



Climate Change 101

By C. Kohn

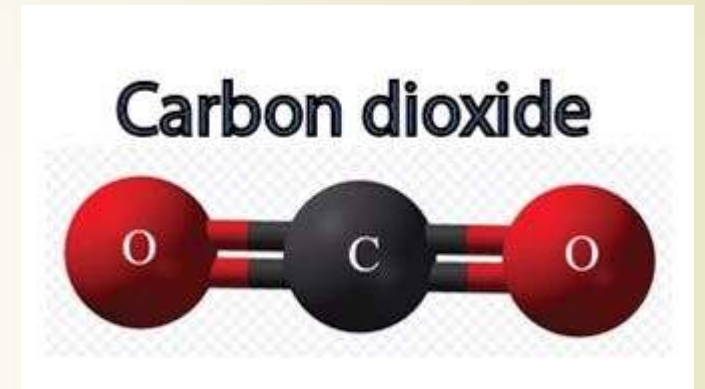
Michigan State University



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Carbon, an Element

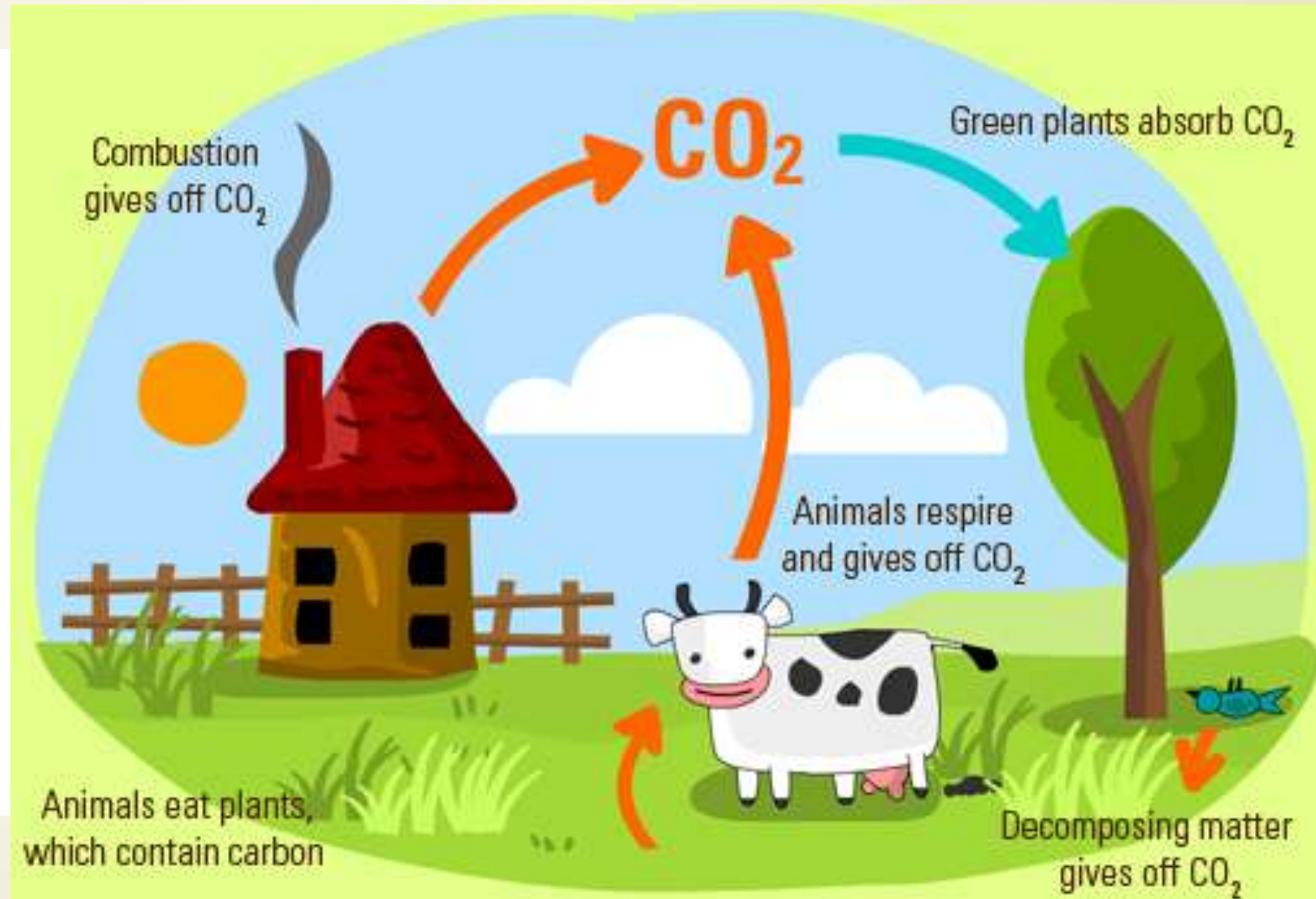
- ➔ Carbon is an element, or a specific kind of atom.
 - ➔ Atoms are the smallest indivisible unit of matter.
 - ➔ Groups of atoms bond together form molecules.
 - ➔ When carbon bonds to two oxygen atoms, it forms a molecule of carbon dioxide.
- ➔ **Carbon atoms are constantly moving to form different kinds of molecules as a result of the biological cycles that allow for life on earth to exist.**
 - ➔ The movement of carbon atoms between different kinds of molecules is called the carbon cycle.



The Carbon Cycle

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- **Simple Fact:** When levels of CO₂ from decomposition, respiration, and burning exceed what can be absorbed by photosynthesis, CO₂ levels will rise and warm the planet.



Key carbon transformations

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- **There are four key transformation reactions that allow for the carbon cycle to exist.**
 - Cellular Respiration – complex carbon molecules are broken down into CO₂ and H₂O. This is necessary to create ATP, the energy of the cell.
 - Photosynthesis – plants absorb CO₂ and H₂O to form complex carbon molecules to be used in respiration.
 - Decomposition – complex carbon molecules that comprised formerly-living organisms are broken down into CO₂ and H₂O.
 - Burning – complex carbon molecules are rearranged into CO₂ and H₂O, giving off light and heat energy in the process.

Climate Change Basics

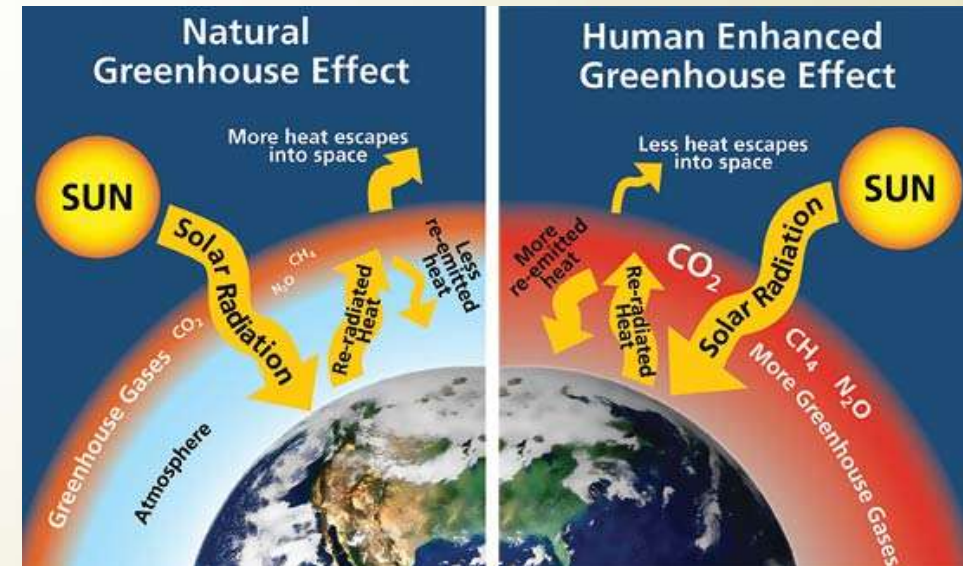
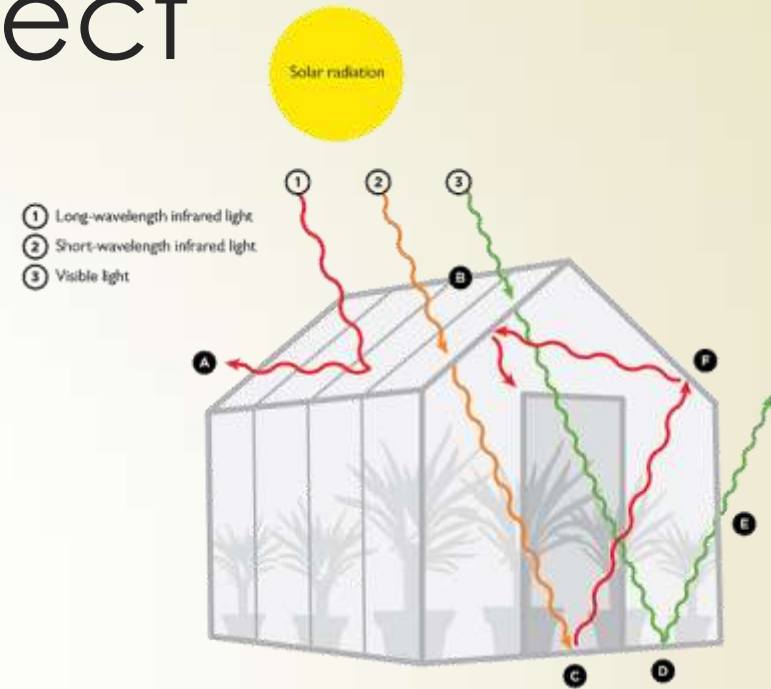
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- ▶ **The carbon cycle used to exist in a general sense of balance.**
 - ▶ The amount of CO₂ released from respiration, decomposition, and burning was roughly equivalent to the amount of CO₂ absorbed by plants during photosynthesis.
 - ▶ This allowed for the atmospheric levels of CO₂ to hover between 200-280 ppm (parts per million).
- ▶ **However, the amount of CO₂ from respiration, decomposition, and burning is now greater than the CO₂ that is absorbed by photosynthesis.**
 - ▶ This allows the CO₂ in the atmosphere to increase by about 3-9 ppm per year.

