Past Climate Reconstruction and Climate Proxies

The past is the key to the present and the future!



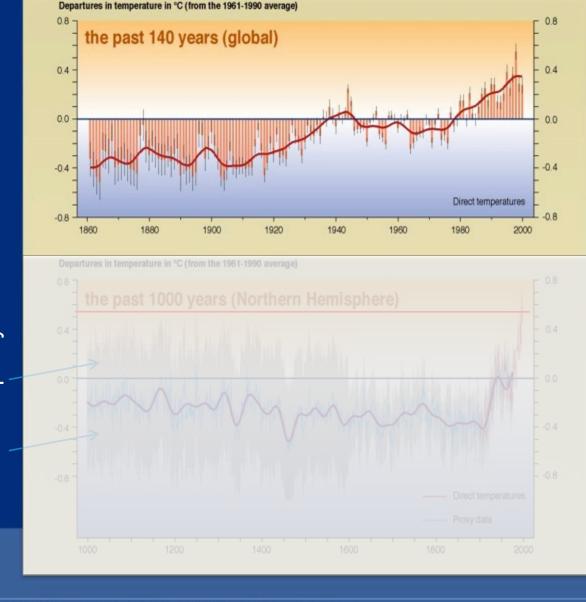




Instrumenta Records

Paleoclimate Records

IPCC



Variations of the Earth's surface temperature for...



SYR - FIGURE 2-3



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

The Instrumental Record

The earliest records of temperature measured by thermometers are from western Europe in the late 17th century and by the early 20th century records were being collected in almost all regions. Records from polar regions began in the 1940s.

The National Climatic Data Center maintains a collection of temperature records from over 7,000 stations worldwide, about 1,000 go back to the 19th century.

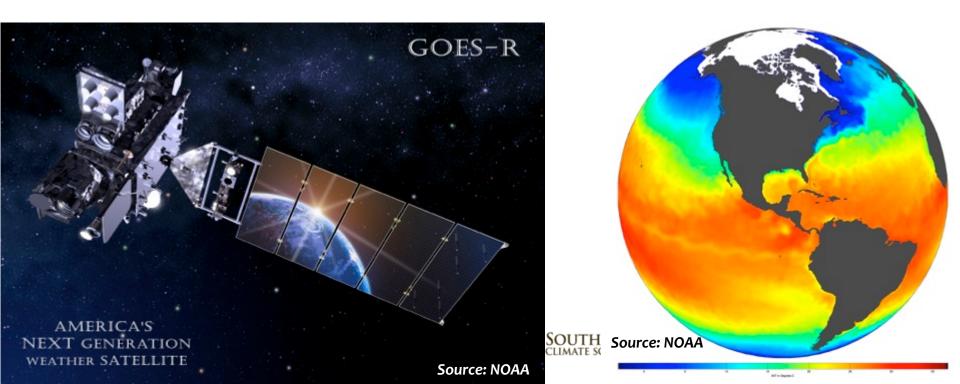
> Temperature observations the first 2 weeks of July 1776 in Thomas Jefferson's Weather Memorandum Book

