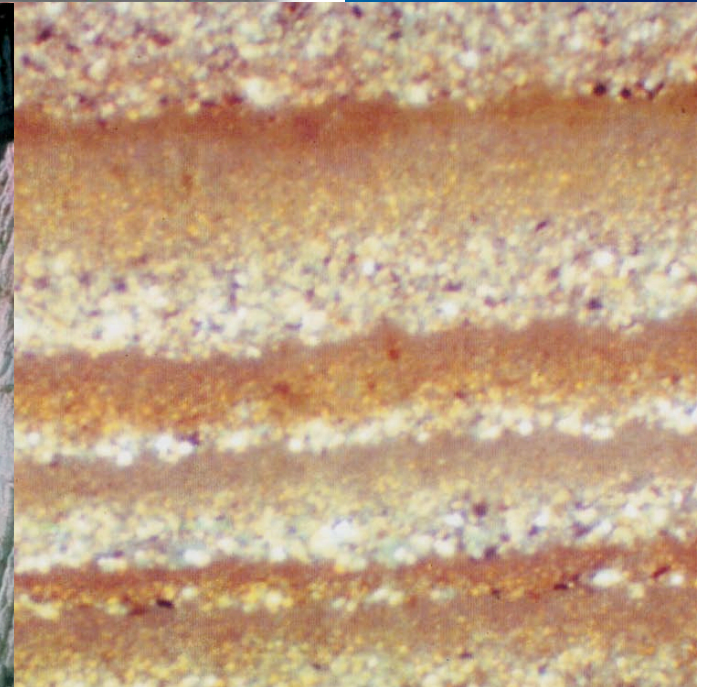
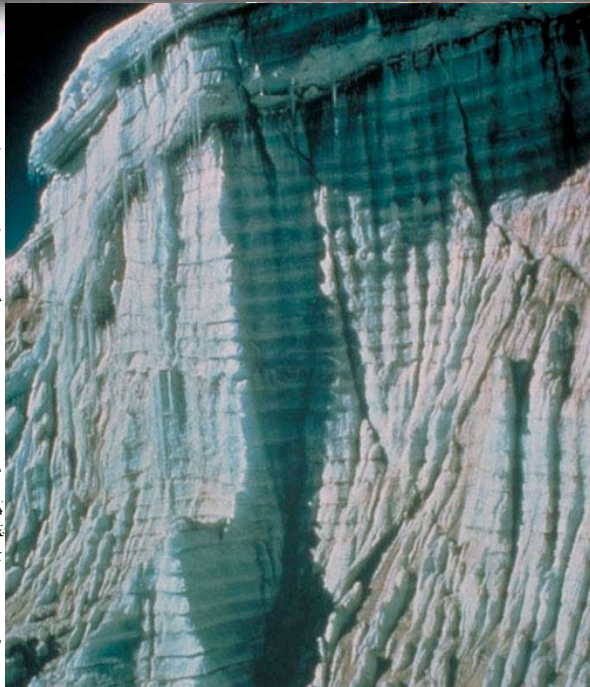


# Natural Archives: Changing Climates

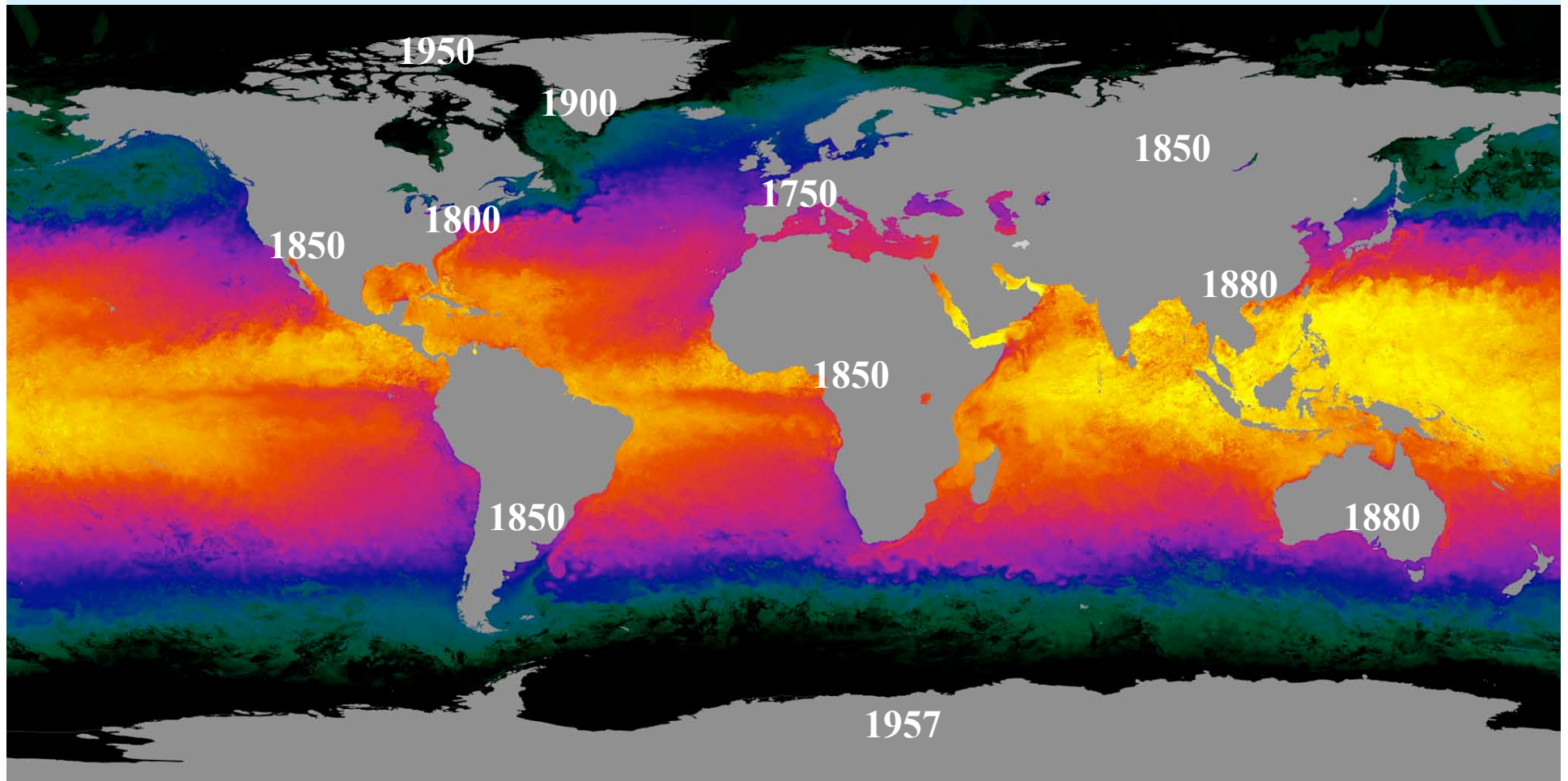
Ray Bradley  
*University of Massachusetts*

廿神燈成隊五月大雨江溢七月江潮  
伏大水高郵州志  
興化縣志  
二十二年七月儀徵土生毛儀徵  
縣志  
二十三年五月至七月大蝗興化  
縣志  
二十四年江都壽婦葉李氏年百歲新  
採  
二十六年六月儀徵地震儀徵  
縣志  
二十八年六月大風雨江溢七月大風雷  
八月大風雨江淮湖海同時異漲儀徵  
縣志  
二十九年秋大水江湖並溢以下皆  
新採  
咸豐元年東臺角斜場海潮漲溢決范公

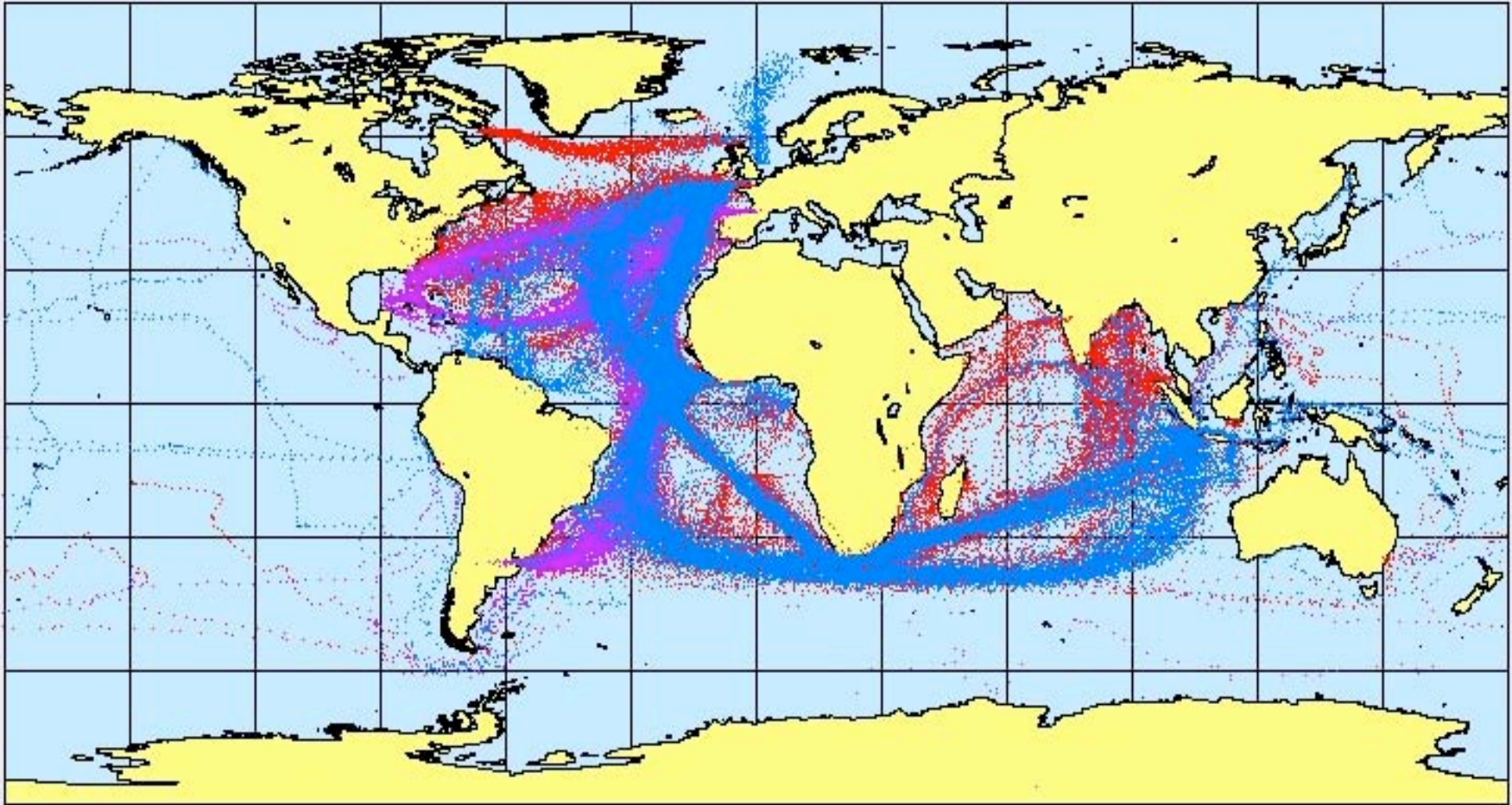




## Earliest instrumental records on land

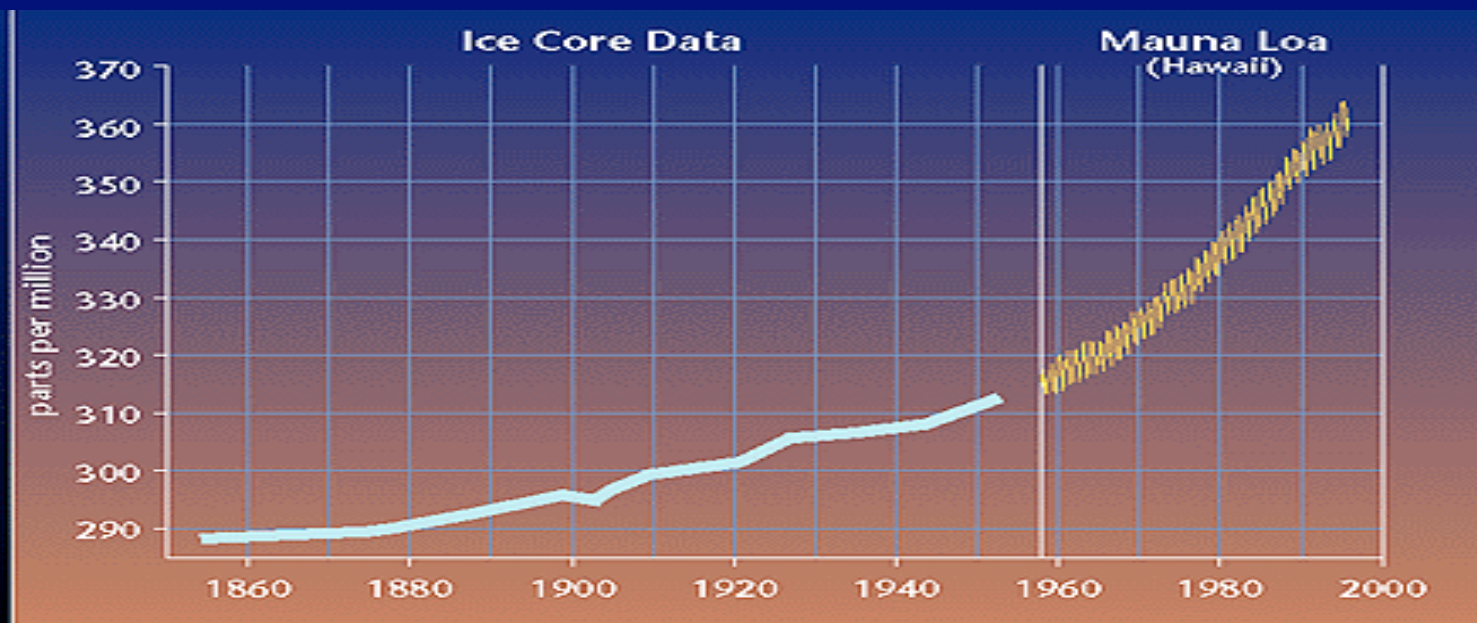
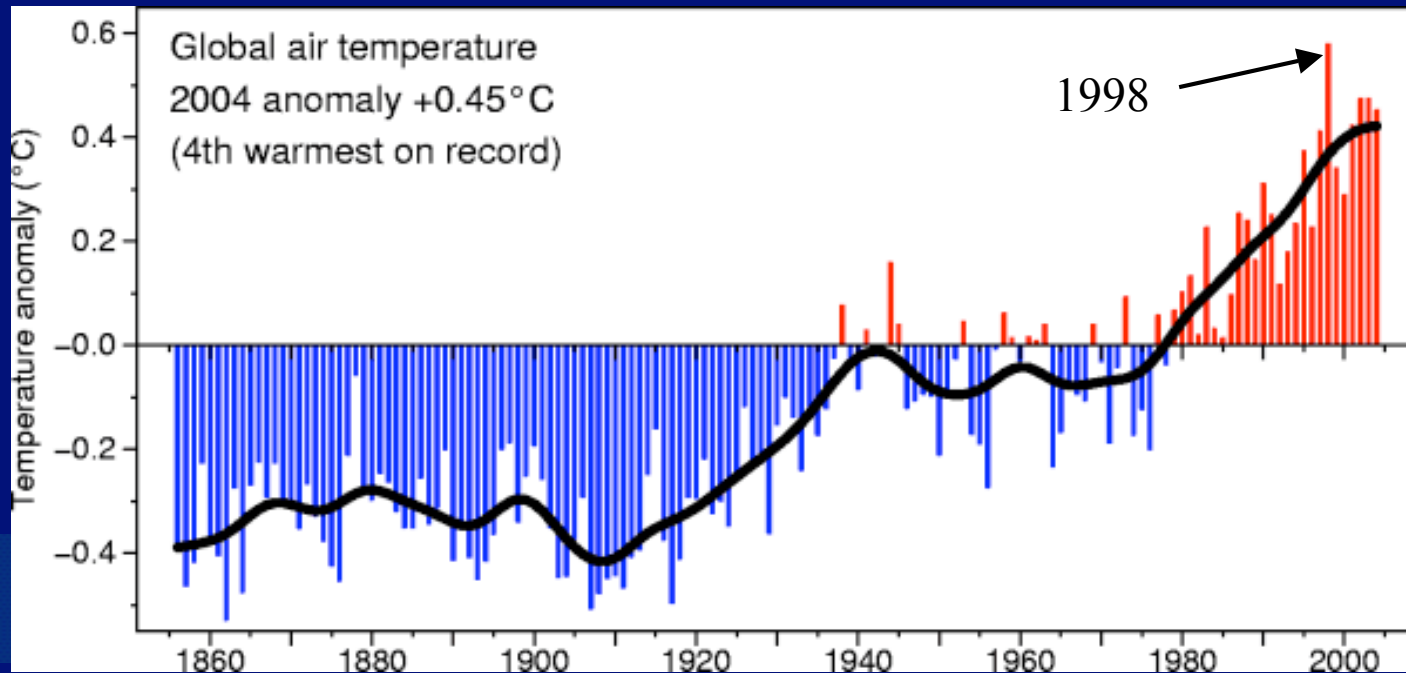


# **Climatological Database for the World's Oceans (CLIWOC):** observations from 1750-1850



Source: <http://www.knmi.nl/~koek/cliwoc.htm>





Sources: Climatic Research Unit, UK & NOAA



Speleothems



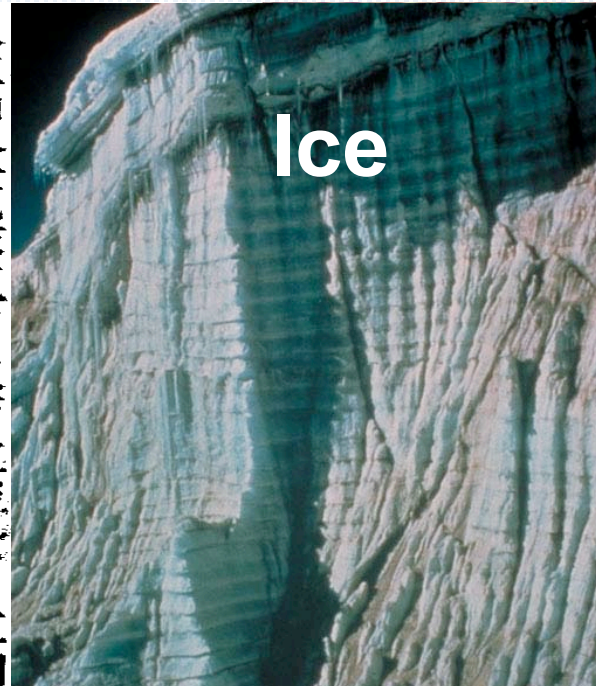
Tree rings



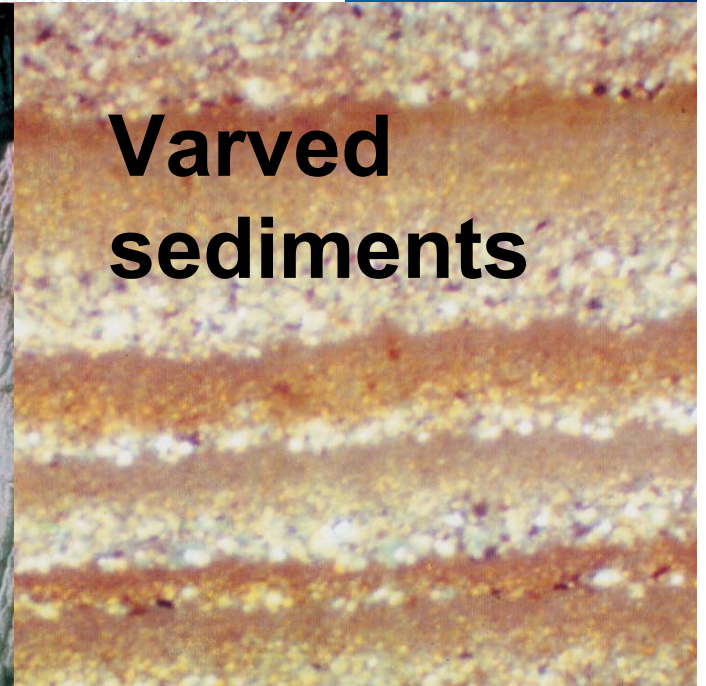
Corals



Historical documents



Ice



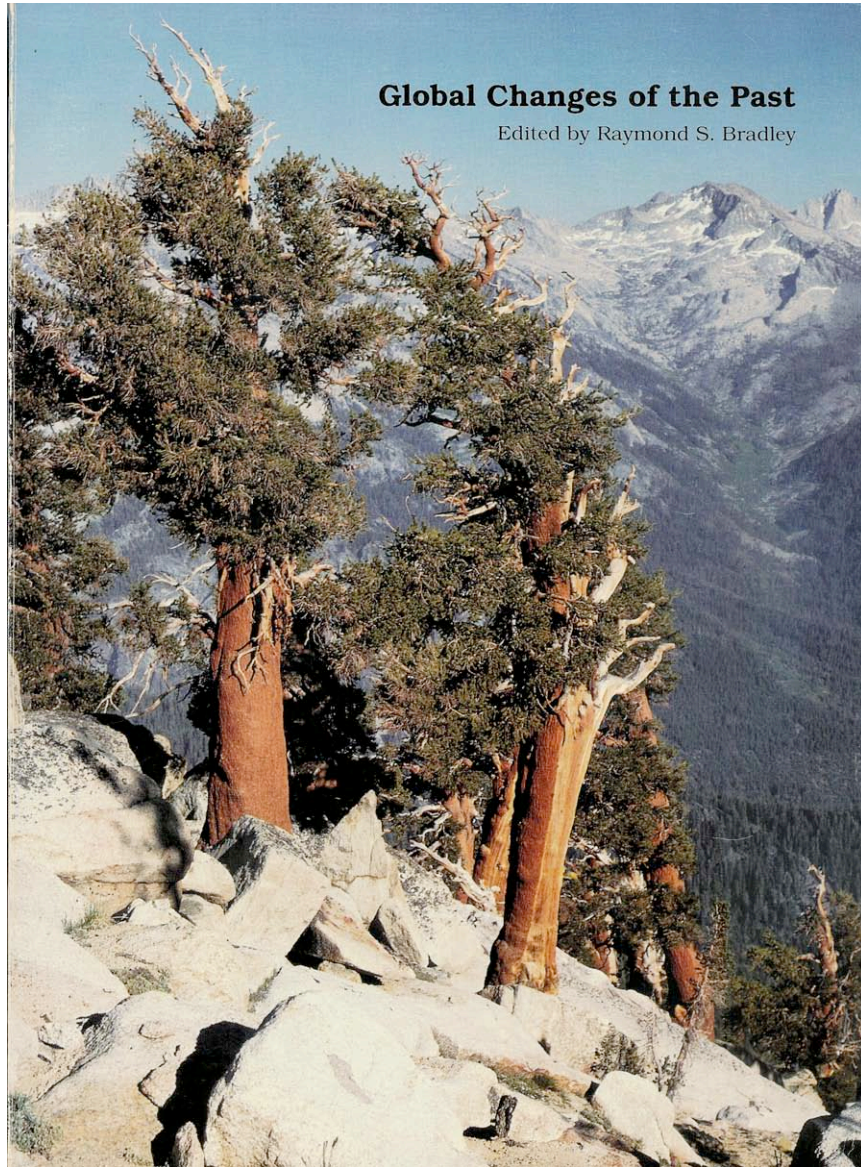
Varved sediments

*...And this our life, exempt from public haunt,  
Finds tongues in trees, books in the running brooks  
Sermons in stones, and good in everything....*

