Welcome

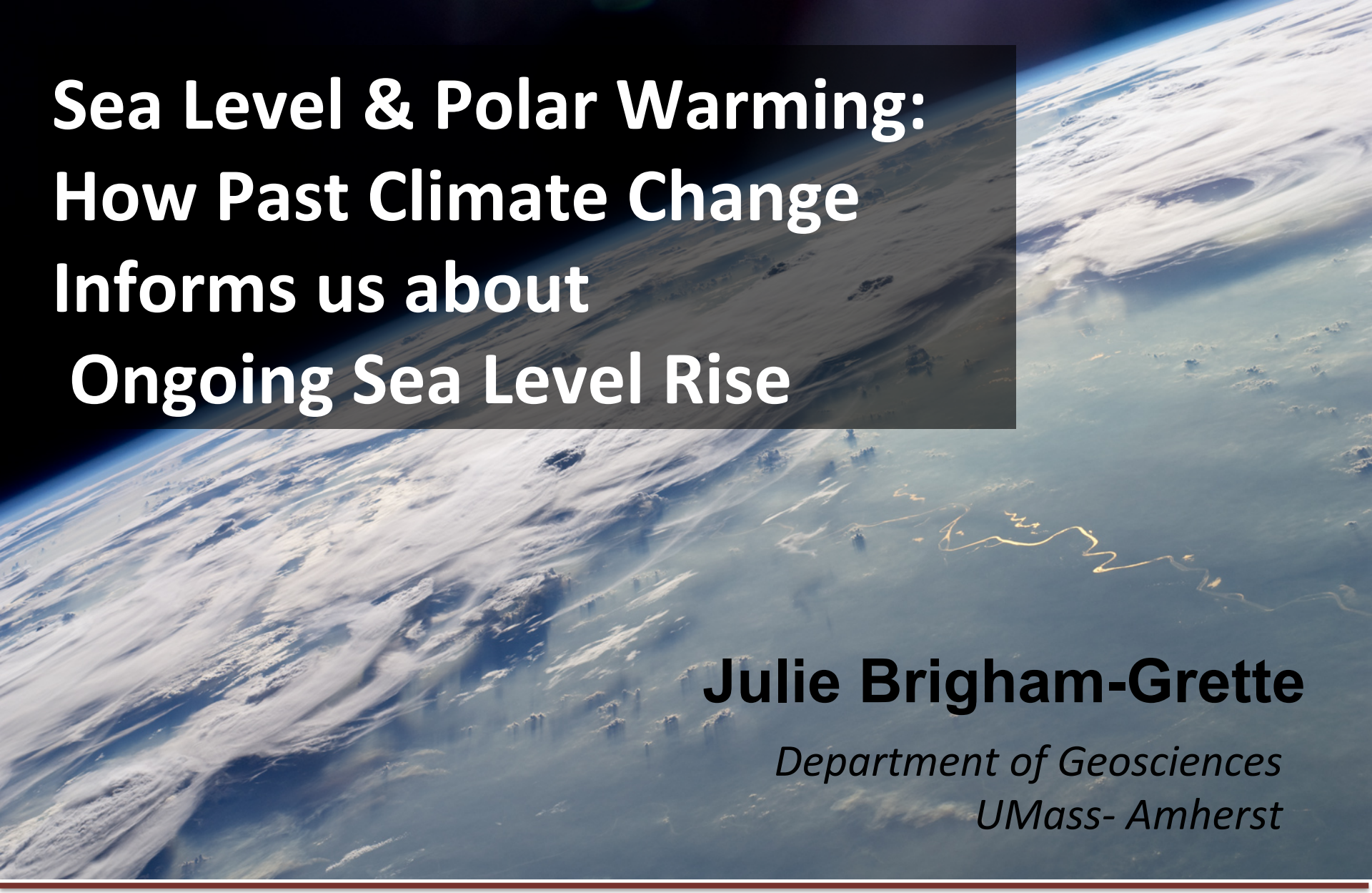
ARCUS Arctic Research Seminar Series

"Sea Level and Polar Warming: How Past Climate Change Informs Us about Ongoing Sea Level Rise"

Presented by Julie Brigham-Grette
University of Massachusetts

ARCTIC RESEARCH CONSORTIUM OF THE UNITED STATES
ARCUS
WWW.ARCUS.ORG
ARCTIC RESEARCH SEMINAR SERIES

Sea Level & Polar Warming: How Past Climate Change Informs us about Ongoing Sea Level Rise



Julie Brigham-Grette

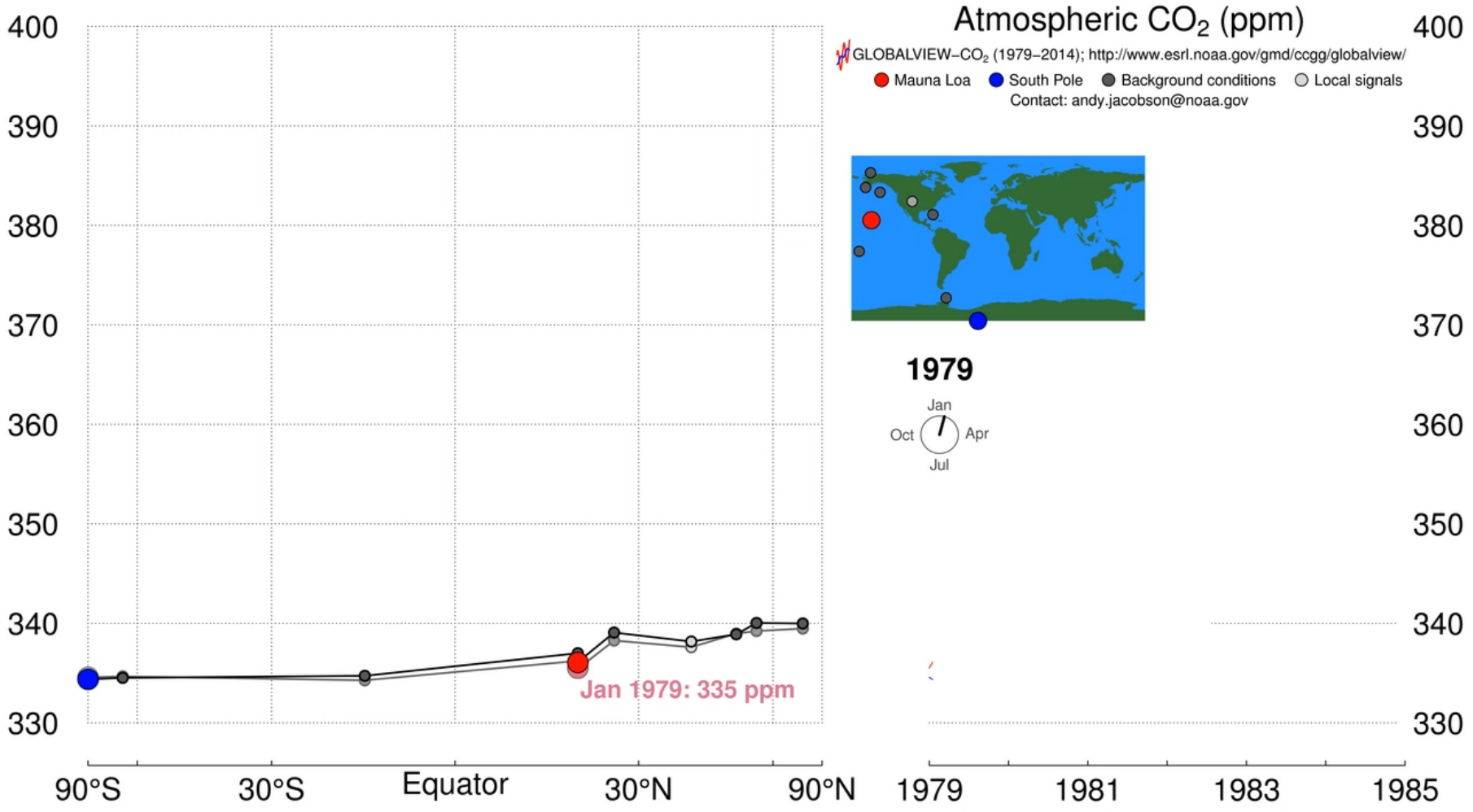
Department of Geosciences
UMass- Amherst

UMASS AMHERST

NSF

CLIMATE SYSTEM RESEARCH CENTER

Humanity has pushed us outside Pleistocene “Normal”



NOAA 2015; Youtube, Pumphandle 2014

SCIENCE IN REVIEW

Warmer Climate on the Earth May Be Due To More Carbon Dioxide in the Air

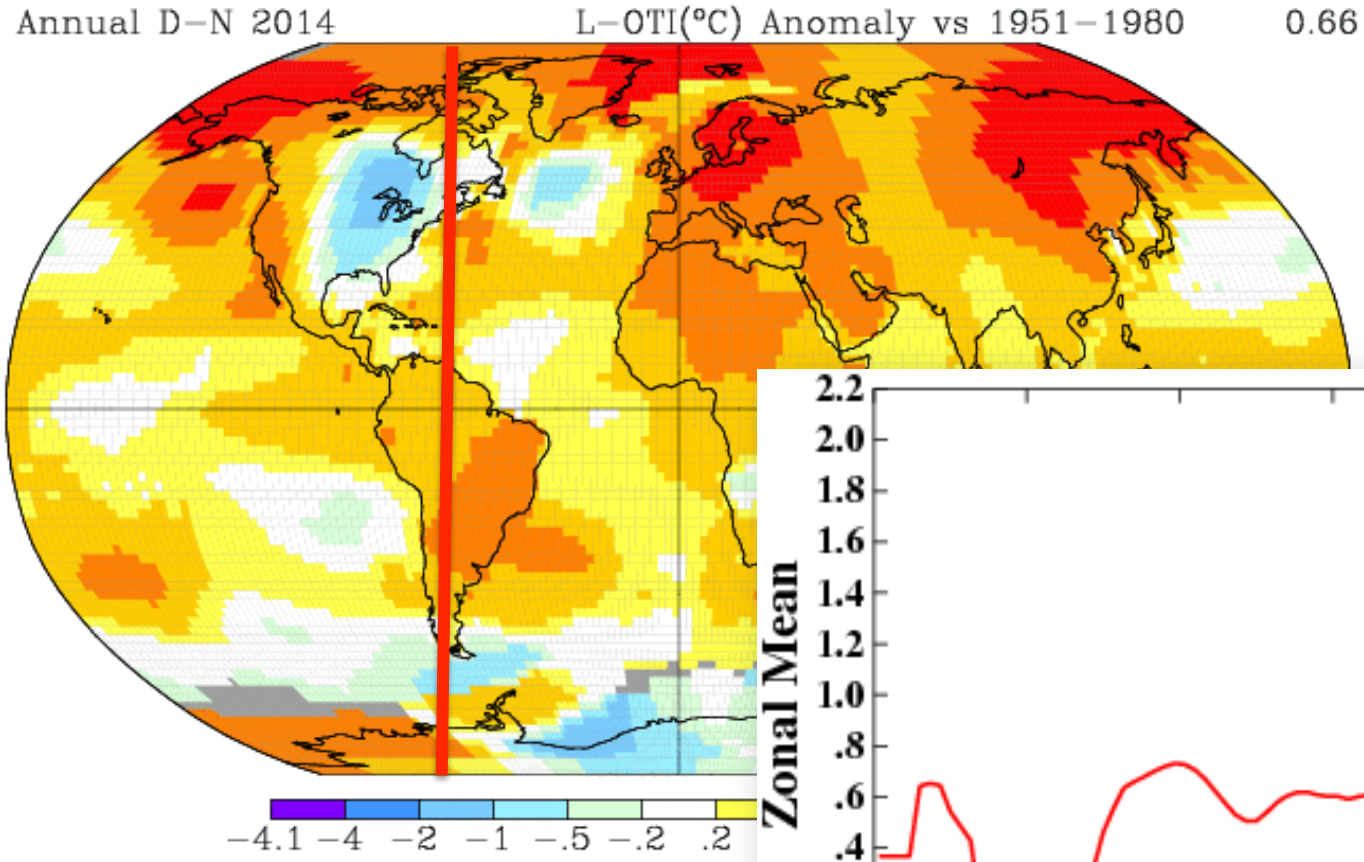
By WALDEMAR KAEMPFFERT

The general warming of the climate that has occurred in the last sixty years has been variously explained. Among the explanations are fluctuations in the amount of energy received from the sun, changes in the amount of volcanic dust in the atmosphere and varia- starches) causes a large loss of carbon dioxide, but the balance is restored by processes of respiration and decay of plants and animals.

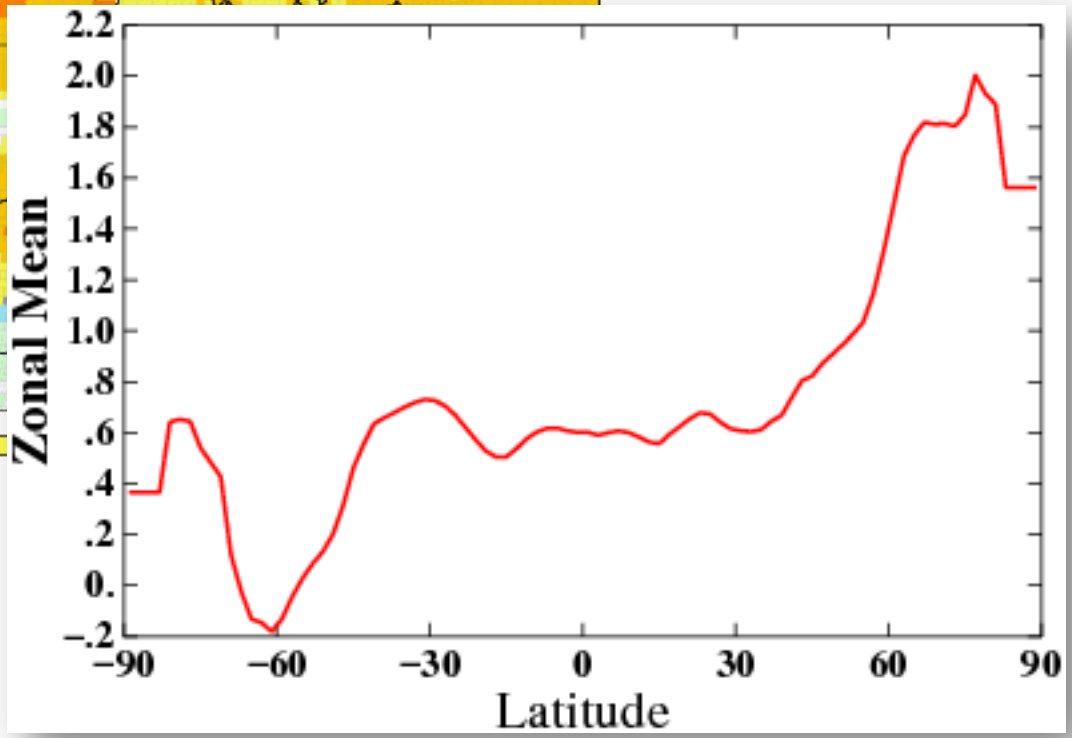
Despite nature's way of maintaining the balance of gases the amount of carbon dioxide in the atmosphere is being artificially in-

New York Times, 1956

Why do we care about Polar Regions?

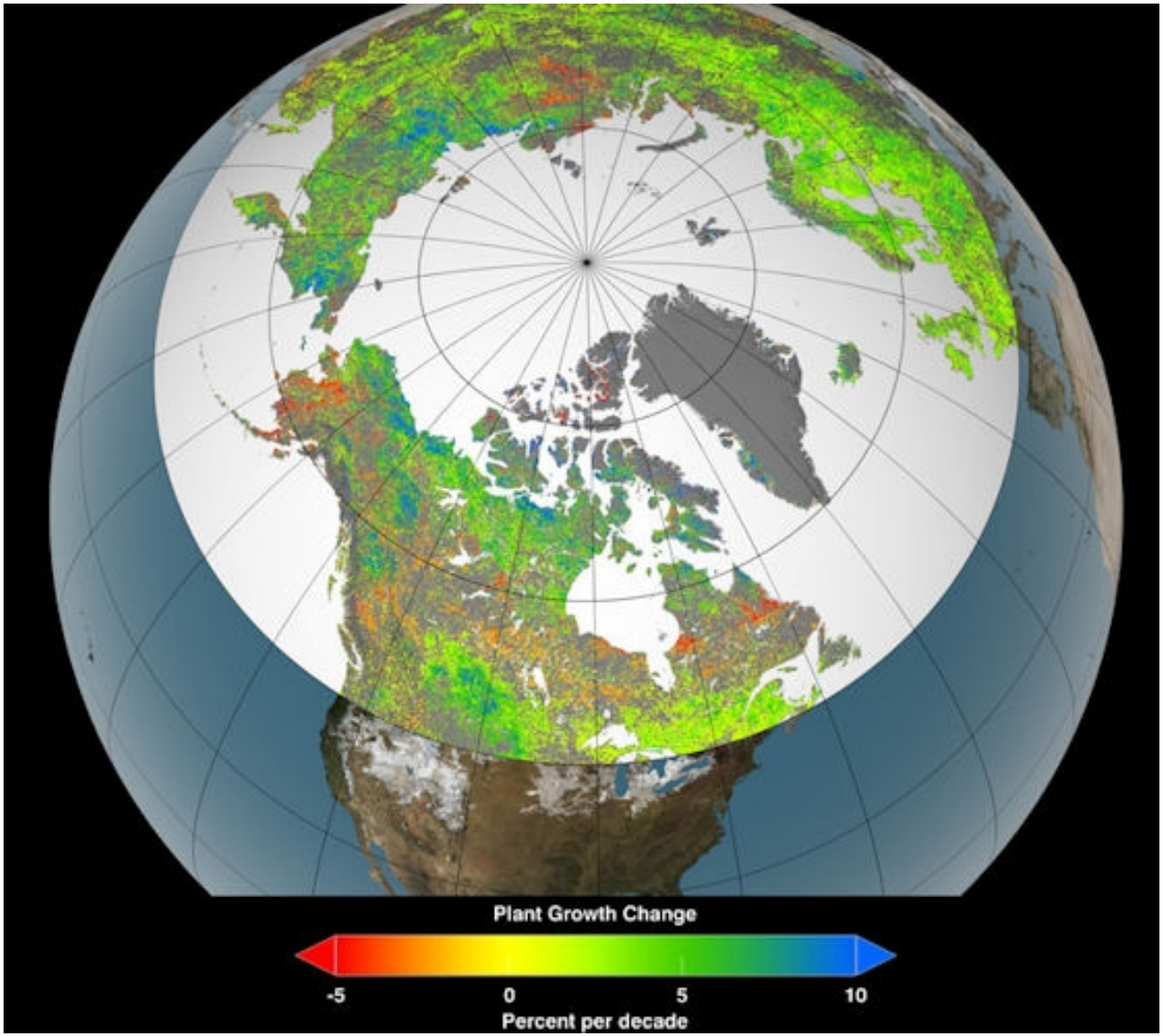


Polar Amplification



http://data.giss.nasa.gov

The Arctic is Greening !



Vegetation growth at Earth's northern latitudes increasingly resembles lusher latitudes to the south based on a 30-year record of ground-based and satellite data sets.

NASA Science News 2013

Arctic Sea Ice continues to disappear

What causes sea level rise?

