NSTA WEB SEMINARS

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NASA/UCAR/NESTA:
Clues to Climates of the Past

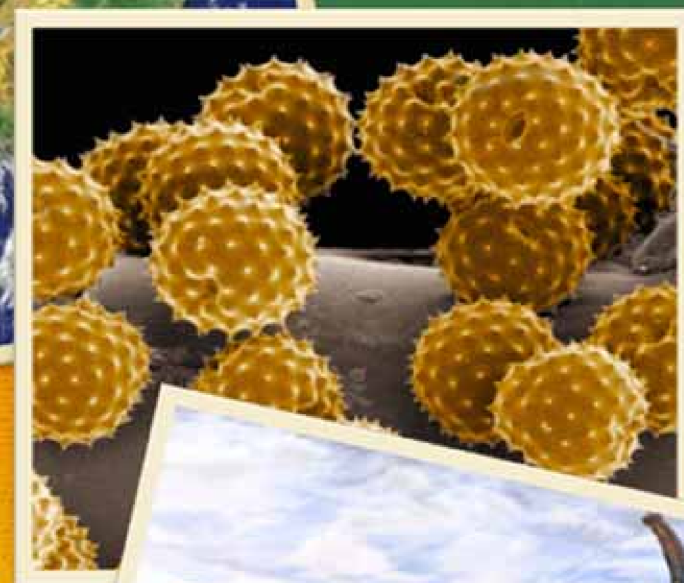
Presented by: Dr. Randy Russell

Tuesday, September 28, 2010

6:30 p.m. - 8:00 p.m. Eastern time

Clues to Climates of the Past

A web seminar for the NSTA community
By the UCAR Office of Education and Outreach
and NESTA with support from NASA.

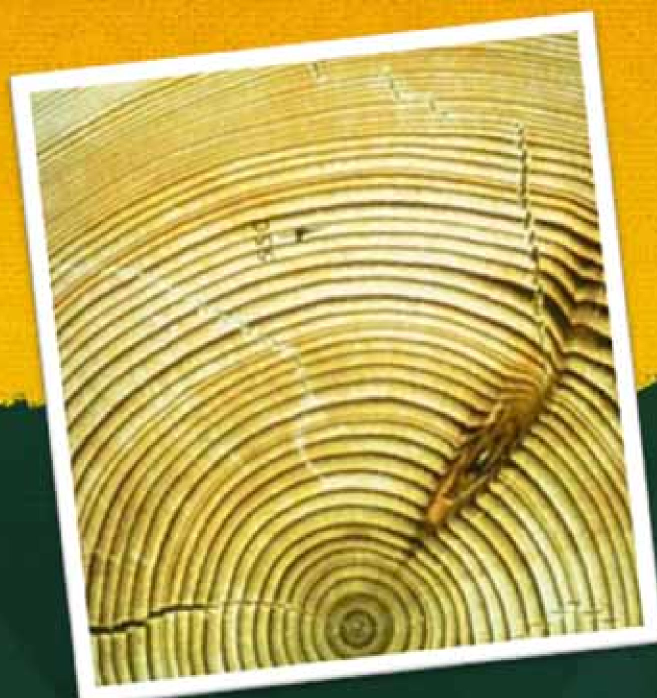


Overview

- How do we figure out past climate?
- Digging the dirt: climate records in rocks and sediments
  - *Paleoclimates and Pollen Activity*
- Tiny clues to massive change: Investigating climate on an atomic level

Presenter:
Dr. Randy Russell
Educational Designer
UCAR Office of Education and Outreach

How do we figure out past climate?



The Instrumental Record

Weather room, Image courtesy of NOAA

- People have been collecting weather records using quantitative instruments for about for about 140 years.
- Temperature, wind speed, precipitation