**As You Like It**  
Wm Shakespeare, II. I. 12



# Tree Ring Archives

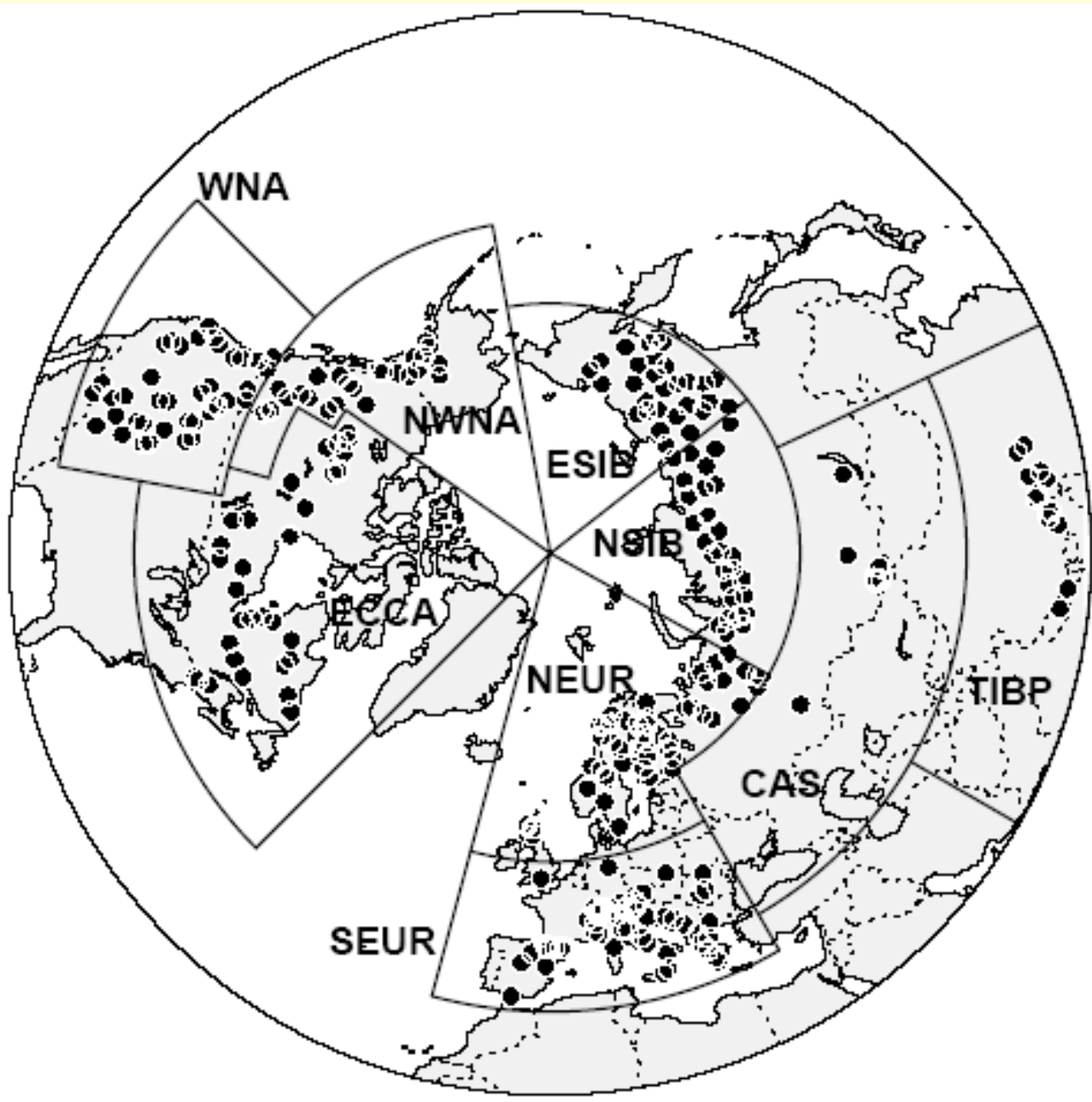


*Source: NOAA WDC-A for Paleoclimatology*

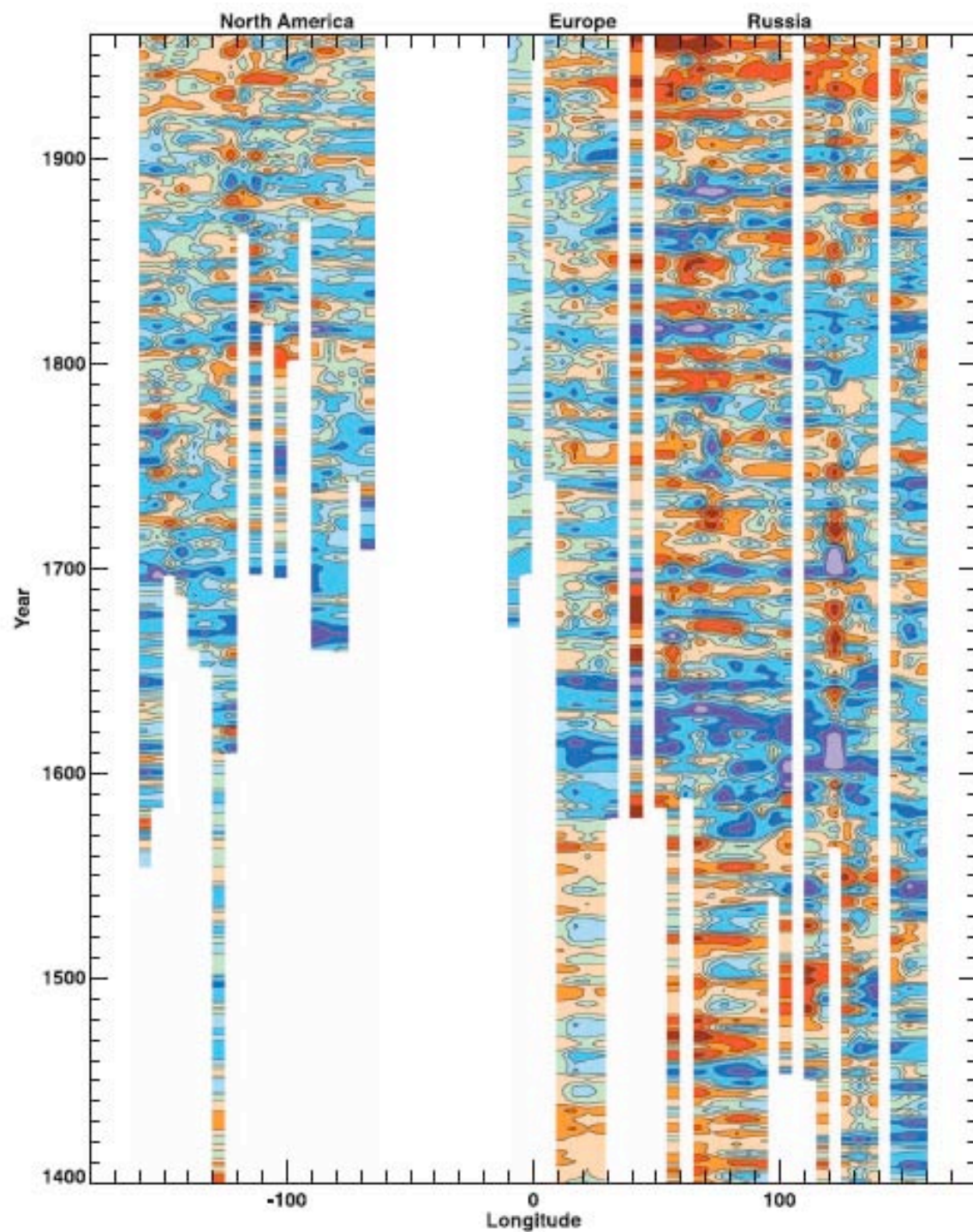


© Richard Reeves 2004

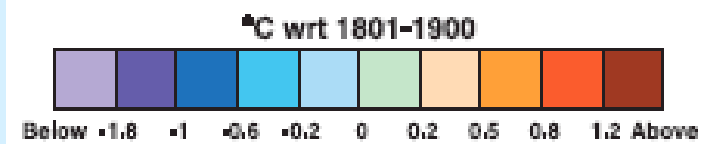




Source: Briffa et al., 2001

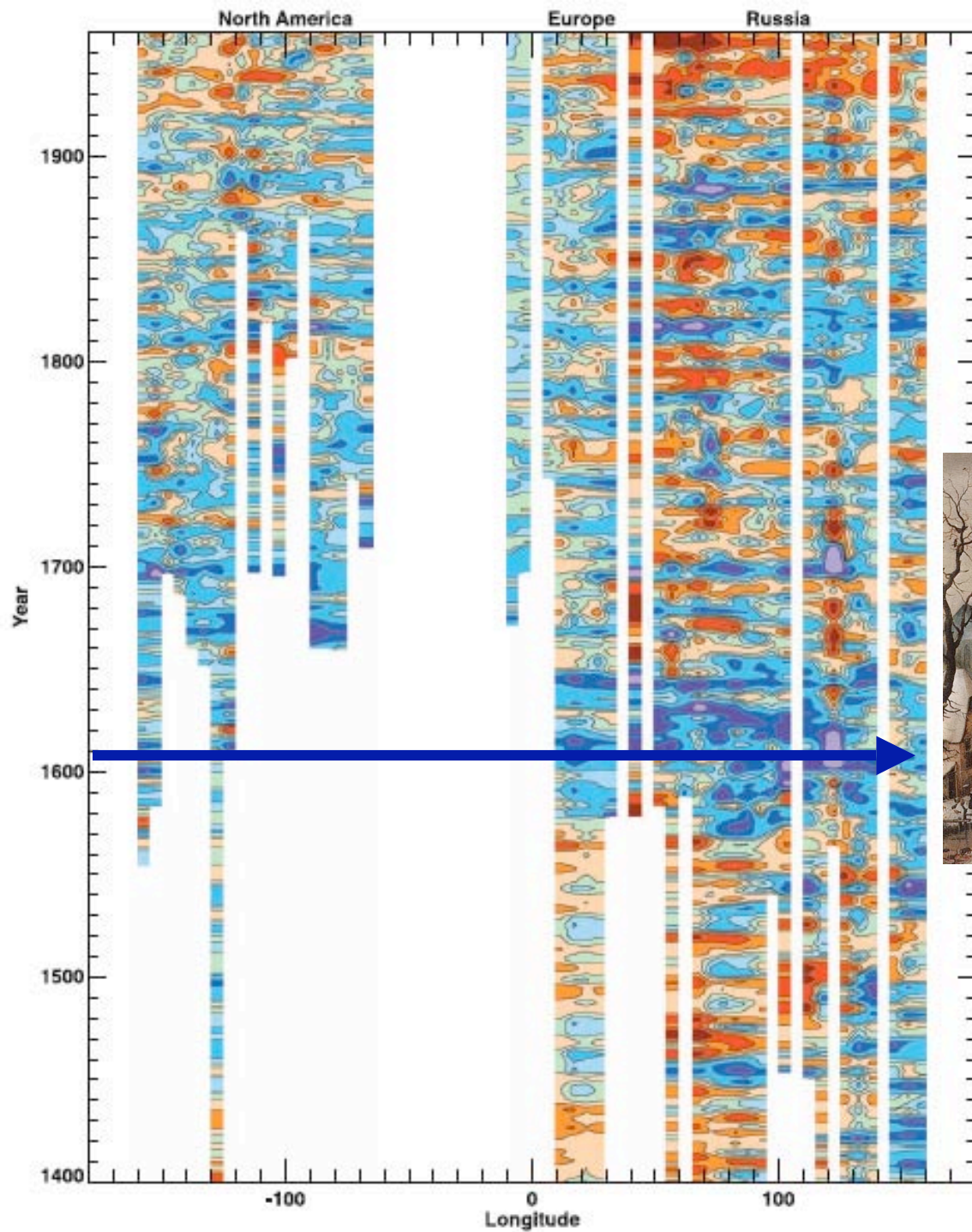


← 1960



Source: *Briffa et al., 2003*



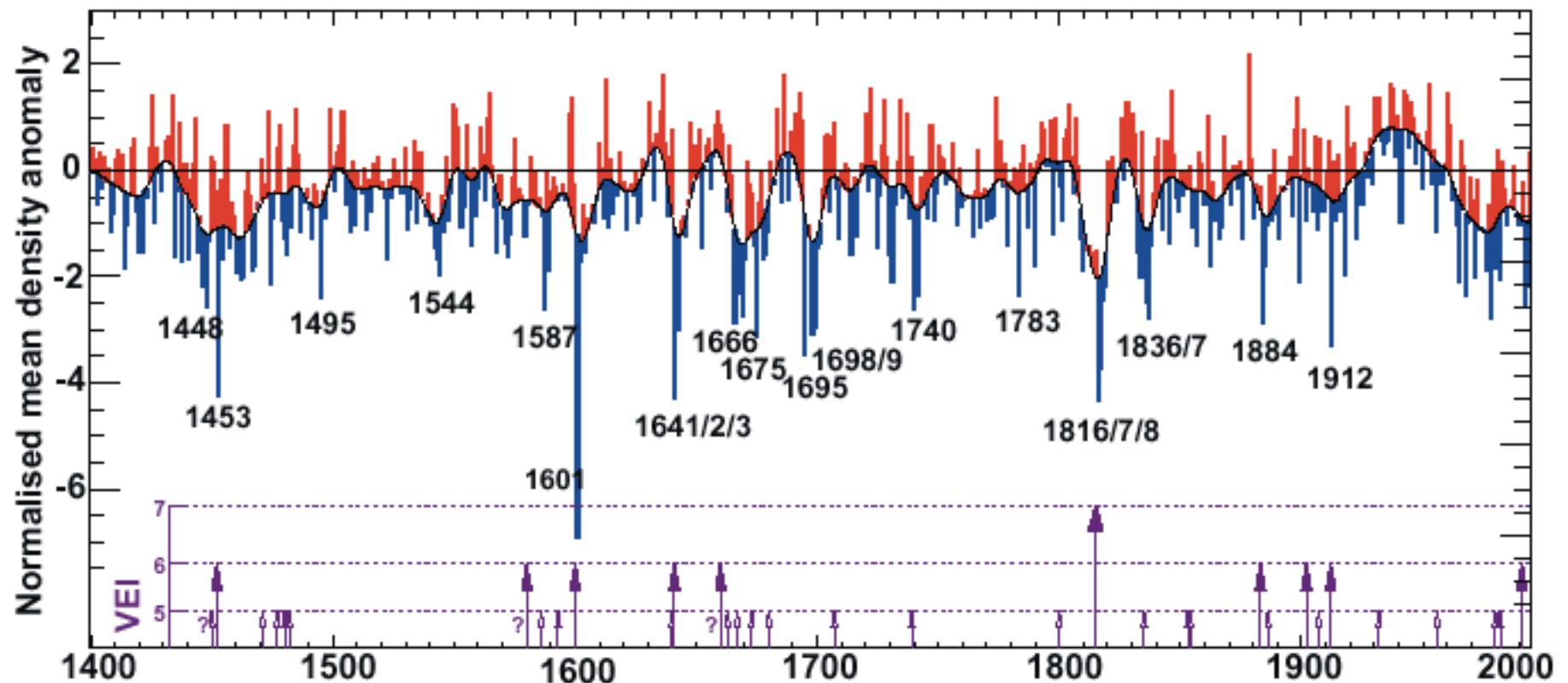


*Hendrik Avercamp*  
~1608



# Explosive Volcanic effects on tree growth at high latitudes: *few eruptions in 20<sup>th</sup> century*

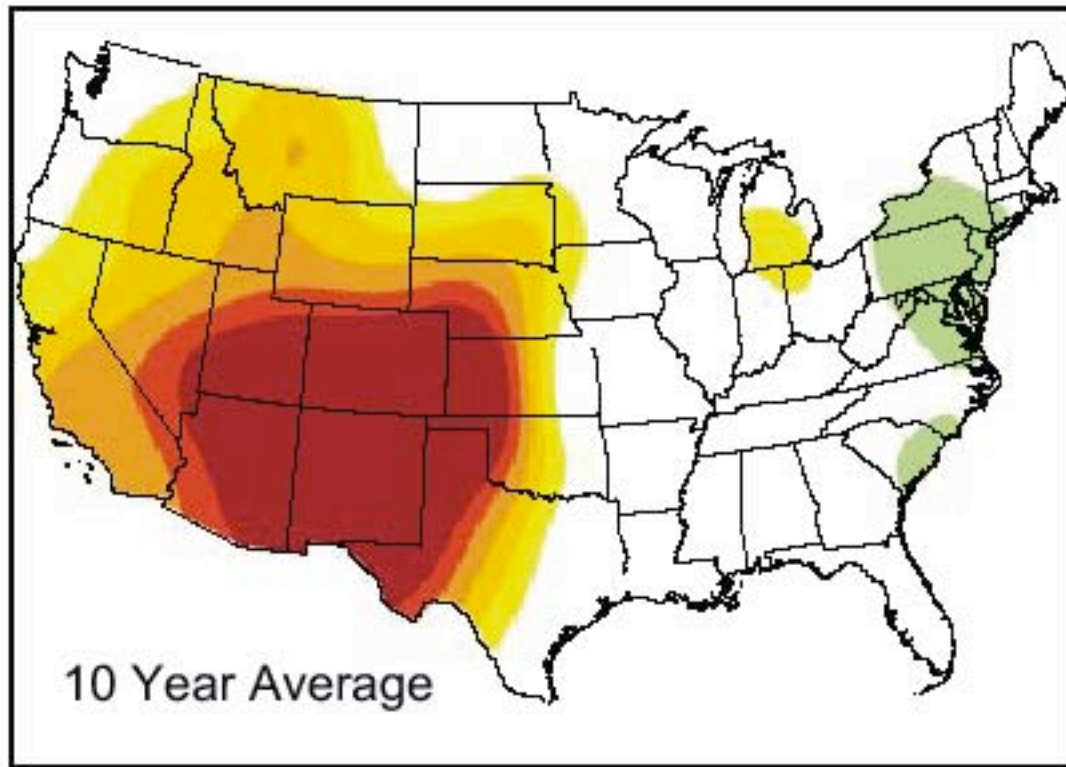
Major impacts in 1453, 1601, 1641-43, 1816-18...



