7.6 Effects of Global Climate Change

College Board Topic 9.5

Related Reading: Chapter 18

Learning Objectives and Essential Knowledge

ENDURING UNDERSTANDING

STB-4

Local and regional human activities can have impacts at the global level.

LEARNING OBJECTIVE

STB-4.F

Explain how changes in climate, both short- and long-term, impact ecosystems.

ESSENTIAL KNOWLEDGE

STB-4.F.1

The Earth has undergone climate change throughout geologic time, with major shifts in global temperatures causing periods of warming and cooling as recorded with CO_2 data and ice cores.

STB-4.F.2

Effects of climate change include rising temperatures, melting permafrost and sea ice, rising sea levels, and displacement of coastal populations.

STB-4.F.3

Marine ecosystems are affected by changes in sea level, some positively, such as in newly created habitats on now-flooded continental shelves, and some negatively, such as deeper communities that may no longer be in the photic zone of seawater.

STB-4.F.4

Winds generated by atmospheric circulation help transport heat throughout the Earth. Climate change may change circulation patterns, as temperature changes may impact Hadley cells and the jet stream.

ESSENTIAL KNOWLEDGE

STB-4.F.5

Oceanic currents, or the ocean conveyor belt, carry heat throughout the world. When these currents change, it can have a big impact on global climate, especially in coastal regions.

STB-4.F.6

Climate change can affect soil through changes in temperature and rainfall, which can impact soil's viability and potentially increase erosion.

STB-4.F.7

Earth's polar regions are showing faster response times to global climate change because ice and snow in these regions reflect the most energy back out to space, leading to a positive feedback loop.

STB-4.F.8

As the Earth warms, this ice and snow melts, meaning less solar energy is radiated back into space and instead is absorbed by the Earth's surface. This in turn causes more warming of the polar regions.

STB-4.F.9

Global climate change response time in the Arctic is due to positive feedback loops involving melting sea ice and thawing tundra, and the subsequent release of greenhouse gases like methane.

STB-4.F.10

One consequence of the loss of ice and snow in polar regions is the effect on species that depend on the ice for habitat and food.

SUGGESTED SKILL

Visual Representations

2.C

Explain how environmental concepts and processes represented visually relate to broader environmental issues.

SUGGESTED SKILL

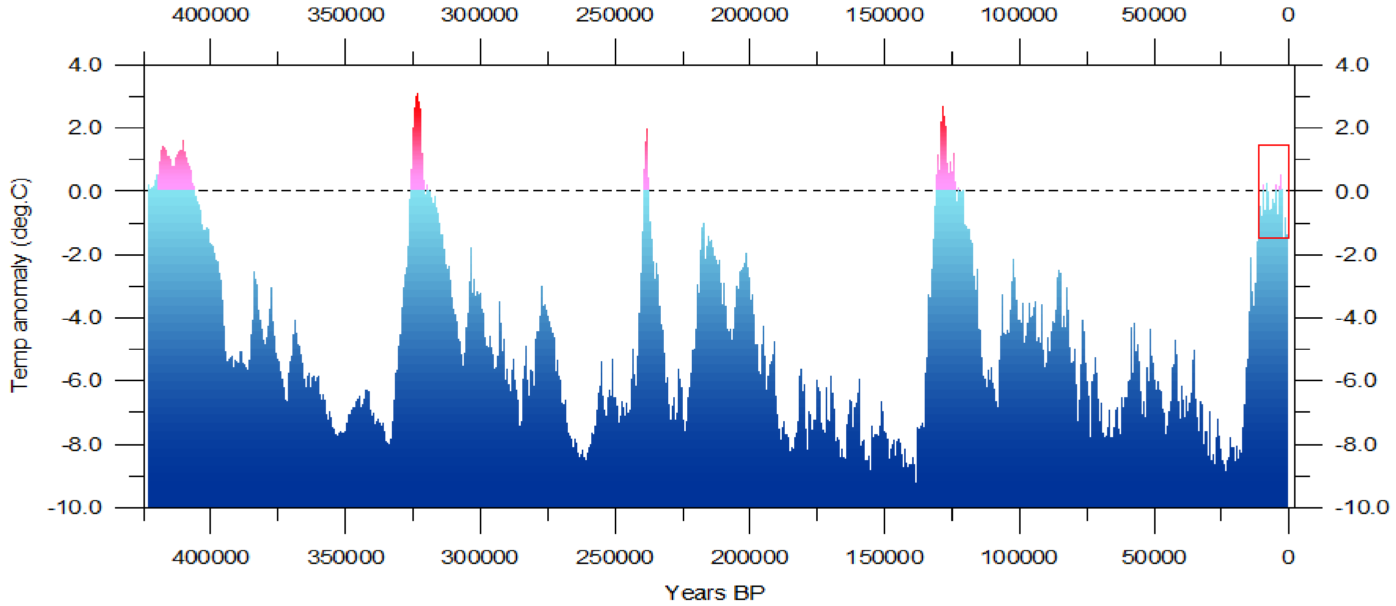
Data Analysis

5.D

Interpret experimental data and results in relation to a given hypothesis.

