Swiss Global Change Day 2008

Climate Change in the Arctic:
Future Lessons from the Past

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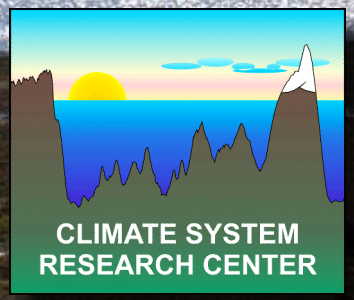
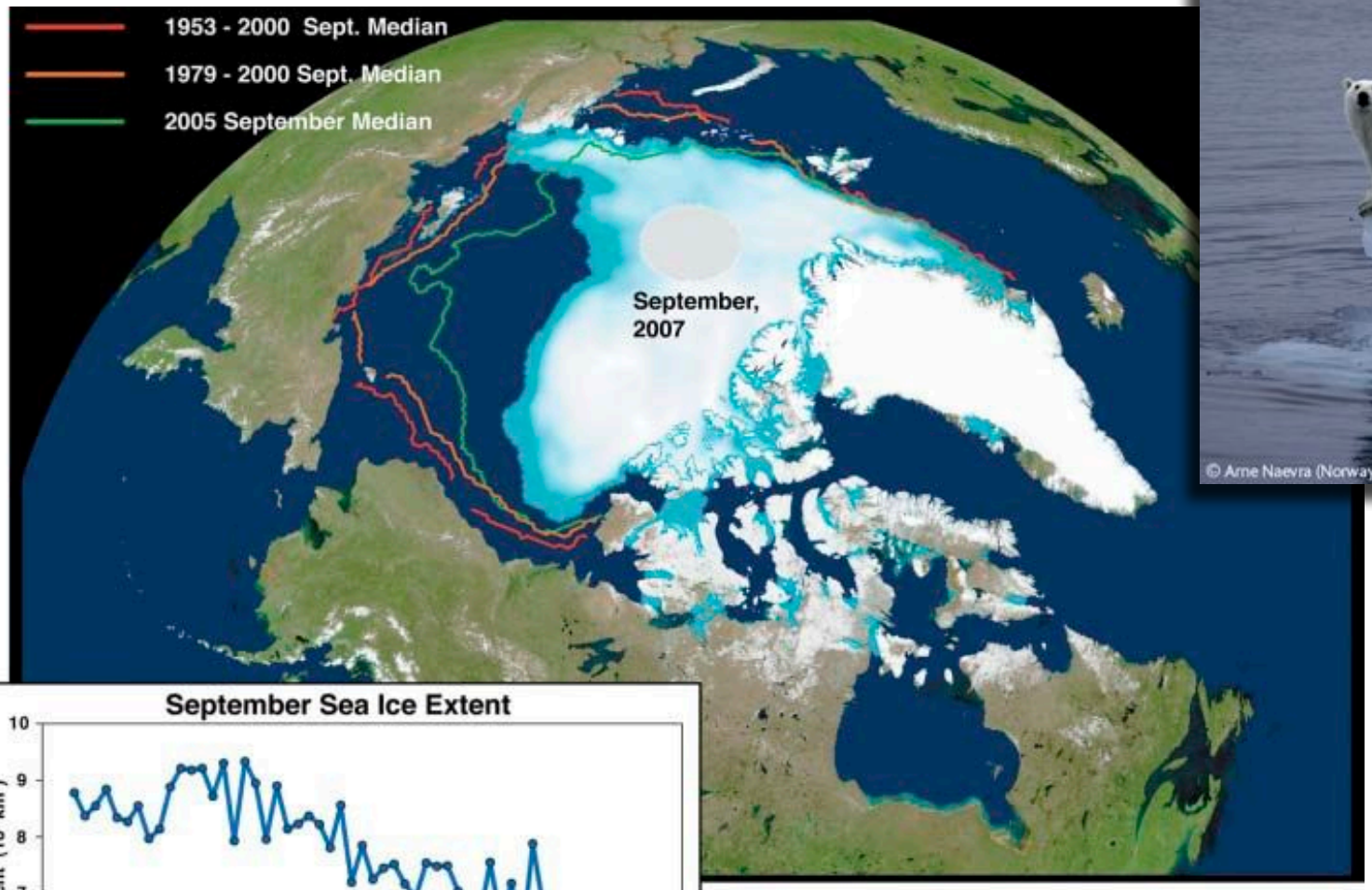
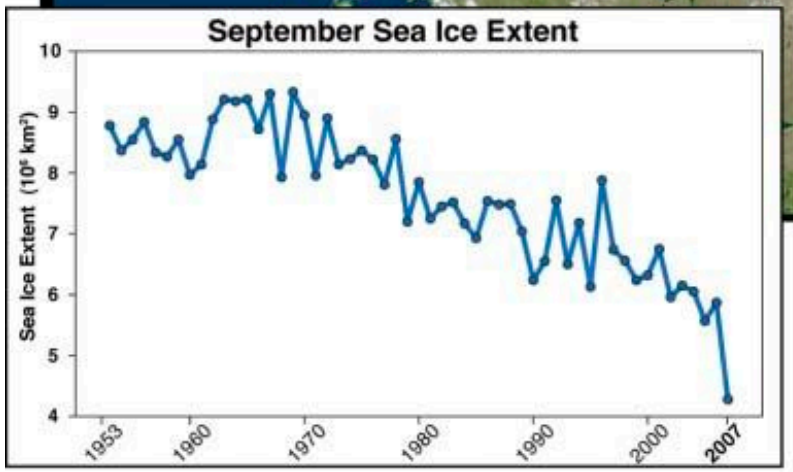
Office Polar Programs



The Arctic is changing!



