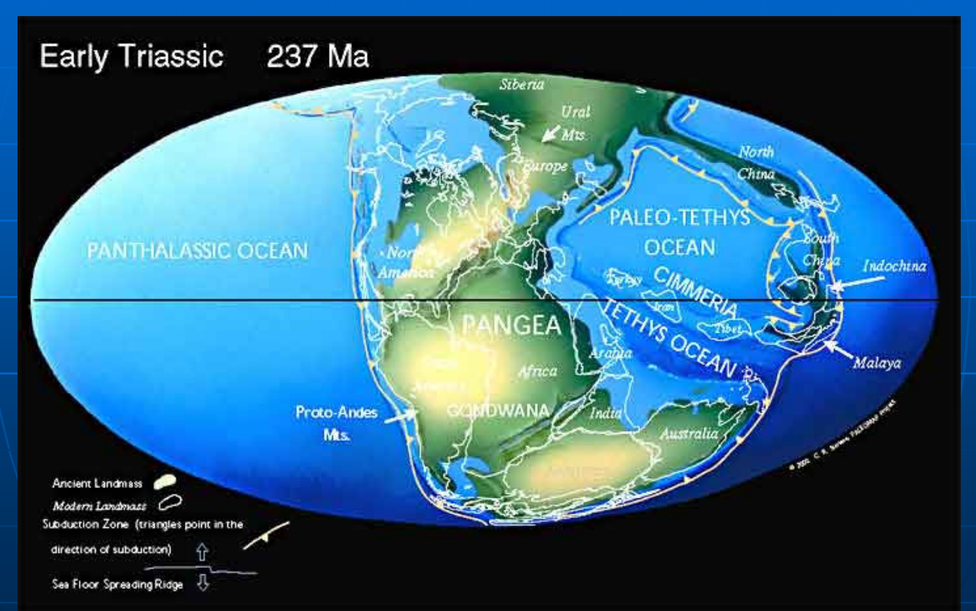
Global Climate Change:
The Natural Controlling Factors

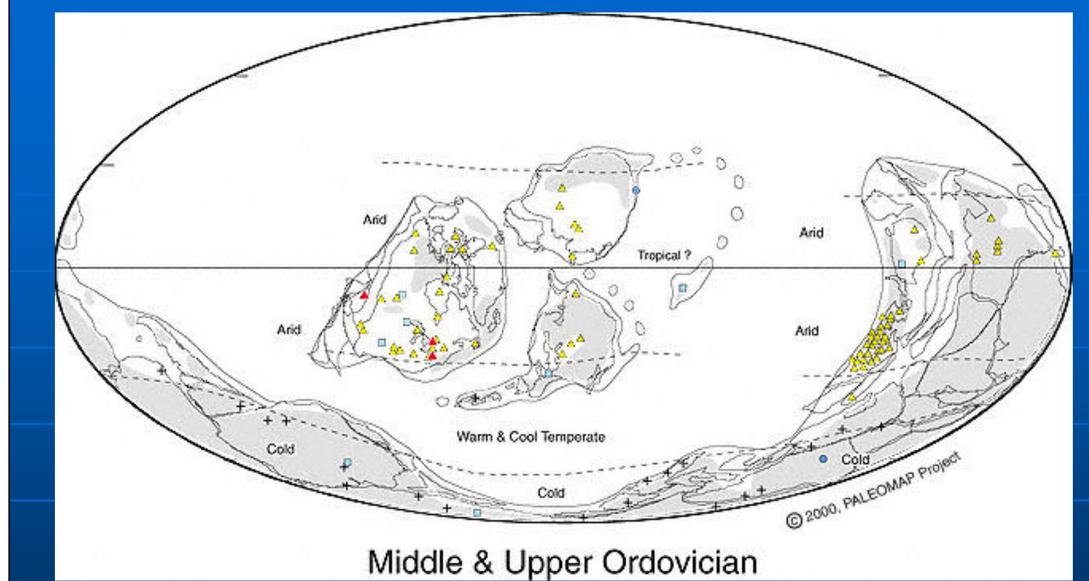
CC 3.32, Lectures 9 and 10

The Controls on Climate

- How much energy reaches Earth?
  - Energy output of the Sun
  - Relationships between Earth and Sun
- How is the heat on Earth redistributed?
  - Movement of energy from the equator to the poles
  - Loss of energy from Earth