Other factors affecting earths climate

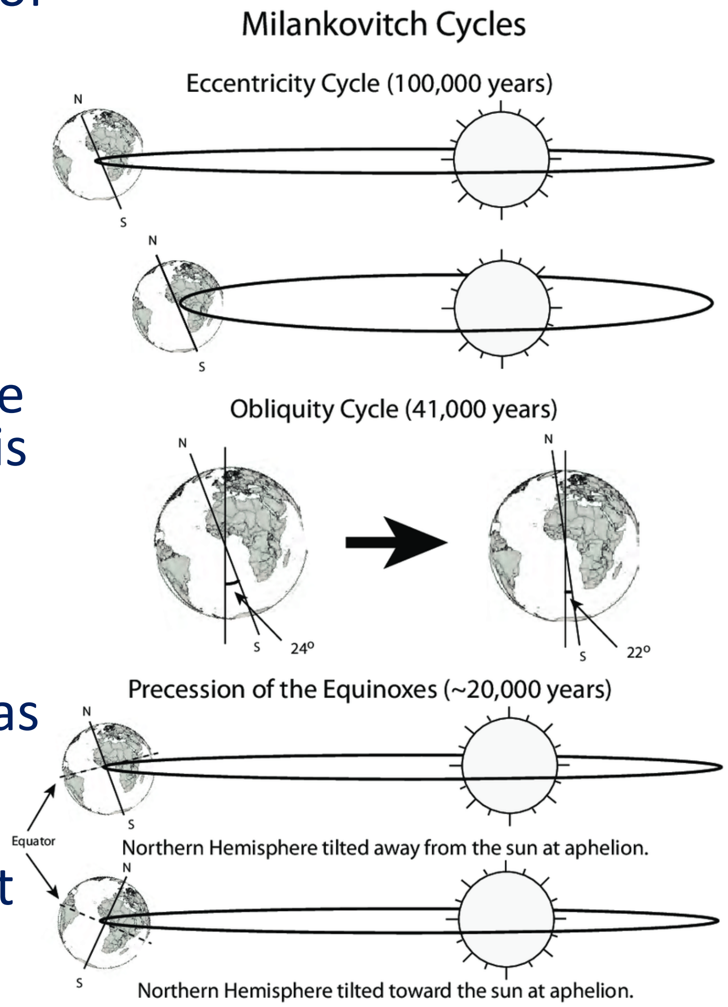
- Besides atmospheric composition, Earth's climate is affected by periodic changes in its movement in space.
- The ***Milankovitch cycles*** describe three periodic variations in earth's movement:
  - ***Eccentricity*** "shape" of Orbit (100,000 year cycles)
  - ***Obliquity*** "Tilt"(41,000 year cycles)
  - ***Precession*** "Wobble" (23,000 year cycles)



- These variations in earths movement have resulted in glacial and interglacial periods over the course of geologic time.
  - ***Interglacial periods*** are warm periods marked by the retreat of glaciers towards the poles.
  - We have been in the midst of an interglacial period for the last 11,000 years.
  - ***Glacial periods*** result when temperatures drop and glaciers advance from the poles toward lower latitudes.
  - The last glacial period peaked 20,000 years ago.
  - The average temperature difference on Earth between glacial and interglacial periods is only about 6˚C.

A closer look at the Milankovitch Cycles

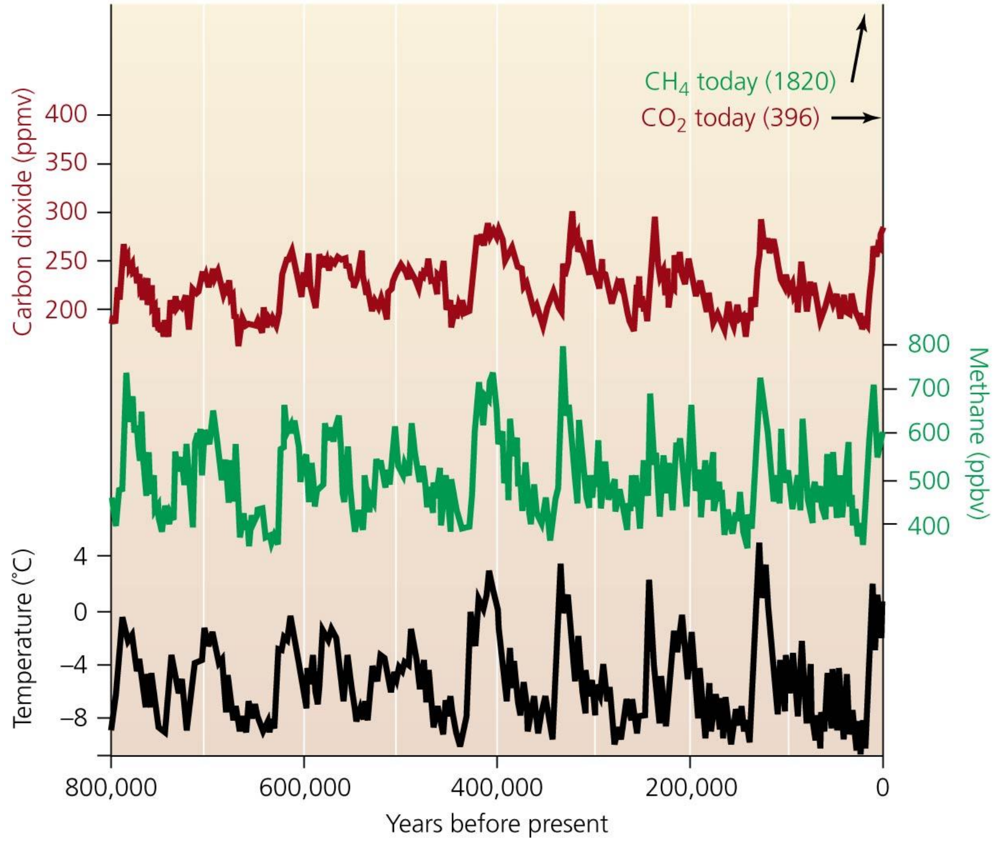
- ***Eccentricity*** describes the shape of Earths orbit around the sun.
  - Varies from very elliptical to almost circular
  - Current orbit is almost at its most circular and getting more circular.
  - The more elliptical the orbit the greater the seasonal variation is on Earth (minor differences)
- ***Obliquity*** measures the angle Earths axis of rotation is tilted.
  - Obliquity is the reason Earth has seasons.
  - The angle of obliquity varies from 22.1° to 24.5°. The current angle is 23.5°
  - The greater the angle of obliquity the more extreme seasons are.



