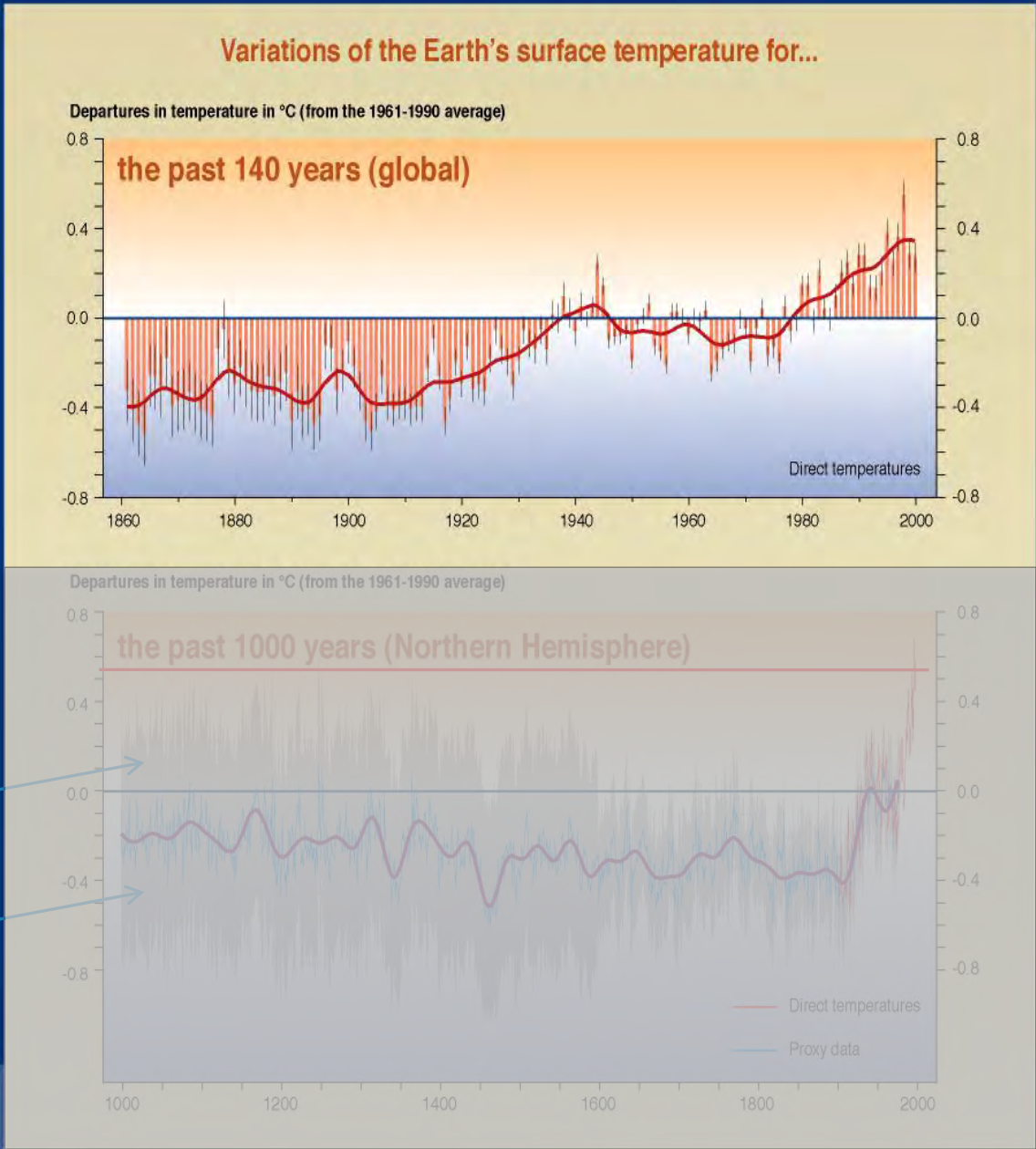


Past Climate Reconstruction and Climate Proxies

Instrumental Records

Paleoclimate Records

Error bars for proxy data



SYR - FIGURE 2-3

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

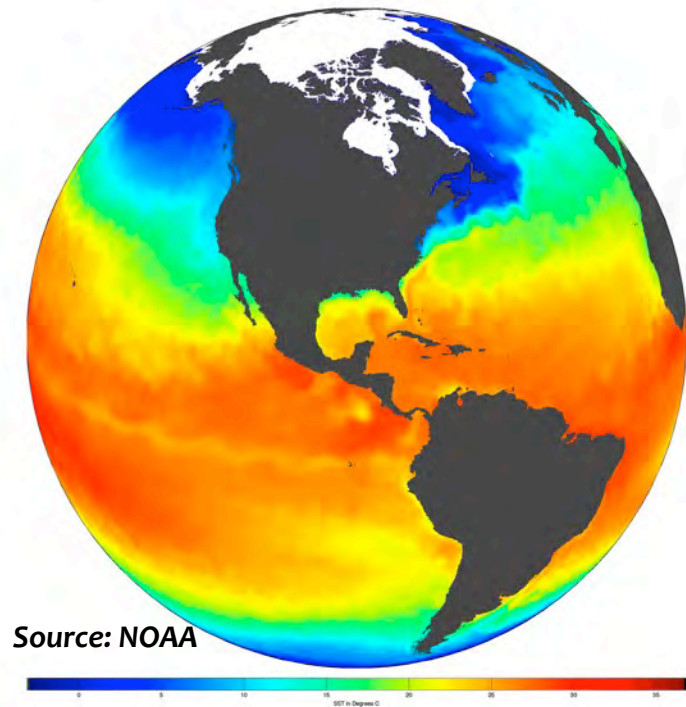
LIBRARY OF CONGRESS, MANUSCRIPT DIVISION

