

NATS 101
Section 13: Lecture 32

Paleoclimate

Natural changes in the Earth's climate also occur at much longer timescales

The study of prehistoric climates and their variability is called *paleoclimate*.

Climate vs. Paleoclimate

CLIMATE

Uses actual weather observations to construct long-term statistics.
Surface records go back about 100-200 years.
Upper air data go back about 50 years.
Ocean temperature measurements go back about 50 years.

Majority of “climate” studies which use observed data focus on the period of twentieth century to present day.

PALEOCLIMATE

Uses indirect measures from natural sources, or proxies, to reconstruct prehistoric climate.

How far back the paleoclimate record can go depends on the proxy data used.

Paleoclimate proxy

Tree rings

Go back about _____ years



Each year tree produces a new layer of cells underneath its bark.

Thickness of the tree rings indicative of the climate conditions for that year. For example:

Thin ring = drought year

Thick ring = wet year

Study of tree rings is called dendrochronology.

UA has one of the best centers in the world to study this—located underneath the football stadium.

What do the black lines on the tree rings indicate?



*Laboratory for Tree Ring Research
University of Arizona*

Paleoclimate proxy

Glacial ice cores

Go back about _____ years



An ice core drill plumbs the depths of a glacier in the St. Elias Mountains, Yukon (photo: Erik Blake)

Each year a new layer of ice from snowfall forms.

Gases and aerosols existing in the atmosphere at the time are trapped within the ice.

Can measure:

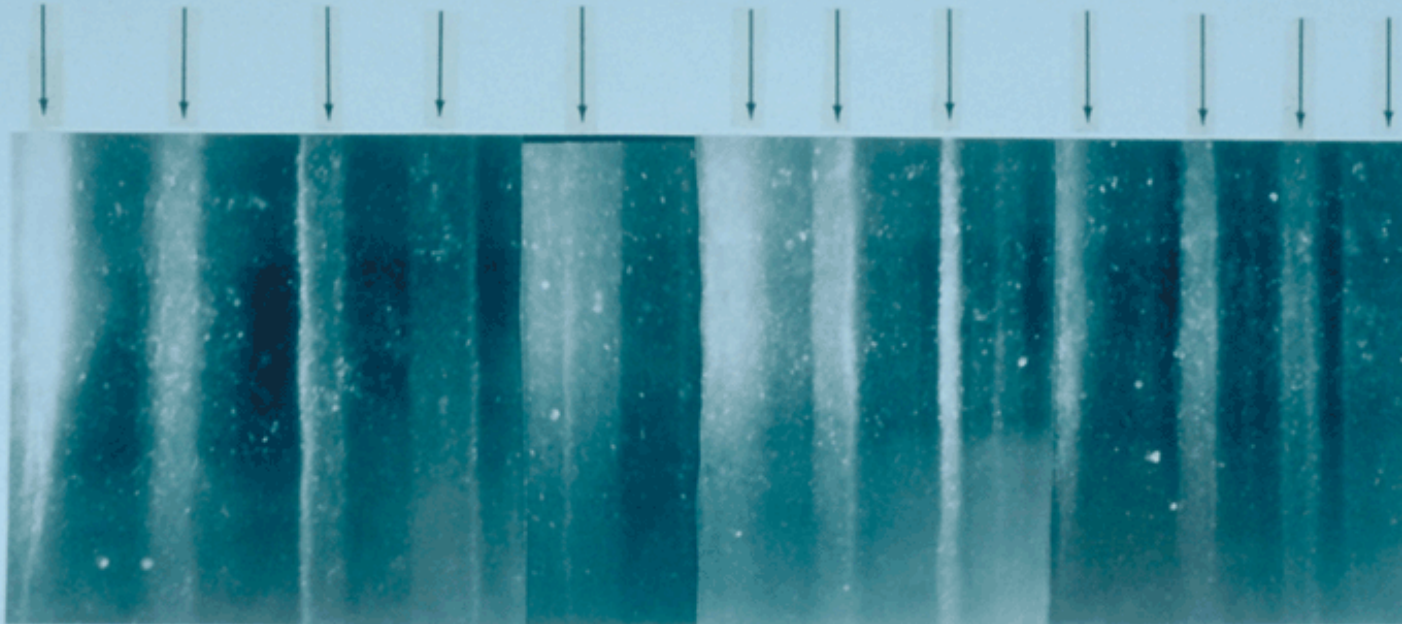
Atmospheric greenhouse gases

Global average temperature

Function of ratio of different oxygen isotopes (O^{18} vs. O^{16})

Aerosols, for example from a large volcanic eruption.

Antarctic ice core example



19 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.

Other paleoclimate proxies

Go back _____ of years

Ocean sediment cores and corals

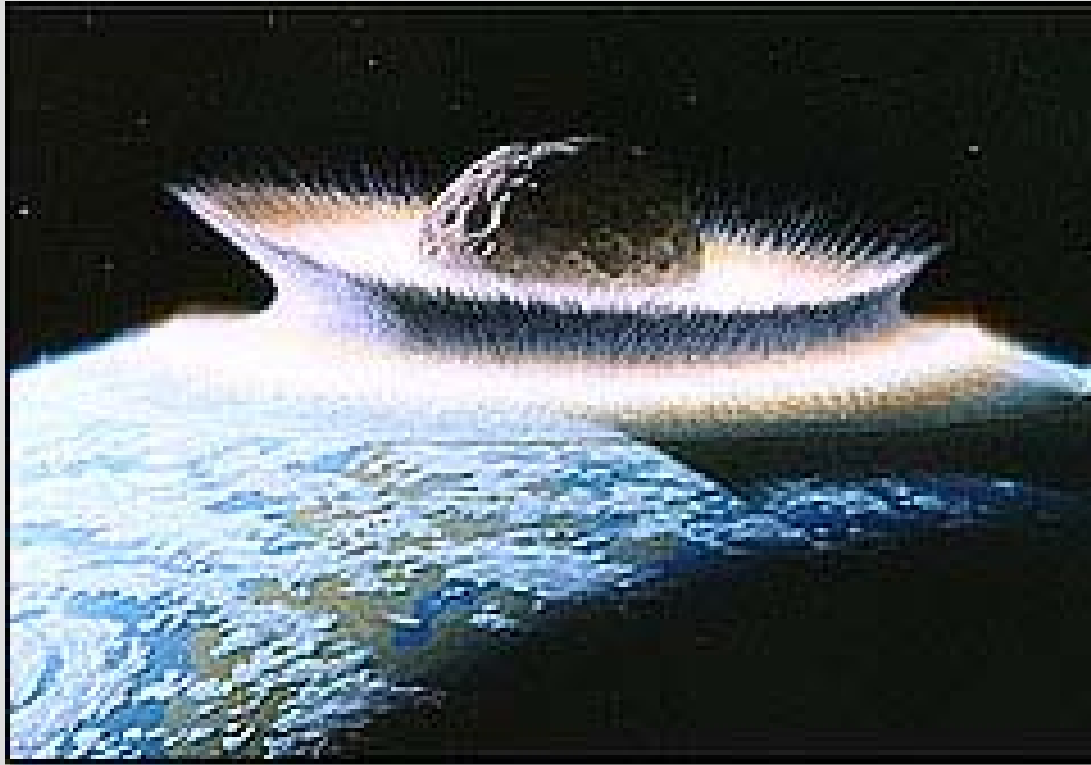
Similar to ice cores in that they record ratio of oxygen isotopes.

