High-resolution simulation of the extent and flow of Antarctic Peninsula glaciers

Nick Golledge

Antarctic Research Centre,
Victoria University of Wellington,
New Zealand

Collaborators:
Alun Hubbard - University of Wales, Aberystwyth, UK
Jez Everest - British Geological Survey, Edinburgh, UK
Jo Johnson / Phil Leat - British Antarctic Survey, Cambridge, UK

28th Sept 2009

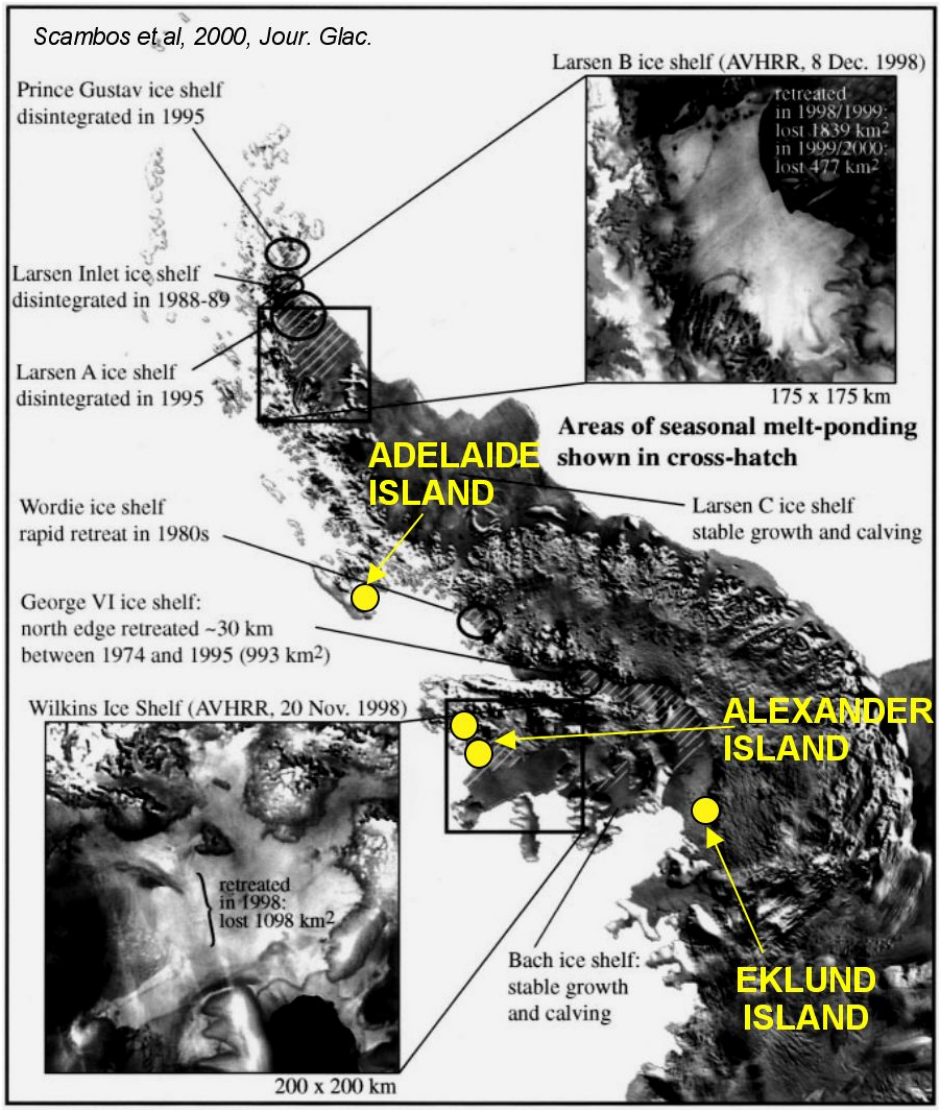
Research questions & model aims

Empirical aims:

- To refine LGM vertical & horizontal extent using cosmogenic isotope exposure dating

Model aims:

- Simulate LGM geometry & add glaciological interpretation to geological archive (swath bathymetry etc)
- Assess sensitivity of LGM APIS to primary forcings (SL / oceanic heat flux / atmos. temp etc)



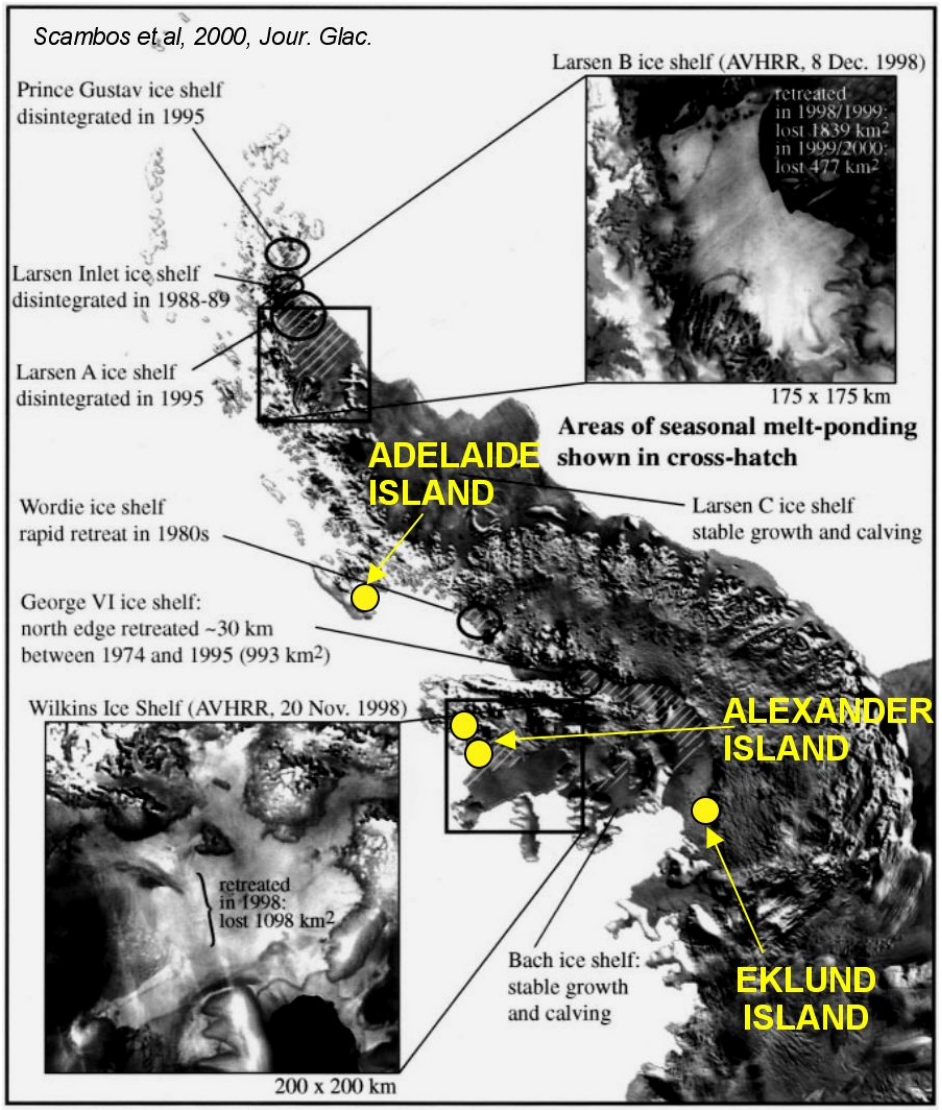
Research questions & model aims

Empirical aims:

