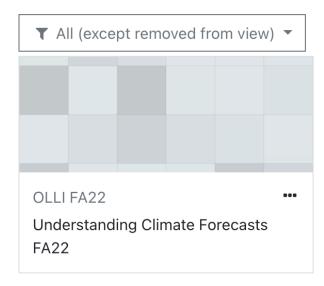


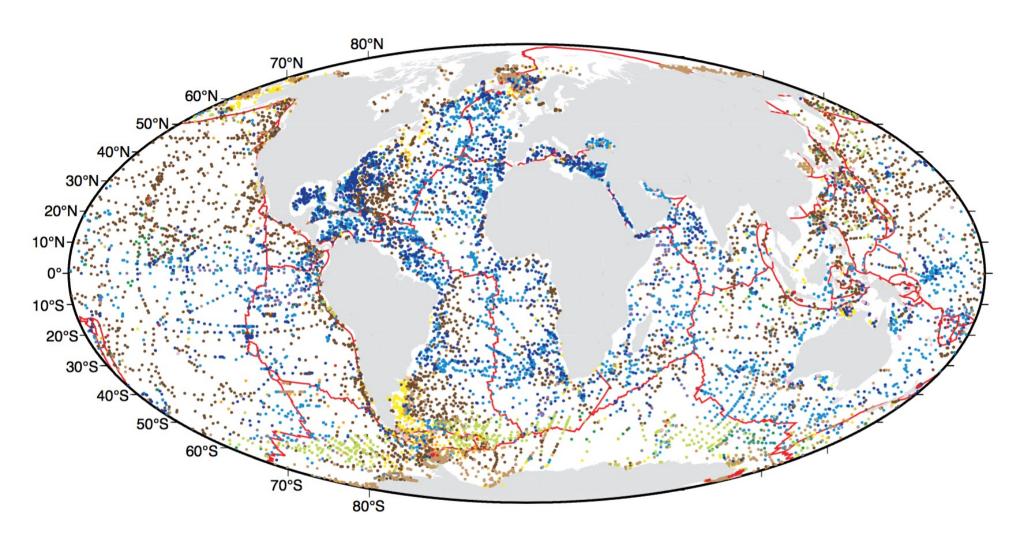
April Abbott aabbott1@coastal.edu

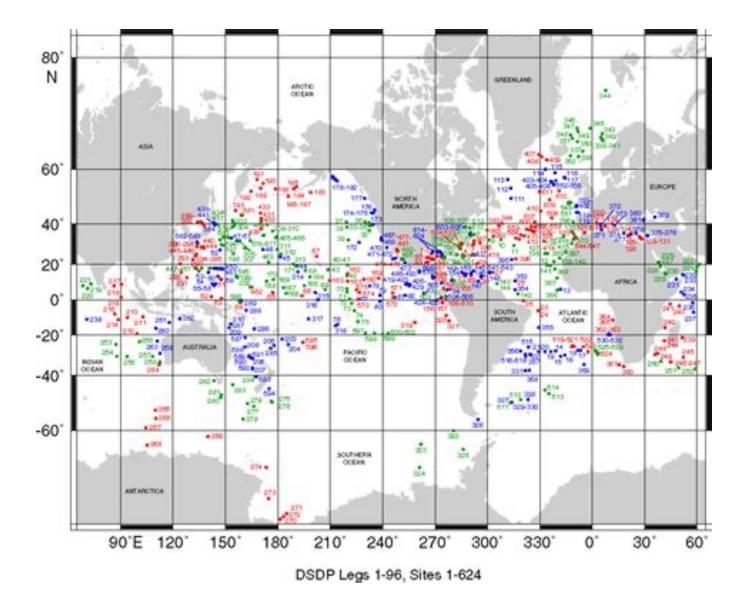
ollimoodle.coastal.edu

Course overview



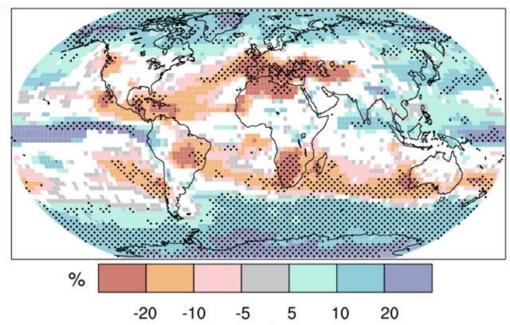
Most of our records come from the ocean







How well do climate models agree?



