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

- 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 \( (b(t), \text{ the accumulation rate history}) \)

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?

Drill site ~2km away in across track direction

Divide

Laird et al, 2010, IEEE
Results are preliminary
- borehole logging (temperature, sonic log, seismics) to start in Nov
- stay tuned ........