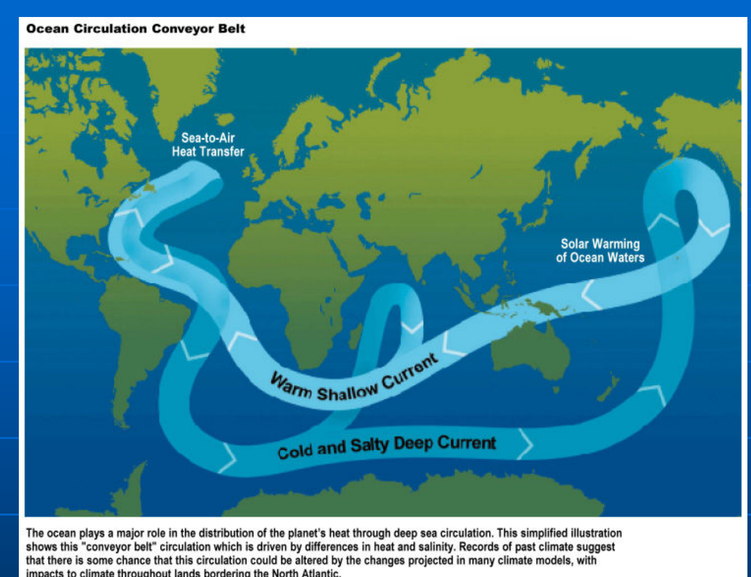
The Earth's surface changes over time…





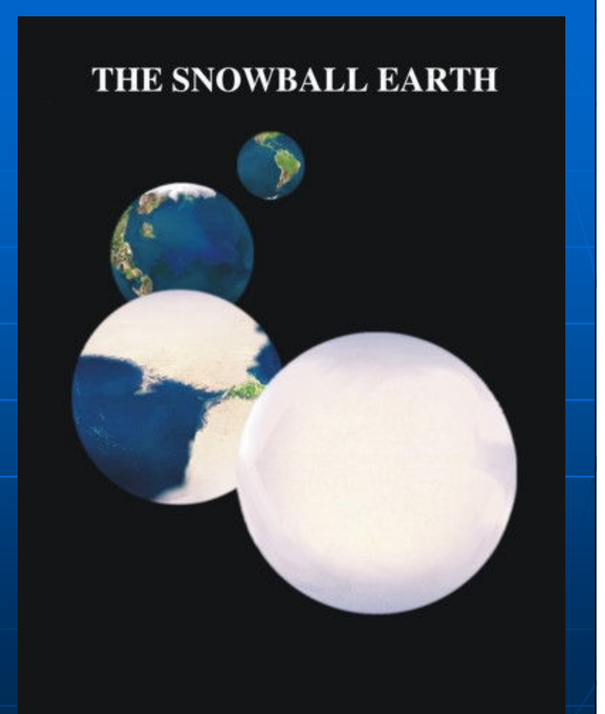
Middle & Upper Ordovician

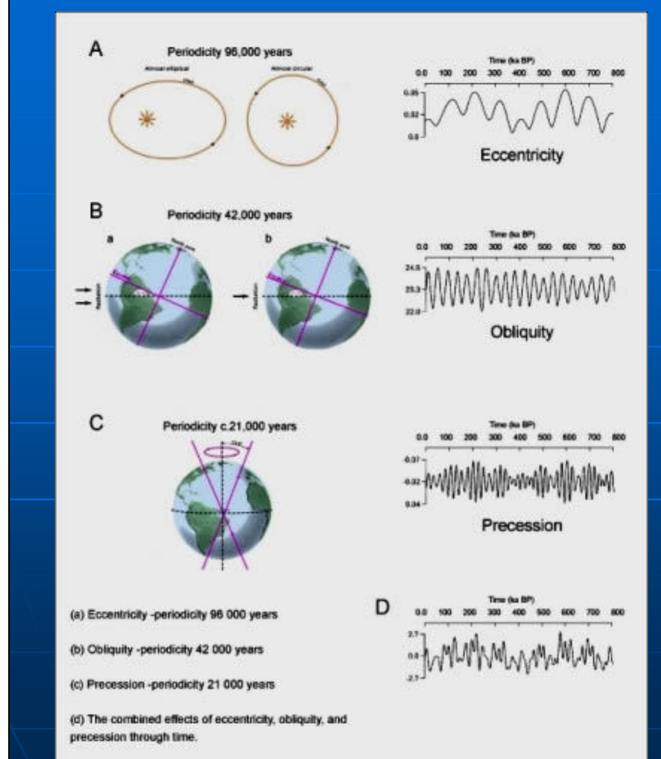
- How much land is at the poles?
  - Land at the poles will allow glaciers to form
  - Glaciers reflect light and so reduce the amount of solar energy heating Earth



- How well can water circulate around the globe?
  - Ocean currents redistribute heat from the equator to the poles
  - If circulation is poor, then temperature will be more extreme

