

# Earth and Planetary Sciences (ES1101)

(Earth's Climate System)  
(Autumn 2021 by Gaurav Shukla)

**Book:** 1) Understanding Earth by Grotzinger & Jordan (Textbook)  
2) Earth: An introduction to Physical Geology by Tarbuck & Lutgens  
3) The Solid Earth: An introduction to global geophysics by Fowler

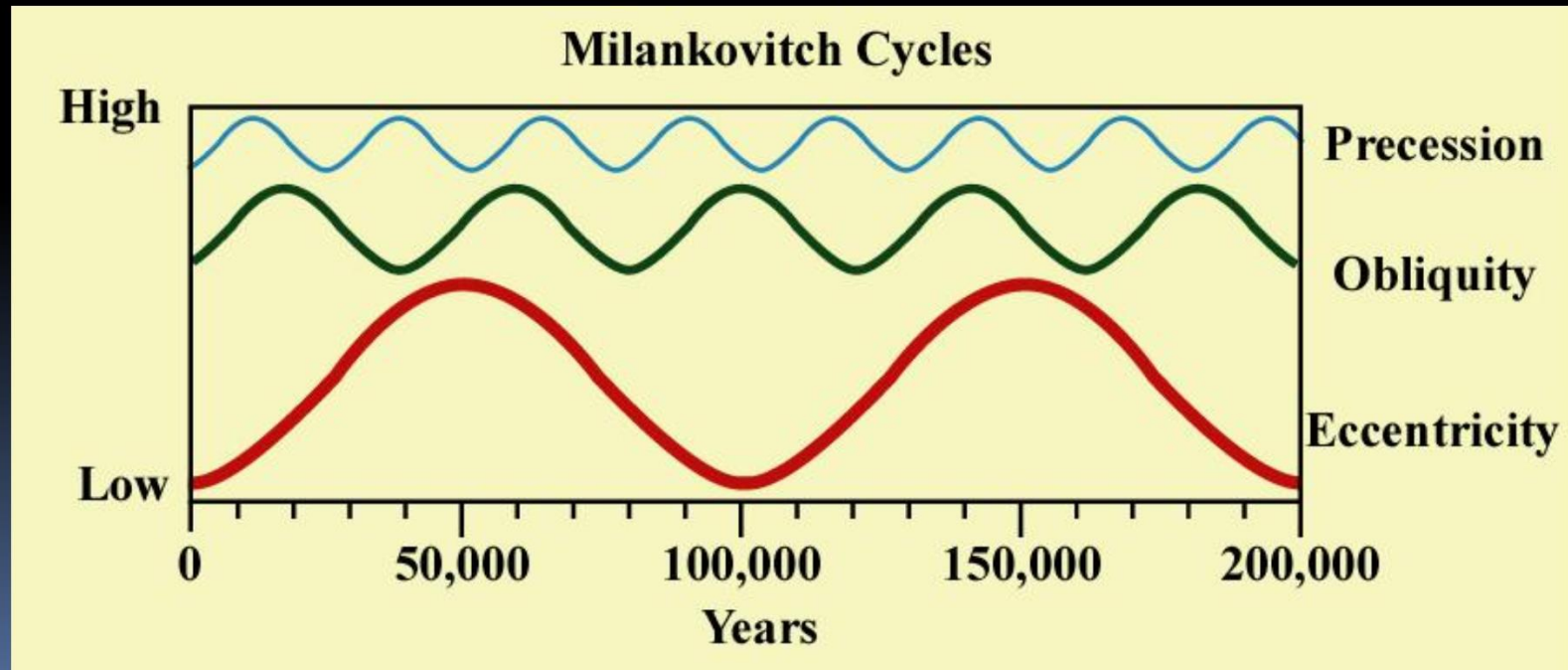
**All three components vary in a cyclical manner.**

**Duration of each cycle:**

**Eccentricity: 100,000 years**

**Obliquity: 40,000 years.**

**Precession: 26,000 years.**



**All three cycles are superimposed and cause variation in the distribution of solar radiation over the seasons.**

**During parts of the cycle:**

**Mild winters, abundant snow and cool summers.**

**Conducive to development of glaciers.**

**Cold, dry winters, hot summers.**

**Glaciers will not develop.**

**The 100,000 year cycle of eccentricity has the greatest effect and corresponds to continental glaciations.**

# Natural Causes of Climate Change

- Volcanic eruptions
- Volcanic ejecta may block sunlight
- Need many eruptions in short time period
- Not observed in recent history



**Factors that indirectly control climatic variations from internal re-organizations are also known as NON-RADIATIVE FORCING**

# Natural Causes of Climate Change

- Movement of Earth's Plates
  - ▣ Change ocean circulation
  - ▣ Extremely slow process
  - ▣ Climate change would be very gradual over millions of years

**Plate tectonics can affect climate because:**

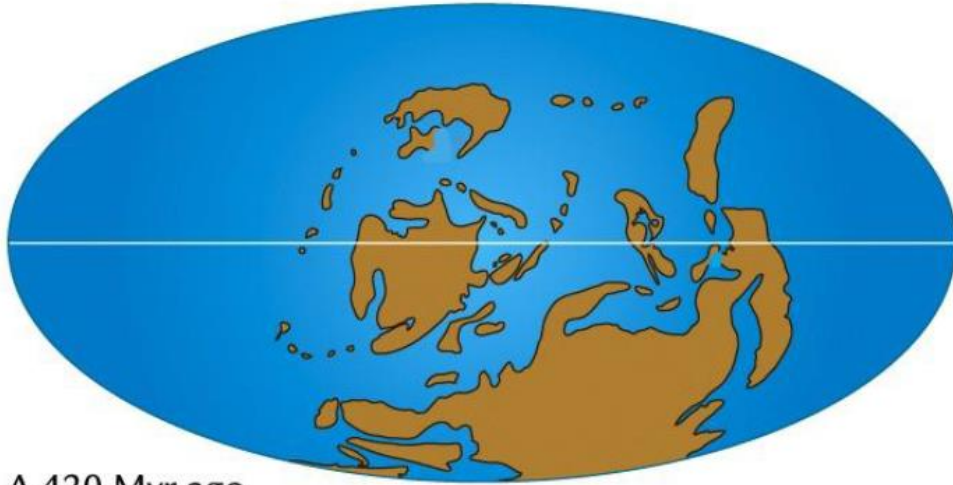
**(1) Continents can change position  
This strongly affects ocean currents.**

