Detecting the Climate Signal in Ocean-terminating Outlet Glaciers

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Introduction

Mass loss from the Greenland and Antarctic ice sheets contributes significantly to global sea level rise.

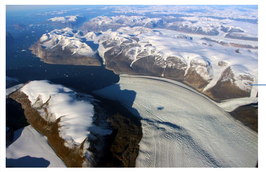
•Since 1992, Greenland has lost about 170 billion tons of ice per year, and Antarctica about 90 billion tons per year.[4]

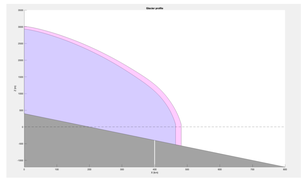
Glacier flow dynamics play a key role in ice mass loss, alongside surface melt and snowfall changes.

•However, glacier flow responds to climate change over years to centuries, causing complex and delayed ice sheet reactions.

Distinguishing climate change signals from natural variability in glacier flow remains challenging.

•Identifying when and where these dynamic signals emerge is essential for accurate sea level rise predictions.





Research Question

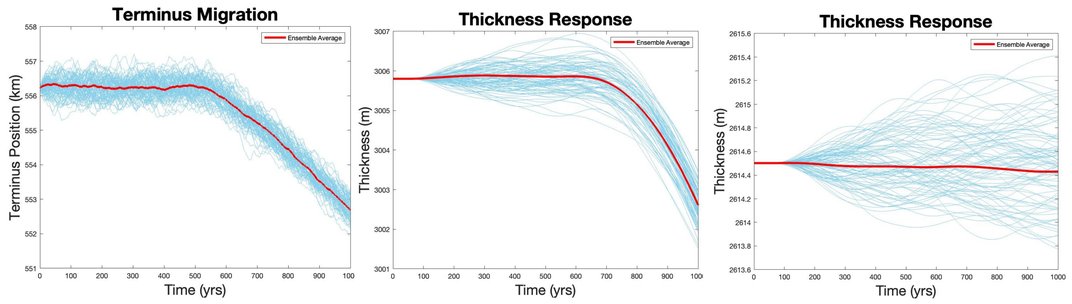
How can we use numerical simulations to predict where and when the climate driven changes in ice flow will emerge in glaciers?

Methods

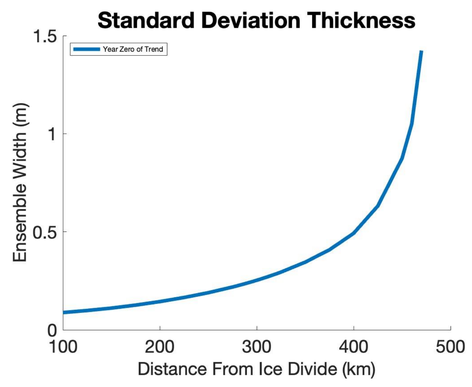
- We use a numerical model that simulates ice flow and basal sliding in one dimension[1,2]
- Used TALAPAS to run many simultaneous versions of the same initial glacier with different realizations of climate variability
- Applied a trend in ether ocean melting, or accumulation to the simulated glaciers
- Fit a best fit line to the ensemble average of thickness and velocity at each time step and point along the glacier. This was the signal used to compute signal to noise. Sigma is the standard deviation at the corresponding points along the glacier:

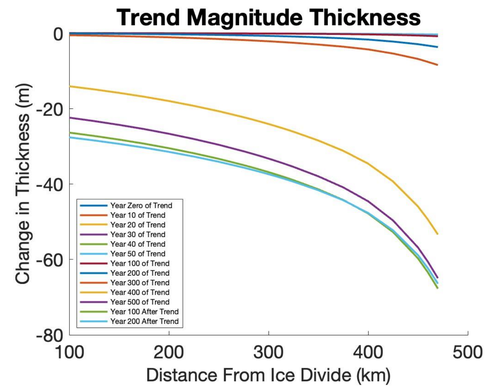
$$SNR_{thick} = \frac{\Delta(thickness)}{\sigma}$$

- Compared the response of glacier with a climate change trend to that of a glacier experiencing only random variability in climate to observe a change from a more stable climate baseline

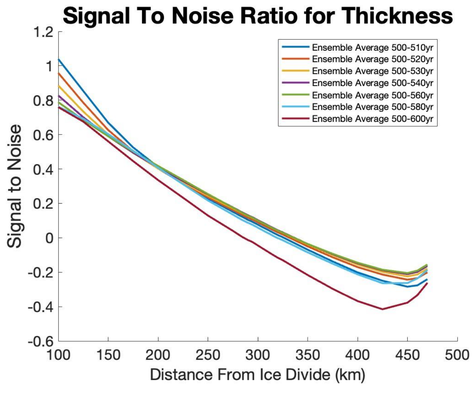


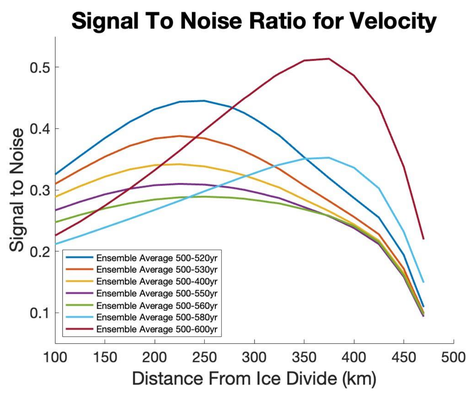
Ensemble response to random variability in accumulation, and then a trend in ocean melt applied over 500 years after a 500-year spin-up period. A) Terminus response when forced B) Thickness response with trend applied C) Thickness Response without forcing





Next, we fit a trend line and computed the slope of the ensemble mean velocity and ice thickness over various time intervals at many locations on the glacier





Finally, the ratio of cumulative change due to the trend to standard deviation is used to compute the signal to noise ratio at every point in time and at each point on the glacier

Conclusions

- Ensemble simulations allowed us to more effectively statistically characterize natural variability and trends
- By analyzing each point in time and along the glacier, we can observe how a trend emerges from background variability both spatially and in time
- So far, our simulations have focused on idealized geometries inspired by regions in northwest Greenland and parts of Antarctica.
- Moving forward, we aim to expand the scope of our simulations to capture a wider variety of glacial settings and continue refining climate forcing scenarios to better assess regional vulnerability to climate change.
- With this method of looking at the climate signal and variability, we can look at where there is a sweet spot for trends to emerge

References

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