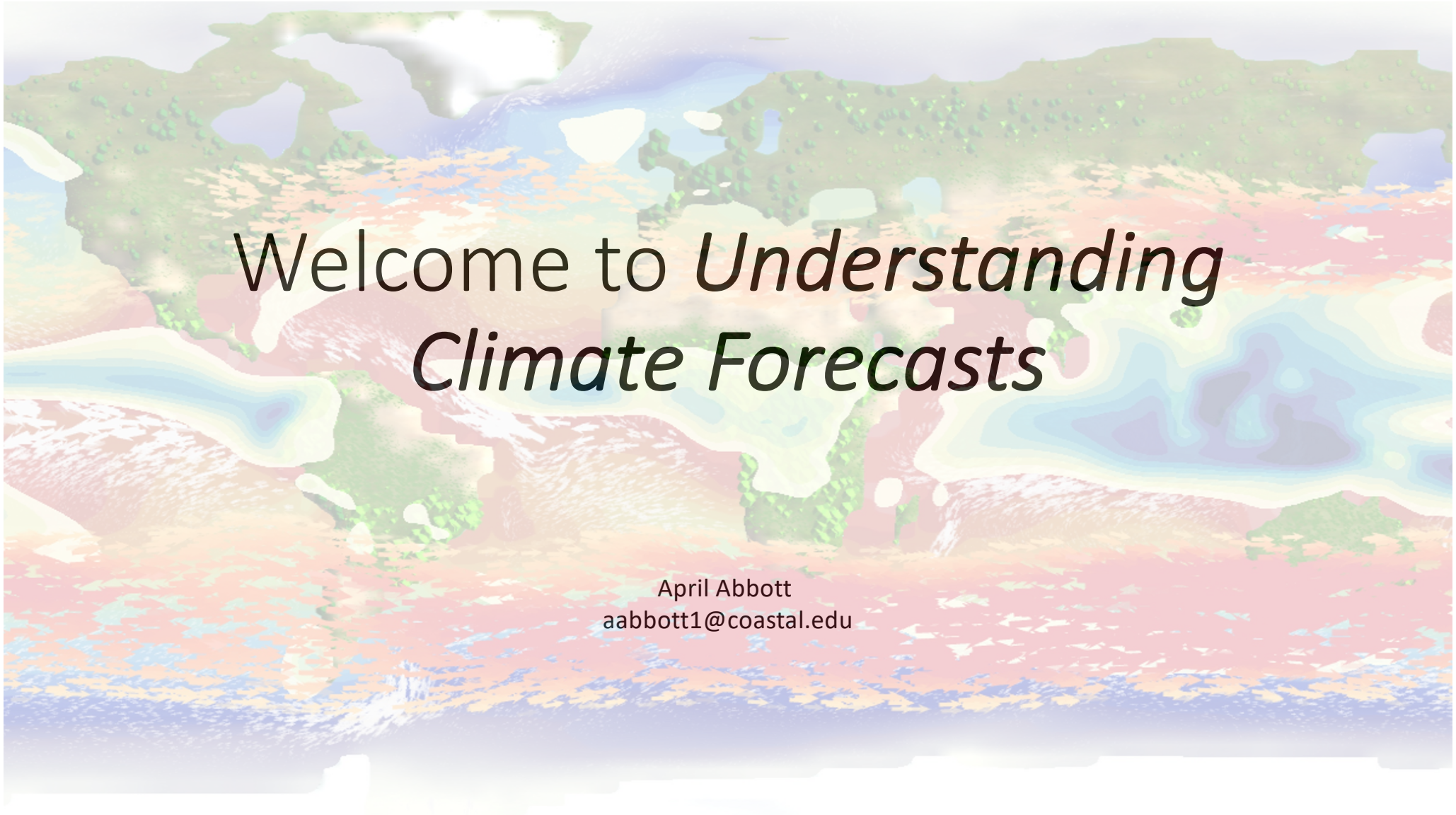

Welcome to *Understanding Climate Forecasts*

April Abbott
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