**(2) It controls the rate of volcanism  
(high when plates moving fast, low otherwise).**

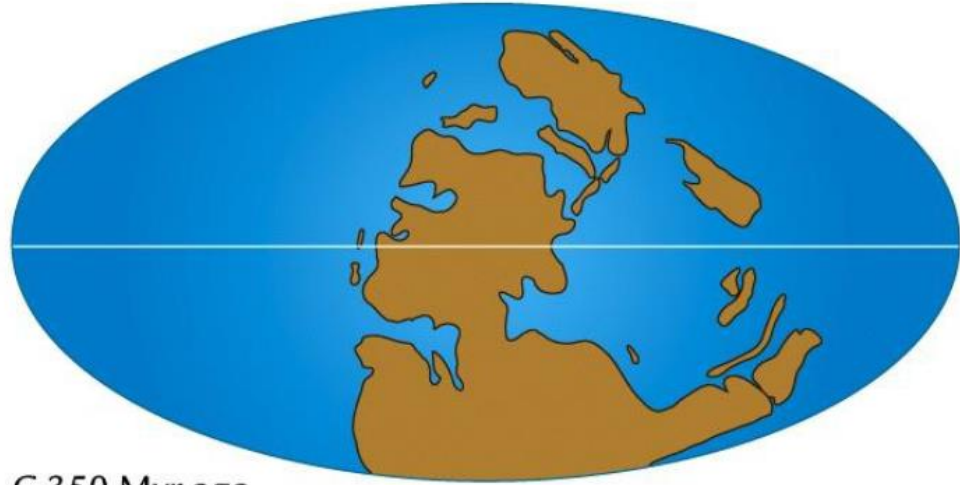
**(3) It controls the rate of weathering  
(high when more continents collide and  
more mountains formed).**



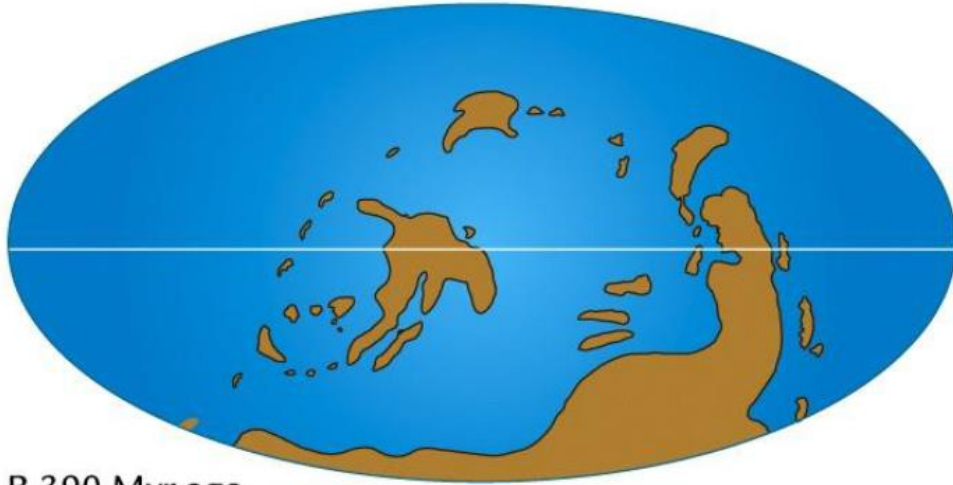
## Changing continent positions: Assembly of supercontinent Pangaea