- ***Axial precession*** describes the wobble of Earth on its rotational axis.
  - This changes the direction in which Earth's axis points relative to the sun and other stars in space.
  - Precession makes seasonal differences more extreme in one hemisphere or the other.
    - Currently the northern hemisphere is tilted away from the sun (winter) when we pass closest to the sun in our elliptical orbit
    - This leads to moderate winters
    - This pattern will reverse in 13,000 years
  - Axial precession also gradually changes the timing of seasons; causing them to begin earlier over time.

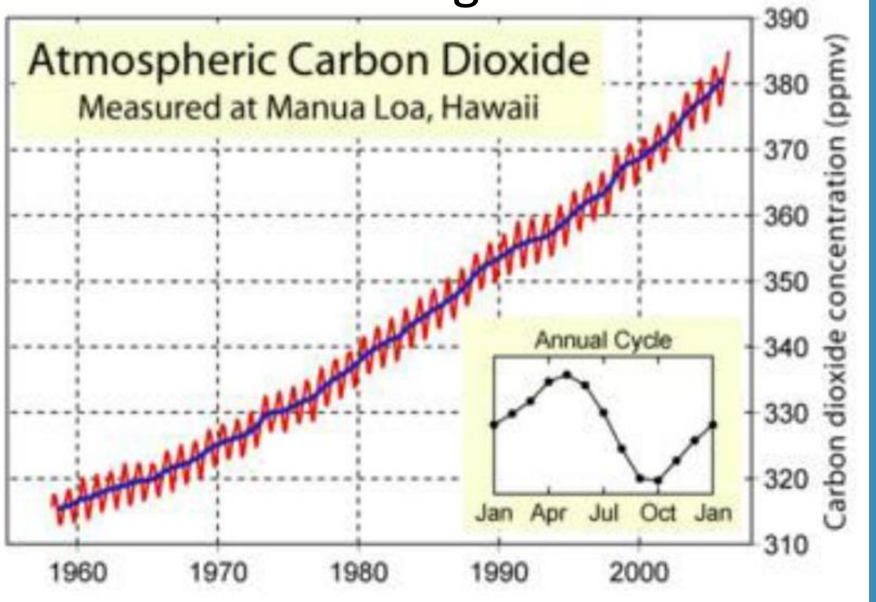
Proxy indicators provide evidence of past climate

- ***Proxy indicators*** are forms of indirect evidence that serve as substitutes for direct measurements of past climate.
  - ***Sediment cores***: In depositional basins such as lakes and oceans trap pollen grains allowing determination of plant species present at a given time and place.
    - Plant species are specific to certain climates.
  - ***Tree rings***: Wide rings generally indicate warmer and wetter climates.
  - ***Pack rat middens***: Can preserve seeds and plant parts for centuries in arid climates.
  - ***Coral reefs:*** Isotope analysis of $CaCO_3$ in coral reefs tells about the concentrations of gases in the atmosphere at the time the coral skeleton formed.
- ***Ice cores*** may be our most important proxy indicators.
  - Tiny bubbles of preserved atmospheric gases, pollen and ash provide data going back 800,000 years.