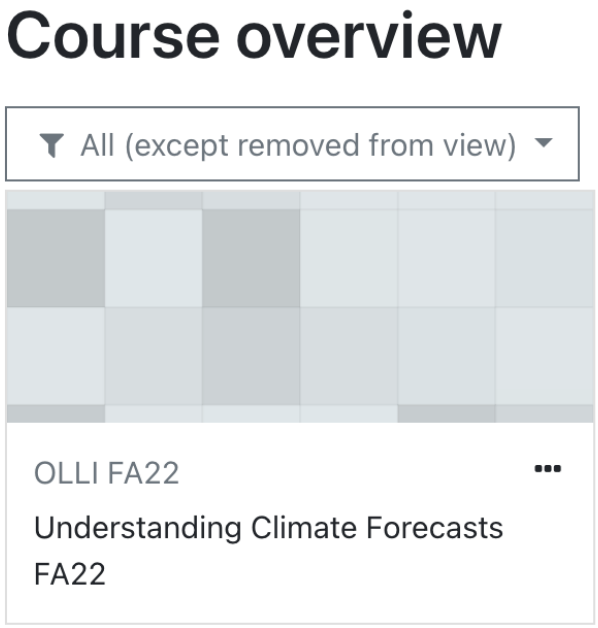
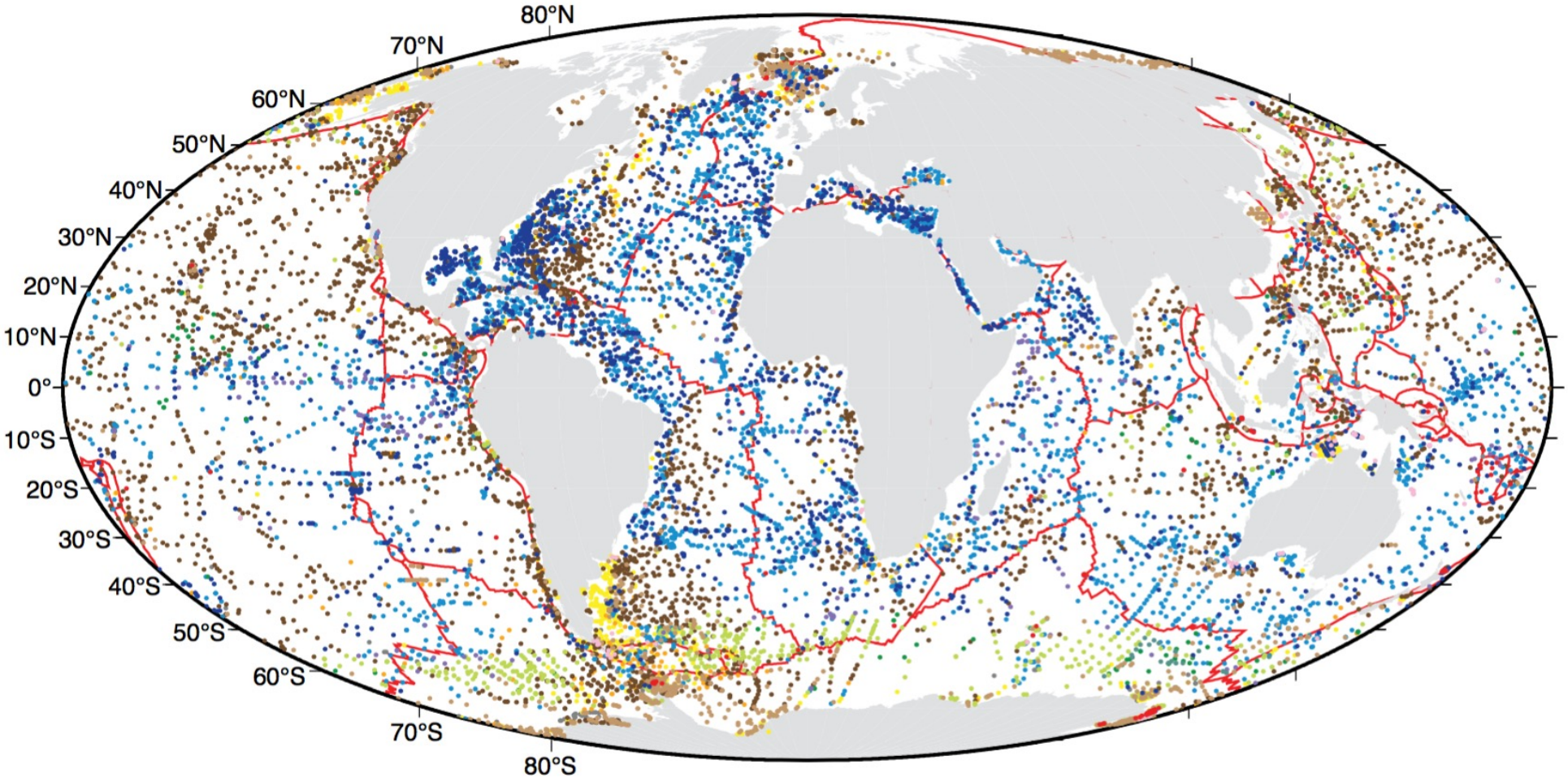
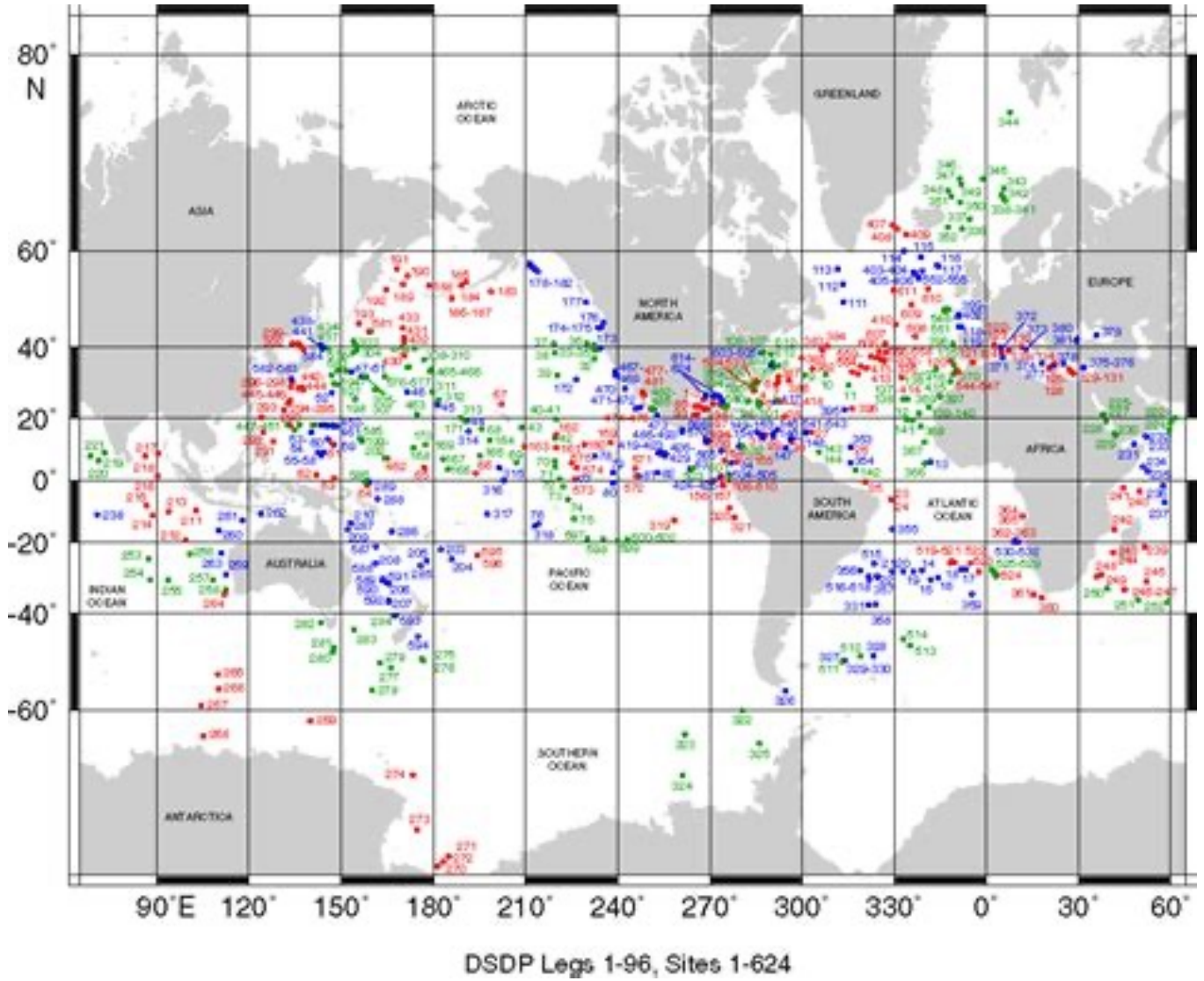
ollimoodle.coastal.edu