- To refine LGM vertical & horizontal extent using cosmogenic isotope exposure dating

Model aims:

- Simulate LGM geometry & add glaciological interpretation to geological archive (swath bathymetry etc)
- Assess sensitivity of LGM APIS to primary forcings (SL / oceanic heat flux / atmos. temp etc)



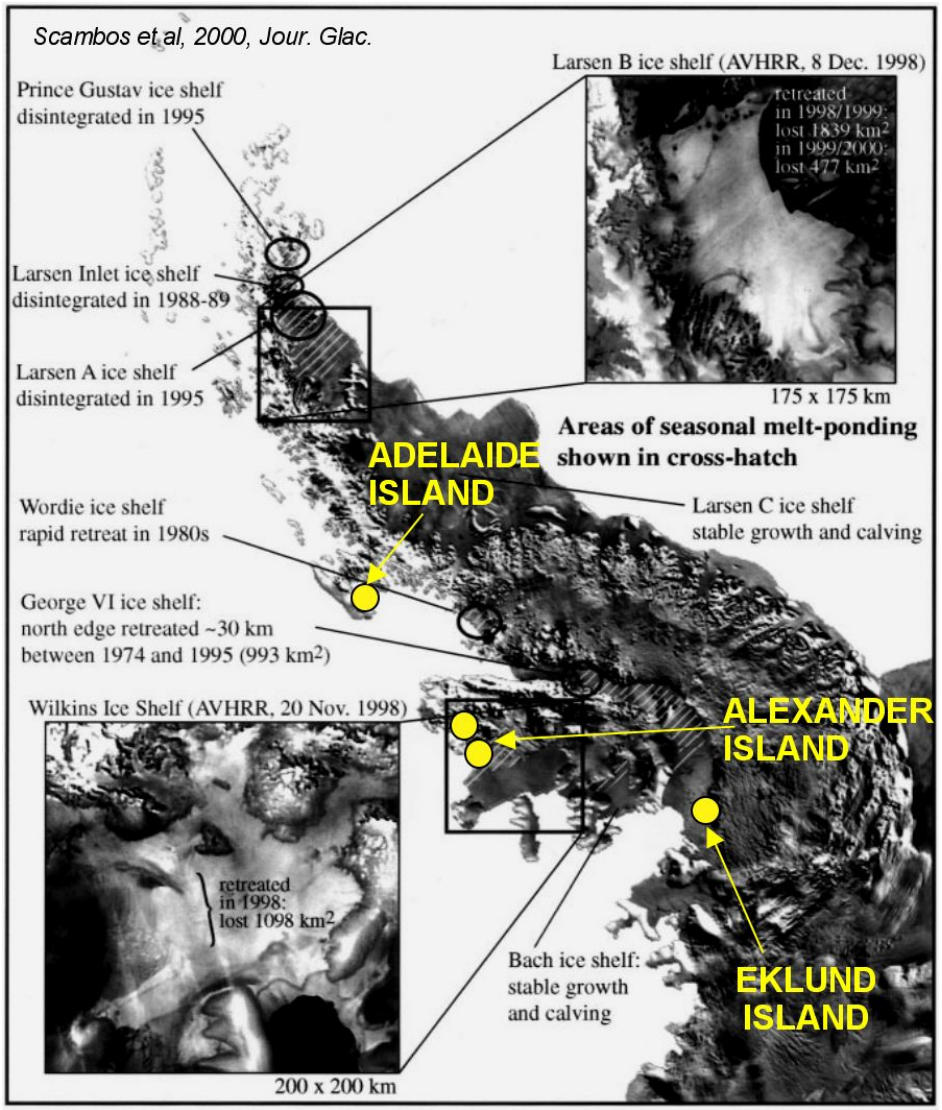
Research questions & model aims

Empirical aims:

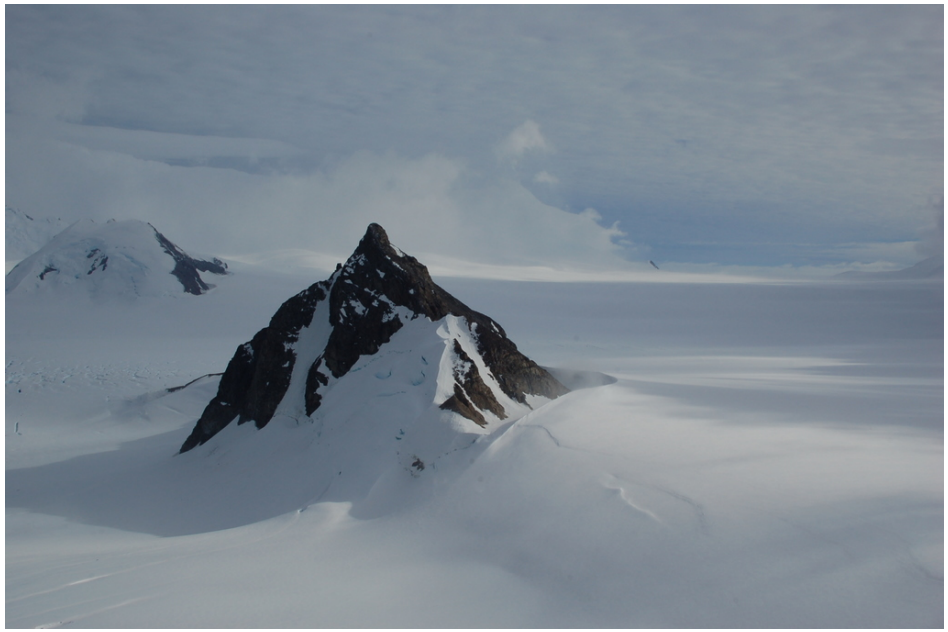
- To refine LGM vertical & horizontal extent using cosmogenic isotope exposure dating

Model aims:

- Simulate LGM geometry & add glaciological interpretation to geological archive (swath bathymetry etc)
- Assess sensitivity of LGM APIS to primary forcings (SL / oceanic heat flux / atmos. temp etc)



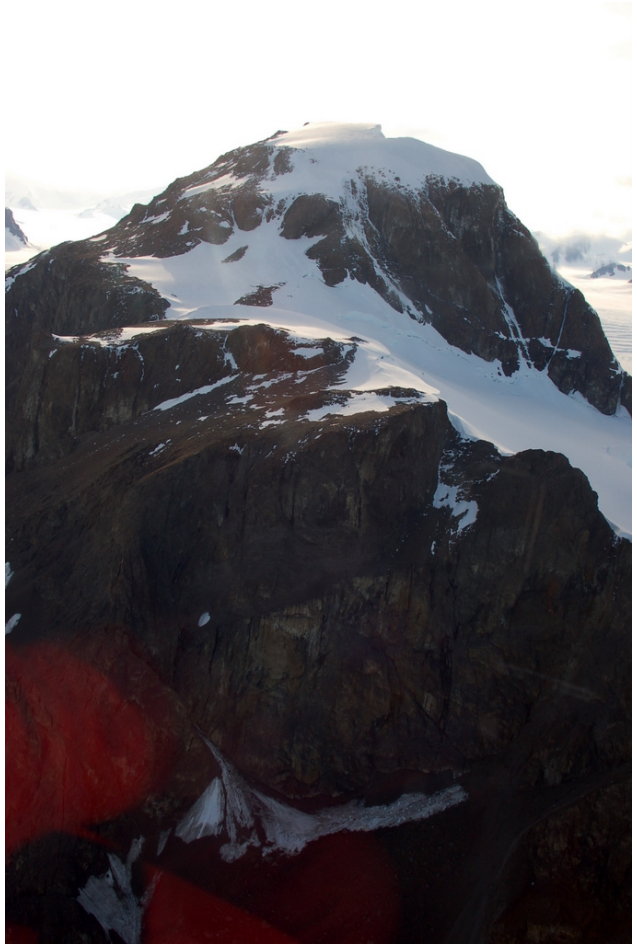
LGM geometry of the Antarctic Peninsula Ice Sheet: max. vertical constraint



- Stork Ridge (Adelaide Isl.) c. 750 m a.s.l, v. weathered bedrock
- *No* erratics (suggests only local ice?)
- Maximum upper limit of LGM ice?