-	Amente	to the more the	1 a man	1 the star	m- 1	hily	and a starting	thous
110	Philadelyn			70.	10.23	49.	\$-30. Q. M.	79-1
1000	on a m		9-12.	762	15290		9-0.	79.
	- 0. P. m.		2-0.P.m	80.0	1.00	1997	4-30 R.m	11.2
and the second sec	CONTRACTOR STATES	CALL AND A CALL AND A CALL	A-4P	82.	1963		8-40.	775
	6. 0. a.m.		6- 30.	812		24	0-30. A.M	
	1-40.4 m.	MORE OF THE PROPERTY OF	9-20	78.		199	8-20. 2- Ac.P.m.	73.1
and the second se	9- 0. P.m.	Contraction of the second s	L 3- 30 Q. 77			1.13	6- 0.	70 4
	5. 30. a.m.		18-0.	76 to	-40.01	103	0-0.	75
and the second se	1- 30, P. m.		9-40.2.7	1000		20	2. 12. a.m.	and the second
and the second se	9-10-	and the second se	27. 0. a.m	72.	33.24		11- 30.	79.
and the second se	6. 0.0.70	and the second	9-0.	m.	1	100	0-0.P.m.	
400000000000000000000000000000000000000	9-0.	A COMPANY OF A COM	8- 30. 9.m		A and		9-15.	
and the second second	100000000000000000000000000000000000000	76.	1 5-30.A.m	10000		27	6-0.a.m	
	9-0.	732	11-0.	74	121414	1.15	3-0.4	and a
5.1	- 0. a.m.	715	2-0.7.1	1		120	3-20 Pm	Sec.
1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	1-0.	72	6-43.	76.		1923	0- 15.	Rott
	1-0.P.m.	74	2-25	76	18.20	-	6-0. R.m.	
	- 0.a.m.	26	9-0.		-	100	4-15	100
	1-0.	75. 14.	6 m. a.m.	73.	min.	134	10 - a. P.m.	-
1000	- 0. P.m.		9-30.	72.	TRAFS.	24.		
			1- 0.P.m	1. 90%	min		9-0	
	0-0.		1-35	70.	- BOARD	0.63	0- 40.P. M.	10 million
A CONTRACTOR OF A CONTRACTOR OFTA CONTRACTOR O	6-0.a.m	CAREER COLLEGE COMPLEX	5-0.	64.			6- 0.Q.M	
	0 0	73	8- 42.	Let.			0-0.	
1000	1-0-P.M.	74. 13	6-30.0.7	and the second second		14	9-0. P.M.	
1000	3-20	75	9-0.	68%			6. o.a.m.	
ALC: NOTE OF	9-30.	74.	7- 30.P.m		1	1		224
	5 - 35 a.m		Contraction and the second		14. 31	100	9-0. P.M.	775
		and the second second second second	9-0.	67.		1	A CONTRACTOR	292
	1-0.	112	5-45.A.D	Contraction of the second	345	-7	6-0.a.m.	712
	2-0. P.m.	80	9-45	68 %		1.1	11-30	A
	5-0.	81.	7-15.P.M	カフマモ		0.65	6 - 0.P.m.	07.
Lange P	8- 15.	80.	9-0.2	717	(福田)	123		101
	9-30.	79. 17	6- 0.a.m	1. 60 2		1.2	7-0.	01
A 2. 1	1-30. a.m.	75.	40	74	1.00		1-20.	Con 1
1 .	1-0	775	9- 30. PM		diam'r.	24	6-20, a.m.	122
8	- n 8m	art 11					a - a - tota	and .
C. Carner	1. 45		10-10.	26		(they	12 - 4	Paz
The second	Contraction of	A CONTRACTOR	8-0.9.1	1 Pat	1000	1995	1 57 mm	A land

Satellite-Derived Temperature Record

Satellite measurements have been used to construct globally complete land and oceanic temperatures since 1979.

Provides a spatially uniform perspective whereas weather observations are biased towards where people are located. Allows for measurements over hard-to-sample areas like the oceans and ice sheets.



Historical Records

Historical documents contain past weather and climate information.

Ship logs are particularly useful for accounts of sea ice, storms, and hurricanes.

Farmers' logs can include useful information such as planting or harvest dates and overall crop health.

Personal diaries are another resource.

