Nested ice-sheet modeling of long-term variations in the Pine Island-Thwaites Glacier basins

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Outline

• Modern data and modeling
• Geologic data, last ~20 kyrs
• Simulations of last 20 kyrs, fit to geologic data
• “Future” simulations with best-fit model
Surface thinning rates (Pritchard et al., Nature, 2012)

**Observations in recent decades:**

- Rapid inland thinning (~0.3 m/y)
- PIG grounding line retreating (~20 km/decade)
- Largest Antarctic sector contribution to sea-level rise (> 0.1 mm/yr)
- Due to ocean melting, increased CDW incursions (cf. Steig et al., Nat. Geo., 2013)

**Mass loss of basins, Gt/yr**
(Rignot et al., Nat. Geo., 2008)

**Terminus retreat, acceleration**
(MacGregor et al., J. Glac., 2012)

**GRACE water-height equiv. trend, uncorrected**
(Shepherd et al., Science, 2012)
Modeling of future PIG/THW has been validated only vs. present or recent decades, and run “only” ~200 to 500 years into the future.

Also: Joughin et al., GRL, 2010; Docquier et al., J. Glac., in review; meeting abstracts: Favier, Gagliardini, Joughin.
Geologic data is available for the last deglacial retreat (~20 ka to modern) in ASE sector

Types of paleo data:

- Bed forms (MSGL, wedges, moraines…)
- Ocean shallow cores (analysis and dating)
- Cosmogenic dating on nearby coastal ranges

Also: Lowe and Anderson, QSR, 2002; Evans et al., Mar. Geol., 2006; Johnson et al., Geol., 2008; Graham et al., JGR, 2010; Smith et al., QSR, 2011; Jakobsson et al., QSR, 2012; Kirshner et al., QSR, 2012; Klages et al., QSR, 2013; and others…
Basic synthesis of paleo-data story *(to be updated!*)

- Grounding lines extended to near the continental shelf break until ~15 kyr.
- Then retreated to mid continental shelf ~12 kr with a large ice shelf.
- Around ~10 ka, the ice shelf collapsed, allowing grounding lines to retreat to near modern positions with very little ice shelf left by ~6 ka.

* Also from C.-D. Hillenbrand et al., Geol., 2013; J. Johnson, M. Bentley, J. Smith, pers. comm.
Simulations of last deglacial period
Ice sheet model and paleo forcing

Model:
- Hybrid combination of SIA and SSA flow equations (Pollard & DeConto, GMD, 2012).
- Uses C. Schoof’s (JGR, 2007) parameterization of flux $q_g$ across grounding lines.
- Ocean melting depends on specified nearby water temperature
- Calving parameterized (depends on divergence)

Paleo Forcing:
- Atmospheric T,P from modern climatology and parameterized past variations (SeaRISE).
- Ocean temperatures (400 m) from A/OGCM simulation of last 22 kyers (Liu et al., Science, 2009).
- Sea level prescribed from ICE-5G (Peltier, 2004).
Compare simulations with data over past 20,000 years

Example A (too advanced ice)

Example B (good ice extents)

Example C (too retreated ice)

Kirshner et al, QSR, 2012

LGM (~15 ka) 13.8-12 ka

12.3-10.6 ka

7 ka-present

Legend
- Ice Shelf
- Grounded Ice
- Modern Grounded Ice
Preliminary step towards large-ensemble validation…“proof of concept”

- Many runs, 30 ka to modern, with different $O$ and $C$ coefficients
- Record grounding line and shelf edge positions on PIG flowline versus time
- Score = r.m.s. difference from Kirshner observations (0.75 g.l. + 0.25 shelf edge)
Individual simulations

**O=20, C=1.5**

Score = 280.9
too little ice

**O=1, C=1.2**

Score = 119.5
too much ice

**O=1, C=1.3**

Score = 58.5
~correct ice

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$O=20$, $C=1.5$

$O=1$, $C=1.2$

$O=1$, $C=1.3$

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$O=20$, $C=1.5$

$O=1$, $C=1.2$

$O=1$, $C=1.3$
Simulation of last 20 kyr, with $O=1$, $C=1.3$
“Future” simulations
Crude “future” simulation with $O=1$, $C=1.3$

- Use best fit model parameter values ($O=1$, $C=1.3$)
- Start from modern ice state (end of 30 ka simulation)
- Crude “future” warming: Increase ocean warming (to +2°C) and atmospheric CO$_2$ (to 4x PAL)
Crude “future” simulation, all-WAIS domain, 10 km grid

~0.6 m / century
Crude “future” simulations, all-WAIS domain.
Plausible parameter and forcing variations.
**Summary** *(preliminary)*

- Comparison with geologic data usefully constrains model parameters.
- Model suggests drastic future retreat in ASE and other WAIS sectors.

**Next Steps**

- Vary other parameters, past and future forcing scenarios, sediment distrib.
- Ongoing collaborations:
  - Large-ensemble techniques: MCMC, pdf’s (SCRiM Network, K. Keller, Penn State).
  - Apply same technique to Ross Embayment (with P. Clark).