The Greenhouse Effect

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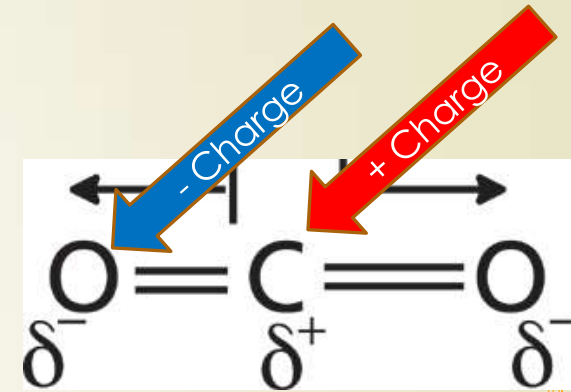
- **Increasing levels of CO₂ are a problem because CO₂ is a greenhouse gas.**
- When sunlight passes through the atmosphere and shines on an object, this light energy is converted into heat energy.
- CO₂ slows the loss of this heat from the surface of the earth.



But why is CO₂ a greenhouse gas?

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- ▶ The individual *atoms* in a CO₂ molecule can scatter thermal radiation in all directions because they have positive & negative net charges.
 - ▶ This enables CO₂ to reflect the energy in all directions, including back towards the earth.
 - ▶ This slows the loss of thermal radiation (aka heat) from the surface of the earth.
 - ▶ *This is similar to how a jacket slows the loss of heat from your body.*
- ▶ Even though CO₂ comprises less than 1% of the atmosphere, without it the world would be 34° C cooler.
 - ▶ But CO₂ is only good in moderation.

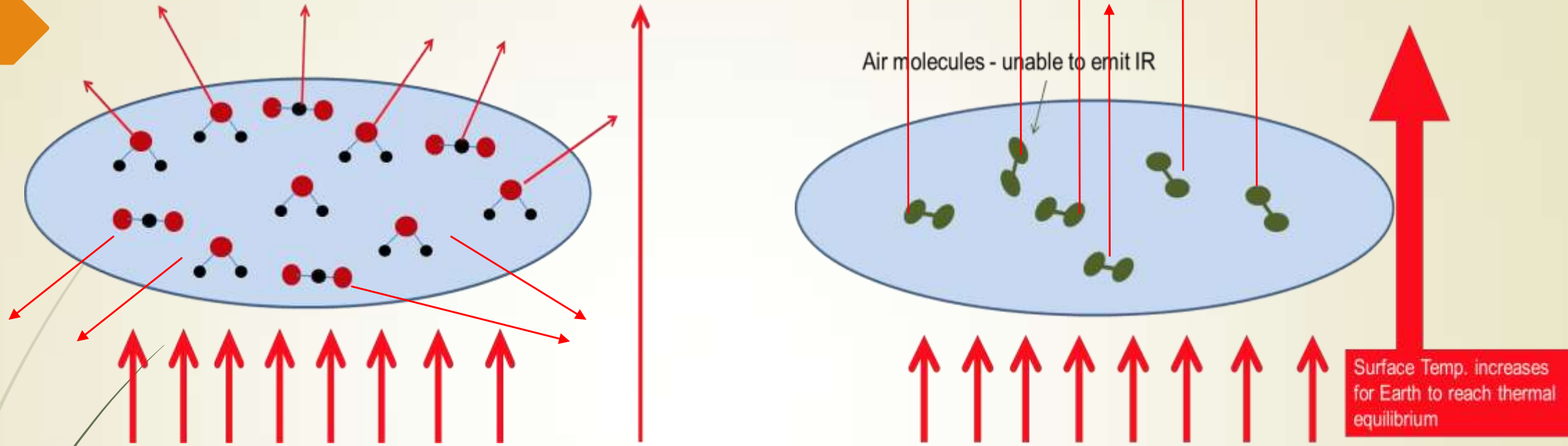


Source: Spectroscopy Online



CO₂ vs. N₂ or O₂

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- **For a molecule to be a greenhouse gas, its individual atoms have to have a net charge (pos. or neg.).**
 - The oxygen atoms in CO₂ are more negative and the carbon atom is more positive.
 - This allows it to re-emit heat energy in all direction (including back towards earth. N₂ and O₂ comprise a much larger portion of the earth's atmosphere but because they have a neutral charge, they allow heat energy to pass through out to space.

Simple, Provable Scientific Facts

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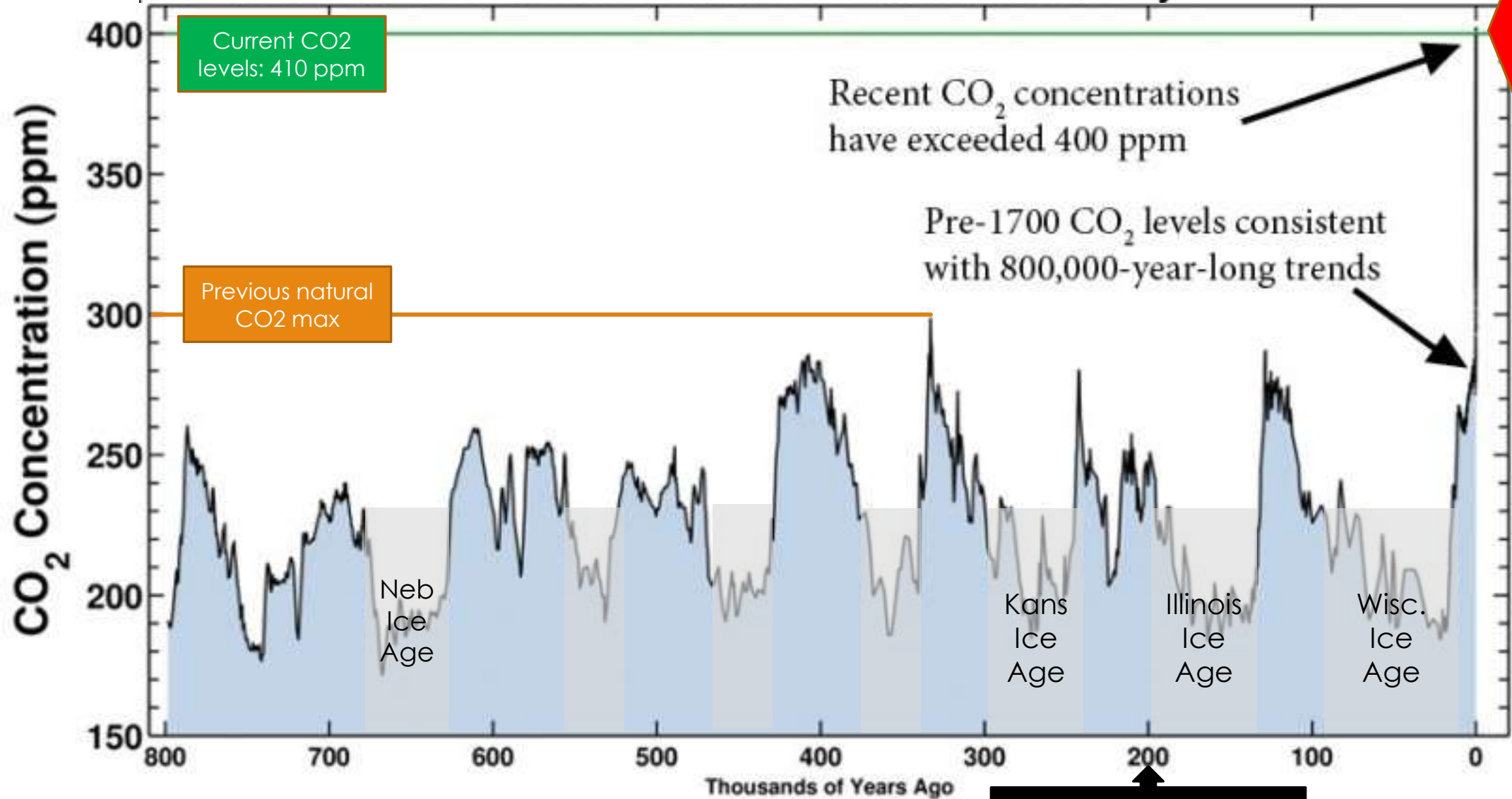
If modern climate change was actually false, one or more of these facts would also have to be false. None of these facts are false.