Direct measurements tell us about the present, models predict the future

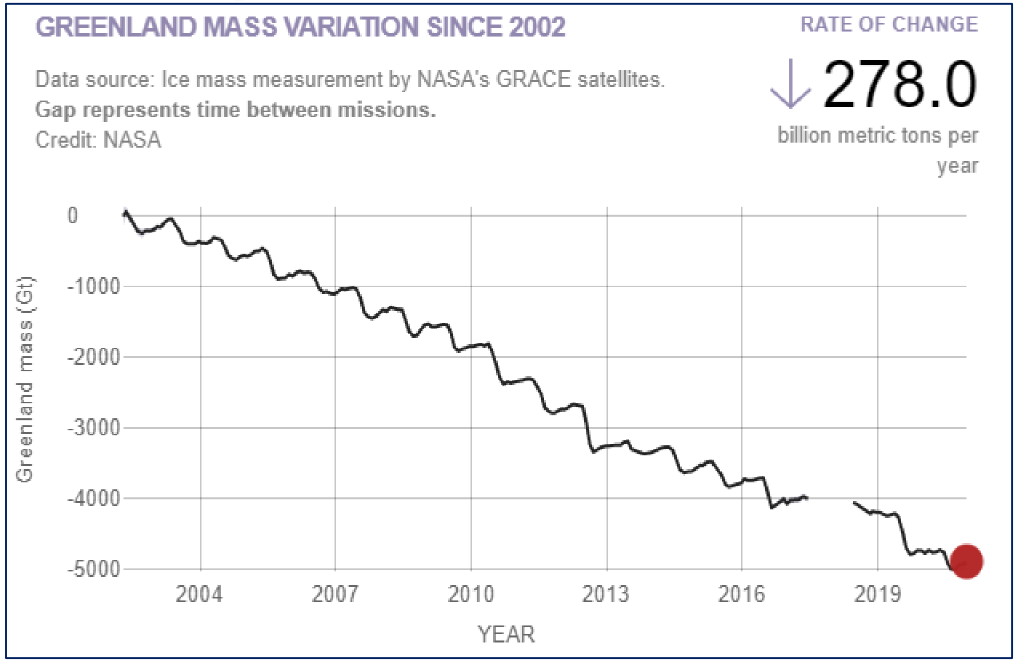
The Keeling Curve



- Direct measurements document daily weather.
  - Regularly kept records of direct climate measurements from around the globe only date back to 1880.
- Direct recording of atmospheric CO_2 began in 1956.
  - Sampling by SIO scientists at Hawaii's Mauna Loa observatory provide a daily record of atmospheric CO_2 concentrations in relatively unpolluted, well-mixed air.
  - Atmospheric CO_2 concentrations have increased from an estimated 280 ppm (1750) to 315 ppm (1956) to 416 ppm (2021).
- To understand climate functioning and predict the future, scientists simulate climate processes using computer models.
  - ***Climate models*** are computer programs that simulate climate processes by combining what is known about current and past climates, atmospheric composition, atmospheric and ocean circulation and their interaction, and feedback effects
  - Modelers provide starting condition and rules and test the model by starting it in the past and seeing if it accurately predicts current climate conditions.

Earths polar regions show more rapid effects of climate change

- **Polar latitudes spend all, or most of the year, covered in snow or ice**.
  - Snow and ice have a high albedo and reflect large amounts of solar radiation.
  - As global temperatures rise, more of snow and ice is melting, exposing darker, lower albedo surfaces below.
  - These darker, lower albedo surfaces absorb greater amounts of solar energy, increasing the rate of warming. (+ feedback)
- **Tundra soils are characterized by a layer of permafrost whose upper surface melts to form boggy, waterlogged soils each summer.**
  - This melt, and the resulting water logging of soils, occurs earlier in the year each year.
  - Waterlogged soils result in anaerobic decomposition, which generates methane. Earlier melt means greater annual production of methane from these soils.
  - Methane is a greenhouse gas and further accelerates warming. (+ feedback)

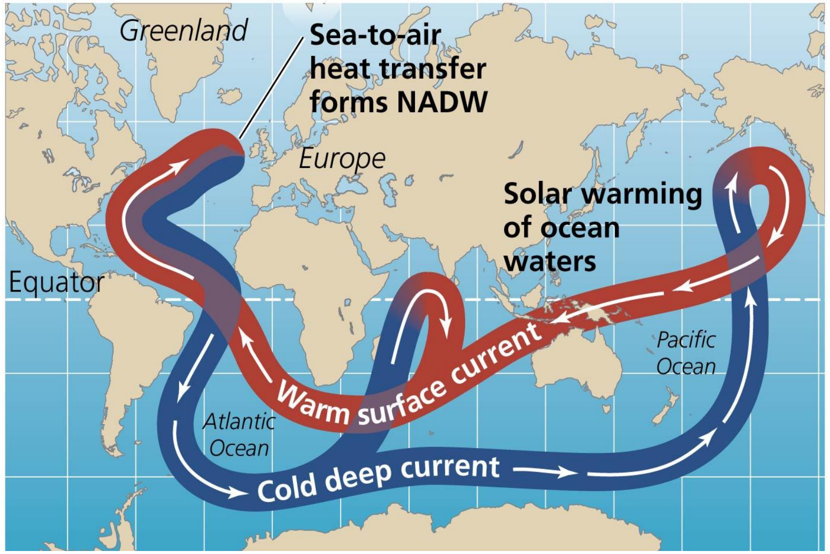


Muir Glacier, Alaska: August 13, 1941 and August 31, 2004

Earths polar regions show more rapid effects of climate change

- Increasing amounts of particulate matter (PM), soot, and dust are being released into the atmosphere (what are the causes?).
  - Dust, soot, and PM are transported toward the poles by atmospheric circulation and deposited on remote ice sheets.
  - Dust, soot, and PM darken the surface and lower their albedo.
  - As the albedo drops, they absorb more solar radiation, accelerating their melting.

