Lab 6 Understanding past climates

1. Isotopes of Oxygen
2. Temperature Change
3. External Forcing

Why study the past climate?

1. Past variability can show climatic extremes that have not been experienced during recorded history

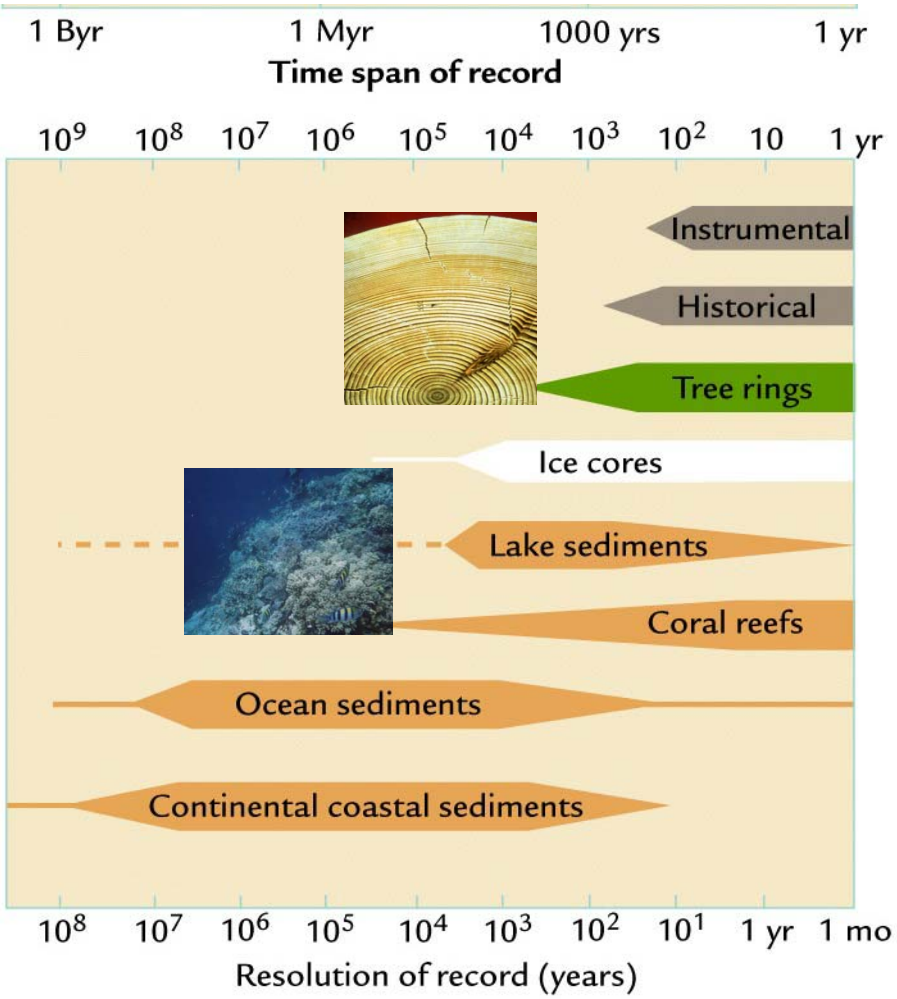
2. In order to understand the effects of human activity on climate, we must establish what the planet, the atmosphere, and climate change was like before human perturbations

3. Constructing and interpreting long-term records of climate are the only means to determine how periodic climate change is (All in all, we are just a blip)

4. Past is prologue

"The farther backward you can look, the farther forward you are likely to see." ***- Winston Churchill***

Proxy Records of Climate



- How can we tell the temperature in the geological past?
- Compare two isotopes of oxygen in ice cores, coral reefs, and sediments.
- What are isotopes?

http://www.ncdc.noaa.gov/paleo/globalwarming/proxydata.html

1) What is an isotope?

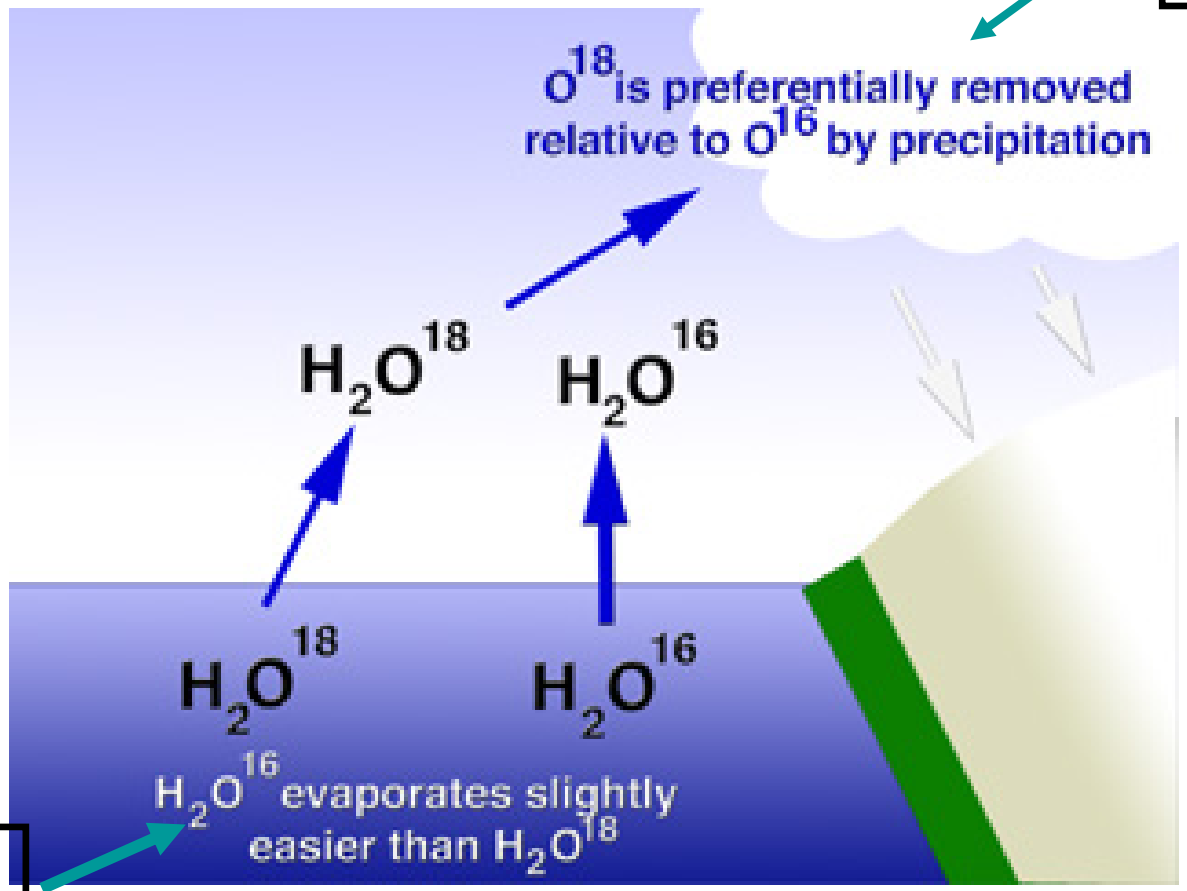
- Isotopes are any of the different types of atoms of the same chemical element, each having a different atomic mass .
- Isotopes of an element have nuclei with the same number of protons (the same atomic number) but different numbers of neutrons. Therefore, isotopes have different mass numbers, which give the total number of nucleons, the number of protons plus neutrons.

