The University of Texas at Austin
Environmental Science Institute

Hot Science - Cool Talk # 36

Ice Adventures: Tracking Evidence of Abrupt Climate Change Across the Tropics

Dr. Lonnie G. Thompson

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Ice Adventures:

Tracking Evidence of Abrupt Climate Change Across the Tropics

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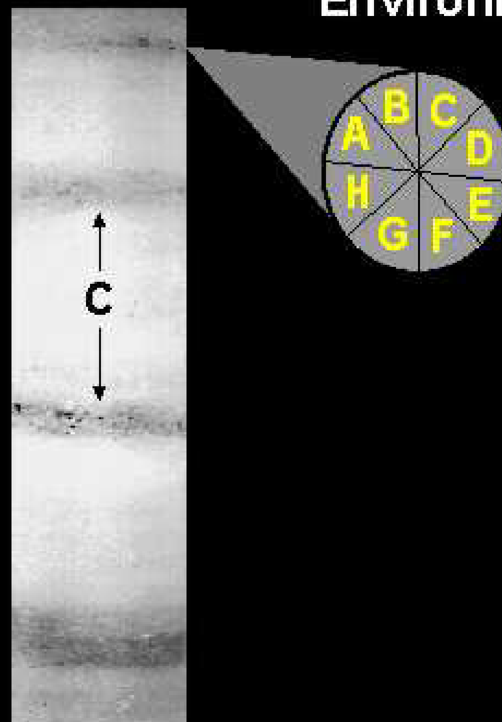
Ice Core Paleoclimate Research Group
http://www-bprc.mps.ohio-state.edu/

Quelccaya Ice Cap, Peru

1977

2002

Ice cores archive a wealth of environmental information



Environmental Data Include:

- A Temperature
- B Atmospheric Chemistry
- C Net Accumulation
- D Dustiness of Atmosphere
- E Vegetation Changes
- F Volcanic History
- G Anthropogenic Emissions
- H Entrapped Microorganisms

Byrd Polar Research Center

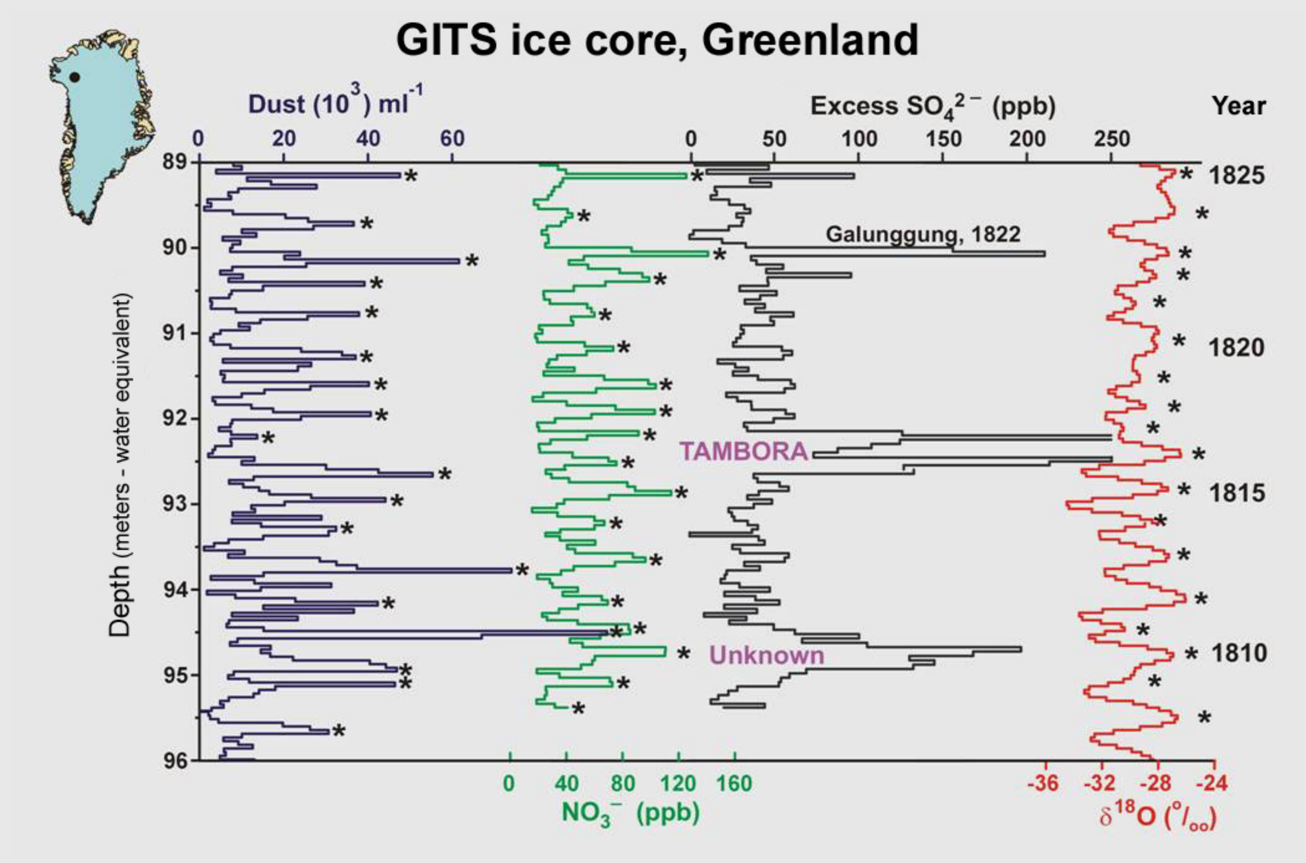
Ohio State University

Class-100 clean room houses the equipment to measure dust, isotopes and chemicals

Freezers for storage and cold rooms for physical property measurements

Machine shop for drill and equipment fabrication

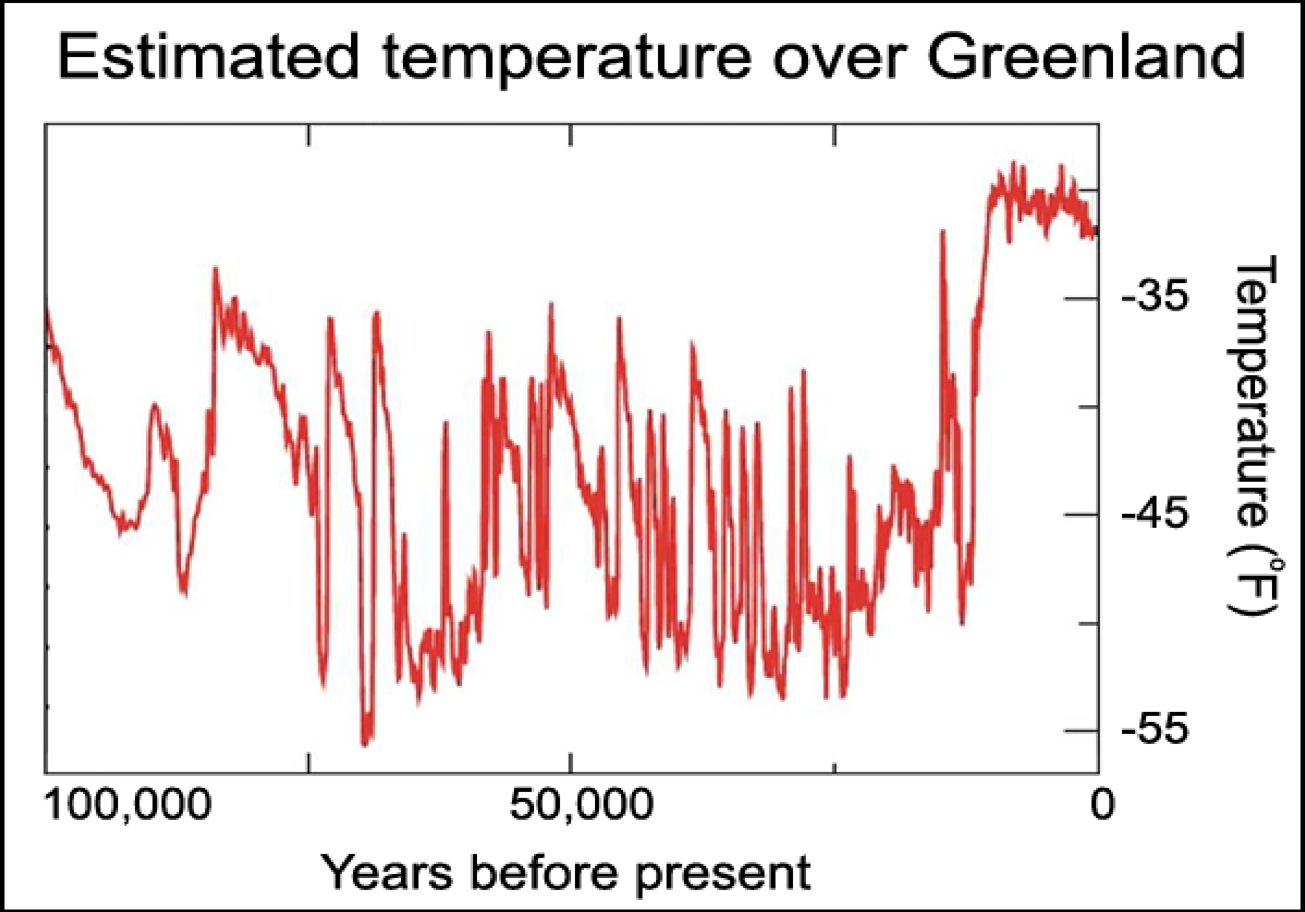
Turning an ice core into an historical record



Mosley-Thompson et al. (2003)

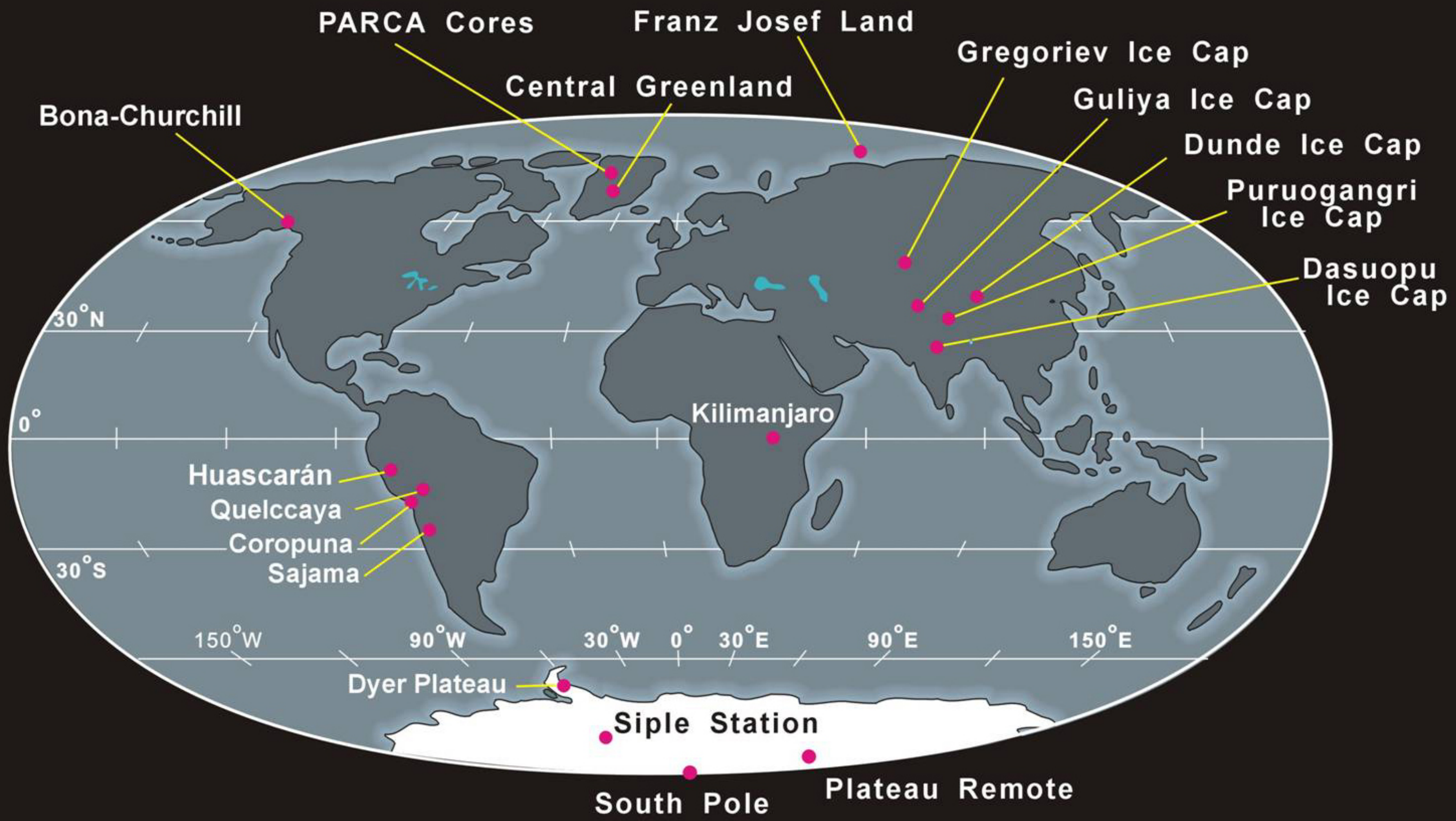
Abrupt climate changes over the last 100,000 years were large and frequent

3 kilometer long ice core

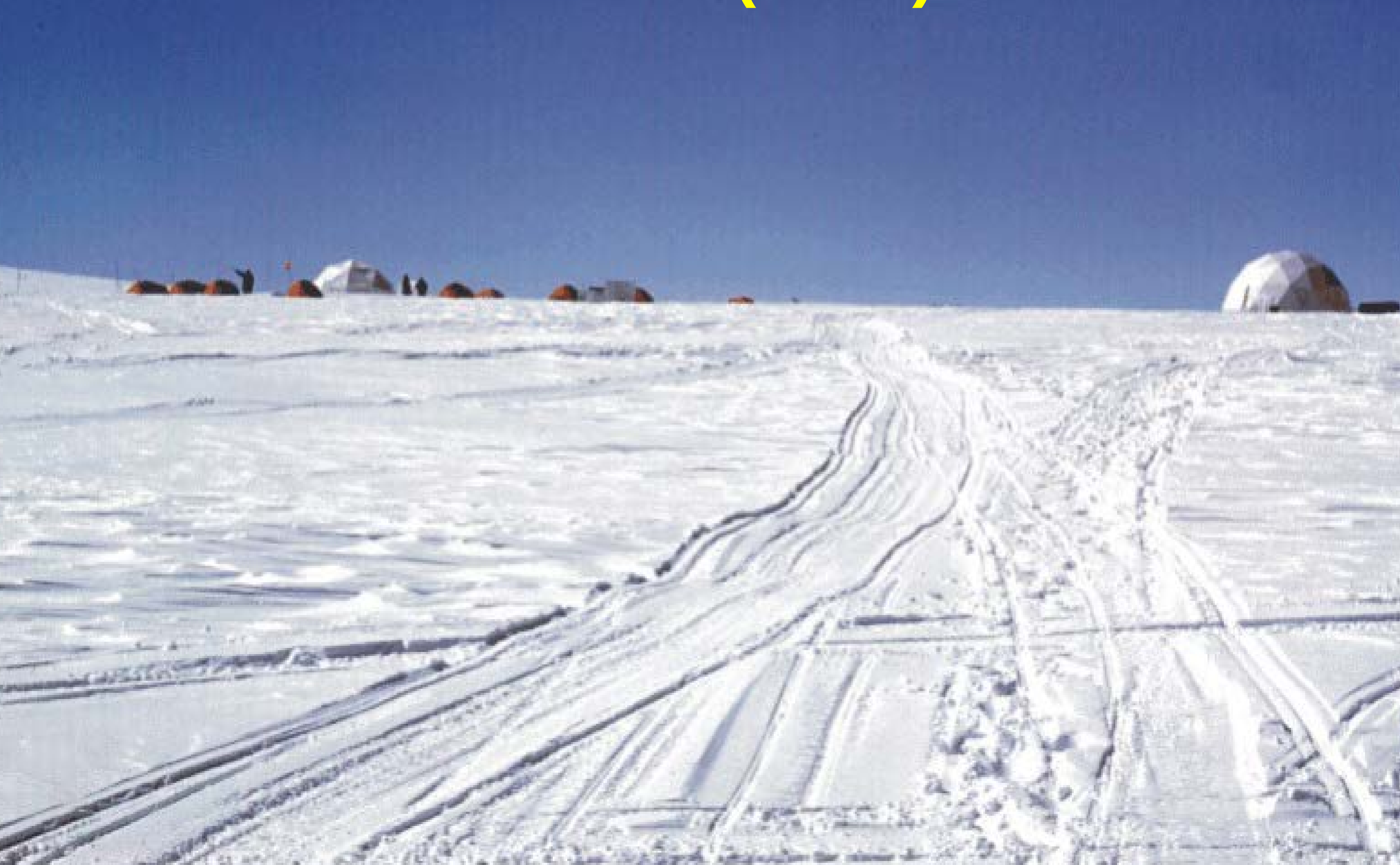


Modified from: Alley (2000)