1. Thermal Expansion (0.4m/deg C)

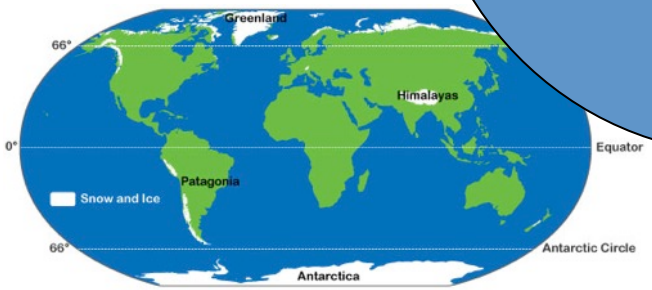
2. Changes in Glaciers & Ice Sheets

3. Other things – subsidence, tectonics

60 m
Antarctica

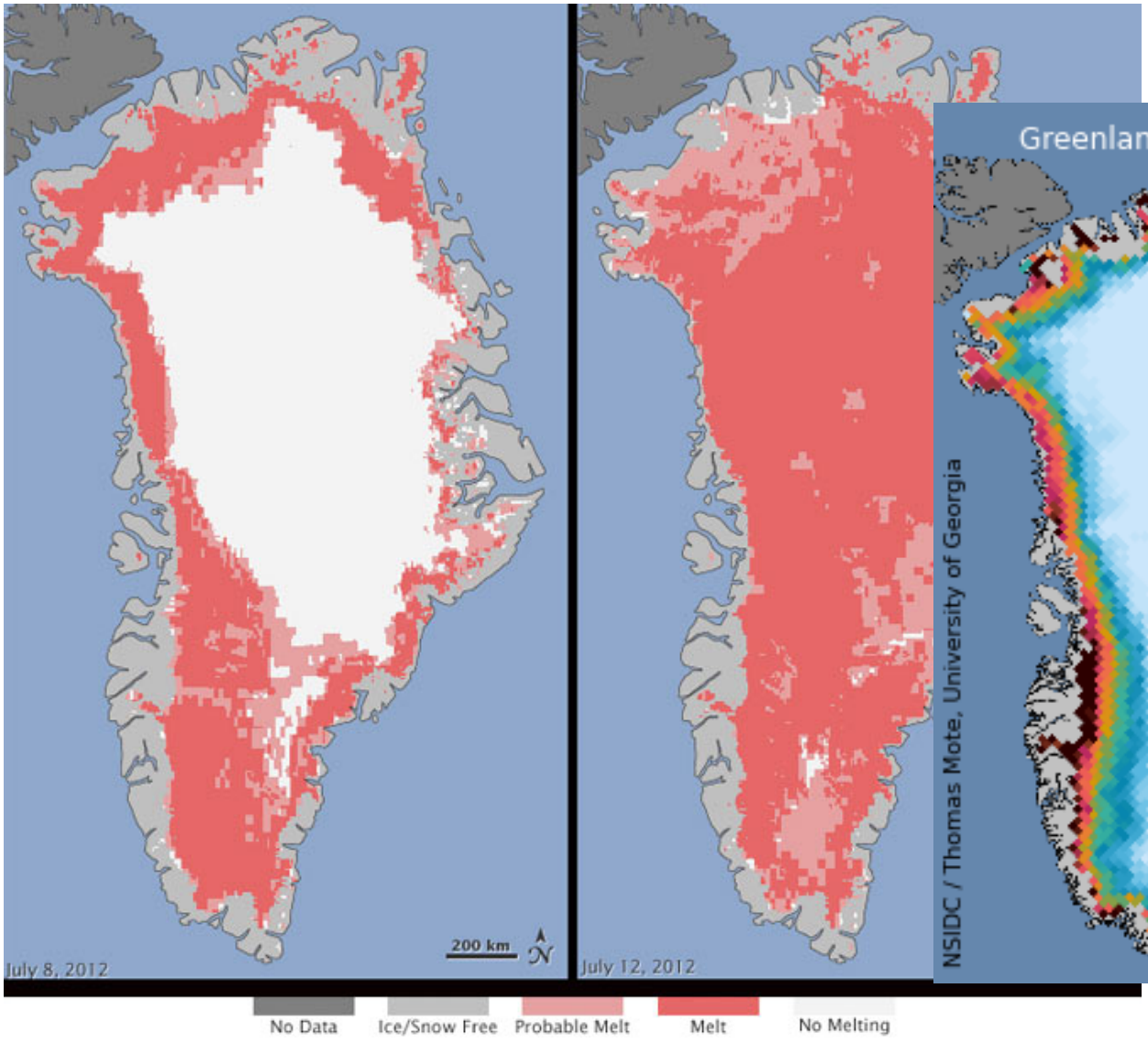
7 m
Greenland

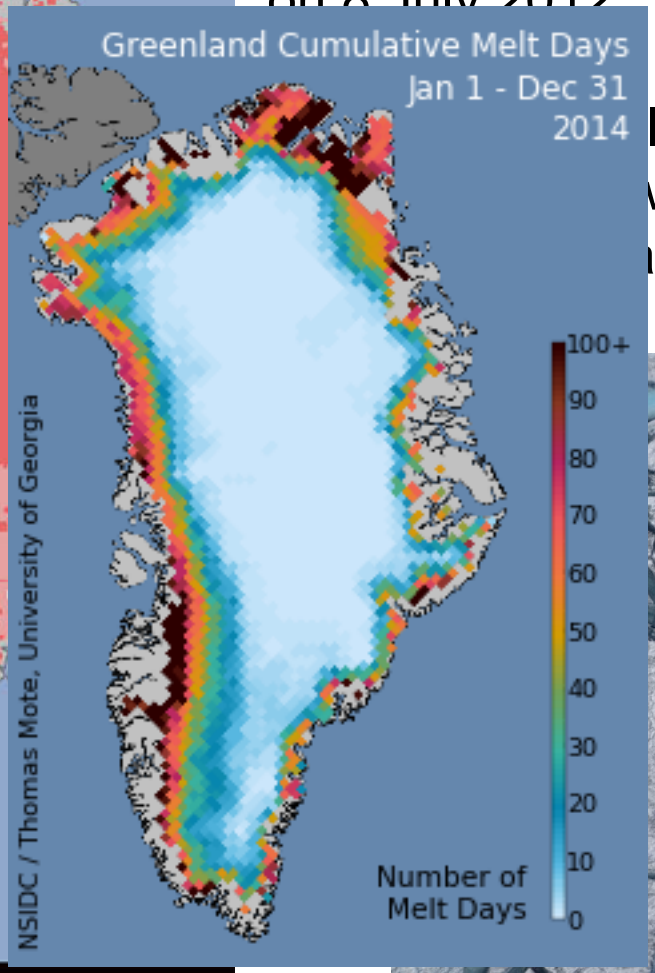
0.6 m
All other glaciers



The left image shows Greenland's ice sheet on 8 July 2012

later, where t the

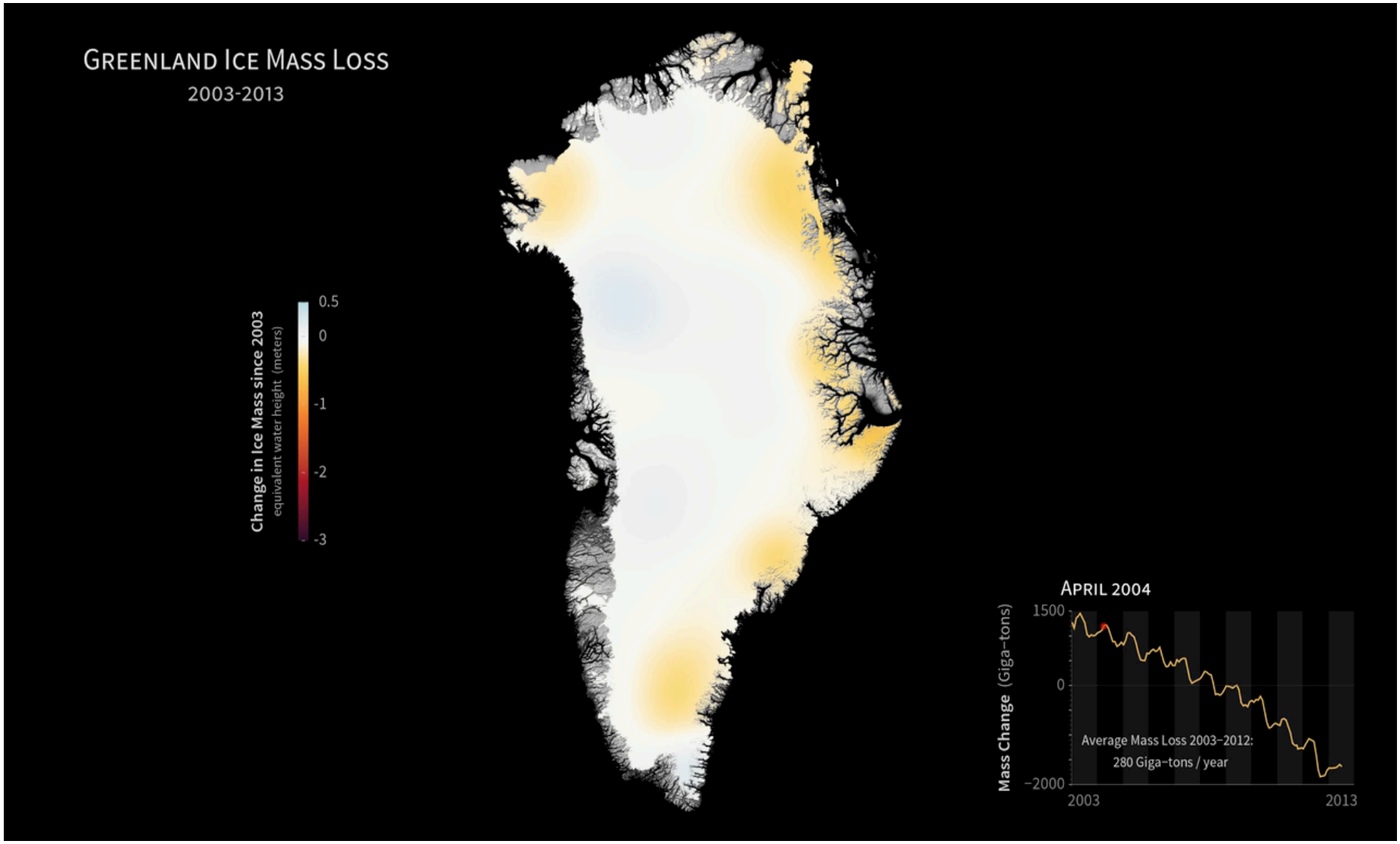




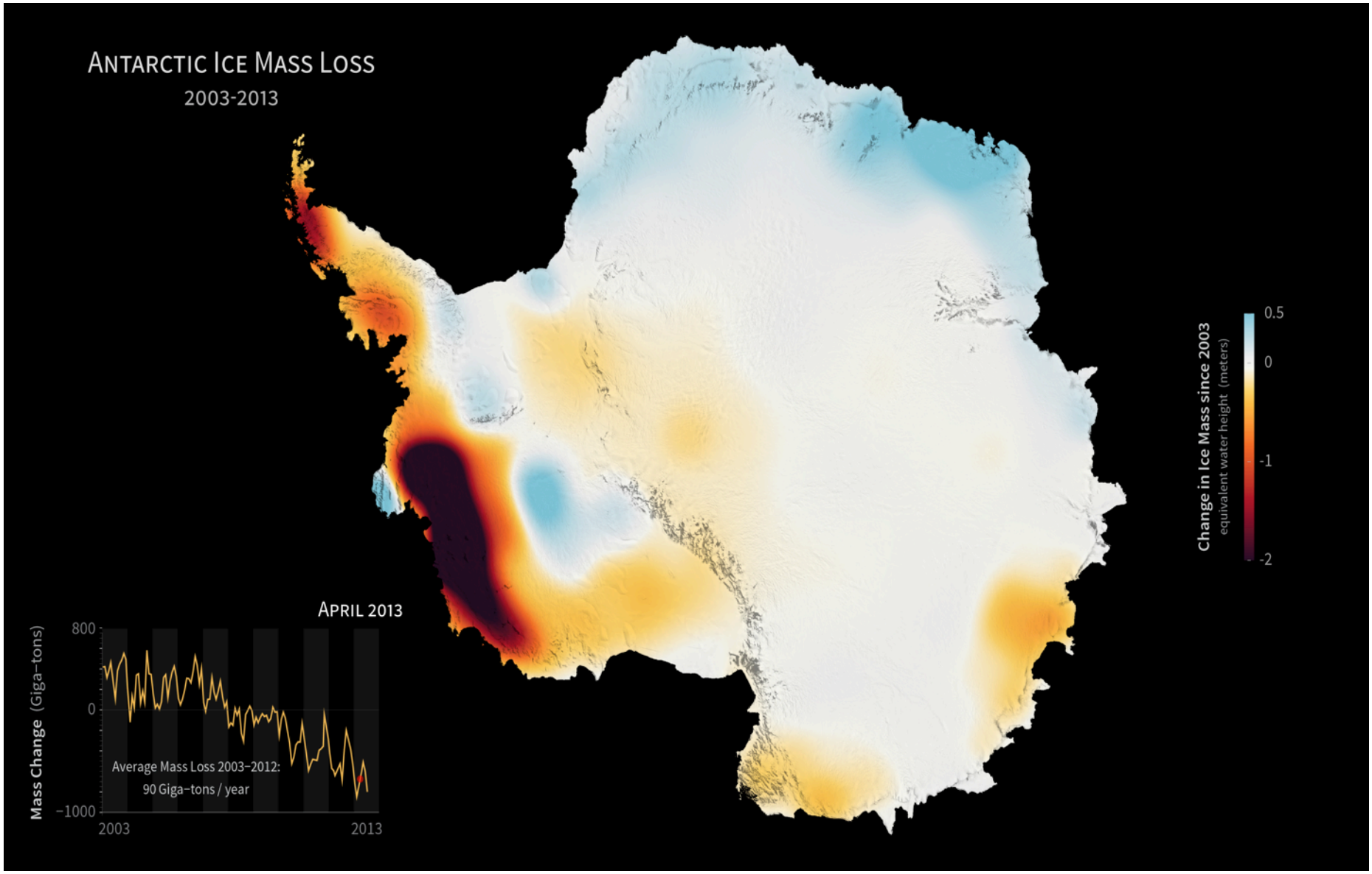
http://www.nasa.gov/topics/earth/features/greenland-melt.html

Arctic Change → Land ice is rapidly melting

https://www.youtube.com/watch?v=qlzE8z0D5Tk



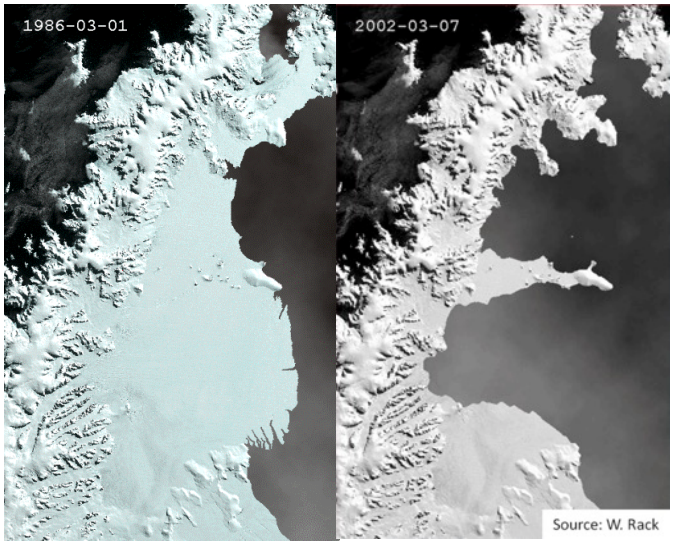
Antarctic Change → marine based ice rapidly melting



GRACE; courtesy of NASA-GISS visualization studio

- Ice shelf disintegration
  - **7 out of 12 Antarctic Peninsula ice shelves either gone or in severe decline**
  - Sudden and dramatic loss associated with intense and extensive surface melt
- Ocean-Ice Sheet interaction
  - Increased warm water intrusions thin buttressing ice shelves, increasing ice-sheet discharge and raising sea level

Satellite images of Antarctic Peninsula showing loss of ice shelves



Courtesy of W. Rack

2010 National Academy Report on IPY -- Polar Research Board

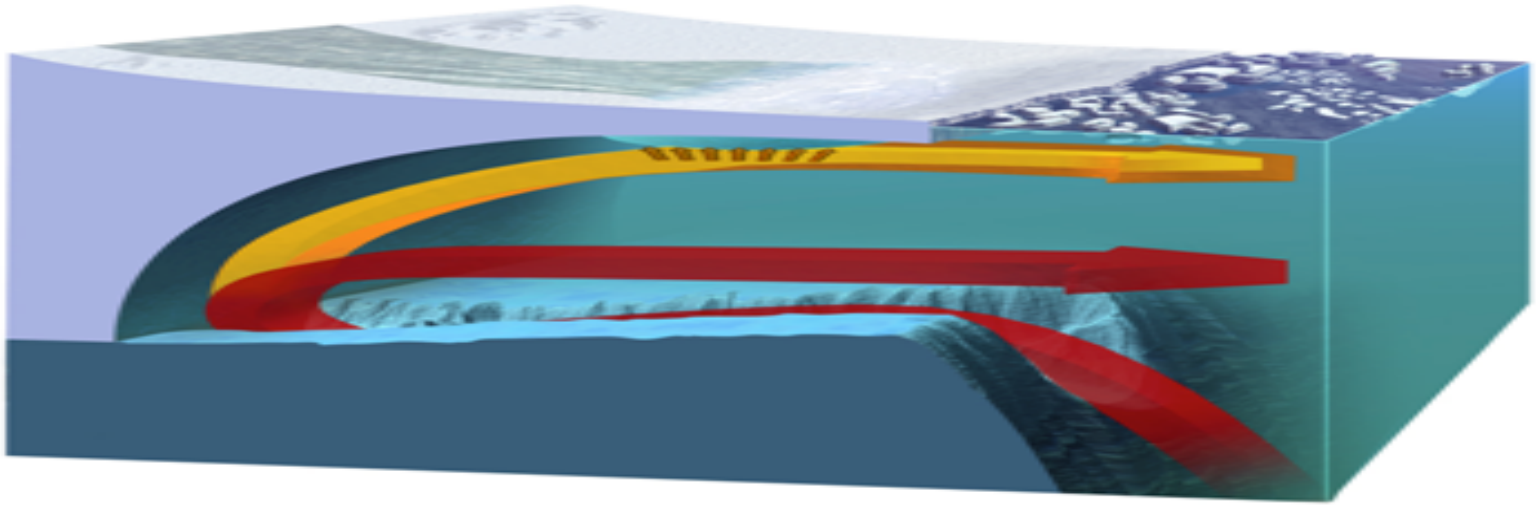
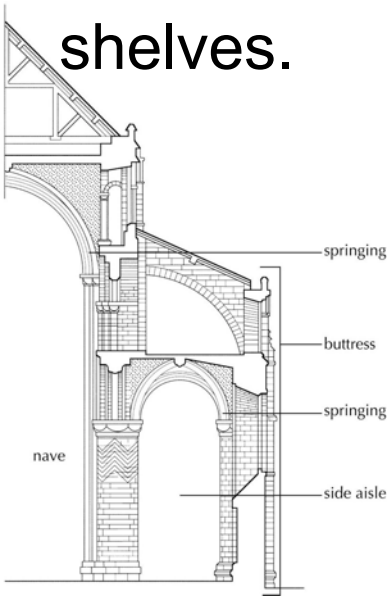


Figure from R.A. Bindschadler

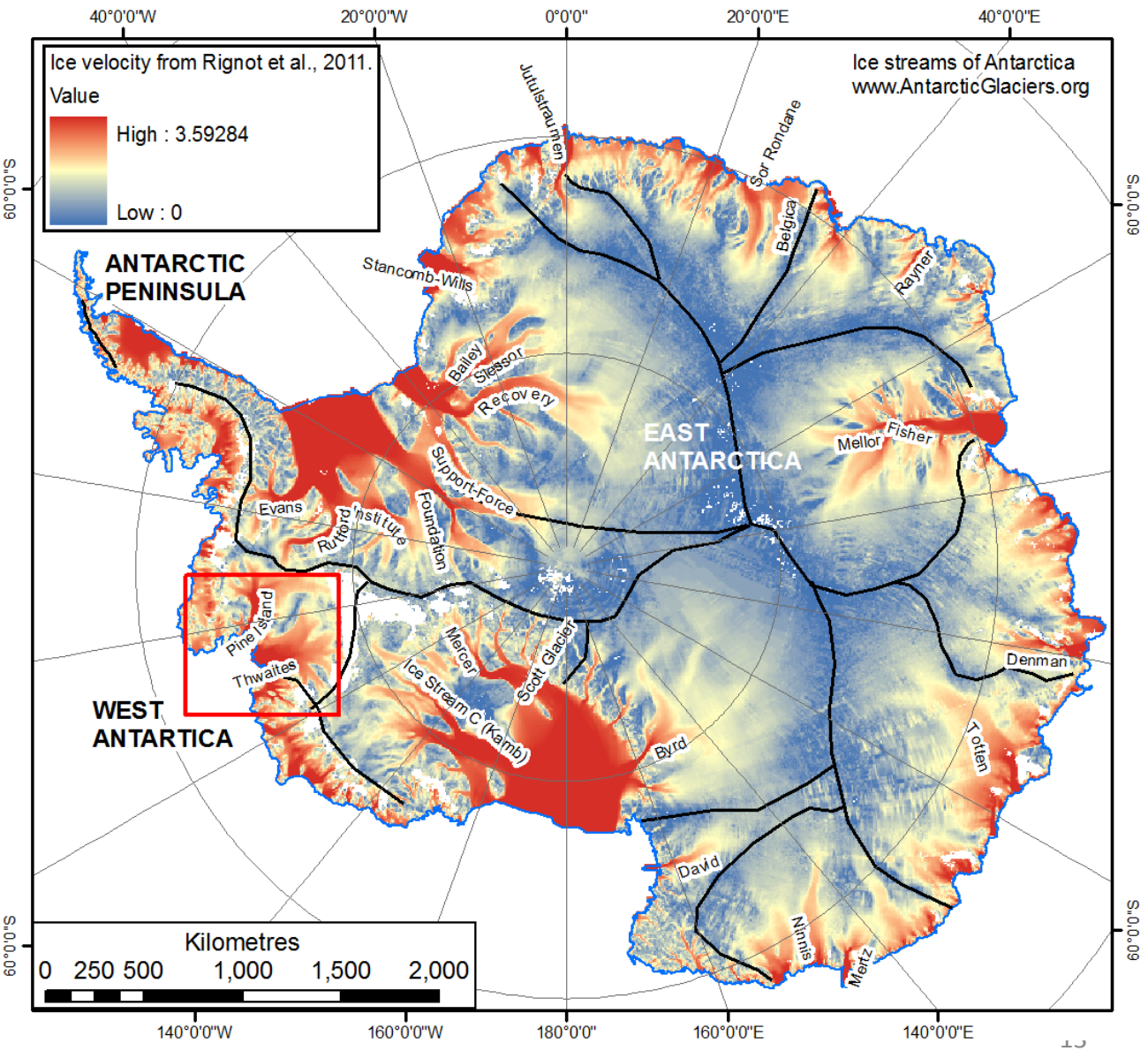
West Antarctic ice Sheet Collapse Has Begun – Its unstoppable!

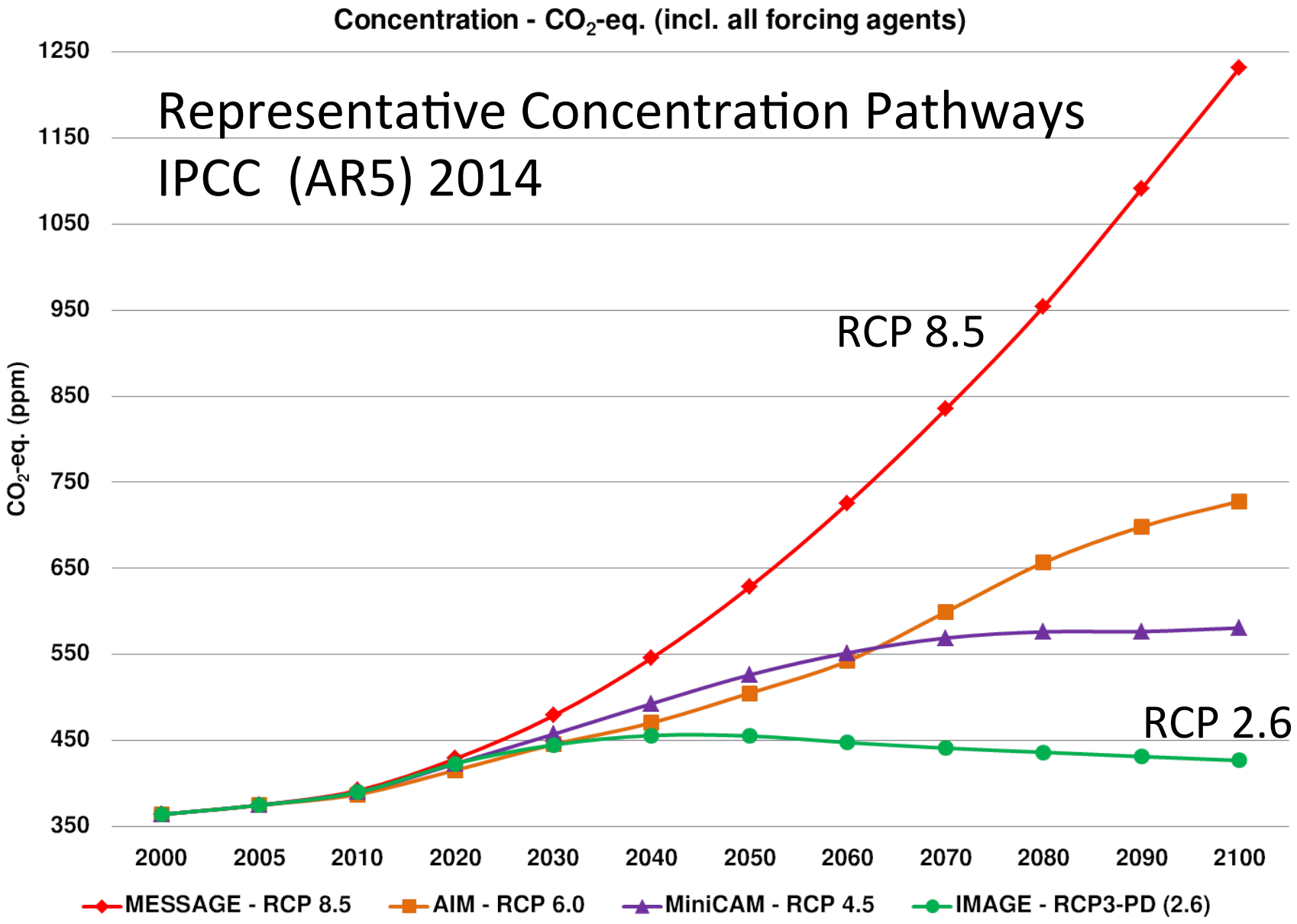
Loss of buttressing
With the loss of the ice shelves.

