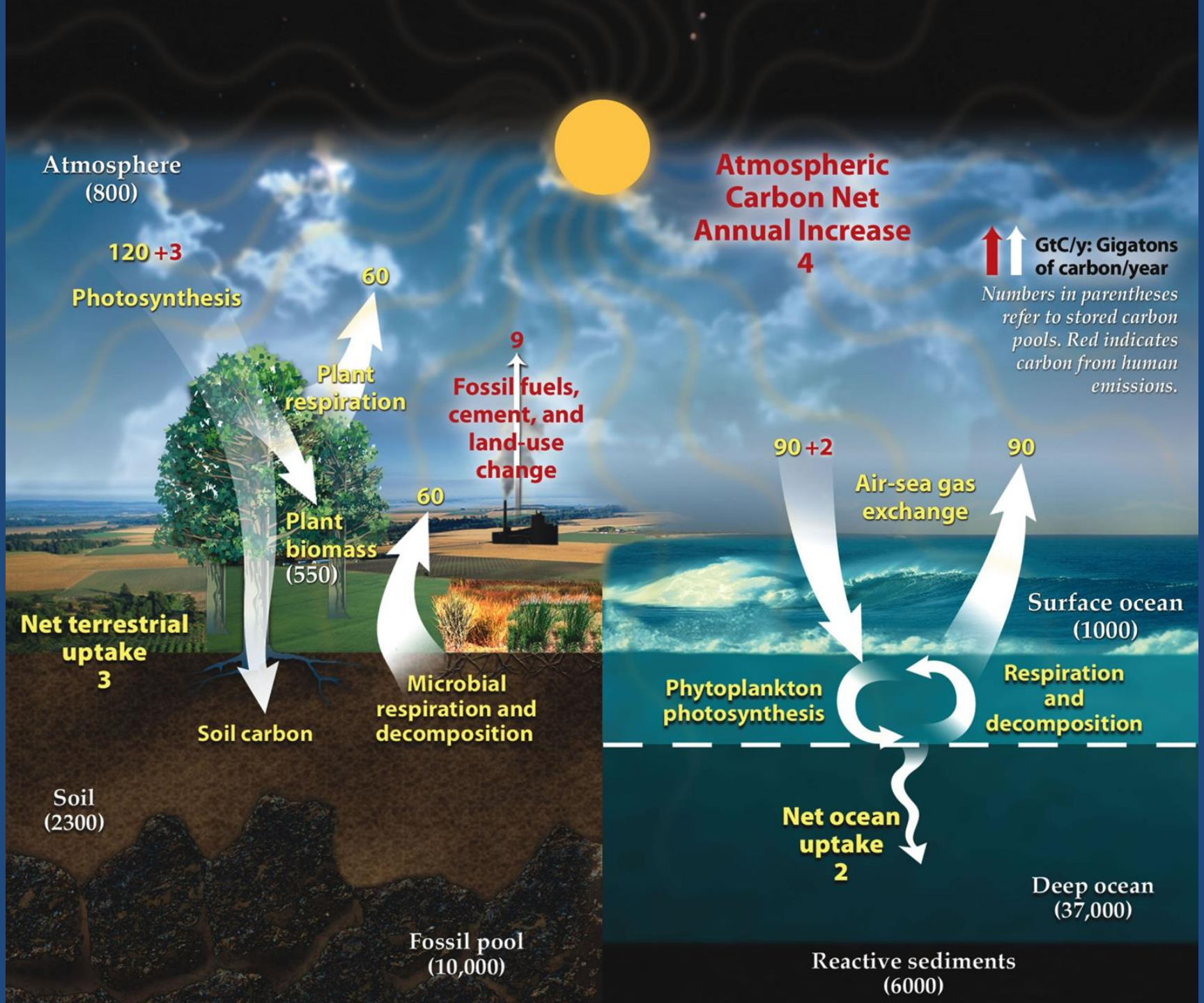
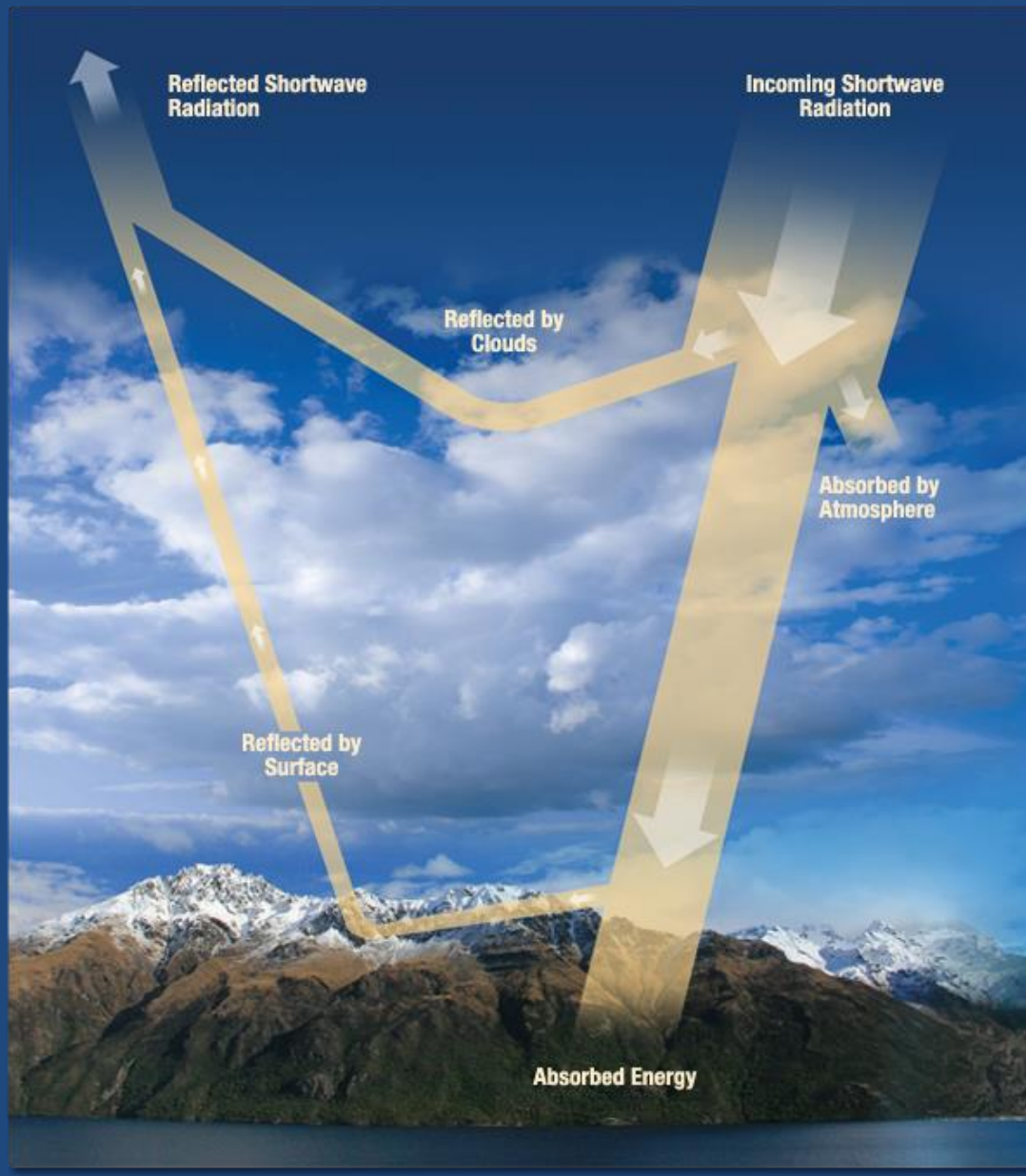

Greenhouse Effect & Climate Change


Atmosphere
(800)
120 +3
Photosynthesis
60
Plant
respiration
9
Fossil fuels,
cement, and
land-use
change
60
Plant
biomass
(550)
Net terrestrial
uptake
3
Soil carbon
Microbial
respiration and
decomposition
Soil
(2300)
Fossil pool
(10,000)
Atmospheric
Carbon Net
Annual Increase
4
GtC/y: Gigatons
of carbon/year
Numbers in parentheses
refer to stored carbon
pools. Red indicates
carbon from human
emissions.
90 +2
90
Air-sea gas
exchange
Surface ocean
(1000)
Phytoplankton
photosynthesis
Respiration
and
decomposition
Net ocean
uptake
2
Deep ocean
(37,000)
Reactive sediments
(6000)

Greenhouse Effect

Light energy from the sun (solar radiation) is either reflected or absorbed by the Earth.



Greenhouse Effect

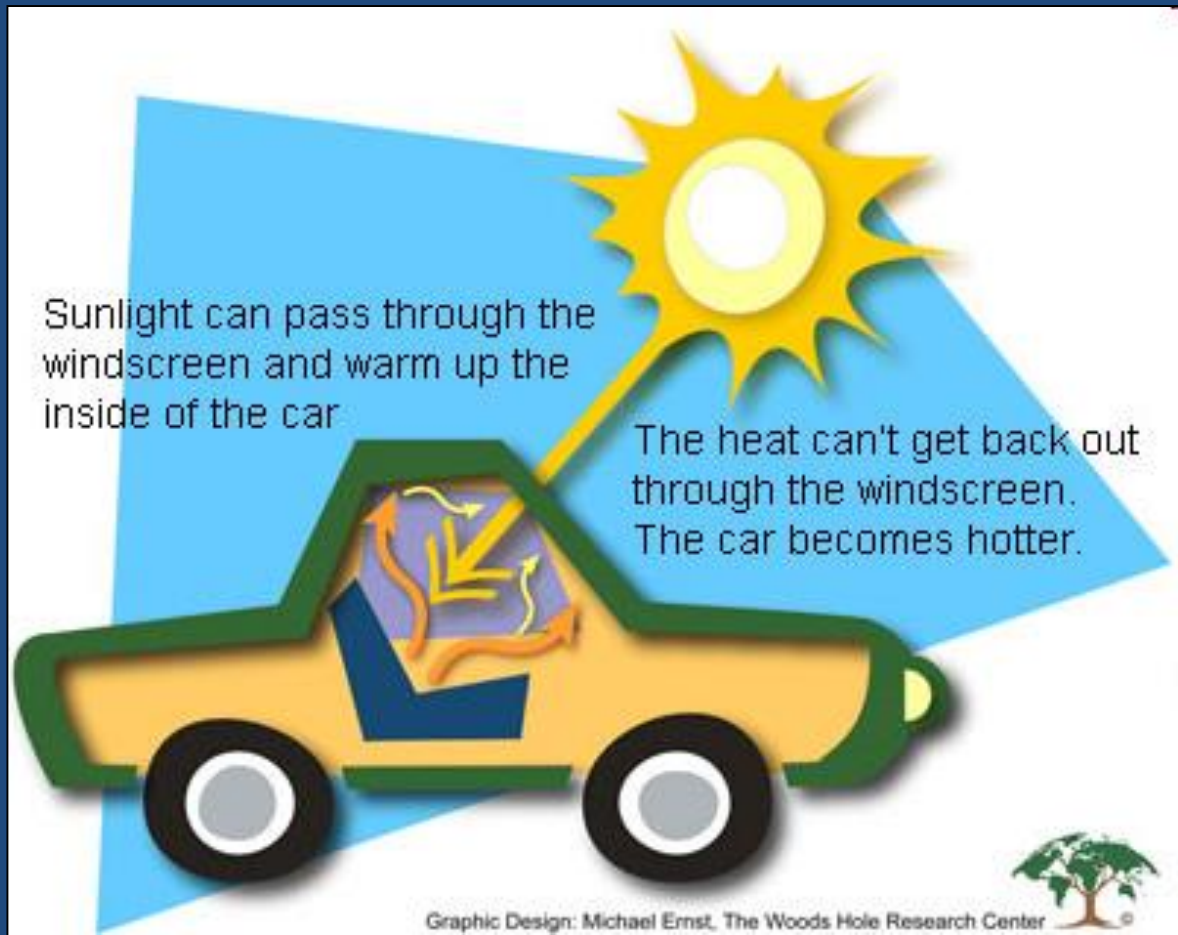
When it is absorbed by the Earth (or something on the Earth), light is converted into heat energy (infrared radiation).

Greenhouse Effect

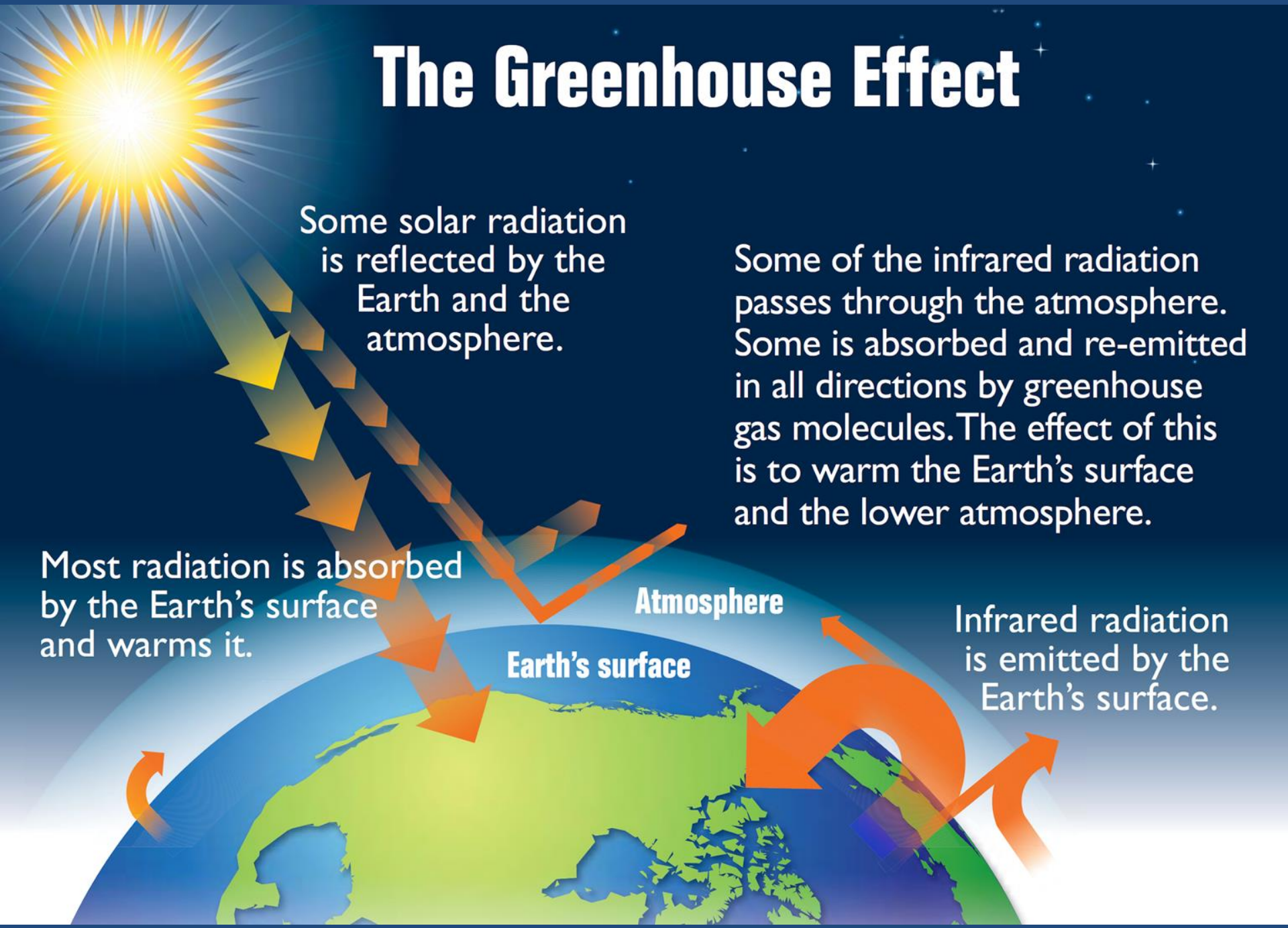
That heat energy either escapes the Earth through the atmosphere, or gets absorbed by greenhouse gases and reflected back down.