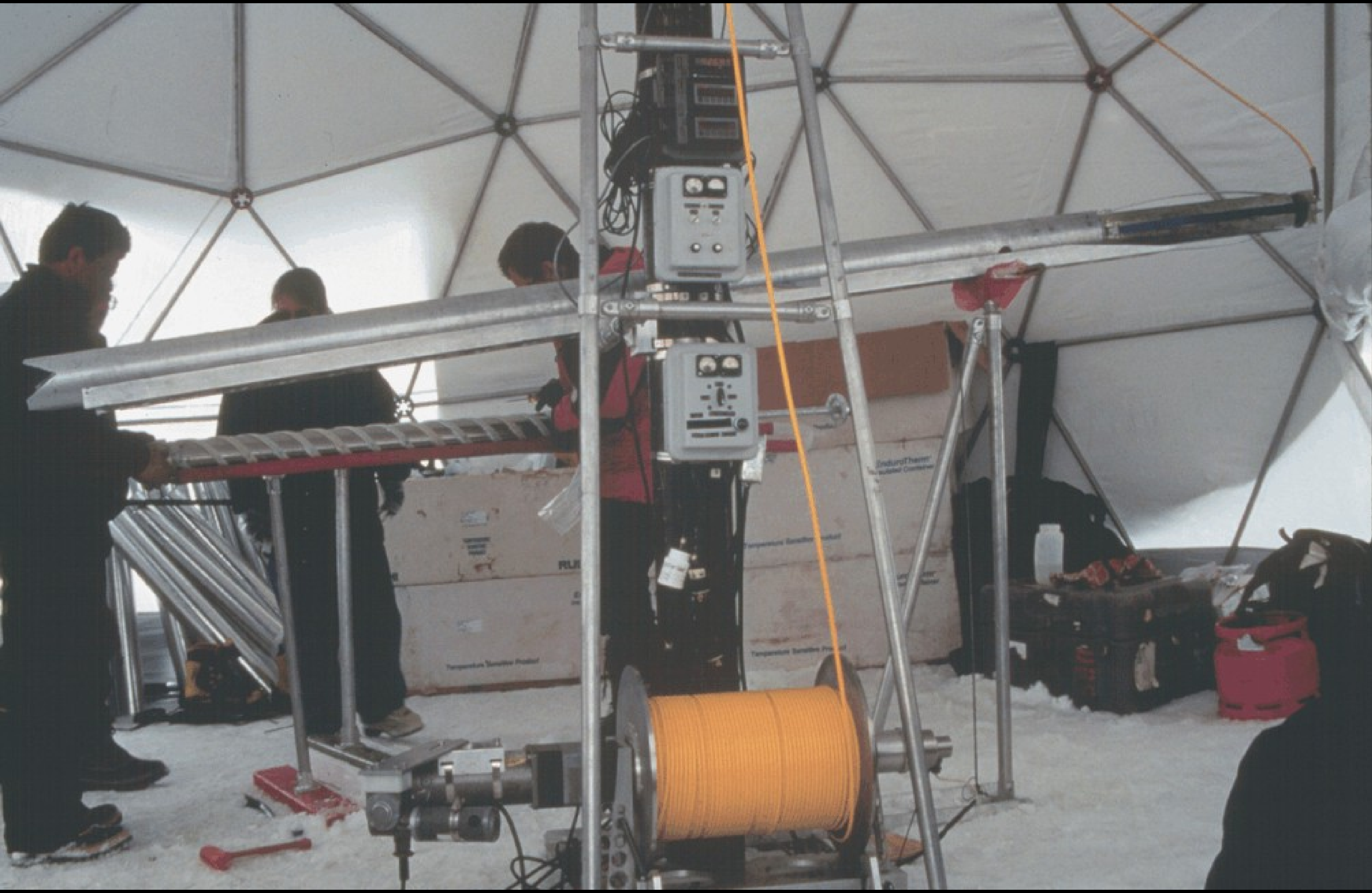
Ohio State Ice Core Sites



Ice core drilling on the Bona-Churchill, Alaska (2002)



Ice core drilling on the Quelccaya Ice Cap, Peru (2003)



Ice core drilling on the Coropuna Ice Cap, Peru (2003)


MOUNTAIN
HARD
WEAR

Coropuna, Peru

Chironomidae

1260 ± 380 years before present

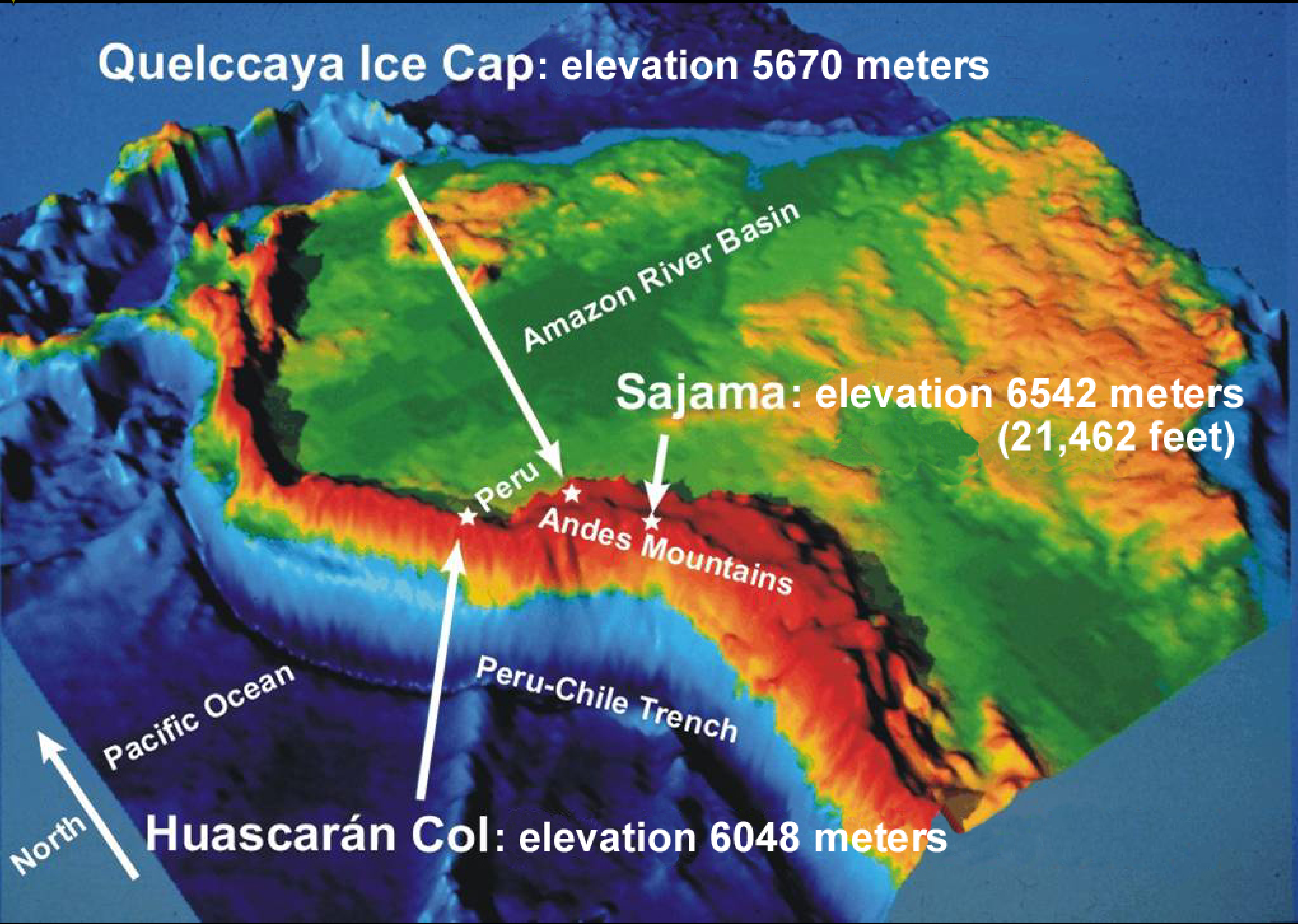
length: 0.7 mm

Sajama, Bolivia

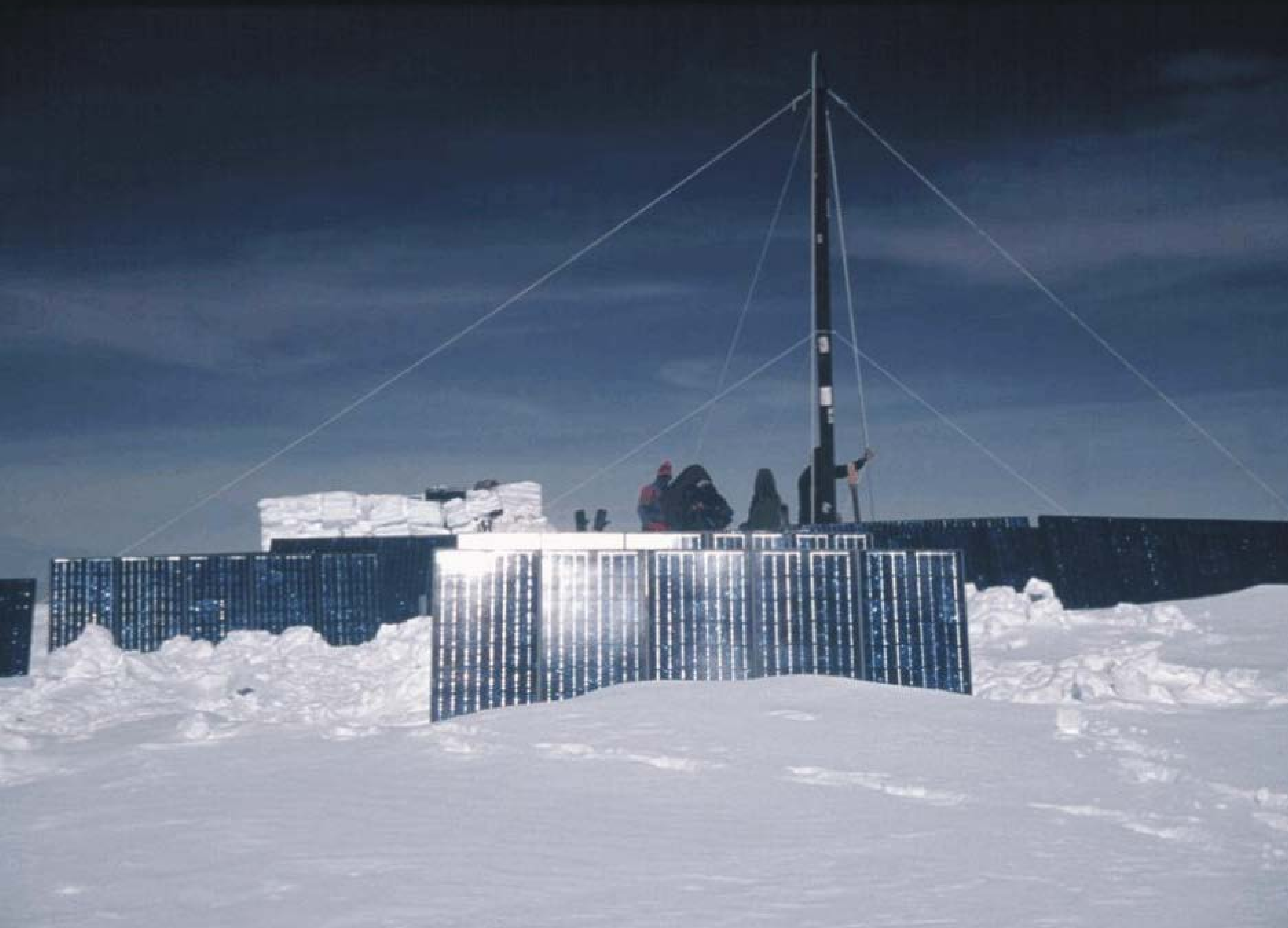
Heteroptera

5620 ± 275 years before present

length: 2.0 mm



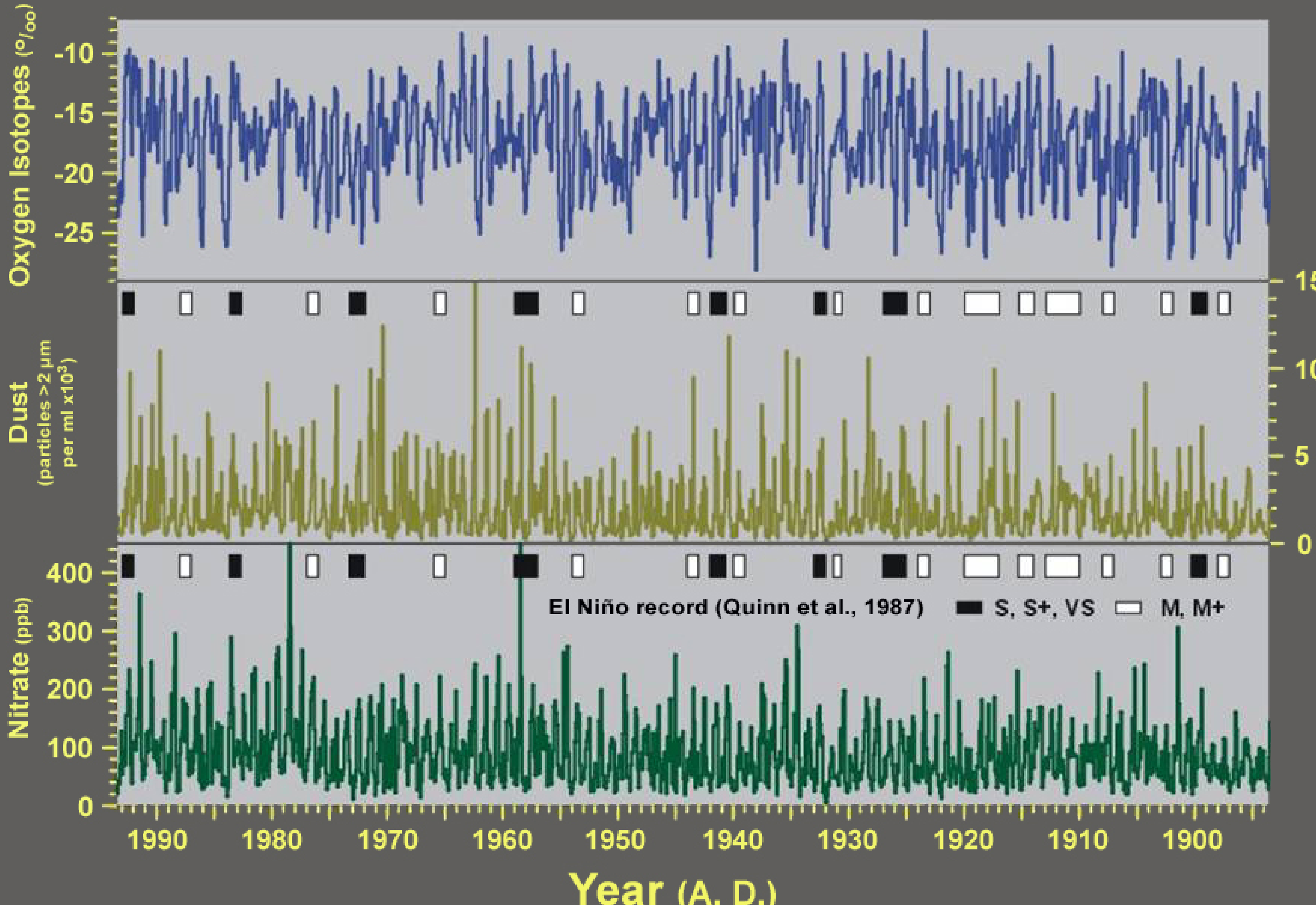
Quelccaya Ice Cap: elevation 5670 meters
Amazon River Basin
Sajama: elevation 6542 meters
(21,462 feet)
Peru
Andes Mountains
Peru-Chile Trench
Pacific Ocean
North
Huascarán Col: elevation 6048 meters



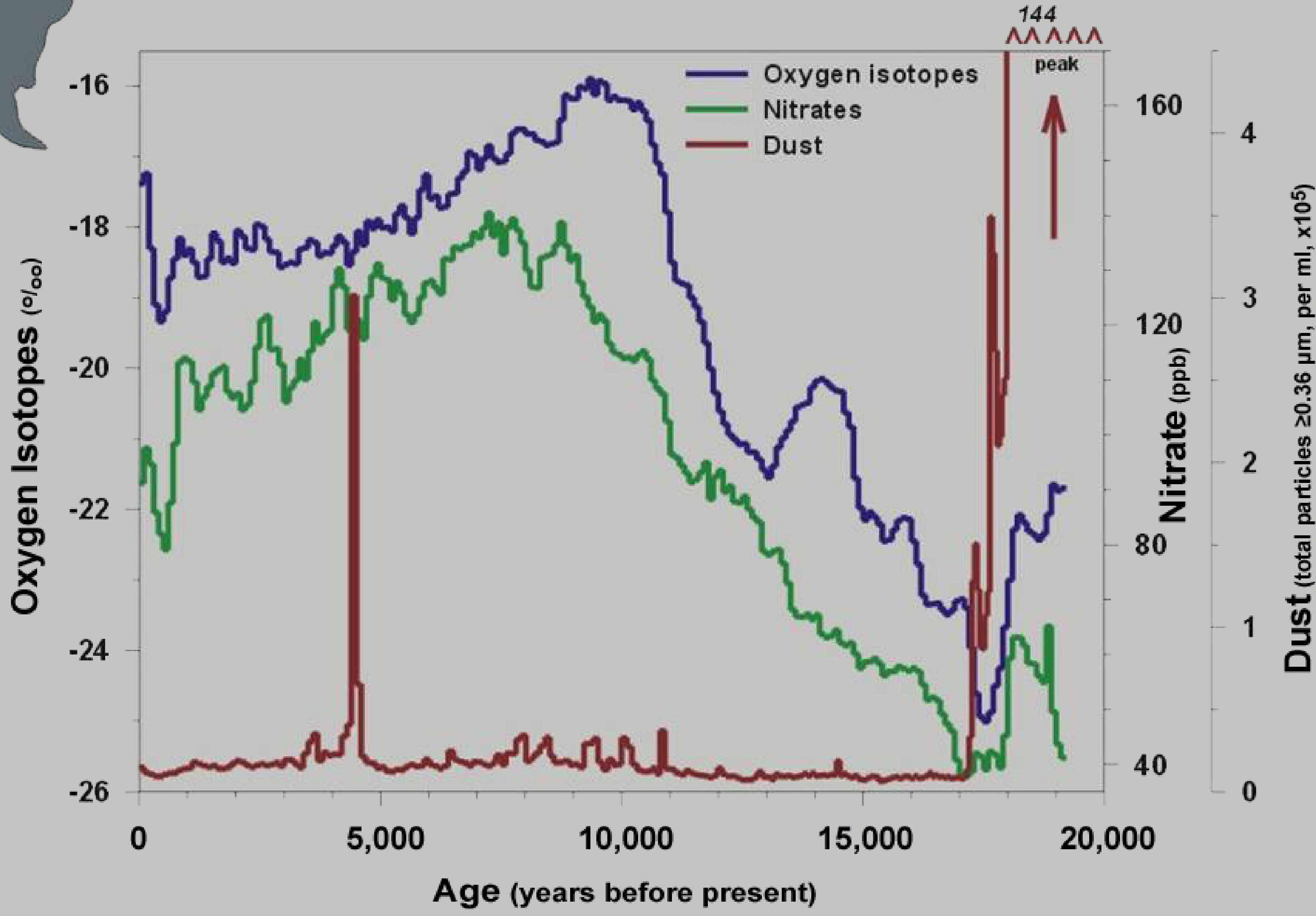
Hauscarán Core 2

Oxygen Isotopes, Nitrates, and Dust

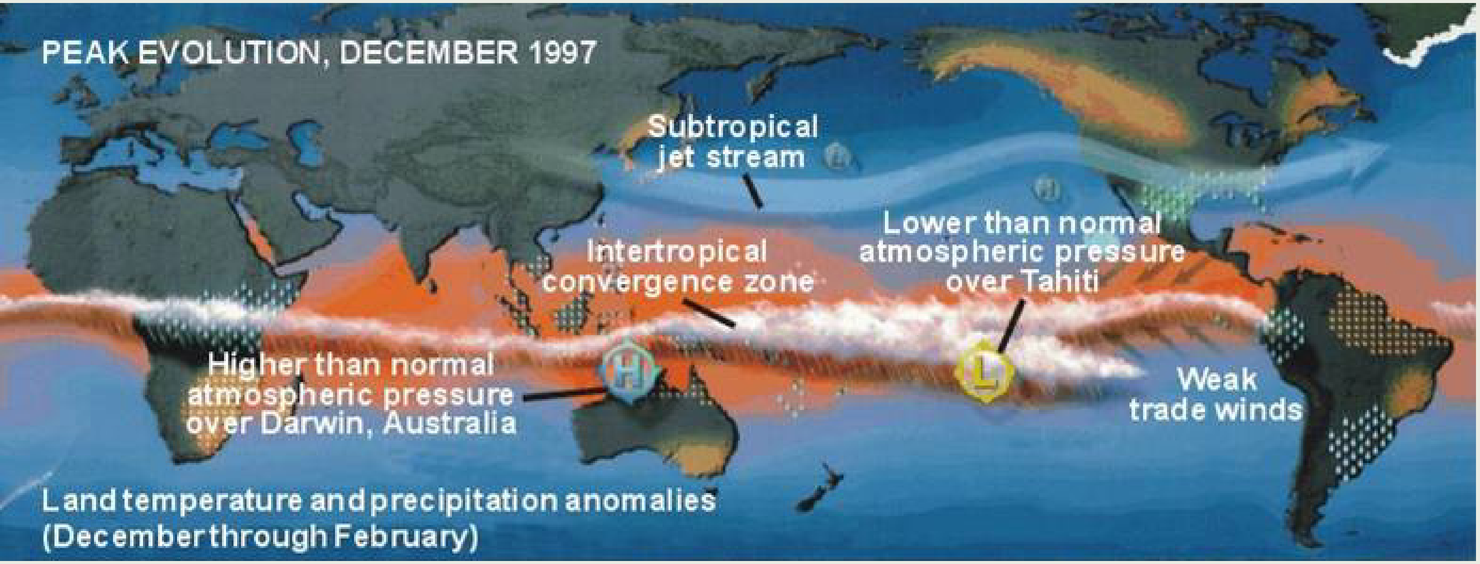
(last 100 years)

