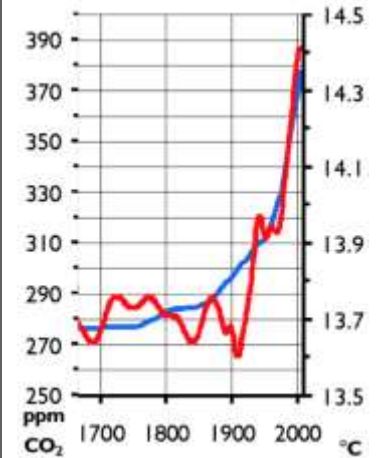


# Ecosystems Unit

Week 2 – How do imbalances cause ecosystem disturbances?

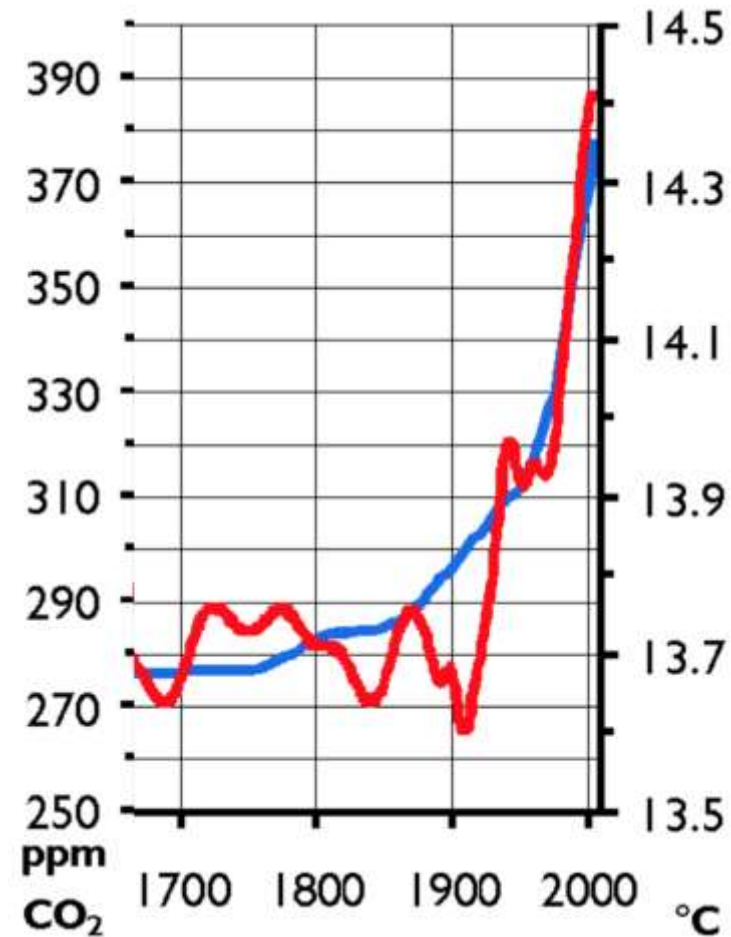


Waterford Biology

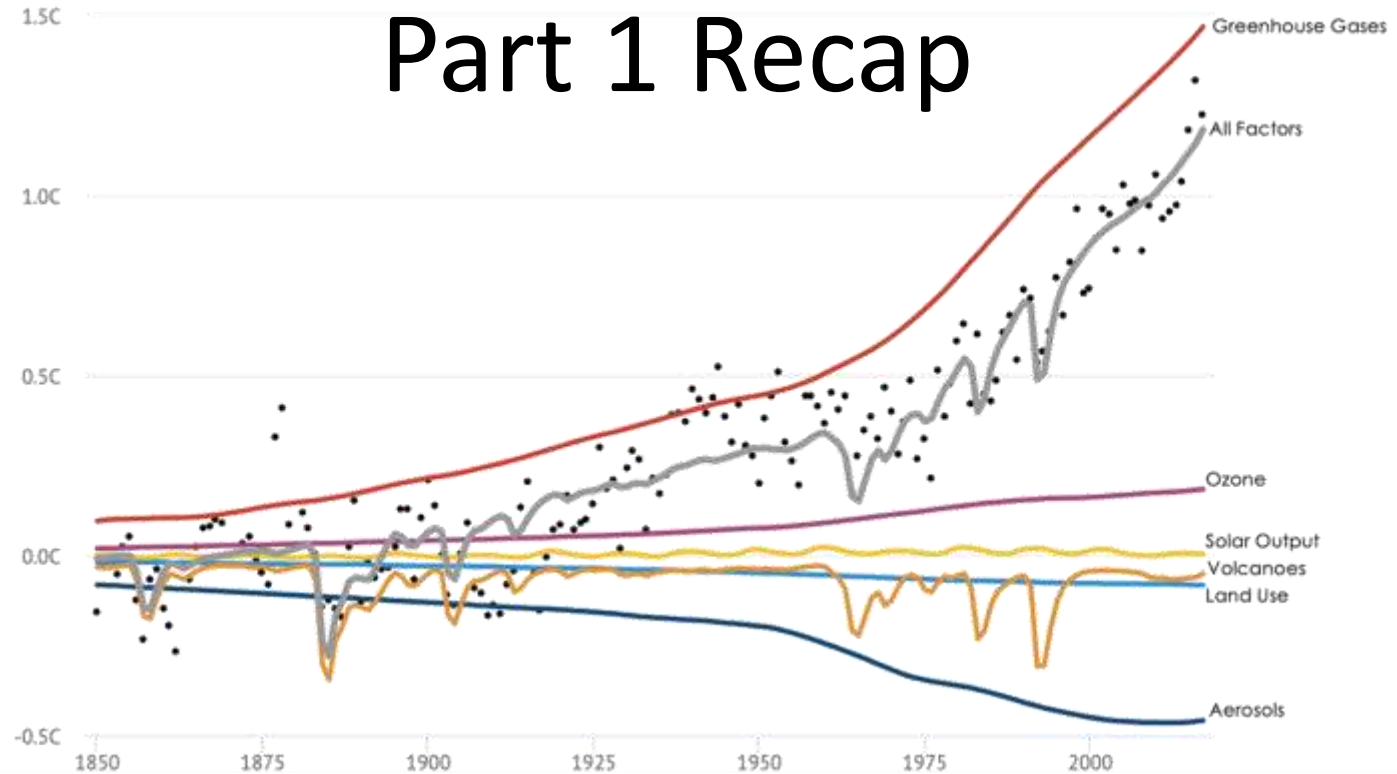
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# Ecosystems Unit – W2 Driving Question

