Iceberg Detection Using SAR Data

Antarctica

Autumn 2023

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Acknowledgments

We express our heartfelt gratitude to Professor Gulab Singh for affording us the invaluable opportunity to undertake this project as an integral component of the GNR642 course on Scattering Models in Microwave Remote Sensing. We extend our sincere appreciation to our dedicated Teaching Assistants for their unwavering support and invaluable guidance throughout the project.

Contents

1 Introduction

We directed our focus towards several key regions in close proximity to Antarctica, namely the **Rose Sea, Drake Passage, Bellingshausen Sea, and Ross Island**. To comprehensively analyze the movement of icebergs in these areas, we employed Sentinel-1 data for **Iceberg A-74** collected over the timeframe spanning from May 2021 to September 2021.

Leveraging this valuable dataset, we conducted a examination of icebergs, resorting to pixel-wise classification to discern their presence. Our pursuit of precision led us to adopt an unsupervised classification approach, specifically the **K-means clustering** method, enabling us to effectively and accurately identify these formidable ice formations within the vast and complex polar environments.

2 Icebergs

Icebergs are a distinctive natural phenomenon, are characterized as floating masses of **freshwater ice** that have broken free from the seaward end of either a **glacier** or an **ice shelf**. These formidable ice formations are not confined to a single locale, rather, they can be found in various regions, including the oceans surrounding **Antarctica**, the seas of the **Arctic** and **subarctic, Arctic fjords**, and even in lakes nourished by glacier meltwater. Notably, icebergs exhibit a remarkable diversity in terms of shape and size, with each one presenting a unique profile.

In recent history, one of the most renowned icebergs, **B-15**, made its appearance, having calved from the Ross Ice Shelf in Antarctica. This colossal iceberg commanded attention with its immense scale, boasting an estimated area of around **12,000** square kilometers, an iconic representation of the sheer magnitude of these natural wonders.

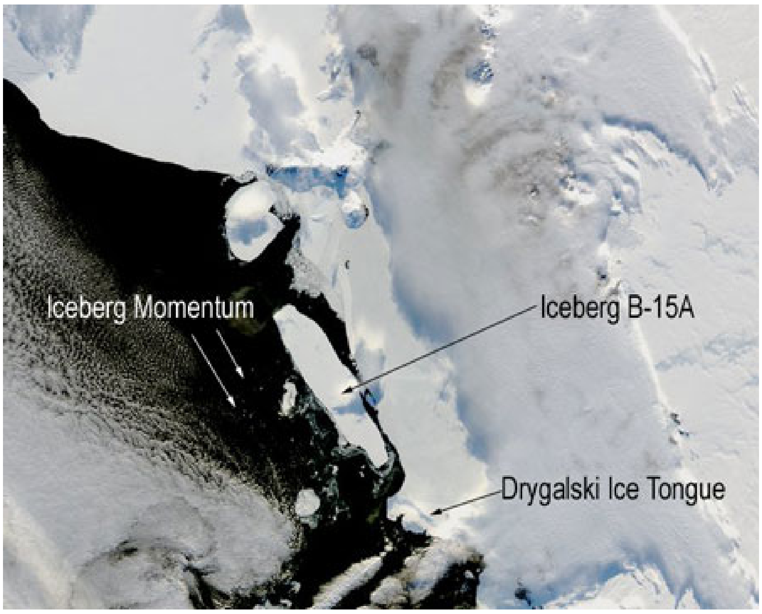


Figure 1: Iceberg B-15

3 Literature Review

V. Akbari and C. Brekke, "Iceberg detection in open water and sea ice using C-band radar polarimetry," 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Fort Worth, TX, USA, 2017, pp. 2298-2301, doi: 10.1109/IGARSS.2017.8127449.

Synthetic aperture radar (SAR) is a valuable tool for detecting and monitoring icebergs in the polar regions. The paper proposes a segmentation-based detection algorithm that uses SAR data to identify icebergs. The algorithm first segments the SAR image into clusters with high and low intensities. Then, it uses the clustering results to select the clusters that correspond to icebergs.

4 Importance

Icebergs play a significant role as a source of fresh water into polar oceans, conveyor of terrigenous minerals from land to ocean or habitats for organisms above and below the sea. Hence, the discharge, melting, and drift of icebergs have large impact on **global atmosphere, ocean, and ecosystems**. In addition, since most of an iceberg sits below the water surface, the trajectories of iceberg movements are important indicators of ocean currents. Monitoring the drifting icebergs is also important because icebergs pose threats to **navigation safety**.

