Histories of ice dynamics and climate inferred from ice cores and radar-detected layers

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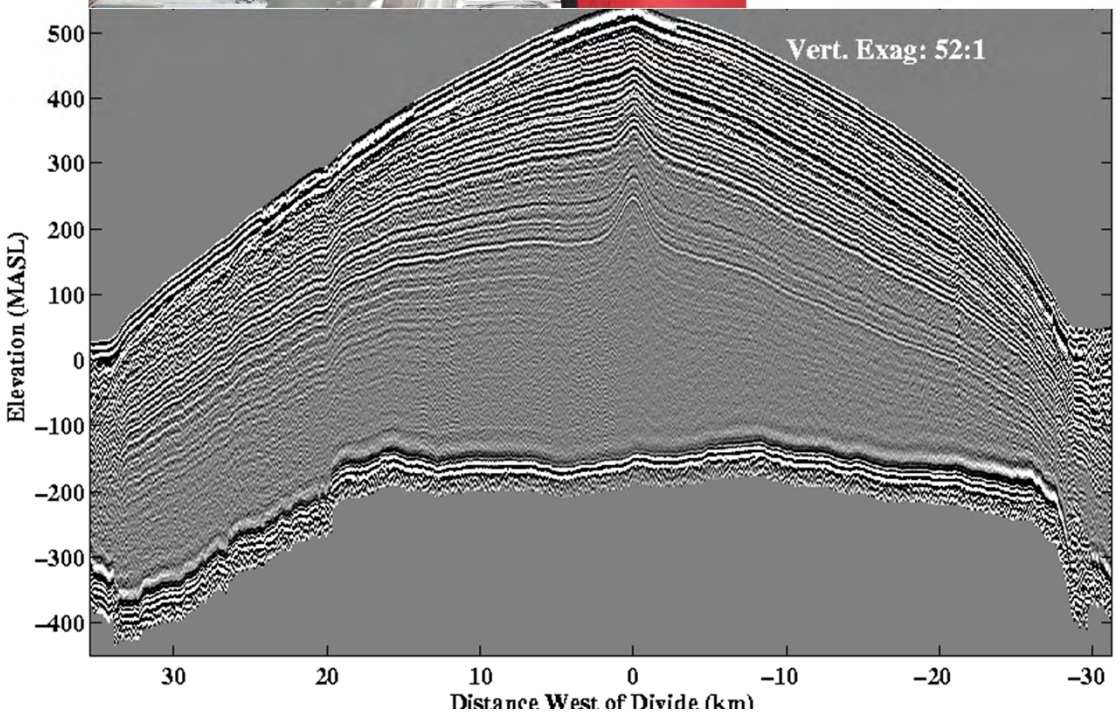
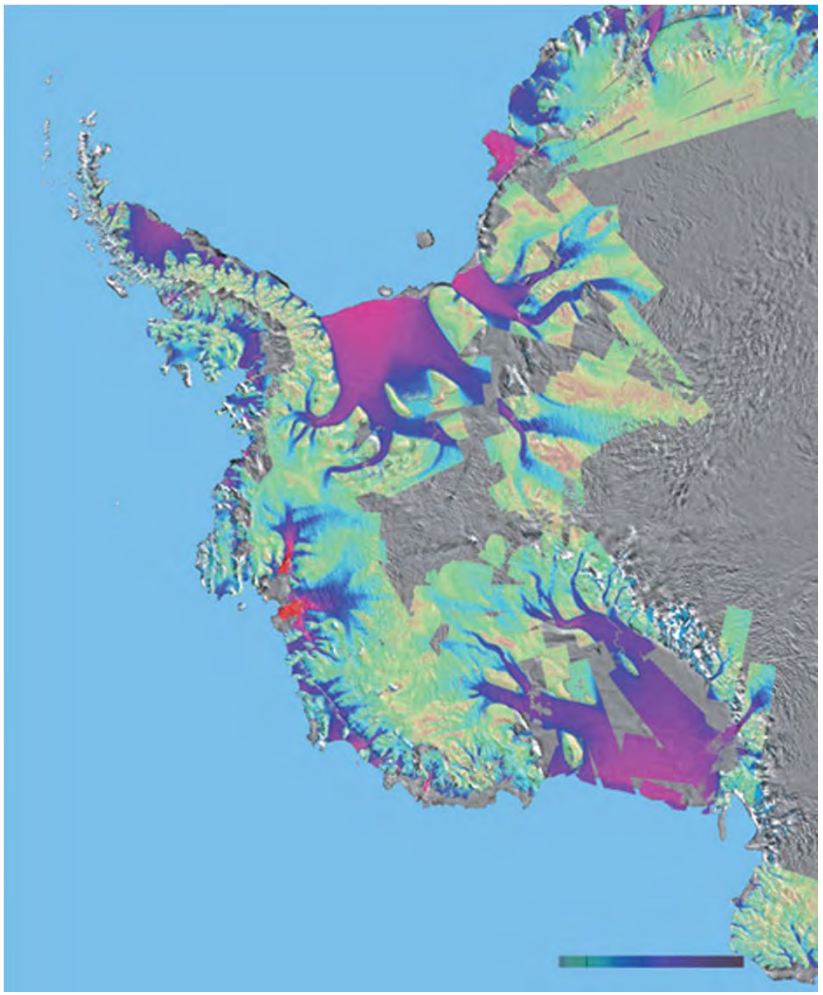
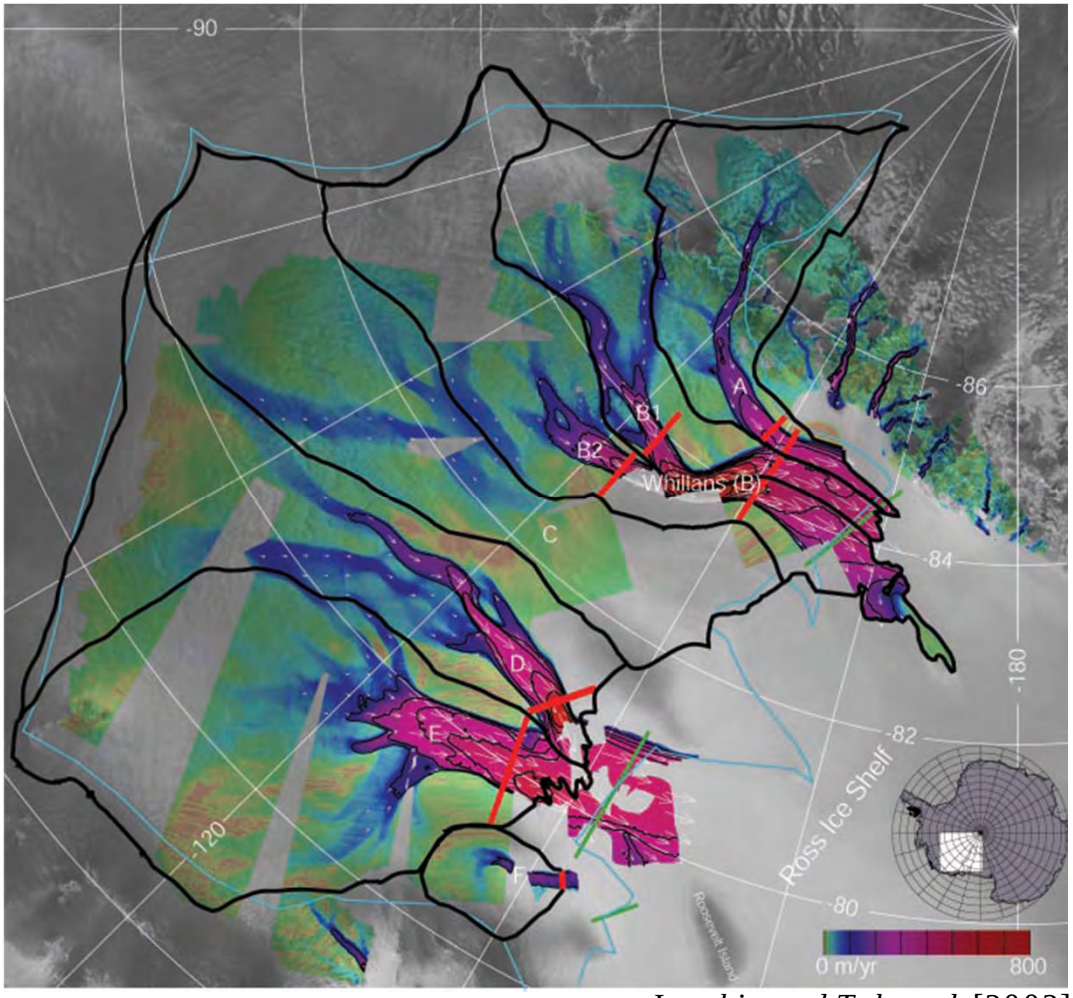