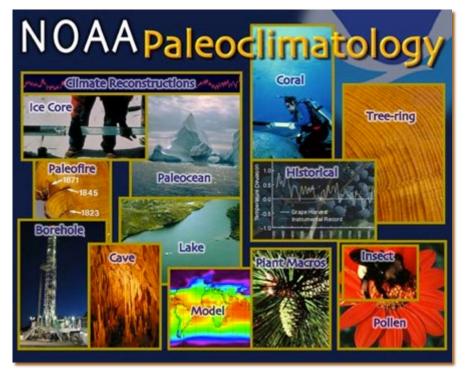
	was measured by	- Senday fame 22 15 .18
1 3 4 5	and the product of th	man and the first and the second of the large
1 1		
$\frac{1}{2} + \frac{1}{2} + \frac{1}$		Lield and course had a sure fair I'll. Manus trough heads literau in
	a 7 4 12 19 8 . 3.4 pt 1x + 1 2021 30 . 3	and the server and th
		These things show not and all antered help the valit with a few love to
		MIATE, Textin she to de, To 120 May have be as there be that the state of the
$\frac{1}{2} \left[\frac{1}{2} \left$		WITH Small Will be the W. a caked sid answer to hat at she the what we down
	* 7 1 Style IN 1 periods to 14 was and 1	und the way of the state of the
Image of a first of the second sec	* 7 5 6 ALM & 411/43/18/25/20 5	Cicke Change of Str. 1 Martin 1 Martin
The start is the first start in the start in the start in the start is thest is the start is the start is the start is the start is		46 S. B Porcel with an analys & daughter a shade herding they
Market 19 Jack melling famIntoMarket 19Market 19 Jack melling famIntoMarket 19Market 19 Jack melling famJack 19Jack 19Market 19 Jack melling famJack 19Jack 19Market 19 Jack melling famJack 19Jack 19Market 19Market 19Jack 19Jack 19Market 19Jack 19Jack 19Ja	a fit in a fight to strange the state	per Store Store 18 8 8 2 throng water, has due to date to and the Channel
$ \begin{array}{c} \label{eq:product} \begin{tabular}{lllllllllllllllllllllllllllllllllll$	Hones on by highers provide New José	The state of rate of well with and of a platead quale Attenses
With the stand as the left as A The 24 Handing through a mark through the stand as the sta		
Market in State 17, 20(1) State 10,		These still time that is a transfile both them I to the Paris I have no been will be
$ \frac{1}{10000000000000000000000000000000000$		mar & Engel. It is so wall appelling and all as a phile land I the of a
$ \frac{1}{2} 1$		Tinde & all the first of the start of the st
Normal for strated Annual Strategies Remain of the strate strate Image in strategies Remain of the strate strate Image in strategies Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate Image in strate strate Remain of the strate strate		a the filler barred ill the part to be the added to be the the state of the self of the self of the self of the
$ \frac{1}{10000000000000000000000000000000000$		anything leave to that a not setting as the of her to and which a party stranged as have
$ \begin{array}{c} & \\ \hline \mathbf{r} & \\$		The Hall i Wildow my fraing load of Rits and stand bint added in a say 10 go (a) Alla
Maximum schwarther Katt - Litter Image: schwarther Katt - Litter		Sand Althe Rider and and the shall be at the first at a
No. No. <td></td> <td>and But a Trank of on and per all gallent all at all of shall be and and and</td>		and But a Trank of on and per all gallent all at all of shall be and and and
Image: Stand	tod remaining in last in Rose R/11 - J/31 +	a part divine of from all to 32.
1 1 <td></td> <td>The CASTAL. I links Barrens the Bell has to be all and a the when</td>		The CASTAL. I links Barrens the Bell has to be all and a the when
Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C. (Wing C.) Wing C.) Wing C.		with the last of the the same throw by share the set of the third have
Image: State of the state o		maler, aller a party with stran land, it about angle or but pater the
A T A ABA A A A A A A A A A A A A A		The system of the fature and the fature
 A A A A A A A A A A A A A A A A A A A		sandle and account but Out & State and a fill and in
 Anders of the set of	1 B 2	a some he through site I be tonis trank allow here states that a the
 Burk 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		All the set all from most said tall in the to and salard and Baland and
Contraction theme and a set of the set		agoing at that this is done patient find and way at any day't bailes aring a
	* Gentling I #9 232000 0012 00 1 4	The first water and a first an organized friend think of their maker that the
The set of	a general and the state of the	like Broyland at an with poor of this and in for and burners
Lapately Banance for Manance Banance T	MA P. P. P. P. P. P. 22 21 1 P. P. P.	attended the and Allowingle way typing . Satte por of water, Budy traderic
	Langhade by Elements to be a Ministra Oliveradase 1	and motions as degrad date of the usual tout dense by bread for the
		Manual St.
Value & to Chapter & and a second a sec	Valution of the Compact by Registrade advanced assumed	And the first the second

Paleoclimatology

is the study of past climate that does not use instrumental observations but proxies from the environment.

Proxies of climate variability are recorded in the rings of trees, coral colonies, ice sheets and glaciers, cave deposits, layers of sediments (pollen, microfossils, and organics) and more.

These natural recorders of climate contain a chronology or way to tell time and they record changes in environment, driven by climate.









Annual Banding

Ice cores Varve sediments Tree rings Corals

Count years Absolute age if date of collection is known

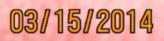
GISP2 National Ice Core Laboratory USGS



Varves of Lehmilampi lake (Eastern Finland), light layer = spring flood mineral layer, dark layer=organic summer-winter layerSouth CI

Tree Rings

03/15/2014



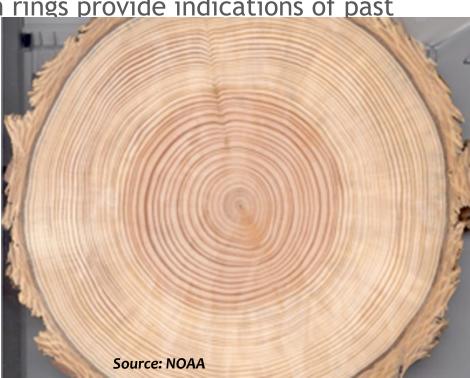
Tree Ring Record

Cross dating of tree rings can provide exact date matches between trees with different ages or from different locations.

