Abstract

The discharge of icebergs into the ocean exerts a direct control on sea-level and plays a key role in determining ocean temperature and salinity in polar regions. Iceberg discharge from the Antarctic Ice Sheet (AIS) accounts for over half of the freshwater flux into the Southern Ocean. Changes in the rate of iceberg melting over time are controlled by the temperature and velocity of the ocean and, therefore, can be used to infer changes in ocean conditions near the glaciers from which the icebergs calved. I propose to investigate iceberg melt volumes and rates in several locations around the AIS using high-resolution satellite images. These data will be compared to satellite remote-sensed sea surface temperature (SST) data and temperatures at depth from Argo floats deployed in the Southern Ocean. This comparative analysis will lead to insights on the complex physical controls on AIS iceberg discharge, which will be beneficial to uncovering how the AIS will react to changes in climate.

Project Description

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The Antarctic has experienced decadal, but highly spatially variable SST changes over the past several decades (i.e.) warming in the Amundsen Sea and cooling in the Ross Sea) (Merino, et al., 2017). Although changes in SSTs are not necessarily representative of changes in the temperature of the subsurface water masses that come in contact with and erode the glaciers and ice streams draining the Antarctic Ice Sheet (AIS), they suggest that widespread but variable changes in ocean temperatures are occurring around Antarctica. Ocean warming is incredibly important for the stability of the AIS because ocean warming leads to glacier thinning and recession, which in turn drives glacier flow acceleration and an associated increase in iceberg discharge (Jenkins et al., 2016). Changes in iceberg discharge strongly influence the volume of the AIS: of the mass accumulated in the Antarctic ~90% is lost as solid ice discharge each year (Gardner et al., 2018).

While iceberg discharge has remained mostly unchanged in Eastern Antarctica for the past 7 years, iceberg discharge has greatly increased from Western Antarctica, with 78% of the increase attributed to glaciers flowing into the Amundsen Sea (Gardner et al., 2018). With 60-80% of net freshwater flux to the Southern Ocean coming from icebergs, it’s important to not only understand the role that ocean temperature change plays in the observed increase in iceberg discharge but also how it influences the rate at which icebergs are converted to liquid freshwater due to melting (Martin & Adcroft, 2010). Pursing the link between iceberg melting and ocean temperature change will provide a better understanding of water temperatures near Antarctic glacial termini, where observations are limited, which will lead to improved predictions of AIS volume change in the coming decades.

My project has two parts. I will construct submarine melt rate and meltwater flux time series (Part 1) for icebergs from 6 glaciers spanning East and West Antarctica. I will compare these values to concurrent ocean temperature trends measured both at the surface and subsurface in the Southern Ocean (Part 2). These pieces will work in tandem to create a better understanding of how ocean temperatures at depth and at the surface differ, and how this difference effects submarine iceberg melt.

Part 1- DEM-differencing to determine melt rate and freshwater flux

To determine melt rate, I will utilize the DEM-differencing method developed by Enderlin and Hamilton (2014). Digital Elevation Models (DEMs) are arrays of regularly spaced elevation values referenced horizontally to a geographic coordinate system. This method requires very high-resolution WorldView stereo satellite imagery (~0.5 m) to estimate changes in surface elevation. These images are available from 2011 through present, enabling the construction of melt rate time series that span nearly a decade. The NASA Ames Stereo Pipeline (ASP) is used to convert the offset between the stereo images collected a few seconds apart to 2 m-resolution DEMs. DEM generation will occur on the University of Maine supercomputing cluster under the supervision of Dr. Ellyn Enderlin (Climate Change Institute & School of Earth and Climate Sciences).

I will use the code developed by Dr. Enderlin to convert changes in iceberg elevations in repeat DEMs to iceberg volume change and melt rate estimates. To estimate iceberg melt rates, the same iceberg must be manually identified and tracked between distinct observations dates. To estimate volume change, the iceberg area is then delineated in each DEM and the surface elevation is extracted for each pixel. Then, the pixel-by-pixel difference is computed between the two DEMs. The mean elevation change can then be converted to an estimated volume change making use of the fact that the iceberg is floating. To distinguish between surface and submarine melt, the volume of ice lost due to surface melting is estimated from output provided by the Regional Atmospheric Climate Model (RACMO) for Antarctica (van Wessem et al., 2017).
Subtracting surface meltwater runoff from the total volume loss leaves volume loss due to submarine melting. Finally, the freshwater flux is calculated by dividing the volume loss due to submarine melt by the time between image acquisition dates.

Part 2- Southern Ocean temperature trends

Subsurface temperature profiles in the Southern Ocean are available from the international

ARGO program, a system of drifting, profiling floats (http://argo.ucsd.edu/index.html). Argo floats are autonomous floats deployed into the global oceans to measure temperature and salinity in the water column, to 2000 m depth. These data will be acquired from the international server (http://www.usgodae.org/cgi-bin/argo_select.pl) and used to provide insight about the water masses moving underneath and adjacent to Antarctic fjords. Currently, these are the only data available potentially linking subsurface temperature measurements at sea with estimated meltwater flux at glacial termini.

Sea surface temperatures (SST) data will be acquired from NOAA's daily Optimum Interpolation Sea Surface Temperature (OISST) analysis (https://www.ncdc.noaa.gov/oisst) program that is based on satellite data. I will acquire the global fields and subset the area around Antarctica for analysis of trends and regional differences. These data are available from 1982 to present, and will be converted to monthly averages as a reanalysis product. SST data will be compared to the measurements of subsurface temperature from ARGO, and each of these to iceberg draft and melt rate.

Relevance to plan of study

This project has been organized and thought out so that all data processing can be completed within the span of a summer. I've had the opportunity to work with Dr. Enderlin learning her DEM-differencing method, and have started the melt rate analysis on the 6 proposed glaciers. I will complete the iceberg processing and data output within the first 2-4 weeks of the summer, and the last 4-6 weeks will be designated for determining temperature trends in the Southern Ocean. My primary goal for the 8 week time period is to compile all of the processed data, and then begin my analysis. After the summer, I will take two semesters of Honors thesis credits (alongside other courses) to complete the analysis in the fall and writing of my thesis in the spring. This will complete my course of study as a marine science major, concentrating in oceanography in the Spring 2019 semester. This coming fall I will apply to graduate school in pursuit of a PhD in the field of polar oceanography. I'm passionate about how climate change is impacting polar regions, specifically Earth's two major ice sheets of Greenland and Antarctica, and how those changes in turn change the ocean environment. This research would serve as an integral component in beginning my career as a researcher, and completing my undergraduate degree with a publishable thesis.

Budget Justification

Total Budget Requested: $3,000

Budget: Stipend Amount: $3,000

Budget: Materials and Supplies: 0

Budget: Travel: 0

Budget: MISC: 0

Budget Justification: The full award will be used as stipend, because the data necessary to complete the project outlined above is open source, or available through a project advisor. Therefore, an average of 30 hours a week, for 8 weeks, with a $10/hr wage totaling $3,000, is desired.