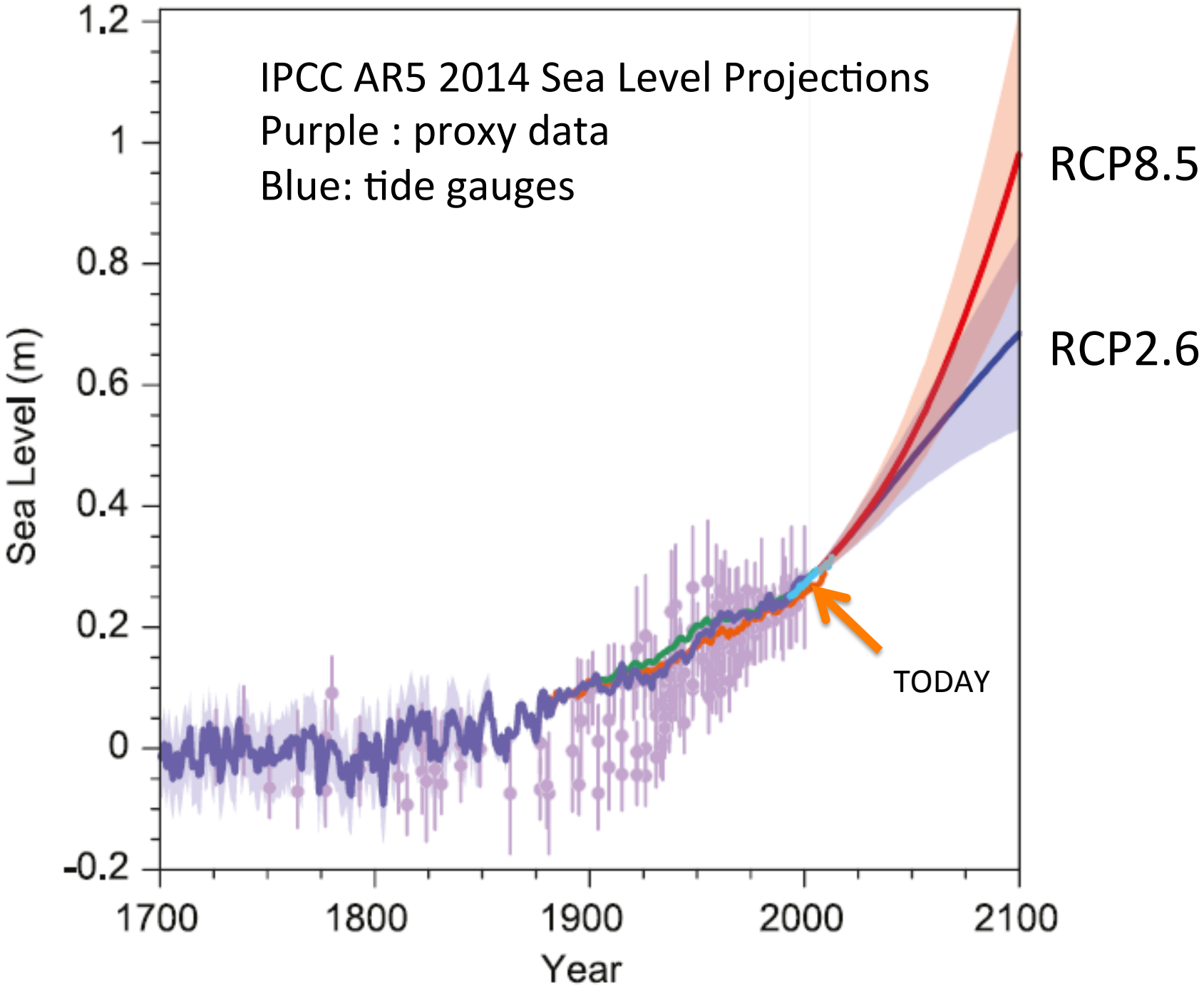


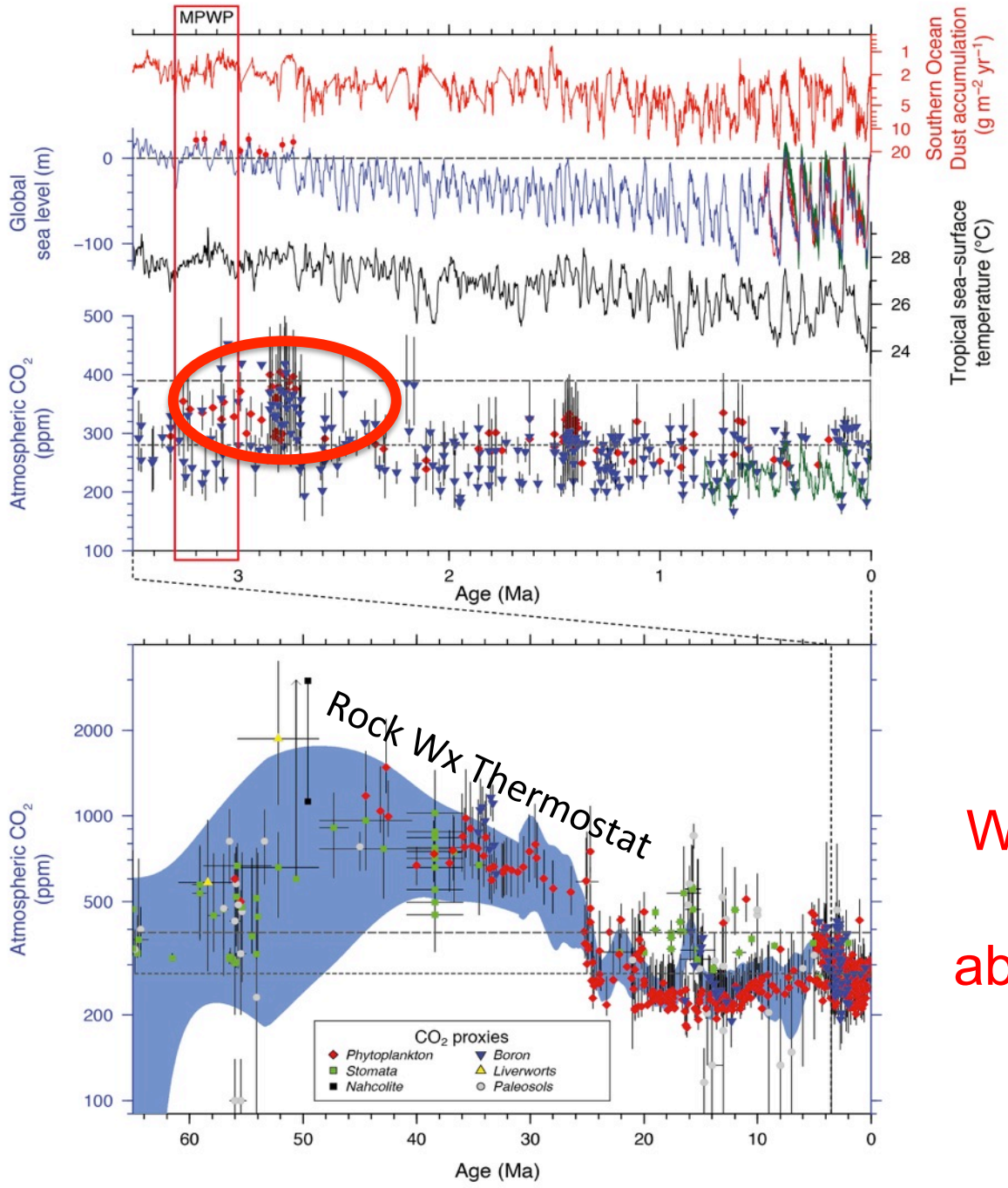
June 2014

Joughin et al 2014
Rignot et al 2014




Concentration - CO_2-eq. (incl. all forcing agents)
Representative Concentration Pathways
IPCC (AR5) 2014
RCP 8.5
RCP 2.6
CO_2-eq. (ppm)
1250
1150
1050
950
850
750
650
550
450
350
2000
2005
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
MESSAGE - RCP 8.5
AIM - RCP 6.0
MiniCAM - RCP 4.5
IMAGE - RCP3-PD (2.6)


IPCC AR5 2014 Sea Level Projections
Purple : proxy data
Blue: tide gauges
RCP8.5
RCP2.6
TODAY
Sea Level (m)
Year
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
1700
1800
1900
2000
2100



We have returned to a Pliocene world with pCO_2 at 400 ppm in a little over a century.

Should we be worried!

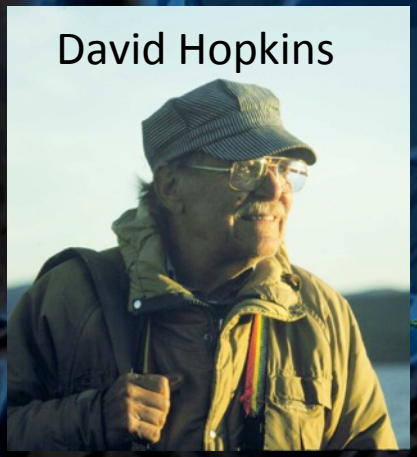
What arctic paleoclimate evidence informs us about climate sensitivity?

IPCC AR5 – Chapter 5

Sea Level History of the Bering Land Bridge

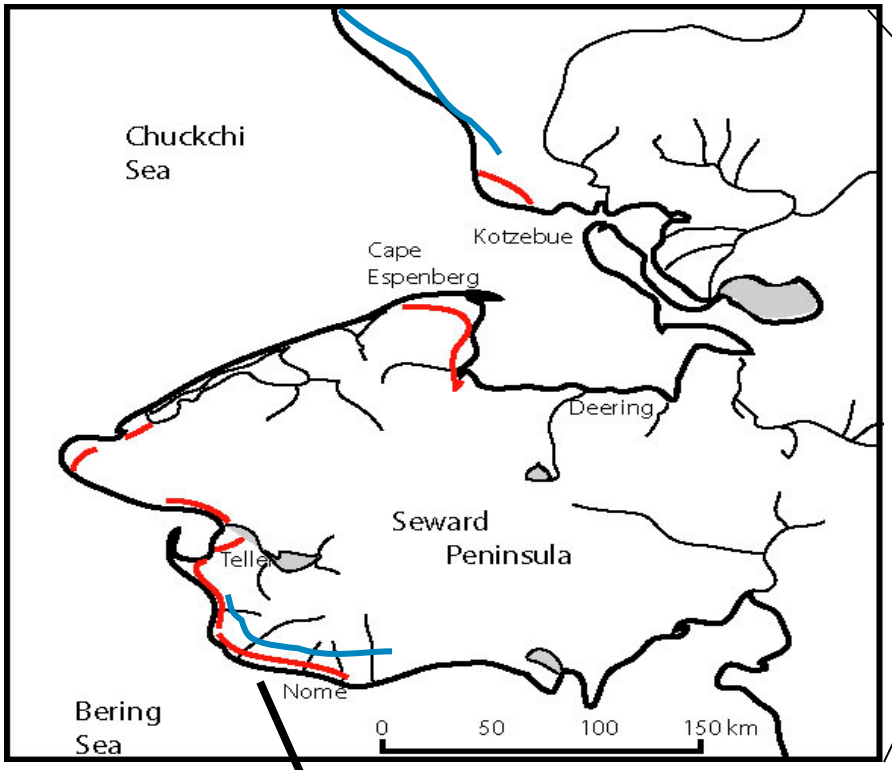
Arctic Coastal Plain

Nome Coastal Plain

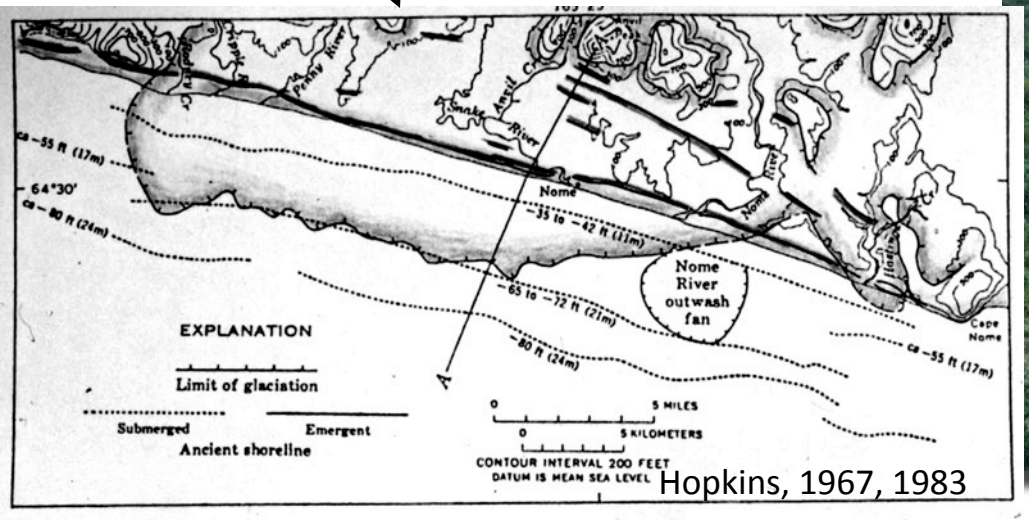


0 250 500 Kilometers

Peninsula today

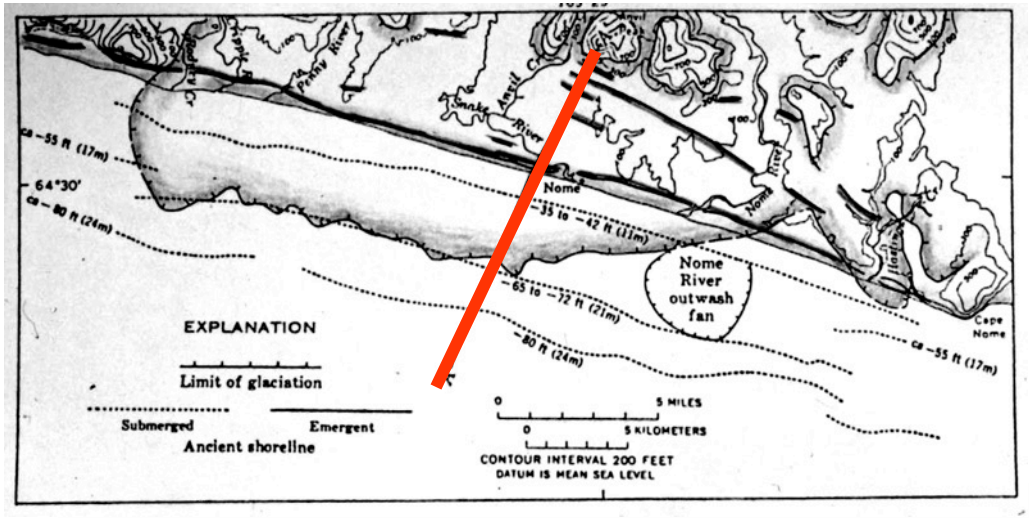


Anvilian Shorelines (MIS 11)



Hopkins, 1967, 1983

Anvilian Shoreline (MIS 11)



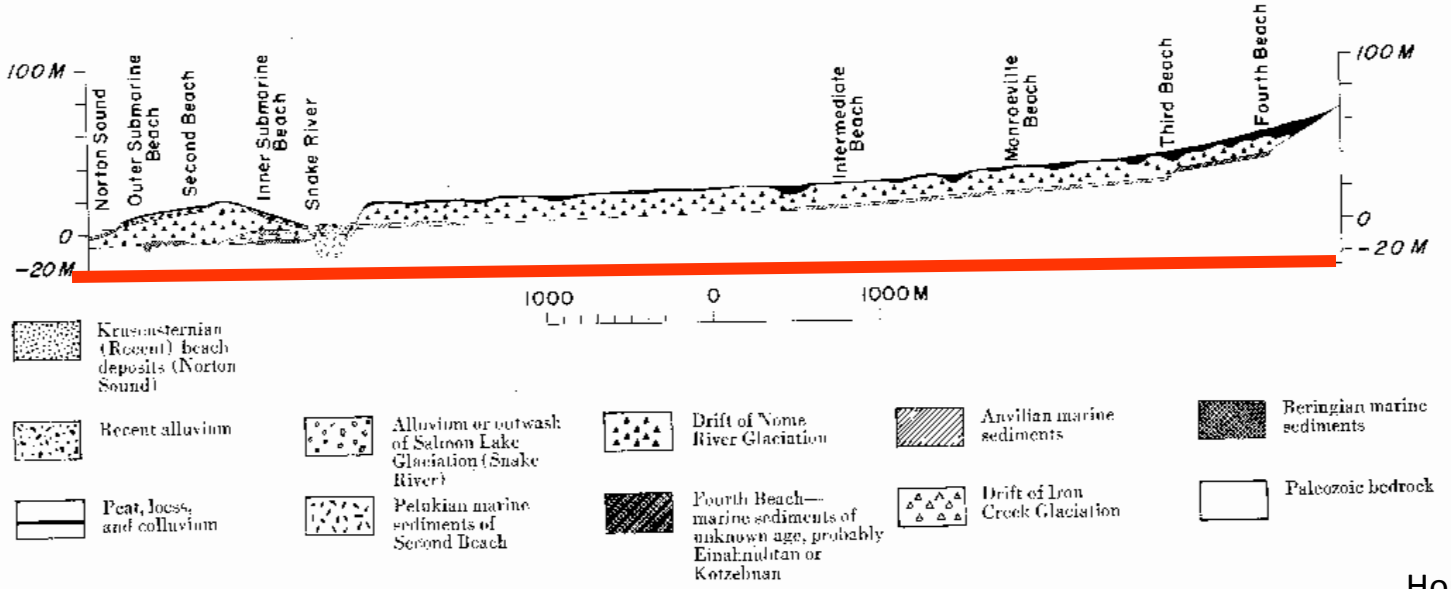
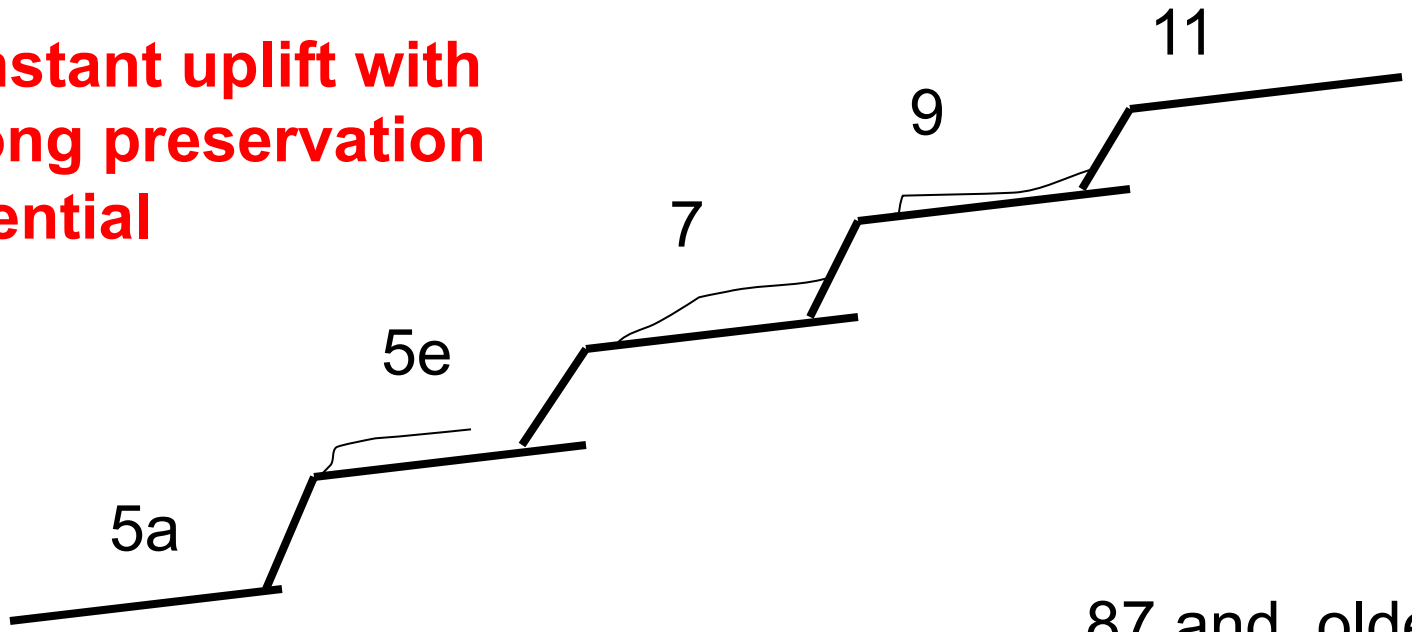


Fig. 2. Cross section through coastal plain at Nome.

