Glacial Change in Antarctica: How we know and what we might do about it

Julia Wellner
Earth & Atmospheric Sciences
University of Houston
Plan

• Antarctic basics

• Who am I and what do I do?

• Thwaites Glacier
  – How it’s changing
  – How do we know

• Geo-Engineering of ice sheets
What would happen if all glaciers melted?

Sea level would rise about 70 m

– many of the world's large population centers would be flooded
Where is all that ice?

~65 m is in Antarctica.
Where is all that ice?

~65 m is in Antarctica
Antarctica: Highest Continent
Antarctica: Highest Continent

WAIS

EAIS

Sea Level
Antarctic Temperature Change
Mass balance is what counts, not temperature anyway

Measurements from:

- SAR Interferometry
- GRACE

Rignot et al., 2008
Ice Behavior is Controlled by Water (2 of 3 ways in Antarctica)
The WAIS, and Peninsula Ice Cap, are:

- Grounded below sea level
- On a Foredeepened shelf
- Many areas have ice shelves
Plan

• Antarctic basics

• Who am I and what do I do?

• Thwaites Glacier
  – How it’s changing
  – How do we know

• Geo-Engineering of ice sheets
Quickly: What do I do?

R/V Mishipeshu  University of Houston
Different Scale
What do we do?
What do we do? Core on sunny days

Photo by Y. Muñoz (2010)
What do we do? Core on cold days

Photo by K. Gavahan (2012)
What do we do? Core Repository
What do we do? Seismic

(2005)
What do we do? Multibeam Swath Bathymetry
What do we do? Collaborate with ocean and bio teams
What do we do? GPS (rebound)

Photos by Y. Muñoz (2010)
What do we do? Go Ashore in Small Boats (cheaper than helo)

(1998)

(2012)
What do we do? Date Sediments

Gamma-ray spectrometry to measure $^{210}$Pb, $^{137}$Cs, other
What do we do? *Sediment size, shape, texture*

- Small conchoidal fractures
- Dish-shaped concavity
Geology, but highly interdisciplinary

Climate and Climate History
- Ice-core record: atmospheric chemistry, paleoclimate, ice dynamics
- Bedrock uplift: record of past and present deglaciation, local mantle viscosity
- Foehn Winds
- Stranded glacial deposits: record of ice extent and elevation

Glacier Dynamics
- Glacier ice flux
- Ice-shelf buttressing
- Basal melting and heat exchange
- Hydrofracture
- Ocean warming/ circulation changes
- Precipitation
- Wave-shelf interactions

Sedimentary Dynamics
- Biologic productivity
- Resuspension and lateral advection
- Meltwater and sediment flux
- Terrigenous sediments
- Grounding zone wedges

Ecosystem Dynamics
- Photosynthetic flux
- Open-marine ecosystem
- Sub-ice-shelf ecosystem
- Geochemical and geothermal flux

Wellner, et al., 2019
Plan

• Antarctic basics

• Who am I and what do I do?

• Thwaites Glacier
  – How it’s changing
  – How do we know

• Geo-Engineering of ice sheets
Future of the West Antarctic Ice Sheet

- Antarctica may contribute up to 1 meter to global mean sea level (GMSL) in this century*. 
- More data is required from Thwaites Glacier to improve predictive climate models.

* Based on DeConto and Pollard, 2016
Future of the West Antarctic Ice Sheet

• Antarctica may contribute up to 1 meter to global mean sea level (GMSL) in this century*.
• More data is required from Thwaites Glacier to improve predictive climate models.

Modeled Scenarios of Antarctic Contribution to GMSL

* Based on DeConto and Pollard, 2016

WAIS: West Antarctic Ice Sheet
EAIS: East Antarctic Ice Sheet
THwaites Offshore Research

https://thwaitesglacieroffshoreresearch.org/
Stability is dependent on:

- Atmospheric conditions
- Oceanographic changes
- Bed topography

Introduction

Ice Extent

Dating

Amundsen Sea
When did Thwaites lift off pinning points?

Need to reconstruct glacier position using **sedimentary facies** and **age modeling**. 
Glacial Marine Depositional Model

Model adapted from Kirshner et al., 2012; Hillenbrand et al., 2013; Smith et al., 2017

1. Grounding Zone Proximal
   - Coarse-grained, Poorly sorted or normal grading

2. Sub-Ice Shelf
   - Laminated silty clay

3. Seasonally Open Marine
   - Diatomaceous, silty clay
   - Larger clasts (*ice rafting*)

Introduction  Ice Extent  Dating  Amundsen Sea
2019 Field Season in the Amundsen Sea

Map of ship track, ice imagery, & preexisting bathymetry near Thwaites Glacier.
Rugged Seafloor Near Thwaites Glacier

Cored on two bathymetric highs that are possible pinning points in the past.

New bathymetry data and core sites around Thwaites Glacier
Preliminary Interpretation - KC04

Clay laminations and sand lenses with sparse gravel

Sandy mud, no gravel

Sandy mud with some gravel

Pebbly sandy mud with cobbles, high shear strength at base
Unpinning of Thwaites Ice Shelf

Introduction

Ice Extent

Dating

Amundsen Sea

Proximal to grounded ice

Subglacial till?
Unpinning of Thwaites Ice Shelf

Gradually less proximal

Proximal to grounded ice

Subglacial till?

Introduction  Ice Extent  Dating  Amundsen Sea
Unpinning of Thwaites Ice Shelf

Introduction

Ice Extent

Dating

Amundsen Sea
Unpinning of Thwaites Ice Shelf

Seasonally open marine
Transitional facies
Gradually less proximal
Proximal to grounded ice
Subglacial till?

Modern Ice Shelf Margin

Introduction  Ice Extent  Dating  Amundsen Sea
Ongoing Work

Dates imminent

Back to field in January
Plan

• Antarctic basics

• Who am I and what do I do?

• Thwaites Glacier
  – How it’s changing
  – How do we know

• Geo-Engineering of ice sheets
Control water flow: Can’t even do that in warm waters

COMMENT

Geoengineer polar glaciers to slow sea-level rise

Stalling the fastest flows of ice into the oceans would buy us a few centuries to deal with climate change and protect coasts, argue John C. Moore and colleagues.

GLACIAL GEOENGINEERING

Two fast-moving glaciers in West Antarctica — Pine Island and Thwaites — are shedding most of the ice lost from the continent into the sea. Slowing them down could delay global sea-level rise by centuries.

ICE FLOW

When the glaciers reach the coast, the ice forms a floating shell in the bay that breaks up, thins and melts.

PROPOSAL A

A pumping station extracts or freezes water at the glacier base, slowing sliding.

PROPOSAL B

A 300-metre-high artificial island jams the ice shelf and buttresses the glacier behind.

PROPOSAL C

A berm up to 100 metres tall blocks warm water from melting the ice shelf base.
Build a pinning point: What about surface melt?

Stopping the flood: could we use targeted geoengineering to mitigate sea level rise?

Michael J. Wolovick and John C. Moore
Stabilizing the West Antarctic Ice Sheet by surface mass deposition

Johannes Feldmann¹, Anders Levermann¹,²,³*, Matthias Mengel¹
Thanks, questions?