LGM geometry of the Antarctic Peninsula Ice Sheet: post-LGM thinning

- Mt. Holt - previously unvisited, potential ‘dipstick’ in Palestrina Glacier
- V. few granitic erratics, mostly local metaseds



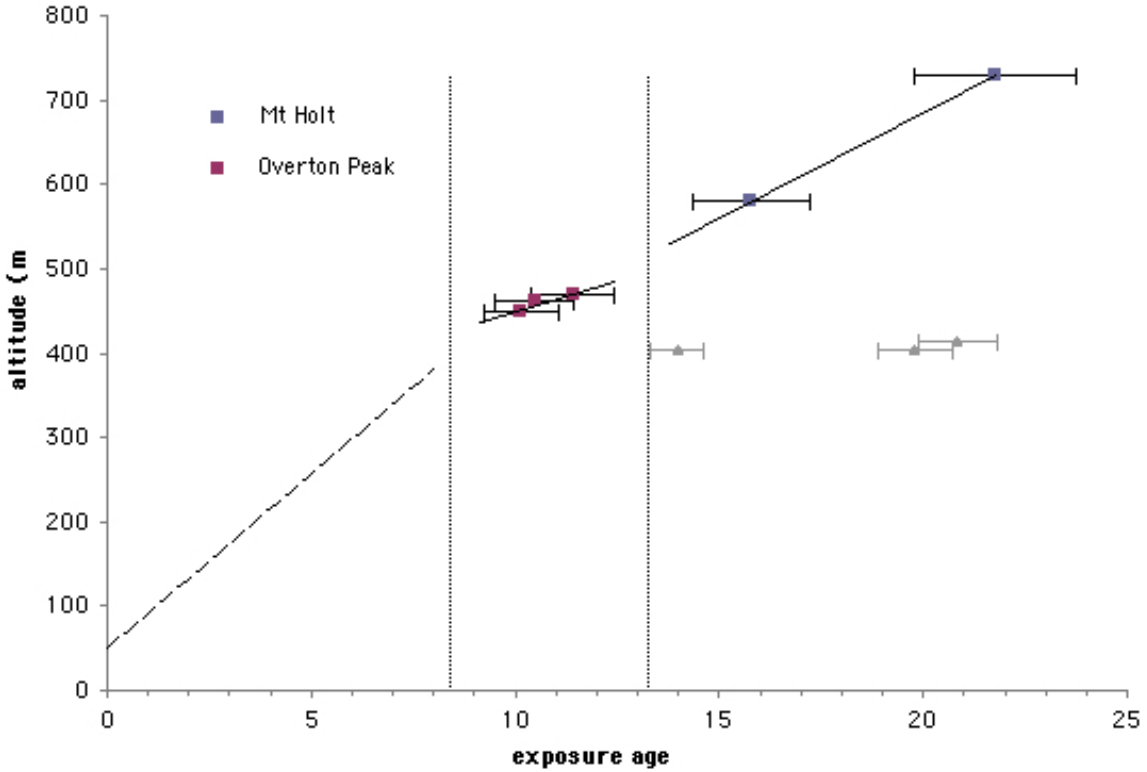
LGM geometry of the Antarctic Peninsula Ice Sheet: post-LGM thinning

- Overton Peak (Rothschild Isl.) - distal from Palmer Land
- Presently surrounded by Wilkins Ice Shelf
- Abundant granite erratics (from east side Alex. Isl.)

LGM geometry of the Antarctic Peninsula Ice Sheet: post-LGM shelf changes

- George VI Sound - ice shelf retreat in recent decades
- Sample site above recent shelf surface(?)
- Thinning history of shelf post-LGM

LGM geometry of the Antarctic Peninsula Ice Sheet



- Progressive quasi-steady thinning from c. 22ka (LGM) – 9ka?
- Rapid thinning / recession from 9ka – present?
- Outliers poss reflect:
  i) supraglacial exposure prior to deposition,
  ii) recycling / inheritance,
  iii) post-depositional downslope movement

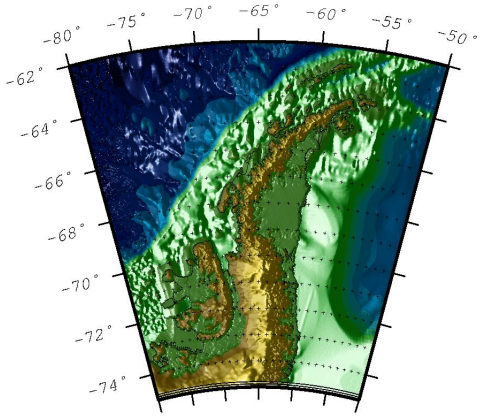
Model requirements

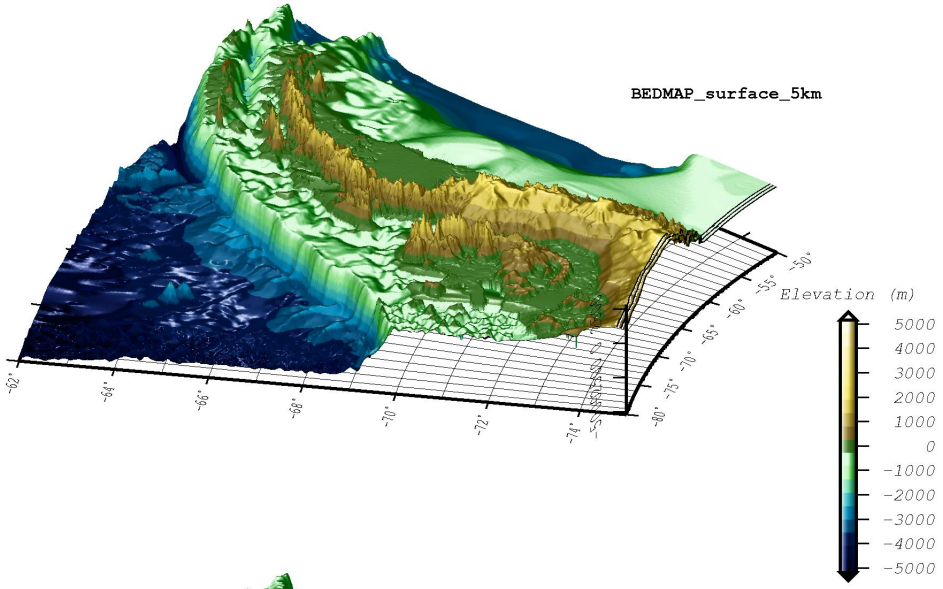
- Must be tractable at high resolution (1-5 km)
- Capable of simulating grounded fast-flow zones
- Able to simulate a dynamic grounding line
- Account for realistic shelf growth / melt
- Atmospheric coupling (PDD) for driving MB
- Transient evolution of basal substrate / hydrology