Earth surface variations may explain million-year-scale climate fluctuations

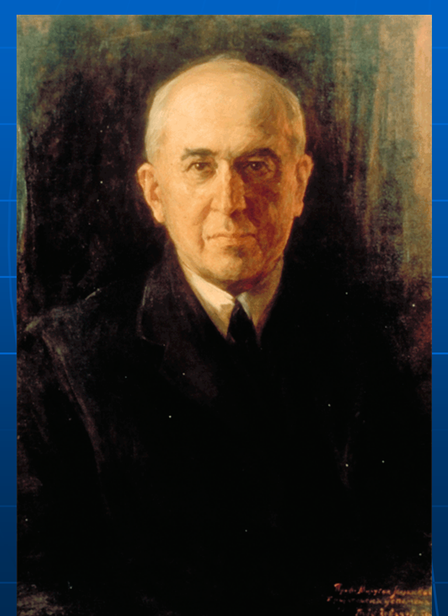




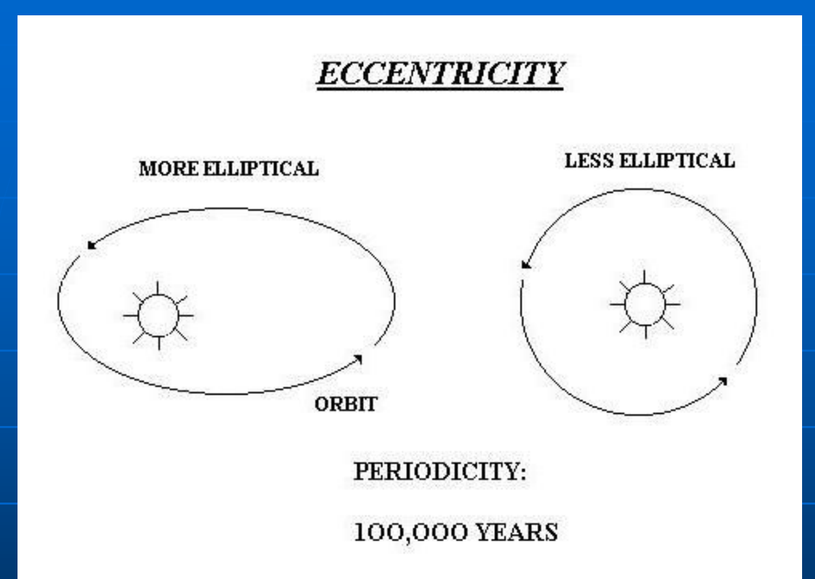
The Earth's orbit changes over time…

…which affects how much solar energy reaches Earth

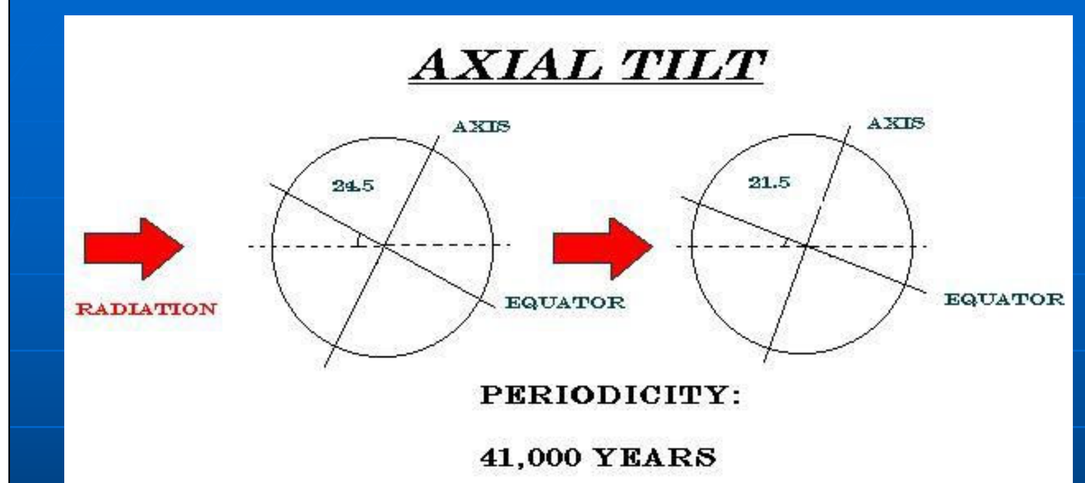
Milankovitch Cycles



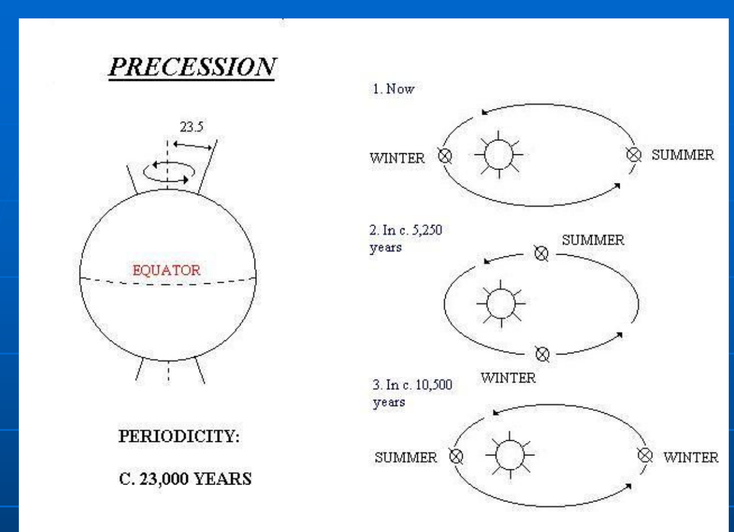
- Milutin Milankovitch was a Serbian mathematician who specialized in astronomy and geophysics
- Milankovitch dedicated his career to developing a mathematical theory of climate based on the seasonal and latitudinal variations of solar radiation received by the earth



- The shape of Earth's orbit varies from circular to slightly elliptical over 100,000 years
- Changes the distance of Earth to the Sun