2) What are the two main isotopes of oxygen that climatologists use to study paleoclimates?

- O^{16}, O^{18}

$$\delta^{18}O \text{ (in ‰)} = [(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{standard}] \times 1000 / (^{18}O/^{16}O)_{standard}$$

^{18}O depleted, ^{16}O enriched → $\delta^{18}O$ more negative

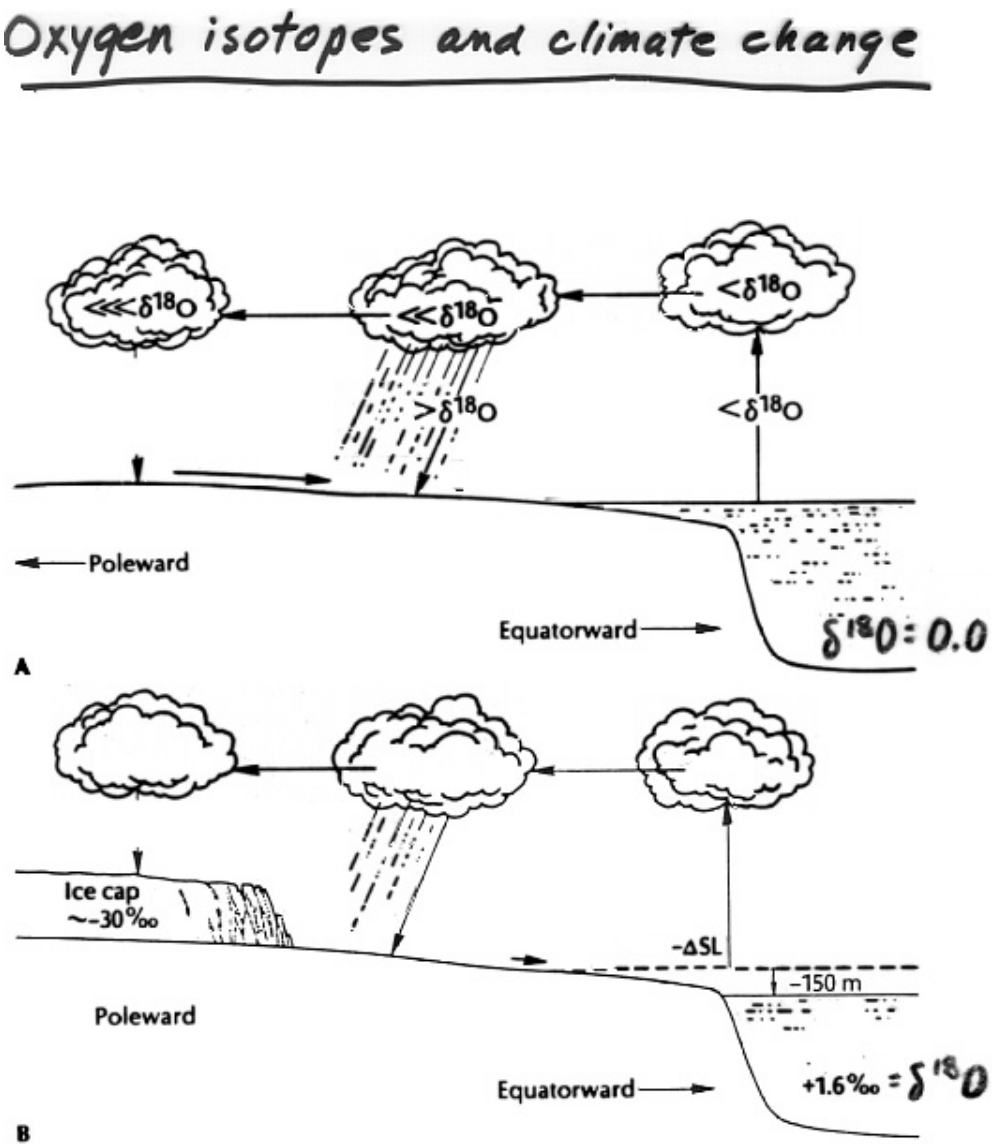


^{18}O enriched, ^{16}O depleted → $\delta^{18}O$ more positive

3) Cooler water will collect more of which type of isotope?

4) Warmer water will collect more of which type of isotope?