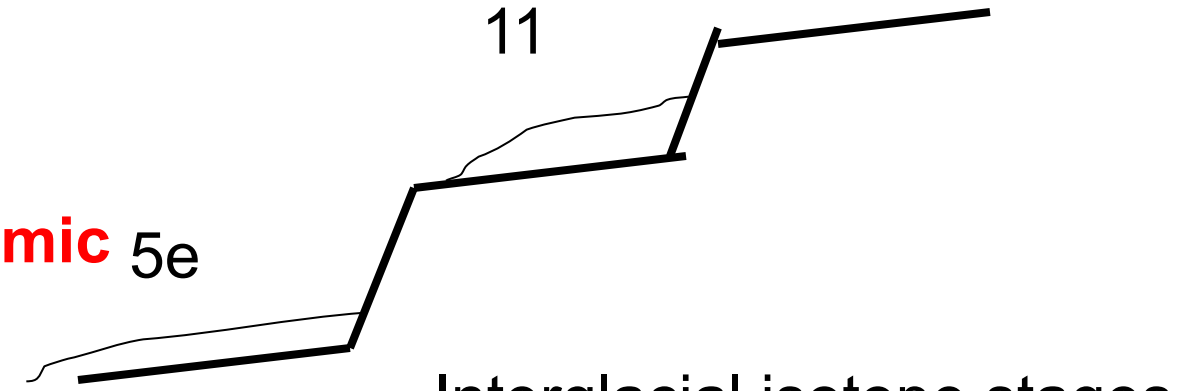
Hopkins, 1967

Constant uplift with strong preservation potential



Event-based stratigraphy

Add GIA/dynamic topography



Interglacial isotope stages

Arctic Ocean

Bering Strait

Arctic Coastal Plain	age	Field Elevations	Nome Coastal Plain
Simpsonian	80ka	7m	
Pelukian	125ka	8-10m	Pelukian
Wainwrightian	410 ka	22-23m	Anvilian
Fishcreekian	~ 1.1 Ma	~30m	Beringian III
Bigbendian	~2.6 Ma	~40m	Beringian II
Colvillian	~3.0 Ma	~40m	Beringian I

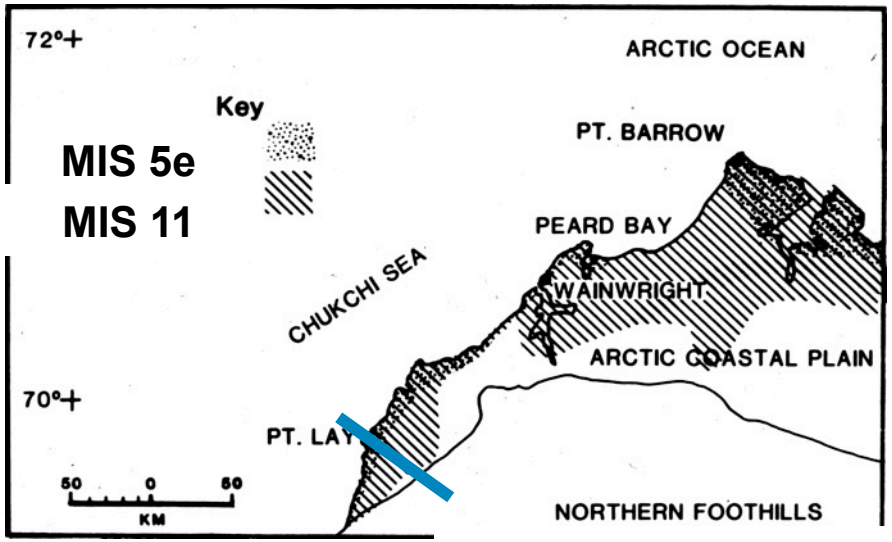
Kaufman and Brigham-Grette, 1993

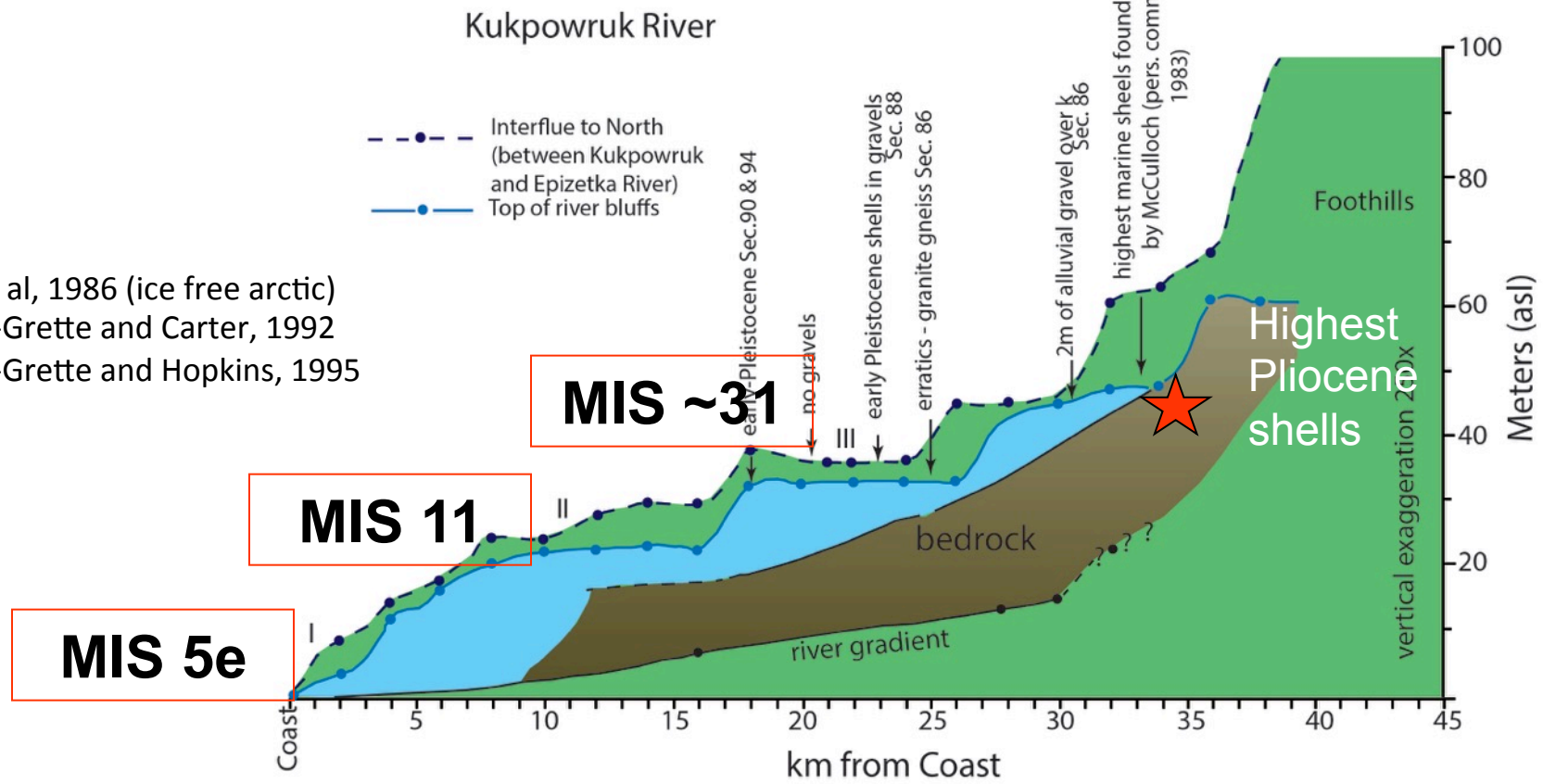
JBG and Carter, 1992

Hopkins, D. Kaufman

North Slope Paleoshorelines

Warm Extralimital Faunas

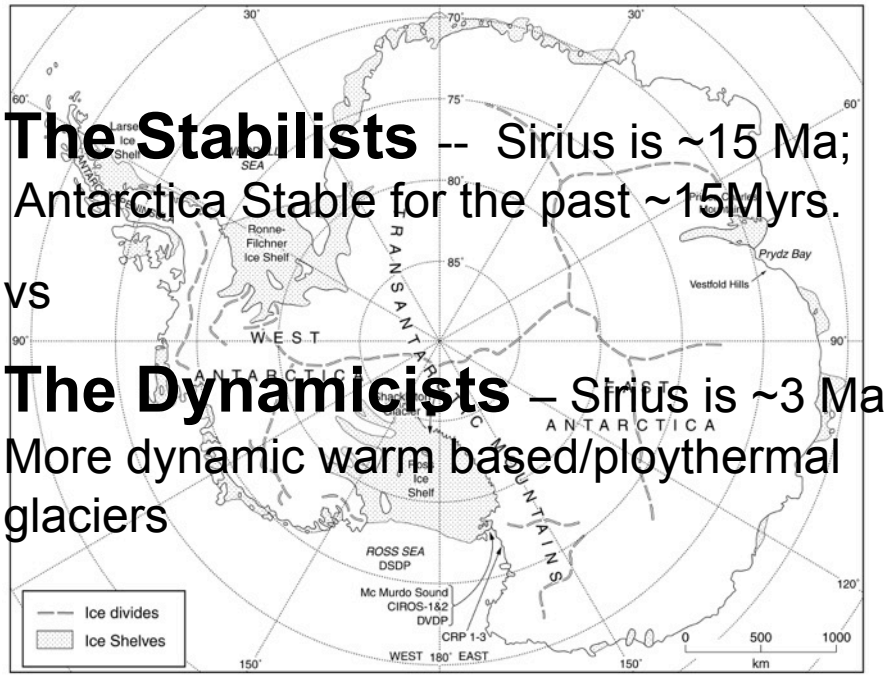




Carter et al, 1986 (ice free arctic)
Brigham-Grette and Carter, 1992
Brigham-Grette and Hopkins, 1995

What Melted to Produce high shorelines?

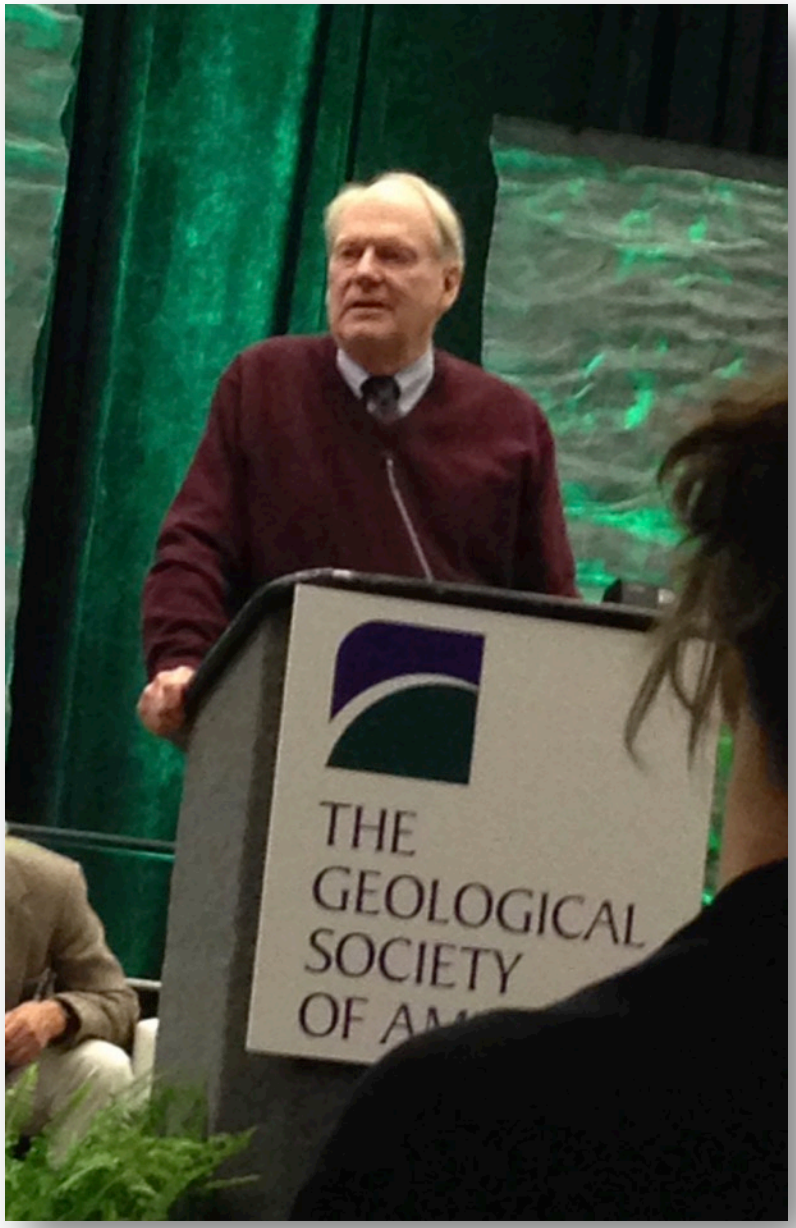
Meeting in late 80s about the Sirius Formation --> **Sirius Debate!**
Temperatures 25°C warmer than today



The Stabilists -- Sirius is ~15 Ma; Antarctica Stable for the past ~15Myrs.

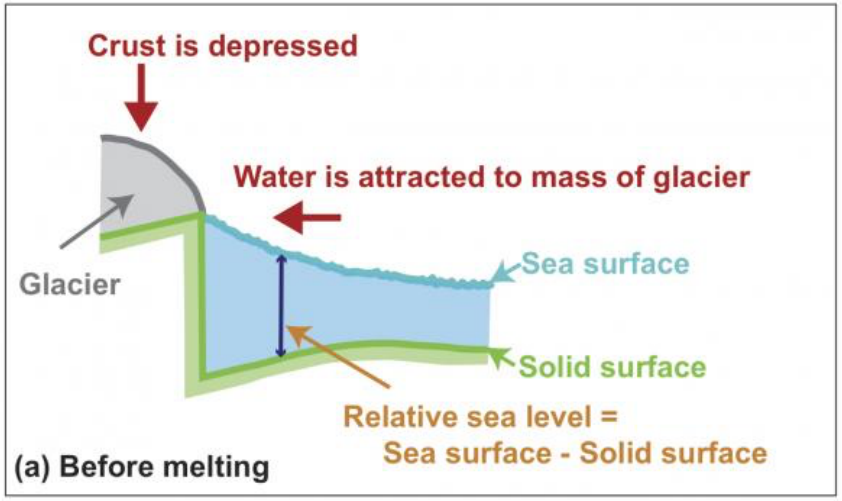
vs

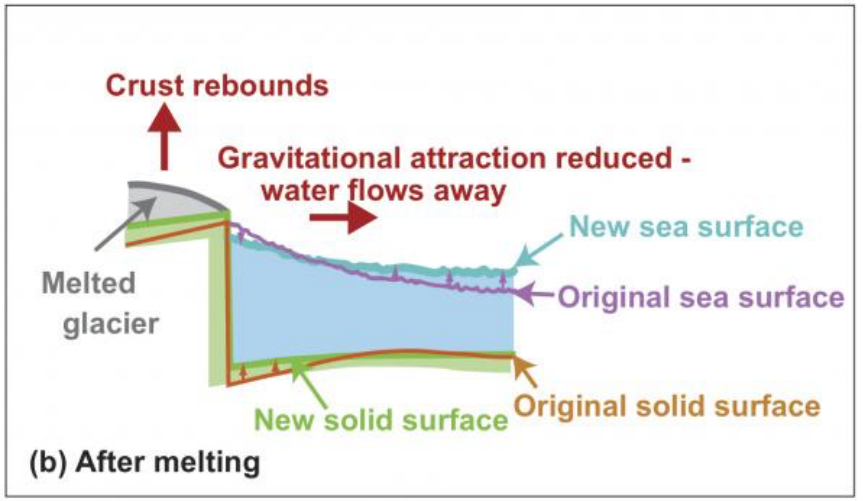
The Dynamicists – Sirius is ~3 Ma; More dynamic warm based/ploythermal glaciers

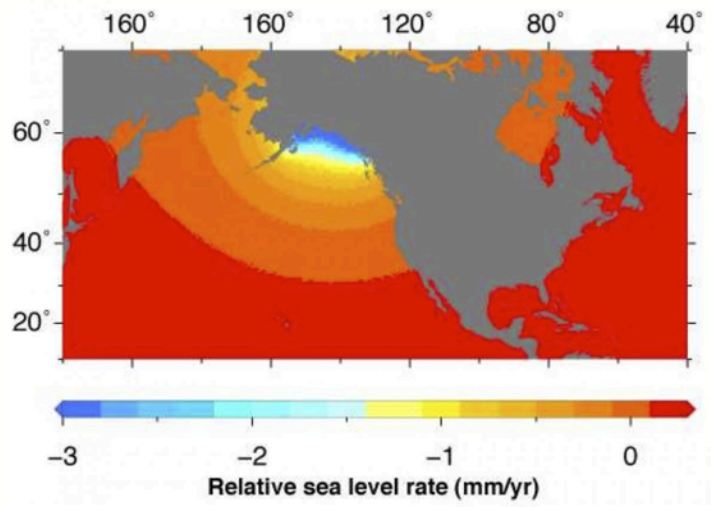


Prof George Denton,
October 2015, GSA
Distinguished Career Award

Spatial variations in sea level and mass change from GRACE gravity data

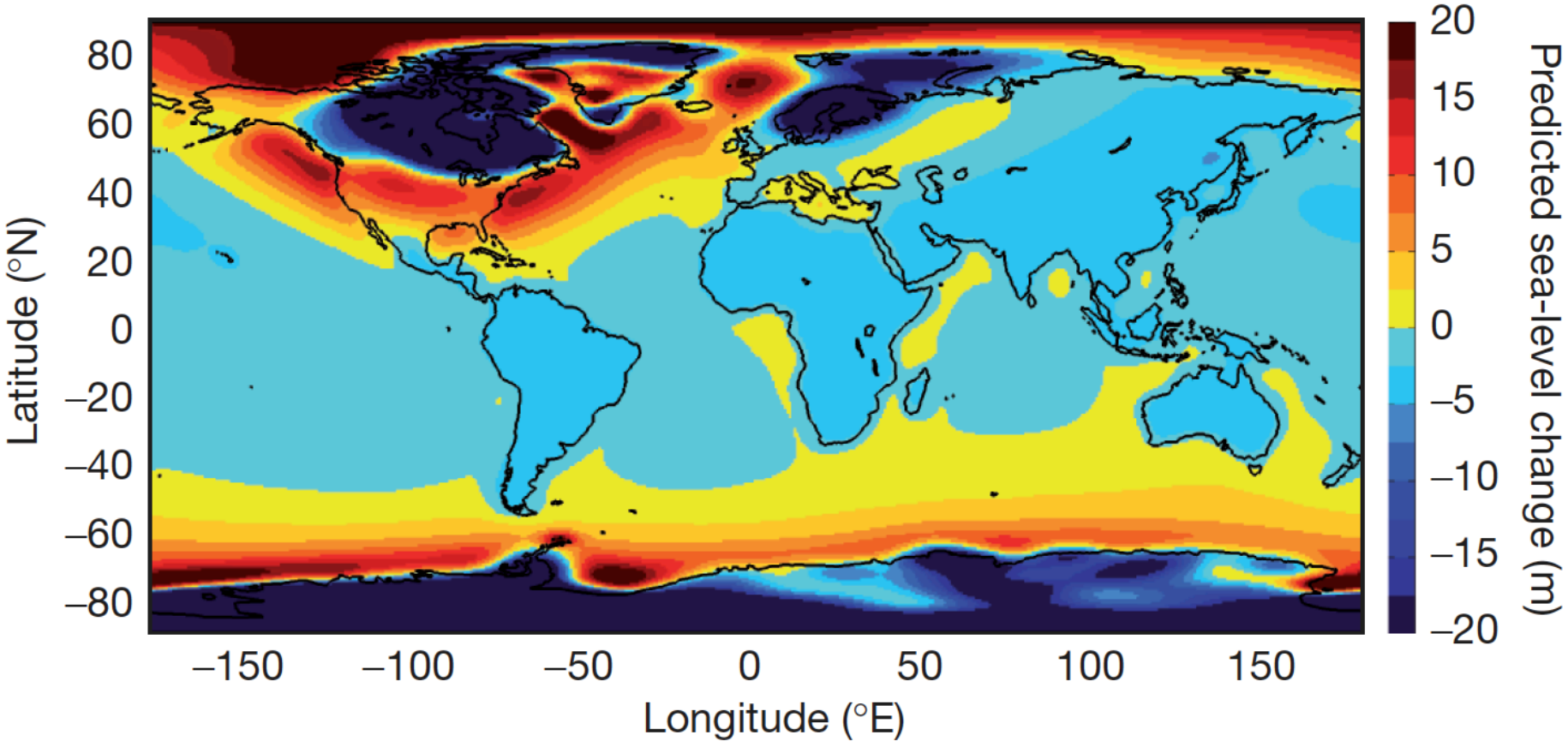






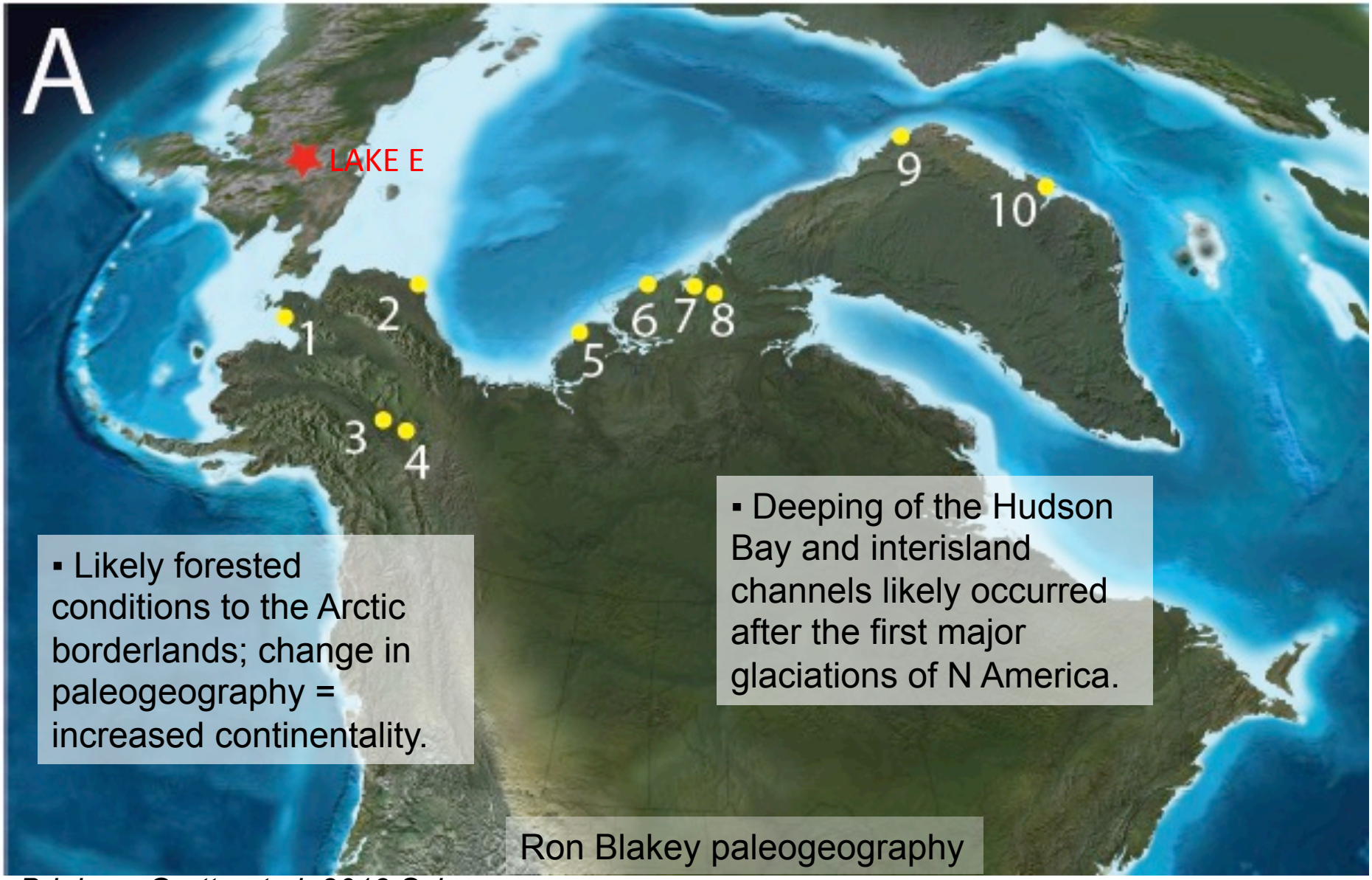
Emma Hill et al 2011

Now we have GIA and Dynamic Topography – e.g.,MIS 11 (410 ka)



Raymo and Mitrovica, 2012

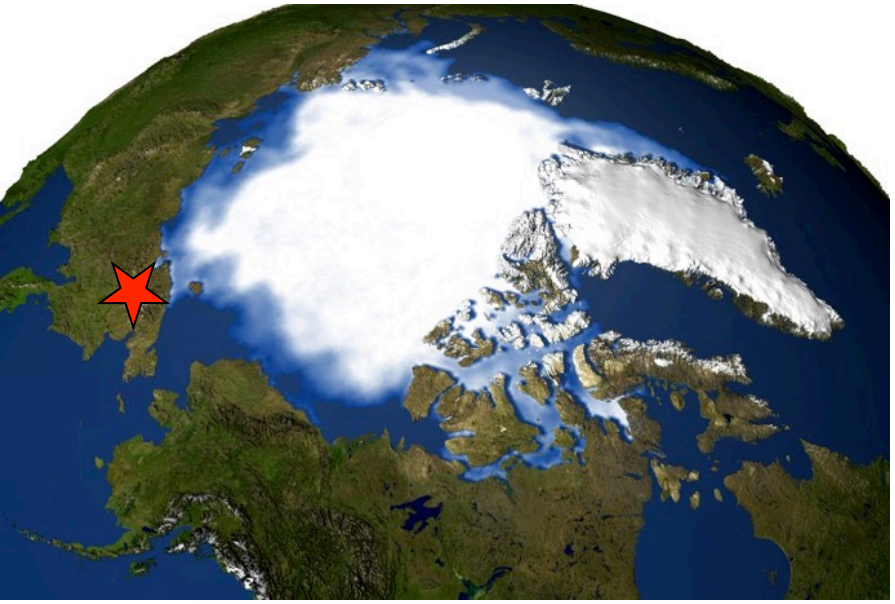
Pliocene - A different Arctic > 3.0 Ma!



Brigham-Grette et al. 2013 Science

Pliocene - A different Arctic > 3.0 Ma!

