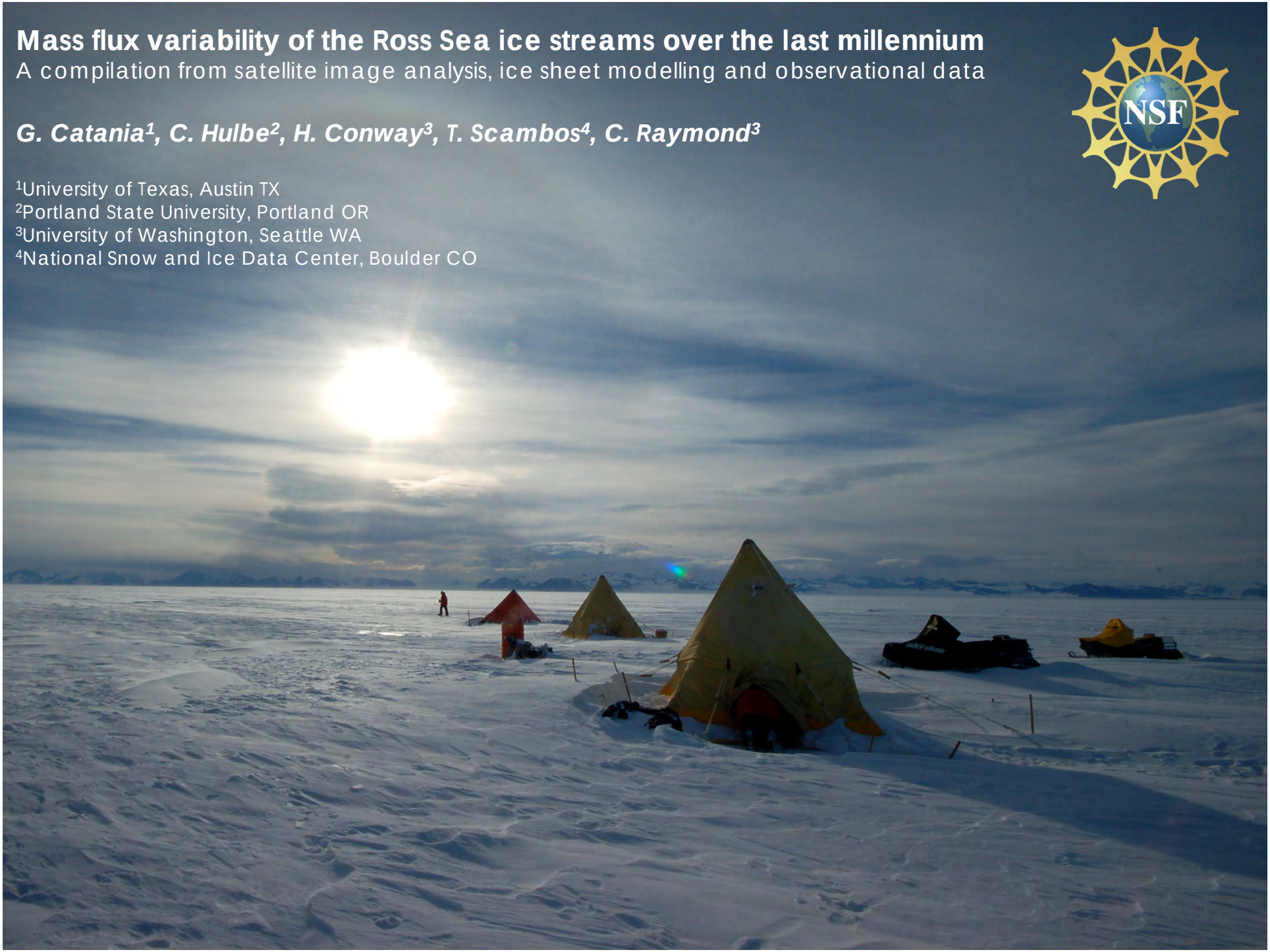
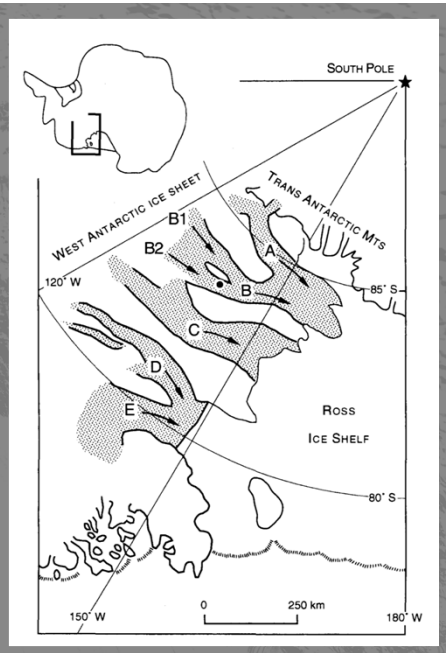
Mass flux variability of the Ross Sea ice streams over the last millennium

A compilation from satellite image analysis, ice sheet modelling and observational data

G. Catania[1], C. Hulbe[2], H. Conway[3], T. Scambos[4], C. Raymond[3]

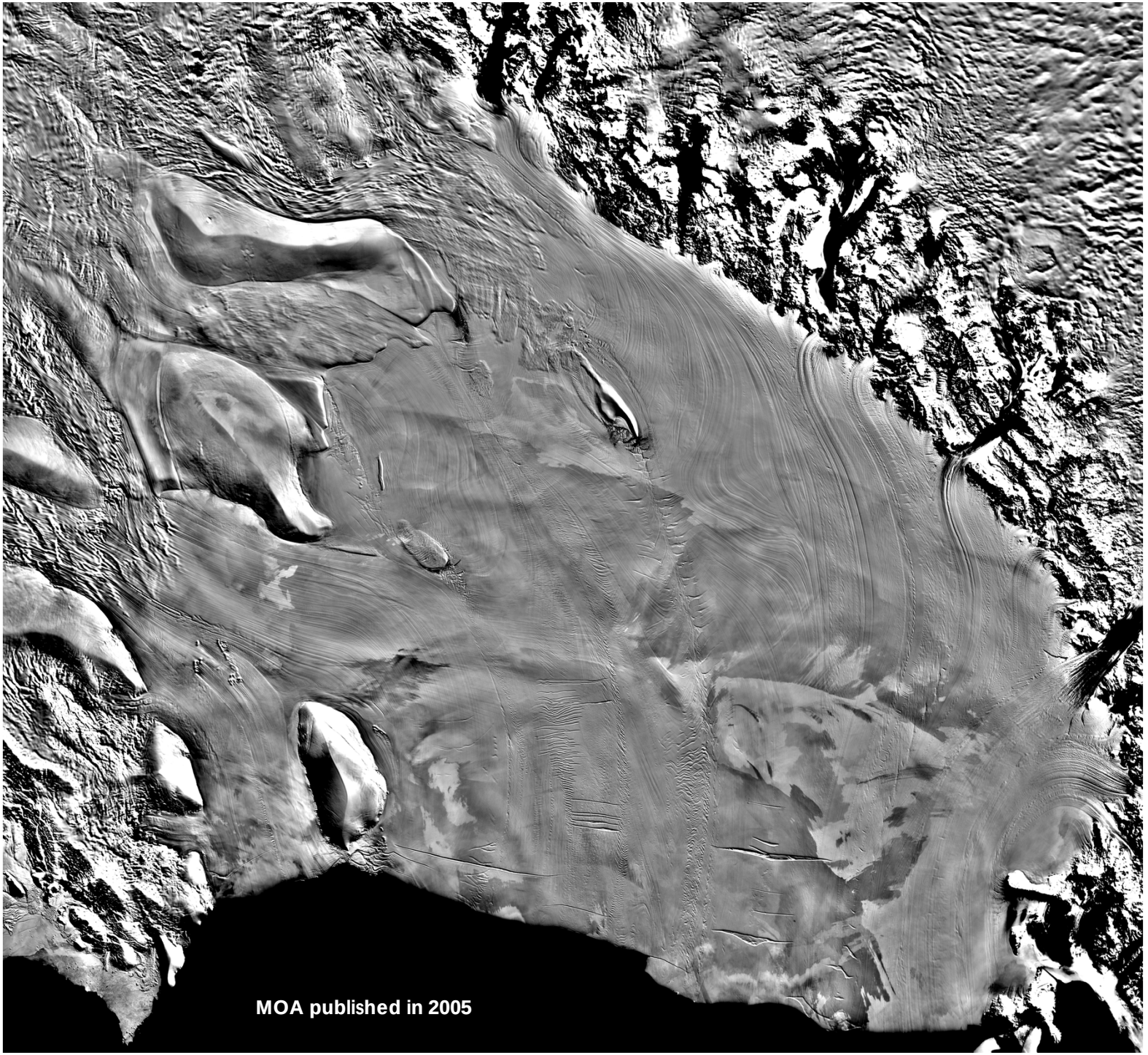
[1]University of Texas, Austin TX
[2]Portland State University, Portland OR
[3]University of Washington, Seattle WA
[4]National Snow and Ice Data Center, Boulder CO

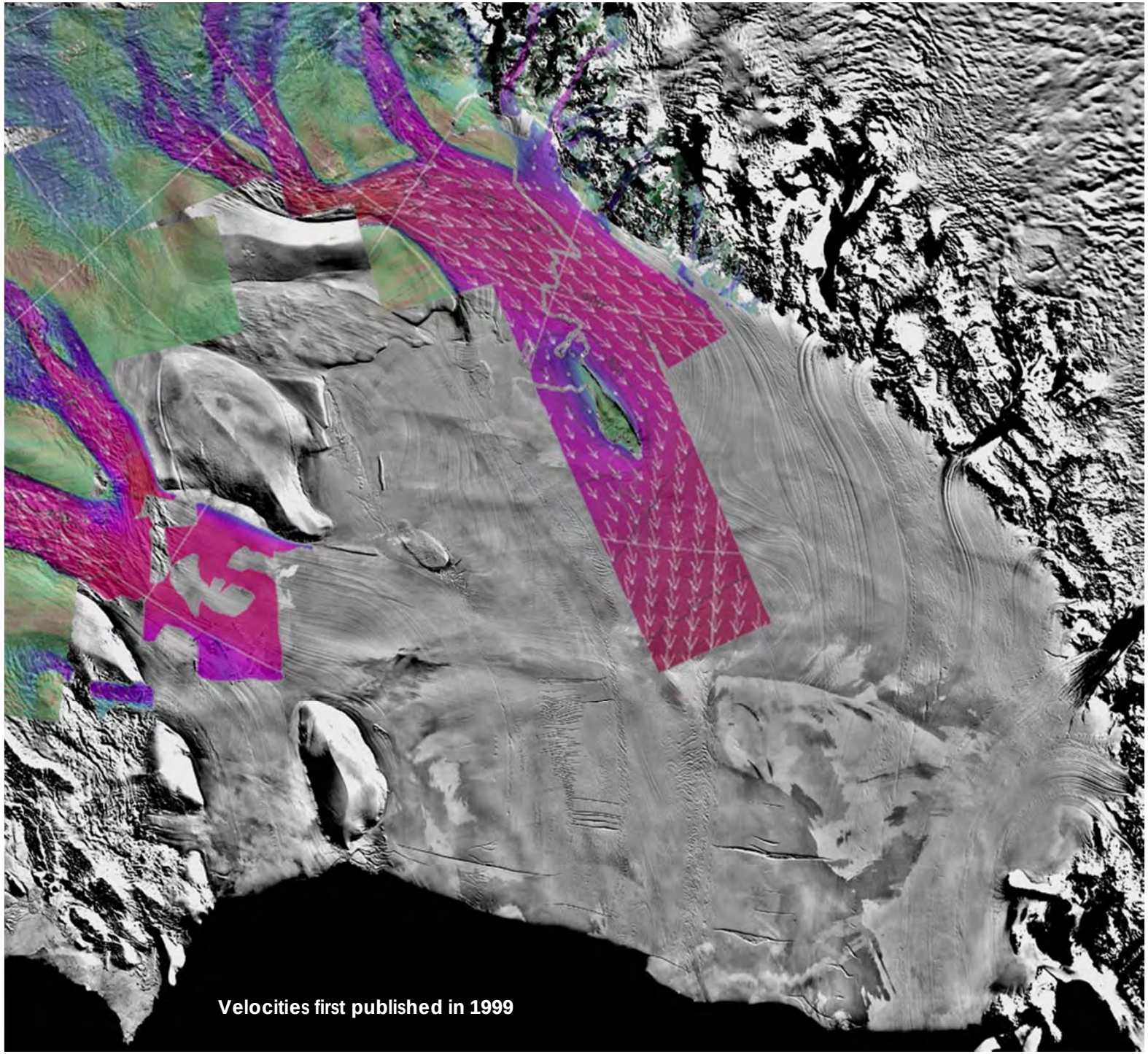




The ice streams are made visible by long belts of chaotic crevassing at their margins.