Date	Time	Temperature (°F)
July 1	8 a.m.	70
July 1	9 a.m.	76
July 1	2 p.m.	80
July 1	4 p.m.	82
July 1	6 p.m.	81
July 1	9 p.m.	78
July 2	5 a.m.	74
July 2	8 a.m.	76
July 2	11 a.m.	75
July 2	2 p.m.	74
July 2	5 p.m.	72
July 2	8 p.m.	72
July 2	11 p.m.	71
July 3	5 a.m.	74
July 3	8 a.m.	76
July 3	11 a.m.	74
July 3	2 p.m.	76
July 3	5 p.m.	76
July 3	8 p.m.	76
July 3	11 p.m.	75
July 4	5 a.m.	75
July 4	8 a.m.	77
July 4	11 a.m.	77
July 4	2 p.m.	77
July 4	5 p.m.	77
July 4	8 p.m.	77
July 4	11 p.m.	77
July 5	5 a.m.	75
July 5	8 a.m.	77
July 5	11 a.m.	77
July 5	2 p.m.	77
July 5	5 p.m.	77
July 5	8 p.m.	77
July 5	11 p.m.	77
July 6	5 a.m.	75
July 6	8 a.m.	77
July 6	11 a.m.	77
July 6	2 p.m.	77
July 6	5 p.m.	77
July 6	8 p.m.	77
July 6	11 p.m.	77
July 7	5 a.m.	75
July 7	8 a.m.	77
July 7	11 a.m.	77
July 7	2 p.m.	77
July 7	5 p.m.	77
July 7	8 p.m.	77
July 7	11 p.m.	77
July 8	5 a.m.	75
July 8	8 a.m.	77
July 8	11 a.m.	77
July 8	2 p.m.	77
July 8	5 p.m.	77
July 8	8 p.m.	77
July 8	11 p.m.	77
July 9	5 a.m.	75
July 9	8 a.m.	77
July 9	11 a.m.	77
July 9	2 p.m.	77
July 9	5 p.m.	77
July 9	8 p.m.	77
July 9	11 p.m.	77
July 10	5 a.m.	75
July 10	8 a.m.	77
July 10	11 a.m.	77
July 10	2 p.m.	77
July 10	5 p.m.	77
July 10	8 p.m.	77
July 10	11 p.m.	77
July 11	5 a.m.	75
July 11	8 a.m.	77
July 11	11 a.m.	77
July 11	2 p.m.	77
July 11	5 p.m.	77
July 11	8 p.m.	77
July 11	11 p.m.	77
July 12	5 a.m.	75
July 12	8 a.m.	77
July 12	11 a.m.	77
July 12	2 p.m.	77
July 12	5 p.m.	77
July 12	8 p.m.	77
July 12	11 p.m.	77
July 13	5 a.m.	75
July 13	8 a.m.	77
July 13	11 a.m.	77
July 13	2 p.m.	77
July 13	5 p.m.	77
July 13	8 p.m.	77
July 13	11 p.m.	77
July 14	5 a.m.	75
July 14	8 a.m.	77
July 14	11 a.m.	77
July 14	2 p.m.	77
July 14	5 p.m.	77
July 14	8 p.m.	77
July 14	11 p.m.	77
July 15	5 a.m.	75
July 15	8 a.m.	77
July 15	11 a.m.	77
July 15	2 p.m.	77
July 15	5 p.m.	77
July 15	8 p.m.	77
July 15	11 p.m.	77
July 16	5 a.m.	75
July 16	8 a.m.	77
July 16	11 a.m.	77
July 16	2 p.m.	77
July 16	5 p.m.	77
July 16	8 p.m.	77
July 16	11 p.m.	77
July 17	5 a.m.	75
July 17	8 a.m.	77
July 17	11 a.m.	77
July 17	2 p.m.	77
July 17	5 p.m.	77
July 17	8 p.m.	77
July 17	11 p.m.	77
July 18	5 a.m.	75
July 18	8 a.m.	77
July 18	11 a.m.	77
July 18	2 p.m.	77
July 18	5 p.m.	77
July 18	8 p.m.	77
July 18	11 p.m.	77
July 19	5 a.m.	75
July 19	8 a.m.	77
July 19	11 a.m.	77
July 19	2 p.m.	77
July 19	5 p.m.	77
July 19	8 p.m.	77
July 19	11 p.m.	77
July 20	5 a.m.	75
July 20	8 a.m.	77
July 20	11 a.m.	77
July 20	2 p.m.	77
July 20	5 p.m.	77
July 20	8 p.m.	77
July 20	11 p.m.	77

The 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.



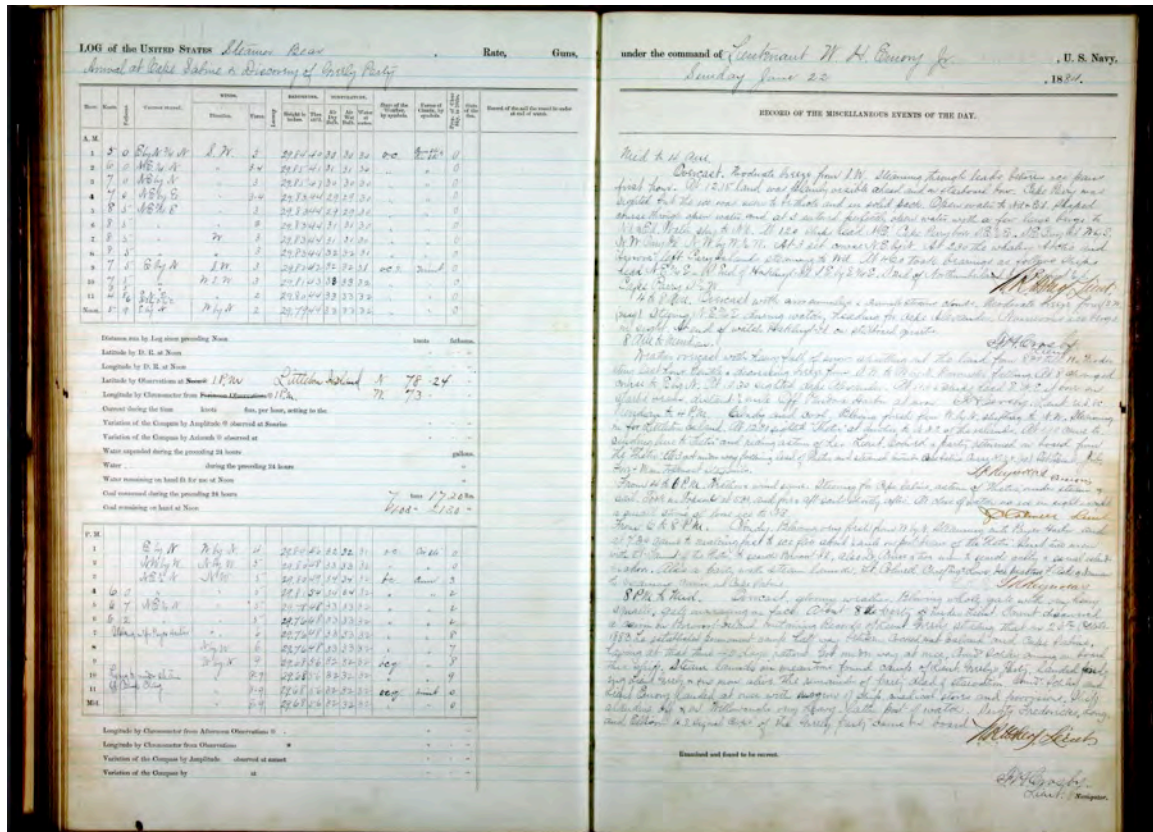
Historical Records

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.