Change in precipitation (mm day-1): average of all IPCC models

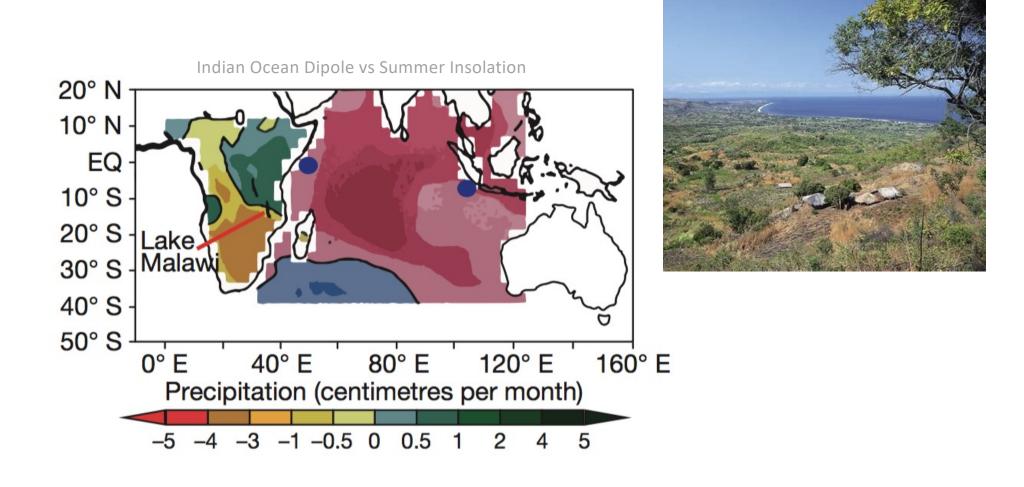
White: less than 66% agreement. Colours: 66% or more agreement.

Black dots: 90% or more agreement

2090s relative to present-day, A1B scenario: June-July-August

© Crown copyright Met Office Source: Intergovernmental Panel on Climate Change (IPCC)

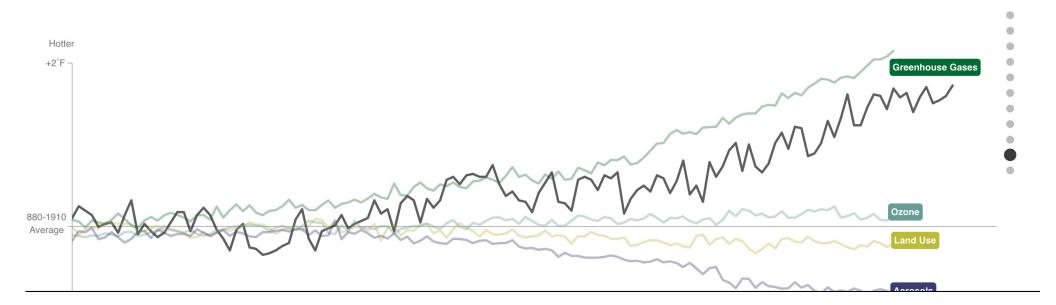
and predictive power for land matters



Climate Change: its happening, its us.

Bloomberg's "What's Warming the World?"

Greenhouse gases warm the atmosphere. Aerosols cool it a little bit. Ozone and land-use changes add and subtract a little. Together they match the observed temperature, particularly since 1950.

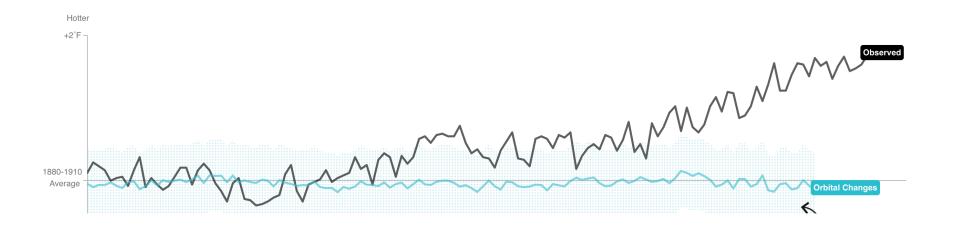


'But Earth's climate has always changed...'

