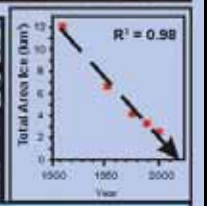
Quelccaya
Ice Cap
Peru

Qori Kalis Glacier, Peru



Kilimanjaro
Africa

Dasuopu
Chinese
Himalaya

South Pole Station

Evidence from Observations of Glaciers and Ice Sheets

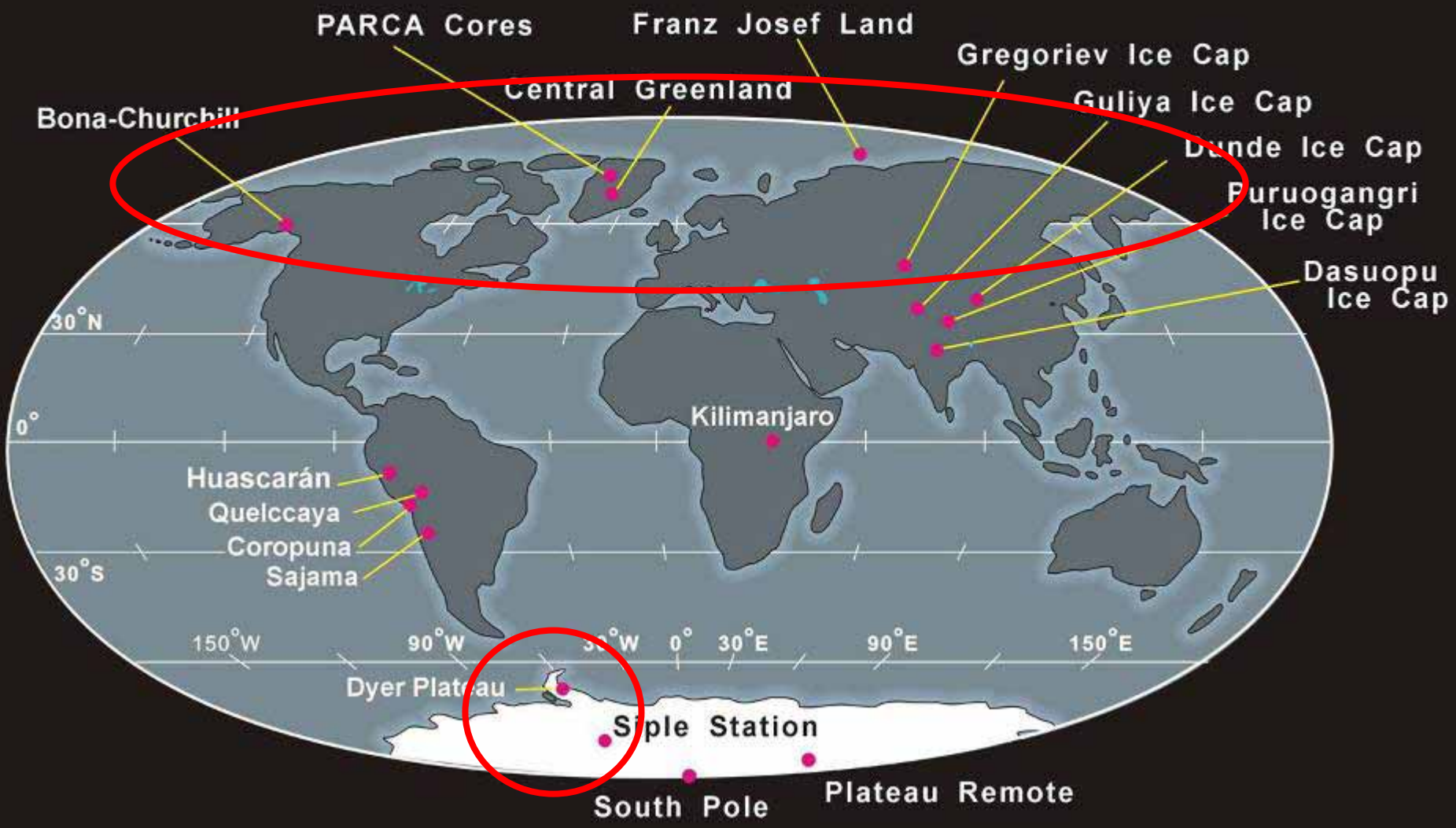
Lonnie G. Thompson
University Distinguished Professor
School of Earth Sciences & Byrd Polar Research Center
The Ohio State University

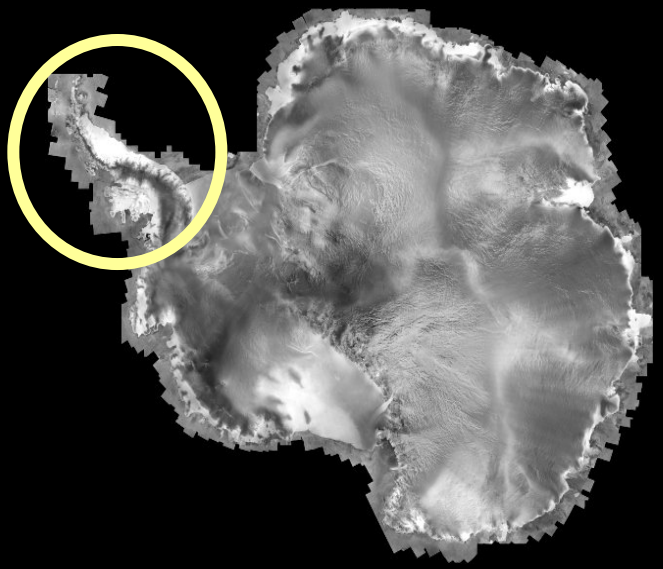
Ice Core Paleoclimate Research Group
Ellen Mosley-Thompson
Henry Brecher
Mary Davis
YC Fang
Sangsuk Lee
Ping-Nan Lin
Victor Zagorodnov

Funding provided by:
NSF: Climate Dynamics and Polar Programs
NASA: Earth Sciences
NOAA: Paleoclimatology
Comer Foundation

Graduate Students: **Liz Birkos, Aron Buffen, Natalie Kehrwald, David Urmann, Lijia Wei**

Areas where the Earth is warming most rapidly at this time

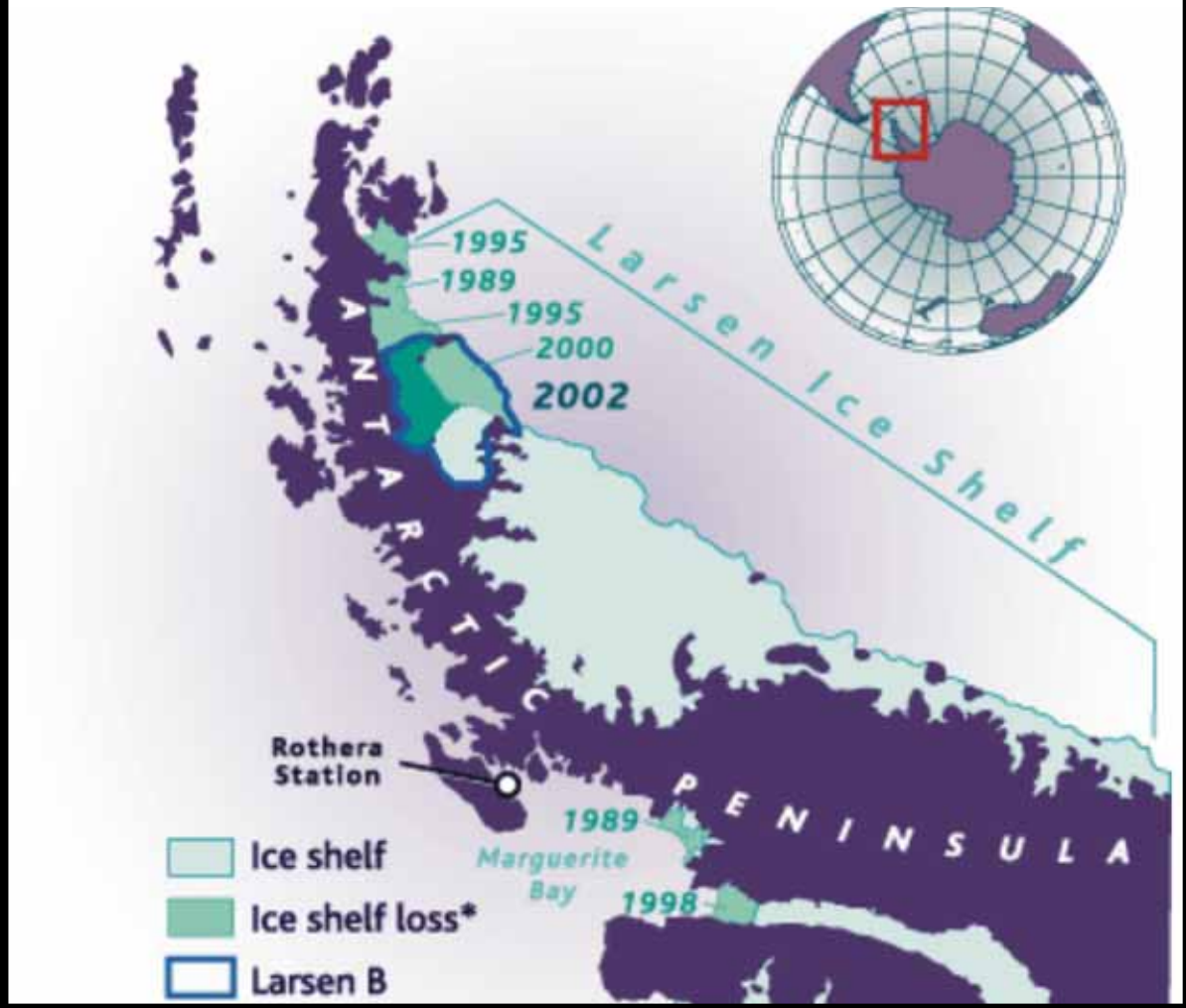




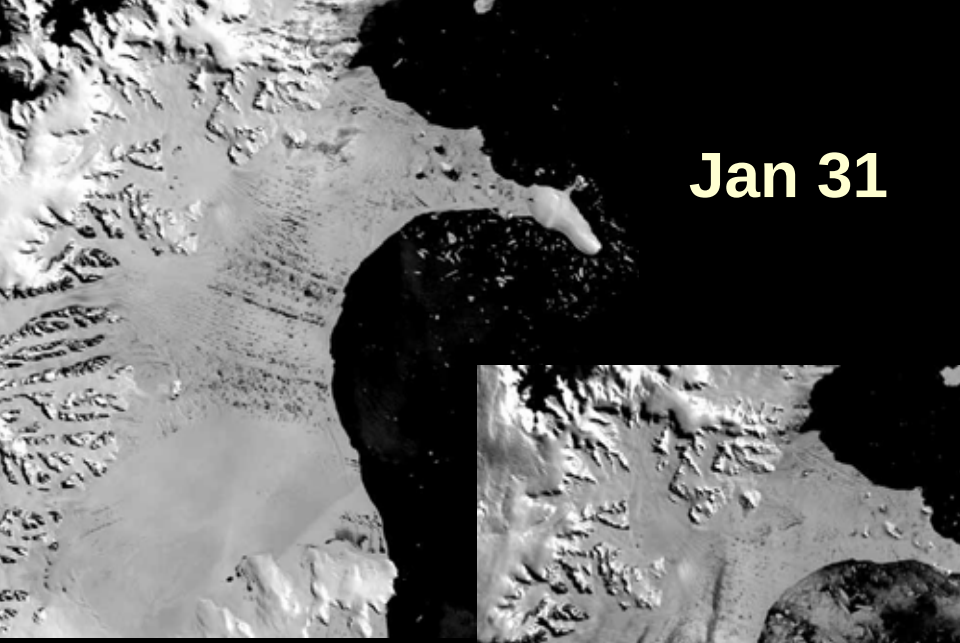
•Earth's cold regions and their icy cover are well documented <u>indicators</u> of climate change

•High latitude/elevation processes are important <u>drivers</u> in climate change

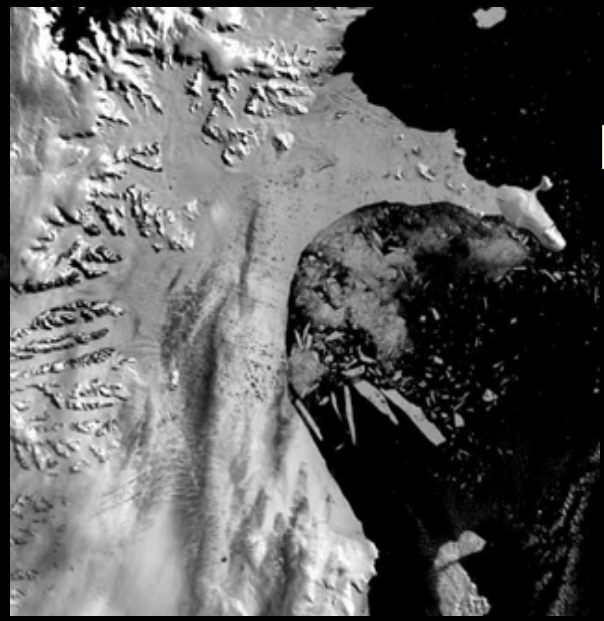
Temperatures in the Peninsula region have warmed ~2.0°C in the last 50 years.