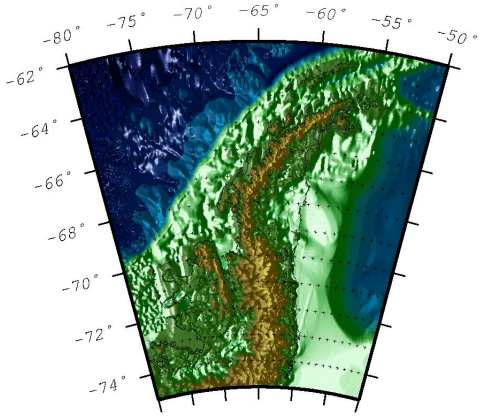
Parallel Ice Sheet Model (PISM)

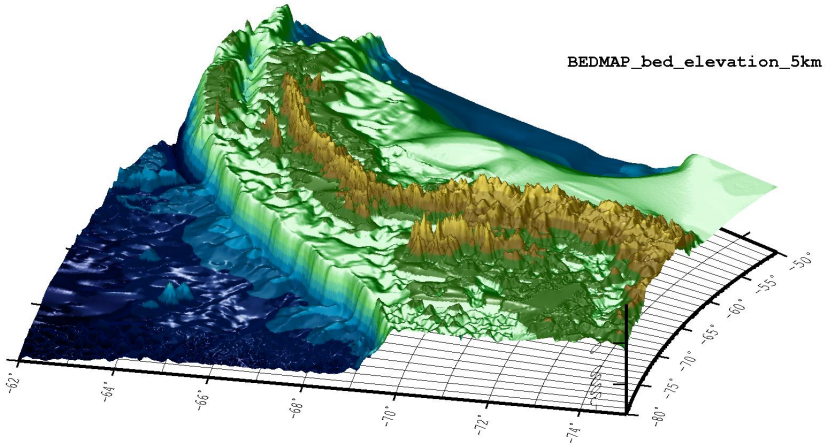
- Resolution: Uses mpi to parallelize processing across multiple cores
- Fast-flow: Solves PDEs for both SIA and SSA - allows grounded, shelf, and 'dragging shelf' flow [plastic till failure] (cf Schoof 2006/2007a)
- Grounding line: (cf Schoof 2007b)
- Shelf melt: Parameterised (oceanic / atmos.) basal / surface melt rate (ohf=0.5Wm^2)
- Atmospherics: PDD parameterisation - c. 10°C range typical for e.g. Adelaide Island
- Substrate: yield stress depends on till friction angle (initially a function of elevation) & effective pressures (evolving substrate pwp): $\tau_c = (tan\ \phi)(\rho g H - \rho_w)$

Model requirements & input data ('boundary conditions')

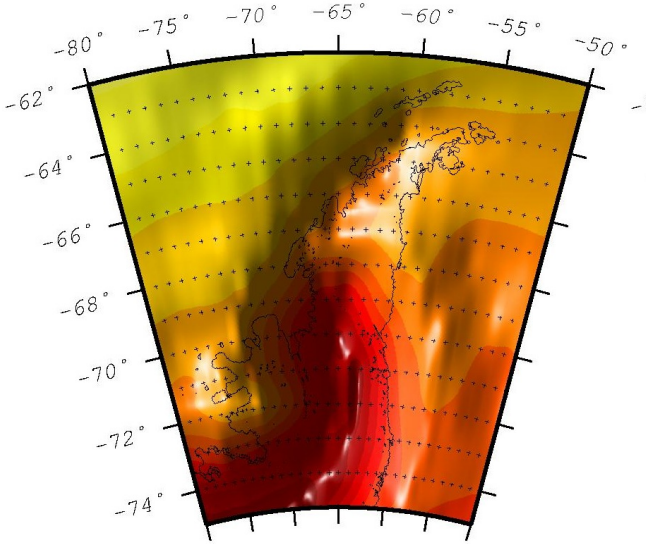




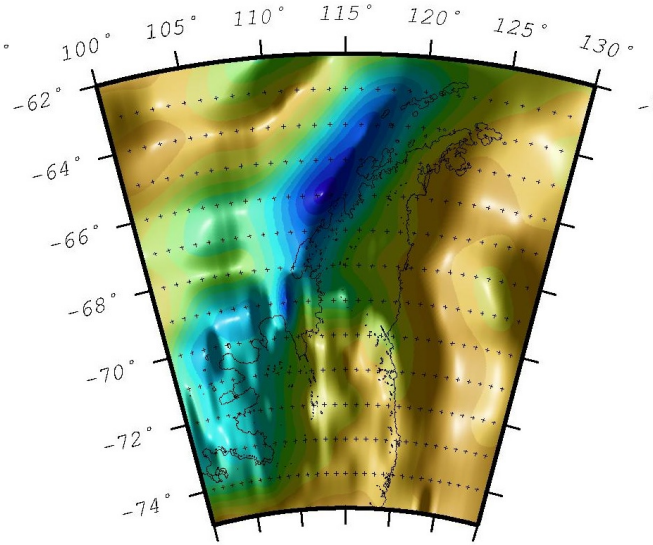




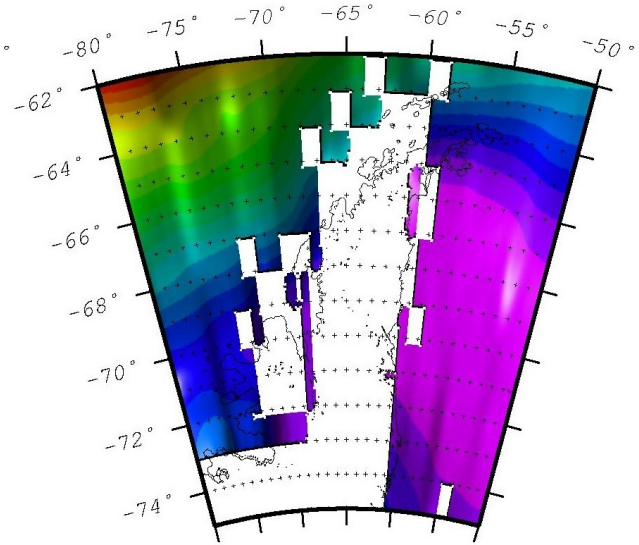
Model requirements & input data ('boundary conditions')



ERA temp (C)

