Mountain Glacier Segmentation Analysis

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Outline

- ➢ Introduction
- ➢ Data
- ➢ Trial Methods
- ➢ 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

Main Objective

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

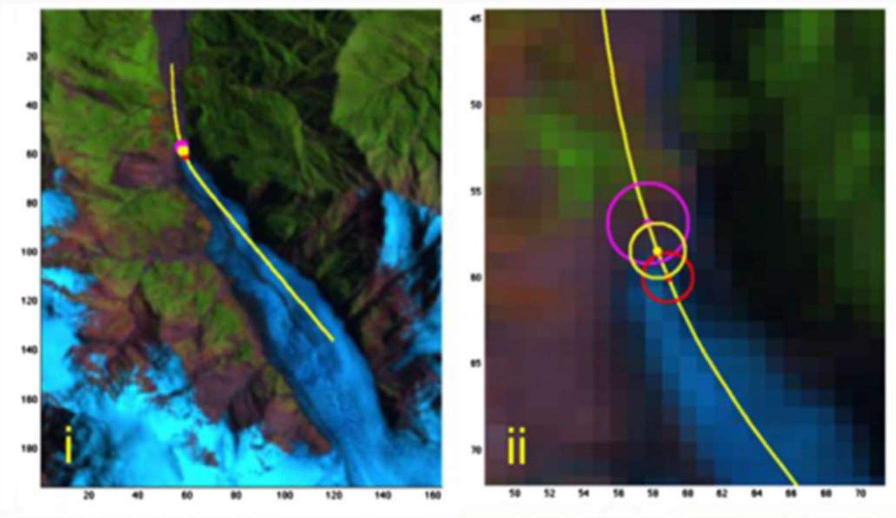
Relevant Literature

TAKEAWAYS:

- More automation needed
- 1-dimension is insufficient

Localization of mountain glacier termini in Landsat multi-spectral images [1]

- ➢ Terminus point measurement
  - Manual
    - Flow path
    - Inflection point
  - 1-Dimensional



Terminus Point Measurement

Relevant Literature

TAKEAWAYS:

- Debris is difficult to segment
- Manual cleaning needed

On the accuracy of glacier outlines derived from remote-sensing data [2]

➢ Accuracy measurement of ice segmentation using remote sensing
  - Debris-covered ice had up to 30% error
  - Manual adjustment needed

Manual Outlines of Guslarferner, Austrian Alps

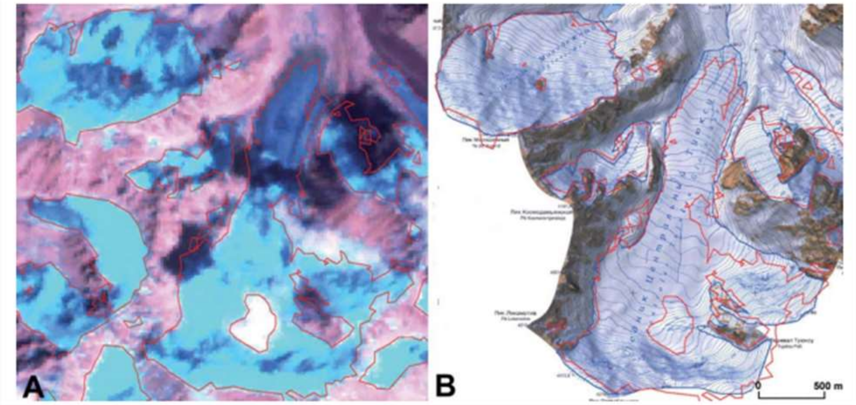
Relevant Literature

TAKEAWAYS:

- DEMS are more accurate than 2D models
- More computationally expensive

Glacier mapping in high mountains using DEMs, Landsat and ASTER data [3]

➢ Combination of satellite and Digital Elevation Models (DEMs)
    - Semi-automated method
    - DEMs increased accuracy
    - Dependent on resolution