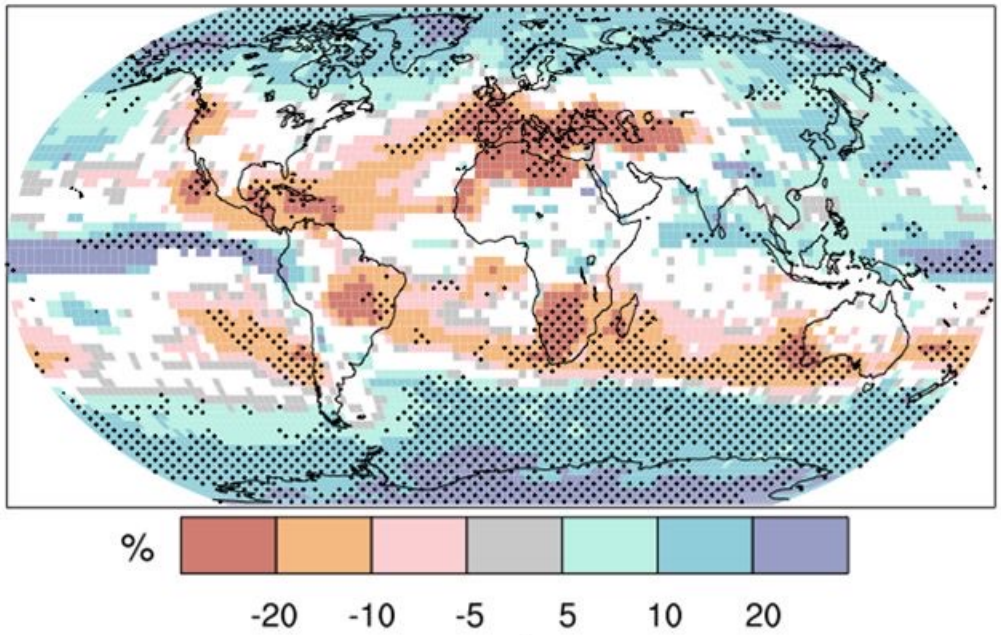
Most of our records come from the ocean





DSDP Legs 1-96, Sites 1-624

How well do climate models agree?



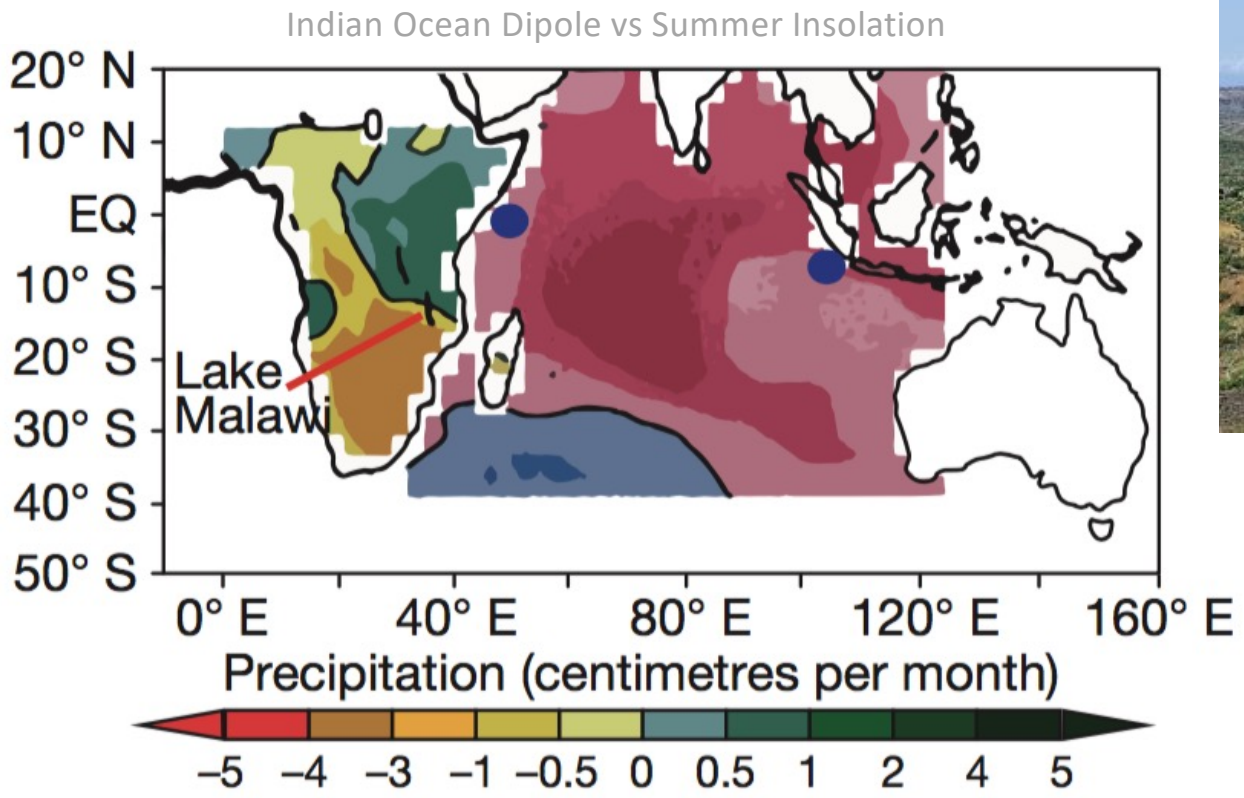
Change in precipitation (mm day^{-1}): average of all IPCC models