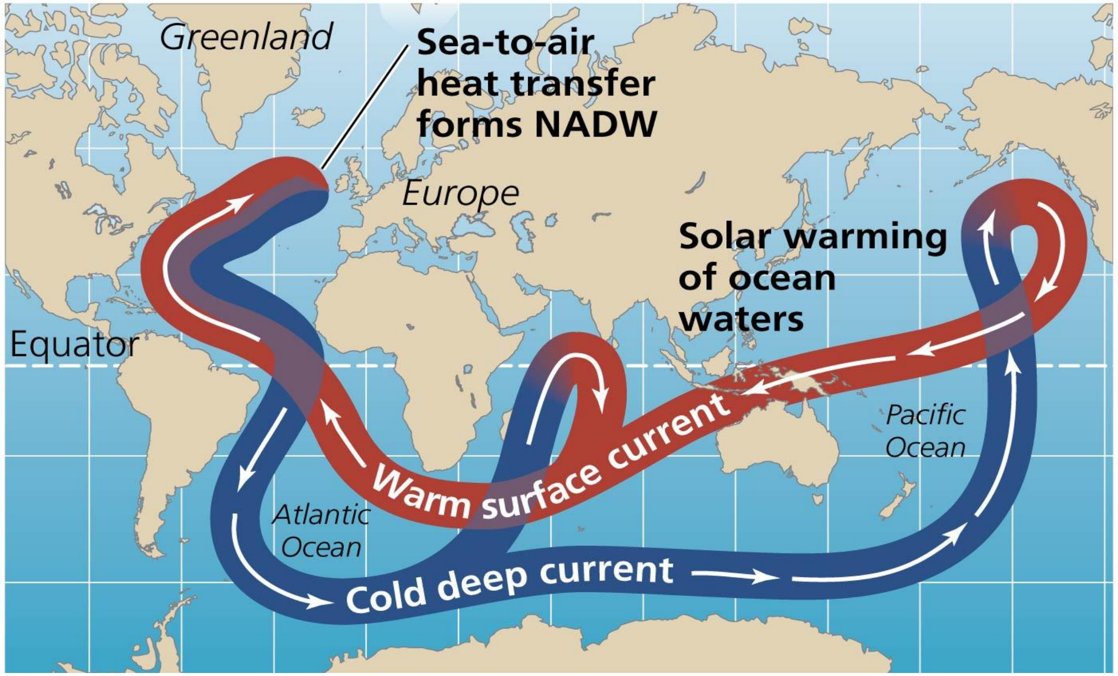
- The high latitudes of the northern hemisphere experience more rapid warming than similar latitudes in the southern hemisphere.
  - Larger land area and less ocean surface (specific heat)
  - Thermohaline circulation transports warm surface water to the north, further accelerating warming. (this may be slowing)



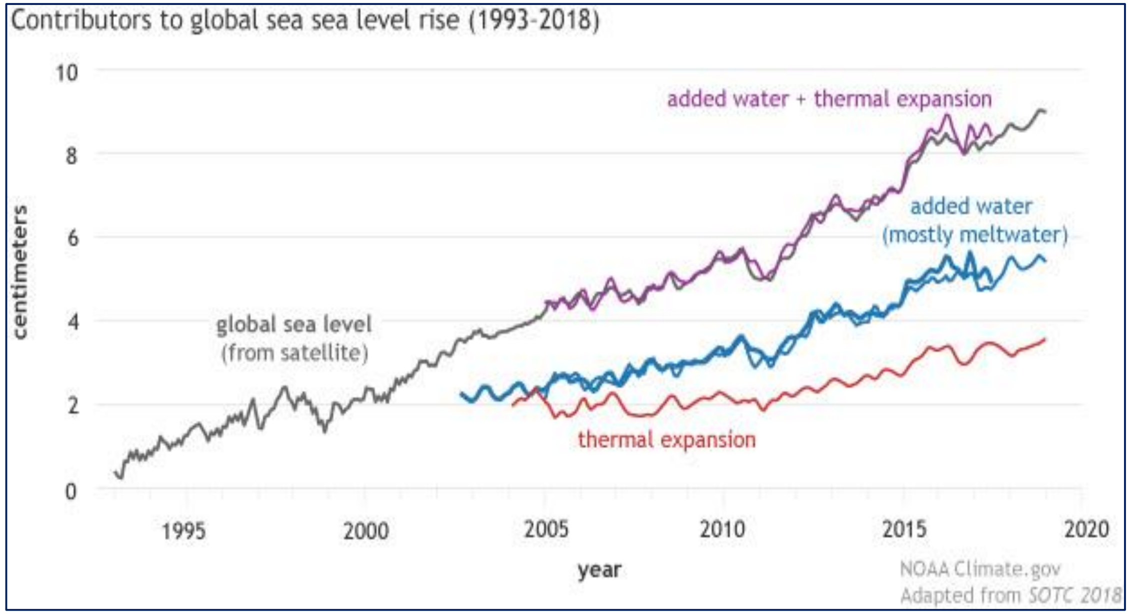
Changes in the extent of sea ice in the northern hemisphere and impacts of warmer temperatures in the arctic.

Rising temperatures impact ocean ecosystems

- Changes to ocean currents
  - Downwelling at the NADW depends on surface waters carried by the Gulf Stream being saltier and denser in order to sink at the NADW.
  - Melting of sea ice and the Greenland ice sheet dilutes surface waters at NADW, slowing downwelling.
  - Slow downwelling, slows global ocean circulation.
  - Cooling of warm surface waters by downwelling at NADW is an important global cooling mechanism, disruption of this will likely lead to even more rapid warming of global temperatures.