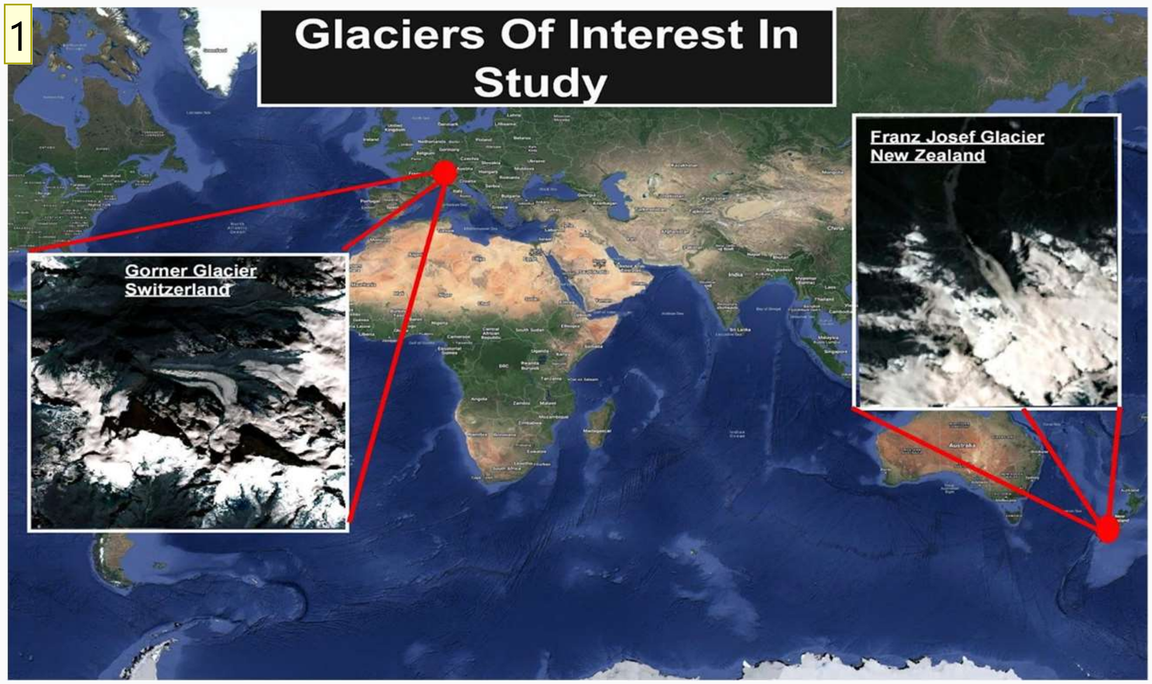
Landsat Segmentation vs Topographic Map

Data

Gorner Glacier
https://cdn.pixabay.com/photo/2020/05/05/13/36/gorner-glacier-5133145__480.jpg

Data

- Global Land Ice Measurements from Space (GLIMS) outlines from 2000 [4]



Slide 9

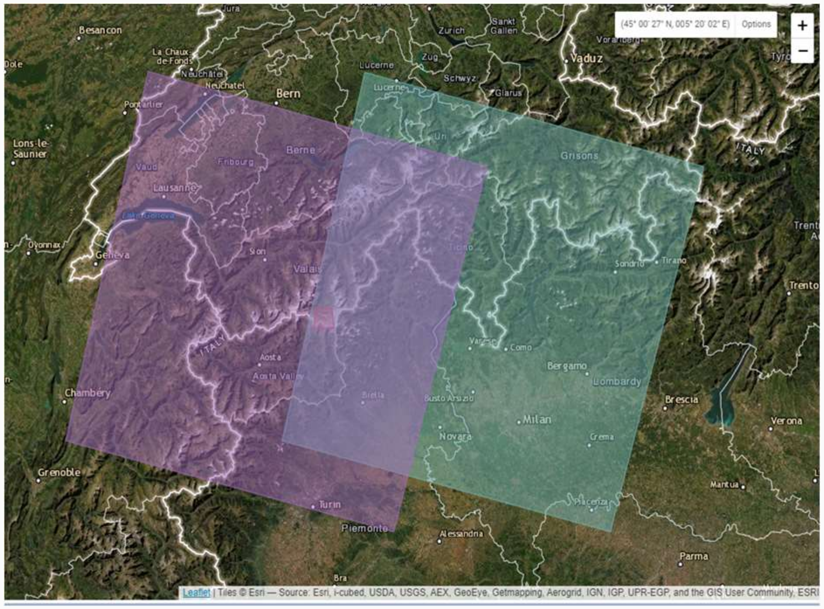
1 cite this?
Grace Stroh, 7/7/2022

Data

- ➢ Gorner: Landsat 4-5 image from 2000 [5]
- ➢ Franz Josef: Landsat 7 image from 2001 [6]

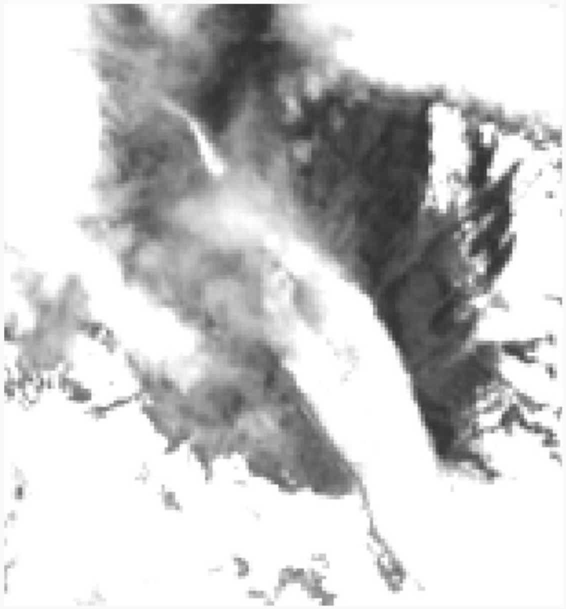
https://landsat.gsfc.nasa.gov/about/landsat-timeline/

