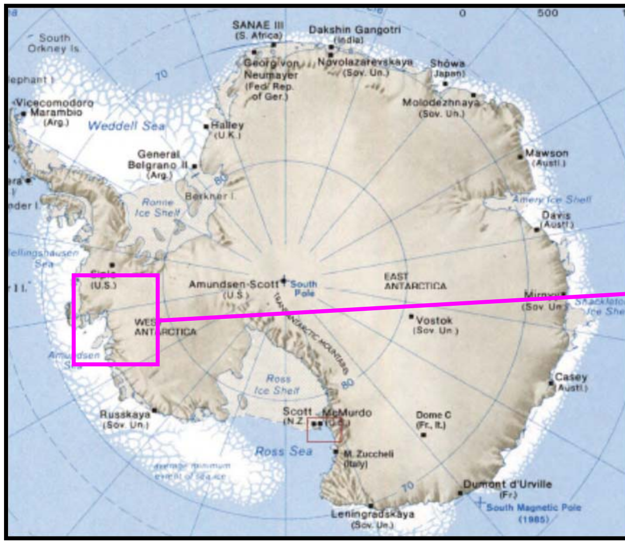
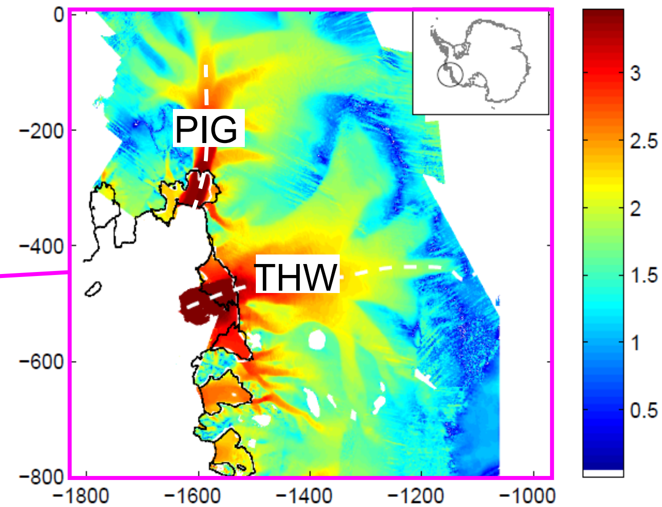
Still preliminary

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

David Pollard (Penn State U.) and Robert DeConto (U. Massachusetts)

WAIS workshop, Algonkian Regional Park, Sept. 2013





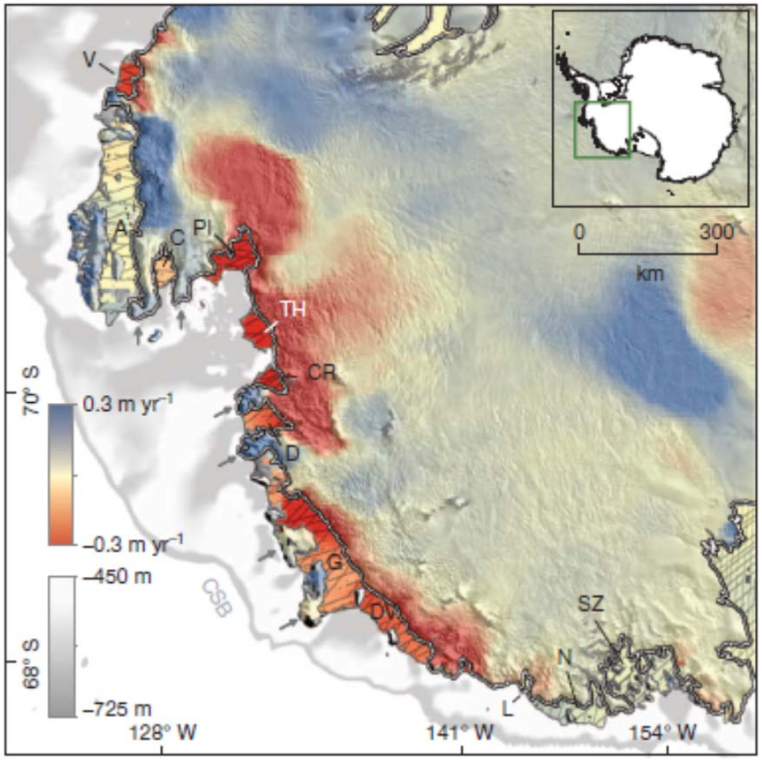
Joughin et al., J.Glac, 2009 (velocities),
from Docquier et al., J. Glac., in review

Outline

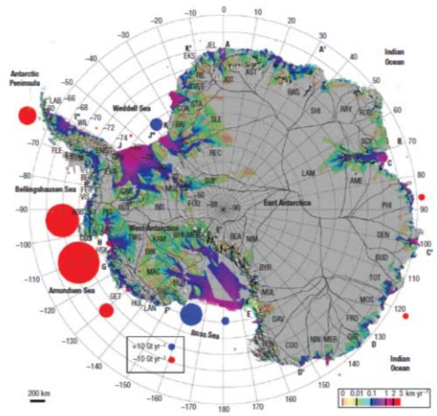
- Modern data and modeling
- Geologic data, last ~20 kyrs
- Simulations of last 20 kyrs, fit to geologic data
- “Future” simulations with best-fit model

PLIOMAX CReSIS

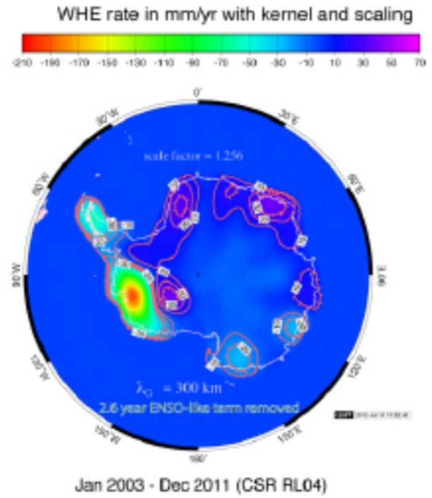
Modern Observations



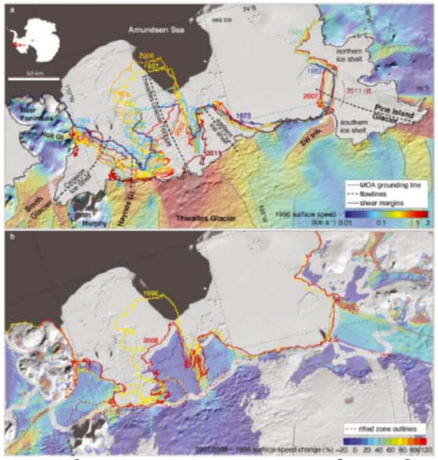
Surface thinning rates (Pritchard et al., Nature, 2012)



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



GRACE water-height equiv. trend, uncorrected (Shepherd et al., Science, 2012)

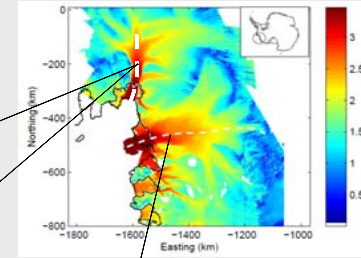


Terminus retreat, acceleration (MacGregor et al., J. Glac., 2012)

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)

Modeling to date

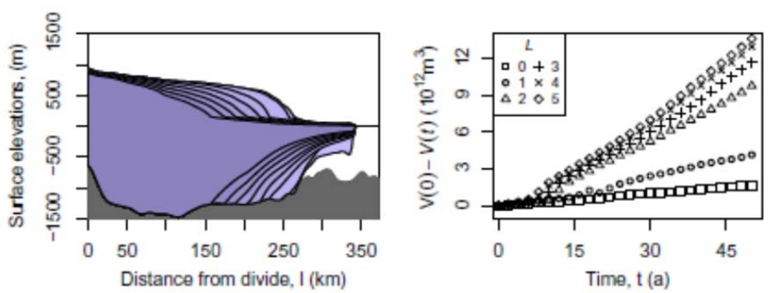


Modeling of future PIG/THW has been

(i) validated only vs. present or recent decades, and

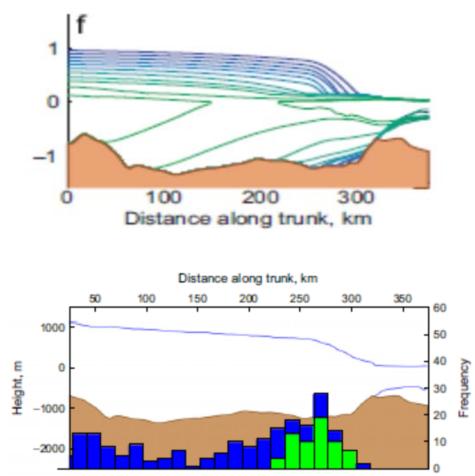
(ii) run "only" ~200 to 500 years into the future