Greenhouse Effect

This is how heat is trapped by the atmosphere and how the Earth stays warm.



The Greenhouse Effect

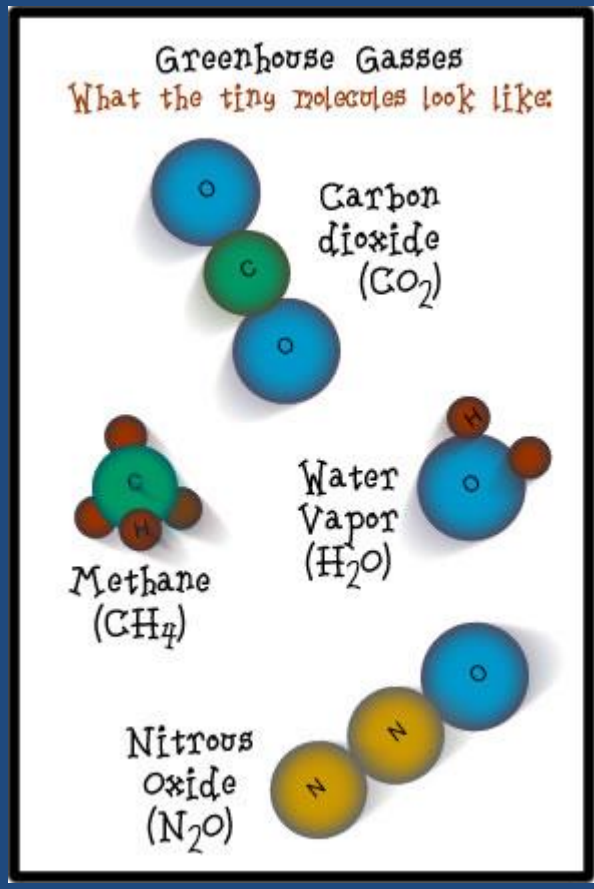


Greenhouse Effect

Greenhouse gases reflect heat & include:

- Water (H_2O)
- Methane (CH_4)
- Carbon Dioxide (CO_2)
- Nitrous Oxide (N_2O)

The first 3 are very natural, and in fact are necessary to keep the Earth warm.

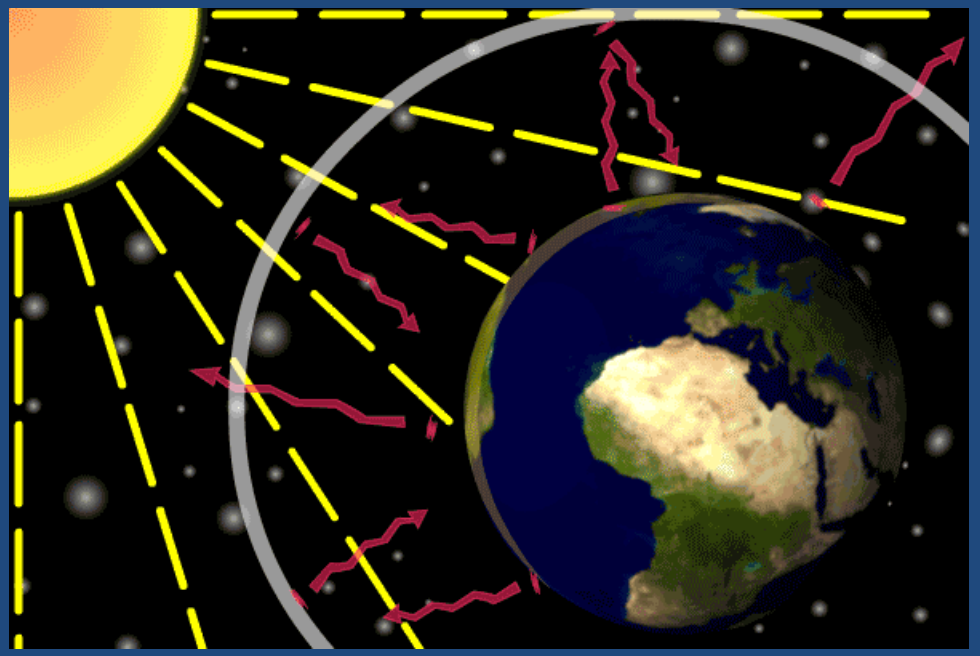


Greenhouse Effect

Nitrous Oxides are formed from combustion of fossil fuels.

Greenhouse Effect

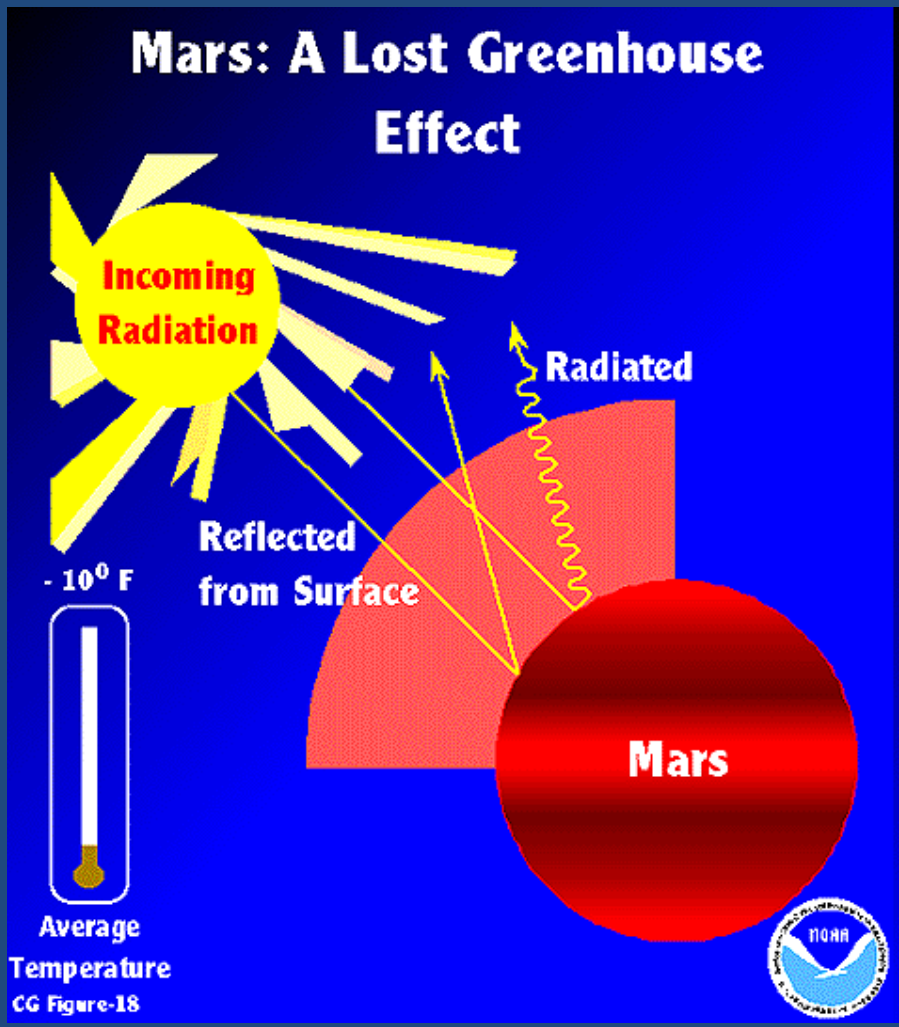
The greenhouse effect is natural and necessary for most life here on Earth.



Without greenhouse gases, the Earth would be too cold for most life.

Greenhouse Effect

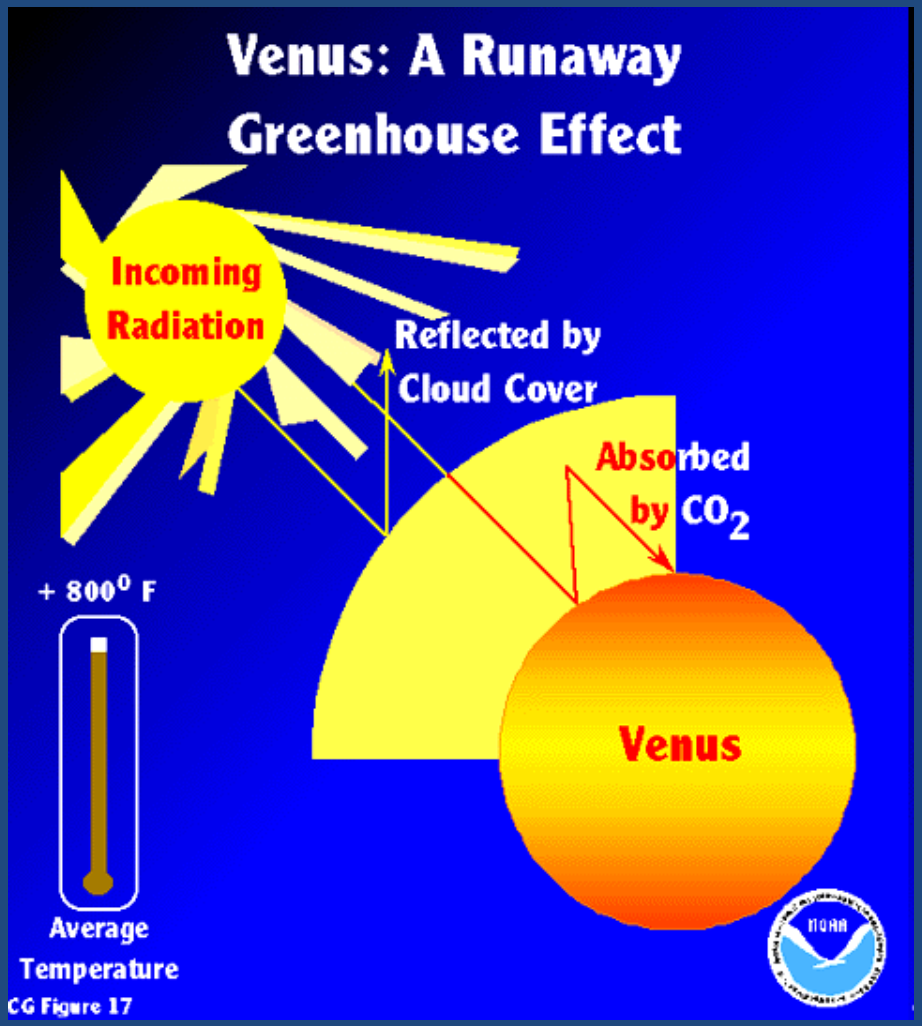
Without the greenhouses gases in our atmosphere the Earth's average temperature would be -16^0C ! This happened to Mars which lost its atmosphere.



Greenhouse Effect

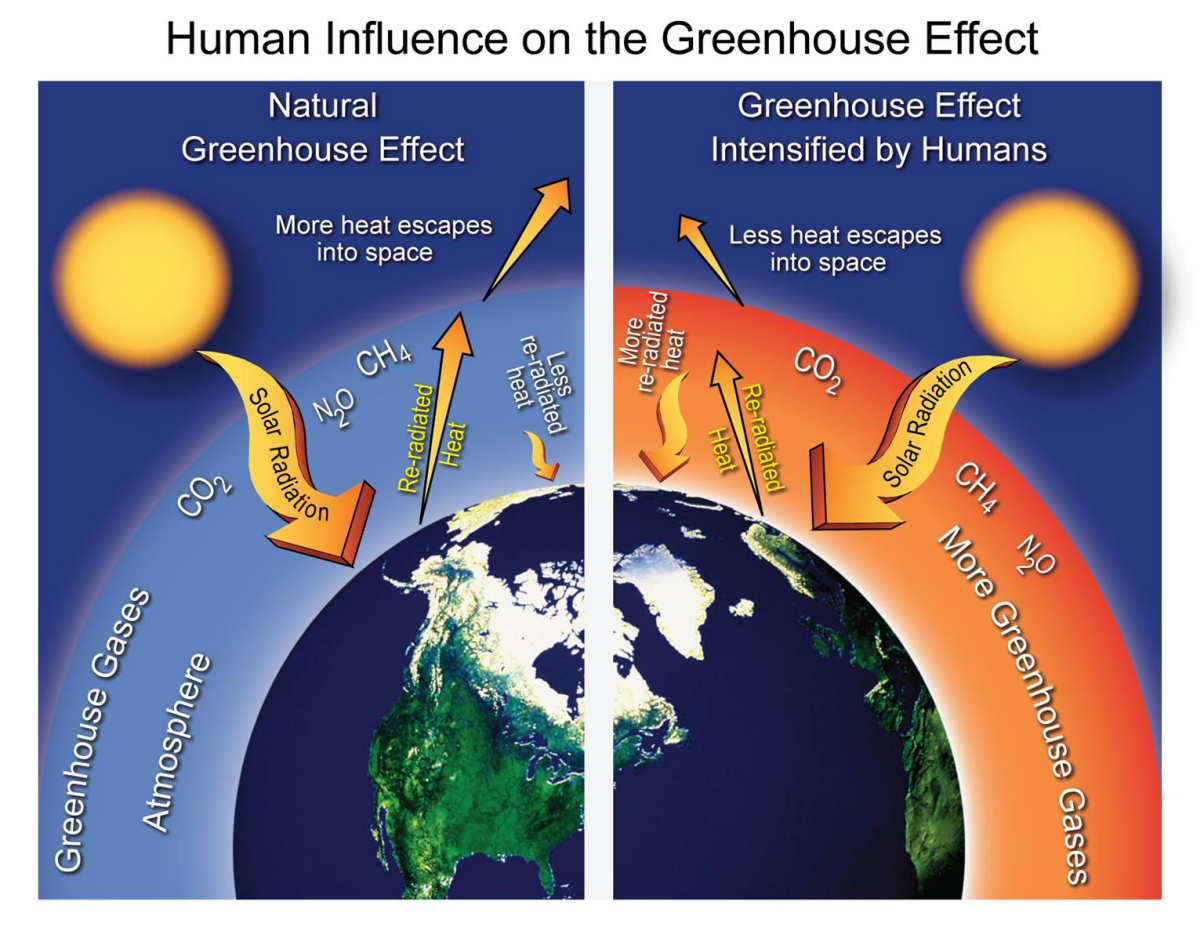
If a planet has extremely high concentrations of greenhouse gases in its atmosphere however it can have a runaway greenhouse effect.