Geologic records

Various dating techniques can record age of rocks.
Indirect evidence of climate via fossilized life forms.

Example: Can measure size of stomata on fossilized leaves to estimate carbon dioxide concentration during dinosaur age.

Dinosaur extinction: 65 million years ago

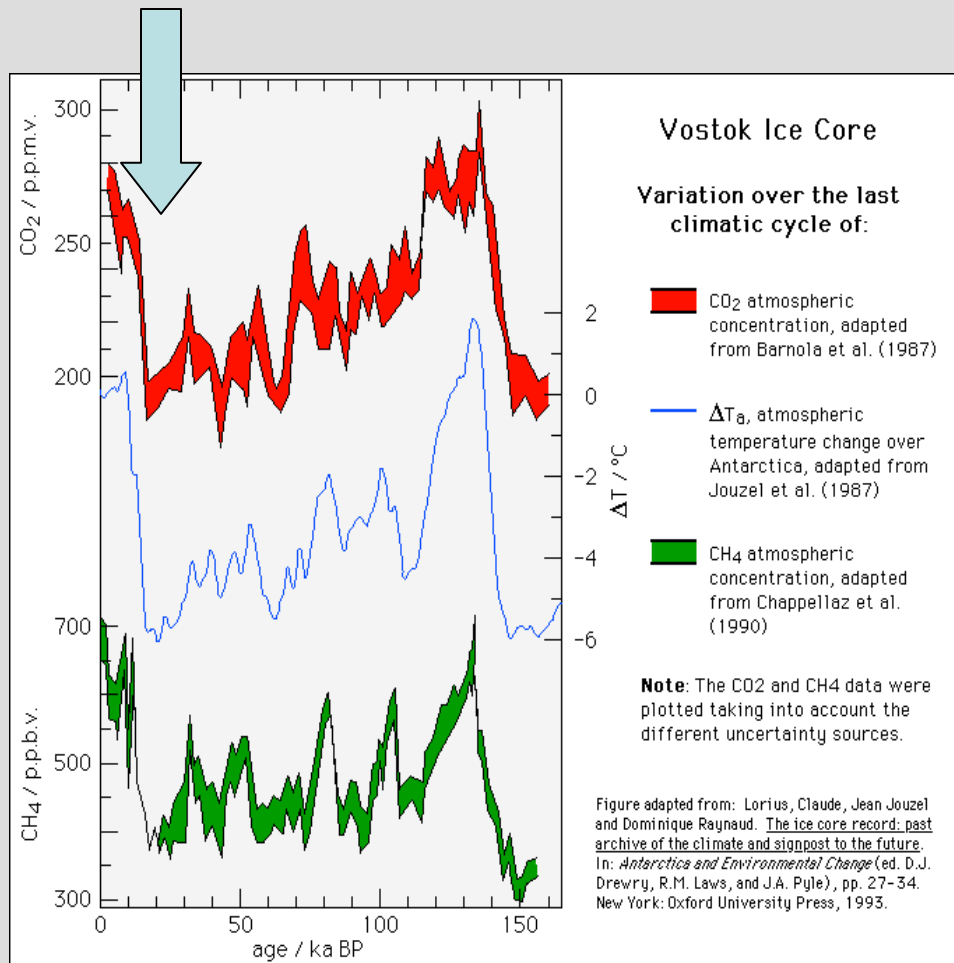


Probably occurred due to an asteroid that hit what is now the Yucatan Peninsula.

Left a well-defined geological boundary that is observed all over the world.

Vostok ice core record: Antarctica (~150,000 years)

