Tracking Iceberg Life Cycles Through Satellite Images

Eliana Gonzalez

Hosts: Alex Huth, Olga Sergienko, Nicole Schlegel

Summary

I developed a method to calculate iceberg areas in the Antarctic using masks of their contours and individual pixel calculation. Paired with imagery downloads, this is an automated process. This allows for more complete tracking of iceberg life cycles including their break-up events while providing a proxy for their melt. This currently works most effectively with MODIS satellite imagery from NASA and the BYU iceberg statistical dataset. Possible future work includes refining the contour selection process and incorporating satellite altimetry to transition from a proxy of melt to a real calculation of melt produced by icebergs.

Introduction

Icebergs account for much of the loss of the Antarctic ice sheet through calving. These icebergs can bring nutrients to the nutrient-poor Antarctic region through their melt as they move from the ice sheet into the Southern Ocean. This input of nutrients allows for phytoplankton blooms, but it also has major impacts on the physical ocean. The addition of freshwater, which is held by the icebergs and released through melt, changes the water column's salinity, and consequently the halocline of the ocean. This affects the ocean circulation and the transportation of nutrients. Monitoring the amount of freshwater input from icebergs is vital as oceans warm, and icebergs contribute an increasing amount of freshwater to the Ocean.

Brigham Young University (BYU) currently offers a set of observational data, tracking the locations of various large icebergs in the Antarctic. The National Ice Center (NIC) also offers observational data. Using the BYU dataset in conjunction with the satellite imagery used to track their locations can provide more insight into the life cycles of icebergs, and how much melt they produce. This project used an already available contour detection and selection algorithm to find the area of icebergs and track their changes over their entire lifespan. By plotting this data, changes in area by melt can be distinguished from changes from break-up events, which can happen throughout the lifetime of an iceberg.

Methods

Data Collection

Using Nuzhat Khan's previous work, I downloaded images from NASA's Terra satellite automatically. The images were downloaded from NASA Worldview with parameters of

15x15km, which resulted in an 1172x1172 pixel image. The resolution used was 250m, however, both the resolution and the boundary parameters can be adjusted in the downloading code. The downloading process used the statistical dataset from BYU's Iceberg Tracking Database to center each image around the geographic coordinates of the iceberg's daily location. I updated this code slightly to download the images as GEOtiffs, allowing for metadata access during area calculations. This process allowed for efficient daily imagery downloading for an entire iceberg lifetime. I also used Nuzhat Khan's contour detection and selection algorithm to retrieve masks of individual icebergs. This code included previous attempts at area calculation, but the only output used from this code was the mask of the iceberg from the uploaded image.

Area Calculation

Readily available area calculation methods for geographic coordinates do not translate well to polar stereographic. A number of the previous attempts for area calculation did not account for the non-uniform grid in polar stereographic. To conserve area correctly, I developed a method to find individual pixel areas, avoid using the grid, and focus on small-scale areas that add up to large icebergs. The developed method is open-sourced and available on GitHub.

The area calculation method counted individual pixels inside the iceberg mask provided by the contour detection and selection algorithm. It did this by first selecting the coordinates, in a pixel format (e.g. 1172x1172 for a 15x15km image) that were inside the mask. This used the white pixel detection from Numpy. Then metadata was extracted from the image to convert all selected pixel coordinates to polar stereographic. I extracted the image boundaries and the pixel dimensions from the metadata so that the pixel coordinates could use the dimension ratios to be converted to polar coordinates. The resolution was also extracted from the metadata to find the pixel size. The resolution was then used to find the four "corner coordinates" of each pixel, considering the original coordinates to be the centers of the pixels. I used the Pyproj ESPG conversion to convert the polar stereographic ESPG: 3031 to the desired latitude/longitude ESPG: 4326. Using the ESPG conversion, the individual pixels were in simpler geographic coordinates, while still conserving area. With the geographic coordinates, widely available area calculation methods could be used. Using Pyproj and Lambert azimuthal equal-area projection, each pixel's area was calculated individually using its four corners as boundaries. The area was added up from all the pixels to give the total iceberg area. Azimuthal equidistant projection could also be used to substitute Lambert azimuthal equal-area projection, as the same area will be found.

Iceberg of Interest

Tabular iceberg A68a was used to test the area calculation method, due to its significant break-up event in December 2020. A68a originated from the Larsen Ice Sheet in 2017 and traveled towards South George Island until 2020 (Fig. 1). A68a exemplifies iceberg melt during its movement out of the Weddell Sea into the Scotia Sea, while also showing a major break-up and fracturing towards South Georgia Island. A68a is also very well studied and was monitored by many scientific groups during its fracturing events, allowing for area comparison to gauge the accuracy of our new area calculation method. This makes iceberg A68a a great example to test area calculation.