Major events such as fire, flood, avalanche, drought, and insect infestation can all be evident.

The regular year to year variations in rings provide indications of past temperature, precipitation and streamflow.

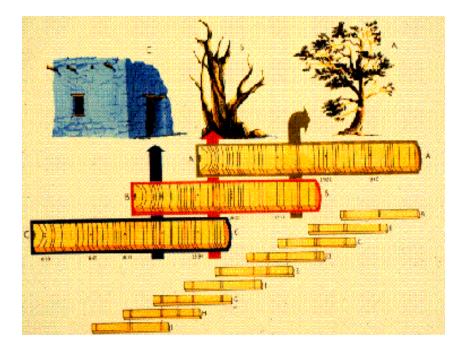
Using petrified or fossilized wood, tree ring records go back more than **10,000 years** in some locations.



Dendrochronology



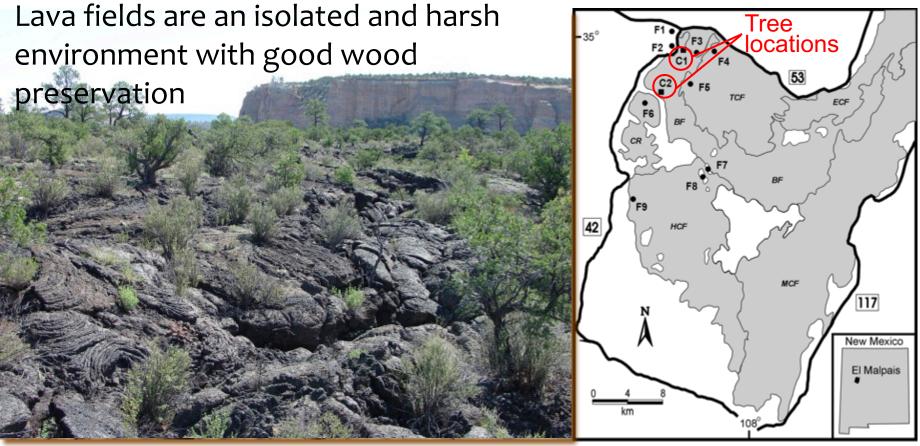
- * Master chronology
 - Many trees from a region are cross-dated
 - * Locally absent years
 - * False rings
- * Quality Checked
 - * COFECHA







El Malpais Tree-Rings



Grissino-Mayer, 2000

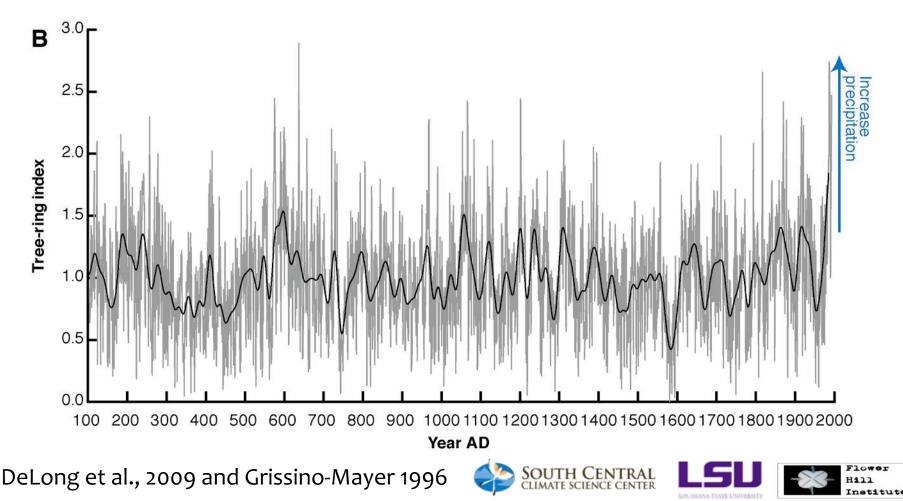
New Mexico region is precipitation sensitive Ring width varies with annual precipitation