LAST ICE AGE
18,000 years ago



Ice Age 18,000 years ago

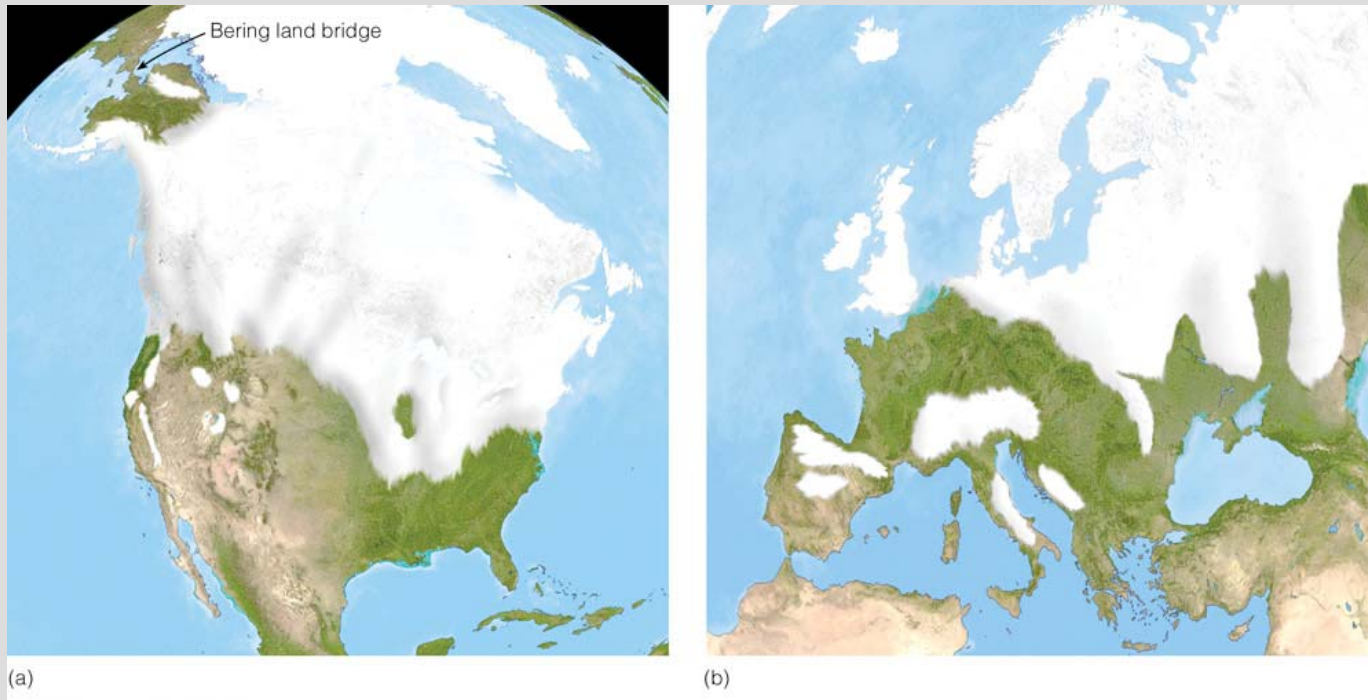
Temperature 6°C colder

CO₂ levels 30% lower

Methane 50% lower

Record shows glacial and interglacial periods which vary on a timescale of tens of thousands of years.

Extent of ice cover in last ice age (i.e. what a change of 6°C can mean)



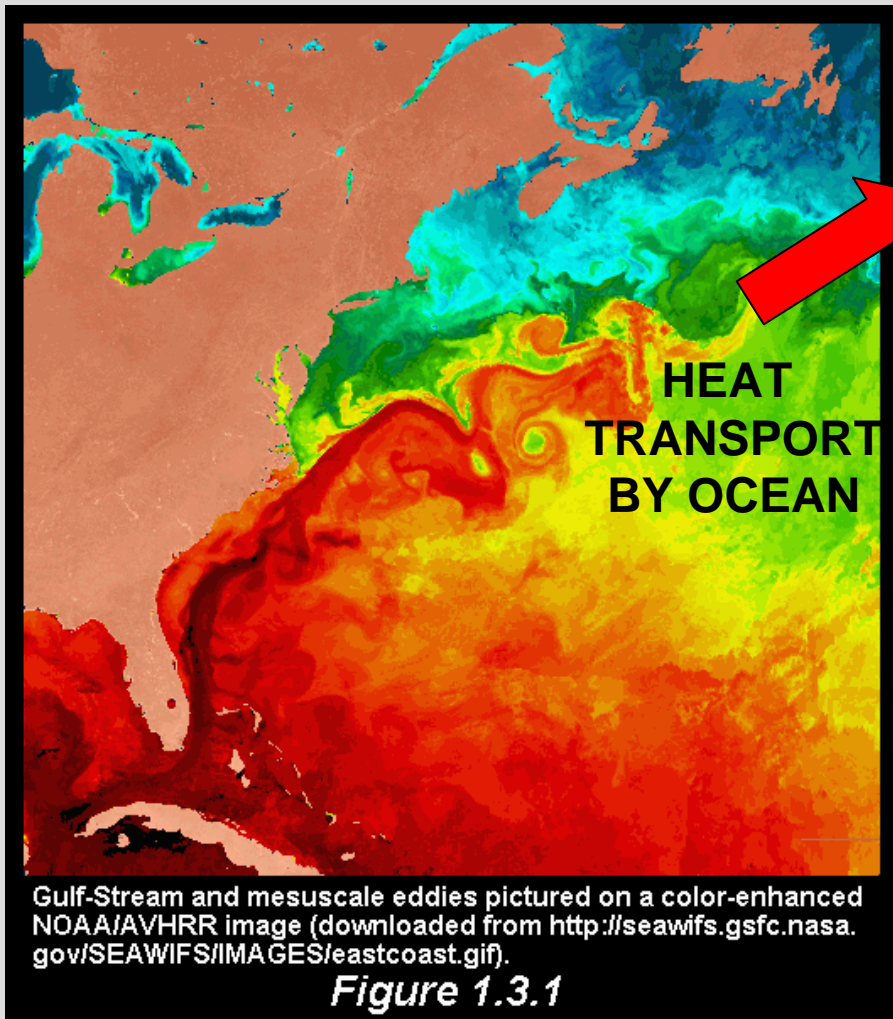
Most of Canada and the northern U.S. covered in ice.

Sea level about 100-125 m lower.

Bering land bridge

Allowed Native Americans to populate Americas??

European Climate and the Influence of the Gulf Stream

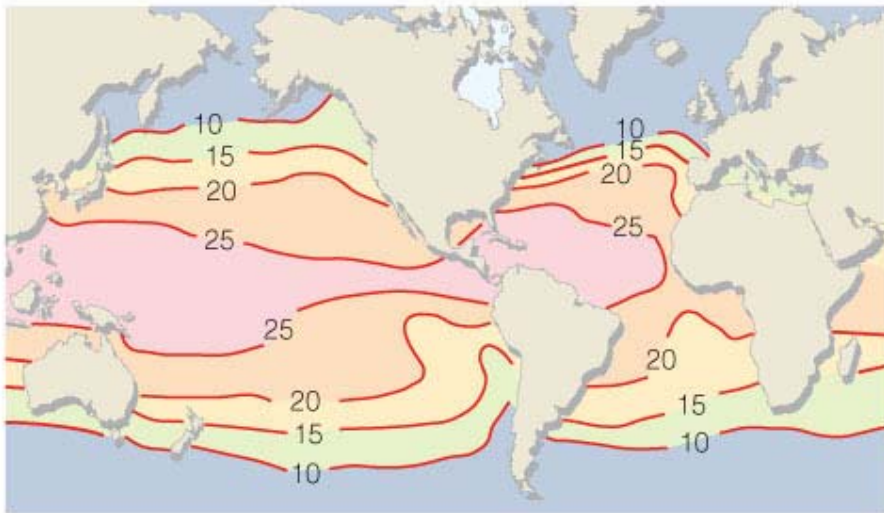


The Gulf Stream current in the North Atlantic transports warm water from the tropics toward Europe.