White: less than 66% agreement. Colours: 66% or more agreement.
Black dots: 90% or more agreement

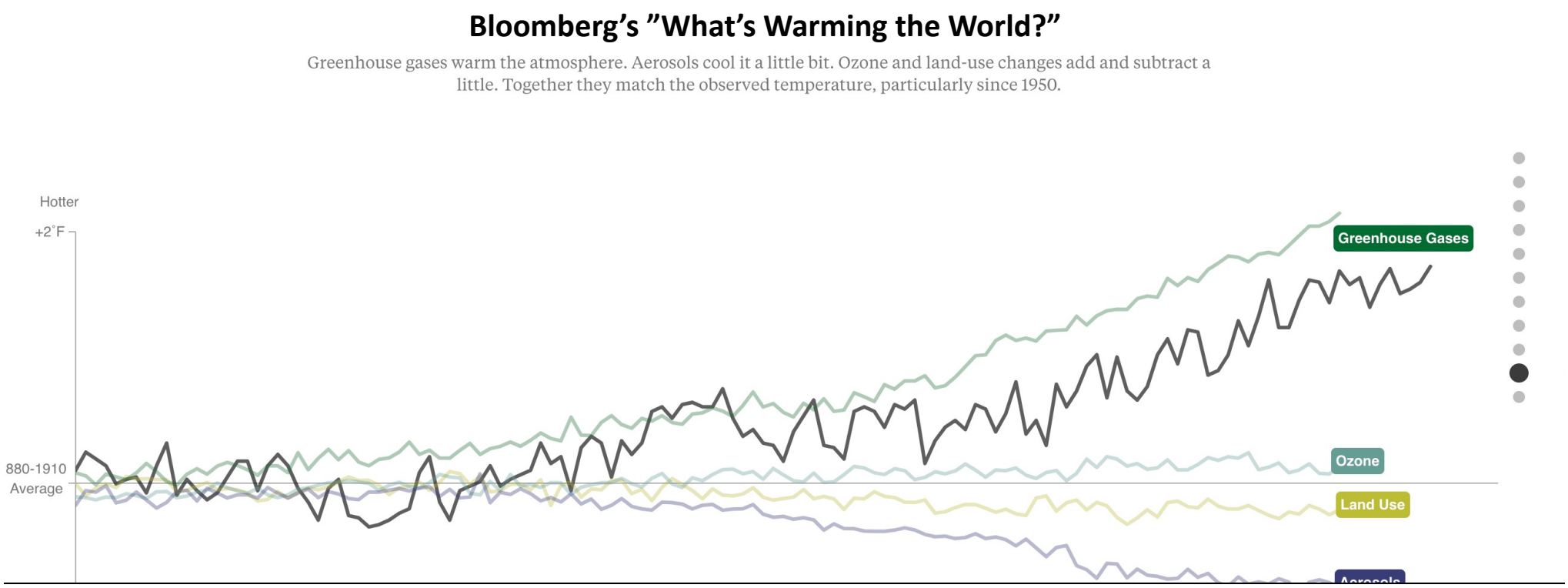
2090s relative to present-day, A1B scenario: June-July-August

Source: Intergovernmental Panel on Climate Change (IPCC)

and predictive power for land matters



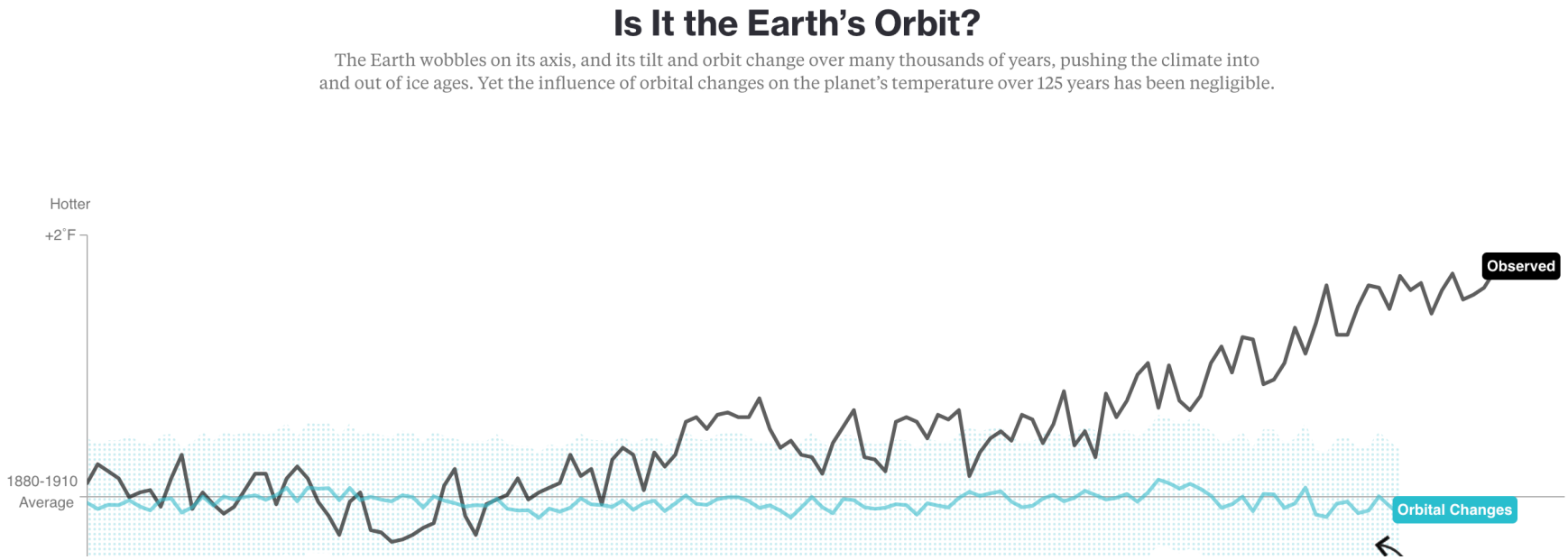
Climate Change: its happening, its us.