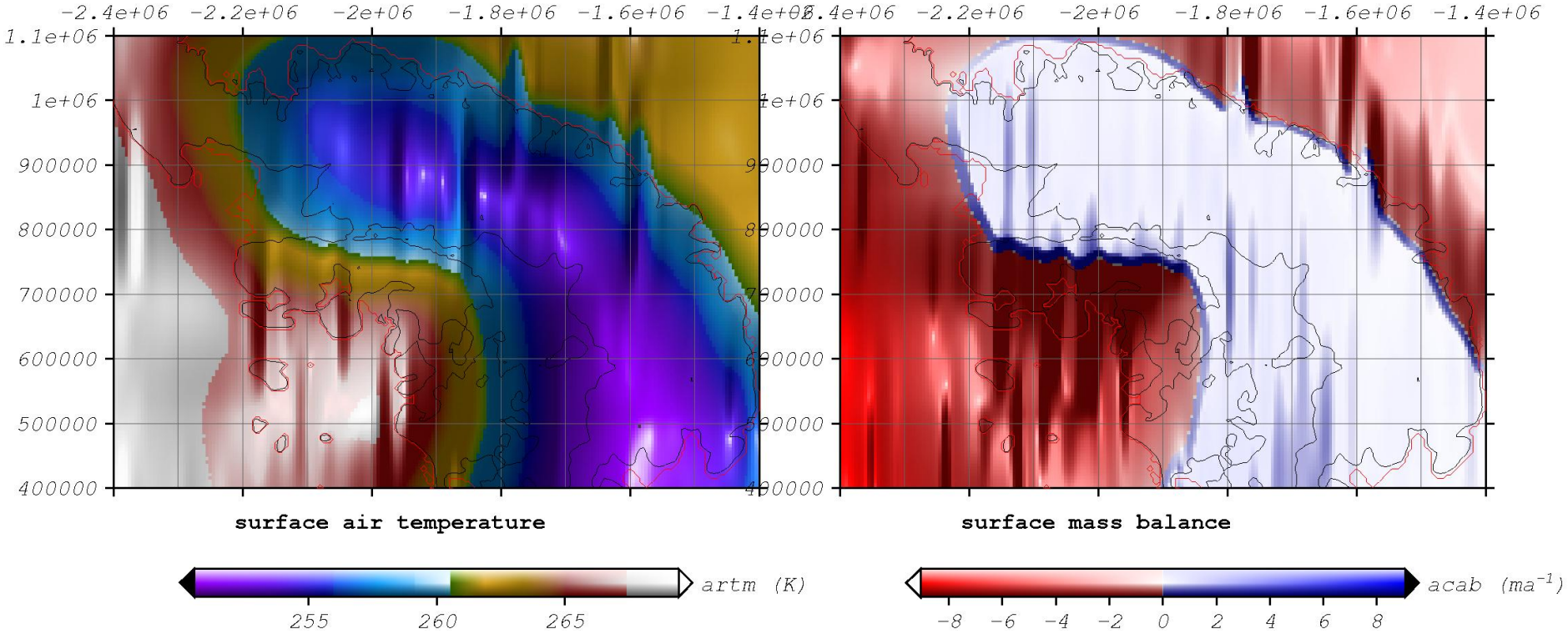


CRU ppt (mm)

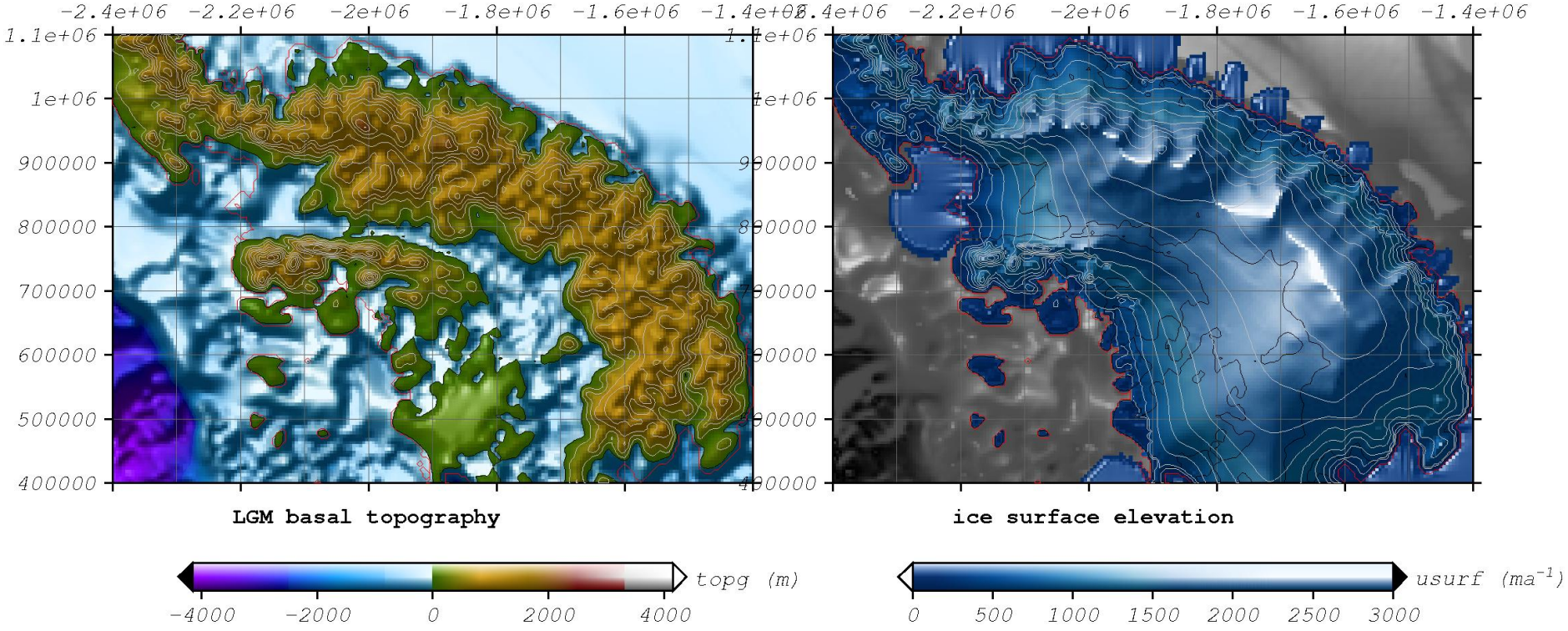


WOCE sst (C)

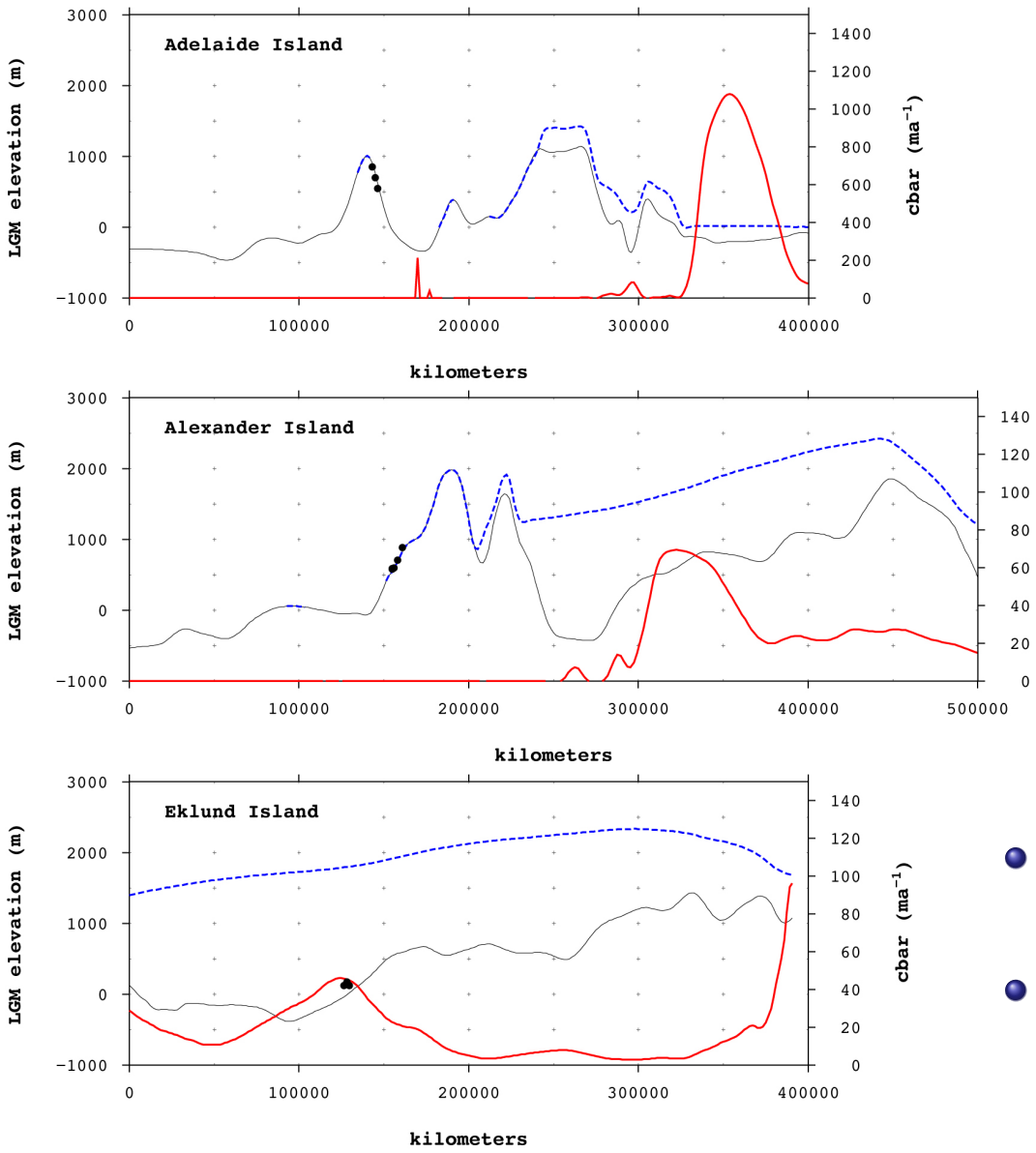
Preliminary output...