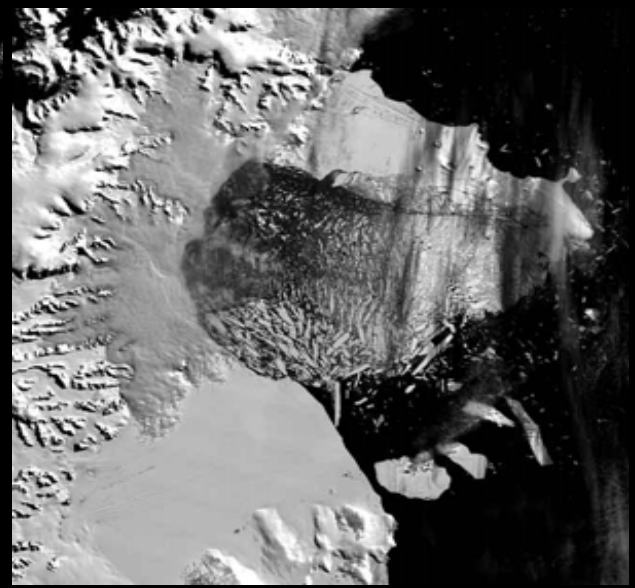
Part of the Larsen B Ice Shelf collapsed in 31 days (2002)



Jan 31



Feb 23



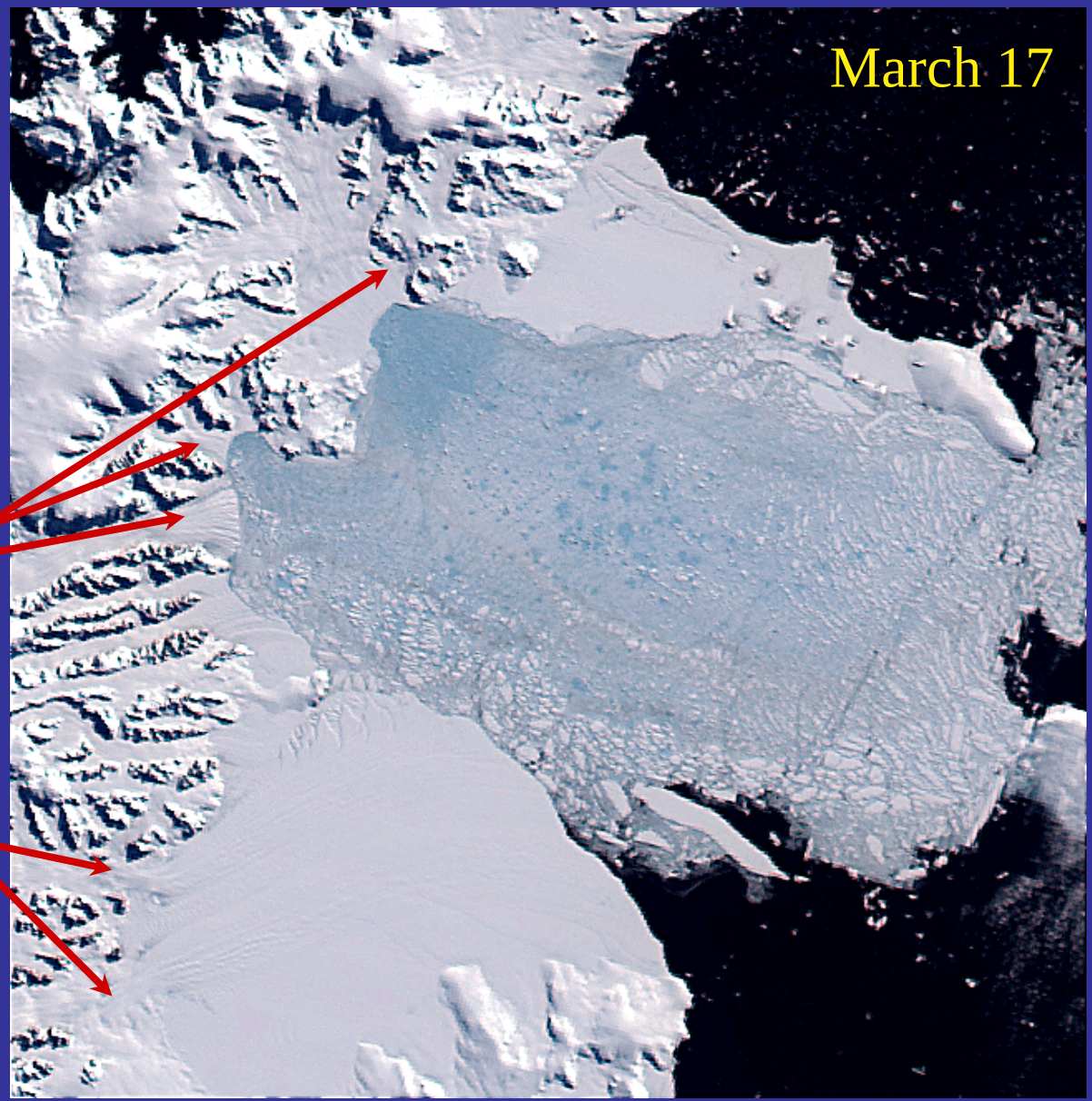
Mar 3

Ice Shelves and the Buttressing Effect

Collapsing ice shelves don't directly raise sea level, but…

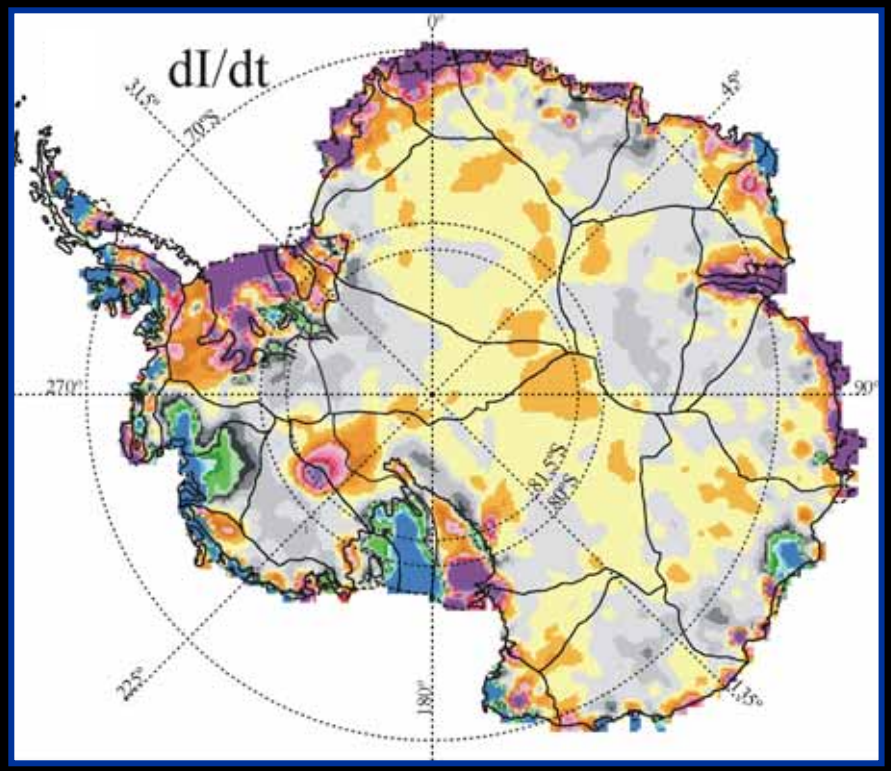
- **Increase in flow speed up to 8-fold**
- **Thinning by as much as 40 m in six months**

- **Glaciers that fed the remaining parts of the ice shelf did not accelerate**

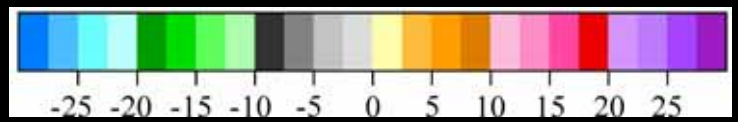


Ted Scambos, NSIDC

Antarctic Ice Sheet Elevation



Ice Thickness Change From Altimetry

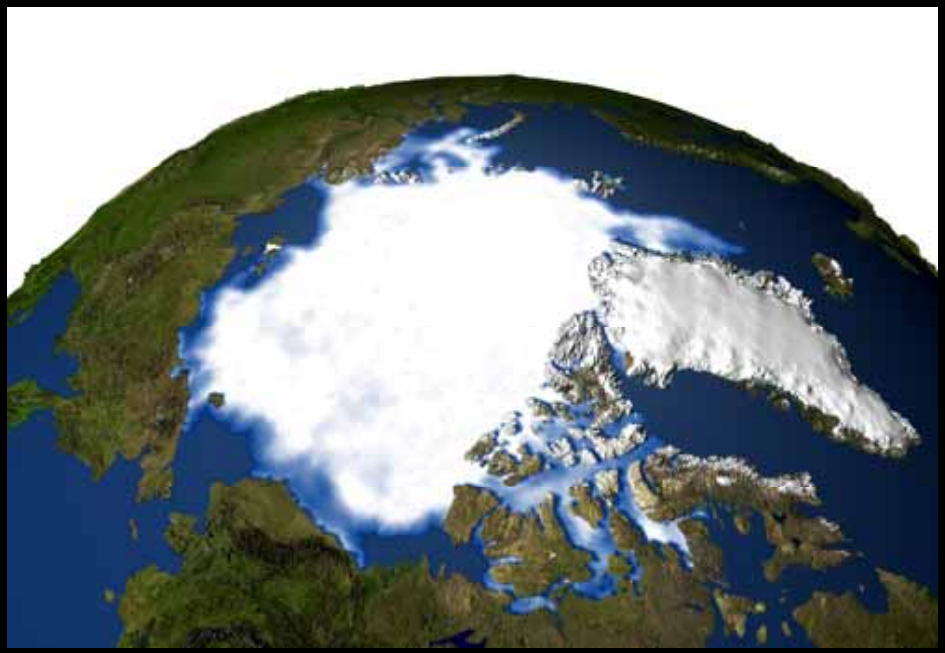


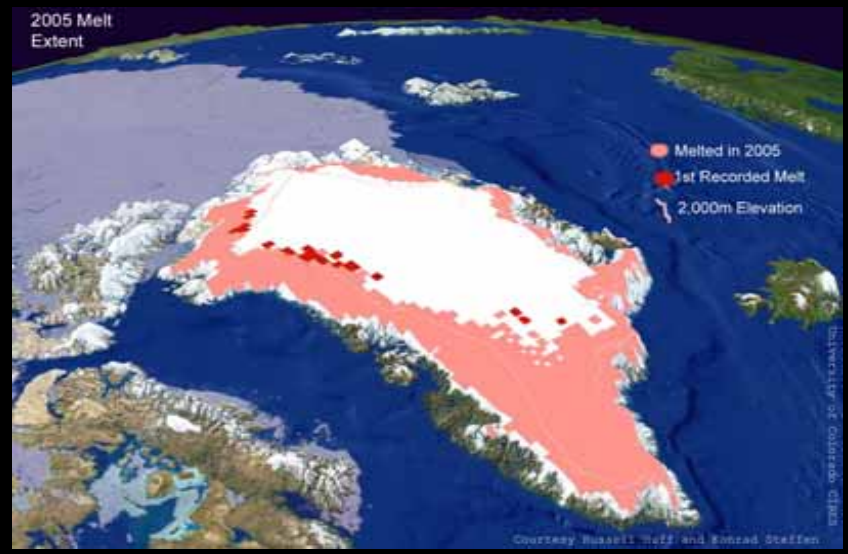
(cm/yr)

Zwally et al. 2005

- **Altimeter data indicate East Antarctic thickening with increased snowfall and surface cooling**
- **Locally, Pine Island and Thwaites Glaciers *Thinning* (0.75-2.5 ma-1; Wingham) and *Accelerating***
- **GRACE 2002-2005: Ice sheet mass decrease at a rate of 152 ± 80 km3/year of ice, equivalent to 0.4 ± 0.2 mm/year of global sea level rise. Much larger than balance calculation (Velicogna and Wahr, 2006)**