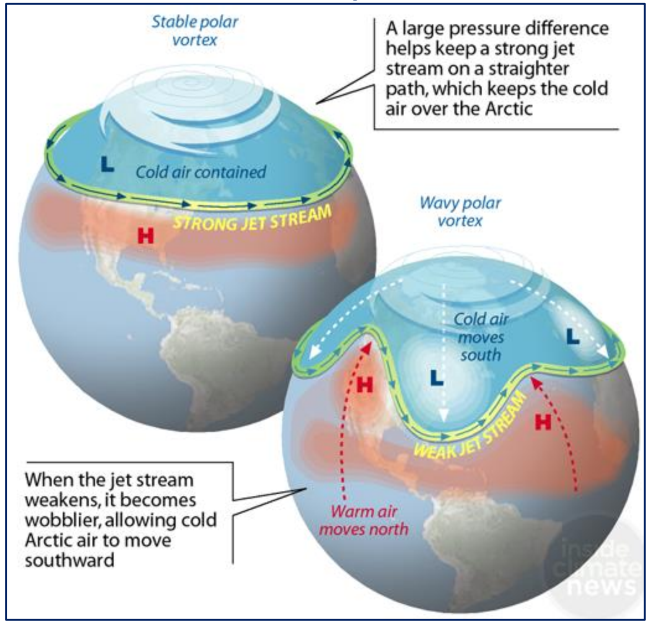


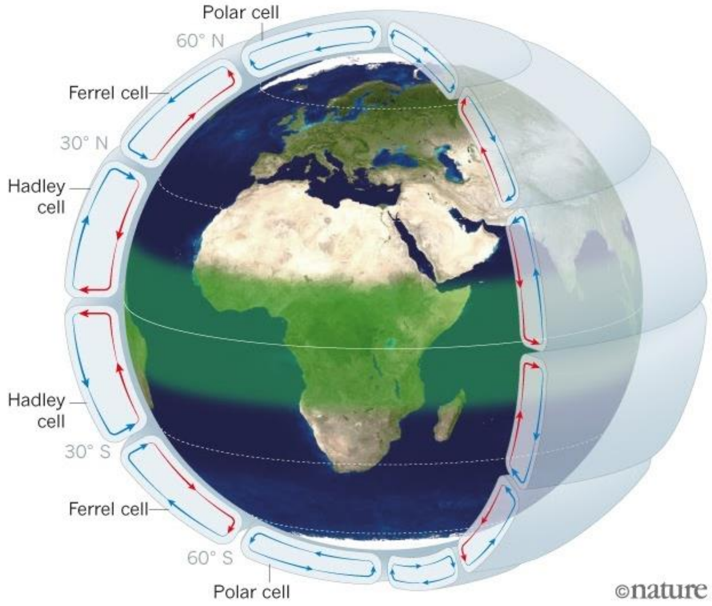
- Sea levels are rising.
  - Results from thermal expansion of sea water and melting of ice caps and glaciers, not melting of sea ice.



Climate change is not just rising temperatures

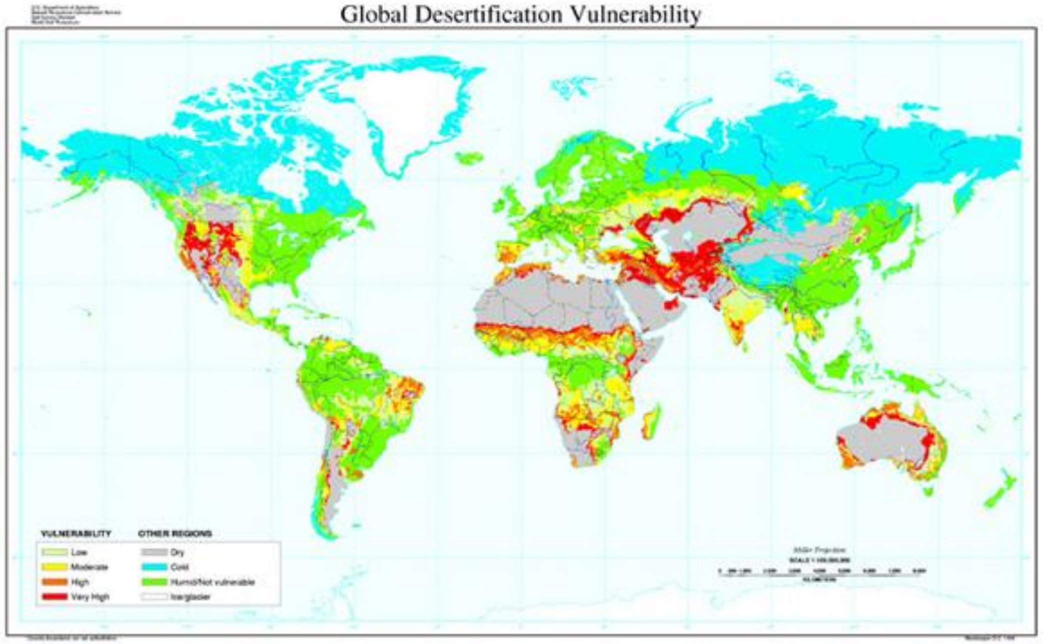
- More rapid warming of the poles reduces temperature and pressure differences between temperate and polar latitudes.
- These changes weaken and destabilize the jet stream.
  - The ***jet stream*** is a high altitude air current that normally blows west ⟶ east with small meanders to the north and south.
  - Slowing of the jet stream increases the N↔S meanders and slows the movement of air masses, and their associated weather patterns, across the Northern hemisphere.
  - Leads to storms and droughts stalling over a region, increasing damage.
- As temperature differences between the poles and tropics decrease, air expanding from the equator travels further before sinking.
  - Widens and weakens the Hadley cells, expanding the tropics and shifting subtropical biomes (dry scrublands and deserts) towards the poles.
- Warmer ocean waters are increasing the frequency and intensity of hurricanes and tropical storms; shifting them into more temperate waters.