Instrumental Temperature Record

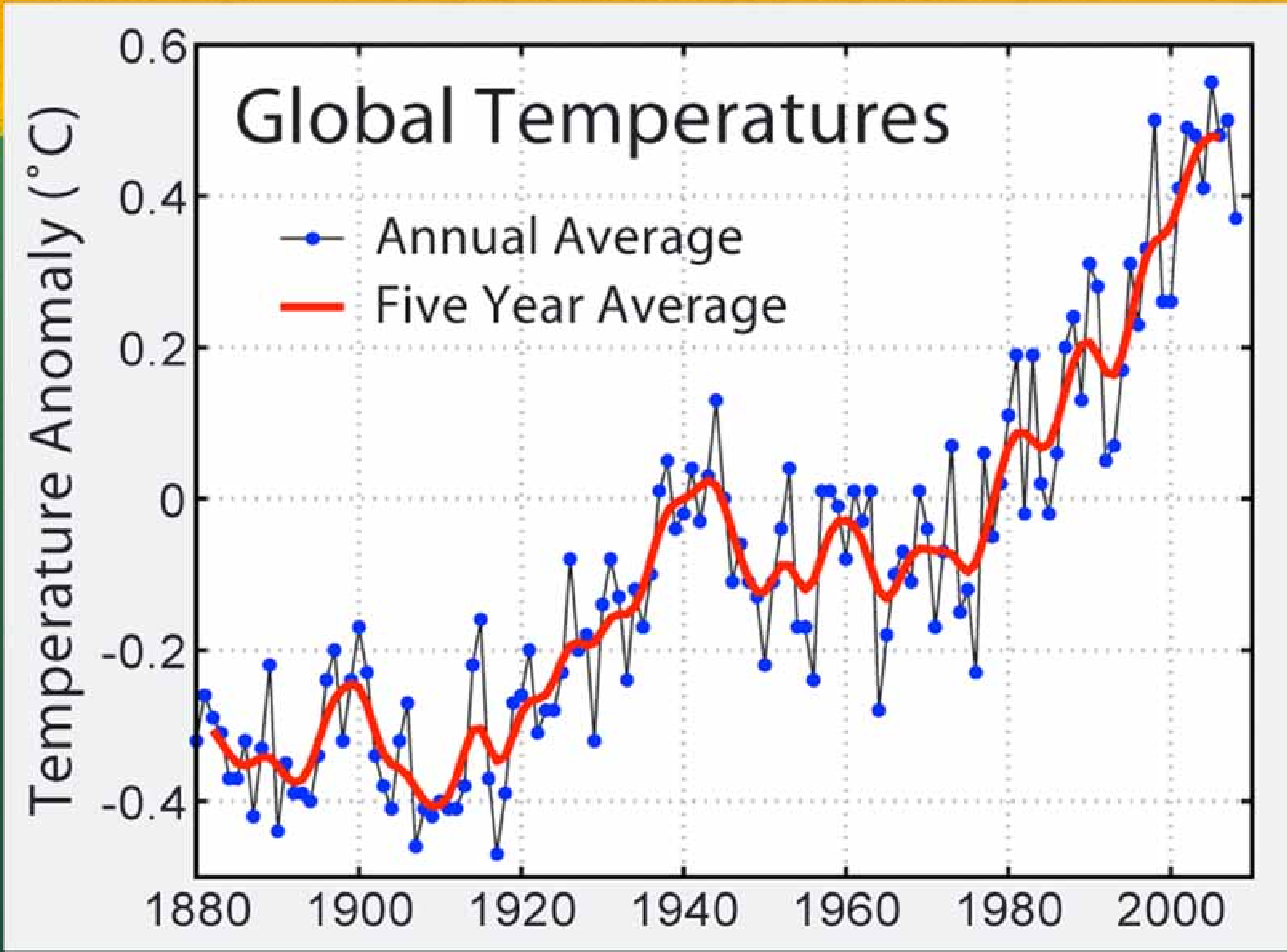


Image: Global Warming Art

Historical Records

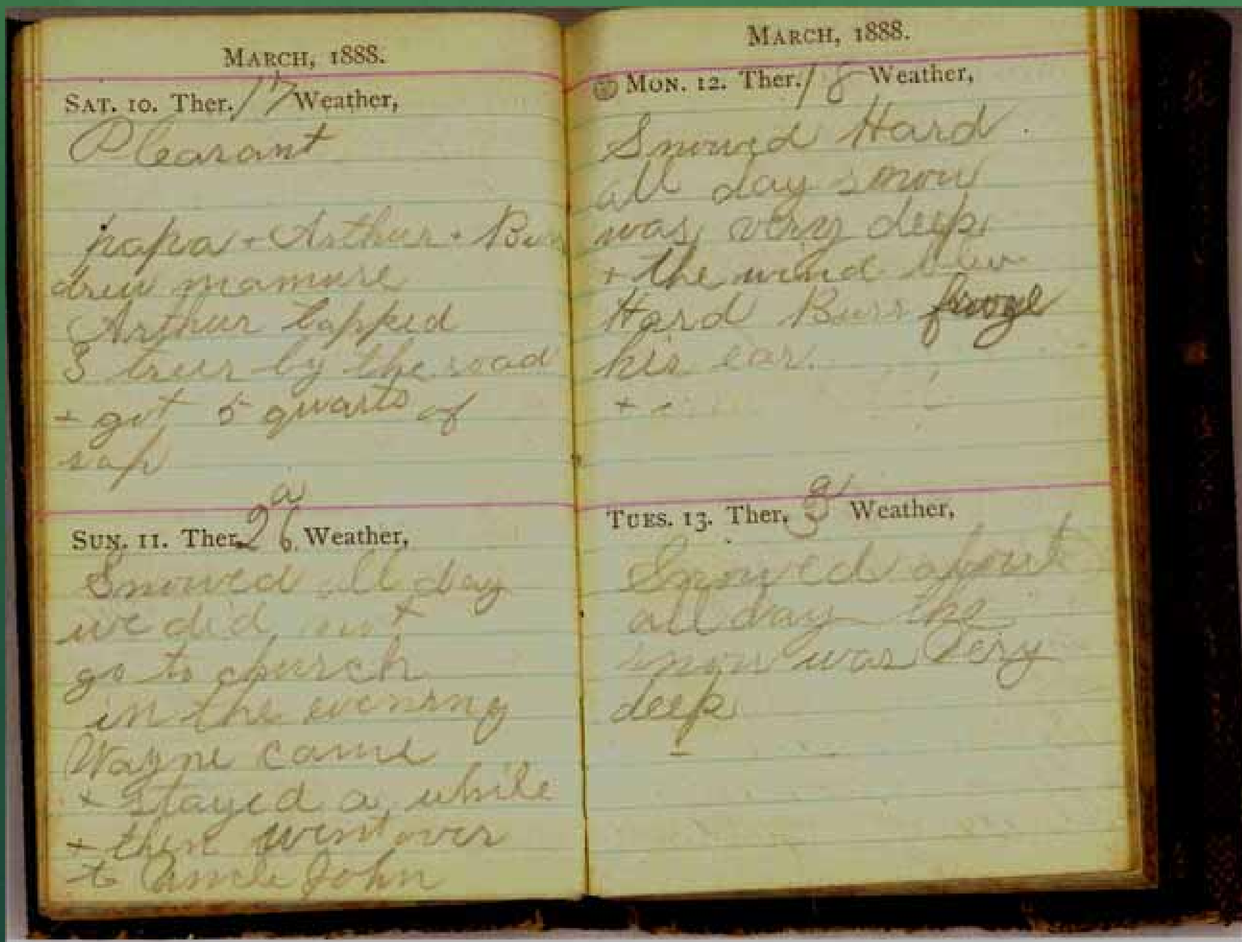


Image: NOAA climate database modernization project

- Records from journals and other documents that describe weather and unusual events like droughts, harsh winters, crop harvests, etc.

Proxy Records

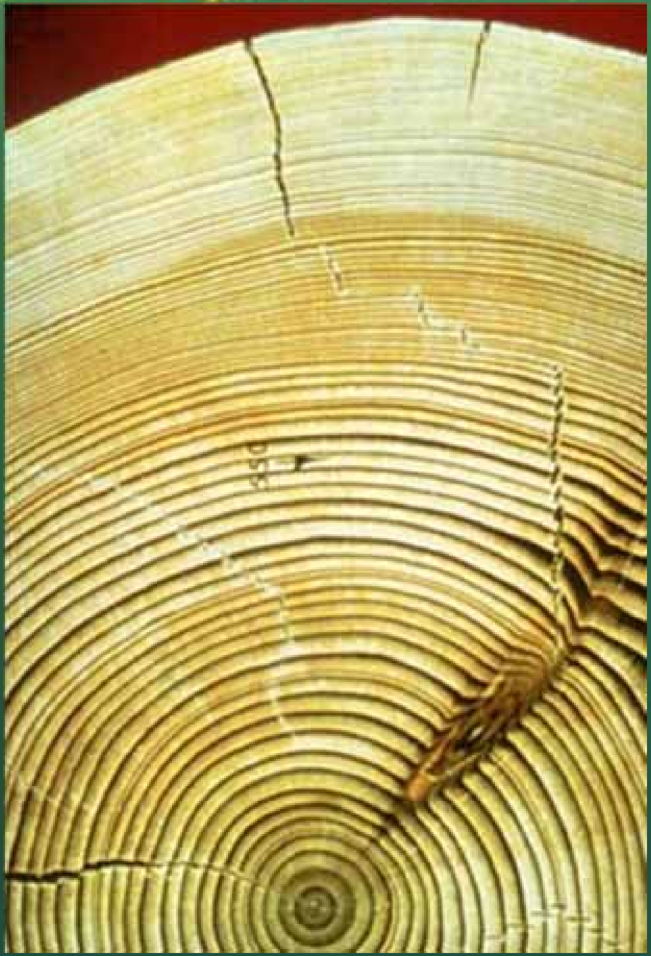


Image: UCAR

- Proxy records are indirect evidence of climate change.
- They help us understand what climate was like before the time of recorded human history.
- These include natural records of climatic conditions preserved in tree rings, ice cores, sediment and rock layers, corals, stalactites, and other places.

Modeling Past Climate

Dependent on billions of calculations, cutting-edge models require fast supercomputers like the one above at the NASA Ames Research Center.

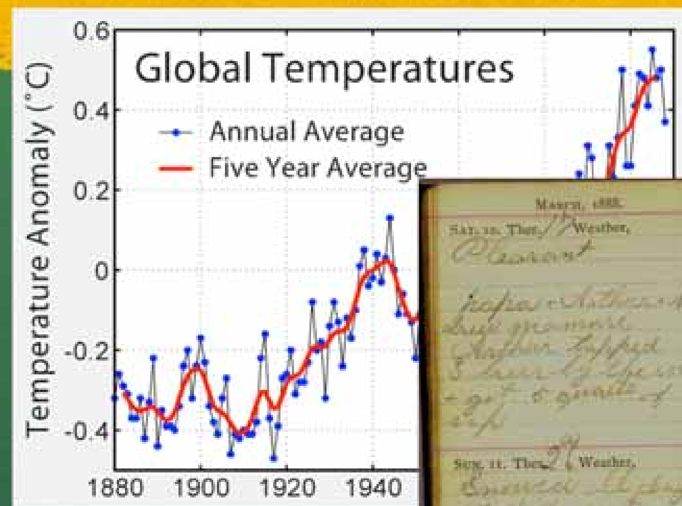
Image: NASA, Tom Trower

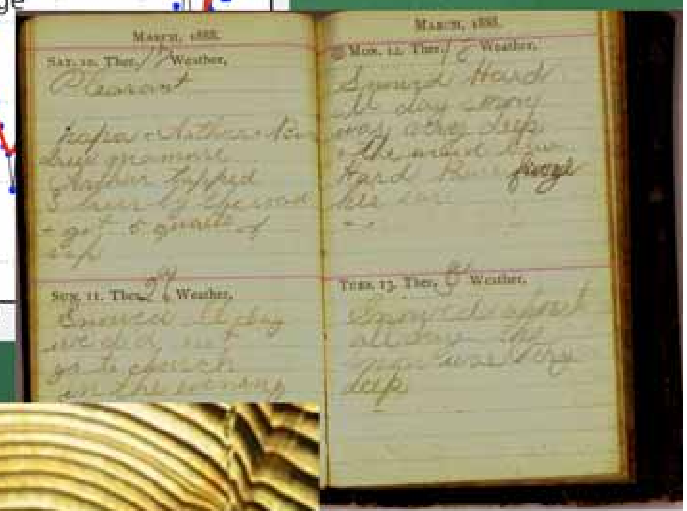
- Climate models, usually used to predict future climate, can be run backwards to estimate what climate was like in the past.
- To check a model of past climate, the model results are compared with proxy data from the same time period.