- How do imbalances in matter and energy cause ecosystem disturbances?
- How do ecosystems enable matter movement and energy transformation?
- How do imbalances in matter and energy occur?
- What happens when matter and energy are unbalanced?
- How does human activity relate to these kinds of disturbances?



# Part 1 Recap



- Earlier we investigated how carbon dioxide and temperature are related.
- We determined that there is a correlation between levels of CO<sub>2</sub> and changes in temperature.
- We also observed that increases in average temperatures correlate with increases in carbon dioxide since the Industrial Revolution.

# Recap of Week 1

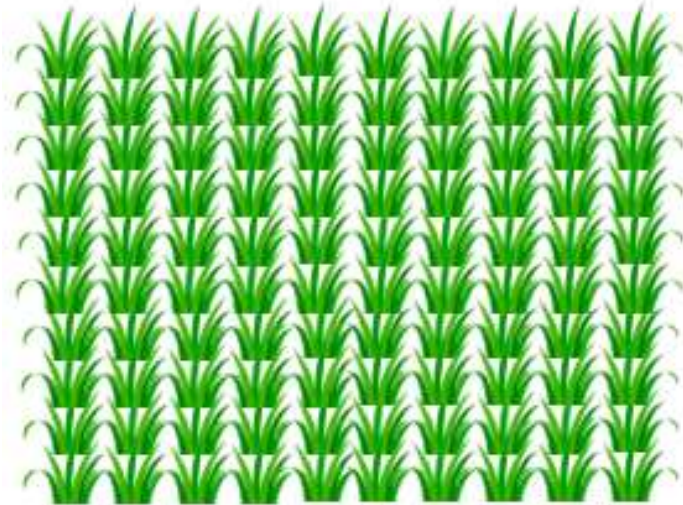
- **Ecosystems are the interactions between organisms and the non-living aspects of their environment.**
- **Rates of photosynthesis and the 10% Rule determine the carrying capacities of ecosystems.**
  - Warmer, wetter, sunnier environments can support greater rates of photosynthesis.
  - More plant biomass production supports greater amounts of consumers like animals.
  - Carrying capacity = number of species a habitat can support.
  - A disturbance is anything that interferes with the movement of matter and the flow of energy.



One unit of wolf biomass...



...would require 10 units of moose biomass, which requires...



...100 units of plant biomass.



# **MATTER & ENERGY IMBALANCES AND ECOSYSTEM DISTURBANCES**

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# Imbalances = Disturbances

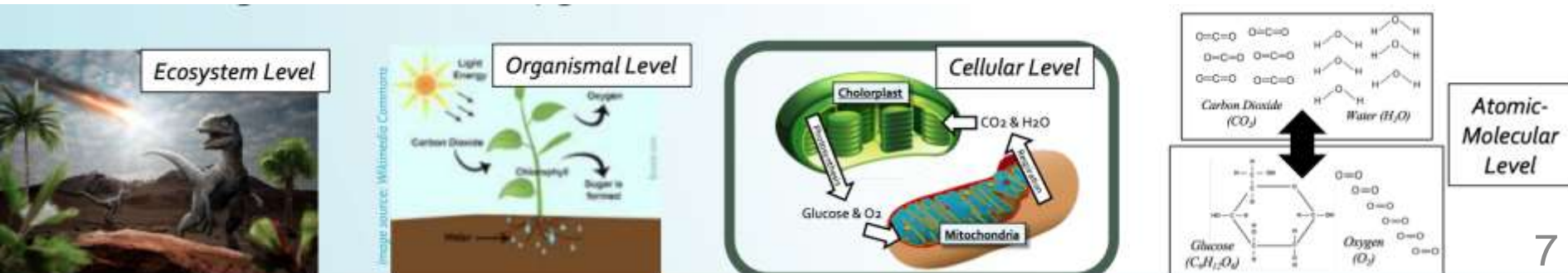
- **Disturbances reduce the carrying capacity of ecosystems by disrupting the matter movement and energy transformation.**
  - For example, an asteroid strike caused the extinction of the dinosaurs by reducing rates of photosynthesis.
  - The asteroid strike released large clouds of dust into the atmosphere, reducing the amount of light available for photosynthesis.
  - This reduced the rate of plant biomass production, reducing carrying capacities and causing widespread extinction.