- 1. Burning a substance convert carbon-based molecules into CO₂ and H₂O.**
- 2. CO₂ is a greenhouse gas (so is H₂O*).**
**H₂O is not as big of a concern because it has a much shorter lifecycle in the atmosphere.*
- 3. Greenhouse gases slow the loss of heat from the planet.**
- 4. The more that is burned, the more CO₂ is released, and the more that heat is reflected back to the earth.**
- 5. CO₂ levels have increased extremely rapidly due to much greater rates of combustion from human activity and the inability of global rates of photosynthesis to absorb the excess CO₂.**
- 6. Increasing levels of CO₂ result in increasing temperature as more and more heat is reflected back to the surface of the earth.**

Latest CO₂ reading
June 06, 2017

409.98 ppm

Carbon dioxide concentration at Mauna Loa Observatory

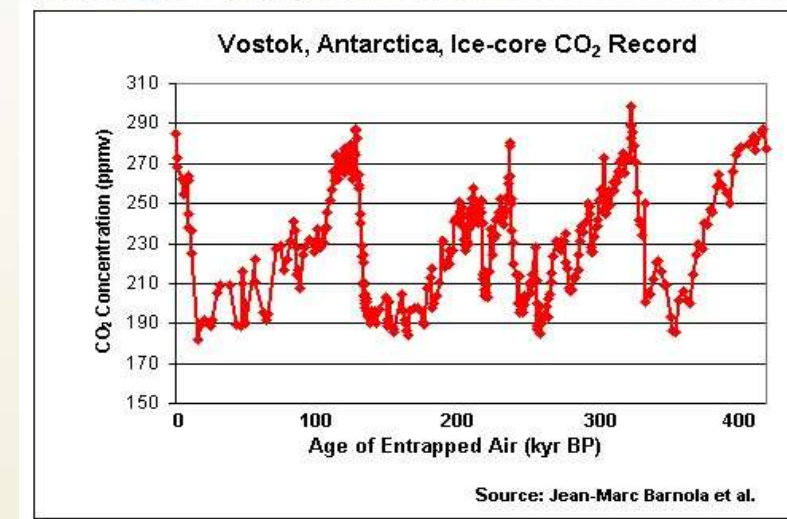


Current rate of increase is 100x the historical average

How do we know this?

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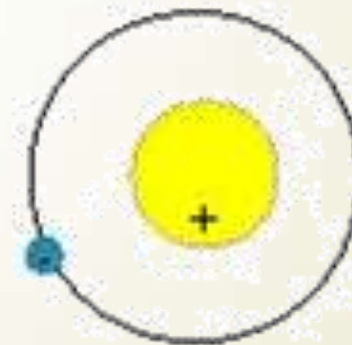
- How can we know what the earth's climate was like 800,000 years ago if we can't even predict the weather 5 days from now?
 - First, weather & climate are clearly very different concepts.
 - [Click here to find out how and why.](#)
- **The best evidence is from Antarctica.**
 - Most of the data comes from the Vostok Research Station.
 - As layers of snow accumulate, they become compressed into ice.
 - As the ice forms, it traps the surrounding air in small bubbles.
 - This air remains undisturbed and completely preserved in that ice.



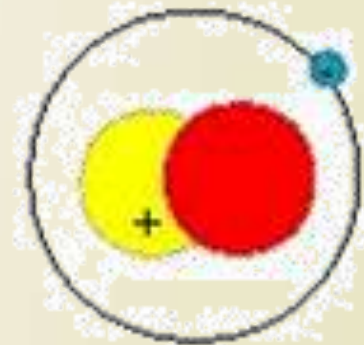
Vostok Ice

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- ▶ **The air bubbles in the ice core data can be dated, measured, and analyzed to tell us what a “natural change” would look like.**
 - ▶ Greenhouse gases can be measured with simple probes (similar to a Vernier probe you may use in your classroom).
- ▶ **Scientists are also able to determine the average annual temperature for each year using an isotope of hydrogen called deuterium.**
 - ▶ Deuterium is essentially a ‘heavy’ form of hydrogen.
 - ▶ The more deuterium in the air, the warmer the atmosphere was for that particular year on average.