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

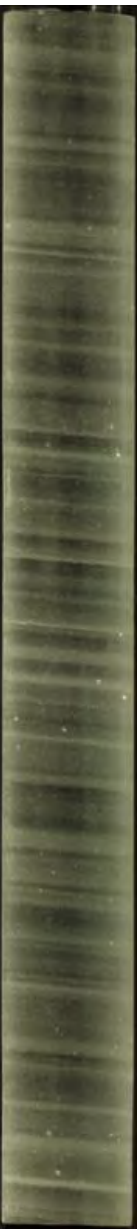
Varve sediments

Tree rings

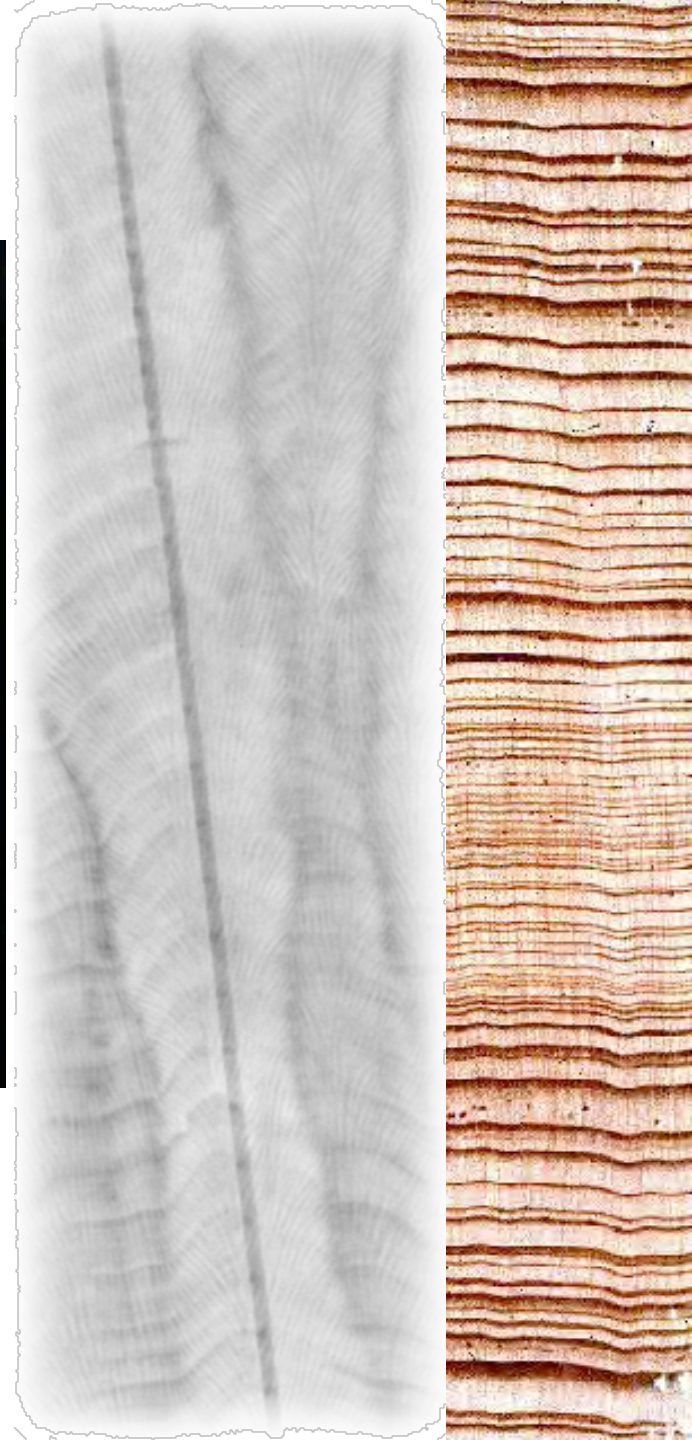
Corals

Count years

Absolute age if date
of collection is
known



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



Tree rings



03/15/2014



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.