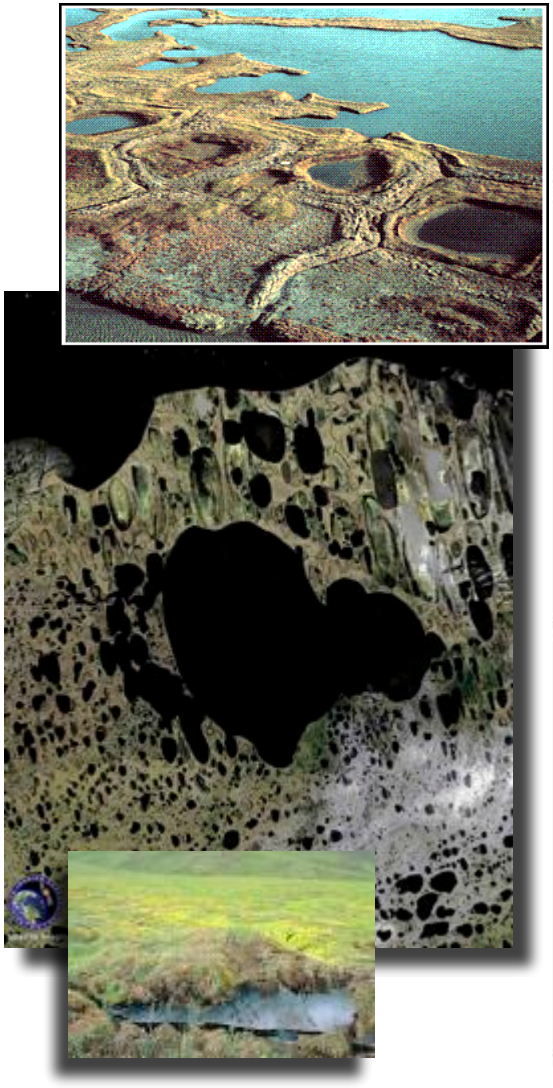


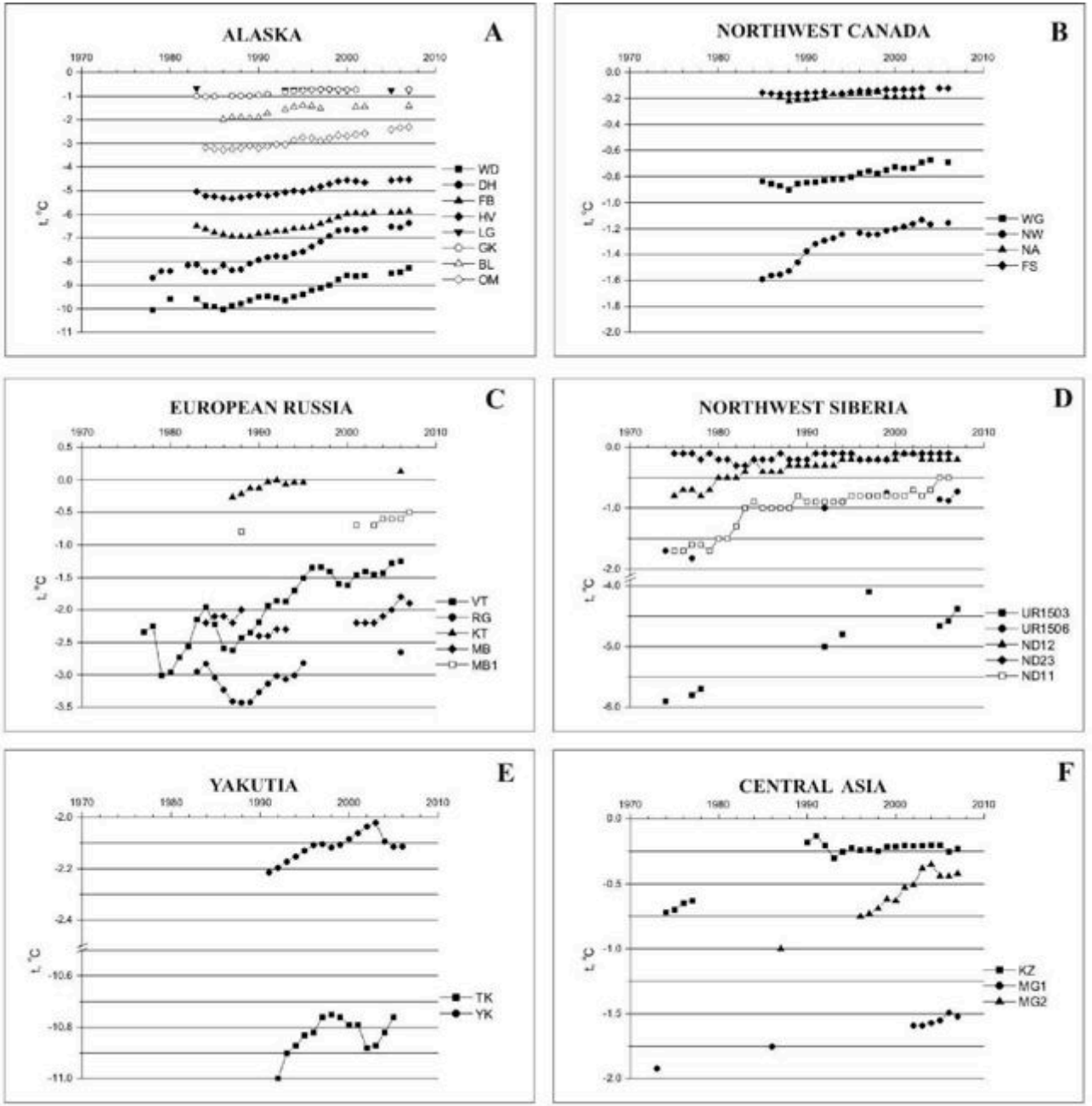
Stroeven et al, 2008 EOS

1937
Bradford Washburn

2006
David Arnold

Permafrost warming





Romanovsky et al, in press

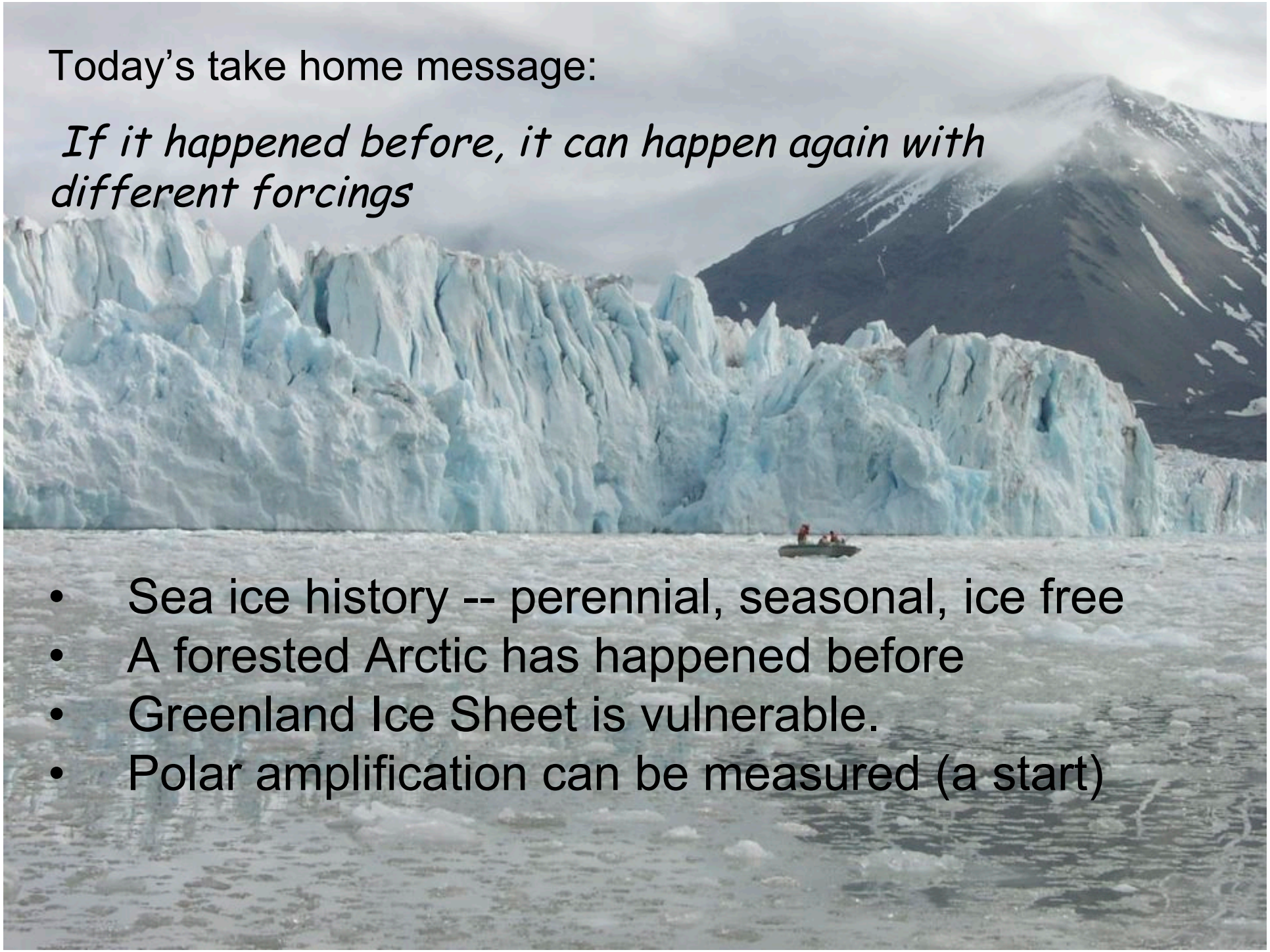
US Climate Change Science Program
www.climatescience.gov

Synthesis and Assessment 1.2
Past Climate Variability and Change in the Arctic and at High Latitudes

How can information about Arctic Paleoclimate inform us about future changes?

Chapter Leads + 25 contributing authors

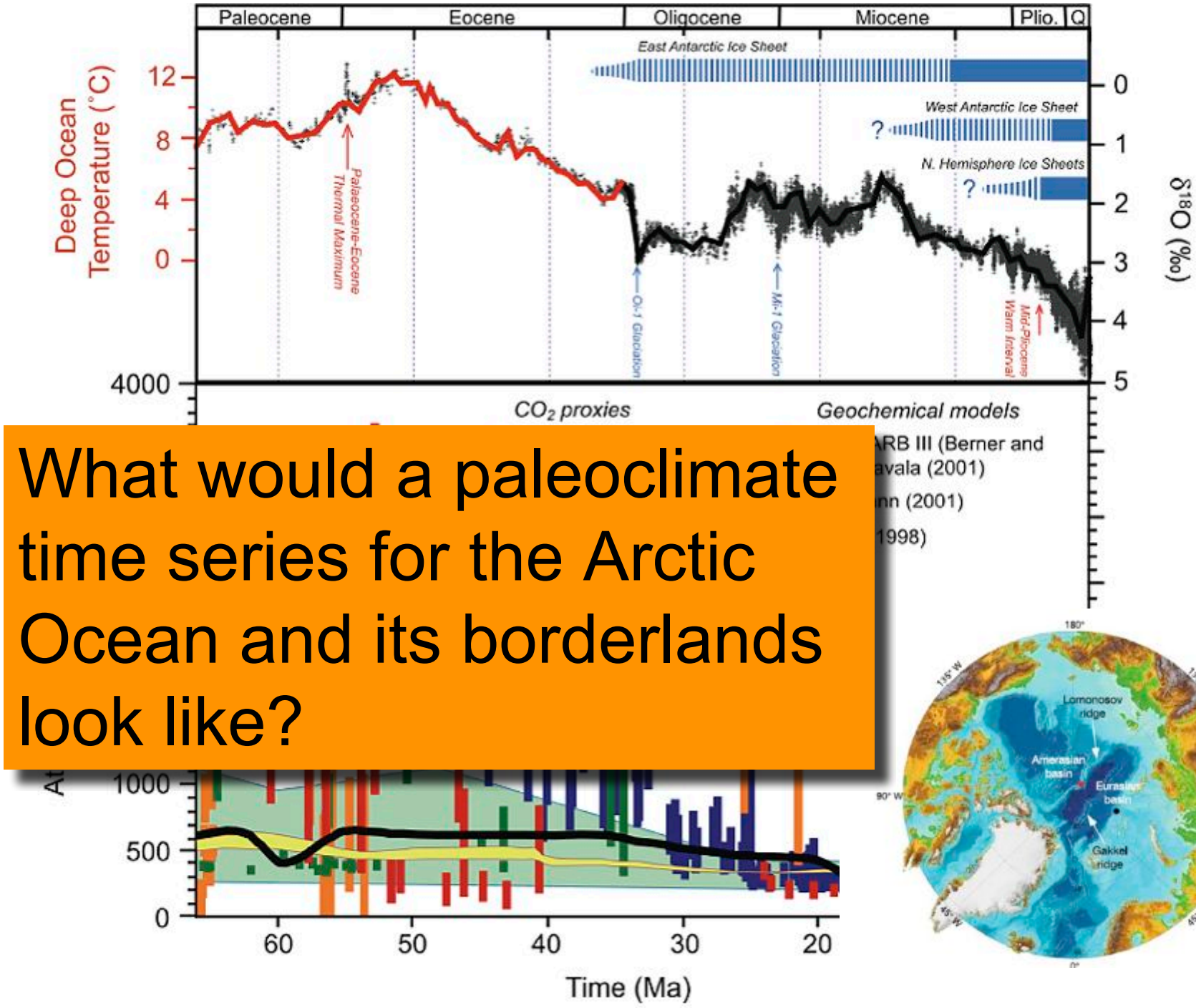
- Past Temperature and Precipitation…….. — Giff Miller & J. Brigham-Grette
- Past history of Sea Ice…… — Leonid Polyak
- Past History of Greenland Ice Sheet……. — Richard Alley
- Rates of Change…….. — Jim White & Richard Alley



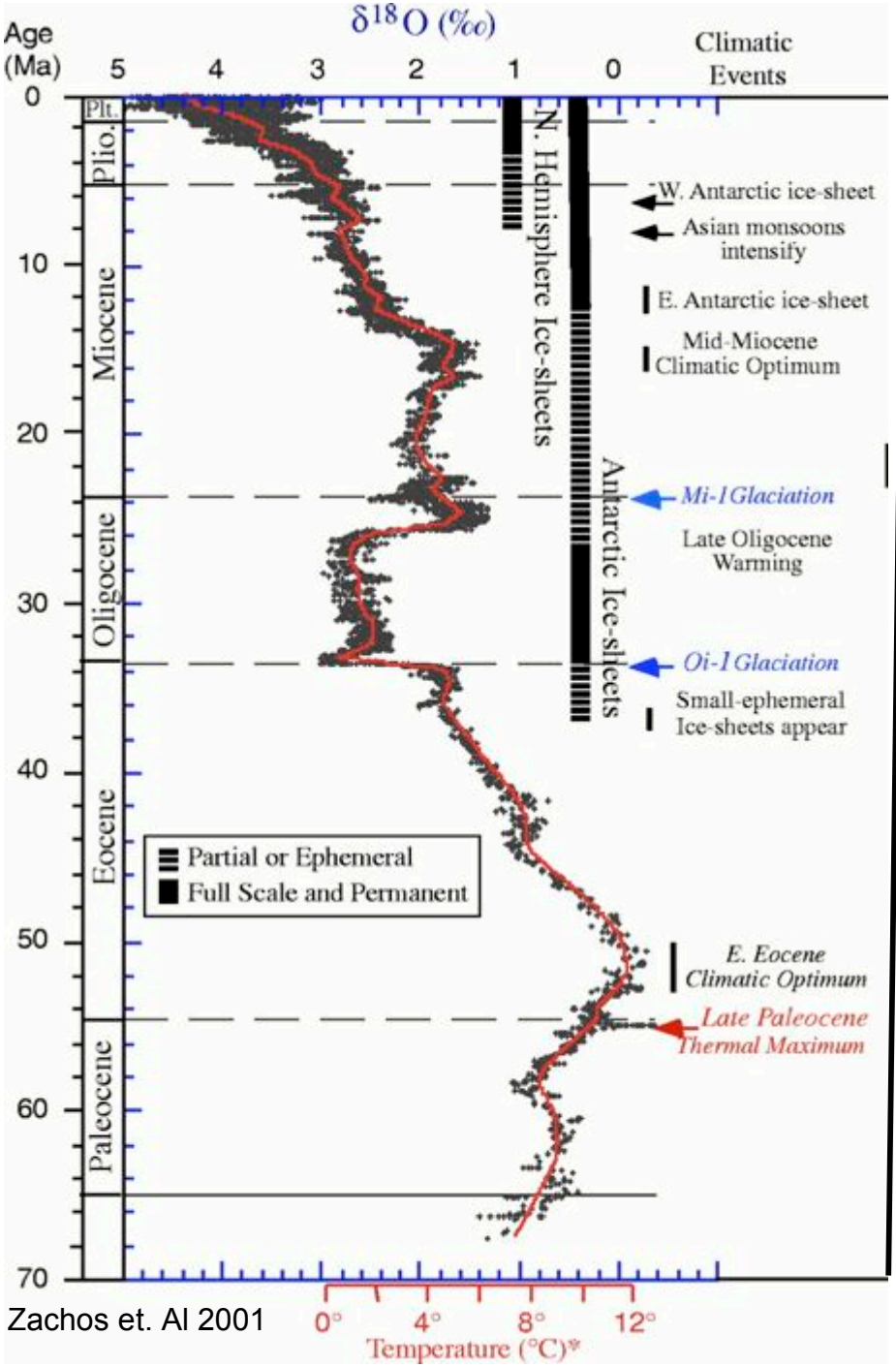
Today's take home message:

If it happened before, it can happen again with different forcings

- Sea ice history -- perennial, seasonal, ice free
- A forested Arctic has happened before
- Greenland Ice Sheet is vulnerable.
- Polar amplification can be measured (a start)



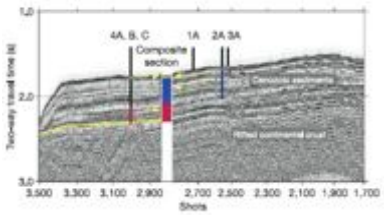
What would a paleoclimate time series for the Arctic Ocean and its borderlands look like?

