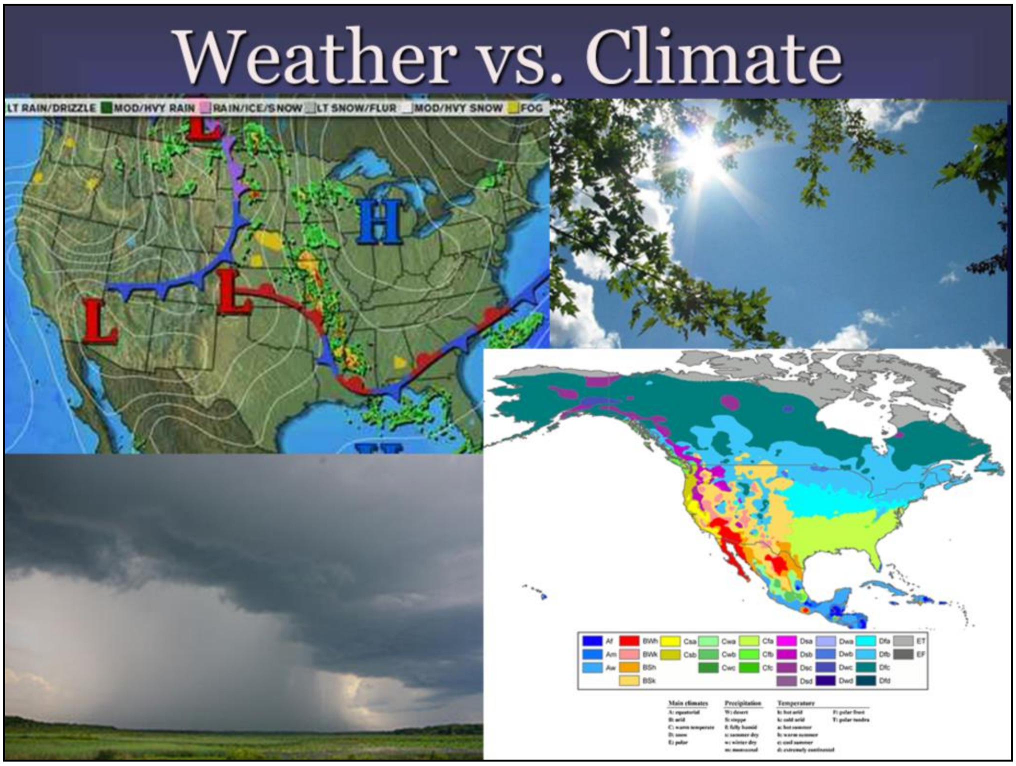
New links: 8/1/2016

http://blog.ucsusa.org/brenda-ekwurzel/why-the-arctic-matters-856

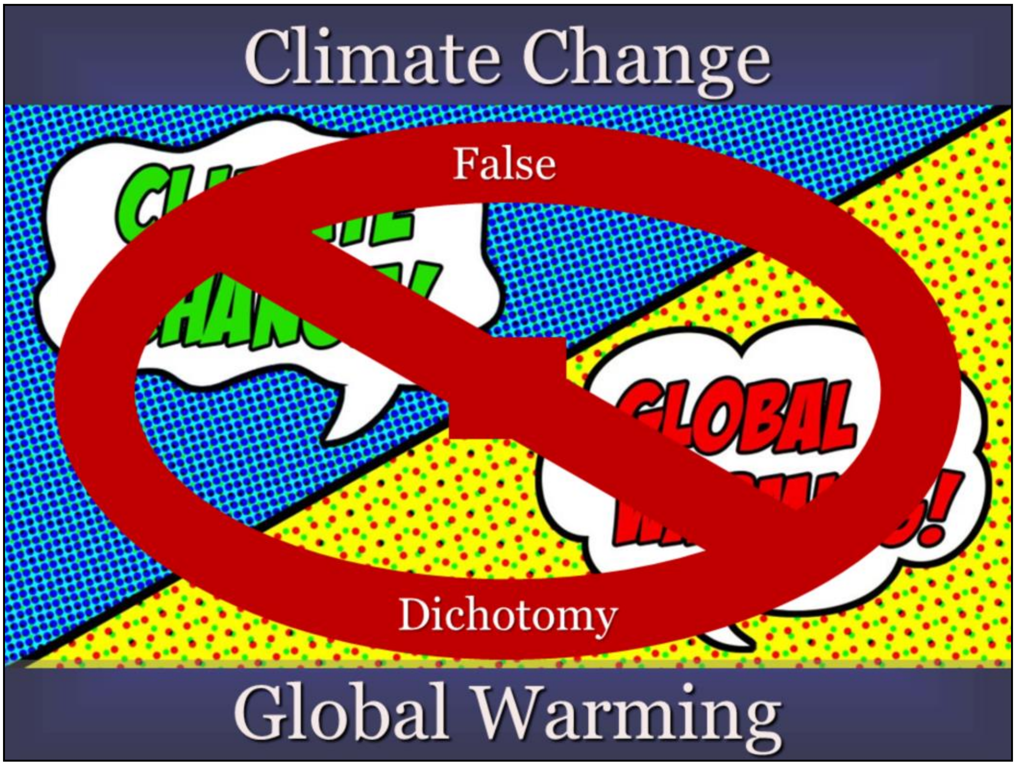
http://blog.ucsusa.org/astrid-caldas/beyond-heat-waves-what-does-14-months-in-a-row-of-record-heat-say-about-global-warming-five-key-points-to-keep-in-mind



In your group, define “Weather” and “Climate”

Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

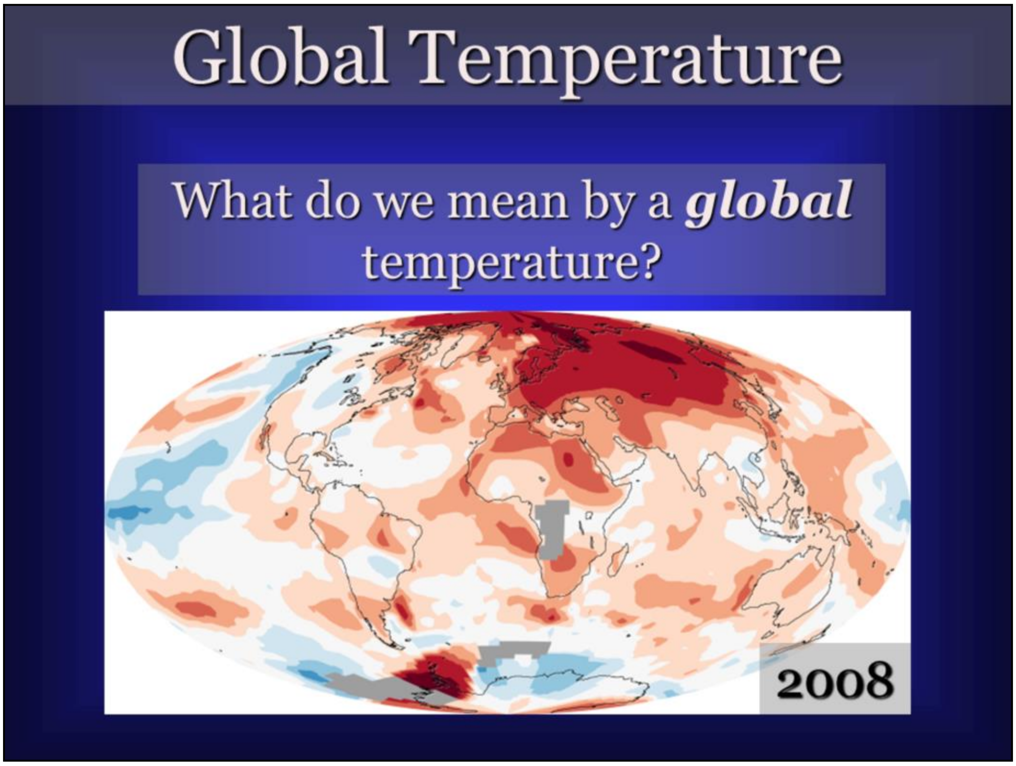
[figures from NOAA and NASA]



Myth: “They” changed the name from global warming to climate change. (warning: whenever you see an unspecified “they” you’re often dealing with crackpots)

Why has the national discourse changed from global warming to climate change? Has it actually changed? What do the two terms mean? Which term more encompasses the issues we need to talk about? Should we just discard the term “global warming” entirely? Why or why not?

Climate change refers to the changes in the global climate which result from the increasing average global temperature. Changes in precipitation patterns, increased prevalence of droughts, heat waves, and other extreme weather, sea level rise, biome changes (e.g. forests type changing, desertification) are all examples of climate change.



Sometimes you hear people say "This was a record cold January" or "Last summer was pretty cool and rainy" and then say "so global warming can't be happening". Are they right? What are we talking about when we say "global warming"?

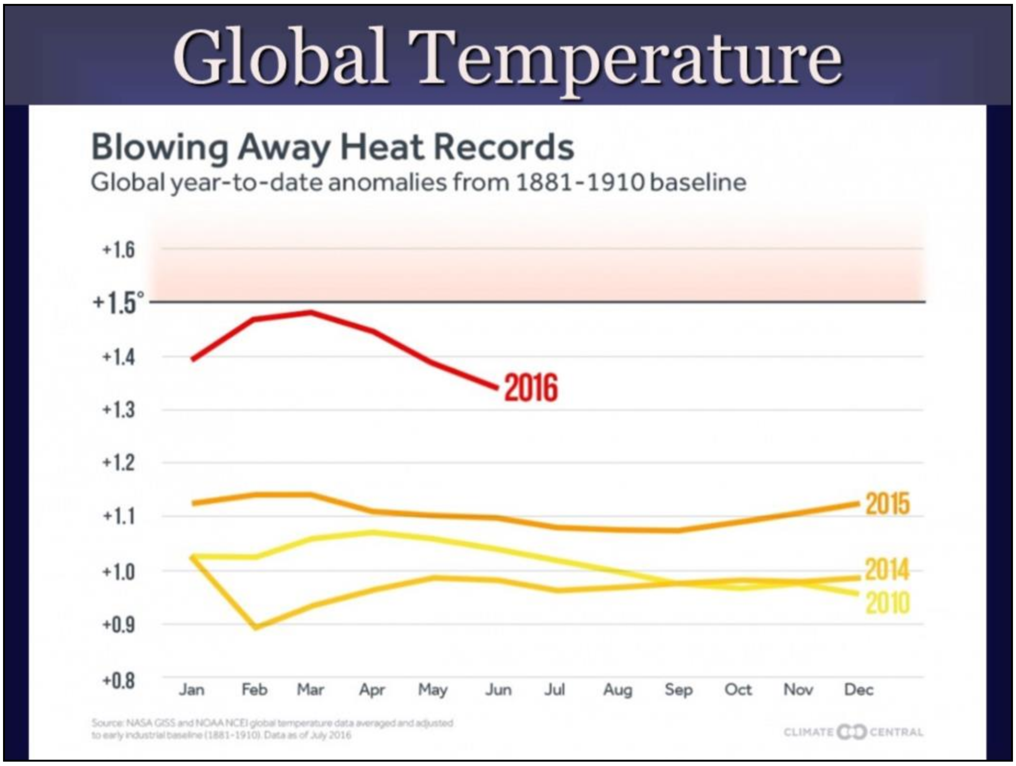
Global warming is the INCREASE in AVERAGE TEMPERATURE over time. In other words, **local** effects (either spatial or temporal) are not what we're talking about, but rather the whole Earth over the course of decades.

We are averaging the temperature anomaly in two ways: 1) over the entire YEAR (time) and 2) over the entire EARTH (location). This latter is what we mean by a GLOBAL temperature change, and these are the numbers most frequently quoted. You can see in this map of 2006, that over the entire year the whole Earth looks a lot hotter than it used to be. There are some local spots which are cooler, as to be expected in any chaotic system.

You see that the whole earth is overall hotter, but there are more cool spots. In fact, 2008 was the coolest year, on average, since 2000. HOWEVER, note that it is STILL in the "top 10" hottest years…all of which have been since 1999. In other words, this last decade EVERY YEAR has been hotter than any year before 1999.

So while one year, or one month, might seem cooler, on average everything is getting hotter. Think of it this way: If you're outside on a hot summer day, and you come into a house which is 70 degrees, you will feel cold. On the other hand, if you are outside on a cold, cold winter day and walk into that same 70 degree house, you will feel warm. Both feelings are good, but the perception of whether it's cold or hot varies based on what you were just in. So a summer like last year's might seem cooler, compared to the previous several years, when if you compare to a decade or two ago, it's actually hotter.