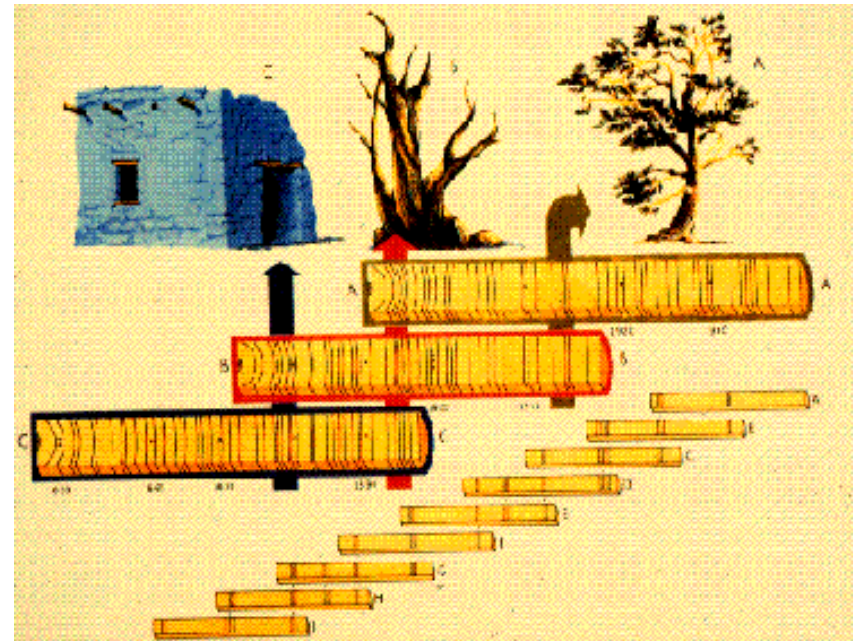


Source: NOAA

Dendrochronology

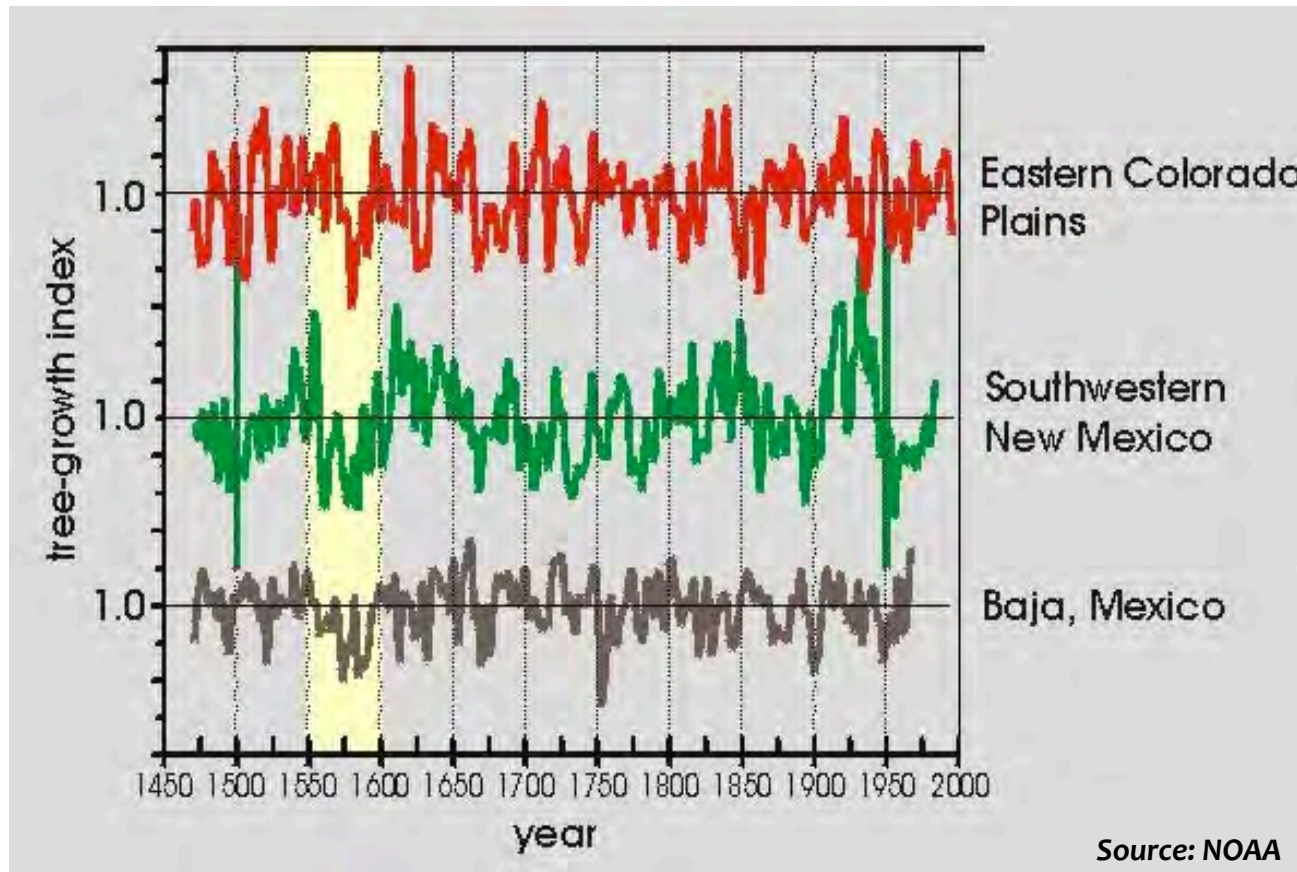


- * Master chronology
 - * Many trees from a region are cross-dated
 - * Locally absent years
 - * False rings
- * Quality Checked
 - * COFECHA



Tree Ring Record Example

A several decade long North American drought in the late 16th century is apparent from tree ring records.



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.

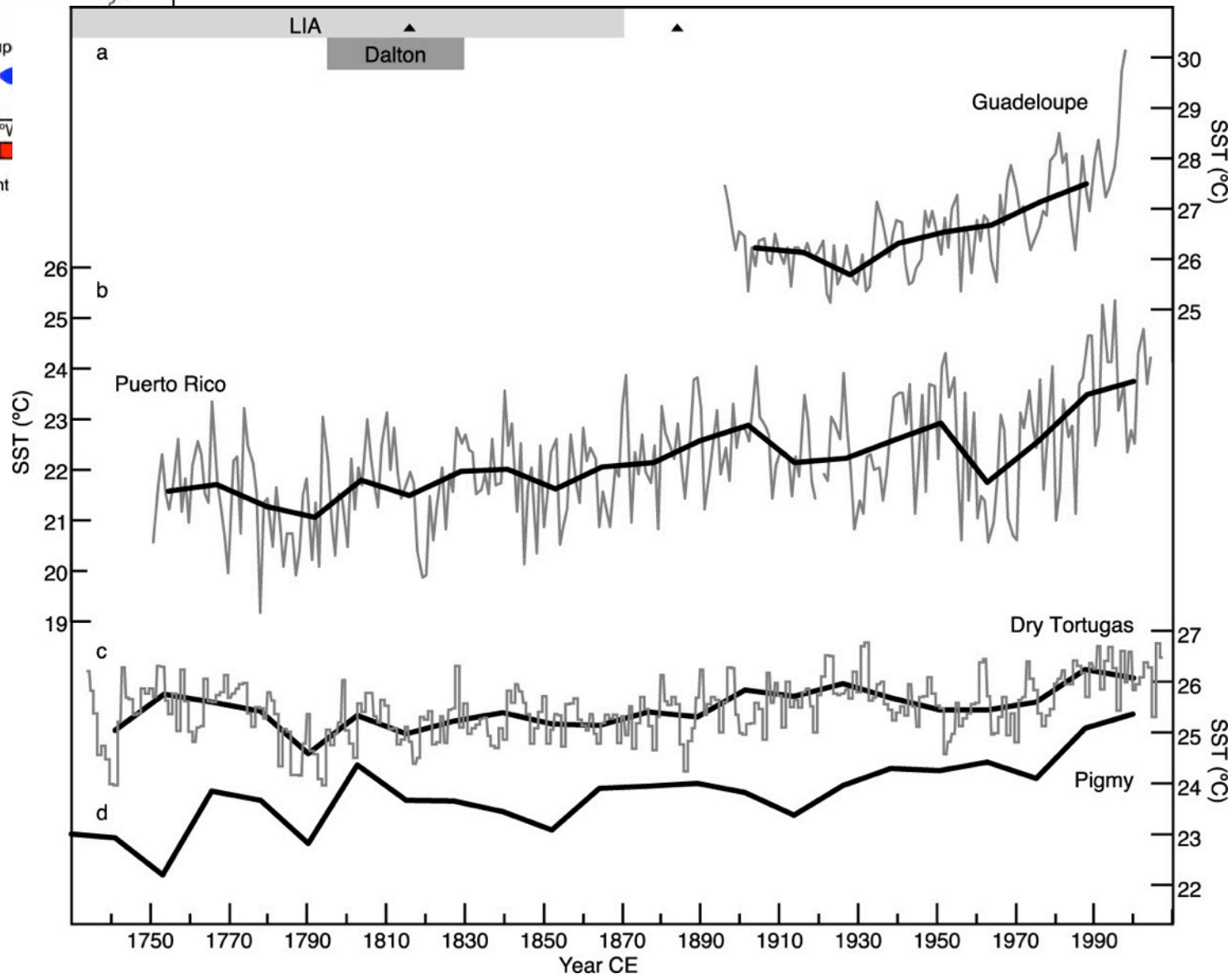
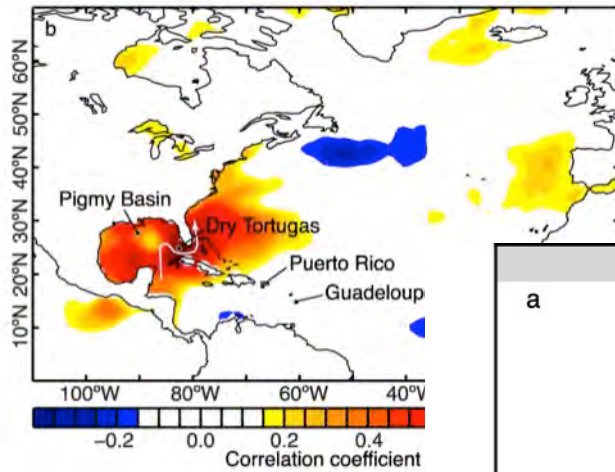
A long core of a coral skeleton can cover hundreds of years and exact dates can be determined based on counting the growth bands or U-Th dating.