The Greenland Ice Sheet



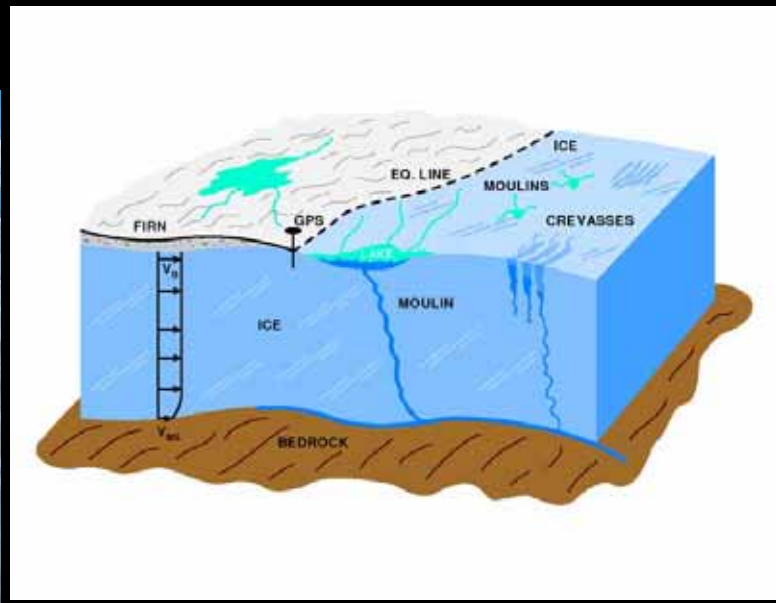


- 7 m sea level equivalent
- Unlike Antarctica, experiences substantial surface melt in the summer time over much of its area
- Rimmed by outlet glaciers with some floating ice tongues; ice shelves are absent

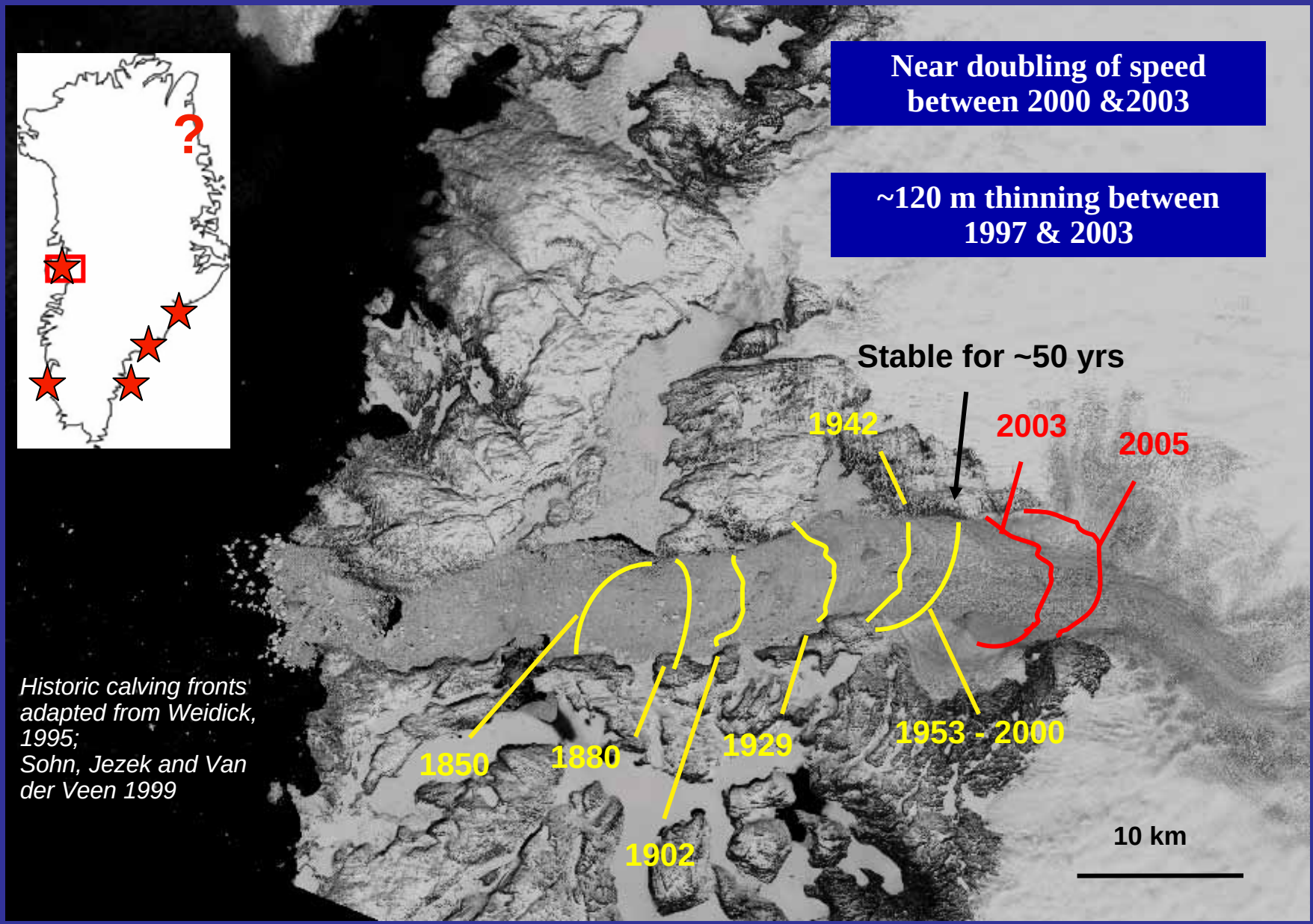
The warming in the Arctic is now well-documented …..
Arctic Climate Impact Assessment
available at http://www.acia.uaf.edu/

East Greenland: summer melt water running into a moulin

Photo by Roger J. Braithwaite

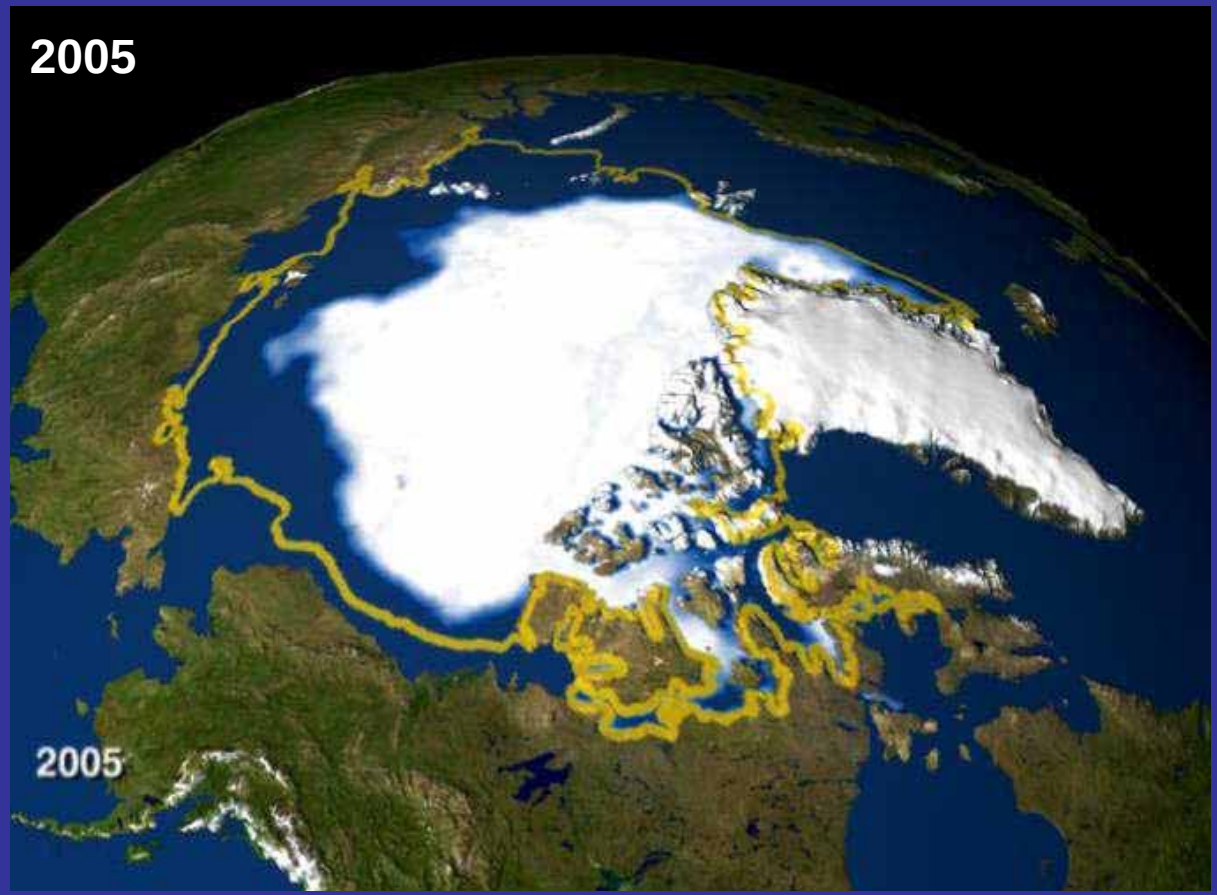


Retreat of the Jakobshavn Ice Stream



Perennial Sea Ice Cover

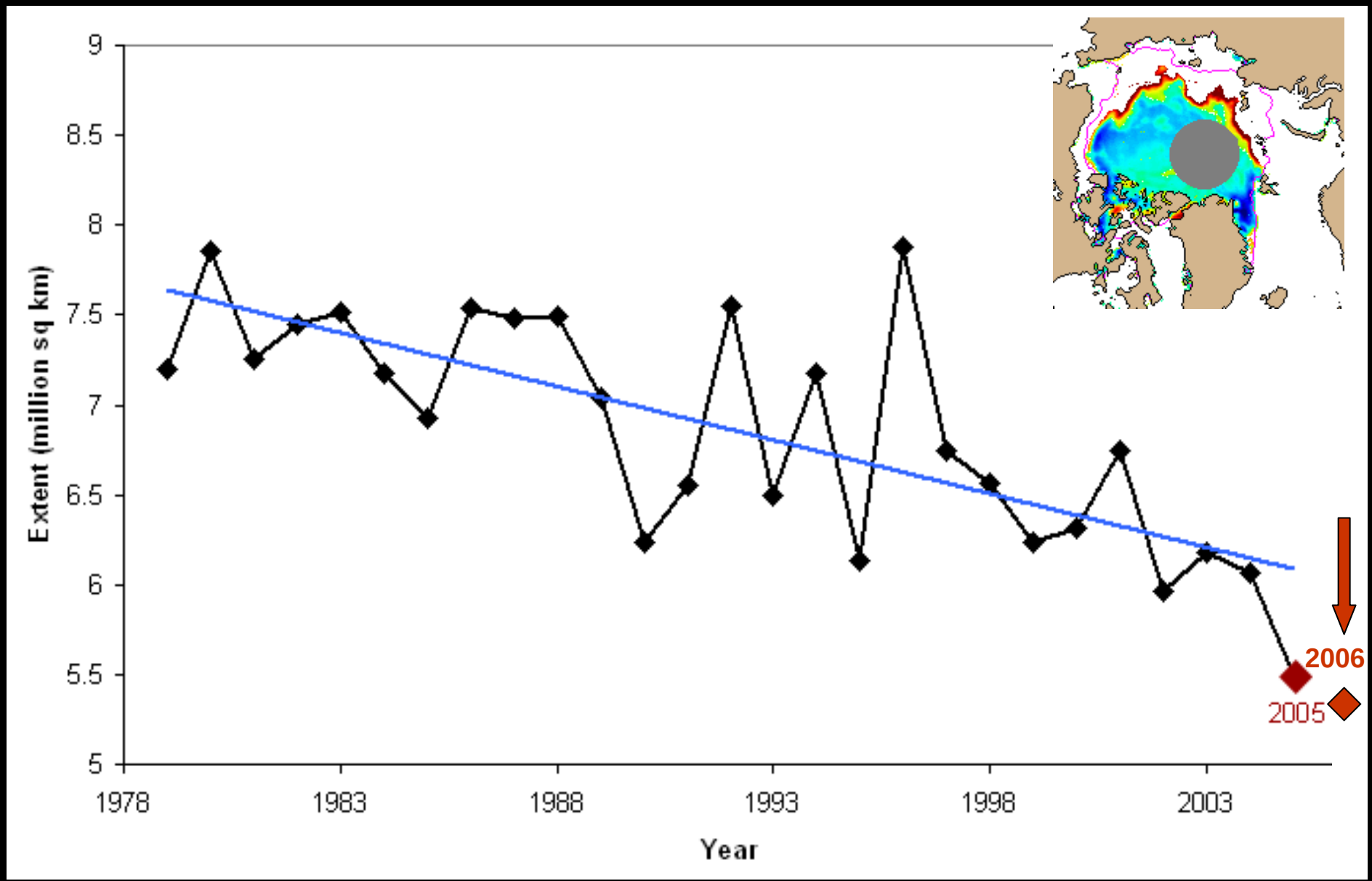
- Significant reduction in perennial sea ice cover over the last 25 years (10% per decade)
- When replaced, it is with younger thinner ice
- Submarine data indicate 40% thinner ice than in the several decades before the mid-1990s