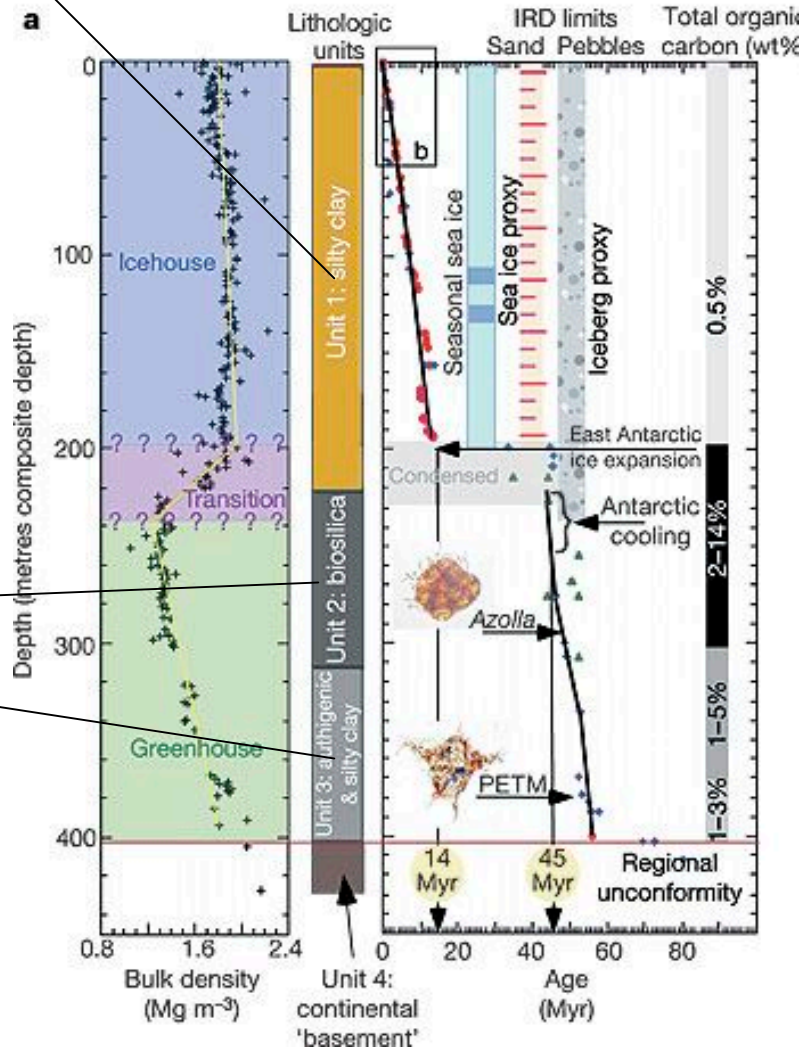


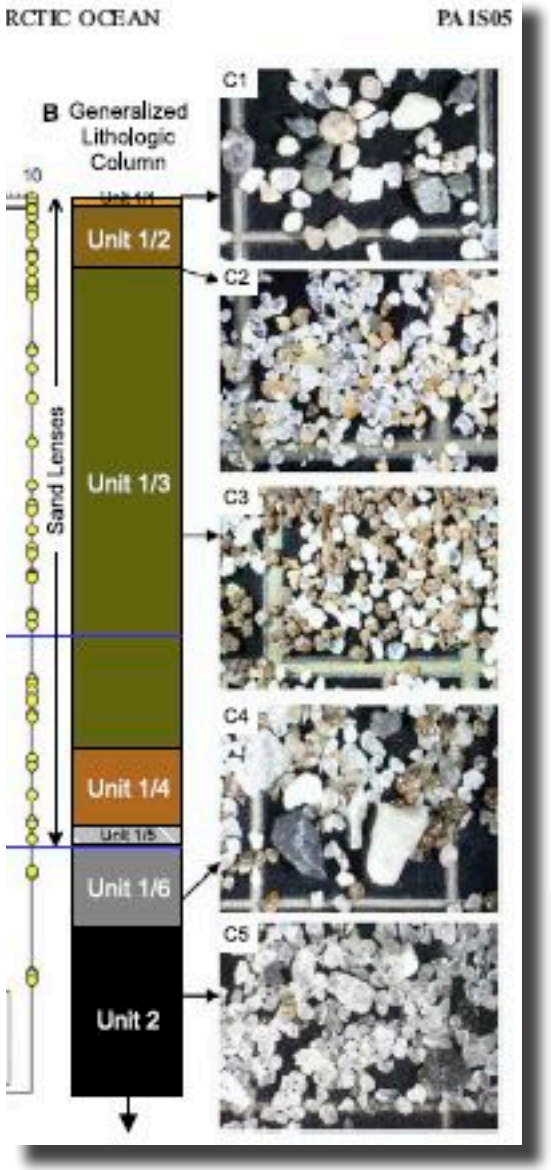
Zachos et. Al 2001

Recovered

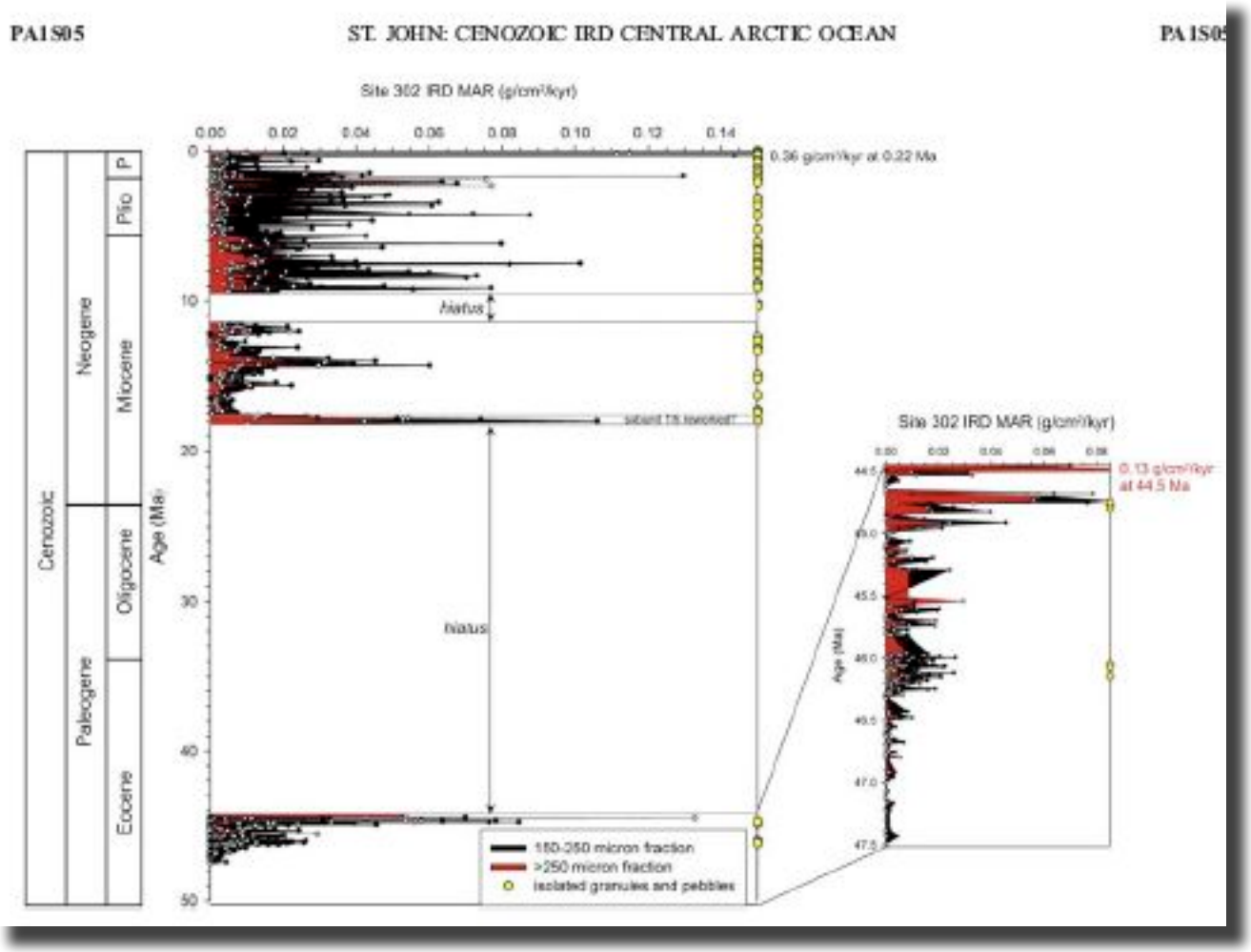
missing







St. John et al., 2007 Paleoceanog.

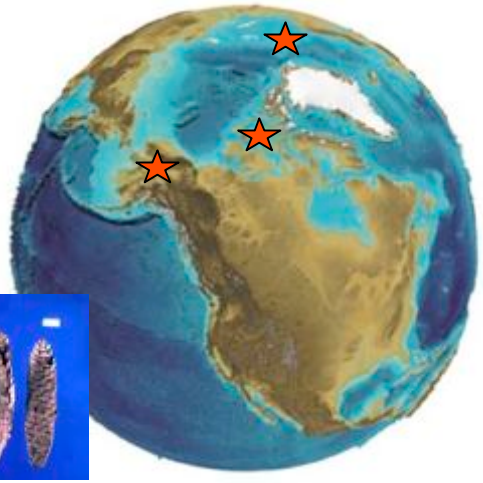


"Sea ice and glacial ice started at 46 Ma; long pattern of glacial ice expansion and decay since Eocene"

"Intensified ice rafting at 14,12,9,8,7 and 6.5 Ma"

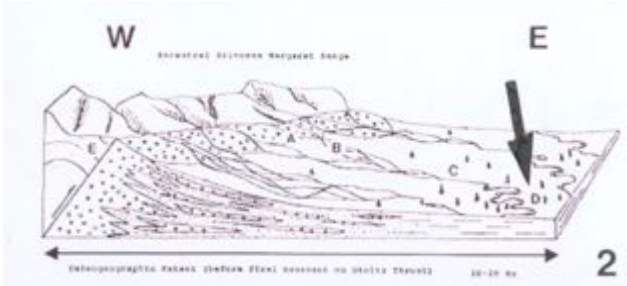
Eocene Tropical Forests of Axel Heiberg Island -- 46 Ma

Buchanan Lake Formation/Eureka Sound Formation



Temperate forest dominated by *Metasequoia* at 77°N paleolat.

Summers rarely less than 25°C; winters never less than 5°C; similar record on Spitsbergen/Alaska (analog to SE China)



- Hippopatamus-like animals
- crocodillians (*Alligator*)
- Giant turtle
- Saki monkeys
- Flying lemurs
- Animals with nocturnal capabilities

Images from http://www.sas.upenn.edu/earth/arctic

Eocene Axel Heiberg Island 46 Ma

Buchanan Lake Formation/Eureka Sound Fm

Northern-most Brontothere

Early Miocene Haughton Astrobleme

Devon Island; ca. 22.4 My

Subtropical forest at 75°N paleolat.