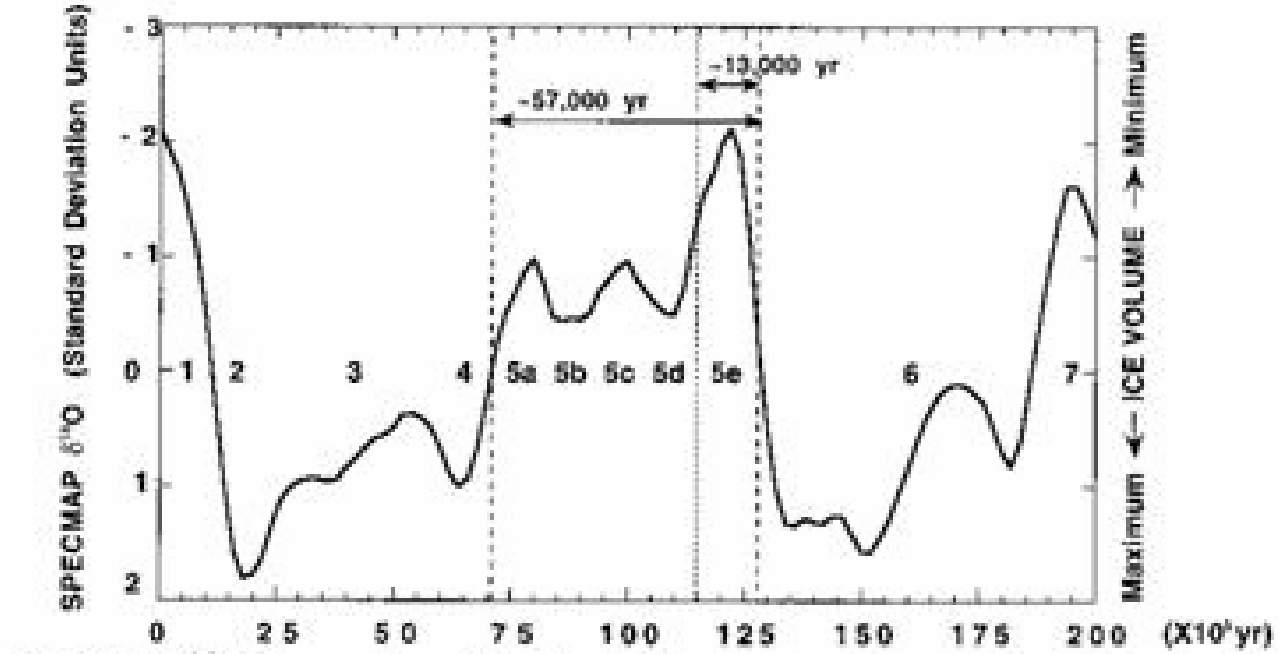
5) The less O-18 found in the glacier ice, the _____ the climate.

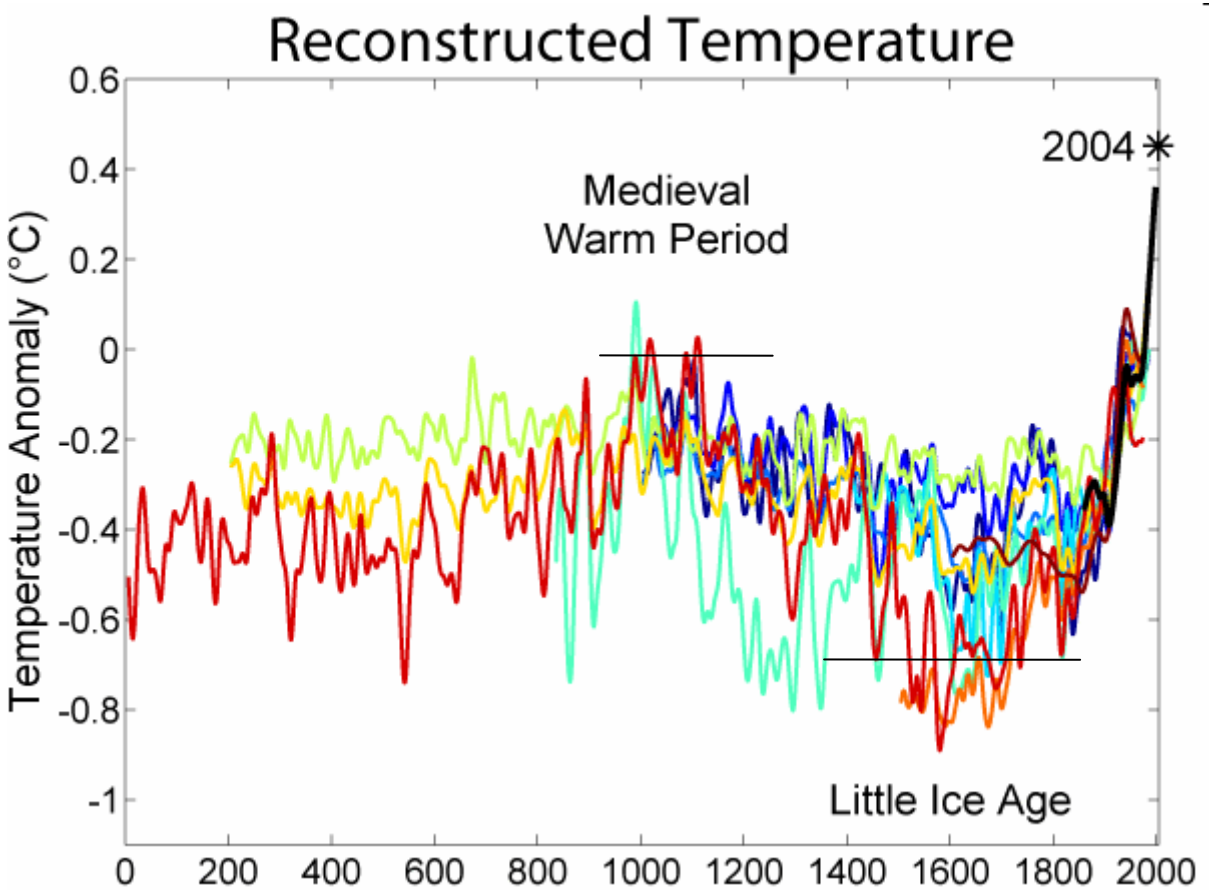


Glacials and Interglacials as recorded by oxygen isotopes

➔ During glacial and interglacial periods there is a change in the isotopic portioning of oxygen.

- *glacials* for colder periods during ice ages; and *interglacials* for the warmer periods.