This is the case with Venus, whose high concentrations of carbon dioxide give it an average surface temperature of 425^0C!!!



Causes of Climate Change

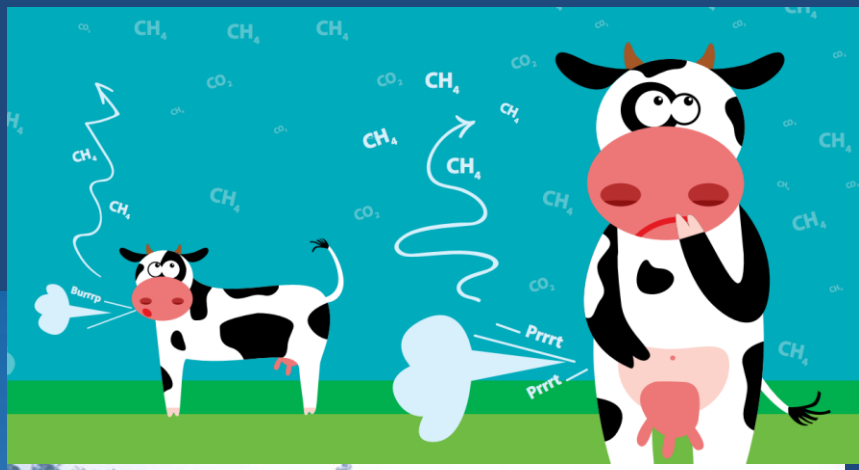
As more CO2 is added to the atmosphere, it traps more heat reflected from the Earth and raises the average global temperature.



Causes of Climate Change

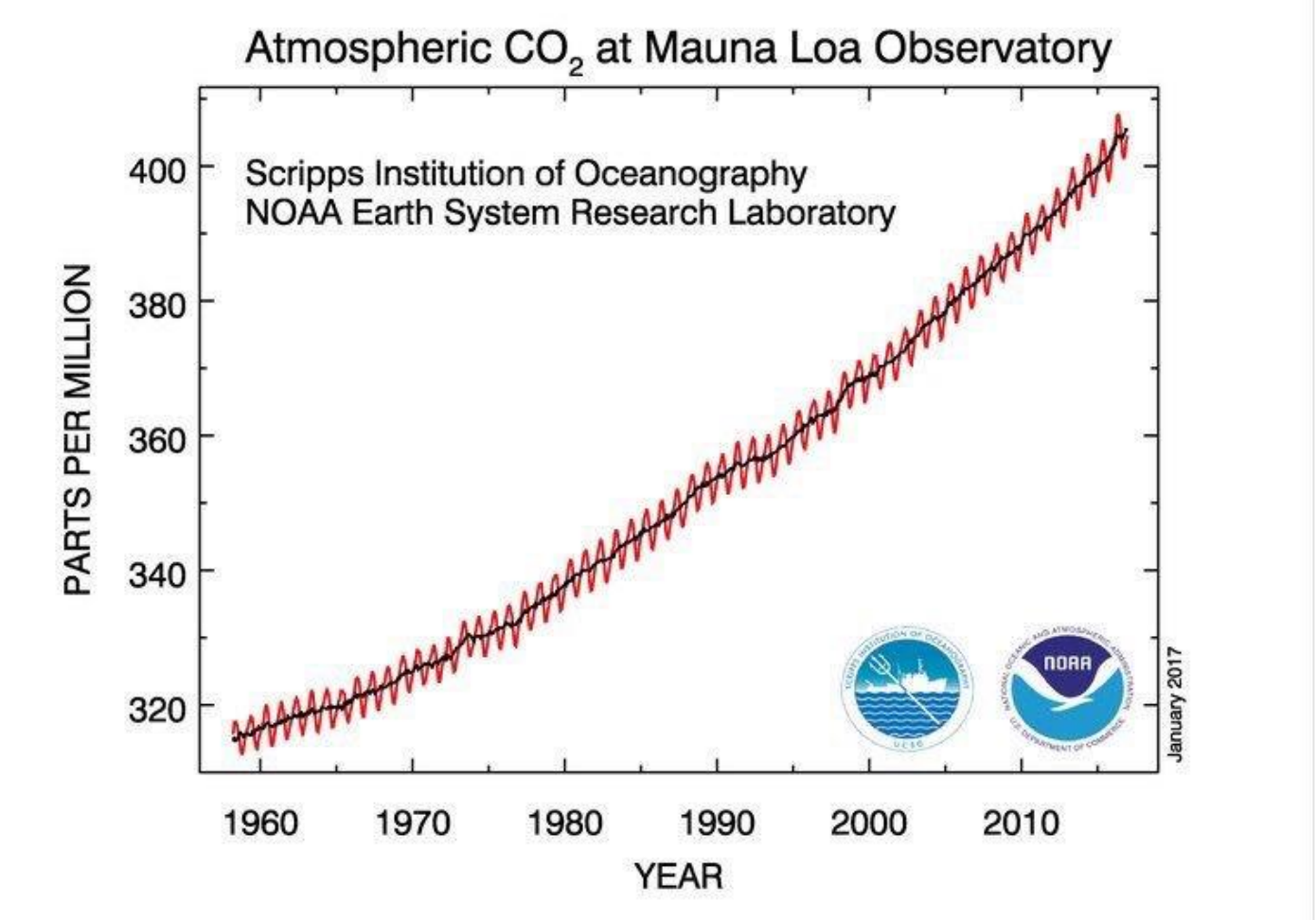
Humans have steadily been adding more CO2 to the atmosphere since the Industrial Revolution by burning fossil fuels, and cutting or burning trees down on massive scales.

Oh and Cows.



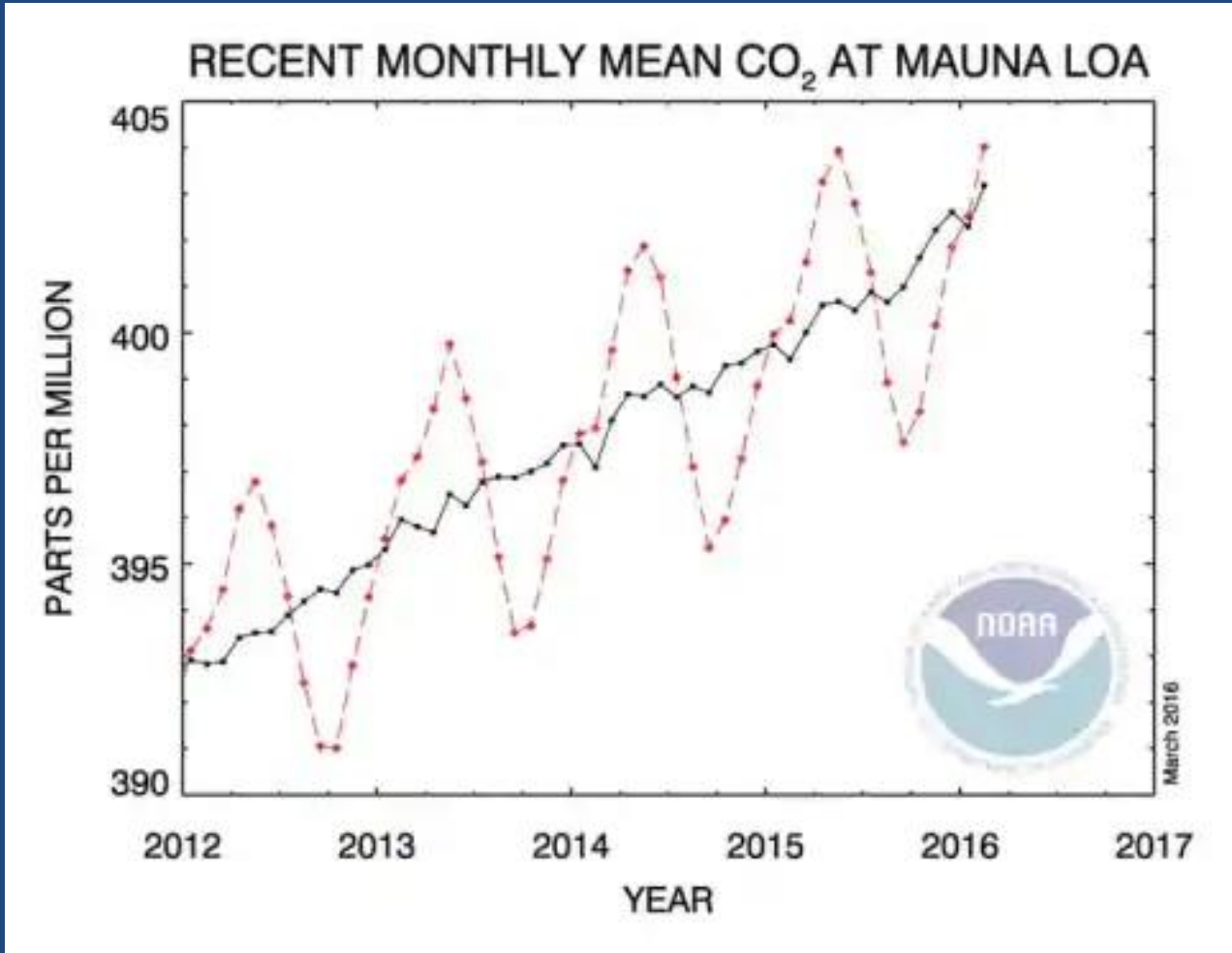
Evidence of Climate Change

CO2 levels in the atmosphere have been recorded since 1958. We have seen a steady increase of almost 100 parts per million since then.

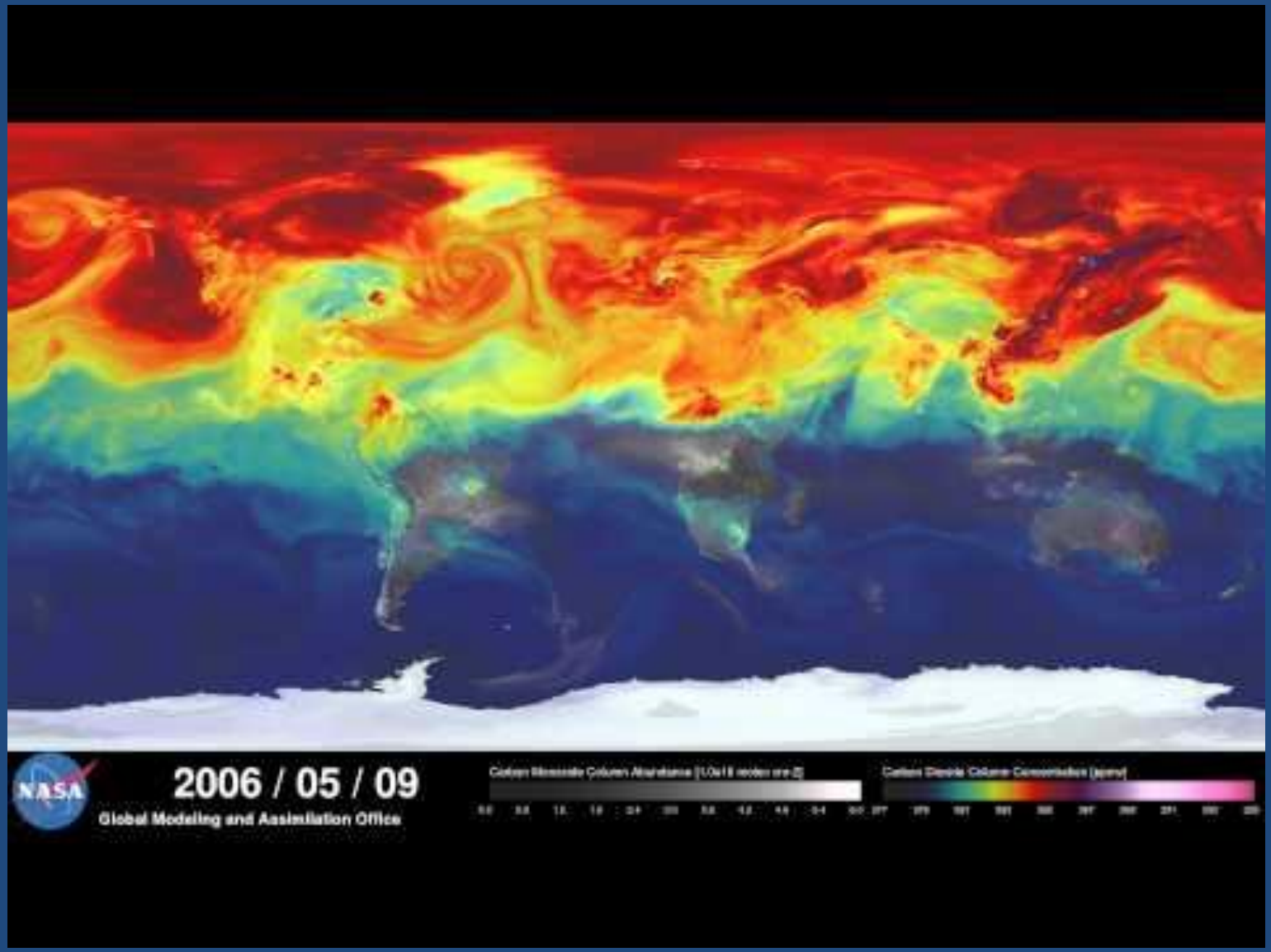


Evidence of Climate Change

CO2 levels in the atmosphere cycle annually, but we still see a steady increase upward.