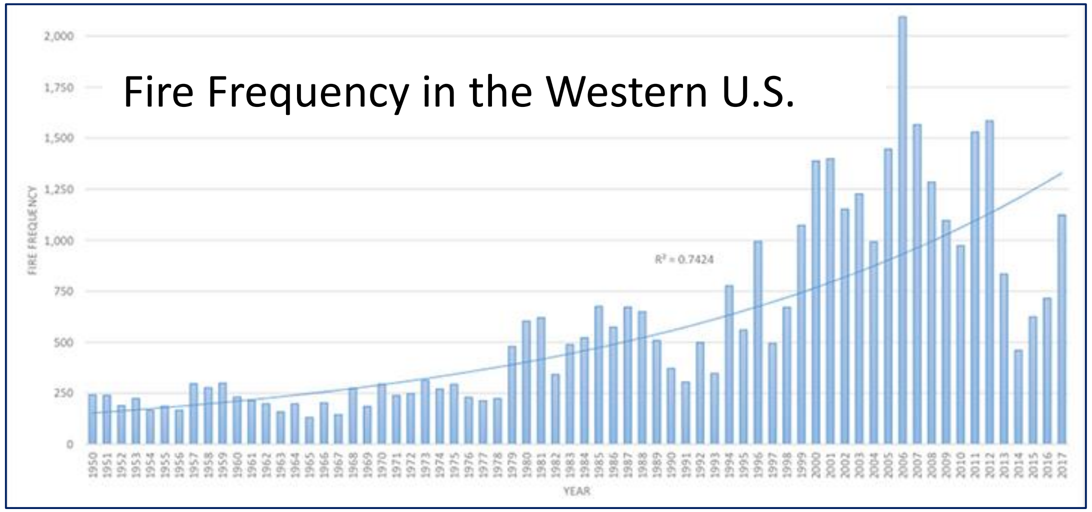
Climate change effects on soils

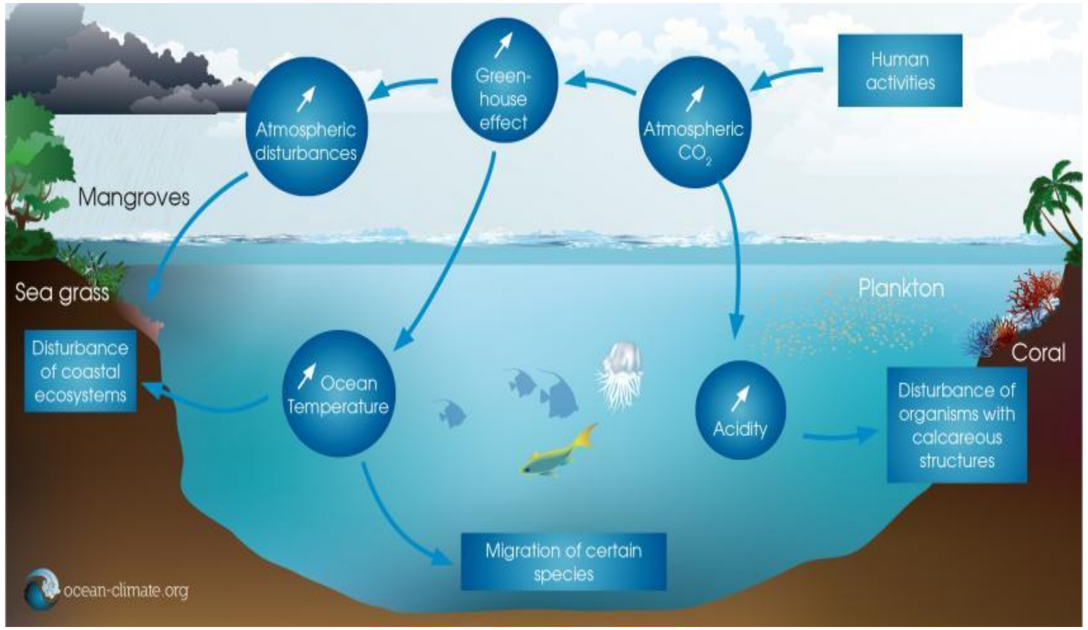
- Increased soil erosion is likely.
  - Increased soil temperatures and increasing evaporation from soils, causing soils to become drier and more prone to erosion.
  - In other regions, climate change may result in increased rainfall, resulting in greater erosion.
  - Changes in climate may benefit soils in some areas, but this is expected to be countered by degradation of soils over even larger areas.
- Changes in soil temperature and moisture will affect chemical, physical and biological properties of soil.
  - Species composition in soils will change as a result.
  - Can lead to changes in the rates of nutrient cycling.
  - Increased rates of decomposition of organic matter, leading to greater CO_2 releases.
  - Decreases in soil organic matter can lead to changes in water holding capacity (permeability) within soils.
- Climate change will increase the land areas threatened by desertification.