As a result, Europe is much warmer than it otherwise would be.

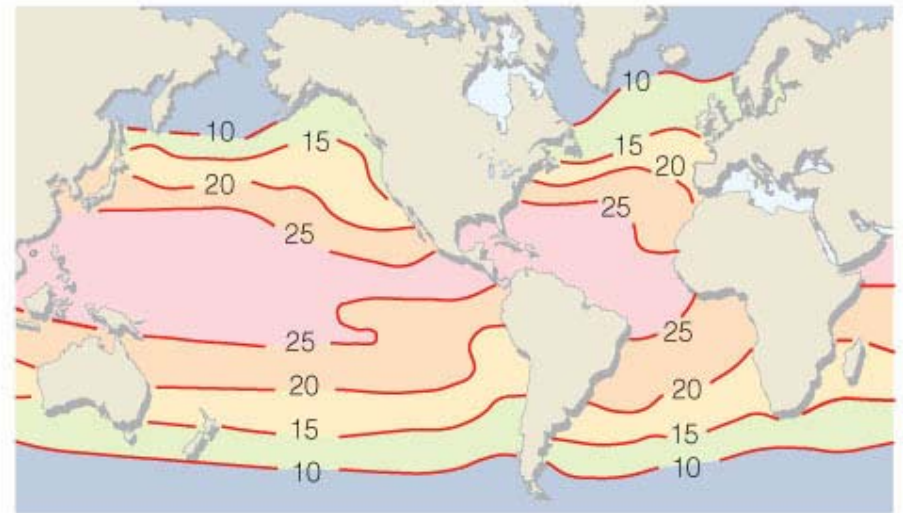
Sea surface temperatures (°C) Last ice age vs. today

ICE AGE



(a)

TODAY

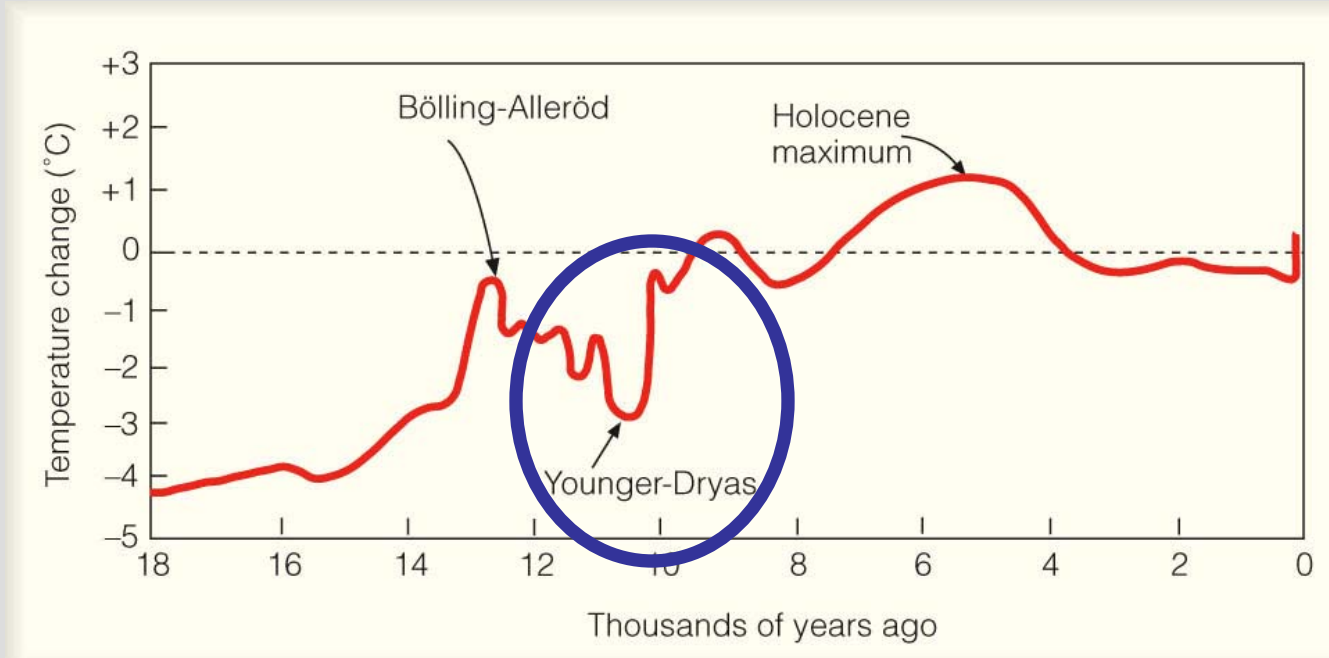


(b)

MUCH COLDER North Atlantic because the Gulf Stream shut down.

Puts Europe and most of North America in the ice box!

Temperature record since last ice age (18,000 years ago to present)



Warming for most of the period.

YOUNGER DRYAS: A rapid cooling period that occurred within a period of about a thousand years, then a return to warming within just a few years!

What caused the Younger Dryas?