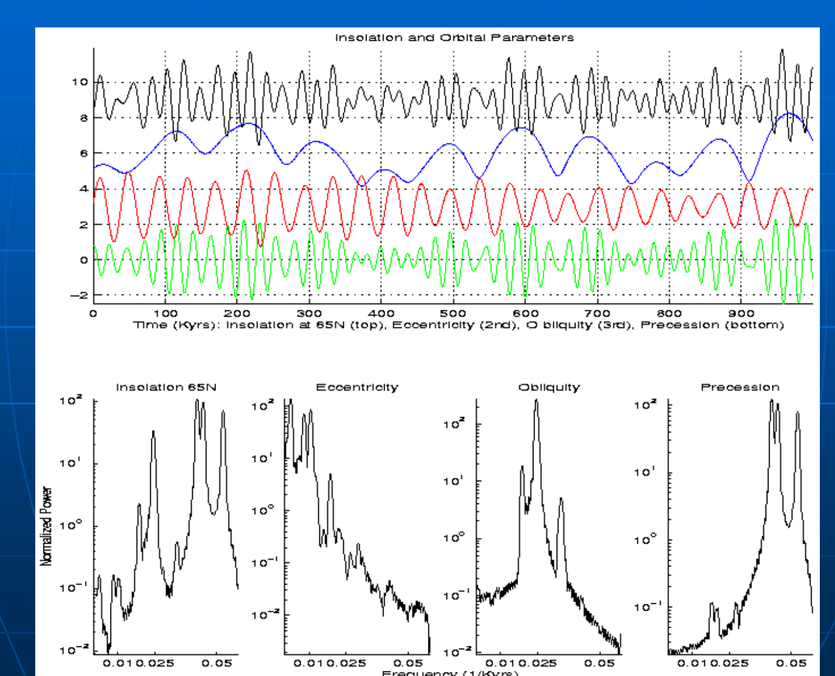


- The tilt of Earth's axis varies from a minimum of 21.5 degrees to a maximum of 24.5 degrees over 41,000 years
- The greater the tilt angle, the more extreme is the difference between seasons

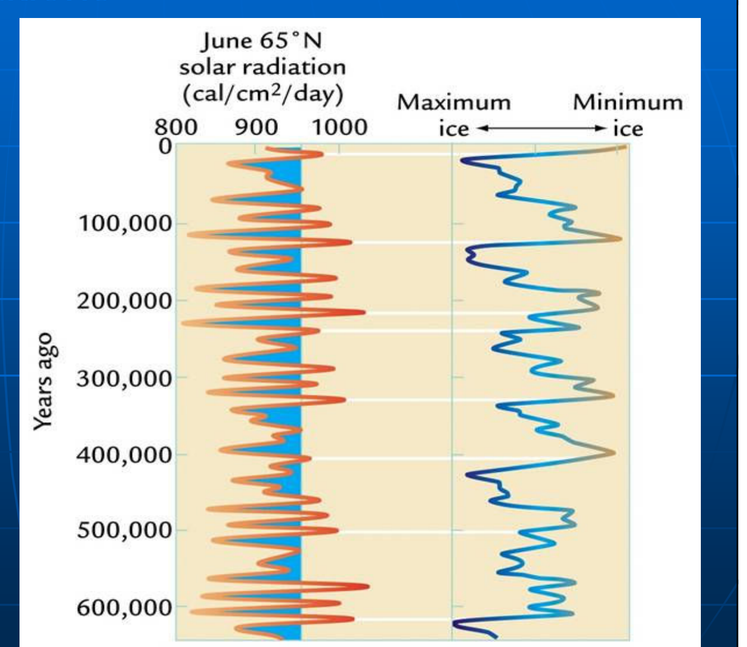


- As it spins, Earth wobbles with a period of 23,000 years
- Can result in greater seasonal extremes

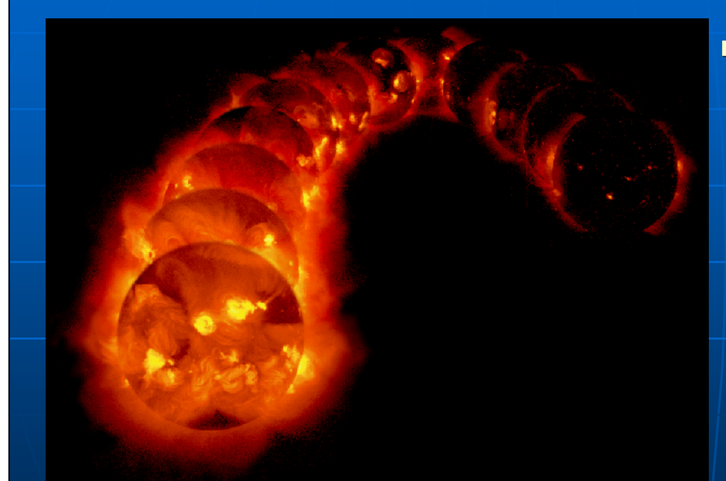
Eccentricity, precession, and tilt variations combine to affect total solar radiation that reaches Earth