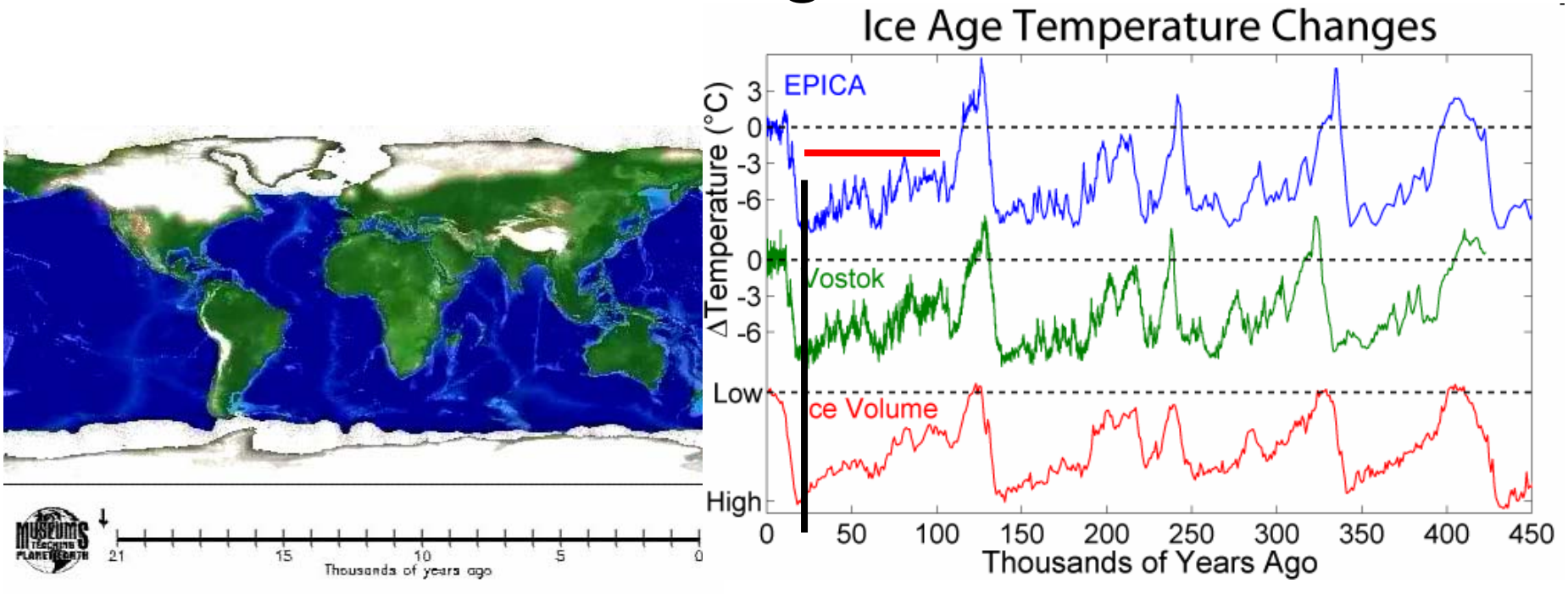
- The Medieval Warm Period (MWP) or Medieval Climate Optimum was a time of warm climate in the North Atlantic region, lasting from about the tenth century to about the fourteenth century. It followed the Migration Period Pessimum or Dark Ages Cold Period and was followed by the Little Ice Age. The MWP is often invoked in discussions of global warming. Some refer to the event as the Medieval Climatic Anomaly as this term emphasizes that effects other than temperature were important.
- The warm climate overlaps with a time of high solar activity called the Medieval Maximum.

Little Ice Age

➔Causes

- Scientists have identified two causes of the Little Ice Age from outside the ocean/atmosphere/land systems: decreased solar activity and increased volcanic activity.
- A 2008 study of sediment cores and soil samples further suggests that carbon sequestration via reforestation in the Americas contributed to the Little Ice Age.

7) How long ago was the last major Ice Age?



In North America the largest ice sheet was the Laurentide Ice Sheet centered on Hudson Bay with other sheets centered on Greenland and in the Canadian Rocky Mountains.

http://earth.rice.edu/MTPE/cryo/cryosphere/topics/ice_age.mov

http://videos.howstuffworks.com/hsw/21464-earths-catastrophic-past-the-last-ice-age-video.htm

8) What are the major contributors to Ice Ages?

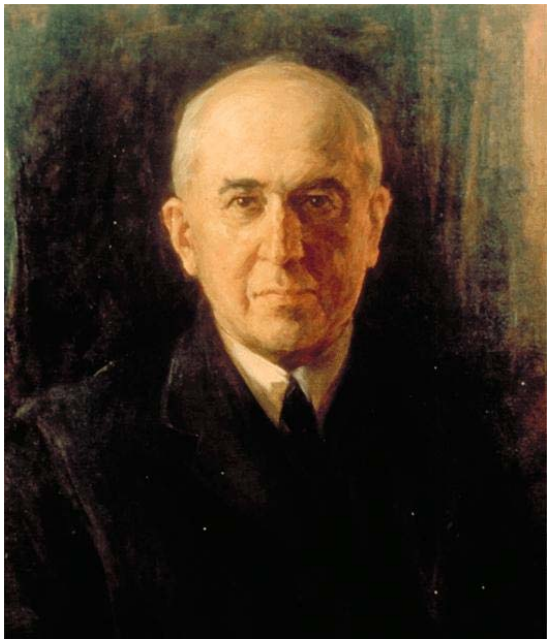
- The causes of ice ages remain controversial for both the large-scale ice age periods and the smaller ebb and flow of glacial–interglacial periods within an ice age.
- The consensus is that several factors are important:

1) atmospheric composition (the concentrations of carbon dioxide, methane);
2) changes in the Earth's orbit around the Sun known as Milankovitch cycles (and possibly the Sun's orbit around the galaxy);
3) the motion of tectonic plates resulting in changes in the relative location and amount of continental and oceanic crust on the Earth's surface, which could affect wind and ocean currents;
4) variations in solar output; the orbital dynamics of the Earth-Moon system;
5) and the impact of relatively large meteorites, and volcanism including eruptions of supervolcanoes.

- The episodic nature of the Earth's glacial and interglacial periods within the present Ice Age (the last couple of million years) have been caused primarily by cyclical changes in the Earth's circumnavigation of the Sun. Variations in the Earth's eccentricity, axial tilt, and precession comprise the three dominant cycles, collectively known as the Milankovitch Cycles for Milutin Milankovitch, the Serbian astronomer who is generally credited with calculating their magnitude. Taken in unison, variations in these three cycles creates alterations in the seasonality of solar radiation reaching the Earth's surface. These times of increased or decreased solar radiation directly influence the Earth's climate system, thus impacting the advance and retreat of Earth's glaciers.

9) What causes Milankovitch cycles? What is the period?