Changes in activity of fast-flowing outlet glaciers and ice streams exert strong control on mass balance of WAIS

- but records of past flow are swept away in a few centuries



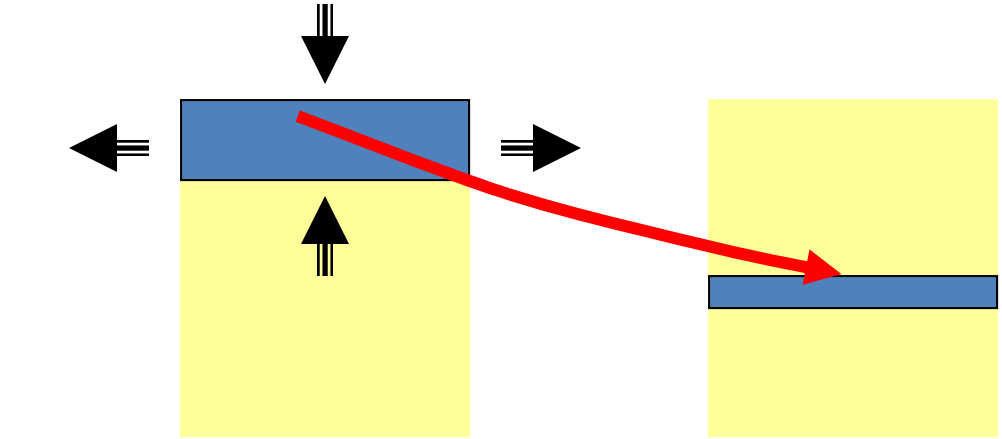
Joughin and Alley [2011]



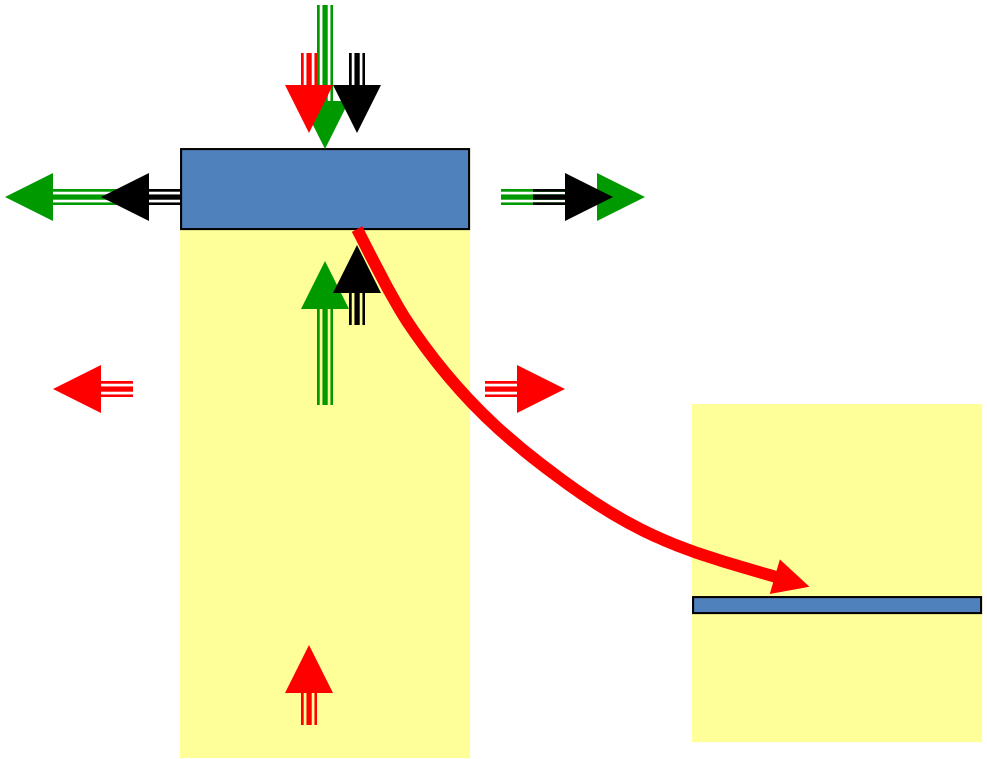
Joughin and Tulaczyk [2002]