Data Challenges



Different Paths and Alignments

Franz Josef with Shadows



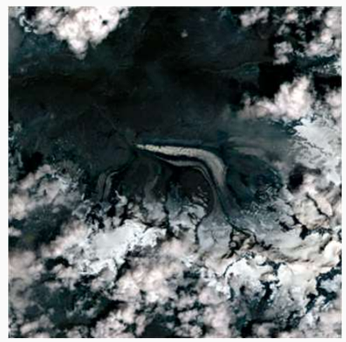
Franz Josef with Cloud Cover

Trial Methods

Gorner Glacier
https://cdn.pixabay.com/photo/2020/05/05/13/36/gorner-glacier-5133145__480.jpg

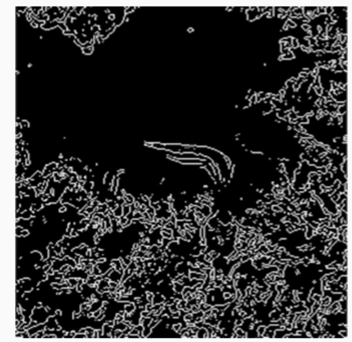
Trial Methods

- Edge Detection
  - Canny & Sobel
  - Threshold: minimum pixel gradient
- Drawbacks:
  - Manual
  - Inaccurate



Initial Image

Canny



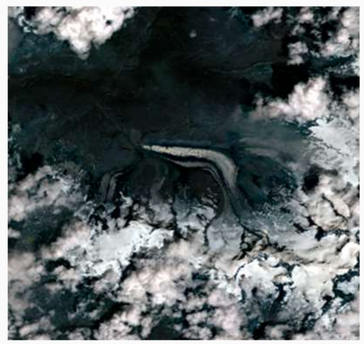
Sobel

Lowest Threshold

Highest Threshold

Trial Methods

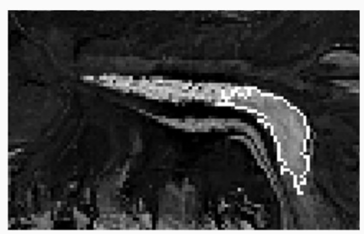
- Region Growing
  - Seed point
  - Mean-based
  - Threshold: number of iterations
- Drawbacks
  - Manual
  - Inconsistent