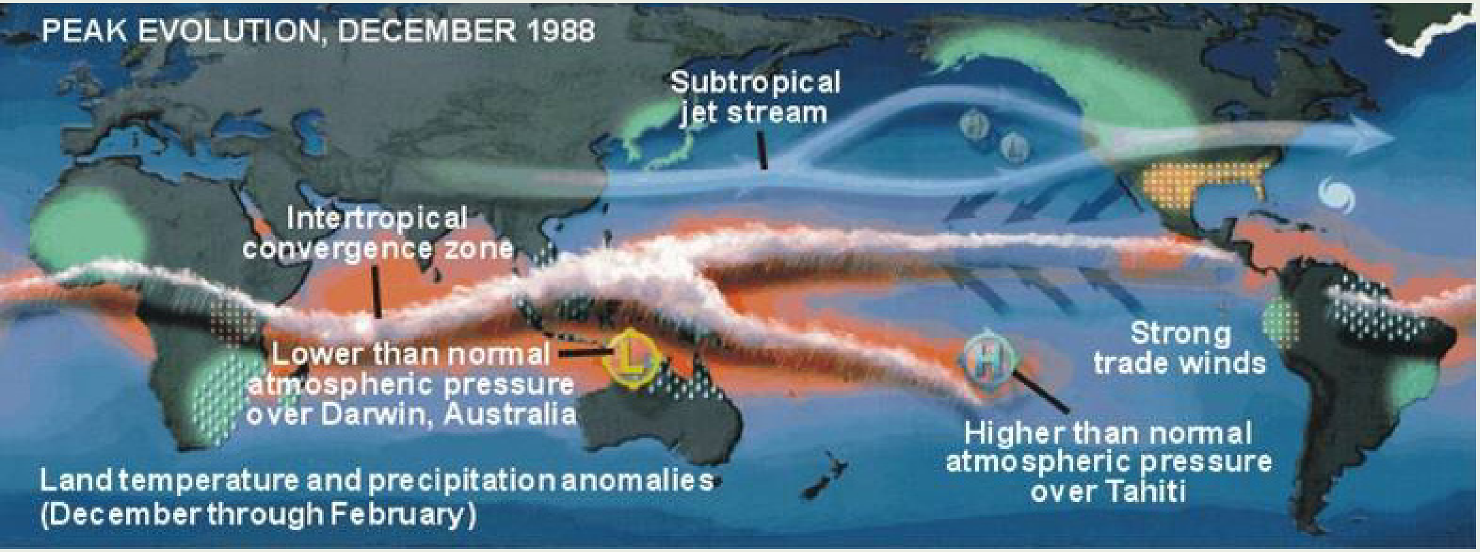


Comparison of Oxygen Isotopes, Nitrate, and Dust from Huascarán Ice Core 2



EL NIÑO

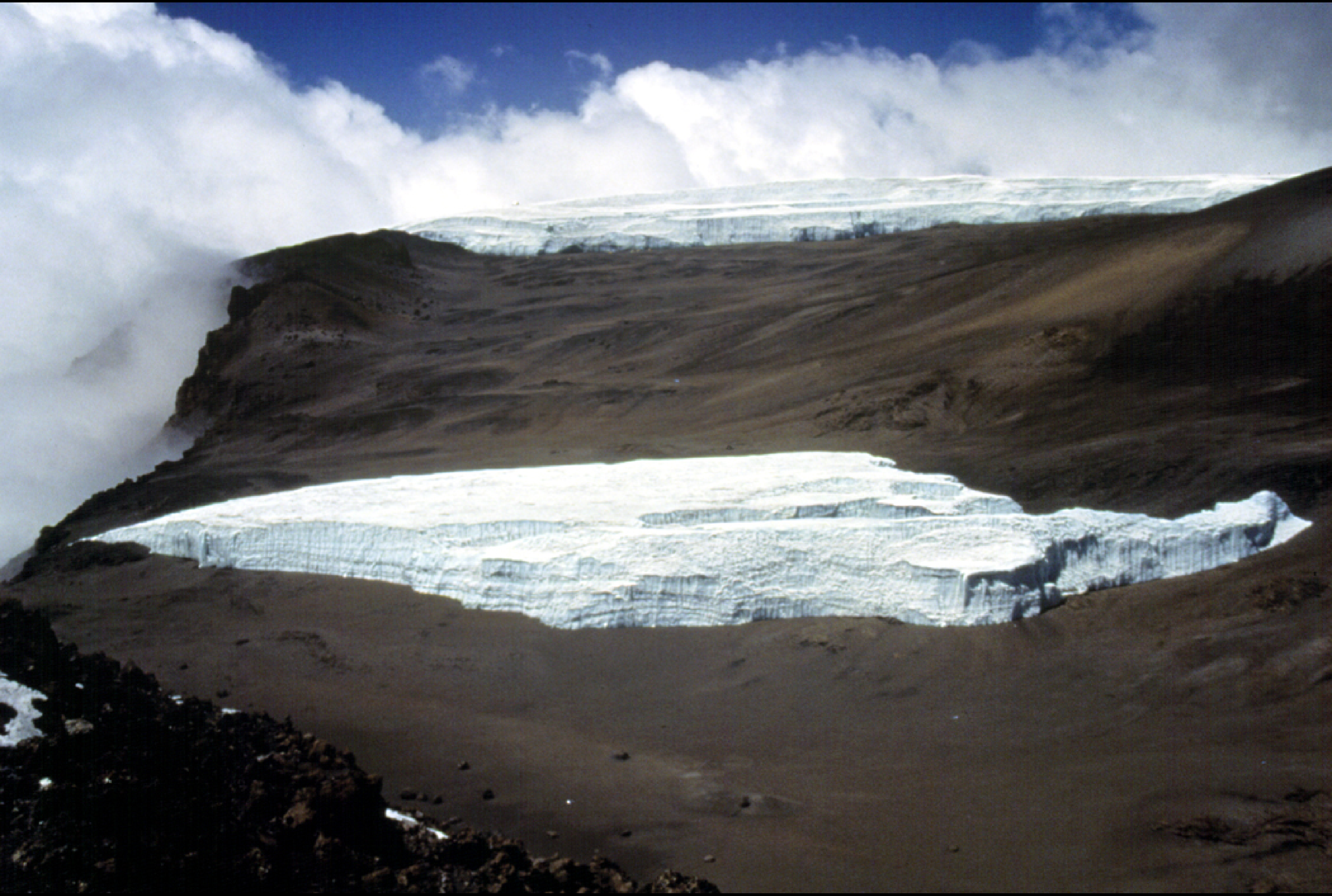




LA NIÑA

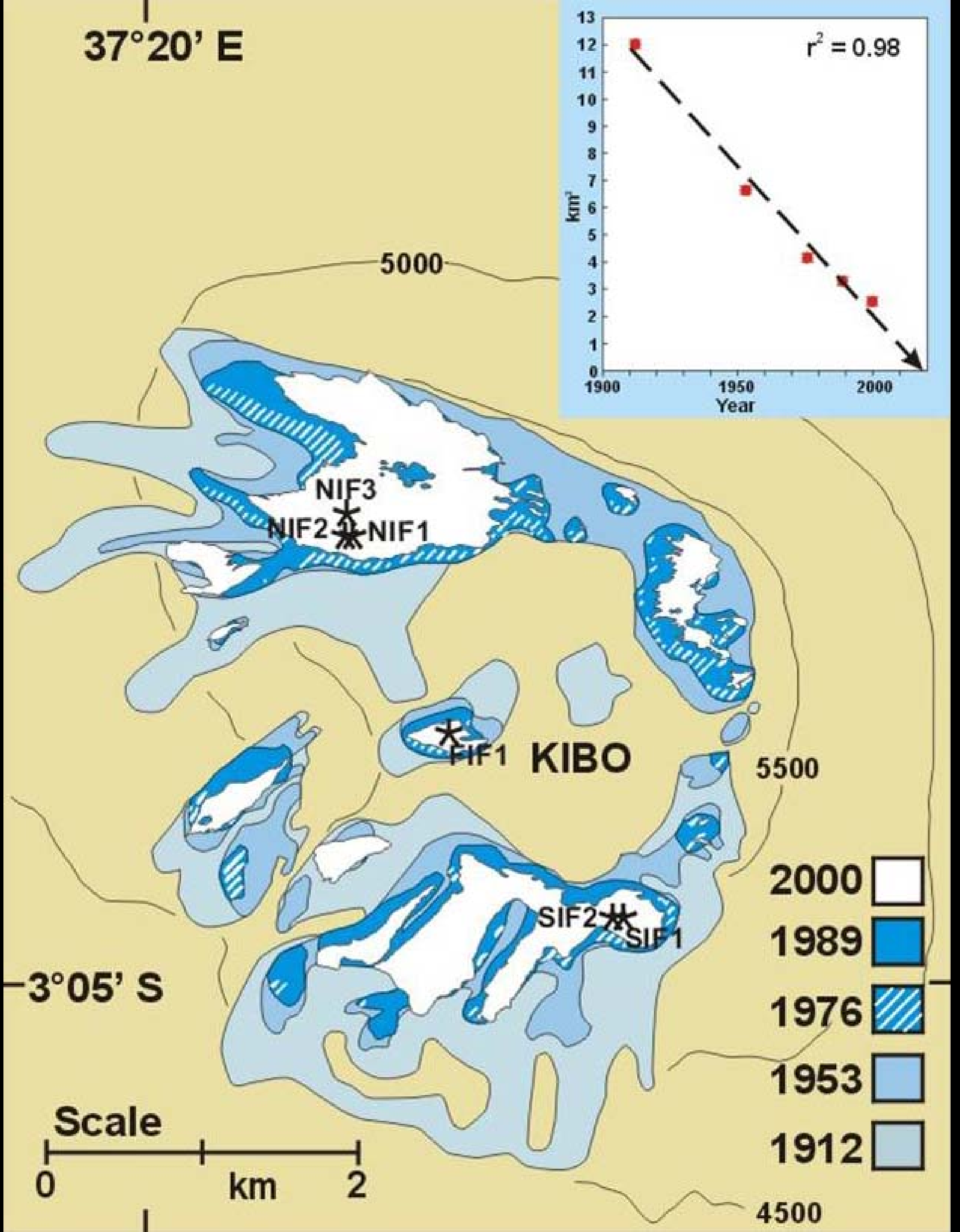
Sources: C. Ropelewski (International Research Institute); K., Trenberth; A. Leetmaa and V. Kousky (Climate Prediction Center); B. Patzert; data from NOAA; art by H. Merscher.


ISC
ISC
ISC
ISC

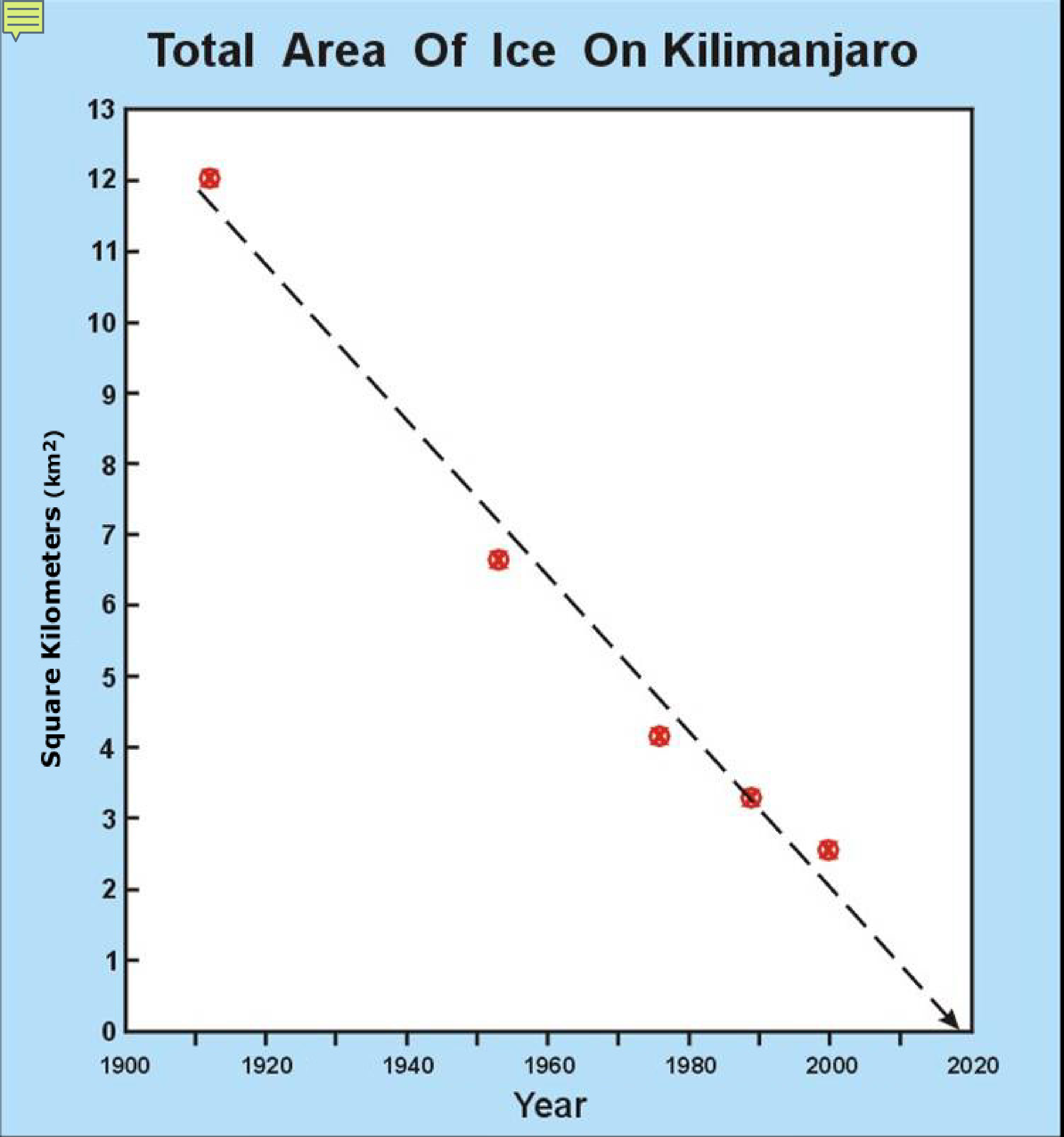



J1586 MT. KILIMANJARO GLACIERS 16 FEB. 2000 BYRD P.R.C.

Total Area of Ice on Kilimanjaro
(1912 – 2000)

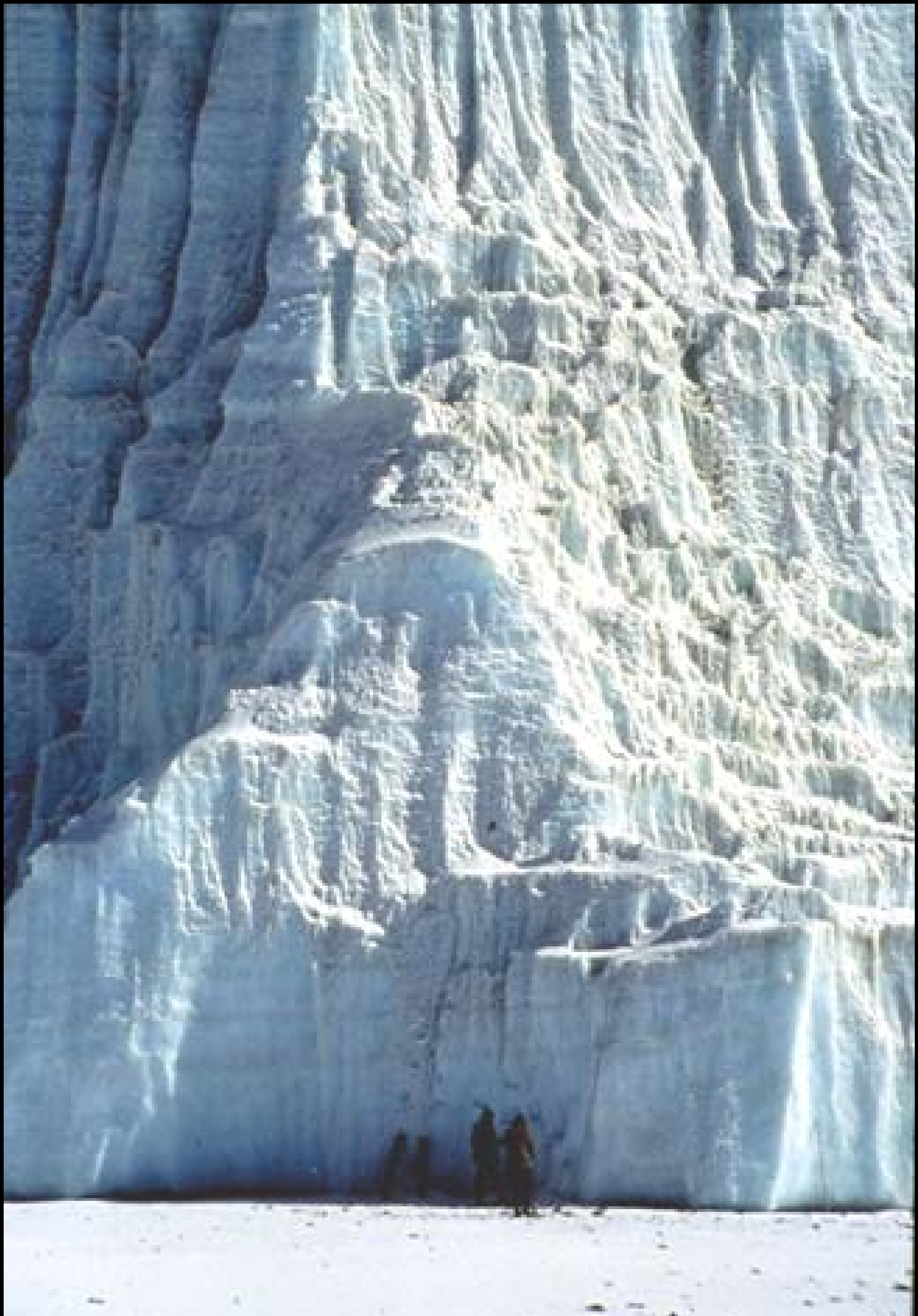


Years 1912 – 1989 after Hastenrath and Greischar (1997); year 2000 after Thompson et al. (2002)