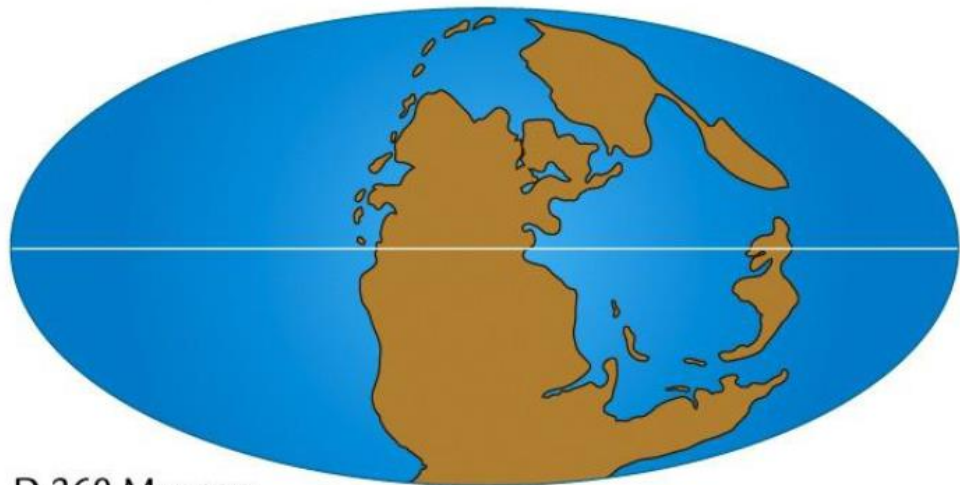
A 420 Myr ago



C 350 Myr ago

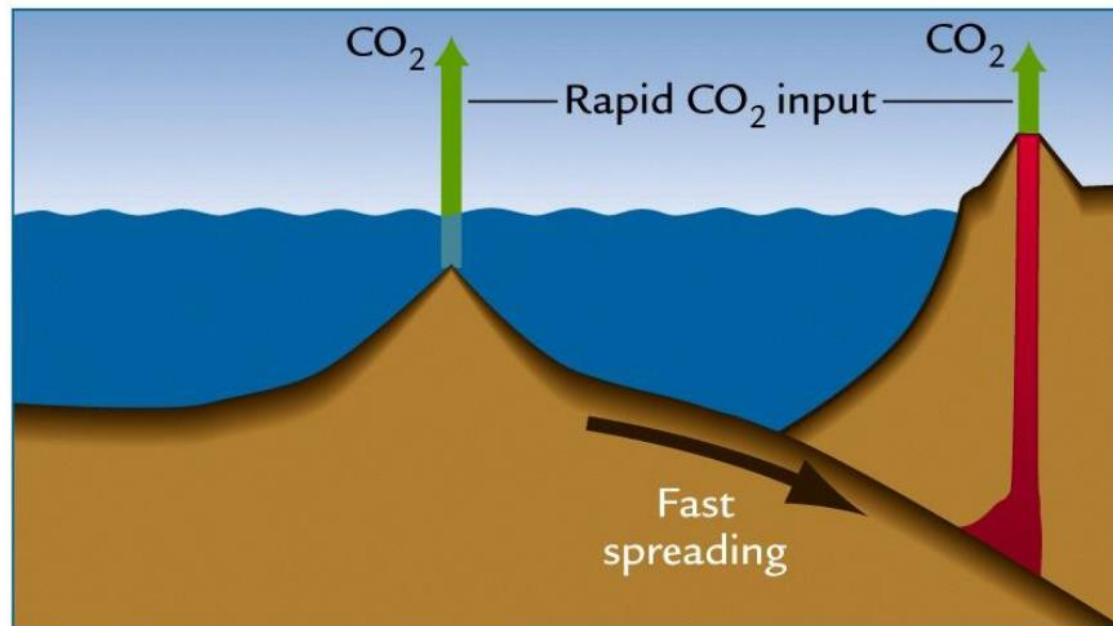


B 390 Myr ago

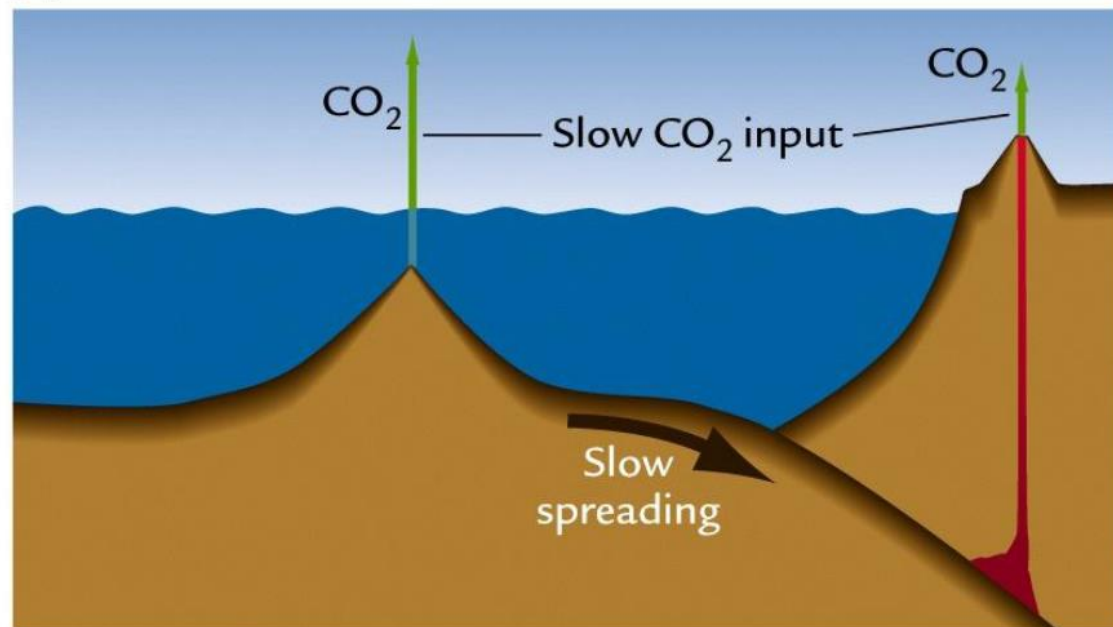


D 260 Myr ago

## Rate of volcanism



A





## Chemical weathering (hydrolysis):



-- removes  $\text{CO}_2$  from atmosphere, puts it in limestone (or carbonate) rock

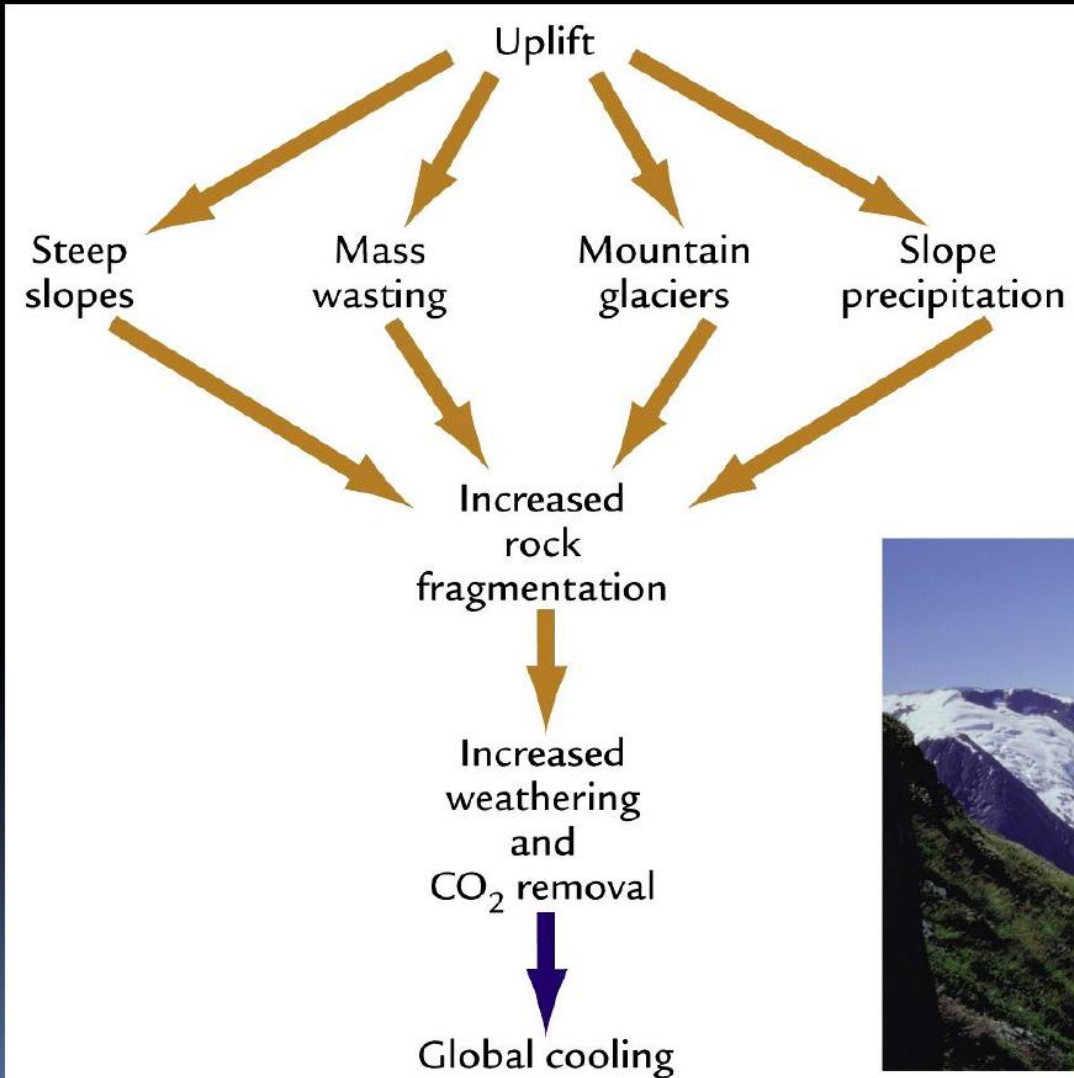
-- proceeds faster if more precipitation, higher temperature, more vegetation