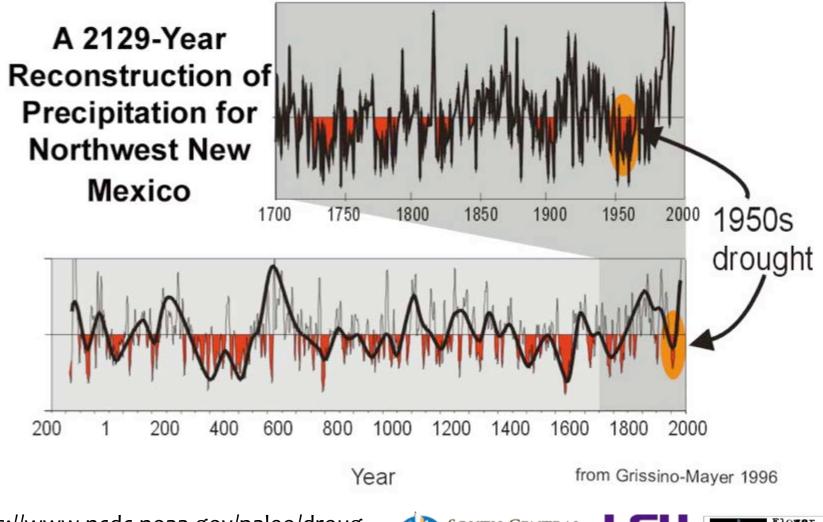


El Malpais Tree-Ring Record

Average tree age = 391 years, 76 trees > 500 years Oldest living tree found is a 1274-year old Douglas-fir.



El Malpais Tree-Ring Record



https://www.ncdc.noaa.gov/paleo/droug ht/drght_grissno.html

Corals as Climate Archives

Corals

A coral is a colony composed of hundreds of thousands of tiny animals called coral polyps.

Coral polyp deposits calcium carbonate, which forms the coral skeleton, and many corals form the coral reef.

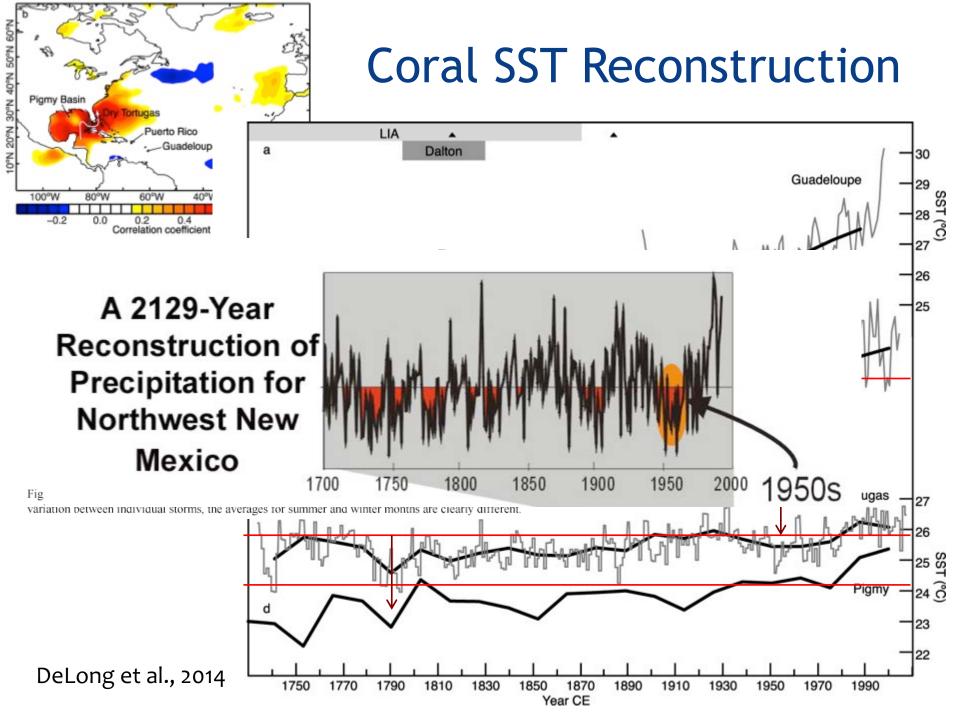
Within the coral skeleton are density bands, similar to tree rings and chemistry with the Skeletal depends on temperature and other environmental conditions.



USGS DeLong

A long core of a coral skeleton can cover hundreds of years and exact dates can be determined based on counting the growth bands or U-Th dating.

Coral records help us understand the tropical climate system, which is a strong driver of global climate.