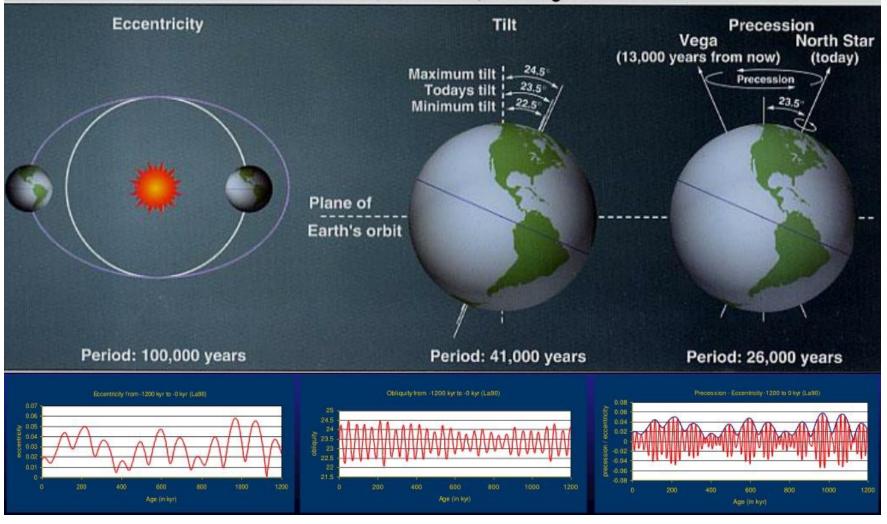
(Yes, we know... that's how we inform our models & why we know this is unprecedented)

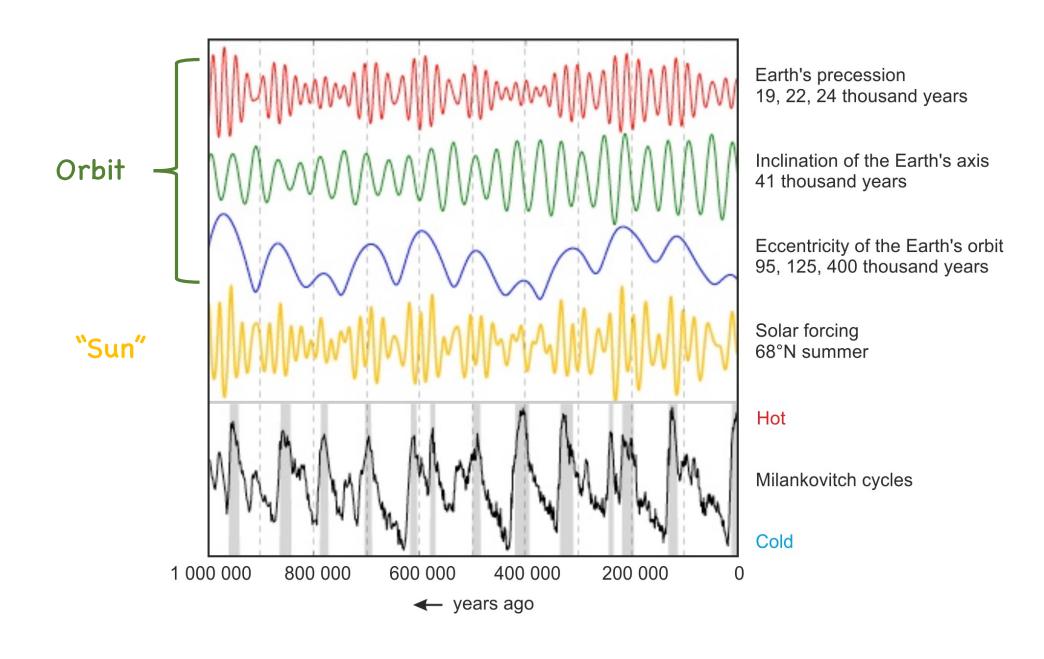
Is It the Earth's Orbit?

The Earth wobbles on its axis, and its tilt and orbit change over many thousands of years, pushing the climate into and out of ice ages. Yet the influence of orbital changes on the planet's temperature over 125 years has been negligible.