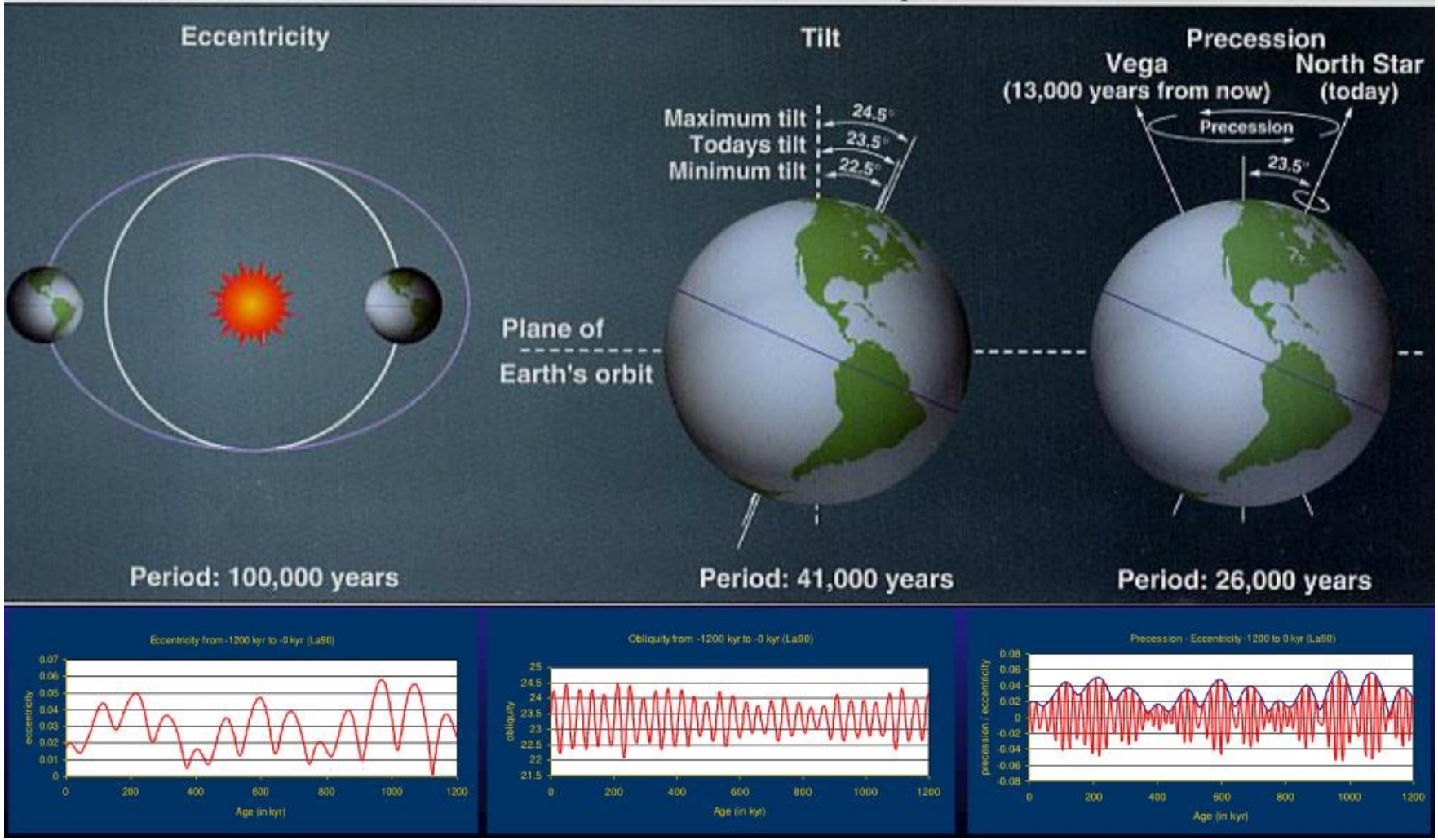
https://www.bloomberg.com/graphics/2015-whats-warming-the-world/?leadSource=uverify%20wall

