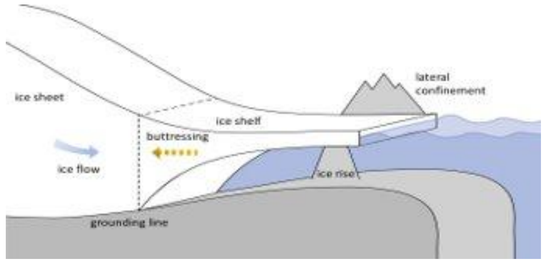
Rough Around the Edges: Is Changing Ice Shelf Roughness a Precursor to Collapse?

Aidan Dealy[1], Stephanie Olinger[1,2], Ashley Morris[1], Brad Lipovsky[1]

[1]University of Washington, [2]Harvard University

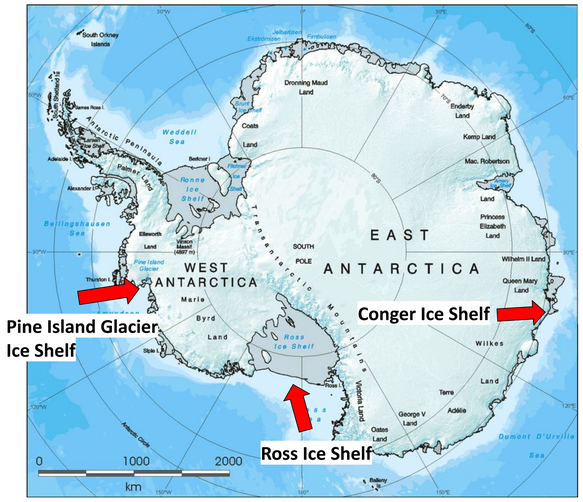
Introduction

The Antarctic Ice Sheet is a large mass of ice lying on top of the Antarctic continent. Ice shelves form as this ice flows off of the continent and onto the ocean, becoming buttressed by offshore islands. These ice shelves provide structural support to the Antarctic Ice Sheet by preventing ice from flowing freely into the ocean. This means that when these ice shelves collapse, there can be threatening consequences in terms of melting and sea level rise. This project aims to better our understanding of ice shelf collapse by using data that we can obtain remotely, such as geometry, to monitor ice shelf structural integrity.



Schematic of the ice sheet system showing the stabilizing role of ice shelves. Figure reproduced from Ronja and Maria, 2019.

This map shows the locations of Conger, Pine Island Glacier, and Conger Ice Shelves. Conger Ice Shelf recently collapsed on March 15th, 2022, so it will be the main focus of this research.



Map showing locations of Ross, Pine Island Glacier, and Conger ice shelves. Figure reproduced from Abrahamsen, 2012.

Methods

We define roughness as the square root of the integral of the Power Spectral Density function (PSD). The PSD is obtained by using a fast Fourier transform to take an elevation profile from an ice shelf and plot the intensity of its dominant wavelengths. This method gives us a single value for roughness.

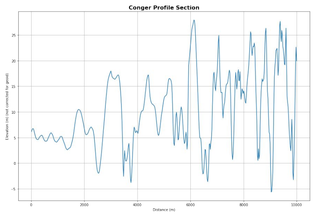


Figure showing a 10000m profile along Conger Ice Shelf

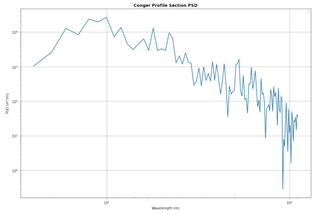
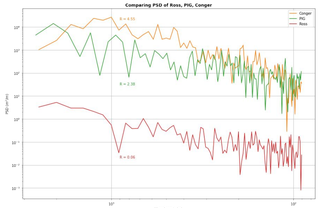


Figure showing the PSD of a 10000m profile along Conger Ice Shelf

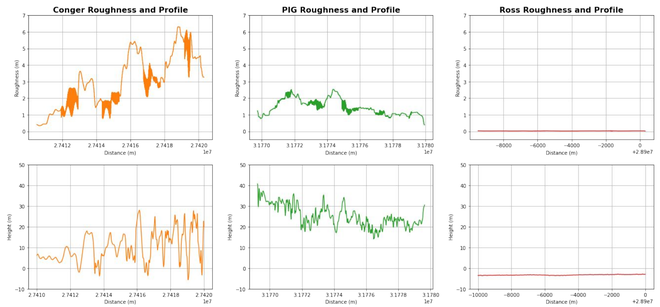
Results

We analyzed three ice shelves with varying characteristics: Ross Ice Shelf, Pine Island Glacier Ice Shelf, and Conger Ice Shelf.

The figure on the right shows the PSD functions for the three ice shelves. This is mostly consistent with the characteristics of these ice shelves. Ross Ice Shelf tends to have less surface fracturing per unit area than Pine Island Glacier and Conger Ice Shelves, so it is understandable that the PSD is a few orders of magnitude lower. The figure below looks at roughness values taken in windows along each ice shelf.



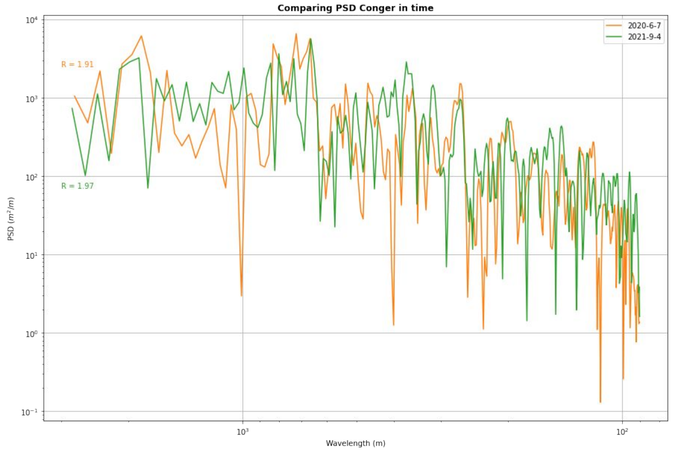
Comparing the PSD of Ross (red), Pine Island Glacier (green), and Conger (orange) ice shelves



Comparing the roughness of Ross (red), Pine Island Glacier (green), and Conger (orange) ice shelves in 1000m windows with 90% overlap

Results

Finally, we can observe how the PSD of one of the profiles on Conger Ice Shelf has evolved as Conger has neared collapse. This figure compares the PSD of Conger Ice Shelf between 2020-6-7 and 2021-8-4.



Comparing the PSD of Conger Ice Shelf between 2020-6-7 and 2021-9-4

Conclusions

The results from the comparison between ice shelves tells us that this method of calculating roughness is generally consistent with our expectations. Ice shelves that are known to be fairly structurally integral exhibit lower roughness values than those known to have less structural integrity. The results from the Conger Ice Shelf time comparison suggest that the collapse of the ice shelf may have been more transient, as there is little change between the PSD functions and roughness values during the study period. Going forward, we hope to process more data, as well as data closer to the collapse date to solidify this argument.

References

Watkins, R. H., Bassis, J. N., & Thouless, M. D. (2021). Roughness of ice shelves Is correlated with basal melt rates. Geophysical Research Letters, 48, e2021GL094743.

Einar Povl Abrahamsen. (2012). Map of Antarctica.

Ronja Reese & Maria Zeits. (2019). Schematic Ice-Sheet-Shelf System.