Evidence of Climate Change



Evidence of Climate Change

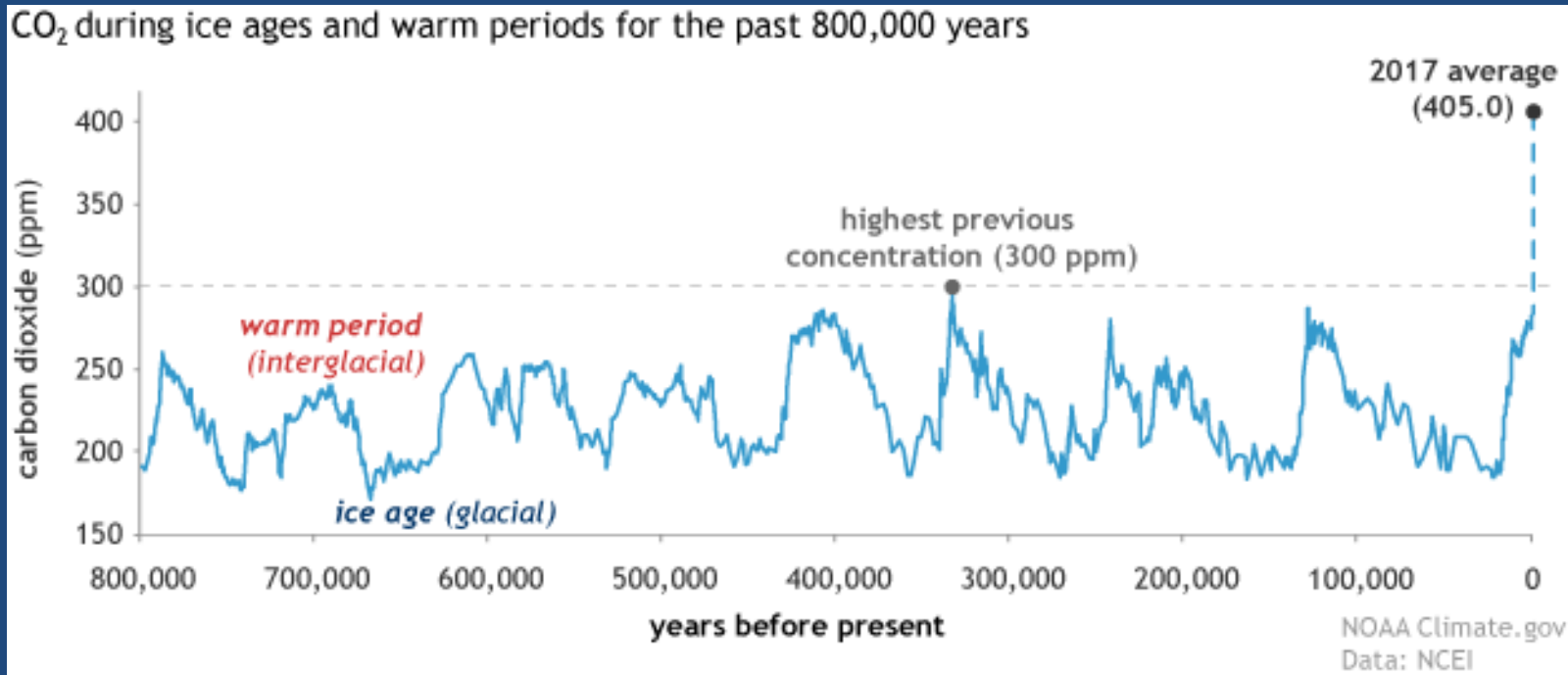
What about the fact that atmospheric CO_2 levels have cycled every 100 million years or so?

We can tell what the levels of CO_2 were in the atmosphere thousands of years ago by analyzing ice cores drilled from ice sheets.

Evidence of Climate Change

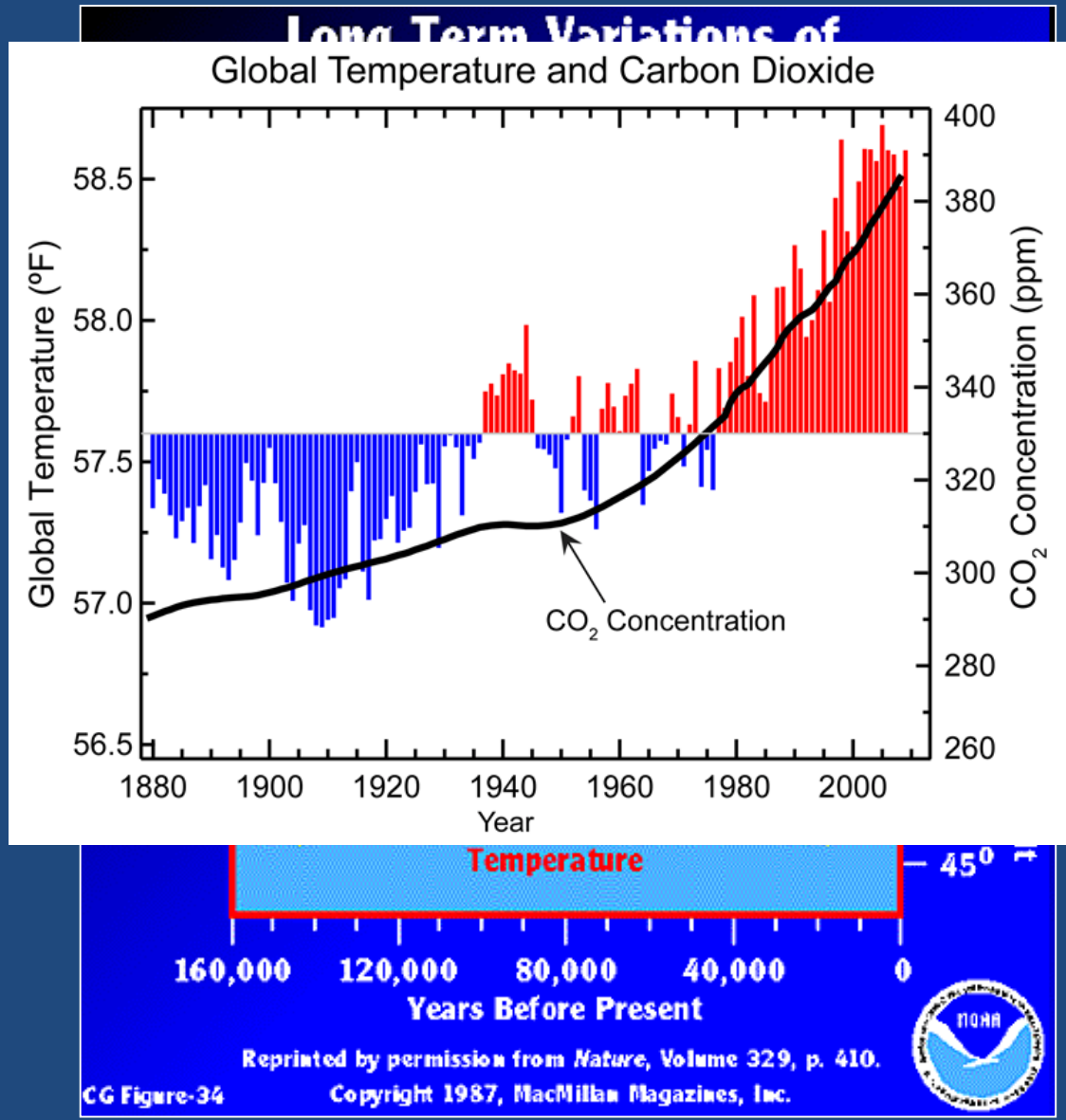
These cores show that CO_2 levels did cycle in the past, but never went over 300 parts per million (ppm) or increased at the rate we see currently. Today we are at 400 ppm.

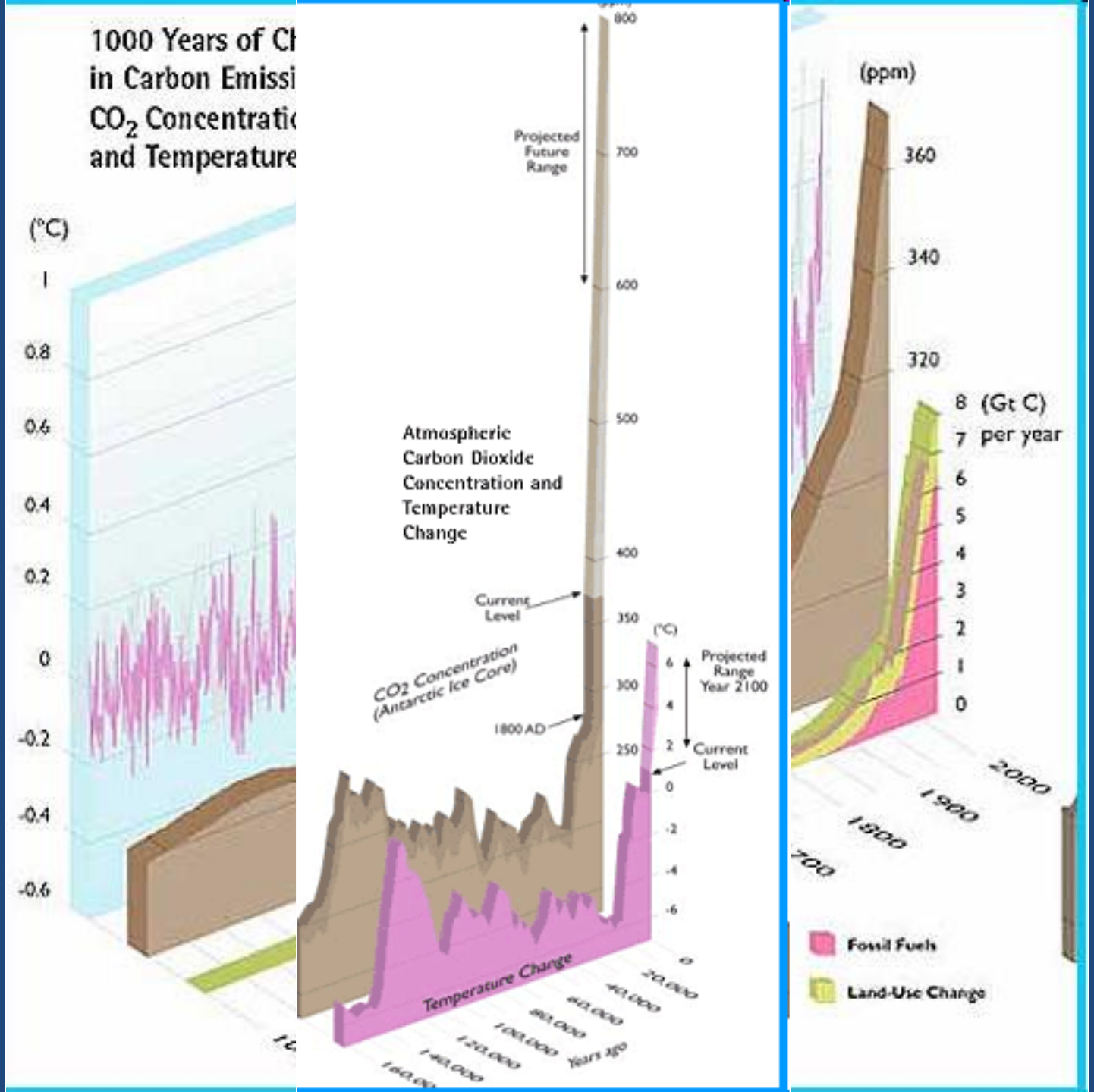
That's higher than CO_2 levels have been for at least the last 3,000,000 years.



Evidence of Climate Change

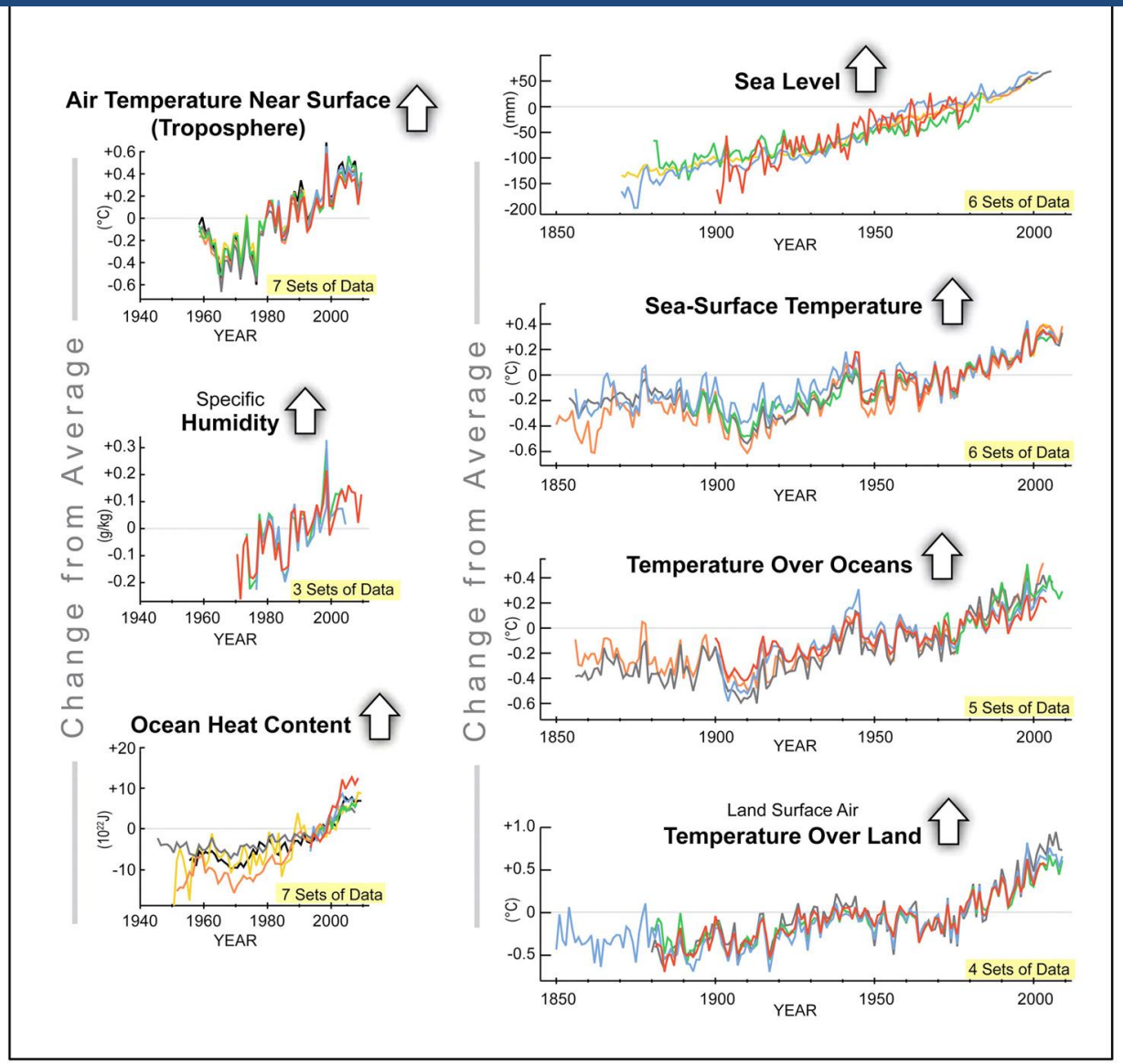
Scientists have concluded there is a direct link between the amount of CO2 pumped into the air and the increase in average temperature the Earth has experienced recently.