Hydrogen

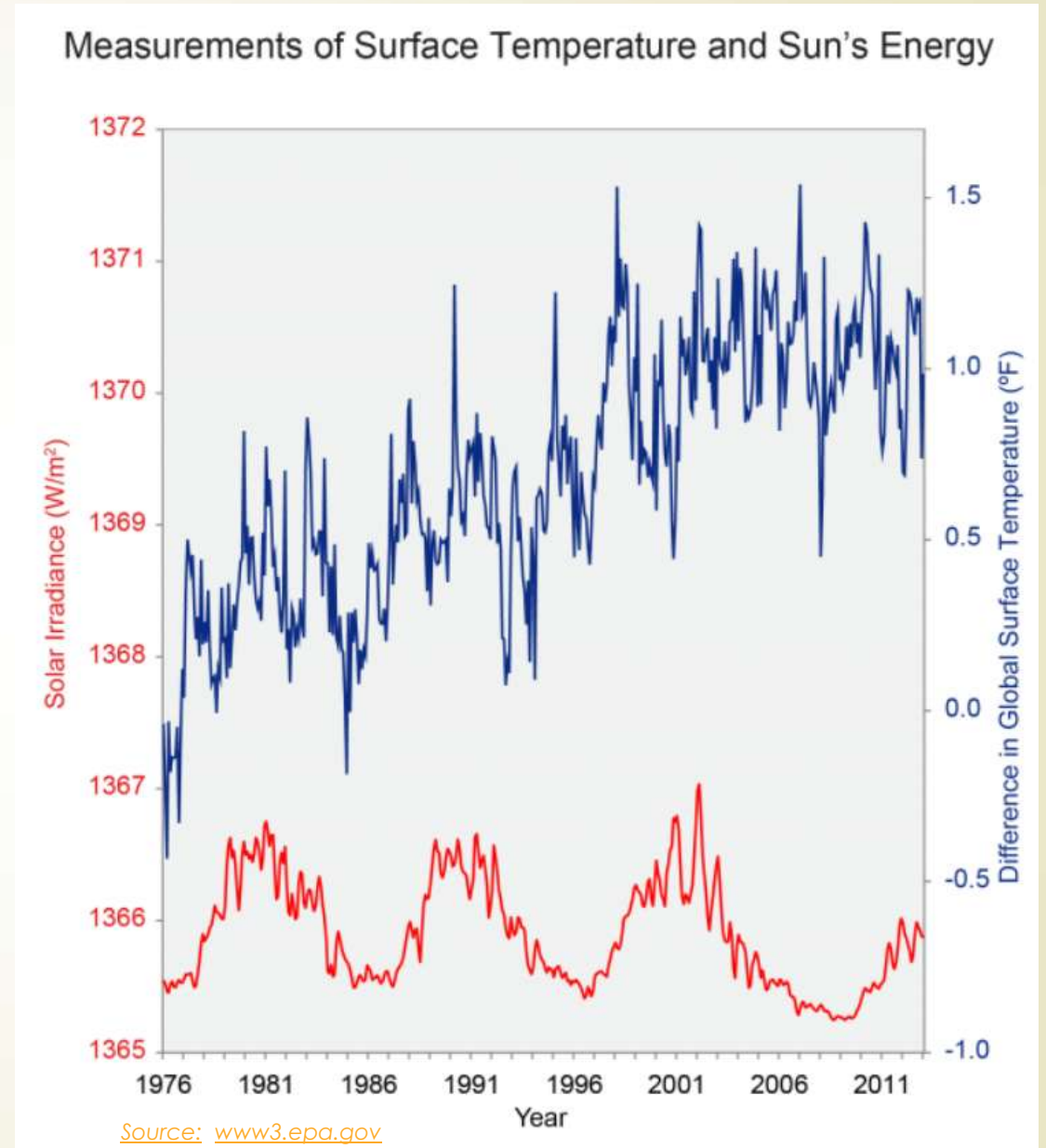


Deuterium

Other Sources of Evidence

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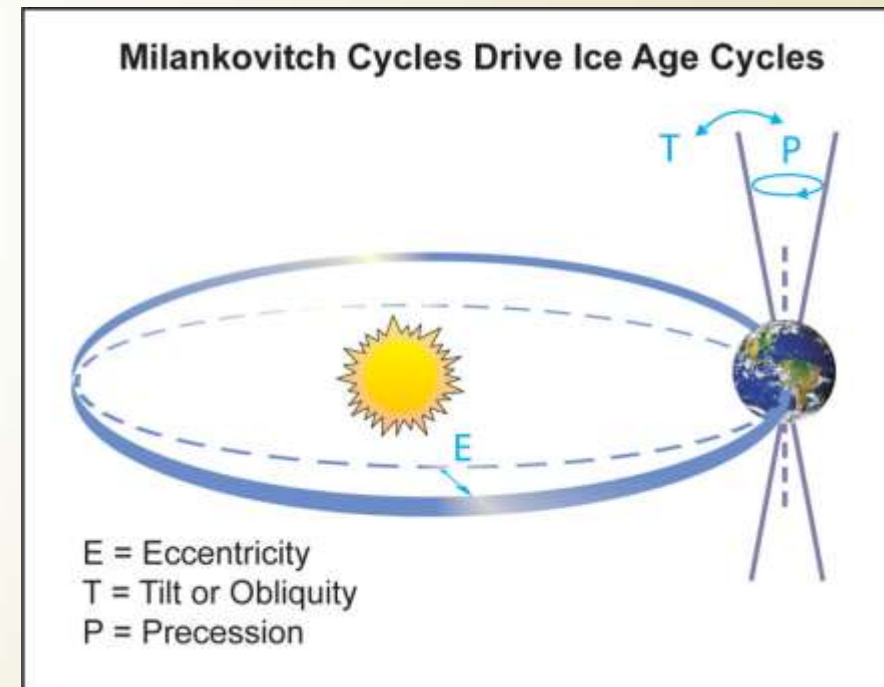
- ▶ **The sun's energy-output does fluctuate on a fairly regular basis.**
 - ▶ However, while these long-term fluctuations have remained fairly consistent, the temperature on the surface of the earth has continued to rise.
- ▶ **This relationship strongly indicates that the cause of the warming of the earth is unrelated to the output of energy from the sun.**



Other Sources of Evidence

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- ▶ **The earth has changes to its rotation and orbit that can affect its climate.**
 - ▶ These changes (called Milankovitch Cycles) are a major cause of changes to the Earth's climate, including ice ages.
- ▶ **However, the rate of change is ten to hundreds of thousands of years for these cycles.**
 - ▶ The rate of change we are currently experiencing is thousands of times faster than what would occur from the Milankovitch Cycles.
 - ▶ $E = 100,000$ years; $T = 41,000$ years; $P = 23,000$ years
Climate Change =



Other Sources of Evidence

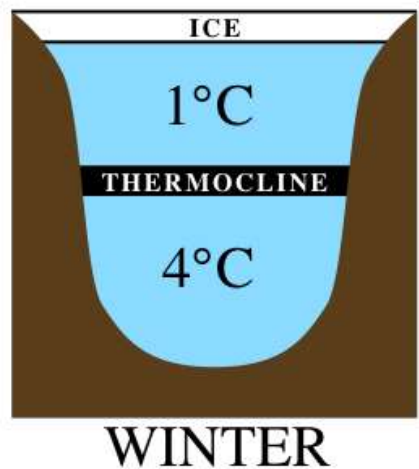
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➤ The atmosphere is measurably warming.

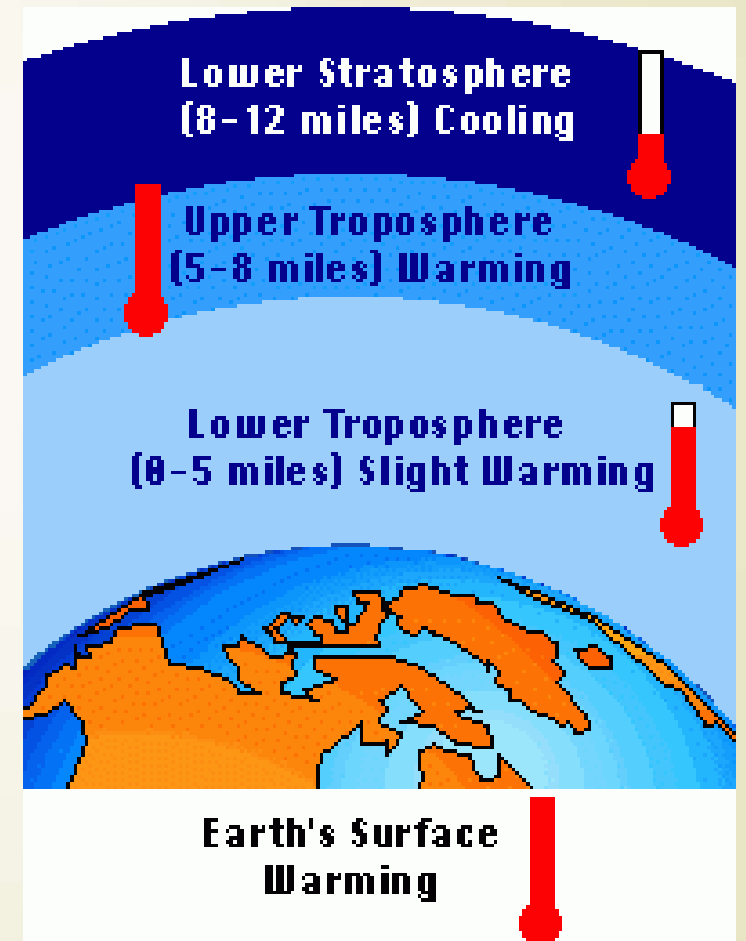
- The earth's surface and the troposphere have experienced measurable warming at an unprecedented pace since the start of the Industrial Revolution.
- However, the stratosphere has actually cooled. Many climate skeptics point to this as proof that climate change is not real (after all, heat rises...right...?).

➤ The reason that the stratosphere is cooling is because of the depletion of the ozone layer in the 20th century.

- The ozone layer insulated the stratosphere.
- Now that the ozone is depleted, heat can more easily escape, resulting in cooling.
- Because the stratosphere is cooling while the troposphere is warming, it creates a thermocline (similar to lakes covered by ice).