Due to such importance of monitoring iceberg behavior, There exists a compelling necessity to develop **automated detection techniques** employing advanced technologies such as **satellite imagery, radar systems, and machine learning algorithms**.

5 Objective

Our project has a clear focus on three core objectives. Firstly, we're developing algorithms to enhance iceberg detection efficiency, ensuring accurate and speedy identification. Secondly, we're delving into iceberg movements to understand their behavior under different oceanic conditions. Lastly, we aim to facilitate research by providing a valuable repository of iceberg detection images to explore the history of iceberg movements.

6 Methodology

Image segmentation is a powerful technique used to separate an image into distinct regions or objects. In the context of analyzing the formation of icebergs, image segmentation can be utilized to delineate different parts of an iceberg, such as the top, bottom, and edges.

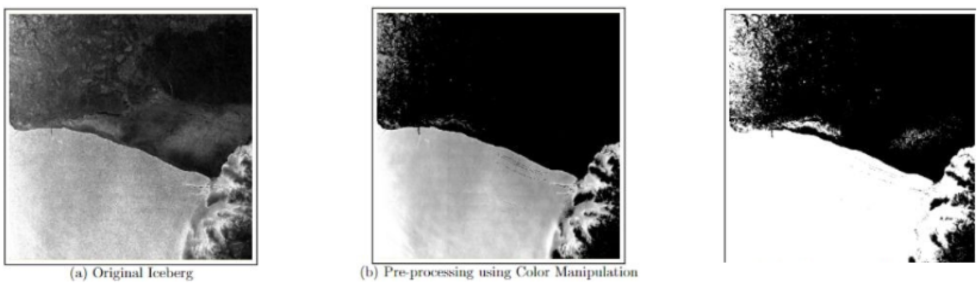


Figure 2

This information can then be used to calculate important physical parameters of the iceberg, such as its volume and surface area, which are crucial for understanding its behavior in the surrounding environment.

Additionally, image segmentation can be used to detect features such as cracks and fissures in the ice, which can provide insight into the mechanisms behind iceberg formation and breakup.

In our analysis of Sentinel-1 SAR data, we follow a two-step process. First, we preprocess the data using SNAP. Then, we use the K Means Clustering algorithm for final iceberg classification. This method helps us categorize icebergs within the data.

7 Preprocessing by SNAP

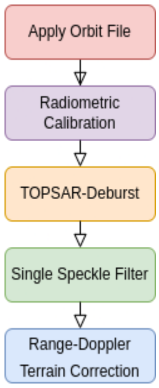


Figure 3: Preprocessing

1. **Apply Orbit**: FileIncorporate precise satellite orbit information, ensuring precise georeferencing for data.
2. **Radiometric Calibration**: Conversion to calibrated radar backscatter values.
3. **TOPSAR-Deburst**: Ensures coherent combination of radar bursts in TOPSAR mode, minimizing phase inconsistencies and enhancing data quality.
4. **Single Speckle Filter**: Reduce speckle noise and enhances data quality.
5. **Range-Doppler Terrain Correction**: Corrects distortions caused by varied topography and enhances quantitative analysis reliability

8 K-Means Clustering

K-Means clustering, an essential **unsupervised** machine learning algorithm, excels in grouping similar data points into 'k' clusters based on their shared attributes. This algorithm finds wide-ranging applications, including image segmentation, image compression, and anomaly detection, where it identifies patterns without prior group knowledge.

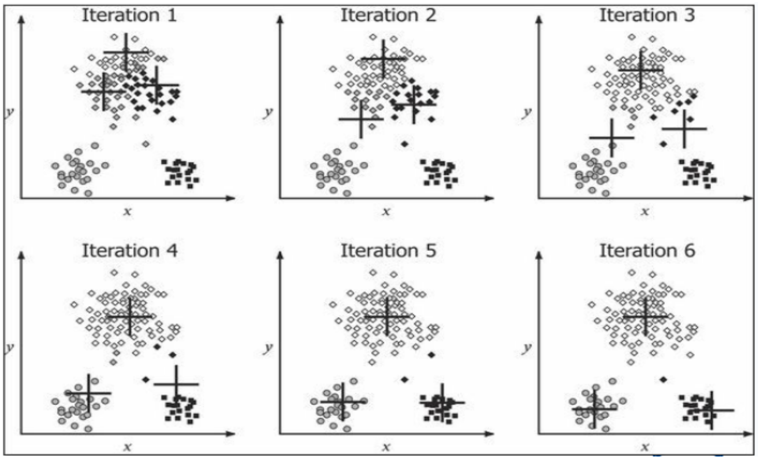


Figure 4: K-means Algorithm at different iterations

What sets K-Means apart is its computational efficiency, enabling it to handle large datasets effectively. This efficiency, combined with its simplicity and adaptability, has solidified K-Means as a preferred choice in various fields, encompassing data analysis and image segmentation. Its ability to uncover hidden structures within extensive datasets renders it an indispensable tool for exploring complex data relationships.