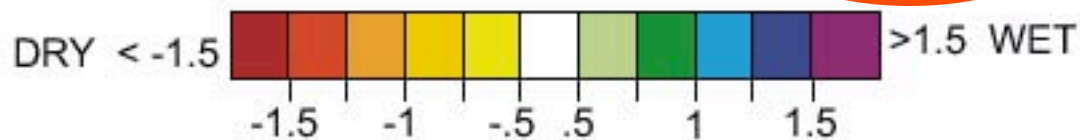
*Source: Briffa et al., 1999*



## 16th Century Megadrought

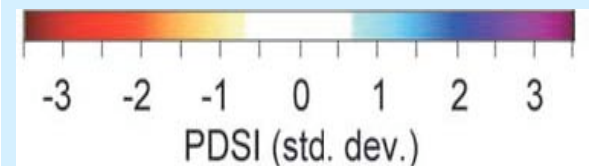
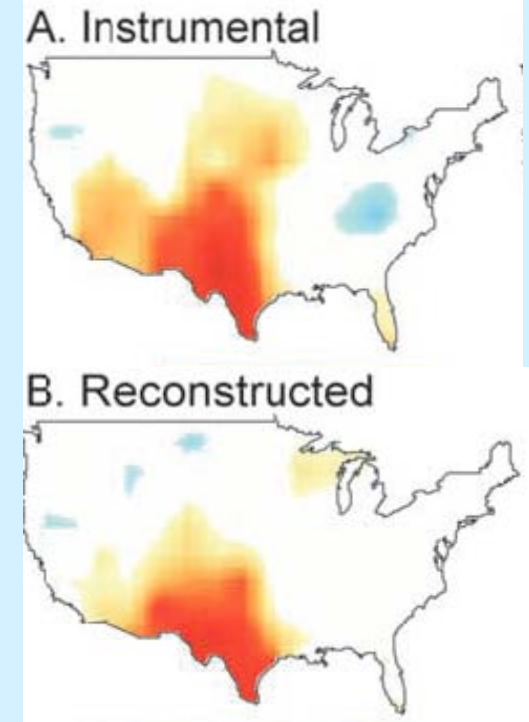


Reconstructed Summer PDSI 1576-1585

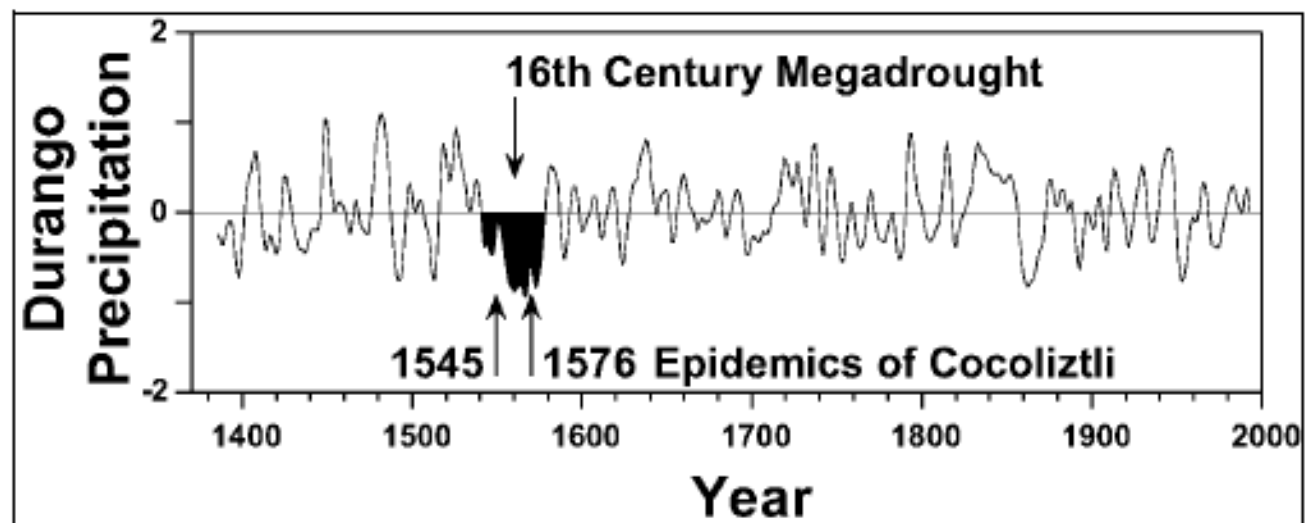


Source: *Stahle et al., 2000*

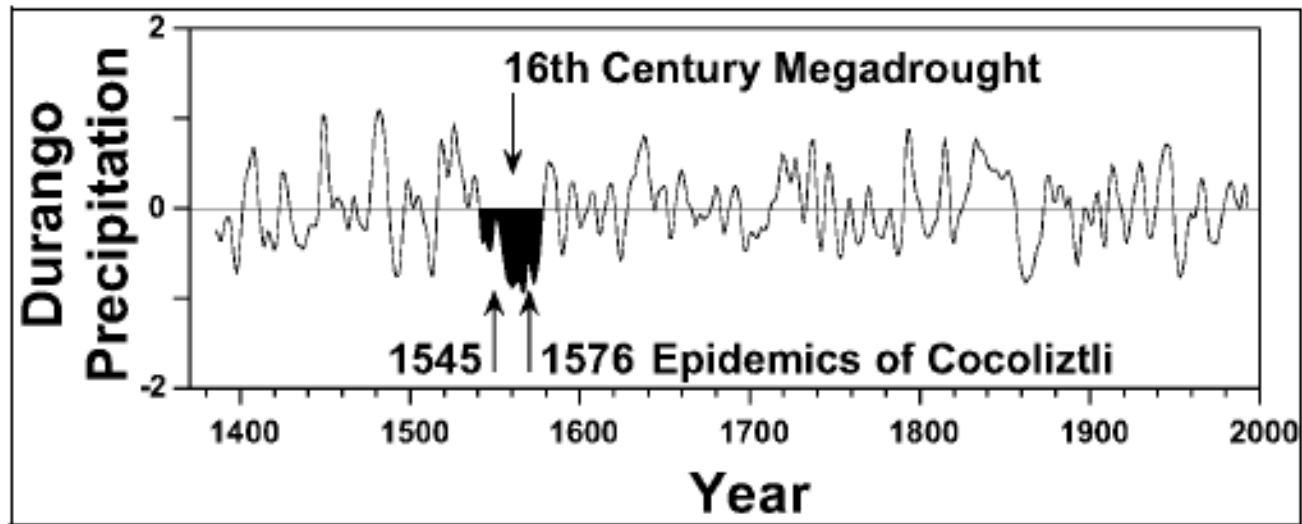
## 20<sup>th</sup> century La Niñas:



Source: *Cole et al., 2002*

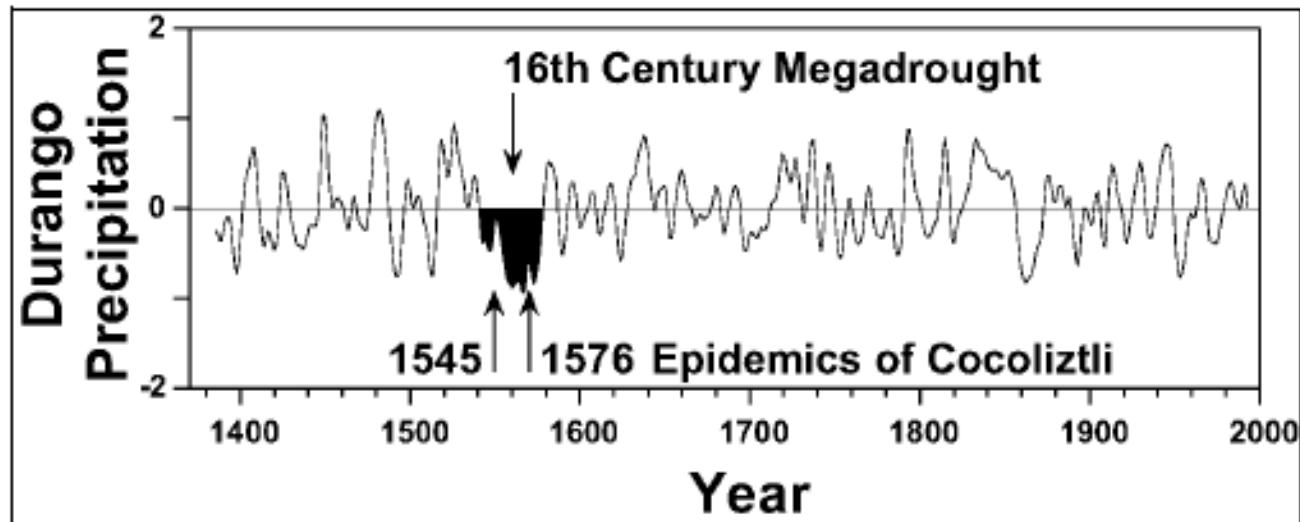




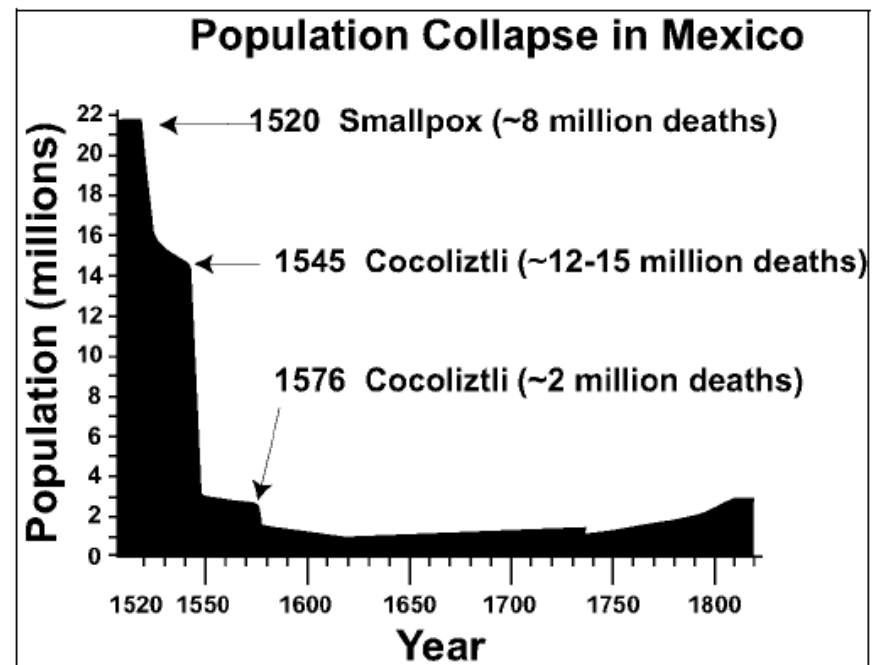


***Cocolitzli...***  
***a rat-borne***  
***hantavirus-like***  
***haemorrhagic***  
***fever...***





***Cocolitzli...***  
*a rat-borne*  
*hantavirus-like*  
*haemorrhagic*  
*fever...*



**Source:** *Acuna-Soto et al., 2002*



河南

道光二十二年五月分

巡撫鄂順安奏

茲據開封等府具報所屬祥符等一百廳州縣均于五月初五初六初七初八十二十三十四十五十六十七十八十九二十二十一二十二及二十四二十五二十七二十八等日得雨一二三四五寸不等。直隸省五月內雖據各屬具報得雨數次而具報深淺者僅止十一州縣其餘或未能悉沾或未能候在現在土脈仍形乾燥秋禾不甚暢茂惟望甘霖霑沛以冀有秋

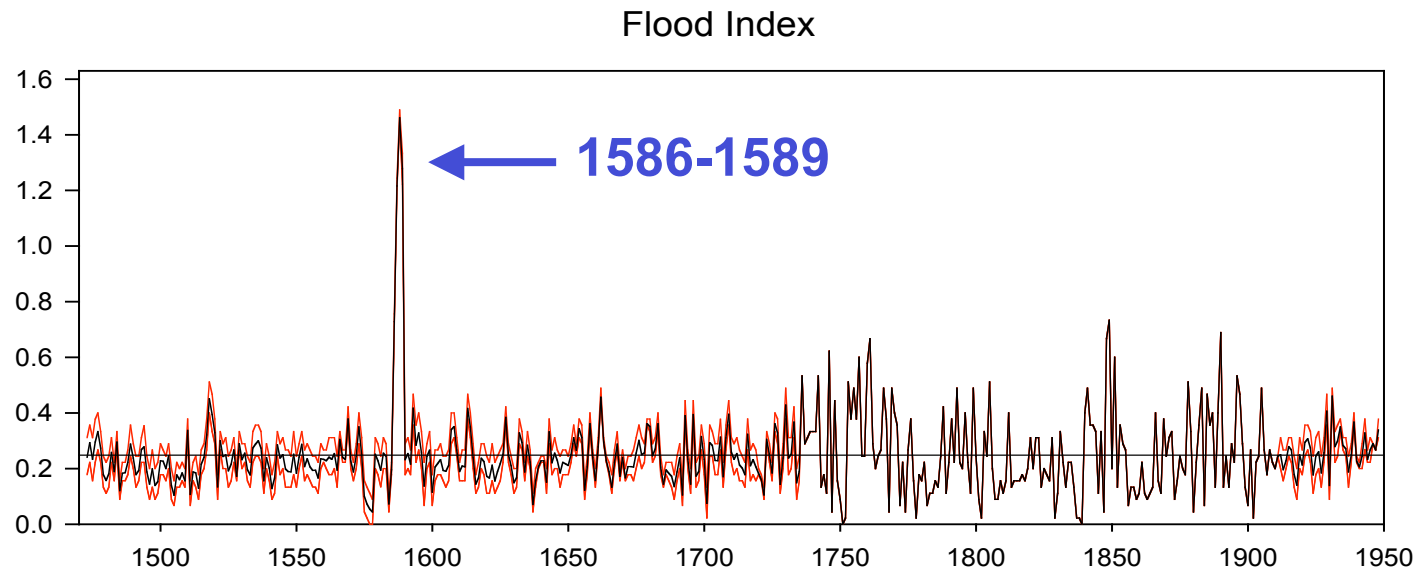
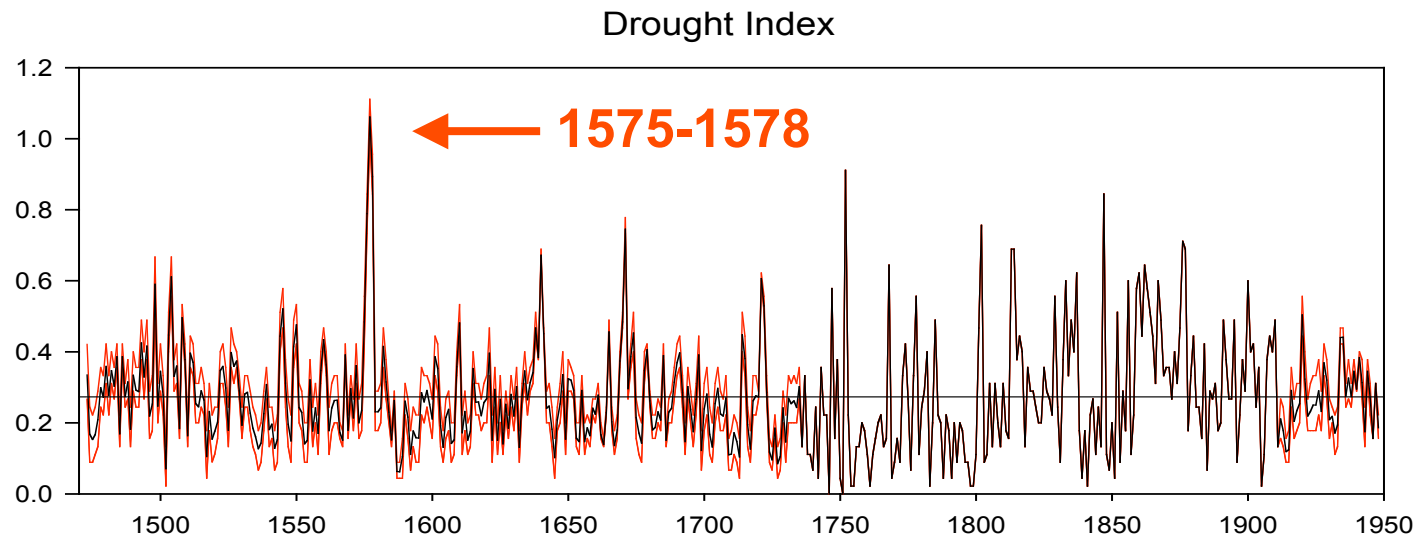
河南

道光二十二年六月分

巡撫鄂順安奏

茲據開封等府具報所屬之祥符等六十七州縣均于六月初二初七初八初九初十十一十二十三十五十六十八十九二十五二十六二十七二十八二十九等日得雨一二三四寸不等。內惟臥州靈寶閿鄉三州縣具報深淺其餘缺雨之四十一廳州縣及雨澤稀少者情形均覺乾旱。觀苗子秋種次結定晚秋收且滋長之際亟須降雨滋培茲有賊于七月初二日戌時起至初三日寅時止甘霖大沛八十四寸連前連日勢甚寬廣各屬同日得雨者現亦陸續報到惟望從此雨澤沾以冀秋收豐稔

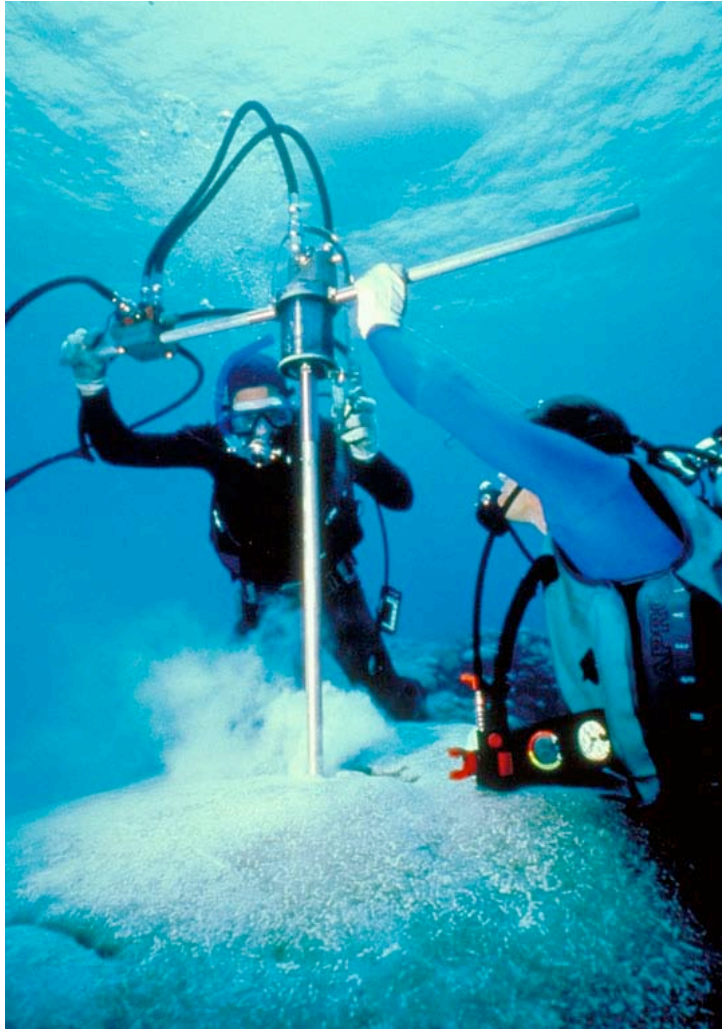
A sample of Yu-Xue-Fen-Cun with rainfall report