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



USGS DeLong

Coral SST reconstruction



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 **400,000 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.

The ice can also be tested for its acidity level.

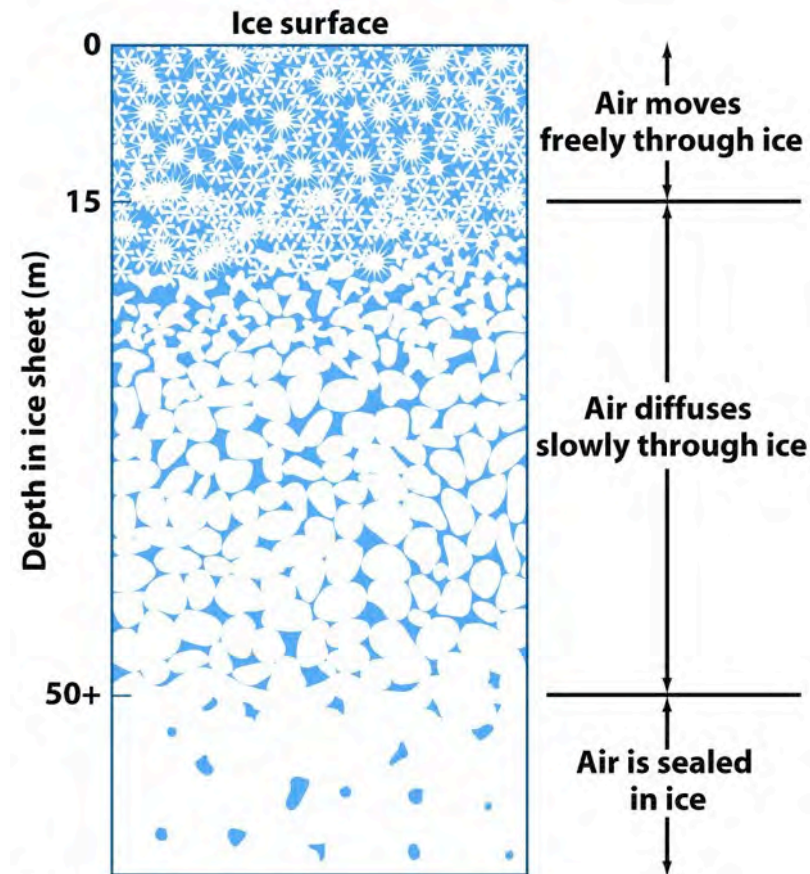
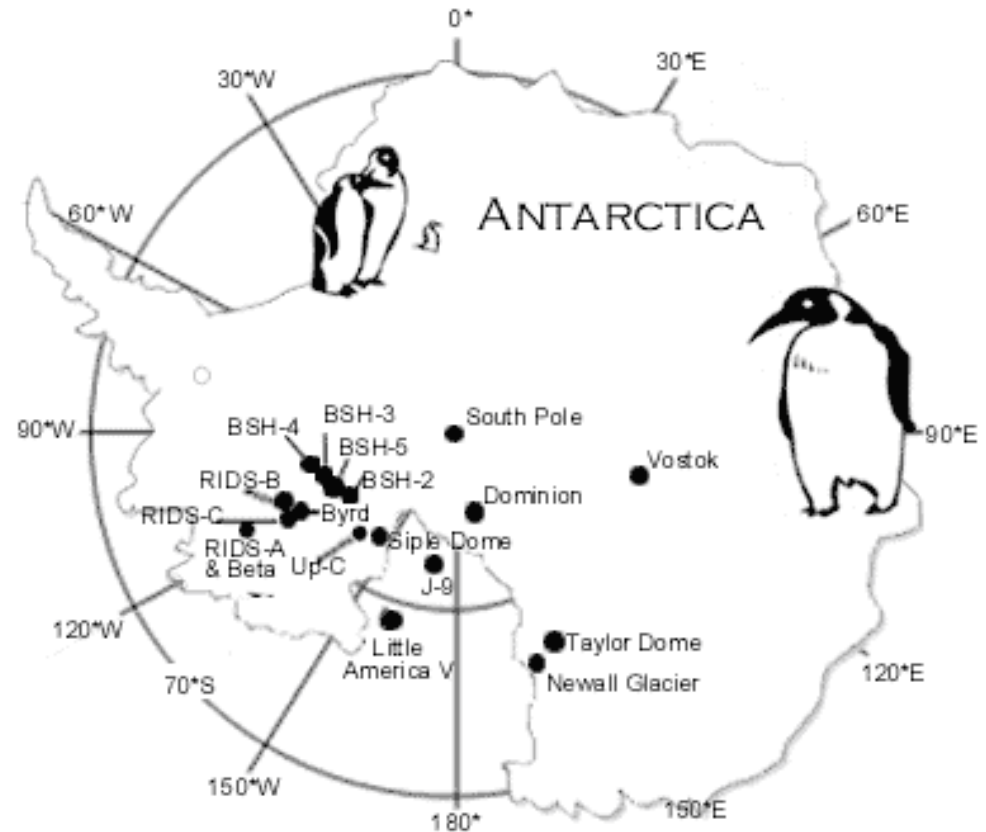
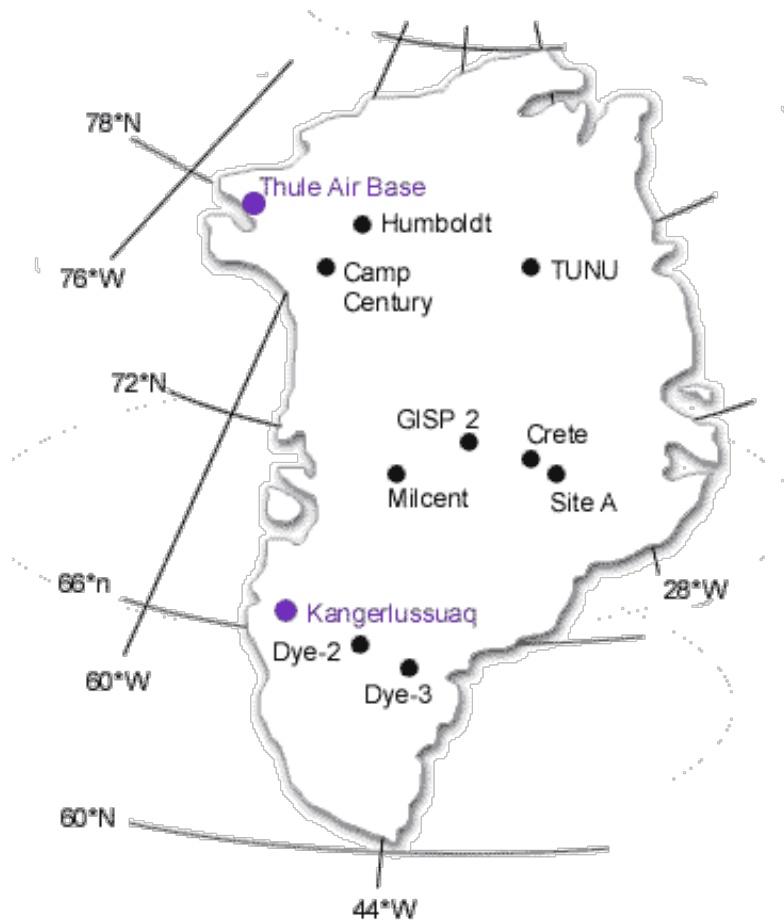