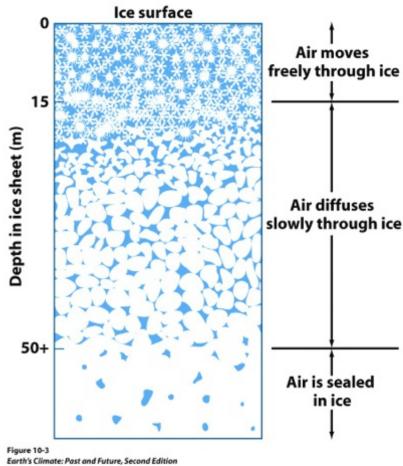
Ice Core Records

The Greenland ice sheet is nearly two miles thick and provides climate history going back 200,000 years.

Parts of the Antarctic ice sheet are even thicker, going back over **700,000 years**.

Layers of dust present in ice cores from past windy seasons or could represent past volcanic eruptions.

Tiny fossil air bubbles are even trapped in the ice, time capsules of past air.



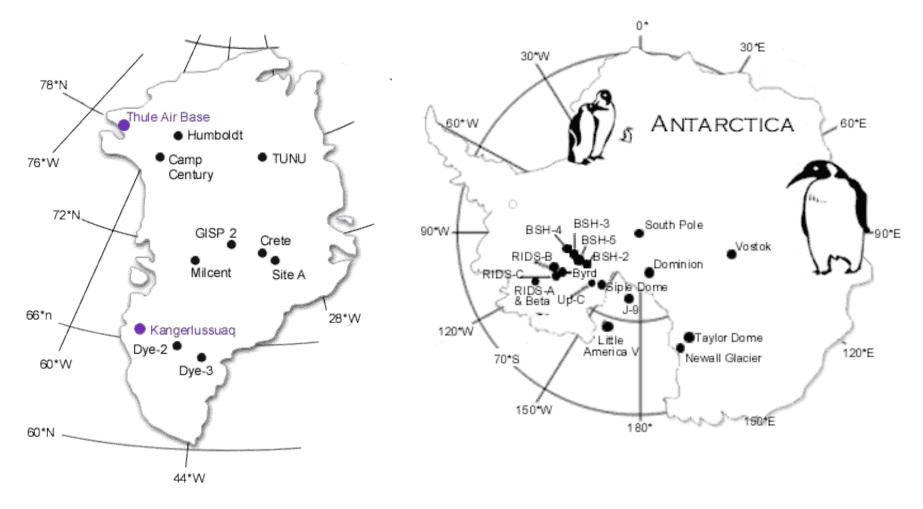
© 2008 W. H. Freeman and Company





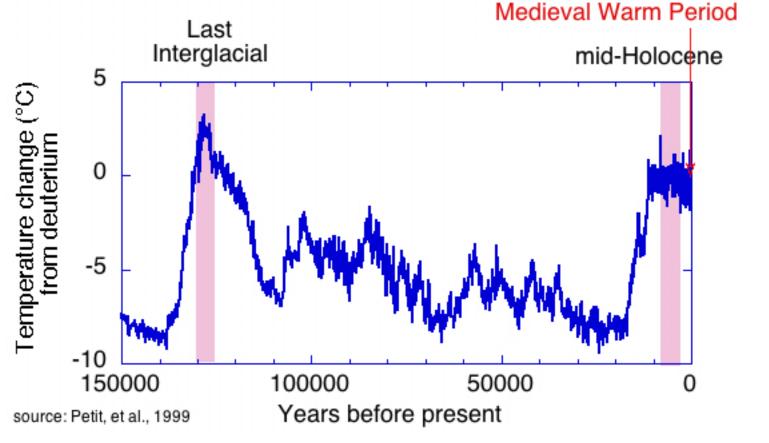
High Latitude Ice Records

Most ice cores have been retrieved from high latitude sites in Greenland (GISP, GISP2, GRIP) and Antarctica (Taylor Dome, Siple Dome, Vostok)