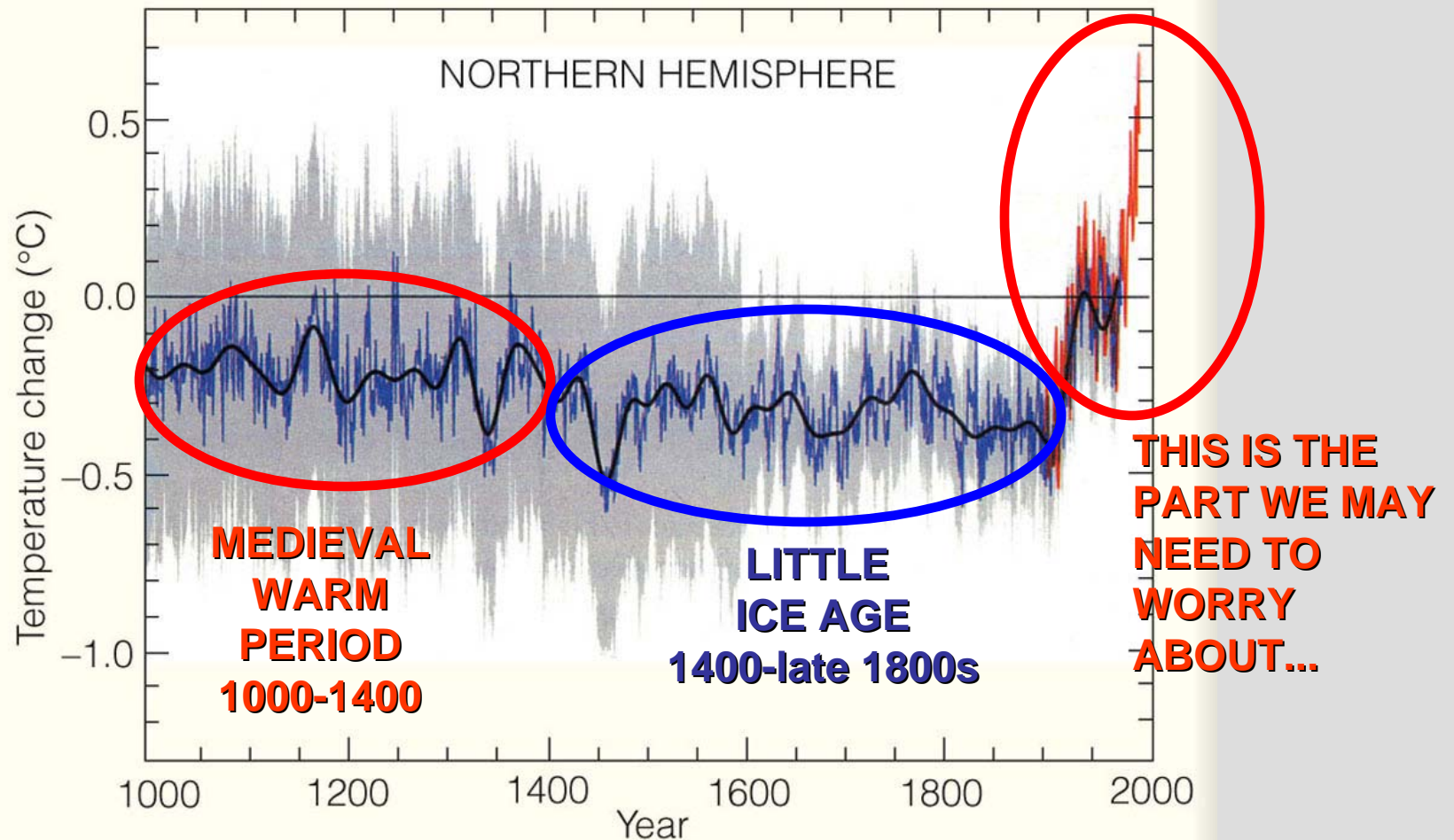


At the ice sheets were retreating, a giant prehistoric lake formed called Lake Agassiz.

The lake eventually broke through the ice sheet and drained into the North Atlantic.

The freshening of the sea water shut down the Gulf Stream and the heat transport toward Europe, *what happened then??*

Temperature record for the last 1000 years Mann's "Hockey Stick"



THIS TEMPERATURE RECONSTRUCTION IS STILL BEING DEBATED!!

What causes long-term climate changes?

Change one or all of the following:

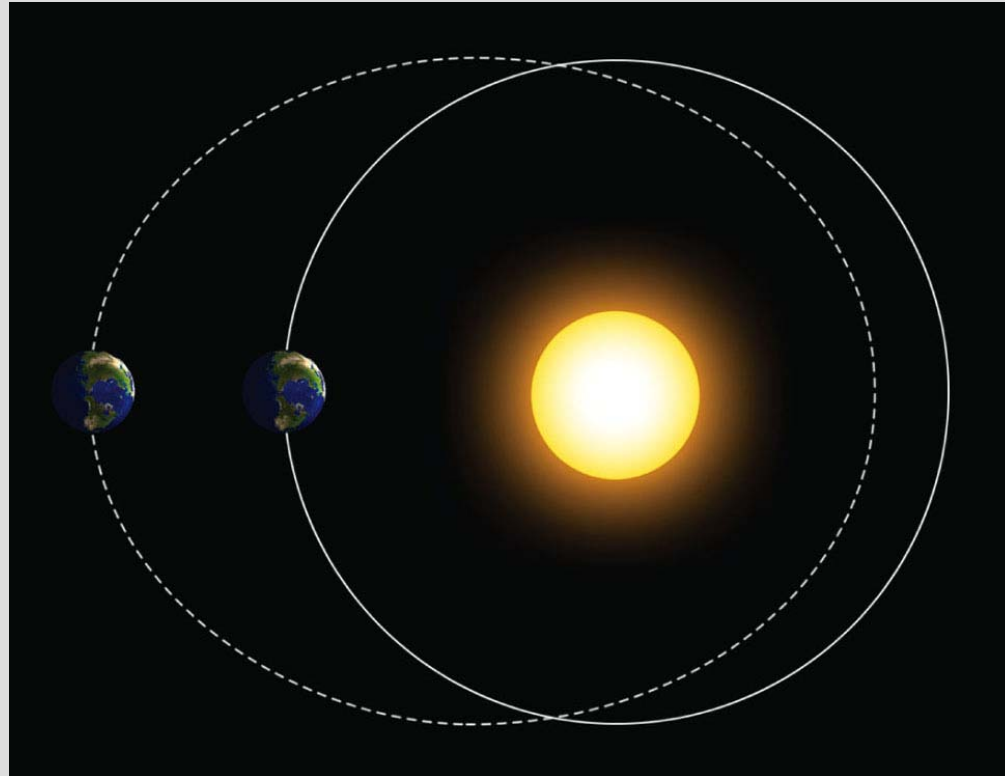
- **ATMOSPHERIC COMPOSITION:** Affect radiative properties of the atmosphere.
Examples: Aerosols, Carbon dioxide
- **EARTH'S ORBITAL PARAMETERS:** Alter the solar energy intercepted by the Earth.
- **EARTH'S SURFACE:** Alter the flow of energy at the surface or change it's distribution
Examples: Landscape change, continental drift.