Figure 10-3
Earth's Climate: Past and Future, Second Edition
© 2008 W. H. Freeman and Company

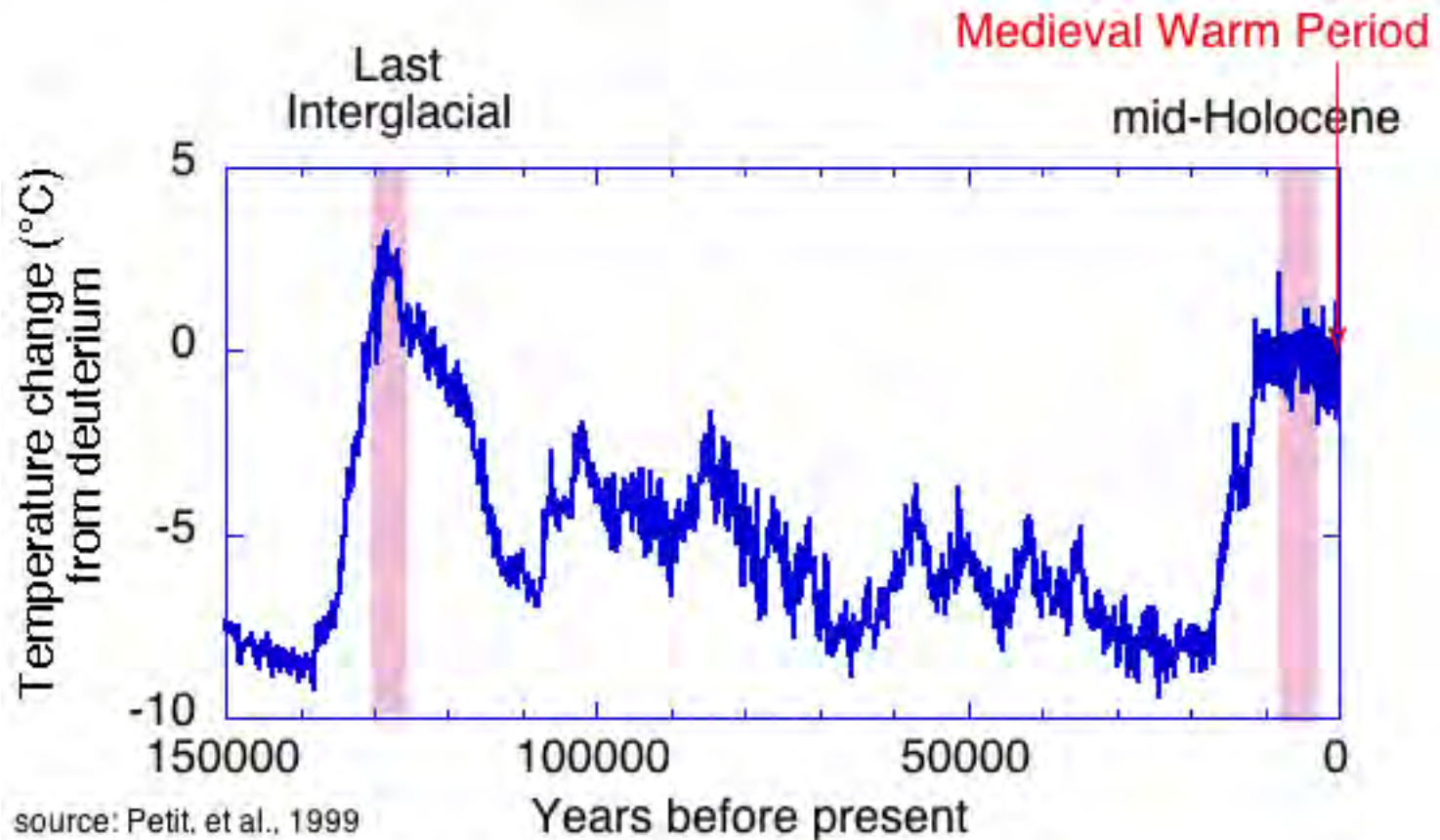
High Latitude Ice Records

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

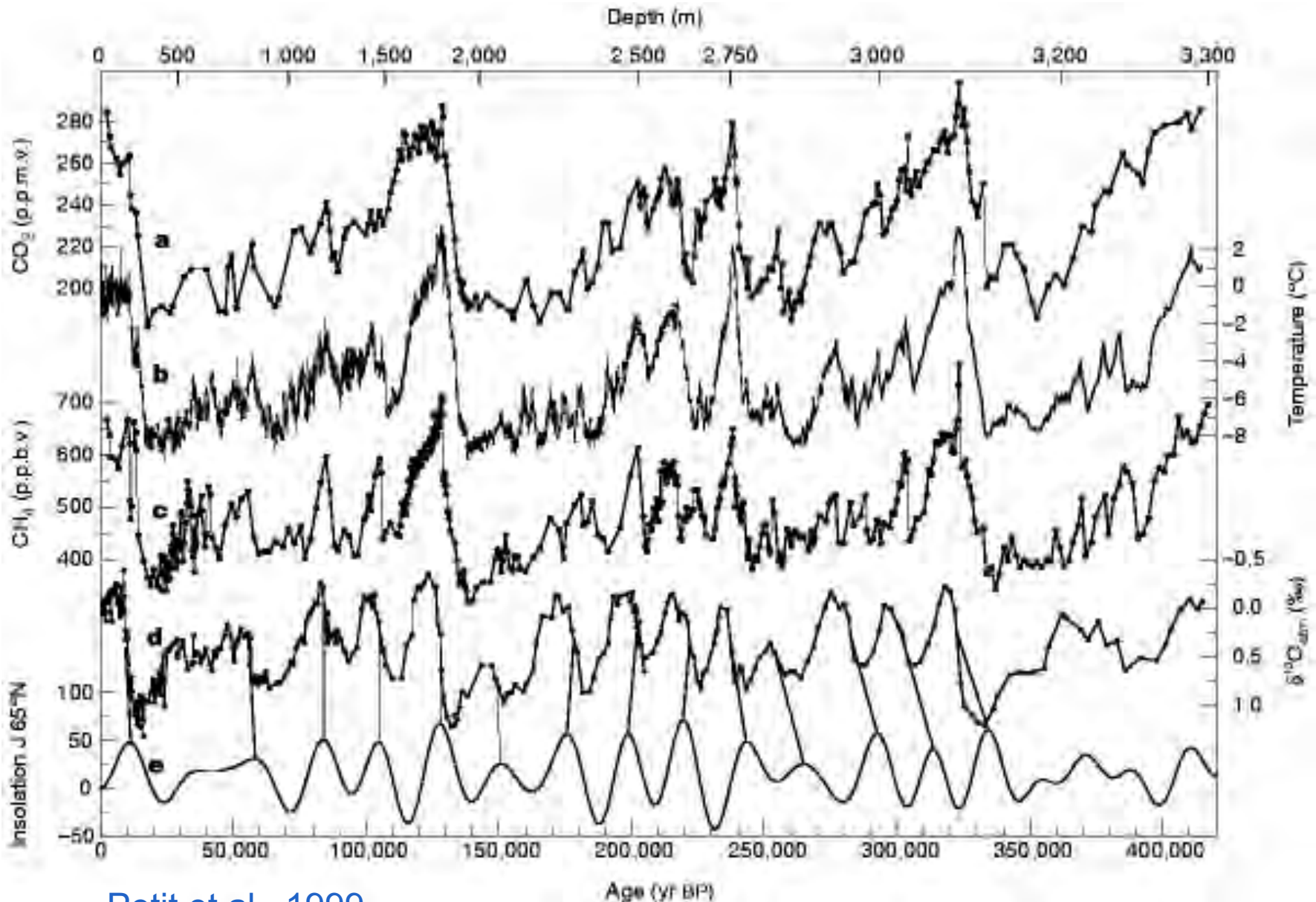


Ice Core Records

Temperature change for the past 150,000 years from an Antarctic ice core based on a hydrogen isotope proxy.



Vostok Antarctica Ice Core Record