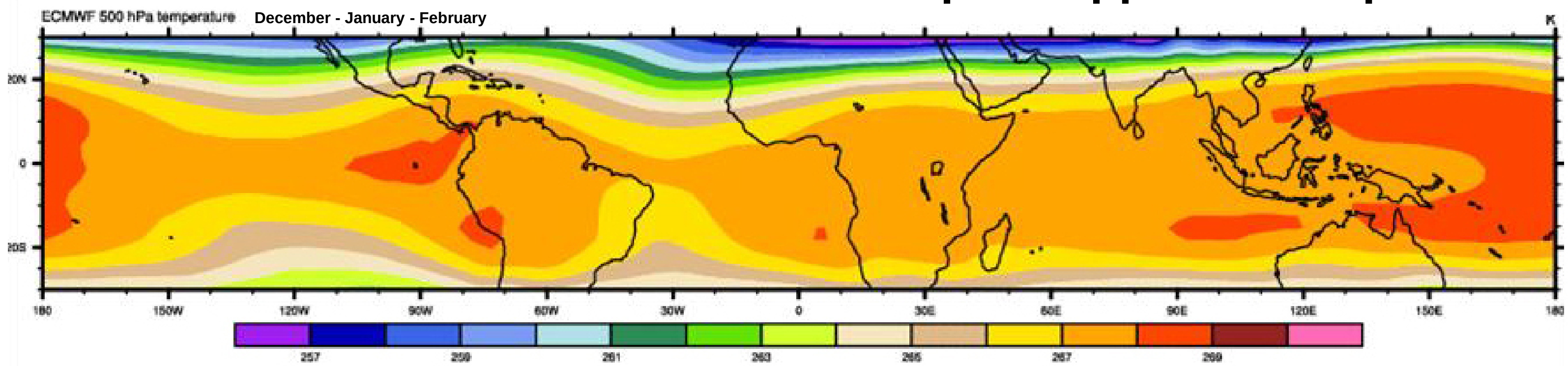
Thompson et al. (2002)

The wall of the Northern Ice Field (Kilimanjaro) has retreated 0.9 m per year since 2000

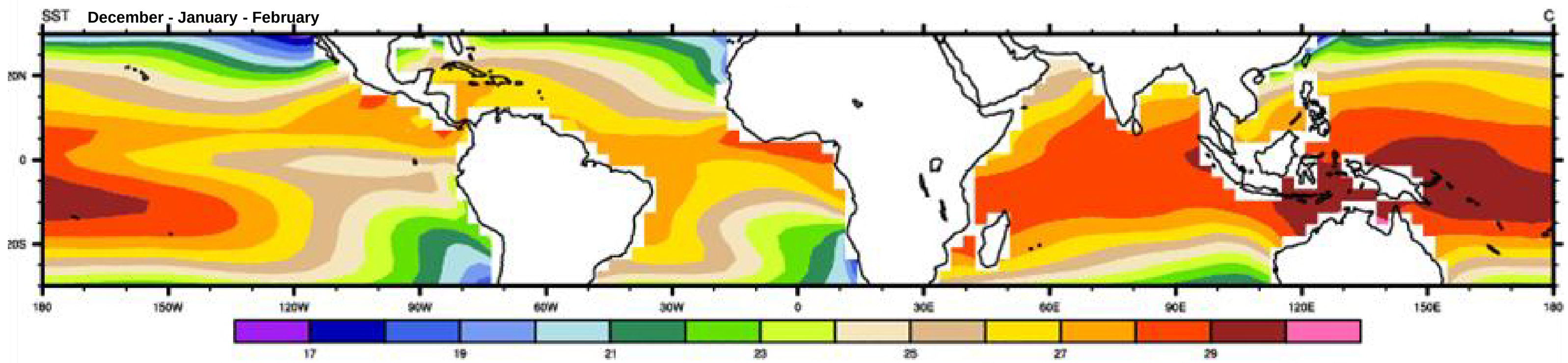


Outburst of water and ice collapse on Fürtwangler Glacier (Kilimanjaro) in spring of 2003

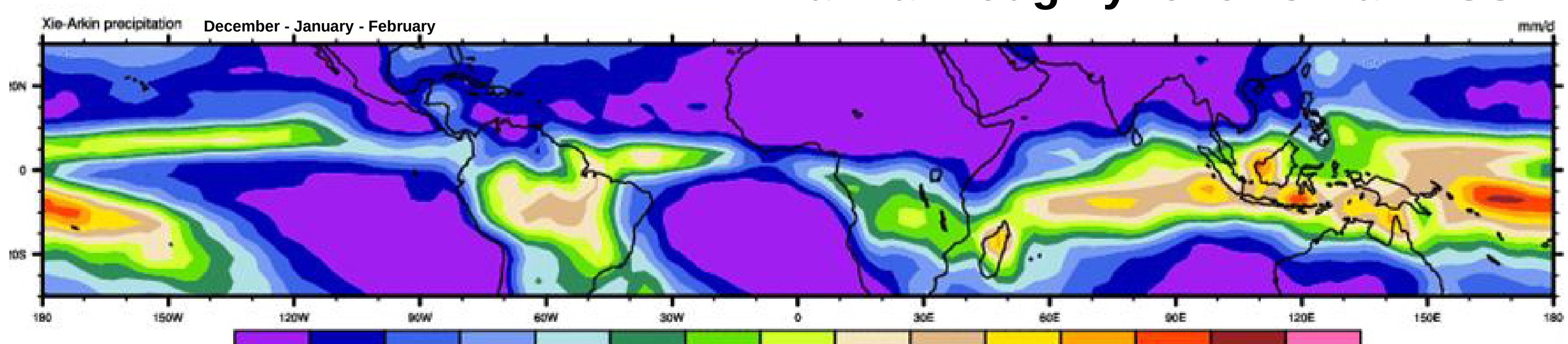
Uniform tropical upper-air temperature



Larger SST (sea surface temperature) variations



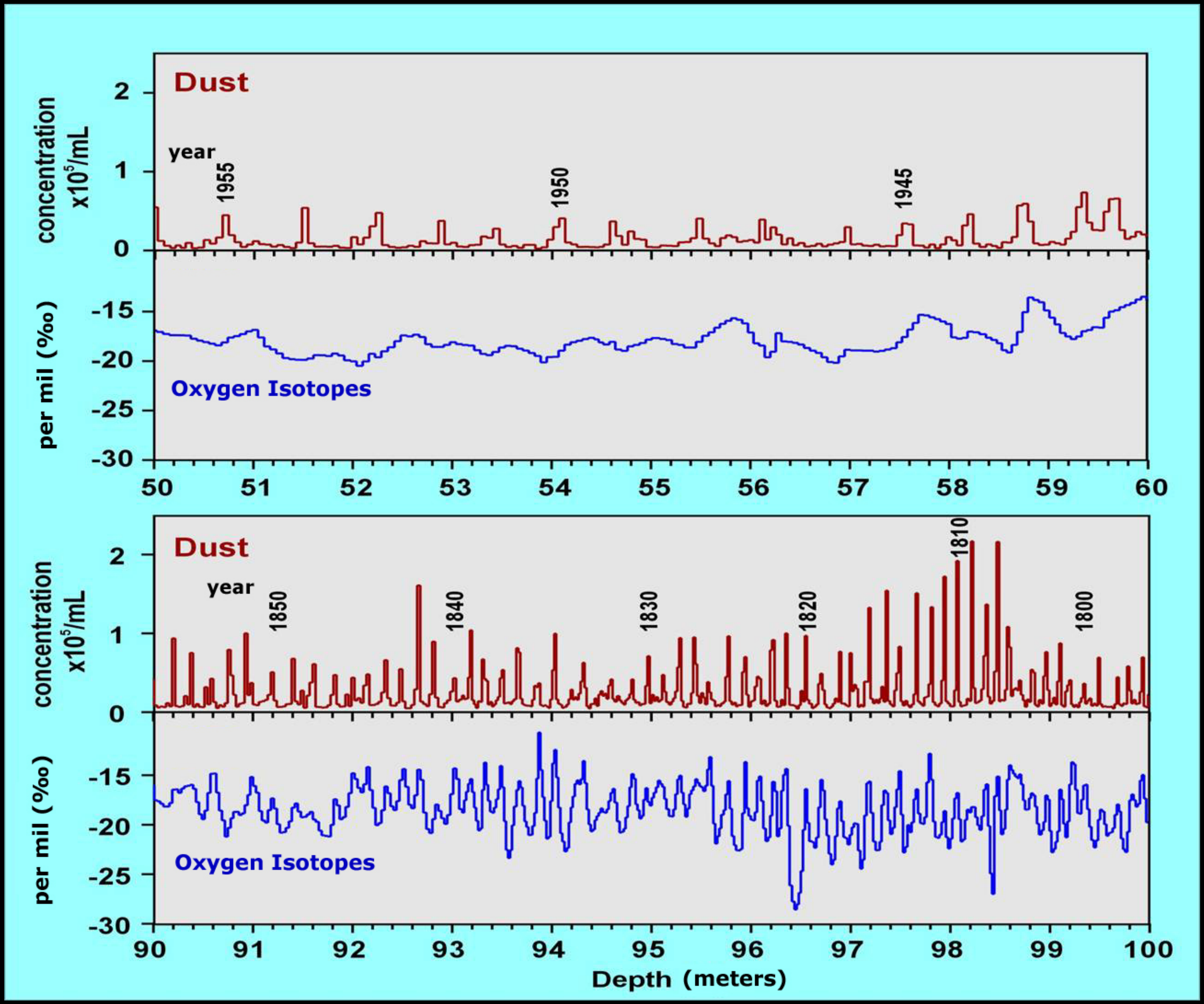
Rainfall roughly follows warm SST



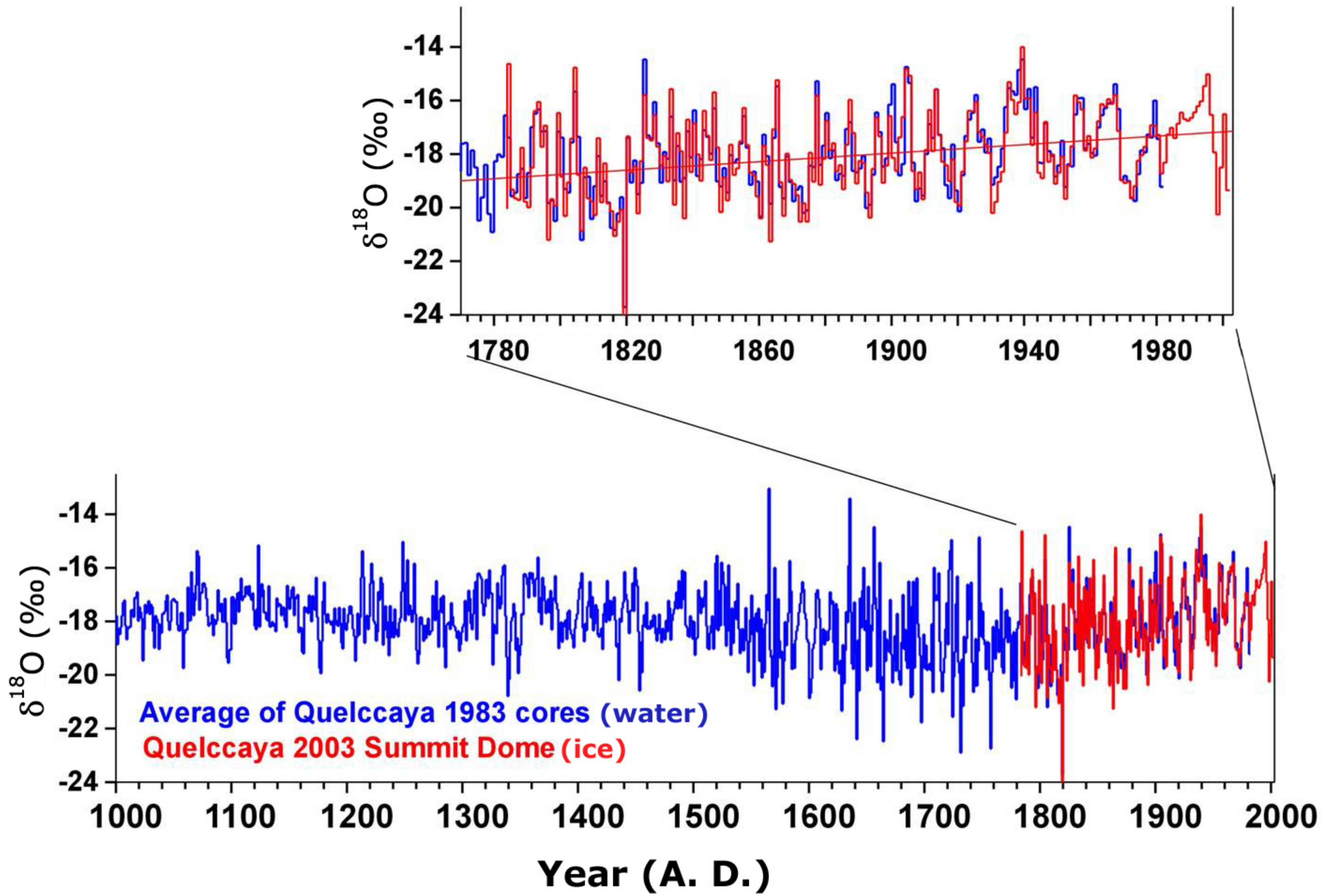
Sobel and Bretherton (2000)


Brazil
Peru
Bolivia

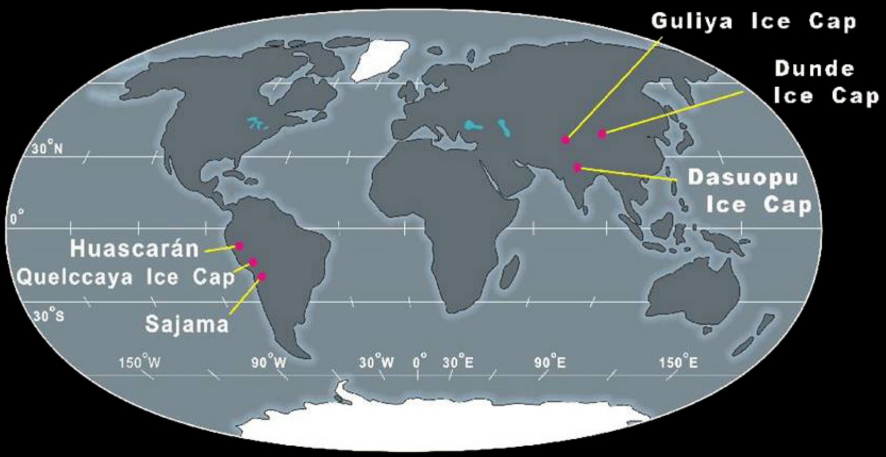
Ice Core Annual Layers

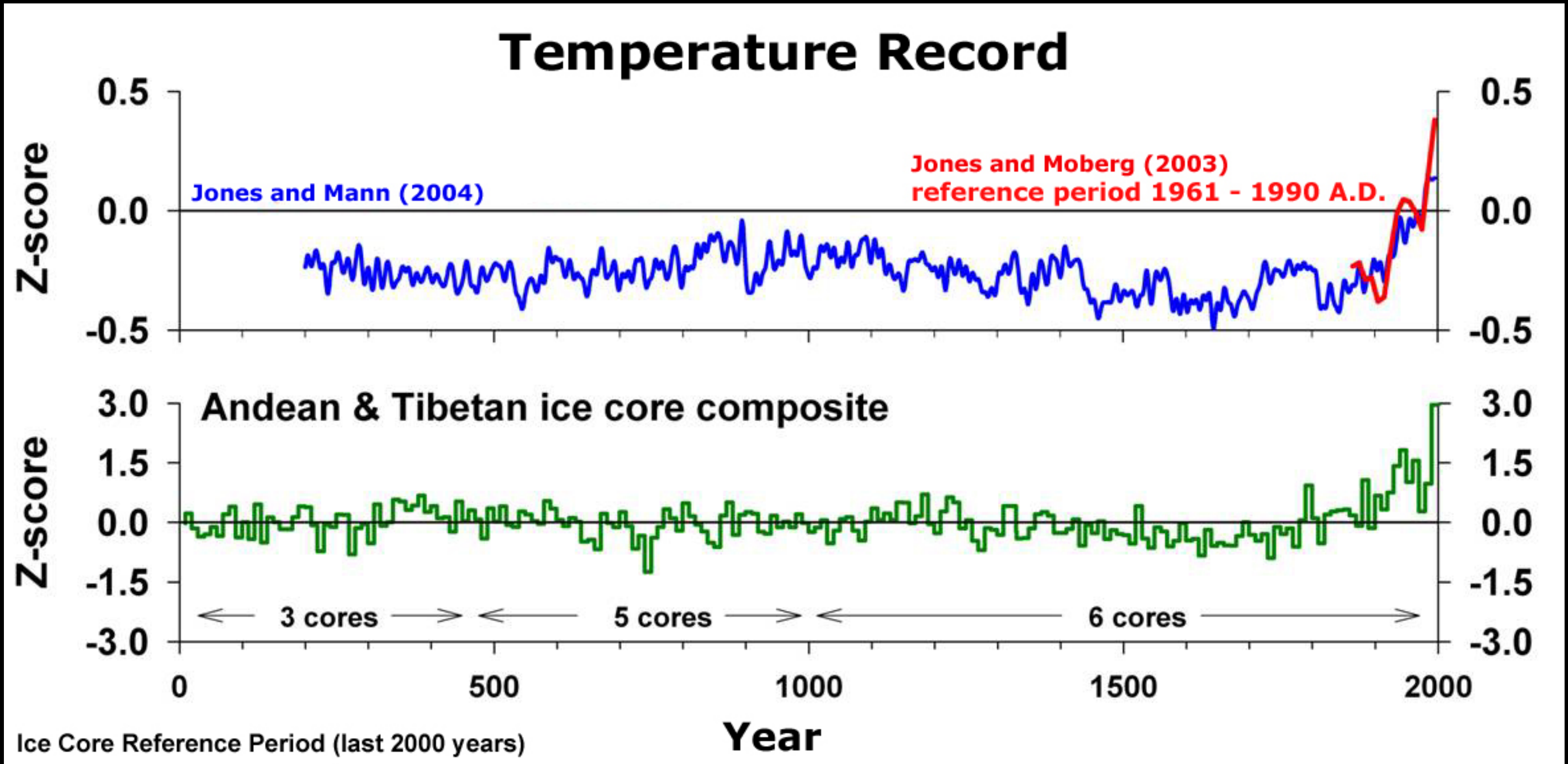


Annual averages of oxygen isotopes from Quelccaya ice cores drilled in 1983 and 2003