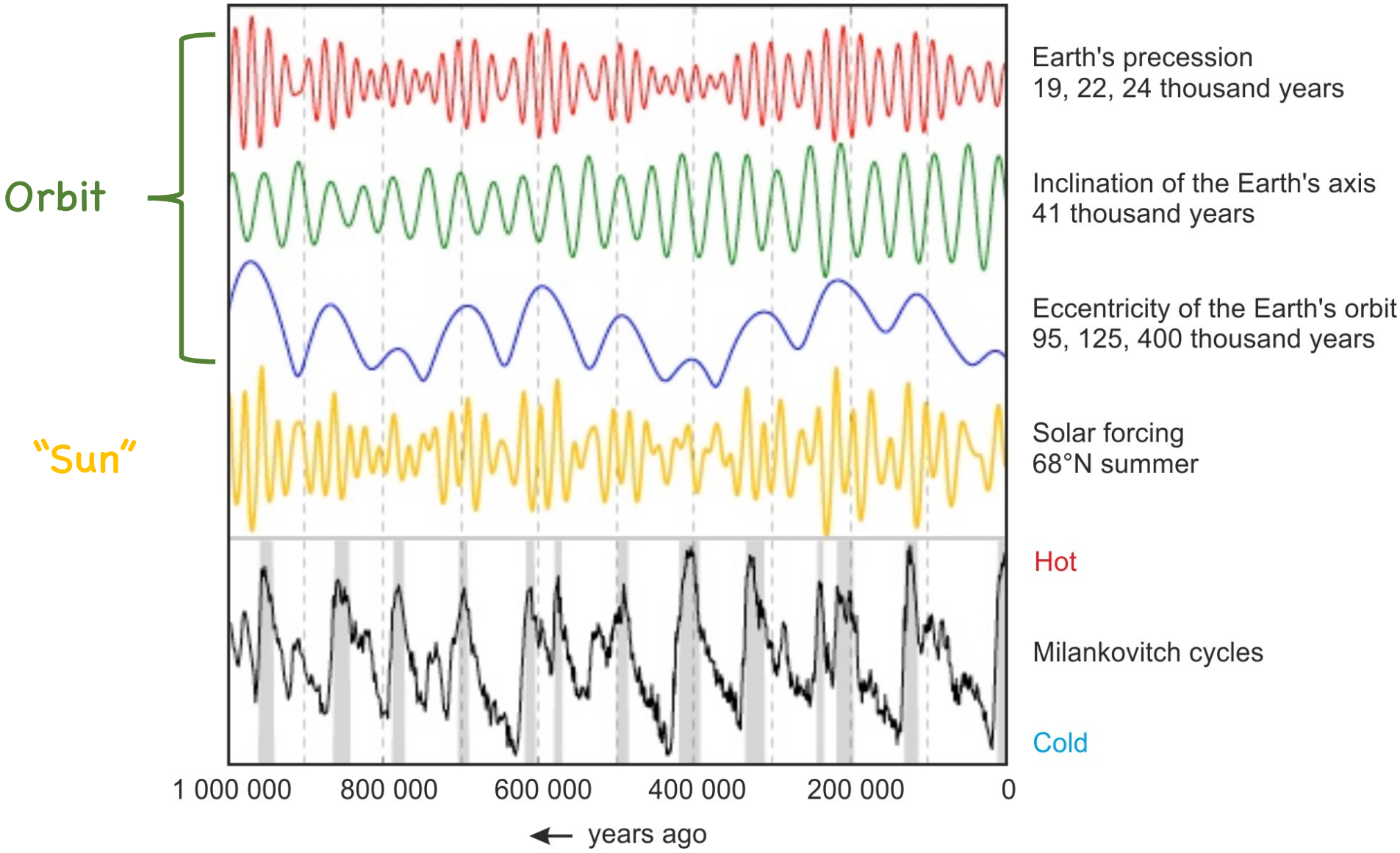
'But Earth's climate has always changed…'