Petit et al., 1999

Ocean Drilling



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

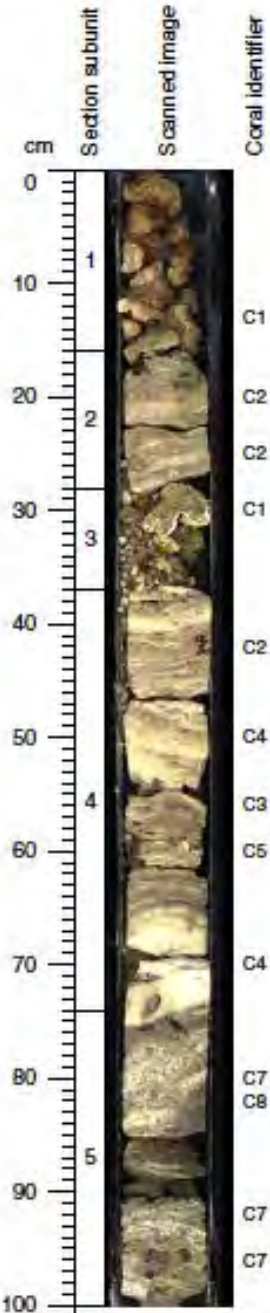


Figure 2-4c
Earth's Climate: Past and Future, Second Edition
© 2008 W.H. Freeman and Company

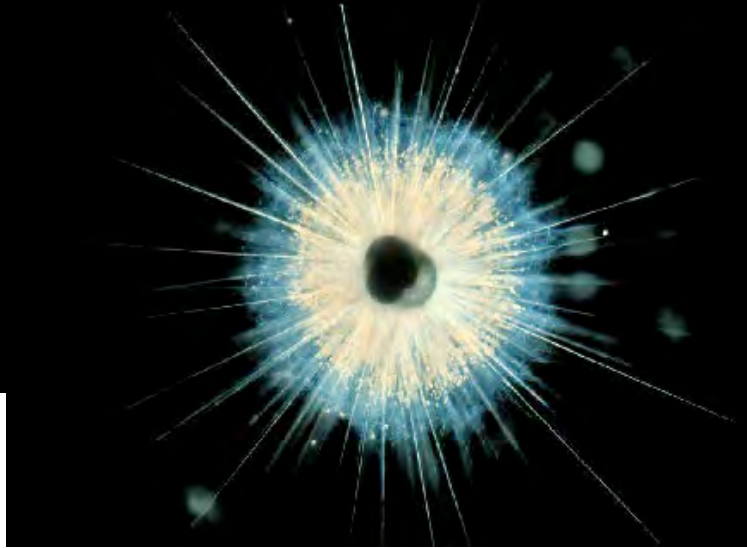
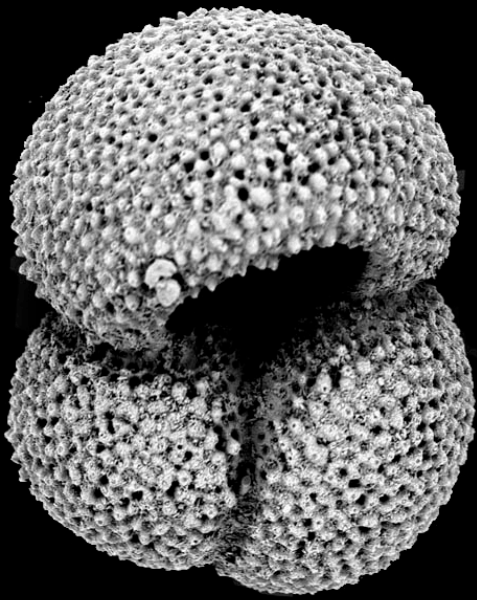


Figure 2-4d
Earth's Climate: Past and Future, Second Edition
© 2008 W.H. Freeman and Company