Source: *Ge et al., 2004*

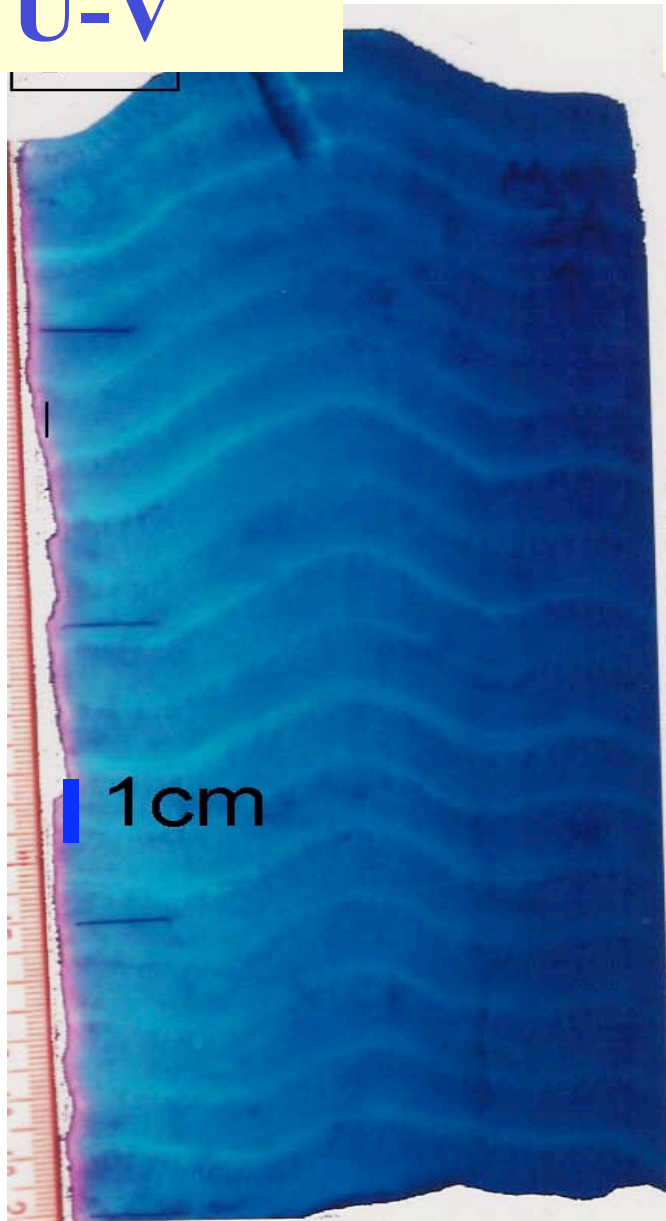


# Banded Corals



**Source:** *NOAA WDC-A for Paleoclimatology*

U-V



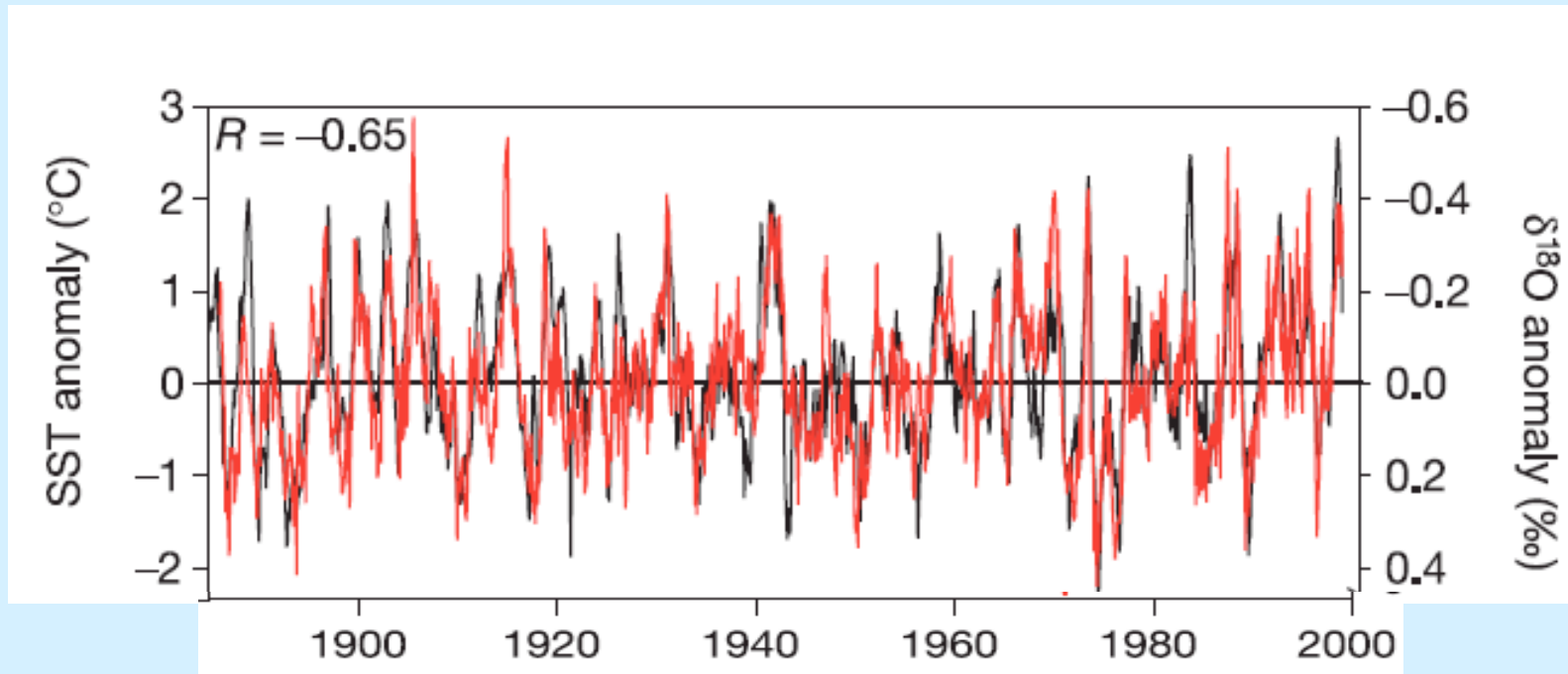
X-ray



Coral from Malindi, Kenya

Source: *R. Dunbar & J. Cole: pers. comm.*

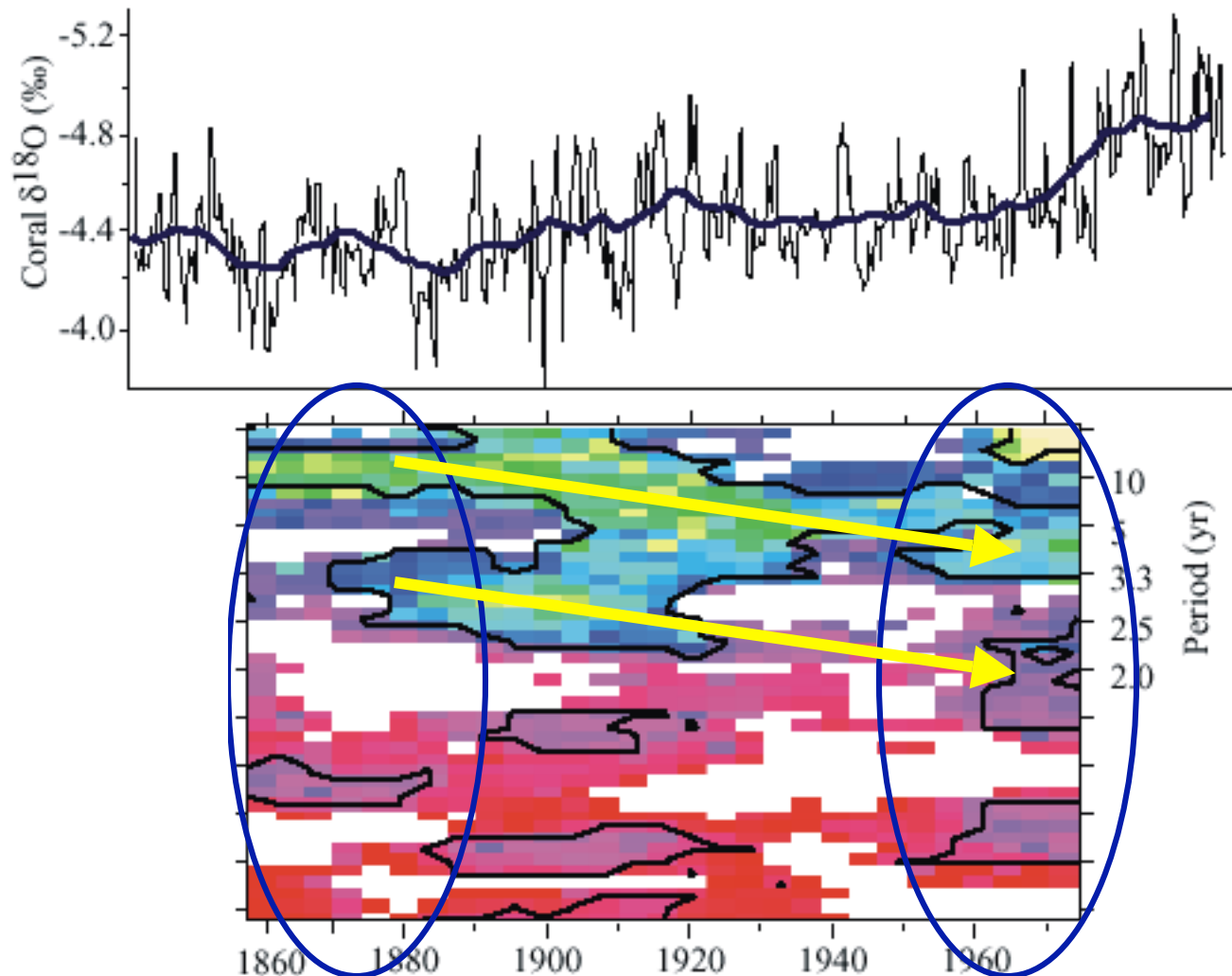




Modern coral  $\delta^{18}\text{O}$  anomalies (red)  
Sea surface temperatures (black)

Source: *Cobb et al., 2003*

## Maiana coral record



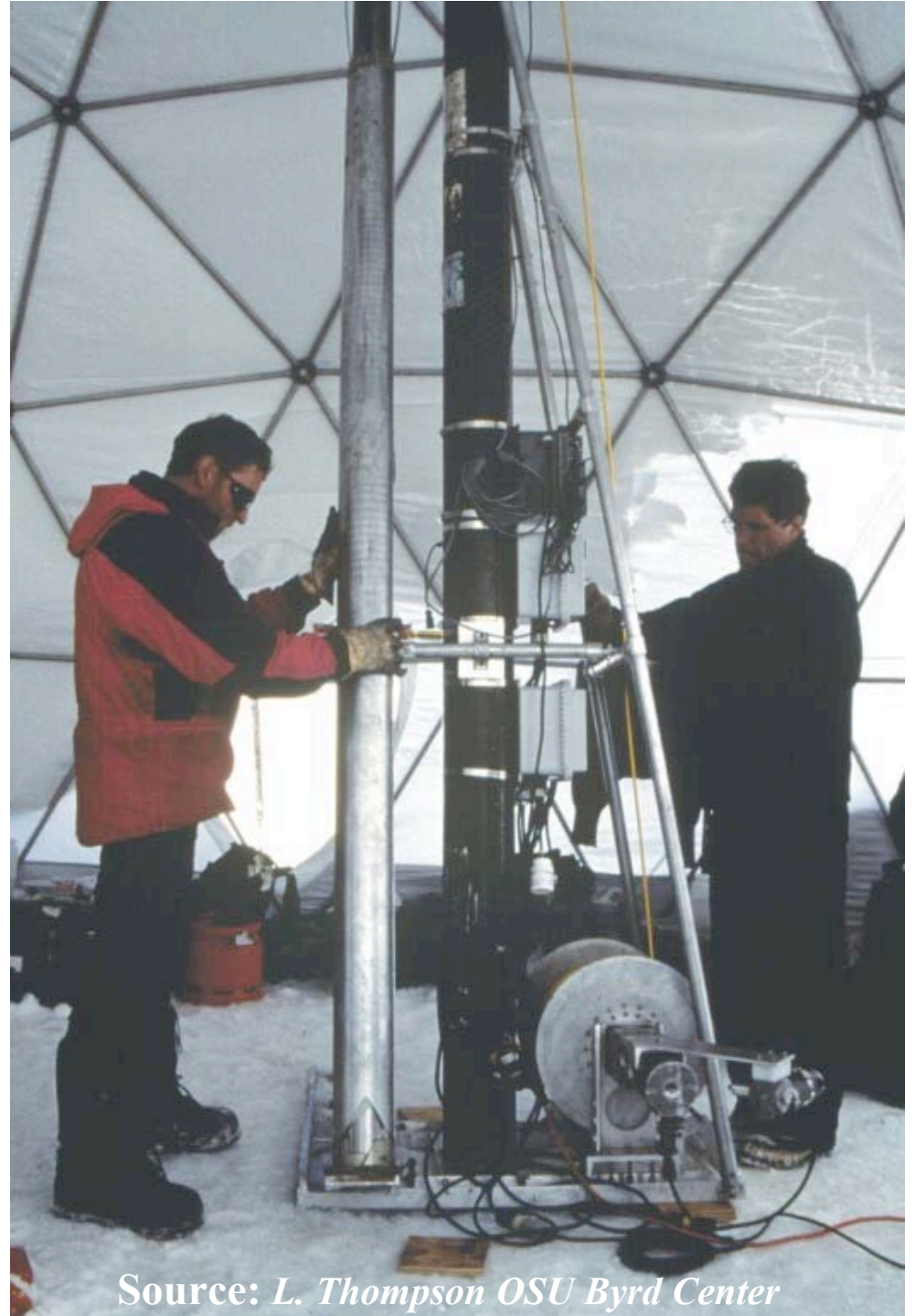
Source: *Urban et al., 2001*

# Quelccaya Ice Cap, Peru



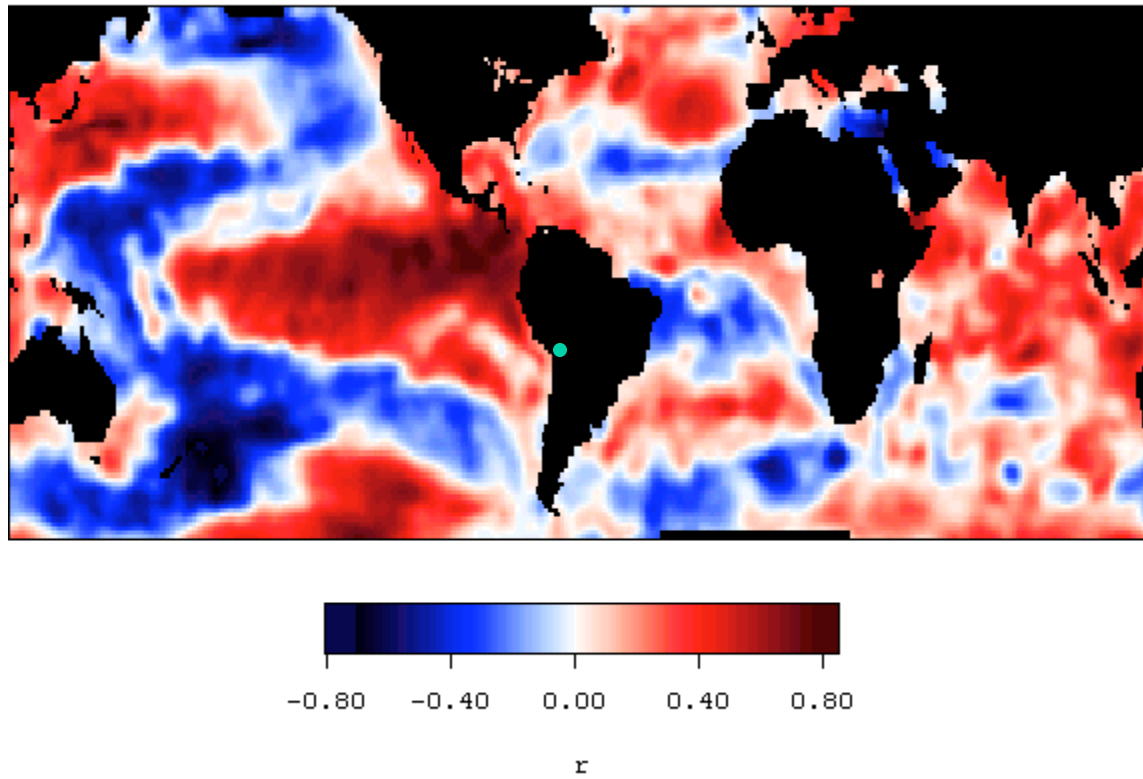
8/8/2003





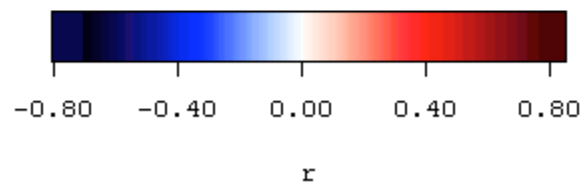
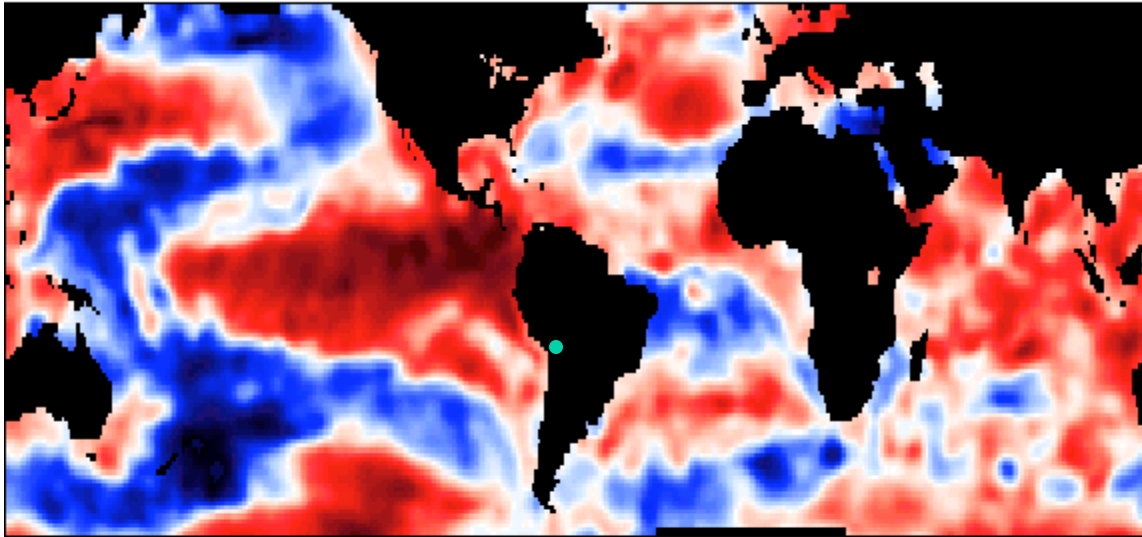
Source: *L. Thompson OSU Byrd Center*

Correlation of DJF SST with Sajama del 180 - 1977 to 1996

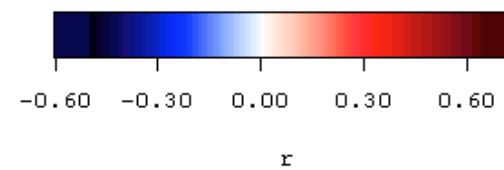
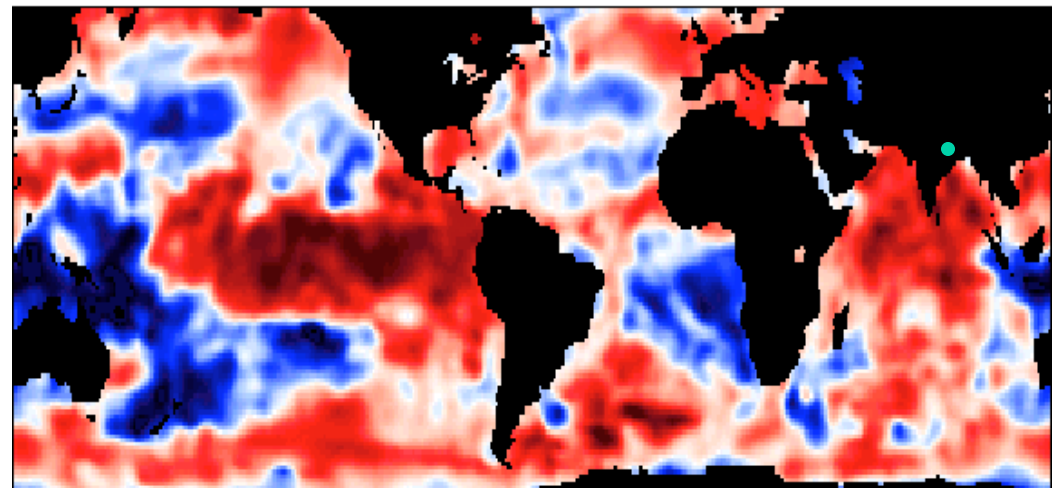


**Source:** *Bradley et al., 2003*

Correlation of DJF SST with Sajama del 180 - 1977 to 1996



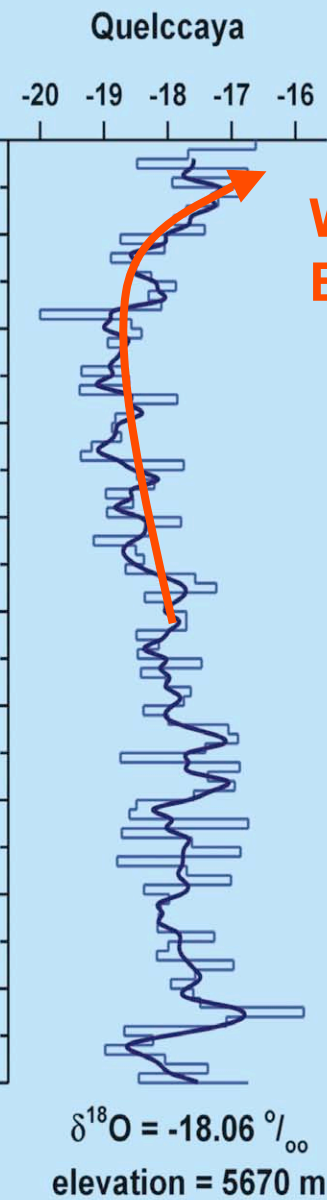
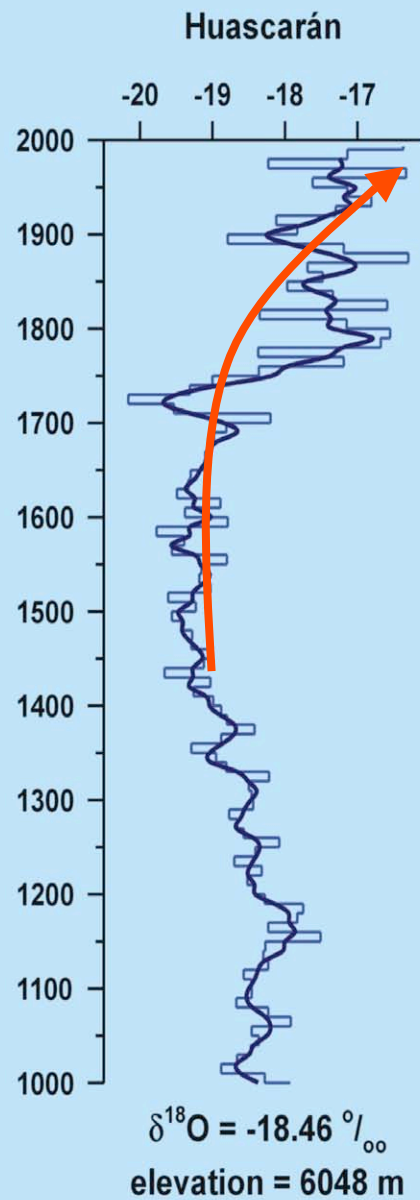
Correlation of JJAS SST with Dasuopu cores 2 & 3 del 180 - 1977 to 1996



