GRID-ML: Multi-Altitudinal Analysis of Remote Sensed Greenland Ice Sheet

Data Science Institute
Columbia University

Team: Braden Huffman, Devan Samant, Hugo Ginoux, Samuel Fields, Sushant Prabhu
Sponsor: Dr. Marco Tedesco | **Mentors:** Dr. Adam Kelleher, Rufina George

Columbia Climate School
Lamont-Doherty Earth Observatory

1 Introduction

The **Greenland ice sheet (GrIS)**, covers **1.7 million square km** with enough water to raise global sea levels by **7 meters**, is critical to Earth's climate and sea level dynamics. Recent **changes in its albedo** have raised concerns about its future stability and contributions to sea-level rise. Utilizing multispectral drone images, our research explores the GrIS to enhance understanding of climate change and sea level rise predictions.

2 Drone Expedition on Greenland

A drone was flown over the GrIS at different altitudes (300 ± 100 feet). Flying at low altitude is longer and more expensive, but provides more detailed images. The goal of this study is to **quantify the loss of information in relation to method sensitivity** between these different heights.

DJI Mavic 3M Drone
(Green,Red,Red Edge, Near Infrared)

3 Methods

Orthorectification

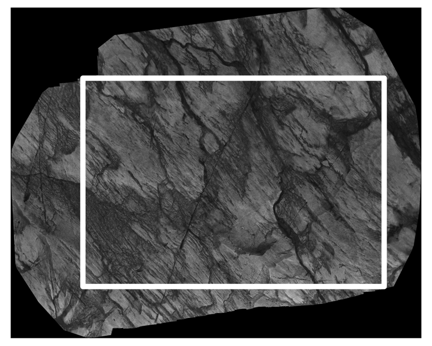
Images with overlap needed to be **stitched together** to form a mosaic. This process also corrected for positional differences of the drone cameras, removing distortions of the terrain.

Albedo Correction

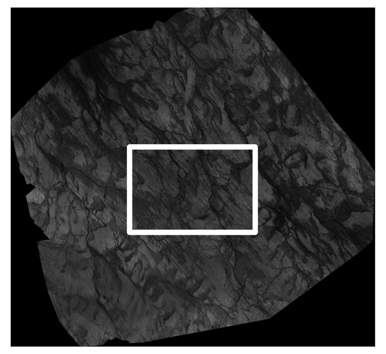
Original images do not factor incoming sunlight and each band is unscaled so commercial software, Pix4D, helped calibrate and **convert pixel values to albedo**, the percentage of light reflected.

Boxed Area

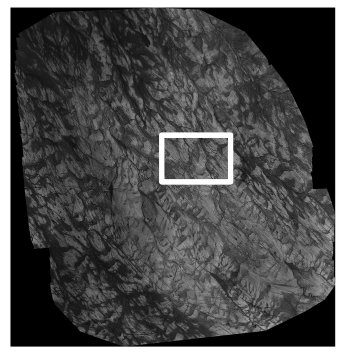
To standardize drone flight paths, we matched a **common area** to analyze among altitudes.



Low Altitude (NIR channel)



Medium Altitude (NIR channel)



Top Altitude (NIR channel)

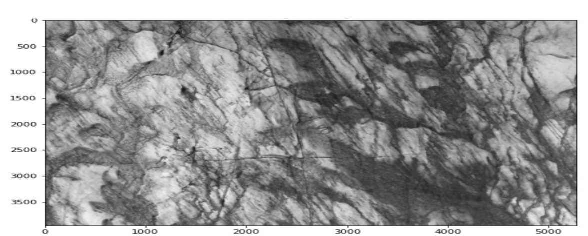
4a 2D Differential Entropy

Gradient image:

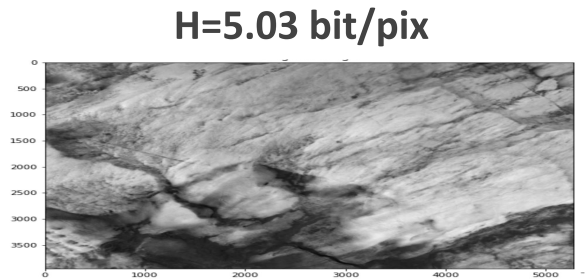
$$\nabla f(i,j) = (f(i+1,j) - f(i,j), f(i,j+1) - f(i,j))$$