## Chemical weathering (hydrolysis):

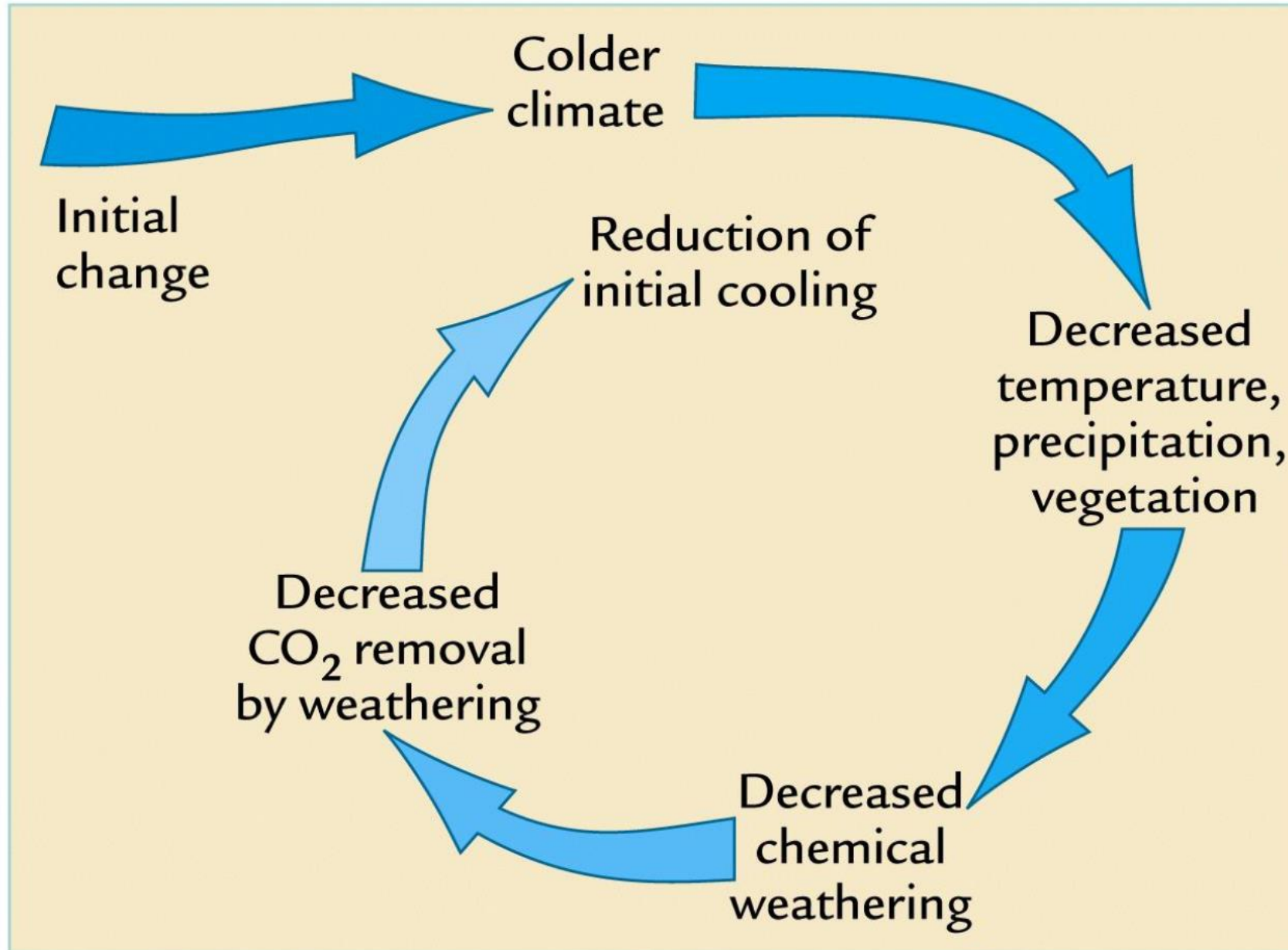


Makes carbonic acid  $\text{H}_2\text{CO}_3$

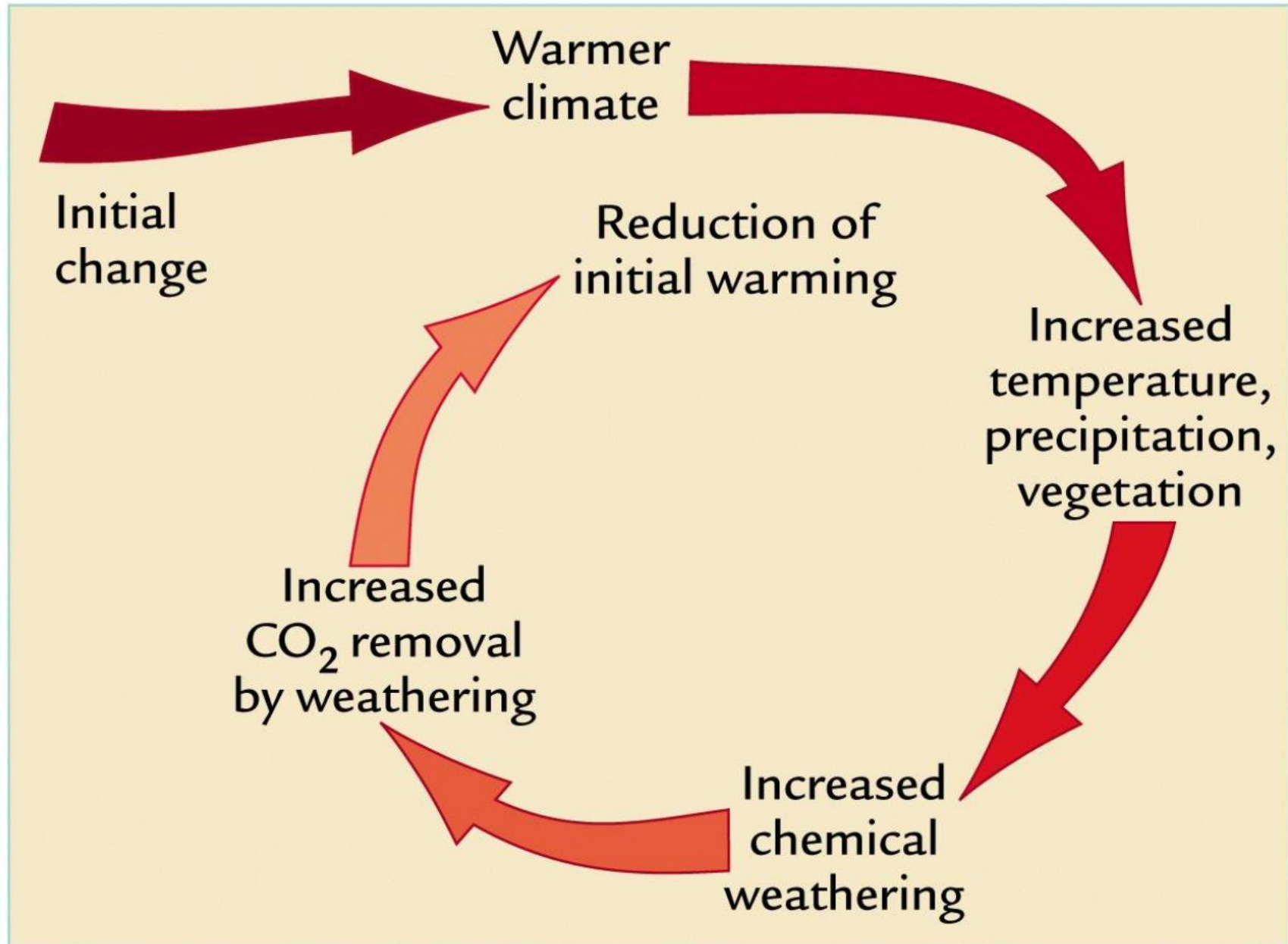
## Changes in amount of uplift of continental rock could regulate amount of weathering