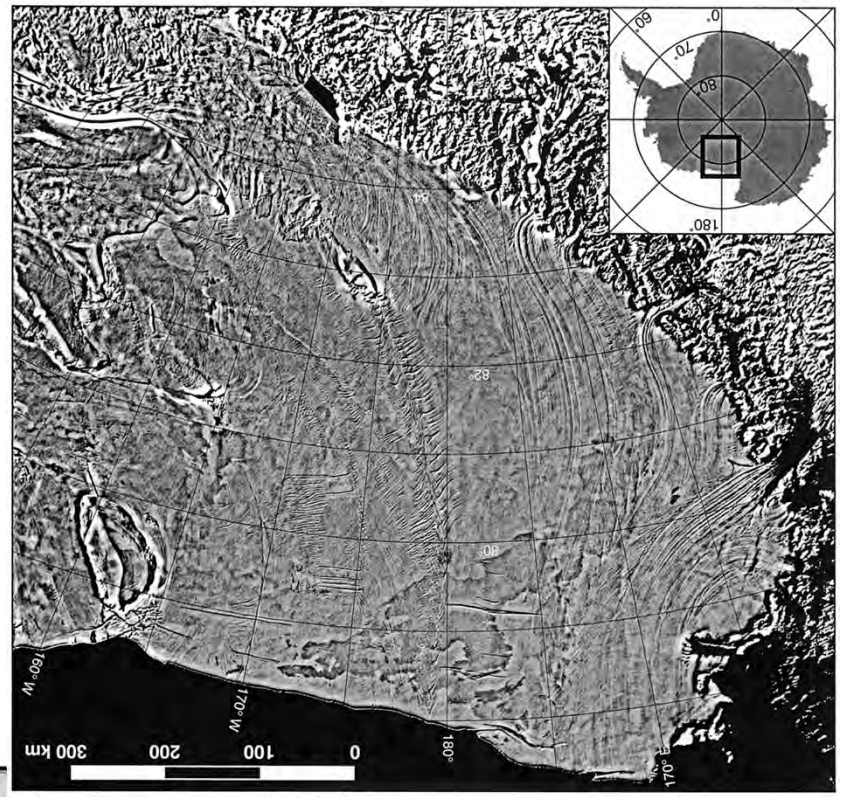
B. Kamb, 1990

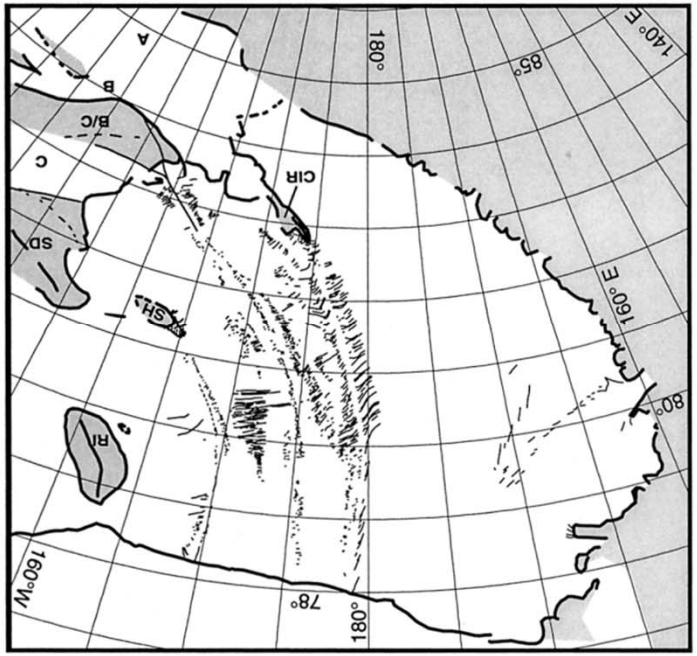

MOA published in 2005

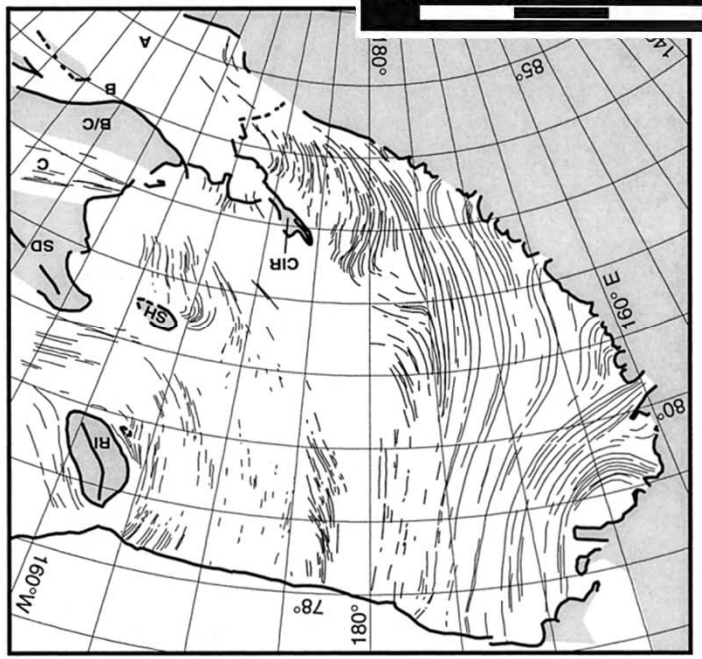

Velocities first published in 1999

Ice flow history from satellite observations

-formation of Steershead Ice Rise ~350 years ago
-narrowing of Kamb Ice Stream ~350 years ago

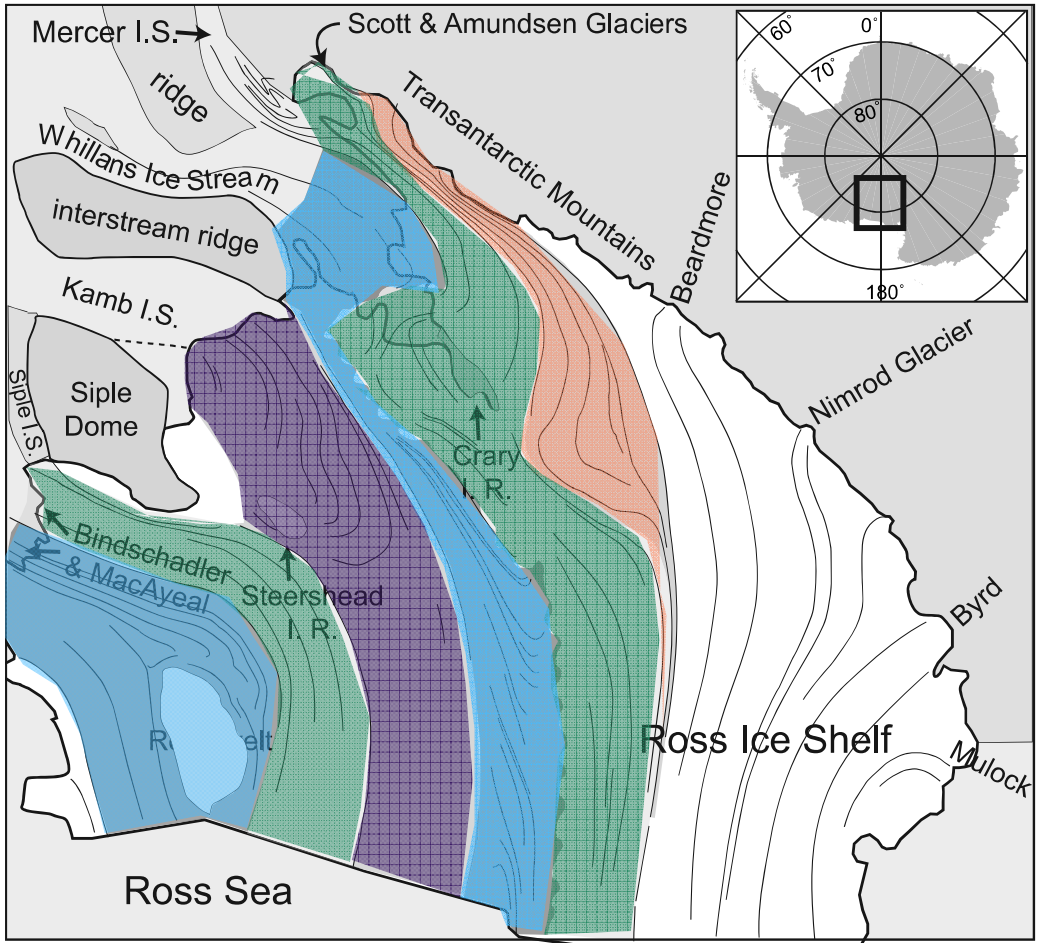


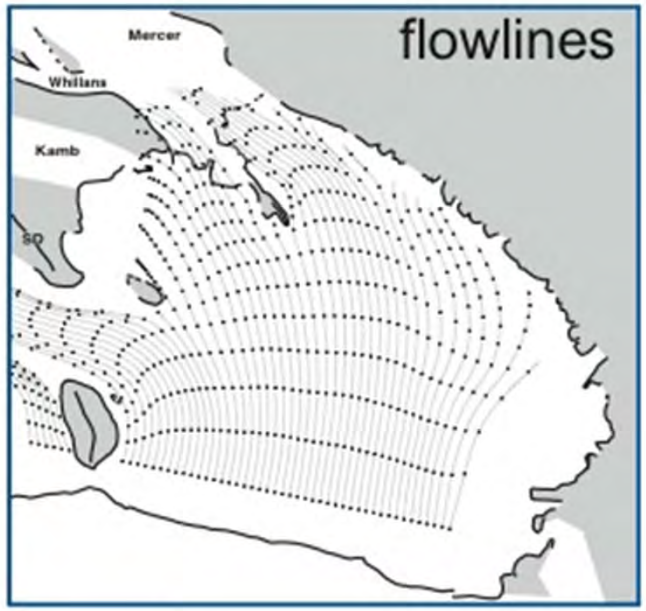


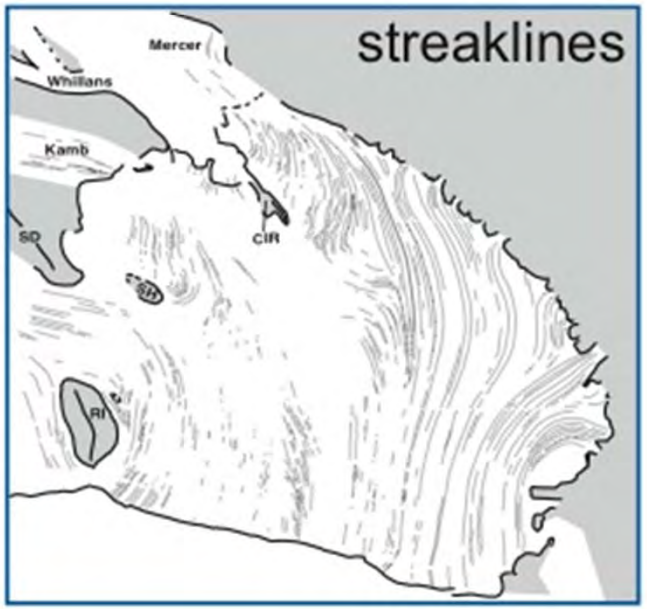


Fahnestock and others (2000)

Ice flow history from satellite observations *and modelling*

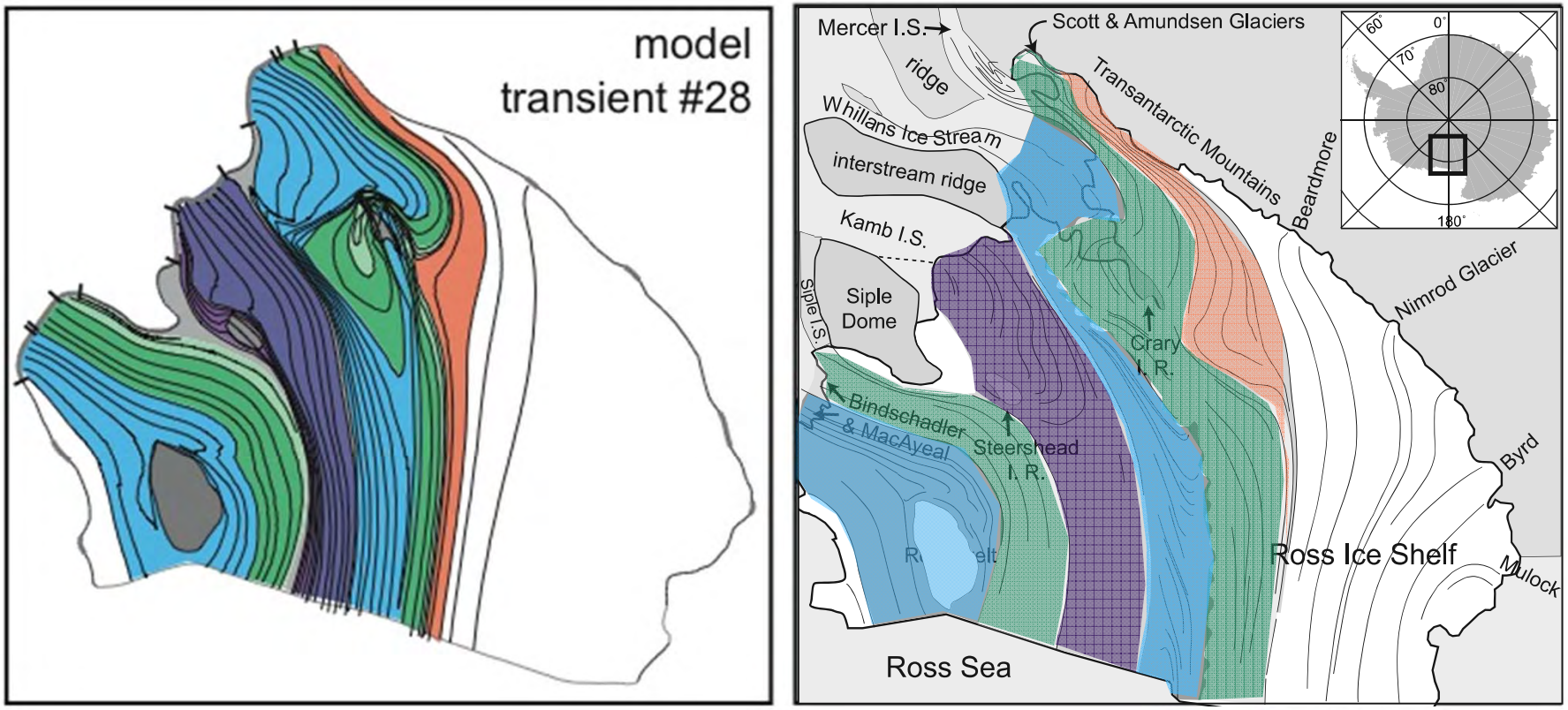






Hulbe and Fahnestock (2007)