Entropy: $H(\nabla f) = \sum_i p_i \log(1/p_i))$

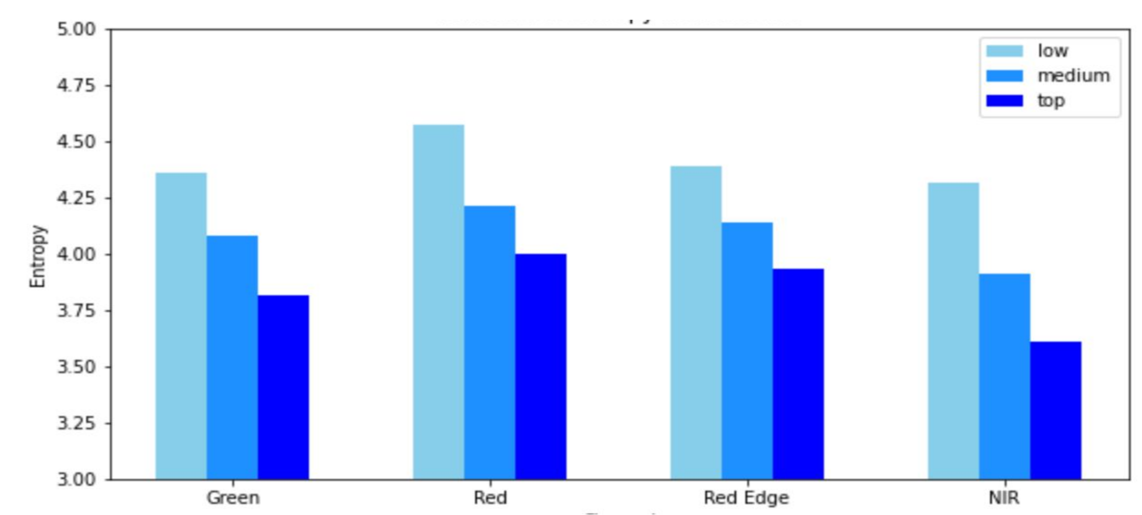
Increasing altitude generated a loss of ~**0.25 bit/pixel** for each channel, although NIR seems more sensitive (0.35).