PIG: Cornford et al., J. Comp. Phys., 2013

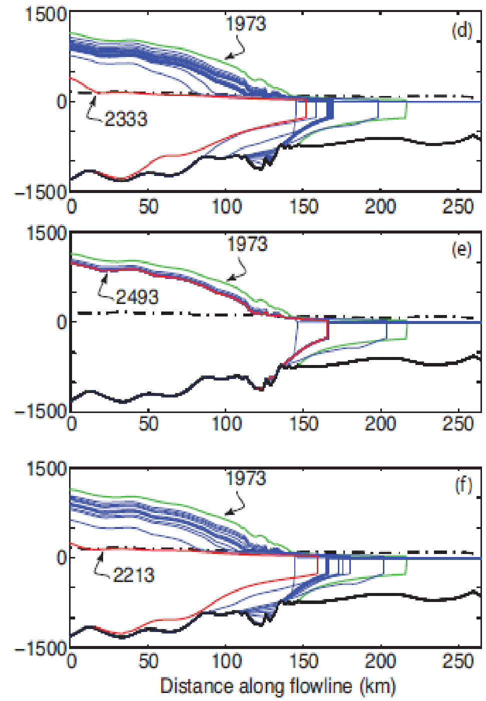


(a) Pine Island Glacier as it retreats (b) Ice loss over time

PIG: Gladstone et al., EPSL, 2012

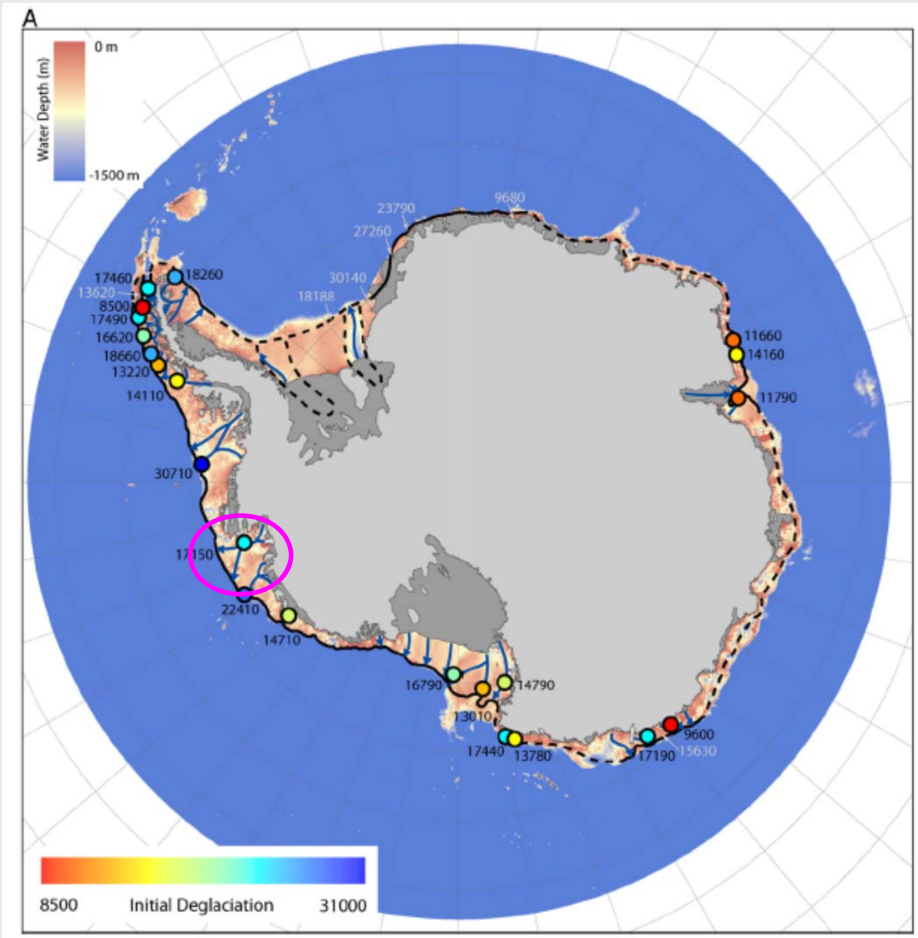


THW: Parizek et al., JGR, 2013

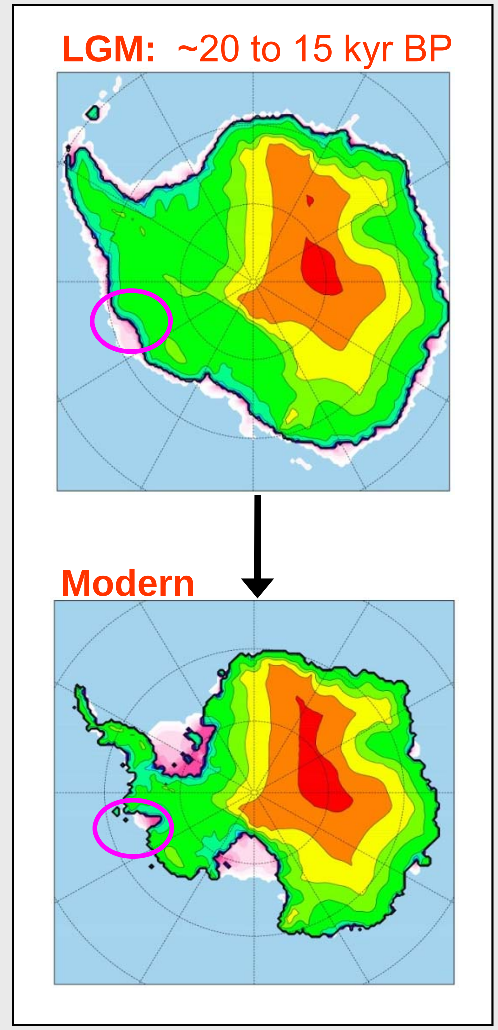


Also: Joughin et al., GRL, 2010;
Docquier et al., J. Glac., in review;
meeting abstracts: Favier, Gagliardini, Joughin

Geologic data is available for the last deglacial retreat (~20 ka to modern) in ASE sector

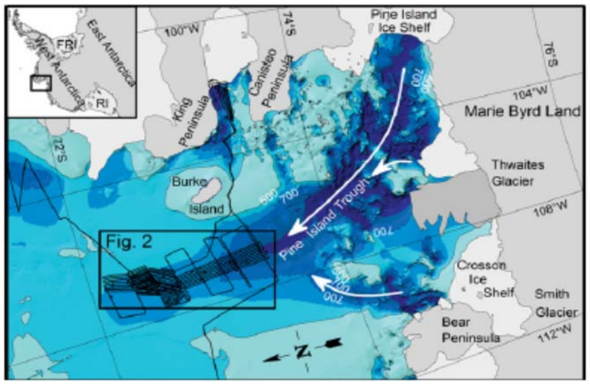


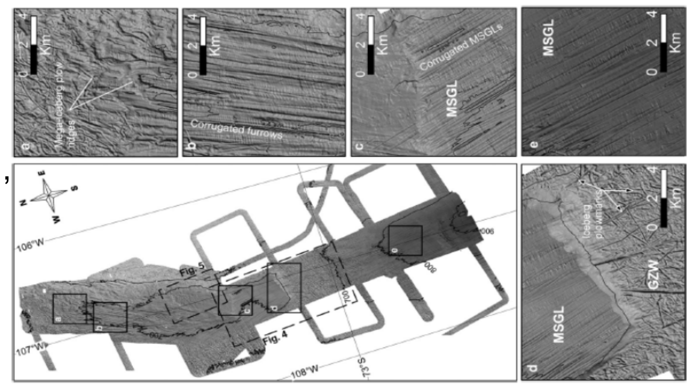
Livingstone et al., 2012, Earth-Sci. Rev.