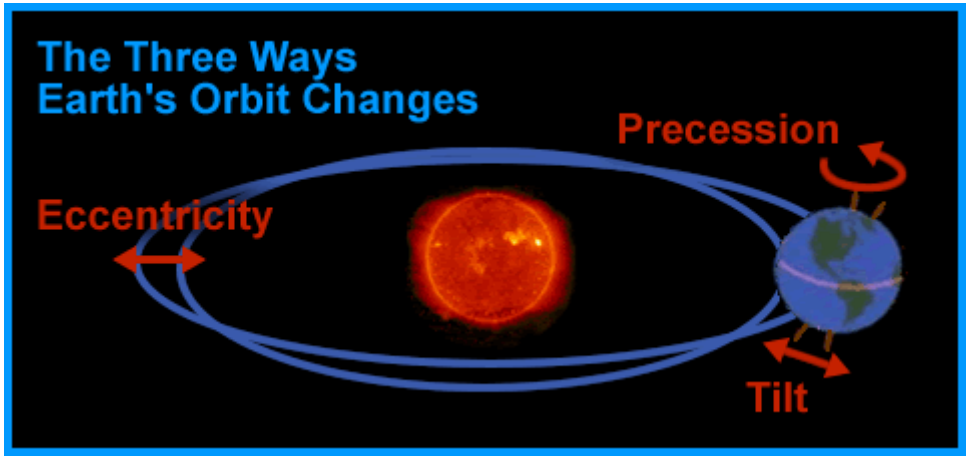
Milankovich cycles



- Milankovich cycles are cycles in the Earth's orbit that influence the amount of solar radiation striking different parts of the Earth at different times of year. They are named after a Serbian mathematician, Milutin Milankovitch, who explained how these orbital cycles cause the advance and retreat of the polar ice caps.
- The periodicity of the Earth’s glacial and interglacial cycles within the present Ice Age have been caused primarily by changes in the Earth’s orbital positions around the Sun.
- These times of increased or decreased solar radiation directly influence the Earth's climate system, thus impacting the advance and retreat of Earth's glaciers.