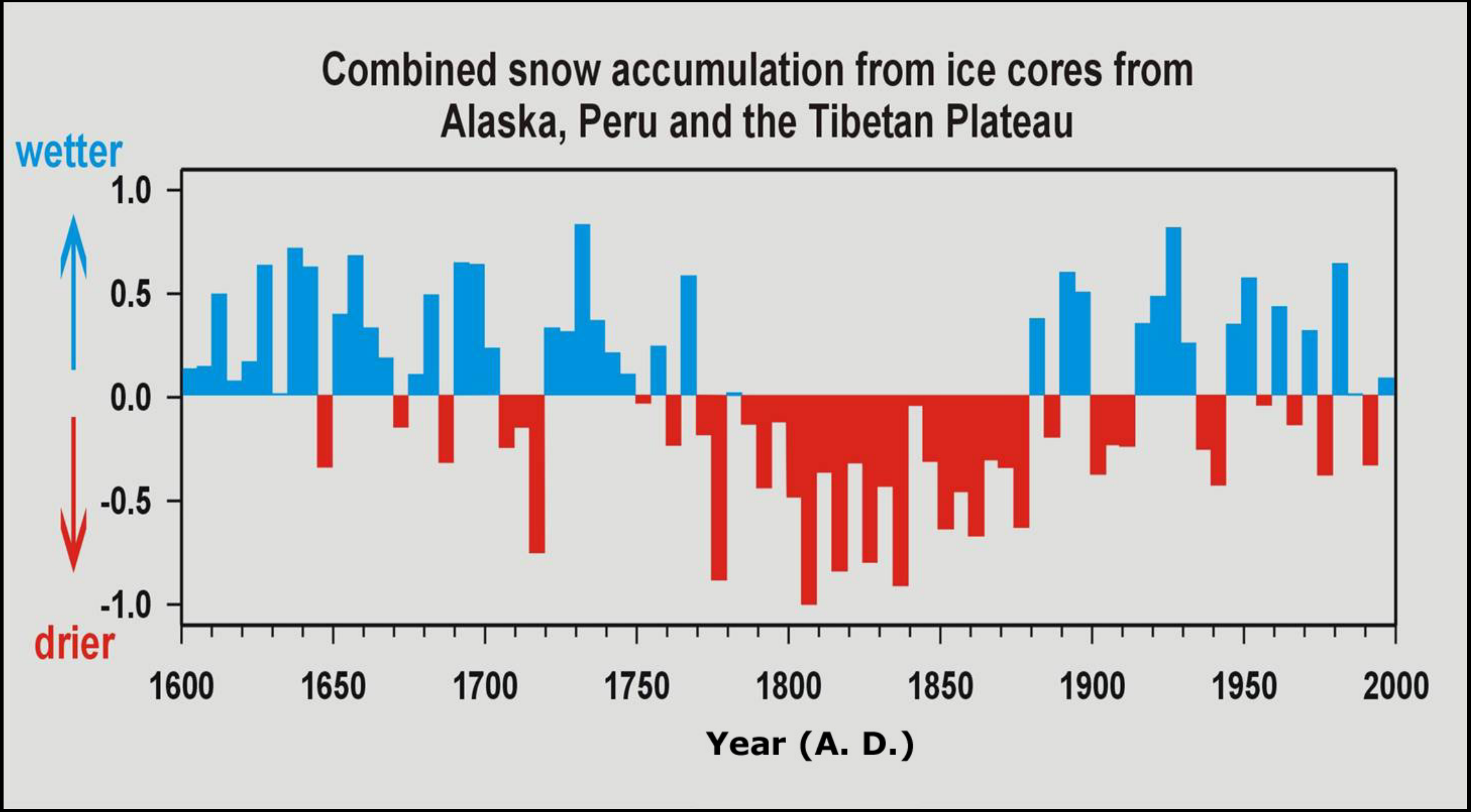


Cores Used in the Ice Core Composite Record





Ice core data for last 1000 years: Thompson et al. (2003)



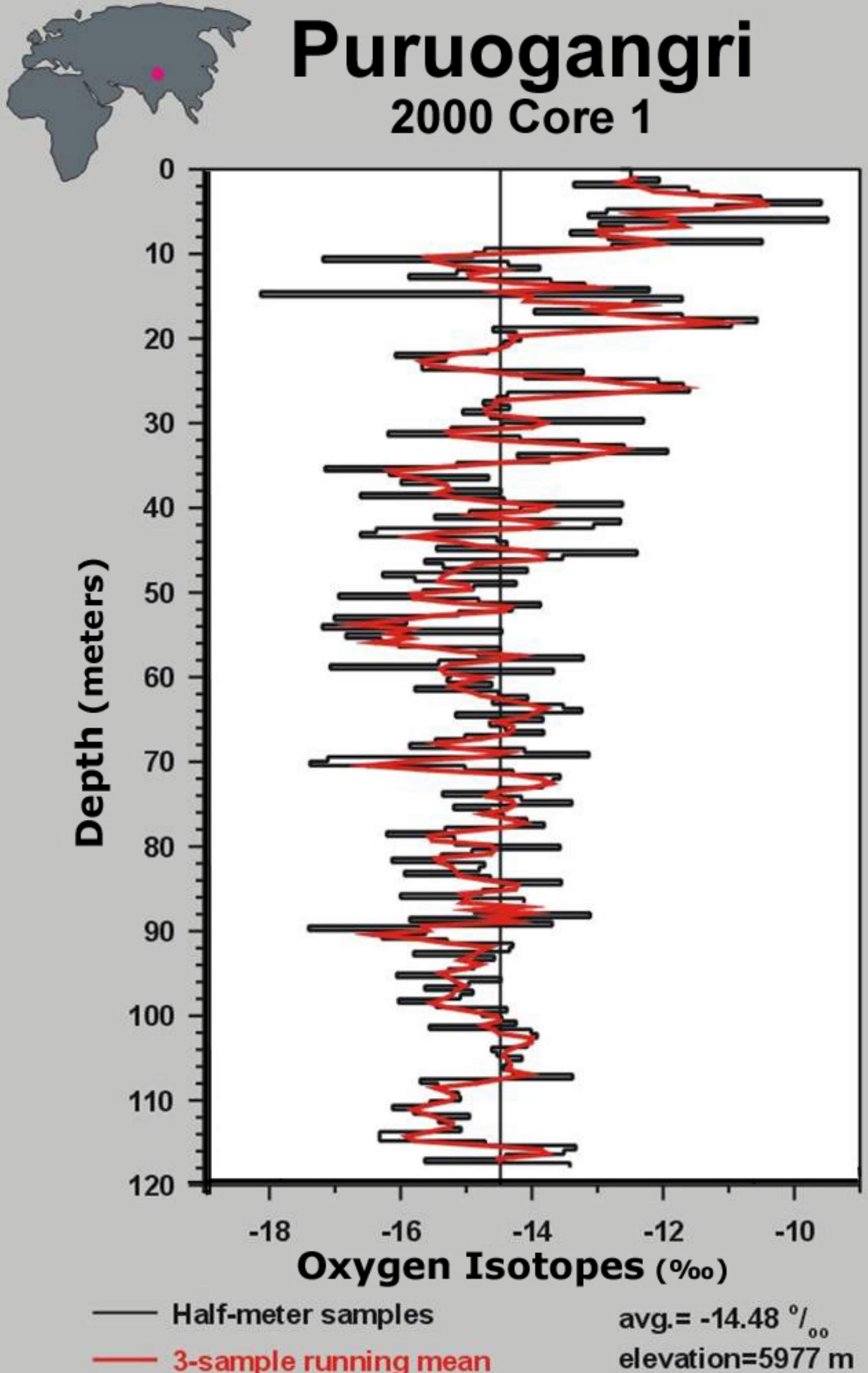
Combined snow accumulation from ice cores from
Alaska, Peru and the Tibetan Plateau
wetter
drier
1.0
0.5
0.0
-0.5
-1.0
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year (A. D.)

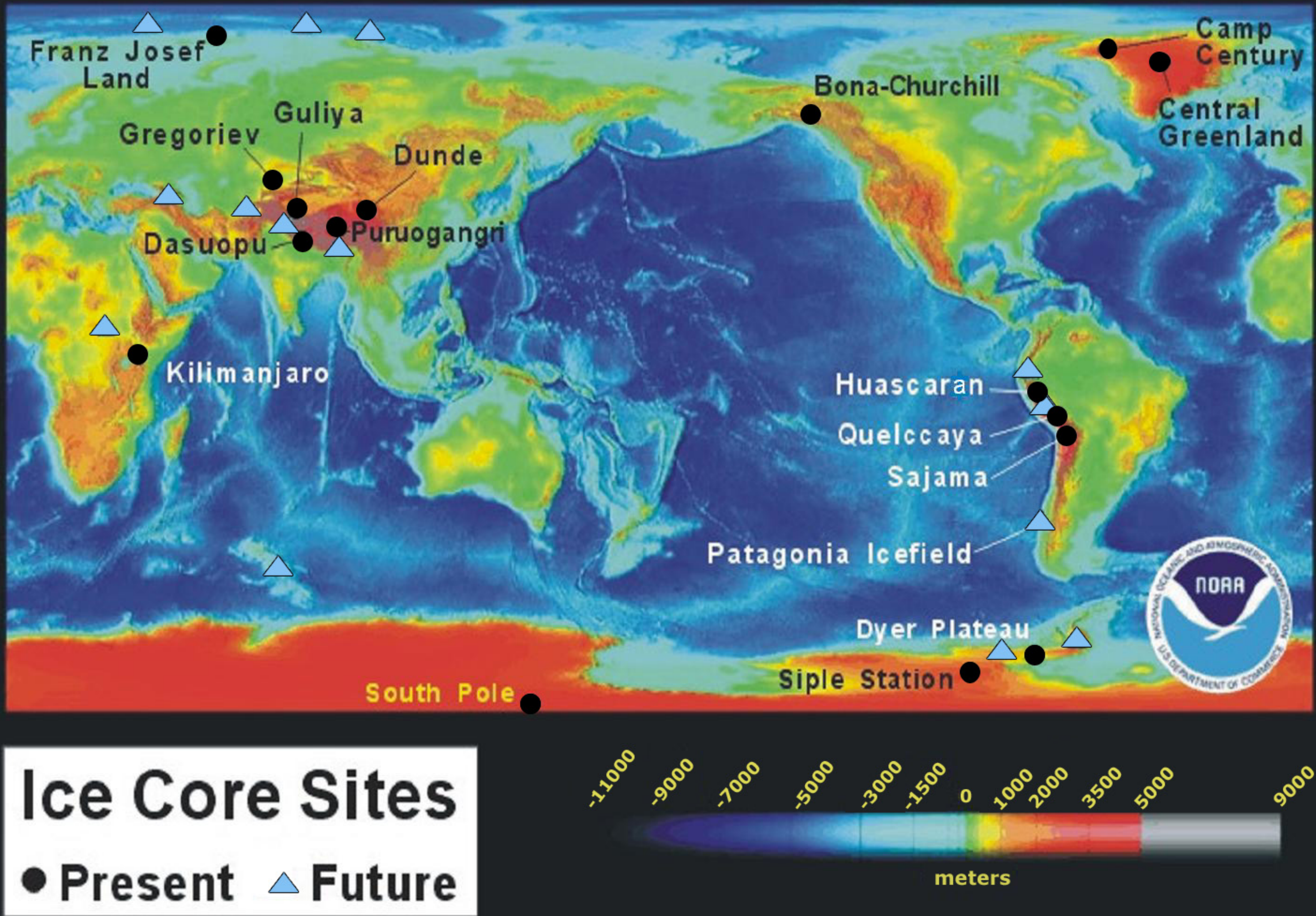
青藏高原第四纪冰川遗迹分布图
QUATERNARY GLACIAL DISTRIBUTION MAP OF QINGHAI-XIZANG (TIBET) PLATEAU
LEGEND
Dunde
Guliya
Puruogangri
Dasuopu
Proposed Research Area
KUNLUN MOUNTAINS

Puruogangri Ice Cap, Central Tibet

Puruogangri Ice Cap Core

Puruogangri
2000 Core 1





Franz Josef Land
Guliya
Gregoriev
Dunde
Puruogangri
Dasuopu
Kilimanjaro
Bona-Churchill
Camp Century
Central Greenland
Huascaran
Quelccaya
Sajama
Patagonia Icefield
Dyer Plateau
Siple Station
South Pole
NOAA
Ice Core Sites
Present
Future
-11000
-9000
-7000
-5000
-3000
-1500
0
1000
2000
3500
5000
9000
meters

McCall Glacier, Brooks Range, Alaska

1958 (Austin Post)

2003 (Matt Nolan)

Muir Glacier, SE Alaska

August, 1941

photo: William Field

August, 2004

photo: Bruce Molnia

Glacier No. 1
China

1960

1990

2001

Lonnie G. Thompson, Bryd Polar Research Center,
The Ohio State University

Glacier National Park, Grinnel Glacier

Photo: Fred Kiser, Glacier National Park archives

Photo: Karen Holzer, U.S. Geological Survey

Glacier National Park, Boulder Glacier

Photo: George Grant, Glacier National Park archives

Photo: Jerry DeSanto, National Park Service

From Hall and Fagre (2003)

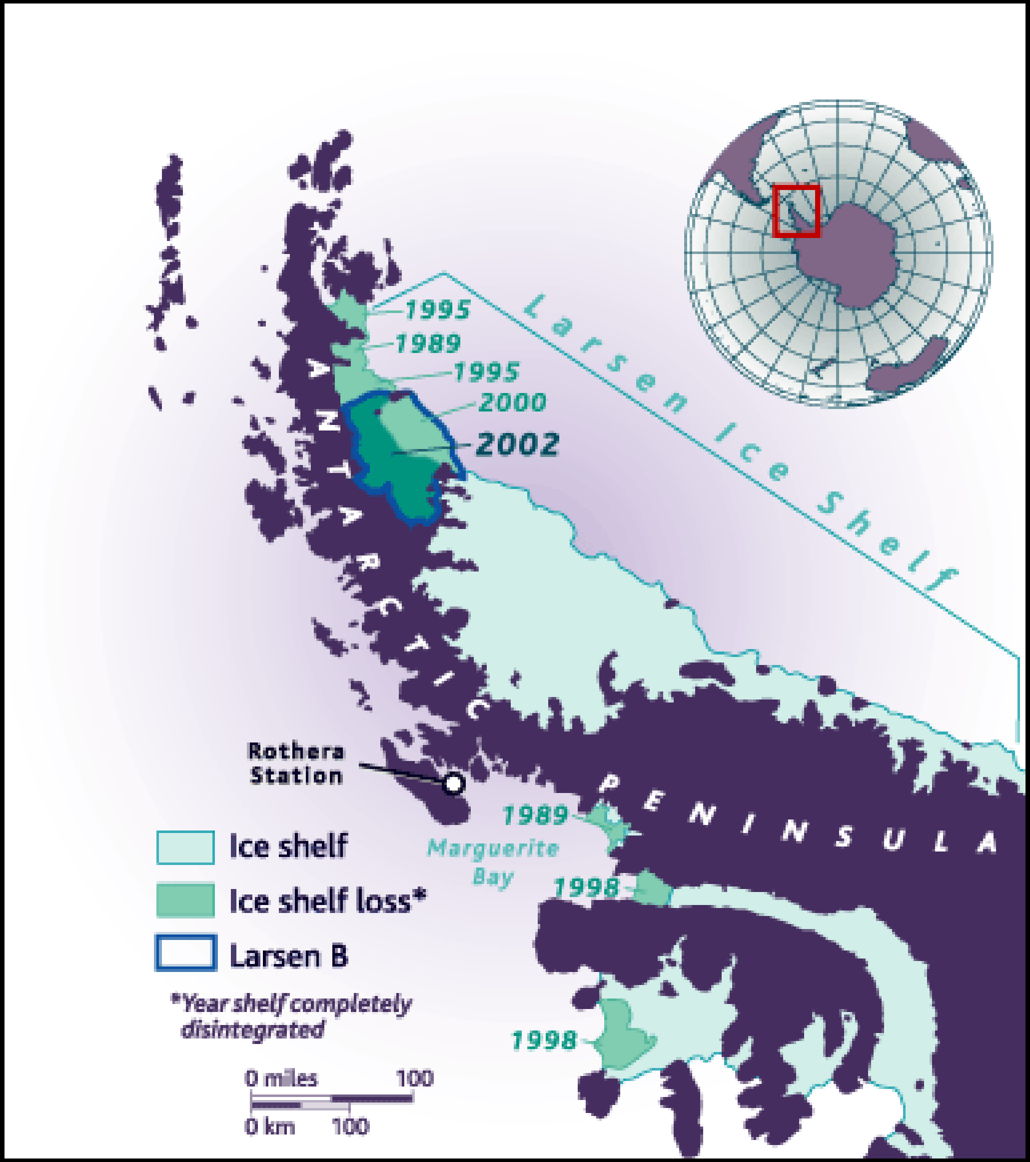
Kilimanjaro, Africa

Source: E. Oehler, Kilimanjaro, 1912

“One of the warning signs that a dangerous warming trend is under way in Antarctica will be the breakup of ice shelves on both coasts of the Antarctic Peninsula, starting with the northernmost and extending gradually southward.”

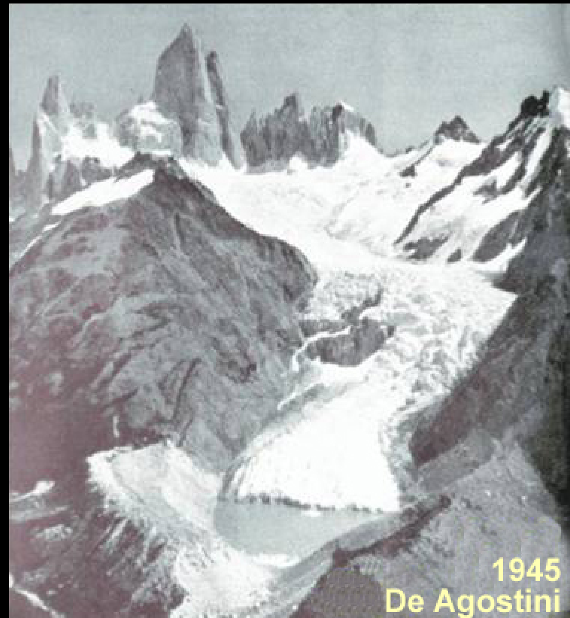
- Concluding statement in Mercer (1978)

The Antarctic Peninsula has lost large chunks of its ice shelves in recent years. Temperatures in the Peninsula region have warmed roughly 2.5°C in the last 50 years.