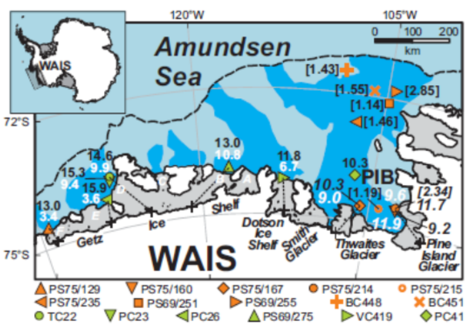
Types of paleo data:

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

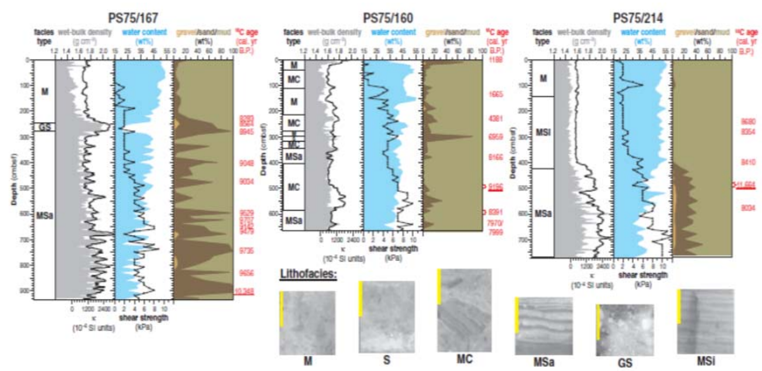




Jakobsson et al., Geol., 2011

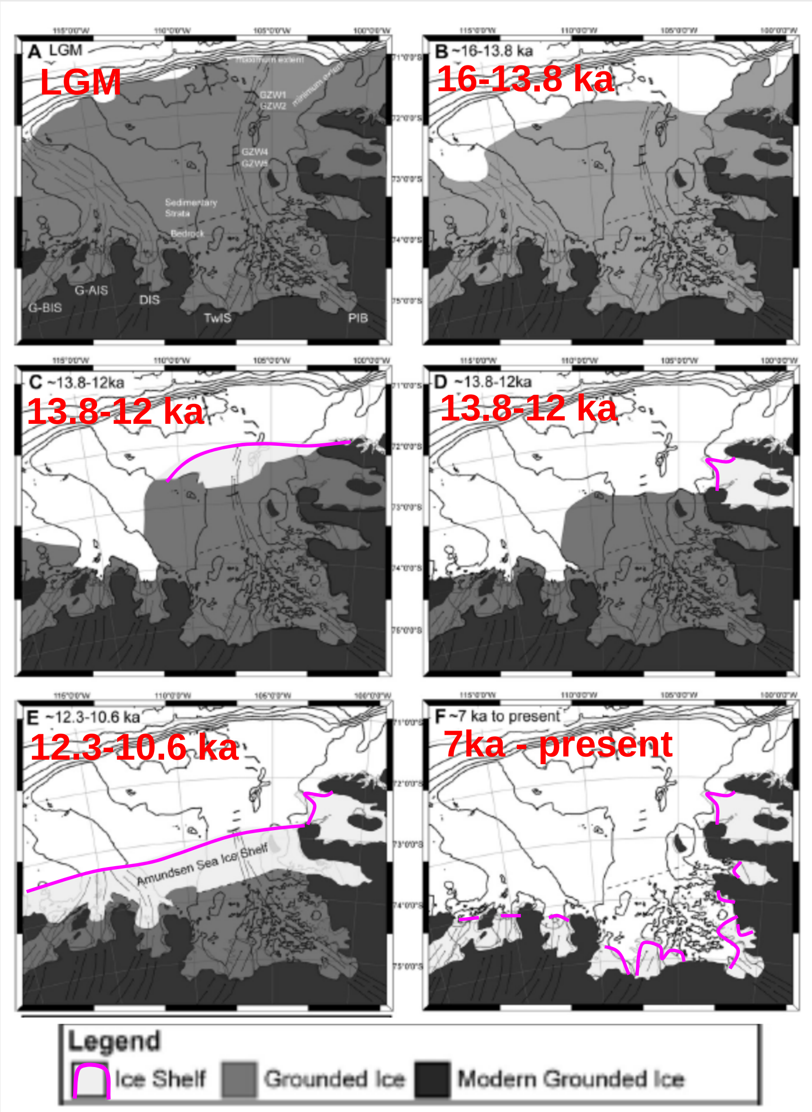


Hillenbrand et al., Geol., 2013



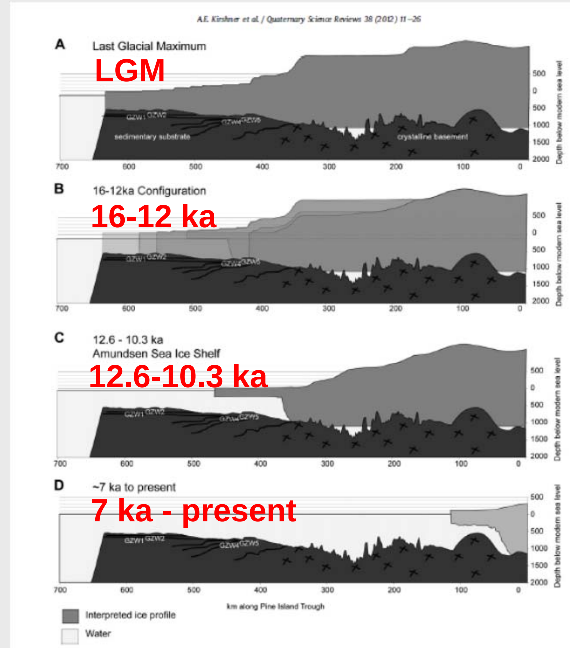
Also: Lowe and Anderson, QSR, 2002; Evans et al., Mar. Geol., 2006; Johnson et al., Geol., 2008; Graham et al., JGR, 2010; Smith et al., QSR. 2011; Jakobsson et al., QSR, 2012; Kirshner et al., QSR, 2012; Klages et al., QSR, 2013; and others…

Basic synthesis of paleo-data story *(to be updated!*)*



Grounding lines and ice shelf extent:

Kirshner et al., QSR, 2012

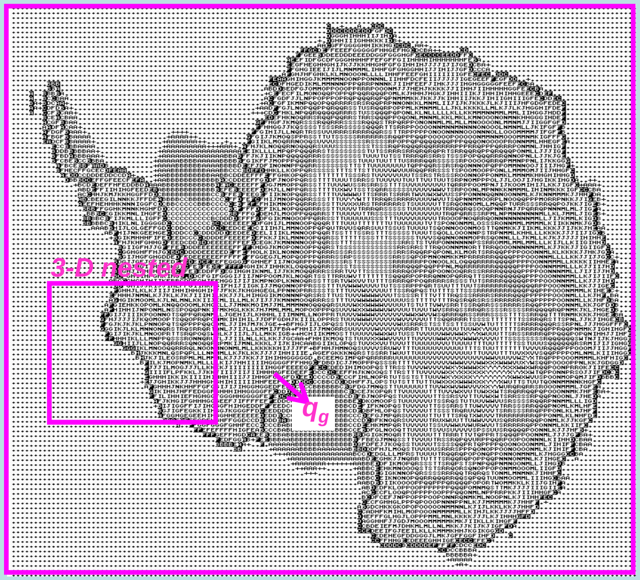


- Grounding lines extended to near the continental shelf break until ~15 kyr.
- Then retreated to mid continental shelf ~12 kr with a large ice shelf.
- Around ~10 ka, the ice shelf collapsed, allowing grounding lines to retreat to near modern positions with very little ice shelf left by ~6 ka.