Review: Ways to Understand Past Climate

Four ways:

- Instrumental Record
- Historical Records
- Proxy Records
- Models





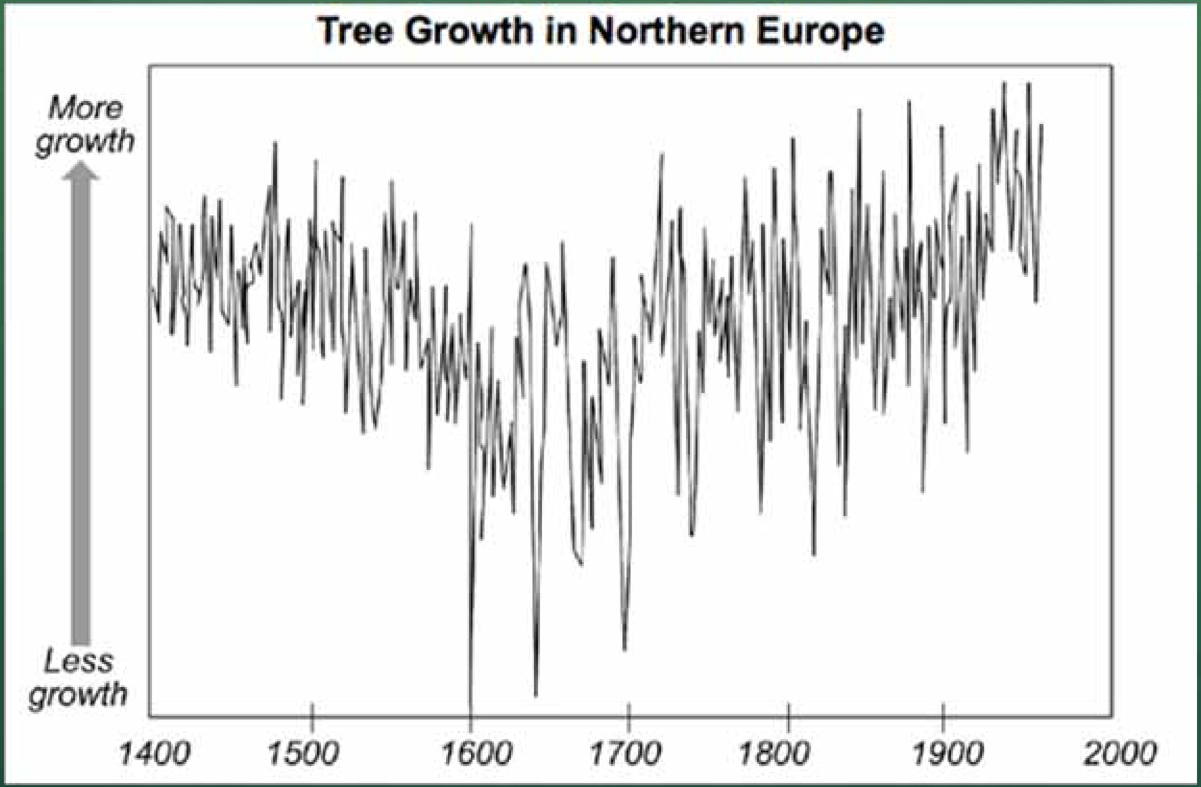
Painting can tell us about past climate.

Which way of understanding climate is this?

Peter Bruegel the Elder, 1565

A. Instrumental Data
B. Historical Data
C. Proxy Data
D. Model Results

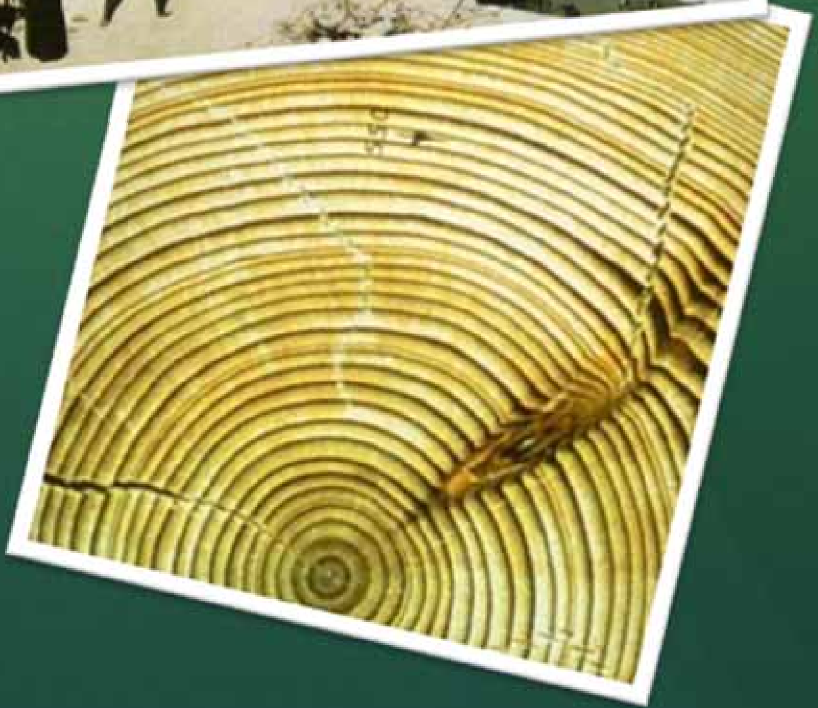
Tree rings tell us about past climate.
Which way of understanding climate is this?



UCAR, Climate Discovery Teacher's Guide

A. Instrumental Data
B. Historical Data
C. Proxy Data
D. Model Results

Questions?



Climate Records in Rocks and Sediments

With a classroom activity modeling proxy data

Three ways to interpret past climate using the the geologic record:

1. Investigate sedimentary rock outcrops and the fossils within them.

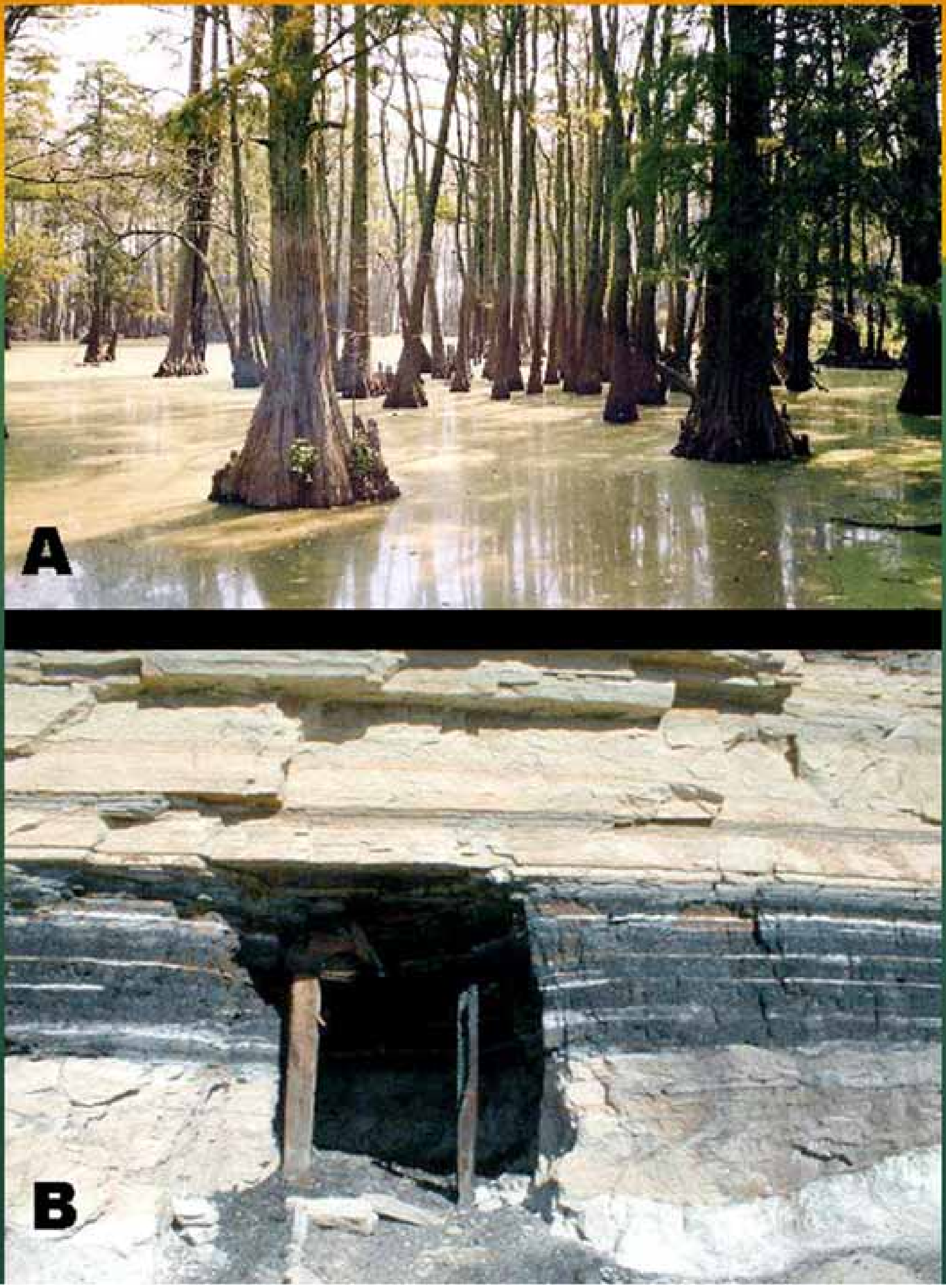
2. Investigate samples of rock from the ocean floor and the millions of tiny fossils within them.