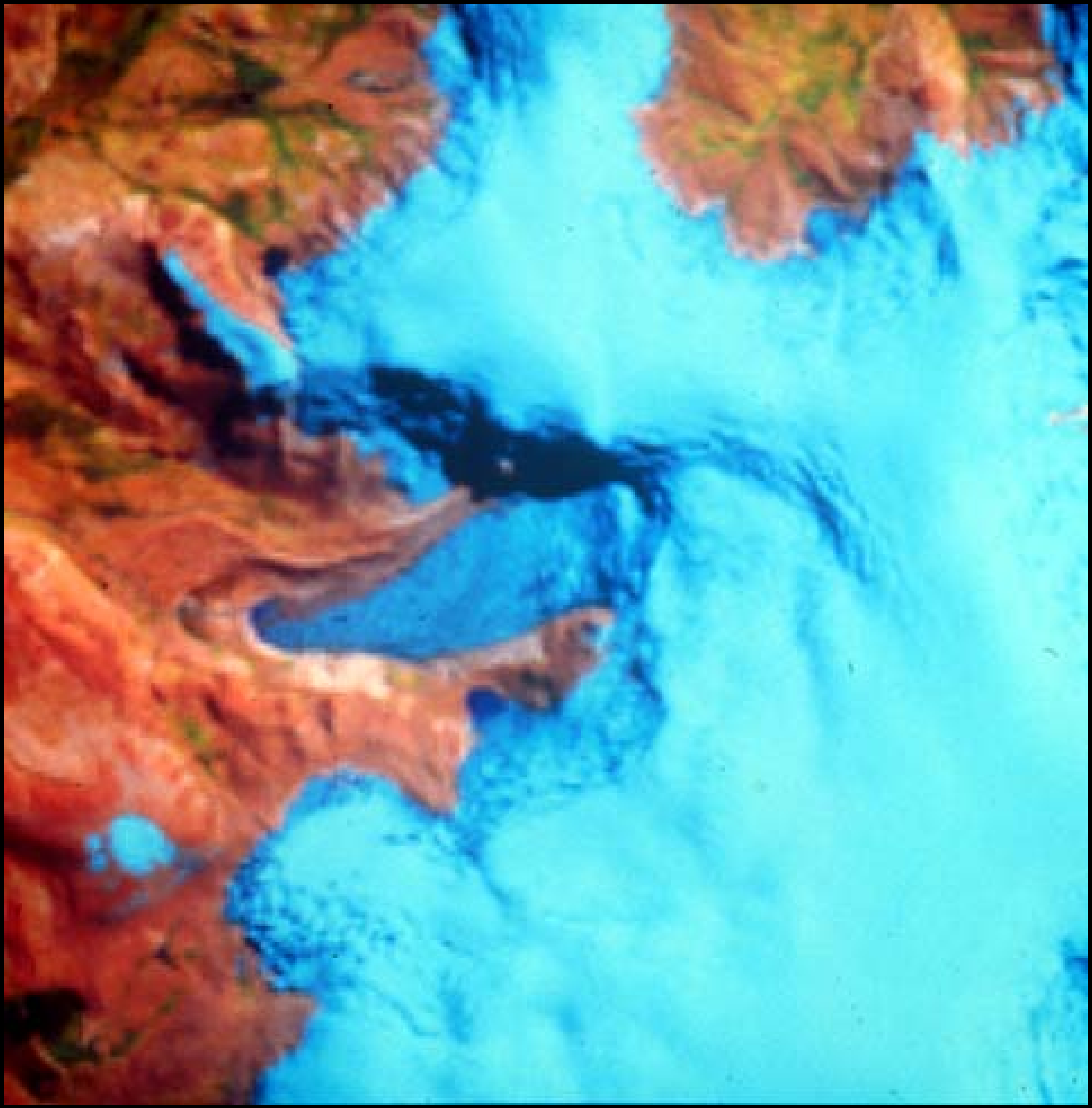
after Kaiser (2002)

Glaciar Piedras Blancas



Glaciar Lanín Norte

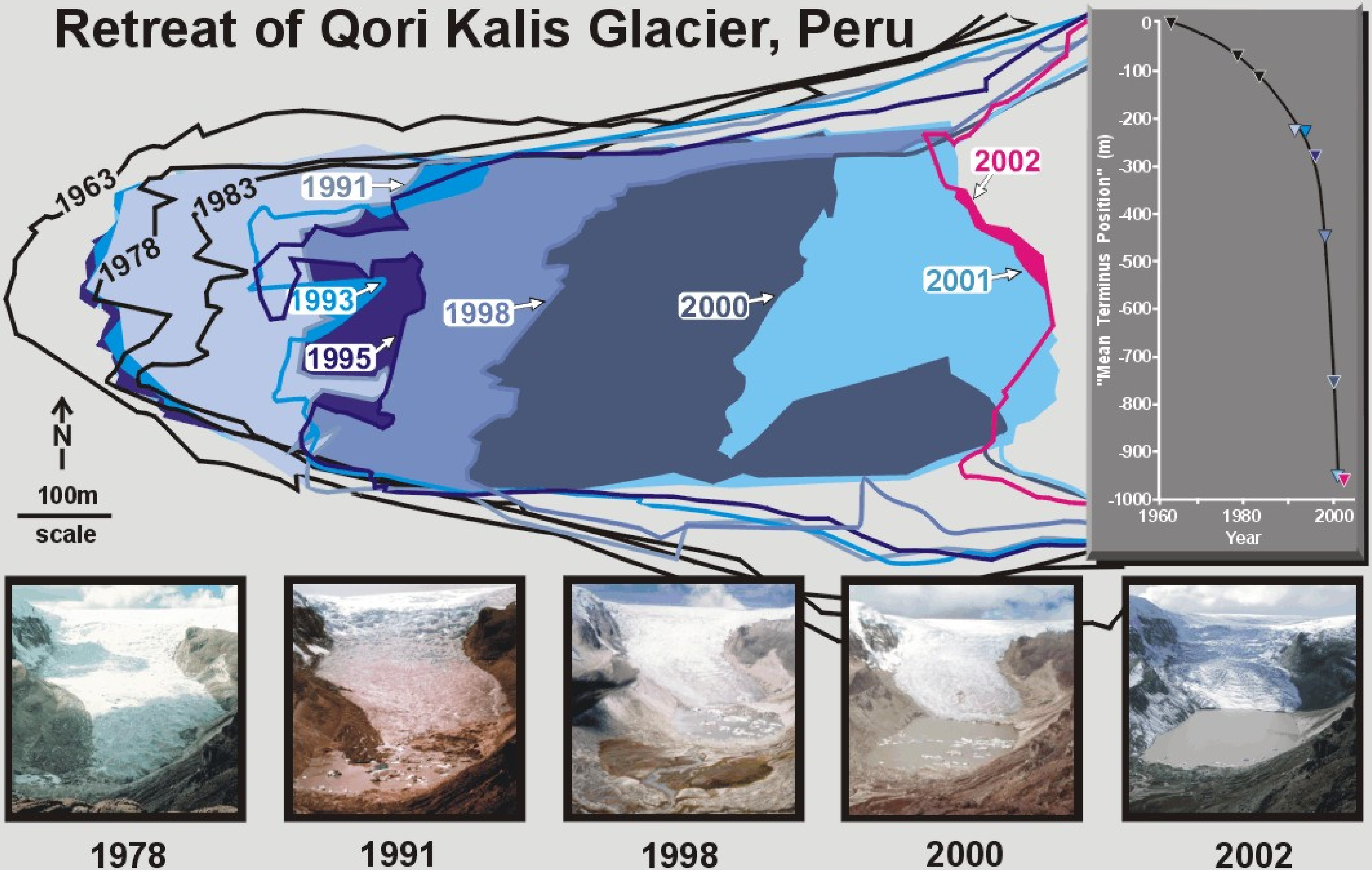
Quelccaya ice cap, Peru



Qori Kalis Glacier, Peru, 1978

Qori Kalis Glacier, Peru, 2002

Retreat of Qori Kalis Glacier, Peru



Oori Kalis Glacier, July 2004

Things we know with certainty

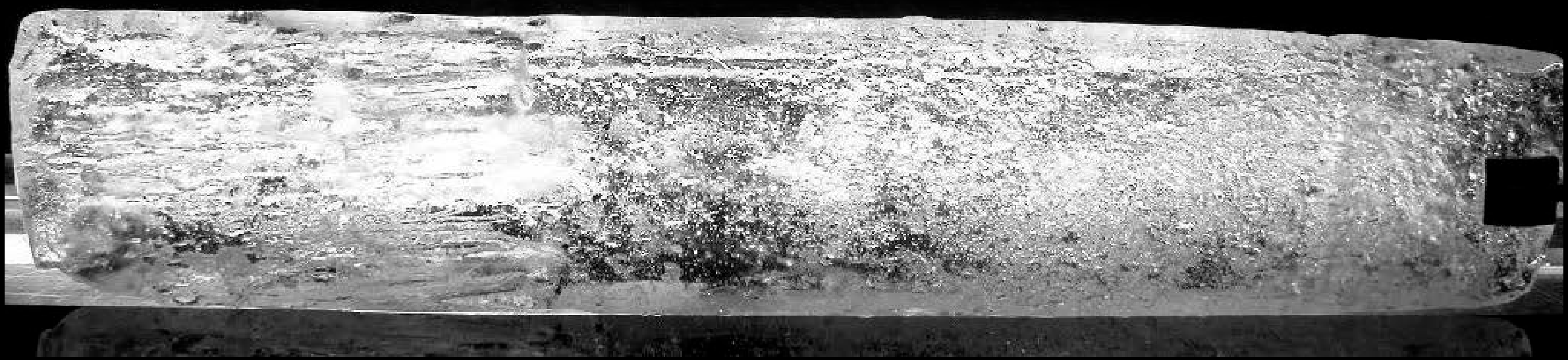
- Glaciers are disappearing and along with them a very valuable paleoclimate archive is being lost.

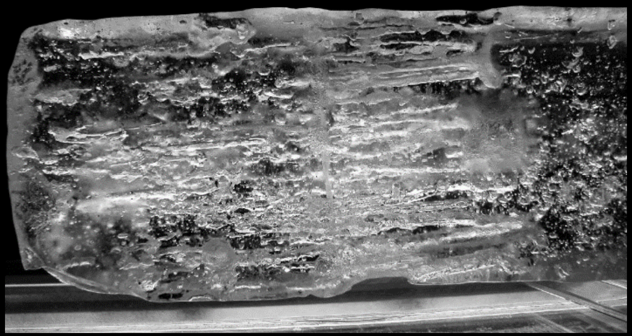
- The loss of glaciers (the world's water towers) threatens the water resources in many parts of the world that are necessary for:
  1) hydroelectric power production
  2) crop irrigation
  3) municipal water supplies

- The loss of glaciers around the world has a direct impact on tourism

Northern Ice Field, Kilimanjaro

Kilimanjaro (2000) Northern Ice Field Core 3

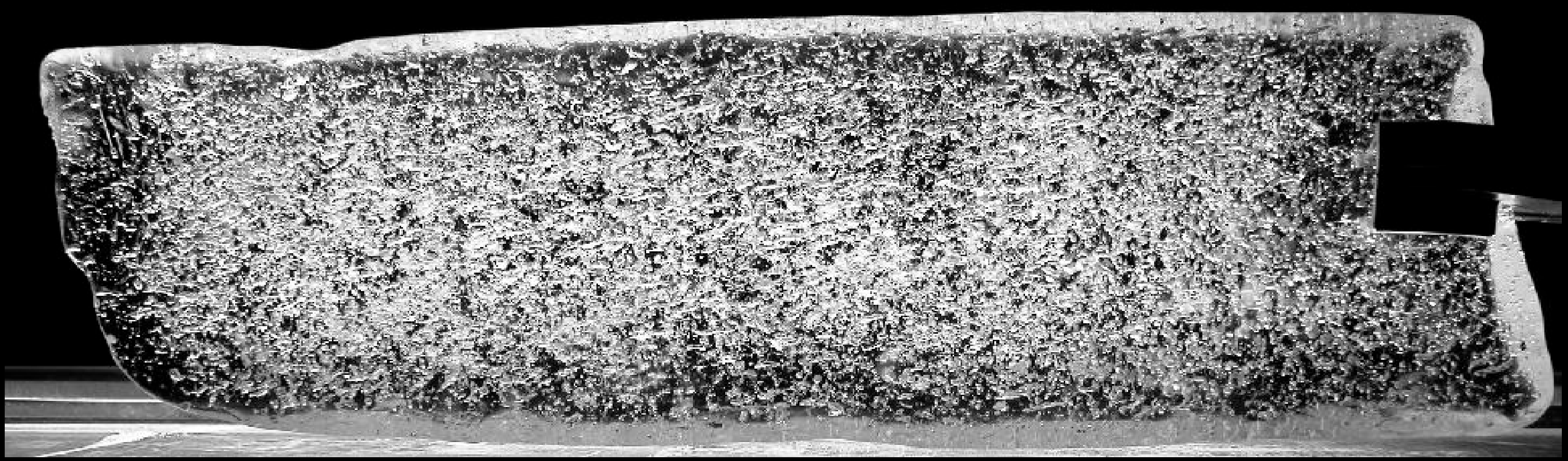




Tube 1: top: 0.00 meters

Elongated bubbles

Tube 43: top: 42.84 meters



“What the Ice Gets, the Ice Keeps”

