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Analysis of Ice Evolution in Graham Land and the Ross Ice Shelf from 2010 to 2020

INTRODUCTION

In this scientific essay, I will focus on the evolution of ice in two very important regions in Antarctica: Graham Land and the Ross Ice Shelf. I will compare the change in ice thickness in both areas with the use of data from sources like NASA's Operation IceBridge from 2010 to 2020. Icebridge was a project from NASA that used radio glaciology, with advanced radar technology that they placed on an airplane in order to measure the ice thickness of some regions in Antarctica. (1) Learning about how the ice sheets in Antarctica are changing over the years is key for understanding the impacts we are doing to the world's environment and predict the sea level rise in future years.

Graham Land and the Ross Ice Shelf are both located on opposite sides of Antarctica. Therefore, due to their different positions and climatic conditions, they should both have experienced different changes in their ice thickness. My essay aims to explore this idea and understand the difference between both evolutions of ice thickness in both locations. I will examine the radar data, and analyze the reasons that influence the ice behavior in each region. By comparing my findings, I hope to understand how Antarctic ice sheets decrease under different climatic conditions and global warming, and what the difference in behavior means for each region.

BACKGROUND

First of all, to properly analyze the differences between their ice evolution, it is important to understand the geographical and climatic characteristics between Graham Land and the Ross Ice Shelf.

Geographically, Graham Land is the northest region of the Antarctic Peninsula, whose furthest ending edge is pointing towards South America. Unlike other parts of Antarctica, this region is known to have a relatively warmer climate, which increases its sensitivity to global warming (2). Due to the increased rate of ice melting and the fast shrinking of some glaciers, Graham Land has experienced a significant environmental change in recent years. All these changes in the environment, are mostly caused by the warmer oceans and high air temperatures, which has increased the impact of global warming on Graham Land and brings a big example of the consequences of climate change in Antarctica. (3)

Location of Graham Land and Ross Ice Shelf in the Antarctic Peninsula. (4)

On the other hand, the Ross Ice Shelf is located in the Ross Sea region in the opposite side of Antarctica. It is the largest ice shelf on the continent, consisting of a huge floating platform of ice with an area of 500,809 square kilometers. (5) The Ross Ice Shelf experiences colder temperatures and normally more steady climate conditions when compared it to Graham Land. However, even though it is considered more stable, the Ross Ice Shelf has a key factor that affects the melting of its ice thickness. The ice platform of the Ross Ice Shelf is affected by the warm ocean temperatures under the ice shelf, which helps with its gradual melting and weakening of the platform. (6)

Therefore, understanding the geographical and climatic differences between both regions is very important, as they play a significant role in how each region's ice thickness has changed due to global warming. So, we will use the radio glaciology data to analyze the change in both locations. Thus, we aim to provide a clearer view of how ice thickness has varied over time in both Graham Land and the Ross Ice Shelf.

METHODOLOGY

To collect and analyze data about the ice thickness changes and basal melt rates in the regions of Graham Land and the Ross Ice Shelf, I will use research articles that have primarily used the data obtained by the radar technology from NASA's Operation IceBridge. For their project, NASA used specialized airplanes equipped with ice-penetrating radar instruments to measure the ice thickness accurately. (1) These radar instruments work by sending radar signals towards the ice surface and measuring the time it takes for the signals to reflect from the bottom of the ice shelves back to the airplane. Therefore, they analyze these reflections and with the help of scientists, they determine the thickness of the ice in that region. (1)

After the radar data they collected is processed and turned into actual thickness measurements, these thickness data points are mapped across a map of the region they are doing the study about. Therefore, if they do this regularly, we can obtain a detailed picture of the ice thickness changes of a region over a certain time. In our case, we will use the data from 2010 and 2020.