Climate change is reducing biodiversity

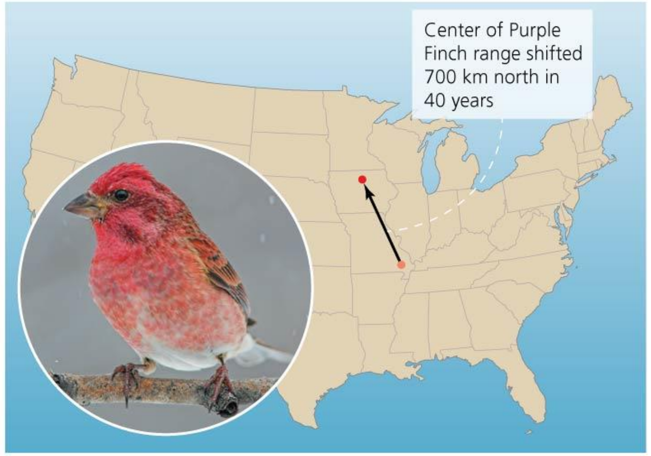
- Habitat change
  - Increasing desertification will convert scrublands and dry grasslands to less productive desert biomes.
  - Forests, grasslands, and scrublands become drier and more fire prone. Fires will be larger, more intense, and more destructive resulting in loss of habitat and biodiversity.
  - Loss of benthic habitats within the photic zone as water gets deeper will shift the range of marine ecosystems such as coral reefs and kelp forests.
    - Warmer waters further threaten coral reefs with coral bleaching and increased atmospheric CO_2 levels increase ocean acidification, leading to the dissolution of $CaCO_3$ reefs.
  - Rising sea level and increased storm surge will increase erosion of coastlines and flood coastal ecosystems.
    - Barrier islands, dune communities, mangrove forests, salt marshes and estuaries.





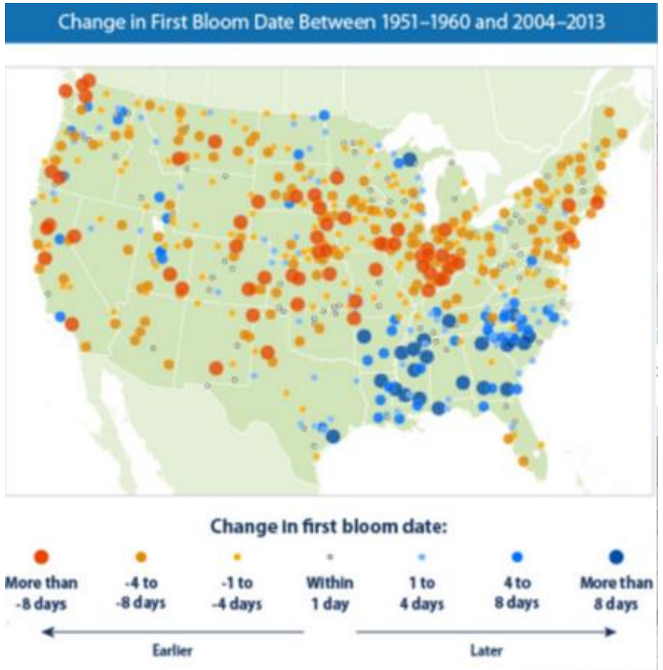
Climate change is reducing biodiversity

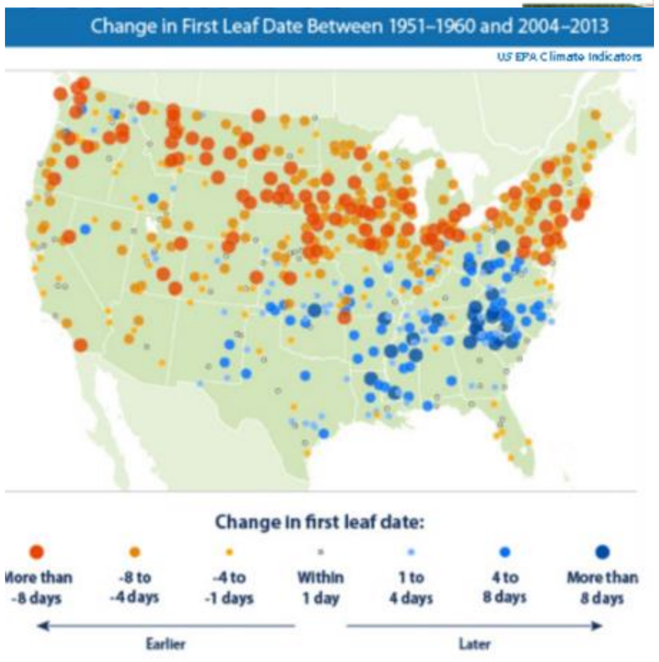
- The rate of climate change may alter habitats faster than some species can adapt.
- Species respond to changing environments by shifting their range.
  - Toward the poles to higher elevations, or shallower water.
  - Species that depend on ice and/or are adapted to cold cannot simply migrate to colder climates.
  - Loss of sea ice = loss of habitat for species that rely on it to hunt or to rest (seals).
  - Changing species distribution is likely to increase competition and cause shifting population dynamics.
- Species respond to changing climate by changing the timing of seasonal phenomena (migrations, breeding) since the timing of these events are responses to seasonal variation in climate.



(a) Birds are moving north

(b) Pikas are being forced upslope





Video Resources

- Global Climate Change
  - https://www.youtube.com/watch?v=QLteLZNXmyI