Milankovitch Theory (Orbital Parameter Theory of Ice Ages)

***Idea:* Regular changes in the Earth's orbital parameters alter the distribution of solar radiation enough to trigger ice ages.**

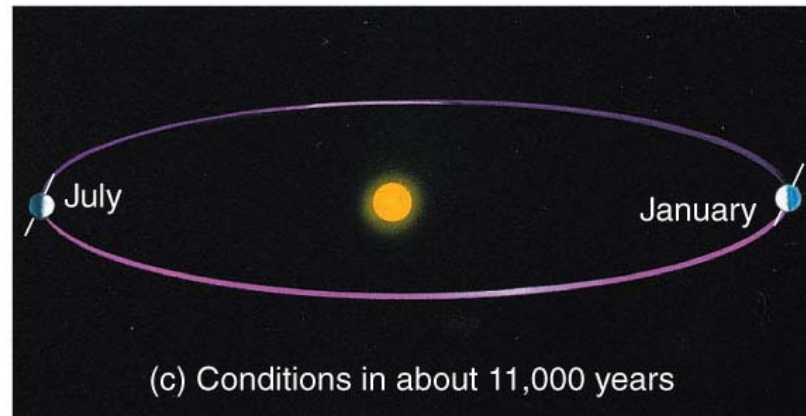
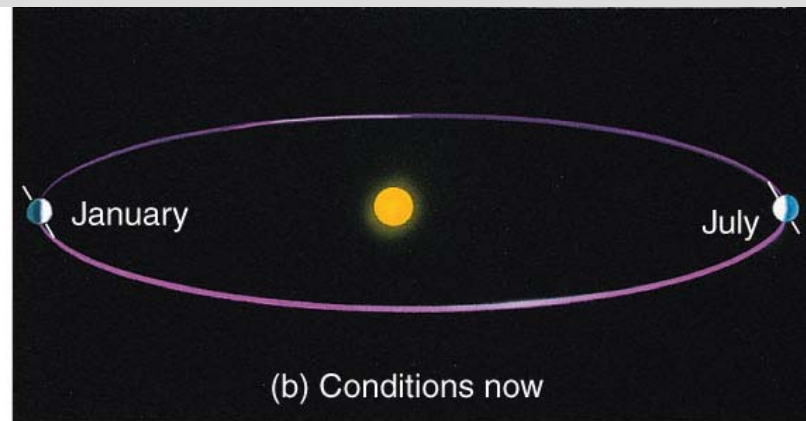
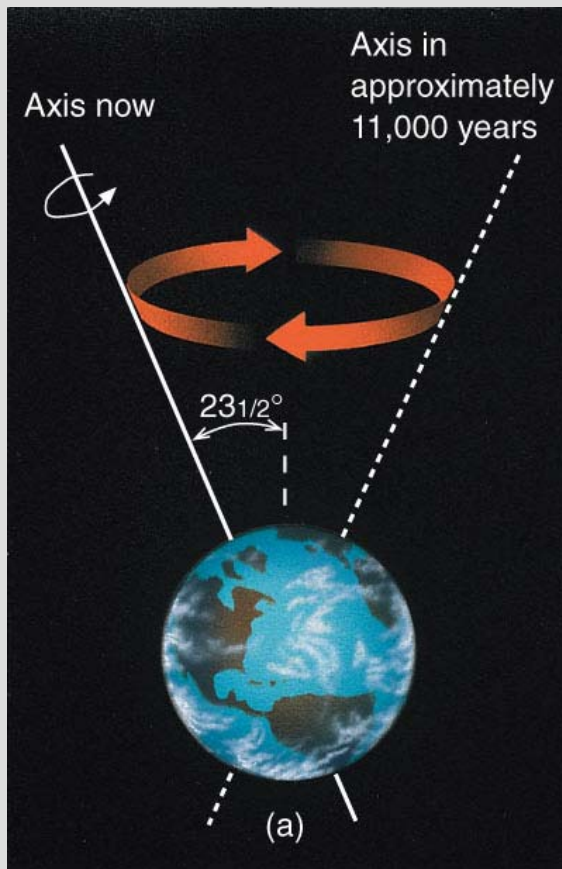
We already discussed these in the lecture on the seasons...