Image Source: [Pixabay](https://pixabay.com/)

# Changes Across 4 Levels

- The effects of an asteroid hitting earth resulted in the extinction of 80% of species due to changes at four levels.
  - The asteroid created large clouds of dust that blocked out sunlight (*ecosystem level*).
  - This affected individual plants (*organismal level*) because it interrupted their ability to photosynthesize (*cellular level*).
  - This reduced the production of glucose and O<sub>2</sub> from CO<sub>2</sub> and H<sub>2</sub>O molecules (*atomic-molecular level*).
- Reductions in rates of photosynthesis reduced the production of plant biomass, reducing ecosystem carrying capacities.



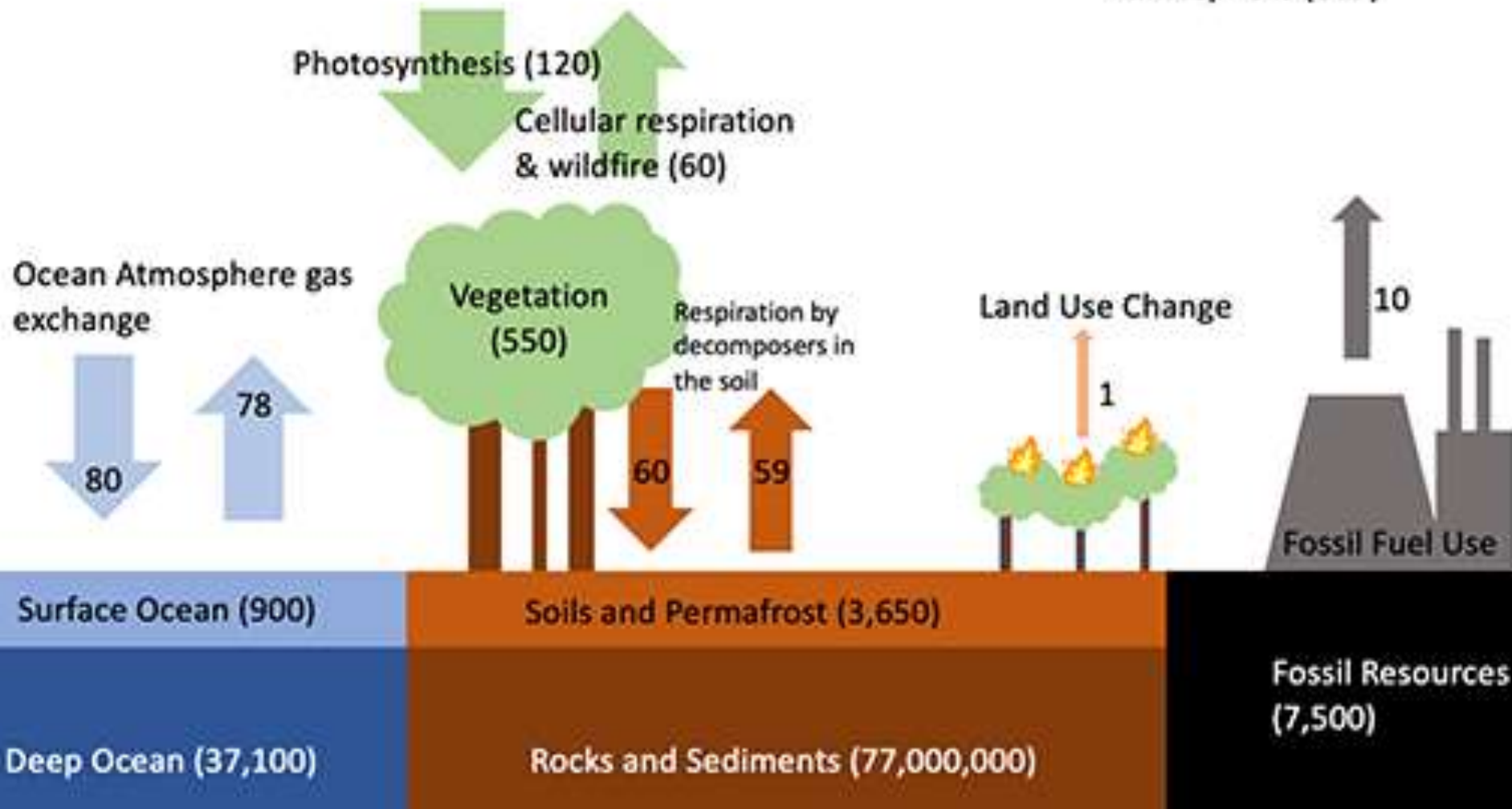
# Imbalances = Disturbances

- **Disturbances can also occur if rates of cell respiration, decomposition, or combustion increase relative to rates of photosynthesis.**
  - This causes biomass to be converted into  $\text{CO}_2$  and  $\text{H}_2\text{O}$  faster than it can be reabsorbed.
- **Currently, the rate of  $\text{CO}_2$  emissions exceeds the amount absorbed through photosynthesis.**
  - This is primarily due to widespread fossil fuel combustion since the start of the Industrial Revolution in the mid-1800s.



*Source: Wikipedia*





This shows the movement of carbon atoms as a result of photosynthesis, respiration, decomposition, and combustion (as well as passive movement into/out of oceans). The movement of carbon atoms is mostly balanced, but combustion of fossil fuels creates imbalances. As a result, more carbon atoms move into the atmosphere as CO<sub>2</sub> than can be absorbed in photosynthesis.