[figure from NOAA]

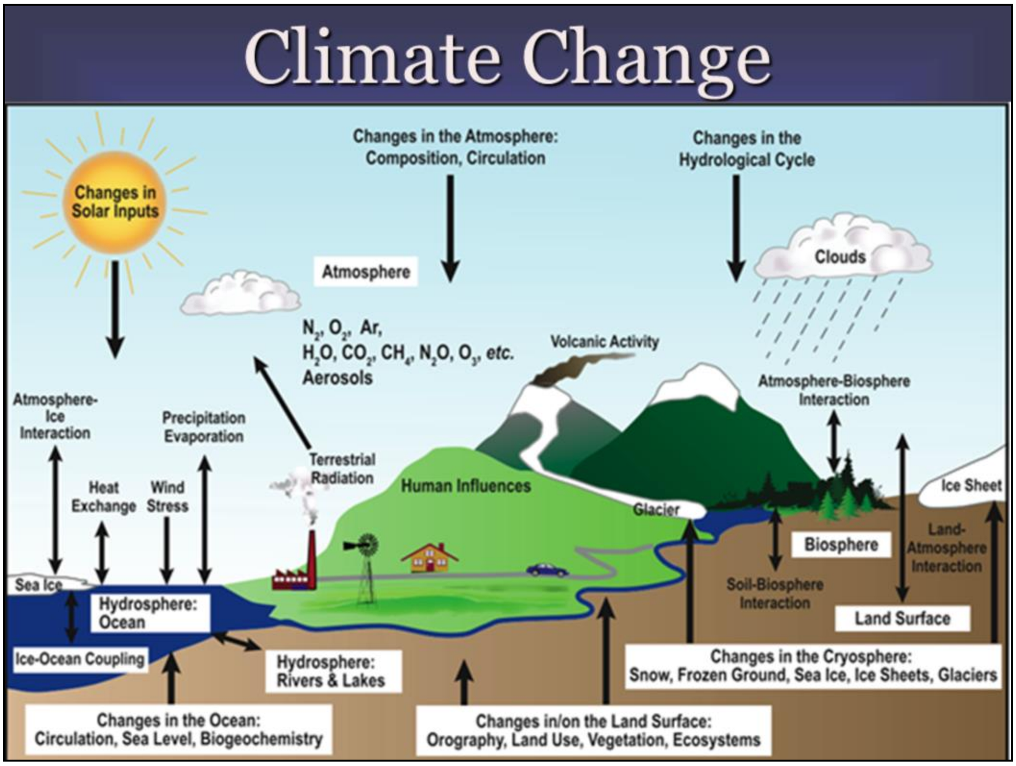


Previous slide: averaging each time at various locations

This slide: averaging total earth, for each month

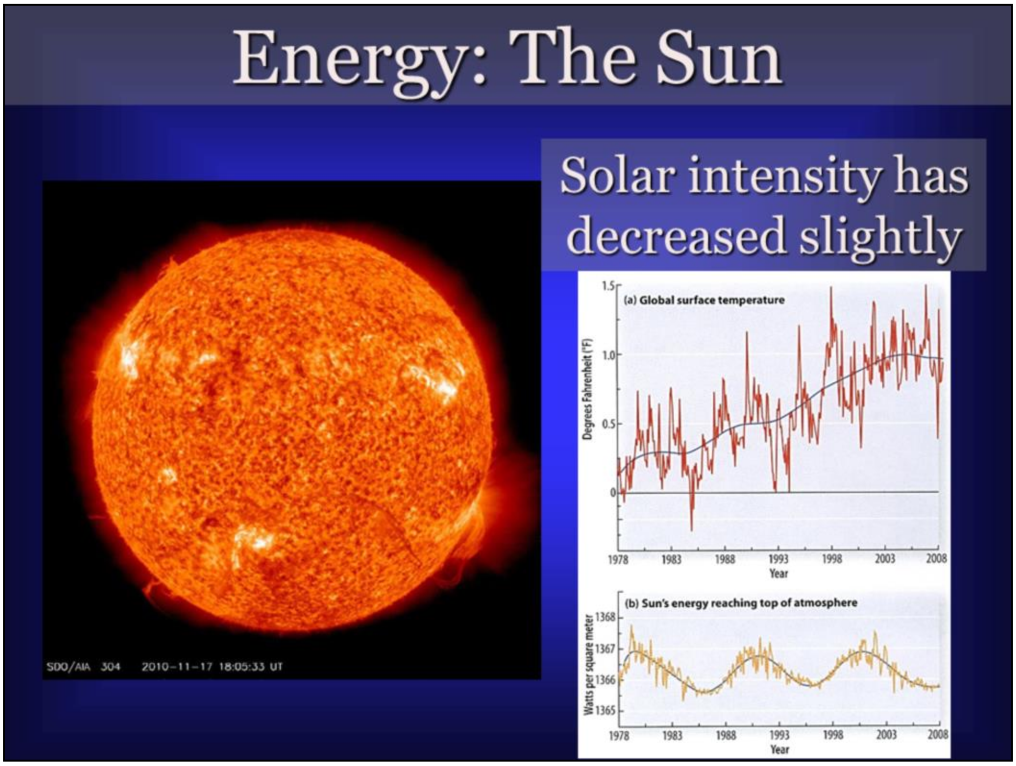
Notice all of the graphs are above the baseline; this has been true since the early 2000s. More than a decade of "above average" temperatures. This is the new normal.

Good times, eh. ☹



It all comes down to **heat exchange**.

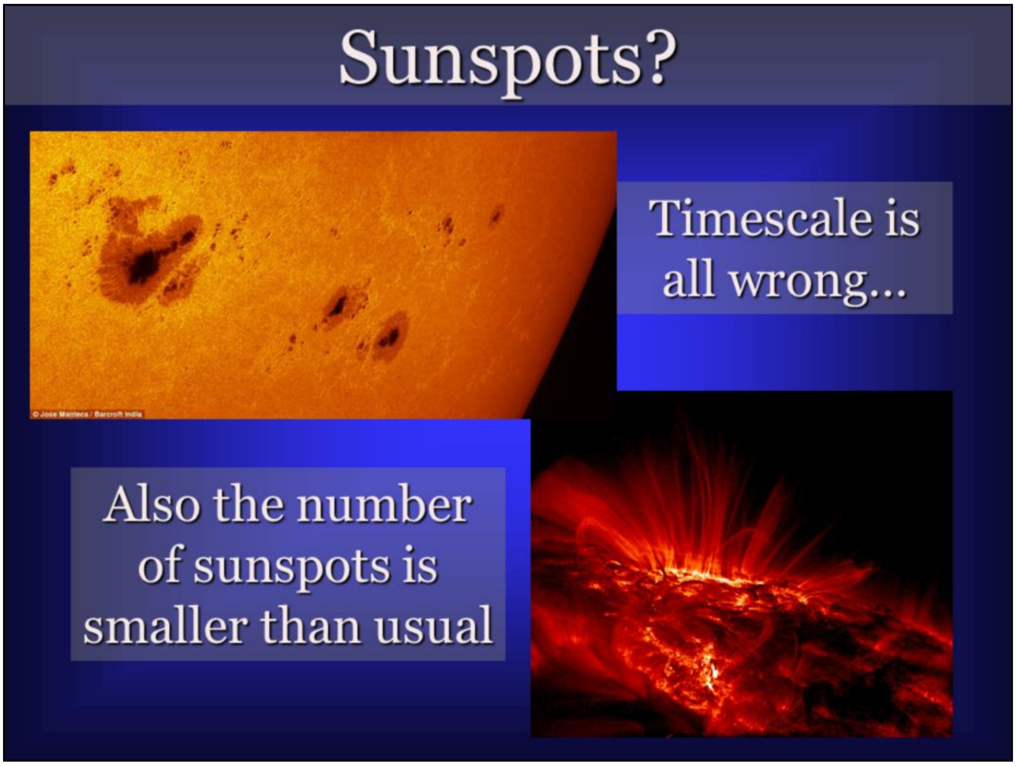
Many of the remaining figures are from the book “Global Climate Change: Turning Knowledge into Action” by David Kitchen (2003).



Almost all of our energy comes from the sun. What if the sun is changing?

Solar intensity (TSI = total solar intensity) does not follow the warming trend at all, and in fact has slightly decreased.

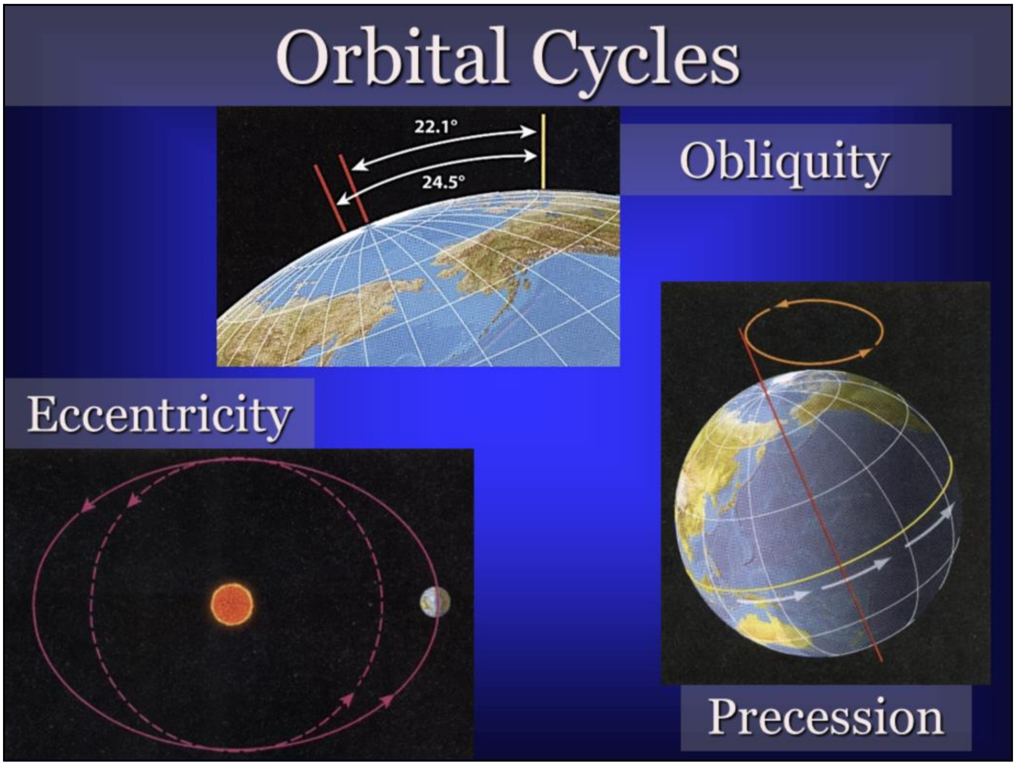
[Sun images from NASA/SDO]



Almost all of our energy comes from the sun. What if the sun is changing?

Sunspots? While they are cooler at the surface, the twisted magnetic fields produce copious x-rays and therefore the energy output increases. (This is not blackbody emission but a different mechanism). Lots of sunspots can increase the solar output.

But….. The sunspot cycle is 11-years, and global warming has had an upward trend for much longer than that. Also the number of sunspots has decreased in this last solar cycle.

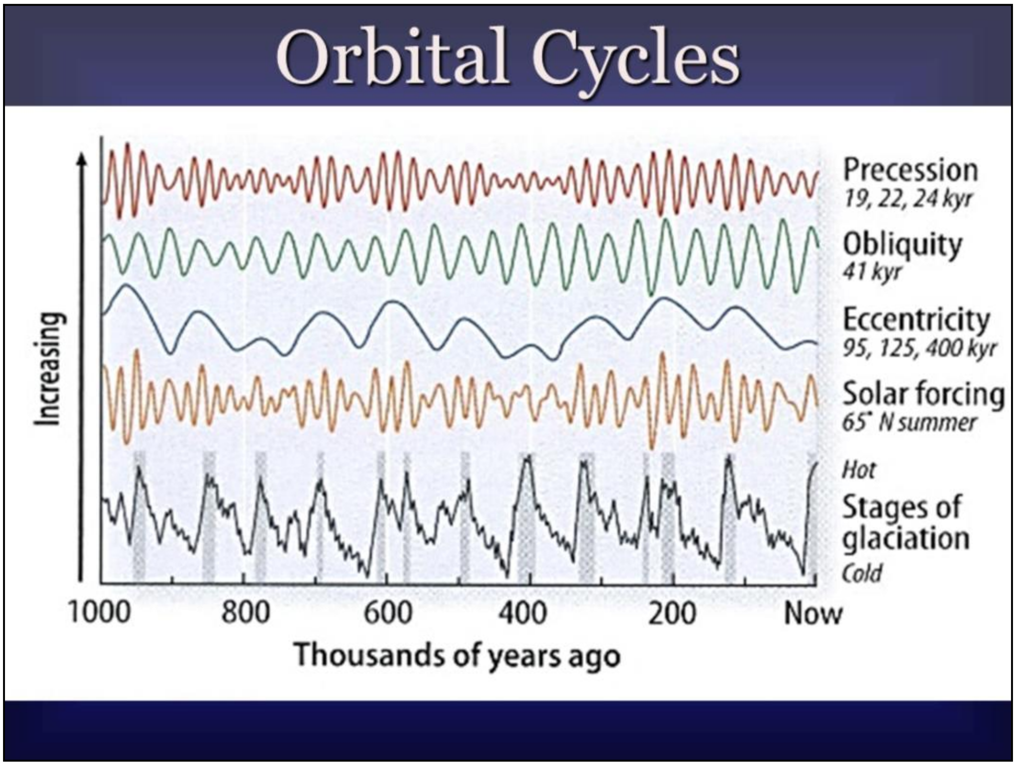


Obliquity: The tilt of the Earth. Our large moon does keep this pretty stable, but it does still vary by about +/- 1 degree. We are currently moving toward a lower tilt, which makes the Earth cooler. Obliquity cycle is about 41,000 years.