- Search for longer-term histories of past flow, which can be extracted from slow-flowing, inland ice

Histories of ice dynamics (thinning/thickening/divide migration) as well as climate (accumulation rate) are contained in slow-flowing ice



- Annual layers get thinner in steady flow



- The layers get thinner even faster when entire ice sheet is also stretched and thinned

- That is, the depth-age relationship contains a record of ice sheet thinning (or thickening) as well as climate

The depth, thickness and age of a layer today depends on:

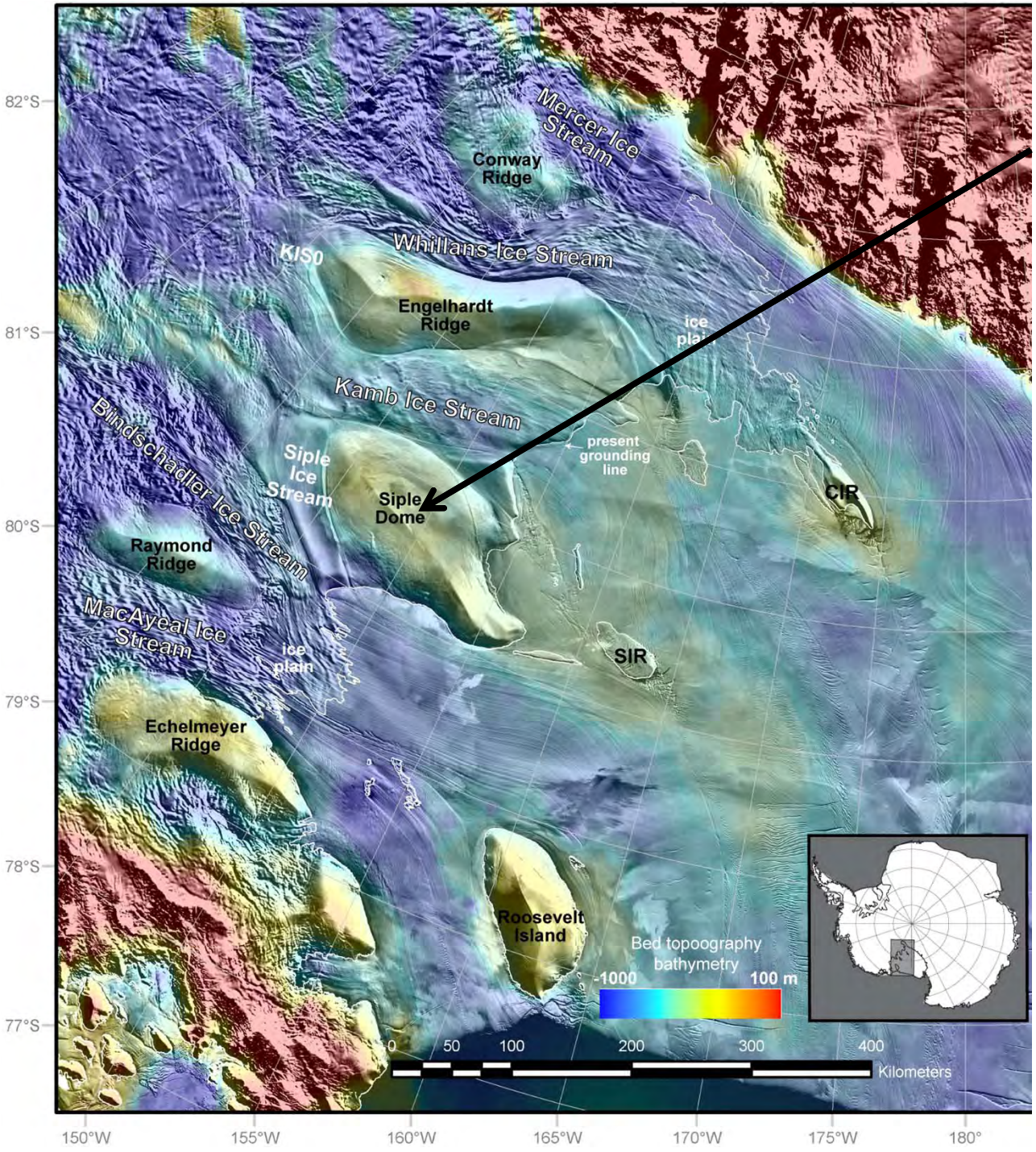
1. past climate ($b(t)$, the accumulation rate history)
2. past ice dynamics (represented by $\Lambda(t)$, a thinning function, which gives the amount of strain thinning of a layer)

Thickness of a layer at time t is:

$$\lambda(t) = \Lambda(t)b(t)$$

- a thin layer at depth might be produced by a lot of strain-thinning and/or low accumulation in the past and vice versa

- a trade-off between accumulation and ice-sheet dynamics
- a transient ice-flow model is needed to estimate $\Lambda(t)$ and investigate possible $\Lambda(t)$ - $b(t)$ histories that are *reasonable* and match the available data

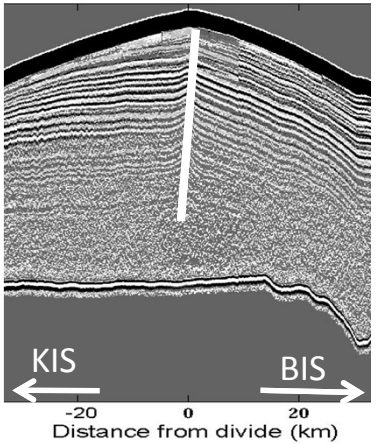


Application to Siple Dome

Data include:

- depth profiles of age and layer thickness (from ice core);
- temperature profile (from borehole);
- shape of radar-detected layers; bump amplitude profile