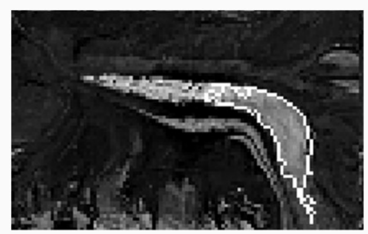
Initial Image

Bad Seed

Figure 52



20 Iterations

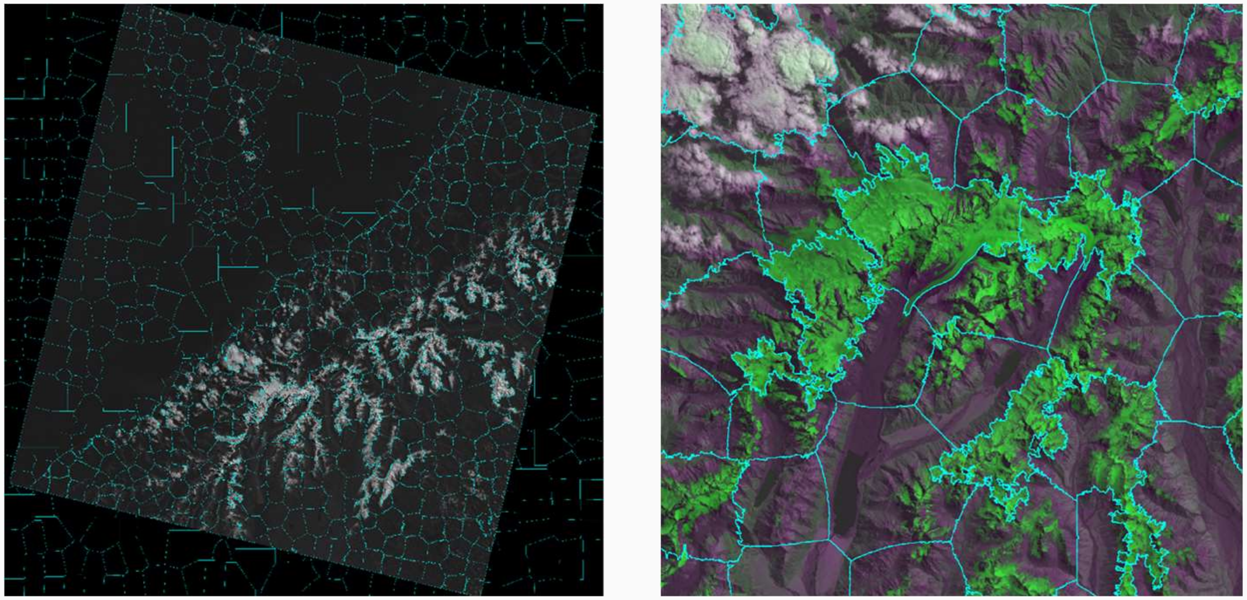


40 Iterations

60 Iterations

Trial Methods

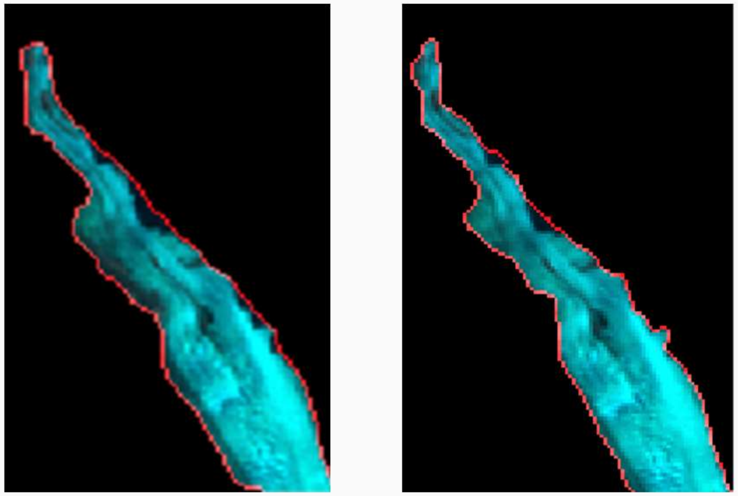
- ➢ Super Pixels
  - ○ Smallest unit
  - ○ Threshold: how many pixels
- ➢ Drawbacks
  - ○ Manual
  - ○ Inaccurate



800 Super Pixels Applied to New Zealand Scene

Trial Methods

- ➢ Freehand Drawing
  - Widely accepted as most accurate [7]
- ➢ Drawbacks
  - Manual
  - Internal variation (95 pixels, ~3000 pixels)



Hand-drawn Masks of Franz Josef

Final Method

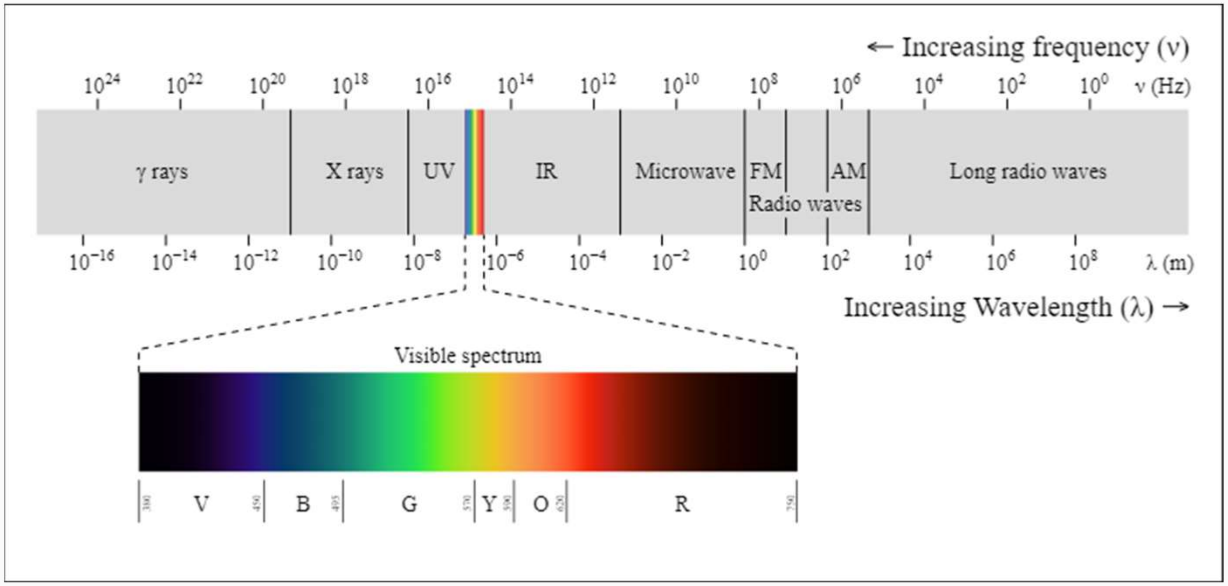
L*a*b* Color Space

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

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

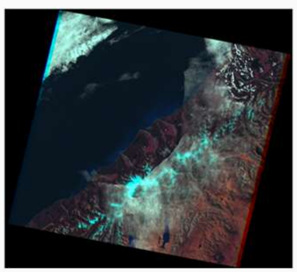
Landsat 4-5 and 7 Bands
https://www.usgs.gov/media/images/landsat-4-5-tm-and-landsat-7-etm-bands-and-their-uses