H=5.03 bit/pix



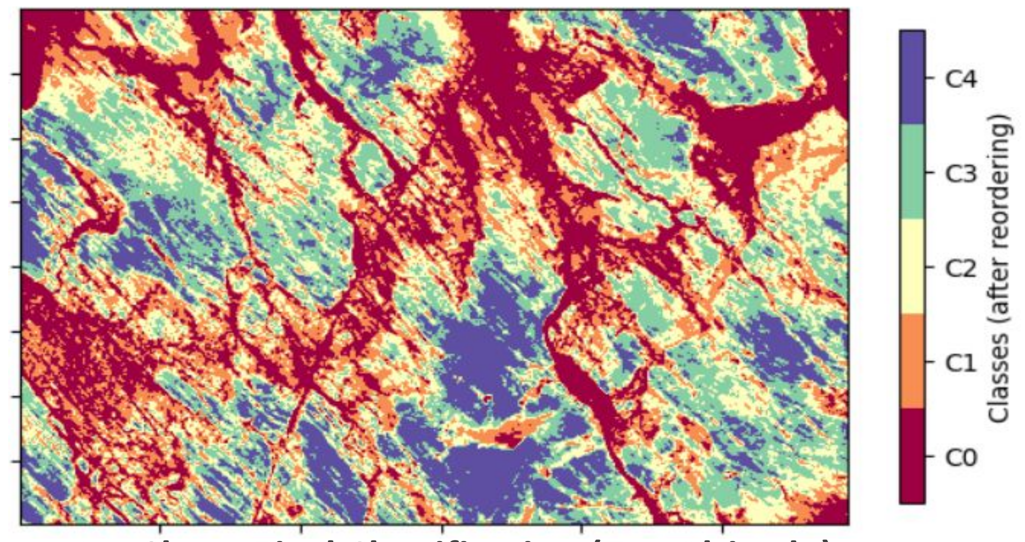
H=4.70 bit/pix



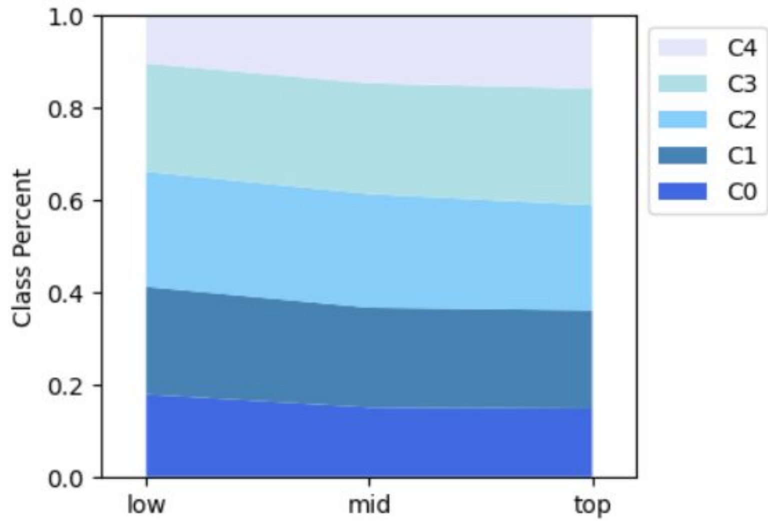
Variation of Entropy with Altitude

4b Multispectral K-Means Clustering

Though centroids differ with altitude, pixel **classifications remained relatively constant** with slight differences for very bright ice area (5.5% classification difference) indicating albedos appear larger at top remote sensing elevations.



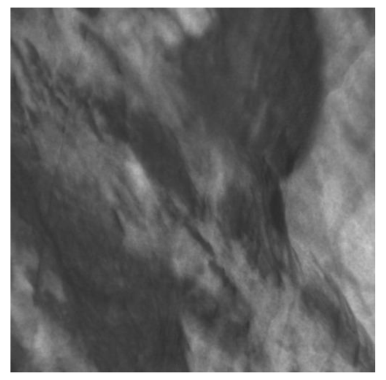
Ice Sheet Pixel Classification (Top Altitude)



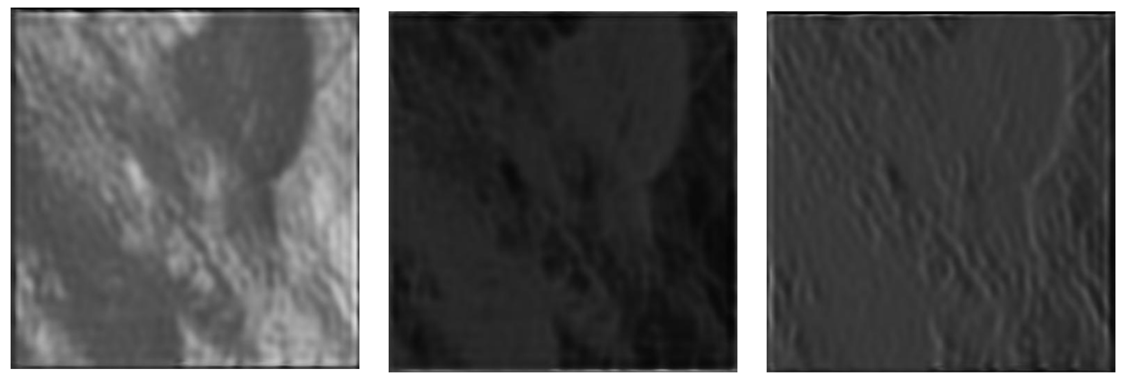
Comparison of Clustering Breakdowns

4c Deep CNN (W-Net)

In order to find underlying patterns in the data we used a deep CNN with two main outputs, **pattern detection, and image reconstruction**. The pattern detection layer eventually feeds into the image reconstruction layer, providing insight about the difference between the multispectral channels of the original image.



Original (NIR channel)



Reconstructed Pattern Channels

5 Conclusion and Future Work

Our **multi-altitudinal analysis** shows entropy loss of **0.5 bit / pixel** in a **200 foot altitude increase**, and we observe k-mean clustering differences of **at most 5.5% pixels per class** from the same altitude change. CNN reconstruction error between the top altitude and medium altitude when trained on the low altitude **was negligible**. Overall, surveying larger areas from greater heights leads to only slight difference in outcomes in our performed tasks. However, further research is needed to confirm whether this relationship remains consistent beyond the range of altitudes tested.

Tedesco, M. et al.: The darkening of the Greenland ice sheet: trends, drivers, and projections (1981–2100), The Cryosphere, 10, 477–496, https://doi.org/10.5194/tc-10-477-2016, 2016.
Xia, Xide, and Brian Kulis. "W-net: A deep model for fully unsupervised image segmentation." arXiv preprint arXiv:1711.08506 (2017).