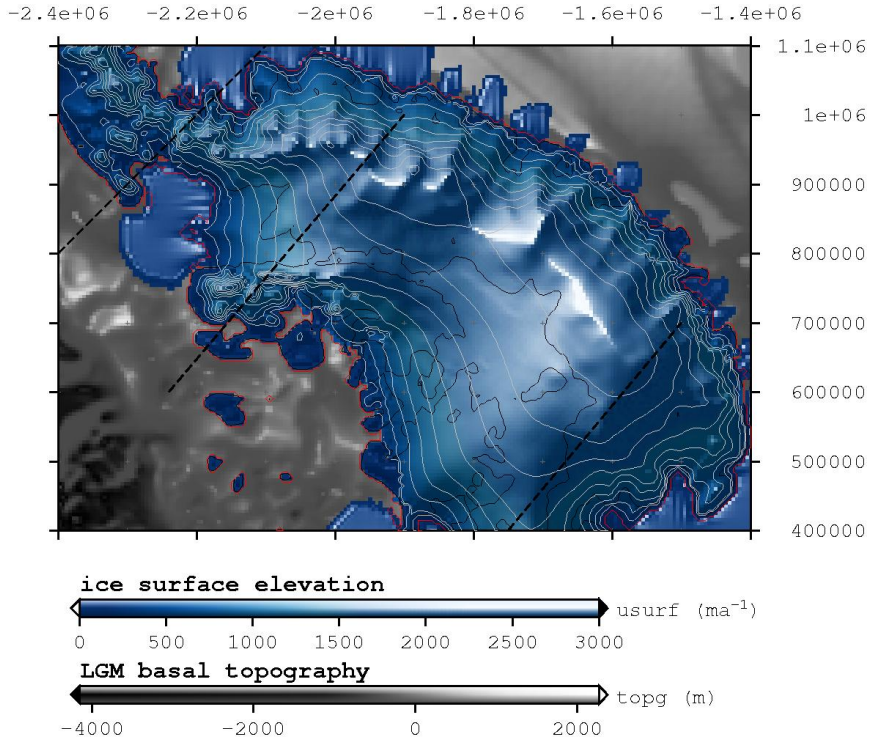


Preliminary output...



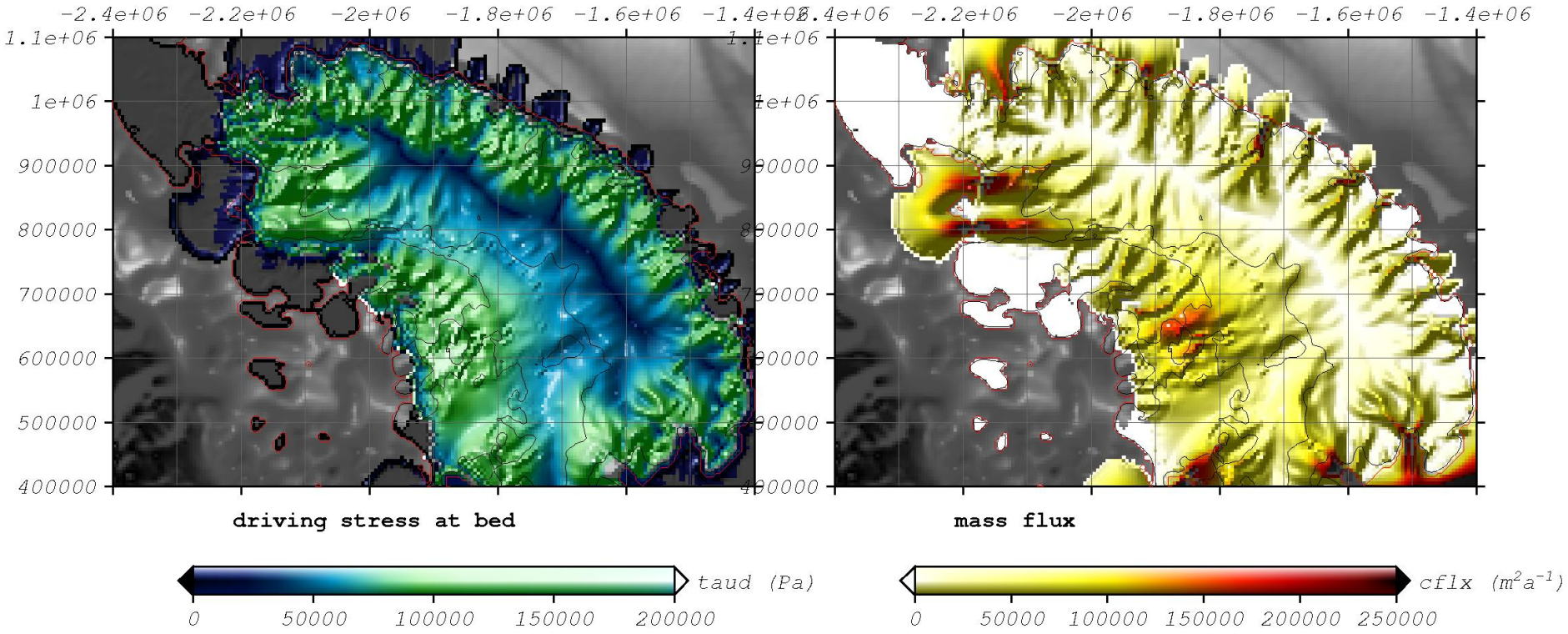
Preliminary output...