# CO<sub>2</sub> = Temp Regulator

- **CO<sub>2</sub> plays a major role in regulating the earth's surface temperatures.**
  - Case in point: both the earth and the moon are roughly the same distance from the sun but have very different surface temperatures.
  - The moon ranges from -300° F to 225° F due to a lack of gases like CO<sub>2</sub>.
- **Gases like CO<sub>2</sub> slow the loss of heat.**
  - This moderates the earth's surface temperatures within a range that allows life to exist.

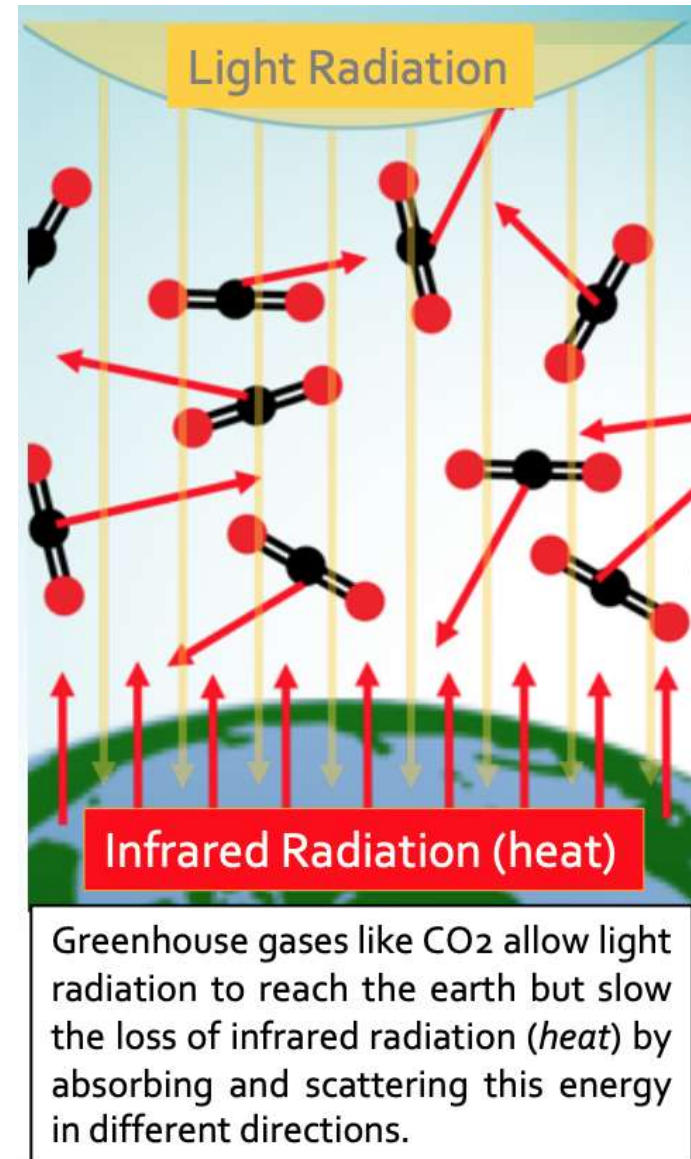
Image Source: [Pixabay](#)



Due to its small size, the moon lacks an atmosphere with CO<sub>2</sub>. As a result, temps on the moon fluctuate between -300° – 225° F

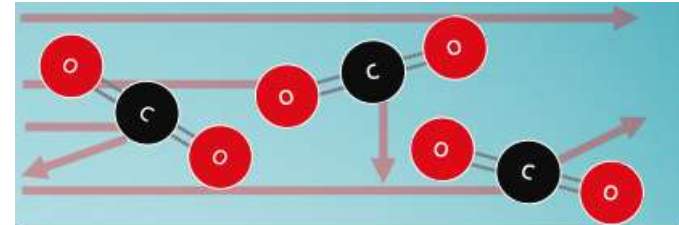
# Greenhouse Gases (GHG's)

- Greenhouse gases (GHG's) like  $\text{CO}_2$  allow light to reach the surface of the earth but slow the loss of heat energy (a condition known as the greenhouse effect).
  - This is also why a car's interior warms up on a sunny day – *light can enter through glass more easily than heat can escape.*
  - While the greenhouse effect is needed to support life, excess GHG's are problematic (like wearing a winter jacket in July).
  - While  $\text{CO}_2$  is only a small proportion of the earth's atmosphere, it is the most abundant greenhouse gas.

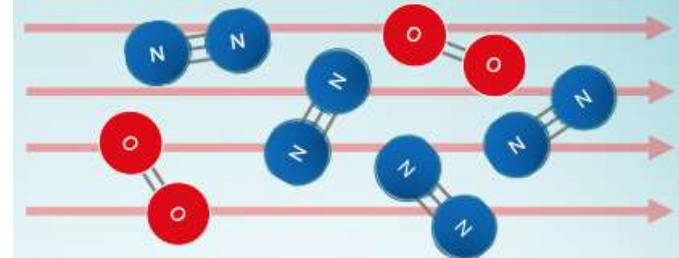


# Absorbing & Re-emitting Heat

- For a molecule to be a greenhouse gas, it must absorb and scatter infrared radiation (the kind of energy we feel as heat).
- To do this, it must...
  - 1. Have more than two atoms.
  - 2. Have two or more elements.
- The molecular structure of CO<sub>2</sub> enables it to absorb infrared radiation and re-emit it.
  - The greater the concentration of CO<sub>2</sub>, the more slowly heat escapes into space.
  - As CO<sub>2</sub> levels rise, infrared radiation will stay in the atmosphere for longer periods, raising surface temperatures.