Source: *Bradley et al., 2003*

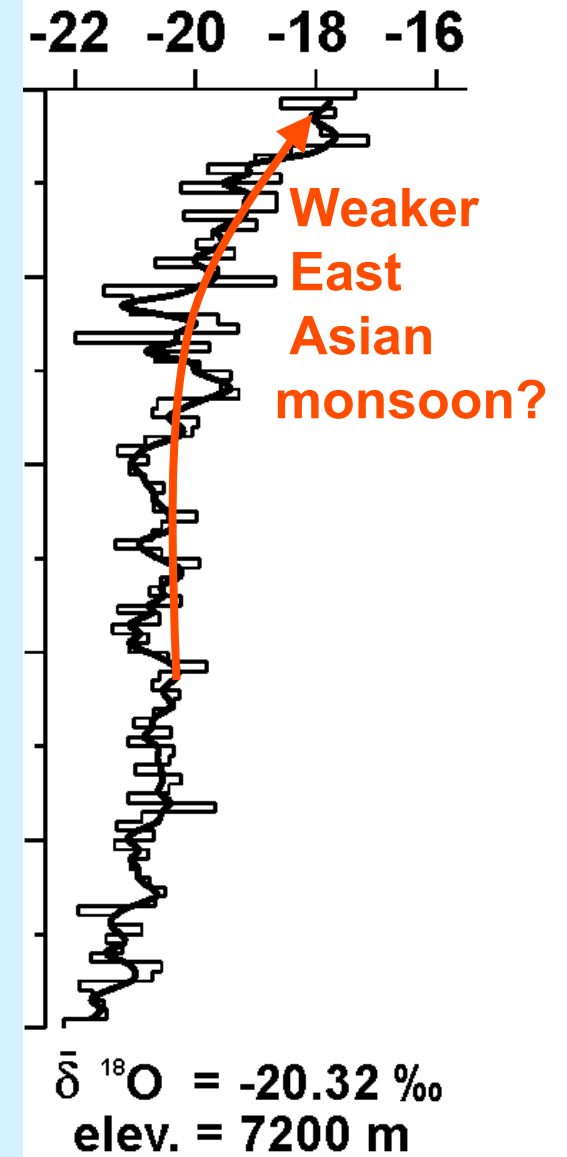


## PERU $\delta^{18}\text{O}$ (‰)

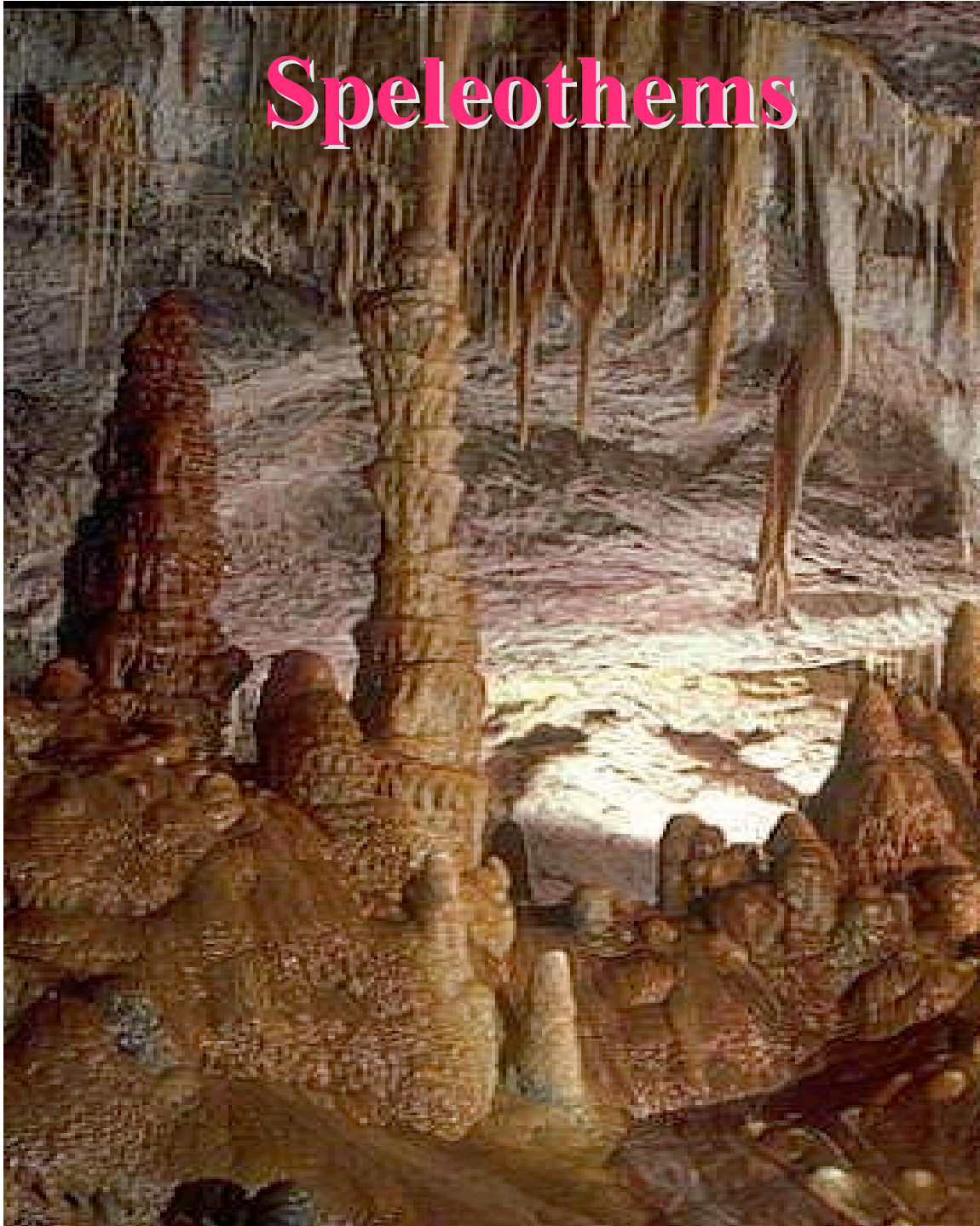


Warmer eastern  
Equatorial Pacific?

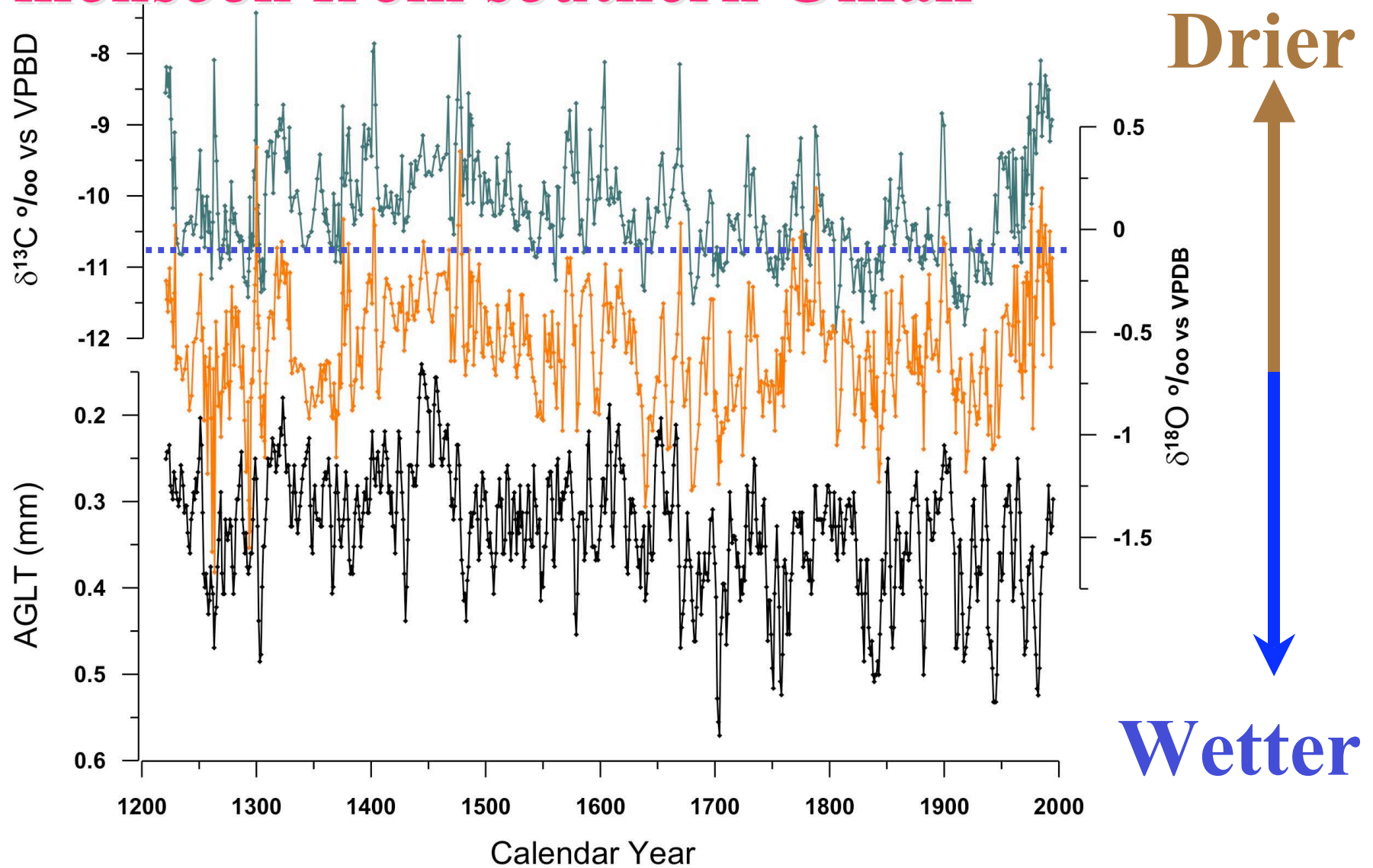
## CHINA Dasuopu



# Speleothems

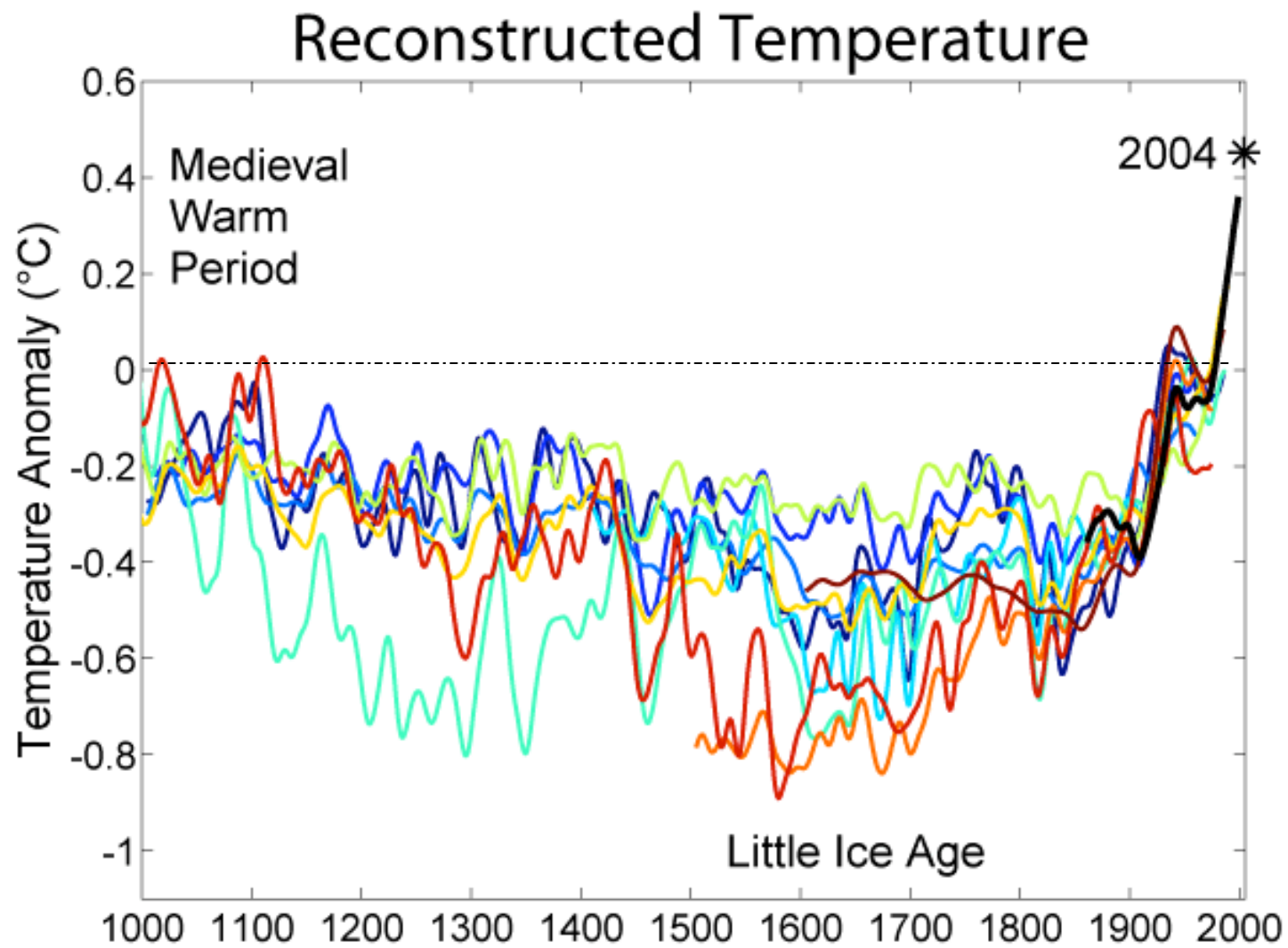


# A speleothem record of the southwestern monsoon from southern Oman



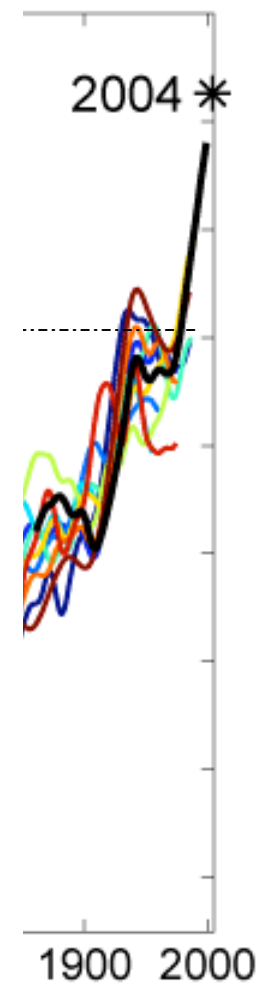
Source: *S. Burns et al., 2002*

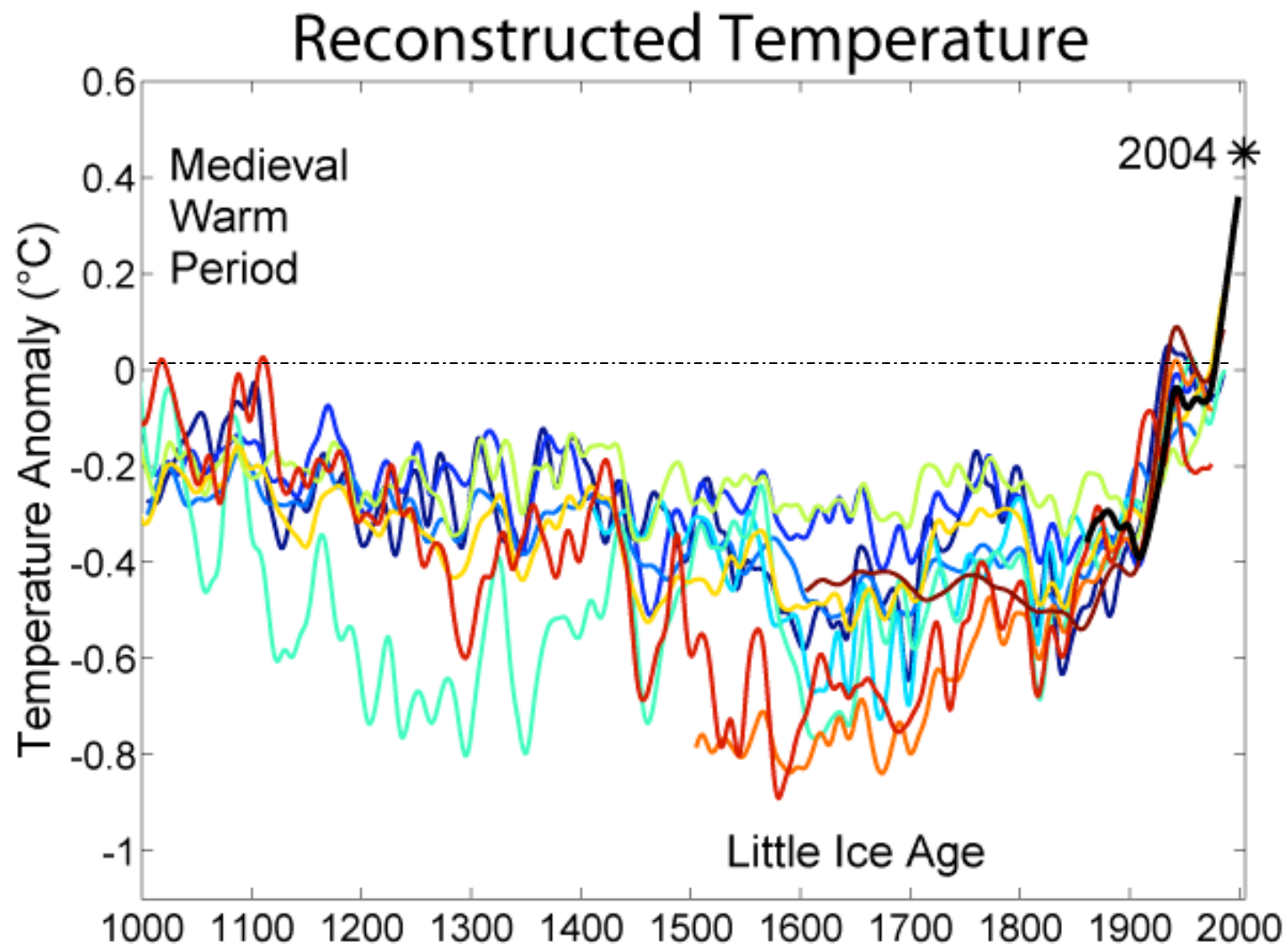




Source: *Wikipedia*

# Temperature

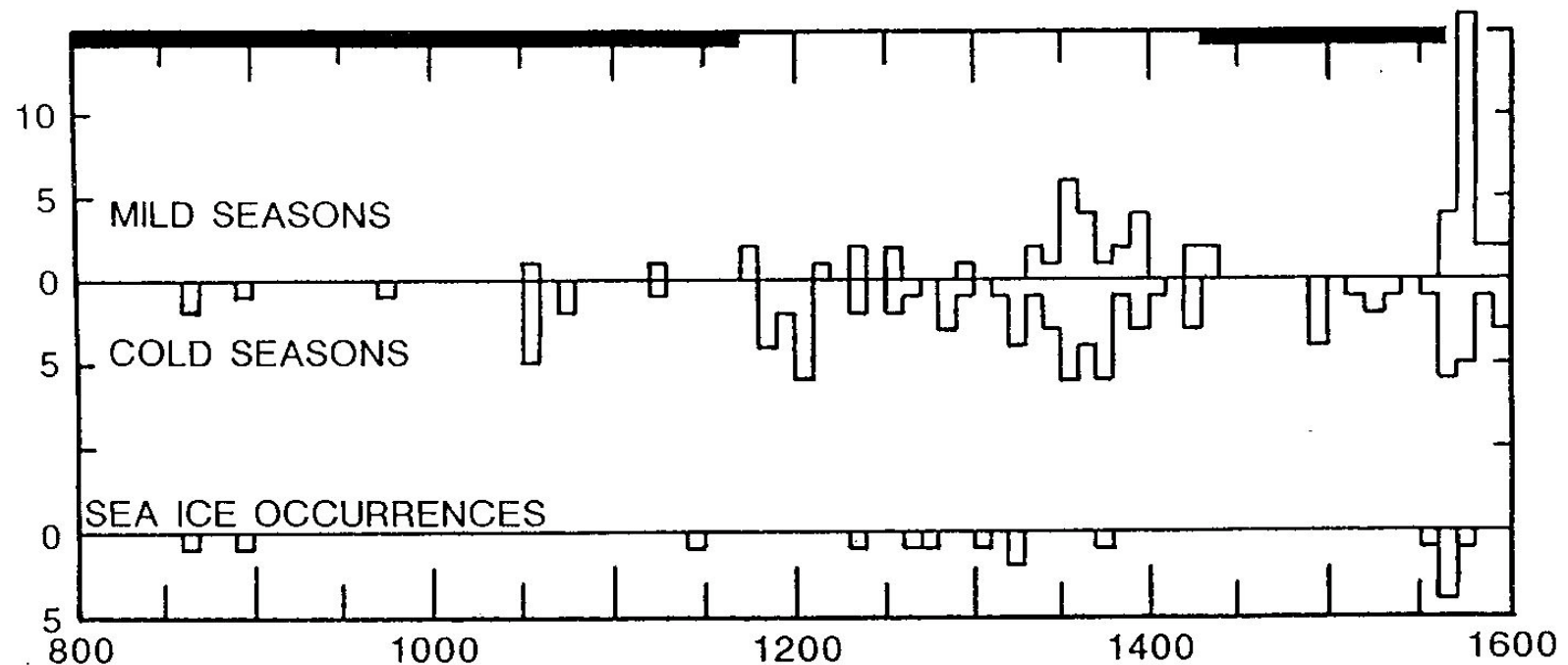




Source: *Wikipedia*





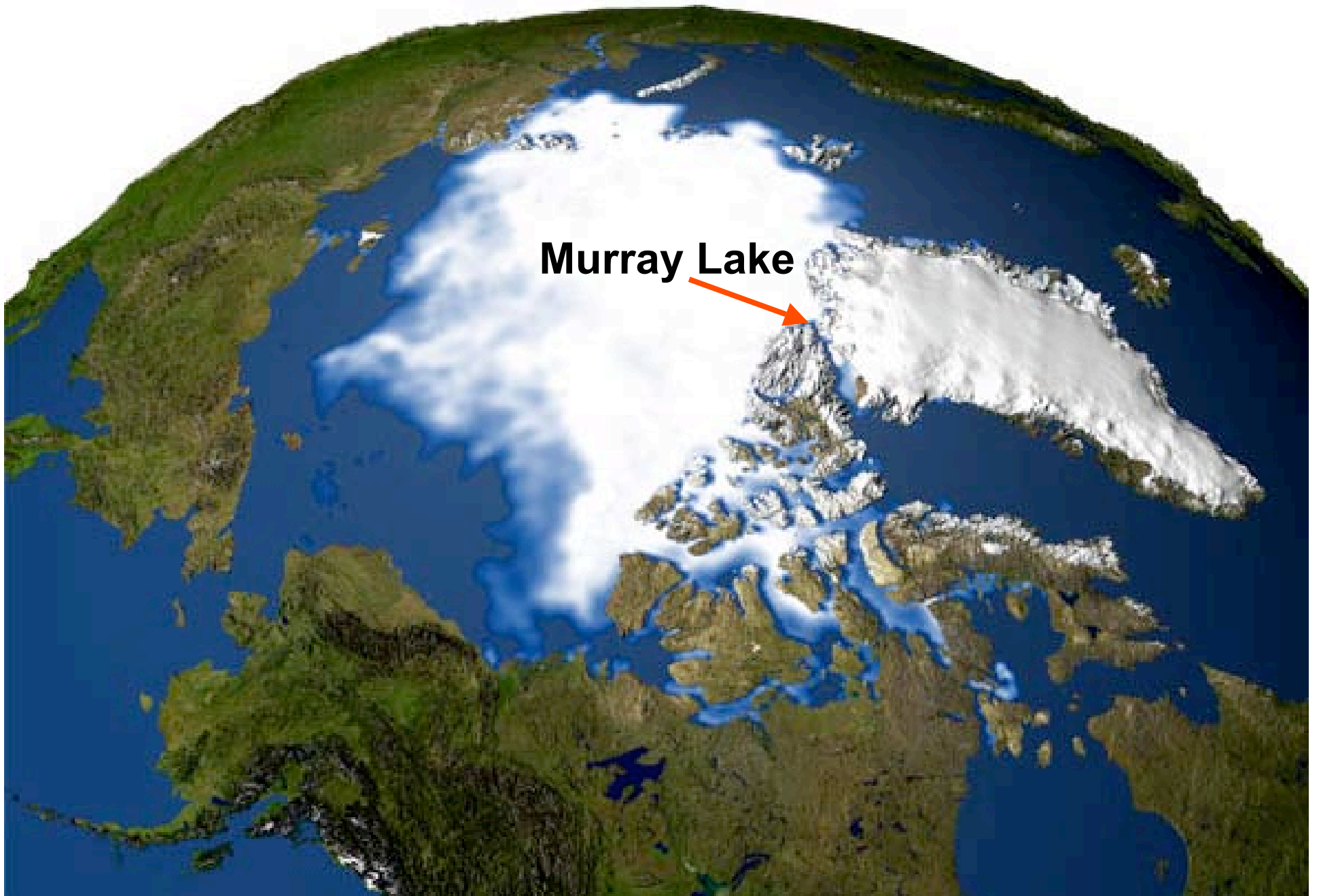


“Several researchers...have suggested that Iceland experienced a mild climate around the time of the Norse settlement (~A.D. 870-930), and in the 11<sup>th</sup> and 12<sup>th</sup> centuries.