## Temperature - weathering feedback:



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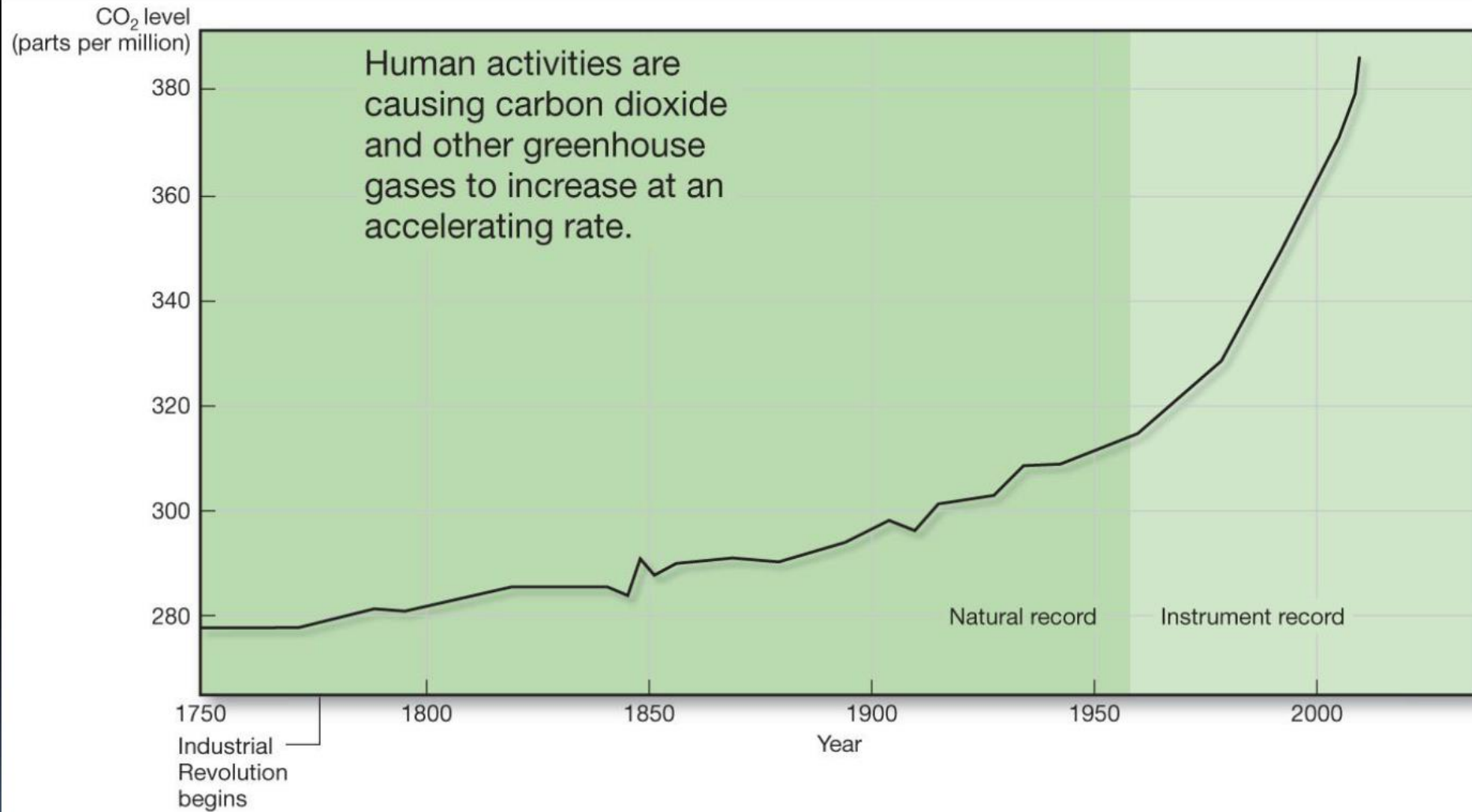




# Greenhouse Gases

- **Water vapor**
  - Most important
  - 66–85% of greenhouse effect
- **Carbon dioxide**
  - Natural part of atmosphere
  - Greatest relative contribution from human activities
  - Burning of *fossil fuels*