3. Investigate samples of sediment from lake bottoms that contain pollen.

#1.
Investigating Sedimentary Rock Outcrops

Example: Sand dunes in arid climates (A) may eventually be preserved as sandstone rocks with characteristics laminations (B).

Windows to the Universe



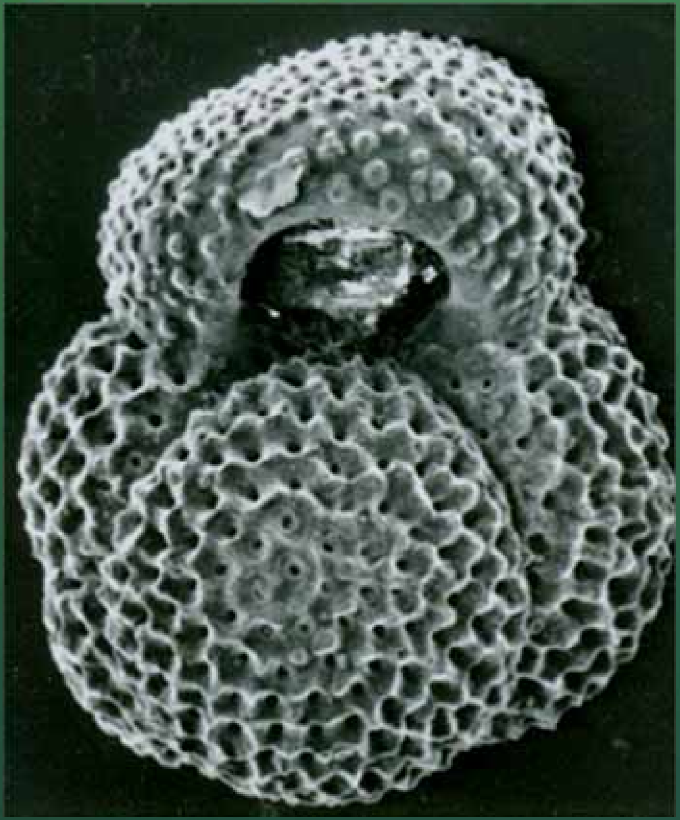
A swamp (A) can become a coal deposit (B) under certain conditions

#2
Investigating Rock from the Ocean Floor

Core samples of the ocean floor (below) are drilled with a rig mounted on the ship (left)

JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) Resolution Ship, run by the Integrated Ocean Drilling Program

What tells the story of past climate in the ocean floor?



A planktic foraminifera, one of several microfossils, used to reconstruct mid-Pliocene paleoclimate.
Image: USGS

Within an ocean core are millions of tiny fossils (microfossils).

Each year, microfossil skeletons and minerals build up layers. The layers eventually become rock.

Scientists infer temperature based on:

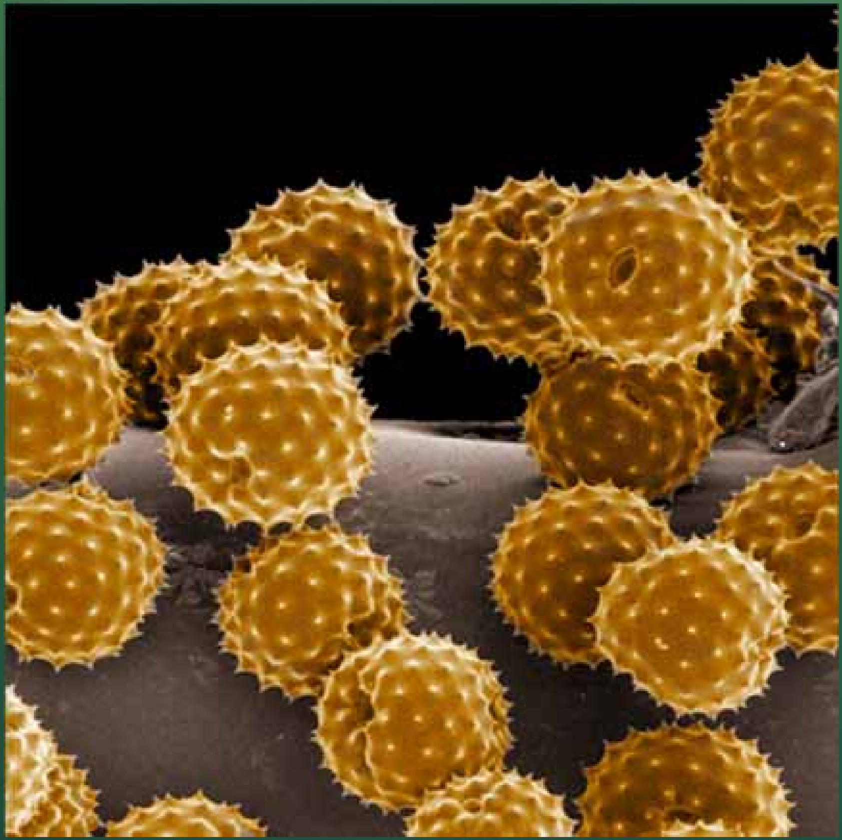
- Chemistry of the fossils *(Described in next section!)*
- Size of the fossil populations *(Generally, larger populations occur with a warm climate.)*

#3
Investigating Sediments from Lake Bottoms

- Sediment accumulates on the bottom of lakes over time forming layers. Most recent layer is at the top of the stack (at the bottom of the lake water.)

Photos:
Above – USGS
Right - Tom Kleindinst, Woods Hole Oceanographic Institution

Pollen records from lake sediment cores tell the climate story for the local area.



Oak Ridge Laboratory

- Plants are distributed across the land based on temperature and precipitation.
- Thus, plants living in an area change as climate changes.
- Knowing conditions that plants prefer, scientists make conclusions about past climate from ancient pollen.

Plants and Climate

Which picture is from a hot and dry climate?

A

B

C

Activity: Paleoclimates and Pollen

Students analyze a model of pollen in sediment samples to determine the type of vegetation and the likely past climate.

Materials for each small group:

- Sample "sediment" layers
- Pie pan or paper plate
- Student handout & "pollen" key

http://www.windows2universe.org/teacher_resources/teach_pollen.html

Students get a key to the "pollen" used in the model.