Ice flow history from satellite observations *and modelling*

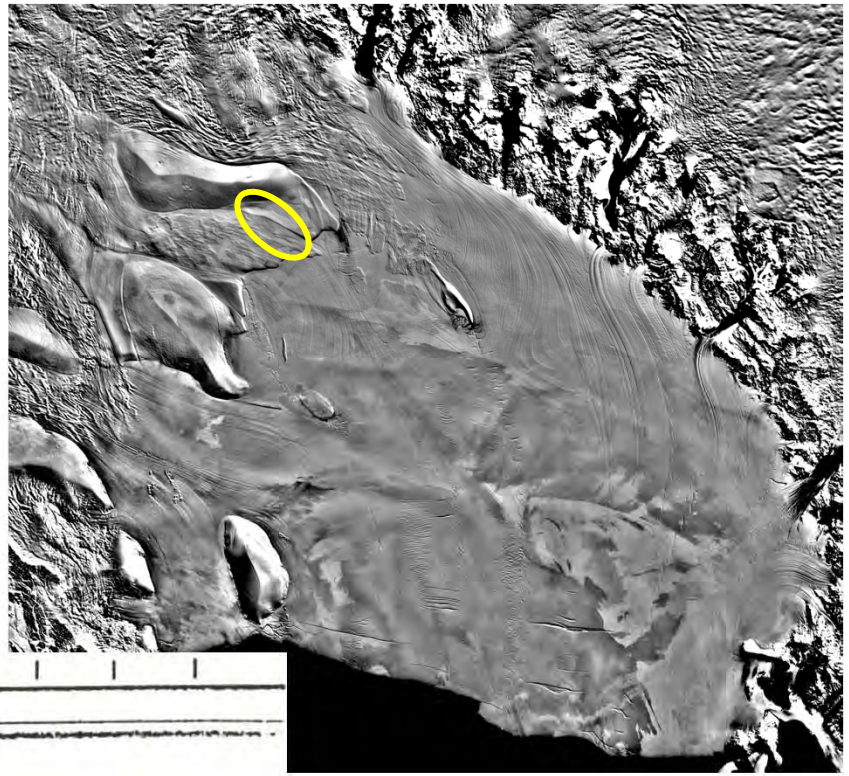


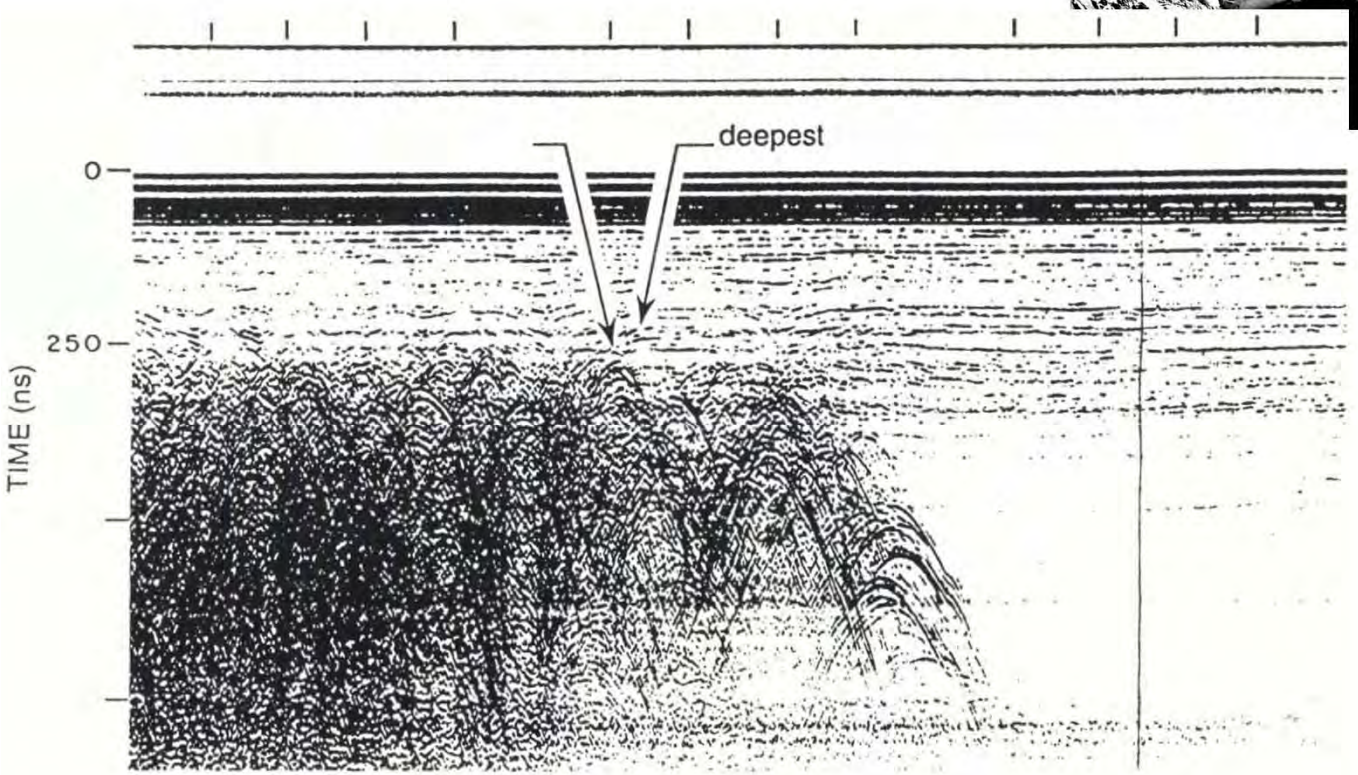
-stagnation of Whillans Ice Stream from 850 – 450 years ago
-stagnation of MacAyeal Ice Stream from 800 and 650 years ago

Hulbe and Fahnestock (2007)

Ice flow history from radar stratigraphy

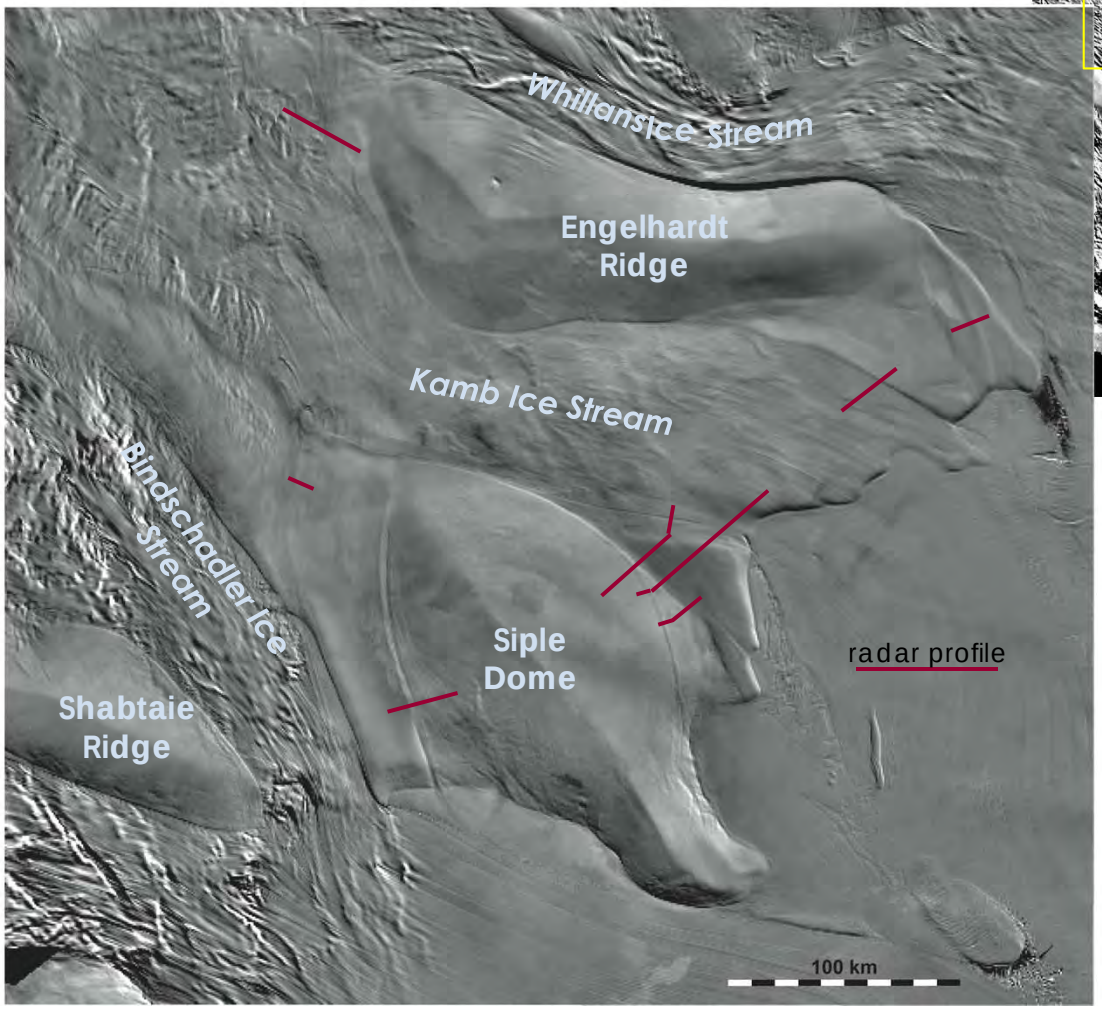
-Kamb Ice Stream stagnated ~150 years ago