Summers about 18°C July; winters -17 to +1°C; similar to southern Maritime Canada

Lake Sediments 48 m thick contain:

rhinocerous

Swans, rabbits, trout

Forests of pine with walnut, beech, hickory, holly, maple, chestnut, basswood -mixed conifer hardwood forest like New England today

(Whitlock and Dawson, 1990)

Late Oligocene to Late Pliocene Beaufort Formation

Western Canadian Arctic Islands; variously dated

Alluvial Sand and Gravel,

Predates interland channels

high latitude circumarctic region at this time was occupied by rich, high-biomass forests of redwood with wetlands characteristic of temperate conditions until nearly 38 Ma

Very Warm interglacials

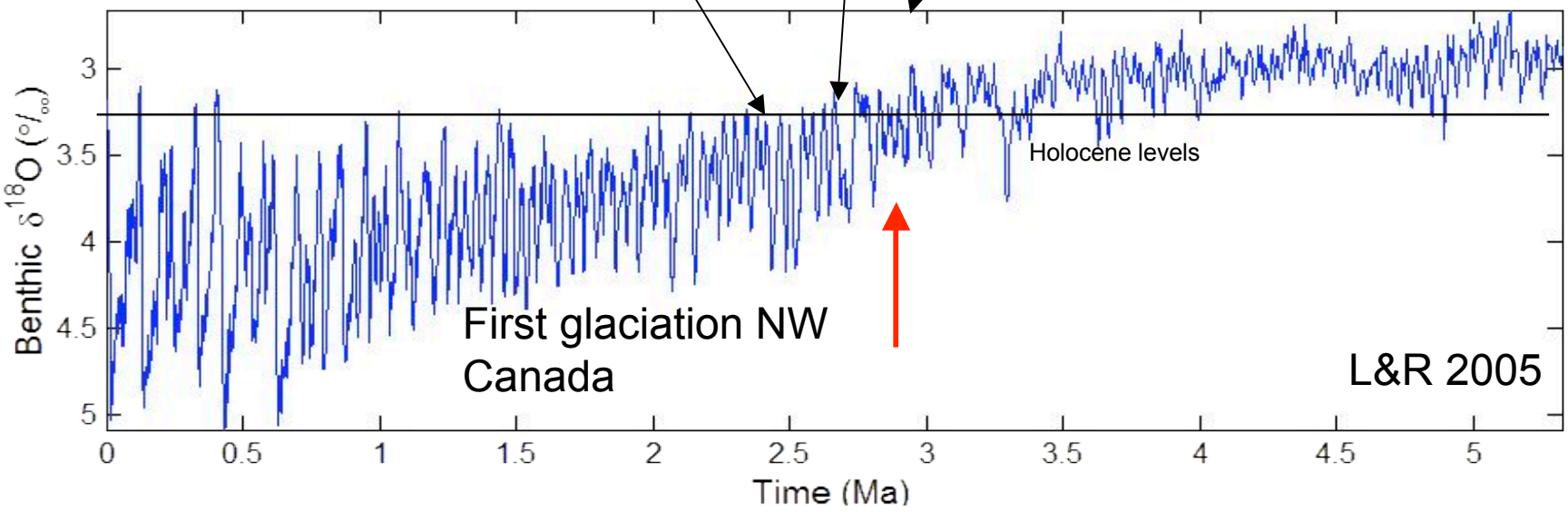
Hvitland Beds
~ 2.6 Ma
With Arctica but Tundra

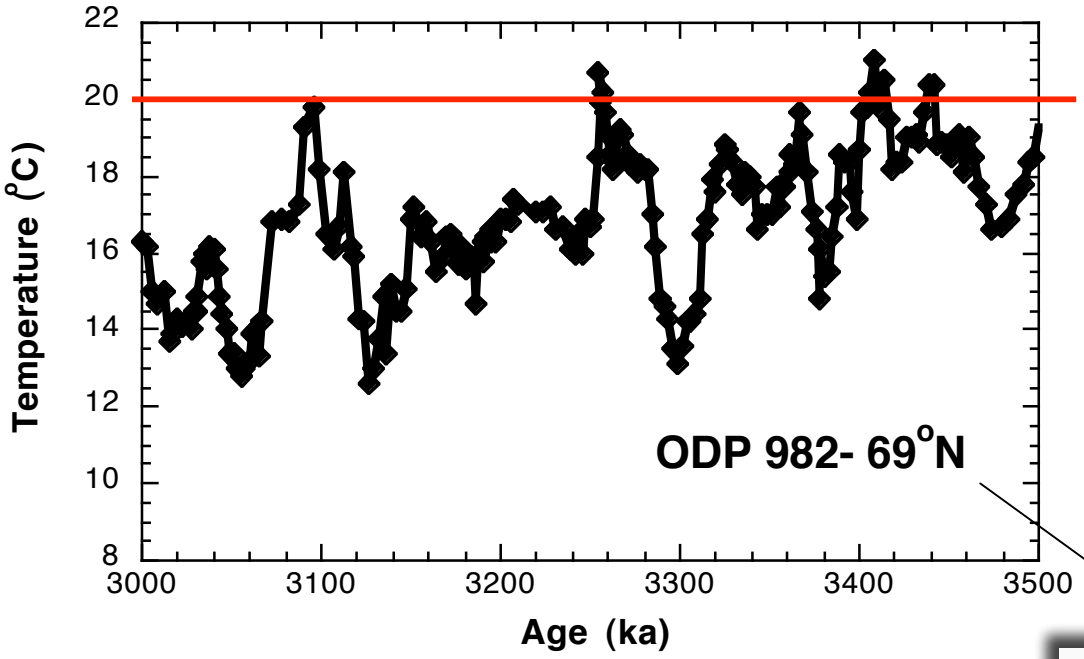
Lodin Elv Fm.
~ 2.8-3.0 Ma
Oldest land record of ice

Kap Kobenhaven Fm
~ 2.4 Ma
Like S. Labrador today; cedar

Beaufort Fm 3.2 Ma
220m Marine sediments
- Arctica islandica
- 5 types of Pines

First evidence of Tundra

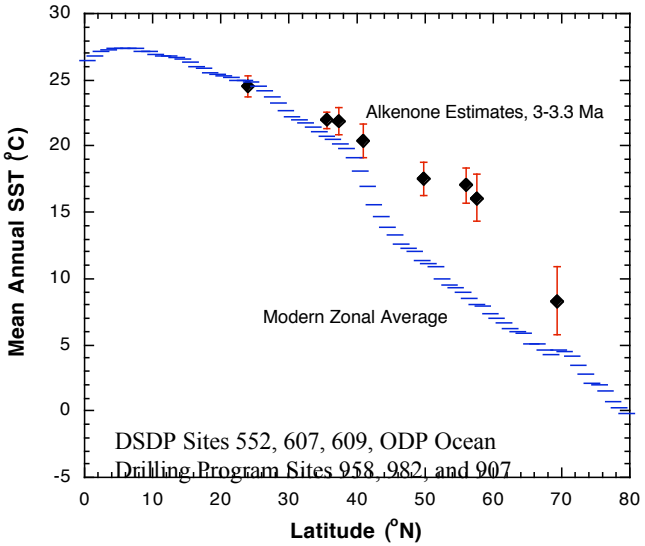




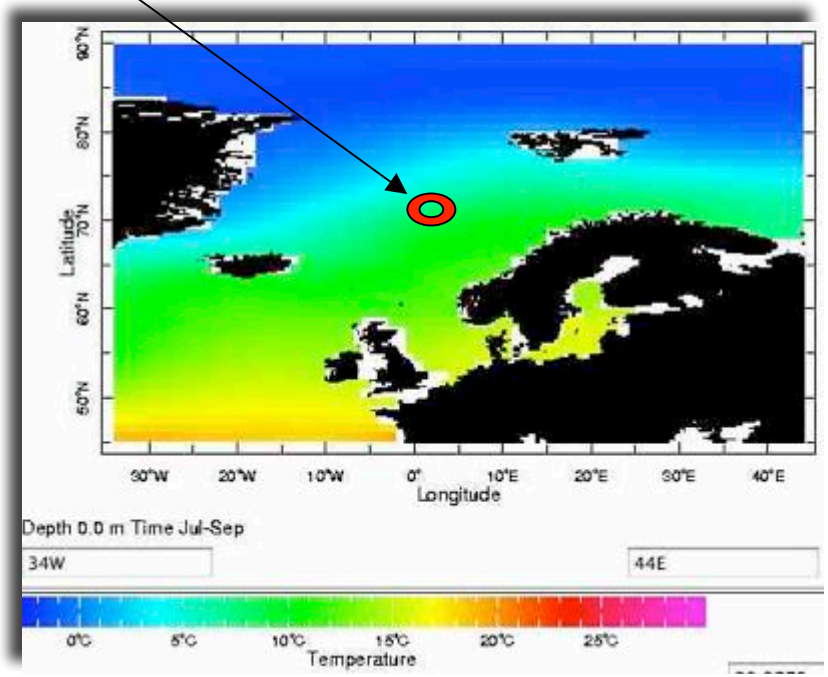
Peak Pliocene SSTs to 20°C

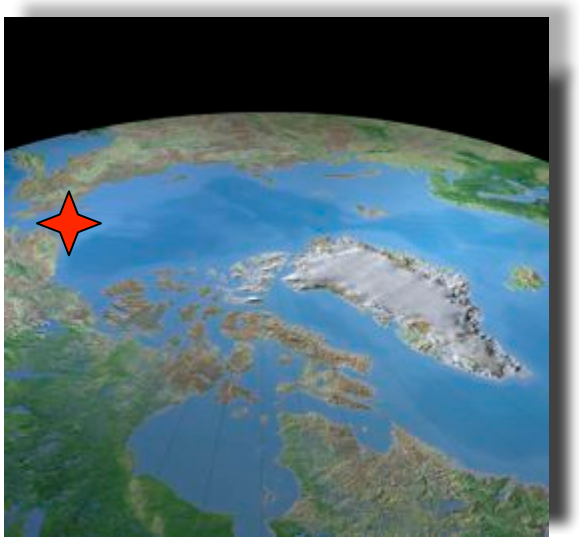
Modern SSTs ~8-10°C

Orbital-scale sea surface temperature variability from the Uk'37 index in sediments of mid-Pliocene age (Lawrence et al., unpublished).