Brigham-Grette et al. 2013



El'gygytgyn Lake
World Class Target

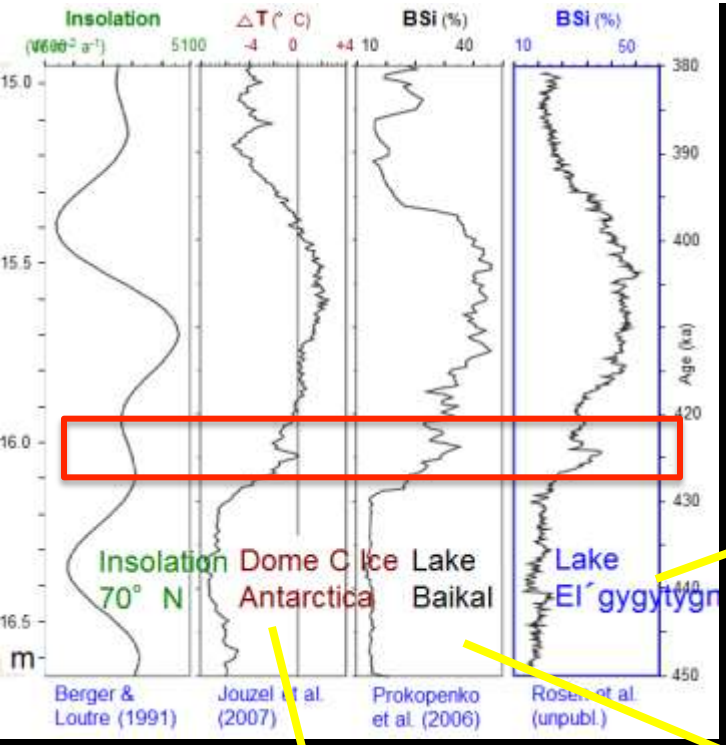
Rhyolitic target rocks
Largest deep unglaciated lake in the entire Arctic

3.58+/- 0.04 Ma
(Layer, 2000)

18 km Diameter
175 m deep lake

El'gygytgyn impact crater
C. Koeberl / Univ. Vienna
(NASA image: digital image processing: GBA Wien / M. Schlegl)

icdp



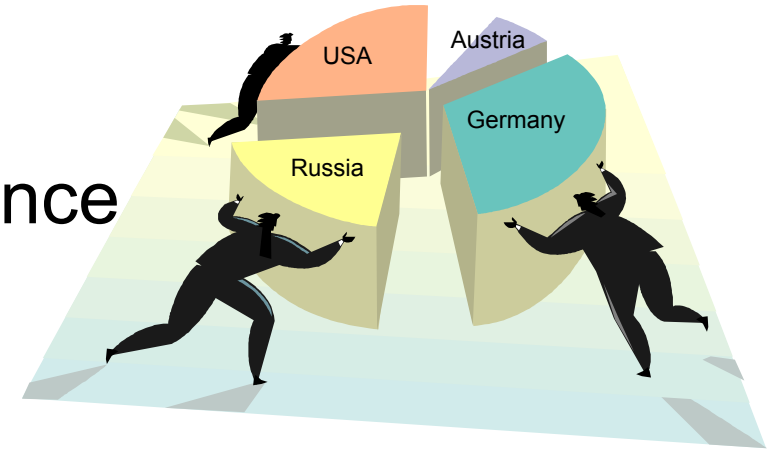
MIS 11

Results from Pilot cores – Globally sensitive !

Two Shared Objectives:

1) Carry out interdisciplinary science

2) Remain colleagues afterward



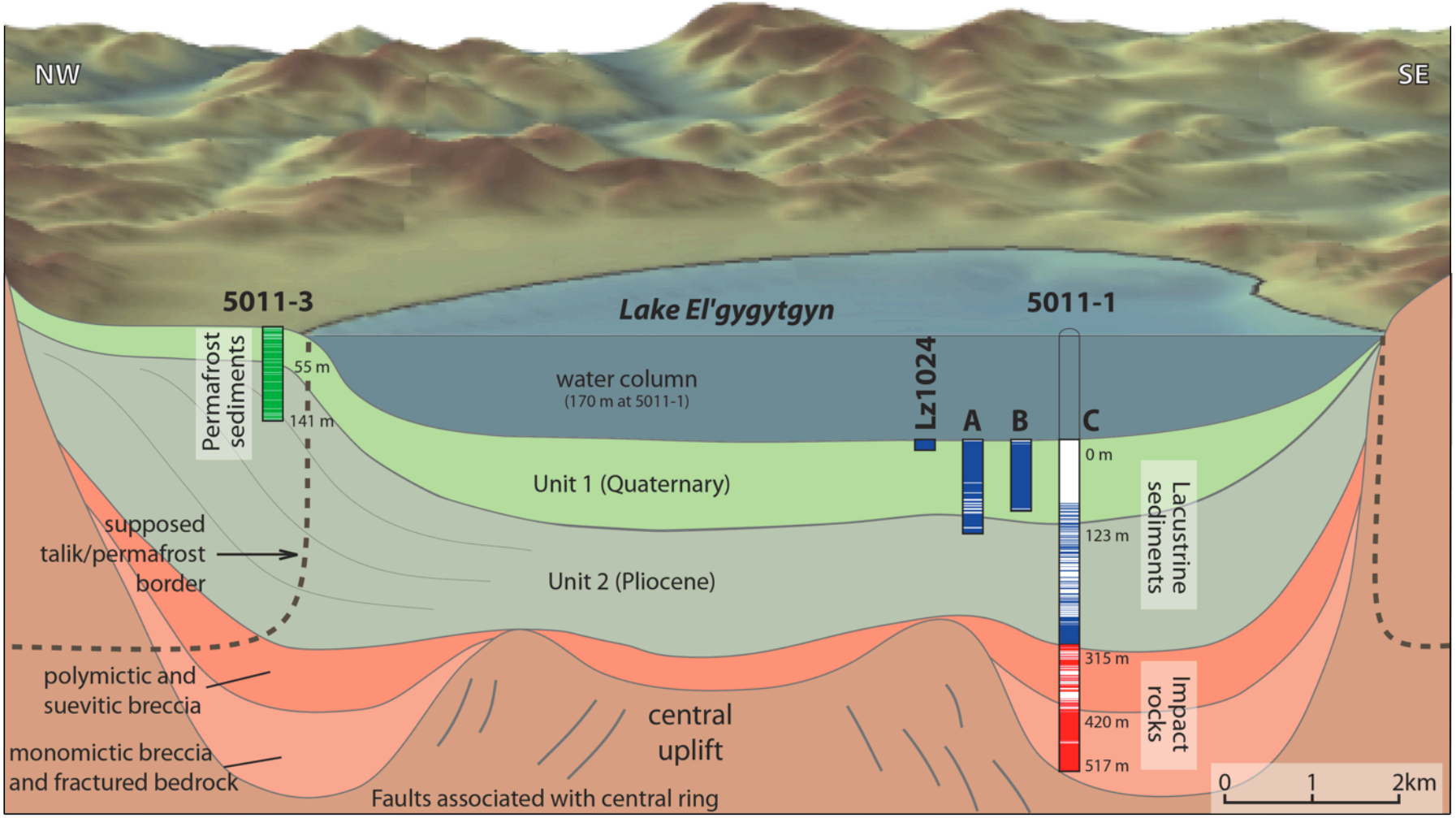
Group Success!

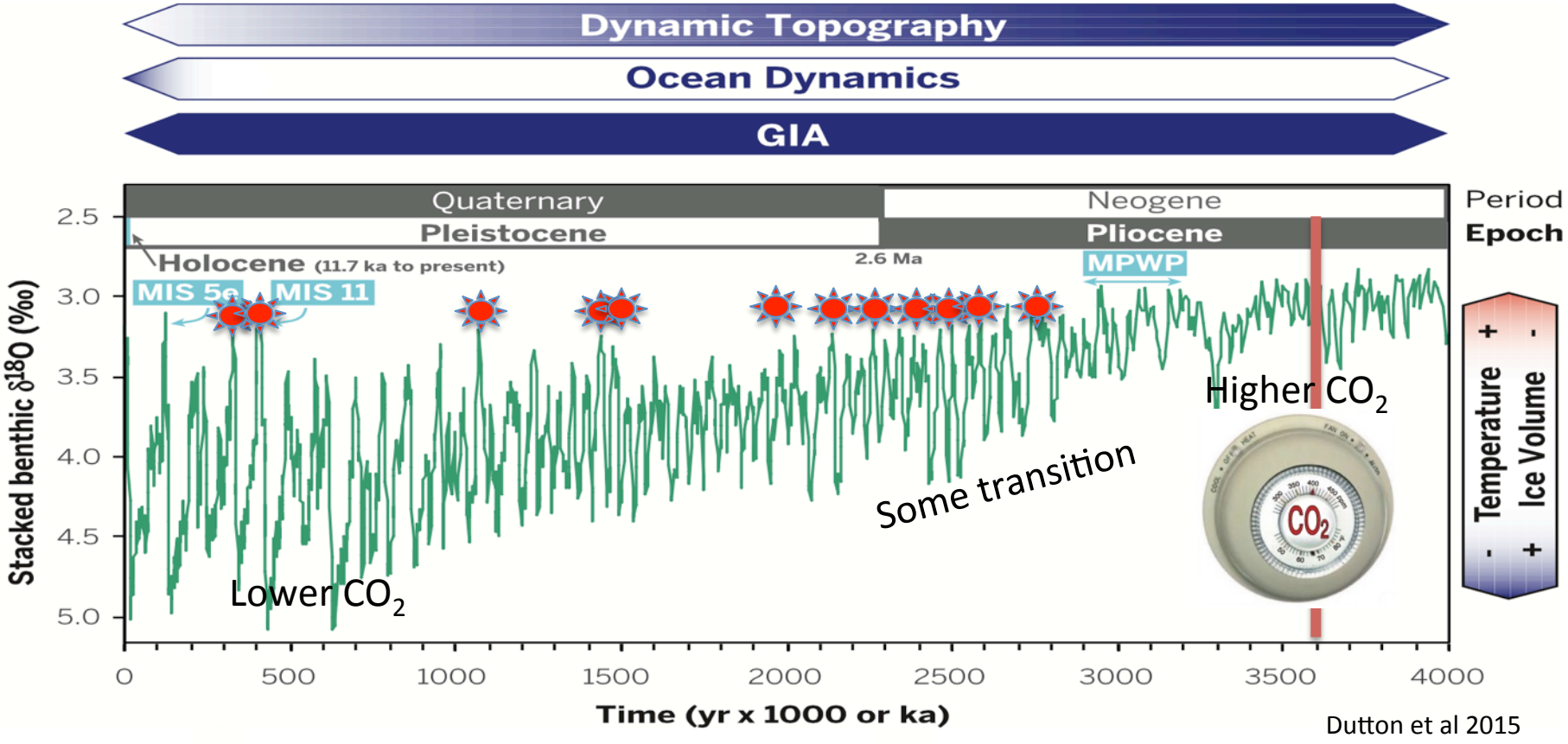
Milestone of International Polar Year 2007-2009

El'gygytgyn Drilling Project

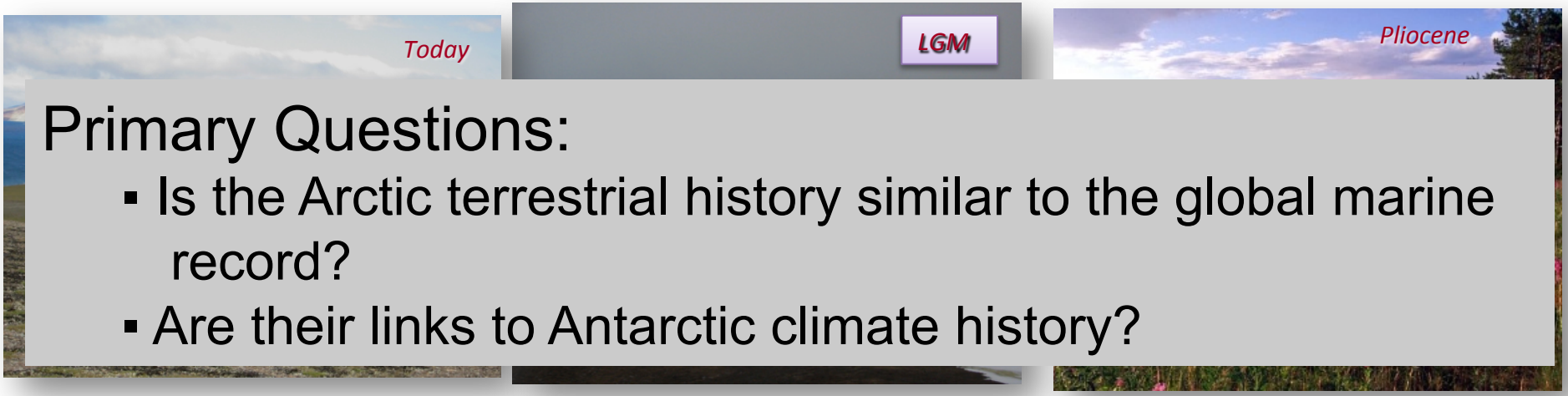
Lake El'gygytgyn

Deepest, oldest unglaciated basin in terrestrial Arctic!





Dutton et al 2015

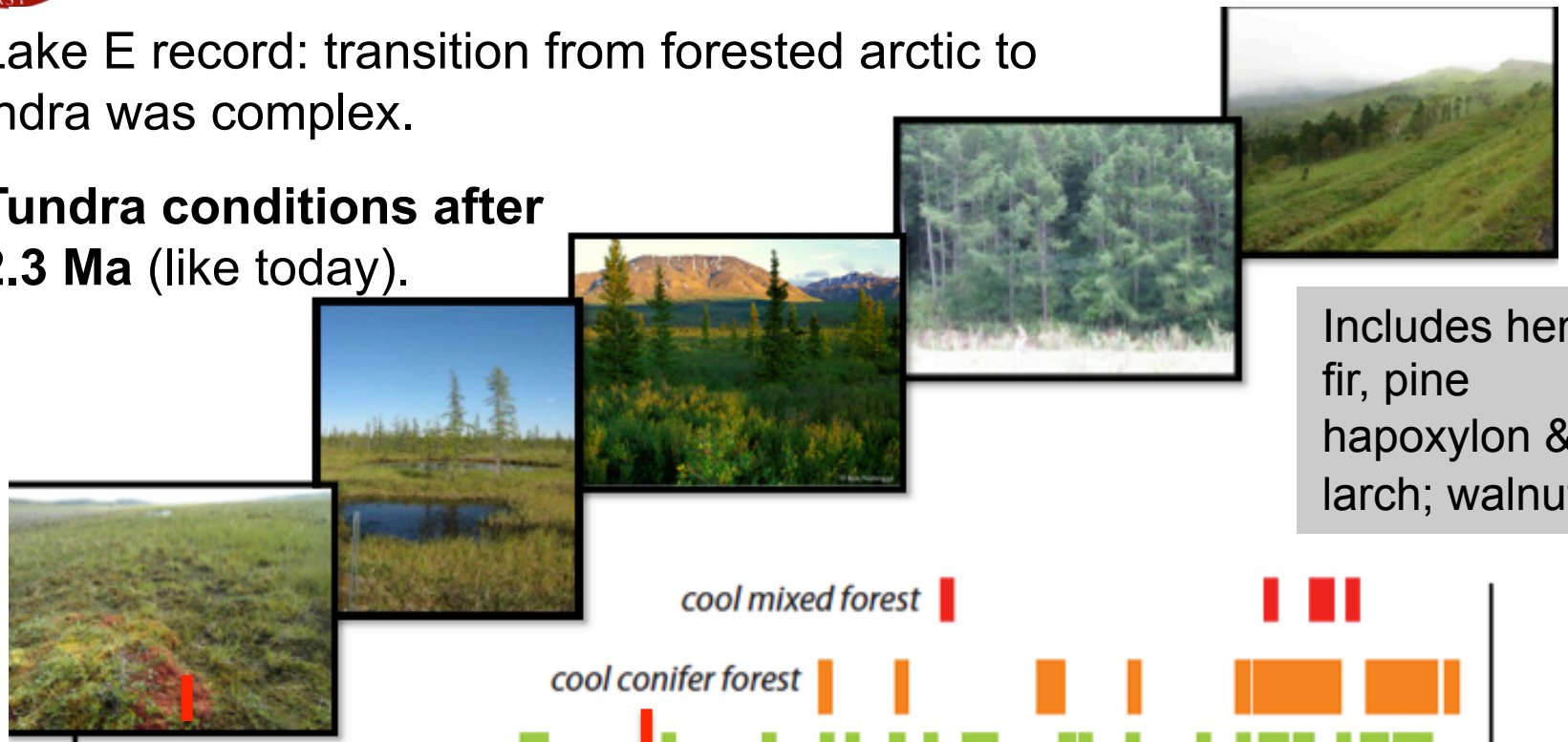


Primary Questions:

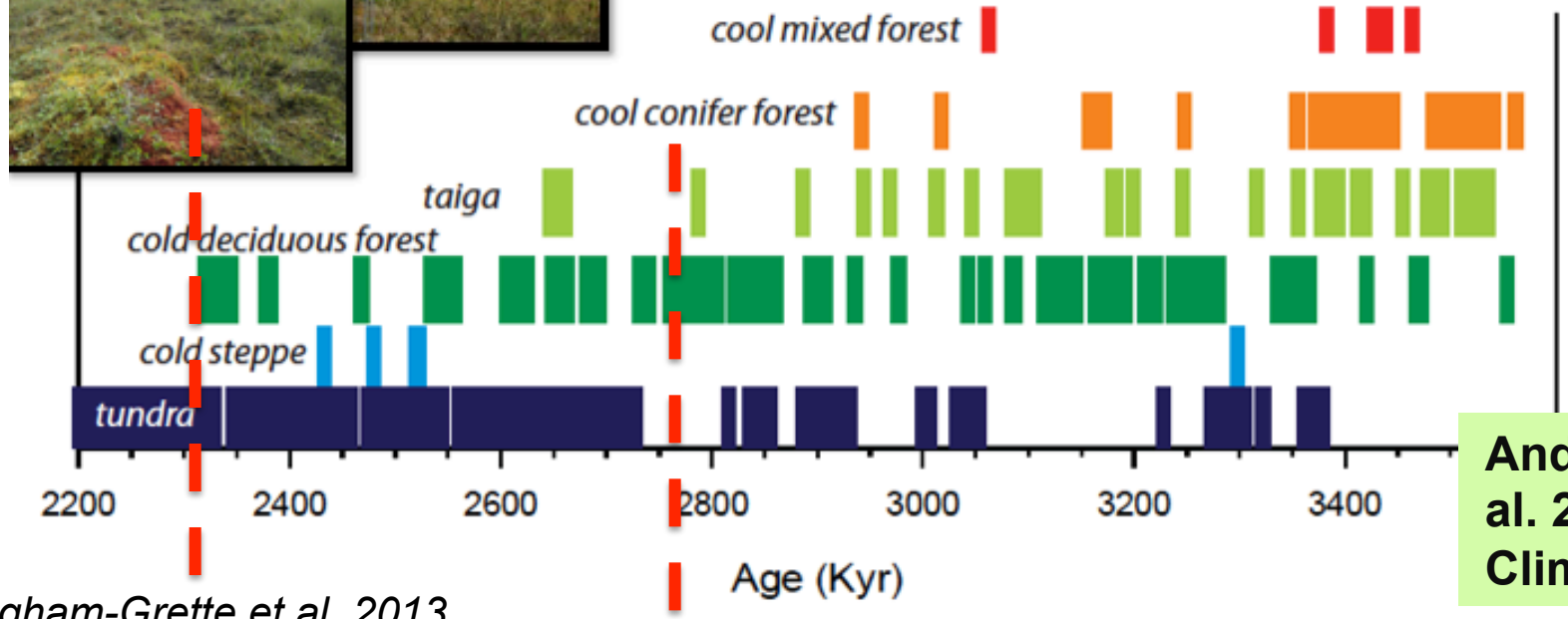
- Is the Arctic terrestrial history similar to the global marine record?
- Are their links to Antarctic climate history?

NHG: stepwise & complex transition

- Lake E record: transition from forested arctic to tundra was complex.
- **Tundra conditions after ~2.3 Ma** (like today).