Eccentricity: How elliptical the orbit is. Earth's eccentricity varies from 0.005 to 0.06 (the latter is still pretty circular!). At the moment the Earth's eccentricity is about 0.017. Eccentricyti cycle is about 100,000 to 400,000 years, depending on the forcing caused by other planets. In and of itself the change in eccentricity is not sufficient to cause climate change. However combined with obliquity and precession, it can have an effect.

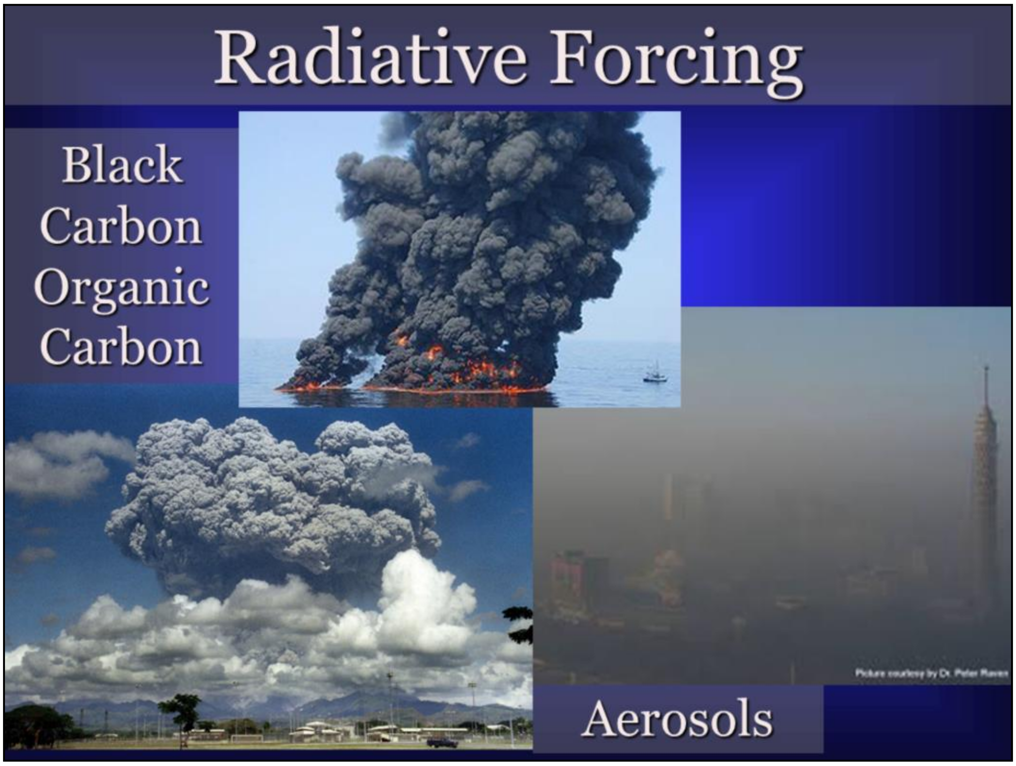
Precession: This is the change in direction that "north" is pointing in space. This cycle lasts about 23,000 years (eventually we will be pointed at Vega instead of Polaris).

If: High tilt, high eccentricity AND northern summer at **peri**helion, this leads to warmer climates. However we are at moderate tilt (and moving smaller) as well as northern summer during **ap**helion.



Notice that the solar forcing caused by orbital cycles (hellow line) corresponds well with the ice ages and interglacial periods (the latter is highlighted in grey on the bottom curve).

So: Should we be going into another ice age? We see this in the climate change denials a lot. Unfortunately, a) not yet and b) we're not because other factors are at play.

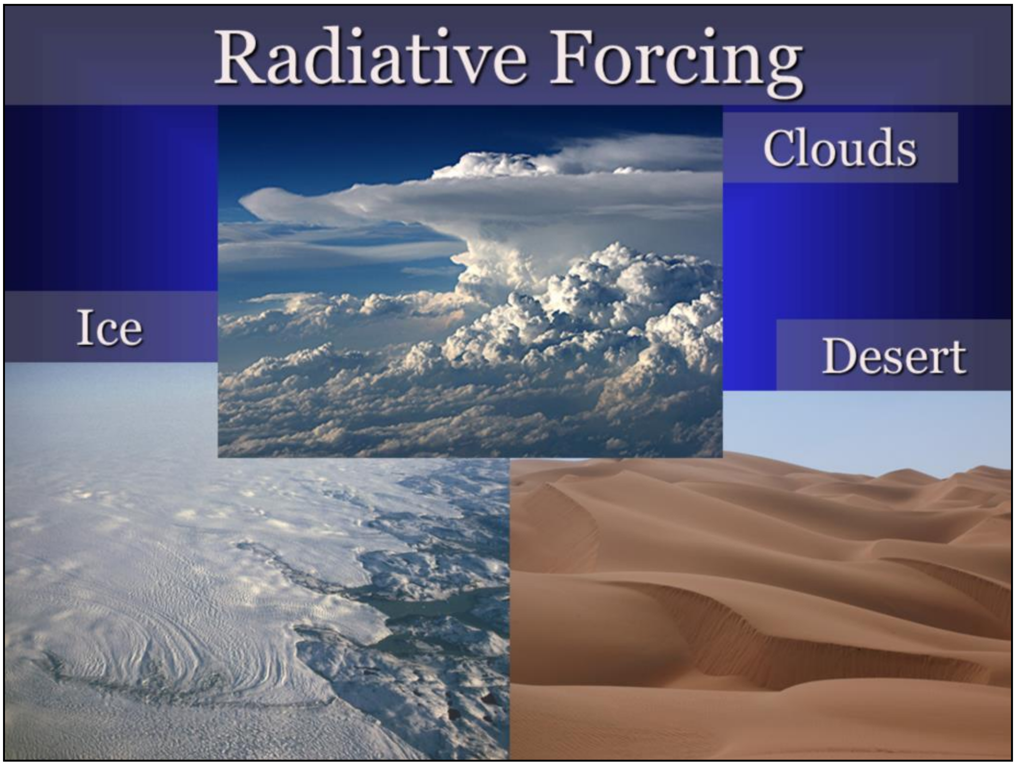


Black Carbon / Organic carbon: incomplete burning of fossil fuels or biomass. Net increase in warming of +0.4 W/m^2

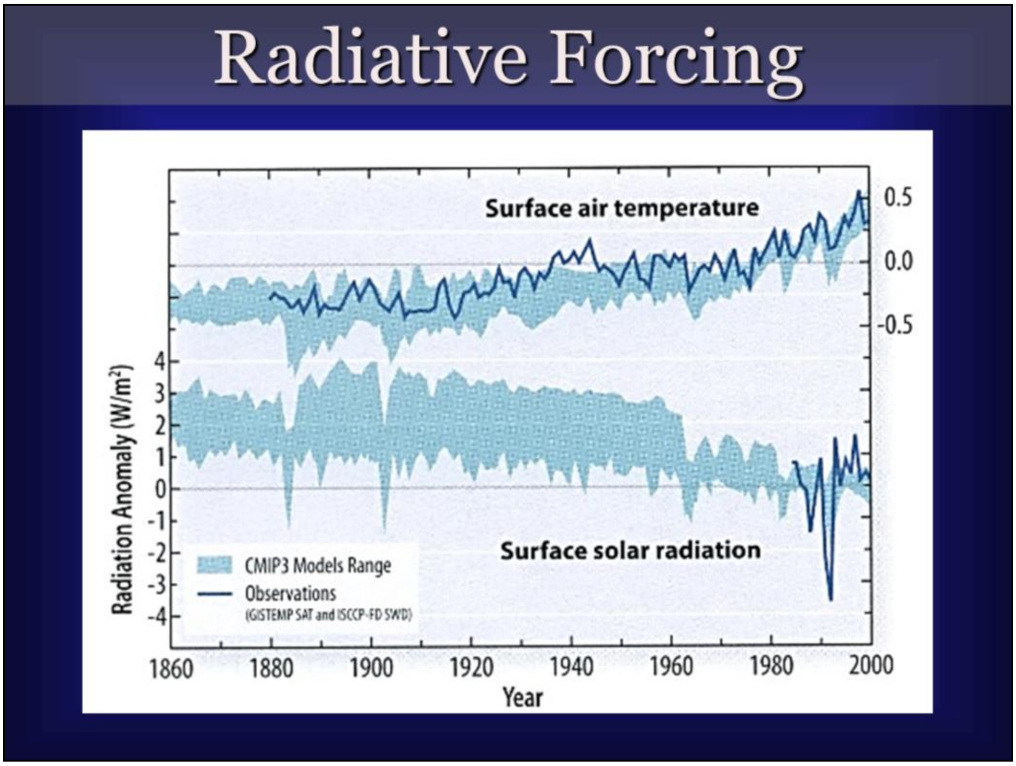
Aerosols: Again fairly complex with some heating and some cooling, but a probably net decrease in radiative forcing of -0.4 W/m^2

These seem to roughly balance out, however there is additional heating because they precipitate out onto snow, making it less reflective.

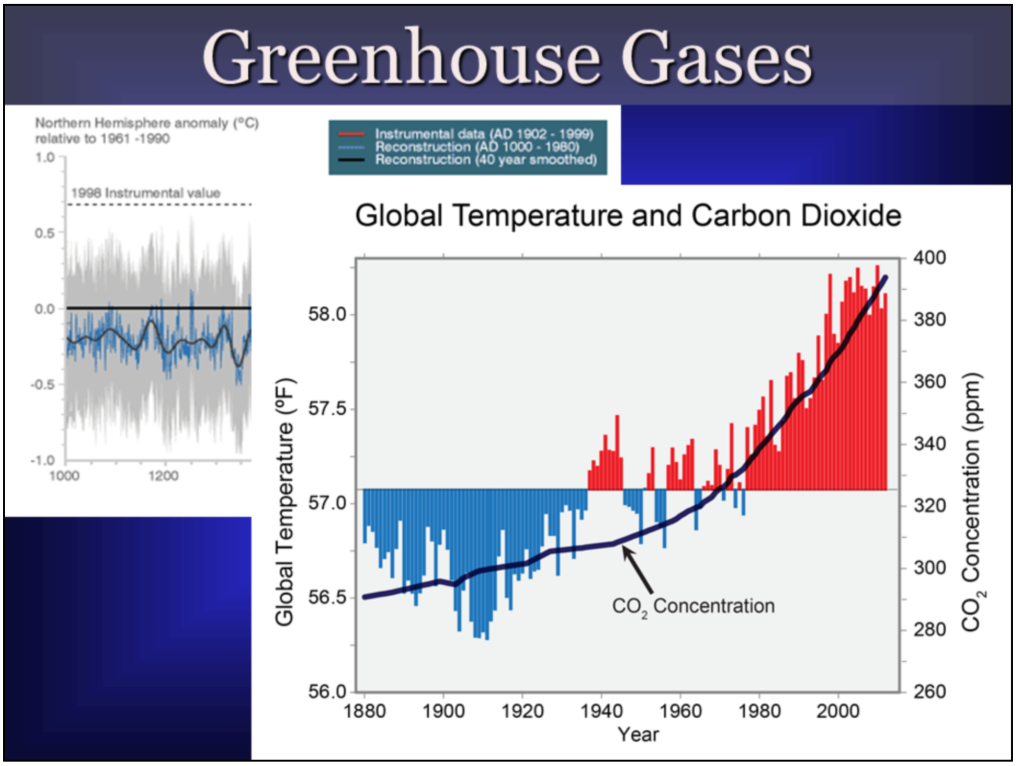
These two factors, because they involve both heating and cooling can be challenging to model. (these particles also can form the nucleation sites for clouds to form) This is complex with some heating and cooling factors, but the net result is a small heating factor of +0.04 W/m^2



All of these things increase the Earth’s reflectivity. There has been a slight increase in albedo over the last decade, mostly due to land use changes (-0.15 W/m^2) and cloud cover (-0.9 W/m^2), not enough to offset the overall impact of warming.



While there has been a slight decrease in *surface* solar radiation, air temperatures have still climbed. The big downward spike was due to the eruption of Mt. Pinatubo in 1991



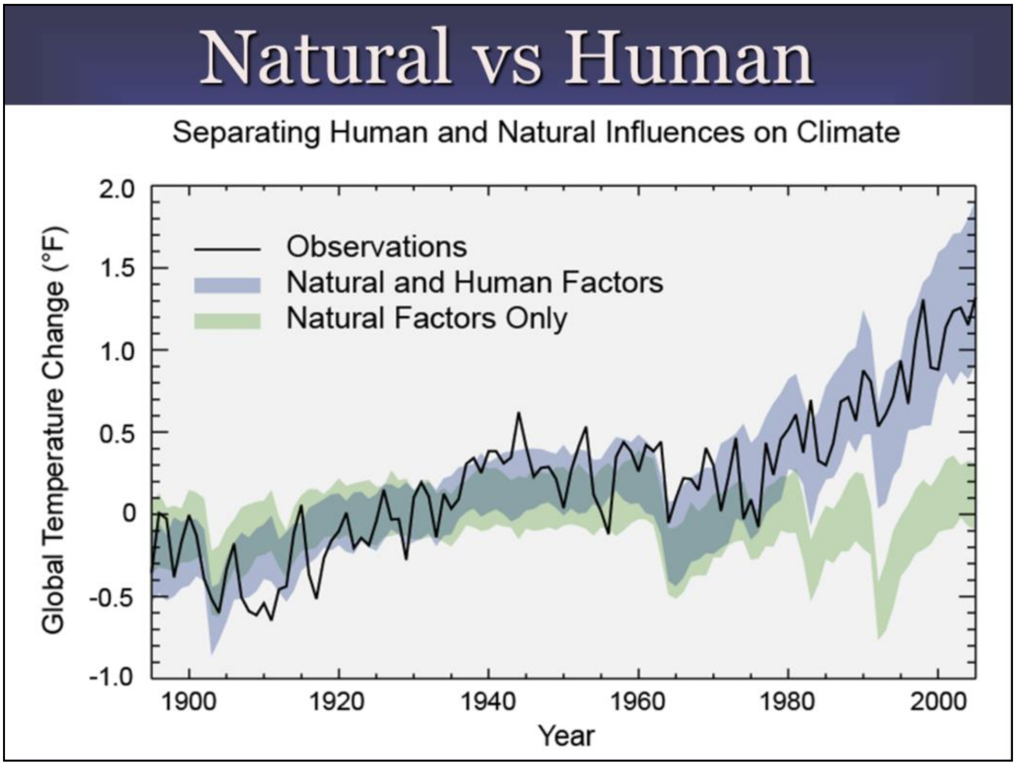
Rising carbon dioxide levels are not under dispute. Nor is the fact that global temperature rises with increasing levels of carbon dioxide.