CO<sub>2</sub> molecules are comprised of three atoms and multiple elements. This makes CO<sub>2</sub> capable of absorbing and scattering infrared radiation, raising global temperatures.



While O<sub>2</sub> and N<sub>2</sub> molecules comprise 99% of the atmosphere, they are unable to absorb and scatter infrared radiation due to their molecular properties.

# Is This Just a Natural Cycle?

- **The changes occurring today are far too rapid to be the result of natural cycles.**
  - Variations in the Earth's orbital path and tilt (called Milankovitch Cycles) change how much solar radiation reaches the earth.
  - This changes global temperatures.
  - The length of these cycles occur range from 26,000 years to 100,000 years.
- **Current changes to climate have occurred in less than 200 years.**
  - This indicates that factors other than the earth's natural climate cycles are responsible for recent warming trends.

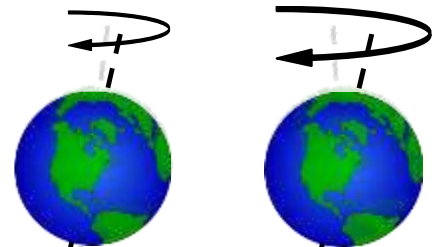
## Milankovitch Cycles



*Circular Orbit vs. Oval Orbit*  
Cycles last 100,000 years.



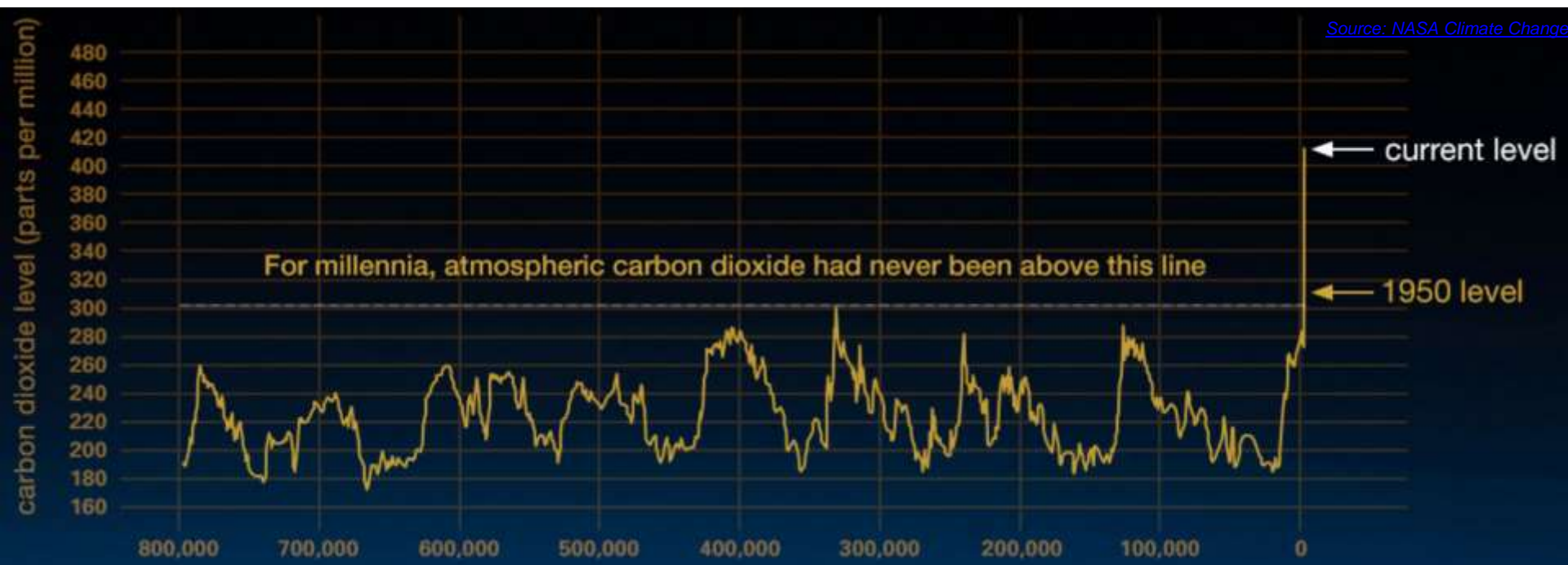
*Less Axial Tilt vs. More Axial Tilt*  
Cycles last 41,000 years.



*Less Wobble vs. More Wobble*  
Cycles last 26,000 years.