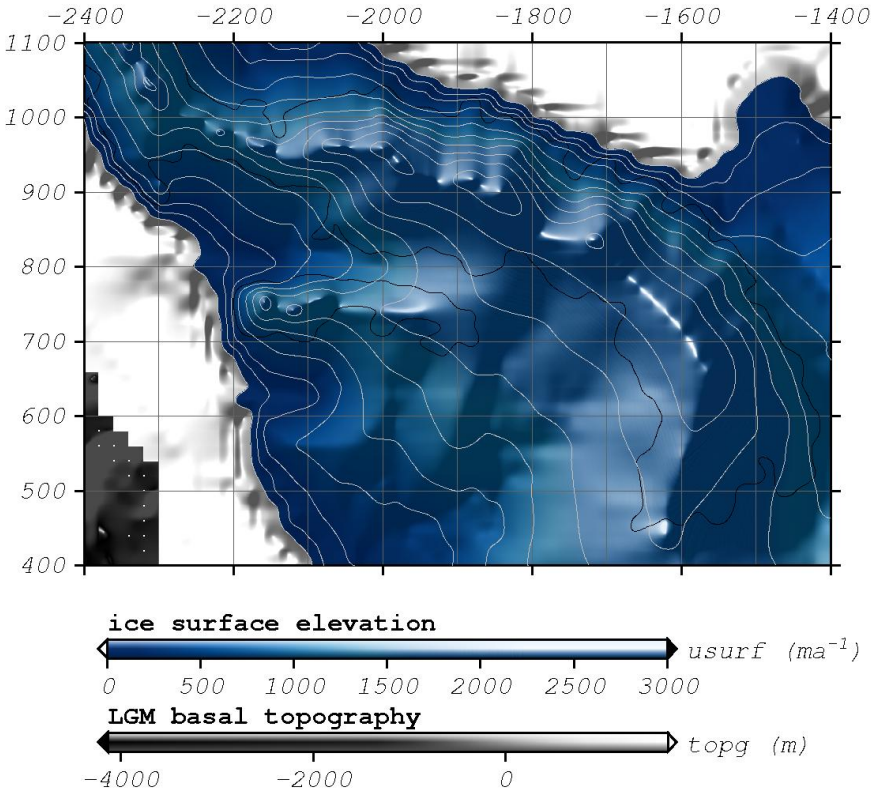


- Ice too thick in central areas, too thin around margins
- Mass balance mainly, poss also ice viscosity? basal sliding?

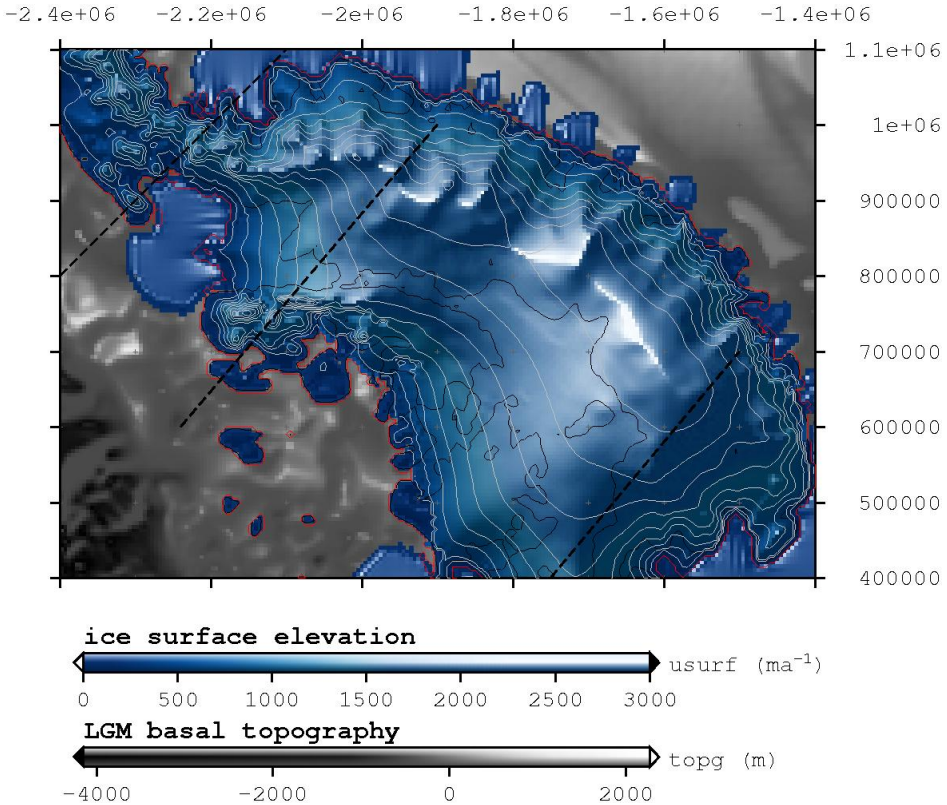
Preliminary output...



Comparisons



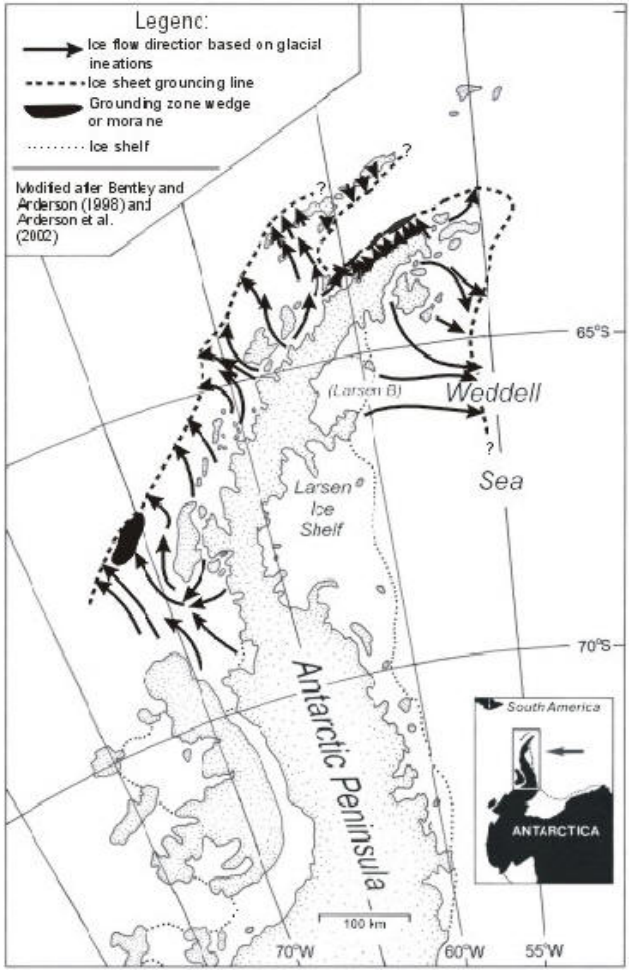
Pollard & DeConto data, pers. comm. 2009



recent PISM run

Summary

- LGM APIS was grounded out to shelf edge - models currently underestimate this lateral extent
- Upper surface poss. c. 700-800 m a.s.l along western islands - southern Alexander Island overwhelmed by Palmer Land ice
- Future high resolution modelling will help establish APIS sensitivity to dominant forcings