1000 Years of Cl
in Carbon Emissi
CO_2 Concentratio
and Temperature
(°C)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Projected Future Range
800
700
600
500
400
350
300
250
Atmospheric Carbon Dioxide Concentration and Temperature Change
Current Level
CO_2 Concentration (Antarctic Ice Core)
1800 AD
(°C)
6
4
2
0
-2
-4
-6
Projected Range Year 2100
Current Level
Temperature Change
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Years ago
(ppm)
360
340
320
8
7
6
5
4
3
2
1
0
(Gt C) per year
2000
1900
1500
700
Fossil Fuels
Land-Use Change

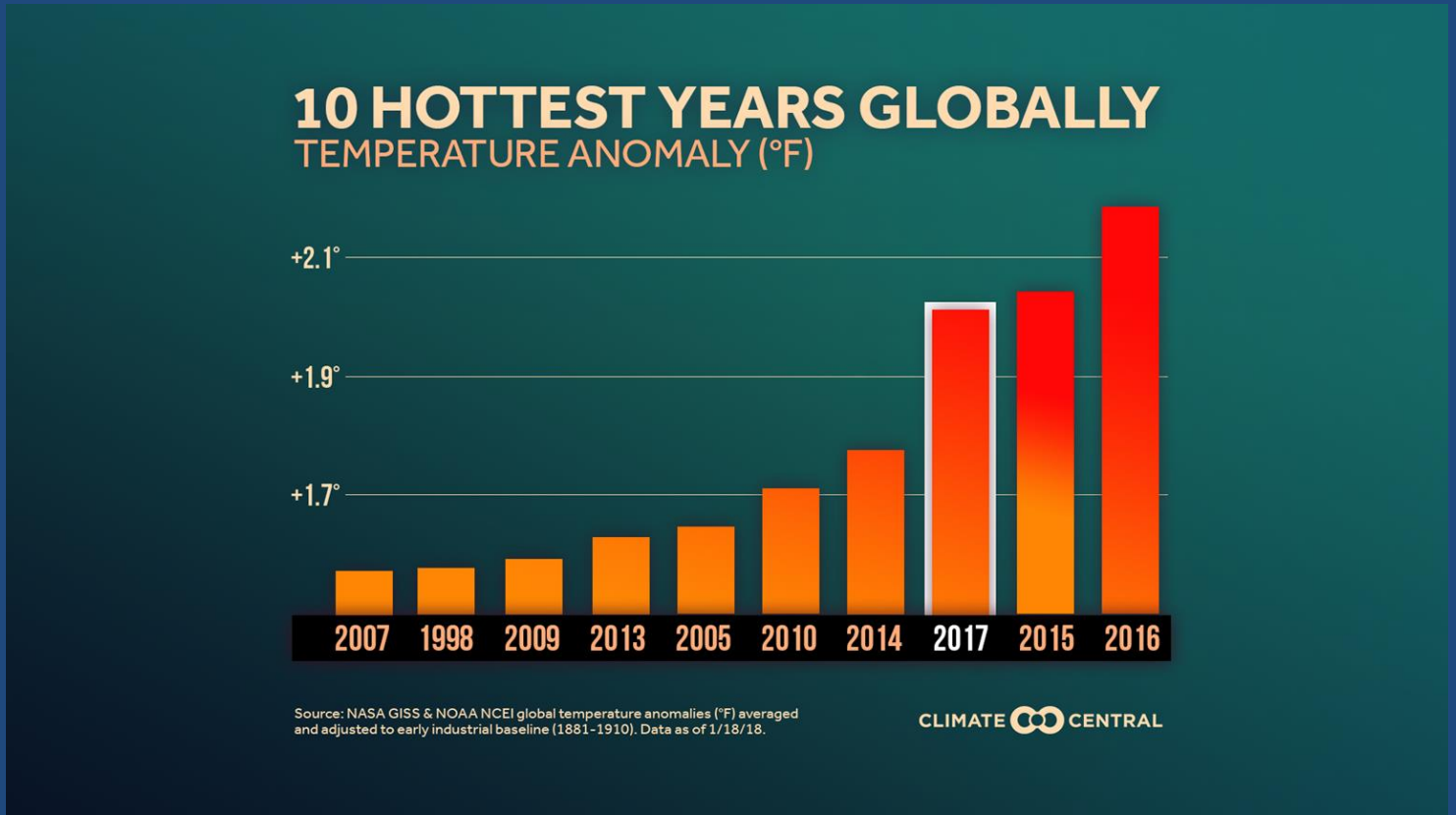
Evidence of Climate Change

We would expect all of the following to increase in a warming world, and that is what we are seeing.



Effects of Climate Change

- High Global Temperatures

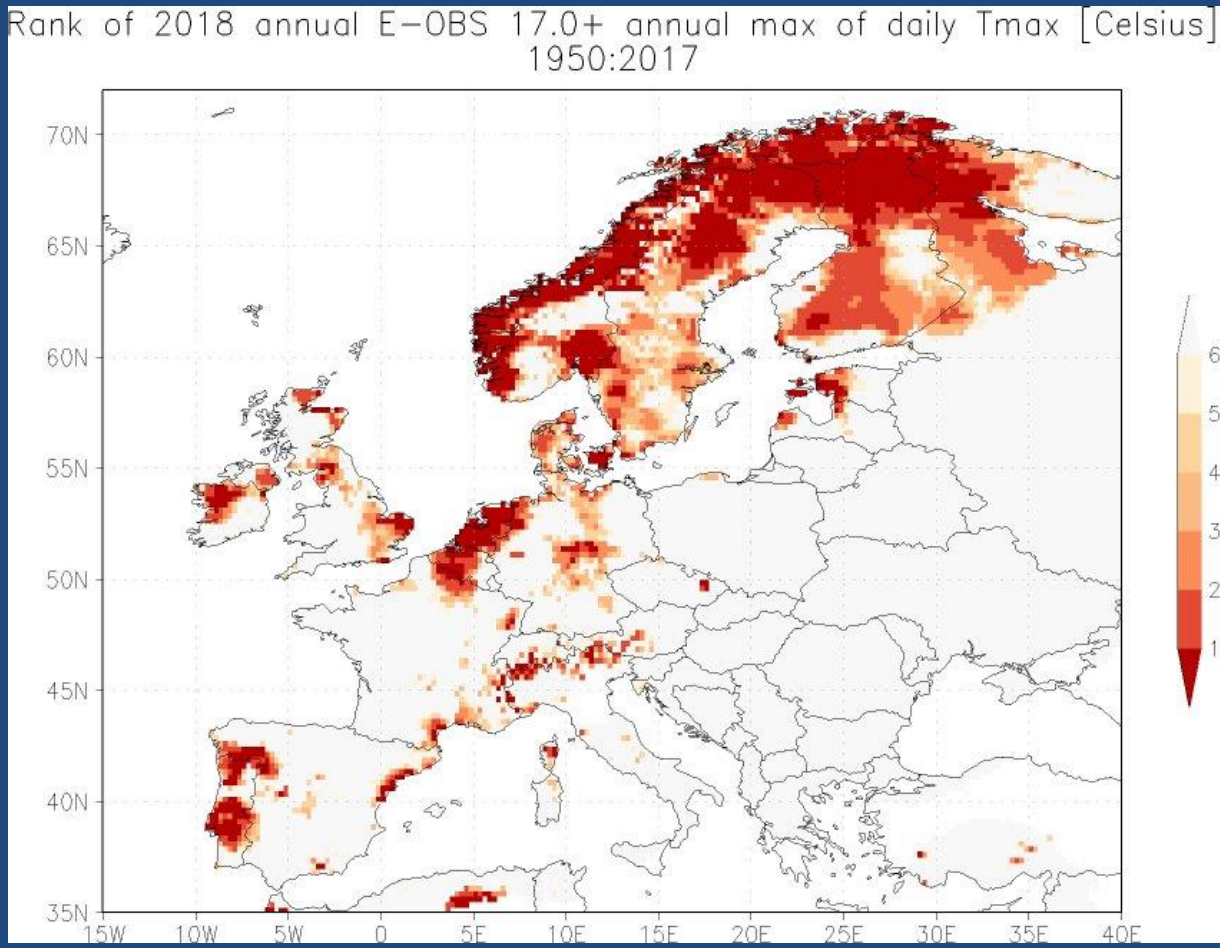


Effects of Climate Change

High Global Temperatures cause more frequent Heat Waves.

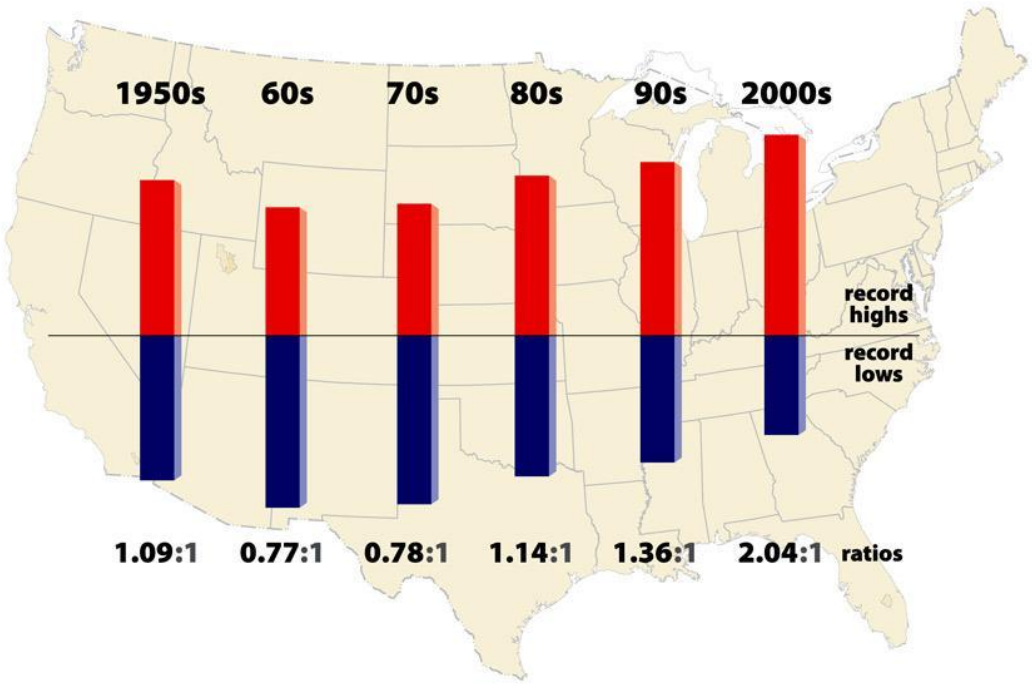
Effects of Climate Change

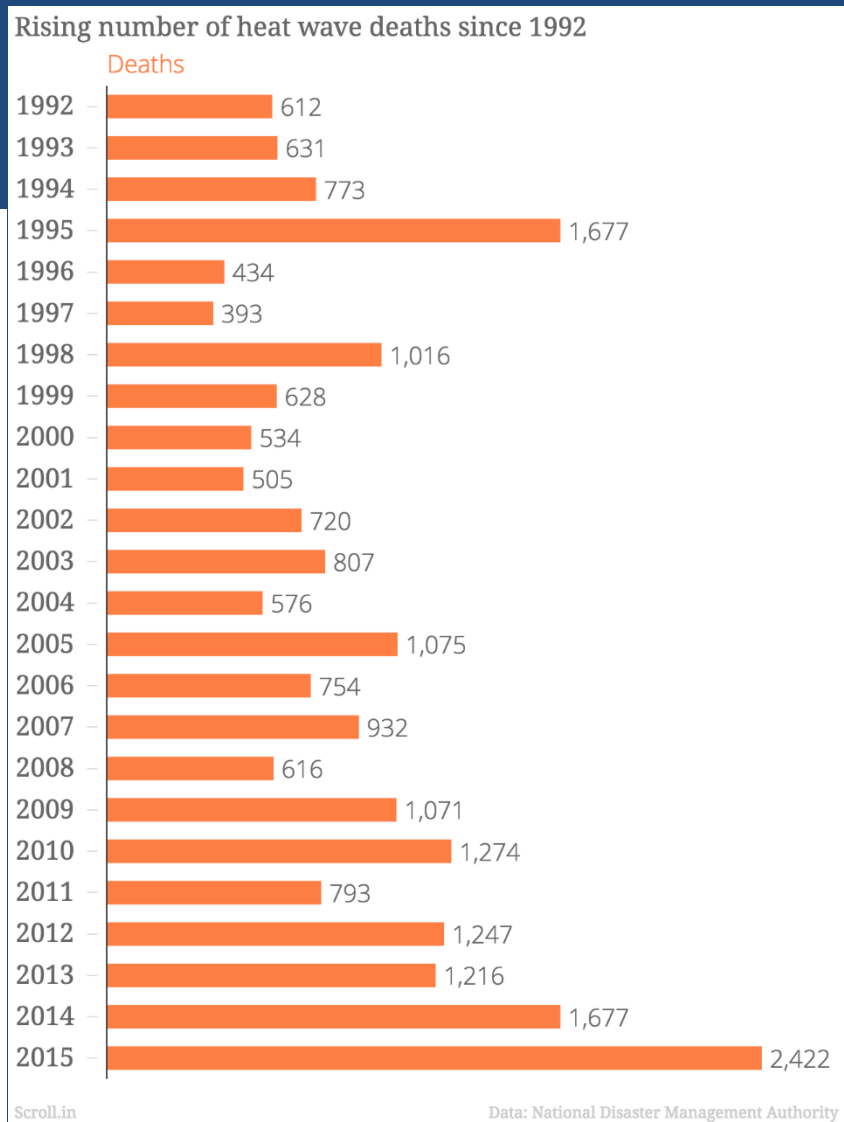
Europe had a massive heat wave in the summer of 2018.