Yellow Line is the 1979-2004 average

Source: GSFC Scientific Visualization Studio and J. Comiso

Arctic Sea Ice Decline Intensifies



September 28, 2005

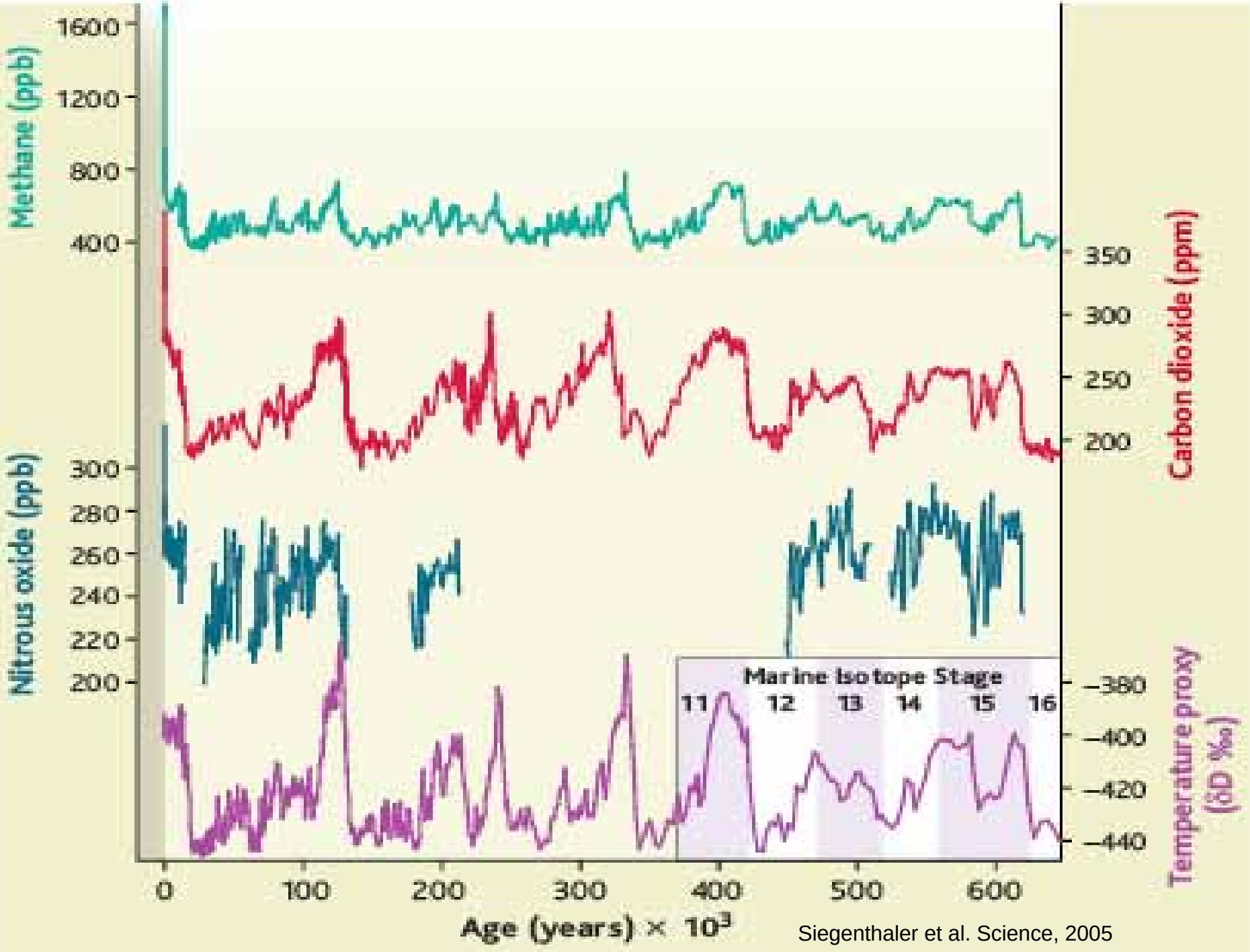
Earth's ice sheets and glaciers preserve long, high resolution histories

1977
Quelccaya Ice Cap, Peru

High temporal resolution

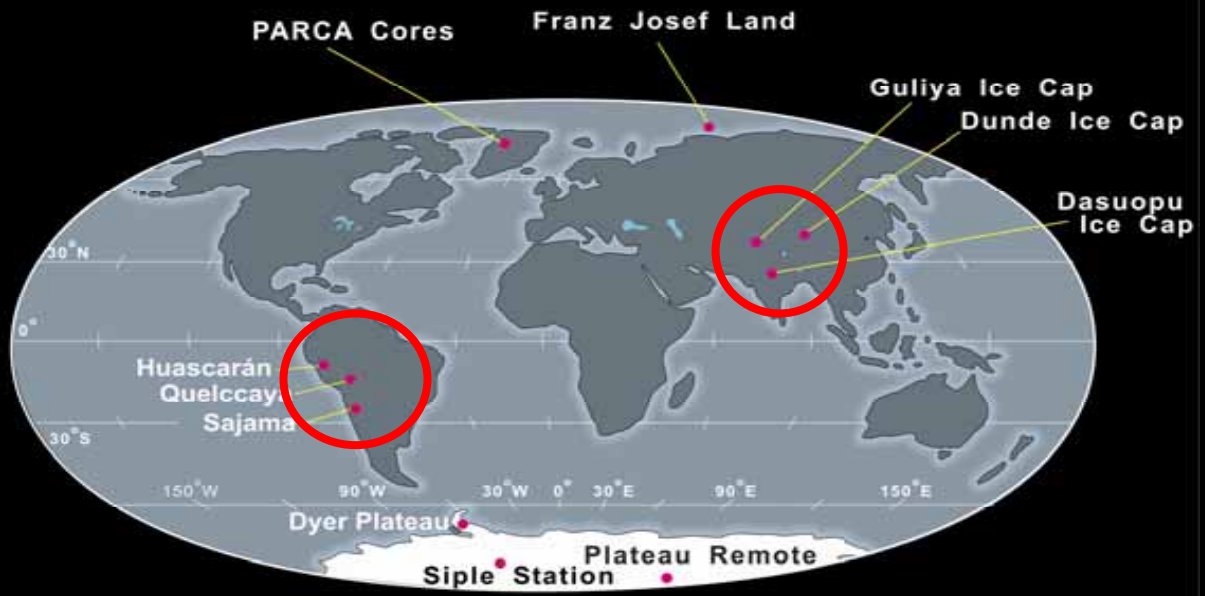
East Antarctica Plateau

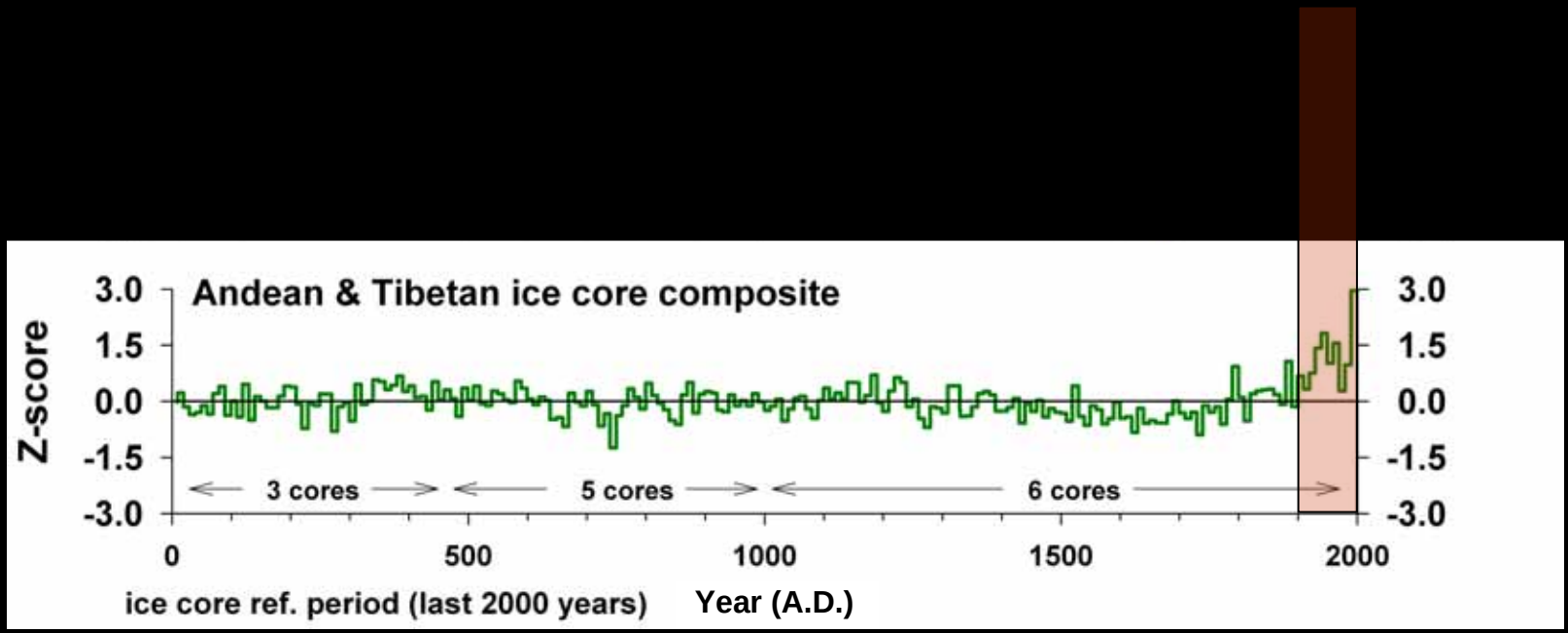
Long records



Siegenthaler et al. Science, 2005

High elevation, low latitude ice cores record large-scale climate changes





Thompson *et al.*, *Climatic Change*, 2003, *PNAS*, 2006

McCall Glacier Brooks Range, Alaska

Austin Post,1958

Matt Nolan, 2003

Muir Glacier, SE Alaska

August, 1941 (photo by William Field)

August, 2004 (photo by Bruce Molnia)