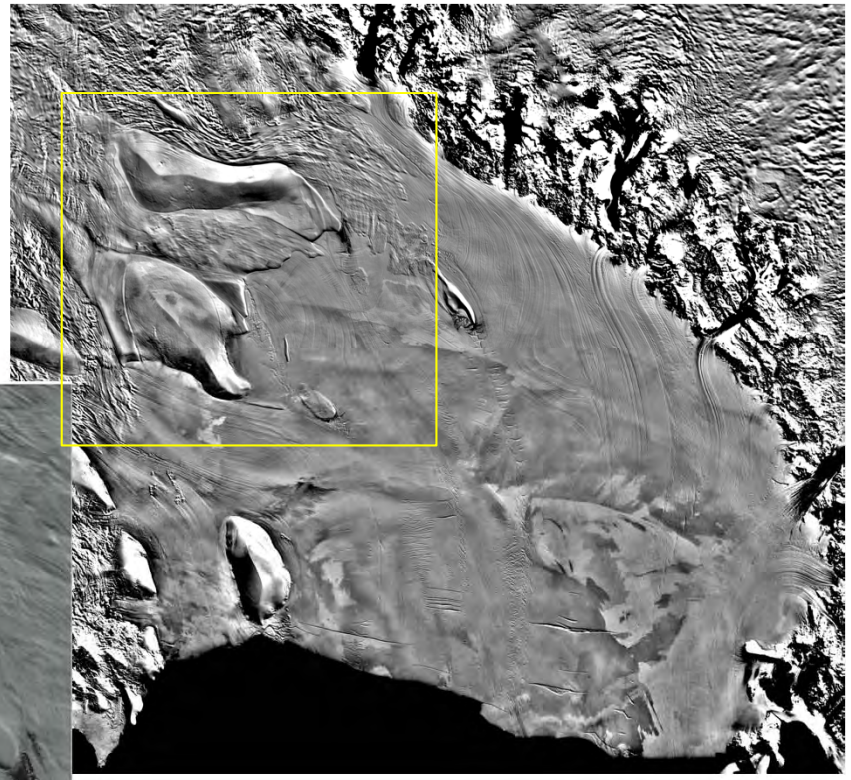




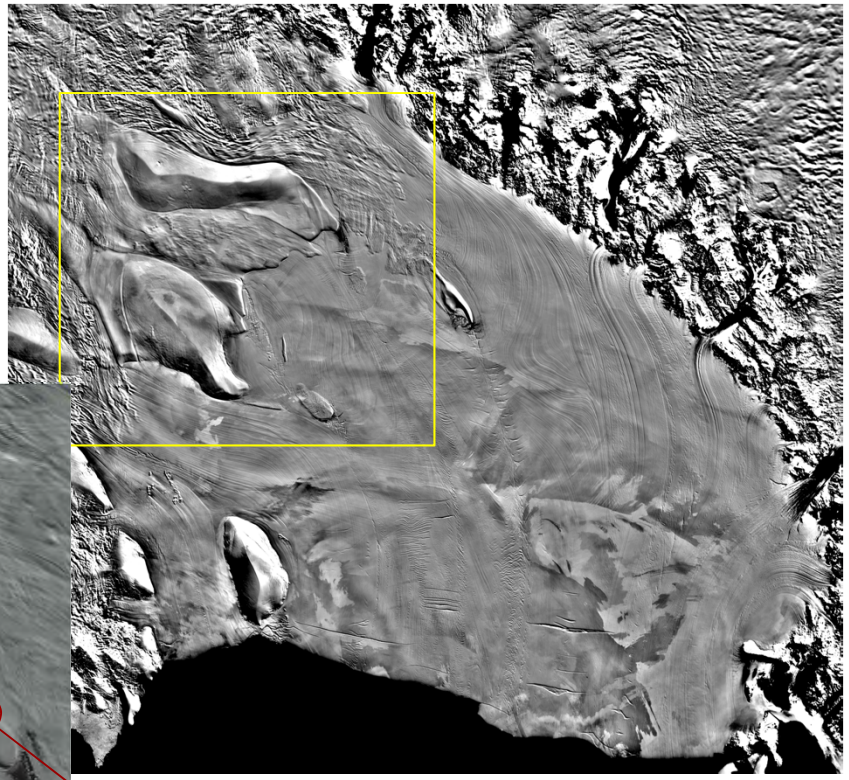
Retzlaff and Bentley (1993)

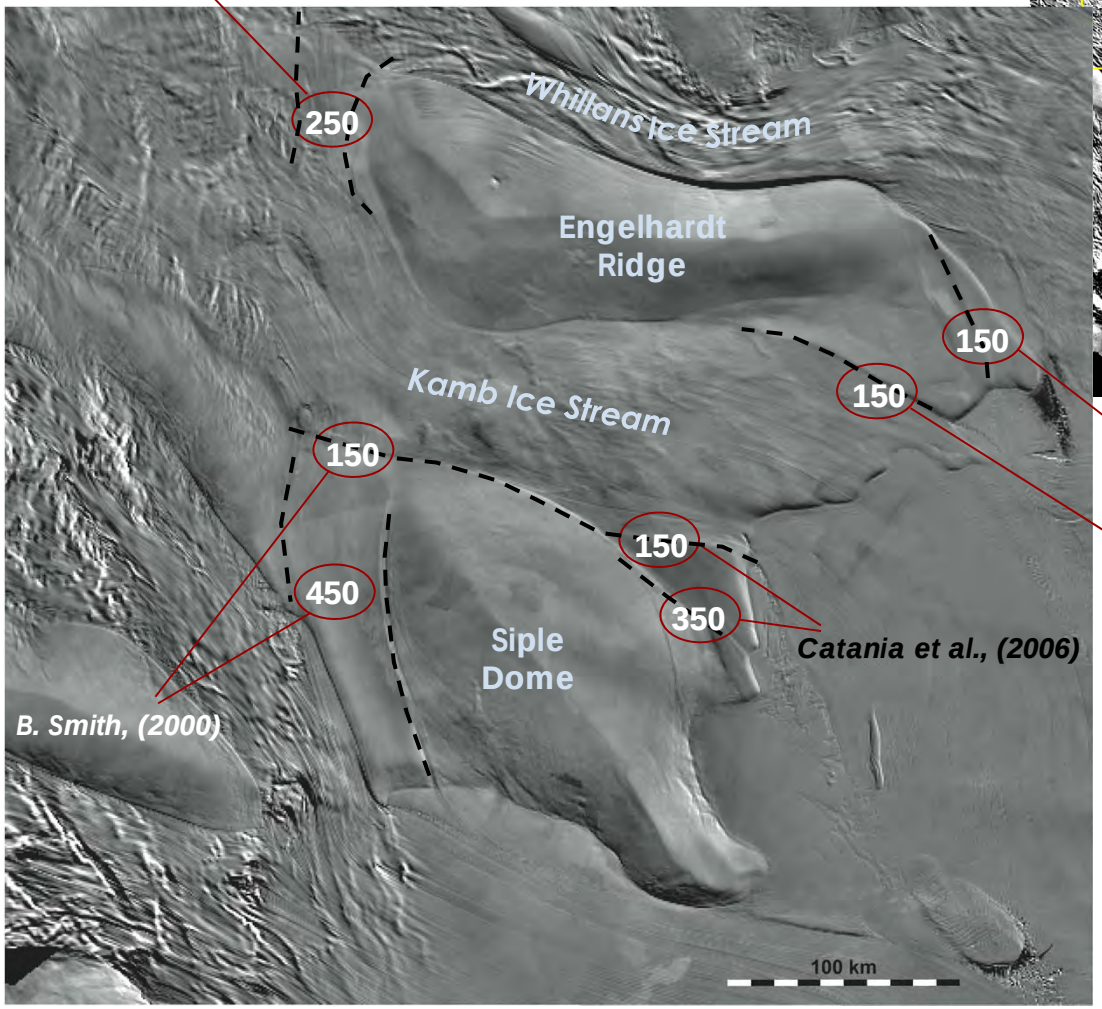
Ice flow history from radar stratigraphy





Ice flow history from radar stratigraphy





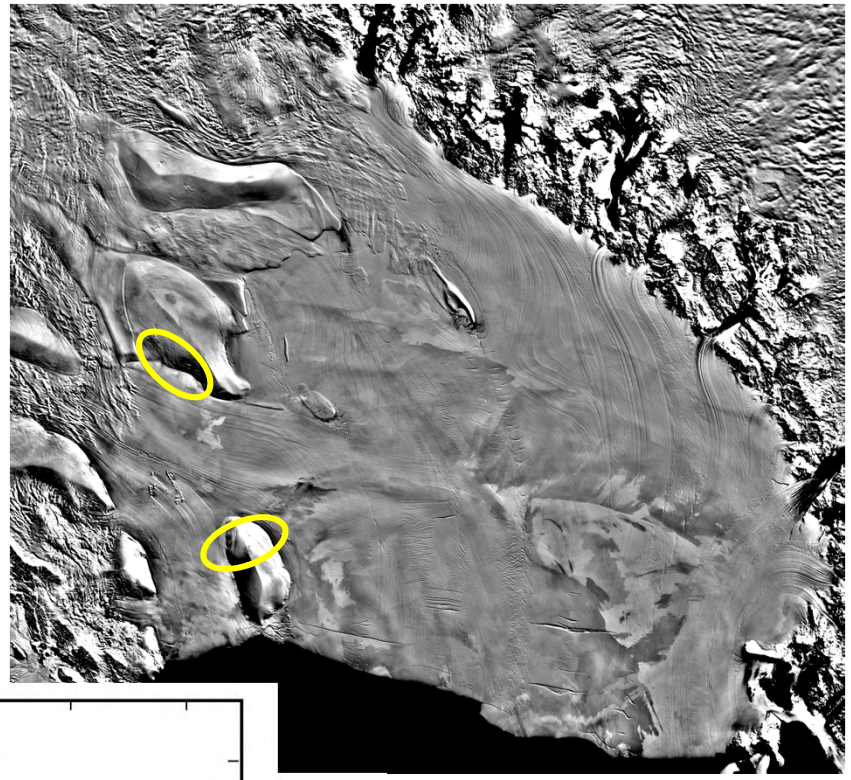
Catania et al. (2003)

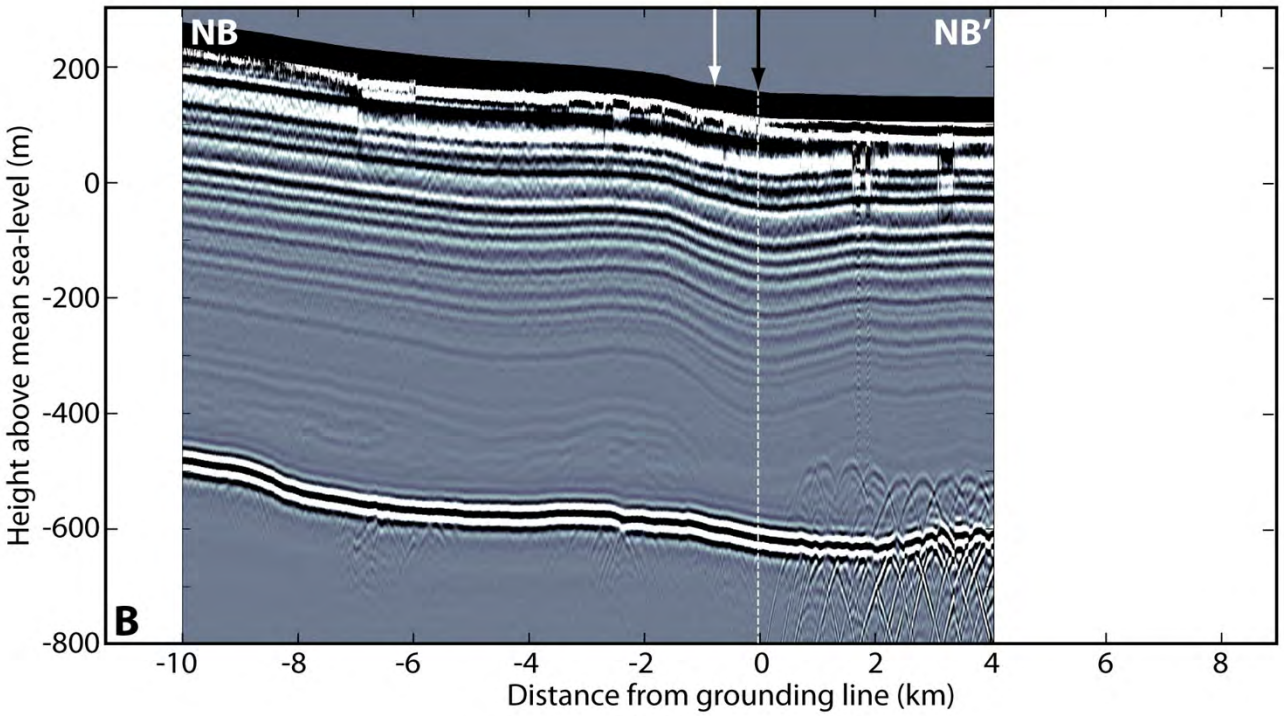
Retzlaff & Bentley, (1993)

Catania et al., (2006)

Ice flow history from radar stratigraphy

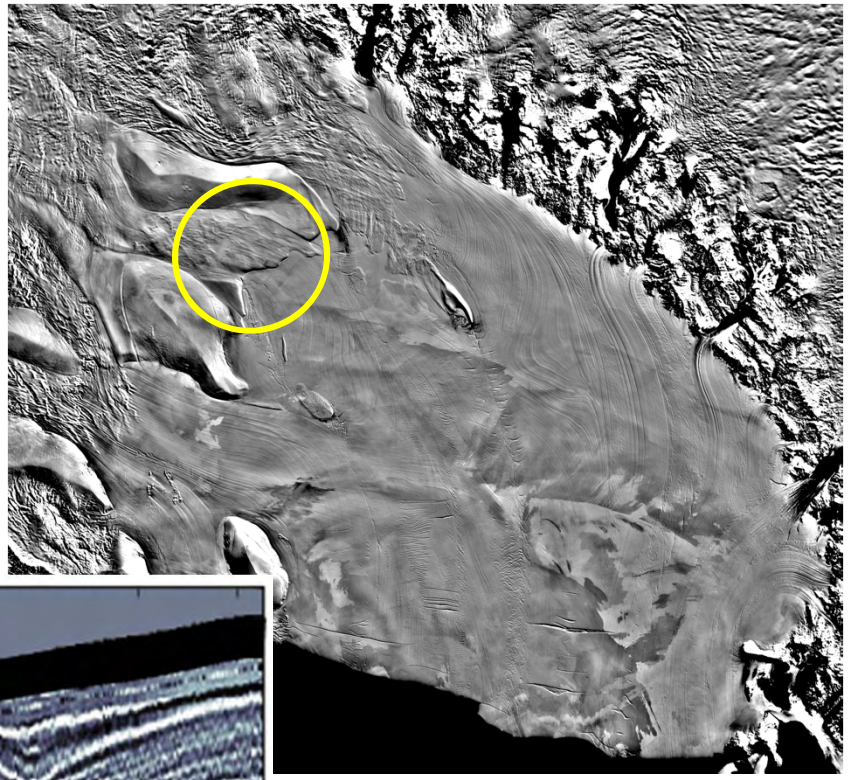
-N. SDM grounding line at current location for ~400 y
-similar duration for Roosevelt Island grounding line