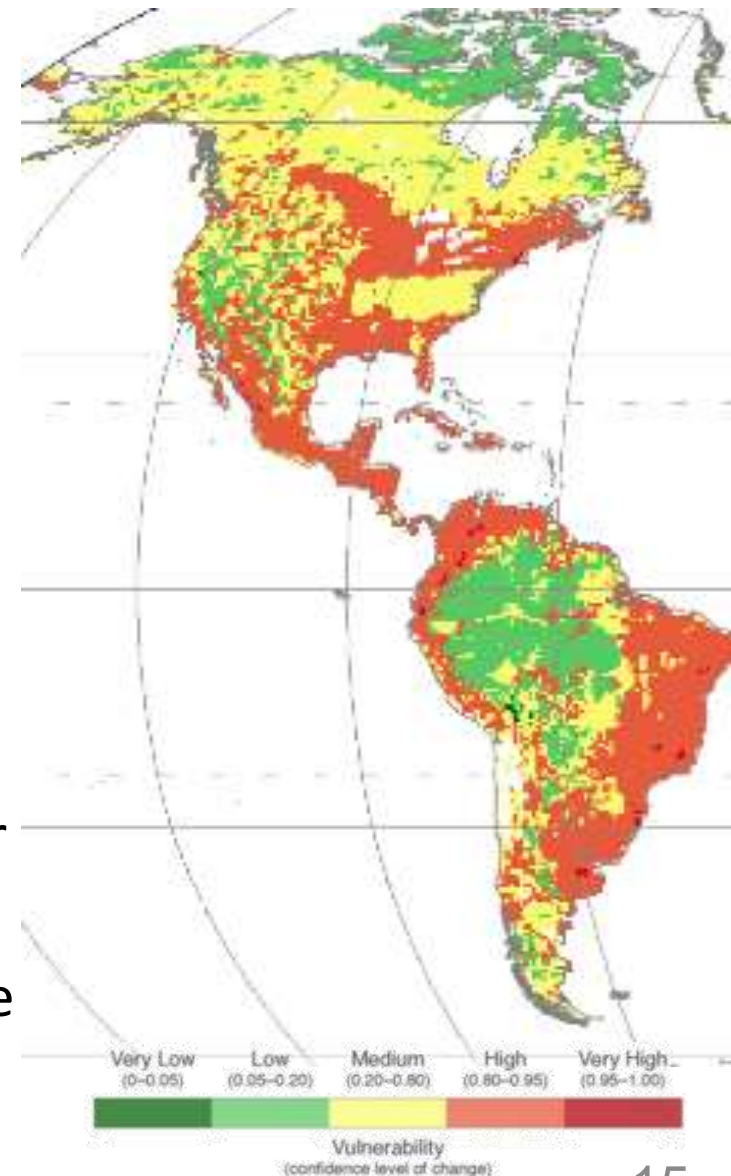
# Unprecedented Spikes in CO<sub>2</sub>

- **Atmospheric CO<sub>2</sub> levels have increased by more than 50% since the Industrial Revolution mostly because of fossil fuel combustion.**
  - In the entire time that humans have existed as a species, there has never been another time in which CO<sub>2</sub> concentrations have this high or have increased at this rate.
  - Climate change refers to ecological disturbances resulting from excessive CO<sub>2</sub> levels in the atmosphere due to human activity.



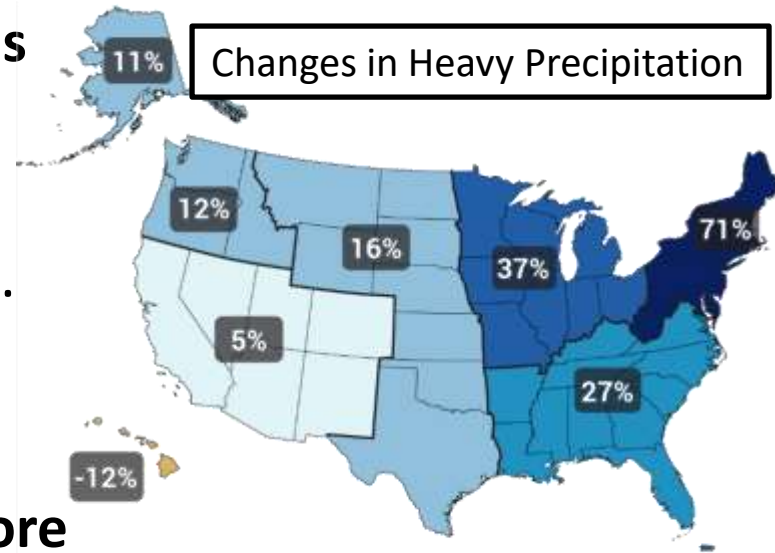
# Ecosystem Disturbances

- **Changes due rising CO<sub>2</sub> levels are causing significant ecosystem disturbances.**
  - A warming climate results in changes in vegetation, displacing the species that depend on that vegetation.
  - Most of North American habitats are vulnerable due to climate change.
- **Some species are directly impacted by warming.**
  - For example, fish like salmon and trout depend on cool water, as warmer water has less dissolved oxygen.
  - As their aquatic habitats warm, they are unable to migrate to new regions with colder water and sufficient oxygen.



# Flooding, Droughts, & Acidity

- **Changing greenhouse gas concentrations also changes precipitation patterns.**
  - A warmer atmosphere can hold onto more moisture for longer timeframes.
  - This increases the frequency of both droughts and flooding.
- **Increasing levels of CO<sub>2</sub> also result in more acidic conditions in marine ecosystems.**
  - As more CO<sub>2</sub> dissolves in water, it forms carbonic acid that can harm marine ecosystems such as coral reefs.
  - This can have significant ramifications as most photosynthesis (70%) occurs in aquatic ecosystems.