Photos: Koji Fujita

Glacier National Park, Grinnel Glacier

Photo: Fred Kiser, Glacier National Park archives

Photo: Karen Holzer, US Geological Survey

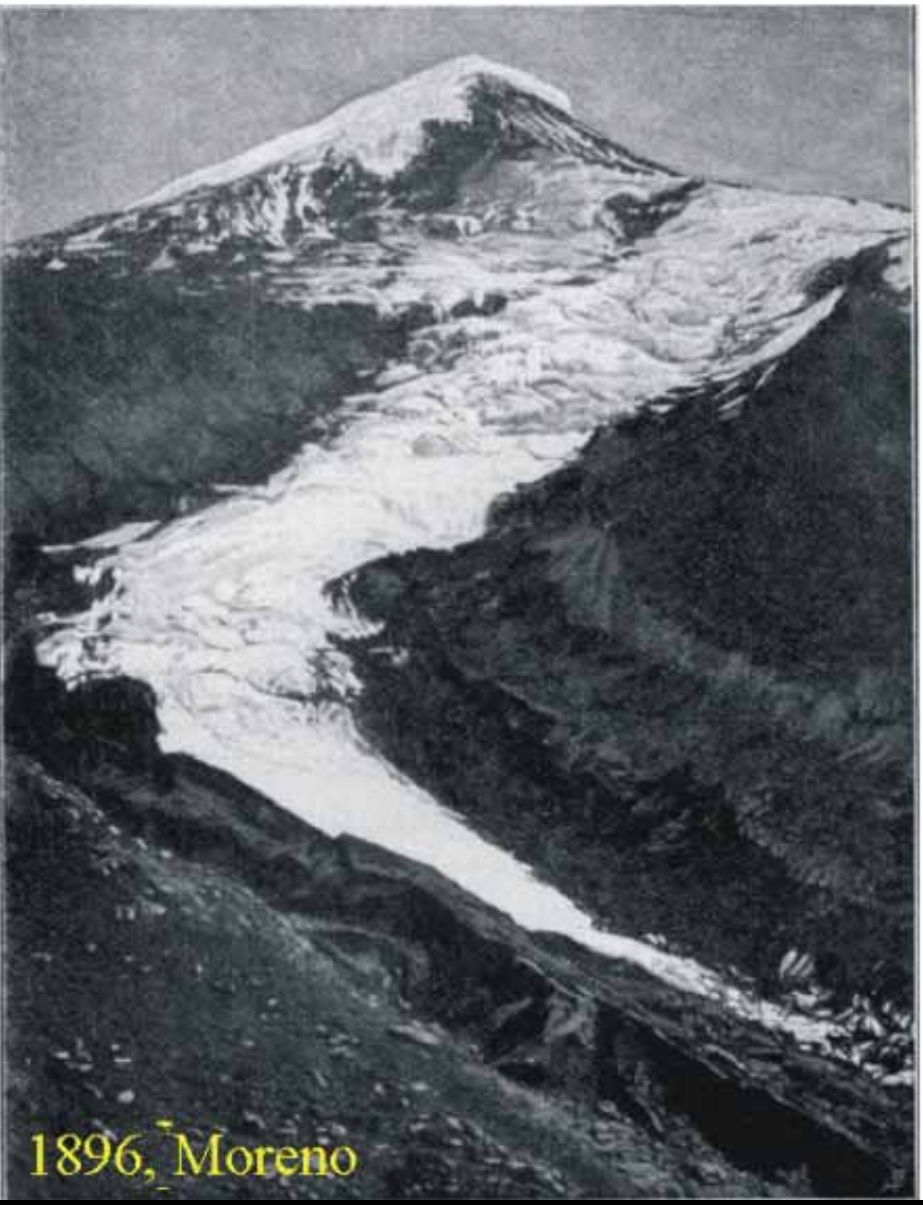
Glacier National Park, Boulder Glacier

Photo: George Grant, Glacier National Park archives

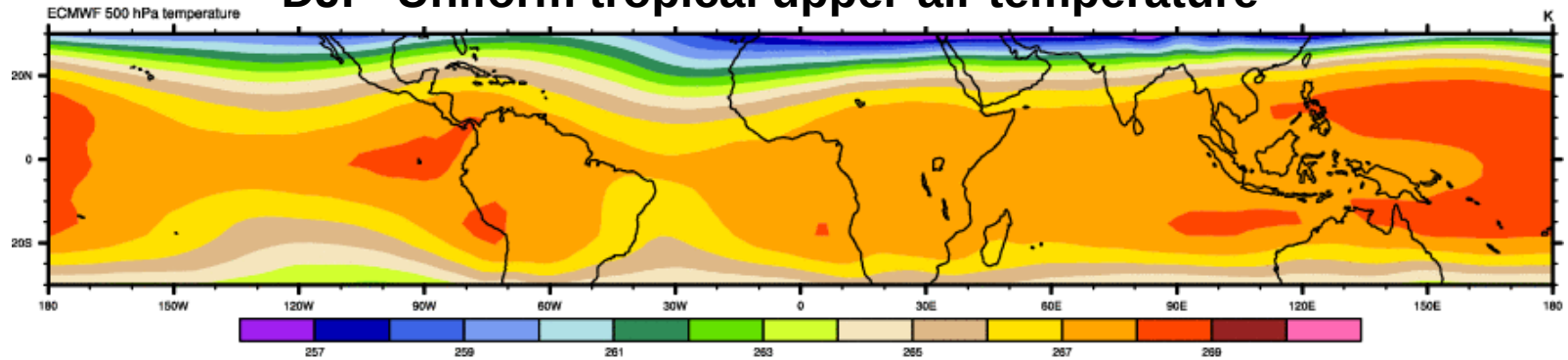
Photo: Jerry DeSanto, National Park Service

Source: *BioScience*, Vol. 53 No. 2, Feb 2003

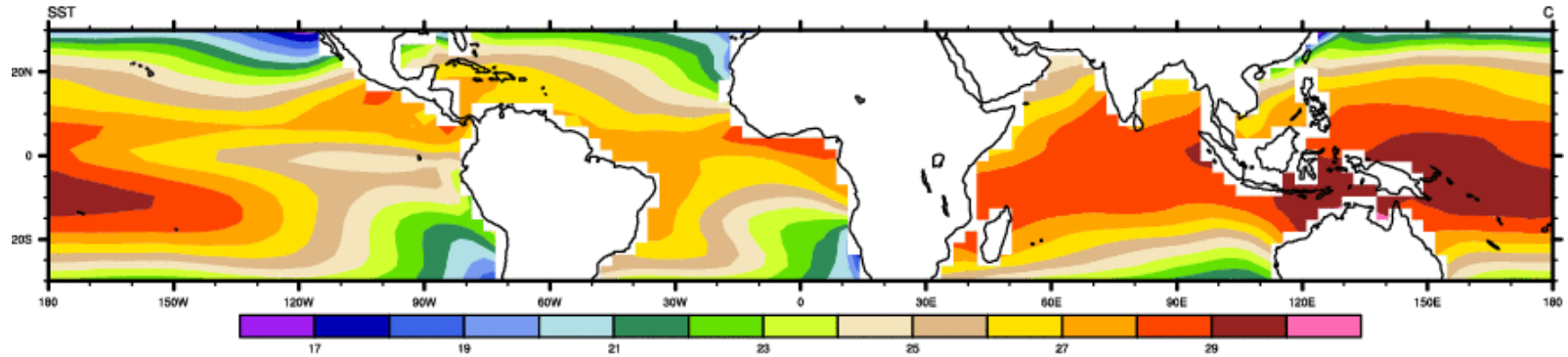
Glaciar Lanín Norte



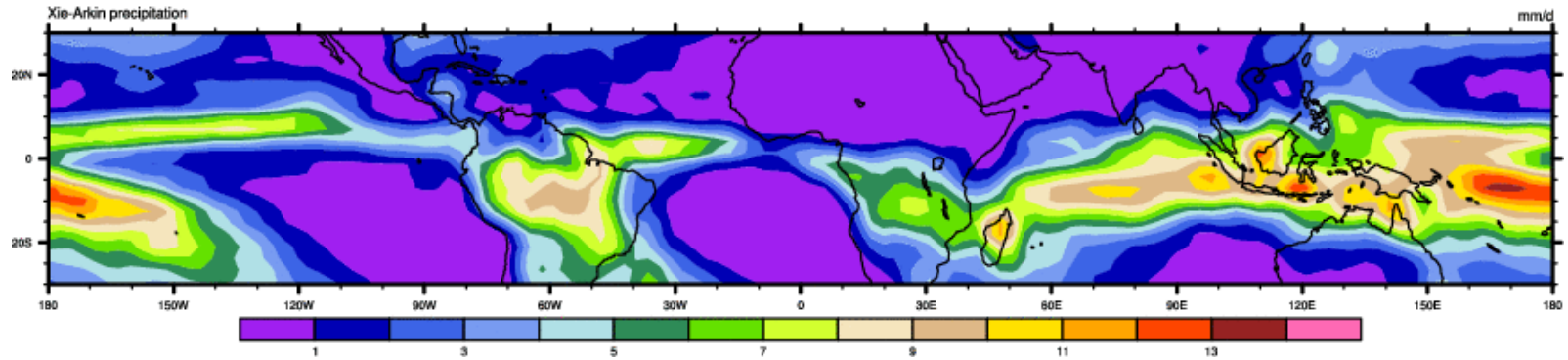
DJF Uniform tropical upper-air temperature



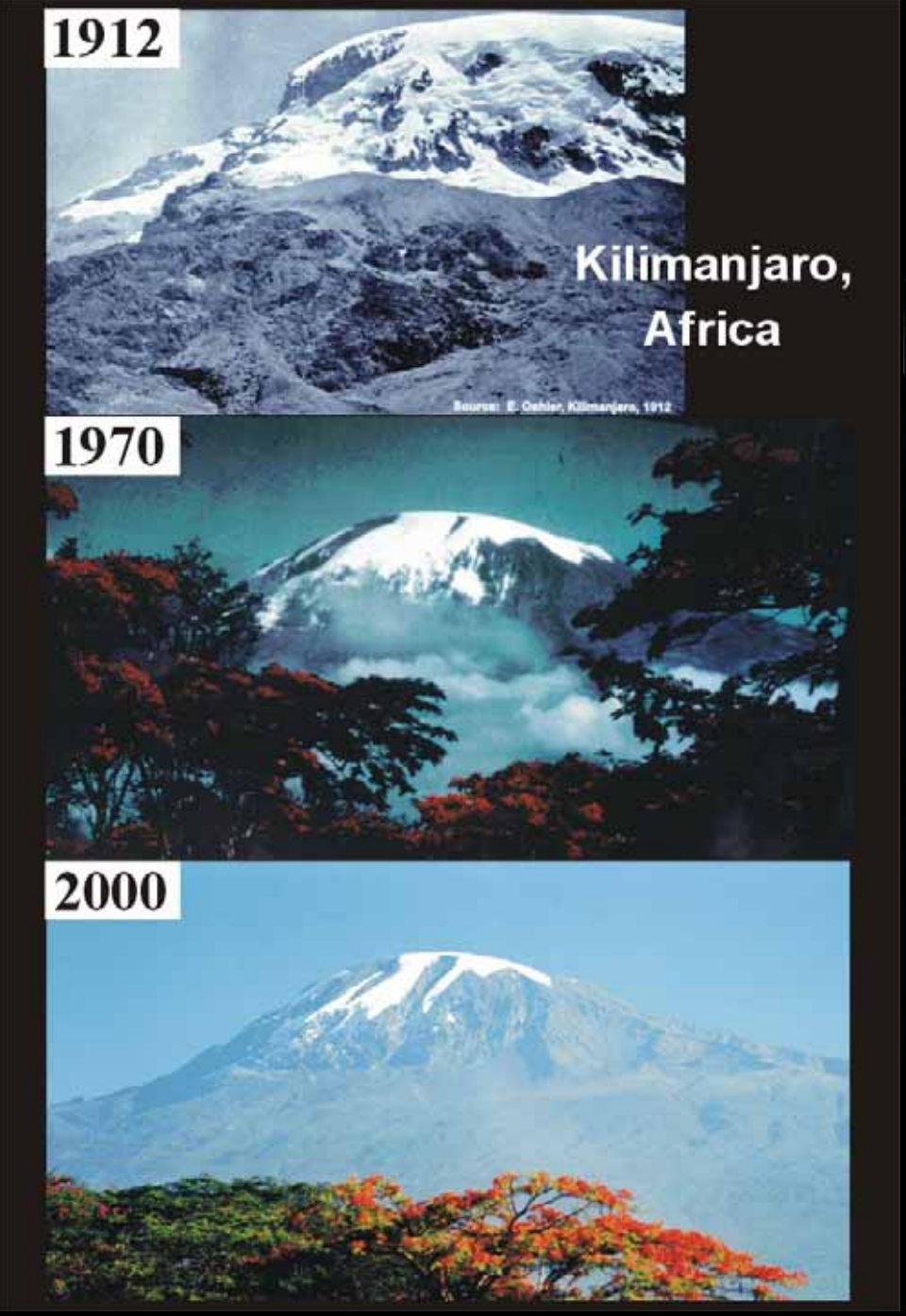
DJF Larger SST variations



DJF Rainfall roughly follows warm SST

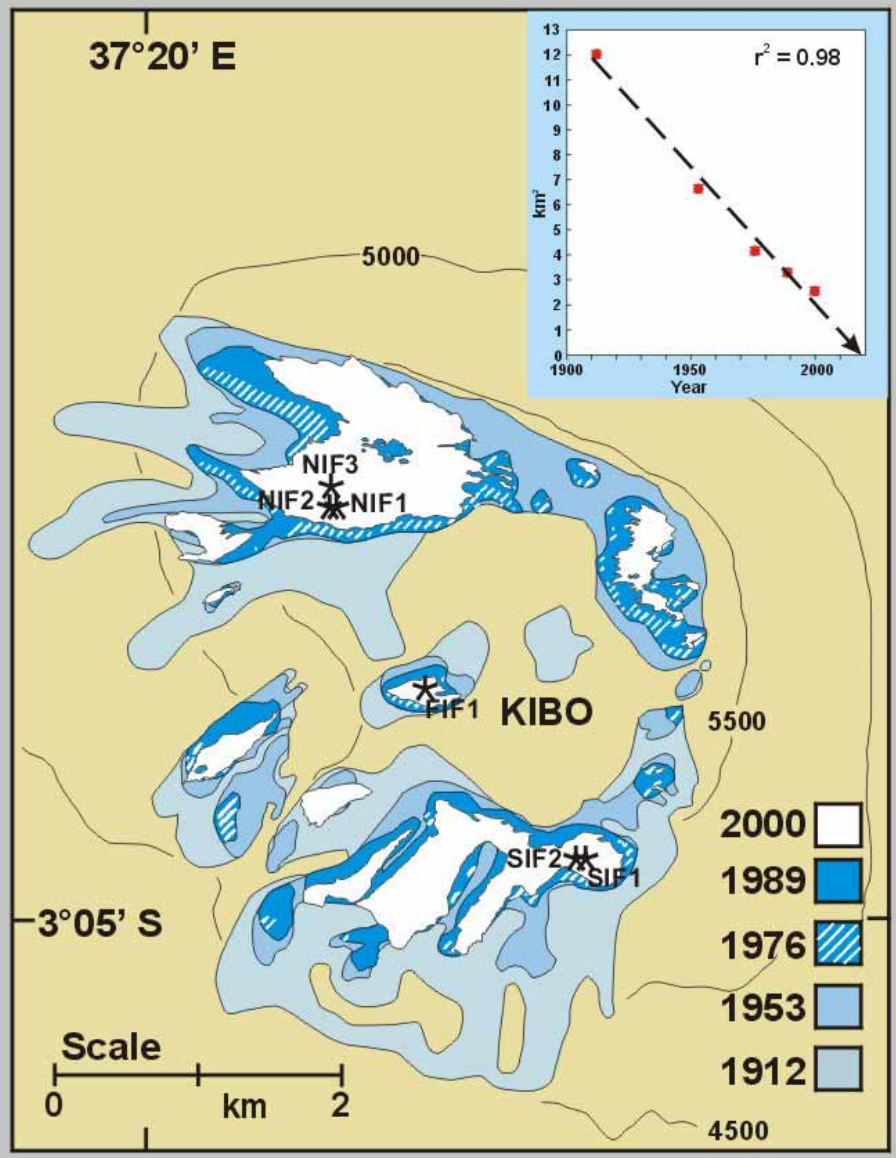


(Sobel and Bretherton, *J. Climate , 2000*



Aerial photo in 2000

Total Area Of Ice On Kilimanjaro (1912, 1953, 1976, 1989, 2000)