Includes hemlock, fir, pine hapoxylon & larch; walnut

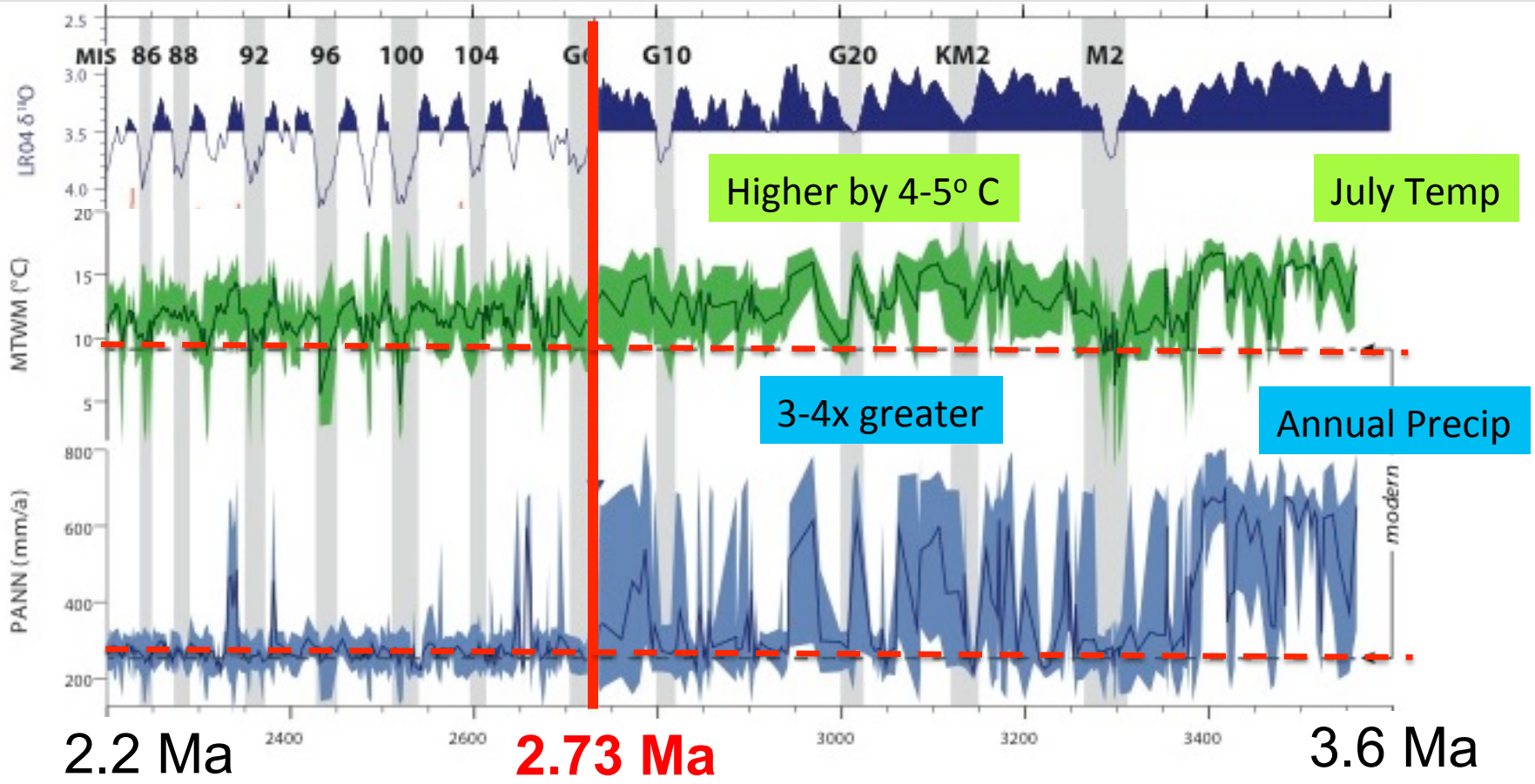


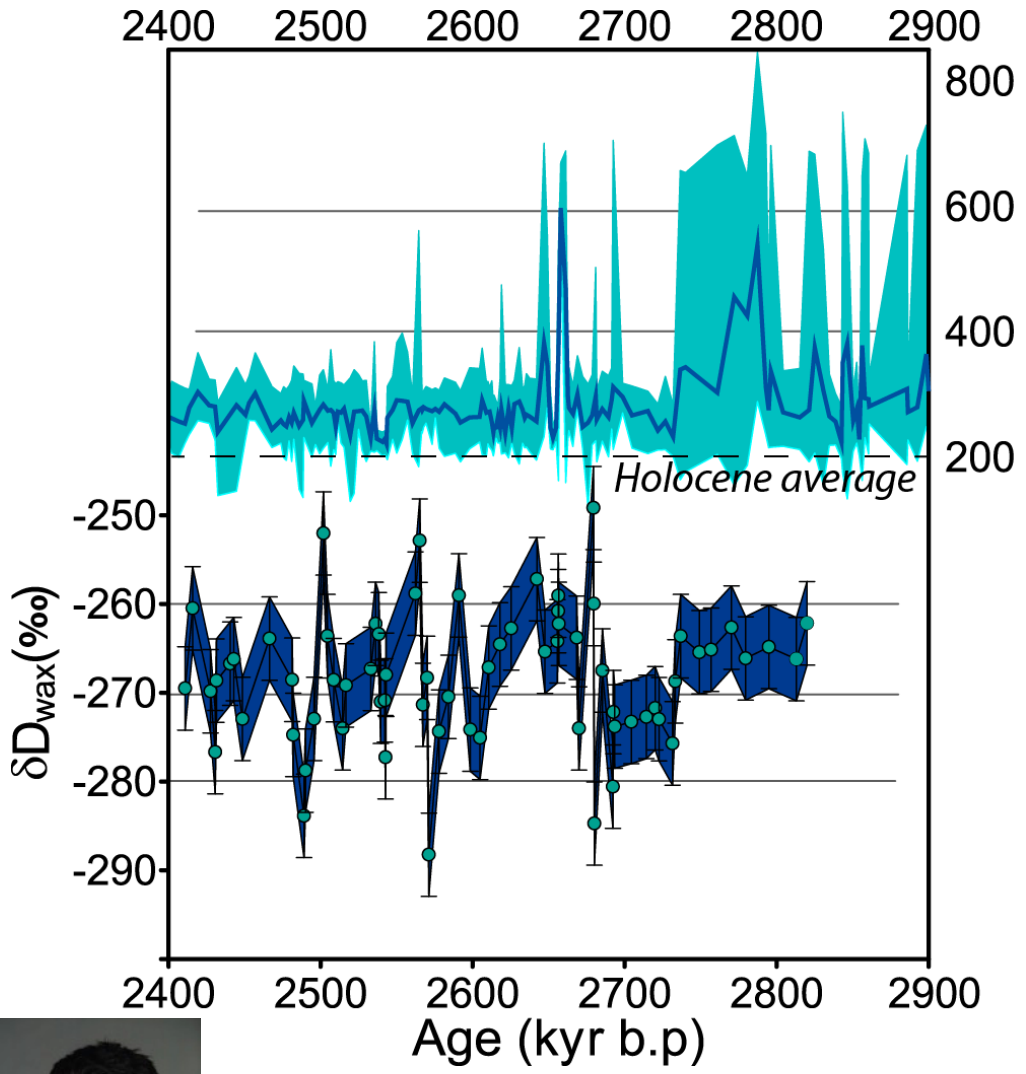
Brigham-Grette et al. 2013

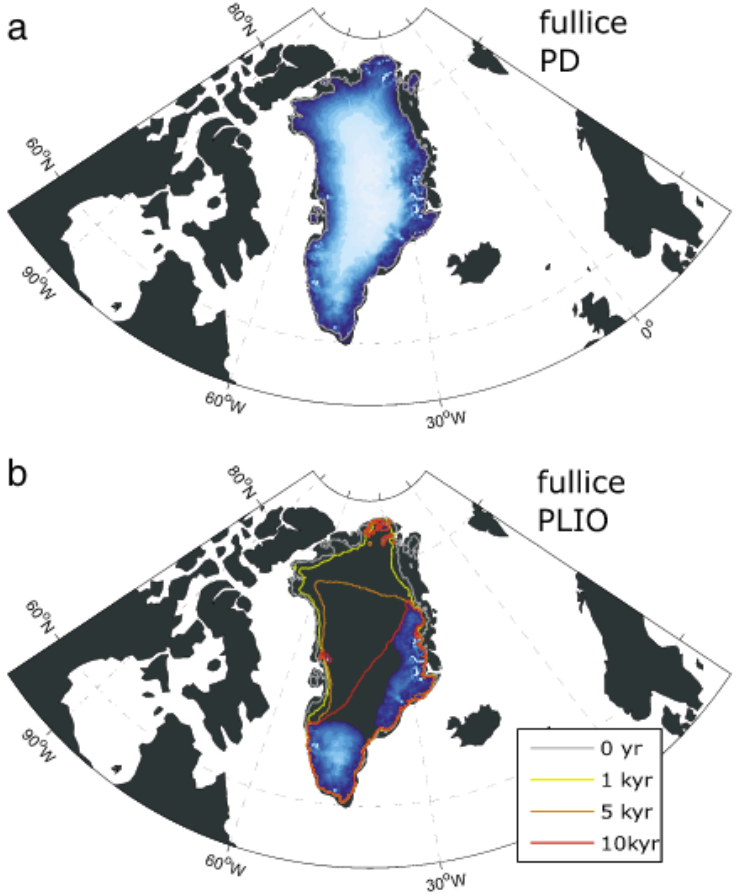
Andreev et al. 2014, Clim. Past

Warm/wet Pliocene; then uncoupled TP

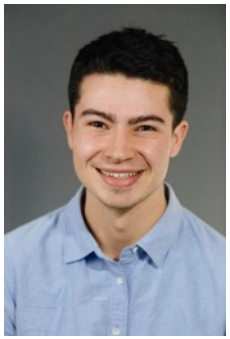
- First major transition: Major drop in precip @ 2.73 Ma
- Coincident w/ change in N Pacific ventilation (onset of stratification)
- Warm summers/high precipitation **uncoupled** after 2.73 Ma except during super interglacials







Konieg et al, 2014, GRL

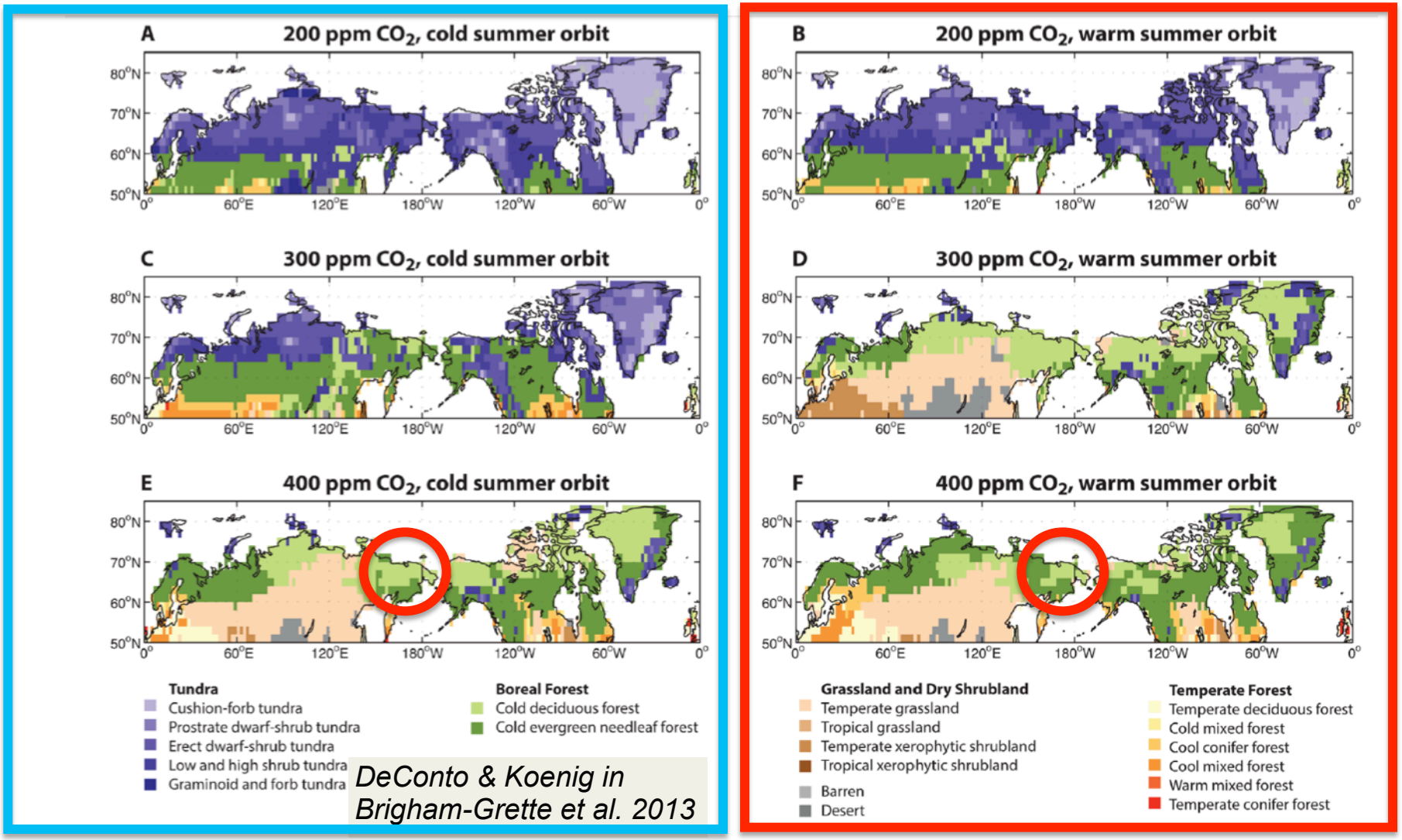


Kiesling et al. in prep

Sea ice impacts Greenland ice volume & climate at Lake E

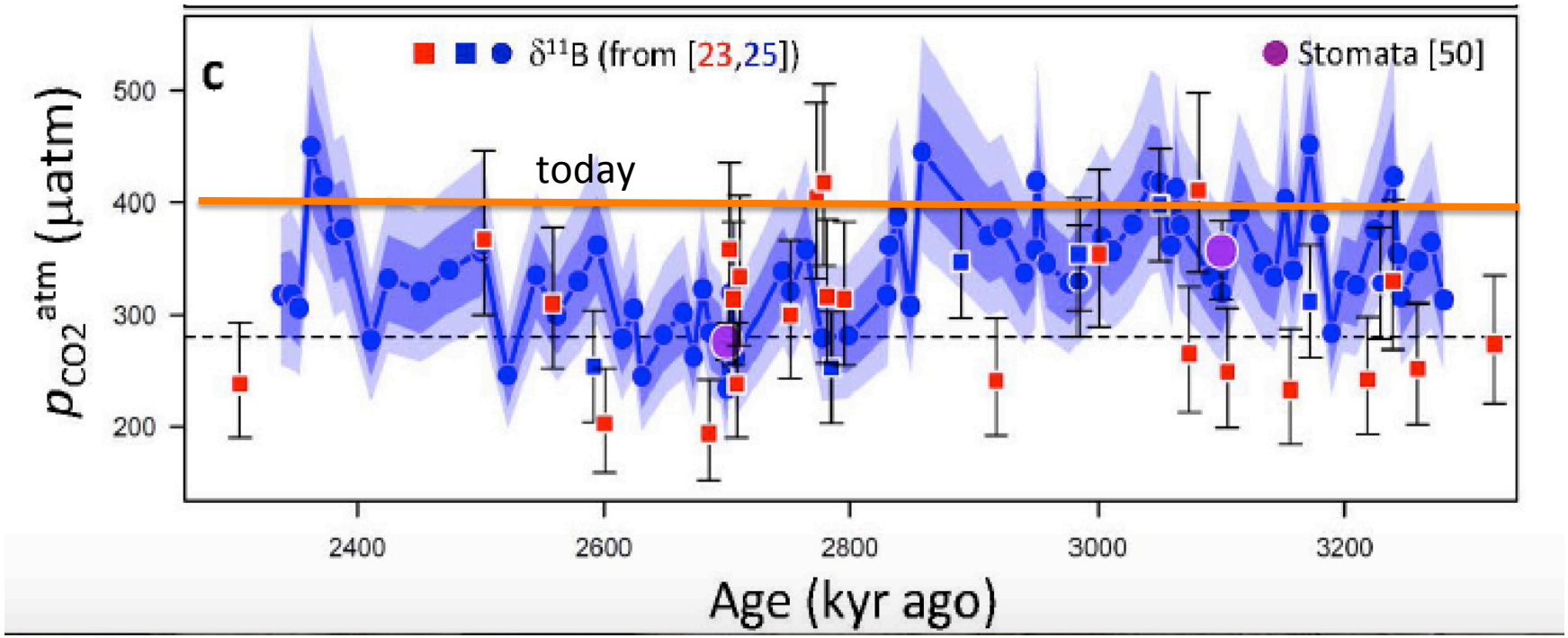
Plio-Pleistocene climate-veg. simulations

- Lack of temperate forest at 400ppm: under-sensitivity of model to CO_2 forcing or possibility that Pliocene GHG levels were higher that proxy reconstructions.



DeConto & Koenig in Brigham-Grette et al. 2013

Pliocene Temperatures



Martinez-Boti et al. 2015

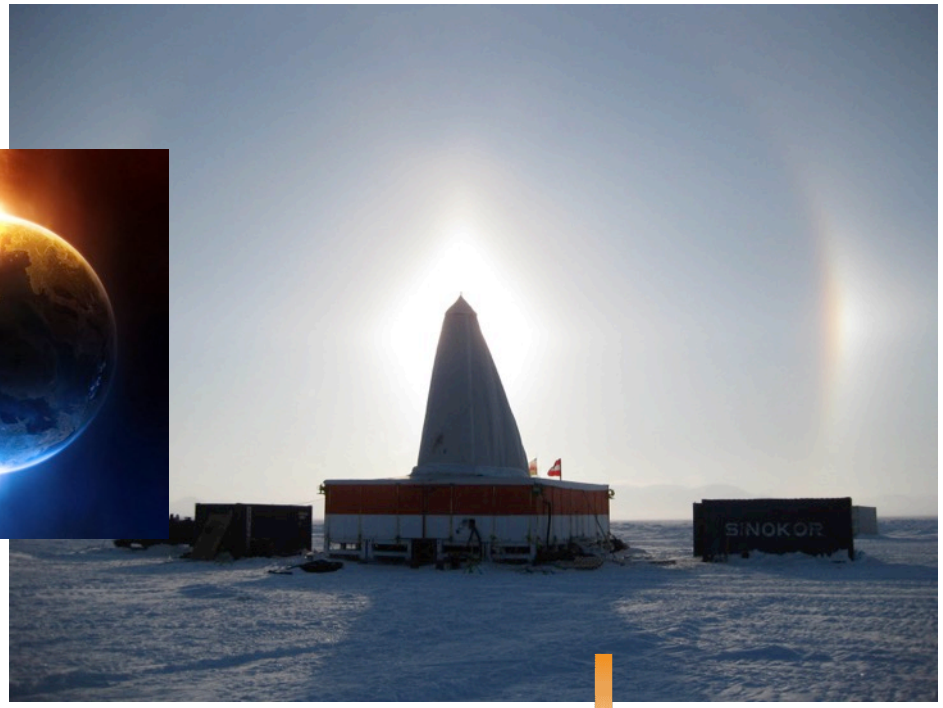
Polar Programs with International partners

ANDRILL

With New Zealand, UK, Italy, Germany,

Lake El'gygytgyn

With Germany, Russia, Austria



ANDRILL

El'gygytgyn
Drilling Project

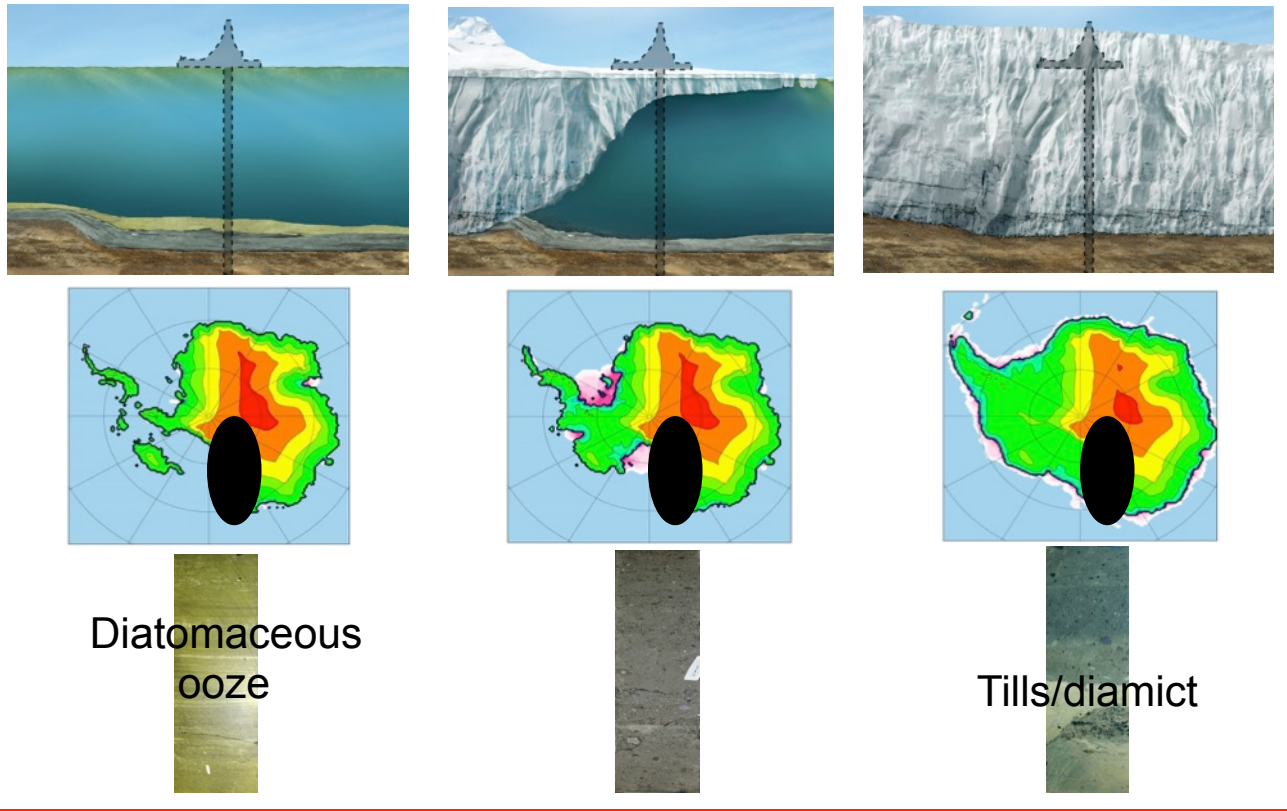
Photos from Catalina Gebhardt, AWI

A record of past WAIS behavior

ANDRILL

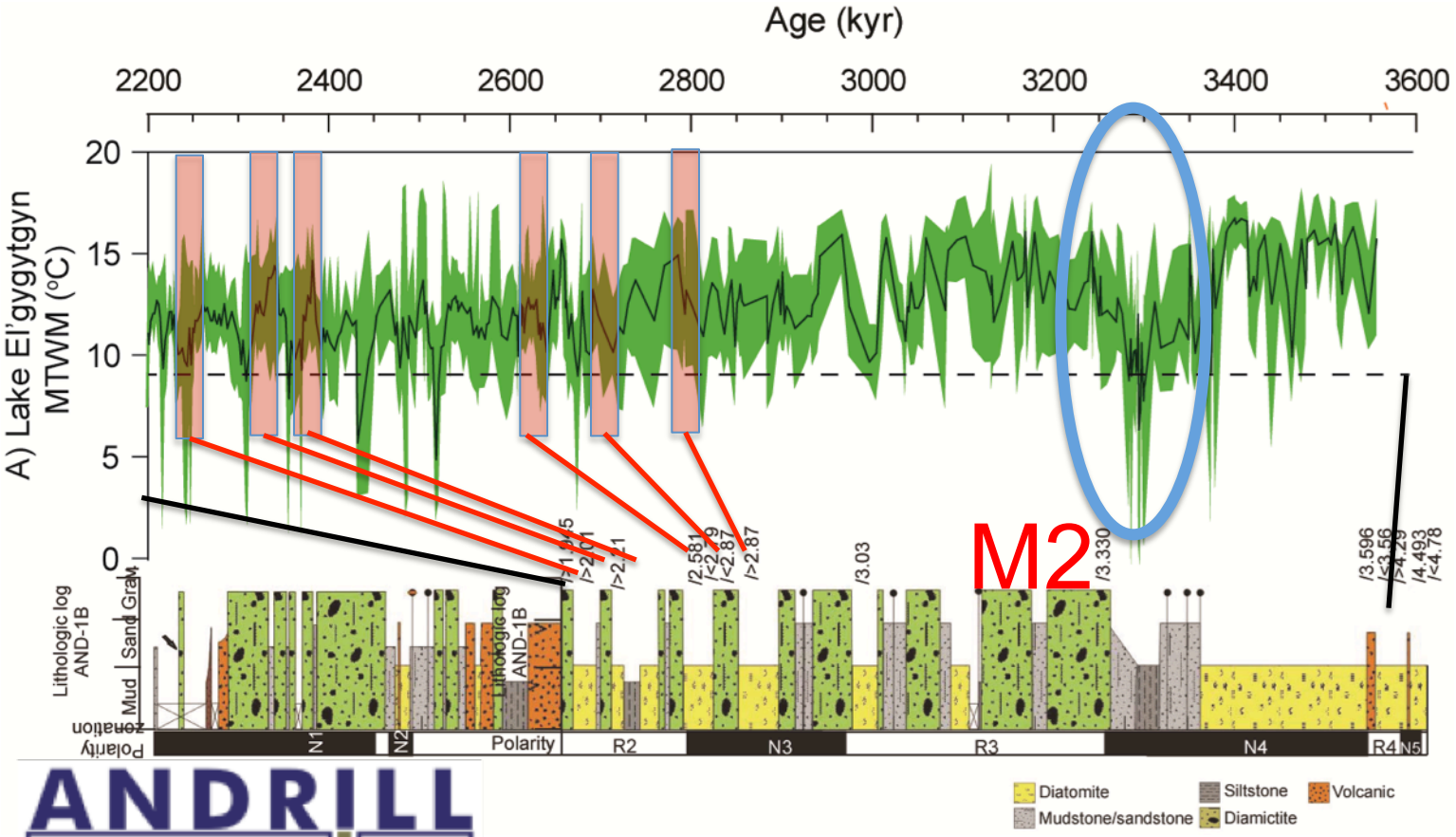
Naish, Powell, Levy, DeConto, and Harwood et al 2009

- ANDRILL(2006-2007) platform on McMurdo Ice Shelf
- Recovered ~1200 m of sediment, ~14 Ma to present
- Best proximal record of ice sheet variations through last few million years



Links between Lake E & Antarctica

- ANDRILL diatomaceous ooze (yellow) suggests the absence of a WAIS
- The first cold snap at 3.3 Ma (the M2 event) occurs **at the same time** the WAIS advances into the Ross Sea after being absent for more than 1.2 Myrs.