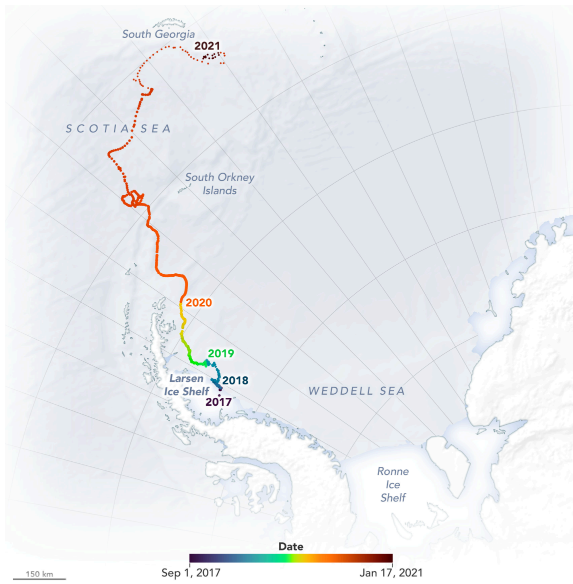

Figure 1. Map of iceberg A68a's trajectory from Larsen Ice Shelf to South Georgia Island.(Source - NASA Earth Observatory)

Results

When the successful area calculation was applied, the break-up event of A68a was found to have happened from December 23rd to December 29th, 2020, with an area loss of 1109 km^2, from 3905 km^2 to 2796 km^2 (Fig. 2). Before this break-up event, the total surface area loss between January 2020 and December 15, 2020, which was immediately before the breakup event, was 1816 km^2 (Fig. 2).

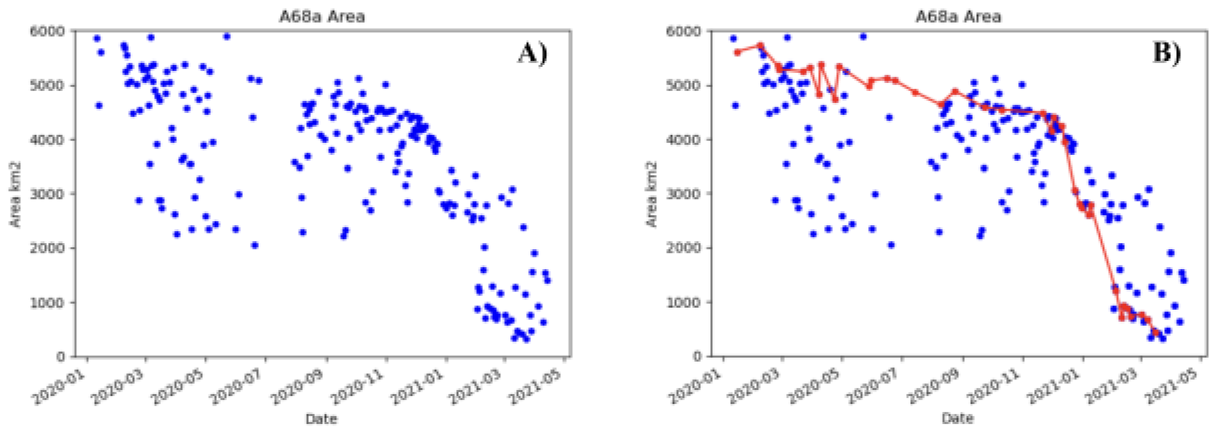

Figure 2. A) Scatter plot of daily areas found for iceberg A68a in 2020 and 2021. B) Scatter plot of daily areas found for iceberg A68a in 2020 and 2021. Red line indicated handpicked images that represent the iceberg area with great accuracy

Some parameters were applied to the data processing of A68a's lifespan. If an image had 90% or more white pixels, out of the pixel total, then it was discarded as an image that was 'Too cloudy'. A similar process occurred with cropped-out images, if more than 75% of the image was blank, the image was discarded as 'Cropped'. Finally, an upper limit of 15% of the total pixels was applied to the mask. That is, if the selected mask occupied more than 15% of the total pixels, the image was discarded, as the mask was greater than about 9000 km^2.

Discussion

These results are comparable to other research documenting the surface area change in A68a. Braakmann-Folgmann et al. (2022) found the same benchmark areas in January 2020, and December 2020 immediately before and after the breakup event (Fig. 3). So our new method is accurate against previous research and provided the expected results. Braakmann-Folgmann et al. (2022) continued to evaluate the volume of iceberg A68a, which may be part of future work for this project.

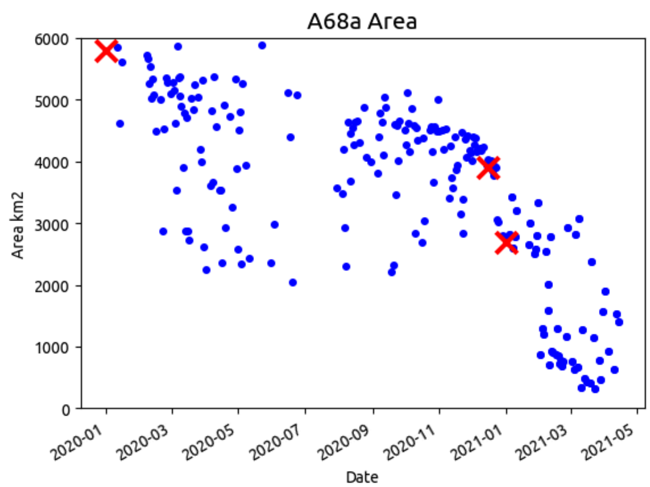

Figure 3. A scatter plot of daily areas found for iceberg A68a for 2020 and 2021 in blue. Red X's represent benchmark areas found for A68a based on previous work. (Source- Braakmann-Folgmann et al. (2022))

These results indicate a high daily surface area loss, however the month-to-month average loss was not equal. Certain months melted faster than others, however, the location may have been a larger factor than seasonality. As A68a drifted further away from the Larsen Ice Sheet and towards South Georgia Island, the area decreased faster, indicating that location may have been the predominant factor.