Ice Core Records

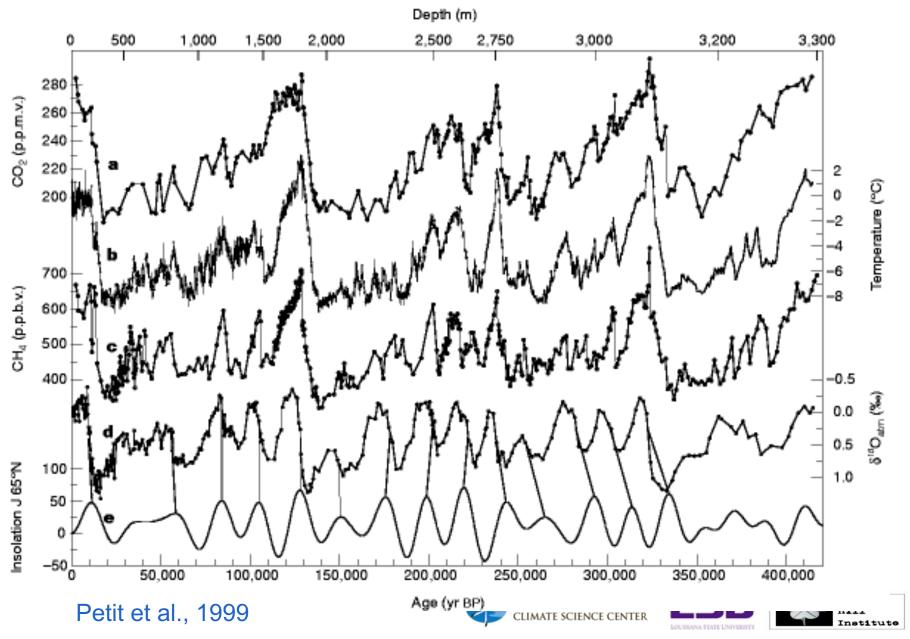
Temperature change for the past 150,000 years from an Antarctic ice core.



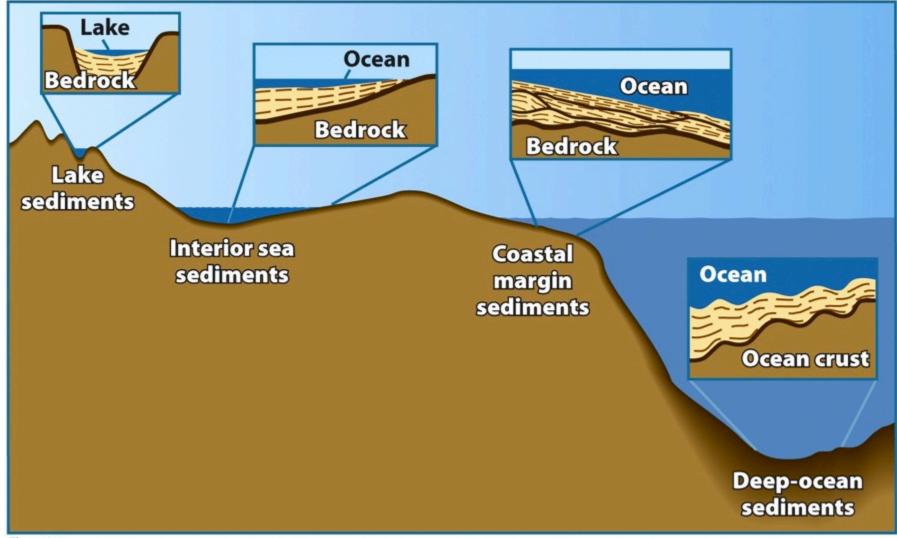




Vostok Antarctica Ice Core Record



Sediments



.

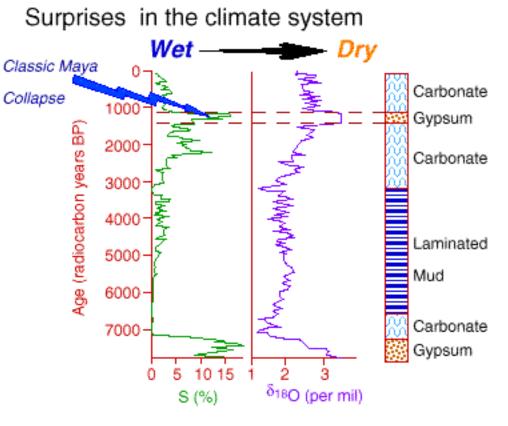
Figure 2-1 Earth's Climate: Past and Future, Second Edition © 2008 W. H. Freeman and Company

Sediment Records

Sediment cores from closed basin lakes in the Yucatan Peninsula indicate evidence of an intense period of drought that coincides with the collapse of the Classic Mayan Civilization.

An archaeological mystery, southern Mayan cities were abandoned between 800 and 900 AD.