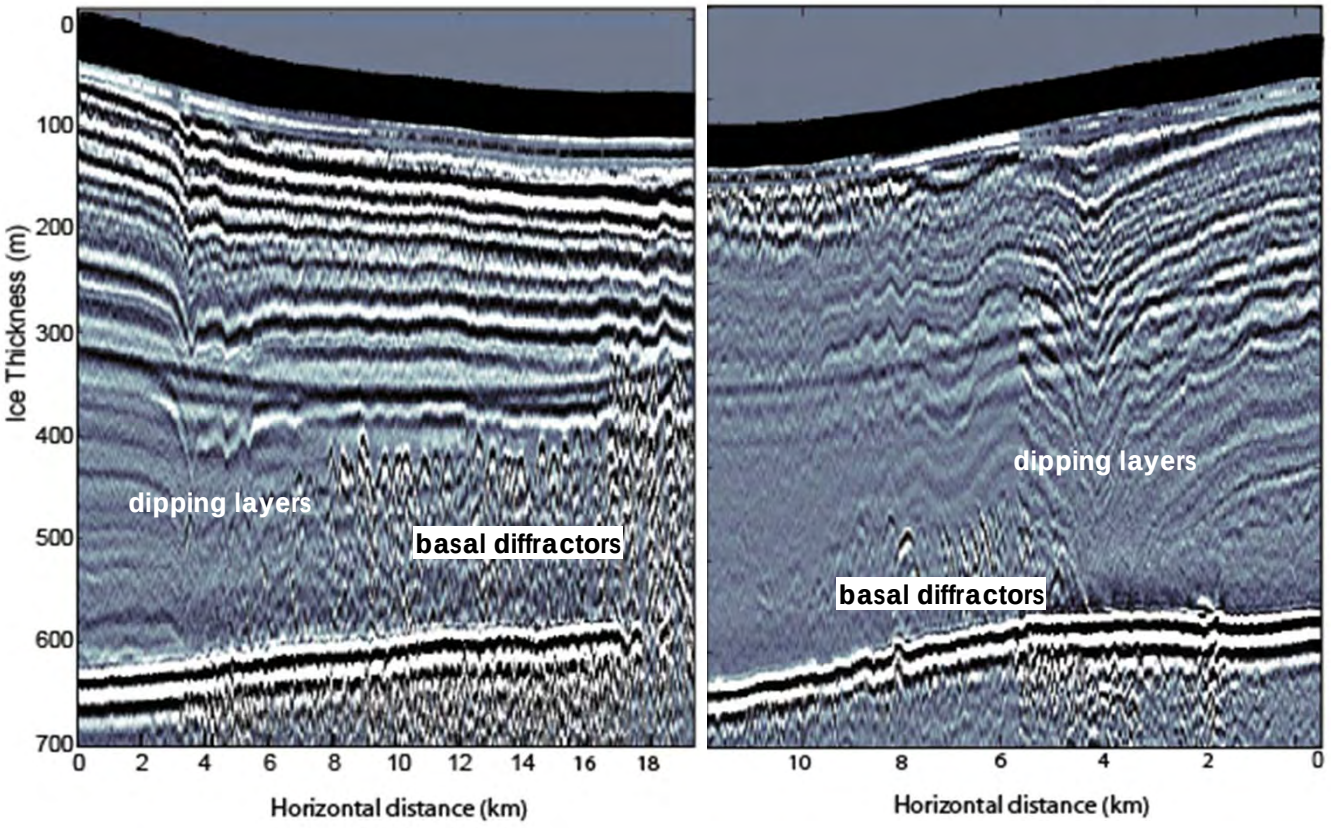


Catania et al., (2010)

Ice flow history from radar stratigraphy



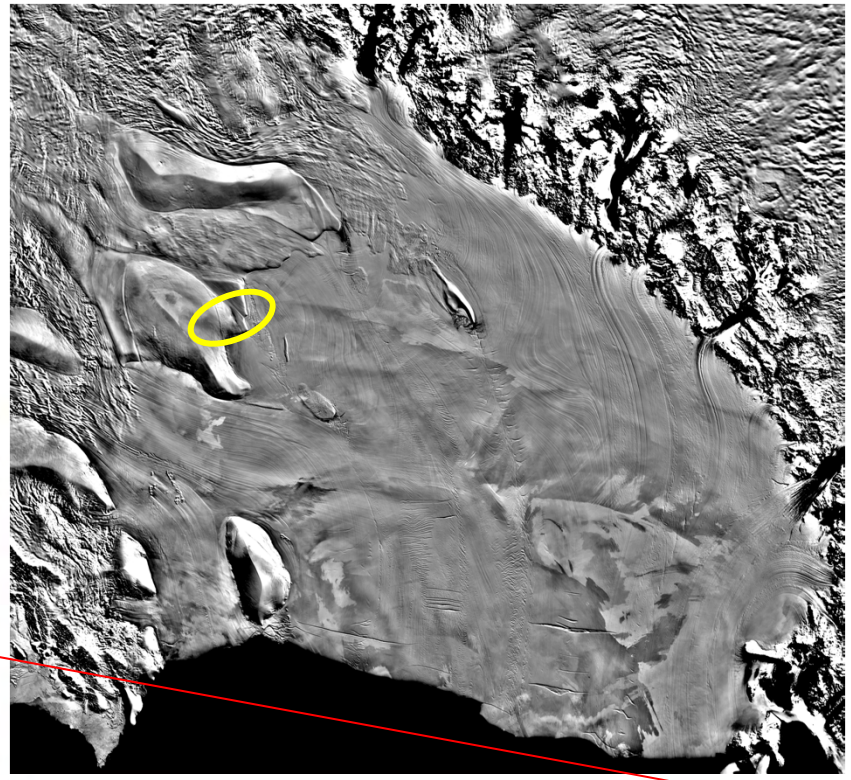
-similar stratigraphy on currently grounded ice implies past grounding line retreat through the trunk of Kamb Ice Stream lasting for a duration of 400 years

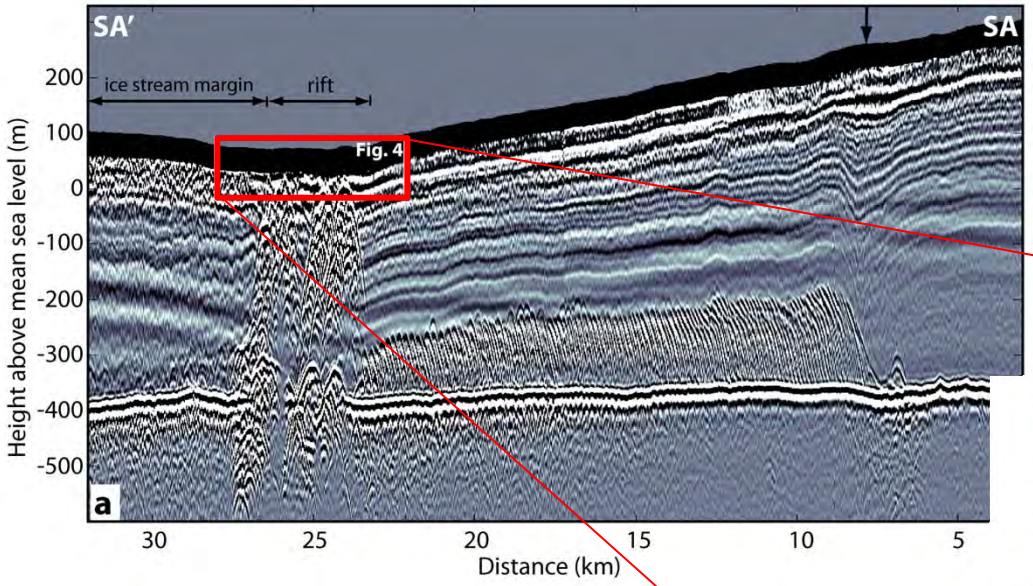


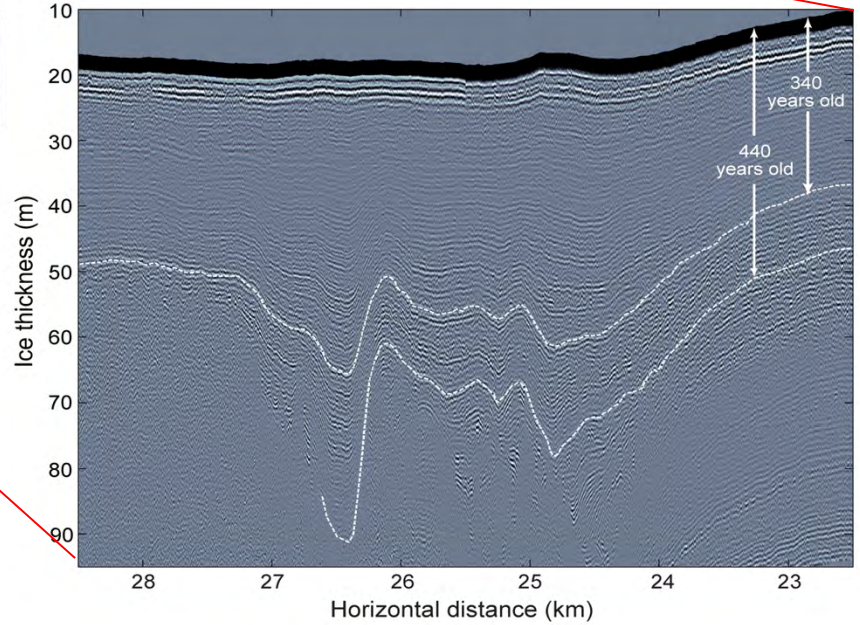
Catania et al., (2010)

Ice flow history from radar stratigraphy

-dating of a buried rift indicates that grounding line re-advance occurred ~440 years ago

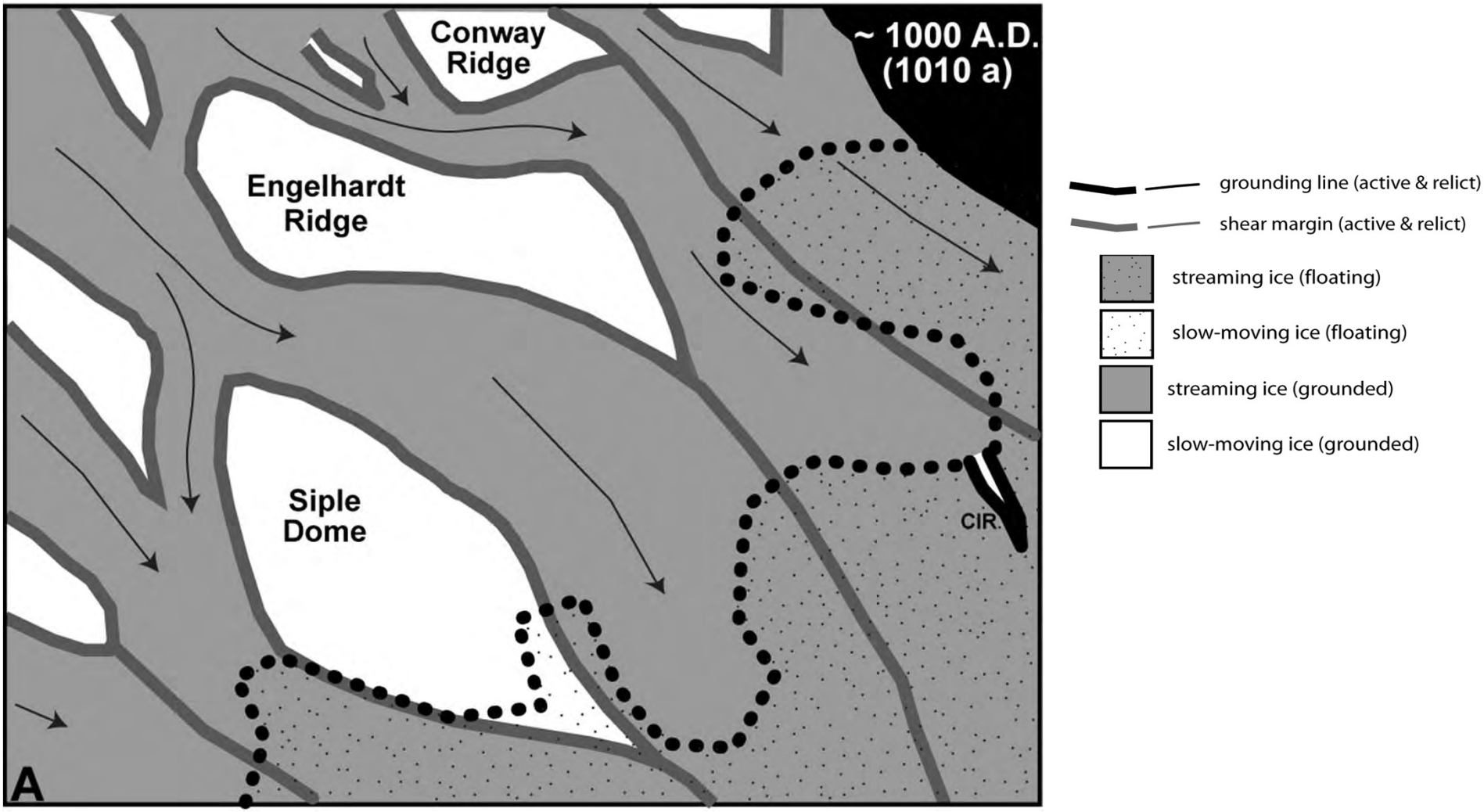






Catania et al., (2010)