Orbital variations may explain millenium-scale climate fluctuations

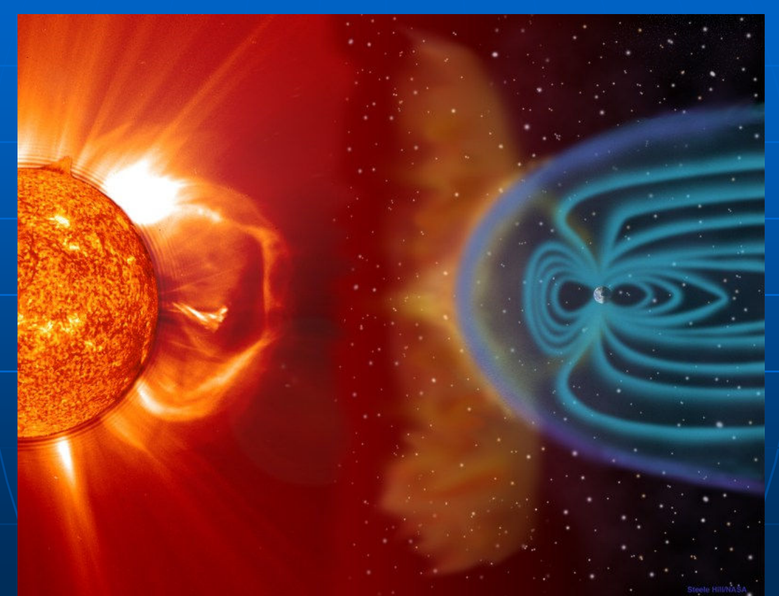


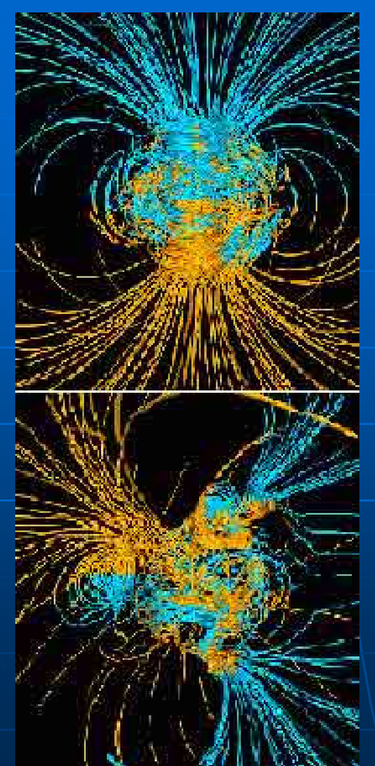
Energy output of the Sun changes over time…



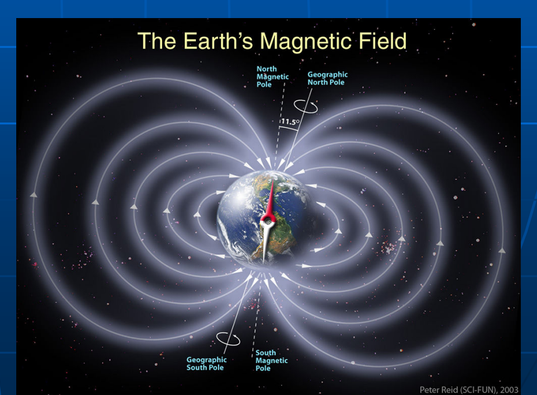
- Photo-mosaic of the Sun
  - X-ray output
  - Every 120 days over 4 years