Why are co2 levels rising? At this point it's pretty clear that it must be man-made emissions, not just natural sources. We mostly talk about CO2 (56%) but other greenhouse gases are Methane (16%), Nitrous Oxide (5%), Ozone & CFCs (%ages are percent of warming caused by these, not % in the atmosphere)

Past climate data reconstructed from tree ring growth and ice cores.

Shows a sharp increase in global average temperature since the industrial revolution.

Note that "zero" is an arbitrary point chosen ~1960. Since global warming had already been occuring for a while, most of the data lie below the "zero" line. Bear in mind that all temperature changes quoted are deviations from the 1960 value – already warmer than the average for the last 1,000 years.

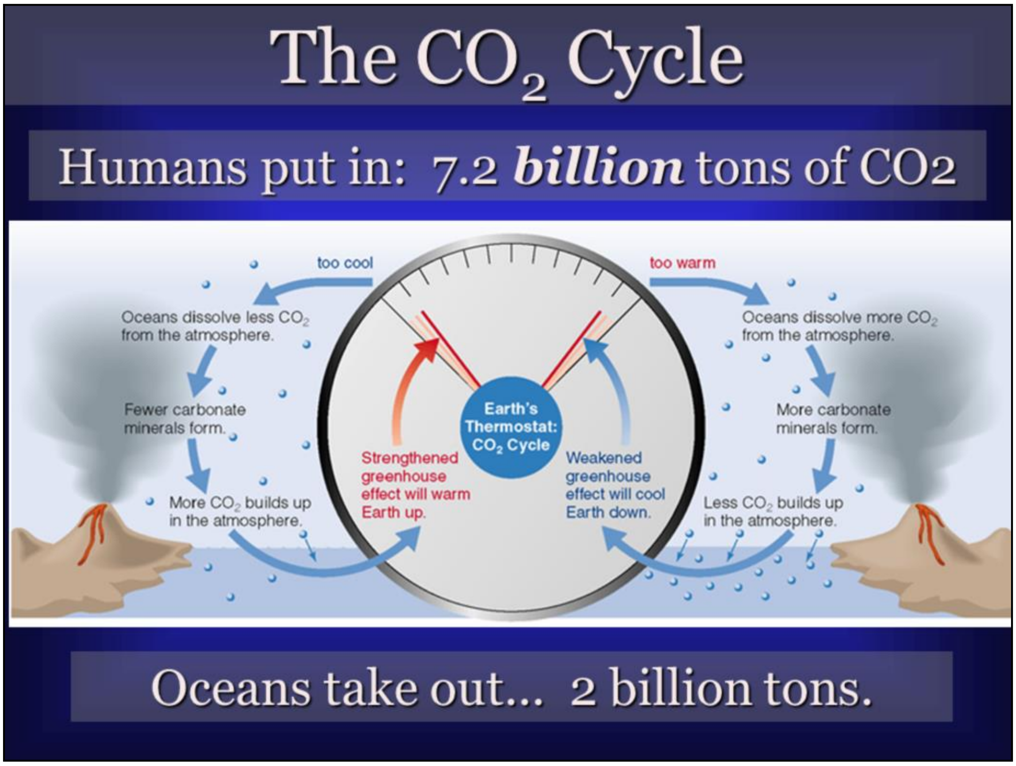


In fact, natural factors are taken into account by all climate models. They show that without our greenhouse gas emissions there should have been a slight cooling trend in the last several decades, rather than warming.

There was a slight dip in the warming trend in the 60s before the environmental controls were put into place to control particulate emissions from coal burning plants.

Show this link:

http://www.bloomberg.com/graphics/2015-whats-warming-the-world/



Even without organic matter or life: CO_2 -> dissolved in ocean. Silicates also in ocean. CO_2 + silicates -> carbonates (e.g. limestone). These are then subducted taking CO_2 out of the way. Temp – if hot (because more CO_2 in atmosphere) more CO_2 gets dissolved and taken out. If cold, it builds up in atm, therefore self-regulating.

An additional 2 billion tons are taken out by an unidentified source, probably most of which are plant ecosystems such as the rainforests, grasslands, etc.

The CO_2 Cycle

Every year the amount we put in increases about 1% per year. (12 billion by 2035)

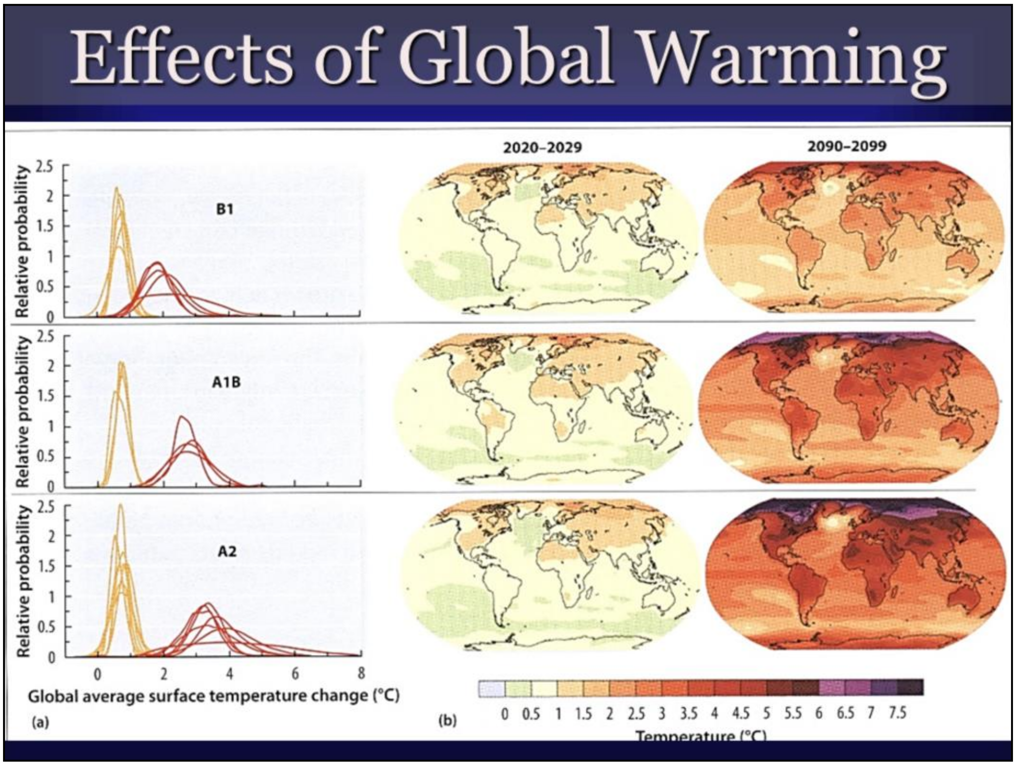
Humans put in: + 7.2 billion tons

Oceans take out: -2.0 billion tons

Other sinks: -2.0 billion tons.

Net Increase: +3.2 billion tons

+8 billion tons by 2035 per year.



What temperature are we now?

Where are we headed?

When does it become really bad?

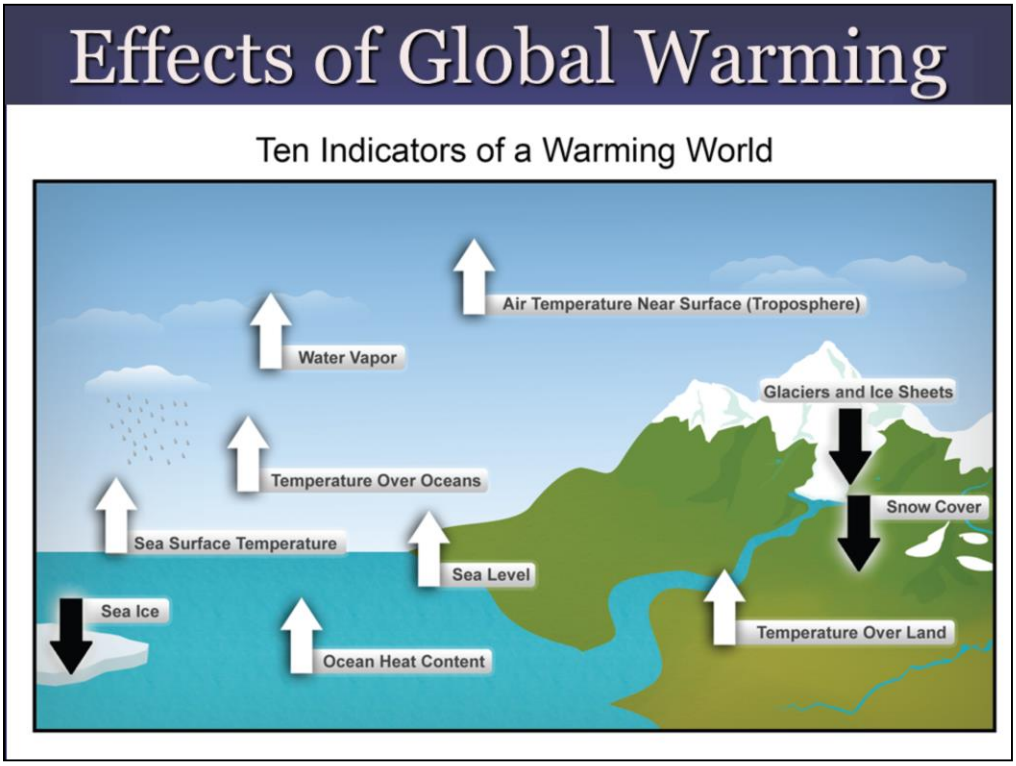
The above figure shows IPCC models for different scenarios of reducing our CO2 emissions.

Temps by 2100:

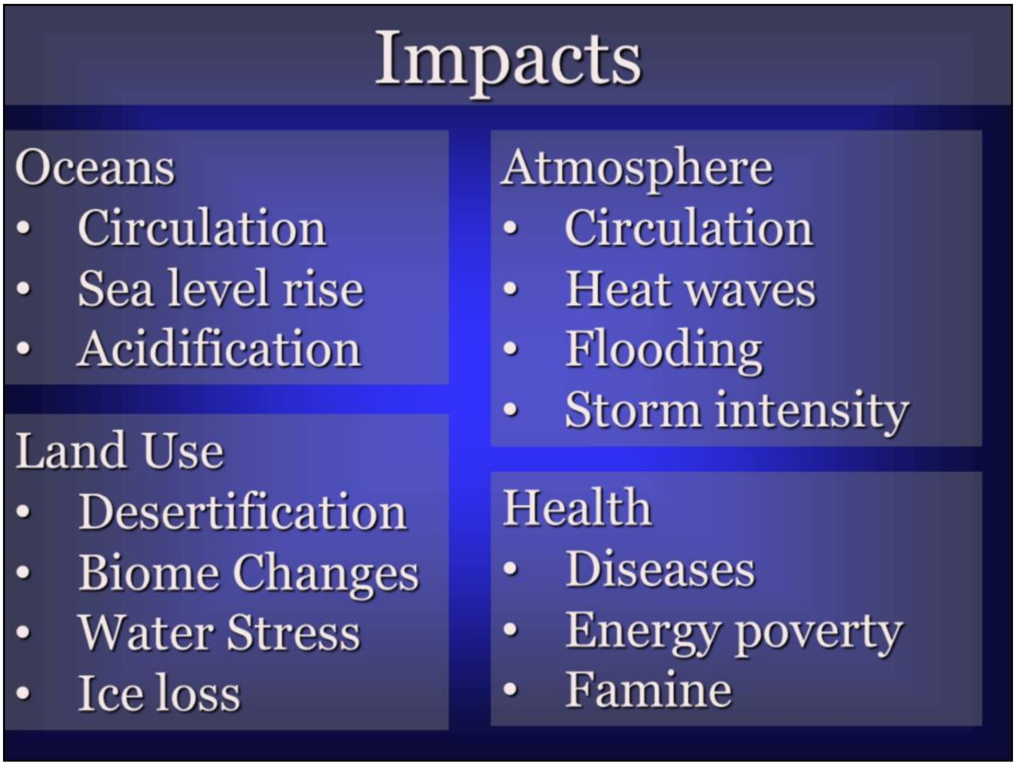
B1 ~1.8 degrees

A1B ~2.8 degrees

A2 ~3.2 degrees [most likely scenario at this time]