1912 - 1989 after Hastenrath and Greischar, *J. Glaciol.*, 1997
2000 after Thompson *et al.*, *Science*, 2002

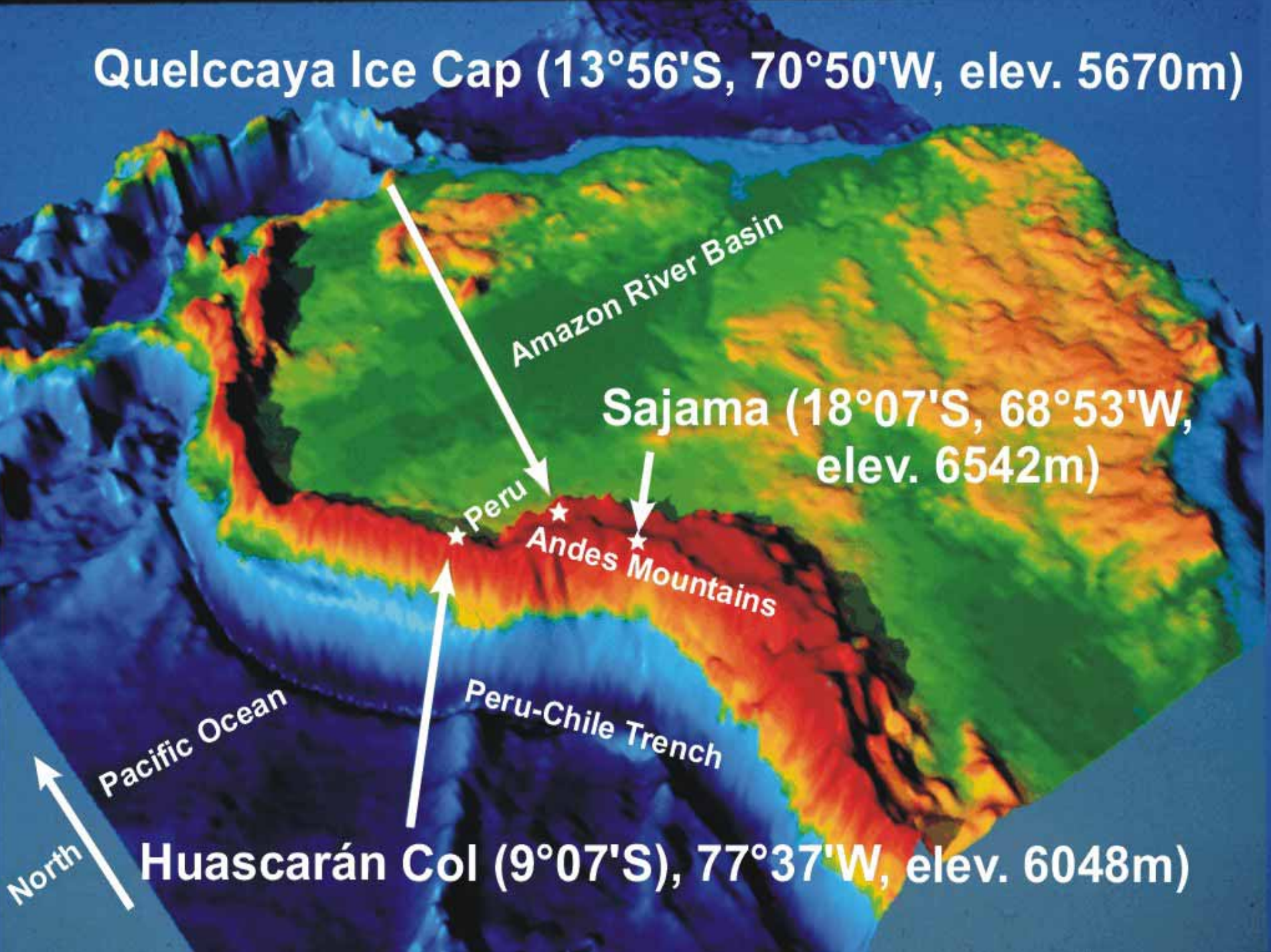
- -2.5 meters in 6 years between Feb. 2000 and Jan. 2006, FWG: -2.5 m
- SIF: over -4.5 m

•Kilimanjaro

Feb 2000

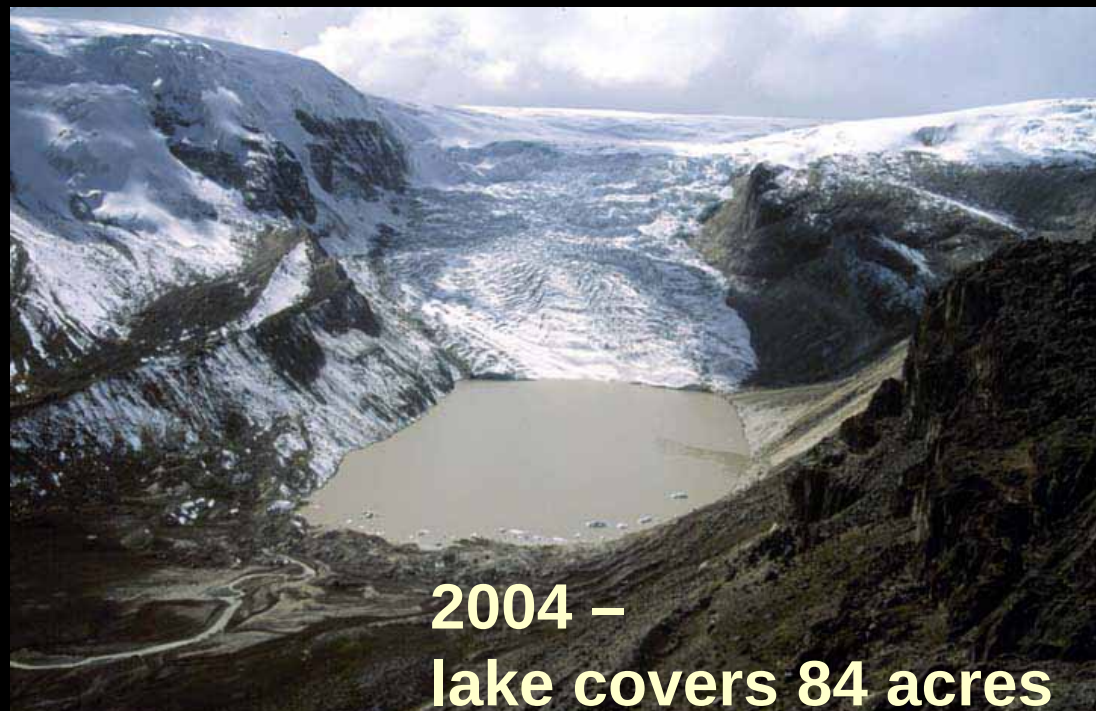
Jan 2006

•22% of the ice cover has been lost since 2000.


Quelccaya Ice Cap (13°56'S, 70°50'W, elev. 5670m)
Amazon River Basin
Sajama (18°07'S, 68°53'W, elev. 6542m)
Peru
Andes Mountains
Pacific Ocean
Peru-Chile Trench
North
Huascarán Col (9°07'S), 77°37'W, elev. 6048m)

Retreat of the Qori Kalis Glacier (Peru)