Herbert and Lawrence, in prep



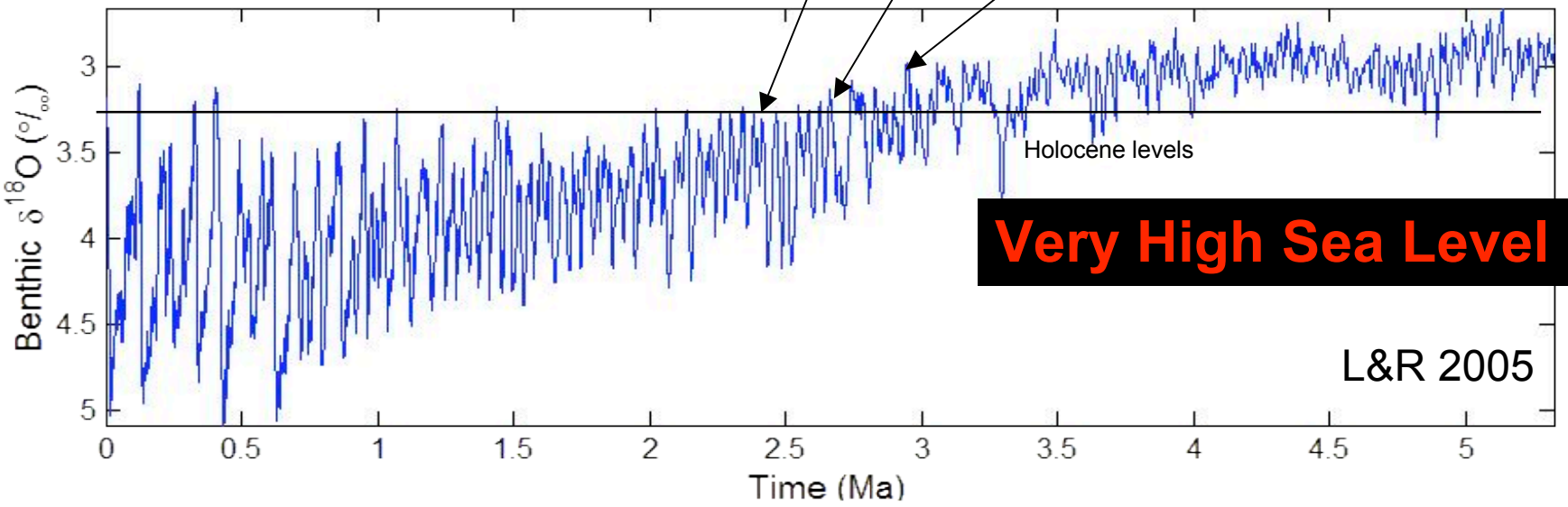


Alaskan NW Coast
Gubik Fm

Fishcreekian Transgression
~ 2.2 to 2.4 Ma +30m

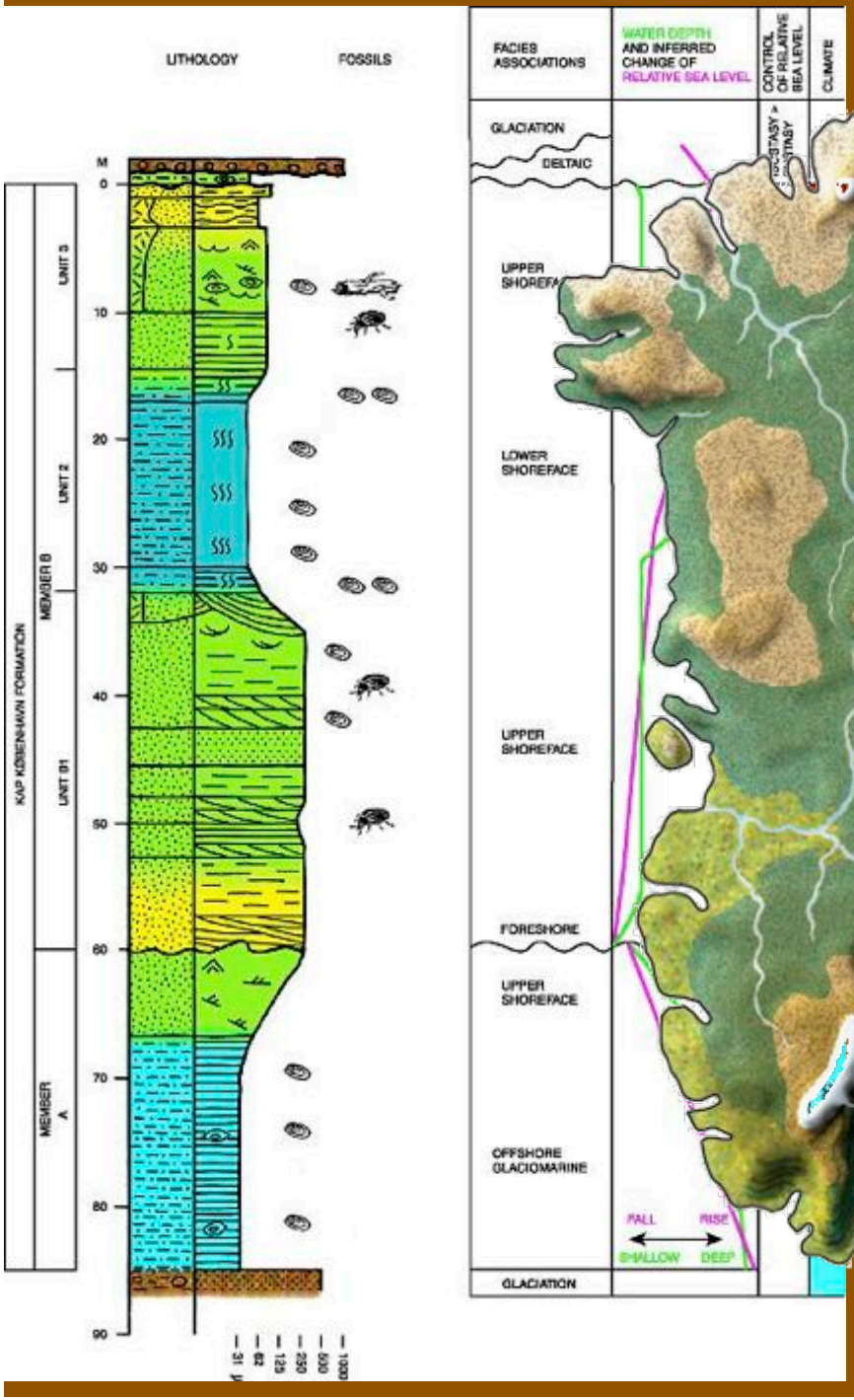
Bigbendian Transgression
~ 2.6 Ma +40m

Colvillian Transpression
~2.8 Ma +40 m



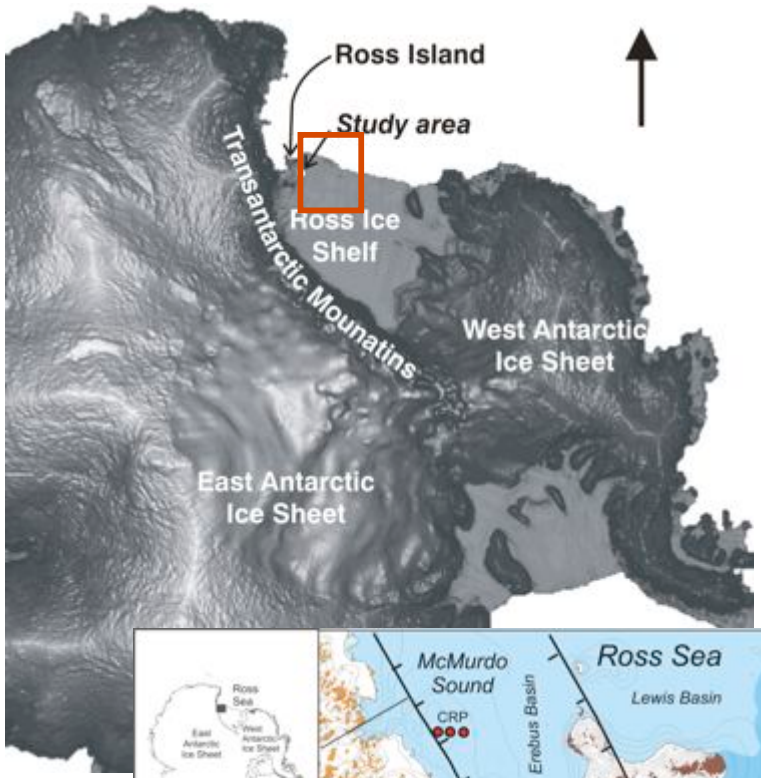
Very High Sea Level

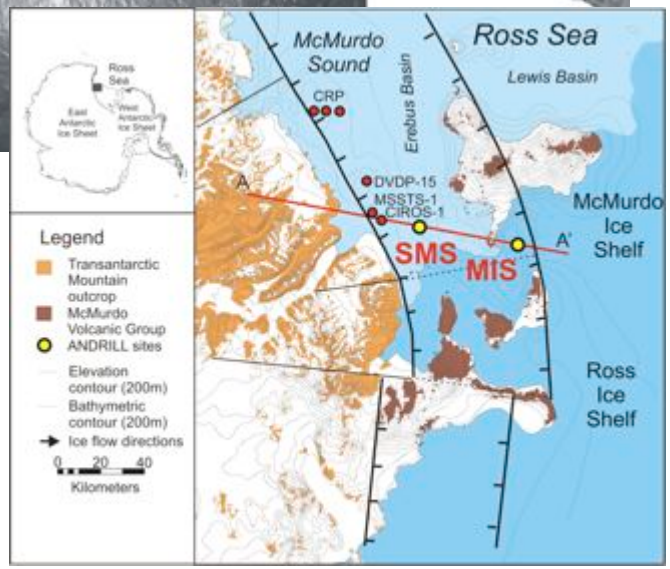
L&R 2005

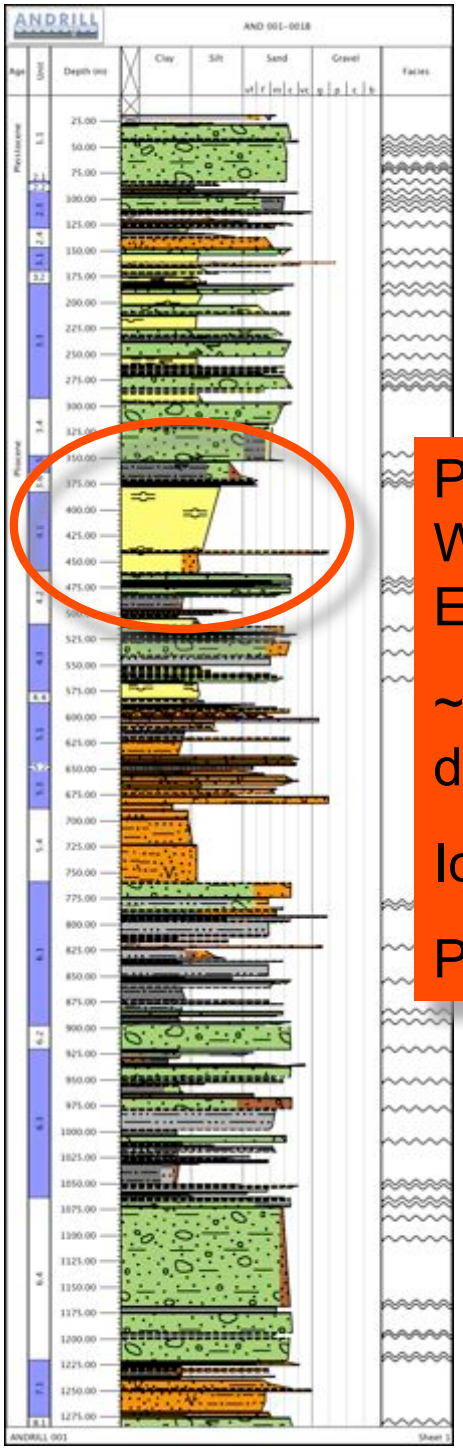


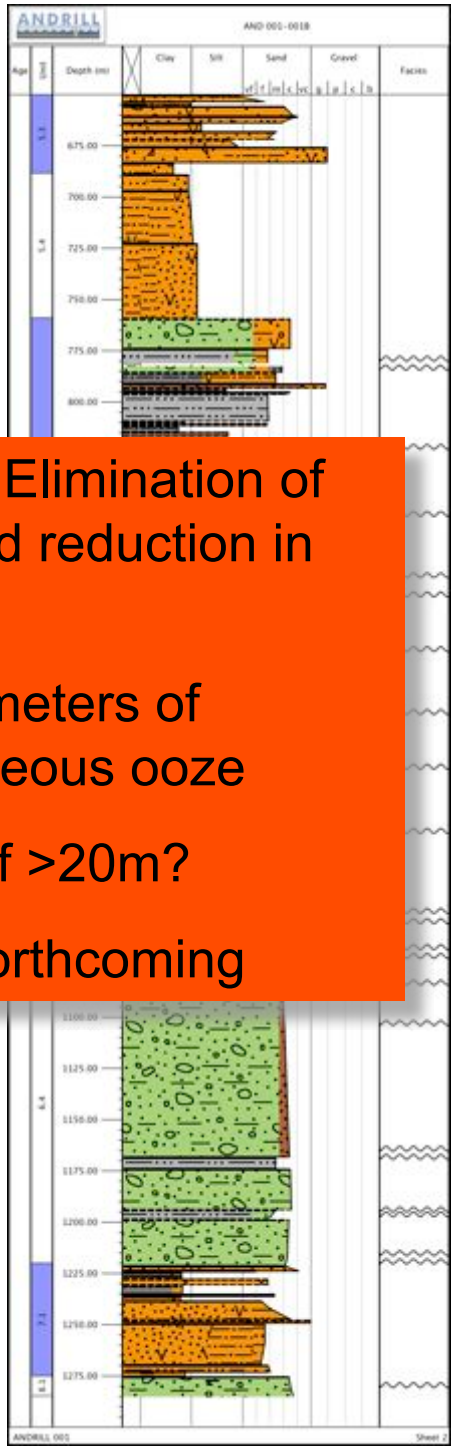
Greenland ice free for the last time?

The Kap København Formation (Tiglian, c. 2.4 ma) Svend Funder et al.