Pollen Key

Code	Color and Shape	Plant Species	Climatic Charactoristics
A		Western Hemlock	Principal dominant tree of many lowland, temperate sites. Requires very moist, temperate conditions for growth.
B		Douglas Fir	Prefers moderately cool to warm sites. Grows best under temperate, somewhat moist conditions.
C		grasses and sedges	These grasses and sedges are typically found in very cool alpine/subalpine meadow sites characterized by very cool summers, harsh winters, and short growing seasons.
D		Alder	Widespread throughout the Paci c Northwest, prefers abundant water and can grow in cool climates.
E		Grand Fir	Grows in cool climates, but not as cold tolerant as trees found at higher altitudes.
F		Engelmann Spruce	Found in cold, usually sub-alpine sites.
G		Western Cedar	Found only in temperate, very moist climates.
H		Lodgepole Pine	Found in areas of very cool climates typically growing on poor soils, often at high altitudes (above 3,500 feet) under the present climate.
I		mixed meadow species	This pollen is from a mixture of plants common to warm meadowlands. Typically, these species grow in areas of warm summer temperatures and summer drought.
J		Oak	Found in warm - temperate sites characterized by dry, warm summers.
K		Alpine Sagebrush	Woody, low-growing shrub that's found only at high-altitude, cold sites.

Students identify the "pollen" in five sediment layers.

Data Table

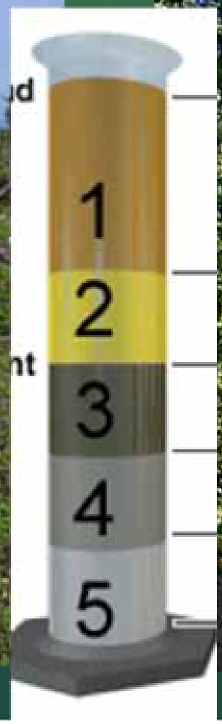
	Sediment Layer				
Plant species	**1**	**2**	**3**	**4**	**5**
Western Hemlock					
Douglas Fir					
grasses and sedges					
Alder					
Grand Fir					
Engelmann Spruce					
Western Cedar					
Lodgepole Pine					
mixed meadow species					
Oak					
Alpine Sagebrush					

Students describe how the environment has changed over time.

Layer #5: 20,000 to 15,000 years ago
The landscape resembled tundra, with alpine grasses and sedges, low shrubs, and a few cold-tolerant trees.

Layer #1: 4,500 years ago to present
The land is covered with extensive coniferous forests, full of hemlock and western red cedar.

Maine Department of Conservation



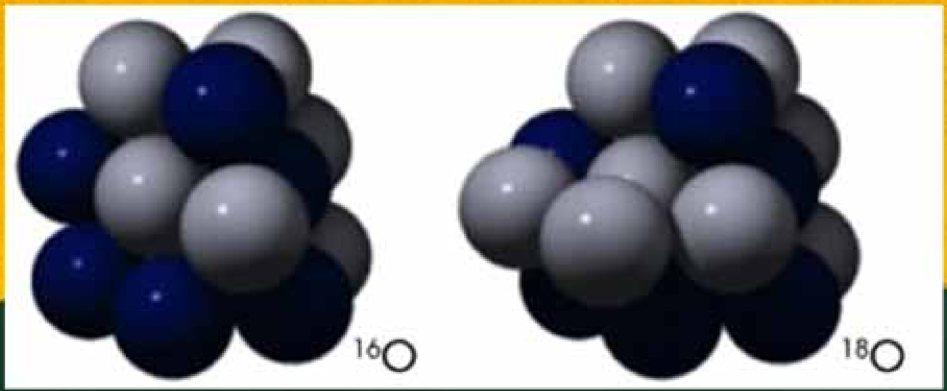
Washington State Parks

Questions?

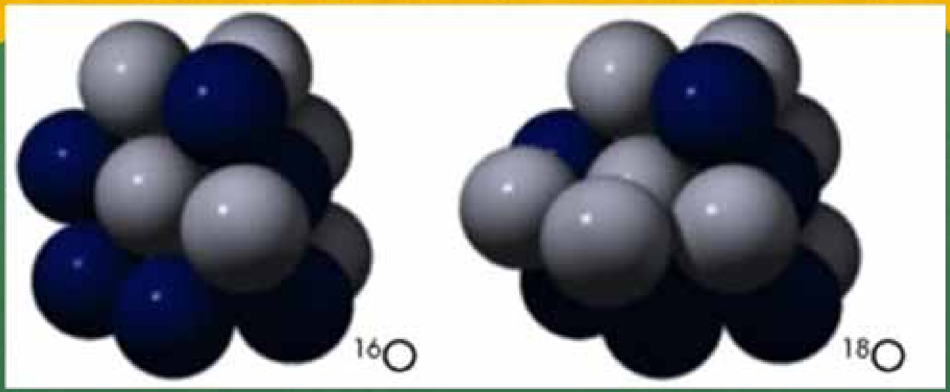

Battle Ground Lake, Washington
Model sediment column
Present
1
2
3
4
5
4,500 years ago
9,500 years ago
11,200 years ago
15,000 years ago
20,000 years ago

Tiny clues to massive change

Investigating climate on an atomic level



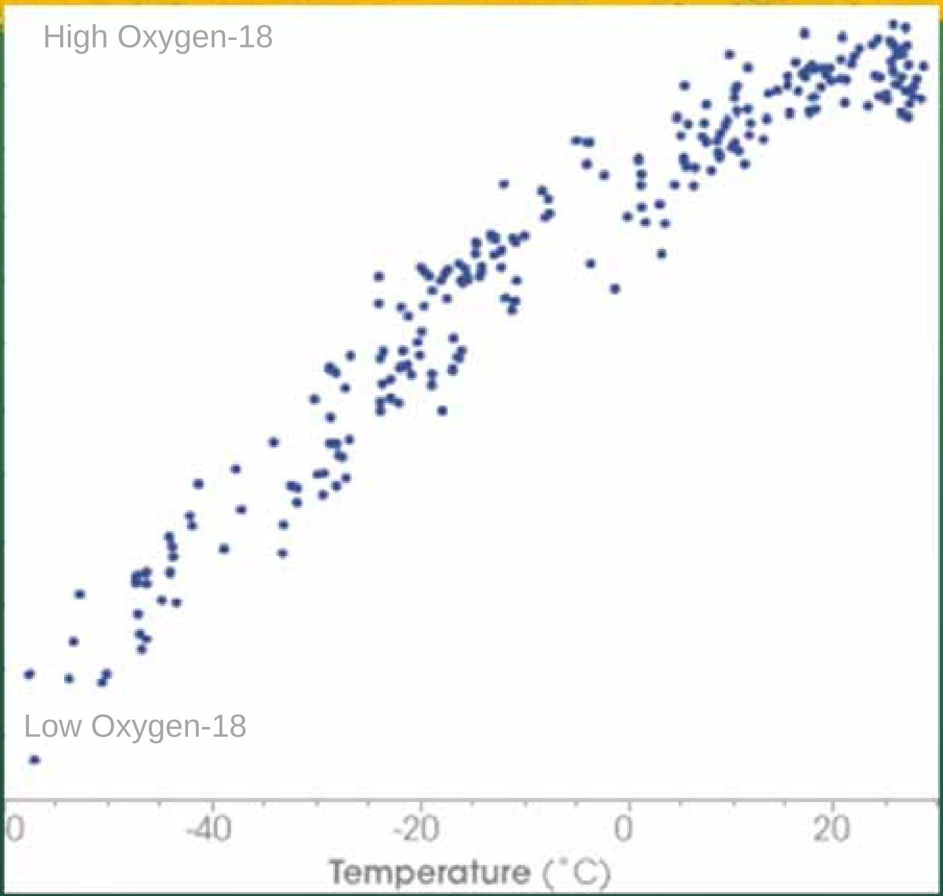
A Tale of Two Oxygen Isotopes…



Light Oxygen	Heavy Oxygen
Oxygen-16	Oxygen-18
8 neutrons, 8 protons	10 neutrons, 8 protons
Lower mass	Greater mass
Very common (over 99% of oxygen)	Less common

… their different mass means they are not evenly distributed in the atmosphere and hydrosphere.