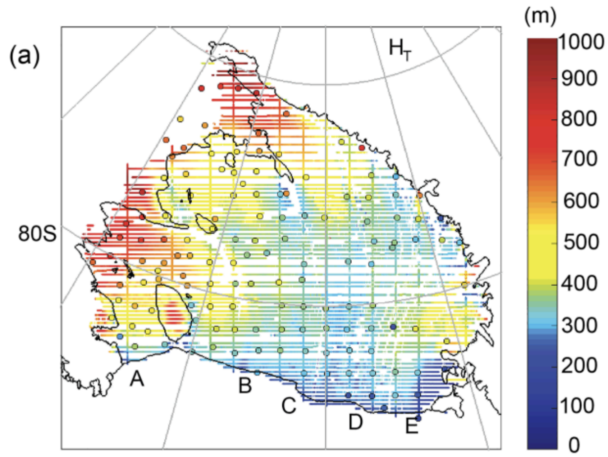
By comparing the repeated radar measurements across multiple years, we calculated the rate of melting beneath the ice shelves, measured in meters per year. These are called basal melt rates and they give us a clear view of how quickly the ice shelves lose ice from underneath, which is crucial for understanding their stability. So, we will analyze the basal melt rates of Graham Land and the Ross Ice shelf, that were obtained through radar technology, to determine the actual changes of ice thickness at the bottom of the ice shelves over time.

All the flight paths from the IceBridge were carefully chosen to cover areas of particular scientific interest, such as Graham Land and the Ross Ice Shelf. We will take advantage of this and use the information gathered during those flights to get a clear picture of how major climate change is affecting different regions of Antarctica.

RESULTS - ROSS ICE SHELF

Ice Thickness and Structure

Using radar data from NASA's Operation IceBridge, we can see how the total ice thickness of the Ross Ice Shelf varies across the whole region. On the West Antarctic side, there are regions of more than 500 meters of thickness, but as we get towards the ocean, it thins gradually, with most of the central shelf ranging between 300 and 500 meters thick. On the other hand, near the front, it gets way thinner. (7) In the following map, we can see an example where in five specific areas, named zones A to E, the ice is less than 300 meters thick.



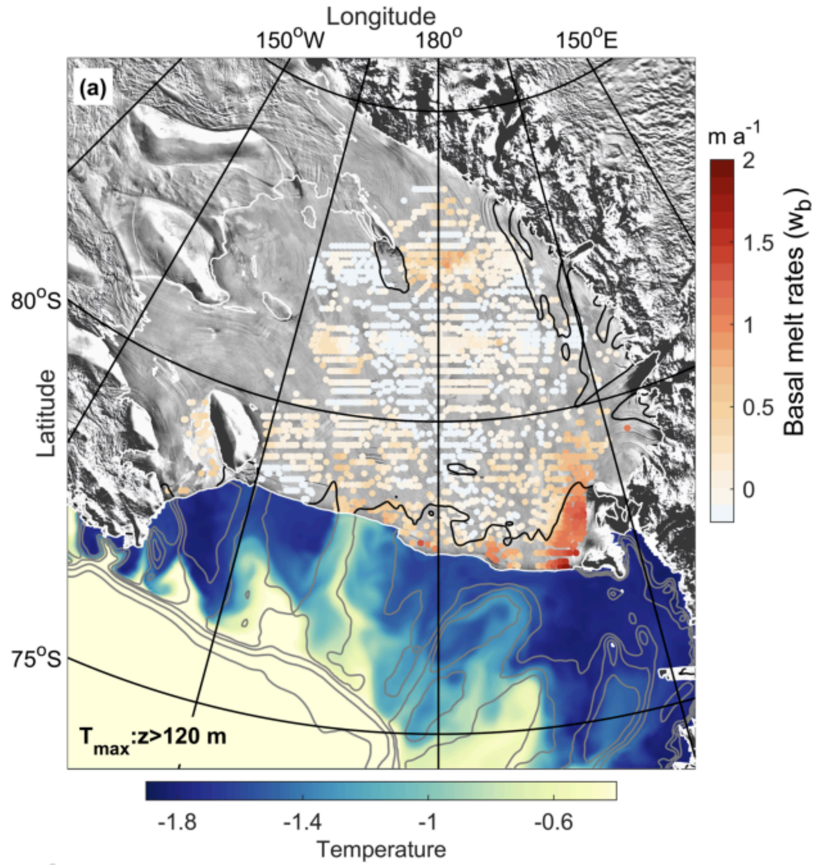
Ice Thickness of Ross Ice Shelf using Radio-Glaciology (7)

Basal Melt Rates and Hotspots

The basal melt rate is a parameter researchers use to analyze how fast the bottom of the ice shelf melts, and it is calculated in meters per year. So, using the data from 2010 to 2020, they concluded that most of the Ross Ice Shelf had low melt rates, between a few centimeters to a few decimeters per year, which means the shelf was relatively stable during that decade.