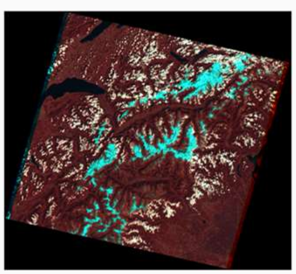


Electromagnetic Spectrum
https://commons.wikimedia.org/wiki/File:EM_spectrum.svg

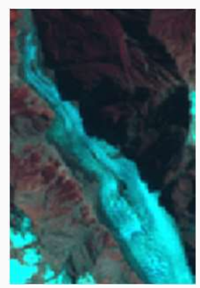
Methods (Pre-Processing Landsat)

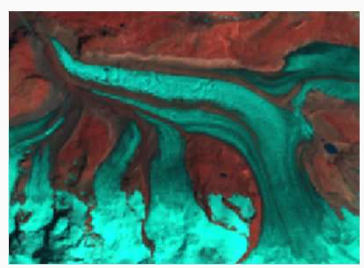
1. Convert to False Color



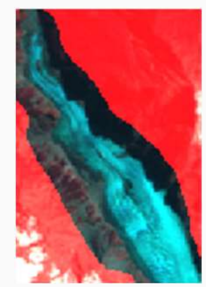


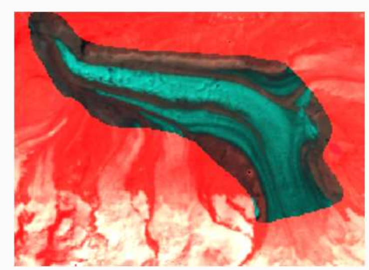
2. Crop and Align





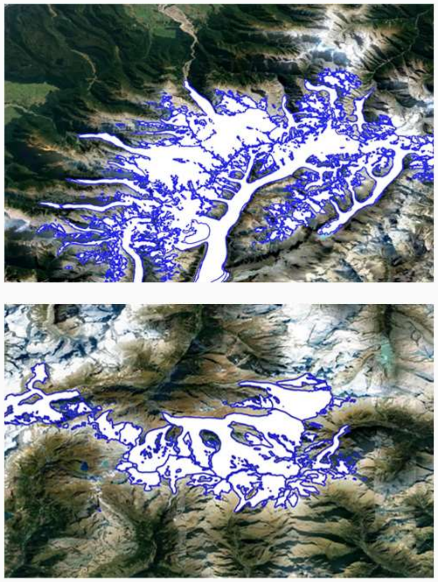
3. Mask





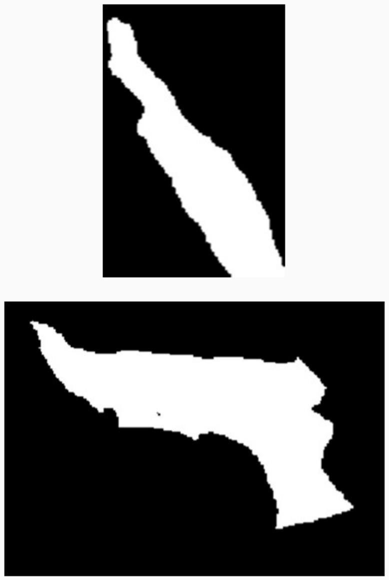
Methods (Pre-Processing GLIMS)