# Atmospheric Carbon Dioxide

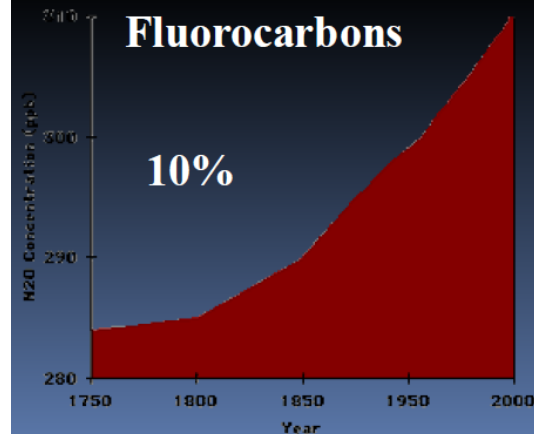
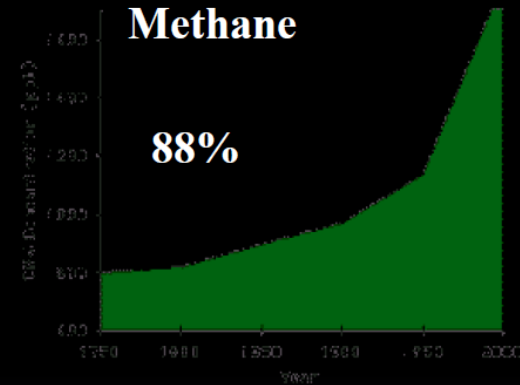
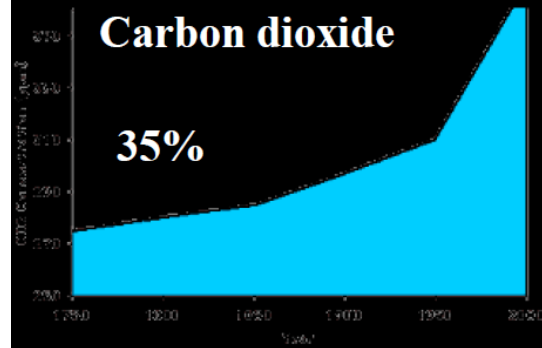


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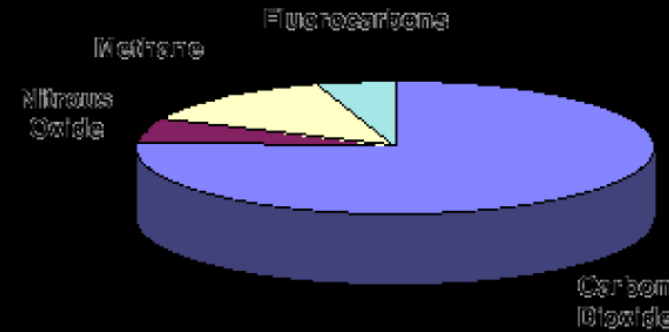
# Greenhouse Gases

- **Methane**
  - Second most abundant human-caused greenhouse gas
  - Great warming power per molecule
  - Landfill decomposition
  - Cattle
- Other trace gases
  - **Nitrous oxide, CFCs, ozone**

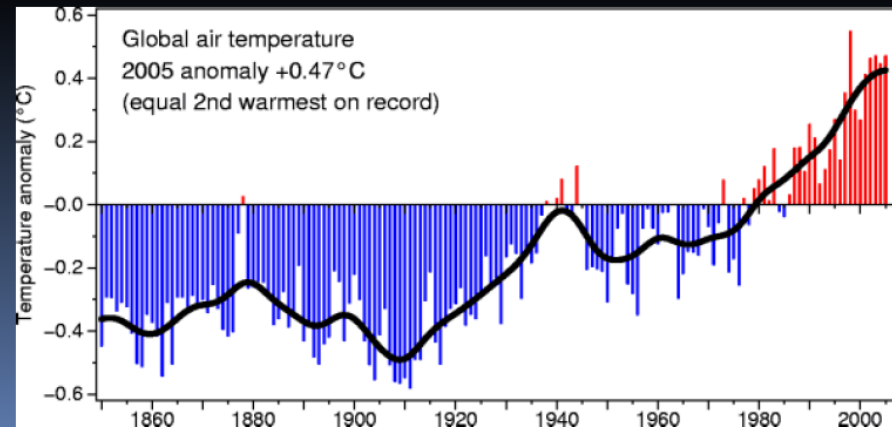
# Why has Earth's temperature been increasing?



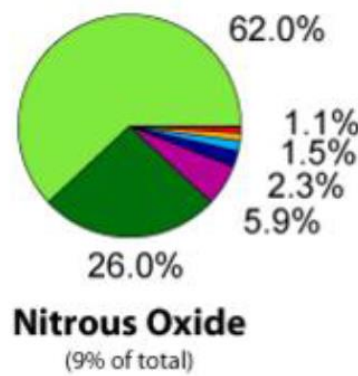
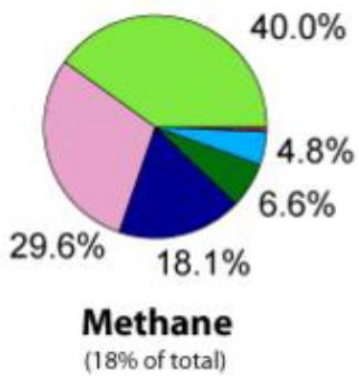
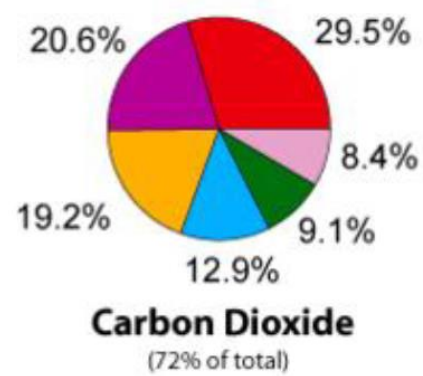
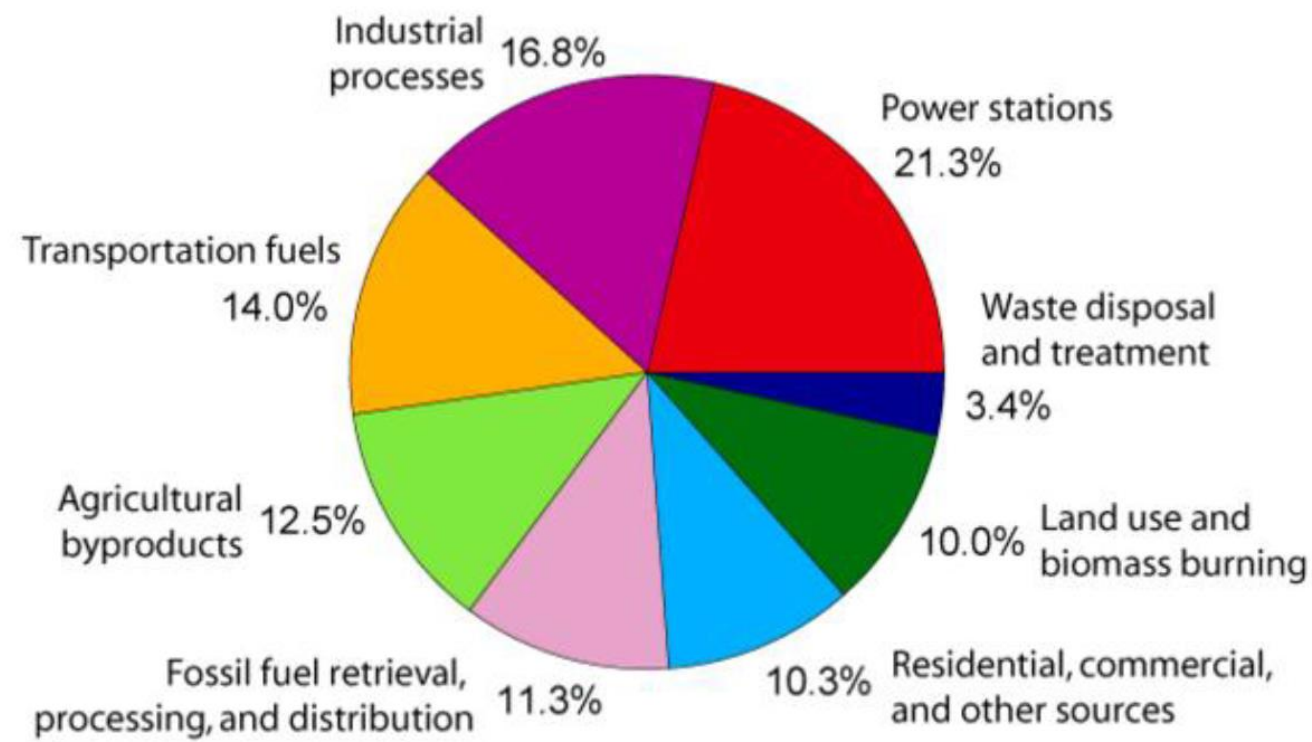
Proportion of Greenhouse Gases (GHG) in the atmosphere.