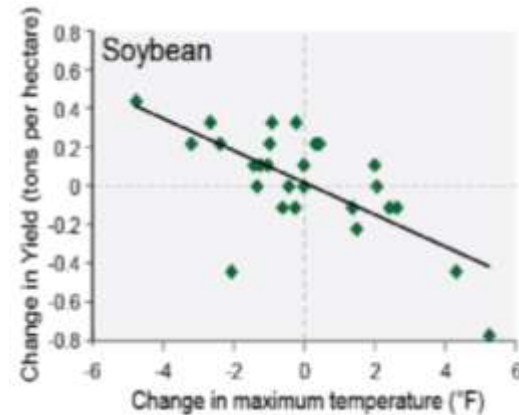
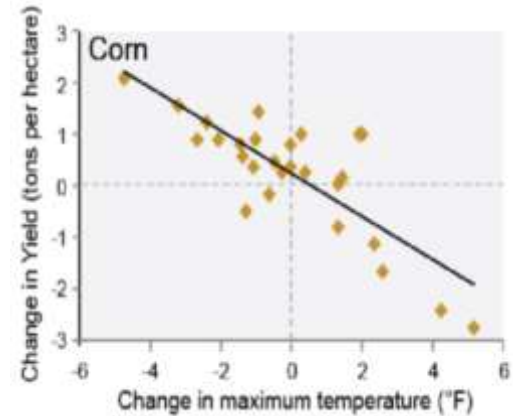


Before (*top*) and after (*bottom*) of marine habitat damage due to ocean acidification. Source: [FACTS](#)



# Impacts on Agriculture

- **Rising CO<sub>2</sub> levels impact a wide variety of human activity, particularly agriculture.**
  - An increase of a few degrees in the maximum summer temperature reduces corn yields by 1-3 tons per acre ([Pryor et al., 2014](#))
  - The US dairy industry loses \$670 million annually due to climate change ([Mauger et al., 2015](#))
  - Increasing the summer growing season by a single day results in a 7.6% reduction in US wheat yields ([Tack et al., 2015](#))
  - Early thaws cause hundreds of millions of dollars in losses to fruit & berry crops ([Hatfield & Tackle, 2014](#))



Crop yields are very sensitive to changes in temperatures. Increasing summer temps reduce yields per acre by tons.

# N & P Imbalances

- **Human activity causes other imbalances, particularly nitrogen & phosphorus.**
  - Fertilizer runoff from fields and yards results in eutrophication in aquatic ecosystems.
- **Eutrophication occurs when dissolved oxygen in aquatic ecosystems is reduced due to excess levels of nitrogen & phosphorus.**
  - Nutrient runoff increases surface algae growth, blocking light for underwater photosynthesis.
  - Impaired photosynthesis and increased decomposition reduces aquatic oxygen levels.
- **This results in dead zones, or areas in aquatic ecosystems that cannot support life.**
  - Currently there is a dead zone in the Gulf of Mexico covering over 6000 square miles.



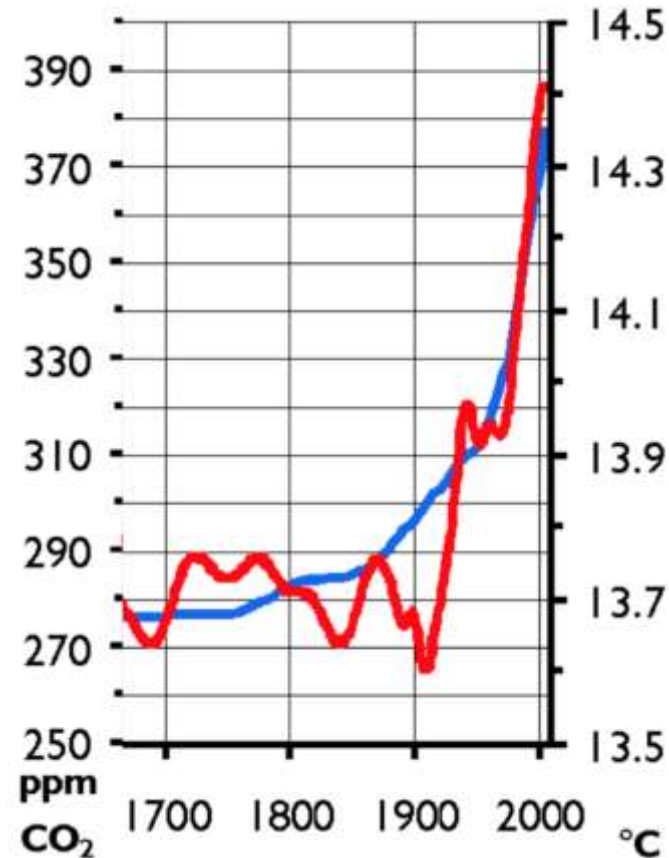
Dead zones are common along the US coastline due to excess levels of nitrogen & phosphorus.