Source: The Adapa Project

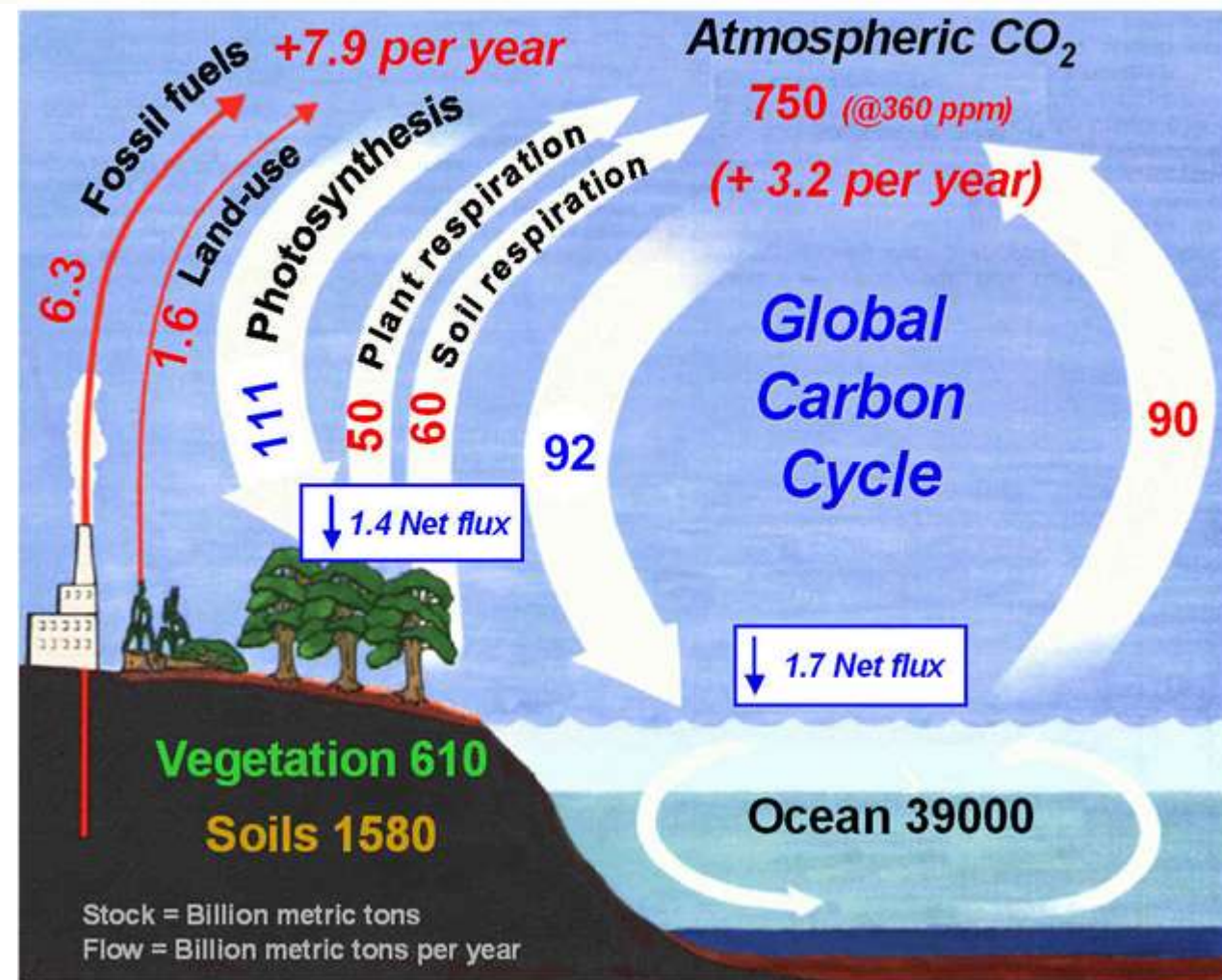


Source: https://science.nasa.gov/science-news/science-at-nasa/2000/ast21jul_1m

We know that this is because of humans

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- ▶ We know that the rise in CO₂ is not from a volcano or any other natural source.
- ▶ Scientists have quantified where CO₂ is coming from and where it goes in what is known as a Flux and Pool model (see below).
- ▶ The amount of increase in CO₂ in the atmosphere corresponds to the amount of CO₂ from human activity.

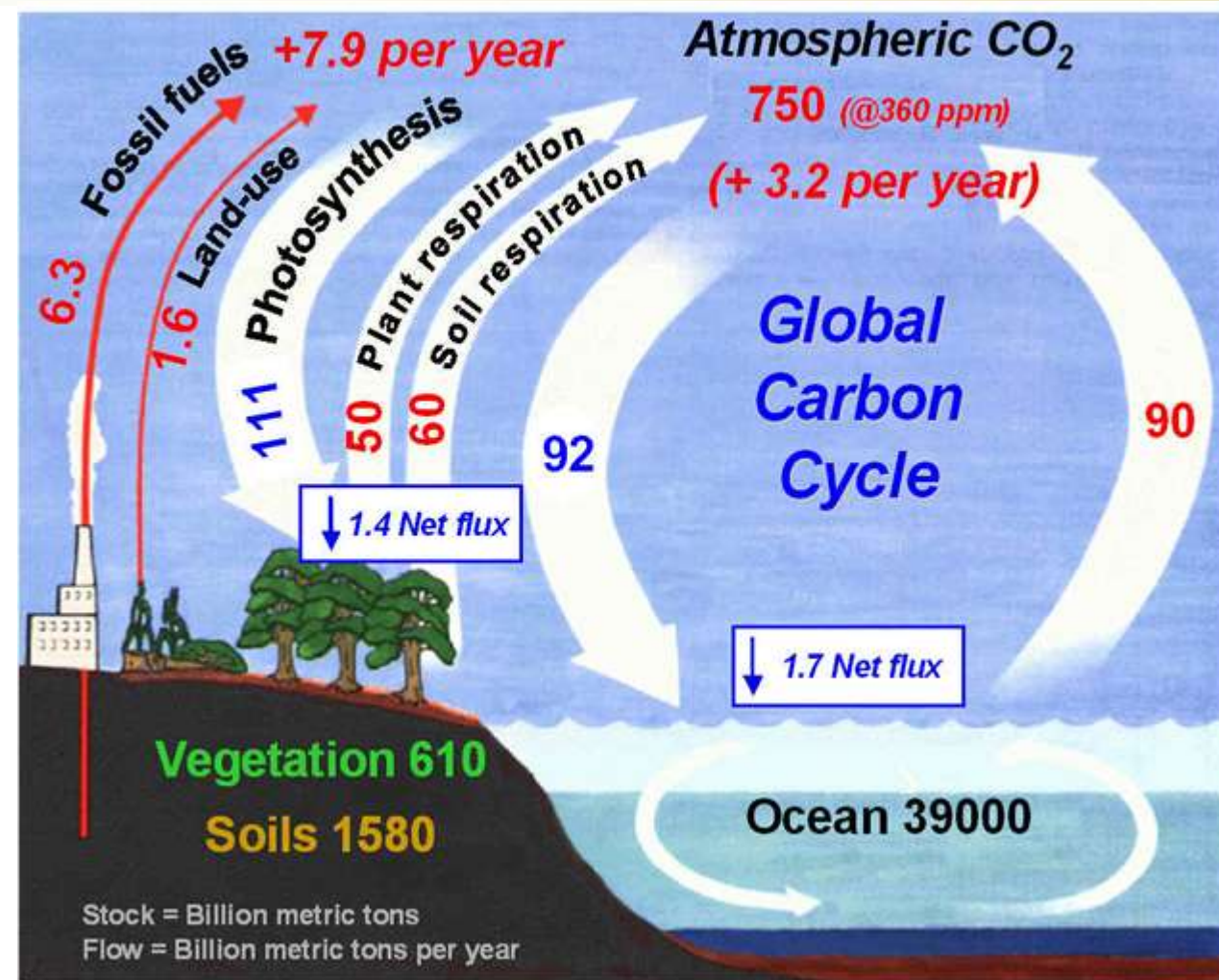


Source: https://globalchange.umich.edu/globalchange1/current/lectures/klings/carbon_cycle/carbon_cycle.html

We know that this is because of humans

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- ▶ Notes that all of the arrows are roughly *balanced* (i.e. CO₂ out = CO₂ in) except for the arrows on the left.
 - ▶ These arrows represent the CO₂ that is released from human activity.
 - ▶ This CO₂ is what is responsible for the annual increase of atmospheric CO₂ and the increase in the Earth's surface temperature.



Undeniable Scientific Facts

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- **CO₂ is released into the atmosphere during decomposition, burning, and respiration.**
- **Levels of CO₂ in the atmosphere have increased faster now than at any other measurable point in the Earth's geological history.**
- **This CO₂ can be traced back to human activity, particularly the burning of carbon-dense fossil fuels (all of that carbon eventually becomes CO₂).**

Undeniable Scientific Facts

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- **CO₂ is a greenhouse gas. This means that it slows the loss of heat from the surface of the earth.**
- **The atmosphere of the earth is warming and at an accelerating rate.**
- **Increasing the temperature of the earth can have enormous ramifications.**
- **The increase of this temperature is not due to solar output, natural cycles, or any other natural cause.**



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The Damage We're Doing

We are hurting our own future.

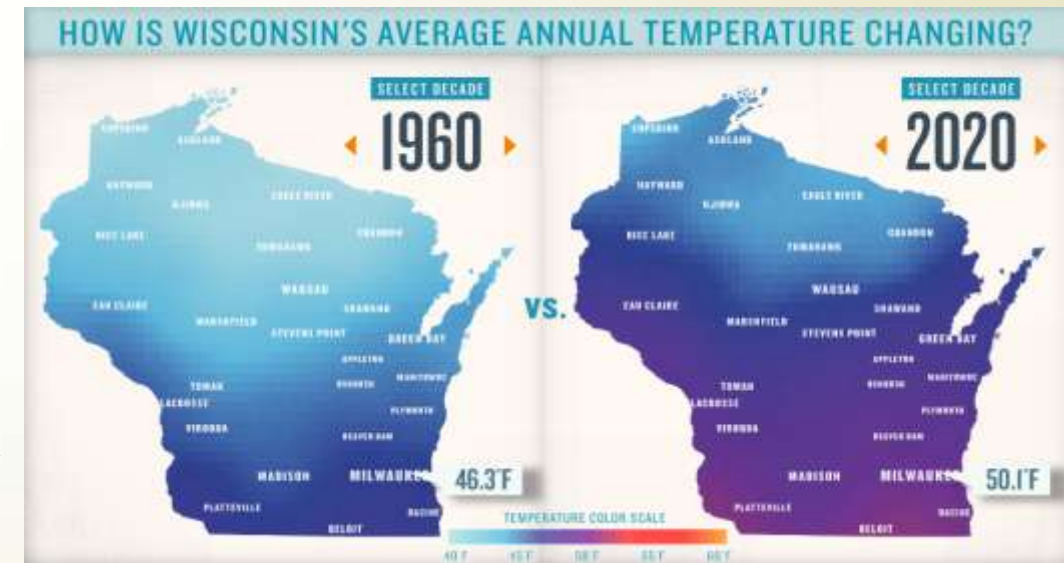
What can we expect in the future?