1. Georeference

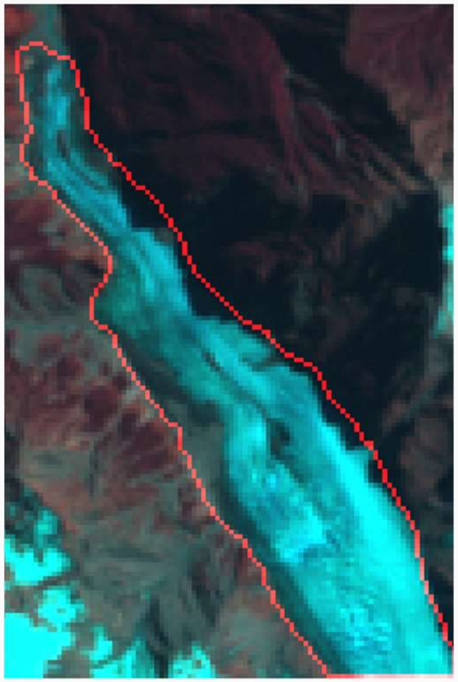


2. Crop and Align

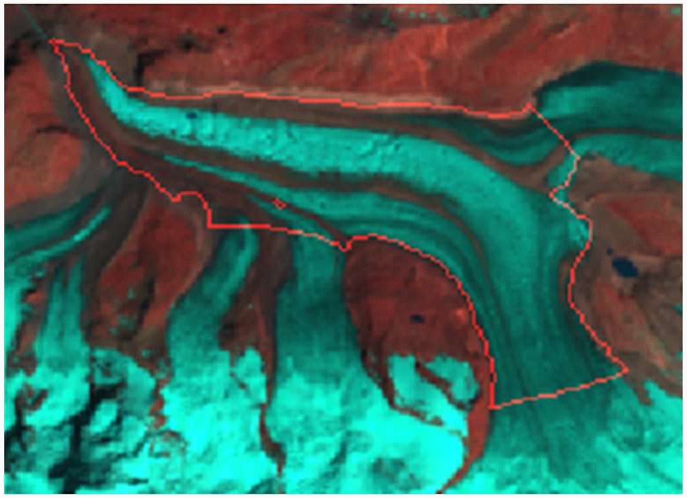
3. Mask



GLIMS Outline On Image

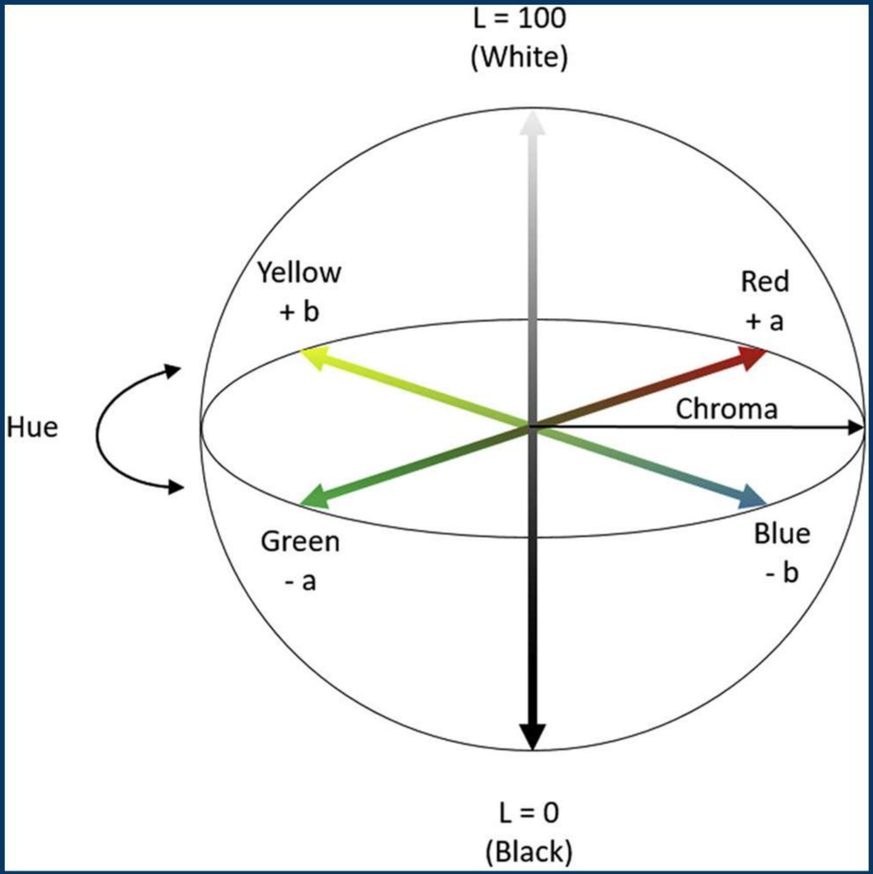


Franz Josef (Shadows within GLIMS)



Gorner (Debris within GLIMS)

L*a*b* Color Space



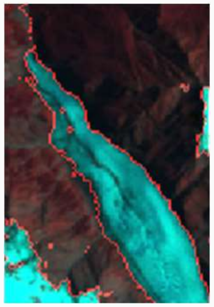
L*a*b* Color Space Diagram [8]

Methods (L*a*b* Color Space)

