Drivers of Ice Shelf Basal Melt on Pine Island Glacier: Ocean vs Geometry?

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Motivation / Questions

- Both ocean conditions and ice shelf geometry impact ice shelf melt rates and buttressing capacity
- There is a growing body of evidence suggesting geometric changes can have a very important impact on ice shelf melting[1,2,3,4]
- Since 2011, there have been major geometric changes on Pine Island Glacier (PIG), including pinning point ungrounding, calving front retreat and a rearrangement of basal channels
- The study aims to understand the relative impact of geometric changes and ocean conditions on PIG ice shelf melt and ice shelf buttressing capacity

Methods

- Annual MITgcm runs using CryoSat-2 derived ice shelf geometries and ocean conditions from moorings in Pine Island Bay (Fig 1)
- MITgcm run at 200m horizontal and 10m vertical resolution
- 3 sets of model runs varying boundary conditions
- We also use buttressing flux response number (BFRN) from De Rydt and Naughten (2024) (Fig 2)

	Ocean	Geometry
Set 1 - Both	✓	✓
Set 2 - OCEAN	✓	✗
Set 3 - DEM	✗	✓

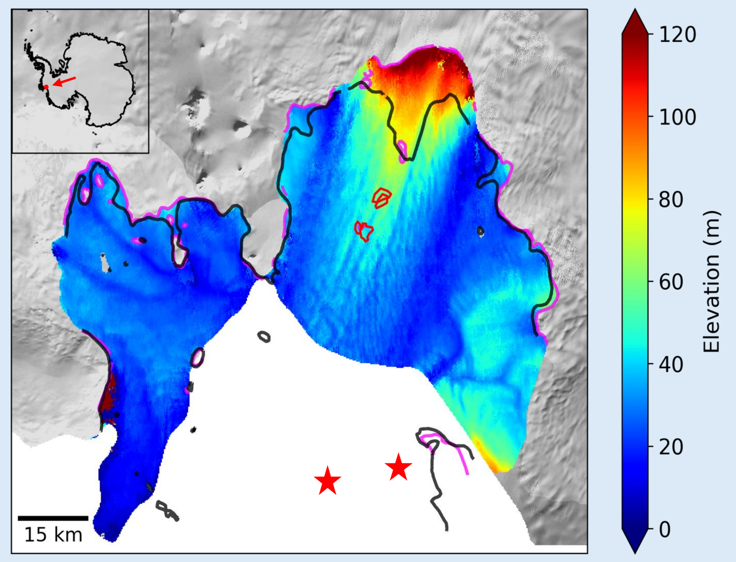


Fig 1: Example ice shelf geometry from CryoSat-2[5] and ocean mooring locations (red stars).