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

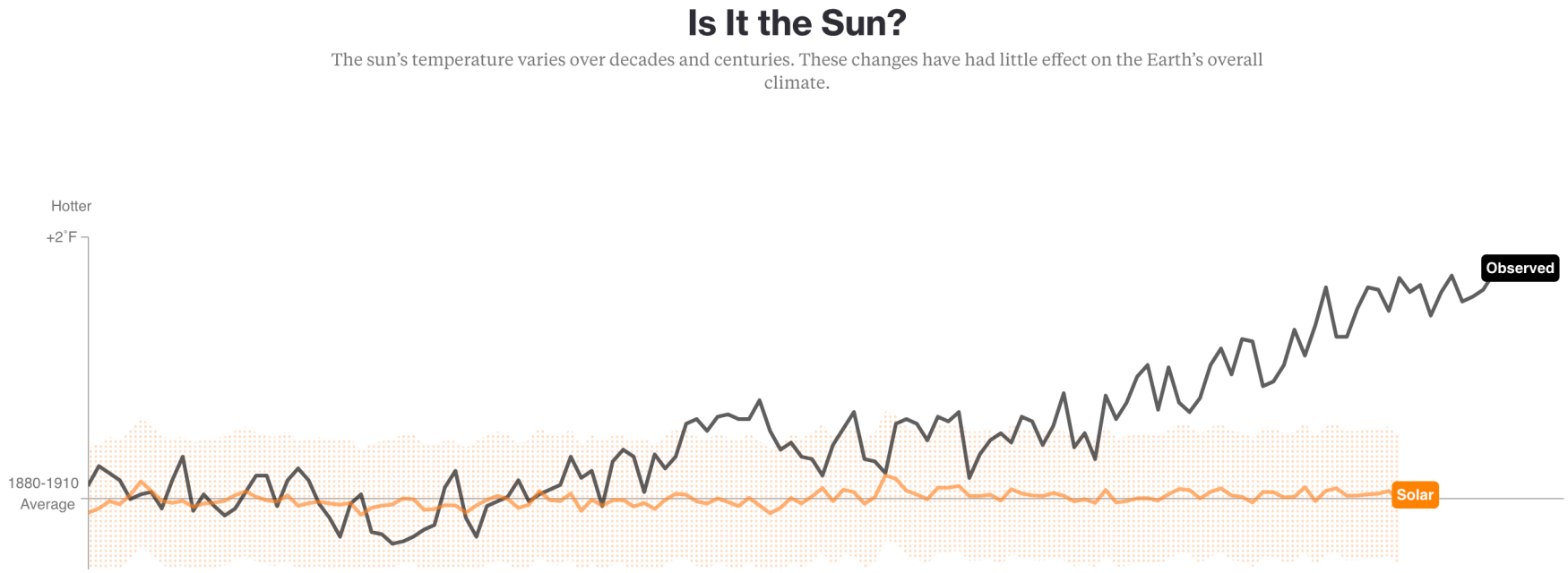


Milankovitch cycles

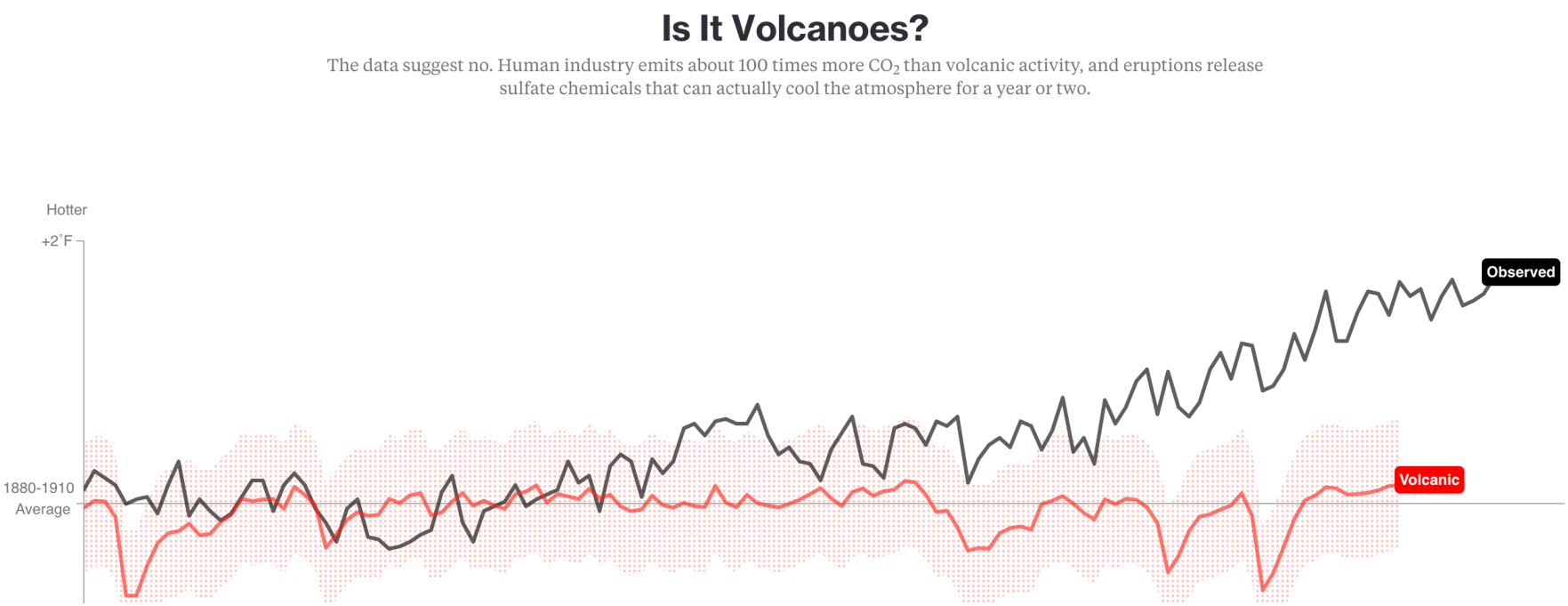



Orbit
"Sun"
Earth's precession
19, 22, 24 thousand years
Inclination of the Earth's axis
41 thousand years
Eccentricity of the Earth's orbit
95, 125, 400 thousand years
Solar forcing
68°N summer
Hot
Milankovitch cycles
Cold
1 000 000
800 000
600 000
400 000
200 000
0
years ago

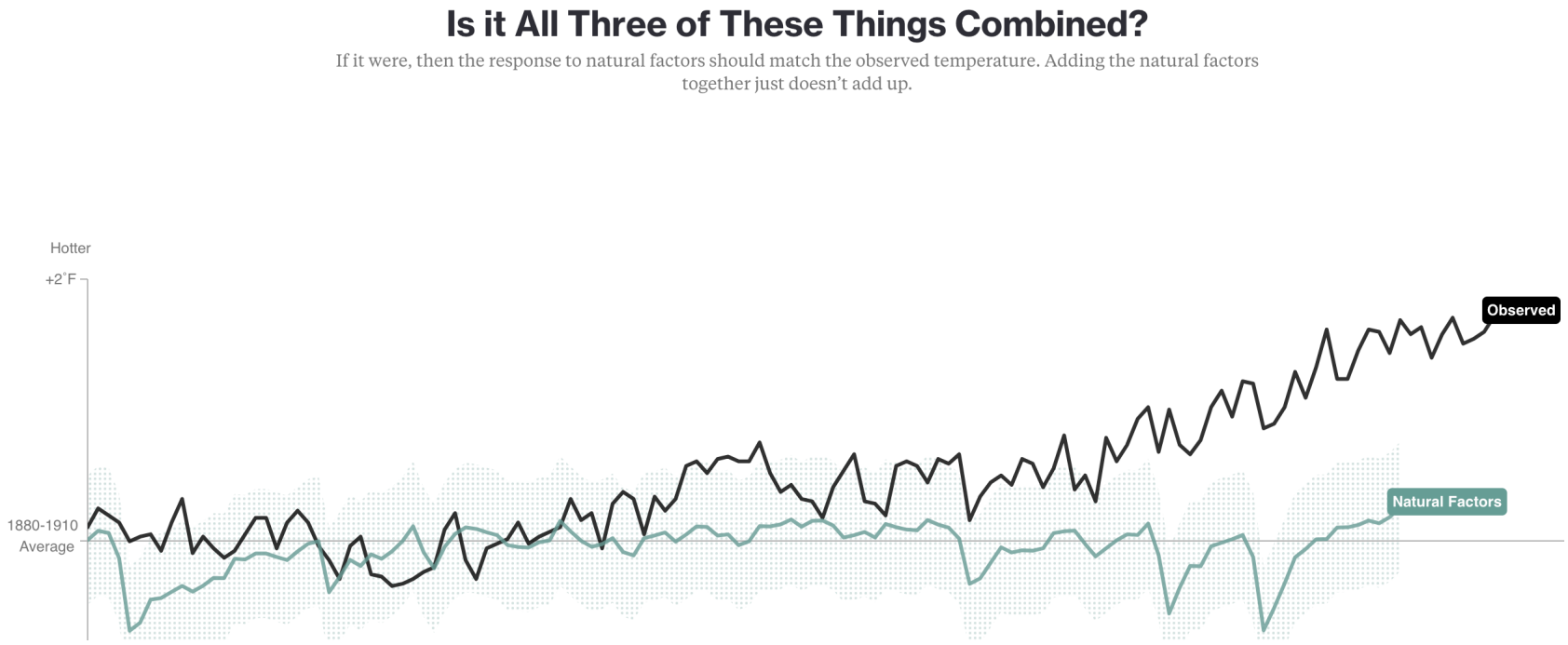
No significant changes in solar radiation…