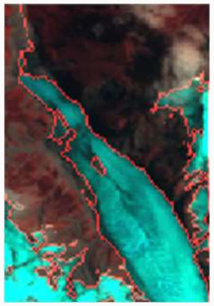
Step 1: Manual Threshold Adjustment

Same Threshold Over Time

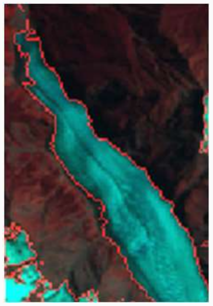
Franz Josef
a* value = -7.501



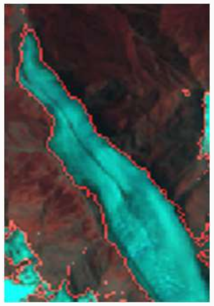
Jan 1990



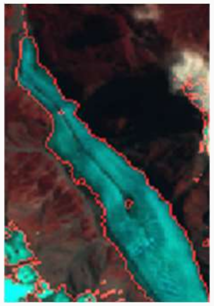
Dec 2003



Feb 2007

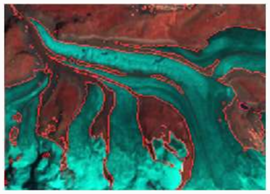


Jan 2008

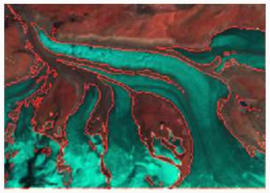


Jan 2010

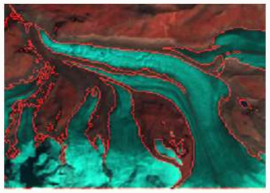
Gorner
a* value = 8.5150



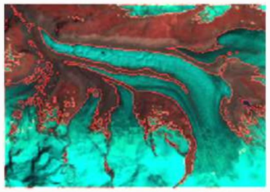
July 1990



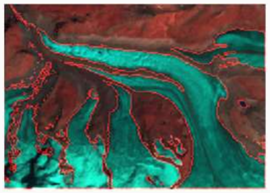
July 2003



Aug 2006



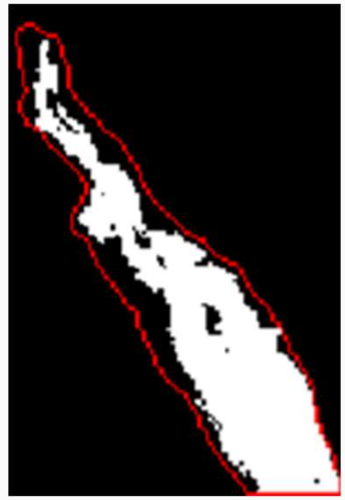
June 2008



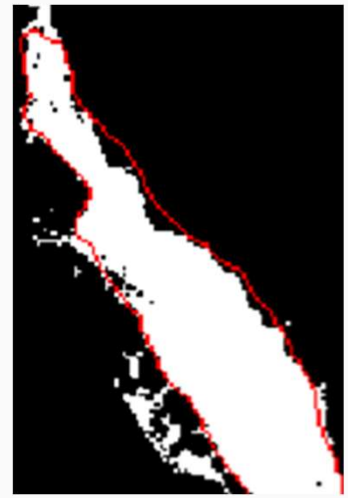
July 2010

Methods (L*a*b* Color Space)

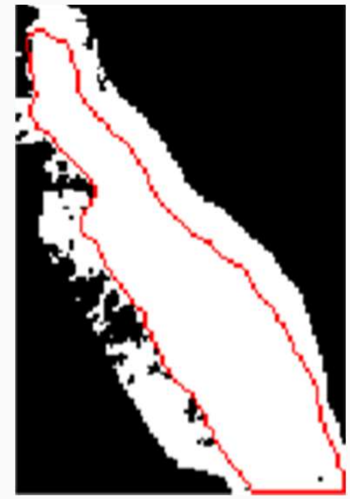
Step 2: Automatic a* Channel Threshold Iteration



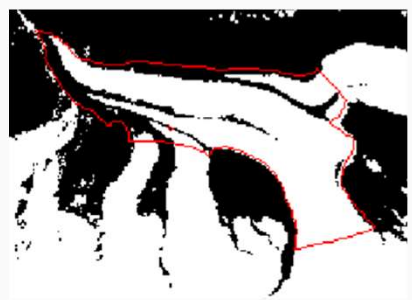
Original Threshold Results

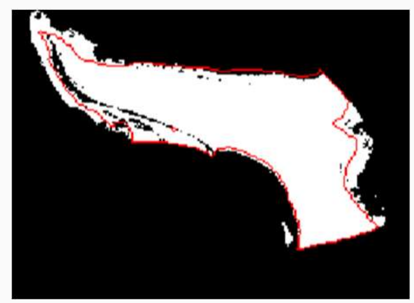


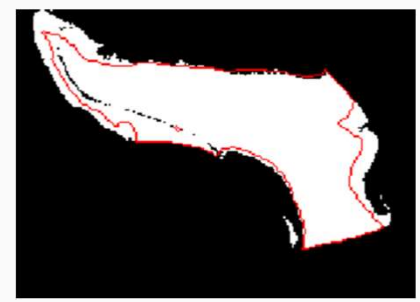
Segmentation Closest to GLIMS



Segmentation After Too Many Iterations







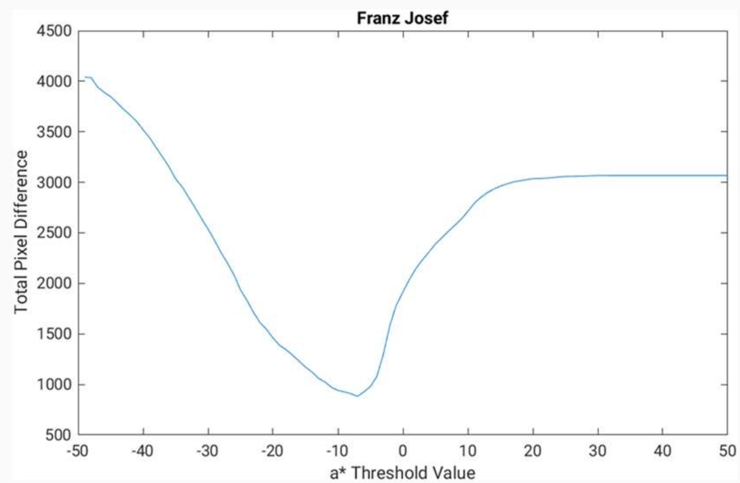
Methods (L*a*b* Color Space)