Milankovitch Cycles

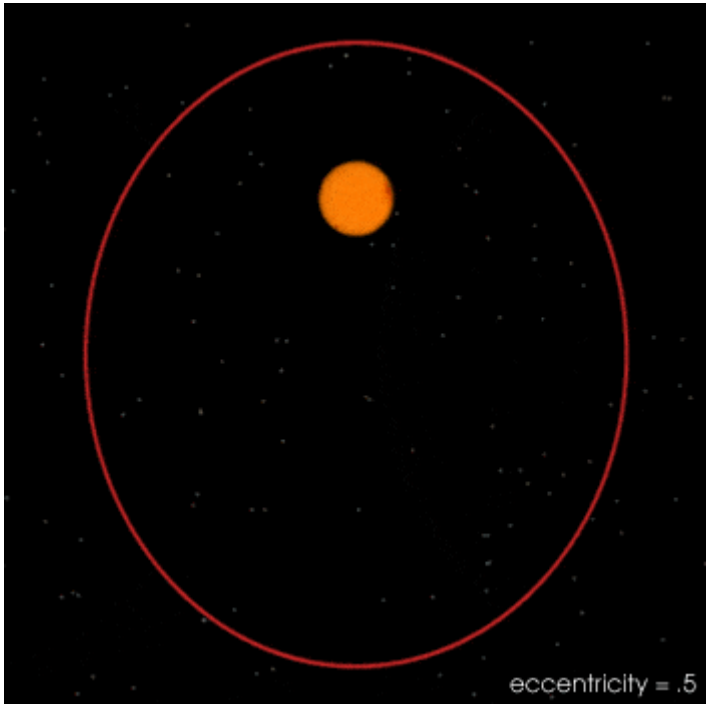
Eccentricity
Obliquity
Precession

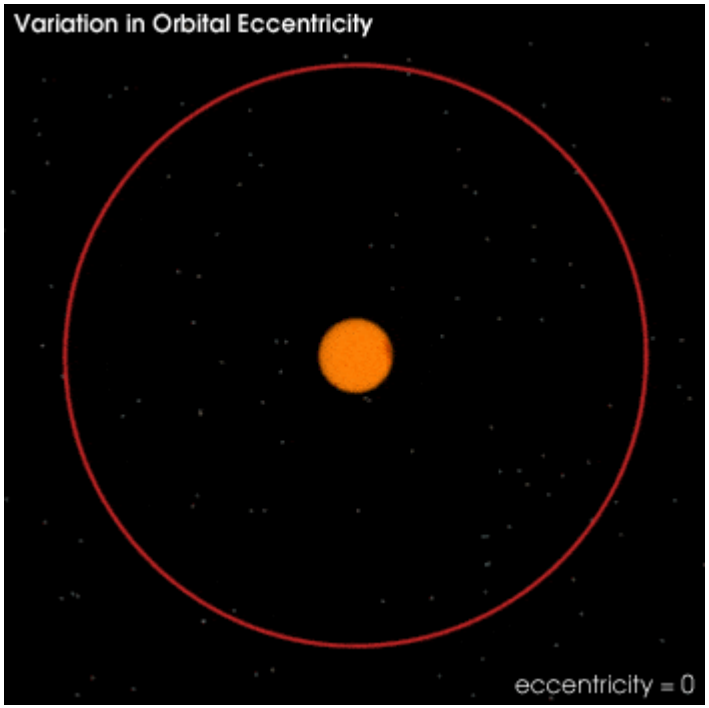


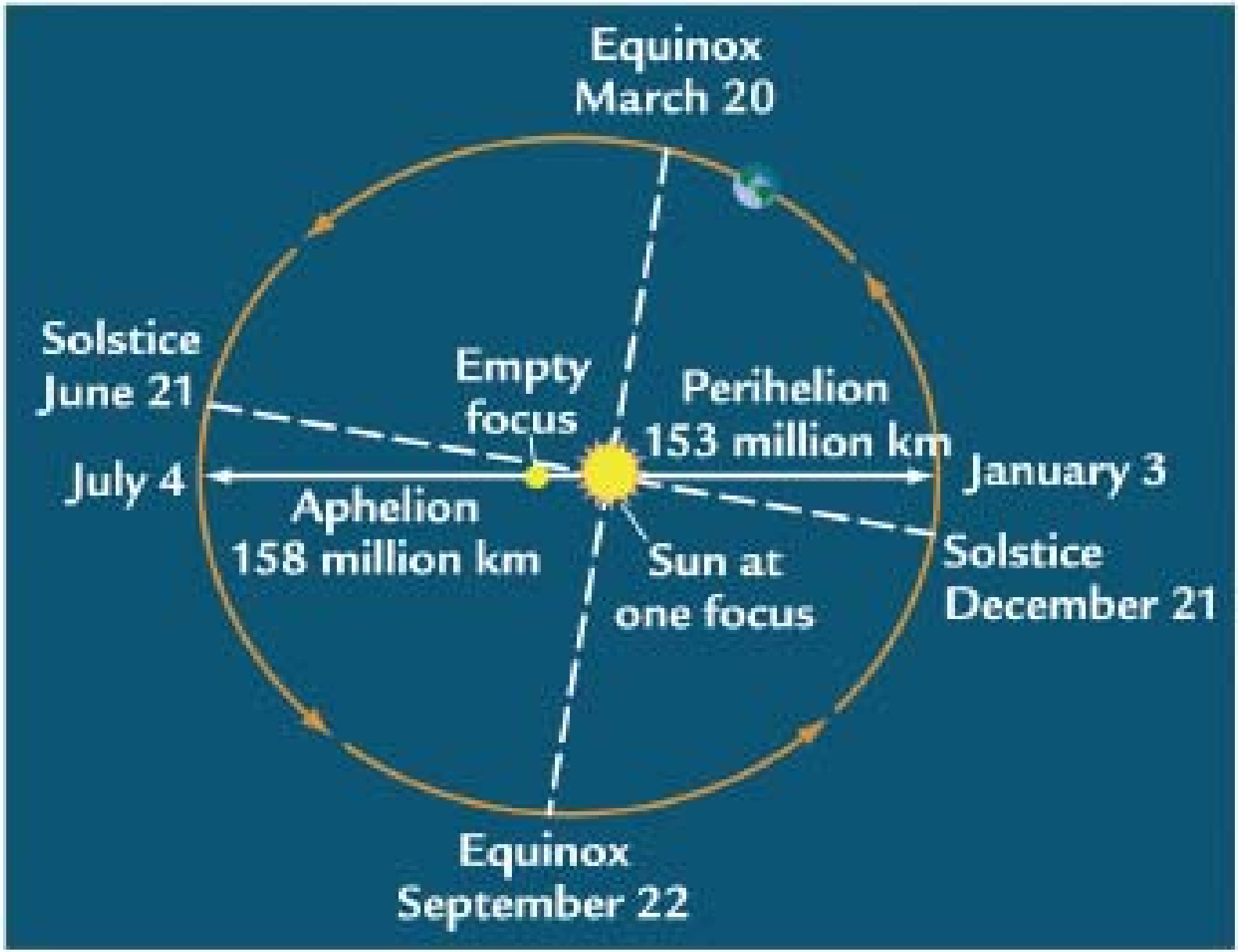
- Variations in the Earth's orbital eccentricity—the shape of the orbit around the sun.
- Changes in obliquity—changes in the angle that Earth's axis makes with the plane of Earth's orbit.
- Precession—the change in the direction of the Earth's axis of rotation, i.e., the axis of rotation behaves like the spin axis of a top that is winding down; hence it traces a circle on the celestial sphere over a period of time.
- Together, the periods of these orbital motions have become known as Milankovitch cycles.
- http://www.youtube.com/watch?v=wLAYRdSnRSI

Eccentricity

- Changes in orbital eccentricity affect the Earth-sun distance.
- The shape of the Earth's orbit changes from being elliptical (high eccentricity) to being nearly circular (low eccentricity) in a cycle that takes between 90,000 and 100,000 years.






Equinox
March 20
Solstice
June 21
Empty
focus
Perihelion
153 million km
July 4
January 3
Aphelion
158 million km
Sun at
one focus
Solstice
December 21
Equinox
September 22

11) What special event happens on the Fall and Spring Equinox?

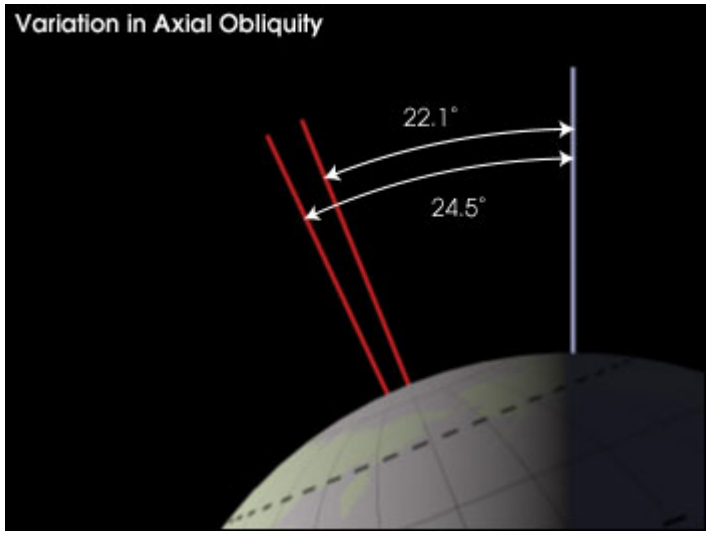
- **Equinoxes** occur twice a year, when the tilt of the Earth's axis is inclined neither away from nor toward the Sun, causing the Sun to be located vertically above a point on the equator.
- An equinox happens each year at two specific moments in time (not a whole day) when the centre of the Sun can be observed to be vertically above the Earth's equator, occurring around March 20 or 21 and September 22 or 23 each year.