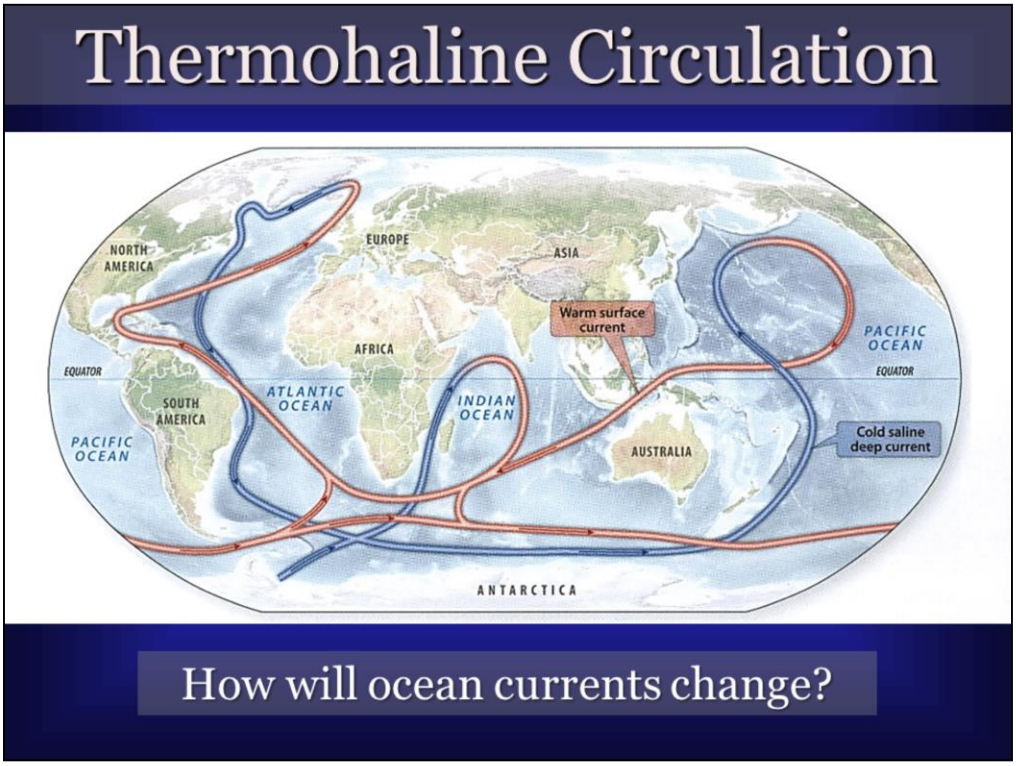


These are not the *only* effects though! There are plenty of other important ones too, though they are effects driven by these factors.



Yeah maybe a problem. Many of these are directly tied to each other.

All of these will led to conflict. Many will lead to (and are already leading to) forced migration.



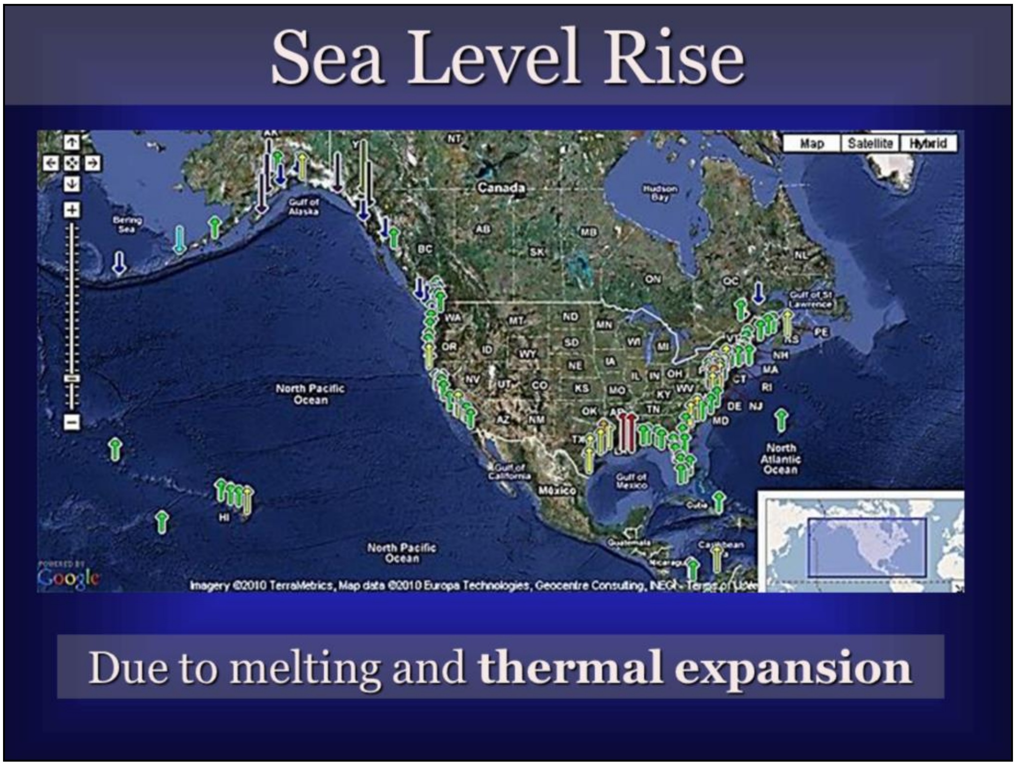
NOTE: Red is a *surface* current and blue is a *deep* current

Right now water near the equator is heated, brought up to higher latitudes, where it cools (and becomes more dense). It then sinks down, slowly displacing water toward the equator, where it then can be heated again.

The trouble with melting the polar ice is that it is fresh water, which has less density than the salty ocean water. It therefore just sits there on the top, blocking the way for the water currents to move toward the polar region (since you can't pile water on top of other water). This will eventually shut down the gulf stream and other major ocean circulation. In addition, the melting of Antarctic glaciers from the bottom is preventing the formation of the Antarctic deep water… a major driver of oceanic circulation.

What happens then? We are no longer bringing heat to the northern latitudes from the equator. The equator gets hotter and hotter, while the poles cool. Potentially this could lead to an ice age… except we keep pumping more CO_2 into the atmosphere. Not only that, recent evidence suggests that shutting down the ocean circulation (at the end of ice ages) actually dumps more CO_2 into the atmosphere as it causes the oceans to release CO_2. So I wouldn't go hoping for an ice age to mitigate our emissions any time soon.

Even if it did happen, the southern latitudes will be too hot to live, and the northern latitudes might be too cold. The band of “just right” will be very small, and much of the fresh water will be locked up in ice.

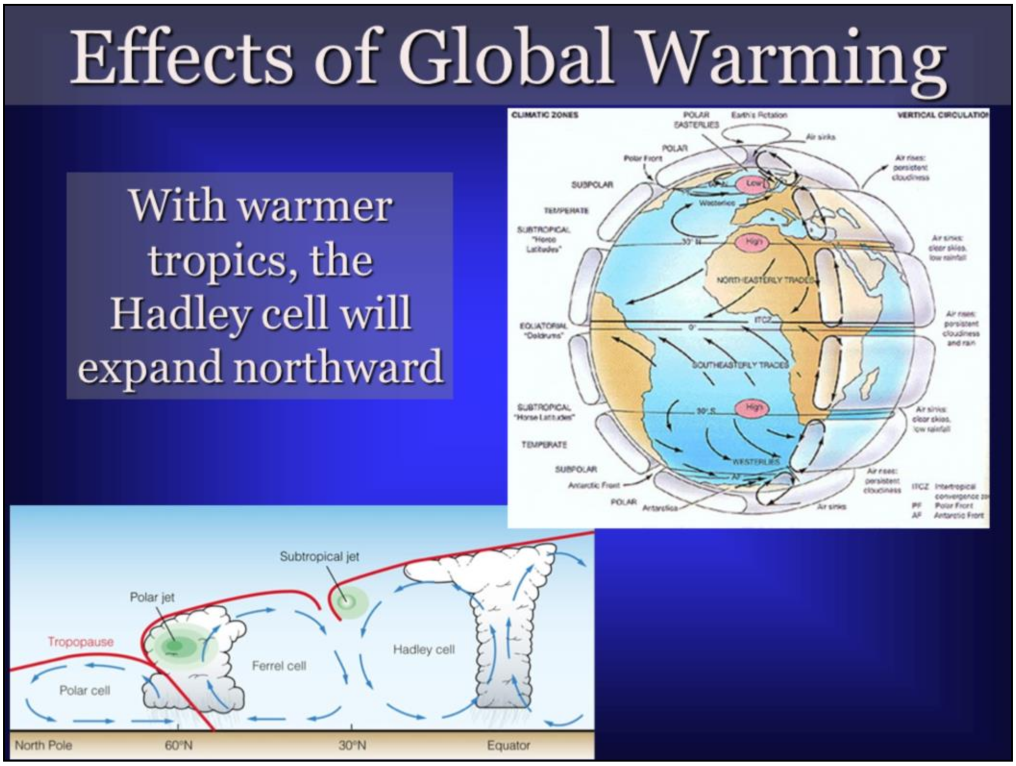


The [Intergovernmental Panel on Climate Change](https://www.ipcc.ch) (IPCC) estimates that the global average sea level will rise between 0.6 to 2 feet (0.18 to 0.59 meters) in the next century ([IPCC 2007](https://www.ipcc.ch)).

Note that all predictions from the 2007 IPCC conference have been shown to be not as bad as what we are continuing to observe. In other words, we're worse off than we'd (conservatively) estimated. The new report can be found at https://www.ipcc.ch/report/ar5 and a summary and many graphics can be found at www.globalchange.gov and nca2014.globalchange.gov (graphics created by NOAA and other organizations involved in the IPCC).


Sea Level Rise
Louisiana and Florida
Mississippi River
Atchafalaya River
Baton Rouge
Lafayette
New Orleans
modern delta
Grand Isle
0
50 km
Mississippi River
Atchafalaya River
Baton Rouge
Lafayette
New Orleans
modern delta
Grand Isle
0
50 km

Credit: NASA



After 100 years? We could rise by more than 6 C (10.8 F)

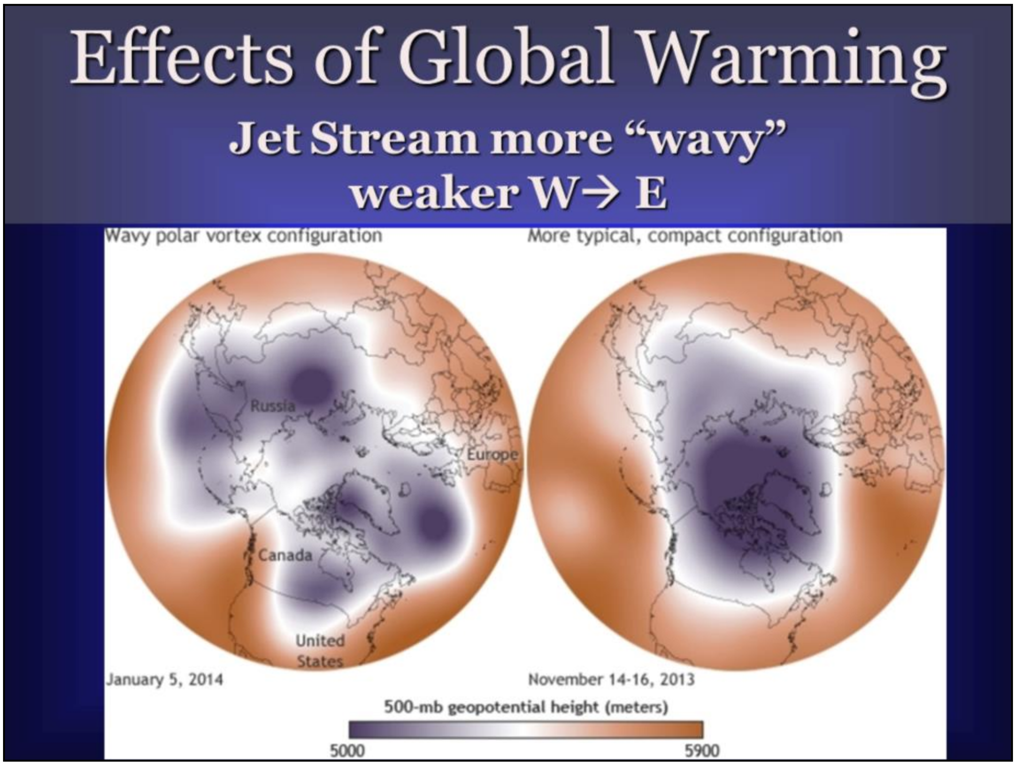


Image source: NOAA

The jet stream influences where airmasses form, how stable they are, and weather patterns including storms, drought, and extreme cold or heat buildup. As the jet stream flows more slowly (~10% slower than before) weather moves more slowly and airmasses become more extreme.