Processes of the water cycle are affected by these oxygen isotopes



As temperature goes up, so does the amount of ^{18}O in precipitation.
NASA graph adapted from Jouzel *et. al.*, 1994

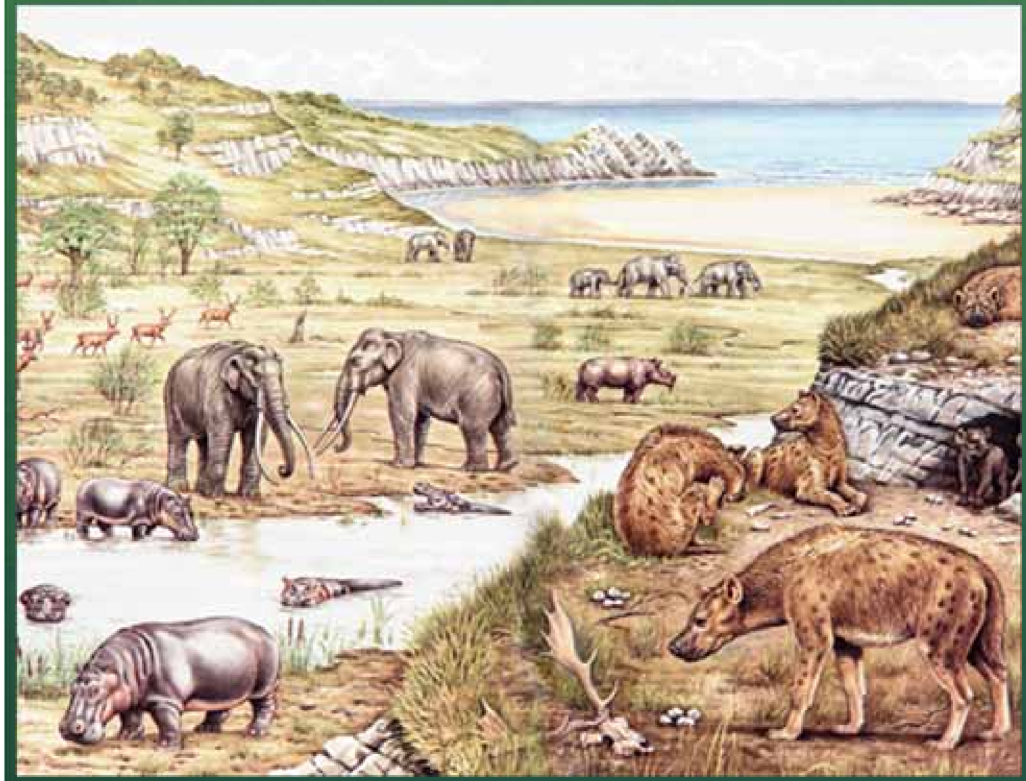
- Evaporation: water molecules with light oxygen evaporate more easily.
- Condensation: water vapor molecules with heavy oxygen condense more easily.
- The concentration of ^{18}O in precipitation decreases with temperature.

During cold, glacial times…

- Cooler temperatures mean less heavy oxygen is evaporated from the oceans, so…
  - Rainwater has lower proportion of heavy oxygen
  - Polar ice has a lower proportion of heavy oxygen
  - Ocean water has higher proportion of heavy oxygen

Field Museum, Chicago

During warm, interglacial times…



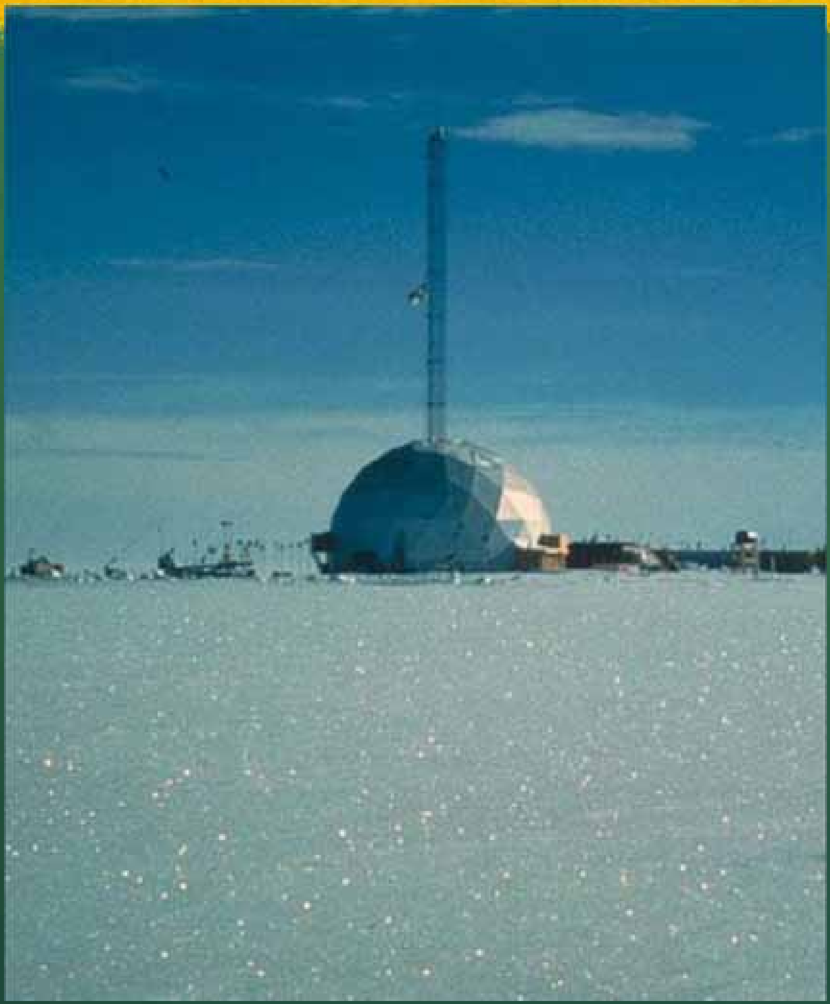
- Warmer temperatures mean more heavy oxygen is evaporated from the oceans.
  - Rainwater has a higher proportion of heavy oxygen
  - Polar ice has a higher proportion of heavy oxygen
  - Ocean water has lower proportion of heavy oxygen

Trent Valley Paleolithic Project, 2006

Differences in Oxygen Isotope Concentrations Reveal Past Climates

- The ratio of these two types of oxygen in water changes with the climate.
- To understand paleoclimate, scientists examine the ratio of heavy and light oxygen in many ways including looking at:
  - Ice sheets
  - Corals and fossils
  - The limestone in cave deposits