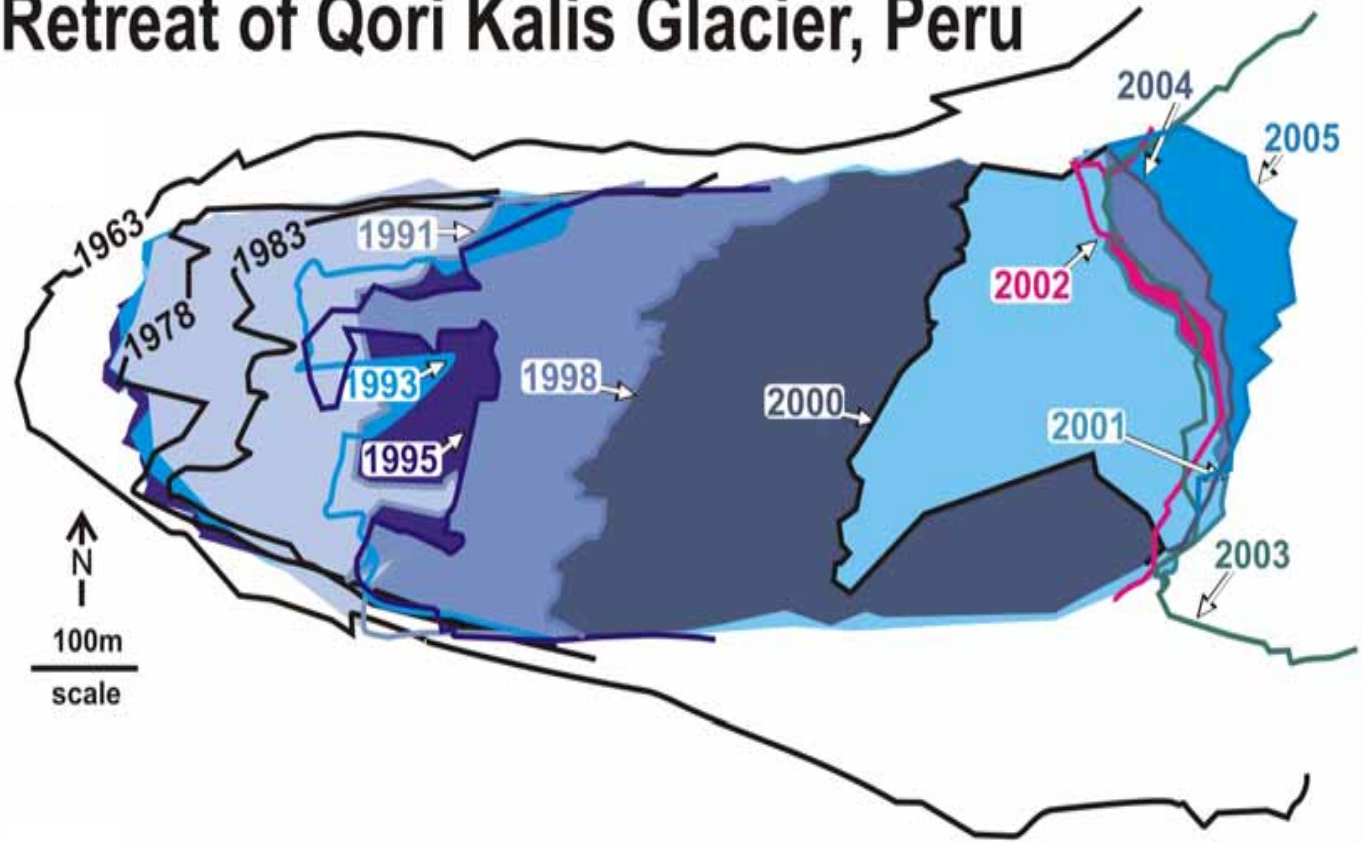
1978 – no lake

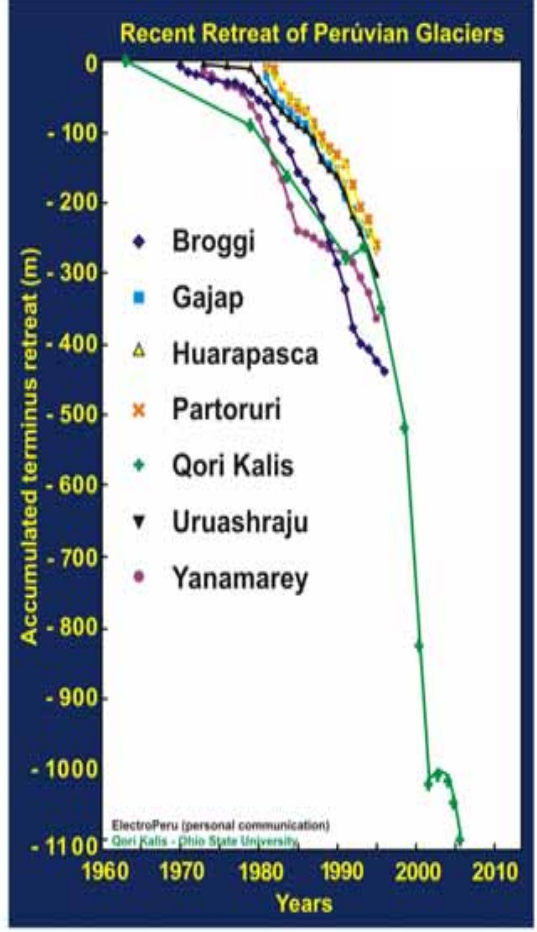


2004 –
lake covers 84 acres


Qori Kalis, July, 2006

Retreat of Qori Kalis Glacier, Peru





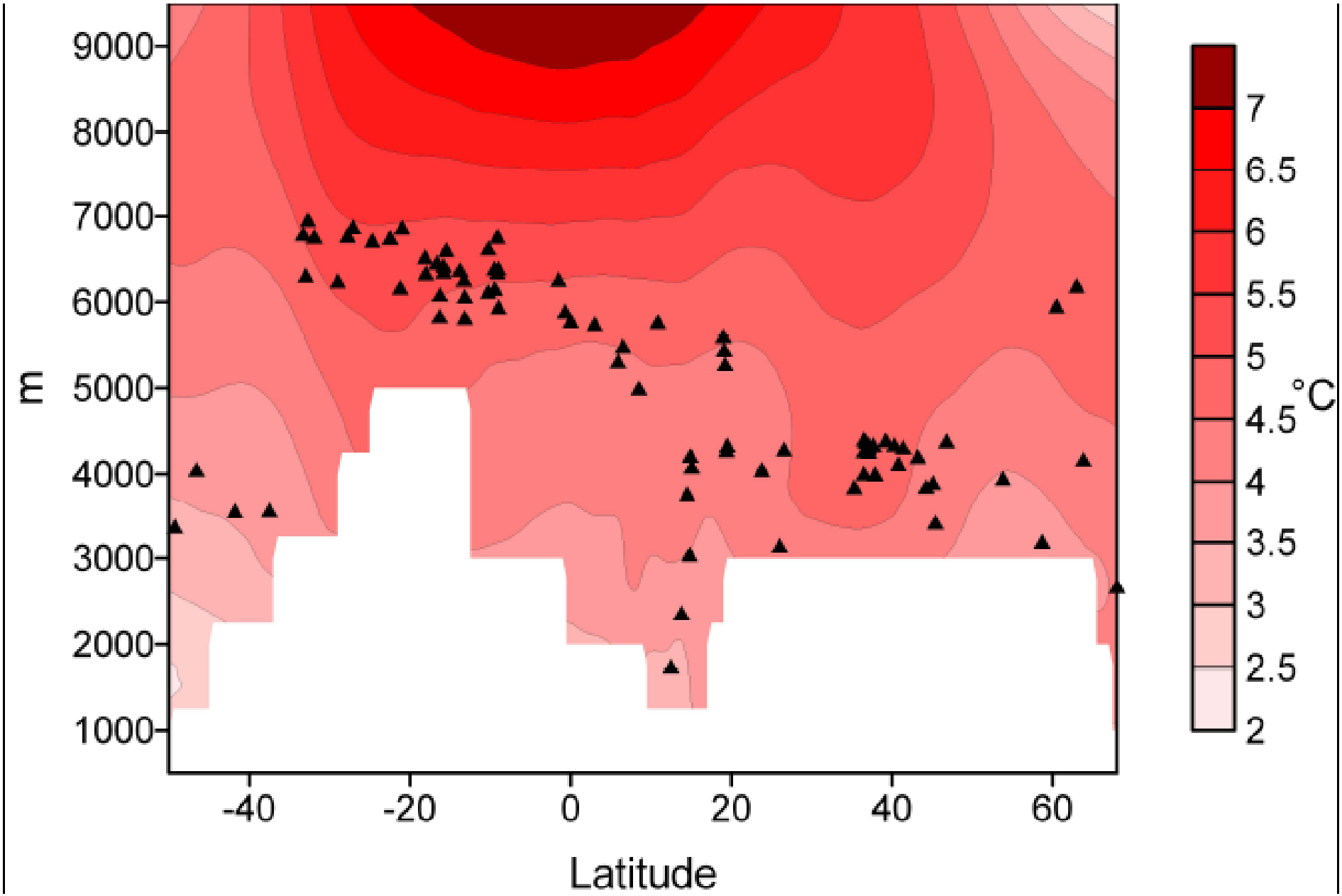
1978

1991

1998

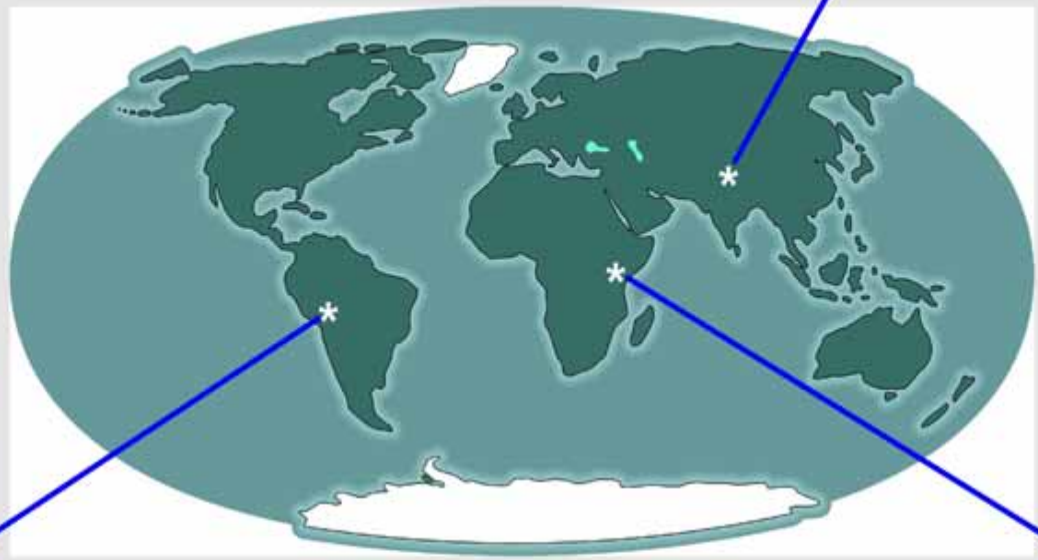
2000

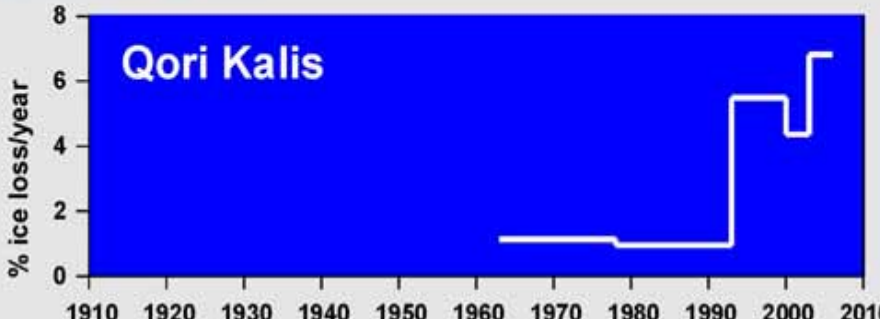
2005

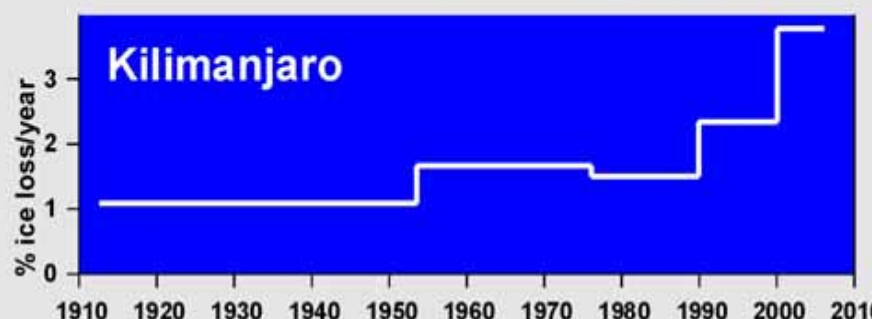


Source: *Bradley et al., 2006*

Ice Loss from Tropical Glaciers







Glaciers, especially tropical glaciers, are

"the canaries in the coal mine"

for our global climate system as they integrate and respond to most key climatological variables such as temperature, precipitation, cloudiness, humidity and radiation.

- Global glacier retreat at the beginning of the 21st Century is driven mainly by **increasing temperatures** although regional factors (i.e., deforestation also may play a role).