- ▶ **As greenhouse gas levels increase, patterns of US precipitation and storm events will change as well.**
 - ▶ Northern areas will likely become wetter, especially in winter and spring.
 - ▶ Southern areas (especially in the West) will likely become drier.
- ▶ **Heavy precipitation will be more frequent as the atmosphere will have more energy to hold more moisture.**
 - ▶ Heavy downpours that once occurred every 20 years are projected to occur as often as every 4 years, raising the risk of flooding in many areas.
- ▶ **The intensity of Atlantic hurricanes is likely to increase.**
 - ▶ For each 1.8° F increase in tropical sea temperatures, there is a projected hurricane rainfall increase of 6-18%. There has been a pronounced increase in the number of Category 4 and 5 hurricanes already.
- ▶ **Snow accumulation will begin later and end earlier.**
 - ▶ This will likely decrease snow cover by approximately 15%.
 - ▶ Warming is expected to occur at a faster rate as less snow reflects sunlight away from the earth's surface.

How will the Midwest change?

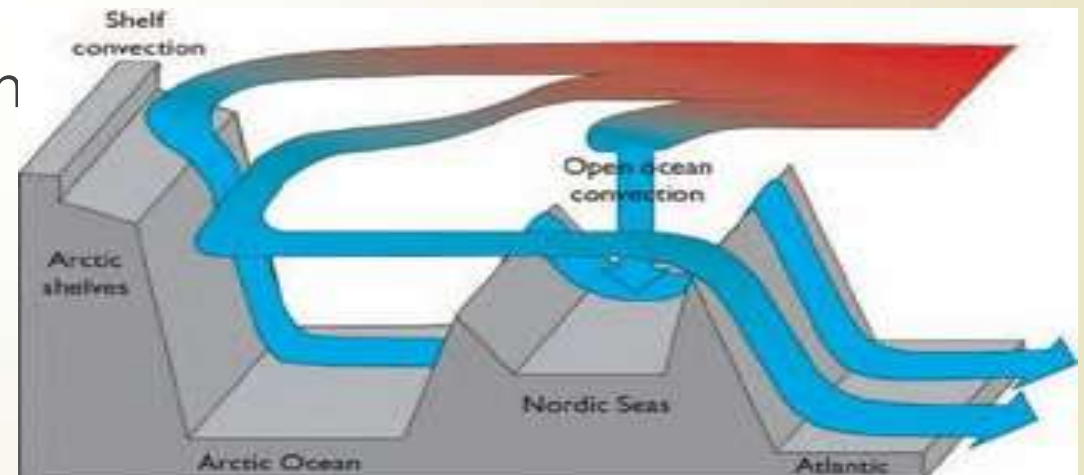
For the Midwest, the changes will be pronounced as well.

- ▶ In 1995, the Midwest endured a 4-day heat wave that caused over 700 deaths in Chicago alone.
 - ▶ *Similar heat waves are projected to occur up to three times per year within the next decades as the climate of the Great Lakes begins to resemble the climate of Texas and Oklahoma.*
- ▶ Heavy downpours and severe droughts in the Midwest are projected to occur twice as often as they did in 1900.
 - ▶ *Floods like those of 2008 and droughts like those of 2012 are expected to continue to occur with greater and greater frequency.*



Thermohaline currents are at risk.

- ▶ **The thermohaline current brings warm air to northern latitudes in places such as Europe and western North America.**
 - ▶ Many northern latitudes have warmer climates due largely to these currents.
- ▶ **If the thermohaline currents were exposed to too much cold freshwater (such as from melting ice), the entire current could be disrupted.**
 - ▶ Fresh water dilutes the dense, cold, salty water.
 - ▶ Dilution reduces the density of this seawater, preventing it from sinking as quickly.
- ▶ **With too much fresh water, the thermohaline current would stop altogether.**
 - ▶ This would cause drastic shifts in the global climate.

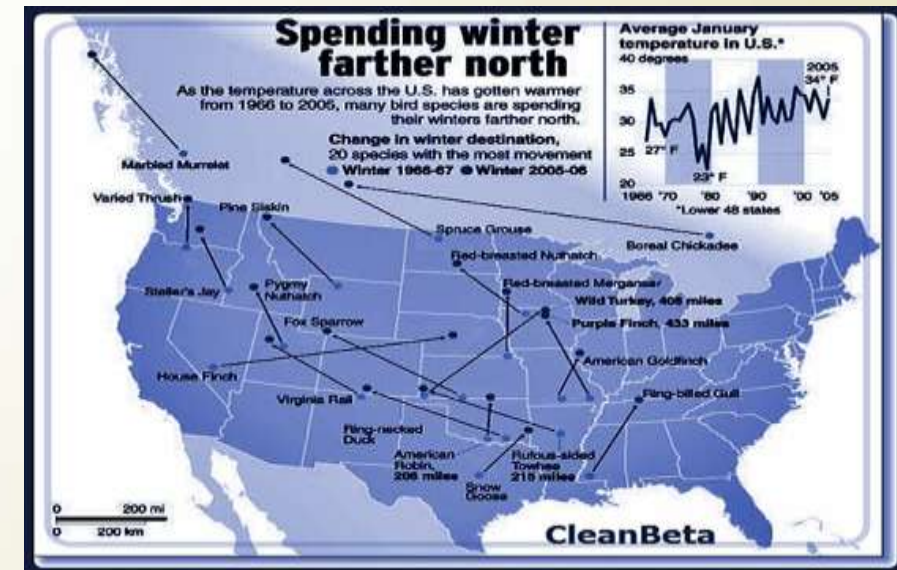


How will this affect ecosystems?

- ▶ **Terrestrial ecosystems are especially at risk due to climate change.**
 - ▶ Rapid changes to the habitats of species will likely cause the extinction of many of those species and a reduction in the services they provide to humans.
- ▶ **Migratory species today are already exhibiting climate change-related changes.**
 - ▶ Warmer springs have led to earlier nesting for at least 28 migratory birds in the US. Northeastern birds are returning 13 days earlier on average than they did in the 20th century. In California, 16 of 23 butterfly species have already adjusted migration timing.
- ▶ **Changes to migratory patterns can lead to mismatches in breeding and food availability.**
 - ▶ Species with specific niche needs will face increased likelihoods of extinction as their growth and survival are reduced by changes to their availability of food

Shifting Habitats

- ▶ As habitat ranges shift northward in the US, it will result in less hospitable habitat and increased competition for some species.
 - ▶ Some species may have nowhere to go because they are already at the northern limit of their habitat range.
- ▶ For example, shifting boreal forests in Alaska are reducing the amount of tundra available for species such as the caribou, arctic fox, and snowy owl.
 - ▶ Oak-hickory forest expansion is decreasing the amount of maple-beech forest habitat available.
 - ▶ Cold water fish, such as trout, are completely losing their habitat as aquatic ecosystem species cannot move as easily as terrestrial species.



Ecosystem Tipping Points

- ▶ **Ecosystem change may occur rapidly and irreversibly because a threshold (or “tipping point”) is passed.**
 - ▶ For example, the Prairie Pothole Region in the north-central US is an ecosystem made up of numerous small, shallow lakes.
 - ▶ *These small lakes are called prairie potholes. These wetlands are critical for breeding grounds for migratory waterfowl (and the duck hunters who depend on them).*
- ▶ **A permanently warmer, drier future for the Dakotas may drop prairie pothole water levels below what is needed for waterfowl reproduction.**
 - ▶ The effects on hunting from temporary droughts of the past may become a permanent fixture.
 - ▶ Similar effects may be felt in other recreational areas, including ice fishing, snowmobiling, skiing, and other winter- or water-based sports.