Oxygen isotopes measured from ice cores

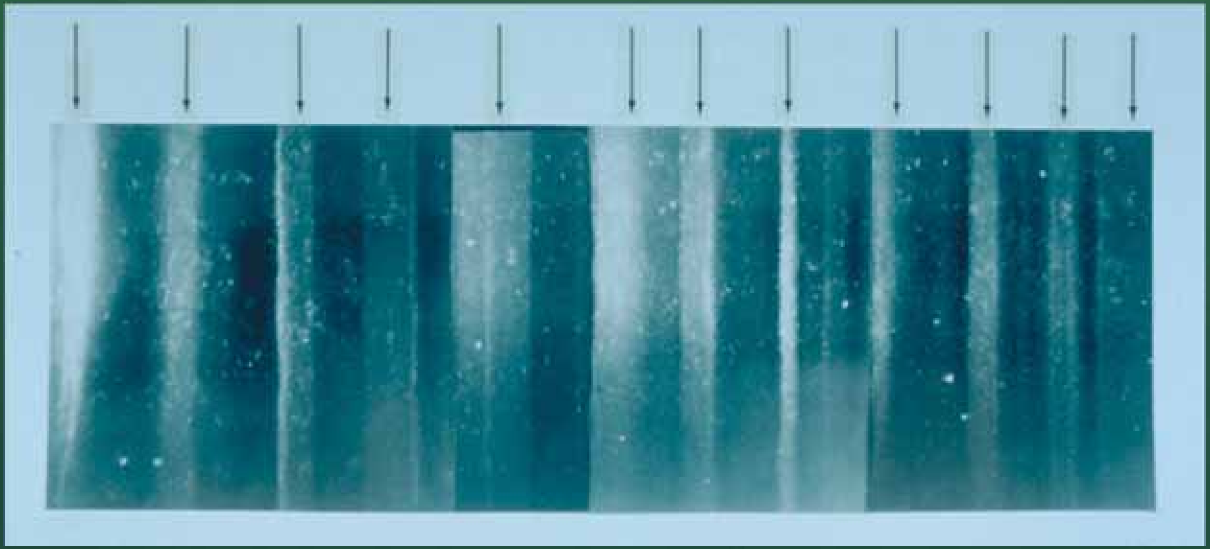


GISP2 drill site, Greenland

Photo Credits:Michael Morrison , GISP2 SMO, University of New Hampshire

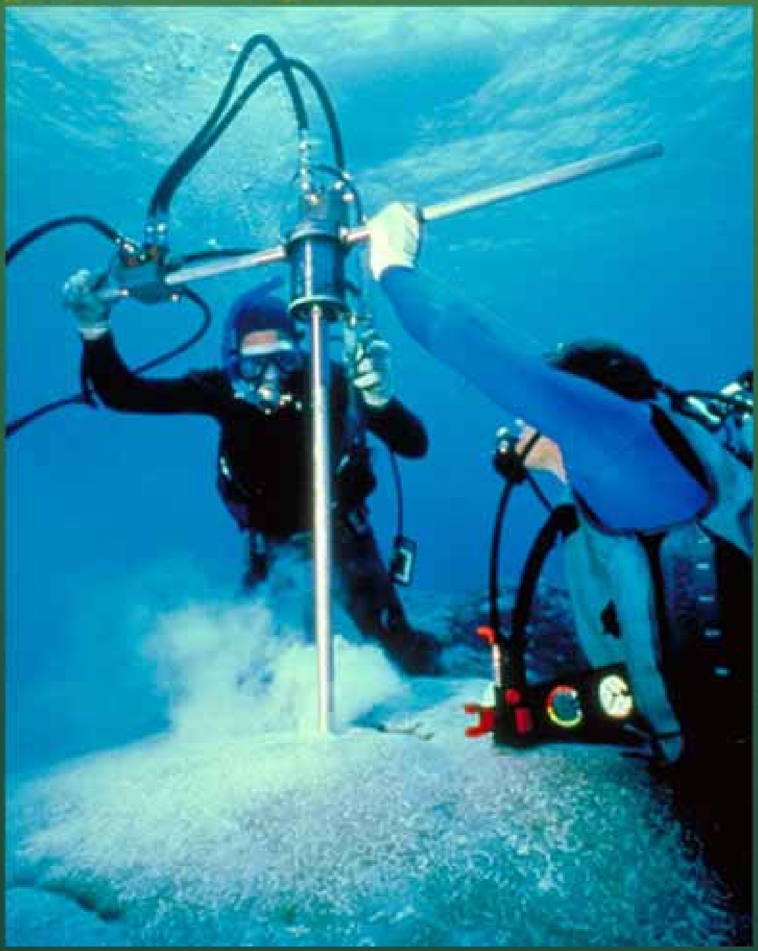
- Ice sheets contain a record of hundreds of thousands of years of past climate, trapped in the ancient snow.
- Scientists recover this climate history by drilling cores in the ice, some of them over 3,500 meters (11,000 feet) deep.

Ice core being extruded from the drill.
(Photo by Lonnie Thompson, The Ohio State University)



19 cm of an ice core showing annual layers illuminated from below by a fiber optic source. There are 11 years in this sample. Arrows indicate summers.
(NOAA)

Oxygen isotopes measured from corals

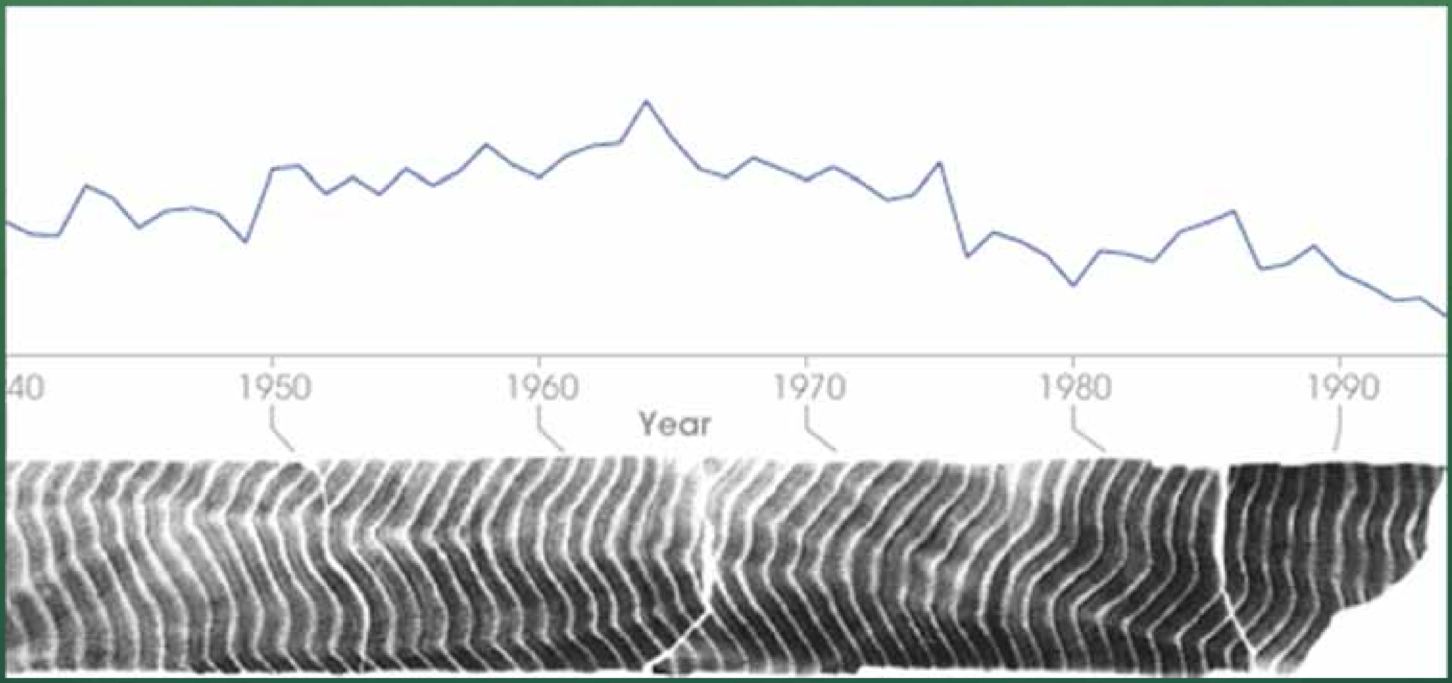


Extracting core with hydraulic drill on coral colony

(Credits:Maris Kazmers SharkSong Photography, Okemos, Michigan)

- The ratio of heavy oxygen (^{18}O) to light oxygen (^{16}O) in a coral skeleton is determined by sea surface temperature at the time when it formed.
- Corals with annual growth rings combine an oxygen-isotope record with precise dating.

Oxygen Isotopes from Coral Layers



- This x-ray of a coral core shows the change in ^{18}O concentration corresponding to the coral's growth.

NASA figure by Robert Simmon, based on data provided by Cole et. al. 2000, archived at the World Data Center for Paleoclimatology