Therefore, using a research study called *Multidecadal Basal Melt Rates and Structure of the Ross Ice Shelf, Antarctica, Using Airborne Ice Penetrating Radar* (7), we can see this diagram, which focuses on those five hotspots (A to E) near the ice front where melting is much higher. There, we can see how the ice melting is decreasing between 0.5 and 2.5 meters per year. In those hotspots, the biggest melt zone is at Hotspot E, located east of Ross Island. They concluded that the reason for this high melting rate is likely due to the warm ocean water flowing under the shelf.

Finally, even though the rest of the shelf is stable, these hotspots are important for the whole ice platform. If the ocean keeps warming, these areas could become weak points that could affect the entire shelf's structure and increase the sea level.



Map showing the basal melt rates of the Ross Ice shelf region.

In the front part, we can see the highest melting rate (0.5 and 2.5 meters per year). (7)

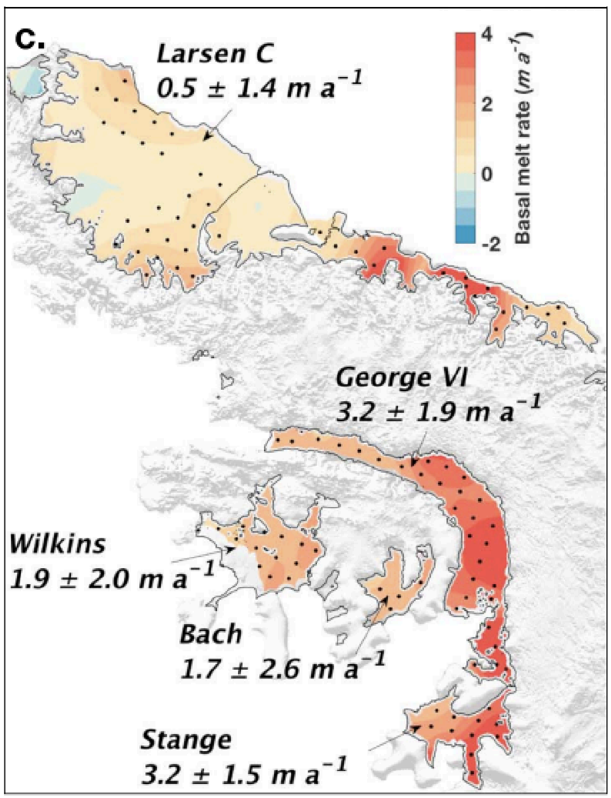
RESULTS - GRAHAM LAND (ANTARCTIC PENINSULA)

Basal Melt Rates and Hotspots

Interestingly, after many years of losing ice thickness, many of the ice shelves in the Antarctic Peninsula, which includes Graham Land, started to show some surface thickening from

2010 to 2020. This means that the top part of their platform got slightly higher, which helped the ice shelves from the peninsula become more stable. Scientists believe that this change was mostly due to the cooler air temperatures during summer that decade, as it allowed more snow to stay on the surface and build up over time. (8)

In the following image, we can see a map of the northern Antarctic Peninsula that shows the basal melt rates from 2010 to 2020 in that area. In this map, the red areas represent a higher melt rate, and that the ice is melting faster, while the blue areas show regions where the ice has low melt rates and is thickening.