[Image Source: Wikimedia](#)

# Revising Our Claims

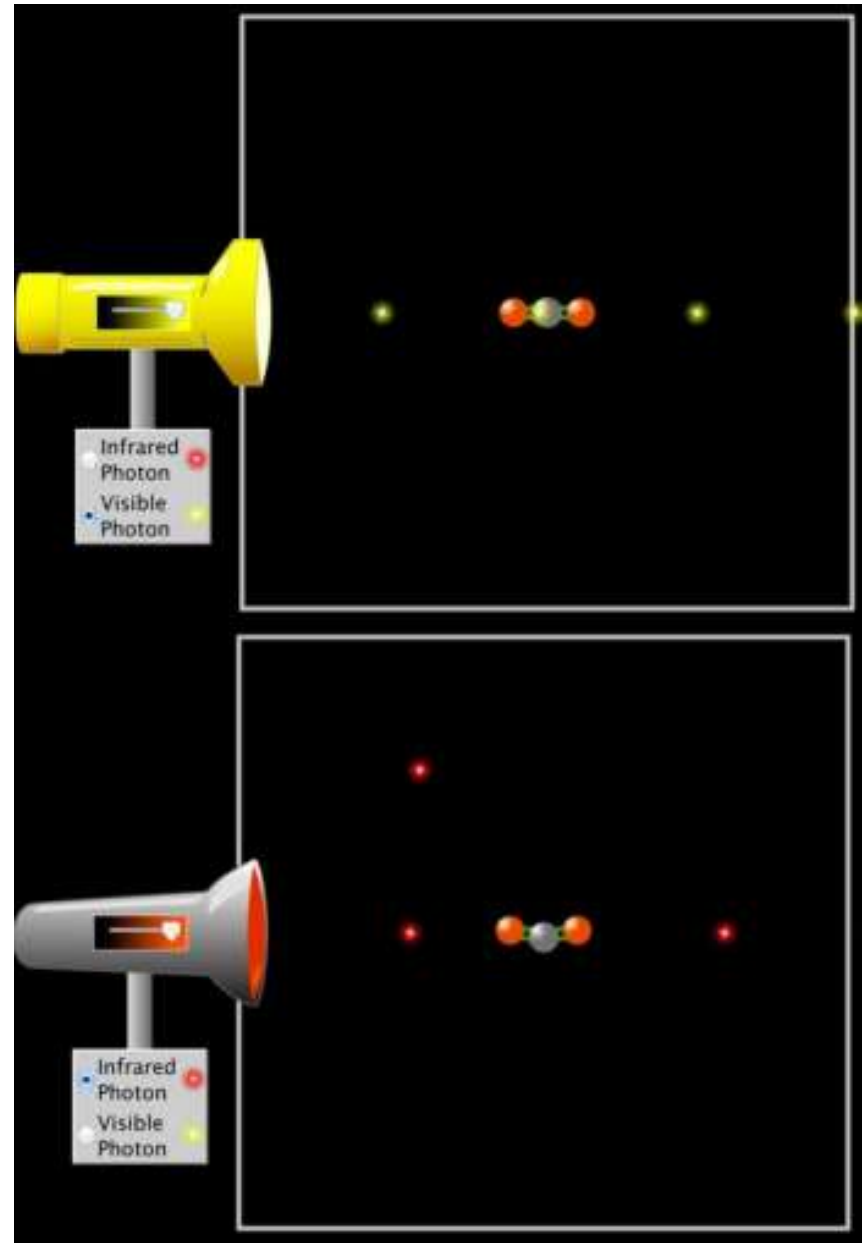
**Re-visit your ideas about our questions.**

- How do imbalances in matter and energy cause ecosystem disturbances?
- How do ecosystems enable matter movement and energy transformation?
- How do imbalances in matter and energy occur?
- What happens when matter and energy are unbalanced?
- How does human activity relate to these kinds of disturbances?



# Looking Ahead: Part 3 Investigation

- In Part 3, you will use a computer simulation to investigate how different kinds of energy (radiation) interact with GHG's.



# Key Points

- Imbalances in the movement of matter and/or the flow of energy can result in disturbances to ecosystem function.
- The extinction of the dinosaurs is an example; dust clouds interrupted photosynthesis, reducing carrying capacities of ecosystems, resulting in mass extinction.
- Currently, there is an imbalance in the movement of carbon atoms because the release of CO<sub>2</sub> through fossil fuel combustion exceeds the rate of absorption of CO<sub>2</sub> through photosynthesis.
- Greenhouse gases like CO<sub>2</sub> allow light to pass through but slow the loss of infrared radiation (heat energy). This is called the greenhouse effect. This helps to moderate the temperature of the earth, but excess greenhouse gases result in climate change.

# Key Points

- While CO<sub>2</sub> represents a relatively small proportion of the earth's atmosphere, it is the most abundant greenhouse gas.
  - More abundant gases like N<sub>2</sub> and O<sub>2</sub> are unable to interact with infrared radiation due to the molecular properties. Because CO<sub>2</sub> has multiple elements and more than 2 atoms, it can reflect infrared radiation back to the surface of the earth.
- The greater the concentration of CO<sub>2</sub>, the more slowly heat escapes into space.
  - CO<sub>2</sub> levels are now at level and increasing at a pace not seen in the history of humans as a species.
- Recent warming trends are unlikely to be part of a natural cycle, as the Milankovitch Cycles require 10,000-100,000 years to occur (whereas modern warming has occurred in less than 200 years).

# Key Points

- Rising CO<sub>2</sub> levels are causing significant ecosystem disruptions, including changing vegetation, reduced oxygen and increased acidity in aquatic ecosystems, and increases the prevalence of flooding and droughts.
  - Increasing CO<sub>2</sub> levels also have significant ramifications for human activity. In particular, agricultural yields are significantly affected by changes in temperature and precipitation patterns.
- Imbalances in other kinds of matter movement, particularly nitrogen and phosphorus cycles, are also resulting in significant ecosystem disruptions.
  - Excess nitrogen and phosphorus results in eutrophication in aquatic ecosystems, causing decreases in dissolved oxygen in the water. This is resulting in massive dead zones off the coasts of North America and elsewhere.