Common Misunderstandings about Climate Change

Common Misunderstandings about Climate Change

➤ **“This is just a natural cycle.”**

- *Natural cycles occur over a 10,000 -100,000 year cycle (Milankovitch Cycles). Modern climate change has occurred over a 150 year period. Natural cycles do not happen this rapidly.*

➤ **“The earth is warming because of the sun/sun spots/solar flares.”**

- *Output of solar radiation has stayed generally constant. CO2 levels have increased.*

➤ **“CO2 is a naturally occurring gas and therefore cannot be a problem.”**

- *Just because something is naturally occurring does not mean it isn't a problem, especially when it occurs in excessively high levels. This is as true for the nitrates & phosphates found manure that cause eutrophication as it is for the CO2 that is causing climate change.*

Common Misunderstandings about Climate Change

- **“There was a time when scientists thought the earth was cooling. Now they say it is warming. They must not know what they are talking about.”**
 - *The earth was due for an ice age, and scientists had concerns several decades ago about when that might begin. This was a valid concern given what we know about Milankovitch Cycles. As climate science has improved, we have learned that an ice age was indeed beginning (again, over a 10,000 year period). [Read more here.](#)*

Common Misunderstandings about Climate Change

- **“It still snows sometimes and there are still days that reach record cold. This proves climate change is not real.”**
 - *The fact that the number of record highs are twice as high as the number of record low temperatures actually supports the idea that the climate is warming.*
 - *A warming climate will not cause all snow to disappear overnight. It will cause it to disappear gradually, which is exactly what is happening.*

Common Misunderstandings about Climate Change

- ▶ **“The amount of ice in Antarctica is actually increasing, so scientists must not know what they’re talking about.”**
 - ▶ The amount of ice gained in east Antarctica have been steady for decades, while the amount of ice loss in western Antarctica more than negates these gains. As a whole, Antarctica is losing ice.
- ▶ **“This is because of volcanoes.”**
 - ▶ There is no data to suggest that this is the case, and CO₂ from volcanic activity is less than CO₂ from human activity. “The carbon dioxide released in contemporary volcanic eruptions has never caused detectable global warming of the atmosphere.”

Common Misunderstandings about Climate Change

- **“The amount of CO₂ from natural sources is far less than the amount of CO₂ from natural sources, so obviously humans aren’t the problem.”**
 - *While the amount of CO₂ from non-human sources is in fact much higher, that CO₂ is also balanced by an equivalent amount of photosynthesis.*
 - *The CO₂ released from human activity is not balanced by an equal amount of photosynthesis and is in fact responsible for the annual increase in CO₂.*

Common Misunderstandings about Climate Change

- **"During Medieval times, Greenland was warm and green. Global warming is nothing new, nor is it caused by people."**
 - *While isolated parts of the world have undergone brief exceptional changes, those isolated incidents are not representative of the planet as a whole.*
 - *E.g. If one person in a group likes the color red, that does not mean that everyone in the group likes the color red.*
 - *Global average data is consistent in that the scope and rate of the changes we are experiencing now are unprecedented in the measurable geological history of the planet.*

Common Misunderstandings about Climate Change

- **“We don’t know enough about climate change to justify any action at this time.”**
- *Similar arguments have been made about vaccines. As a result of the anti-vaccination campaign, a series of previously eliminated diseases are re-emerging. [Click here to learn more.](#)*
- *The fact is, climate change is relatively simple – too much CO₂ from human activity is causing the earth to warm. [We’ve understood this problem since 1896.](#)*
- *Failure to act on climate change will have enormous ramifications on our ability to feed, support, and defend human populations. See data later in this presentation.*

Common Misunderstandings about Climate Change

- **“We can’t afford to fight climate change.”**
 - *We can’t afford not to. Already, climate change is causing economic losses in the billions. See data later in this presentation.*
 - *The best estimates indicate that the US could effectively fight climate change for the cost of about \$20-30 billion.*
 - *This is well within the economic capability of the US economy and should be seen as an investment that would prevent far greater economic losses that are already occurring.*

Common Misunderstandings about Climate Change

- **“A warmer planet may be good for humans. It may mean that we can grow more food.”**
 - *While climate change may in fact extend the growing season and expand where crops can be grown, the losses from flooding and drought will almost certainly more than negate these gains.*
 - *In fact, a plethora of peer reviewed research is already showing that American agriculture is currently losing billions of dollars per year due specifically to the impacts of climate change.*
 - *Note that peer reviewed research is very different from what most Americans see on social media.*
 - *The next few slides summarize these findings.*

Impacts of Climate Change on Ag

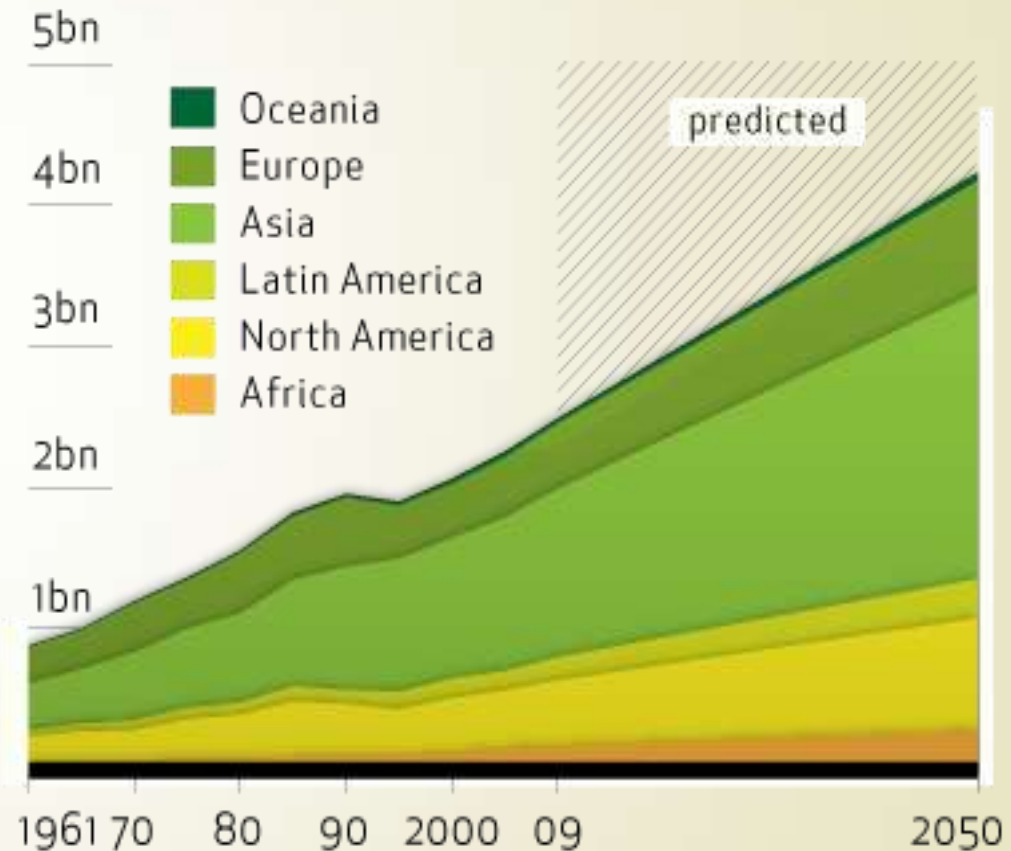
Our pending failure to feed billions of people.

The 2050 Challenge

+70%

- ➔ **The world population is expected to increase to 9 billion people by 2050.**
 - ➔ This increase will require an increase in food production of **70%**.
 - ➔ However, agriculture is at significant risk of a systemic failure due to climate change.

CEREAL CROP PRODUCTION (tonnes) Source: FAO/STAT



Source: Farming First

Decreased Rice Production

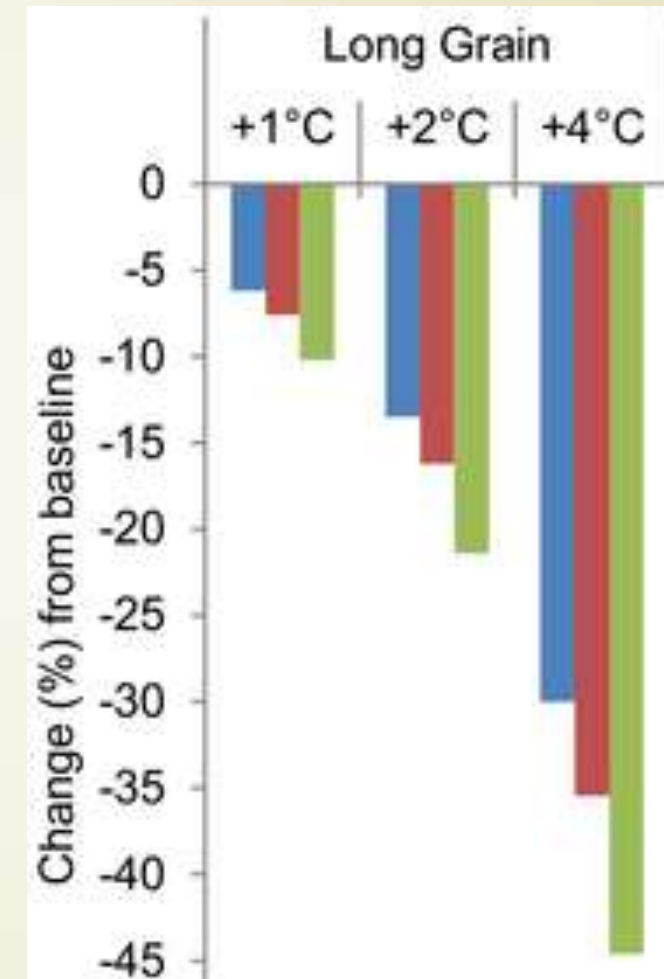
+70%

➔ Rice is the most widely consumed food staple in the world.