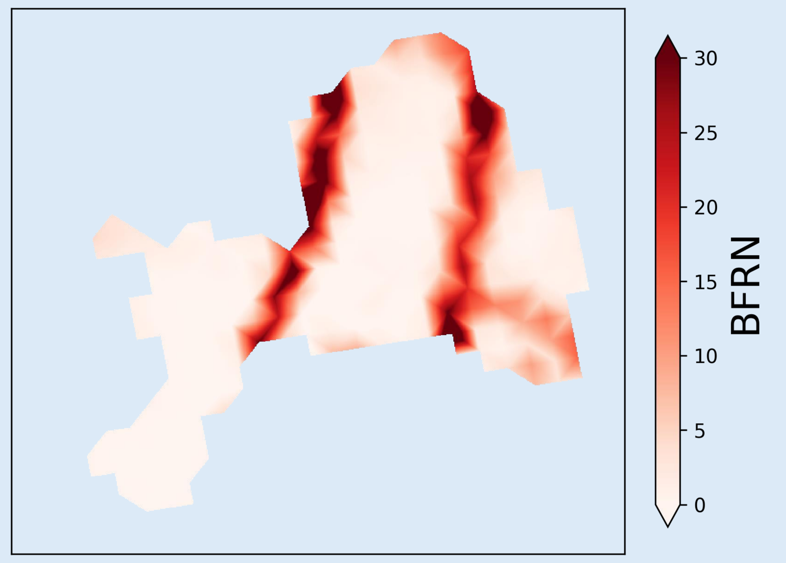
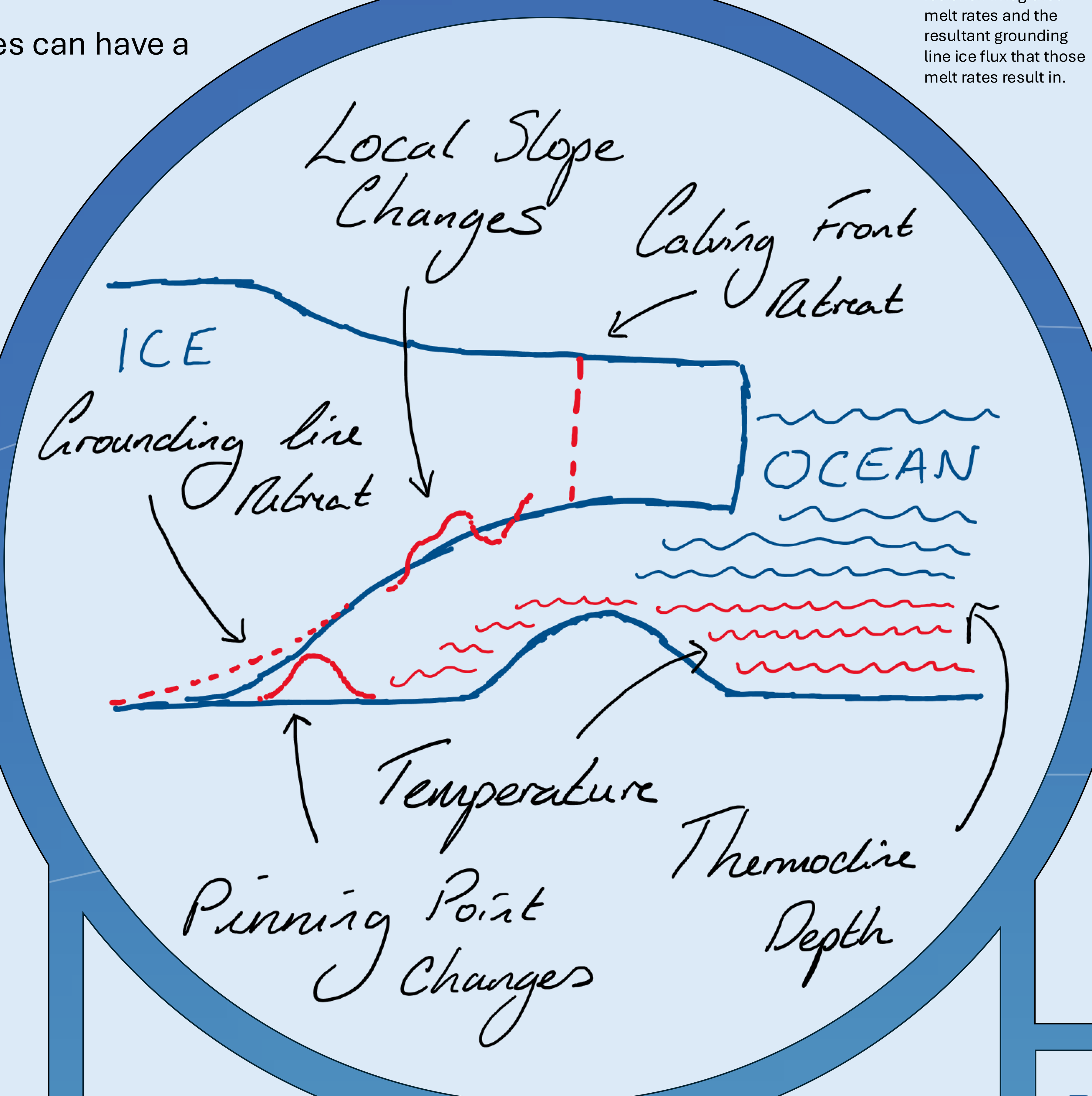


Fig 2: Buttressing flux response number on PIG ice shelf from De Rydt and Naughten (2024).