Milankovitch cycles

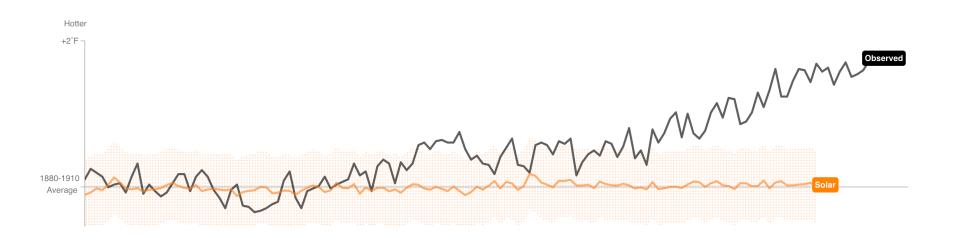




No significant changes in solar radiation...

Is It the Sun?

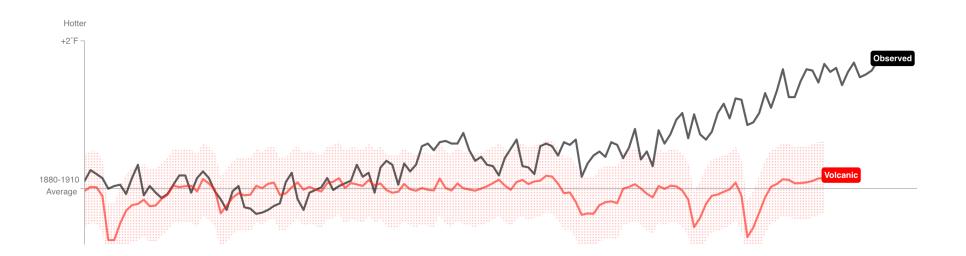
The sun's temperature varies over decades and centuries. These changes have had little effect on the Earth's overall



Not volcanoes..

Is It Volcanoes?

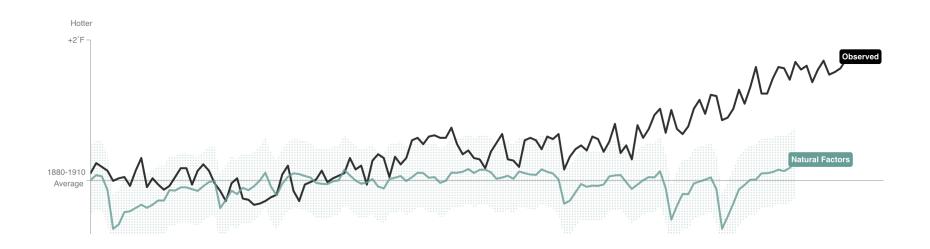
The data suggest no. Human industry emits about 100 times more CO_2 than volcanic activity, and eruptions release sulfate chemicals that can actually cool the atmosphere for a year or two.



Orbit + Sun Strength + Volcanoes

Is it All Three of These Things Combined?

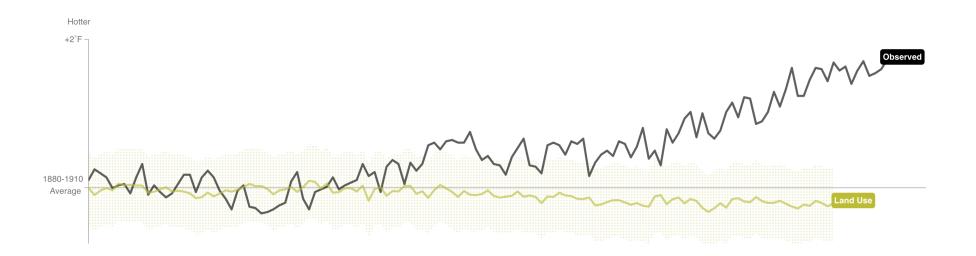
If it were, then the response to natural factors should match the observed temperature. Adding the natural factors together just doesn't add up.



Deforestation? (should be slight cooling!)

So If It's Not Nature, Is It Deforestation?