Rising GHG concentrations correspond reasonably well with rising temperatures.



# Annual Greenhouse Gas Emissions by Sector

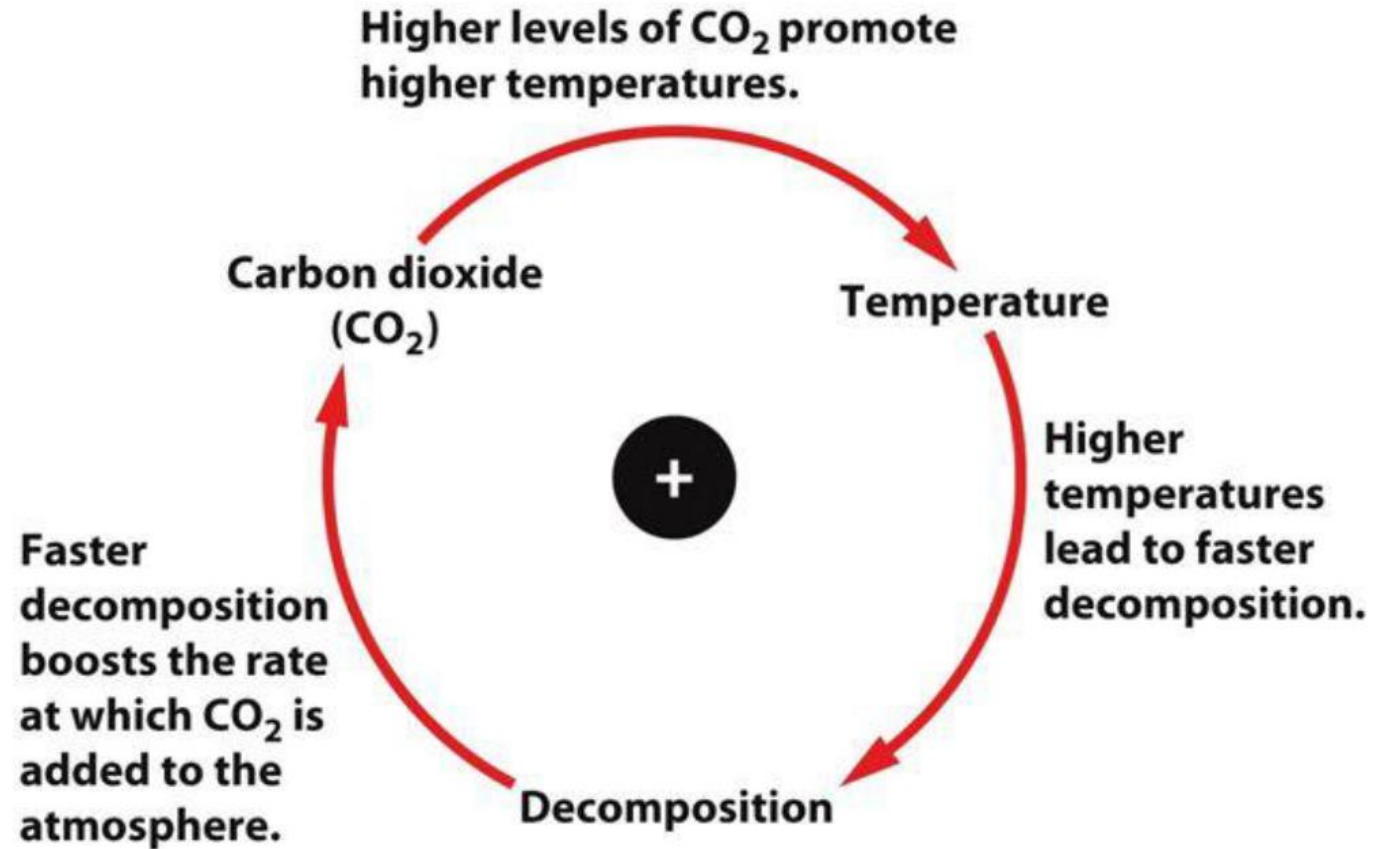




# Earth's Climate System

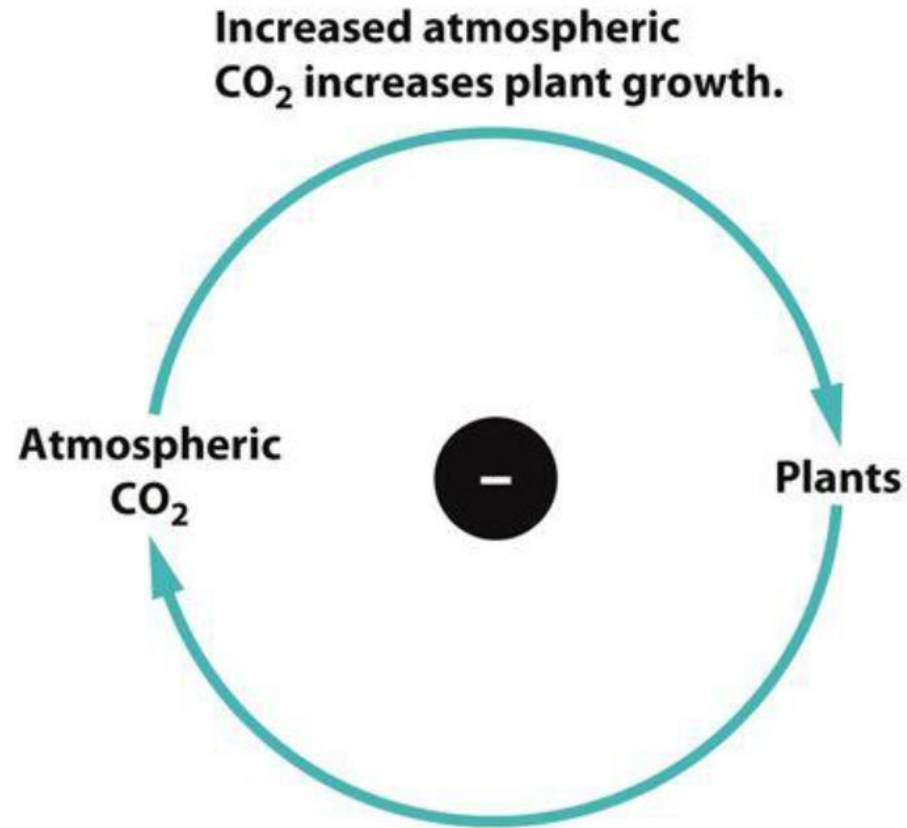
- **Feedback loops** – modify atmospheric processes
  - Positive feedback loops – enhance initial change
  - Negative feedback loops – counteract initial change

# Positive Feedback Loop



## Positive feedback system

# Negative Feedback Loop



Increased plant growth increases uptake of  $\text{CO}_2$  from the atmosphere, thereby decreasing the amount of  $\text{CO}_2$  in the atmosphere.

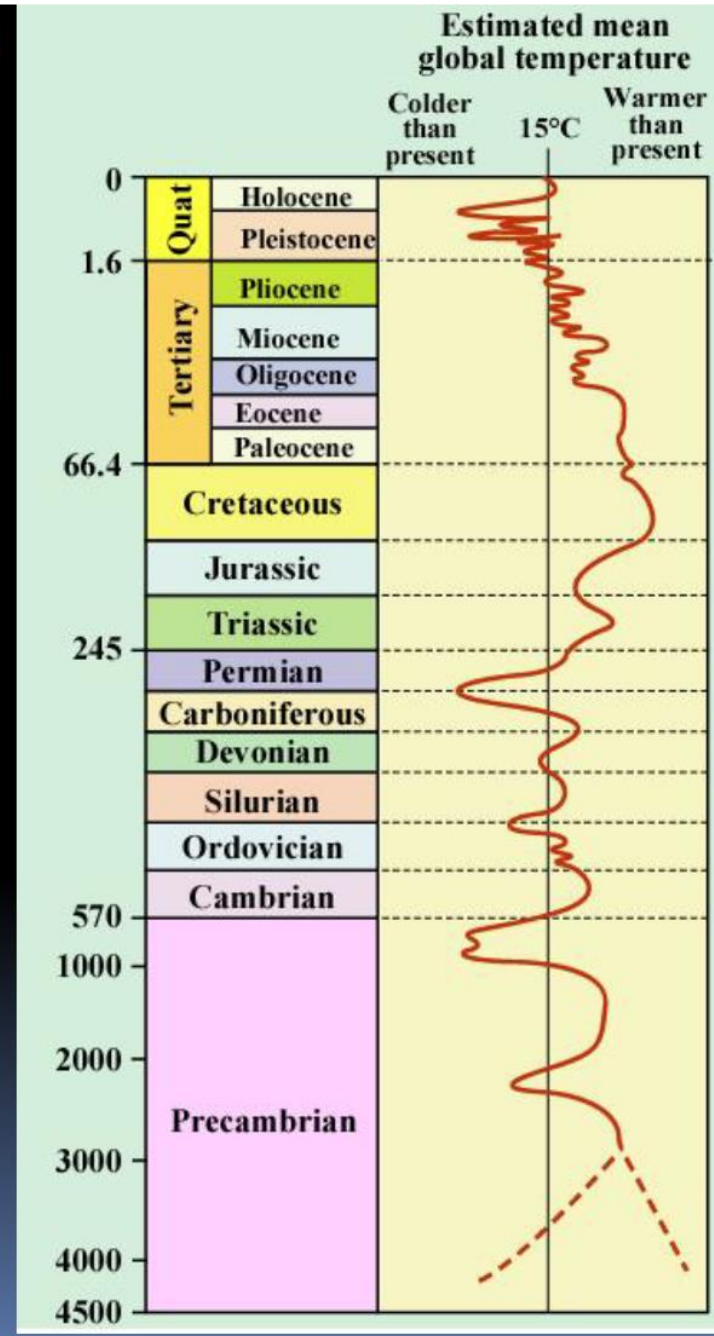
**Negative feedback system**

# Climate Change Over Geologic Time

**Tertiary and Quaternary periods have experienced wide fluctuations over relatively short spans of time with overall cooling towards the present.**

**The Quaternary is characterized by repeated continental glaciation.**

**The Cretaceous Period was the warmest time in all of geological history (average global temperature is estimated to have been 20 degrees C).**



# Snowball Earth

- Several times in the history of the Earth, icesheets covered the entire Earth, the last one is in Plietocene
- Favorable conditions for snowball Earth: low latitude cluster of continents (increasing albedo), reduced incoming solar radiation, low CO<sub>2</sub> partial pressure (probably due to enhanced weathering and hence enhanced withdrawal of CO<sub>2</sub>)
- $\delta^{18}\text{O}$  in sediments is a measure of ambient temperature

$\delta^{18}\text{O} = 18\text{O}/16\text{O}$  relative to a standard