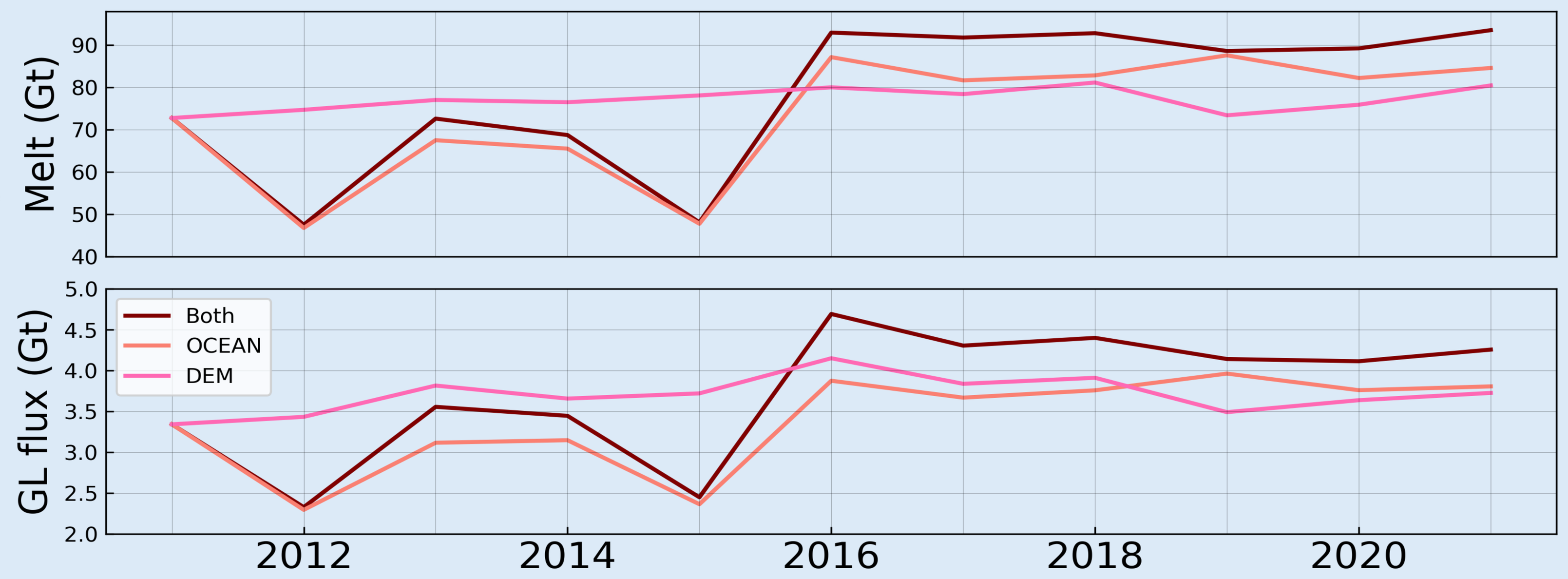


Key Takeaways

- Temporal variability of melt controlled by ocean conditions in the model
- Spatial distribution of melt controlled by geometry through changes in ocean circulation
- Geometry alone varies grounding line flux by 24%

Results: Temporal Variability

Fig 3: Time series of ice shelf integrated melt rates and the resultant grounding line ice flux that those melt rates result in.



Ocean conditions largely control temporal variability (r = 0.98). Geometric changes only impact the temporal variability of melt by 10% but impact buttressing by 24%.