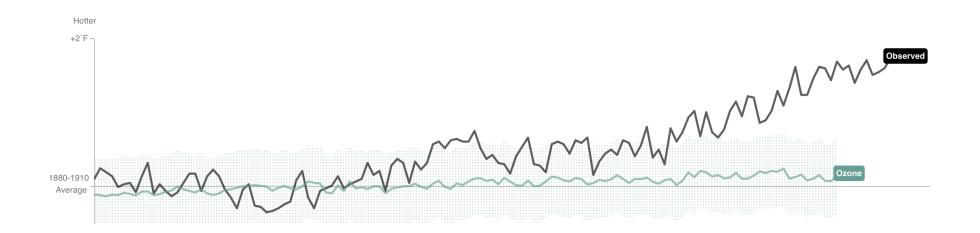
Humans have cut, plowed, and paved more than half the Earth's land surface. Dark forests are yielding to lighter patches, which reflect more sunlight—and have a slight cooling effect.



Ozone doesn't work either...

Or Ozone Pollution?

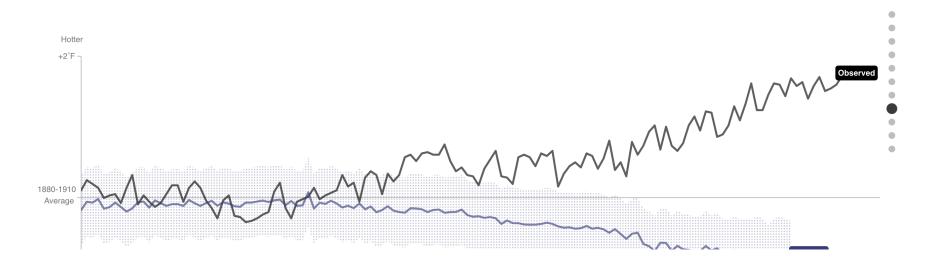
Natural ozone high in the atmosphere blocks harmful sunlight and cools things slightly. Closer to Earth, ozone is created by pollution and traps heat, making the climate a little bit hotter. What's the overall effect? Not much.



Aerosols may actually be 'hiding' the warming

Or Aerosol Pollution?

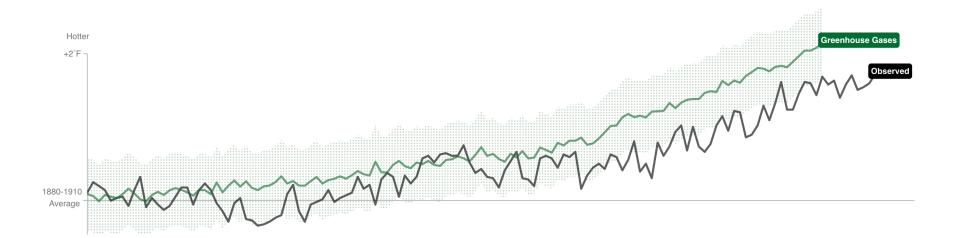
Some pollutants cool the atmosphere, like sulfate aerosols from coal-burning. These aerosols offset some of the warming. (Unfortunately, they also cause acid rain.)



Human-produced greenhouse gases (primarily CO₂)

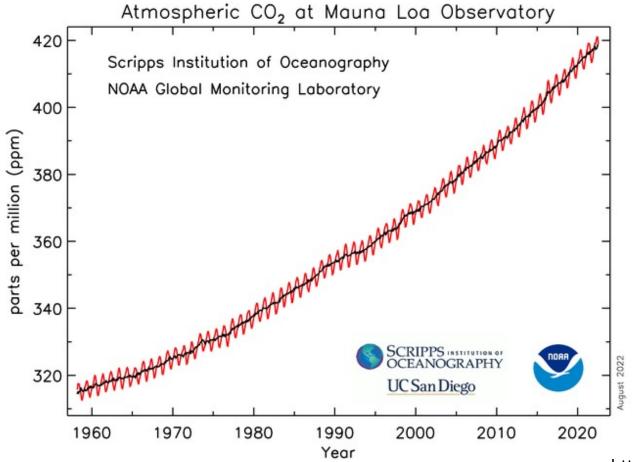
No, It Really Is Greenhouse Gases.

Atmospheric CO_2 levels are 40 percent higher than they were in 1750. The green line shows the influence of greenhouse gas emissions. It's no contest.