Eccentricity: Shape of the orbit



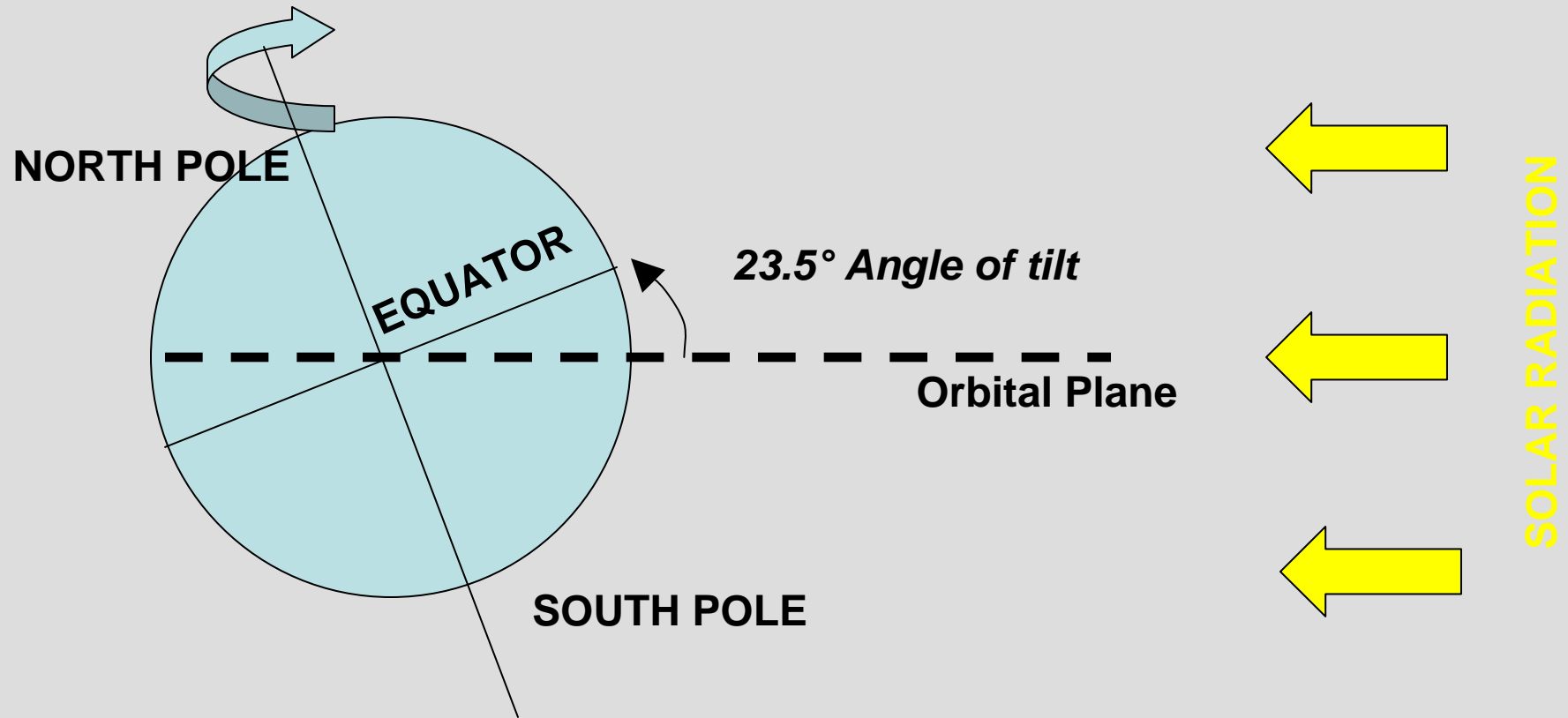
Timescale of Variation = 100,000 years

Precession: Axis Wobble



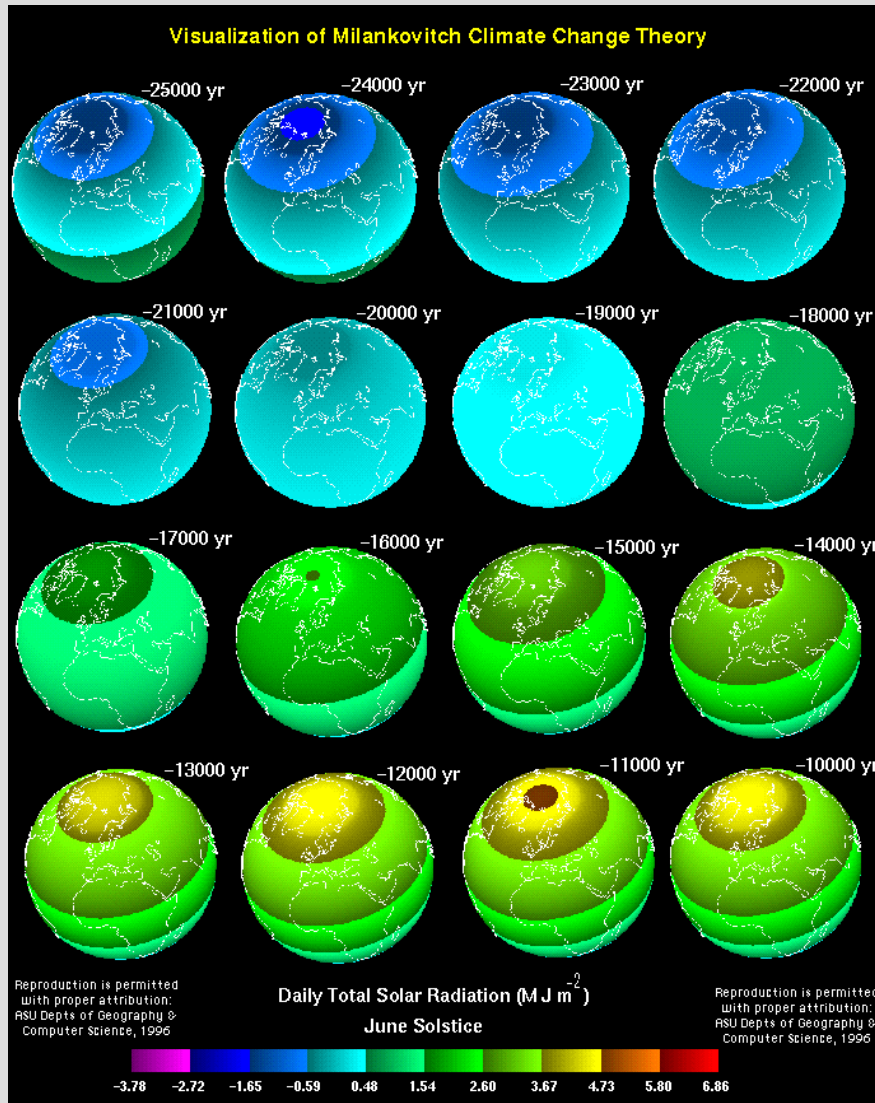
Timescale of Variation = 23,000 years

Obliquity: Earth's Tilt



Timescale of Variation = 41,000 years

Solar radiation variability at the North Pole over thousands of years



Changes in the orbital parameters change the incoming solar radiation at the North Pole by about 15%

This is likely coupled with a biological response which affects the uptake of carbon dioxide in the ocean