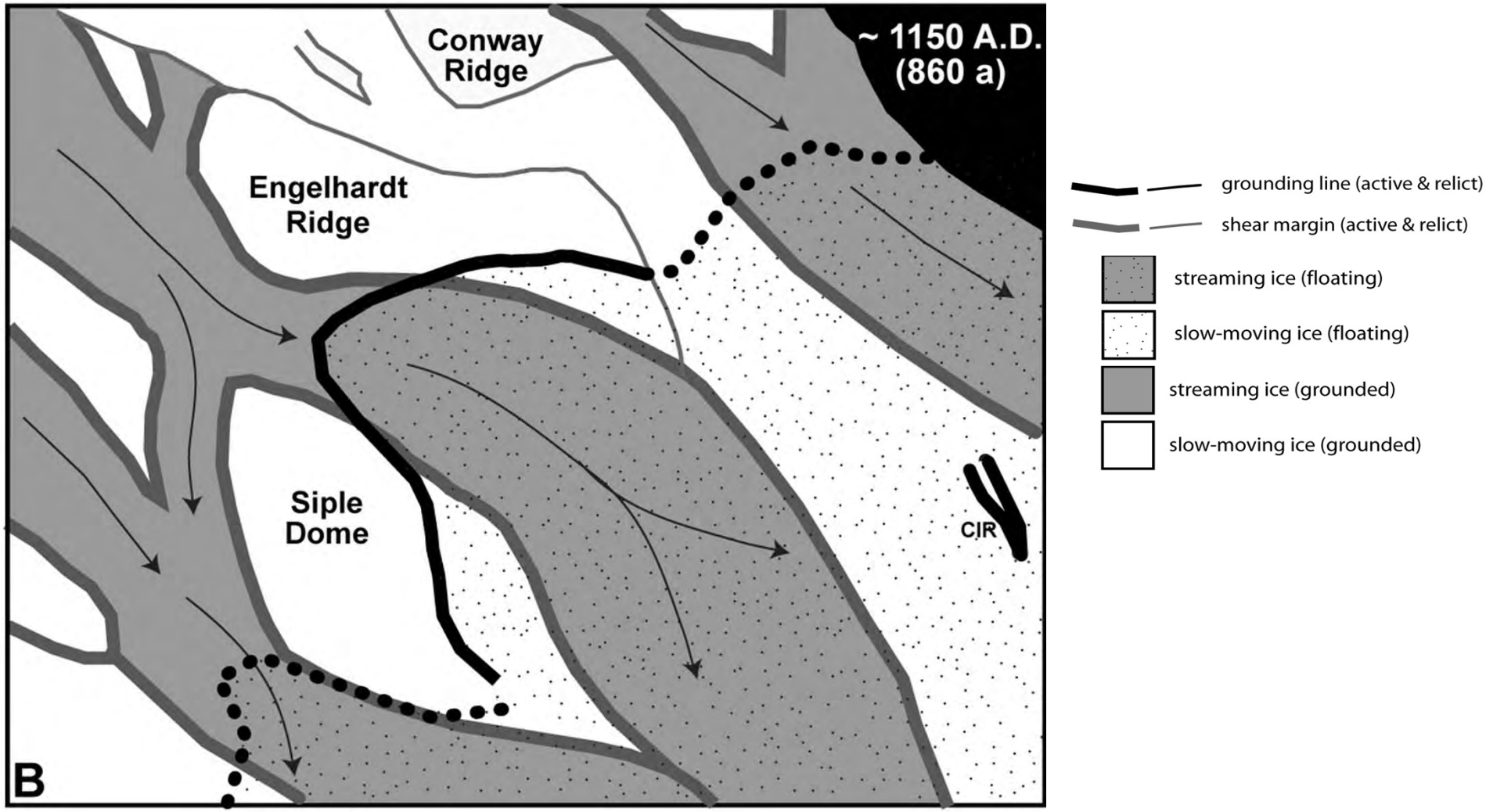
Compiled Ice Flow History



Compiled Ice Flow History

-WIS stoppage causes grounding line retreat *(i.e. thinning)* for KIS

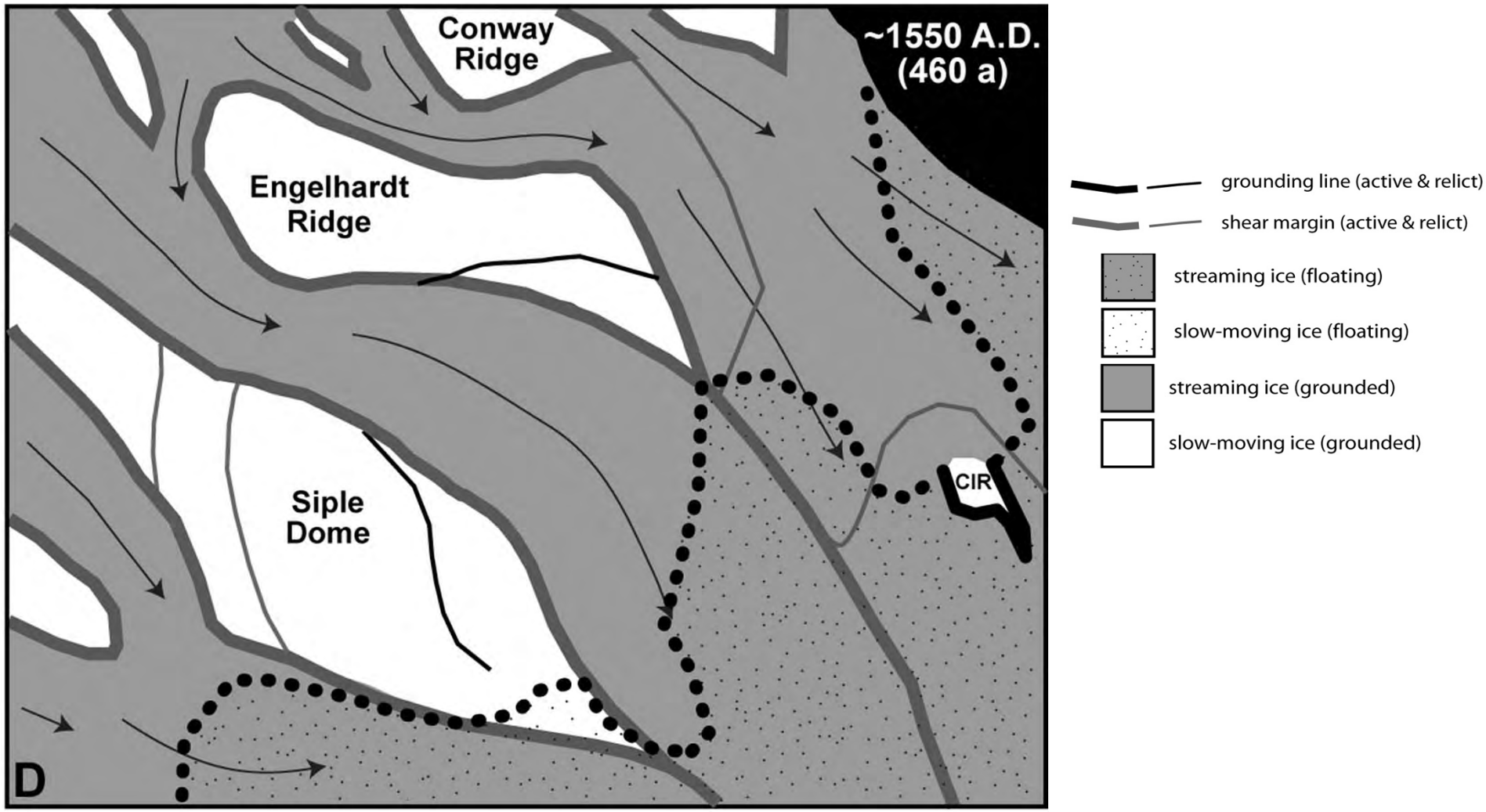
-MacIS also stopped during this period



Compiled Ice Flow History

-re-start of WIS causes grounding line re-advance *(i.e. thickening)* for KIS

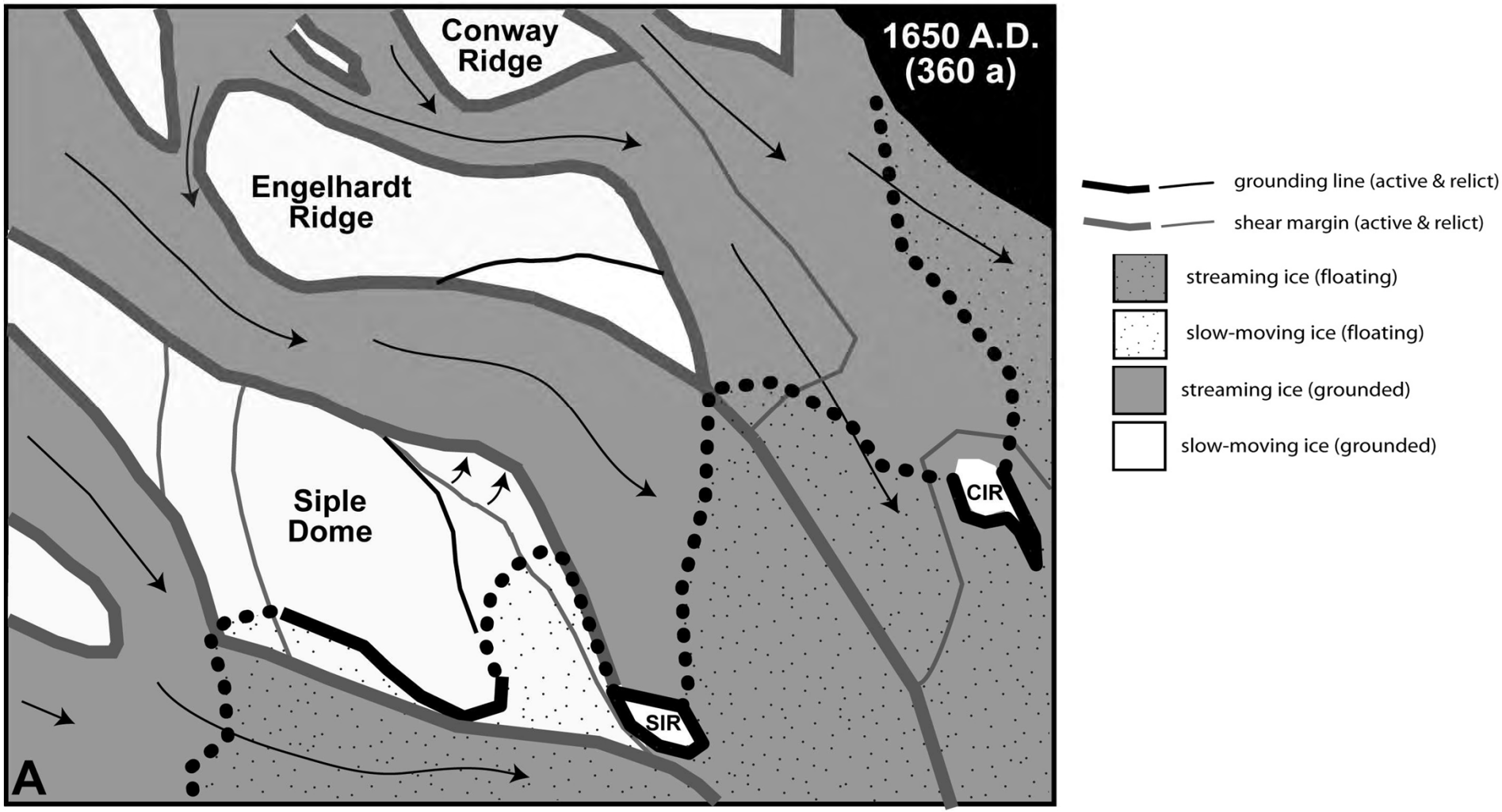
-SIS shutdown



Compiled Ice Flow History

-retreat of northern SDM grounding line to present location *(thinning from SIS shutdown)*