The **Greenhouse** Effect E Some of the infrared Some solar radiation is radiation passes through reflected by the atmosphere the atmosphere and is and earth's surface lost in space Outgoing solar radiation: 103 Watt per m² G AS Some of the infrared radiation is absorped and re-emitted by the Solar radiation passes through greenhouse gas molecules. The the clear atmosphere. direct effect is the warming of the Incoming solar radiation: earth's surface and the troposphere. 343 Watt per m2 Qurface gains more heat and infrared radiation is emitted again Solar energy is absorbed by the earth's surface and warms it and is converted into heat causing the emission of longwave (infrared) 168 Watt per m² radiation back to the atmosphere

Mauna Loa Curve or "Keeling Curve"



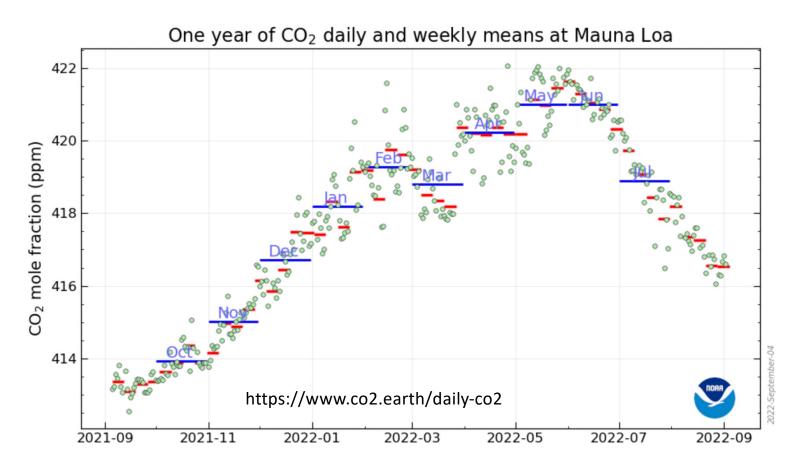
Dr Charles Dave Keeling, measuring atm. CO₂ since 1958 (-2005)



Medal of Science 2001

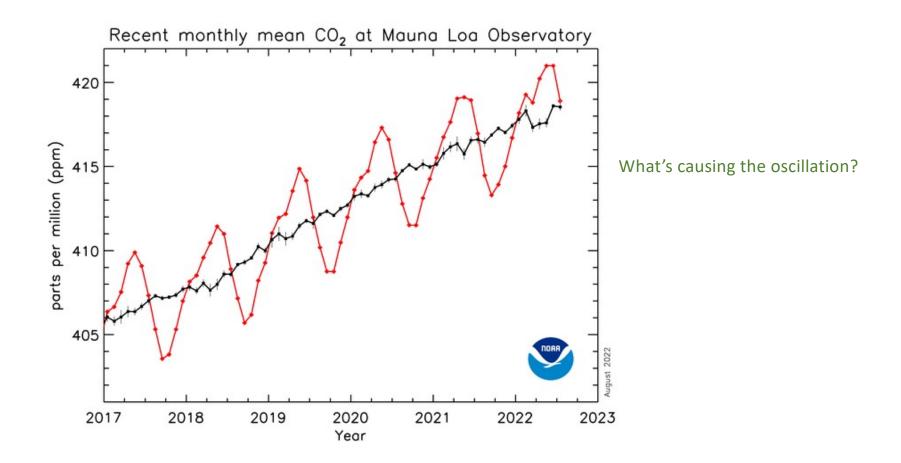
https://keelingcurve.ucsd.edu/

Mauna Loa Curve or "Keeling Curve"



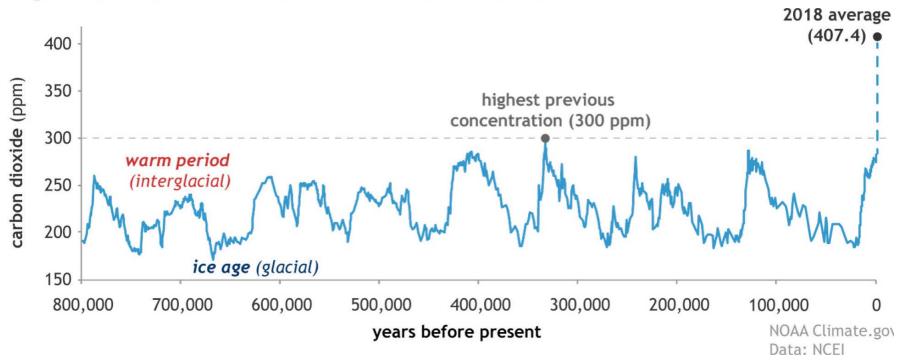
Preliminary weekly (red line), monthly (blue line) and daily (green points) averages at Mauna Loa for the last year.