**There is no concrete evidence for this, as there are no contemporary documents for this time....there is no firm foundation of data for a so-called “Climatic Optimum” during the early years of Iceland’s history”**

A. Ogilvie: *Acta Archeologica*, 1990

**Murray Lake**









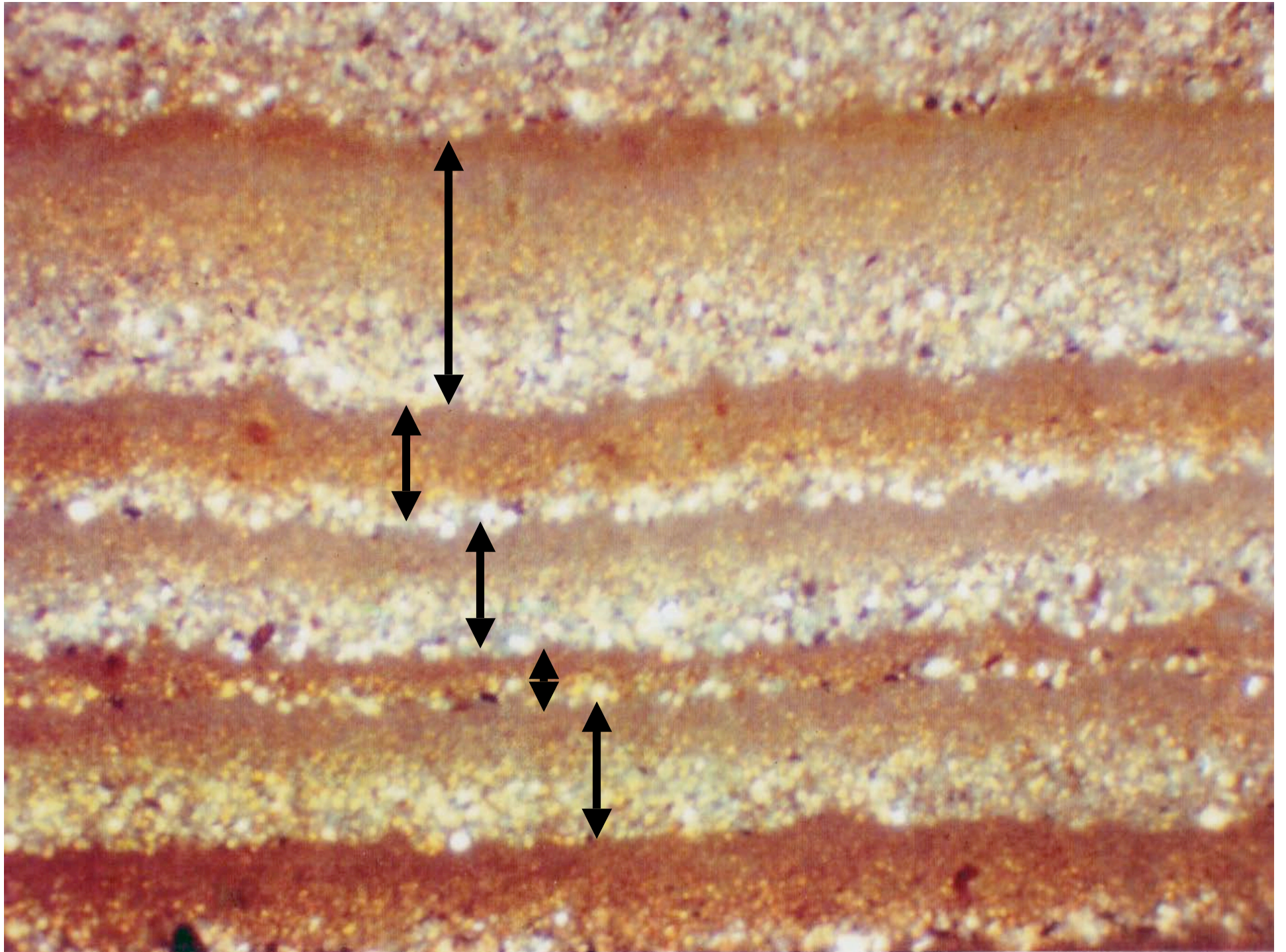
# Effects of Higher Temperatures on Arctic Lakes

Increased duration of ice-free period  
More melting/runoff—greater sediment flux  
Higher nutrient flux

## RESULT:

More biological productivity/diversity (diatoms)  
Thicker annual sediment layers (varves)  
Increase in median grain size



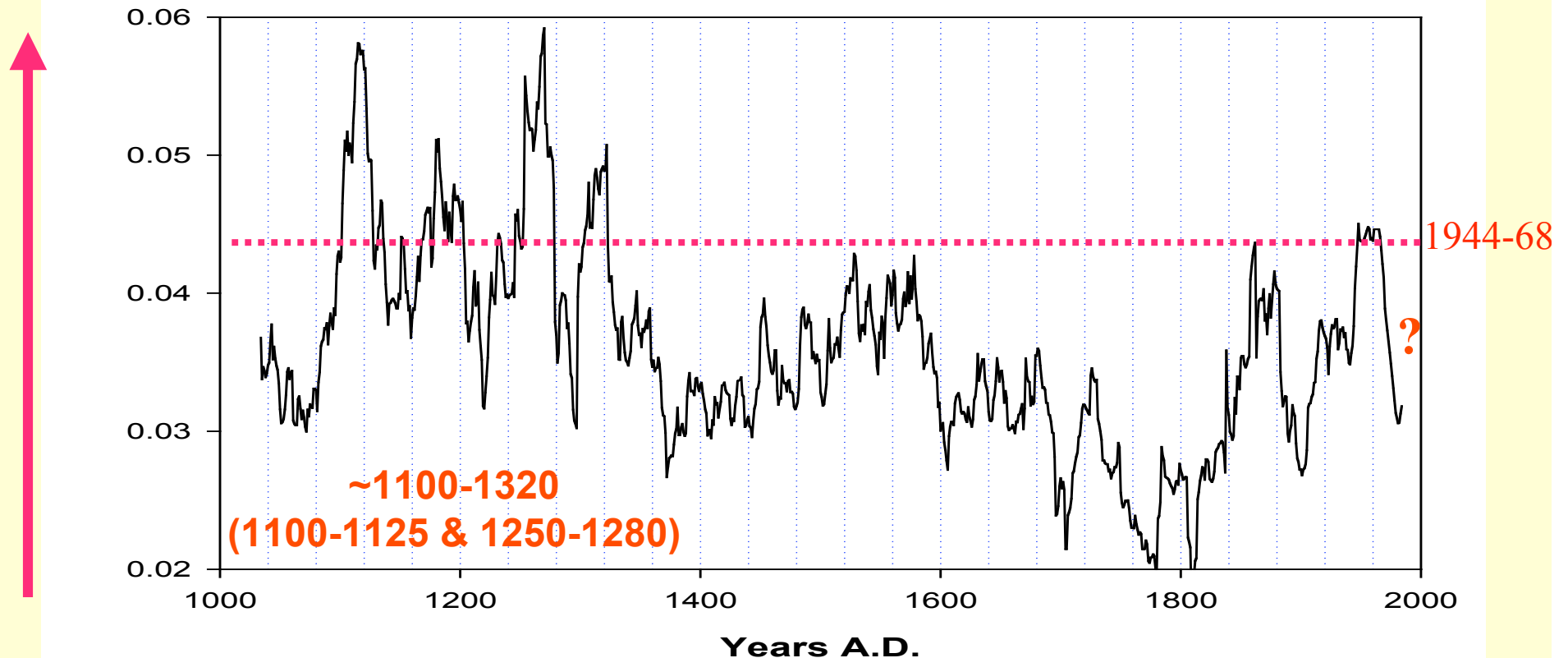




# Lower Murray Lake, northern Ellesmere Island (81.5°N)

Annual sediment flux\* (g cm<sup>-2</sup>) since ~A.D.1030:

**Warmer  
summers**



*\*25 year running mean*

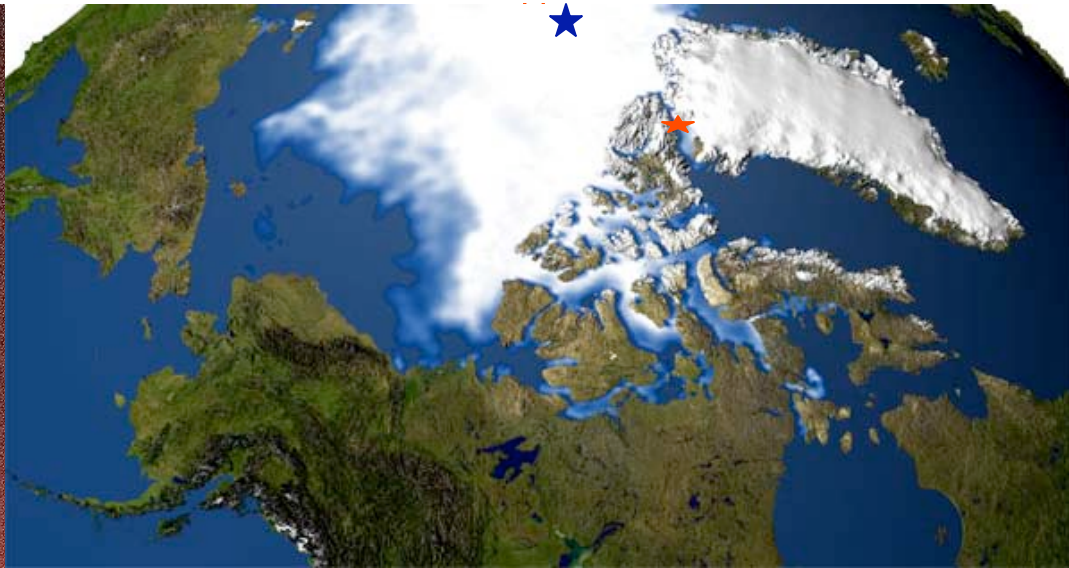
*Source: Patridge, 2005*



**Murray Lake**

**Bache  
Peninsula**





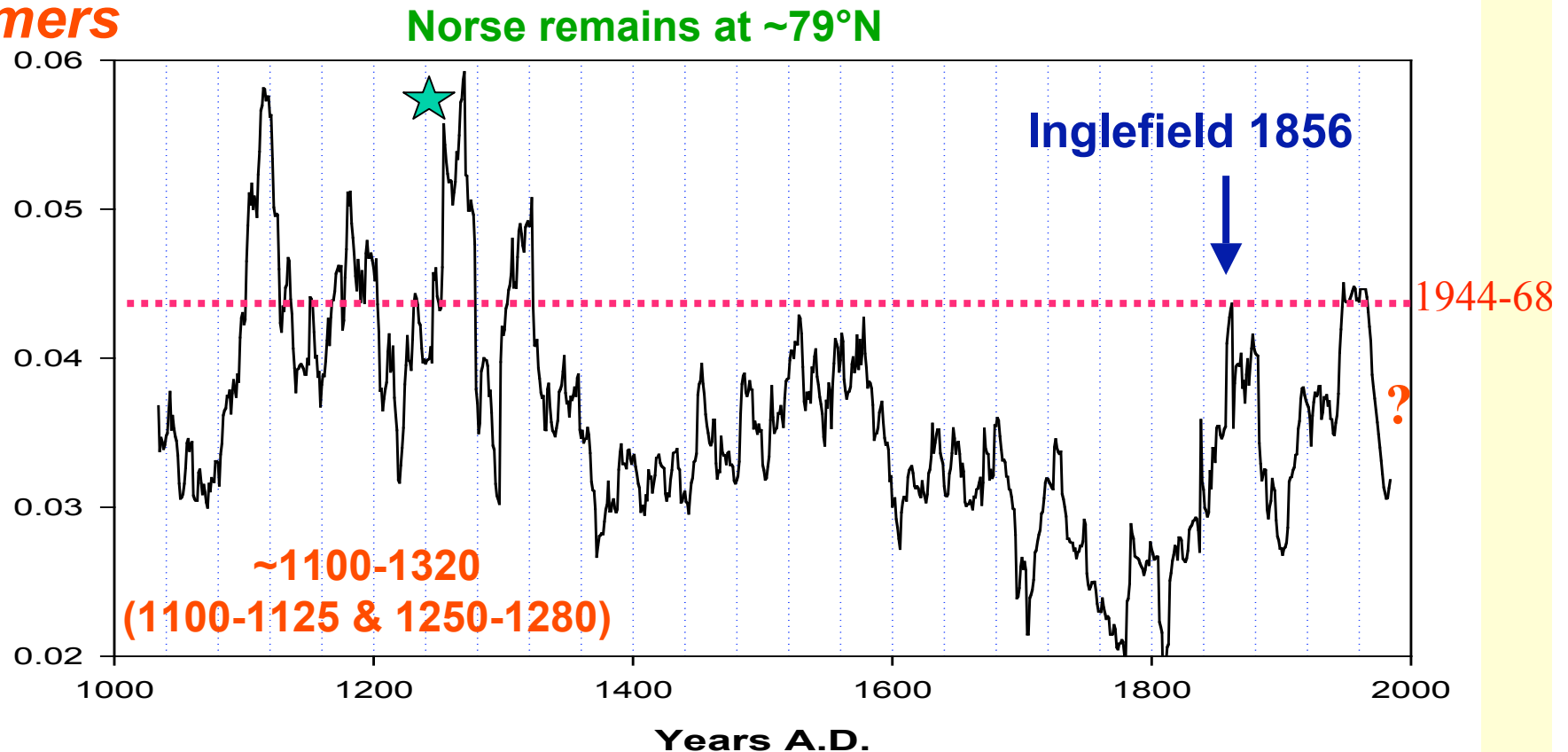
Source: *Schlederman, 1996*



# Lower Murray Lake, northern Ellesmere Island (81.5°N)

Annual sediment flux\* (g cm<sup>-2</sup>) since ~A.D.1030:

**Warmer  
summers**

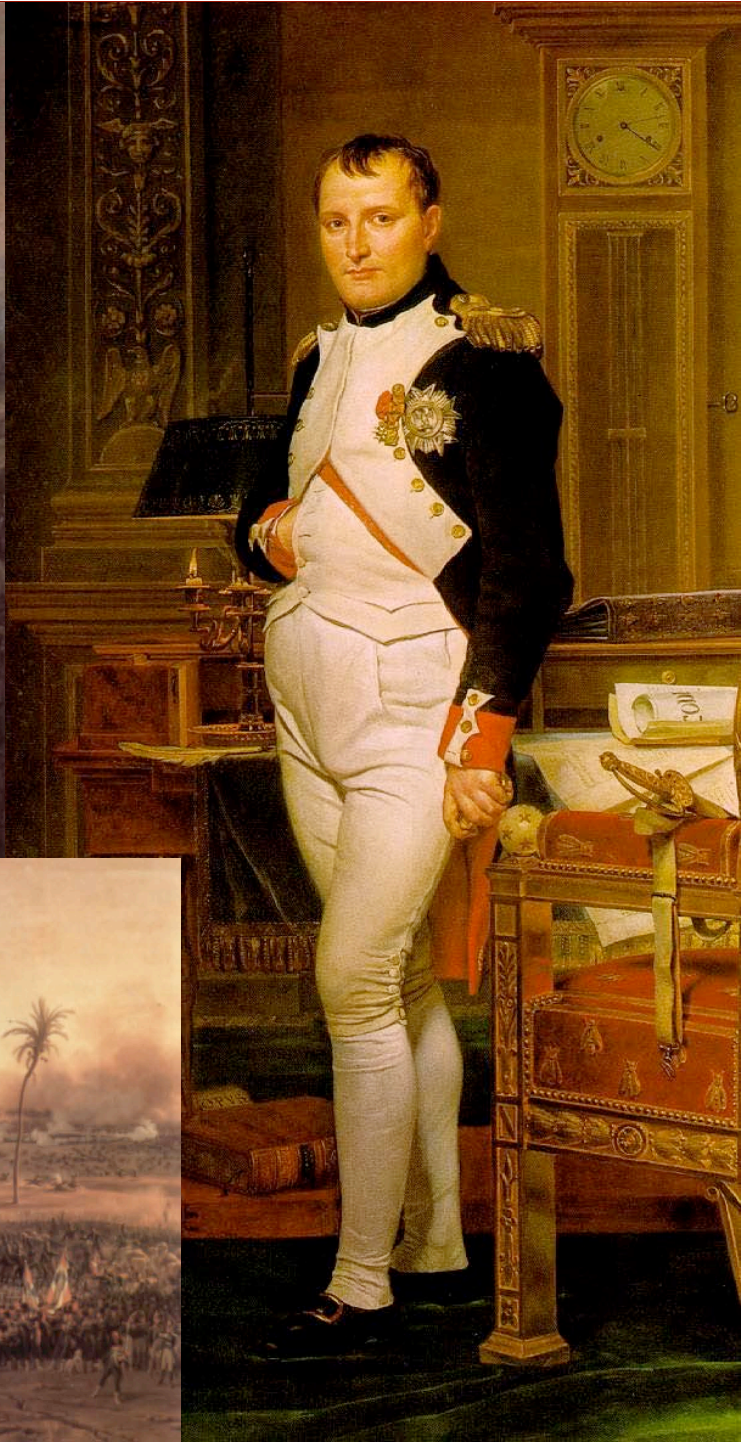


*\*25 year running mean*

*Source: Patridge, 2005*

- 1) Natural archives unlock a world that humans experienced.....  
.....but no longer remember
- 2) Natural archives record both forcings *and* system responses
- 3) They enable us to put contemporary changes in a historical perspective...









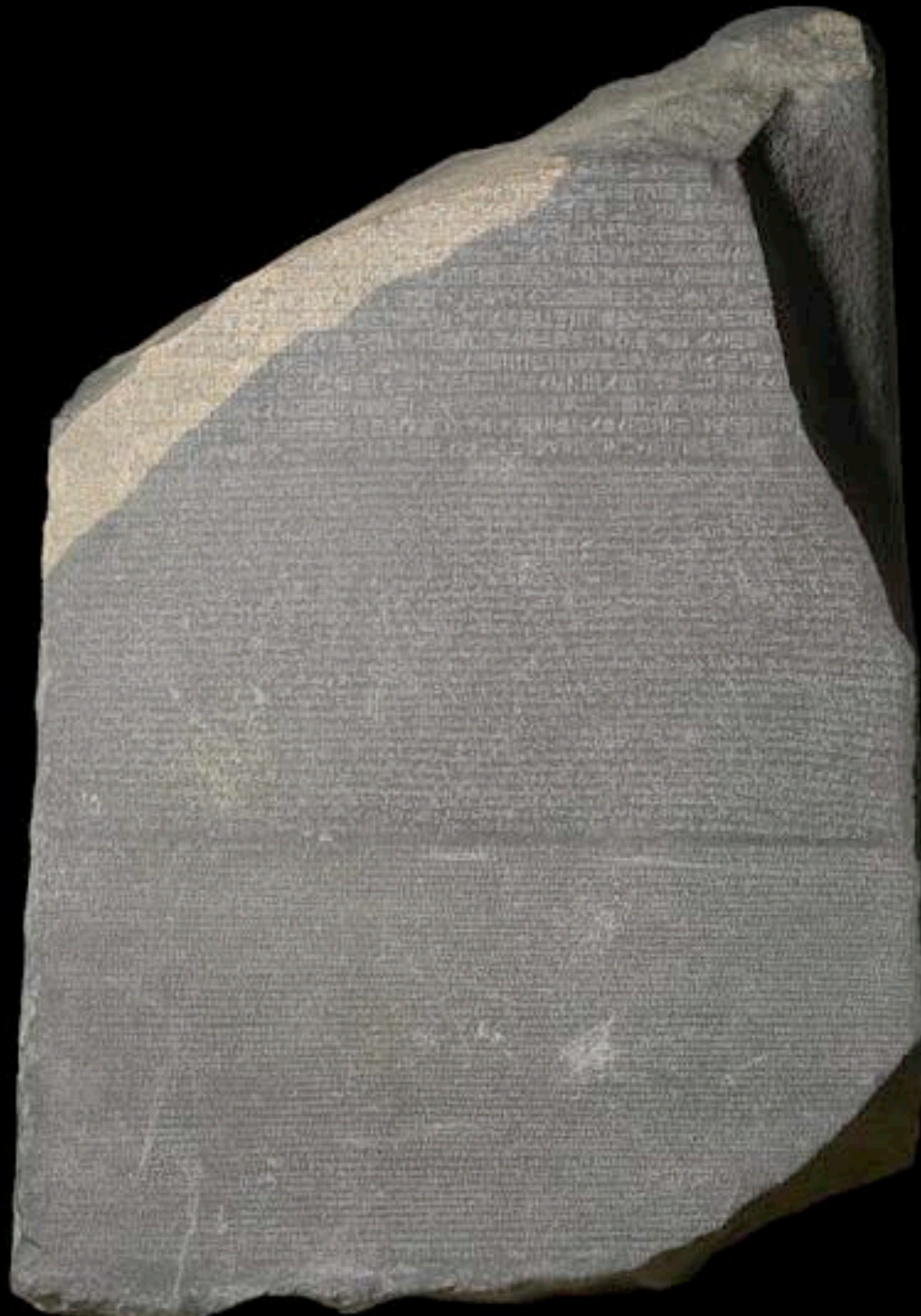
# Jean-Francois Champollion (1790-1832)



*“Precis du systeme  
hieroglyphique des  
anciens Egyptiens”  
(1824)*

# The Rosetta Stone:

An essential archive that unlocked our cultural history...