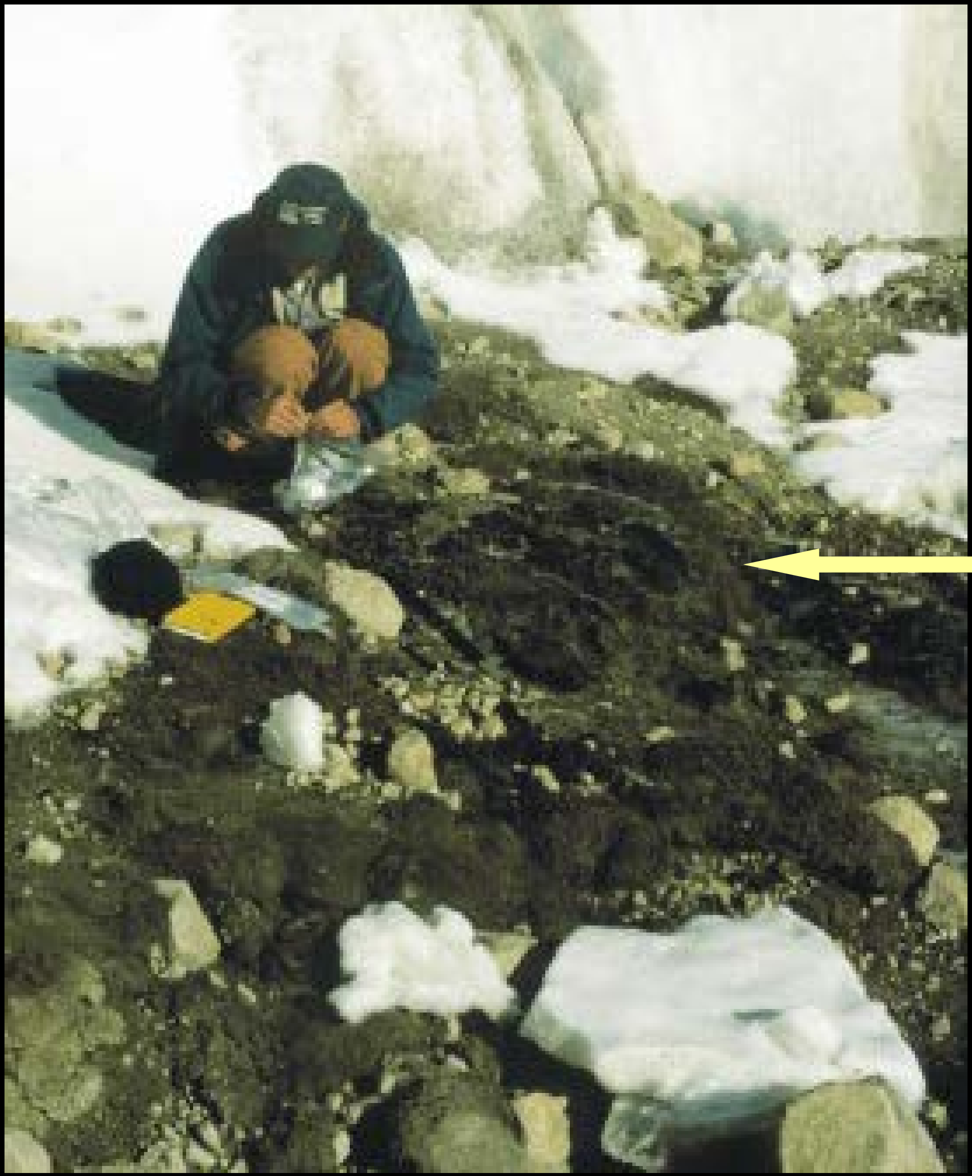
- Sir Ernest Shackleton
1915

Quelccaya, Peru

1977

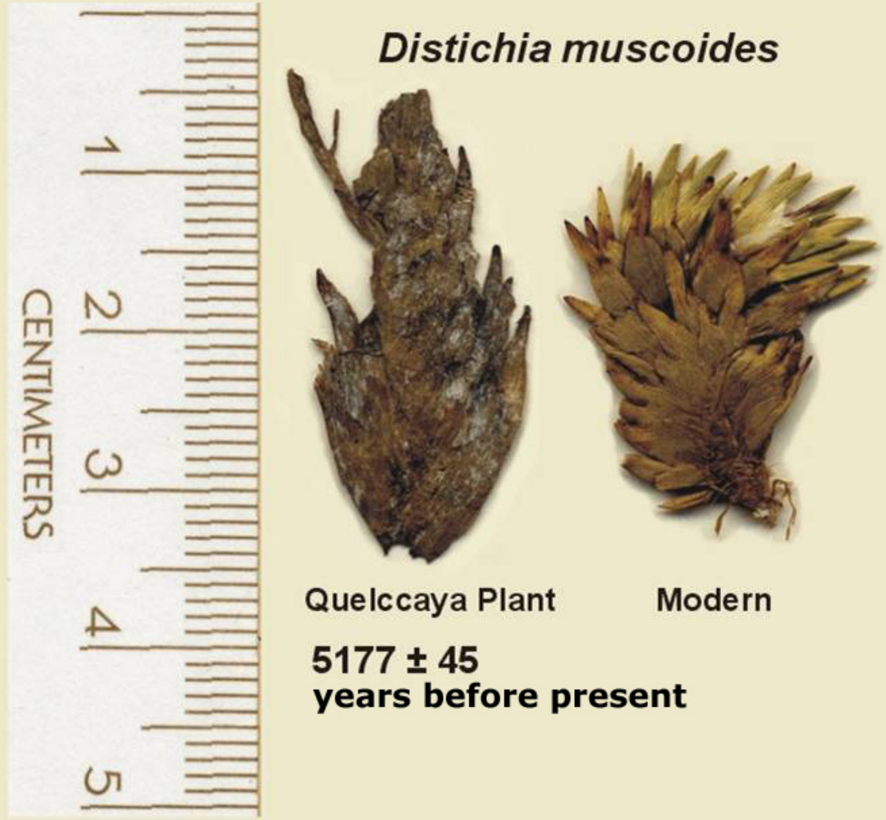
2002

Quelccaya Ice Cap, 2002



Plant

200 – 400 meters above its modern range



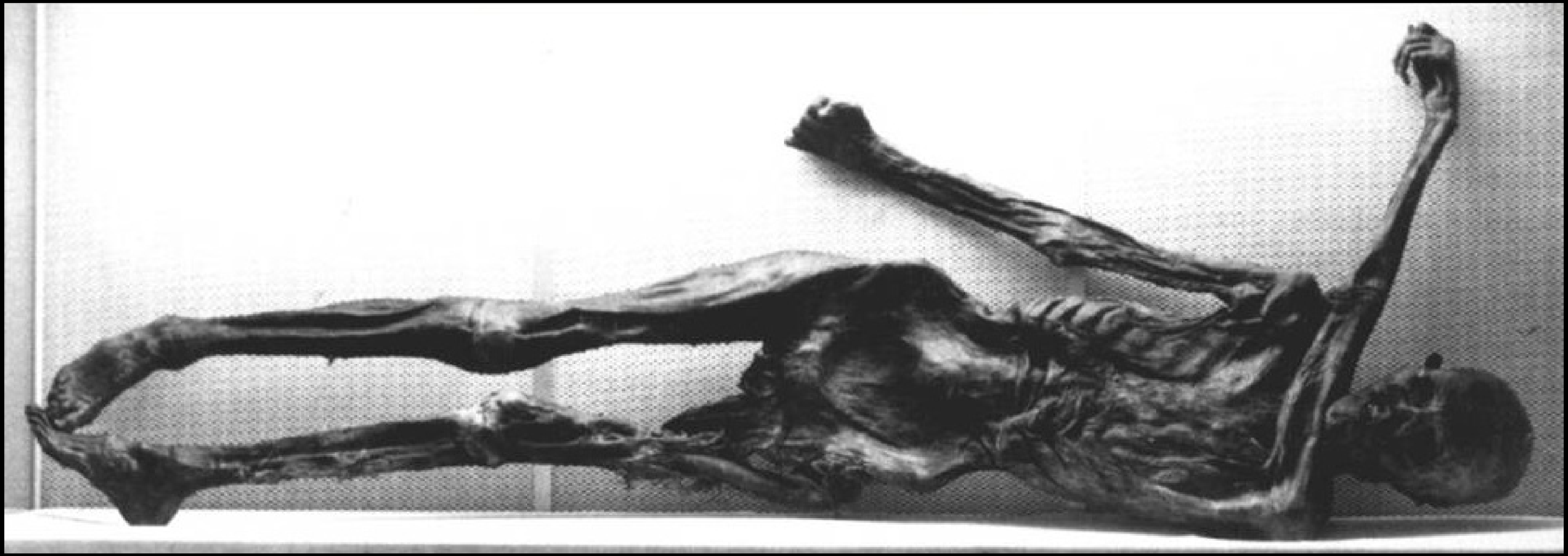
Radiocarbon dates of plants from base of Quelccaya Ice Cap

	^{14}C age	Error (+/-)	Calibrated age (Before 1950 A.D.)	Relative area under probability distribution
Lawrence Livermore National Laboratory				
Sample 1 First run	4470	60	5284-5161 (1σ)	.534
			5302-4961 (2σ)	.926
Sample 1 Second run	4525	40	5186-5121 (1σ)	.413
			5311-5047 (2σ)	1.000
Sample 2 First run	4530	45	5186-5120 (1σ)	.396
			5317-5040 (2σ)	.993
Sample 2 Second run	4465	40	5278-5171 (1σ)	.580
			5295-4967 (2σ)	.984
National Ocean Sciences AMS Facility at Woods Hole Oceanographic Institution				
Sample 1	4530	45	5186-5120 (1σ)	.396
			5317-5040 (2σ)	.993
Sample 2	4510	40	5188-5119 (1σ)	.404
			5307-5040 (2σ)	.988

“The Tyrolean Iceman” – “Otzi”

“Man from the Hauslabjoch”

Age 5175 ± 125 years



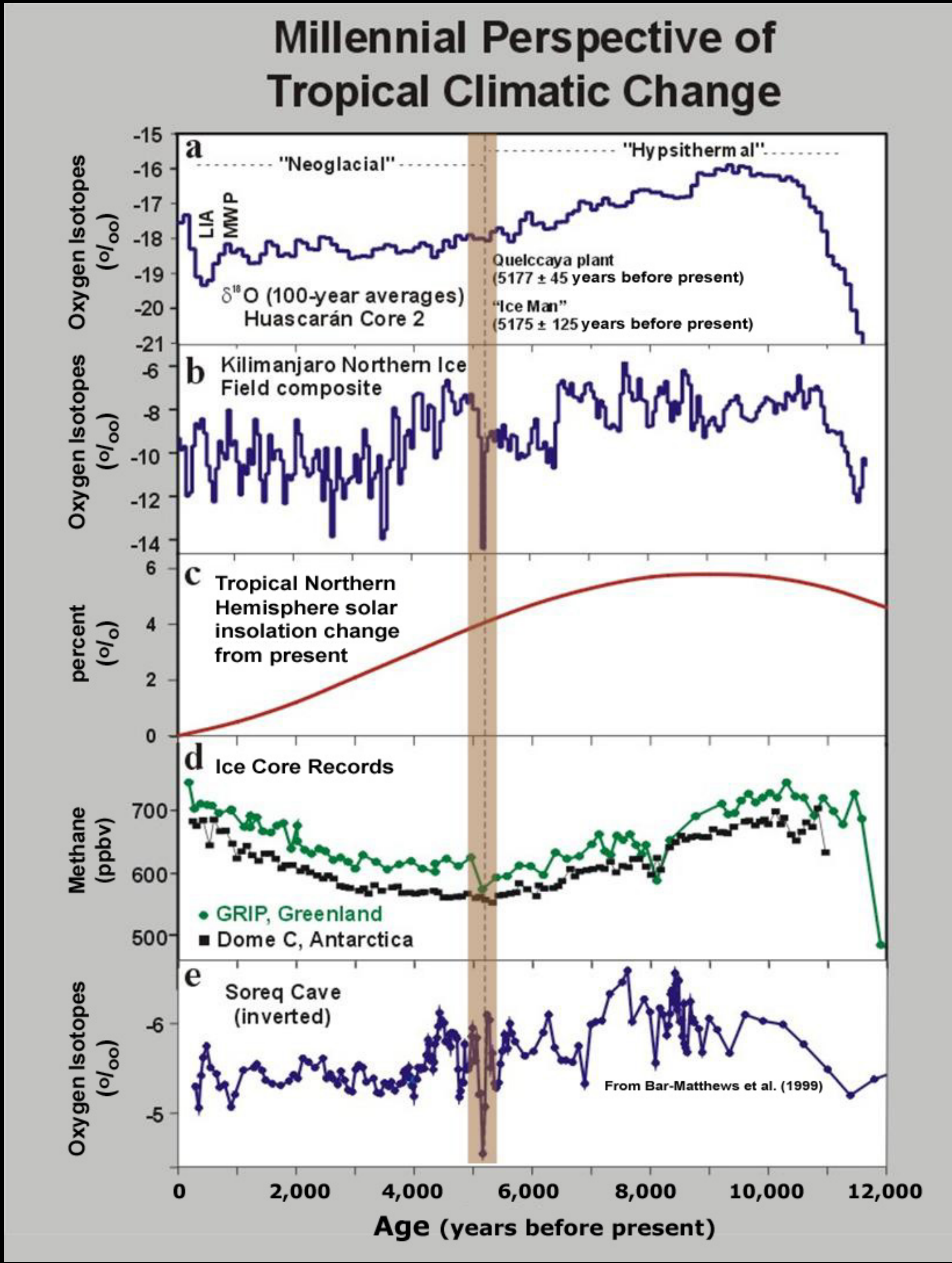
Source: http://info.uibk.ac.at/c/c5/c552/Forschung/Iceman/iceman-en.html#Finding

Does the abrupt climate event at ~5,200 years before present mark the transition from early Holocene “Hypsithermal” to late Holocene “Neoglacial” conditions?

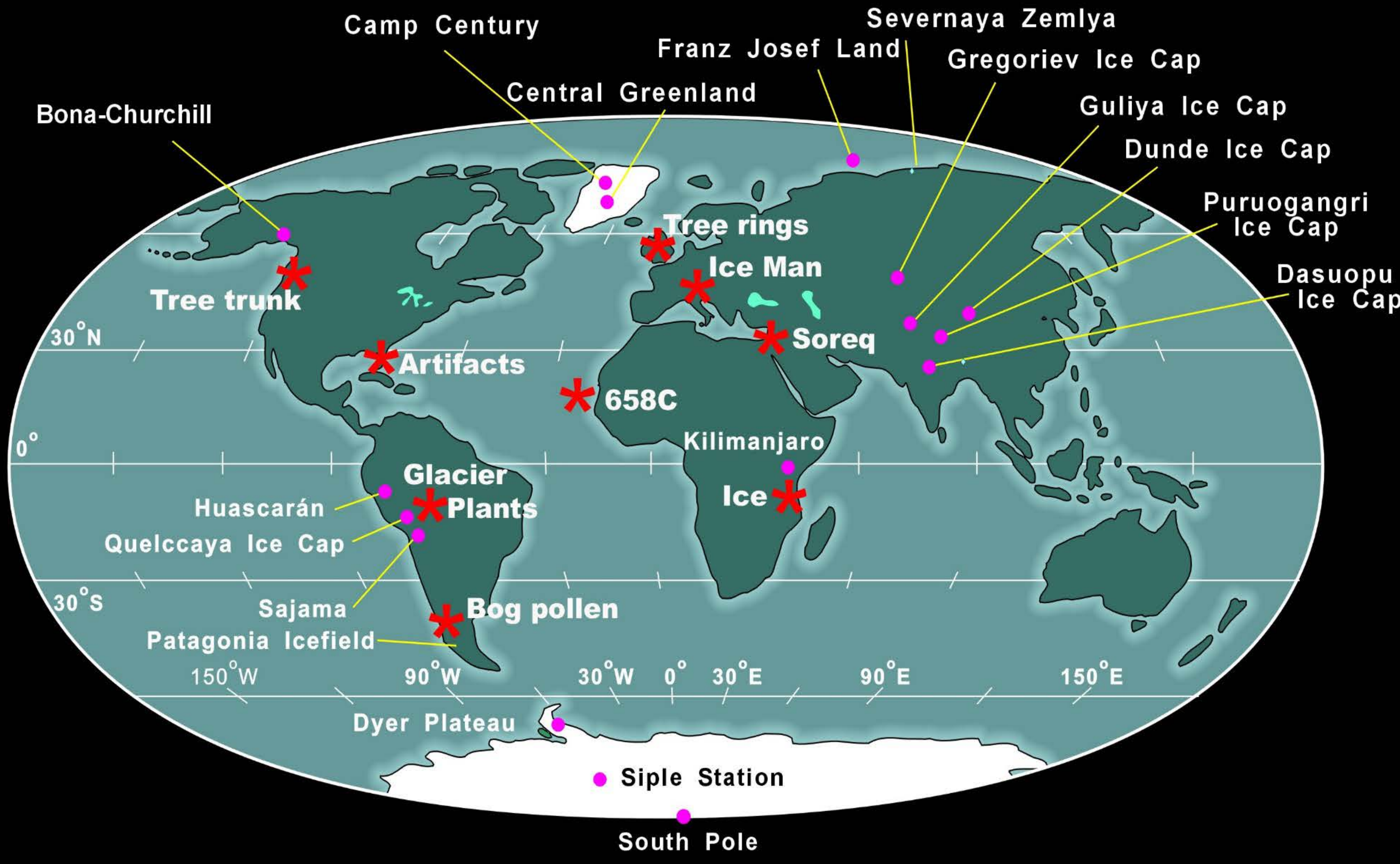
Do these abrupt (non-linear) events result from linear climate forcing?

Was a critical threshold exceeded?

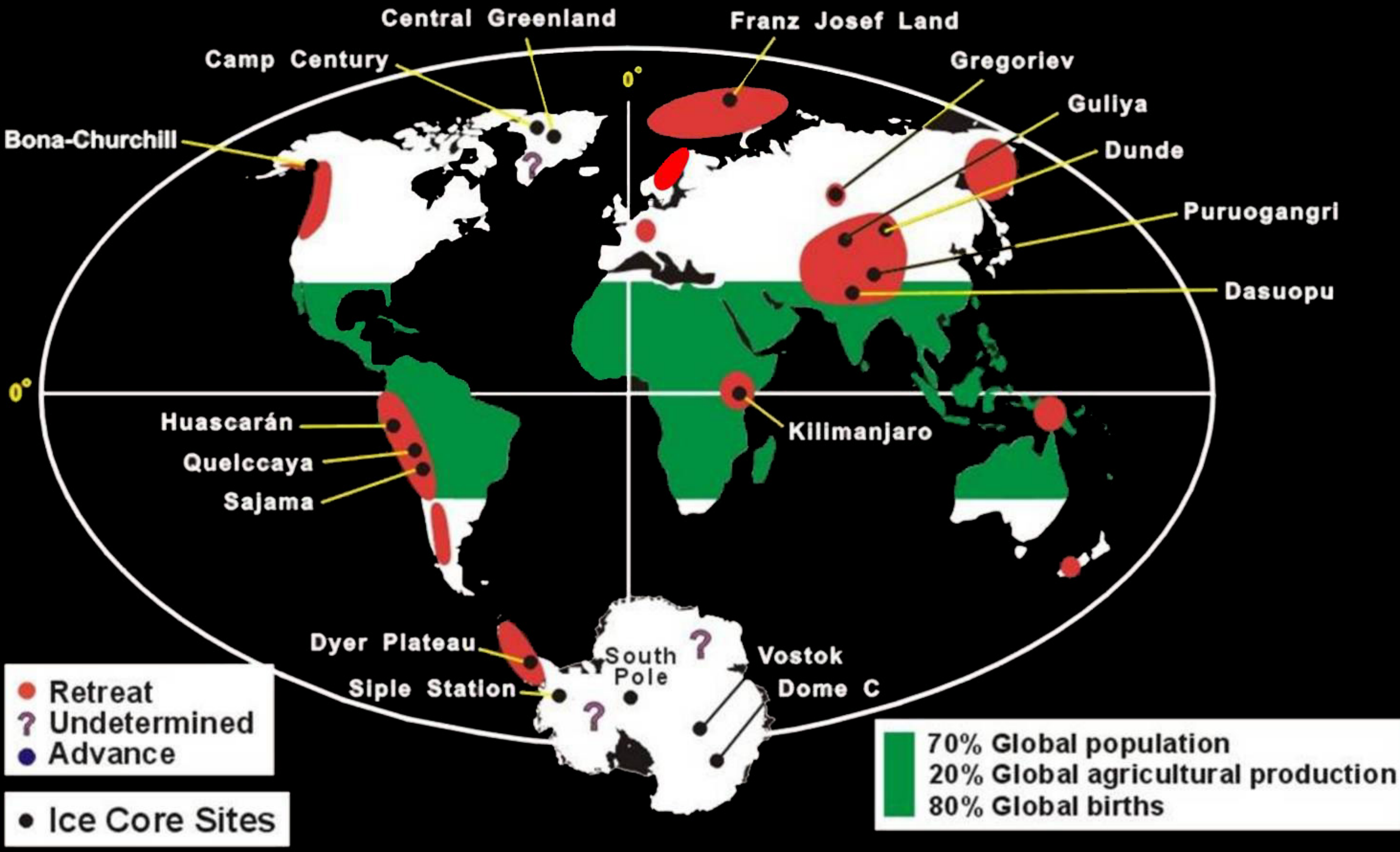
What is the role of non-linear feedbacks?



Sites with 5,200 Year Abrupt Climate Change Evidence*



20th Century Changes in Ice Cover

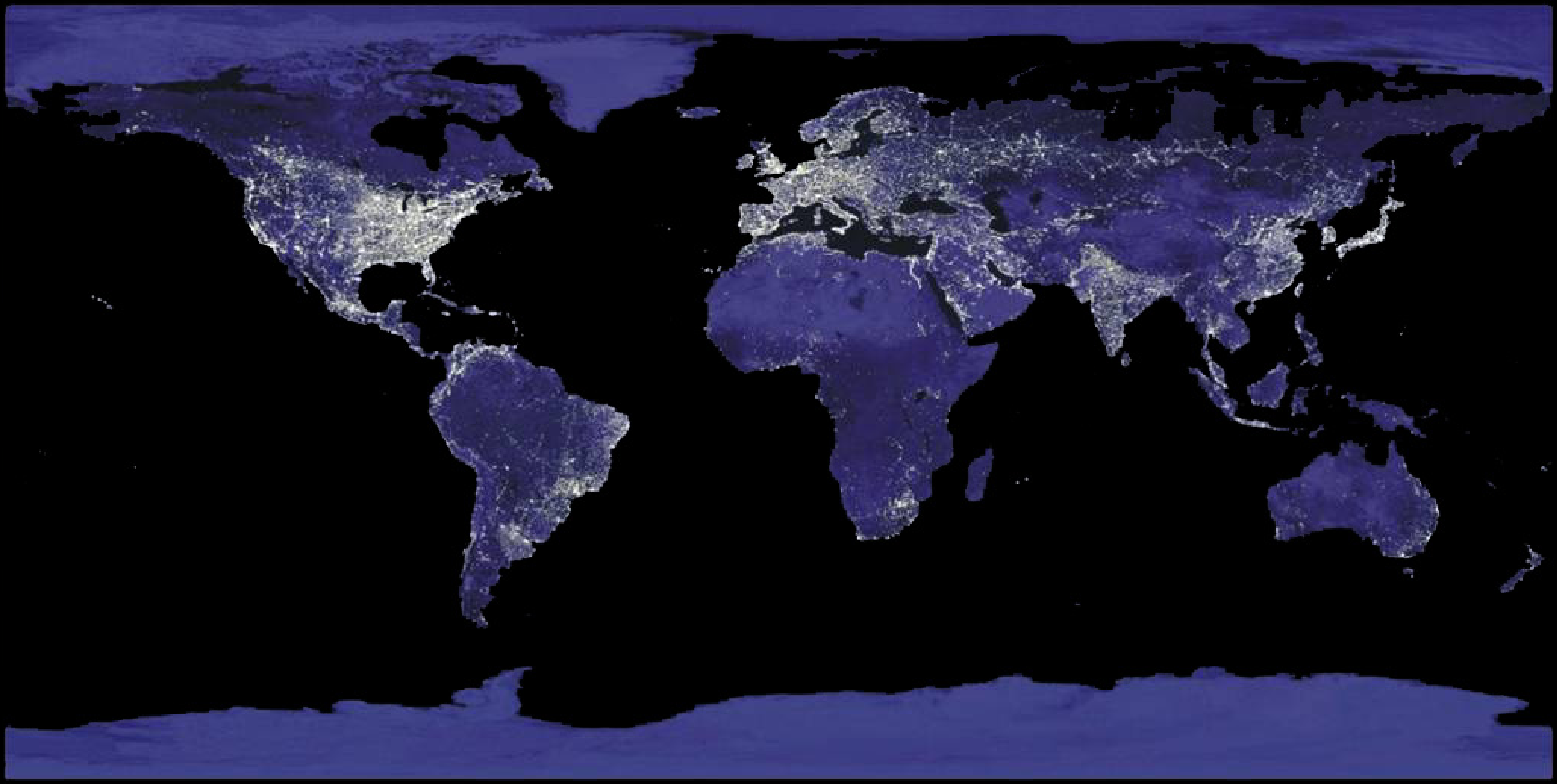


Consequences of Melting Glaciers

1. **The Loss of Nature's Water Towers**: the loss of glaciers is documented around the world and the rates of loss are increasing.