Pliocene Elimination of WAIS and reduction in EAIS

~100 of meters of diatomaceous ooze

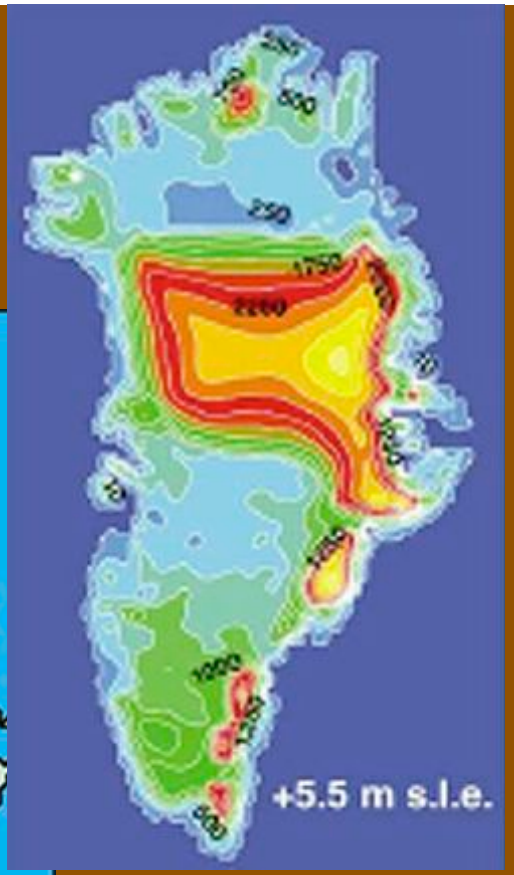
Ice lost of >20m?

Papers forthcoming

Eemian ice sheet models

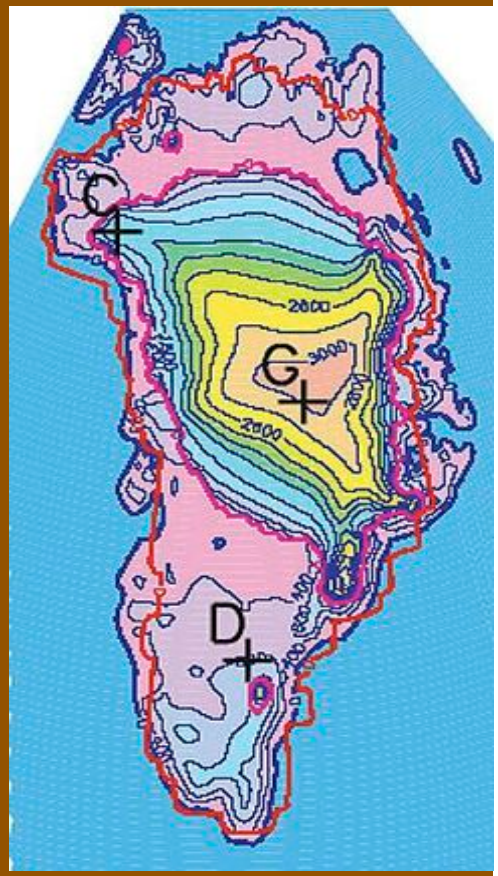
Letréguilly et al. 1991

Cuffey & Marshall 2000



Huybrechts 2002

Tarasov & Peltier 2003



CAPE Synthesis: CircumArctic Last Interglacial 5e Reconstruction

CAPE Project members,

Quaternary Science Reviews, 2006

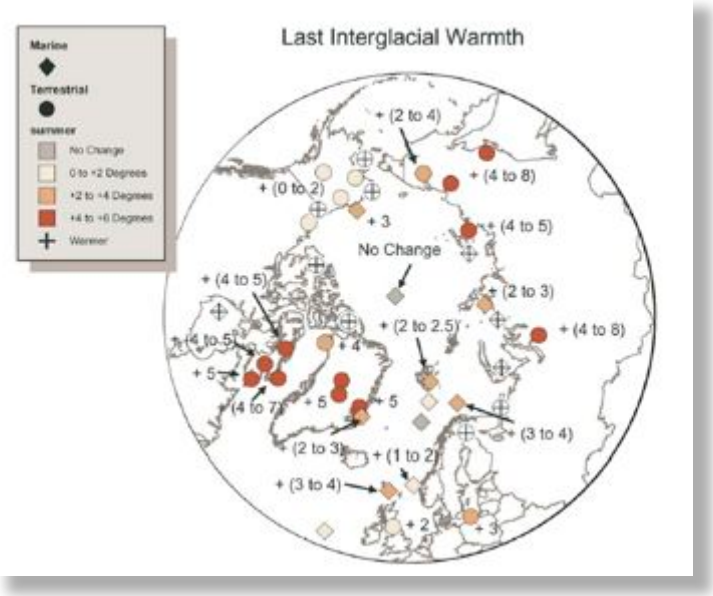
Science, 2006

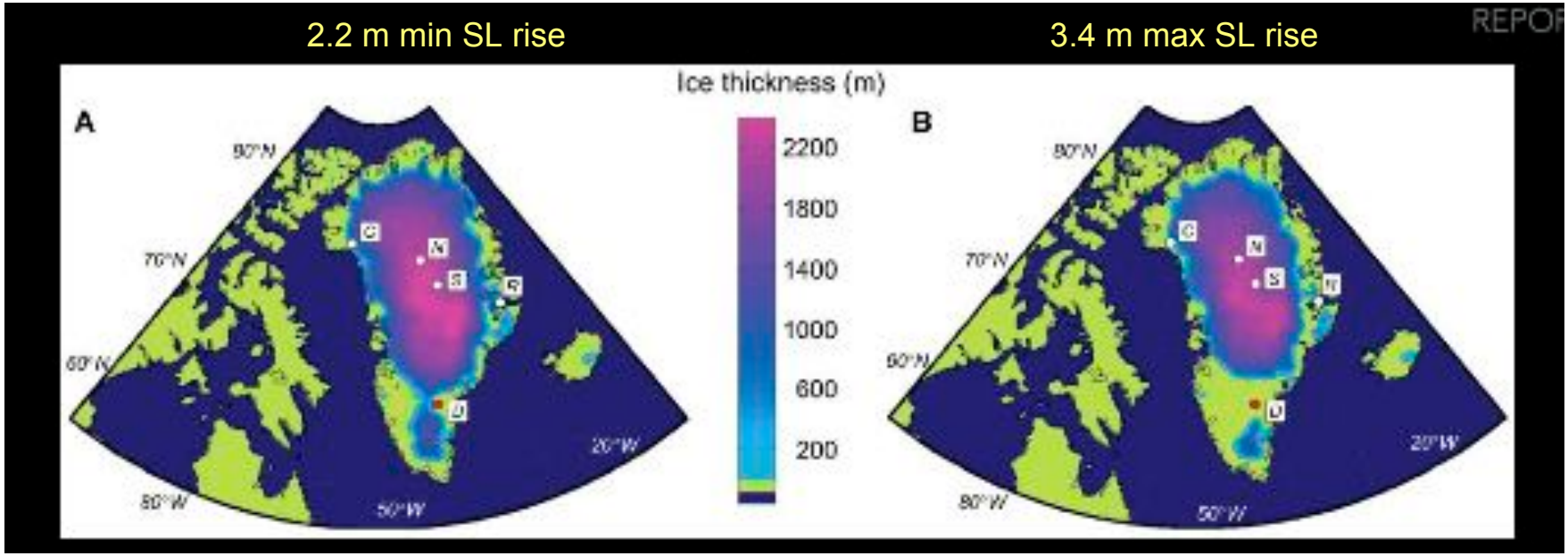
Summers 4-6^{o}C above present;

insolation 11% higher in May, June and July

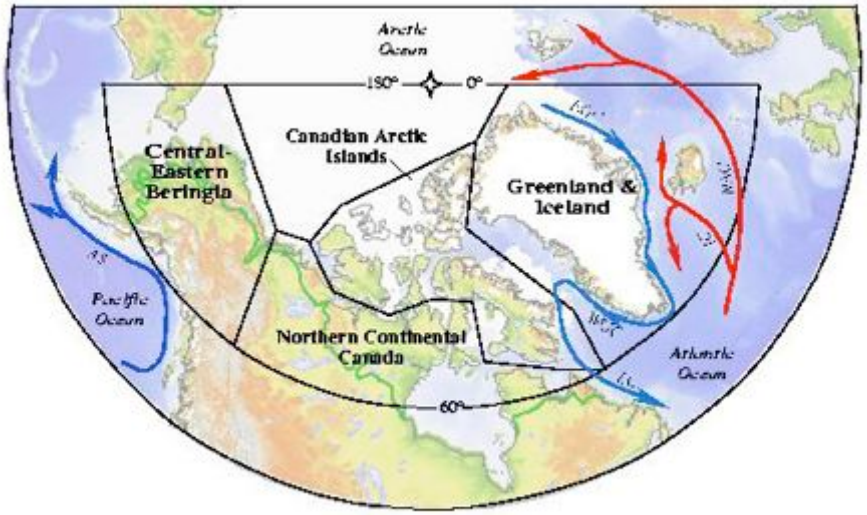
Winter sea ice 800 km N in Bering Strait; no tundra in Russia

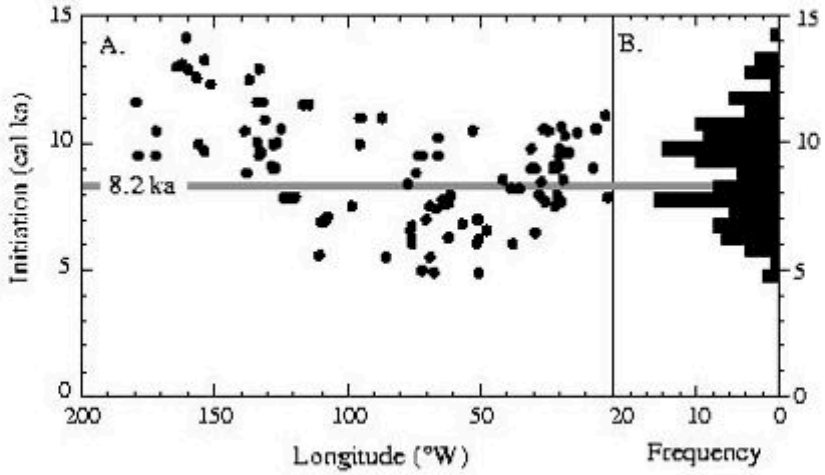
Some ice free summers (Norgaard-Peterson etal)