There is a limited amount of data for certain seasons, specifically austral winters. The high cloud coverage during austral winter, especially July, prevents accurate data from this season and also lowers the amount of data points available, accuracy aside. Months such as December and January have lower cloud coverage and allow for more accurate contours to be detected, and more data points for area calculations and monthly changes. This makes area estimates in certain seasons more reputable than others and currently leaves months like July's area calculations up to average.

The current results cannot speak to exact melt rates, as they only measure surface areas. These surface area losses, which are due to melting, can be used as a proxy for iceberg melt, but for calculating freshwater input into the Southern Ocean, satellite altimetry would have to be included to account for the volume of these icebergs.

Future Work

Some of the inaccuracies due to contour detection, and more importantly, selection, could be addressed with machine learning. It might be able to be addressed with more parameters in place as well, though I was not successful. The algorithm often selects the incorrect contour, even though it has identified the iceberg as a possible contour (Fig. 3). The current code offers some thresholds for data, but incorporating machine learning, or dynamic bounds may be useful to select the correct contour even when the areas of the contour options are similar. Machine learning might allow the algorithm to select the contour that is usually towards the center of the image, rather than a cloud in the corner.

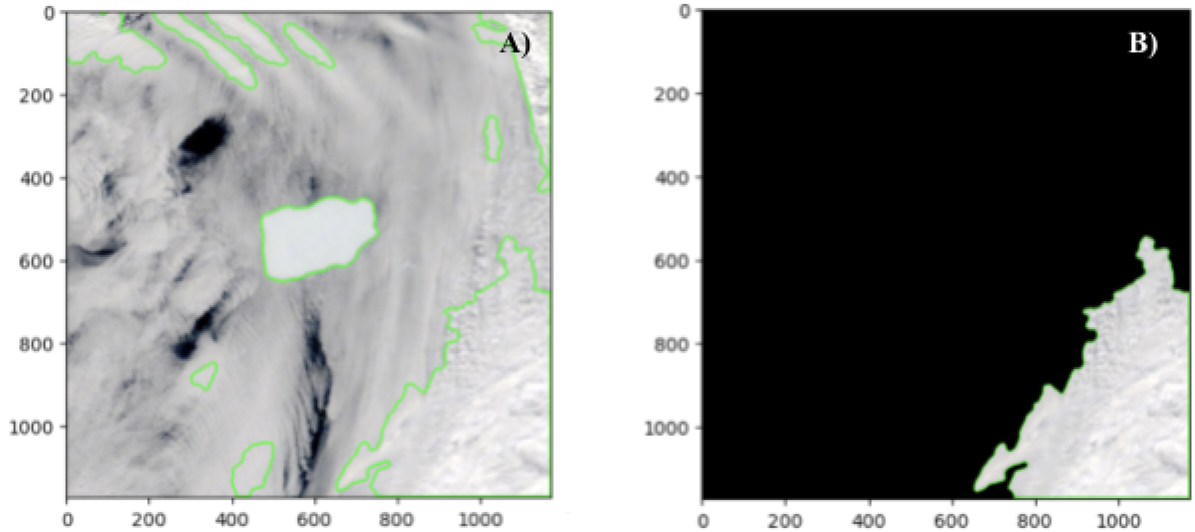

Figure 3. A) Iceberg A68a on 01/26/2021 from NASA satellite Terra. The algorithm by Nuzhat Khan created green contours around all white areas in the image, correctly contouring iceberg A68a in the center. B) A cloud from panel A was selected by the algorithm by Nuzhat Khan, instead of the iceberg shown in panel A.

With more satellites tracking the earth's surface, younger icebergs could have multiple datasets to compare their results across, to make for more accurate averages and tracking of changes and break-up events. This was attempted, but I was unable to select the right band to allow the algorithm to find the iceberg. This may also help the data gaps in austral winters where current contours are inaccurate due to cloud coverage.

As previously mentioned, incorporating satellite altimetry from satellites might allow for a more complete understanding of the melt produced by these icebergs. With a set of interior coordinates produced by the area calculation method I developed, CSV files from IceSat-2 and CryoSat-2 altimetry can be cross-referenced with the coordinates to find their volumes. This work has already been done for A68a by Braakmann-Folgmann et al. (2022). Similar methods can be applied to create a streamlined process to track multiple icebergs in open-sourced code.