Effects of Climate Change

Heat Waves





Effects of Climate Change

High Global Temperatures

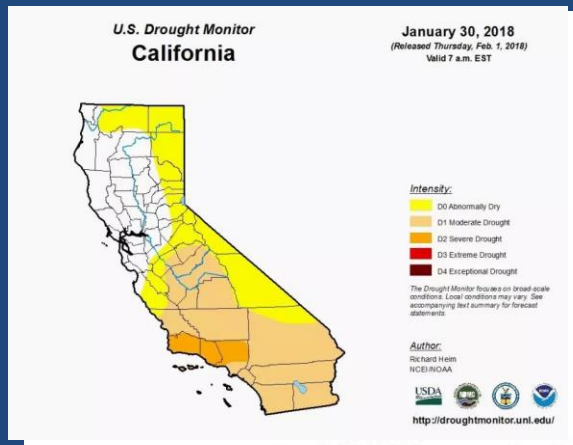
Lead to Droughts

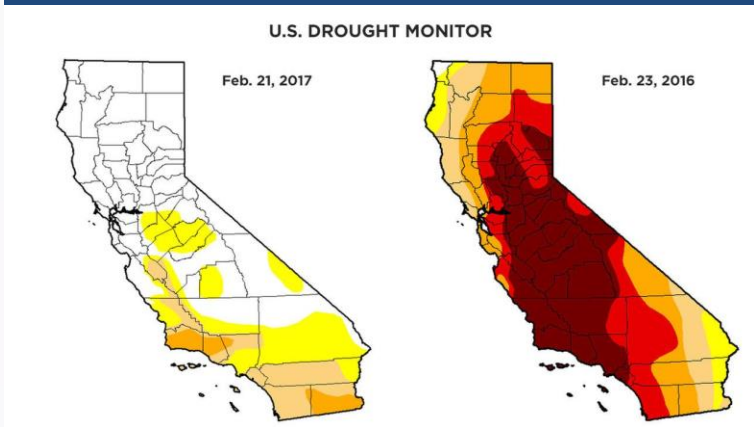
Effects of Climate Change

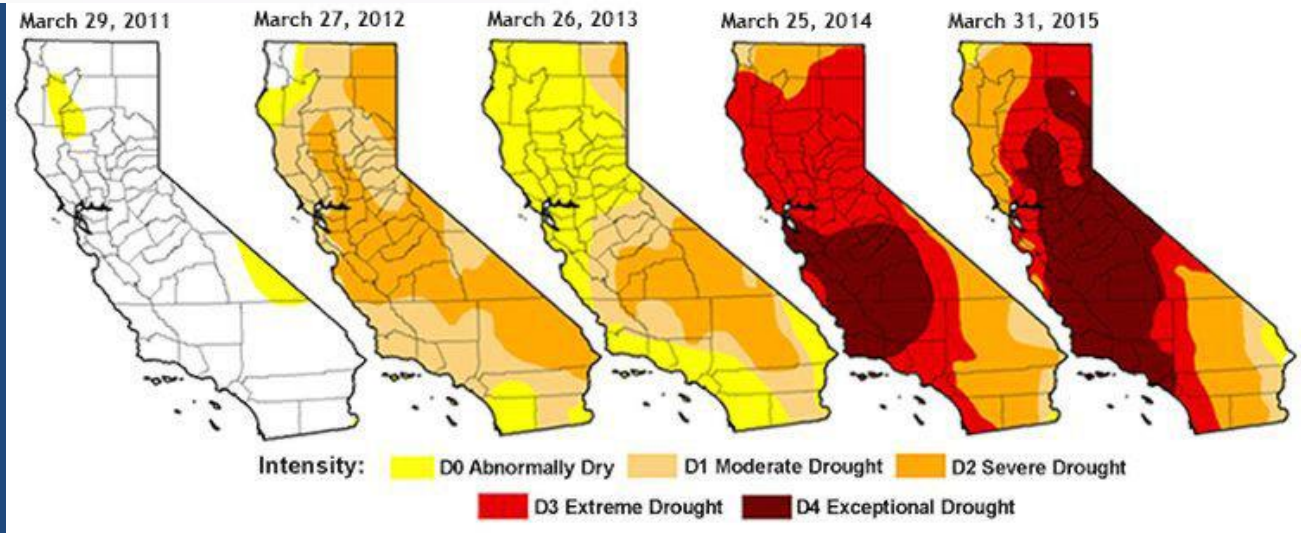
High Global Temperatures

Lead to Droughts

California had the worst drought in recorded history a few years ago. This year and last year were better.





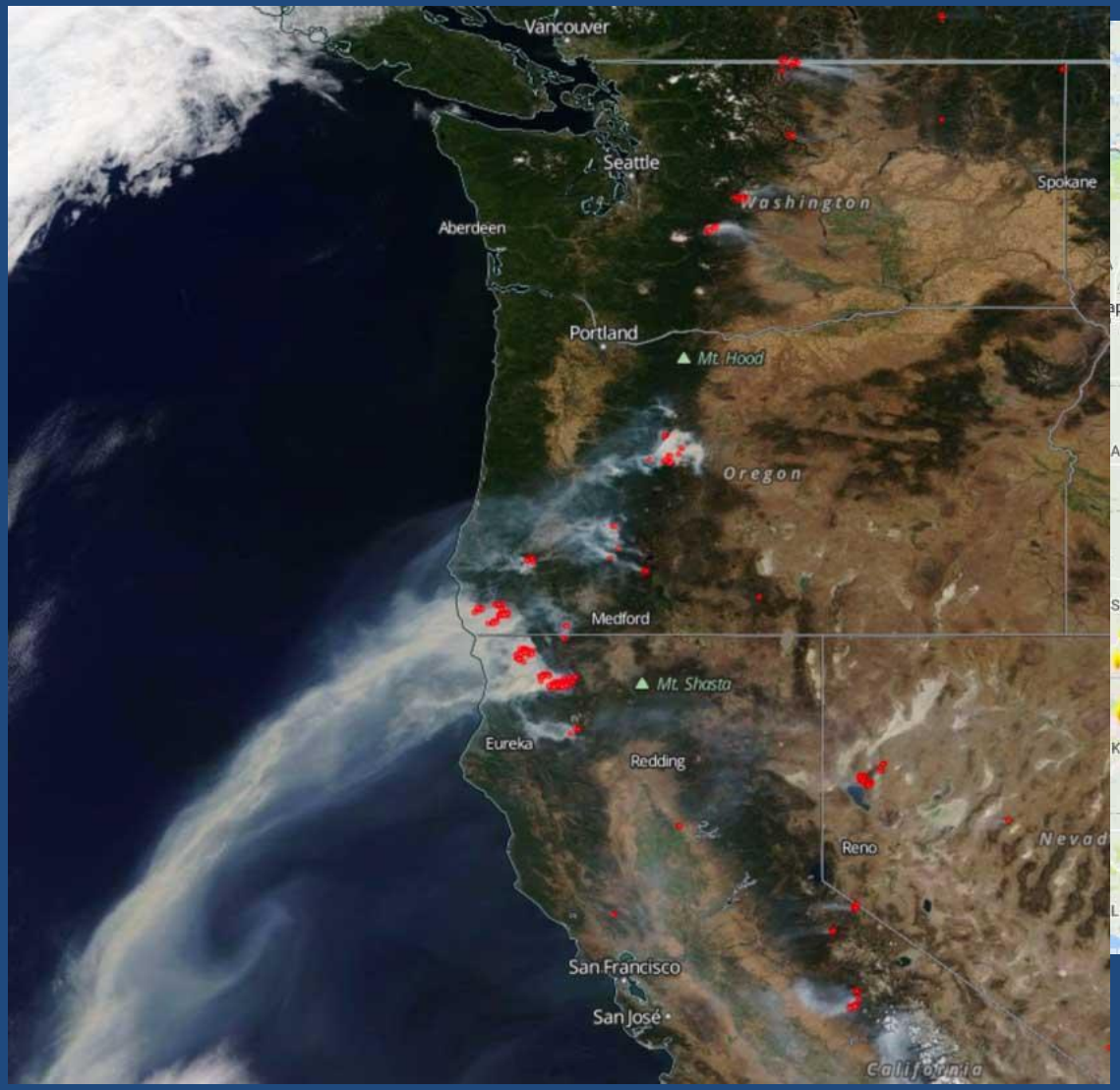


Effects of Climate Change

High Global Temperatures

Lead to Droughts

Which lead to wildfires



Effects of Climate Change

High Global Temperatures

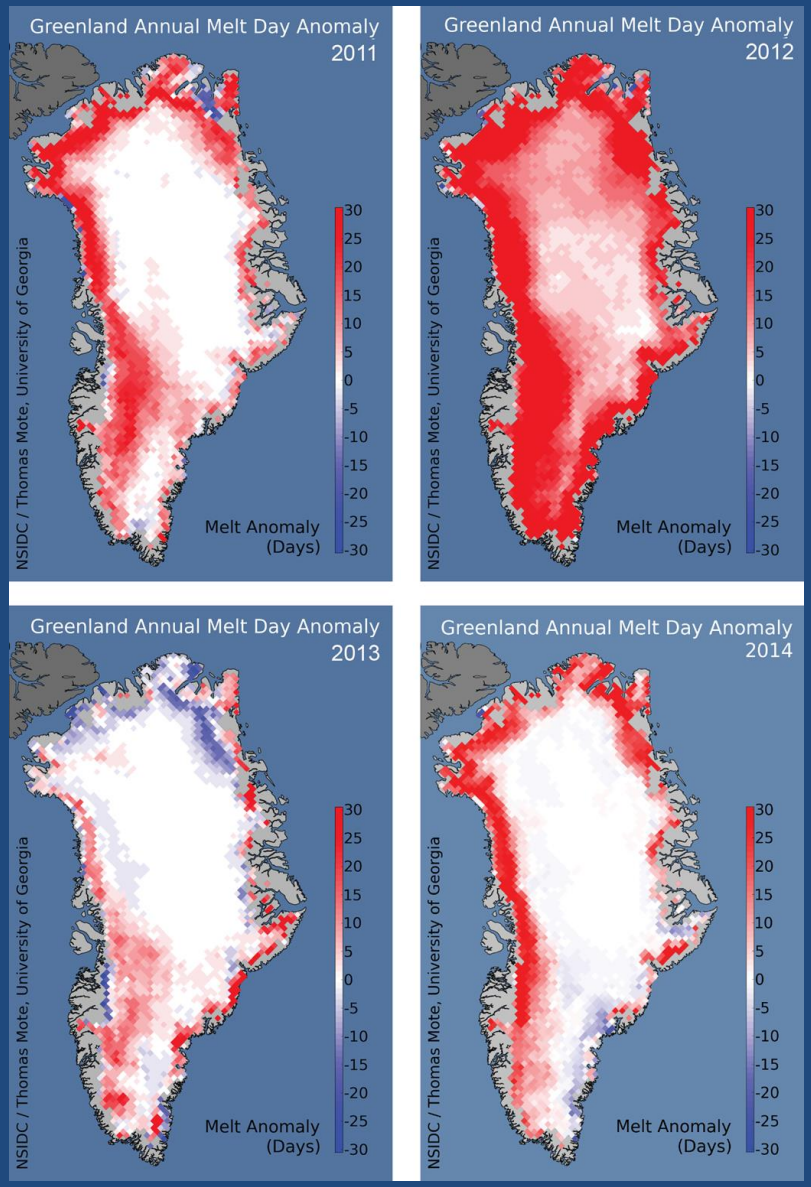
Also lead to more glacial ice melting.

Effects of Climate Change

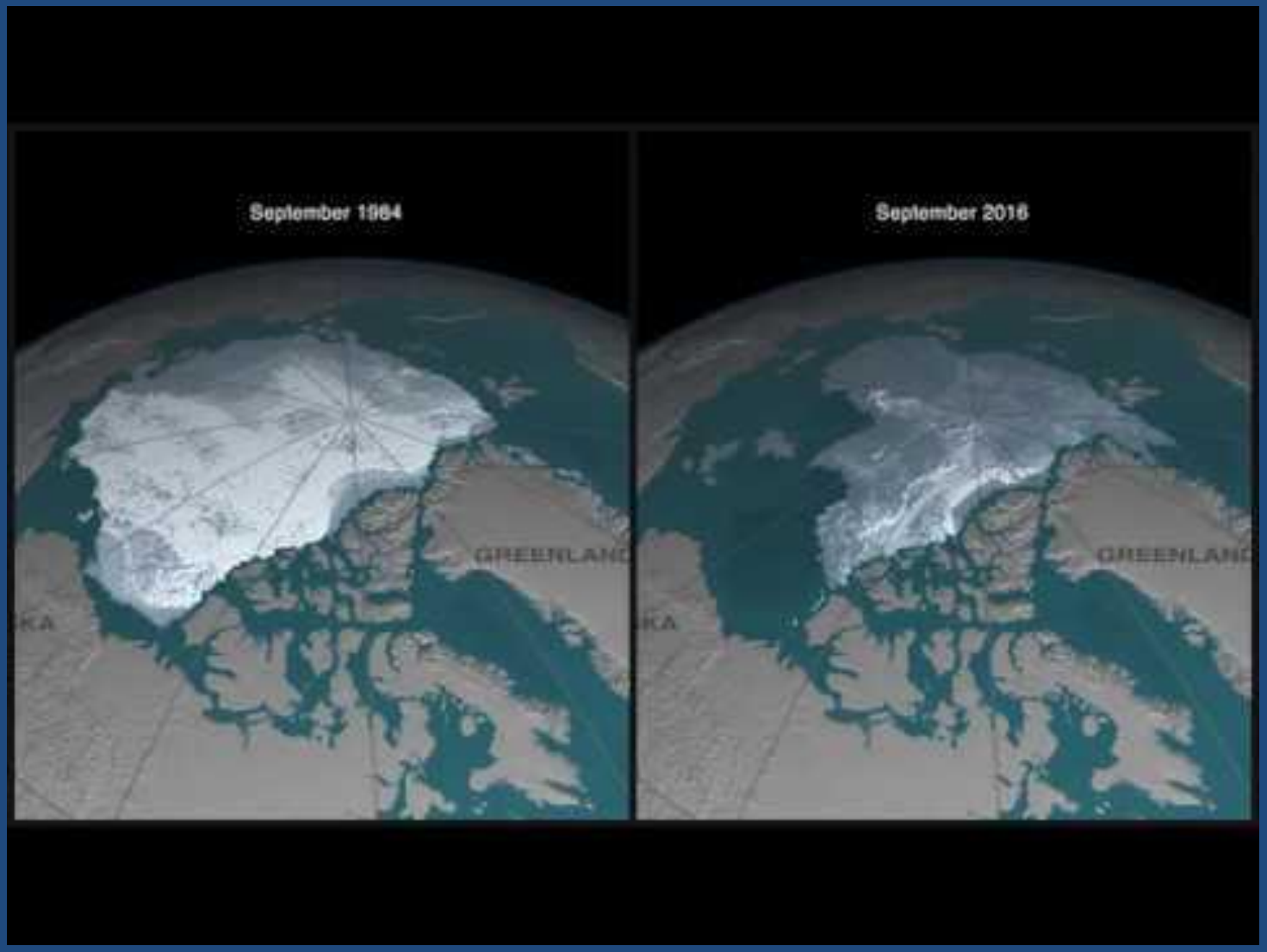
High Global Temperatures

Lead to more glacial ice melting.