** Also from C.-D. Hillenbrand et al., Geol., 2013; J. Johnson, M. Bentley, J. Smith, pers. comm.*

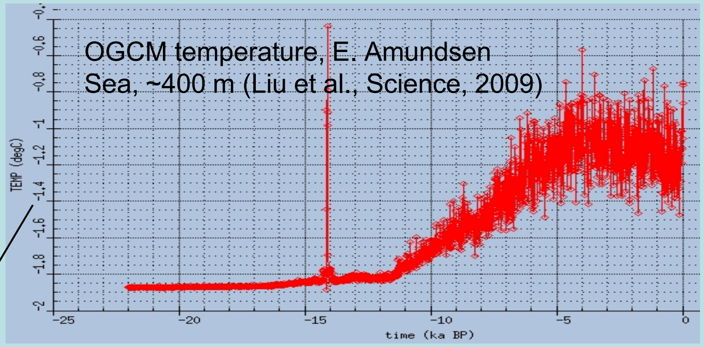
Simulations of last deglacial period

Ice sheet model and paleo forcing



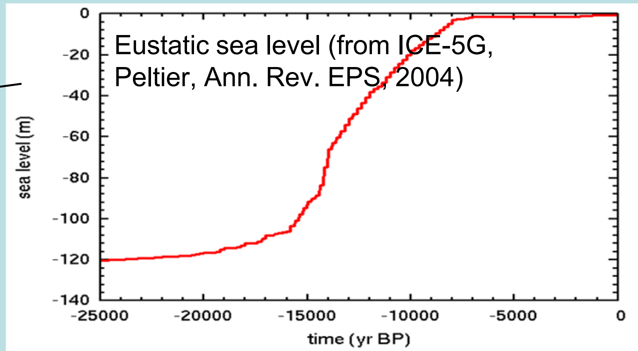
Model:

- 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)



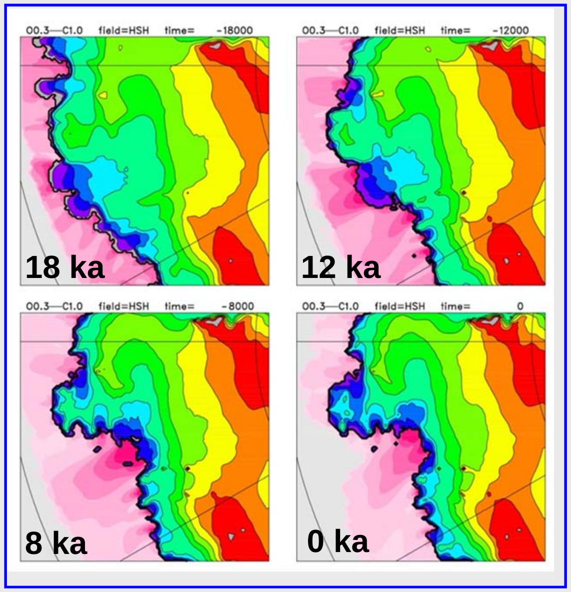
Paleo Forcing:

- Atmospheric T,P from modern climatology and parameterized past variations (SeaRISE).
- Ocean temperatures (400 m) from A/OGCM simulation of last 22 kyrs (Liu et al., 2009).
- Sea level prescribed from ICE-5G (Peltier, 2004).

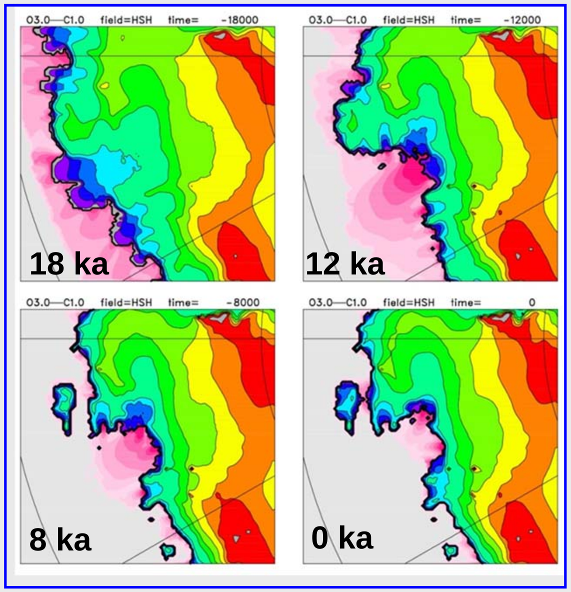


Compare simulations with data over past 20,000 years

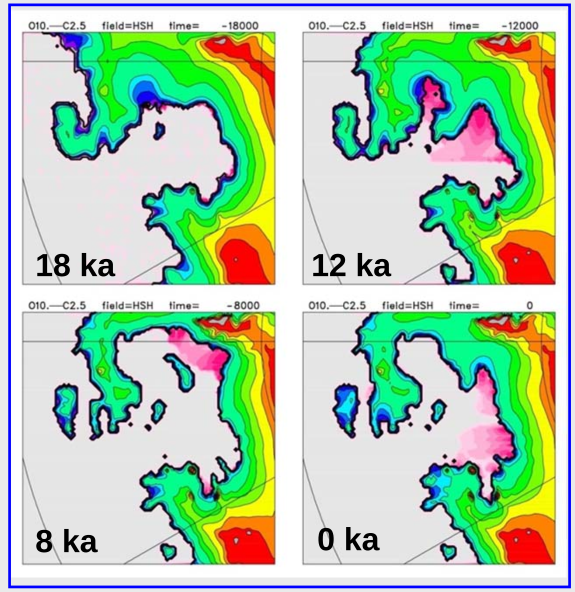
Example A (too advanced ice)

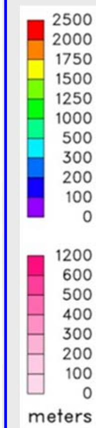


Example B (good ice extents)

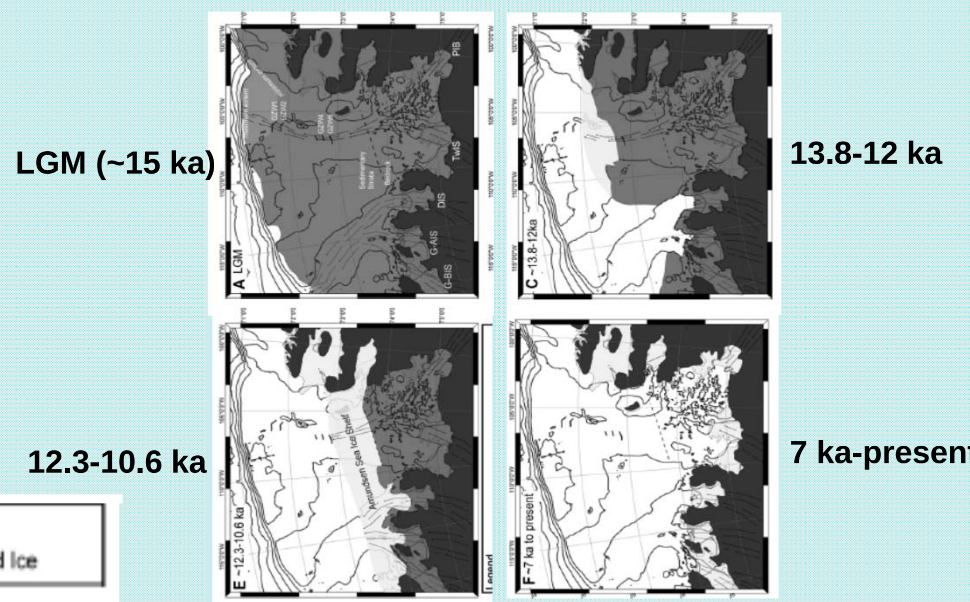


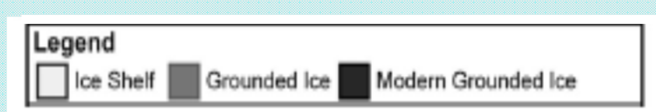
Example C (too retreated ice)