Siple Dome



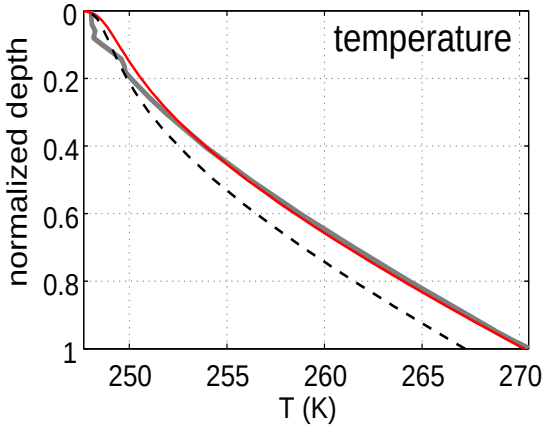
Best-fit to data

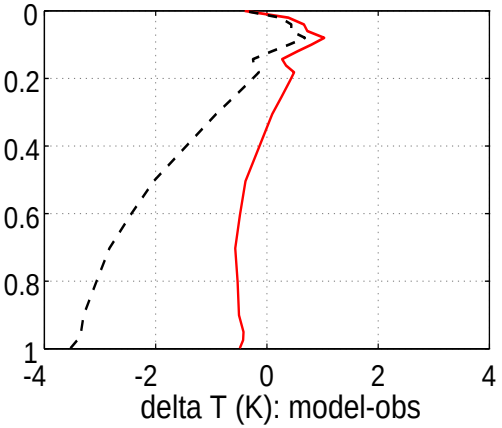
- thinning of ~300m; started ~14kyrs ago (Price et al., 2007)

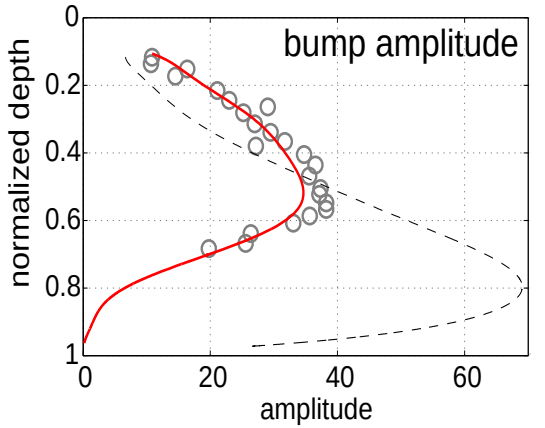
timing of thinning consistent with exposure-age dates of moraines in the TAM:

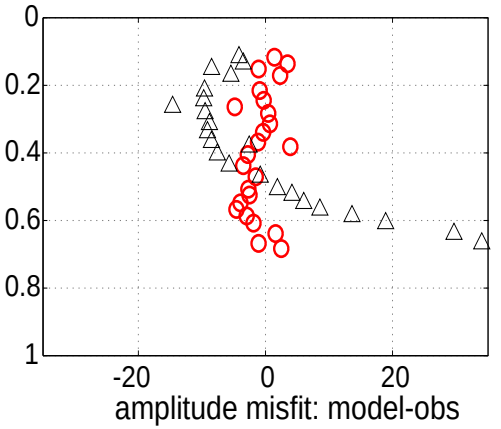
- thinning was underway at Reedy Glacier by 13kyrs BP (Todd et al., 2010)

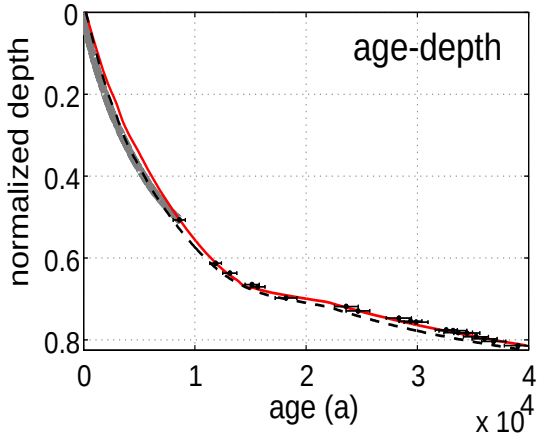
- thinning also underway in the early Holocene at Beardmore and Scott (Spector and Stone, 2011 - see Poster)