In the above figure we have shown how cluster centre updates at each iteration and finally changes the to optimal value. Number of cluster is a hyperparameter. The above algorithm can be used to cluster points into categories like ice, water etc. once we know the centre of the features of the clusters.

9 Results

9.1 Rose Island, Antarctica

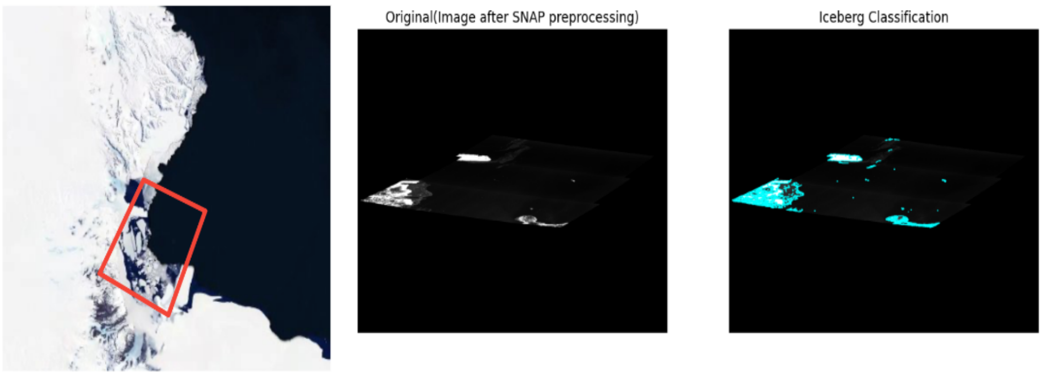


Figure 5

9.2 Rose Sea, Antarctica

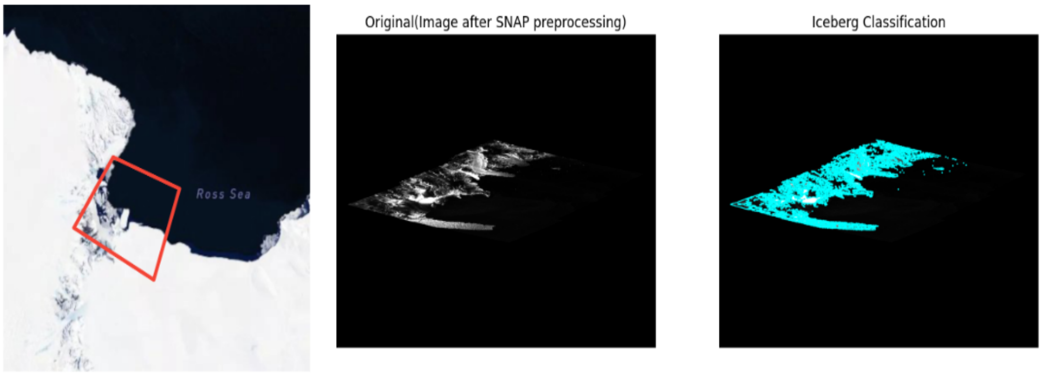


Figure 6

9.3 Drake Passage, Antarctica

Figure 7

9.4 Bellingshausen Sea, Antarctica

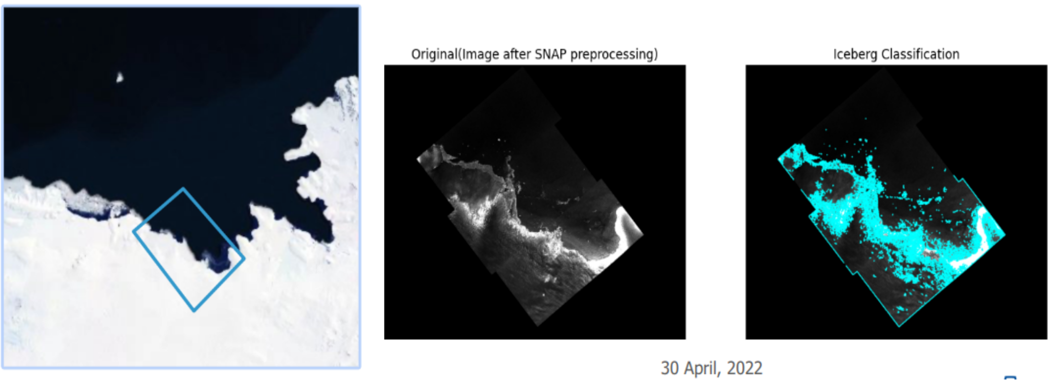


Figure 8

9.5 Iceberg A-74

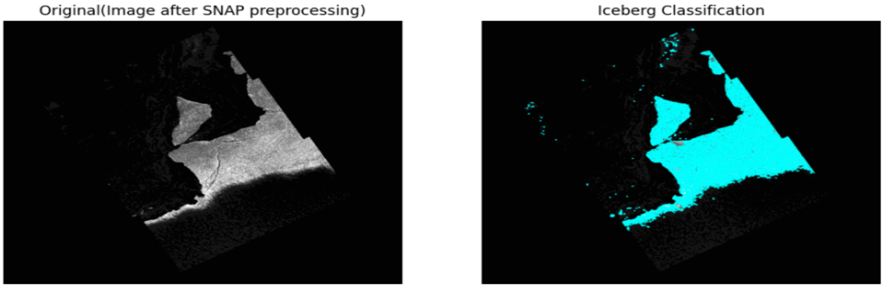
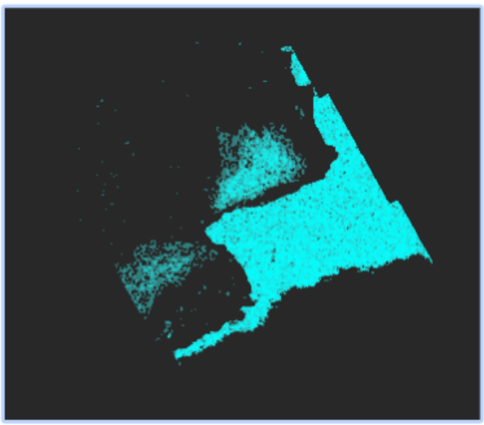


Figure 9

Iceberg A-74 is an iceberg that calved from the north side of the Antarctic Brunt Ice Shelf in February 2021. The iceberg measured 1,270 square kilometres (490 sq mi) soon after calving. We analysed its movement using data of 4 months starting from May 2021 to September 2021.

Date(Start)	Date(End)	Distance Covered(n mi)	Average Speed(n mi/day)
05 May 2021	17 May 2021	3.4	0.3
17 May 2021	29 May 2021	2.2	0.2
29 May 2021	10 June 2021	1.2	0.1
10 June 2021	22 June 2021	1.8	0.15
22 June 2021	04 July 2021	4.6	0.4
04 July 2021	16 July 2021	1.7	0.15
16 July 2021	28 July 2021	3.6	0.3
28 July 2021	09 Aug 2021	6.2	0.5
09 Aug 2021	21 Aug 2021	39.2	3.26
21 Aug 2021	02 Sept 2021	11.1	0.92
02 Sept 2021	14 Sept 2021	3.5	0.3

Average Speed (between May 2021 and Sept 2021)	1.06



Path traced by Iceberg

10 Further discussion

Iceberg calving: The process of chunks of ice breaking off from the tip of a glacier or ice sheet is known as iceberg calving. The causes of iceberg calving, such as ocean temperature and glacial melt rates, could be further studied.