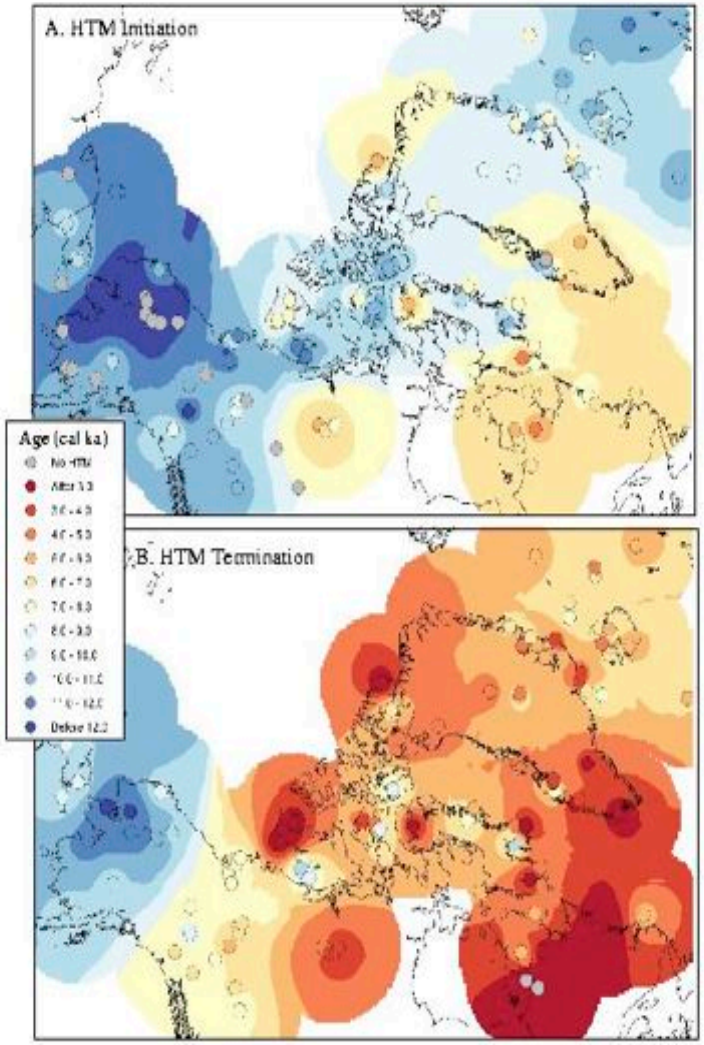




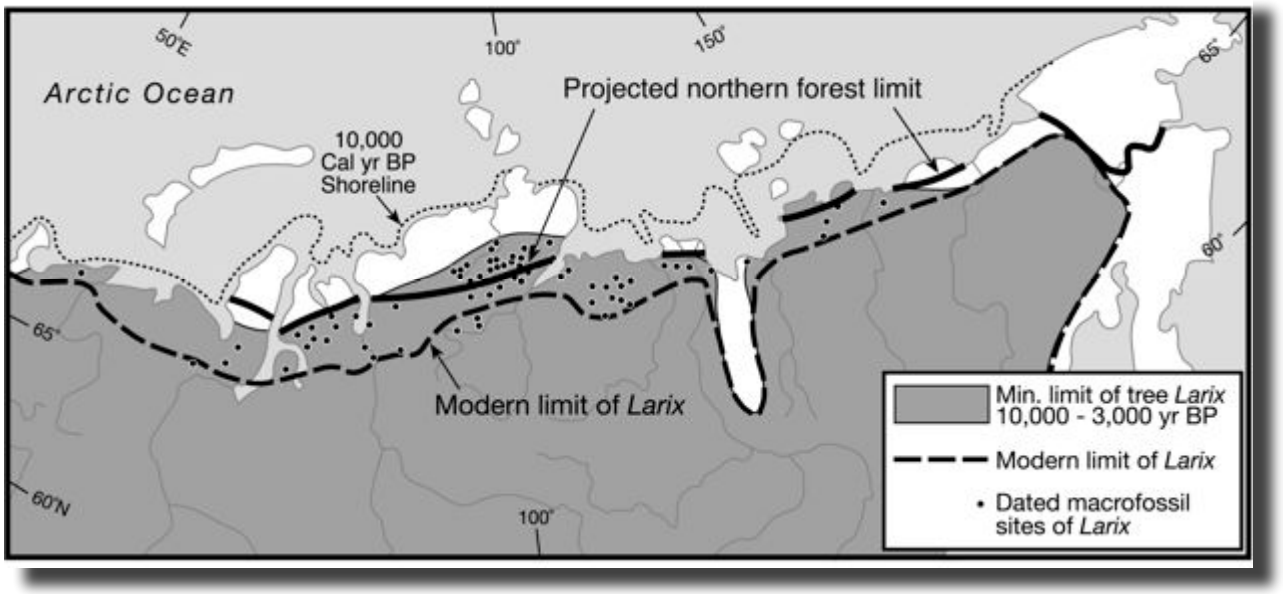
Holocene Thermal Maximum





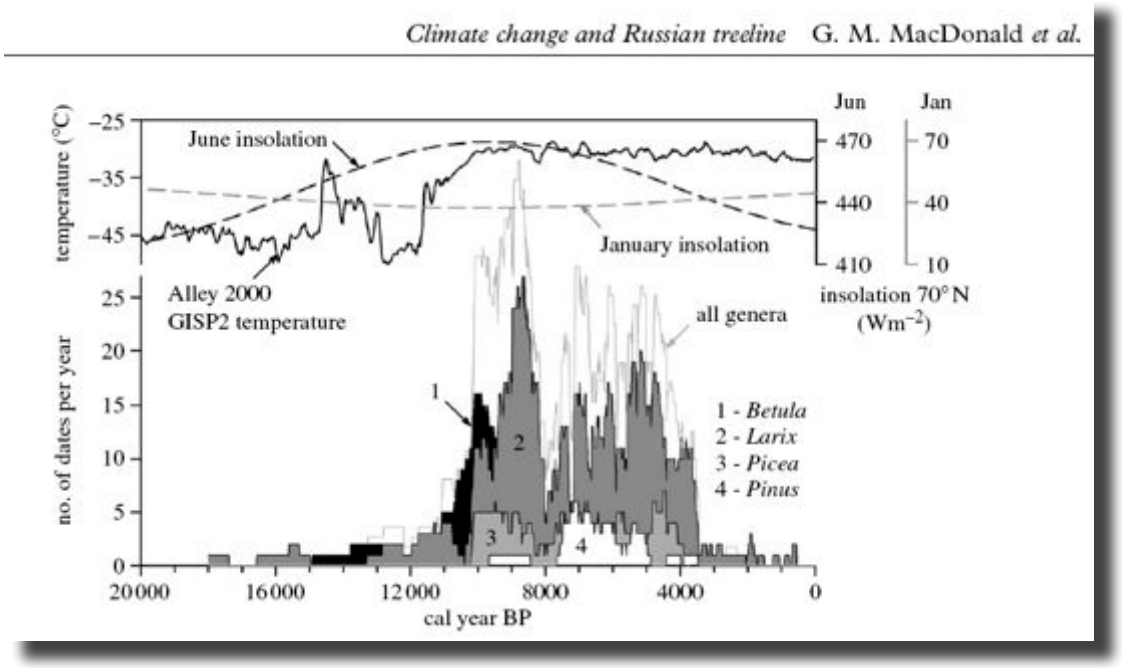


Kaufman et al.
Figure 7

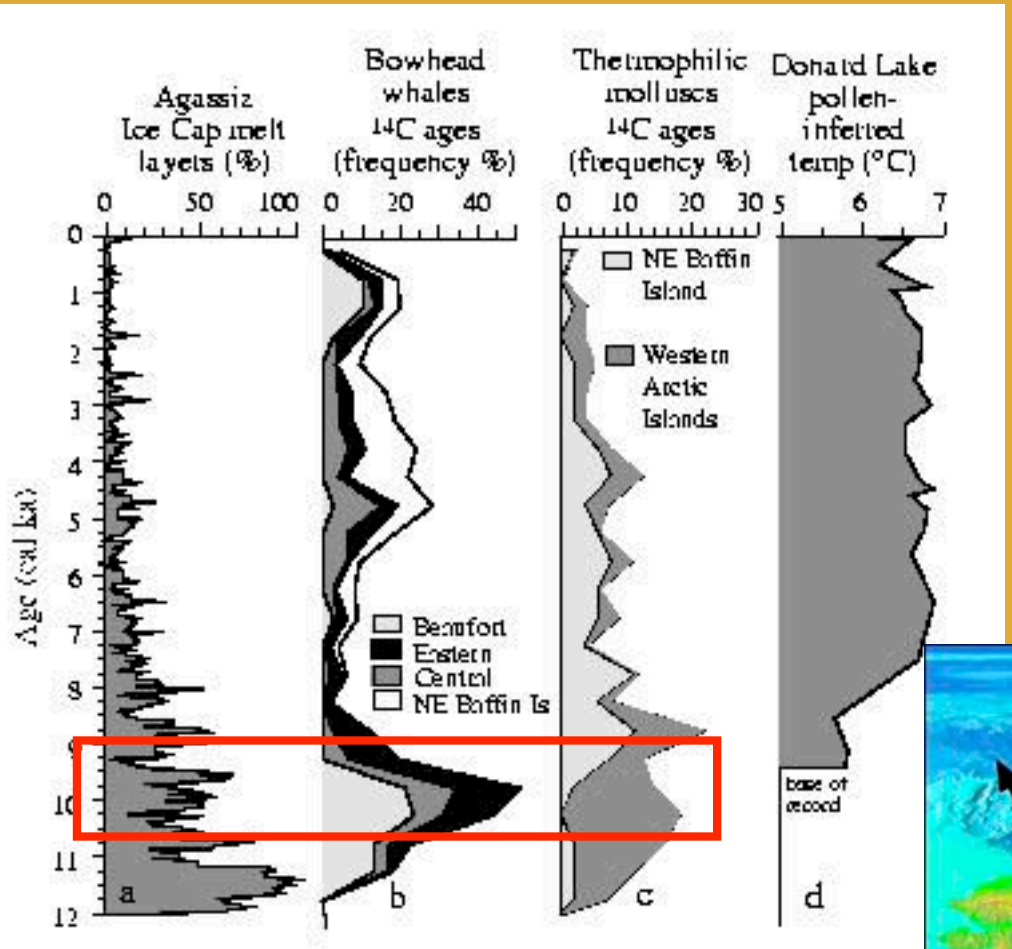


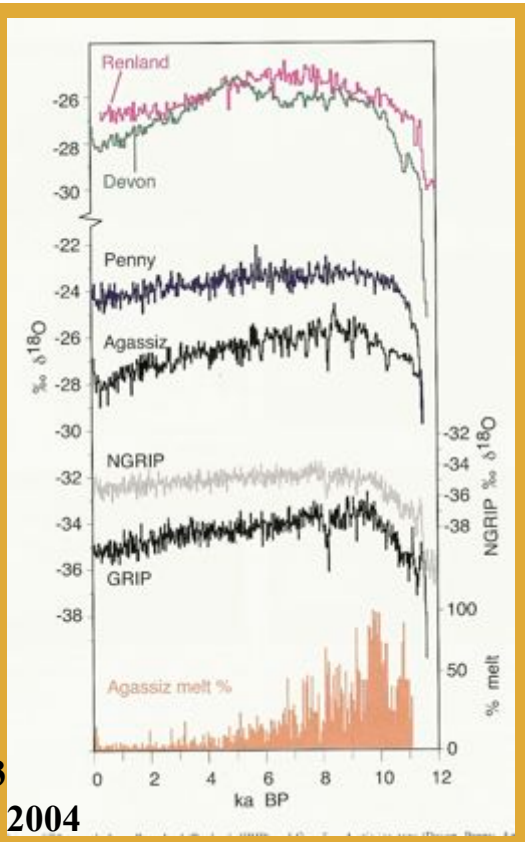
Northward Russian treeline expansion in early Holocene