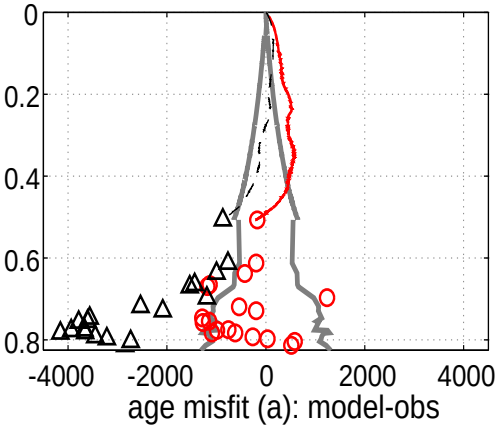






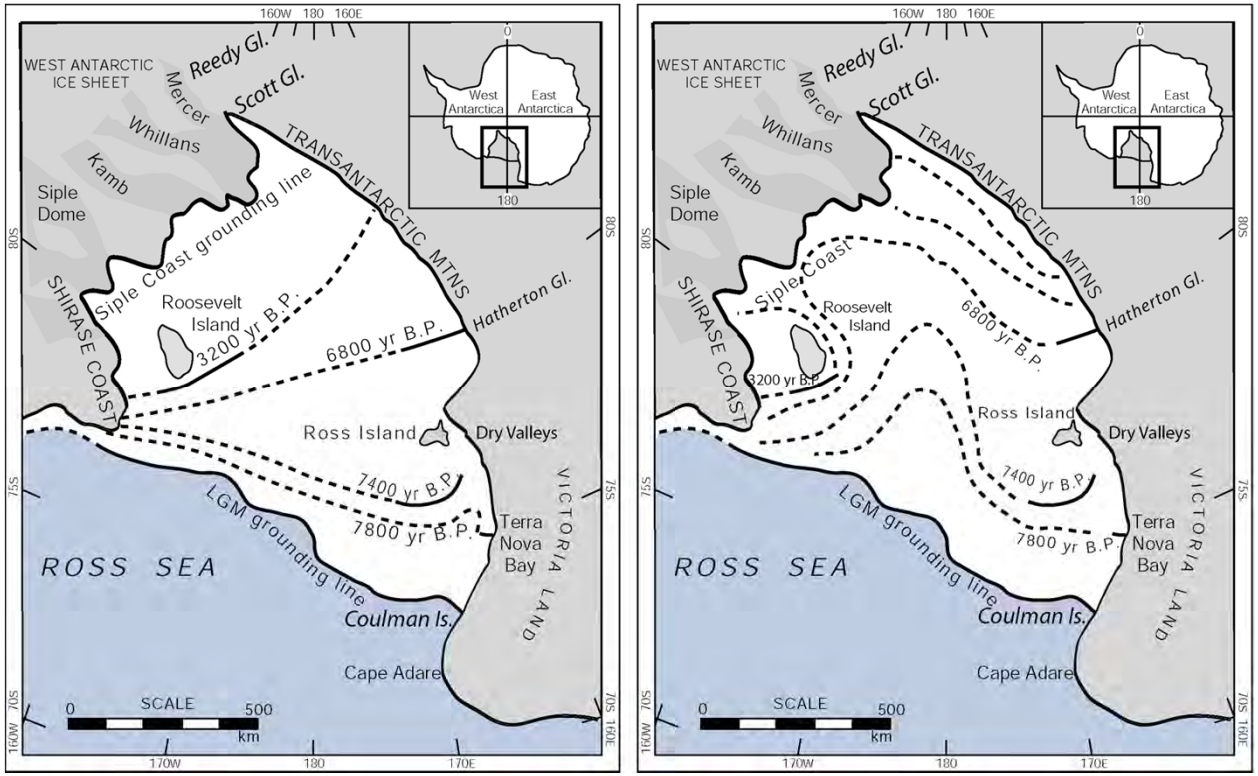




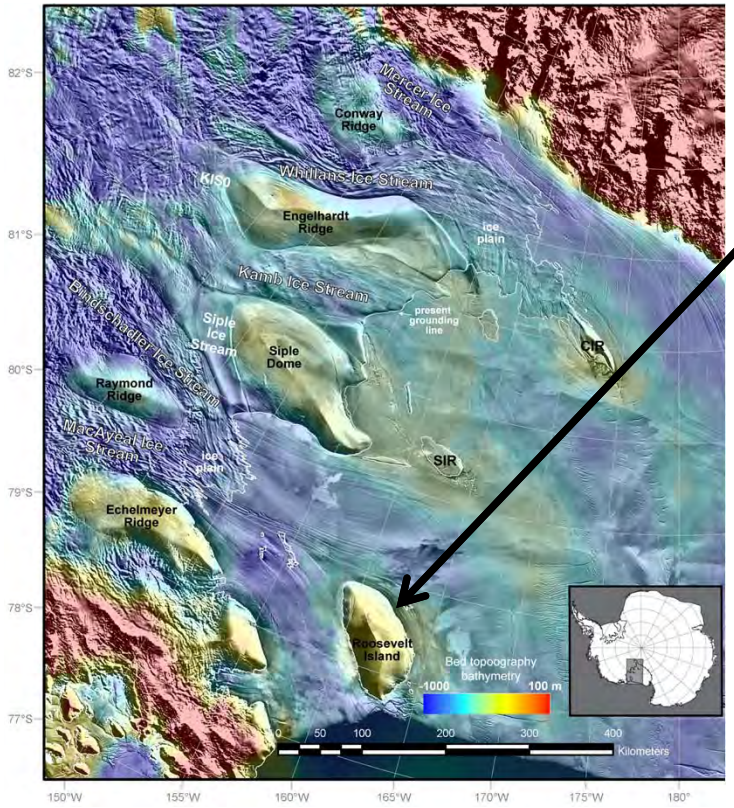


Implication of modest thickness change at Siple Dome raises the possibility of a low-profile ice sheet in the central Ross Embayment during the LGM

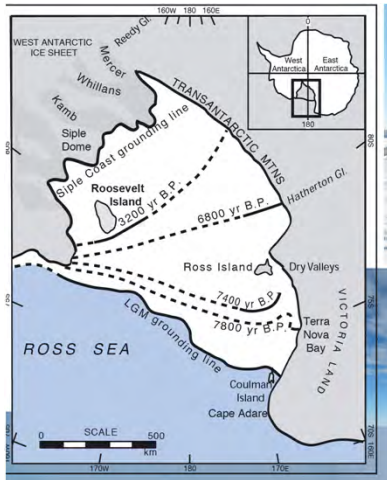
- low profile is consistent with the idea that the ice stream beds remained slippery through the glacial cycle (*Raymond, 2000; Parizek and Alley, 2004*)
- also consistent with marine evidence from the central Ross Sea that suggests the LGM advance of the grounding line reached a maximum ~27.5 ^{14}C kyr BP followed soon after by open-marine sedimentation *(Bart and Cone, In Press).*

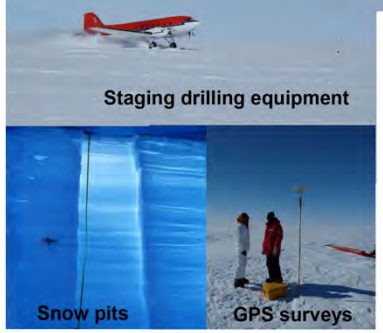


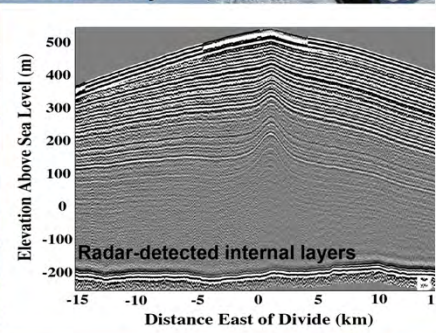
We hypothesize that a modification of the “swinging gate” style of deglaciation is in order.



To test this hypothesis we have started a collaboration (NZ, Britain, Denmark, Germany, Italy, France, Australia and US) to core Roosevelt Island







- previous work used the bump-amplitude profile to infer thinning of 300m and onset of divide flow ~ 3kyr BP;

- dating the layers will yield longer-term histories of thinning and climate in the eastern Ross Sea.