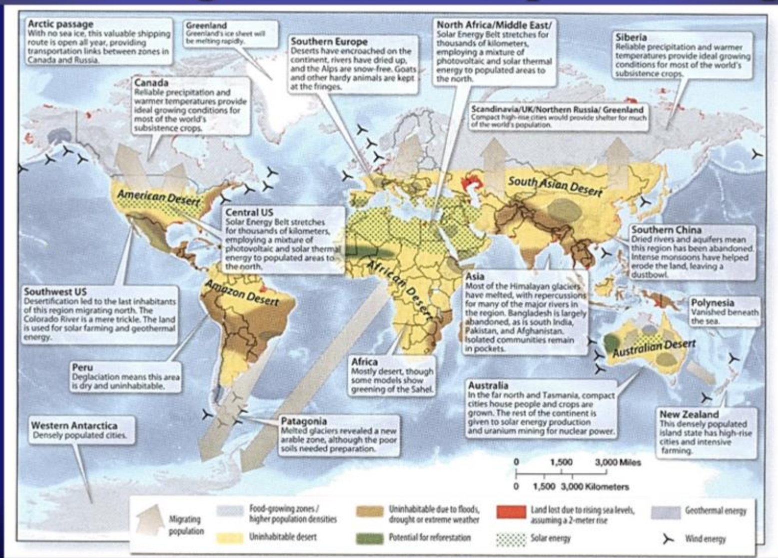
Notice how fare down the jet stream travels into the U.S. compared to the more typical configuration on the right. We have seen the wavy configuration on the left become more common than it used to be.

http://iopscience.iop.org/article/10.1088/1748-9326/10/1/014005;jsessionid=5A7CE45E1B881276BD4390A3A2919E49.c4.iopscience.cld.iop.org

http://rsta.royalsocietypublishing.org/content/373/2045/20140170

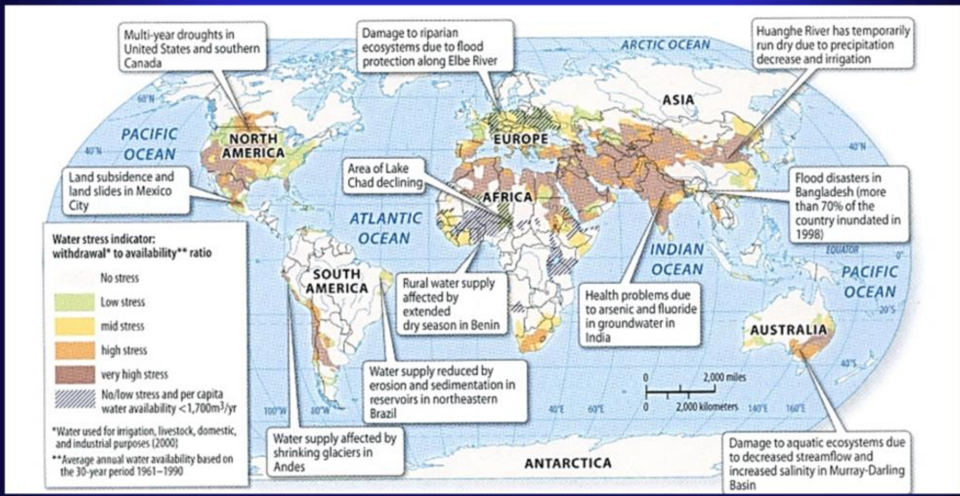
Effects of Global Warming

Biome Changes due to atmospheric changes



Effects of Global Warming

Water Stress



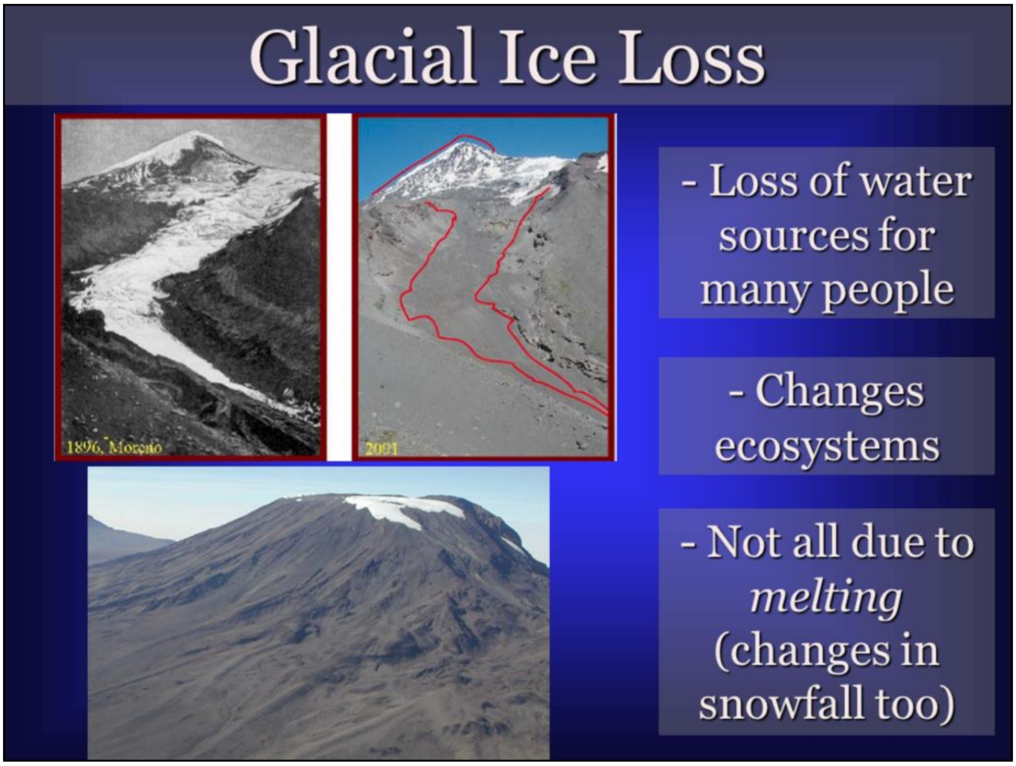
We are also seeing an increase in extremely heavy precipitation (even this year 2014 we have double the usual amount) *as well as* an increase in the number of very dry days.

Erosion along the Alaskan coast. Credit and quote: Ground Truth Trekking

Oh and by the way, tundra and permafrost melting methane release… which is a greenhouse gas

Siberian methane hole due to explosive methane release from the permafrost.

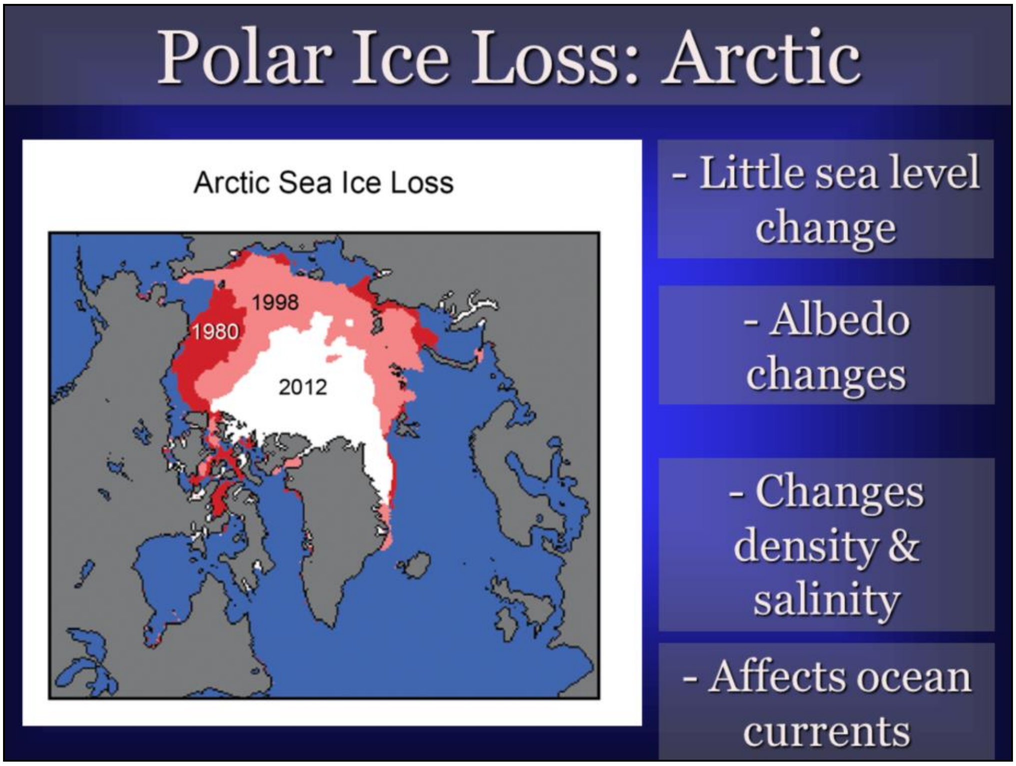
Methane hydrates at the bottom of the ocean may also destabilize. However, as temperatures rise, the pressure will rise due to ocean expansion, so this is less likely.



The top glacier's loss is mainly due to melting.

The snow cap on Mt Kilimanjaro is due to less precipitation on the mountain.

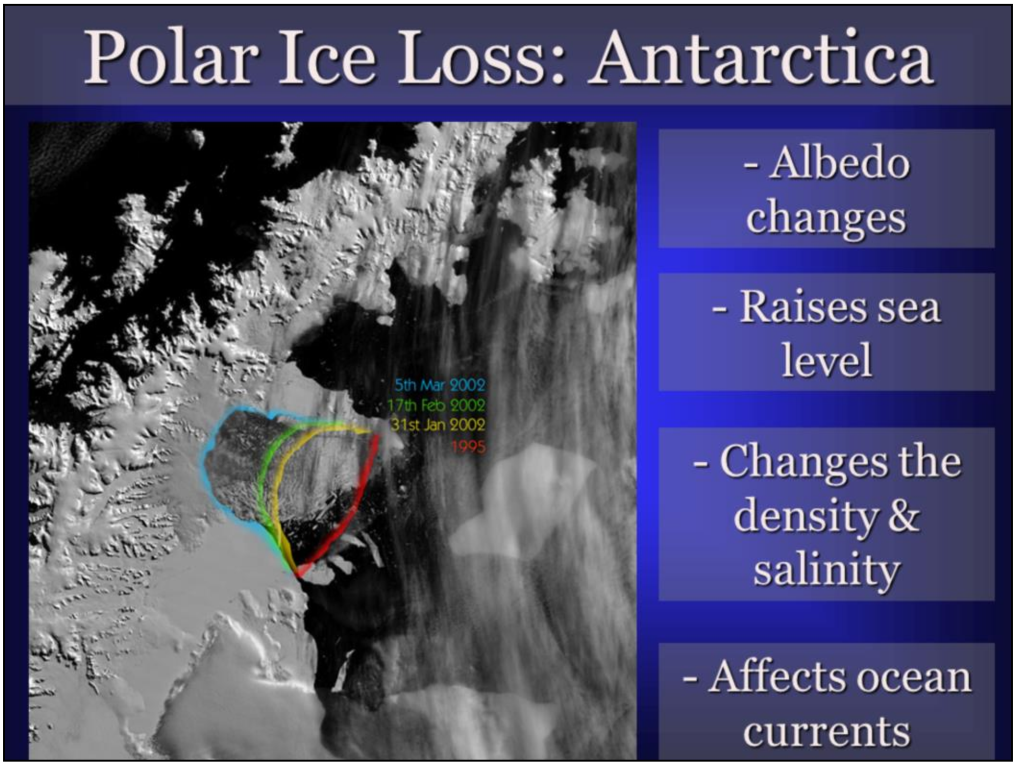
A ***very few*** glaciers are growing due to increased precipitation but it is NOT the norm; most are disappearing.



Since the ice primarily floats in the water, melting it does not significantly change sea level – aside from the fact that it can now expand along with the rest of the water as it heats up.

Changes in albedo (reflectivity) mean that more sunlight will be absorbed instead of reflected back to space – causing more heating

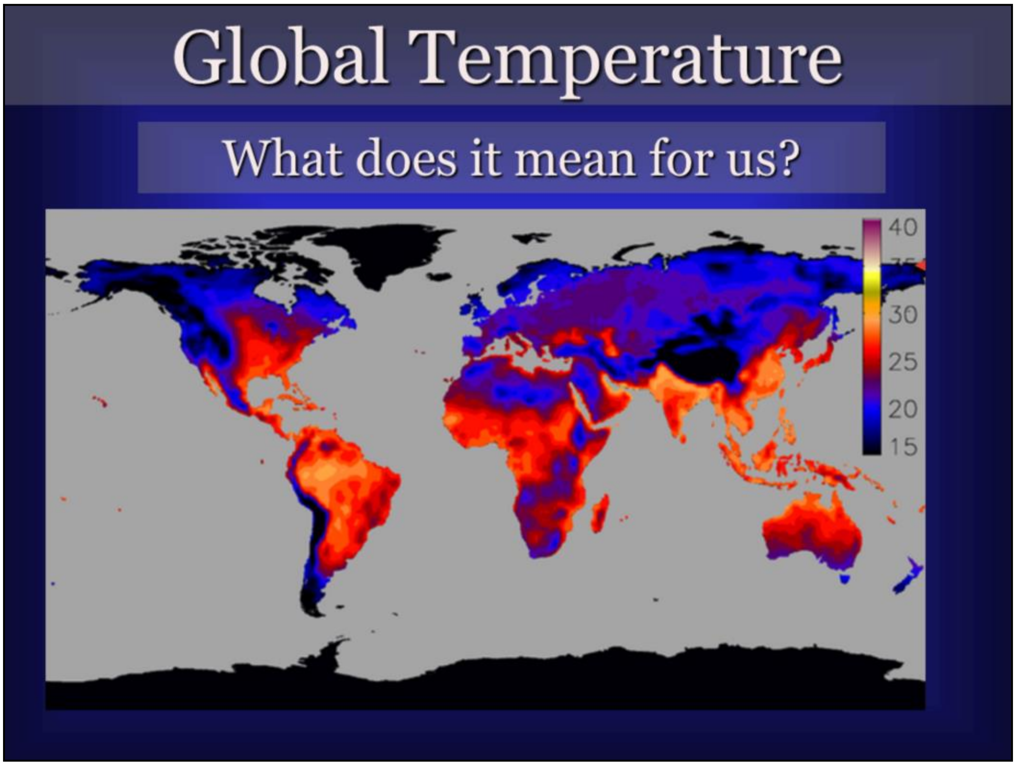
If we follow current trends (without adding more greenhouse gases) the Arctic will be ice free at the end of the century. Worst case: ice free by 2050…



Since most of the ice sheet in Antarctica resides on land, when the ice melts it adds water to the ocean.