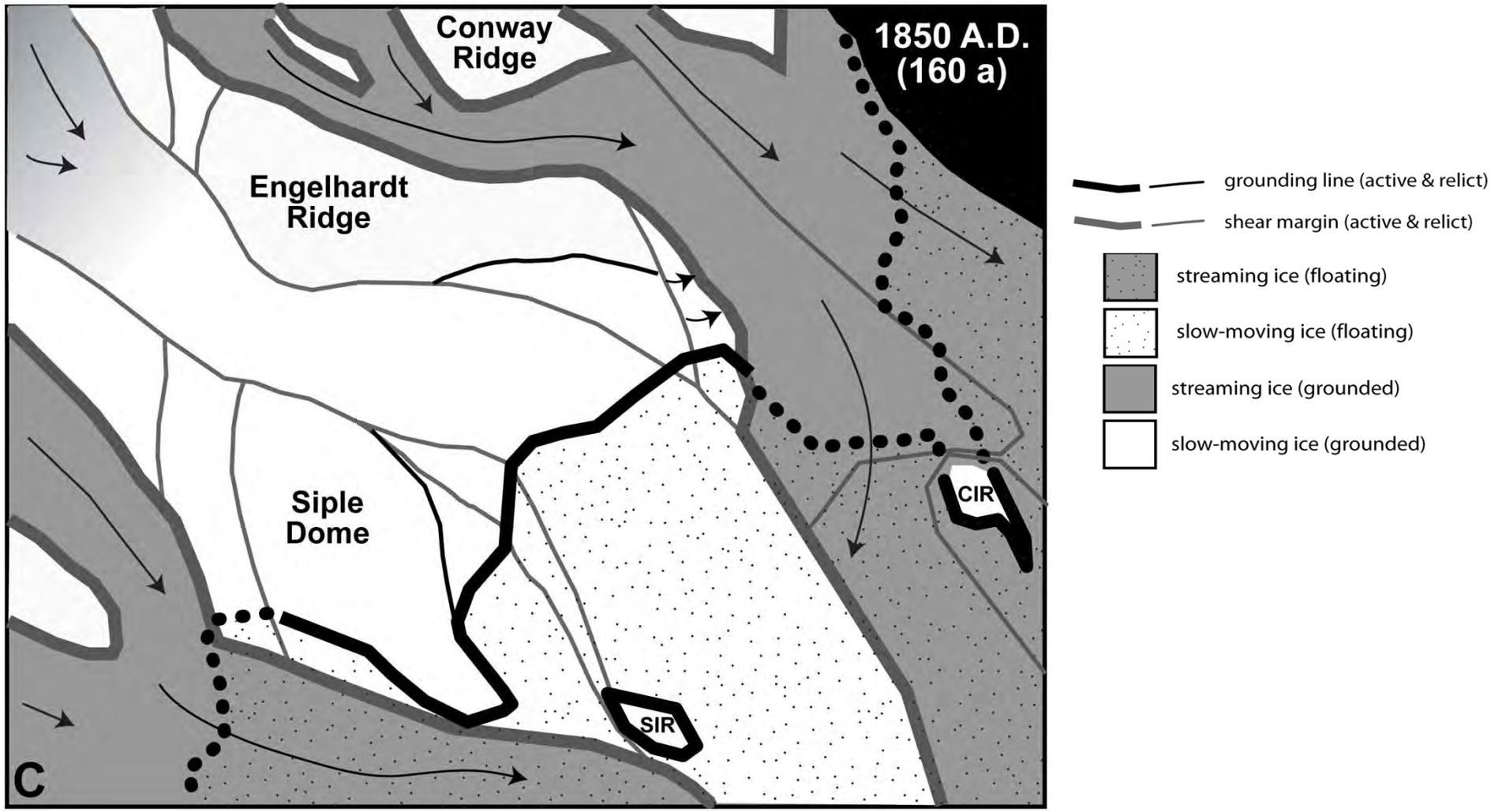
-Steershead forms *(thickening from KIS)* causes KIS to narrow (and reduces discharge)



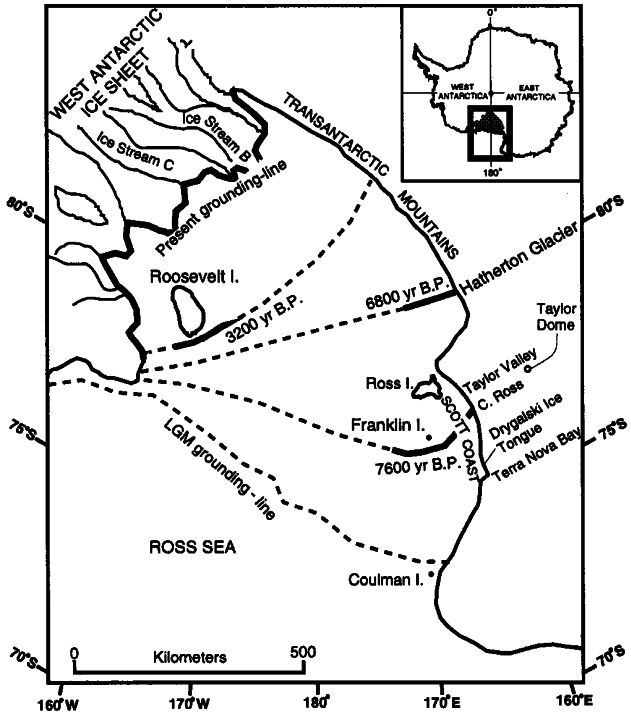
Compiled Ice Flow History

-total shutdown of KIS

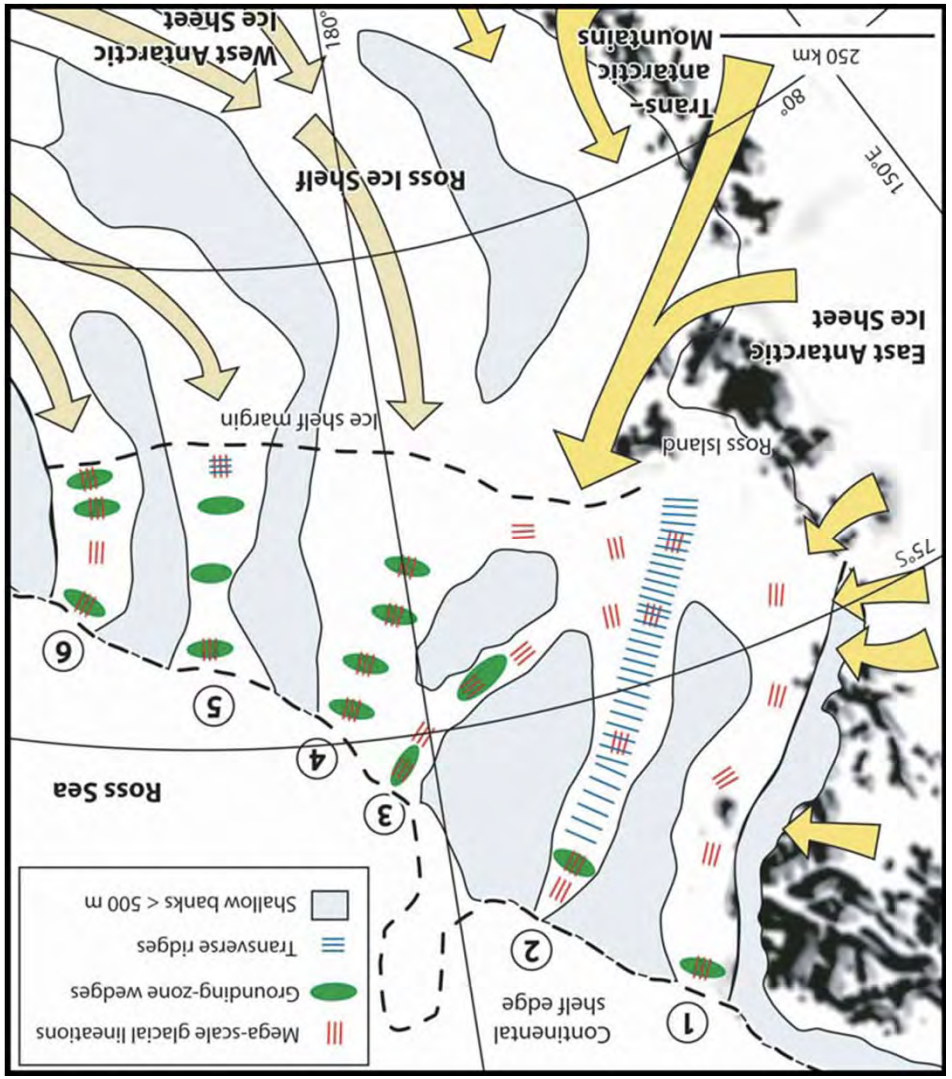
-synchronous narrowing of WIS → expect shutdown in ~50-100 y and g.l. retreat



Putting ‘recent’ changes in context



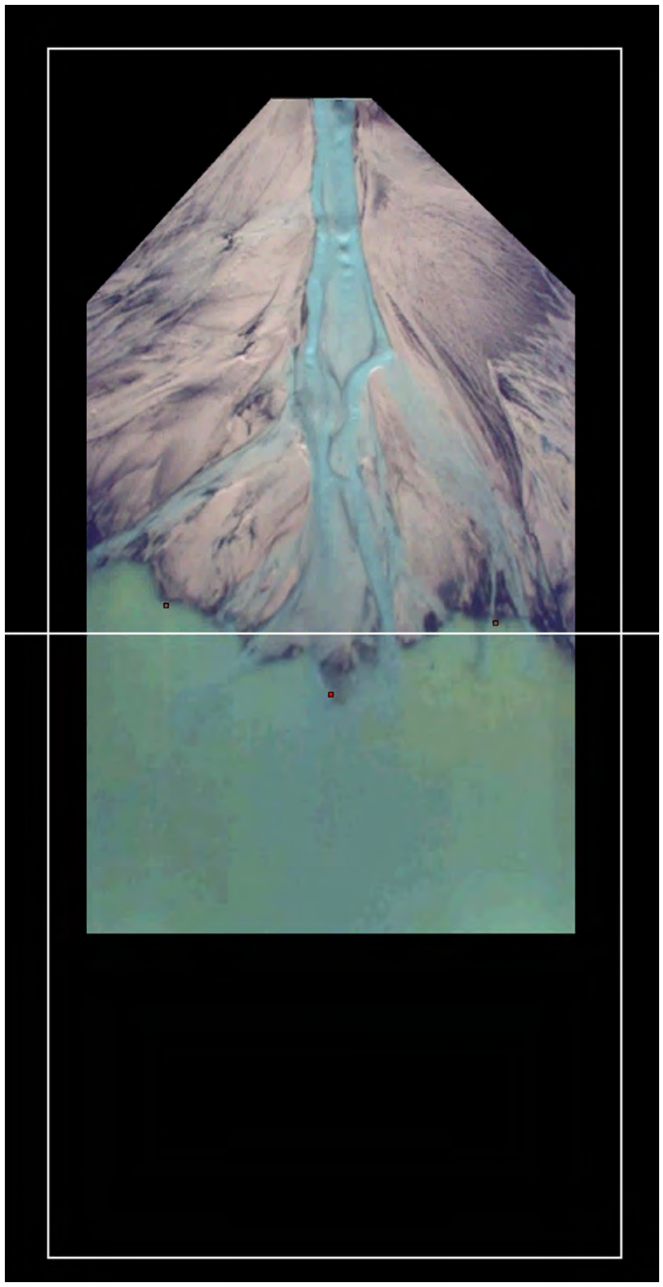
Conway and others (1999)



Dowdeswell and others (2008)

-grounding line retreat has been ongoing since the end of the LGM
-sedimentary record indicates that grounding line retreat within the ice stream troughs is non-steady

Putting ‘recent’ changes in context



we might look to other disciplines where internal variability occurs but over **much faster time scales**