Both Earth and Sun have magnetic fields



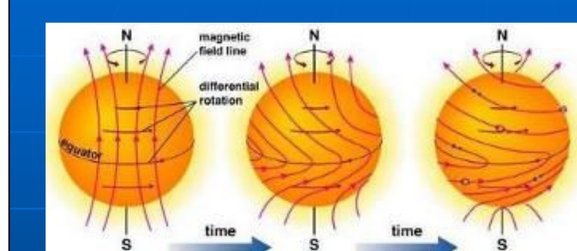


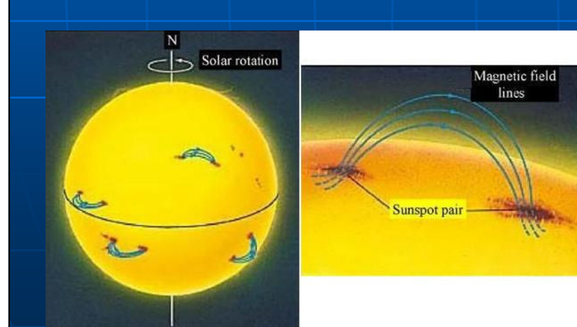
- The polarity of Earth's magnetic field reverses on the order of hundreds of thousands of years



- The polarity of the Sun's magnetic field reverses every 11 years

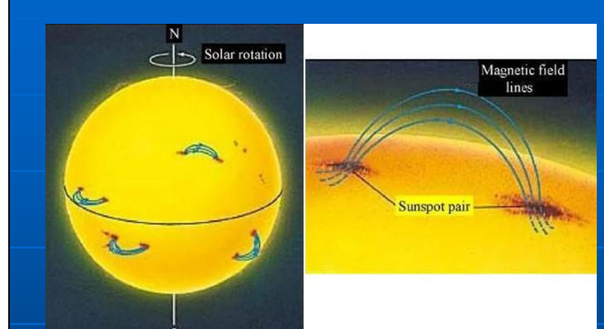
Complex Magnetic Field on the Sun

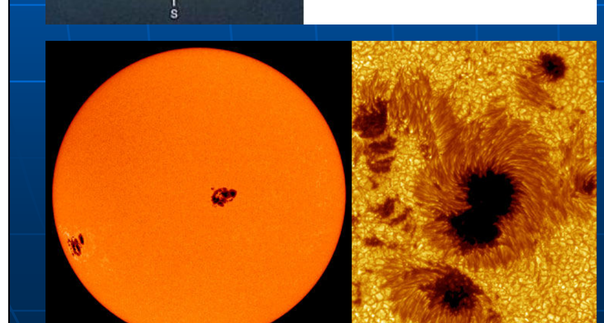




- The surface of the sun spins faster at the equator than at the poles
- Magnetic lines of force are twisted and distorted