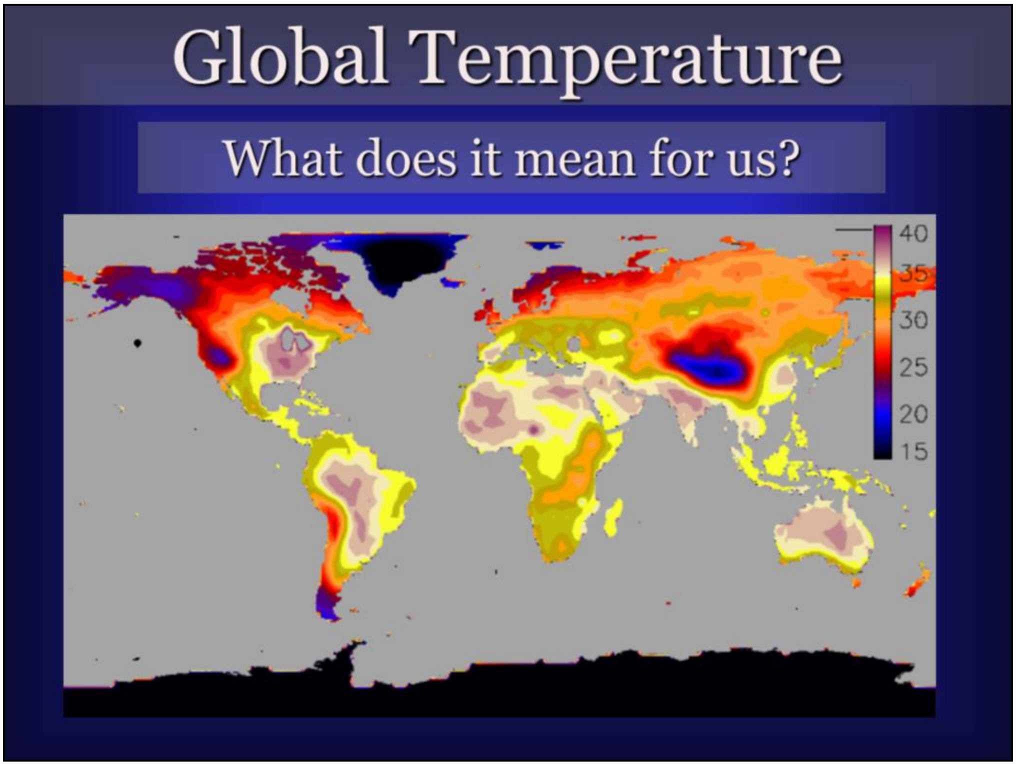
Antarctic ice is melting at a rate faster than ever before, and current observations suggest it will be very difficult to stop, as most of the melting is occurring from the bottom of the glaciers.

Already the Antarctic bottom current is shutting down.



Now: No part of the Earth is too hot for us to live. Estimated maximum temperatures for survivability for mammals (including us) is about 35C.

Sherwood & Huber, PNAS, 2010



10 C hotter…. Lots of places become uninhabitable. How might we, as a population of 7 *billion* people, manage this?

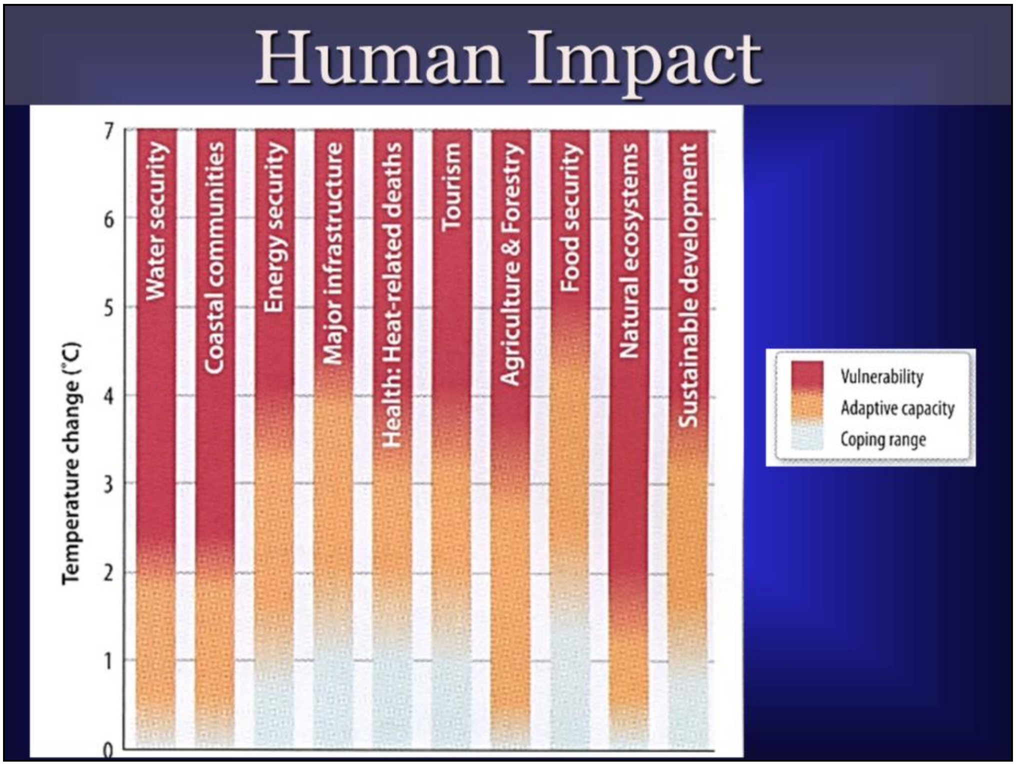
Air conditioning? The power requirements are wicked high, and only exacerbate the problem. Besides, how do we air condition for our livestock?

What about those who cannot afford it?

Is this responsible?

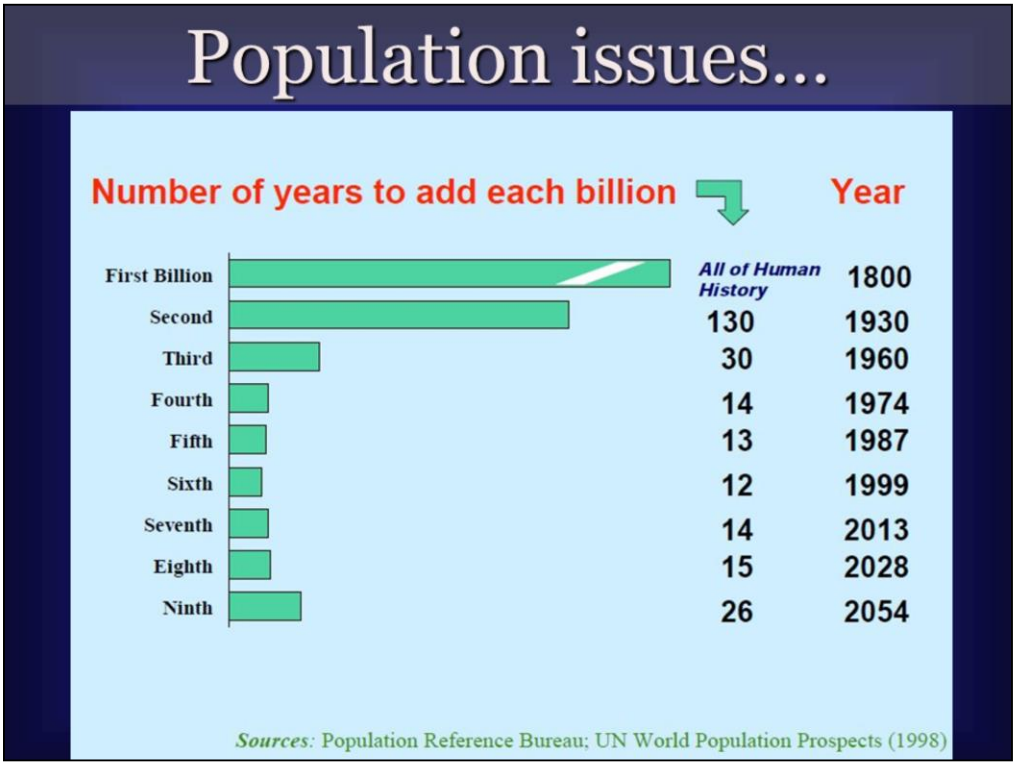
And it won't be long before we hit the next billion…

Sherwood & Huber, PNAS, 2010



Current scenario? 3.2 C

But after 100 years…. 6C if nothing done. Danger!

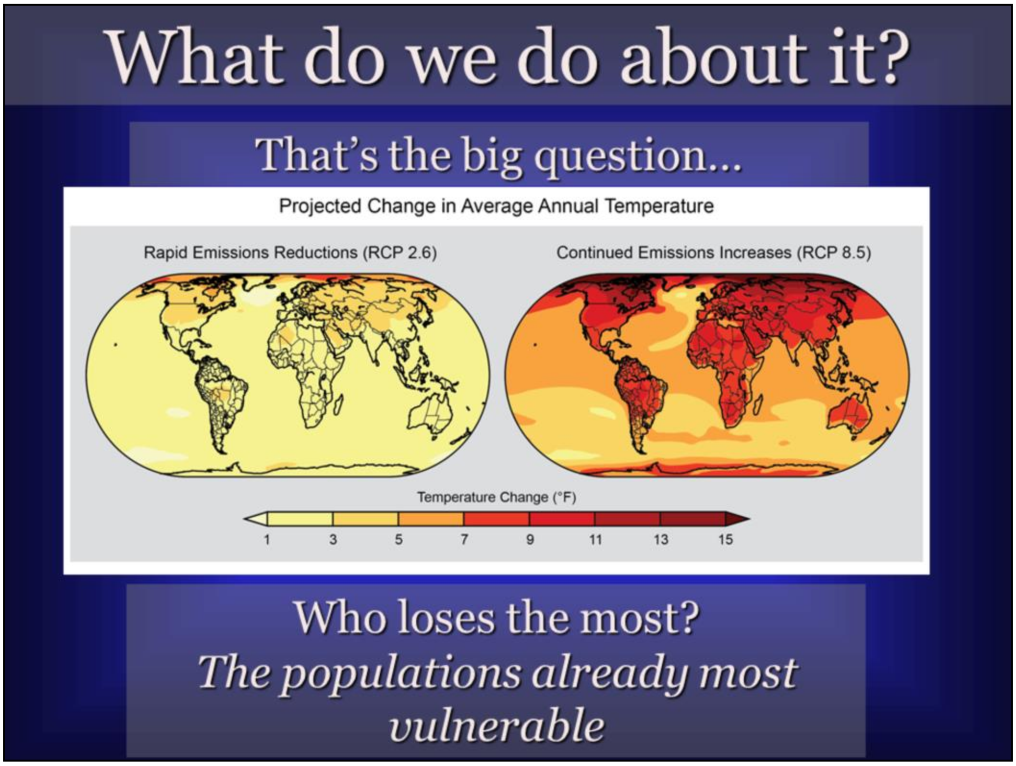


What are drivers behind putting more CO2 and Methane into the air, deforestation and other drivers of climate change?

Population population population.

As other countries develop more, they will begin to use more resources as well. We need to develop ways that everyone can enjoy a good standard of living (and perhaps define that) without continued use of resources. People like to say technology will save us, but in reality we also need to seriously reduce populations for sustainable living.

Projections suggest we will add another ***2 billion*** people by 2050.