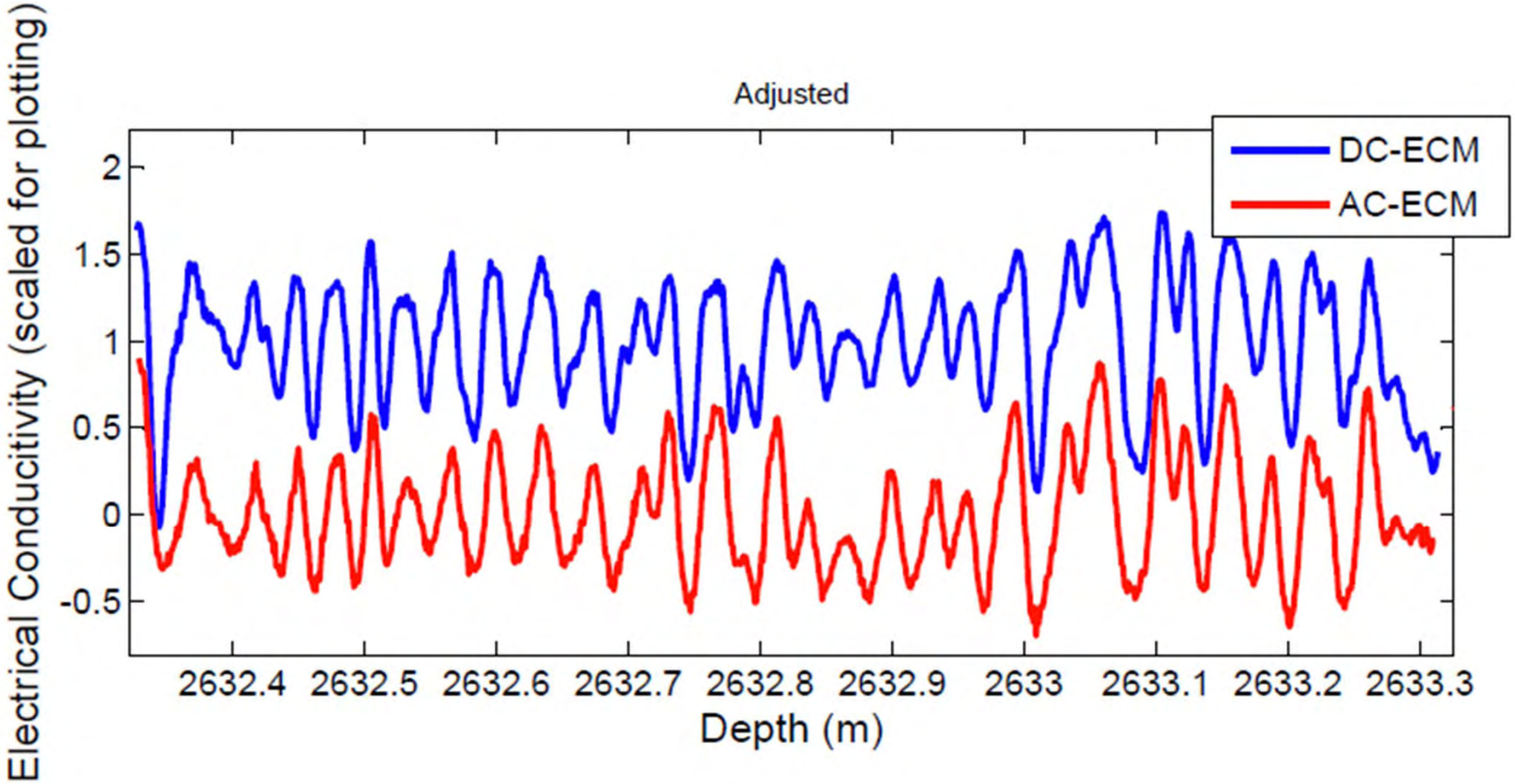
Additional geophysical studies (GPS, Radar) and camp set up in 2010-11;