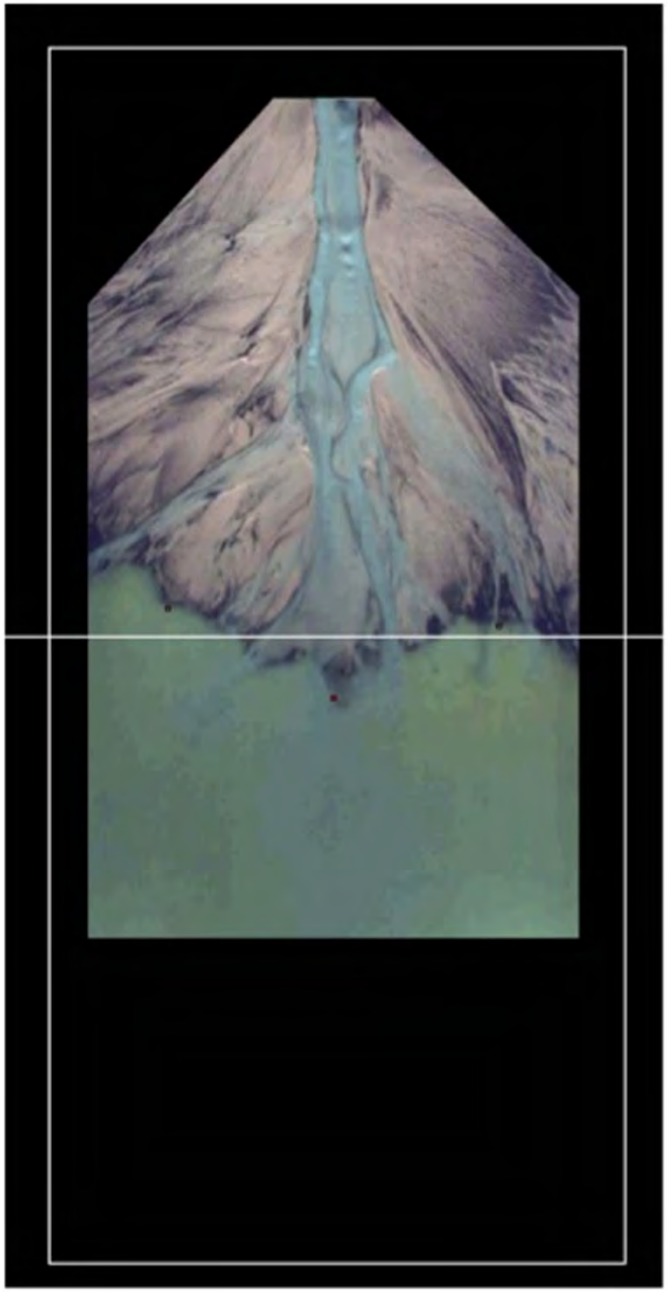
-e.g. examination of shoreline position (a function of sea-level and sediment flux) during forced sea-level changes (no changes in sediment/water flux)

-during sea-level rise shoreline position is more variable than during sea-level fall

-sea-level changes either work with or against the sediment transport regime and can thus magnify or diminish the effects of forced change in sea-level

Kim and others (2006)

Putting ‘recent’ changes in context



we might look to other disciplines where internal variability occurs but over **much faster time scales**

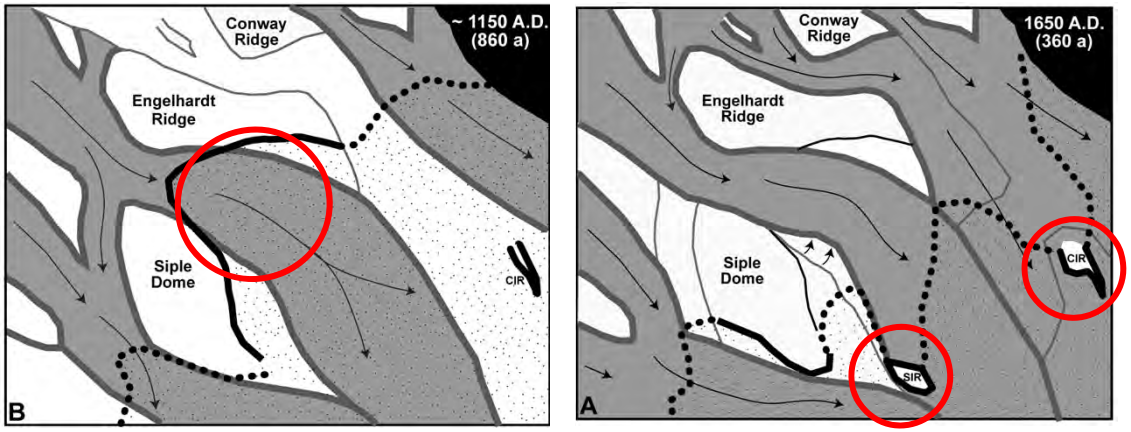
-e.g. examination of shoreline position (a function of sea-level and sediment flux) during forced sea-level changes (no changes in sediment/water flux)

-during sea-level rise shoreline position is more variable than during sea-level fall

-sea-level changes either work with or against the sediment transport regime and can thus magnify or diminish the effects of forced change in sea-level

-similarly, sea-level changes either work with or against ice thickness changes and can amplify or diminish changes in the grounding line/discharge due to changing sea-level

-more variability during sea-level rise is to be expected

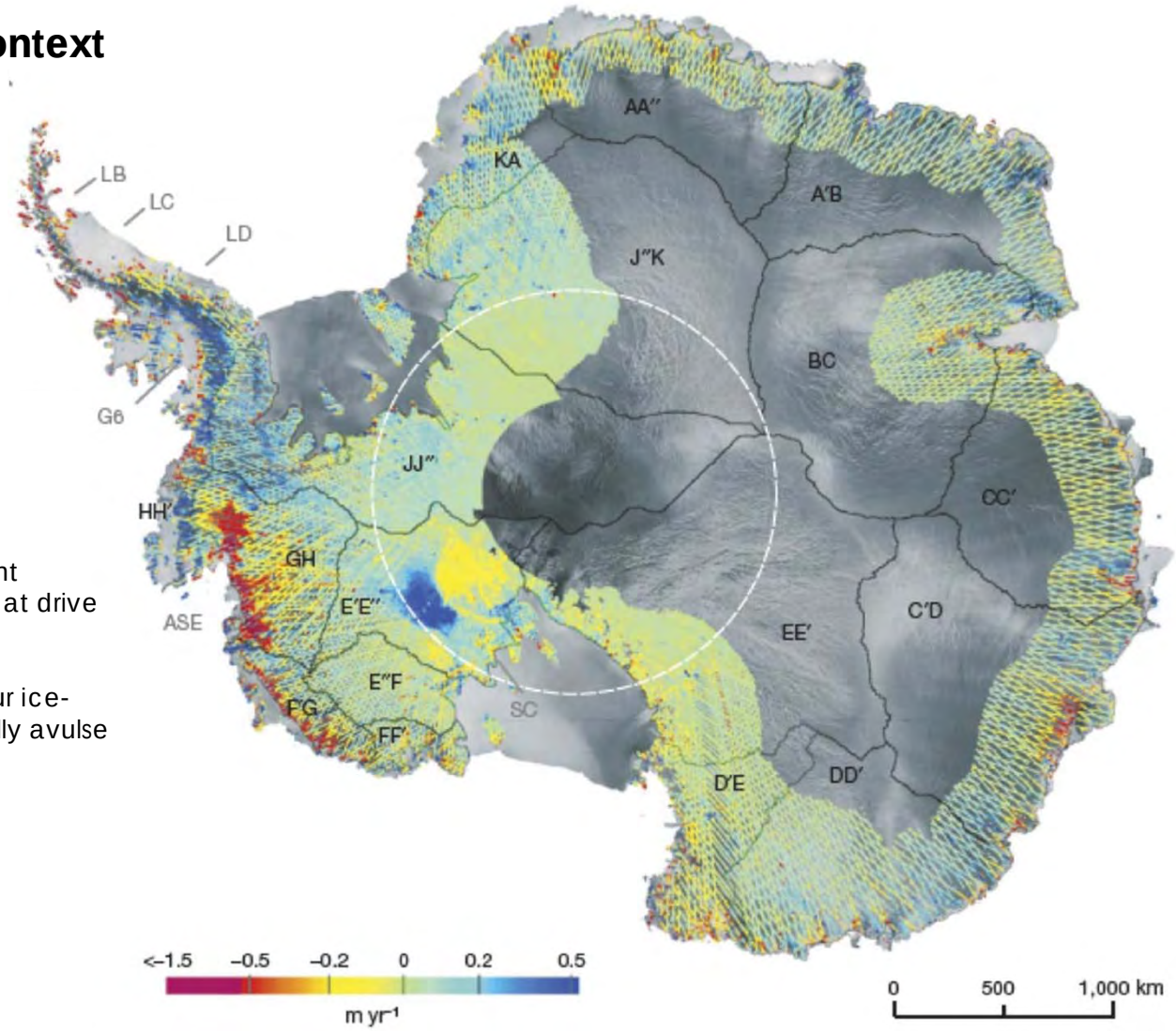


Kim and others (2006)

Putting ‘recent’ changes in context

-stream channel avulsion occurs as sediment deposition causes local changes in slope that drive flow

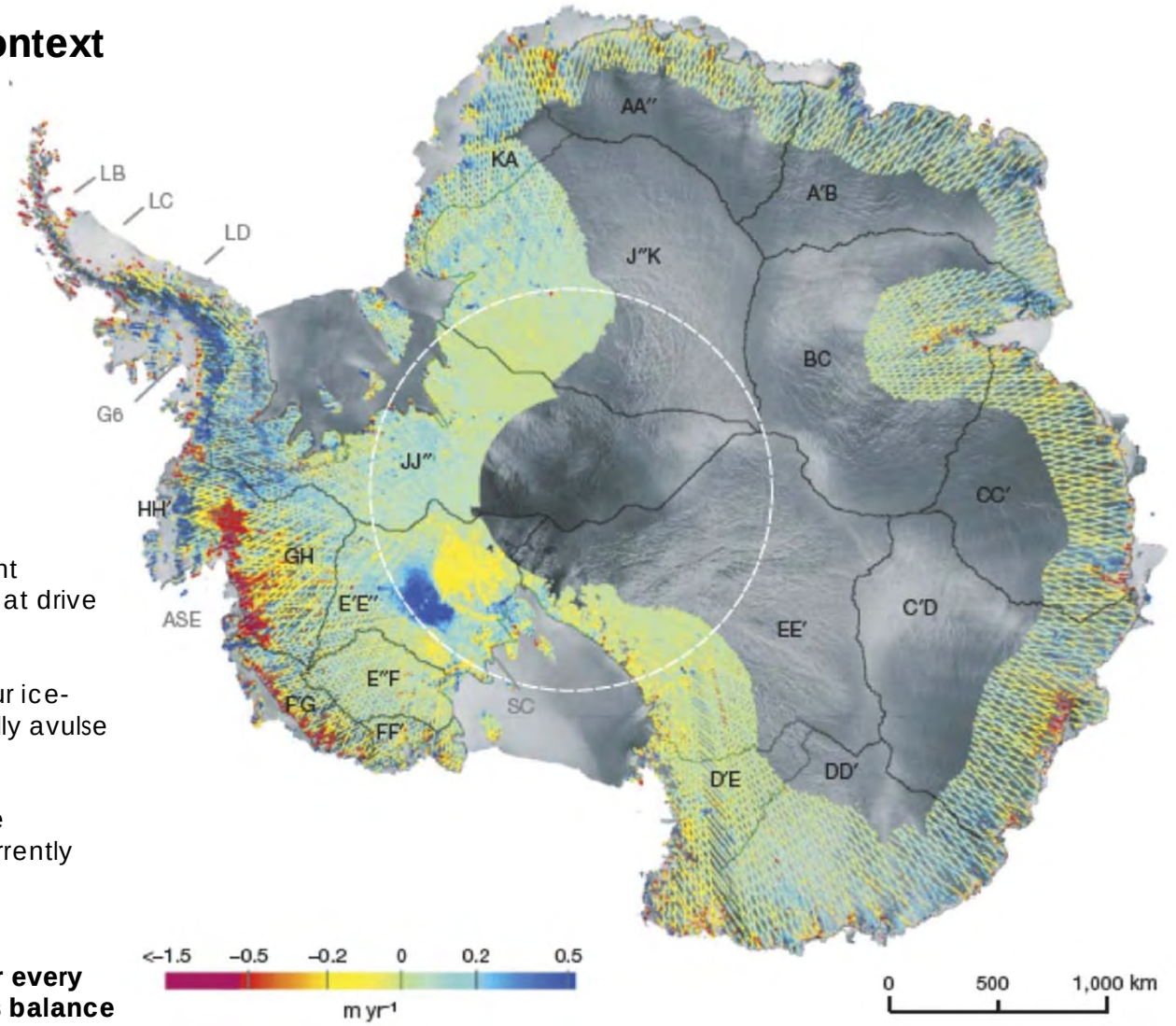
-we suggest that this may be common in our ice-system e.g. Kamb Ice Stream may eventually avulse toward Whillans*



*pure speculation

Pritchard and others (2009)

Putting ‘recent’ changes in context



-stream channel avulsion occurs as sediment deposition causes local changes in slope that drive flow

-we suggest that this may be common in our ice-system e.g. Kamb Ice Stream may eventually avulse toward Whillans*

-impact of variability is felt on mass balance estimates for this embayment which are currently positive (Joughin and Tulaczyk, 2002)

-our observations suggest that changes in discharge, which occur rapidly <10a, occur every 100a making near-term predictions of mass balance challenging

*pure speculation

Pritchard and others (2009)

Remembering Barclay Kamb

Remembering Barclay Kamb


COMBUSTIBLES
(BURNABLES)

Preparing to lower a core drill to the base of the ice stream are (from left) Howard Conway, Hermann Engelhardt, Judy Zachariasen, and Neil Humphrey.