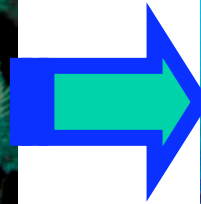
The Rosetta Stone is a priceless  
record of *cultural* history...





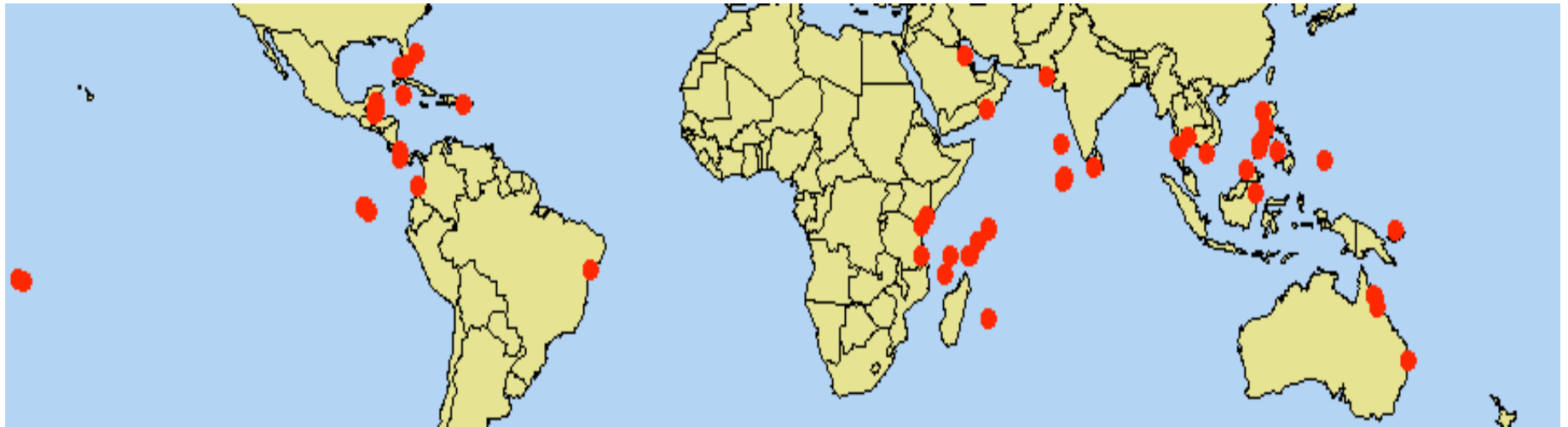
**Natural archives** are  
priceless records of our  
*environmental* history...

# Loss of paleoclimatic information through deteriorating coral archives...





# The 1997-98 Global Coral Bleaching Episode



**“Without doubt this is the most geographically widespread bleaching event ever recorded...”**



*-- UNEP World Conservation Monitoring Centre*

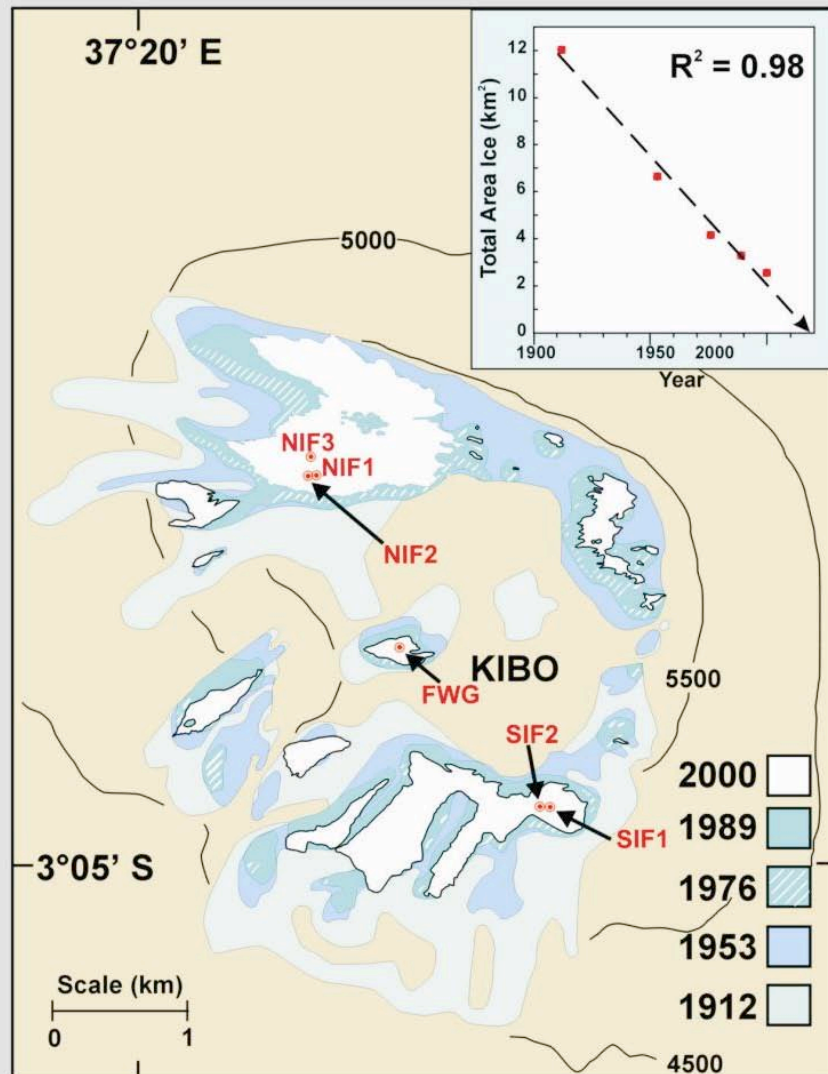
# The 1997-1998 Global Coral Bleaching Event: Australian consequences

“Aerial surveys of 654 reefs show that extensive bleaching occurred along the entire length of the Great Barrier Reef (GBR) from Elford Reef (17°S), to Heron Island (23°S)....

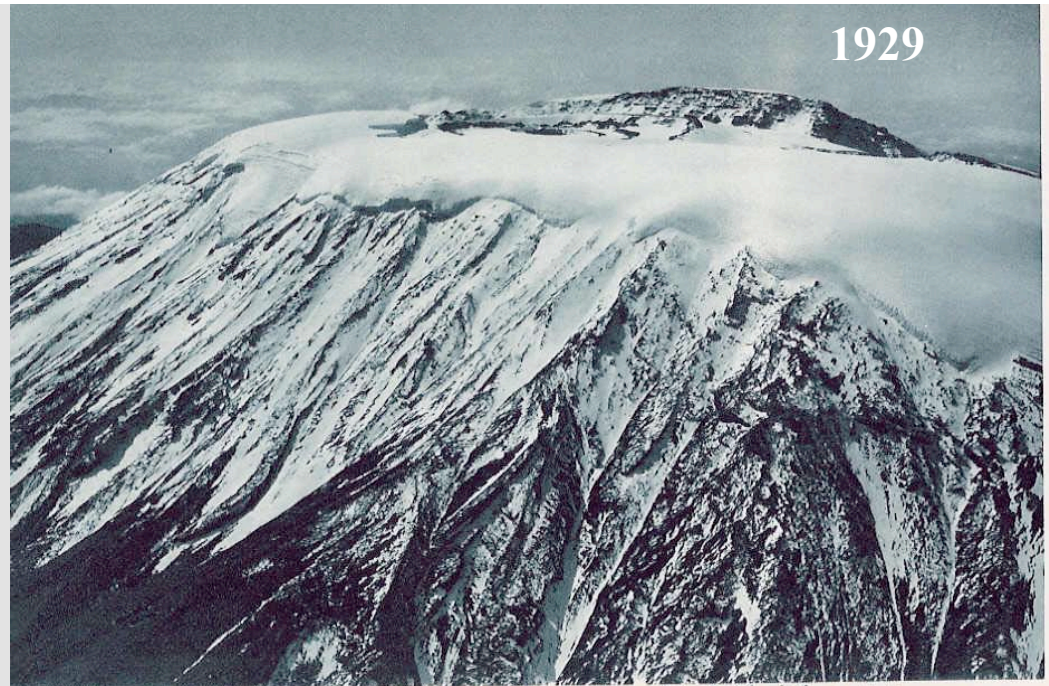
...Over 100 coral species bleached, including bleaching and partial death of large *Porites* colonies that were centuries old. This bleaching appeared to be a combined effect of raised temperatures, exacerbated in the central GBR by massive flows of rainwater in January...”

--Dr. Clive Wilkinson, AIMS, Queensland

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



1989 to 1912 maps are from Hastenrath and Greischar.  
The 2000 map was produced at Ohio State Univ.





# Kilimanjaro Icecap today



# Kilimanjaro Ice Cap in 2025?



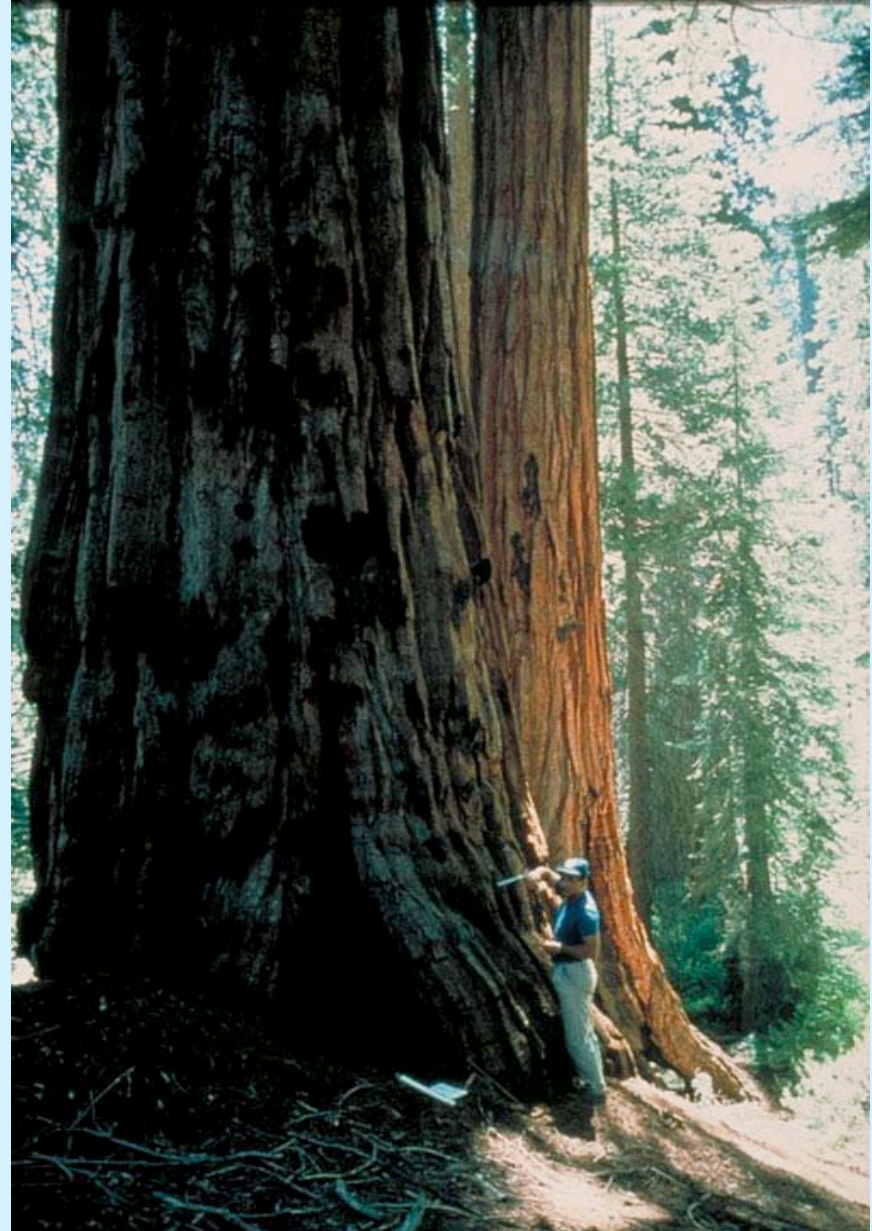


# Chacaltaya, Bolivia, ~5240m





**Old growth trees:  
Natural archives  
of the earth's  
climatic and  
environmental  
history**



***Giant Sequoia***



# Loss of Tree Ring archives due to clearcutting and forest fires

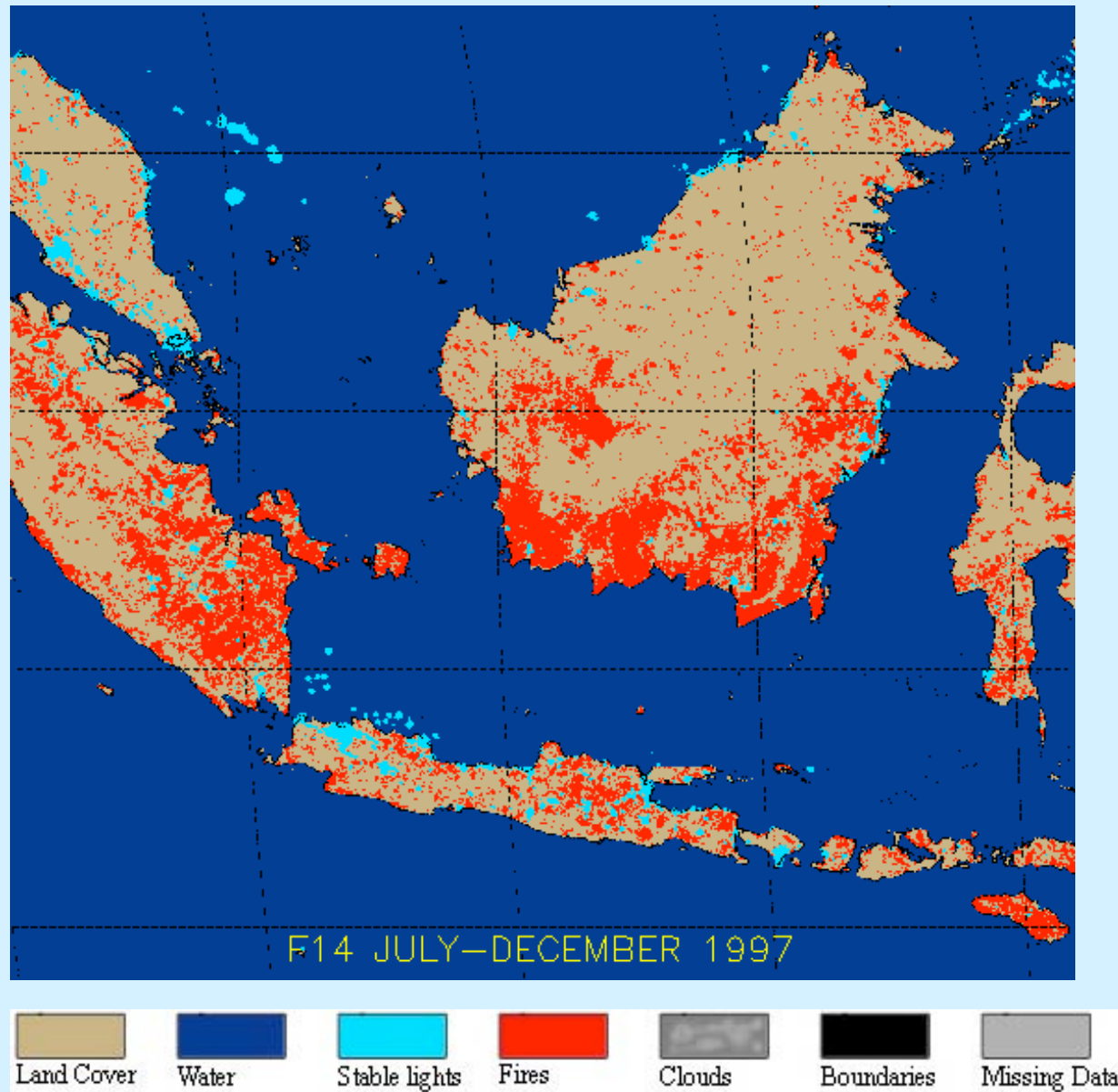


Finnish clearcutting in green belt area, N.W.  
Kostamukscha, Karelia, Russia.  
©Greenpeace / Weckenmann #0.95.423.03.03



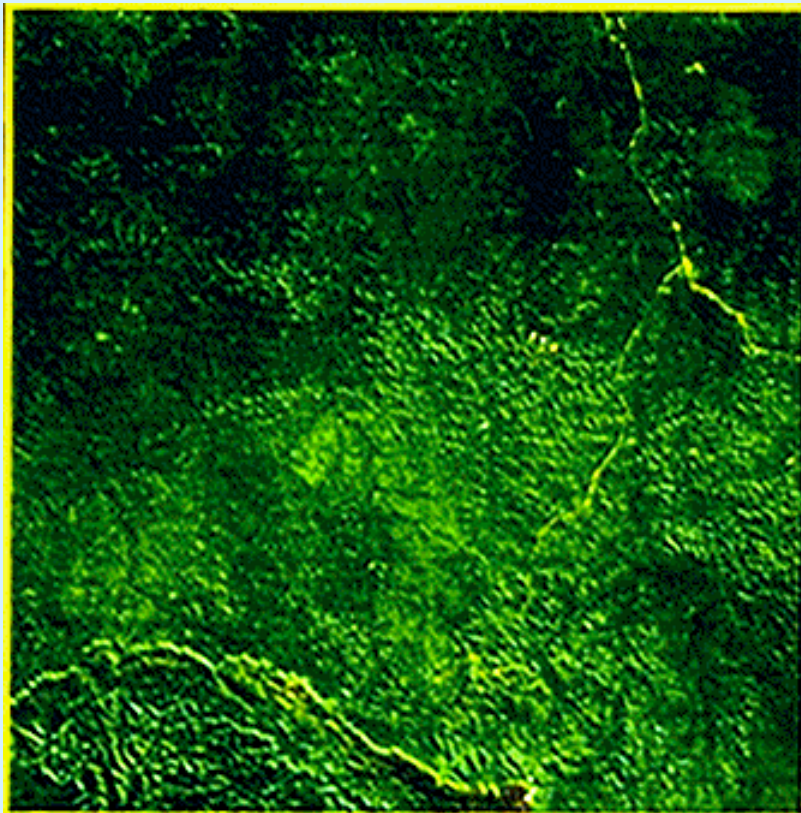
*Source:*  
*Karen Wattenmaker/NOAA Web Site*