Coring will start in October 2011 ……

Emerging results from WAIS Divide

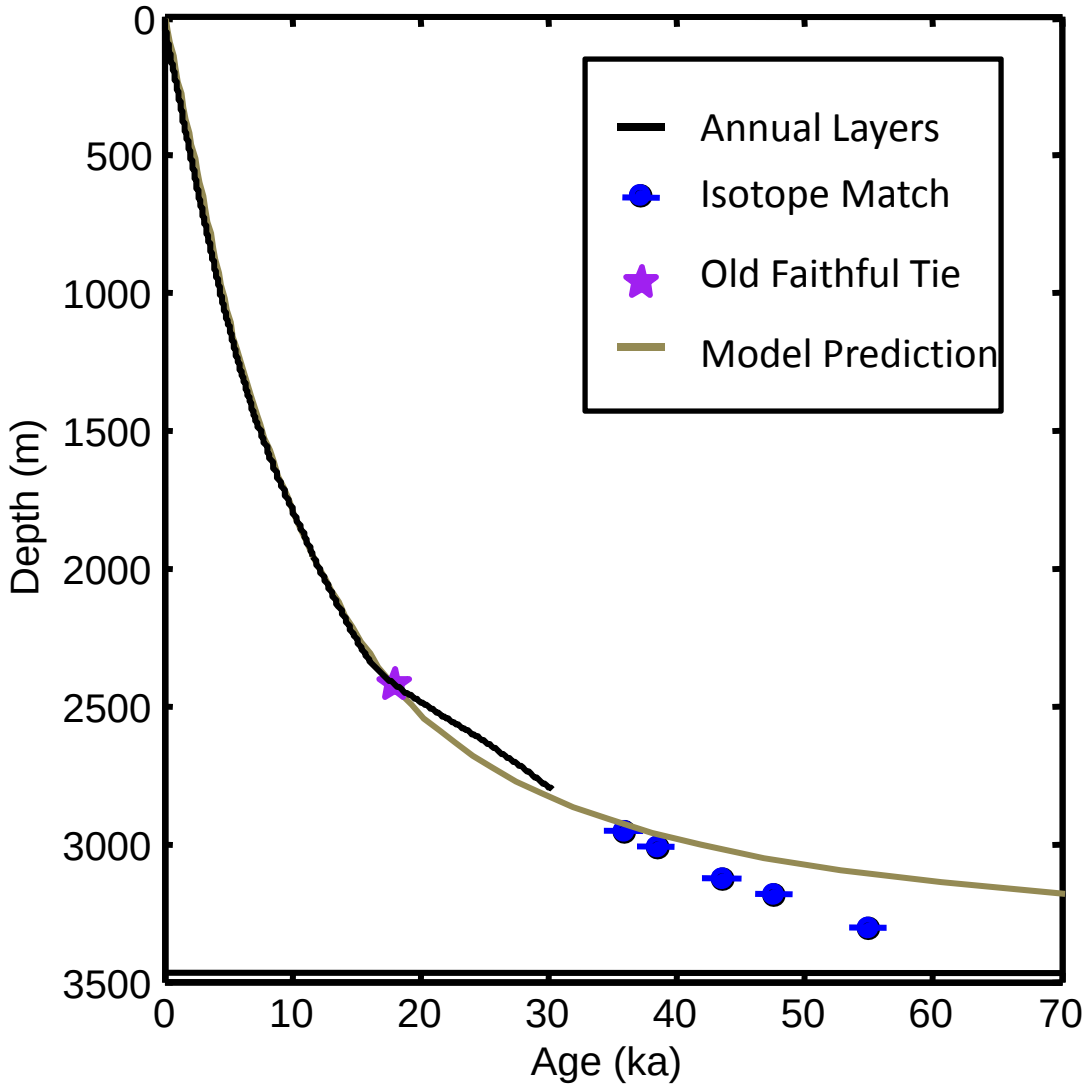
New timescale WDC06A-5

***T.J. Fudge**, Kendrick Taylor, Ken McGwire, Howard Conway, Edwin Waddington, Thomas Neumann, James White, Bruce Vaughn, Jay Johnson, Jeff Severinghaus, and Michelle Koutnik*



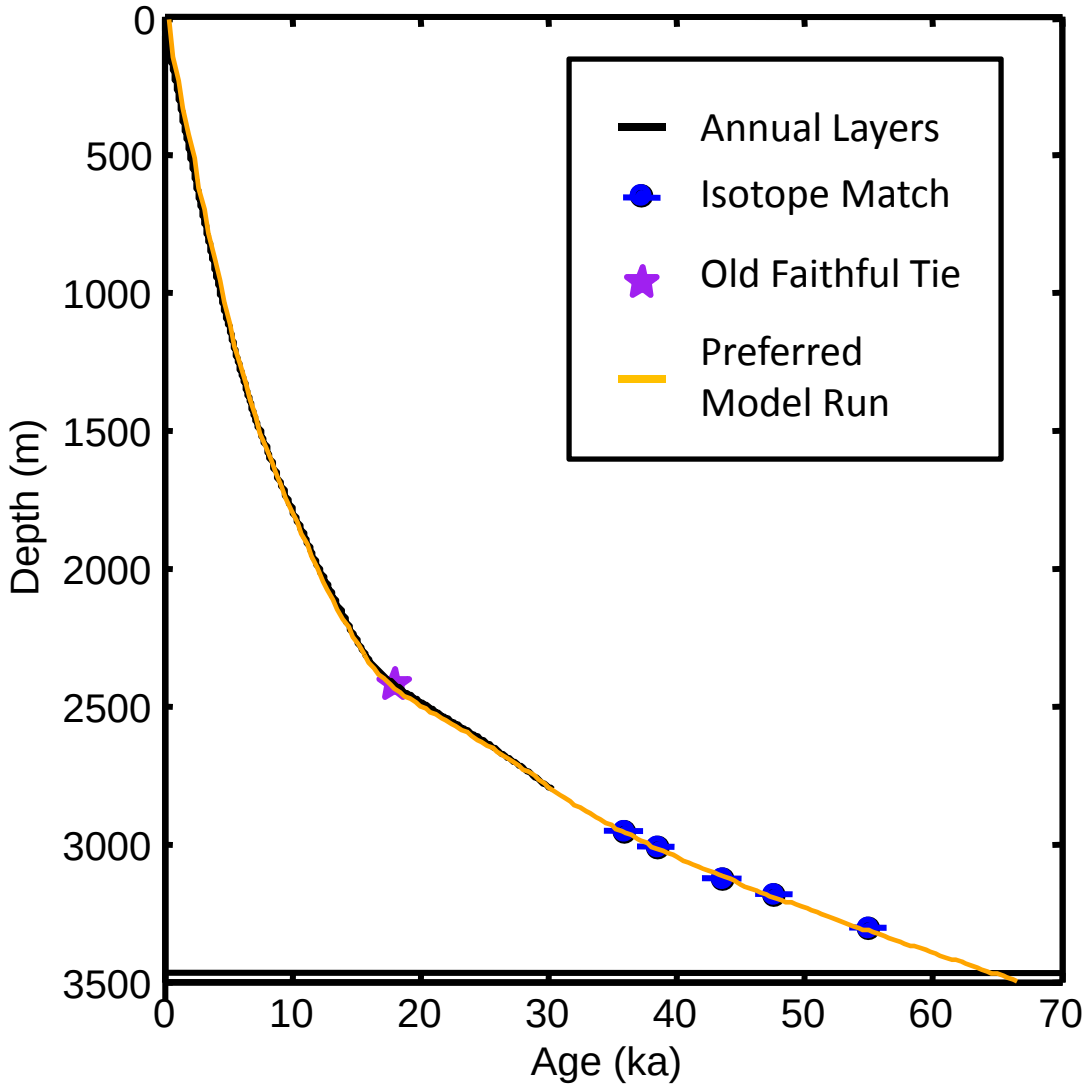
Timescale WDC06A-5

- Annual resolution to 2800 m from Electrical Measurements
- Water isotope match to Byrd time scale for 2900-3330 m