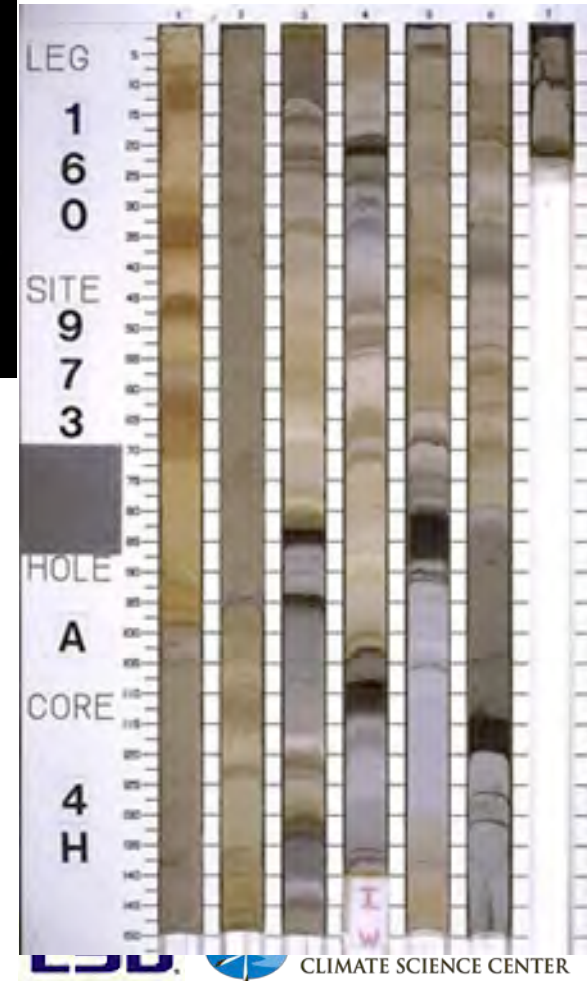
Core Photo



Marine Sediments



22



Sediments

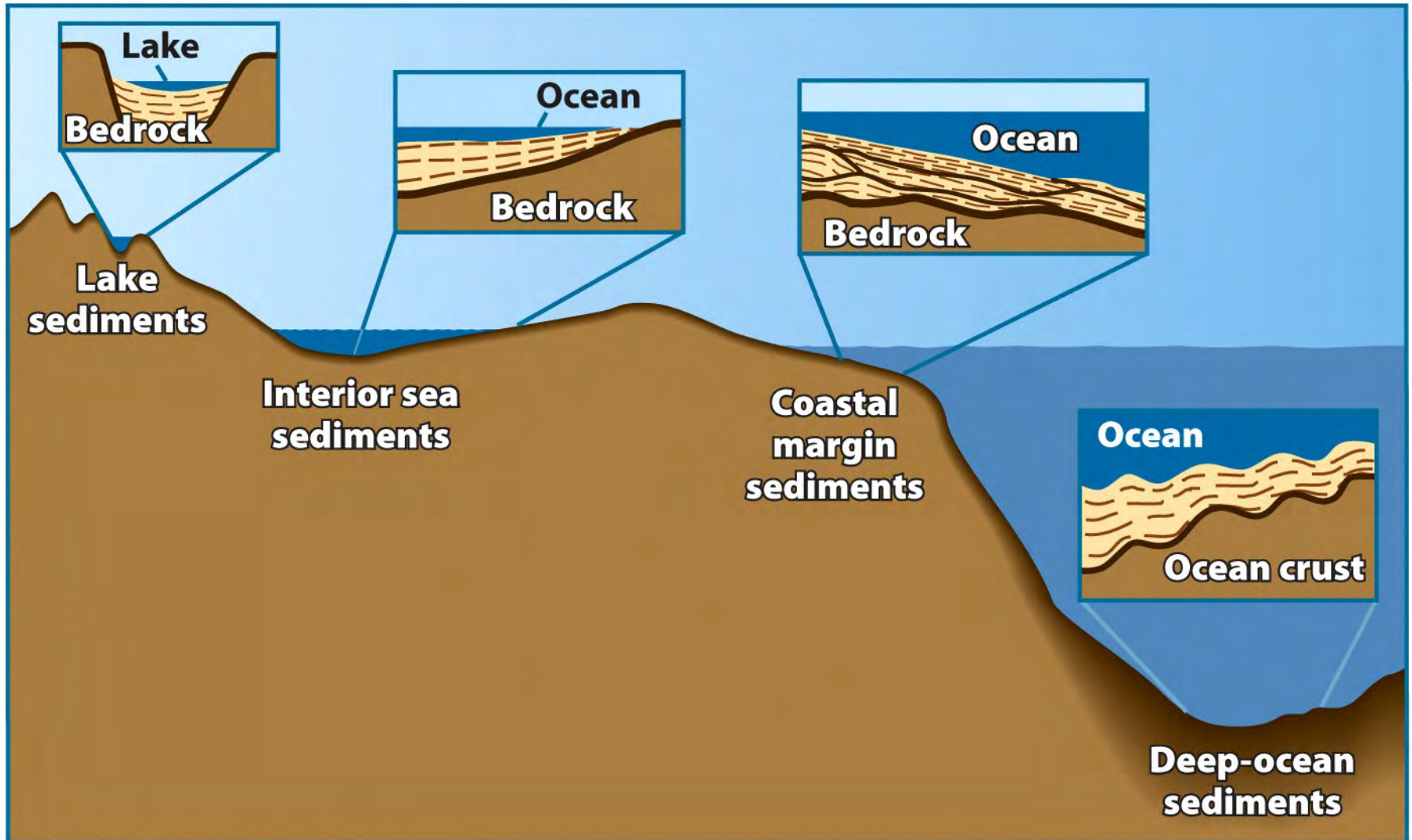


Figure 2-1
Earth's Climate: Past and Future, Second Edition
© 2008 W. H. Freeman and Company

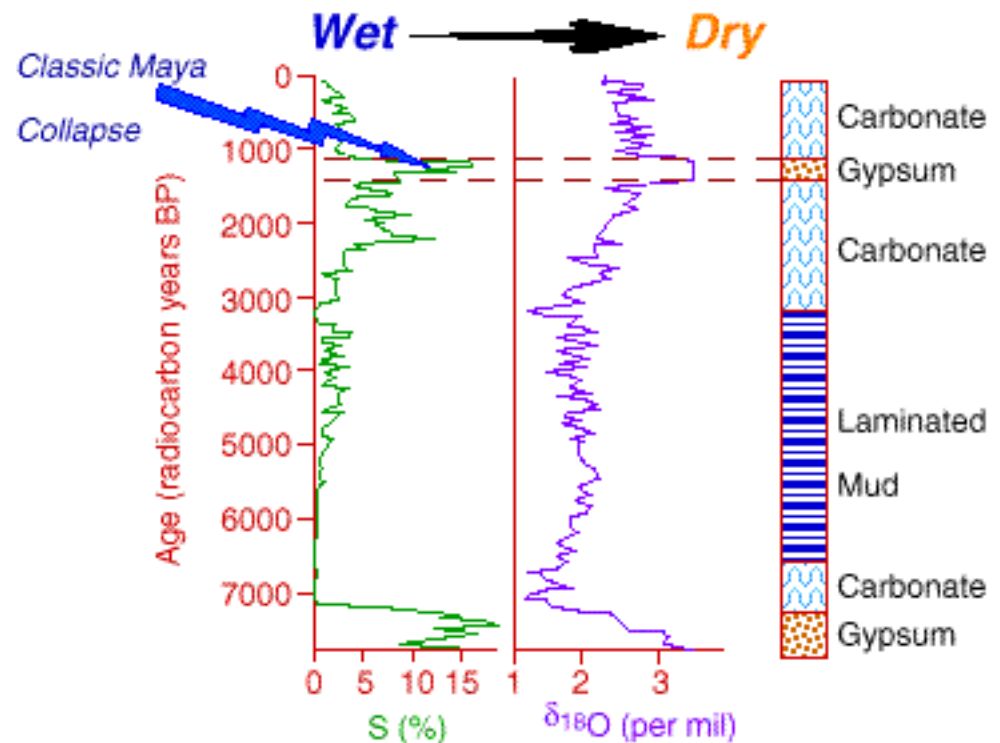
Sediment Record

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

Surprises in the climate system



(Hodell et al, 1995 *Nature*)

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.