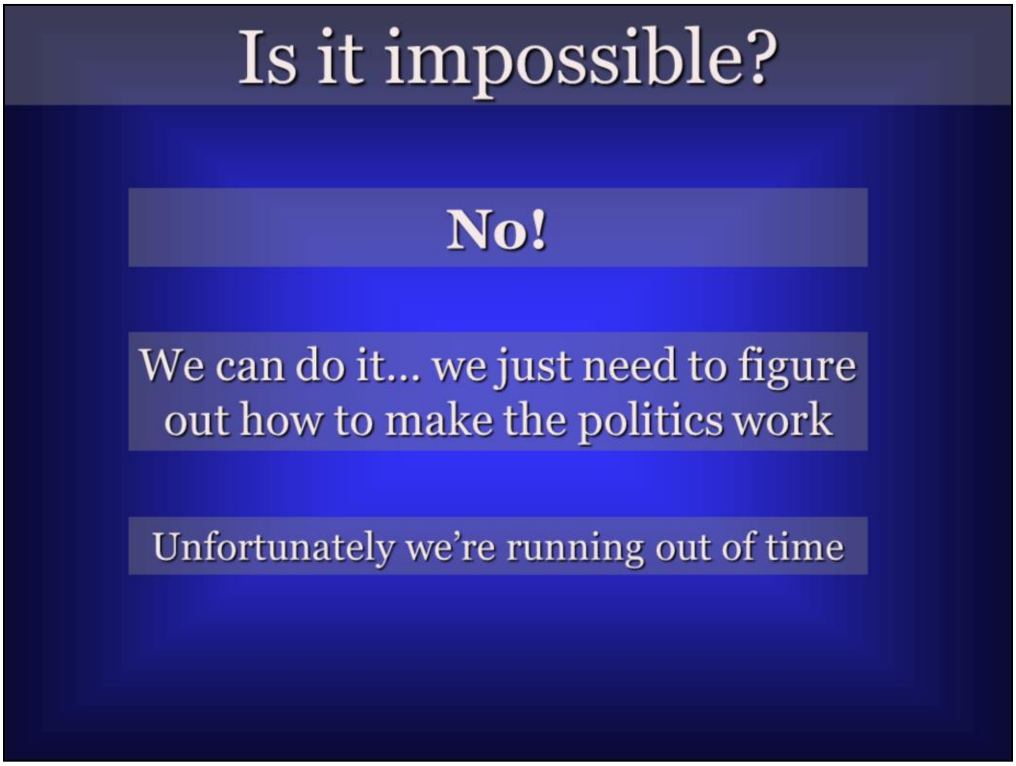


Left: assuming we rapidly reduce our emissions, we will still see a large change in average temperature. It may not sound like much (3-5 degrees F here in MN) but remember that's an *average*.

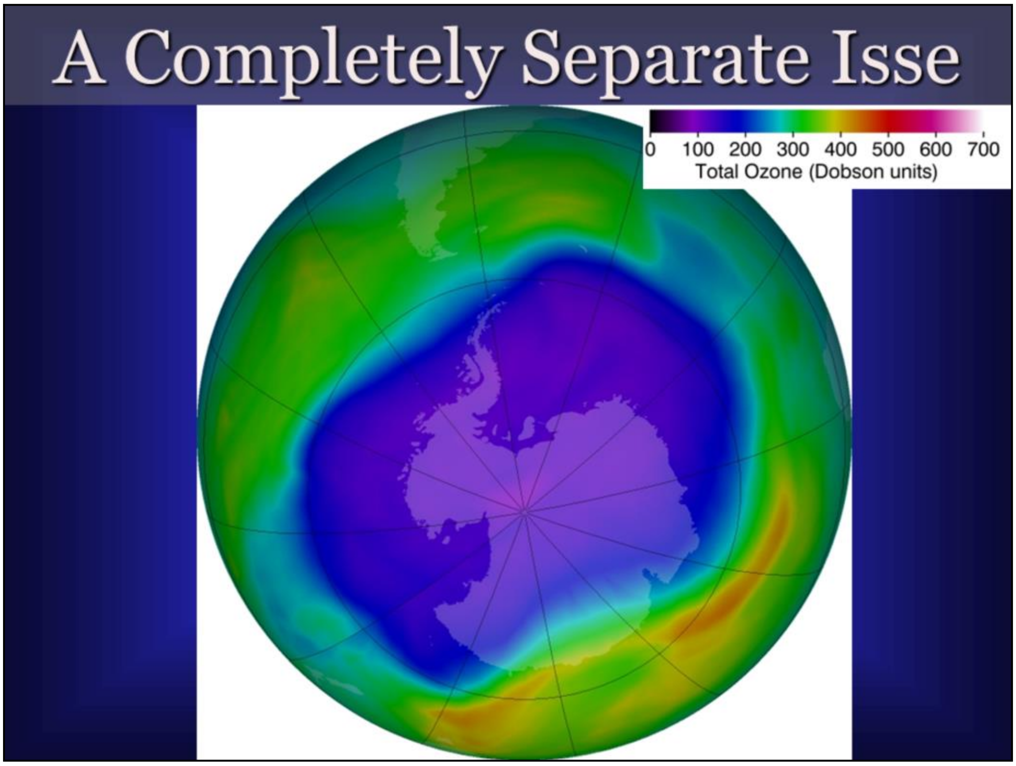
Right: If we continue to increase our emissions.

Who loses the most? **The populations already most vulnerable.**

Who has the power here? Which nations?



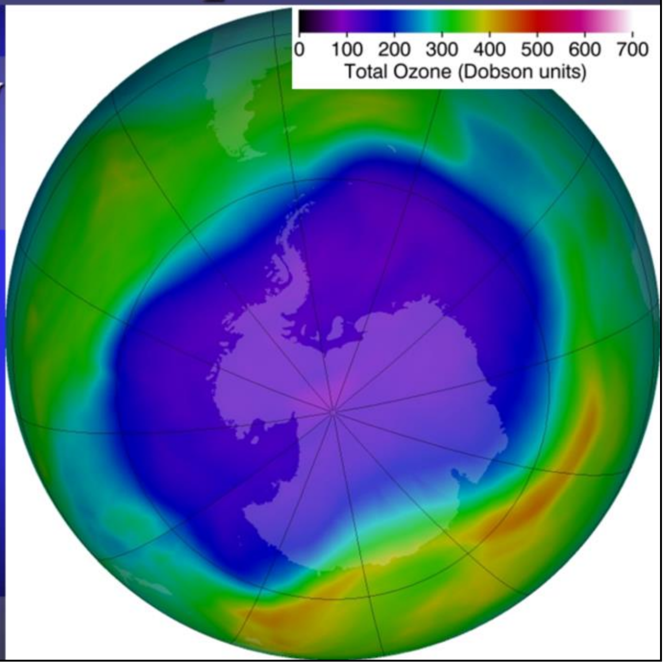
Who has the power here? Which nations?



Ozone Depletion

Ozone Depletion

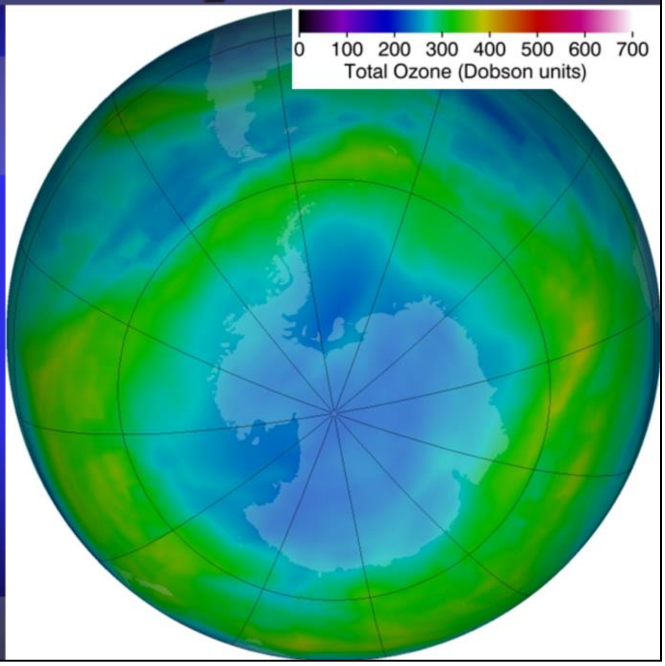
When we do try to fix something...



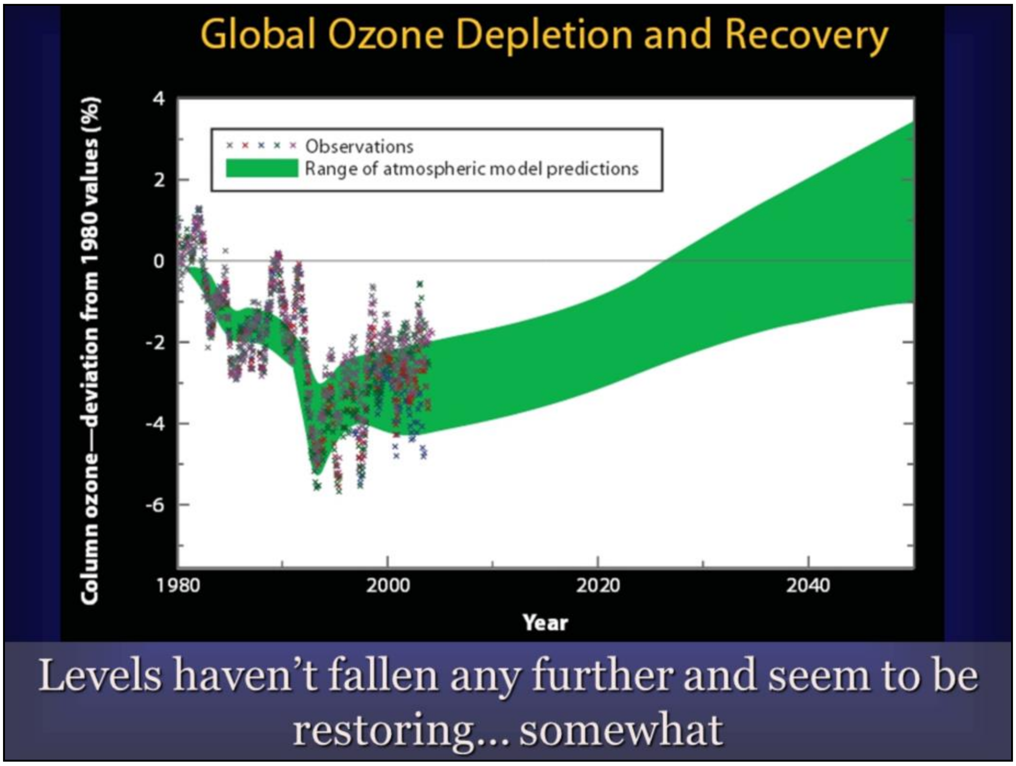
Sept 1996

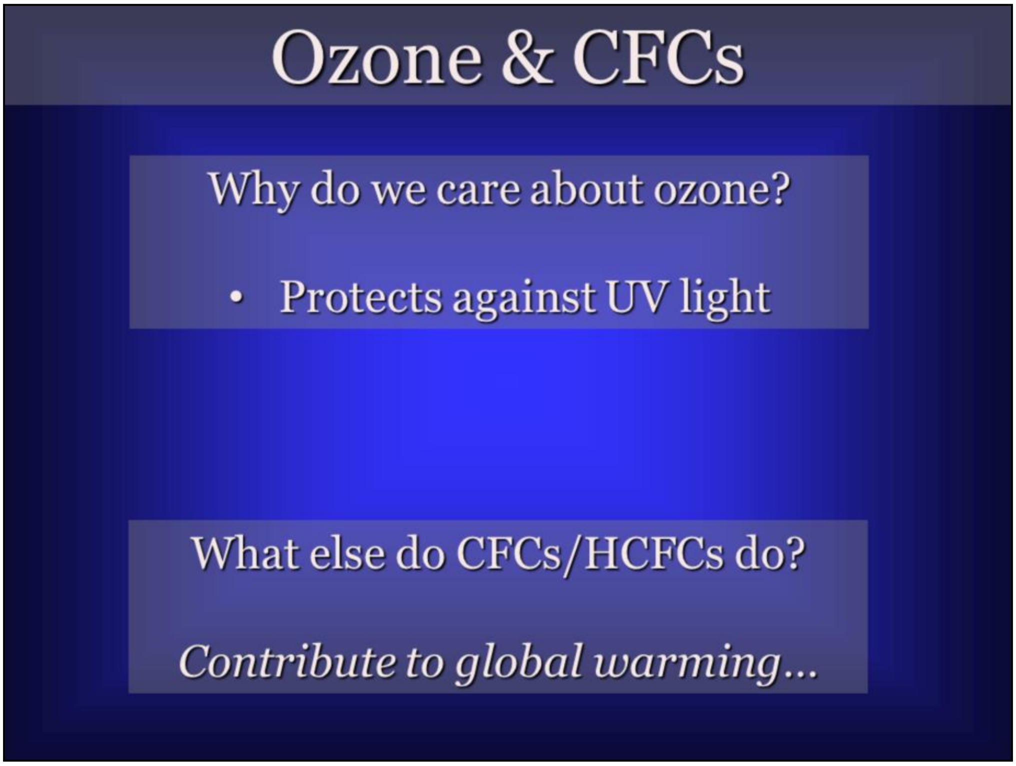
Ozone Depletion

We do kind of ok…



July 2013


Global Ozone Depletion and Recovery
Observations
Range of atmospheric model predictions
Column ozone—deviation from 1980 values (%)
4
2
0
-2
-4
-6
1980
2000
2020
2040
Year
Levels haven't fallen any further and seem to be restoring... somewhat



CFCs are chlorofluorocarbons

HCFCs also have hydrogen.

In 2013, the US and China have agreed to lower the number of CFCs and HCFCs to help both problems. (you know it's bad if we're agreeing with China)