# Fires in Indonesia: July-Dec 1997

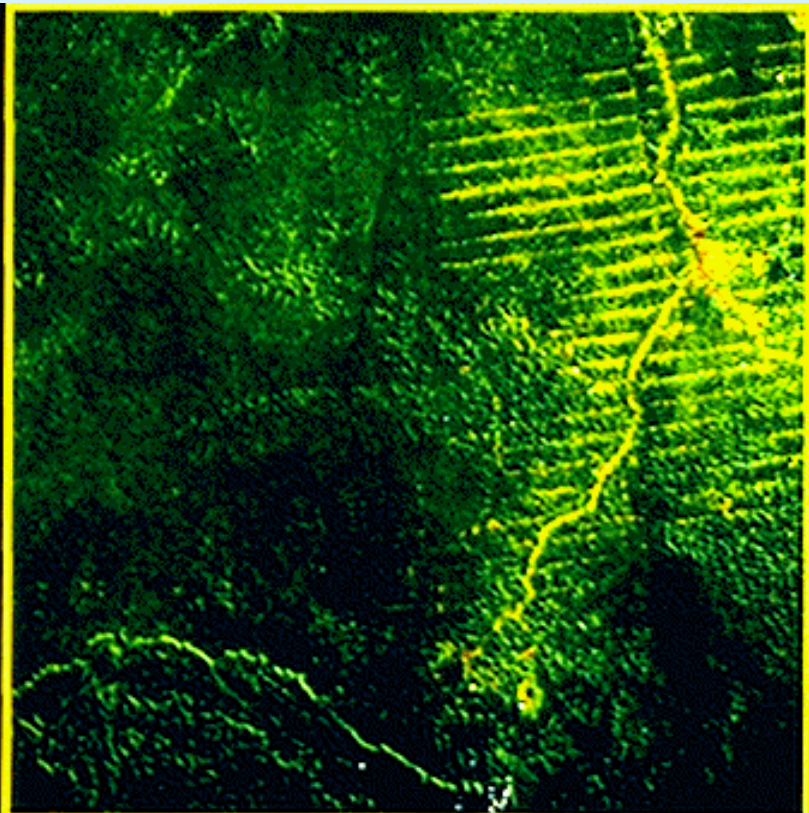


# Clearcutting in Rondonia, Brazil

1975



1986







Speleothems



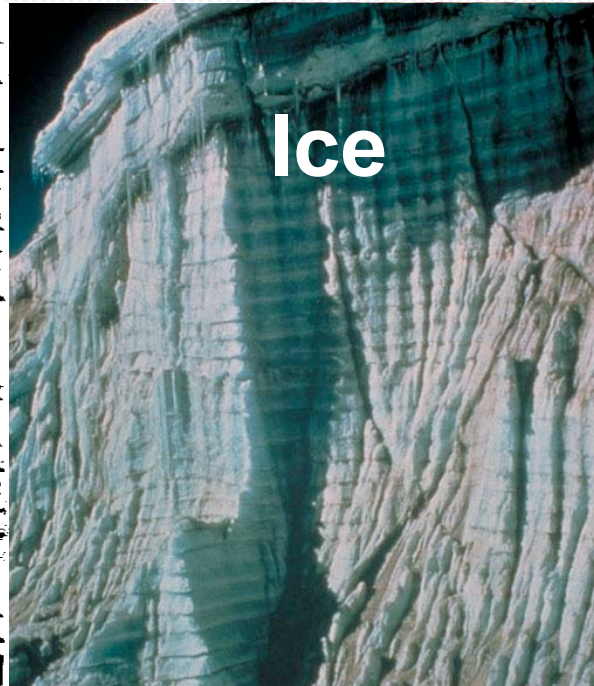
Tree rings



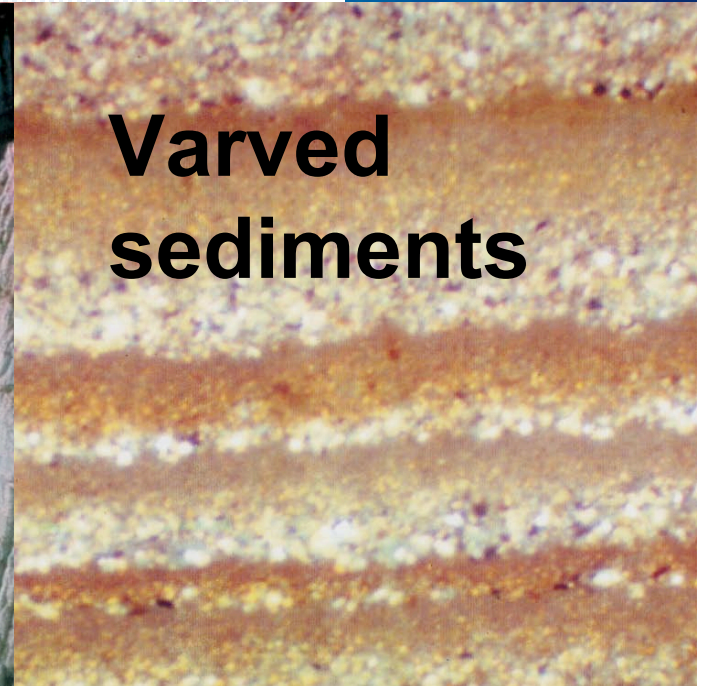
Corals



Historical documents



Ice



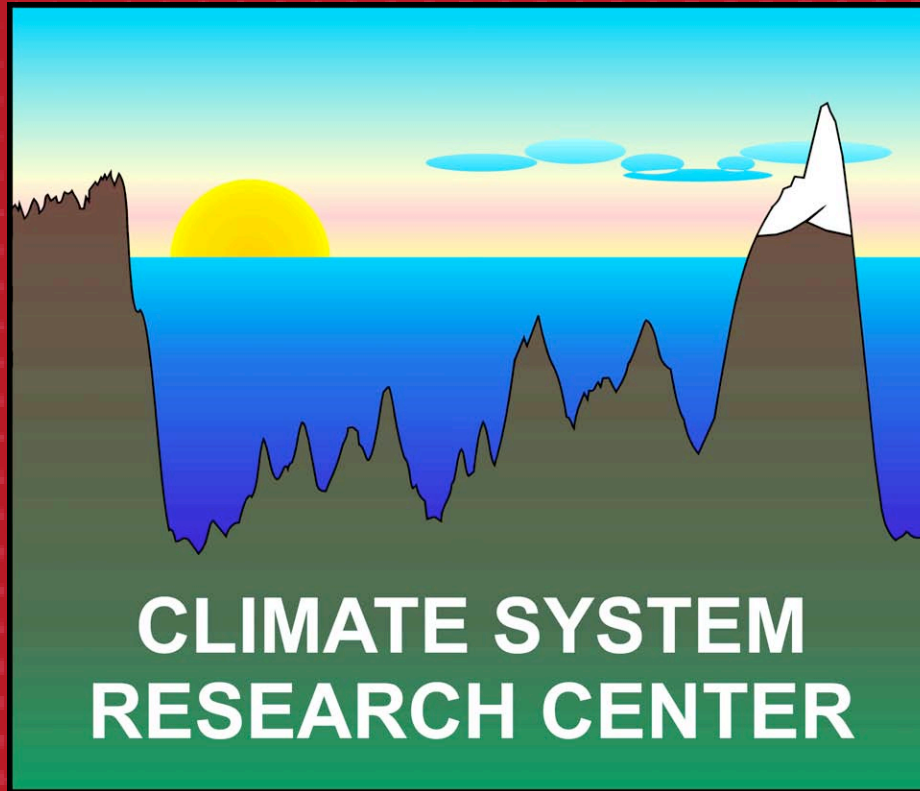
Varved sediments

*“If men could learn from history, what lessons it might teach us. But passion and party blind our eyes, and the light which experience gives is a lantern on the stern, which shines only on the waves behind us...”*

**Coleridge, 1831.**







University of Massachusetts  
Amherst

[www.paleoclimate.org](http://www.paleoclimate.org)



**For accurate information about  
climate change & global warming,  
see:**

**<http://www.realclimate.org>**



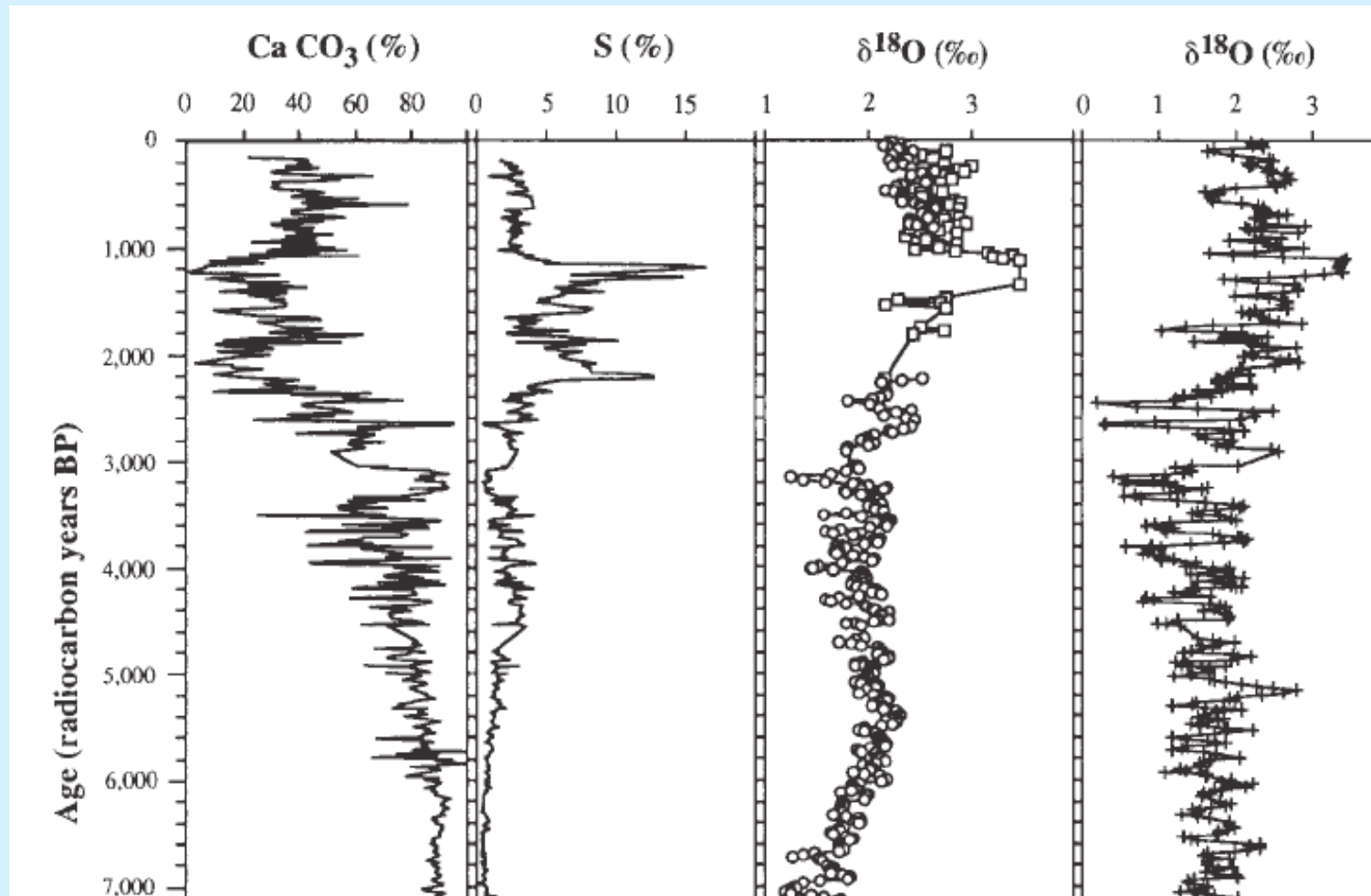
**Coba  
Quintana Roo  
Mexico**



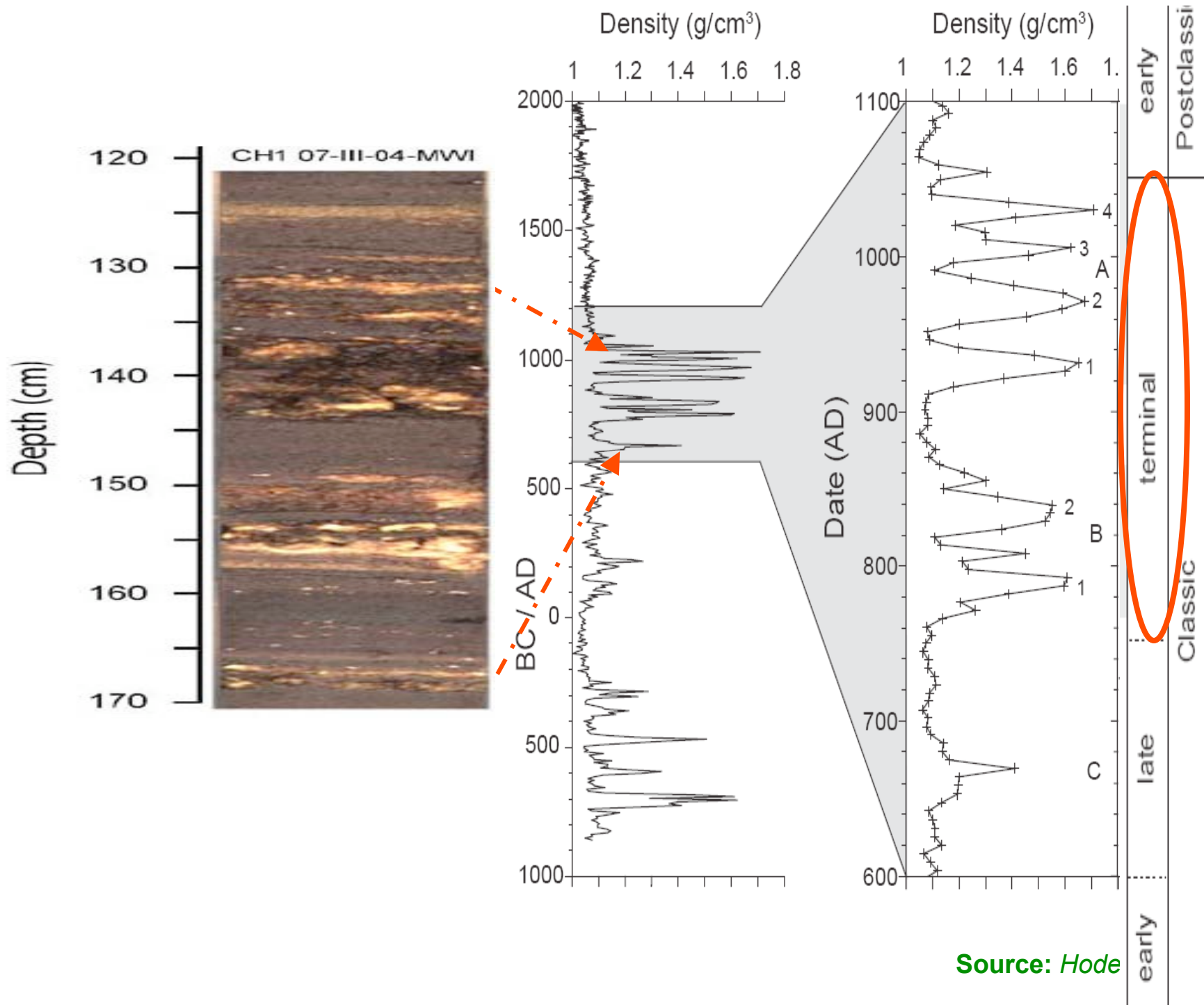




# Lake Chichancanab, Yucatan, Mexico

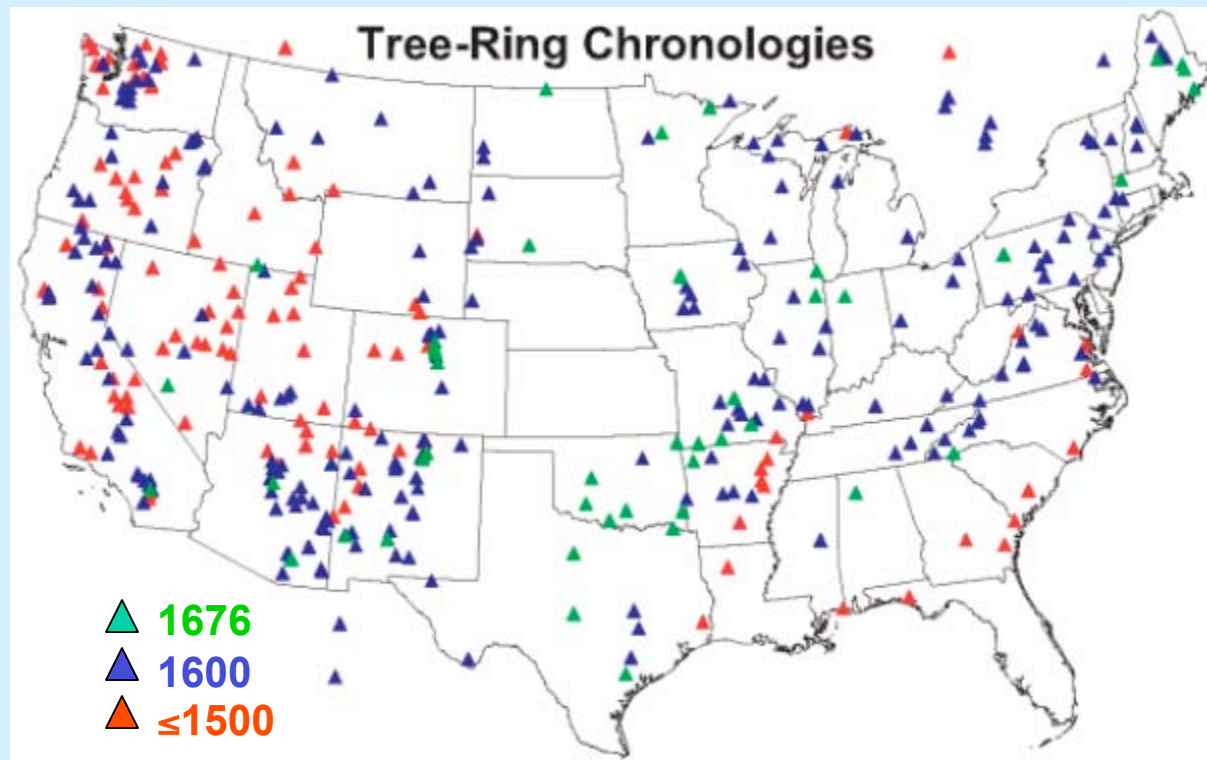


Source: Hodell et al., 1995



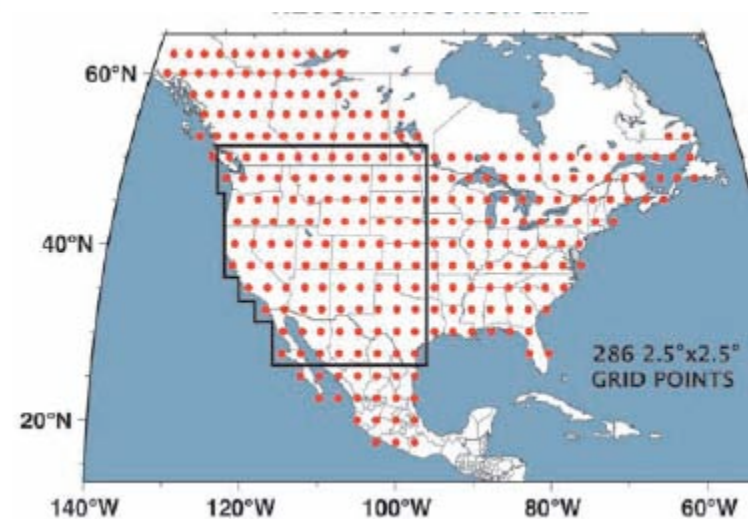
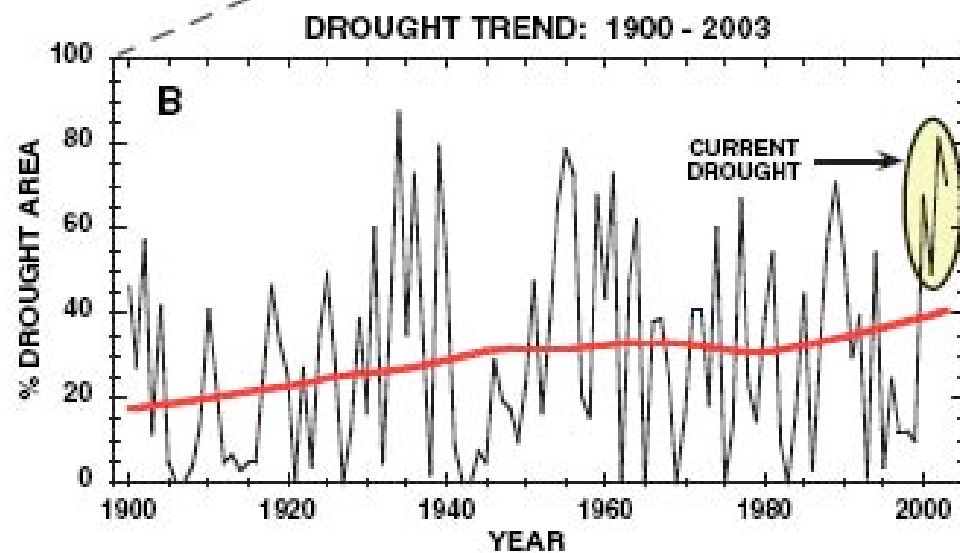
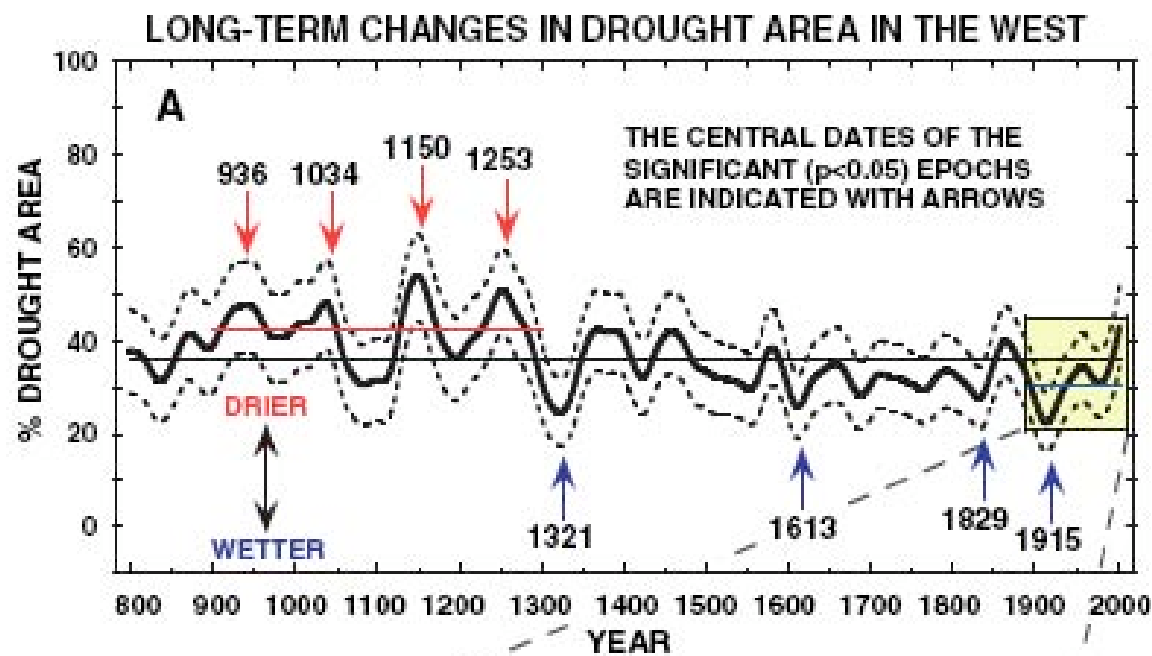
Source: Hode

1995



Source: *Fye et al., 2003*





Source: Cook et al., 2004