MacDonald et al. 1998,2007

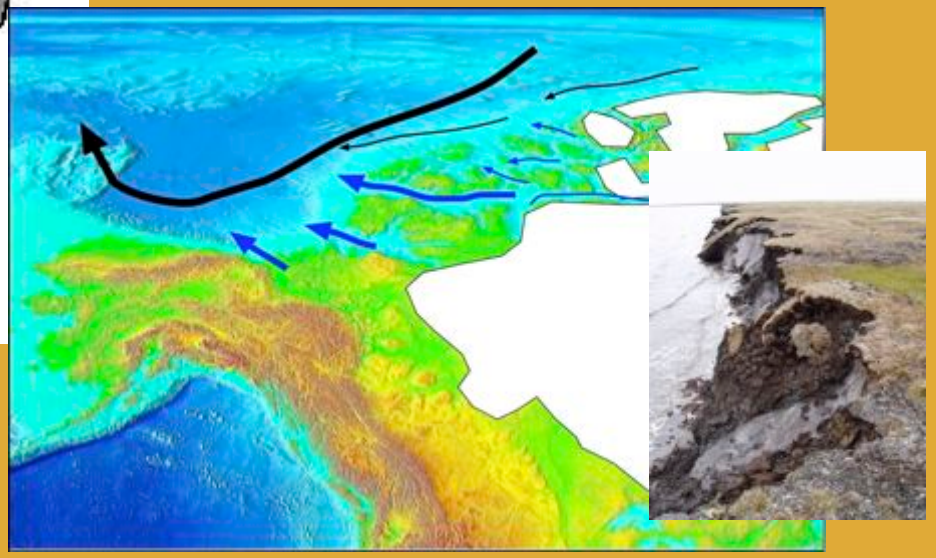


Early Holocene Thermal Max

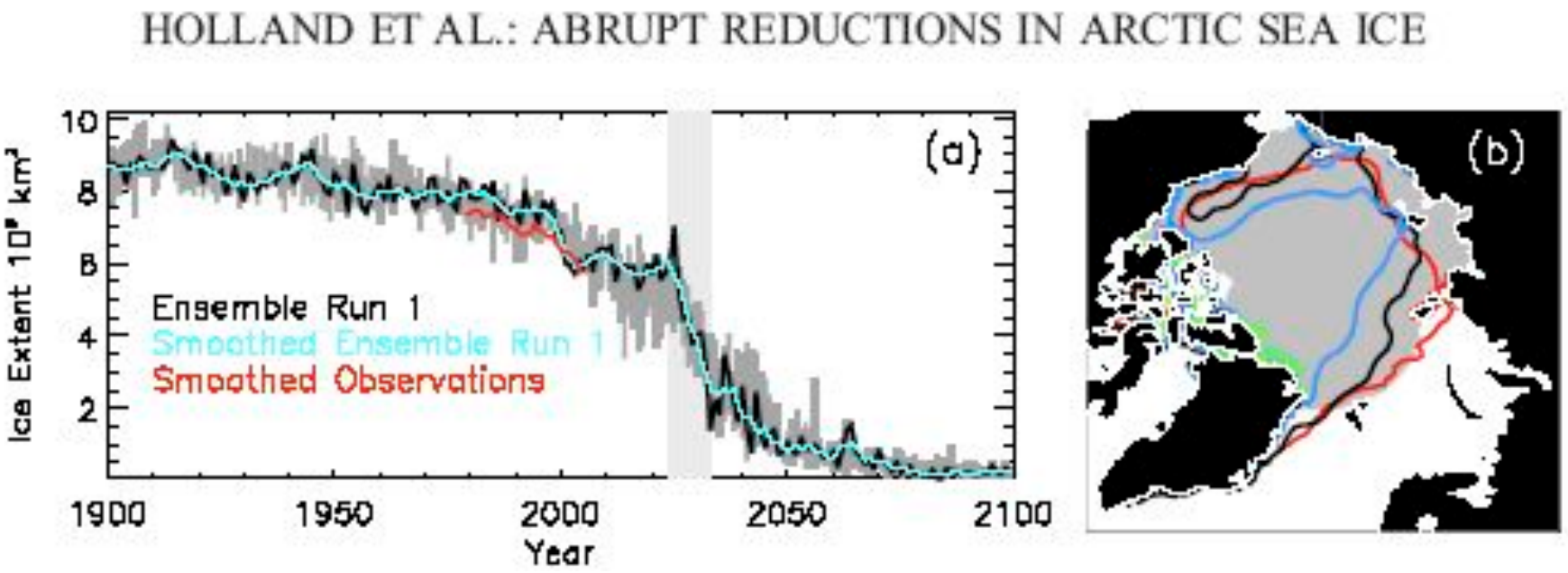




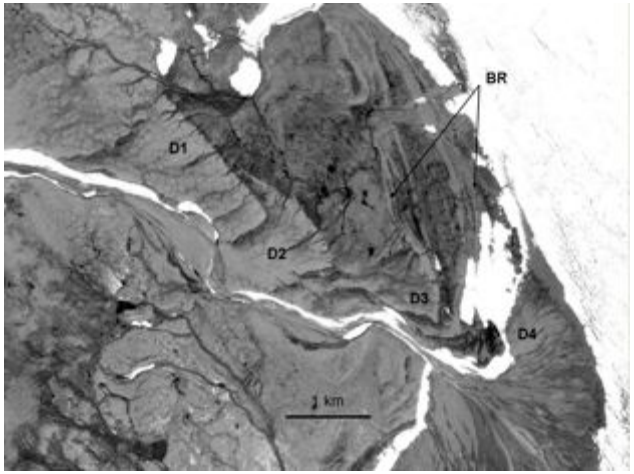
Bradley et al., 2003
Fisher & Koerner, 2004

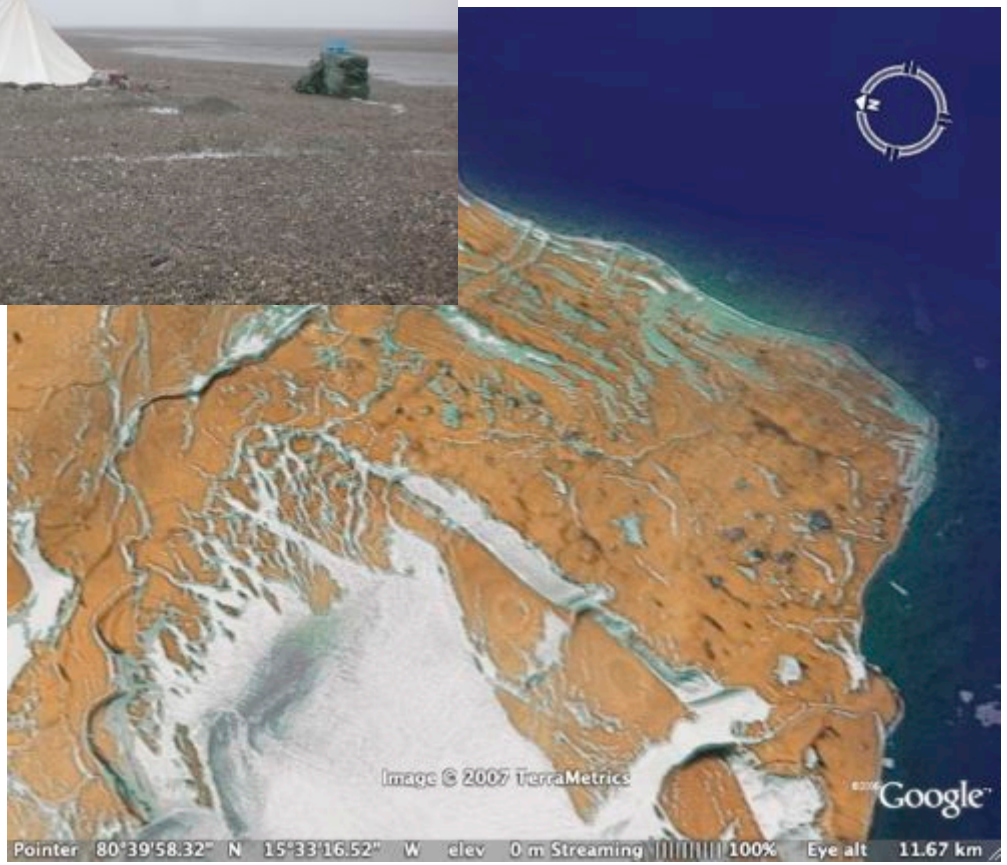


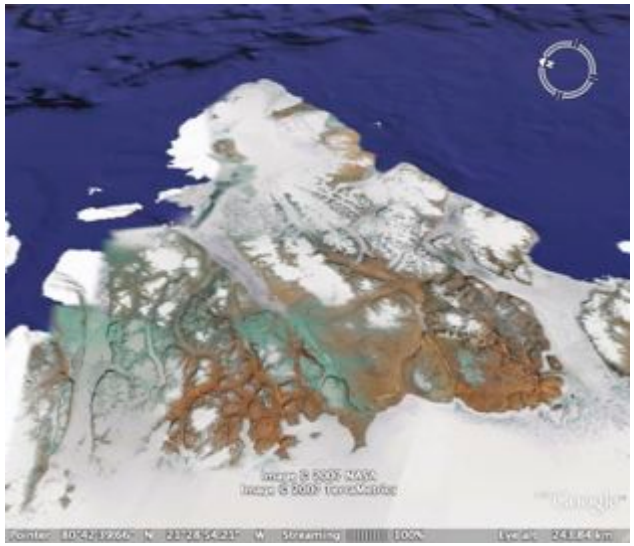
Decreasing sea ice in the arctic -- last place to become ice free will be NE Greenland



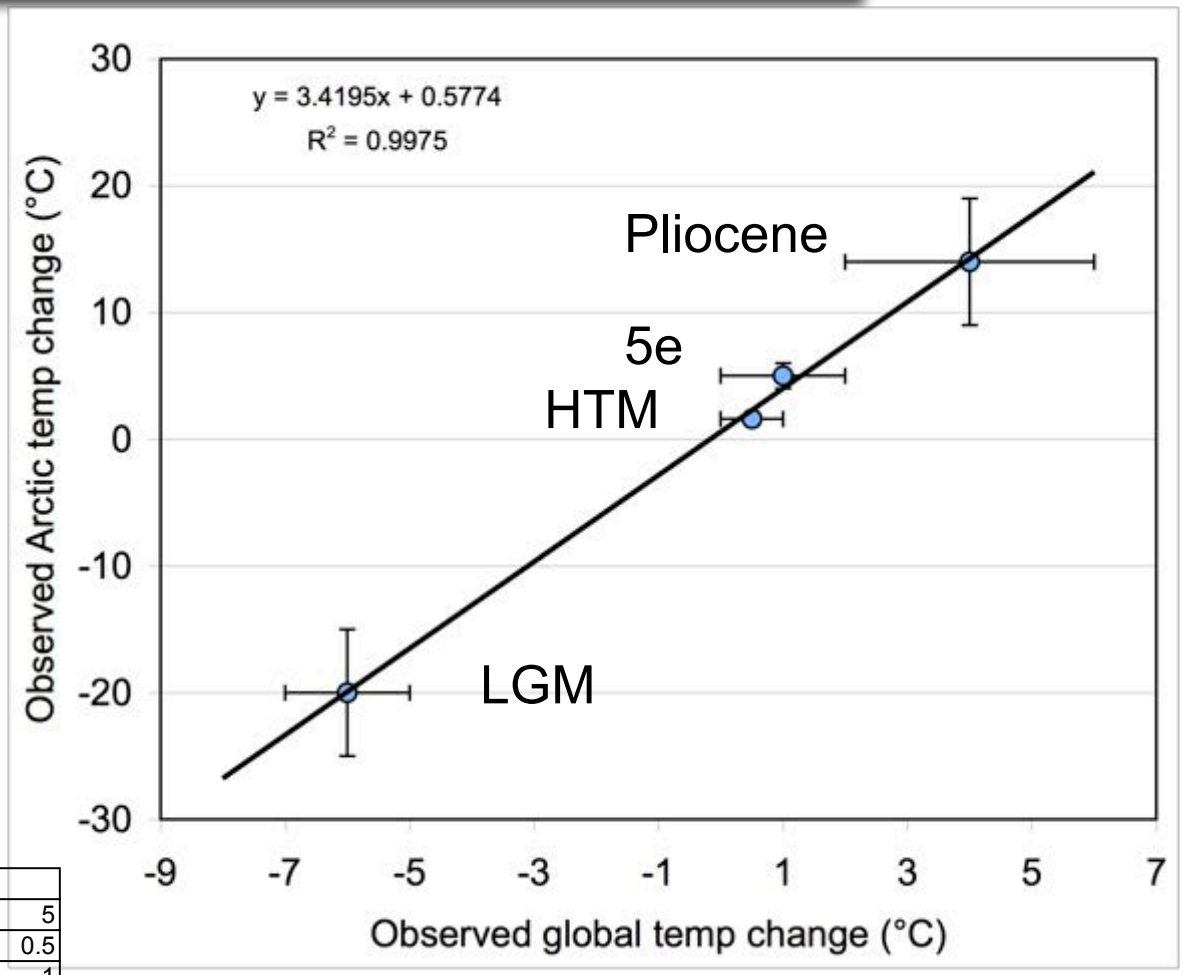
Ice Free Arctic in Summer
6-9 ka - Svend Funder, 2007







Polar Amplification



Interval	Global dT	±	Arctic dT	±
LGM	-6	1	-20	5
HTM	0.5	0.5	1.6	0.5
LIG	1	1	5	1
Pliocene	4	2	14	5
PETM				
Eartly Cenozoic		?	15	

Miller and BG et al., in prep.;
US CCSP

A few lessons for the future:

- Sea ice history -- complex! central Arctic basin insensitive?
  - – chronology, resolution issues require assessment
  - – conditions only slightly warmer than now can radically reduce sea ice cover -- deja vu
- Small temperature forcing results in a forested Arctic
  - –has happened before,
  - – at intervels of Eocene, Oligocene, Miocene, Pliocene
- Greenland Ice Sheet is vulnerable
  - – No ice cap as recently at 2.4 Ma; smaller ice cap in 5e
- Polar amplification can be measured -- forcings for earlier warm periods differ, but actual amplification serves as a benchmark by which models can be judged for their ability to simulate realistic polar amplification over a wide range of conditions.