Results: Spatial Variability

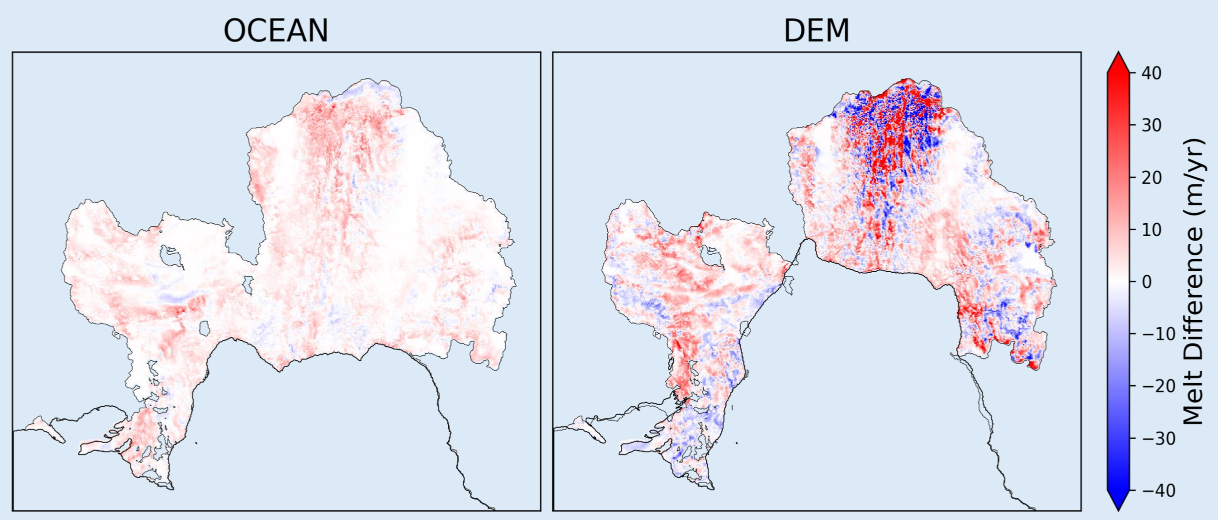


Fig 4: The change in the spatial distribution of ice shelf melt rates between 2011 and 2021 for OCEAN and DEM model runs.

Geometric changes control the spatial distribution of melt which is critical for controlling buttressing capacity.

Results: Circulation

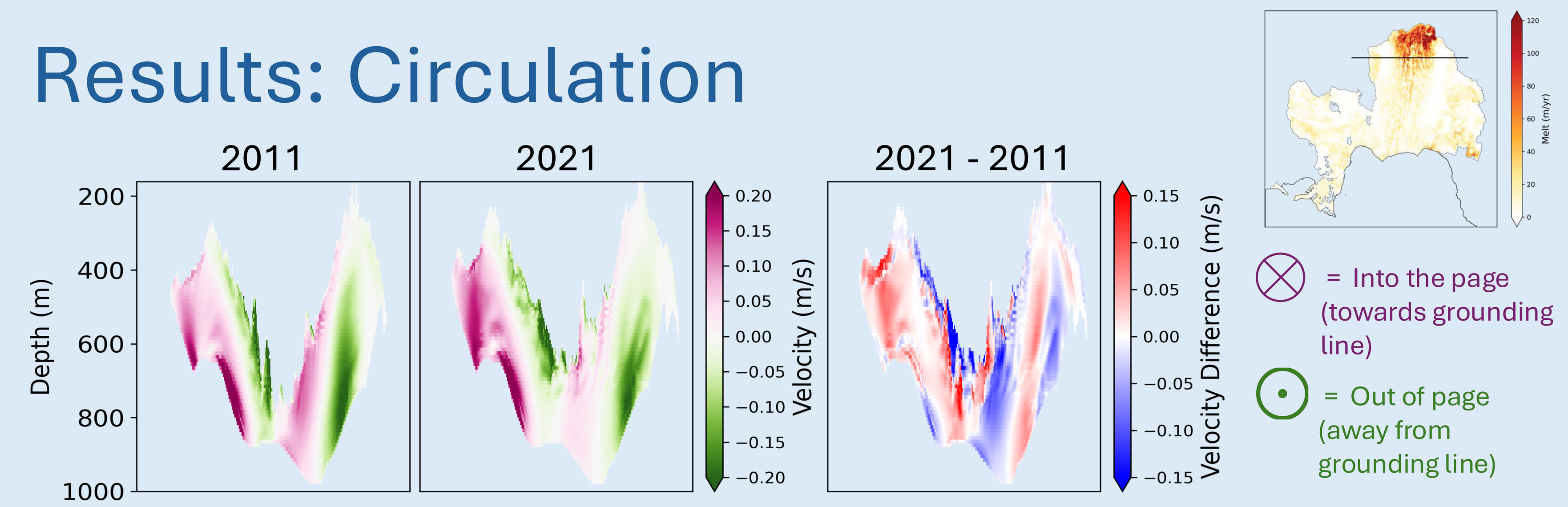


Fig 5: Ocean velocity across the transect in the top right. Showing circulation changes beneath the ice shelf due to geometric changes between 2041 and 2021.

References
1 – Holland et al.: Strong Ocean Feedback During the Recent Retreat of Thwaites Glacier. Geophysical Research Letters, 2023.
2 – Bett et al.: Coupled ice-ocean interactions during future retreat of West Antarctic ice streams in the Amundsen Sea sector. The Cryosphere, 2024.
3 - De Rydt and Naughten: Geometric amplification and suppression of ice shelf basal melt in West Antarctica. The Cryosphere, 2024.
4 – Bradley et al.: The Influence of Pine Island Ice Shelf Calving on Basal Melting. JGR Oceans, 2022.
5 – Lowery et al.: Spatio-temporal basal melt and basal channel evolution on Pine Island Glacier Ice Shelf with CryoSat-2. Pre-print. The Cryosphere, 2025.