Quelccaya Ice Cap, 2002

200 – 400 m above its modern range

Distichia muscoides

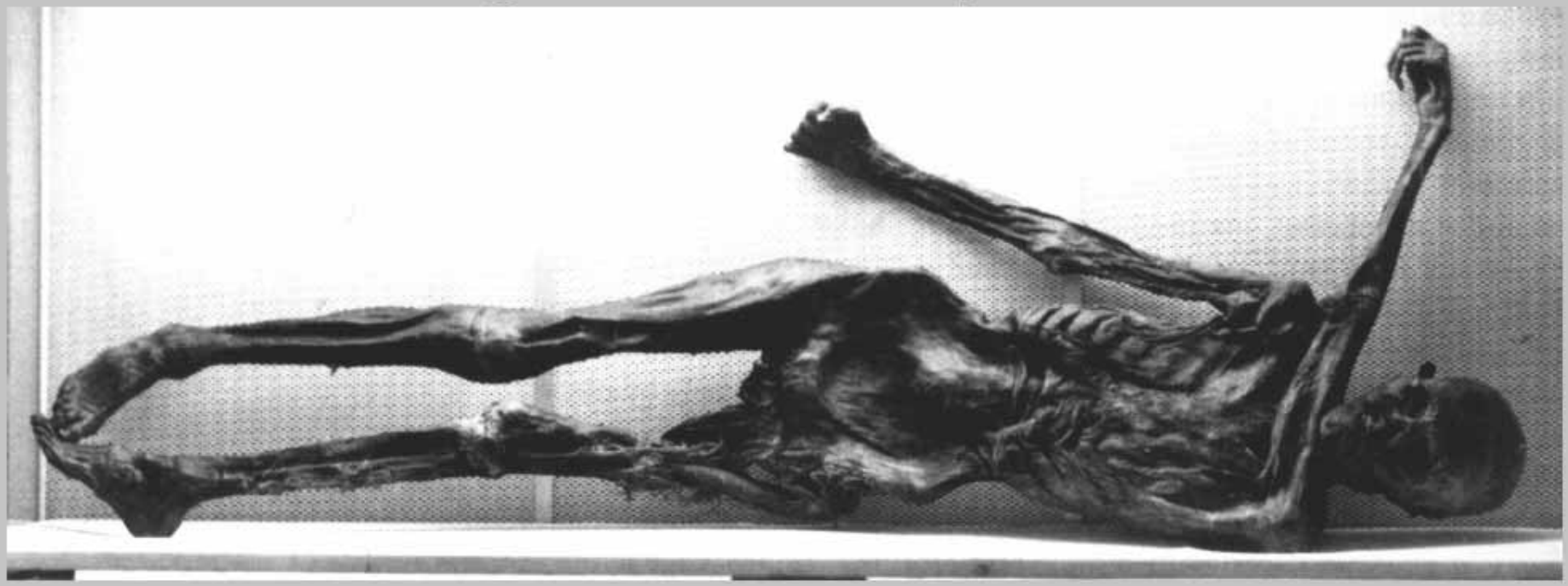
Quelccaya Plant

Modern

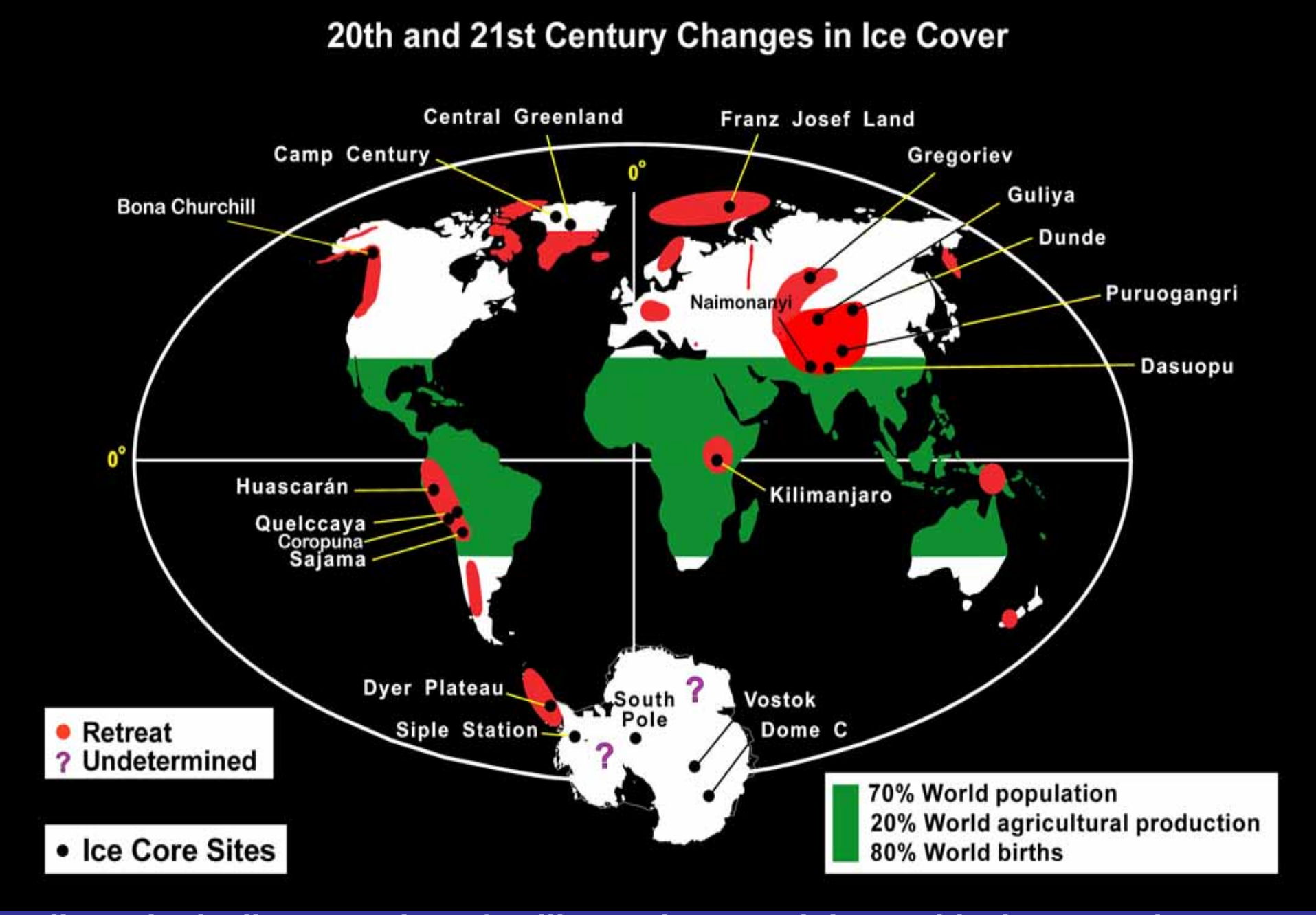
5177 ± 45 yr. B.P.

"The Tyrolean Iceman" - "Ötzi"
"Man from the Hauslabjoch"

Age 5175 ± 125 years



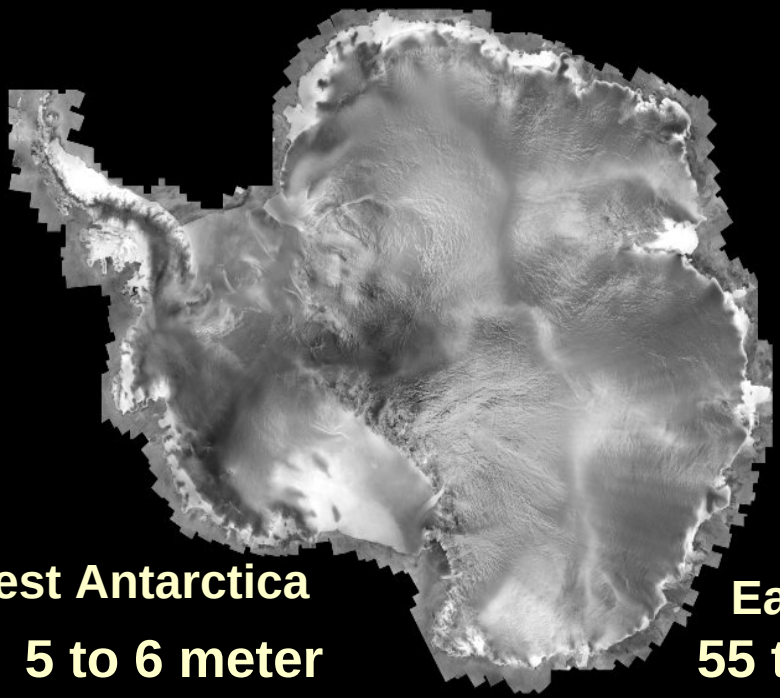
Source: http://info.uibk.ac.at/c/c5/c552/Forschung/Iceman/iceman-en.html#Finding



•Climatologically we are in unfamiliar territory, and the world's ice cover is responding dramatically.

Sea level is currently rising about 2 to 3 mm a year.
This is due to
- thermal expansion of ocean
- alpine glacier mass loss (+ thermal expansion) = 0.5 meter sea level rise
- ice sheet mass loss
- pumping groundwater (irrigation)

Antarctica



West Antarctica

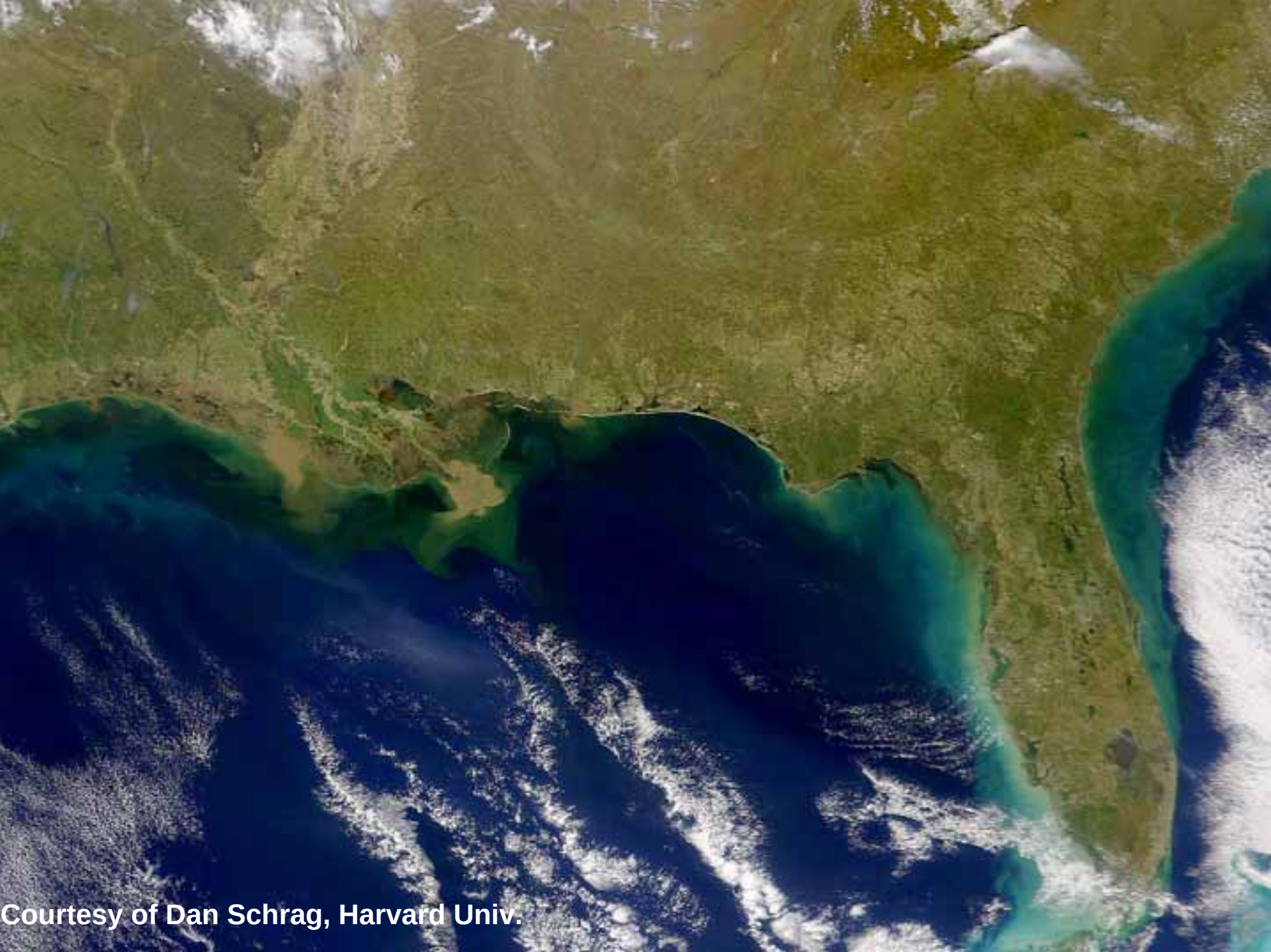
5 to 6 meter sea level rise equivalent

East Antarctica

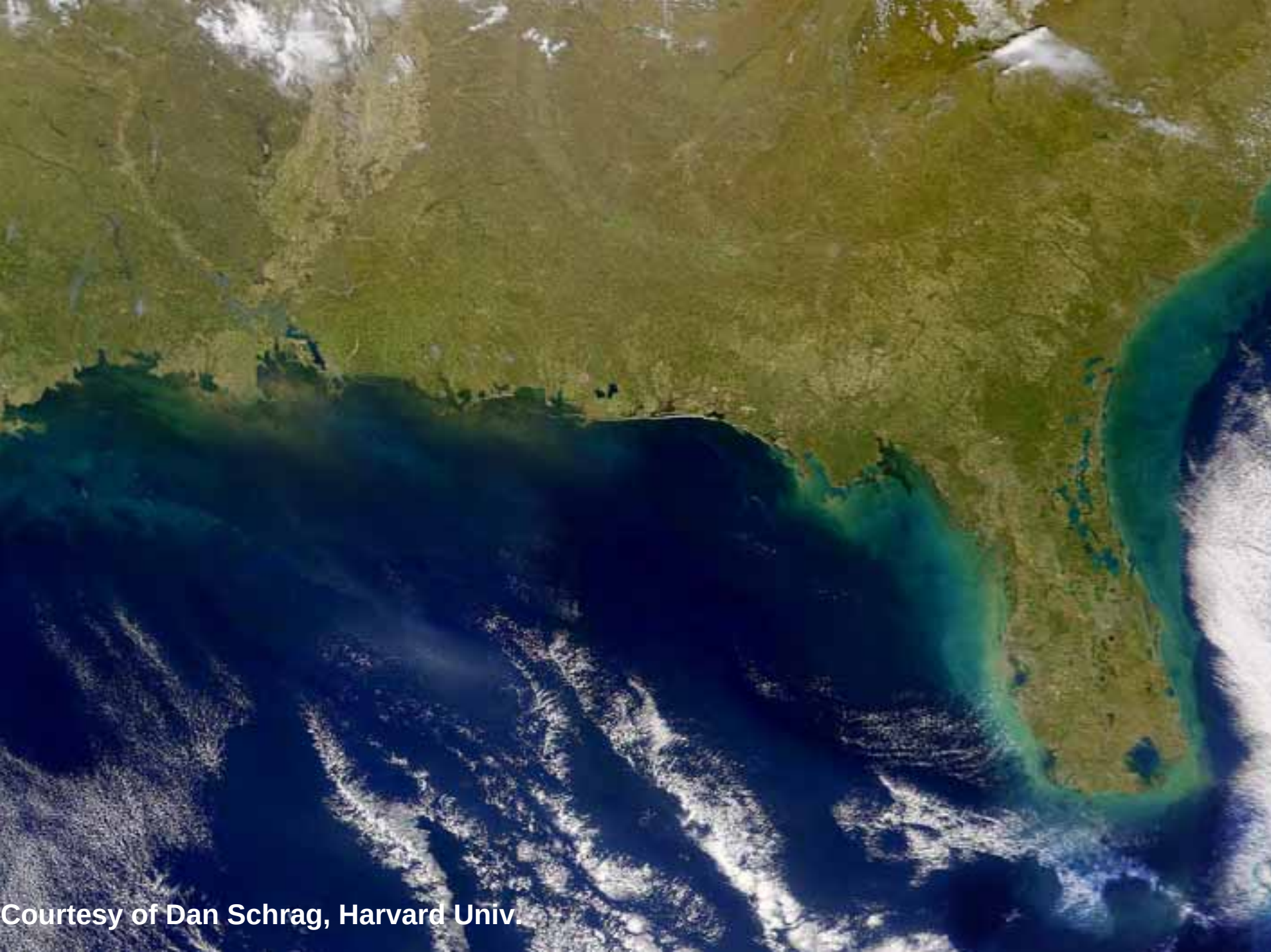
55 to 60 meter sea level rise equivalent

6 to 7 meter sea level rise equivalent

Greenland



Courtesy of Dan Schrag, Harvard Univ.



Courtesy of Dan Schrag, Harvard Univ.

Key points made in this presentation

The 20th century is the warmest in the last 2000 years and in several places the warmest in over 5000 years.

Ice cores provide unique information that extends our knowledge of the Earth's climate history.

Climatologically we are in unfamiliar territory, and the world's ice cover is responding dramatically

Observed rapid changes in Greenland and Antarctica are not predicted by climate models (slow and linear response to climate forcing; fast glacier flow not included)

Glaciers in most parts of the world are rapidly melting and their loss will affect 2 to 3 billion people and valuable paleoclimate archives will be lost forever.

Glaciers are our most visible evidence of global warming. They integrate many climate variables in the Earth system.
Their loss is readily apparent and they have "no political agenda".

For Global Warming --- Nature is the Time Keeper!