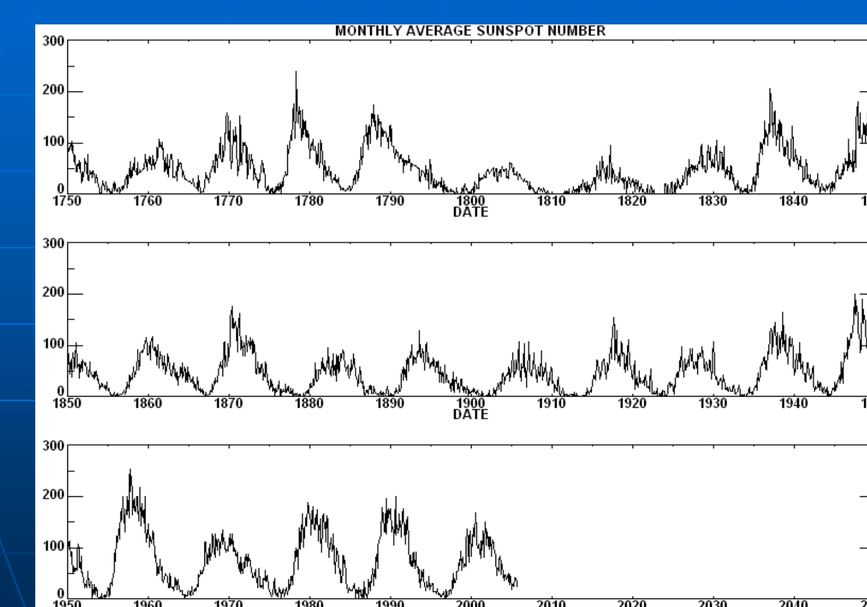
Sunspots



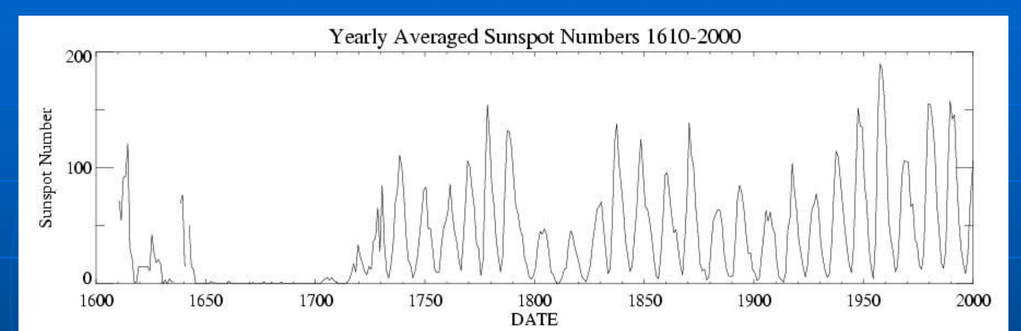


- As the magnetic lines become more distorted they emerge from the surface
- These emergence points are relatively dark, and are called sunspots
- The Sun is brightest when there are more sunspots

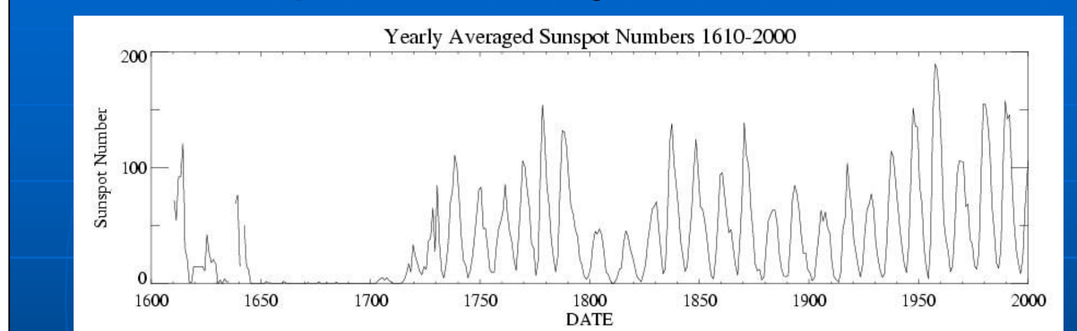
Number of sunspots change over time

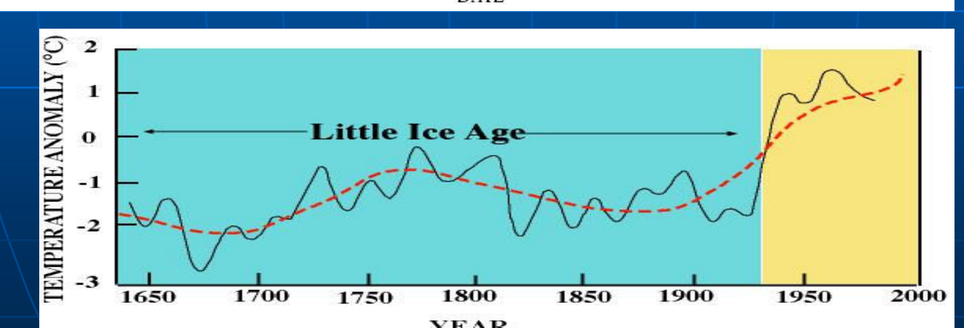


Maunder Minimum



Sunspot Activity and Climate





Solar output may explain decade/century climate fluctuations