Step 2b: Selecting Minimum Error

Segmentation - GLIMS

GLIMS - Segmentation

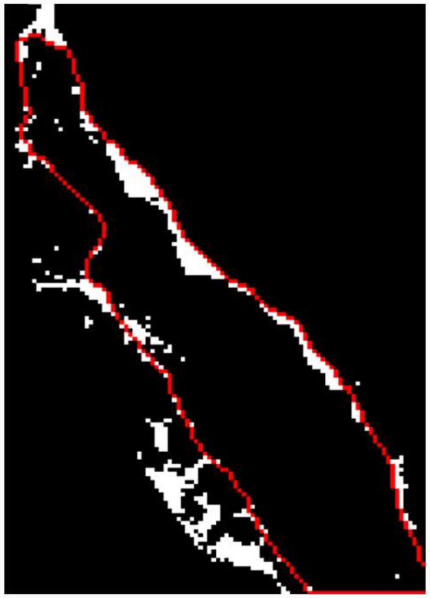
Total Error



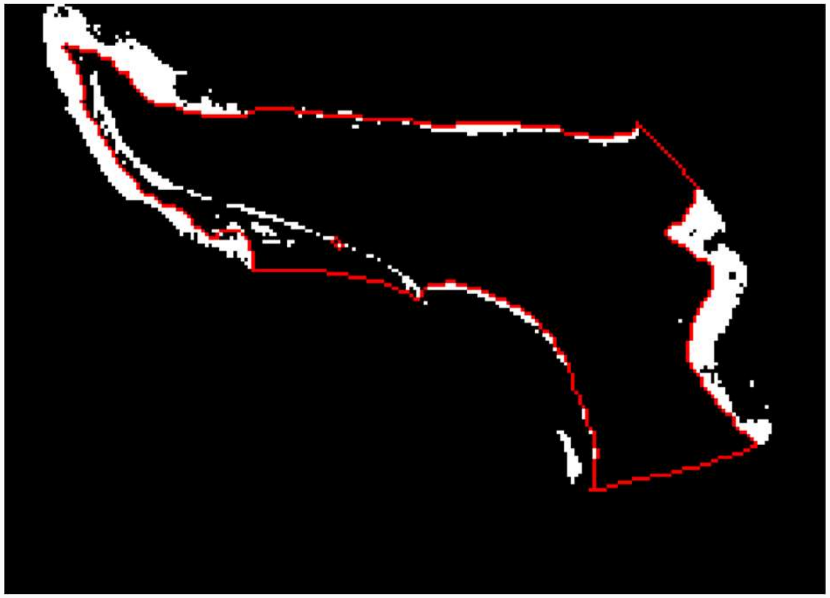
Total Error vs Threshold Value

Results

Franz Josef GLIMS Outline Over Error
(21.71% error)

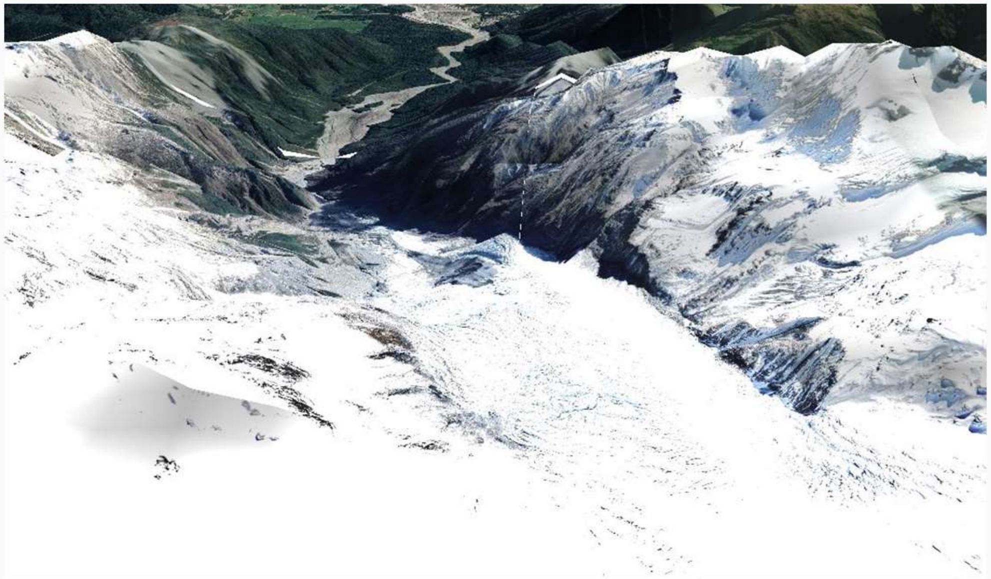


Gorner GLIMS Outline Over Error
(19.87% error)



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?