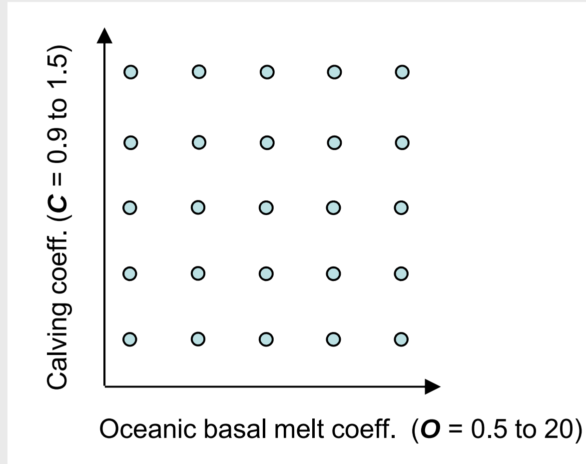
Kirshner et al, QSR, 2012

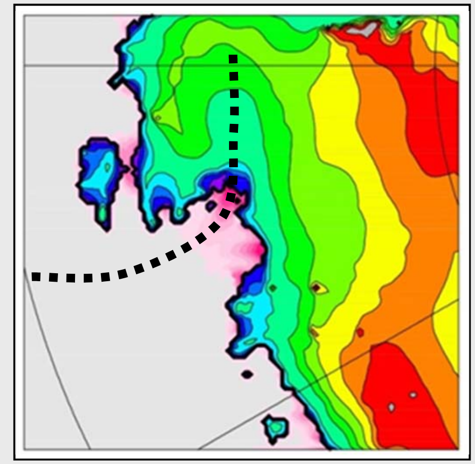


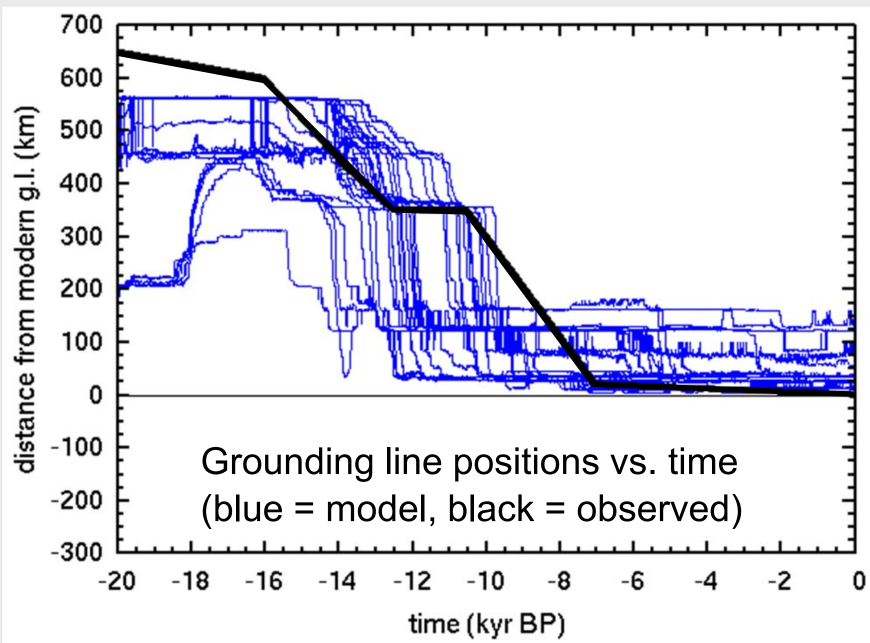


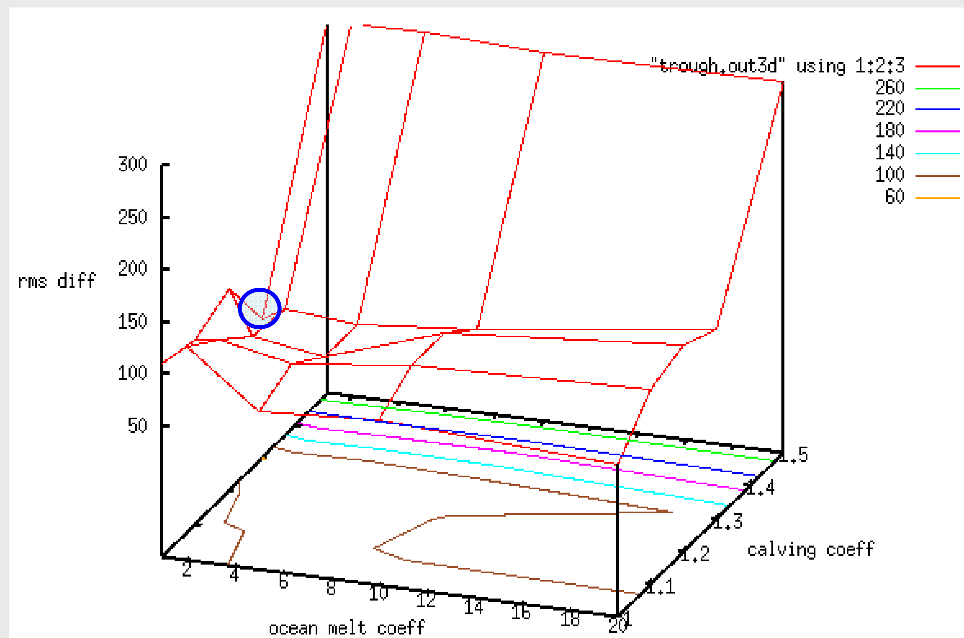
Preliminary step towards large-ensemble validation…"proof of concept"

- 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)