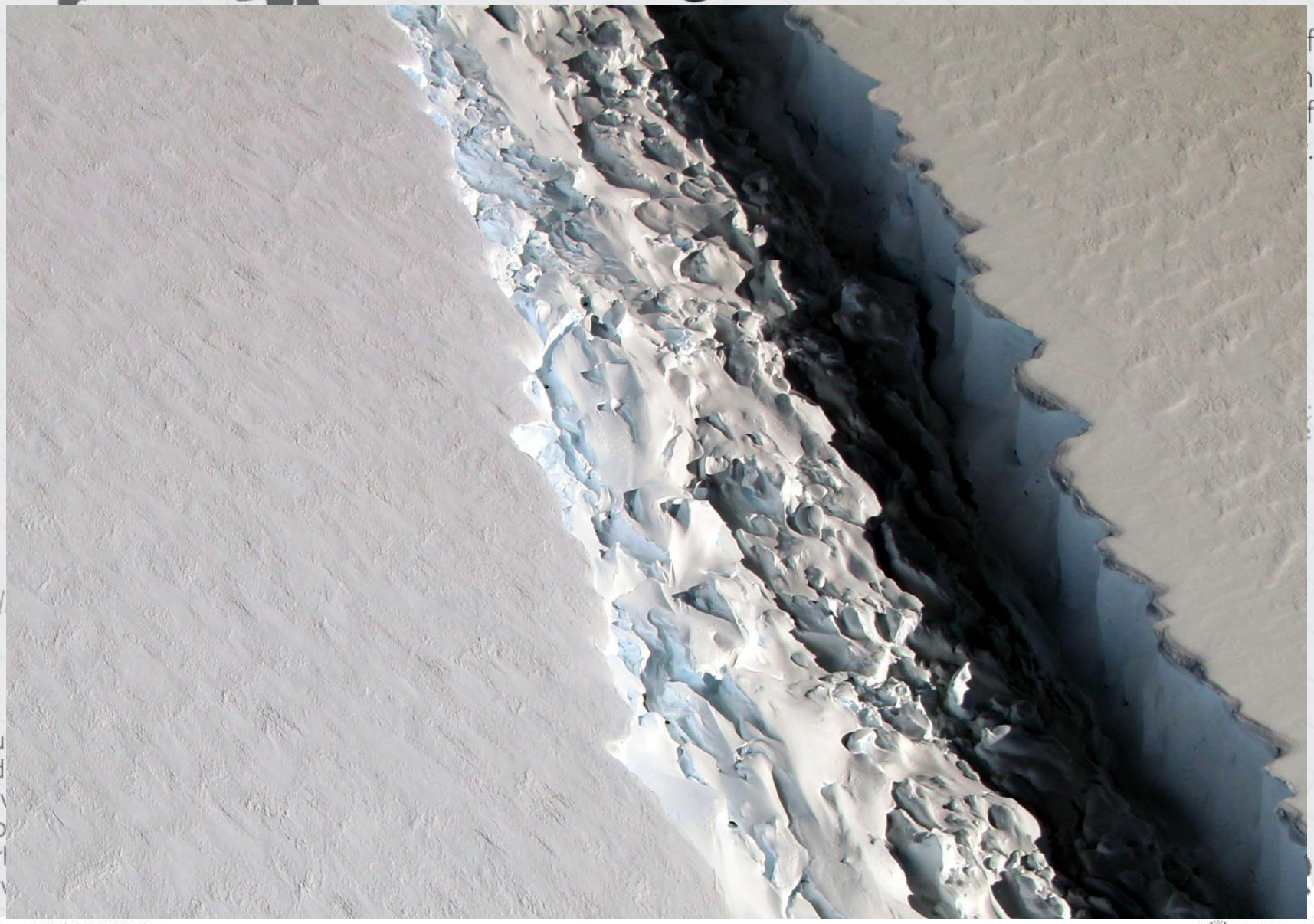
This is especially troubling in Greenland



Effects of Climate Change



Giant iceberg breaks off of Antarctica



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W. Foo, 12/07/2017

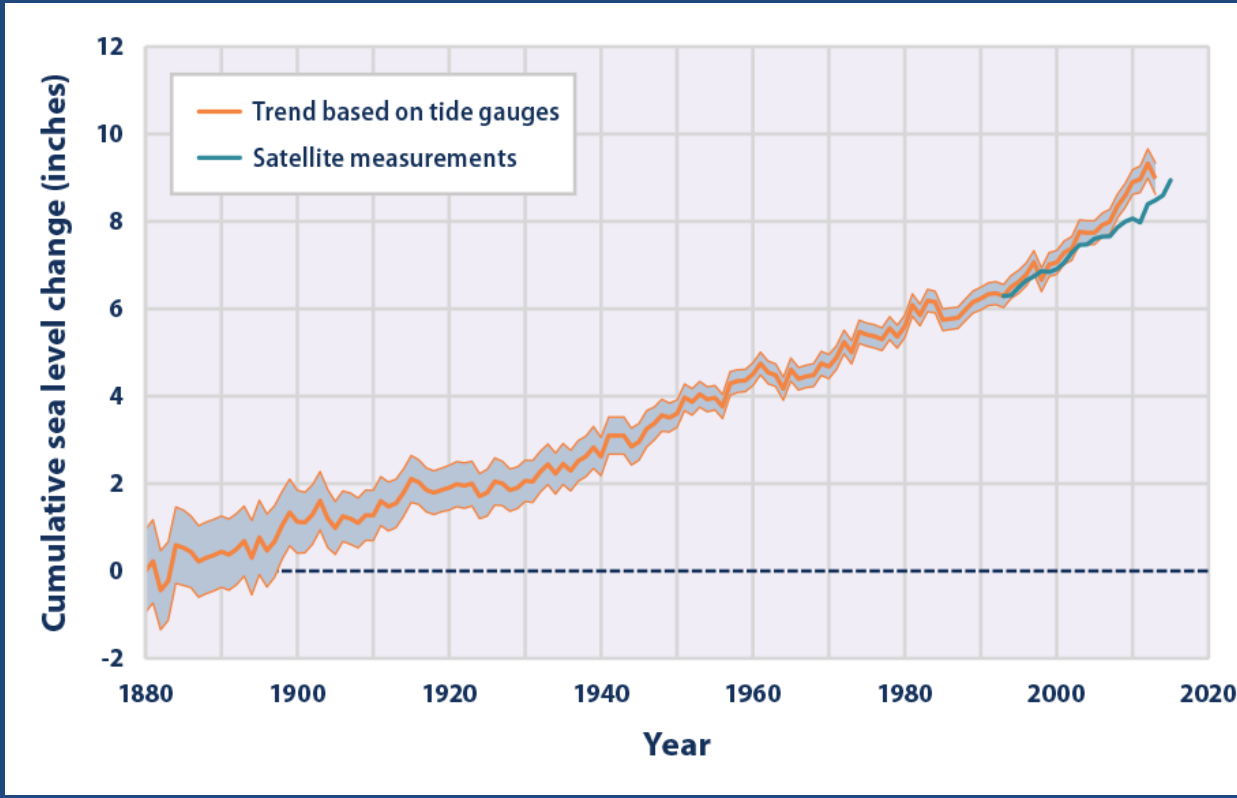
REUTERS

Effects of Climate Change

High Global Temperatures

Lead to more glacial ice melting.

Which will lead to rising oceans.



Effects of Climate Change

Just how much will the oceans rise in your lifetime?

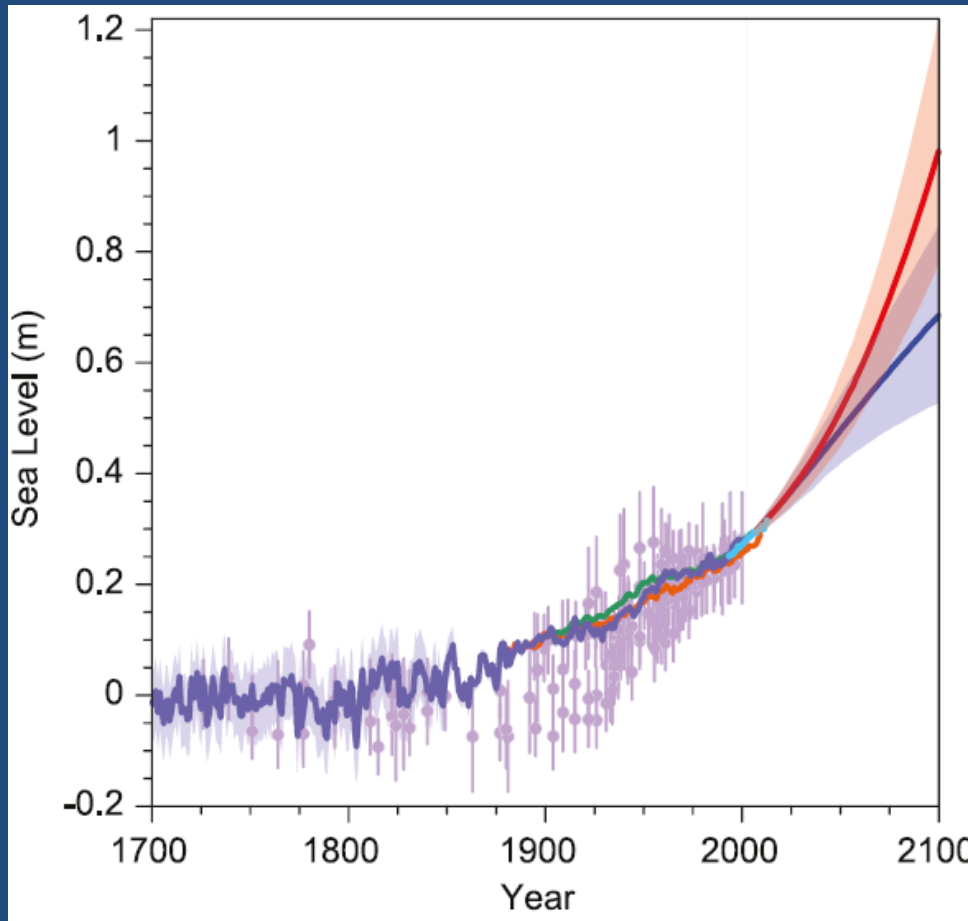
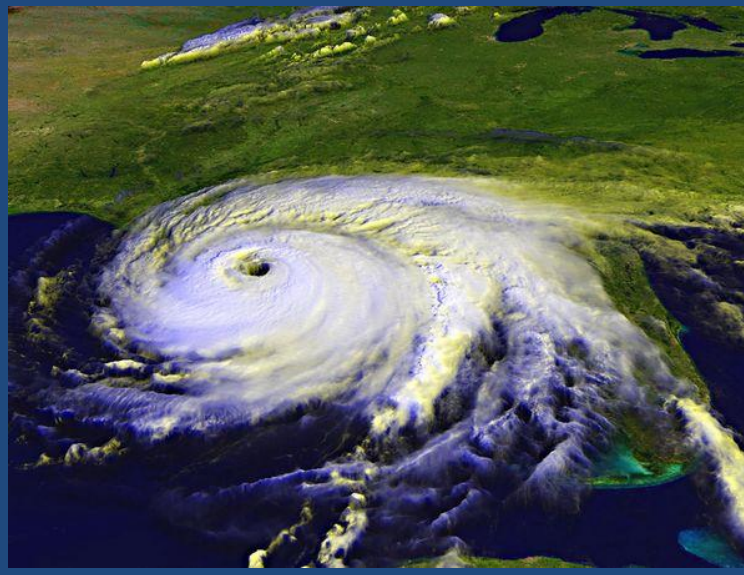
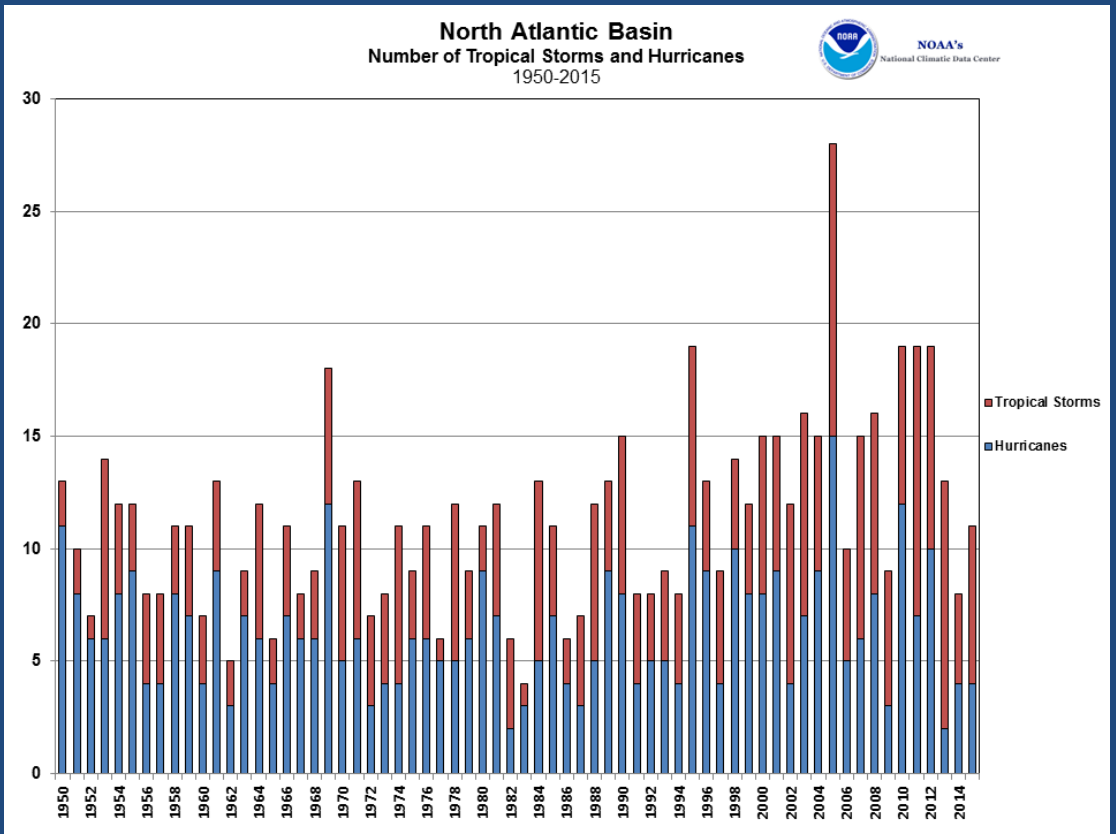


Fig. 1. Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.