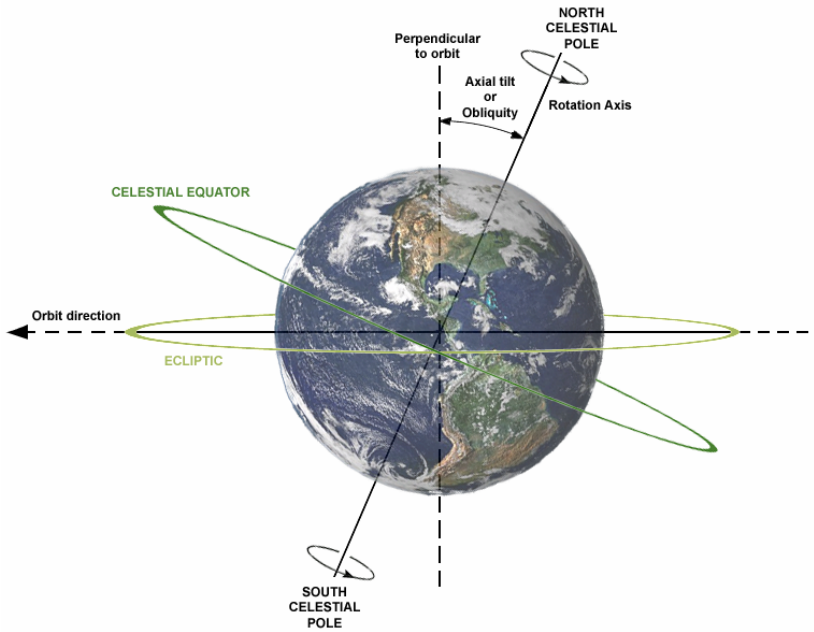
11.5) Define Aphelion and Perihelion.

- **Aphelion** -- the point on its orbit when the Earth is farthest from the sun
- **Perihelion** -- the point on its orbit when the Earth is closest to the sun

Obliquity (change in axial tilt)

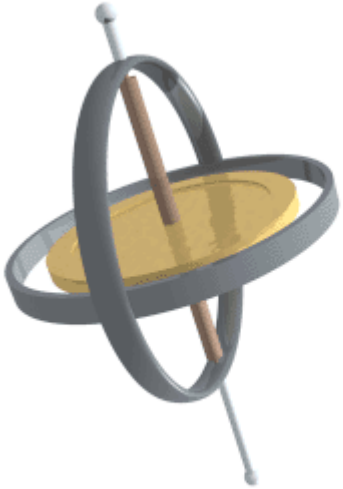
- As the axial tilt increases, the seasonal contrast increases so that winters are colder and summers are warmer in both hemispheres.
- Today, the Earth's axis is tilted 23.5 degrees from the plane of its orbit around the sun.
- During a cycle that averages about 40,000 years, the tilt of the axis varies between 22.1 and 24.5 degrees.