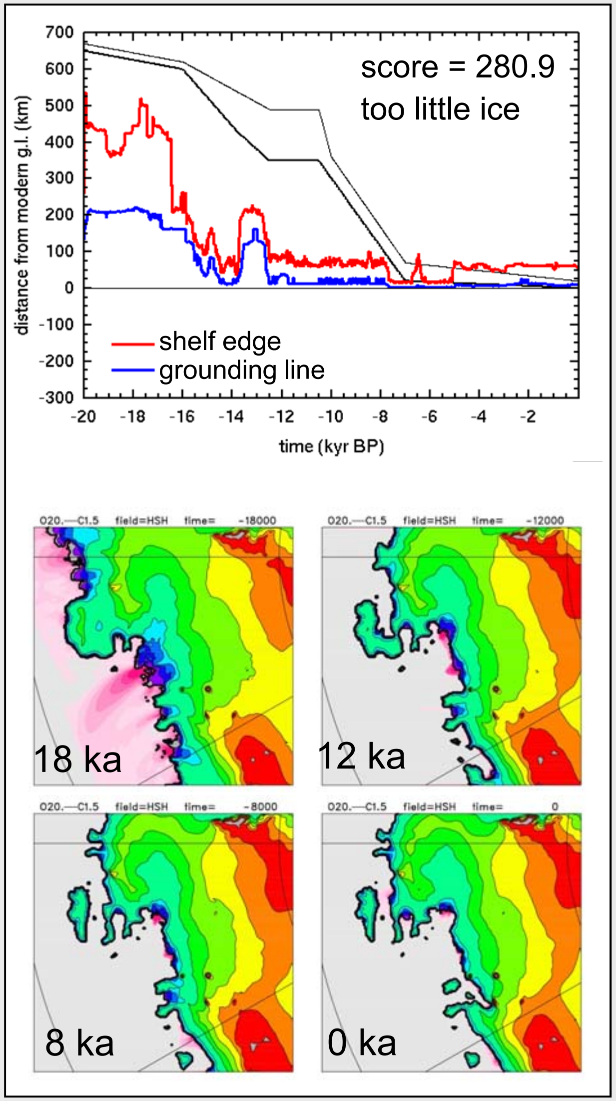




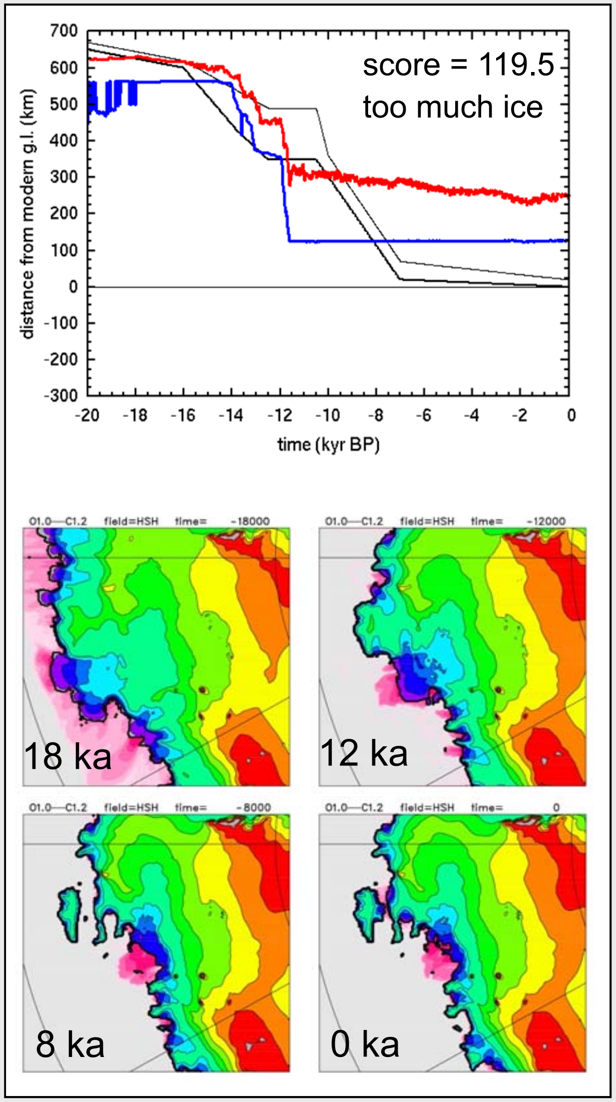


Individual simulations

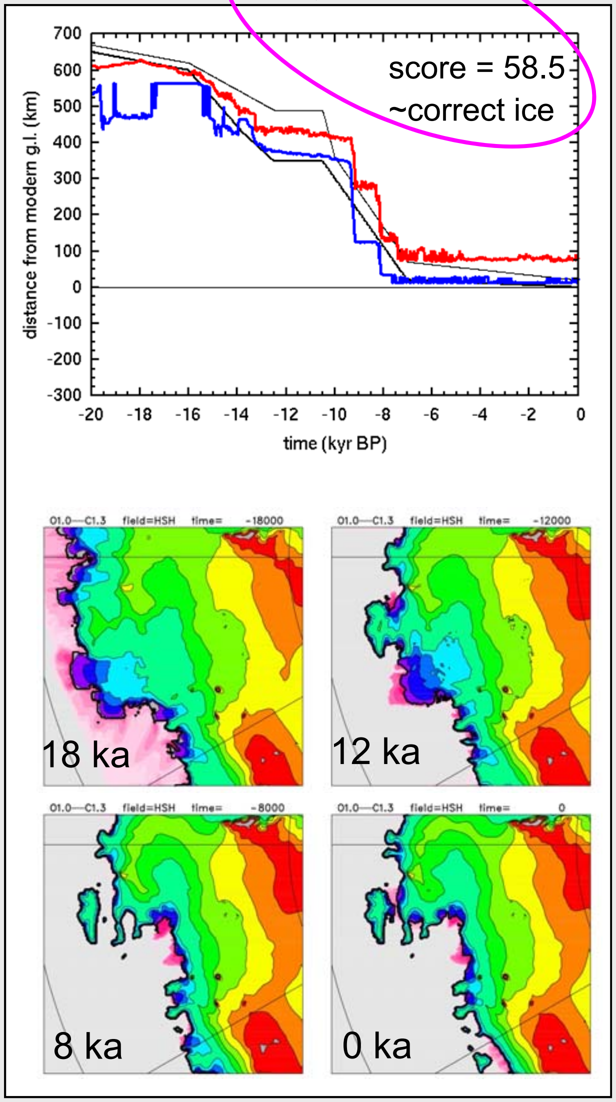
O=20, *C*=1.5

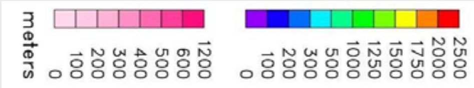


O=1, *C*=1.2

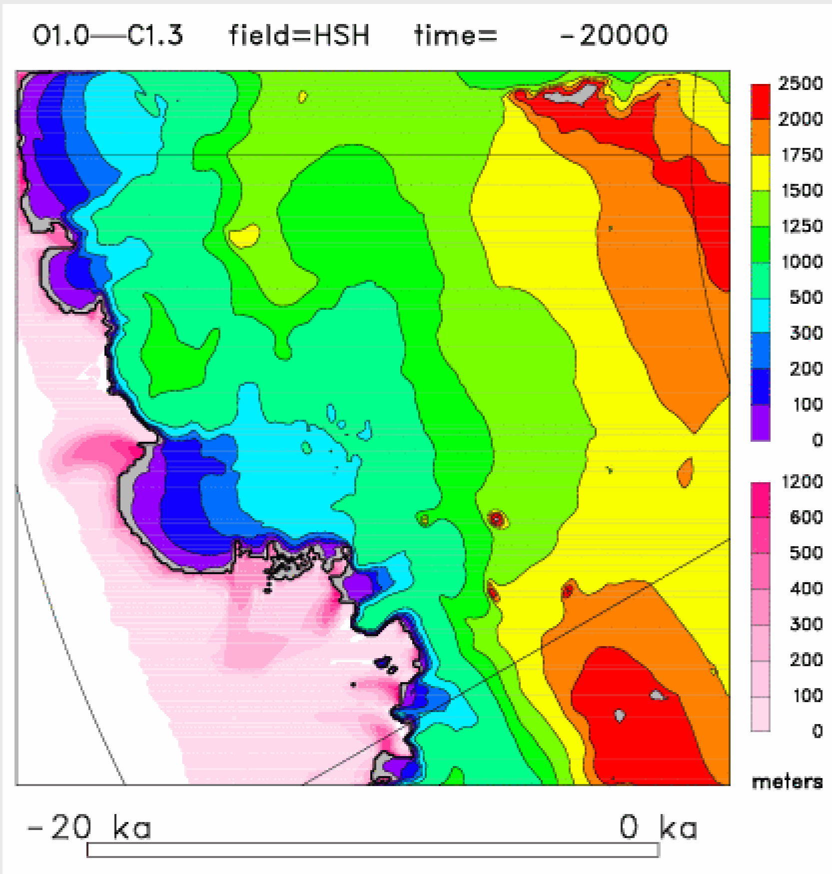


O=1, *C*=1.3



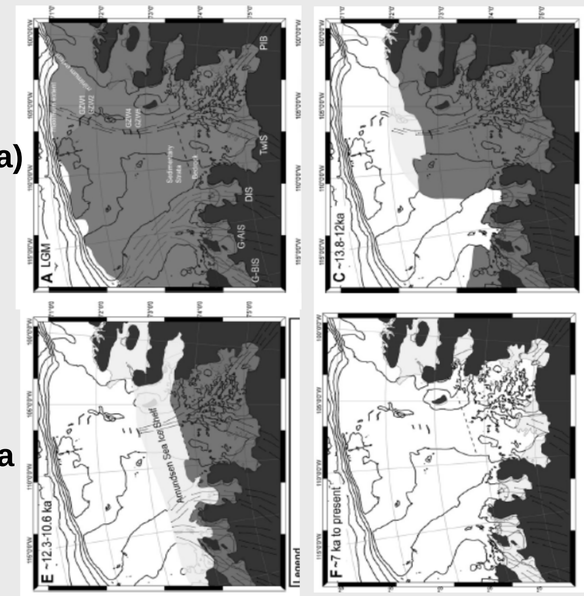


Simulation of last 20 kyr, with *O*=1, *C*=1.3



LGM (~15 ka)