➔ A 1°C increase in average growing season temperature **reduces rice yields by 6-11%**.

➔ In our lifetimes, temperatures are expected to rise by as much as 5.4°C.

■ Lyman NB, Jagadish KSV, Nalley LL, Dixon BL, Siebenmorgen T (2013) Neglecting Rice Milling Yield and Quality Underestimates Economic Losses from High-Temperature Stress. PLoS ONE 8(8): e72157. <https://doi.org/10.1371/journal.pone.0072157>

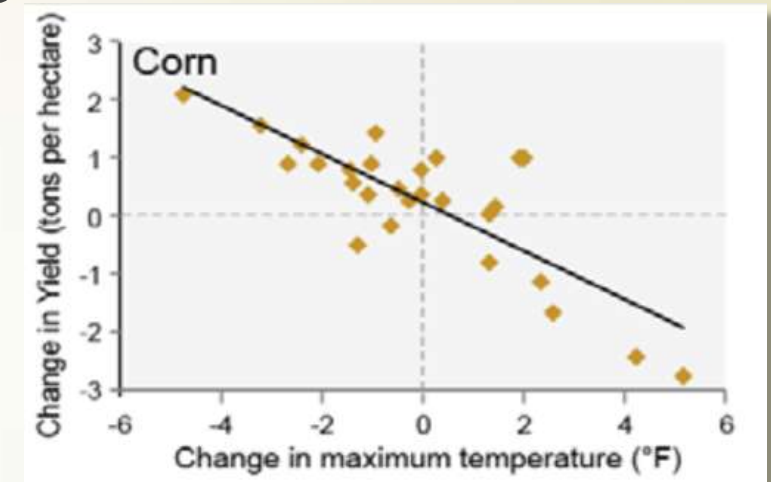


Corn & Wheat

+70%

- **Corn is the most widely consumed grain in the United States and 65% of US corn occurs in the Midwest.**

- An increase of 10° F in the maximum summer temperature **reduces corn yields by nearly 2 tons of grain per acre.**



- **Adding a single additional growing degree day results in a 7.6% reduction in US wheat yields.**
- The number of growing degree days is expected to increase by 30% by mid-century.

- Mishra, V., and K. A. Cherkauer (2010), [Retrospective droughts in the crop growing season: Implications to corn and soybean yield in the Midwestern United States](#), *Agricultural and Forest Meteorology*, 150(7-8), 1030-1045
- Tack, J., Barkley, A., & Nalley, L. L. (2015). Effect of warming temperatures on US wheat yields. *Proceedings of the National Academy of Sciences*, 112(22), 6931-6936.
- National Oceanic and Atmospheric Administration. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment Part 3. Climate of the Midwest U.S. NOAA Technical Report NESDIS 142-3

The Future of Agriculture

+70%

- **Currently the US dairy industry has 1.9% production losses due to climate change, representing \$670 million in losses to the industry.**
 - This amount is expected to increase to **6.3%/losses of \$2.2 billion by the end of the century.**

- Mauger, G., Bauman, Y., Nennich, T., & Salathé, E. (2015). Impacts of Climate Change on Milk Production in the United States. *The Professional Geographer*, 67(1), 121–131. Key, N., & Sneeringer, S. (2014). Potential Effects of Climate Change on the Productivity of U.S. Dairies. *American Journal of Agricultural Economics*, 96(4), 1136–1156. AND Klinedinst, P. L., Wilhite, D. A., Hahn, G. L., & Hubbard, K. G. (1993). The potential effects of climate change on summer season dairy cattle milk production and reproduction. *Climatic Change*, 23(1), 21–36.



Fruit is especially sensitive

+70%

- ▶ An early thaw/freeze cycle can cause hundreds of millions of dollars in losses to fruit & berry crops.
 - ▶ Premature budding due to a warm winter caused **\$220 million in losses of Michigan cherries in 2012.**

- ▶ USGCRP (2014). Hatfield, J., G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall, and D. Liverman, 2014: [Ch. 6: Agri-culture. Climate Change Impacts in the United States: The Third National Climate Assessment](#), J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 150-174



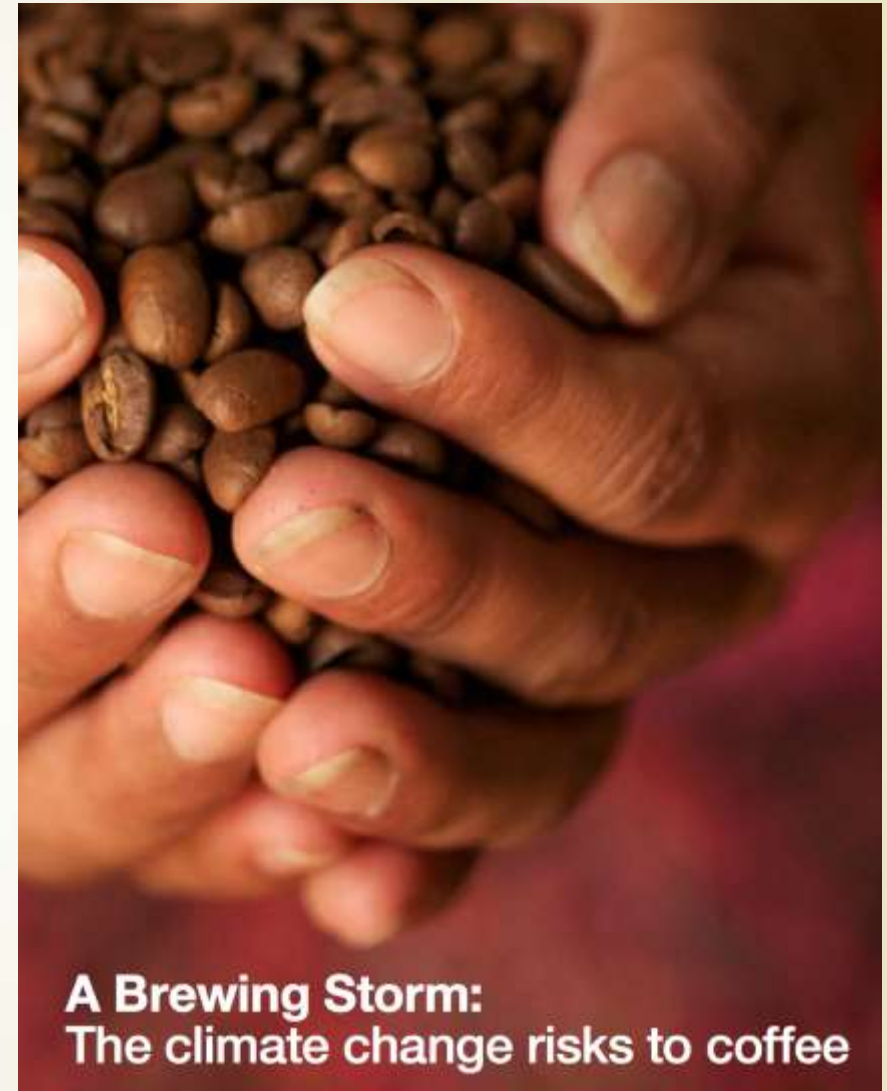
Source: SgForums.com

An uncaffeinated future?

+70%

- **“Climate change is projected to cut the global area suitable for coffee production by as much as 50% by 2050.”**
- **“By 2080, wild coffee...could become extinct.”**

- The Climate Institute. (2016). A Brewing Storm: the climate change risks to coffee | The Climate Institute. Retrieved May 3, 2017, from <http://www.climateinstitute.org.au/coffee.html>



**A Brewing Storm:
The climate change risks to coffee**

A Tenuous Future At Best

+70%

- **We face imminent decisions about the future of human civilizations.**
 - A simultaneous surge in human population and an unprecedentedly-rapid climate shift may be beyond the capacity of ecosystem services to support human civilizations.
 - Failure to adequately address these issues could result in global epidemics of widespread starvation and armed conflict.
 - Scientists are anticipating long-term impacts with a similar or greater magnitude of ramifications to ag as the Dust Bowl.