Mauna Loa Curve or "Keeling Curve"



[CO₂] through time

CO₂ during ice ages and warm periods for the past 800,000 years



Latest CO2 reading

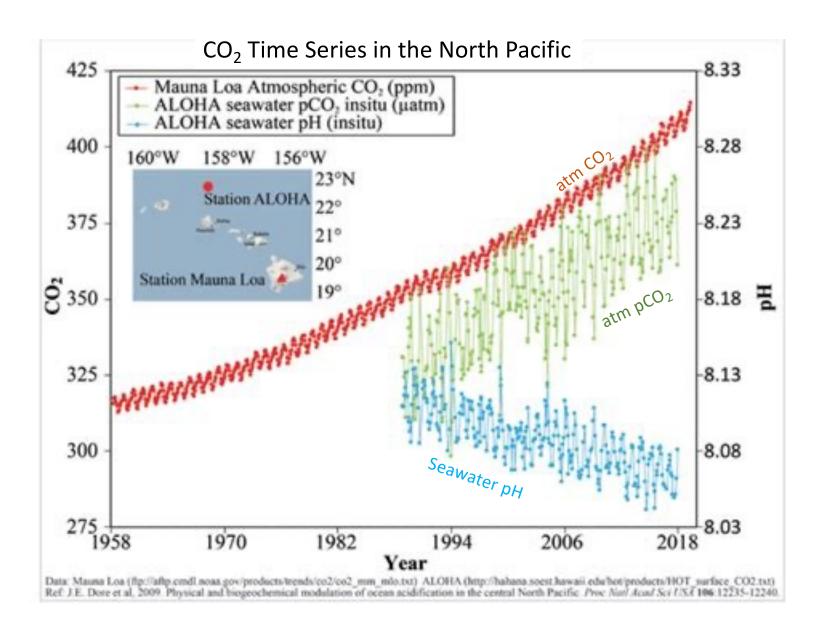
Ice-core data before 1958. Mauna Loa data after 1958

May 11, 2019

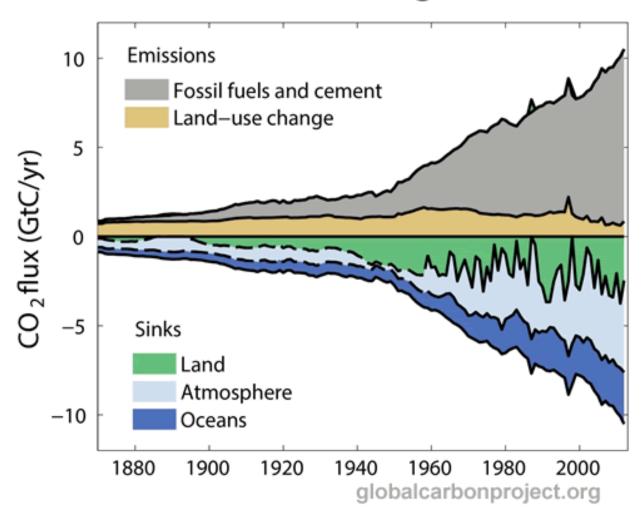
Concentration (ppm)

ე^{∾ 250}

415.26 ppm



The Global Carbon Budget 1870-2012



To date the ocean has taken up 25-30% of the excess, how will this change with more CO_2 ?

"simple chemistry: carbon dioxide dissolves in water. It reacts with seawater, creating carbonic acid. Carbonic acid releases hydrogen ions, which combine with carbonate in seawater to form bicarbonate, a form of carbon that doesn't escape the ocean easily."