Oxygen isotopes (and others) measured from speleothems

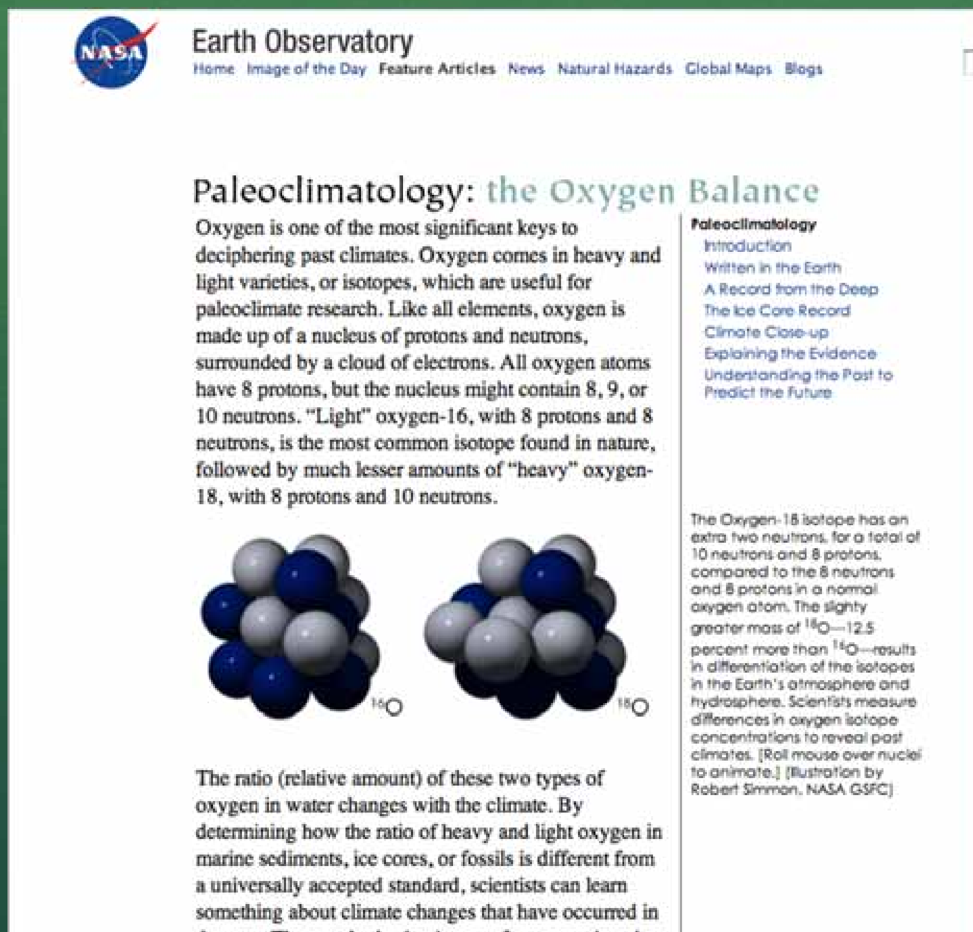
Speleothem from Niedzwiedzia cave in the Sudeti Mountains, Poland
Courtesy of Dr. James Baldini

- Speleothems are cave deposits, limestone deposited from rain water and ground water that gets into the cave.
- Researchers look at isotopes of many elements, including O, Ca, Mg, Sr, Ba, and P.

Learn more!

NASA Earth Observatory

Paleoclimatology: The Oxygen Balance



Earth Observatory

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Paleoclimatology: the Oxygen Balance

Oxygen is one of the most significant keys to deciphering past climates. Oxygen comes in heavy and light varieties, or isotopes, which are useful for paleoclimate research. Like all elements, oxygen is made up of a nucleus of protons and neutrons, surrounded by a cloud of electrons. All oxygen atoms have 8 protons, but the nucleus might contain 8, 9, or 10 neutrons. "Light" oxygen-16, with 8 protons and 8 neutrons, is the most common isotope found in nature, followed by much lesser amounts of "heavy" oxygen-18, with 8 protons and 10 neutrons.

^{16}O ^{18}O

The ratio (relative amount) of these two types of oxygen in water changes with the climate. By determining how the ratio of heavy and light oxygen in marine sediments, ice cores, or fossils is different from a universally accepted standard, scientists can learn something about climate changes that have occurred in

Paleoclimatology
Introduction
Written in the Earth
A Record from the Deep
The Ice Core Record
Climate Close-up
Explaining the Evidence
Understanding the Past to Predict the Future

The Oxygen-18 isotope has an extra two neutrons, for a total of 10 neutrons and 8 protons, compared to the 8 neutrons and 8 protons in a normal oxygen atom. The slighty greater mass of ^{18}O—12.5 percent more than ^{16}O—results in differentiation of the isotopes in the Earth's atmosphere and hydrosphere. Scientists measure differences in oxygen isotope concentrations to reveal past climates. [Roll mouse over nuclei to animate.] (Illustration by Robert Simmon, NASA GSFC)

http://earthobservatory.nasa.gov/Features/Paleoclimatology_OxygenBalance/

Questions?

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Paleoclimatology: Introduction

by Holli Riebeek · design by Robert Simmon · June 28, 2005

"The perched bowlders which are found in the Alpine valleys... occupy at times positions so extraordinary that they excite in a high degree the curiosity of those who see them. For instance, when one sees an angular stone perched upon the top of an isolated pyramid, or resting in some way in a very steep locality, the first inquiry of the mind is, When and how have these stones been placed in such positions, where the least shock would seem to turn them over?"

Louis Agassiz, *Etudes sur les Glaciers*, 1840.

Paleoclimatology

Introduction
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Understanding the Past to Predict the Future

http://earthobservatory.nasa.gov/Features/Paleoclimatology/

Climate and Global Change on Windows to the Universe

http://www.windows2universe.org

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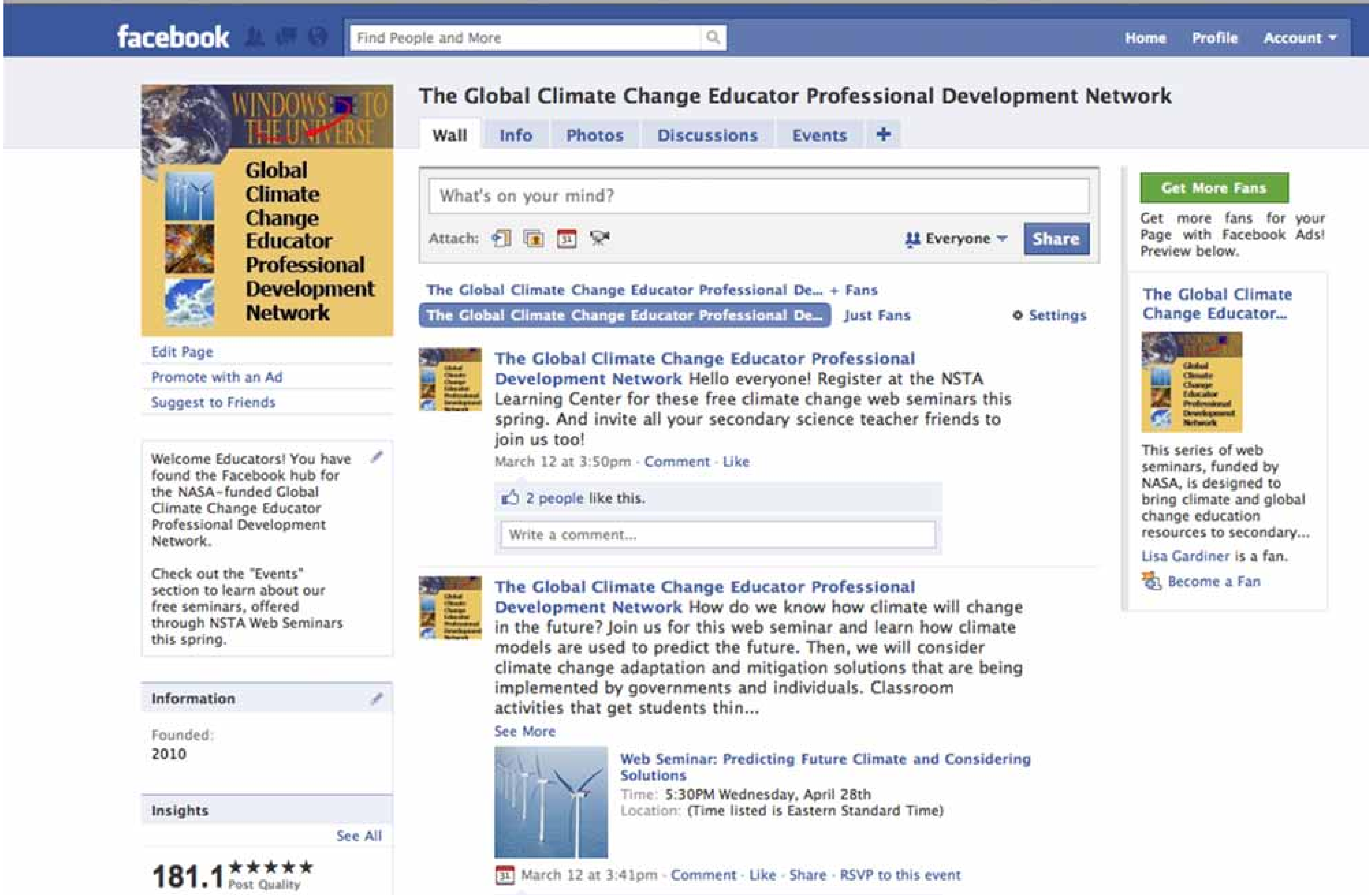

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