Map showing the basal melt rates of the Northern Antarctic Peninsula from 2010 to 2020. (8)

In the northest part of the map, we can see Larsen C, one of the main ice shelves in Graham Land. Before 2010, Larsen C had been slowly getting thinner, but from 2010 to 2020, it started to gain thickness on its surface. The surface melting decreased, and it allowed more snow to stay on top of the shelf, and at the same time, the amount of melting under the ice shelf (called basal melt) stayed very low, around just a few tenths of a meter per year, which shows that Larsen C was quite stable during this period. (8)

However, one part of Larsen C showed a very high melt rate. Near the Bawden Ice Rise (the red area at the northern tip), we can see how, in that area, the bottom of the shelf was melting much faster, up to 4 meters per year. This area is very important because it helps keep the ice shelf in place, as if the ice there keeps melting at this speed, it could weaken the whole structure of the Larsen C Ice shelf and affect its stability. (8)

Interestingly, on the same map, we can see how on the other side of Graham Land, in the western ice shelves like George VI, Wilkins, Bach, and Stange the basal melt rate was much higher during that decade. Even though their surfaces also gained some height due to snow, the melting underneath was much stronger. These shelves experience warmer ocean temperatures, which melt the ice from below.

For example, the George VI Ice Shelf had some of the highest melt rates, especially in its southern area, where the bottom of the shelf melted up to 7 meters per year. Also, the Wilkins Ice Shelf lost ice from its bottom at a lower rate, around 1.9 meters per year, and its surface got a bit higher between 2013 and 2016. (8)

Overall, while some parts of the ice shelves in Graham Land got higher and looked more stable from above, many were still melting from below, especially those on the warmer western side. Thanks to radio glaciology, we can extract data like the basal melt rates, which help us to appreciate facts like this, since we can’t get them through the naked eye. From 2010 to 2020, the western side lost about 84 billion tons of ice per year, while the eastern side, where Larsen C is situated, lost 51 (8). This fact shows a big difference between the two sides of the Northern Atlantic Peninsula, and it highlights how the ocean's temperature has affected the melting of the ice shelves in Antarctica.

COMPARATIVE ANALYSIS

After analyzing the data I collected from both the Ross Ice Shelf and Graham Land, we can see many clear differences in their ice thickness and melting changes from 2010 to 2020, due to their different climatic conditions. In both regions of Antarctica, it showed some stability and an increase in their surface areas during that decade, but their basal melt rates and melting patterns varied significantly.

Overall, the Ross Ice Shelf, which is colder and larger, showed mostly low and stable melt rates on its whole area, typically only a few centimeters to decimeters per year. However, we also saw how in some hotspots near its ocean front, it experienced way higher melt rates due to warm ocean currents. Therefore, the Ross Ice Shelf remained relatively stable in general, but has potential vulnerabilities in specific spots of the region..

On the other hand, Graham Land's ice shelves showed different behavior. The eastern side, especially Larsen C, showed very low basal melting and a relatively stable pattern. The region even experienced some thickening at its surface. However, on the western side of Graham Land, which includes shelves like George VI and Wilkins, they experienced much higher melt rates due to warmer ocean waters. So they lost way more ice from underneath their surface, and changing its thickness and stability.

These different behaviors highlight the strong influence of ocean temperatures and the location for the ice shelf's stability. From 2010 to 2020, the Ross Ice Shelf benefited from its colder environment, while Graham Land, especially its western side, was more vulnerable to warming ocean currents, which heavily impacted its basal melt rates and how fast the ice was melting in that area.

CONCLUSION

In conclusion, after carefully analyzing all the radar data from 2010 to 2020, we can see how Graham Land and the Ross Ice Shelf have experienced very different ice thickness changes and melting behaviors during that decade. This difference is mostly due to their different climates and geographic locations. In the case of the Ross Ice Shelf, it benefits from its colder climate and the whole region remains mostly stable with low melting rates overall, although we found some hot spots that showed higher melting rates due to the warmer ocean temperatures near the front. On the other hand, Graham Land, especially its western side, experienced warmer ocean currents, which caused the region to have much higher basal melt rates and ice loss from underneath, despite some surface thickening from the top.

Therefore, understanding these different behaviors is very important to understand the effects of global warming and to show us how sensitive Antarctica is to climate change. After analyzing the research findings, we can conclude that while most parts of Antarctica might look stable from the top, some specific vulnerable small areas can influence the whole region's ice stability, eventually causing a global increase in sea levels worldwide.

Finally, I want to emphasize how important climate change is for our future. So doing research articles like this is key for understanding more about this big problem we are facing. It is crucial to keep monitoring these regions closely, and especially the critical hotspots with the higher basal melt rates, as they could cause a major change in our planet.

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