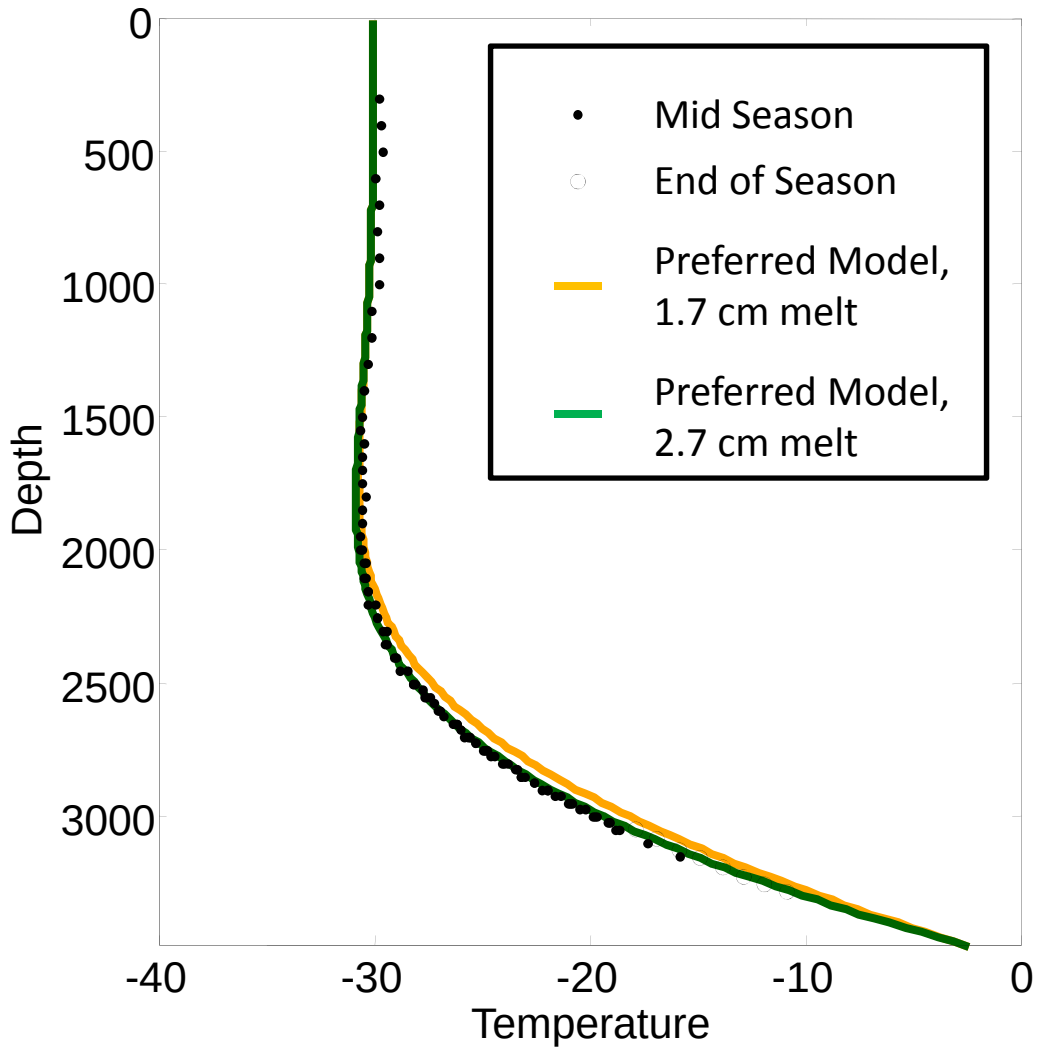
Depth-Age Scale Suggests Basal Melting

- 1-D Dansgaard-Johnson model with basal melting and sliding
- Basal melt rate of 5-30 mm a^{-1} (17 mm a^{-1} preferred)
- Geothermal flux of 130-380 mW m^{-2} (250 mW m^{-2})



Temperature profile also suggests basal melting

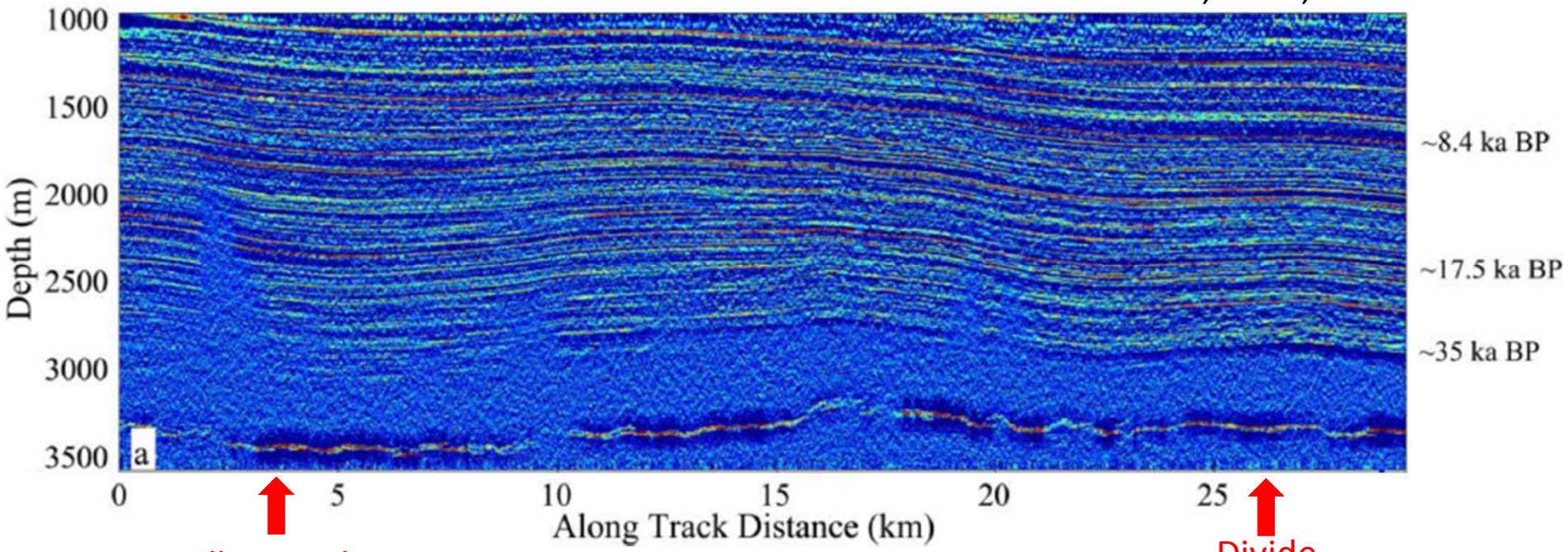
- multiple mm of melt necessary to match the steep temperature gradient near the bed



Radar-detected layers do not show evidence of draw down

- large (>20 km) scale melting rather than localized melting?

Laird et al, 2010, IEEE



Drill site ~2km away in across track direction

Divide

Results are preliminary

- borehole logging (temperature, sonic log, seismics) to start in Nov
- stay tuned ……