At Lake E summer temp remained at levels = to the Early Holocene; **were not glacial in character.**

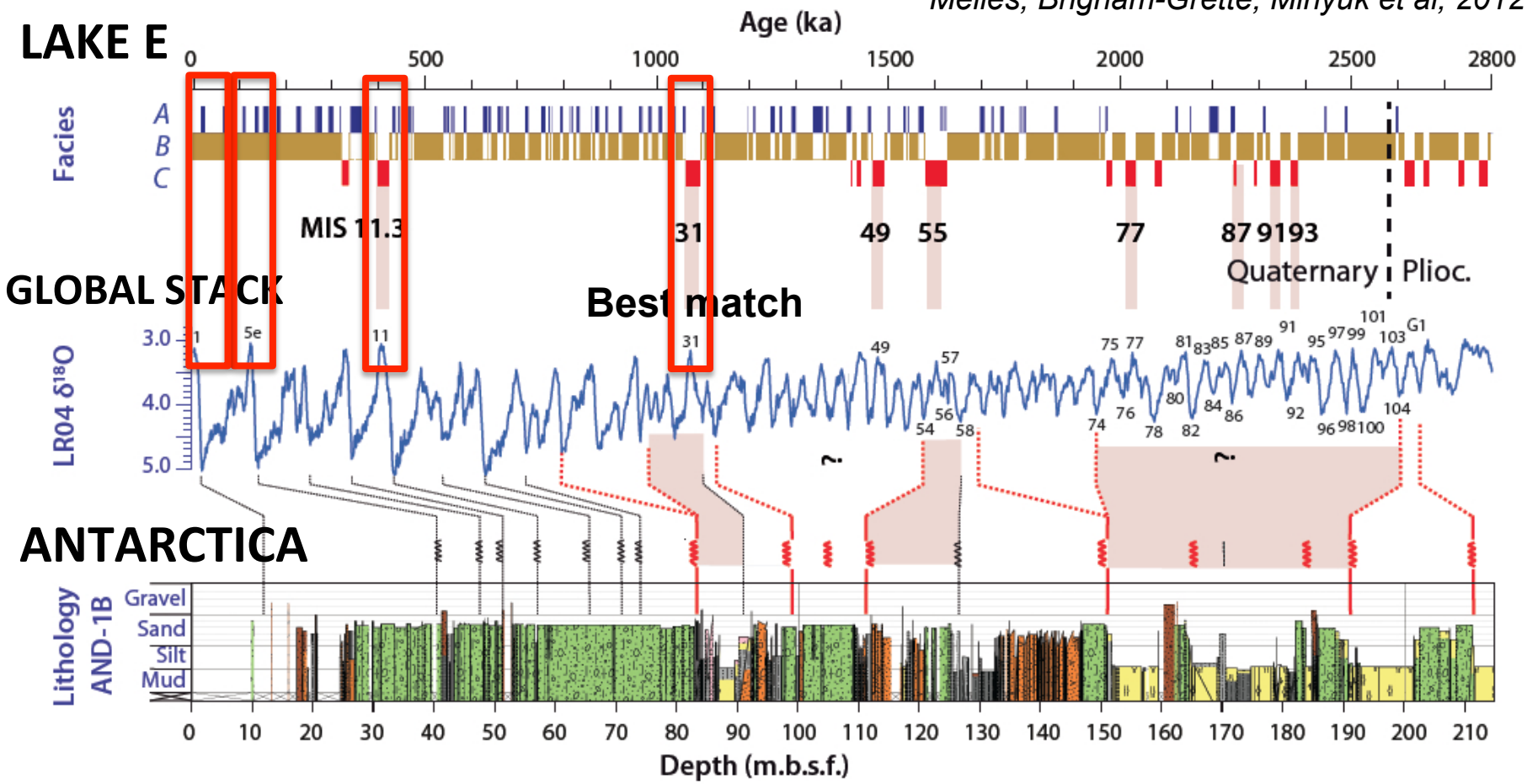
How to match up Super IGs?

Yellow = no ice
Green = ice expansion

Brigham-Grette et al. 2013
McKay et al. 2012 Andrill

~17 Superglacials @ Lake E since 3.2 Ma

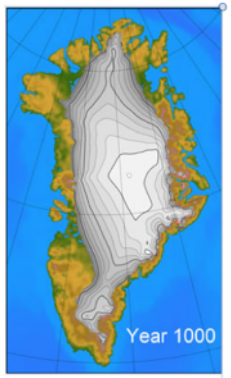
Melles, Brigham-Grette, Minyuk et al, 2012



- It is likely that most of the super interglacials at Lake E occur when **WAIS retreats**.
- Best match in MIS 31: orbitally forced warming in Antarctica was followed by extreme warmth in the Arctic **half a precession cycle later**.

Super interglacial strength important to GIS

Greenland likely smaller during MIS 5e (2-3 m of sea level); even smaller during MIS 11 and 31?

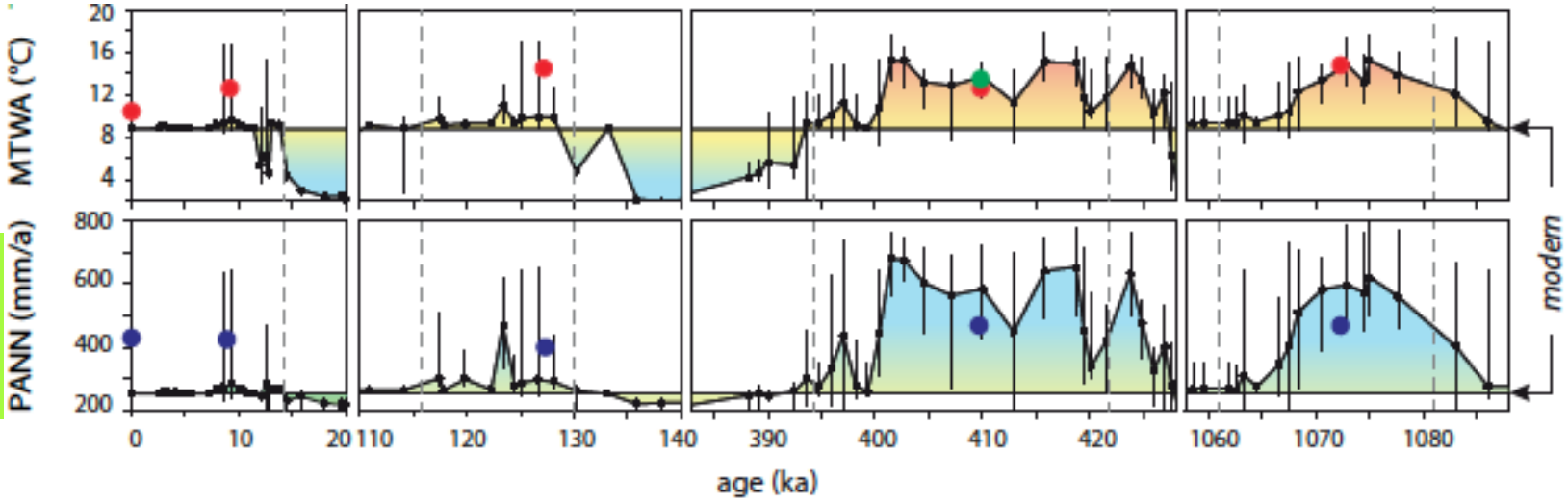


?

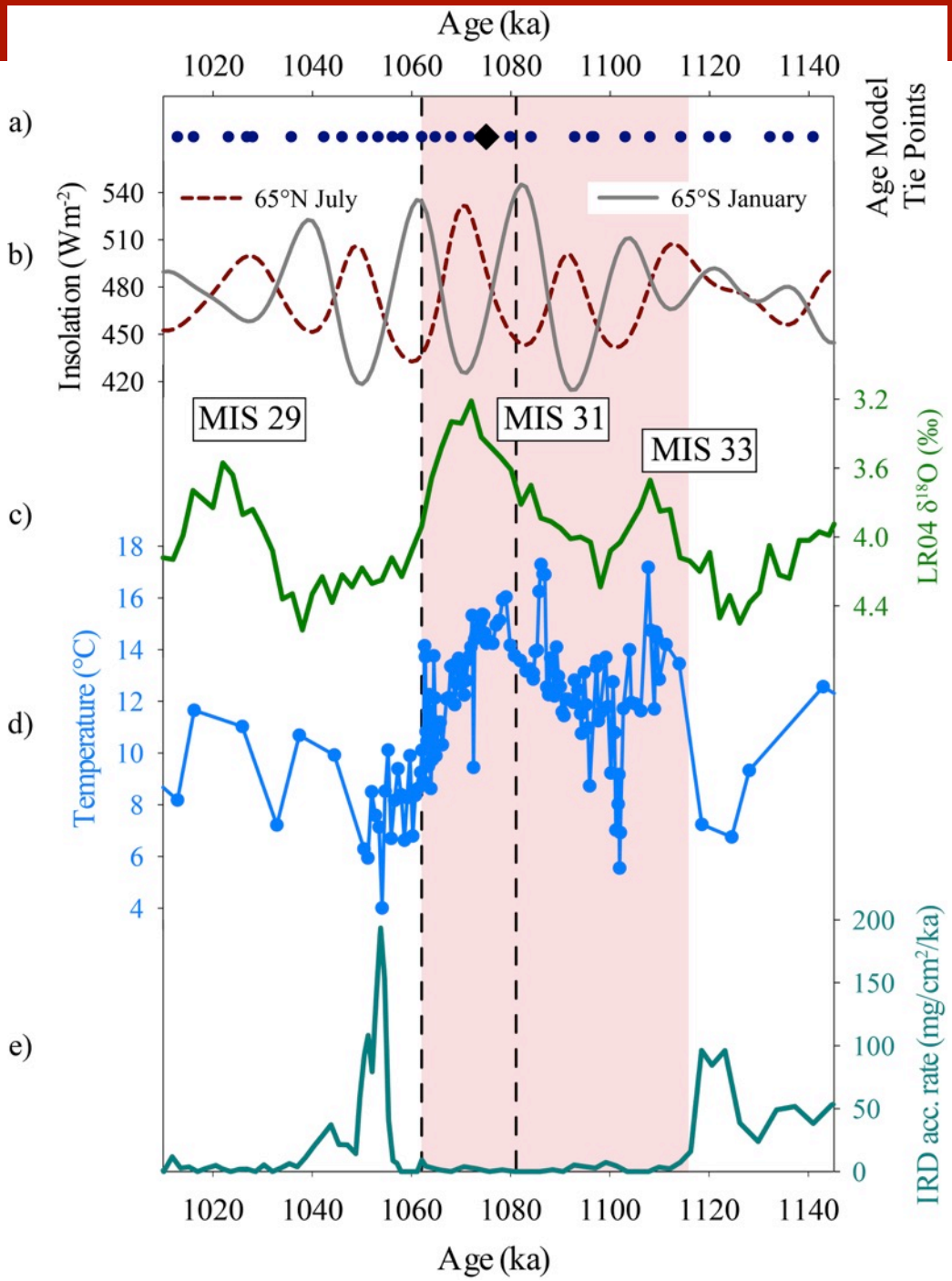
MIS 1 5.5 11 31

July Temp

Mean Annual Precip



Melles, Brigham-Grette, Minyuk et al Science 2012



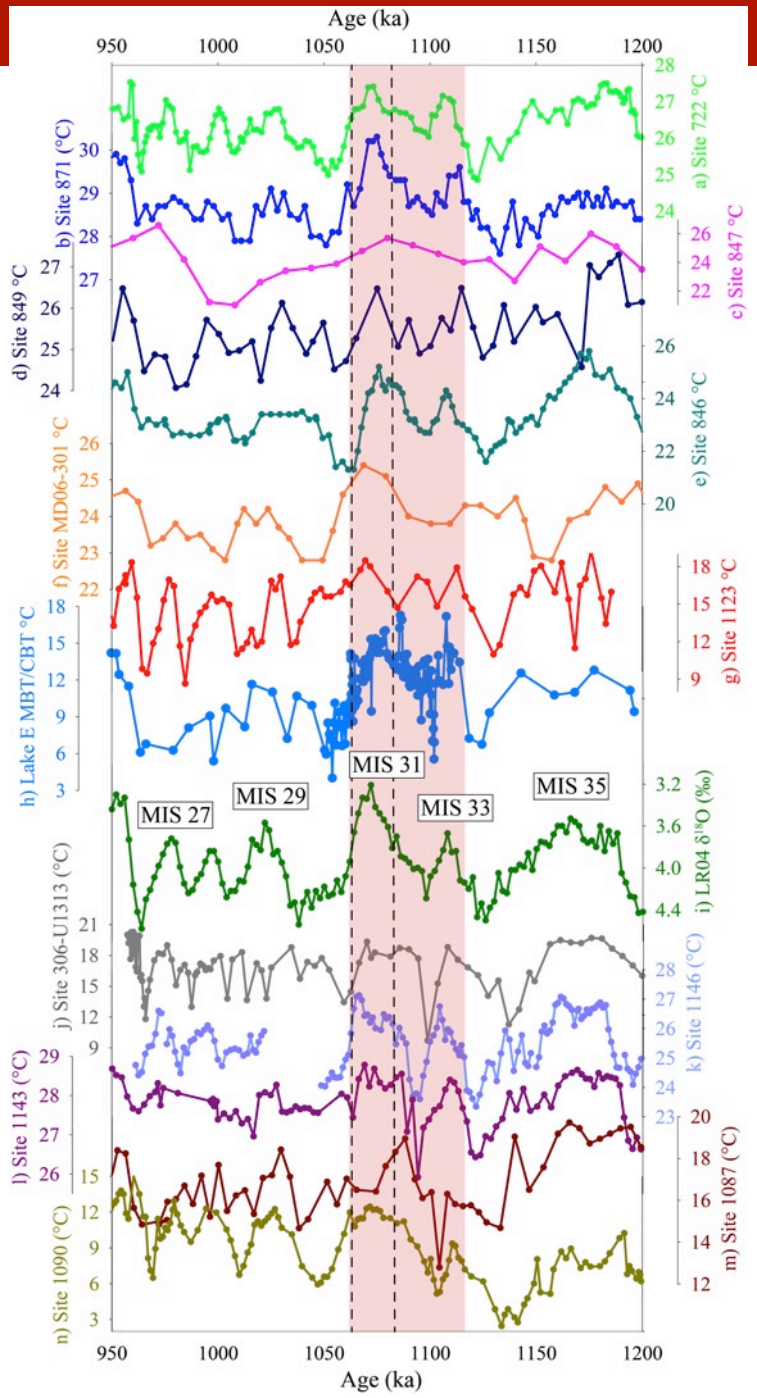
Lake E temperatures during MIS 31

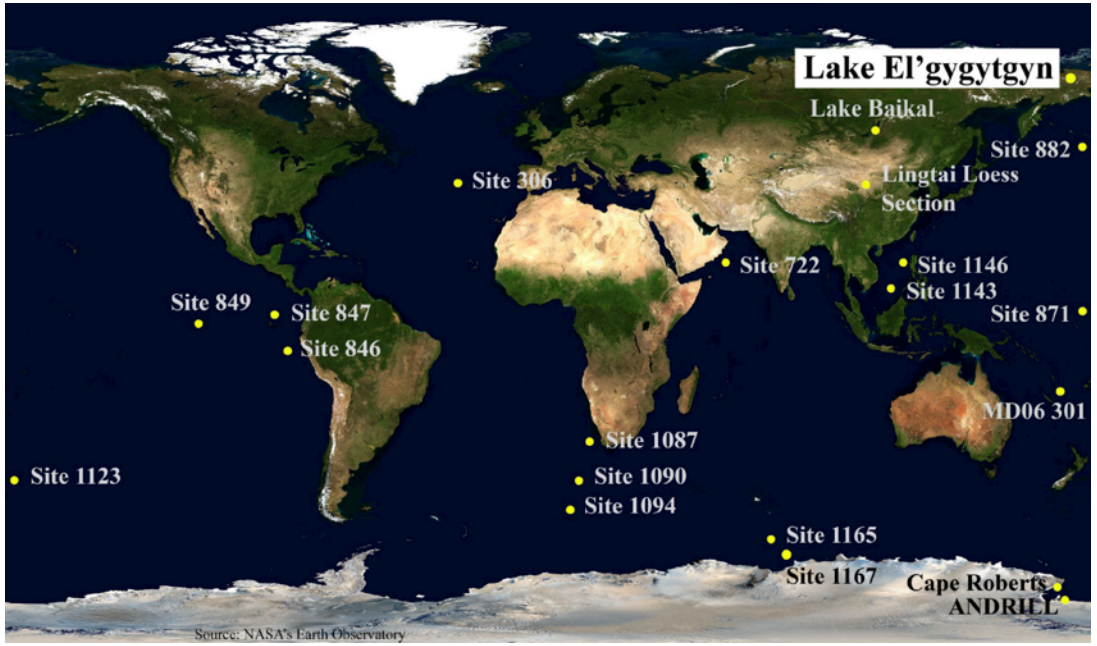
And interglacial variability

No IRD around Antarctica

Teitler et al., 2015

De Wet et al. in press ESPL

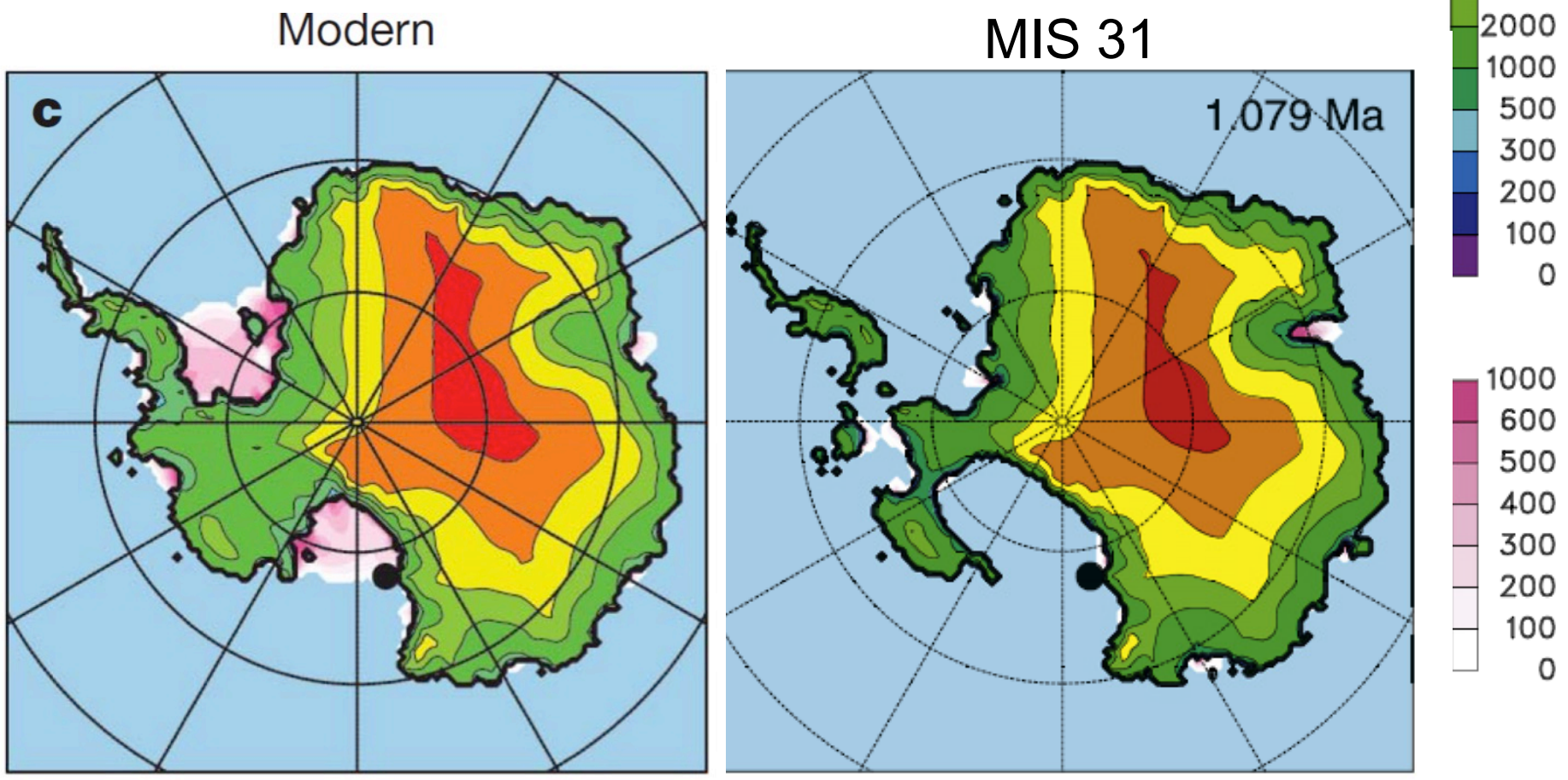




De Wet et al. in press ESPL

MIS 31 (1.1 Ma)

- Proxy evidence for WAIS collapse during MIS 31
- Peak collapse of the West Antarctic Ice Sheet during MIS 31 occurs in phase with peak SH insolation (Deconto et al., 2012)



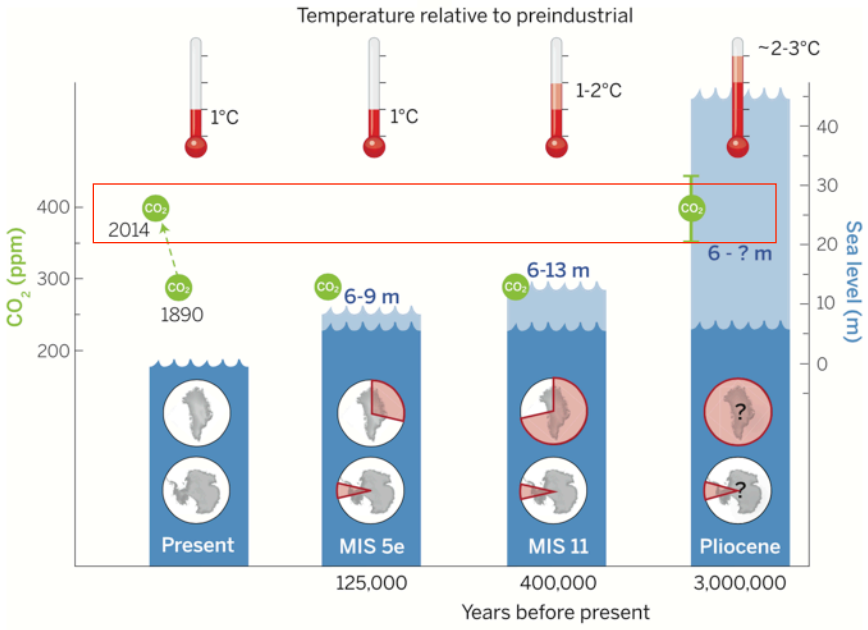
UMASS AMHERST
Geosciences

Antarctic vs. Northern Hemisphere Ice Variability

CLIMATE SYSTEM RESEARCH CENTER

Primary Questions:

- Is the Arctic terrestrial history similar to the global marine record? Yes, and more to learn
- Are their links to Antarctic climate history? Yes



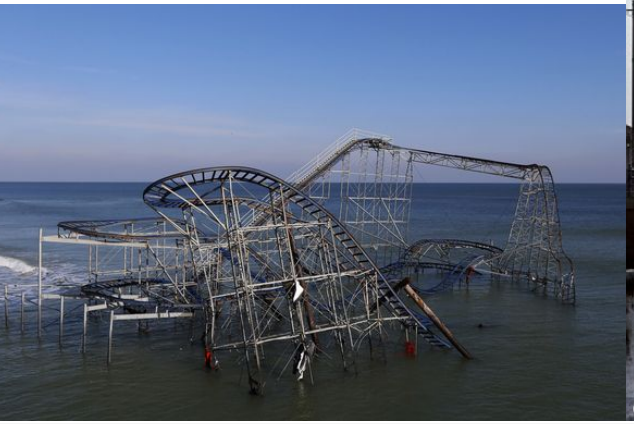
Dutton et al. 2015

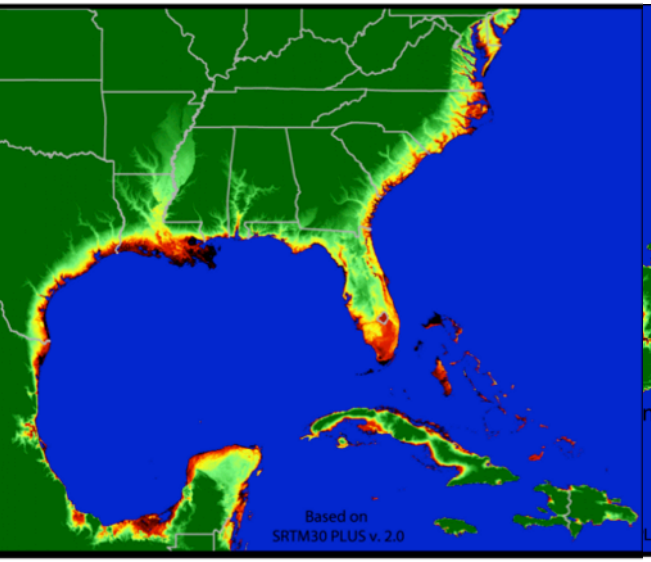
- Despite unconformities in the ANDRILL record, its possible most super interglacials from Lake E record the retreat of WAIS; maybe Greenland?
- Earlier Interglacials inform us of vulnerability of ice sheets to collapse
- Its perhaps easier than we thought.
- CO_2 in our present atmosphere has pushed us in to the “Pliocene world”.

