 8 th International Symposium on High Mountain Remote Sensing Cartography, La Paz (Bolivien), 20 March 2005 - 27 March 2005. Karl-Franzens-Universität Graz, 37-48.

(4) GLIMS and NSIDC (2005, updated 2018): Global Land Ice Measurements from Space glacier database. Compiled and made available by the international GLIMS community and the National Snow and Ice Data Center, Boulder CO, U.S.A.

(5) U.S. Geological Survey, 2000, Landsat 4-5 Dataset, accessed June 29, 2022 at URL https://earthexplorer.usgs.gov/

(6) U.S. Geological Survey, 2001, Landsat 7 Dataset, accessed June 29, 2022 at URL https://earthexplorer.usgs.gov/

(7) Kutuzov, S., & Shahgedanova, M. (2009). Glacier retreat and climatic variability in the eastern Terskey–Alatoo, inner Tien Shan between the middle of the 19th century and beginning of the 21st century. *Global and Planetary Change*, *69*(1-2), 59-70.

(8) Ly, B., Dyer, E. B., Feig, J. L., Chien, A. L., & Del Bino, S. (2020). Research Techniques Made Simple: Cutaneous Colorimetry: A Reliable Technique for Objective Skin Color Measurement. *The Journal of investigative dermatology*, *140*(1), 3–12.e1. https://doi.org/10.1016/j.jid.2019.11.003

Thank You

Questions?