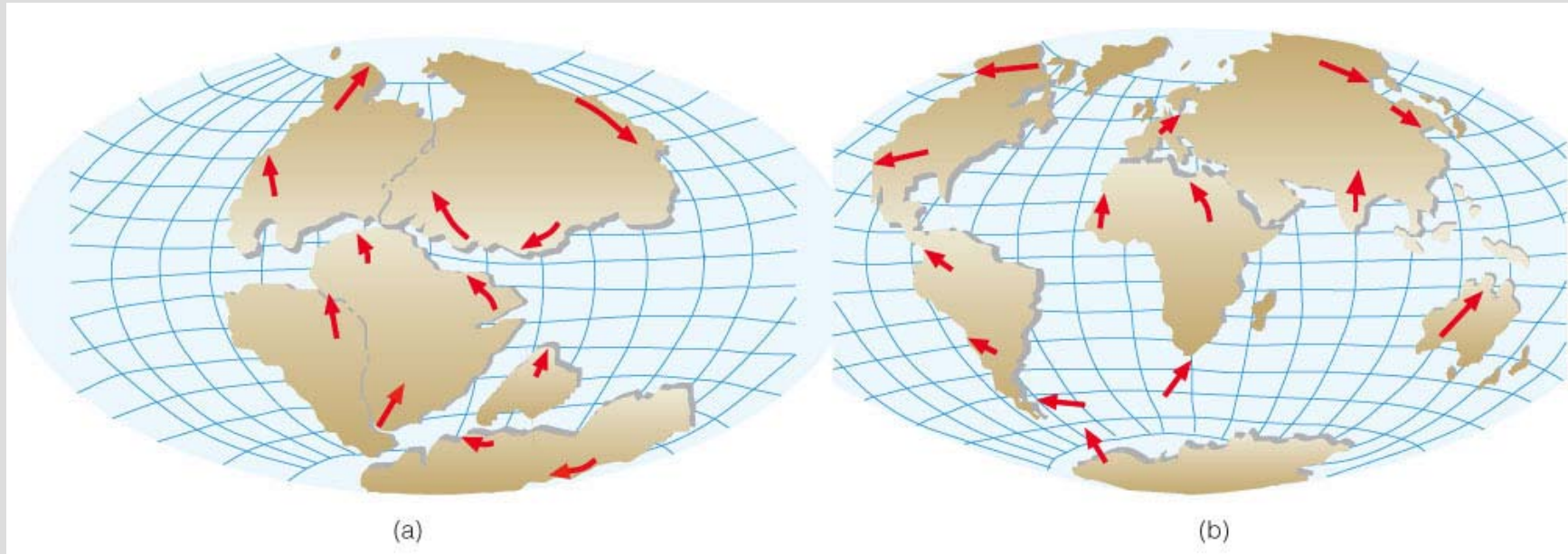
These two effects probably are responsible for the regular occurrence of ice ages.

REALLY long term climate change on the scale of millions or billions of years is due to continental drift.

Continents 180 million years ago vs. today

180 Million Years Ago

Today



Global wind and ocean currents completely different from today because of the difference in continental positions.

The world's climate was a LOT different.

What was the climate of Arizona like at this time?

Besides changes in the ocean, there are a couple of other factors which can influence natural climate variability on the scale of years to decades.

Volcanic Eruptions



Mt. Pinatubo in 1991

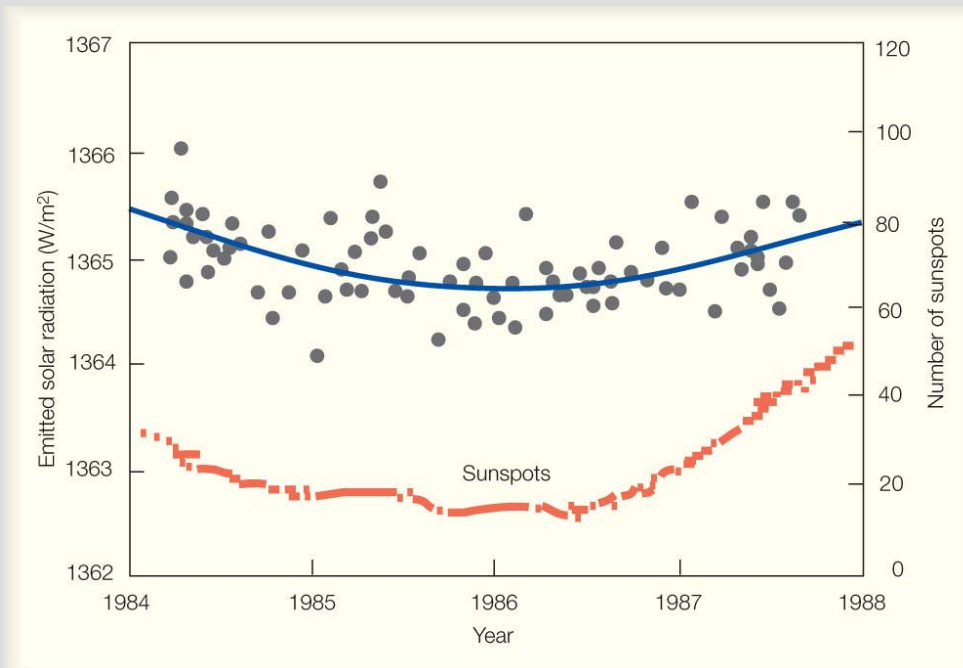
Really big explosive eruptions inject sulfur and particles of ash and dust into the stratosphere.

These form haze particles which reflect sunlight.

Result: global temperatures decrease for a few years after the eruption.

Most dramatic example was eruption of Mt. Tambora in Indonesia in 1815. The following year was called the “year without a summer.”

Sunspot cycle



Causes a slight variation in the output of solar radiation.

Occurs on a 22 year time scale.

My opinion

A lot of people have discovered interesting statistical relationships between solar activity and climate, but explaining physical causality is elusive.

Summary of Lecture 33

The study of prehistoric climates and their variability is called paleoclimate.

Paleoclimate uses indirect measures from natural sources, or proxies.

Tree rings: ~1000 of years

Ice cores: ~100,000 years

Ocean sediments and corals: millions of years

Geologic record: billions of years

These proxies can give information about: composition of atmospheric gases, temperature, precipitation, and aerosol content.

As shown in ice cores, ice ages occur on the time scale of tens of thousands of years. Temperature and greenhouse gas concentration are closely related in the ice core record.

After the last ice age, a warming trend occurred till about the present day, except for the Younger Dryas period. This probably occurred due to a shutdown in the Gulf Stream.

Long-term climate change is caused by changes in atmospheric composition, orbital parameters, or the surface. Orbital parameter changes likely trigger ice ages.

Review Questions

Chapter 16 Questions

Questions for Review: 1,2,3,4,6,7,8,11

Questions for Thought: 1,2,4,5,6