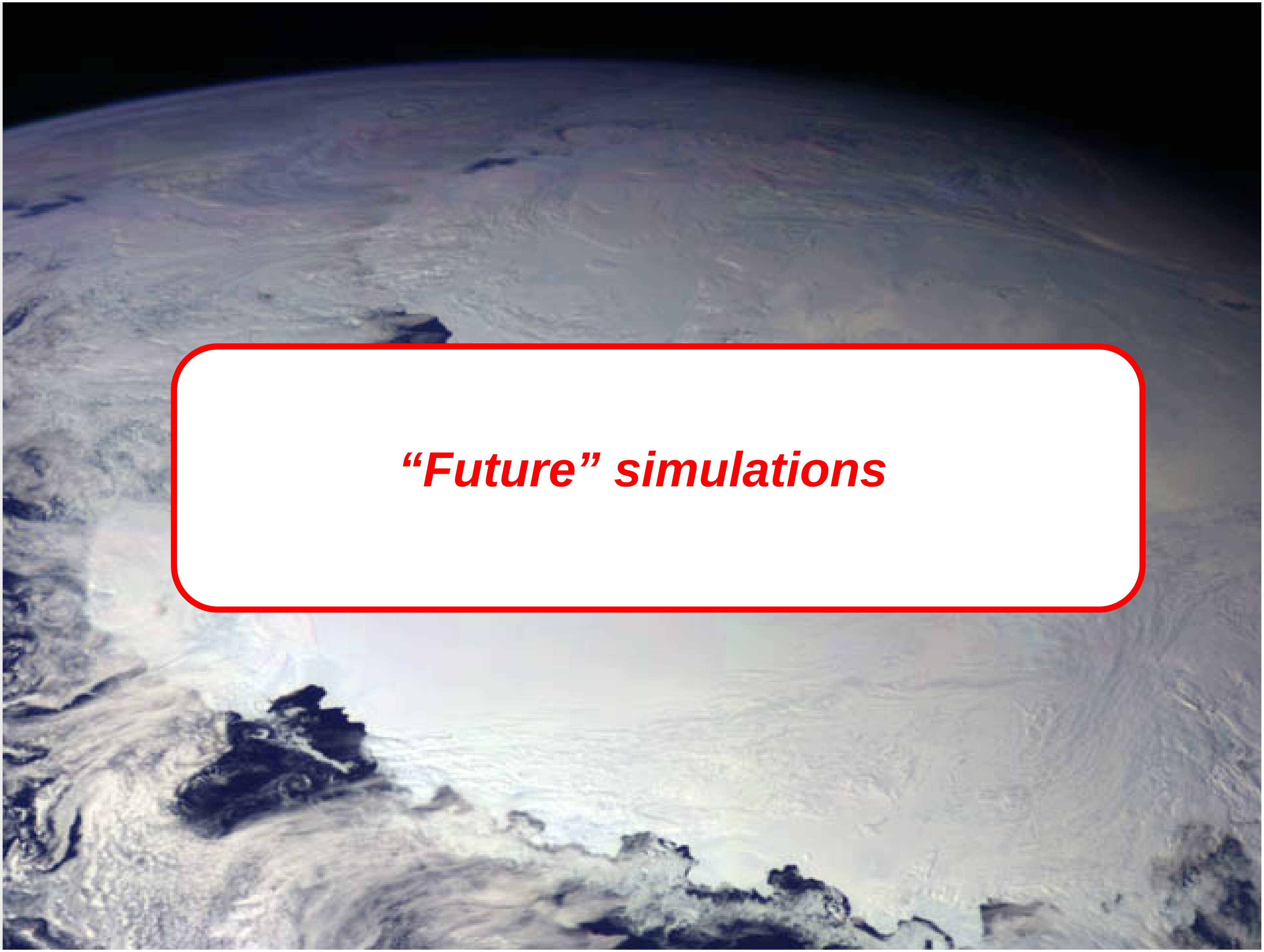
13.6-12 ka



12.3-10.6 ka

7 ka-present

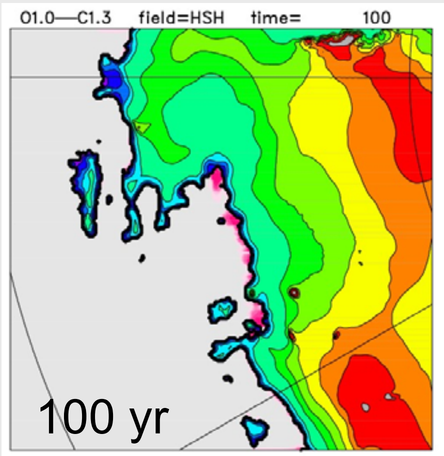
Kirshner et al, QSR, 2012

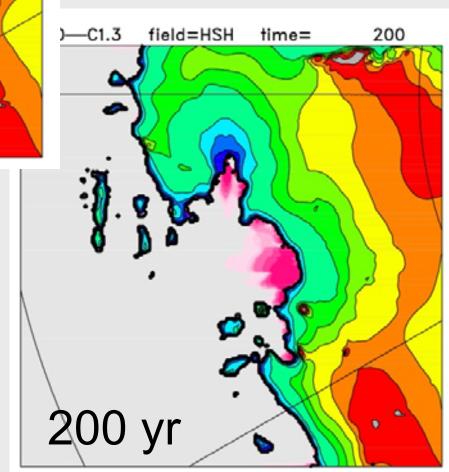


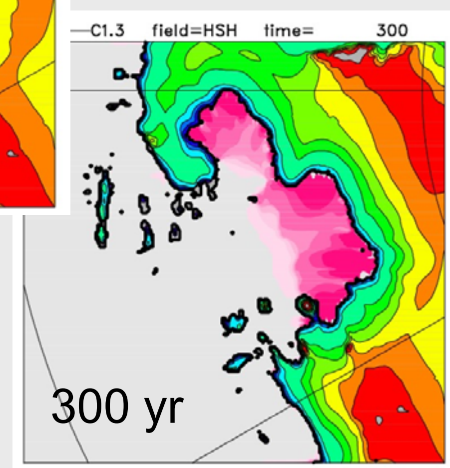
“Future” simulations

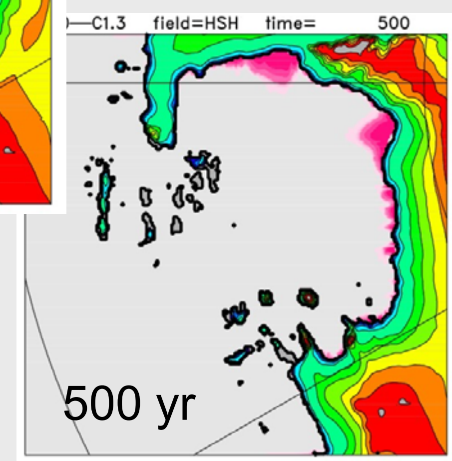
Crude “future” simulation with *O*=1, *C*=1.3

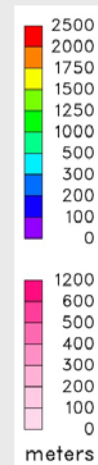
- Use best fit model parameter values (*O*=1, *C*=1.3)
- Start from modern ice state (end of 30 ka simulation)
- Crude “future” warming: Increase ocean warming (to +2^{o}C) and atmospheric CO_2 (to 4x PAL)