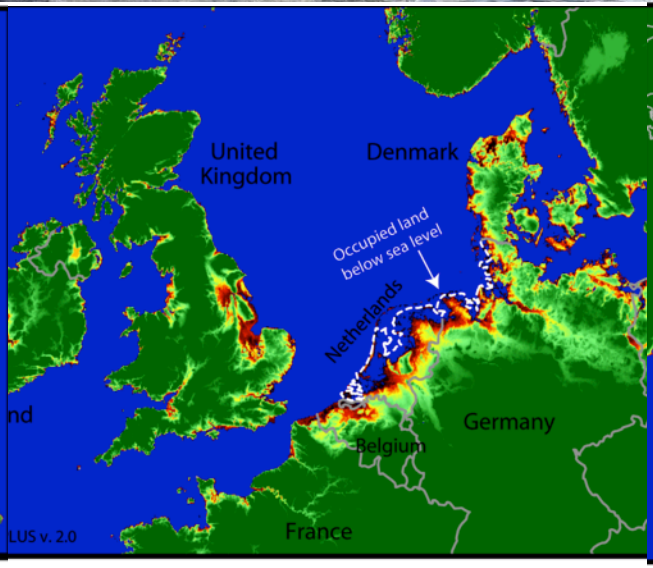
UMASS AMHERST
Geosciences

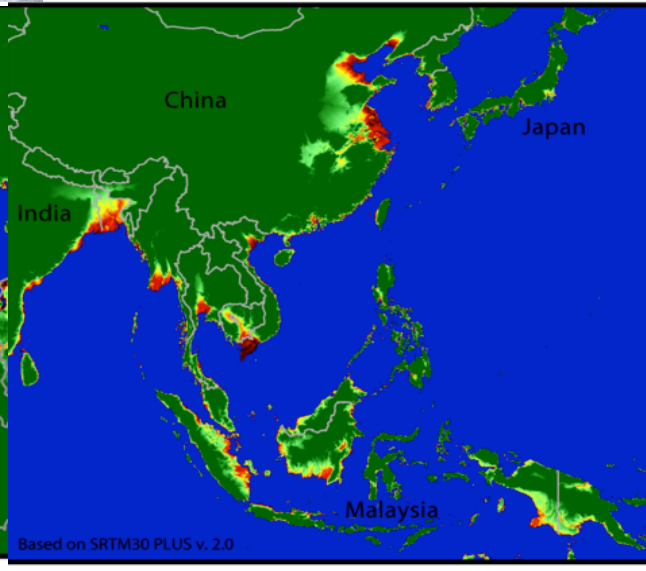
Antarctic vs. Northern Hemisphere Ice Variability

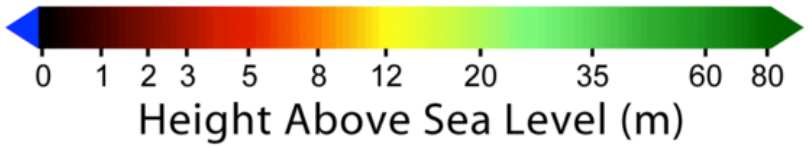
CLIMATE SYSTEM RESEARCH CENTER



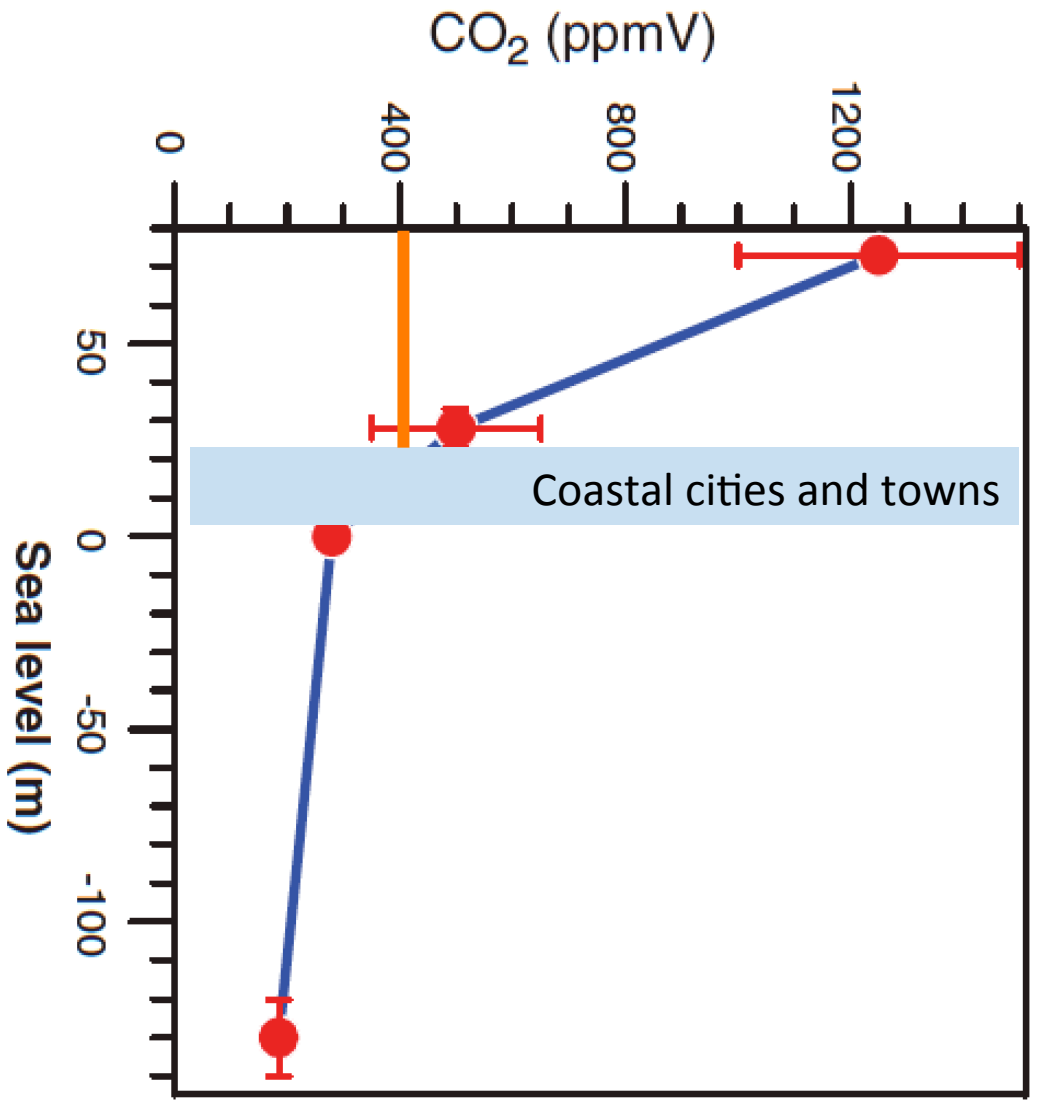








CO_2 and sea level in the past



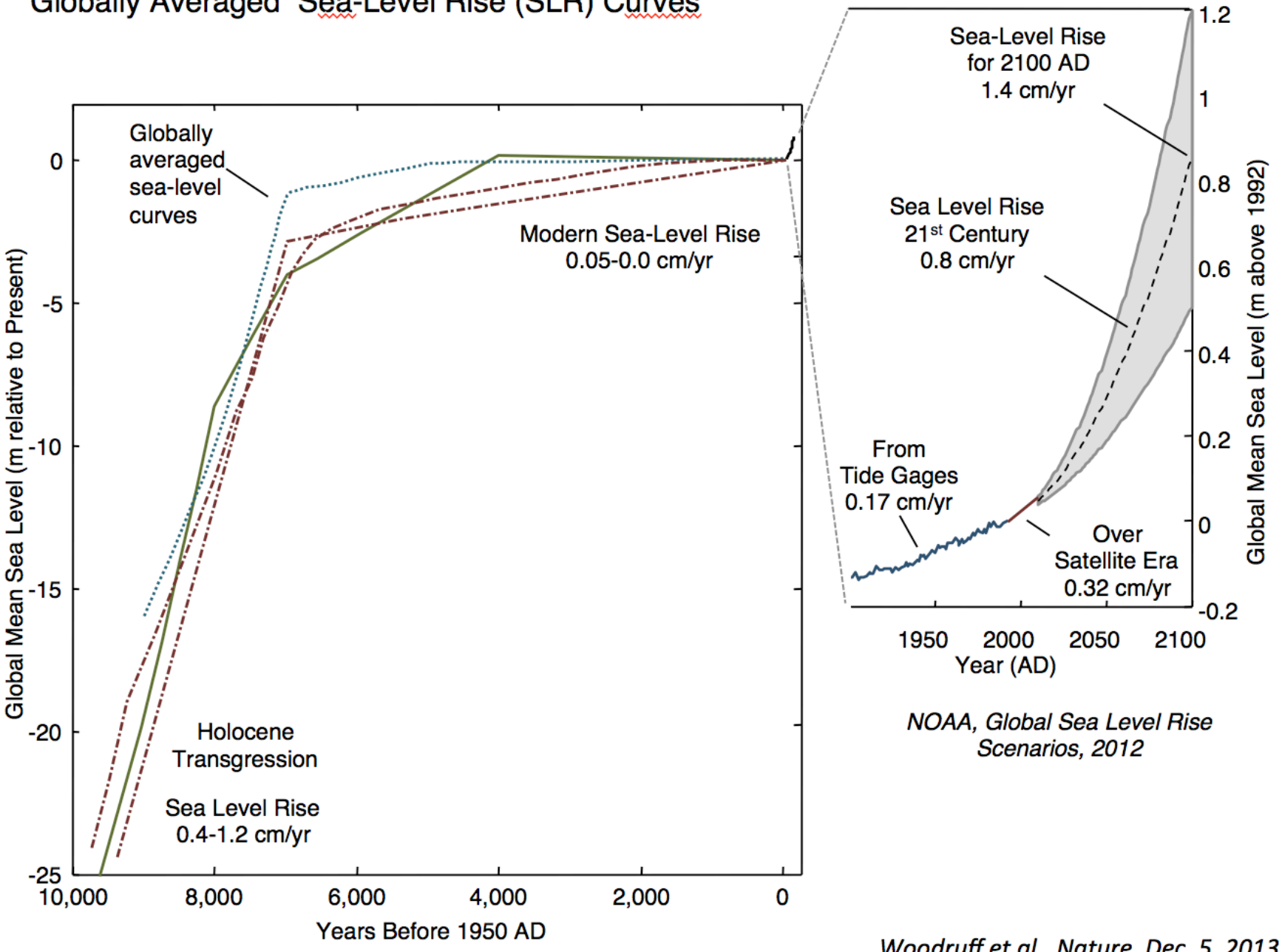
We cannot be complacent given our infrastructure and societies at risk.

Alley et al. 2005, Science

“THERE IS SUCH A THING AS BEING **TOO LATE.** AND WHEN IT COMES TO **CLIMATE CHANGE,** THAT **HOUR IS ALMOST UPON US.**”

President Obama
Anchorage AK
August 2015

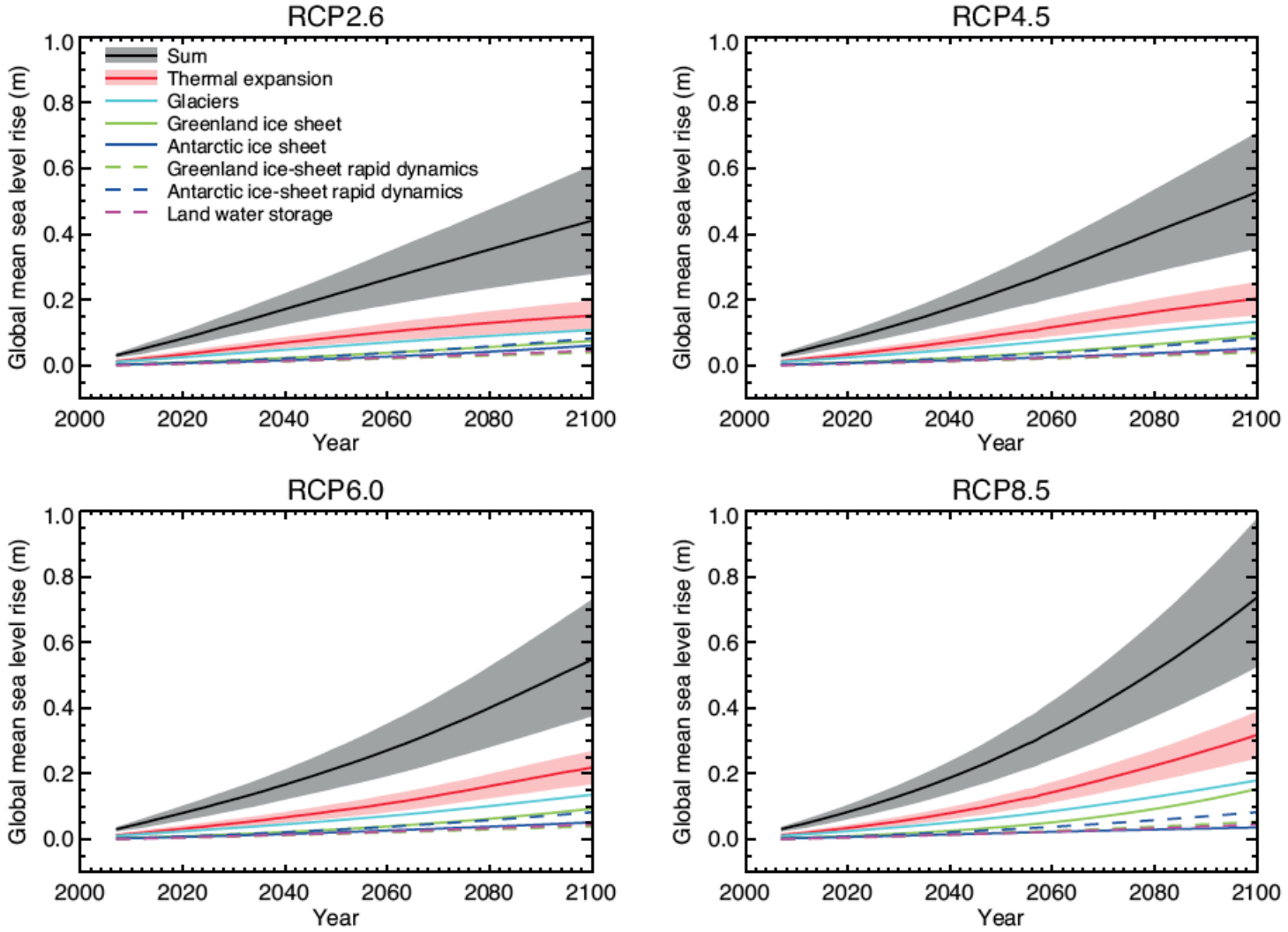
Globally Averaged Sea-Level Rise (SLR) Curves



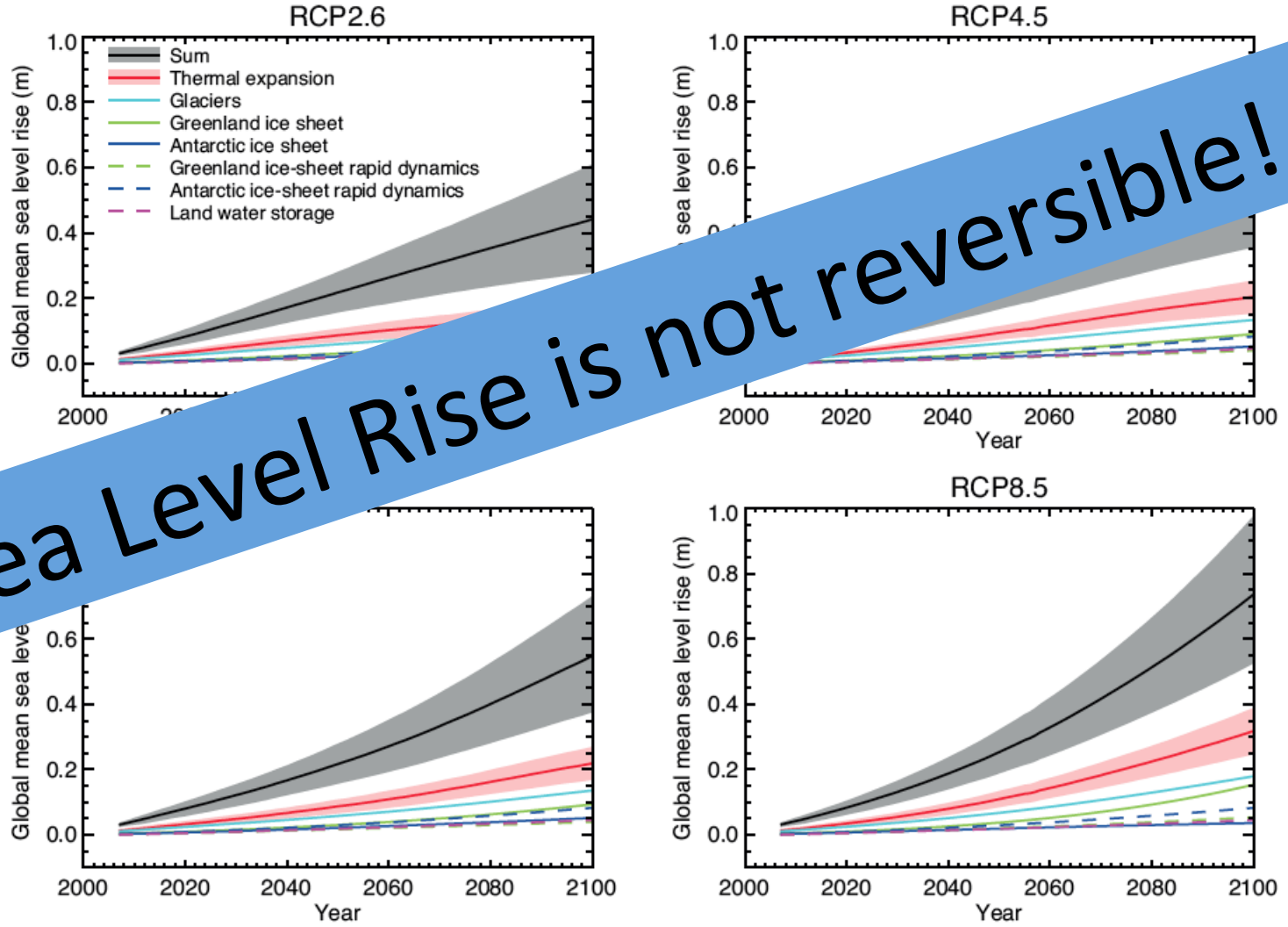
NOAA, Global Sea Level Rise Scenarios, 2012

Woodruff et al., Nature, Dec. 5, 2013

To understand the future, we need to understand the past.
Paleoclimate data and new models say
IPCC estimates too conservative



To understand the future, we need to understand the past.
Paleoclimate data and new models say
IPCC estimates too conservative



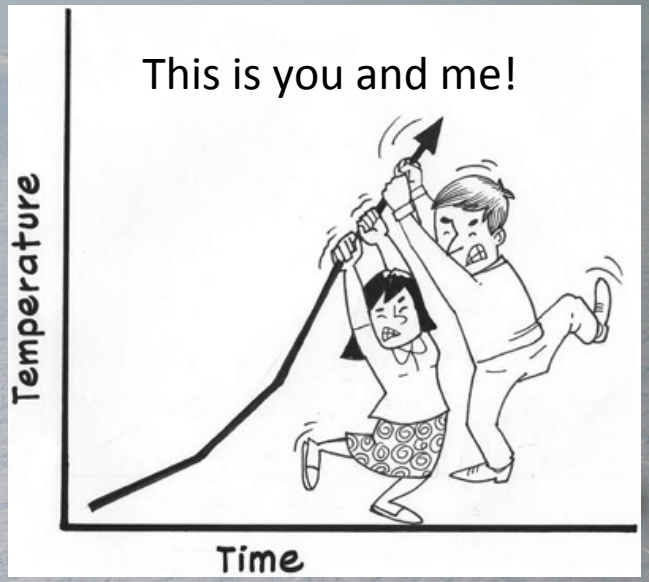
“I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.”

“I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.”

- Thomas Edison, speaking with Henry Ford & Harvey Firestone, 1931

If we don't change the direction we are headed, we will end up where we are going!

Chinese proverb



Thank you !

UMASS AMHERST

CLIMATE SYSTEM RESEARCH CENTER

Thank You!

- Questions? Please type your question into the Question "?" window.
- Please join us for our next seminar on 18 February: "Crazy Weather and the Arctic Meltdown: Are They Connected?" by Jennifer Francis.
- An archive of this presentation will be available online at https://www.arcus.org/research-seminar-series