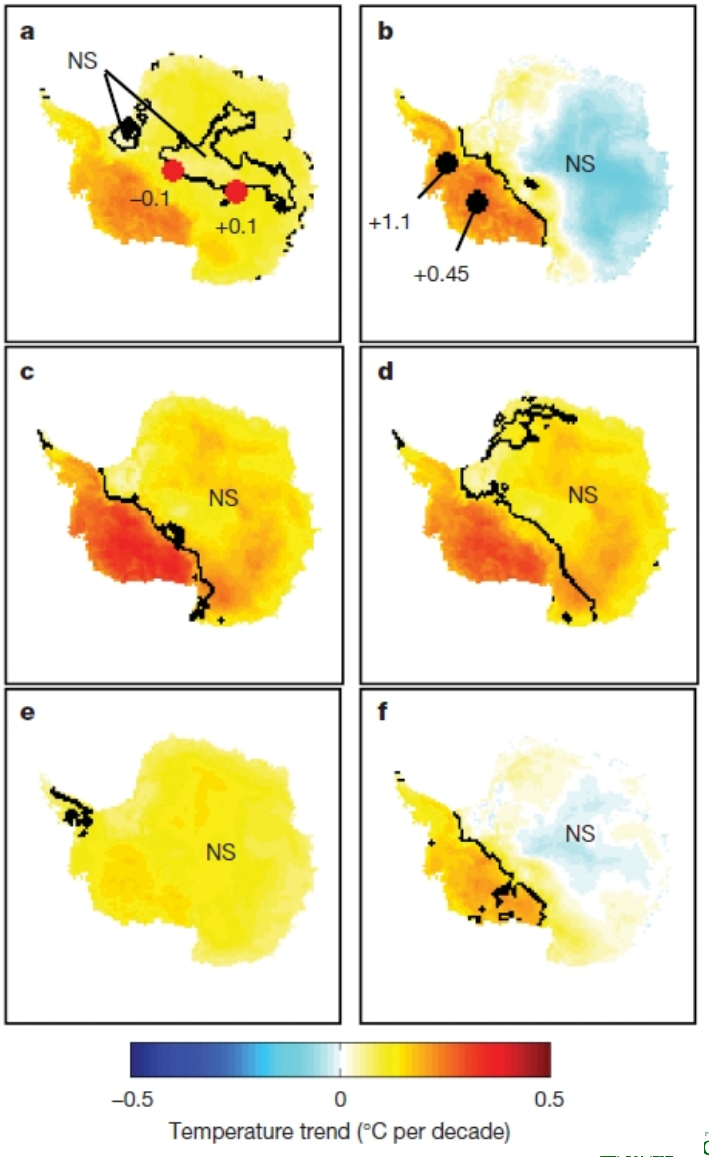


Anderson et al., 2002

Inverse modelling of retreat forcings

Deglaciation of the Antarctic Peninsula Ice Sheet

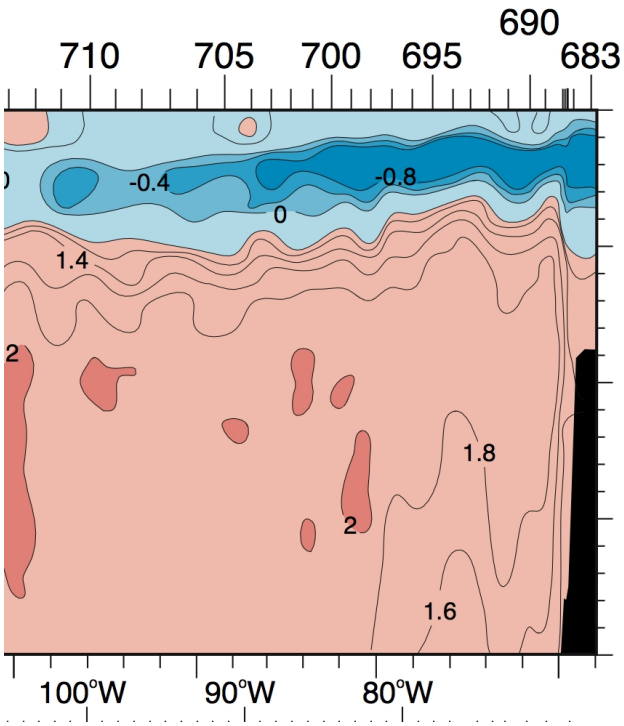
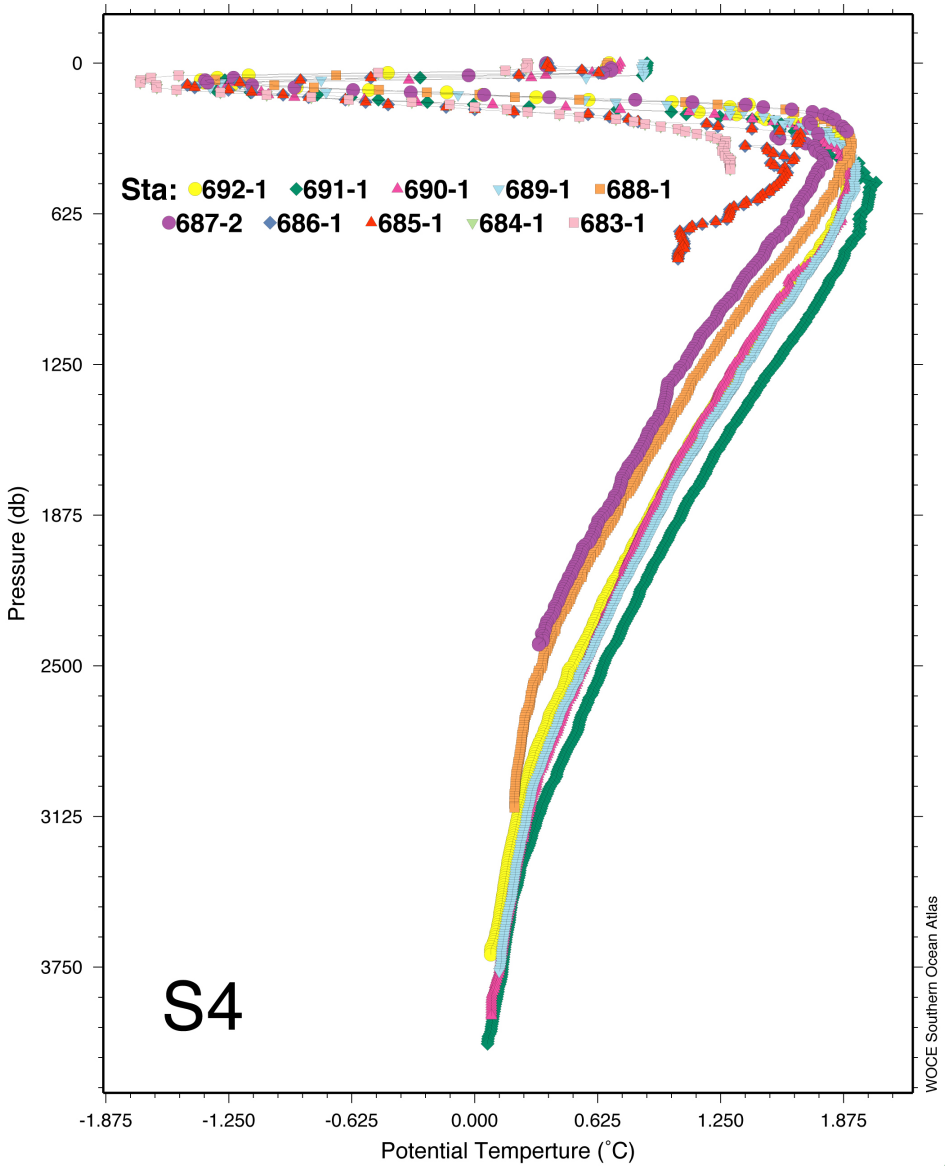
- Antarctic Peninsula is currently one of the fastest warming parts of the globe
- 87% extant glaciers currently thinning or accelerating (Cook et al. 2005)
- Peninsula sensitive to SAM / ENSO variability (esp. west) - but mainly summer influence
- Tropical heat flux - winter warming - 84% net warming from ACC upwelling
- Future estimates of glacier recession & contribution to sea level rise depend on understanding sensitivity of APIS to individual forcings



Steig et al., 2009

Oceanic heat flux - Antarctic Peninsula shelf water

- Ant. Pen. shelf waters composed surface (max 400-500m) cold water (c. 0 – -1°C)
- Steep thermocline in mid-depths - $\Delta T = 2 - 3°C$



(WOCE Hydrographic Atlas)