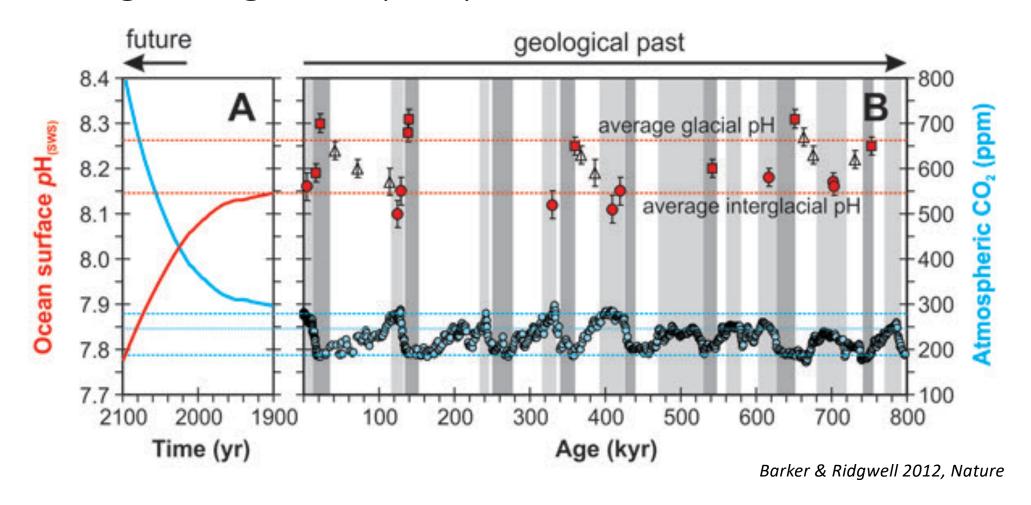




"As temperatures rise, carbon dioxide leaks out of the ocean like a glass of root beer going flat on a warm day"

Putting change into perspective

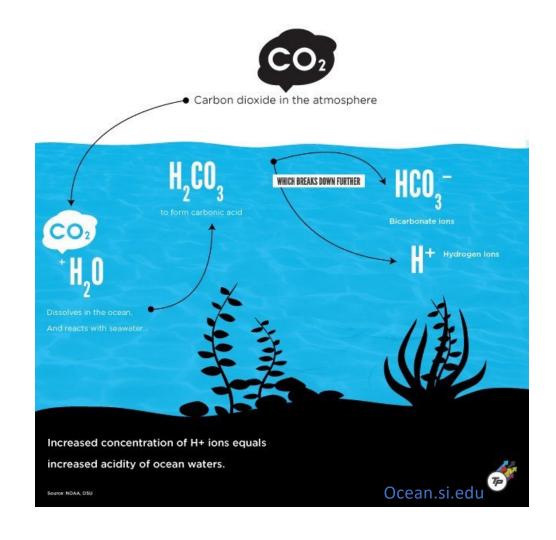
In humans, normal blood pH is 7.35 to 7.45 a drop of 0.2 can lead to coma, even death



In the past 200 years...
ocean water has become
30% more acidic
... faster than any known
change in ocean chemistry in
the last 50 million years

while the chemistry is well known... the biological impacts are <u>not</u>

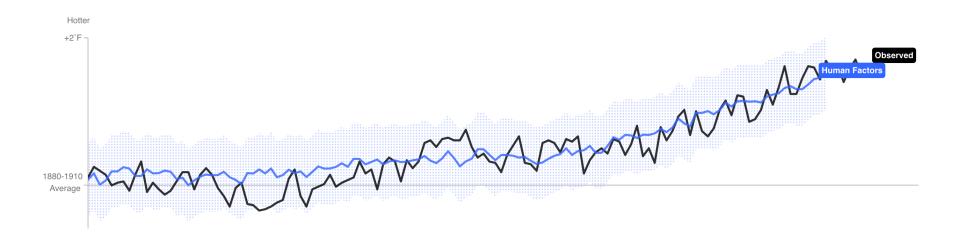
OCEAN ACIDIFICATION EXPLAINED



GHG + Deforestation + Aerosols + Ozone

See for Yourself

Greenhouse gases warm the atmosphere. Aerosols cool it a little bit. Ozone and land-use changes add and subtract a little. Together they match the observed temperature, particularly since 1950.



What type of changes?

- Rising Sea Levels
- Rising Global Temperatures
- Warming Oceans
- Changing Precipitation
- Shrinking Ice Sheets
- Increasing Extreme Events
- Ocean Acidification
- Ocean Deoxygenation