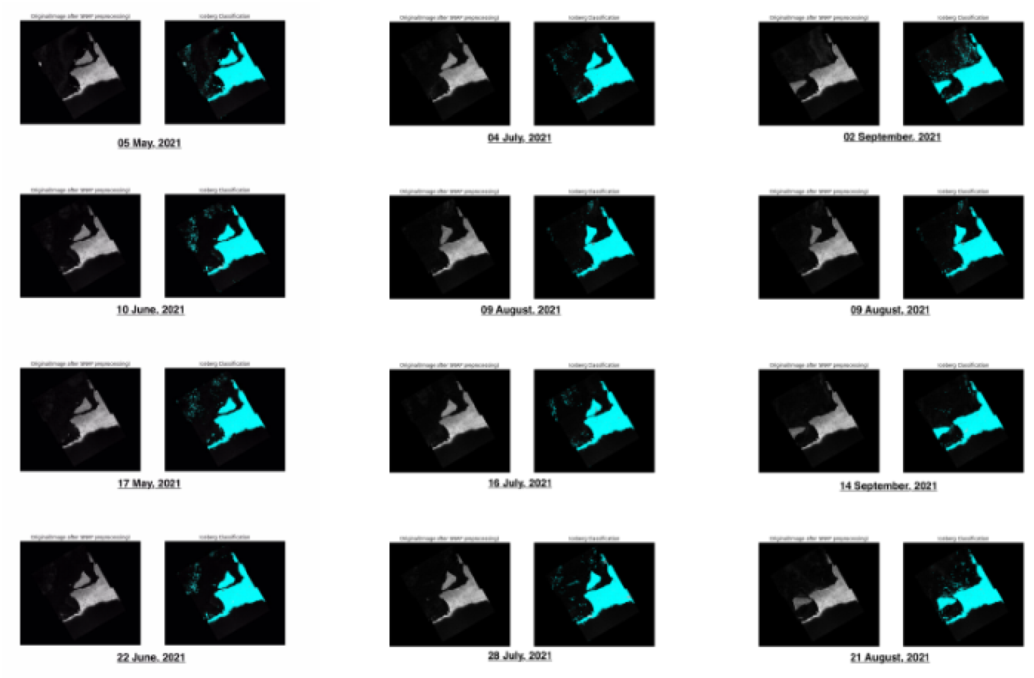
Iceberg trajectory forecasting: Iceberg movement forecasting is essential for offshore buildings and shipping. The use of machine learning and other cutting-edge modelling methods to accurately predict iceberg trajectories could be explored in further study.

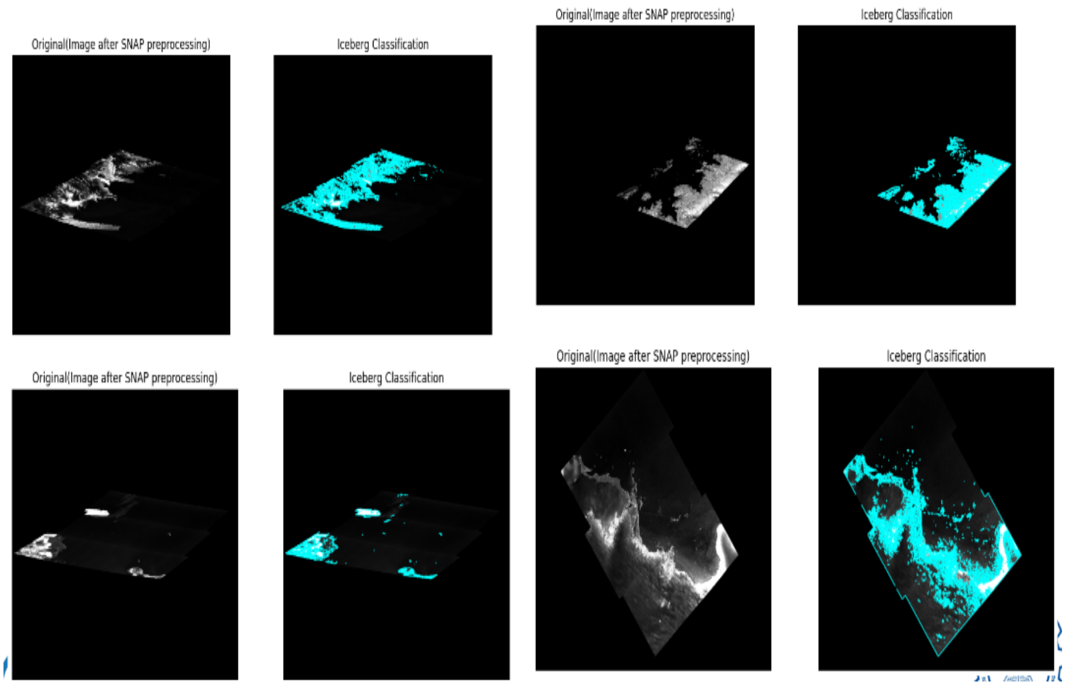
Economic effects: The shipping and offshore sectors may be significantly impacted by icebergs that are drifting. The possible economic costs and benefits of various mitigation strategies for iceberg-related incidents could be examined in more detail.

11 Conclusion

Our analysis of iceberg detection and movement using machine learning algorithms has yielded promising results, particularly in the prediction of the trajectories of these floating hazards. This achievement carries significant practical implications, notably for the realms of shipping and offshore operations. It also contributes to a deeper comprehension of and enhanced mitigation strategies for the impact of climate change on polar regions. Looking ahead, there is potential for further development in this technology, which could enhance our ability to forecast iceberg movements with greater precision. This, in turn, holds the promise of reducing risks and bolstering safety measures in these critical regions.

12 Appendix





13 Sources

- SNAP and Sentinel Toolboxes
- ASF Data Search (alaska.edu)