Mexican Paleoclimate and Civilization Collapse



(Hodell et al, 1995 Nature)





Ocean Drilling



Figure 2-4b Earth's Climate: Past and Future, Second Edition





Earth's Climate: Past and Future, Second Edition © 2008 III: H. Freeman and Company

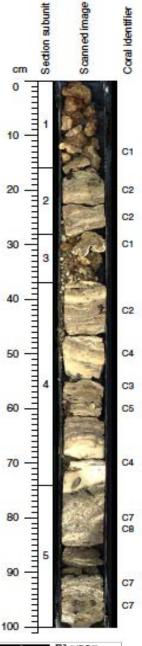


Figure 2-6d Earth's Chevels - Aust and Future, Second Edition 0.2009 W.H. Ferencer, and Comparis







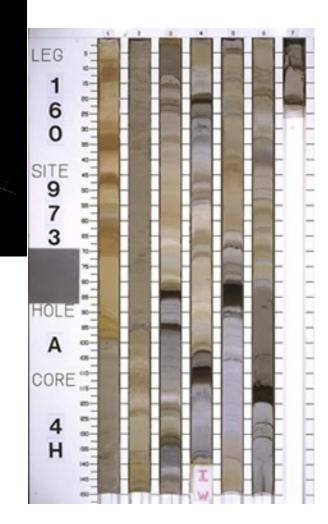


Core Photo

Marine Sediments







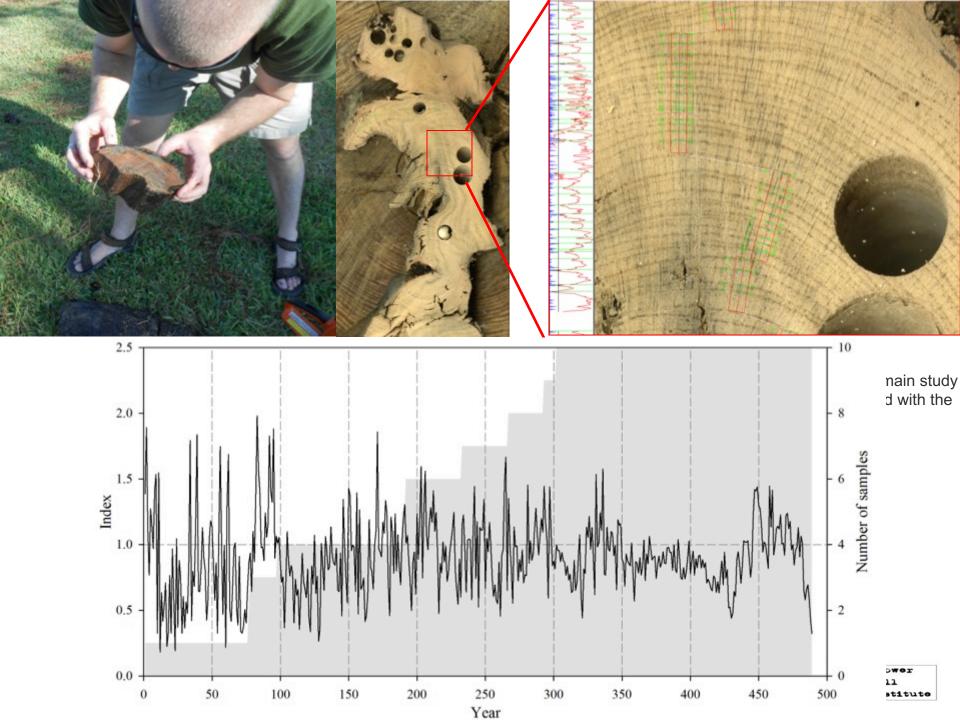






Multi-beam image of the ancient cypress forest site off the coast of Alabama. Vertical relief is not to scale.





Pollen

Tupelo (Nyssa aquatica)

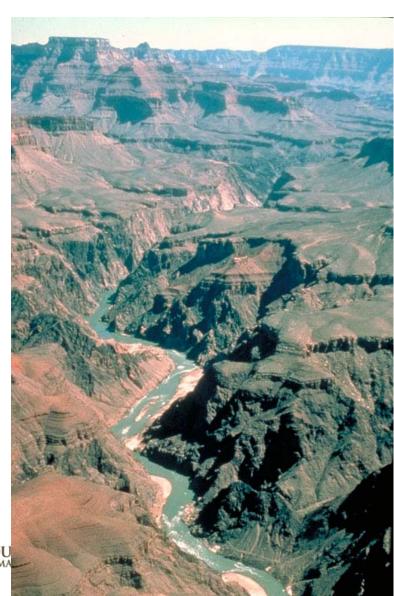
Pine (Pinus spp.

Bald Cypress Taxodium distichum

Other Proxy Records

The geologic, fossil and sediment record also provide indications of Earth's past climate.

Pollen grains are especially well preserved in sediment layers, like at the bottom of a lake or ocean.



Questions and Discussion