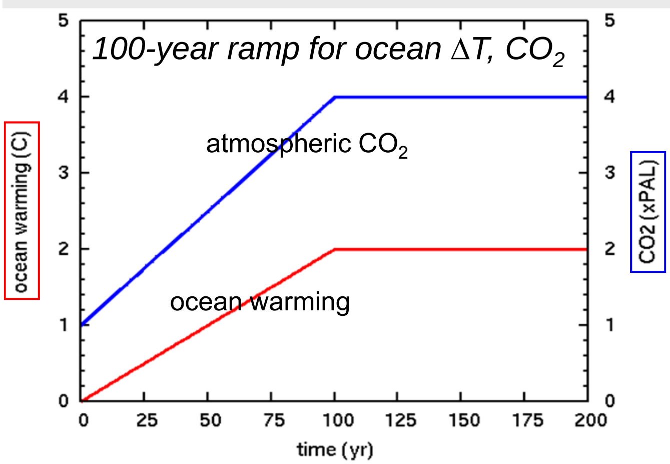




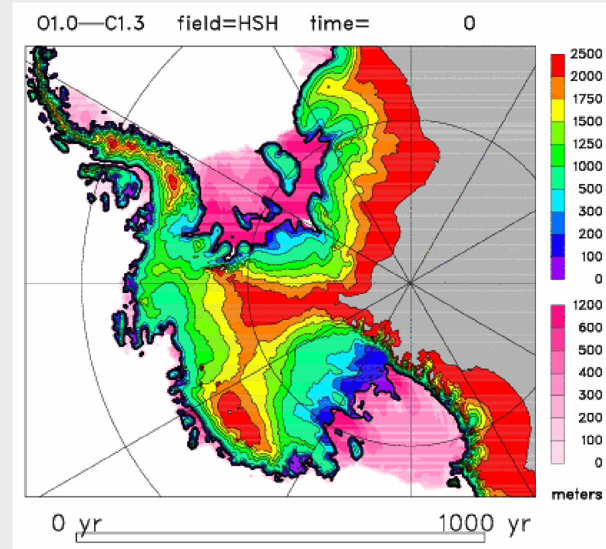


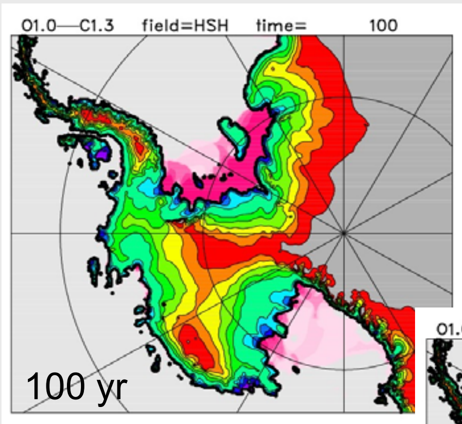


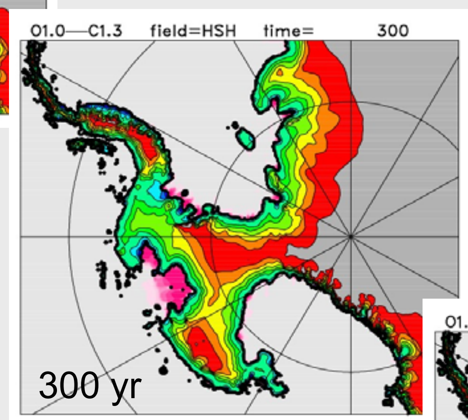


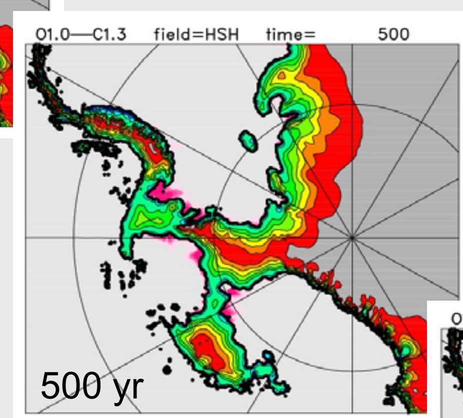


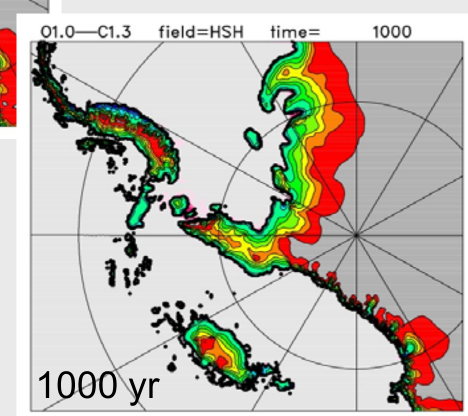
Crude “future” simulation, all-WAIS domain, 10 km grid

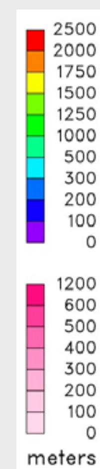


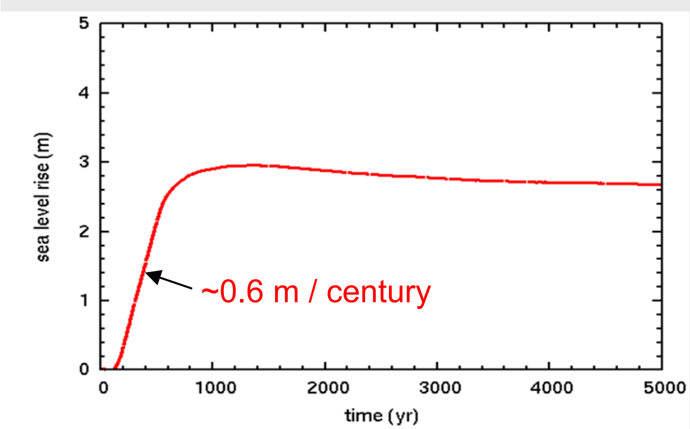






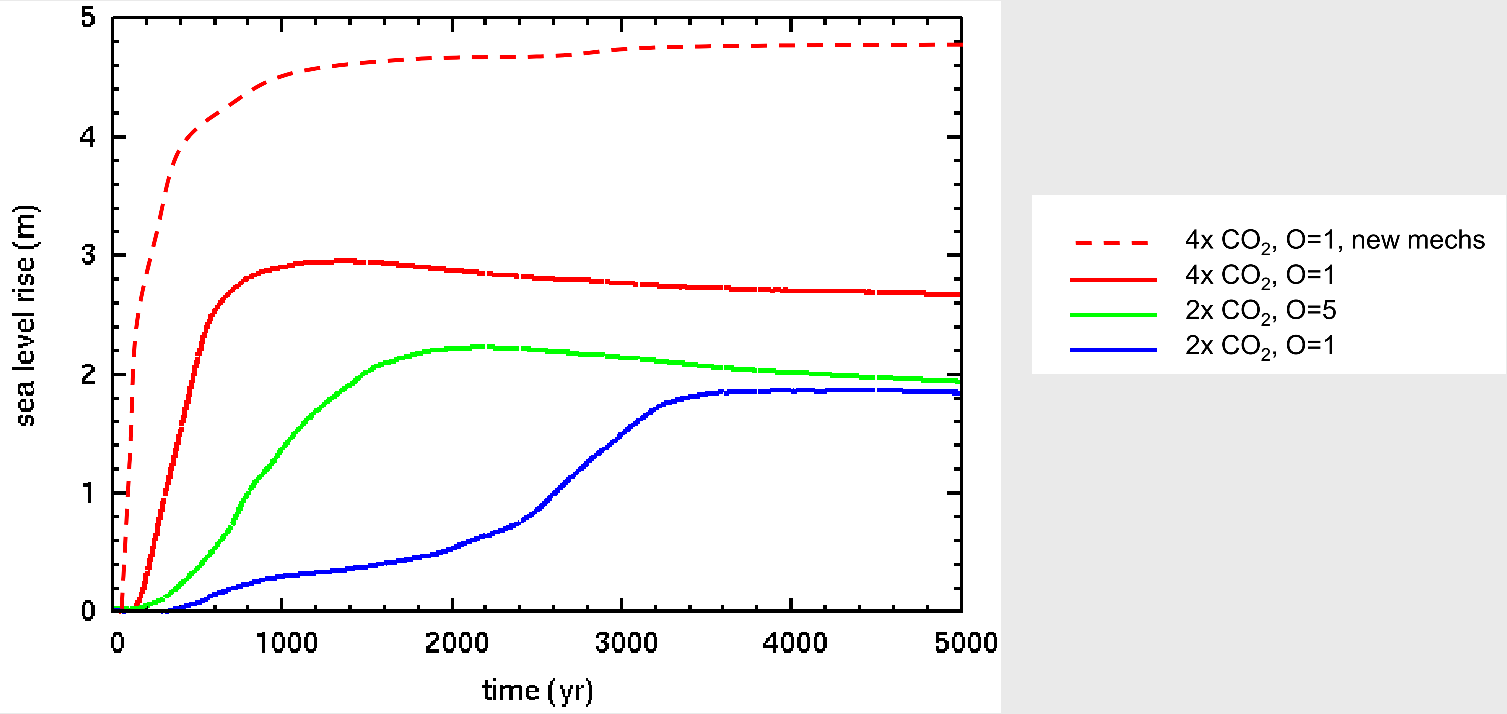






Crude “future” simulations, all-WAIS domain.

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:
  - Geologic data, interp. (British Antarctic Survey, C.-D. Hillenbrand, J. Johnson, J. Smith).
  - Large-ensemble techniques: MCMC, pdf's (SCRiM Network, K. Keller, Penn State).
  - Apply same technique to Ross Embayment (with P. Clark).