2. **Ice on Earth:** ice covers about 10% of Earth's continental area. Most of that ice—more than 32 million cubic kilometers---- shrouds Antarctica and Greenland, but around 100,000 cubic kilometers are locked in the mountain glaciers.

3. **Sea Rise due to Melting Glaciers and Thermal Expansion of Oceans**: alpine glacier melting and thermal expansion of the world's oceans will raise sea level by ~0.5 meters, displacing 100 million people in Bangladesh alone.



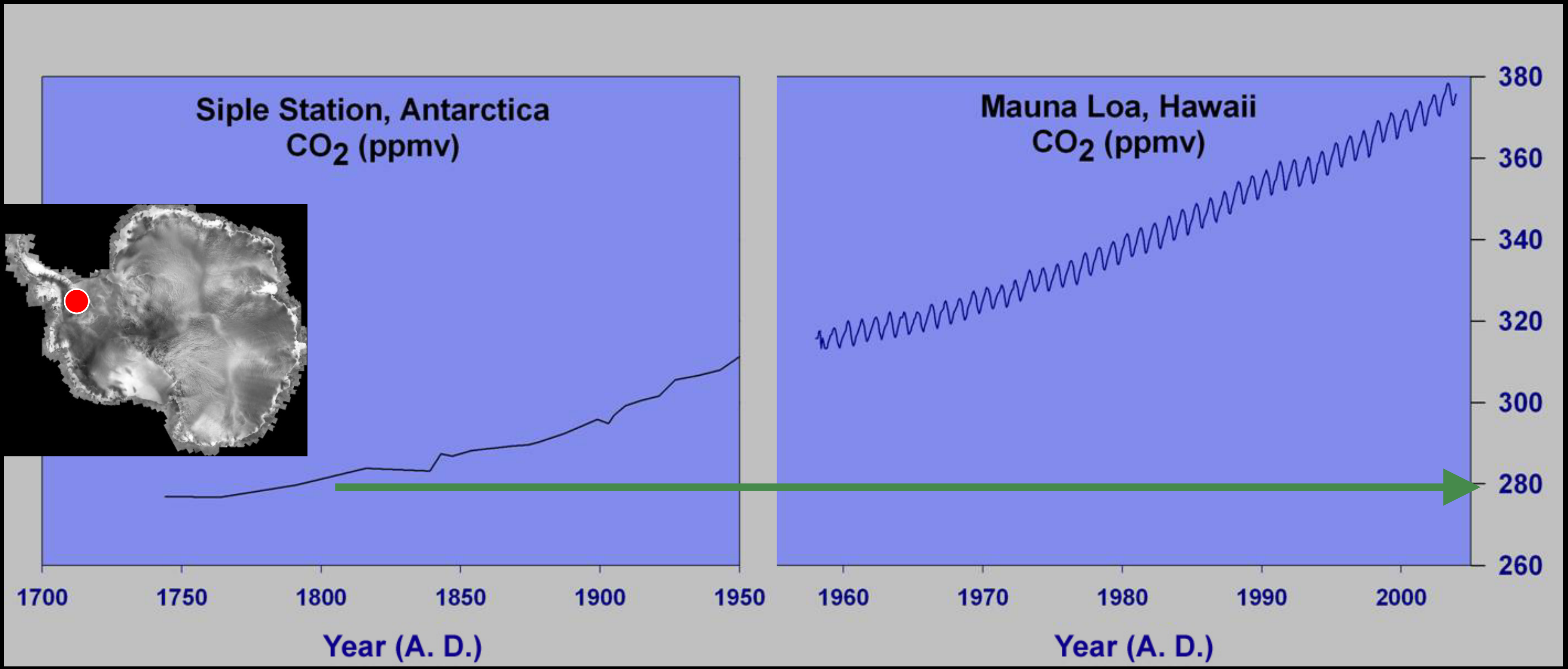
Earth at Night

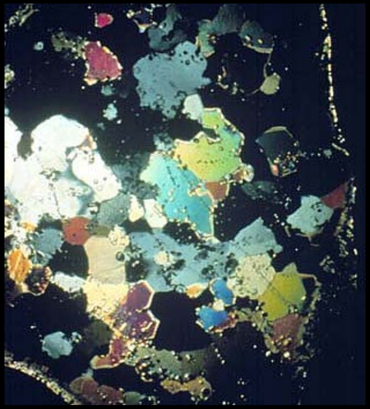
Source: http://antwrp.gsfc.nasa.gov/apod/ap040822.html

“As world population has doubled and as the global economy has expanded sevenfold over the last half-century, our claims on the earth have become excessive. We are asking more of the Earth than it can give on an ongoing basis, creating a bubble economy.“

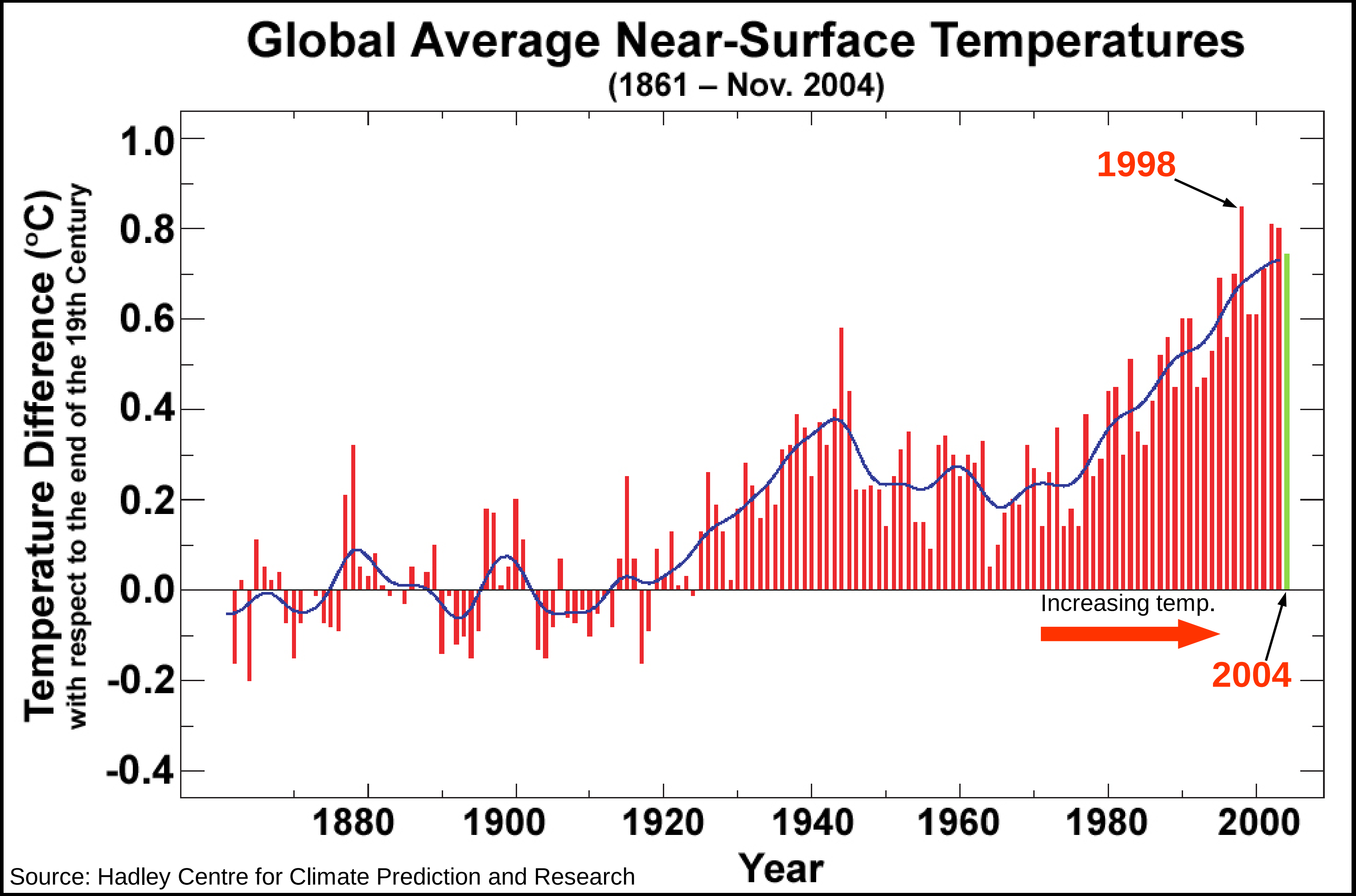
\- Brown (2003)

Carbon Dioxide Concentrations



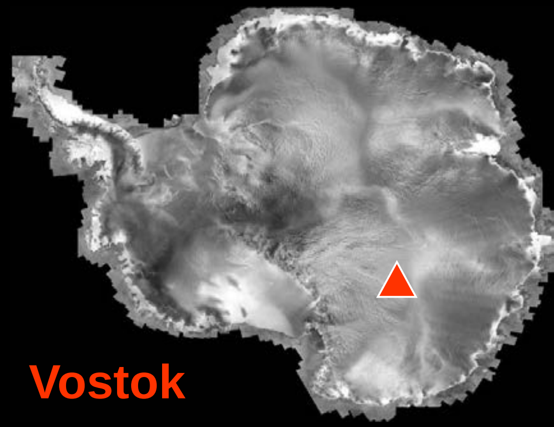


There is concern because we are living in a time of unprecedented changes – some of these changes are occurring at rates that we have not witnessed in the past (including the geologic record)

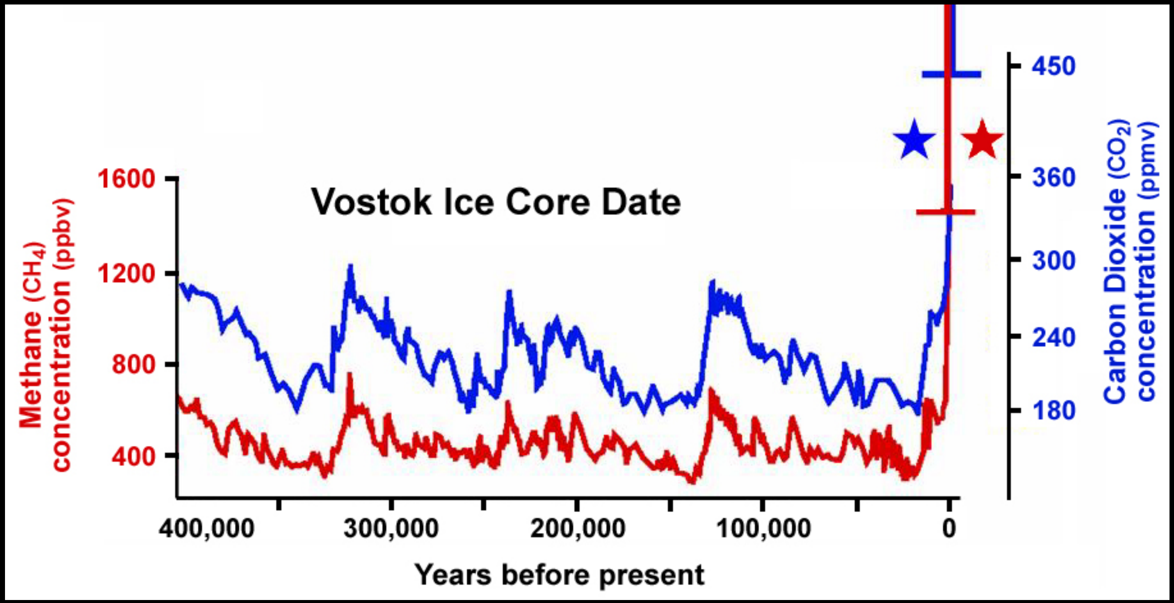


2004 was the 4th warmest year on record.

From: http://www.metoffice.com/research/hadleycentre/pubs/brochures/B2004/global.pdf



The Vostok ice core extends back through multiple glacial and interglacial stages - recording the changes in the composition of the Earth's atmosphere.

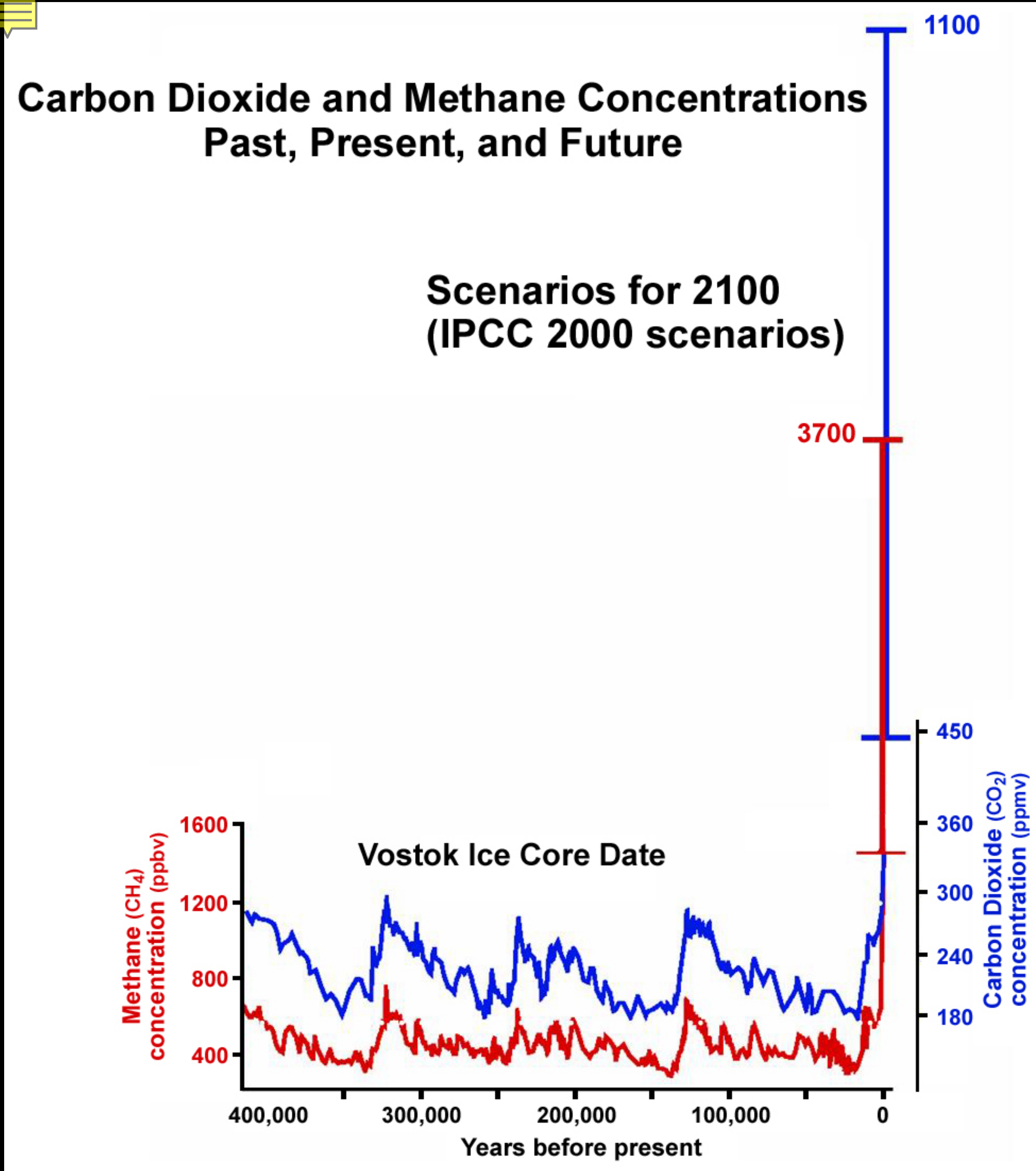


Today's atmospheric concentrations:

★ CO_2 = 378 ppmv

★ CH_4 = 1750 ppbv

Houghton et al. (2001), Petit et al. (1999)



In 2100:
★CO_2 ~ 1100 ppmv

In 2100:
★CH_4 ~ 3750 ppbv

Today's atmospheric concentrations:

★CO_2 = 378 ppmv
★CH_4 = 1750 ppbv

Houghton et al. (2001)

OUR OPTIONS

IGNORE?

Do nothing in particular, and allow the market forces to work through the problems?

MITIGATE

Actively mitigate against the production of greenhouse gases, and reduce the extent of the change.

Will market forces lead us onto a substitution path for energy resources, or will we have to do more than that?

Market forces alone are not going to produce the big switch in energy resources that is required if we are serious about a significant reduction in carbon dioxide production. So we will need to actively reduce our dependencies on fossil fuel.

ADAPT

Adapt to significant change that is inevitably ahead of us, managing the multiple risks that can be foreseen.

Crisis

危機

Danger

危

Opportunity

機

Dr. Lonnie G. Thompson

Lonnie G. Thompson is a Distinguished University Professor in Geological Sciences and Research Scientist in the Byrd Polar Research Center, both at The Ohio State University. His long list of awards most recently includes the 2005 Tyler Prize for Environmental Achievement which was announced in March. Dr. Thompson has received over 50 grants and published nearly 200 scientific articles. He maintains an active field research program, in which Dr. Thompson drills ice cores from Earth’s most daunting peaks. He was the first to show that it was possible to get deep cores from high mountain peaks. Then he extracted paleoclimate records showing how temperatures on our planet has changed during recent geologic times. Three years ago, Dr. Thompson showed that the famous snows on Mt. Kilimanjaro, Africa, have been there for more than 11,000years, but may be gone in 2015. His research lab is quickly trying to collect ice cores from endangered tropical glaciers, such as Mt. Kilimanjaro, before warming destroys them.