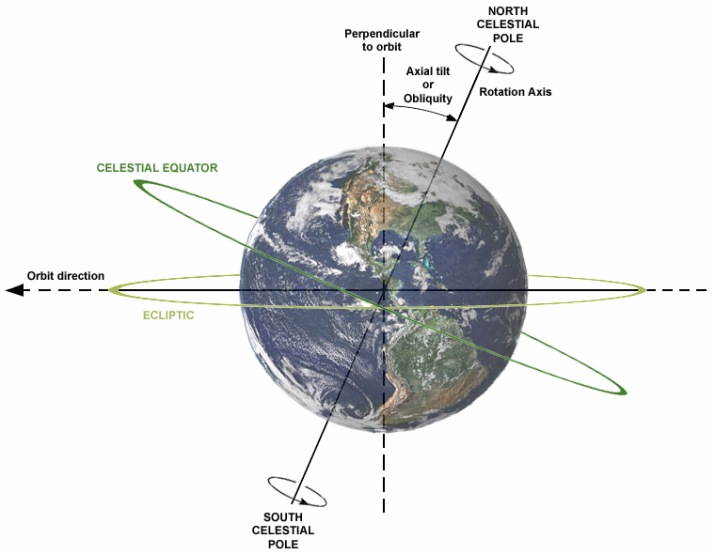


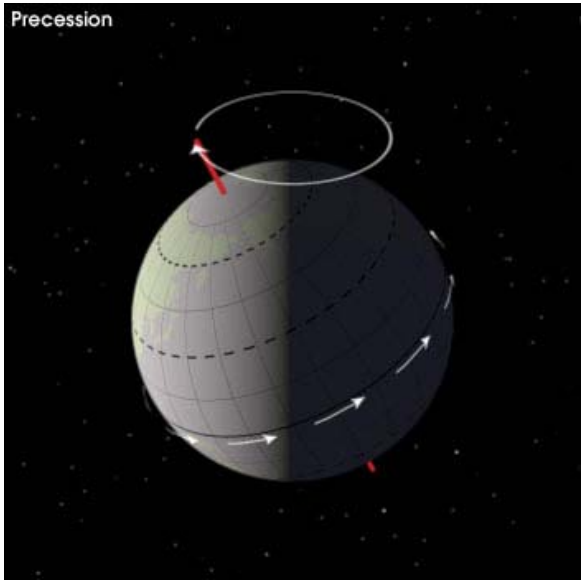


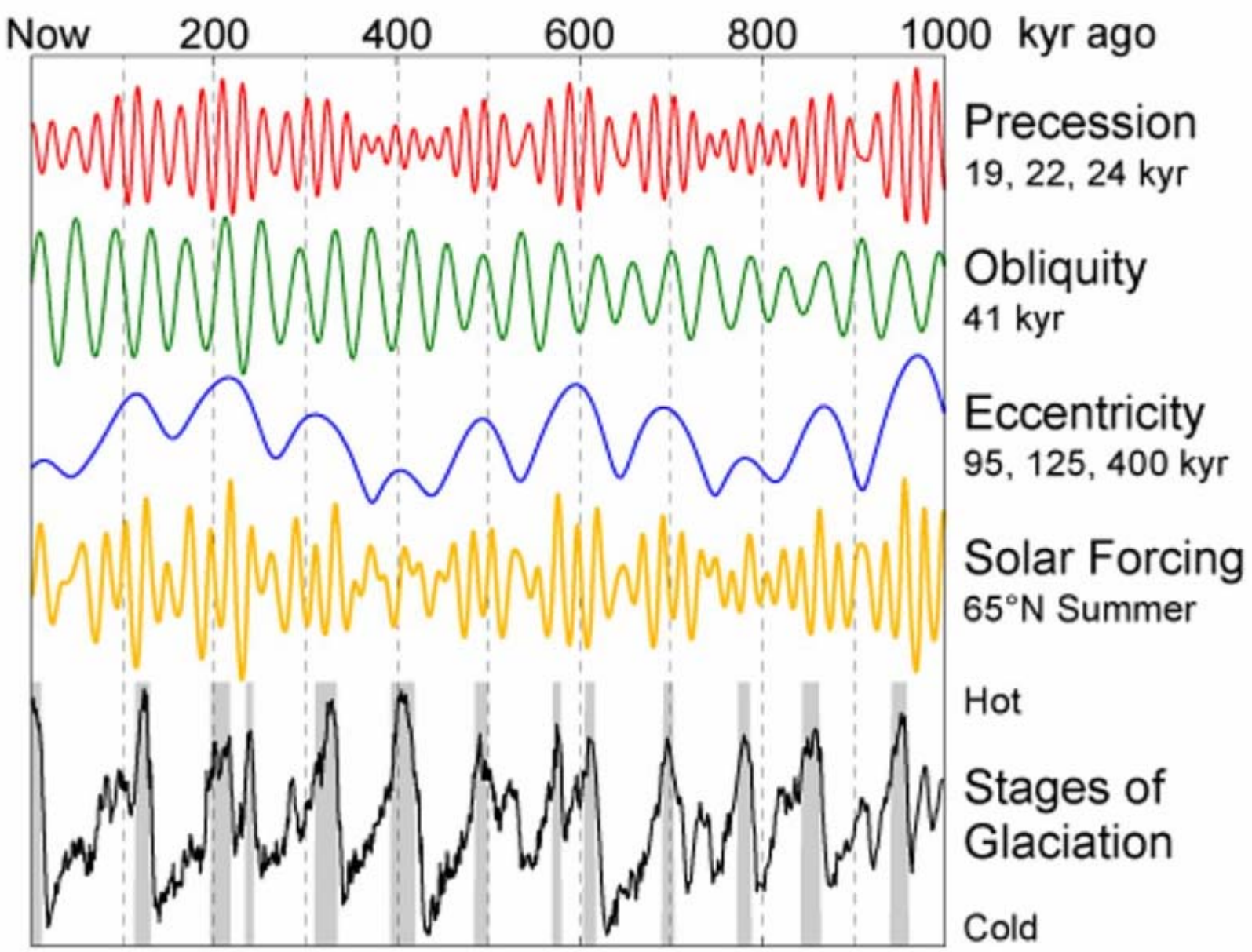
Precession

- Changes in axial precession alter the dates of perihelion and aphelion, and therefore increase the seasonal contrast in one hemisphere and decrease the seasonal contrast in the other hemisphere.
- Has a periodicity of 23,000 years.
- Precession is caused by the gravitational pull of the Sun and the Moon on the Earth.







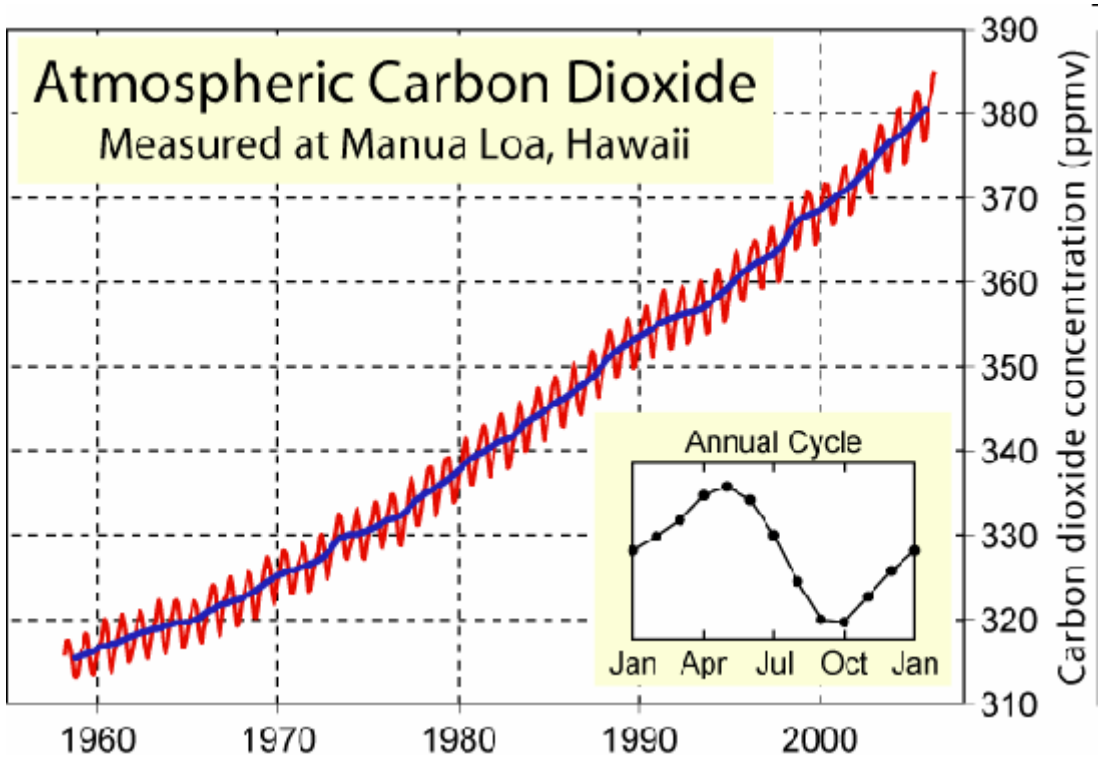

Now
200
400
600
800
1000
kyr ago
Precession
19, 22, 24 kyr
Obliquity
41 kyr
Eccentricity
95, 125, 400 kyr
Solar Forcing
65°N Summer
Hot
Stages of Glaciation
Cold

- 12) Define Eccentricity.
- 13) Eccentricity has a cycle every _____ years.
- 14) Define Precession.
- 15) Precession has a cycle every _____ years.
- 16) Define Obliquity.
- 17) Obliquity has a cycle every _____ years.

10.5) Are we in a solar Maxima or minima right now?

- **Solar maximum** or **solar max** is the period of greatest solar activity in the solar cycle of the sun. During solar maximum, sunspots appear.
- Solar maximum is contrasted with solar minimum. Solar maximum is the period when the sun's magnetic field lines are the most distorted due to the magnetic field on the solar equator rotating at a slightly faster pace than at the solar poles. The sun takes about 11 years to go from one solar maximum to another and 22 years to complete a full cycle.
- The last solar maximum was in 2001, and the next one should be sometime in 2012

18) Historically, carbon dioxide concentrations were about _____ppmv. Today, they are at _____ppmv



Isotopes of Carbon