Effects of Climate Change

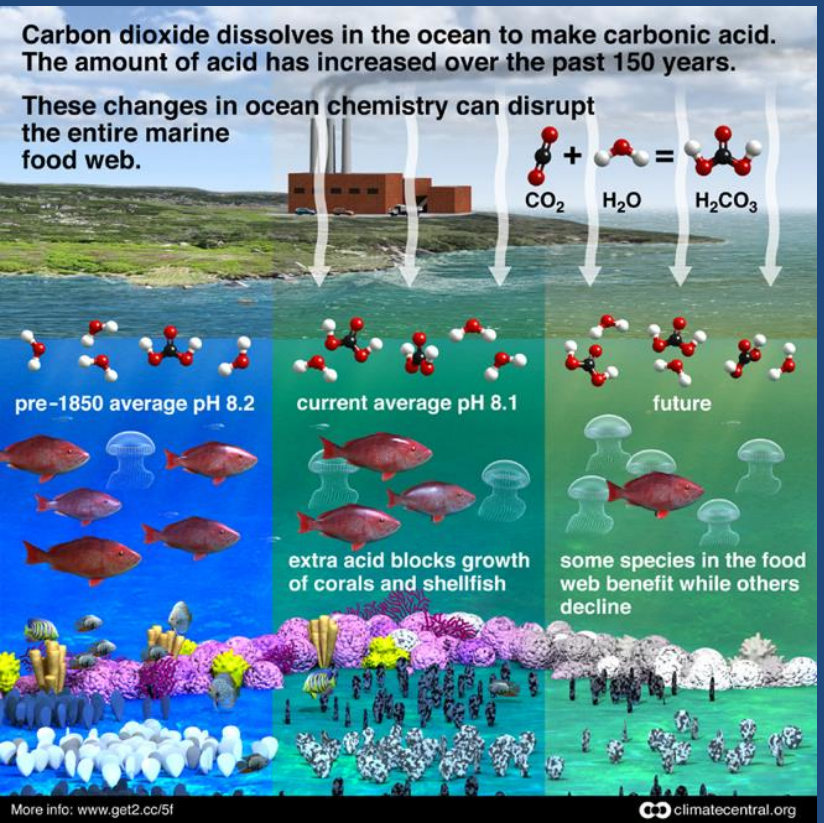
Rising Sea Levels Leads to more Extreme Weather

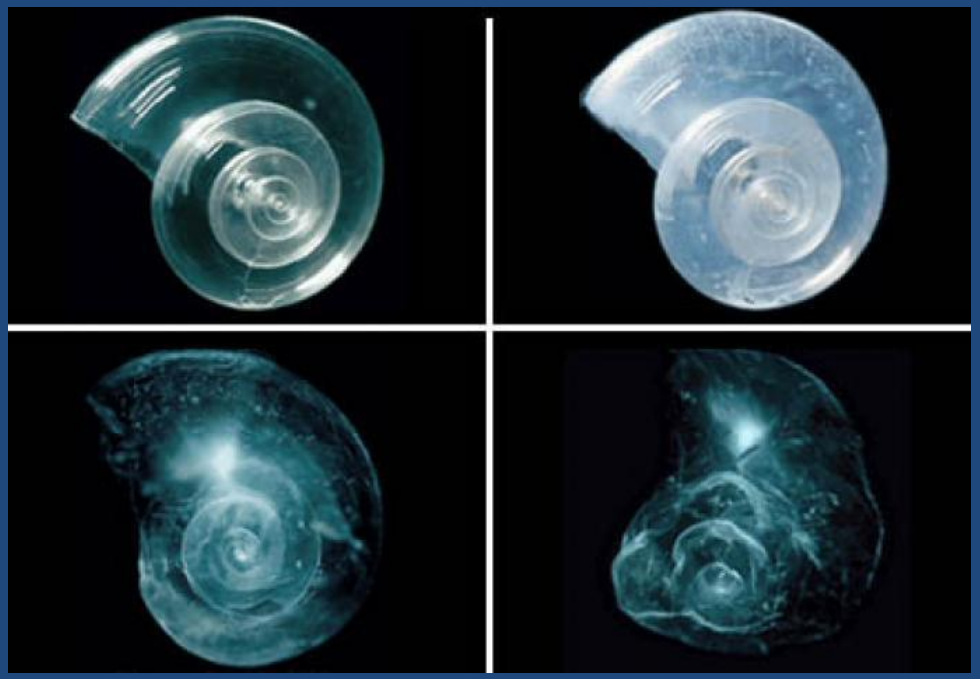




Effects of Climate Change

The ocean absorbs much of the excess carbon dioxide in our atmosphere, leading to ocean acidification.





Effects of Climate Change

Leads to ocean acidification

Which can cause coral bleaching

Feedback Loops

Climate change is being exacerbated by feedback loops.

Remember:

Positive feedback tends to promote instability in systems (think spiraling out of control).

Negative feedback tends to promote stability in systems (think again about homeostasis).

Positive Feedback: Albedo

One example of positive feedback with climate change would be albedo.

Albedo measures how reflective a surface is in a fraction or %.

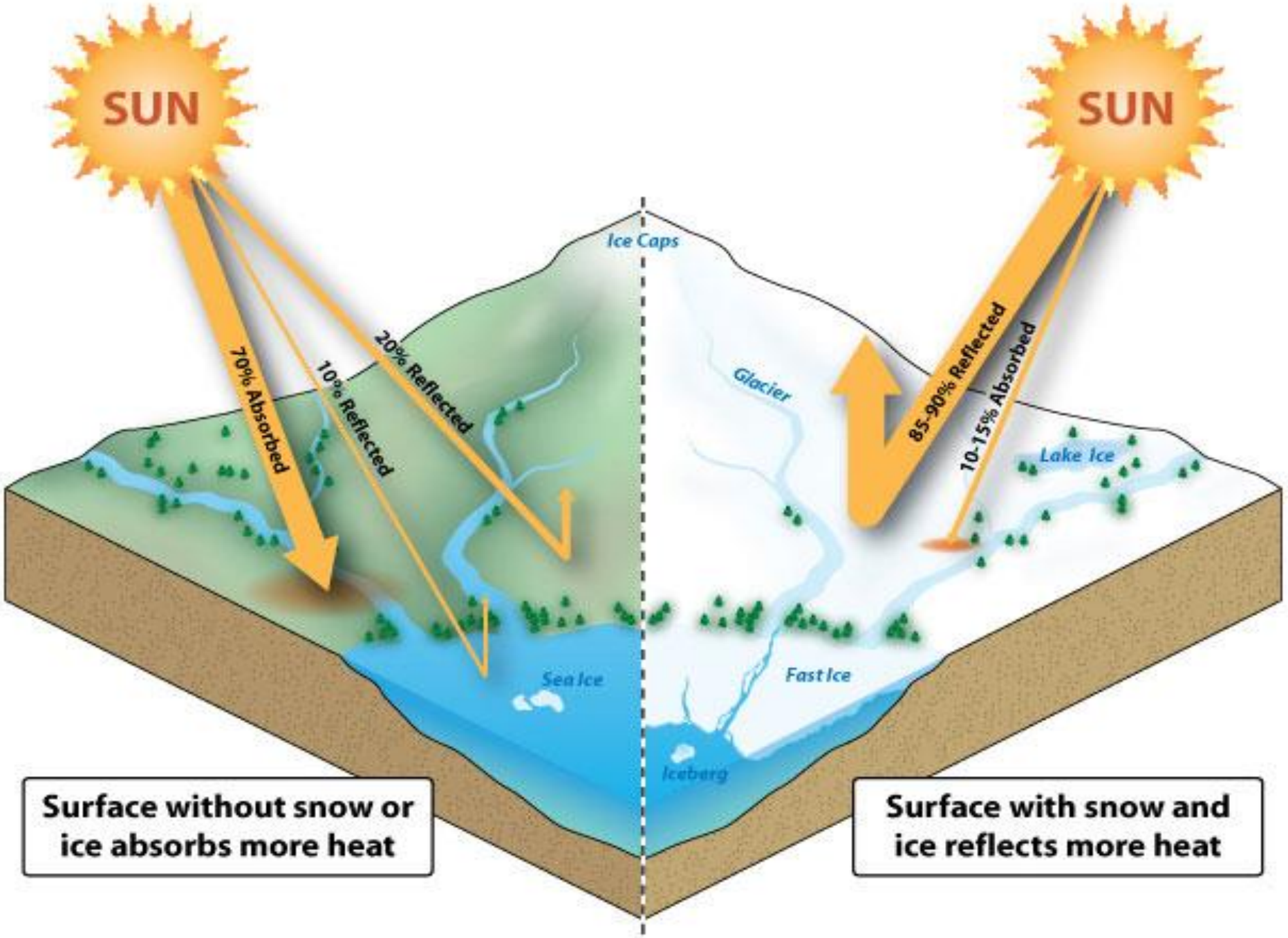
The higher the albedo:
The more reflective the surface.

Table showing albedos of different materials from "Fundamentals of Remote Sensing and Airphoto Interpretation" by Avery and Berlin 1992

Material	Percent Reflected
Fresh Snow	80-95
Thick Cloud	70-80
Water (sun near horizon)	50-80
Old Snow	50-60
Light soil	25-45
Thin Cloud	20-30
Dry soil	20-25
Wet soil	15-25
Deciduous forest	15-20
Dark soil	5-15
Asphalt	5-10
Crops	10-25
Coniferous forest	10-15
Water (sun near zenith)	3-5

Albedo

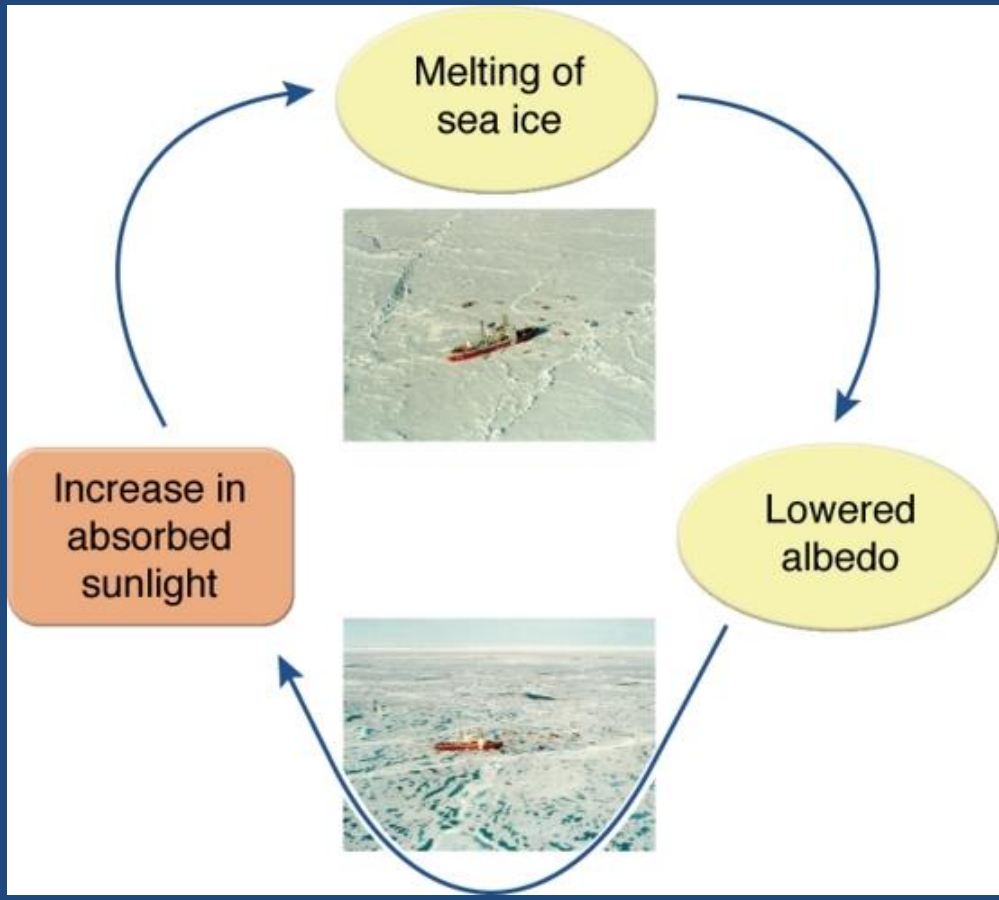
This is why snow and ice help keep the planet cool. They have a high albedo, and therefore light energy is not converted into heat but reflected back off into space.



Positive Feedback

We call this a positive feedback loop where:

A produces more of B, which then in turn produces more of A.



Melting sea ice creates a lower albedo, which then in turn causes more ice to melt.

Climate change Vocabulary

Greenhouse Effect

Greenhouse Gas

PPM

Ocean Acidification

Albedo