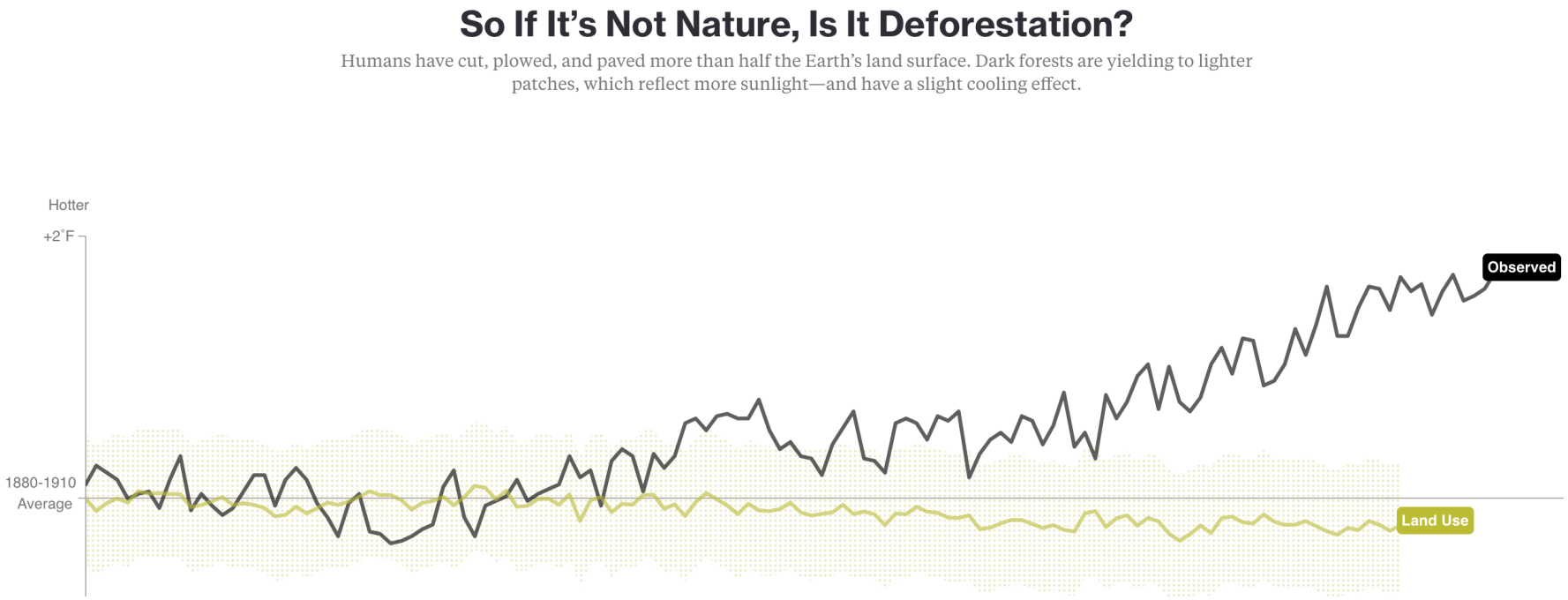
Not volcanoes..



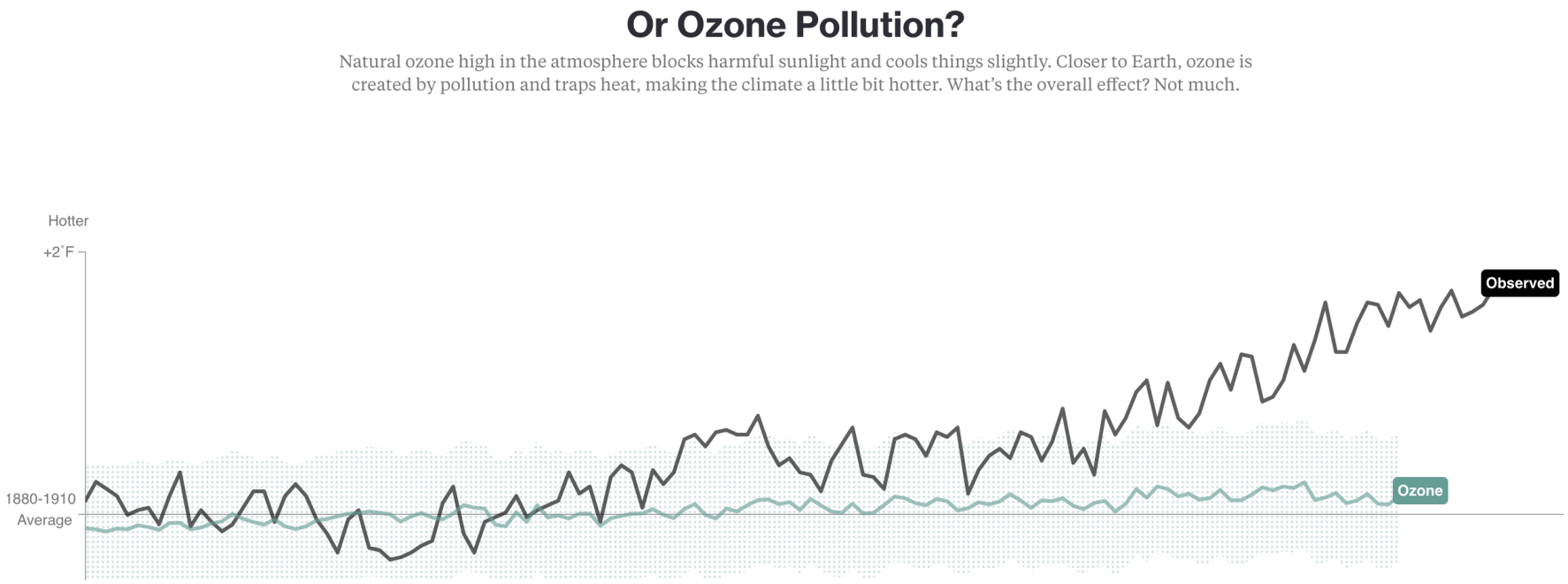
Orbit + Sun Strength + Volcanoes



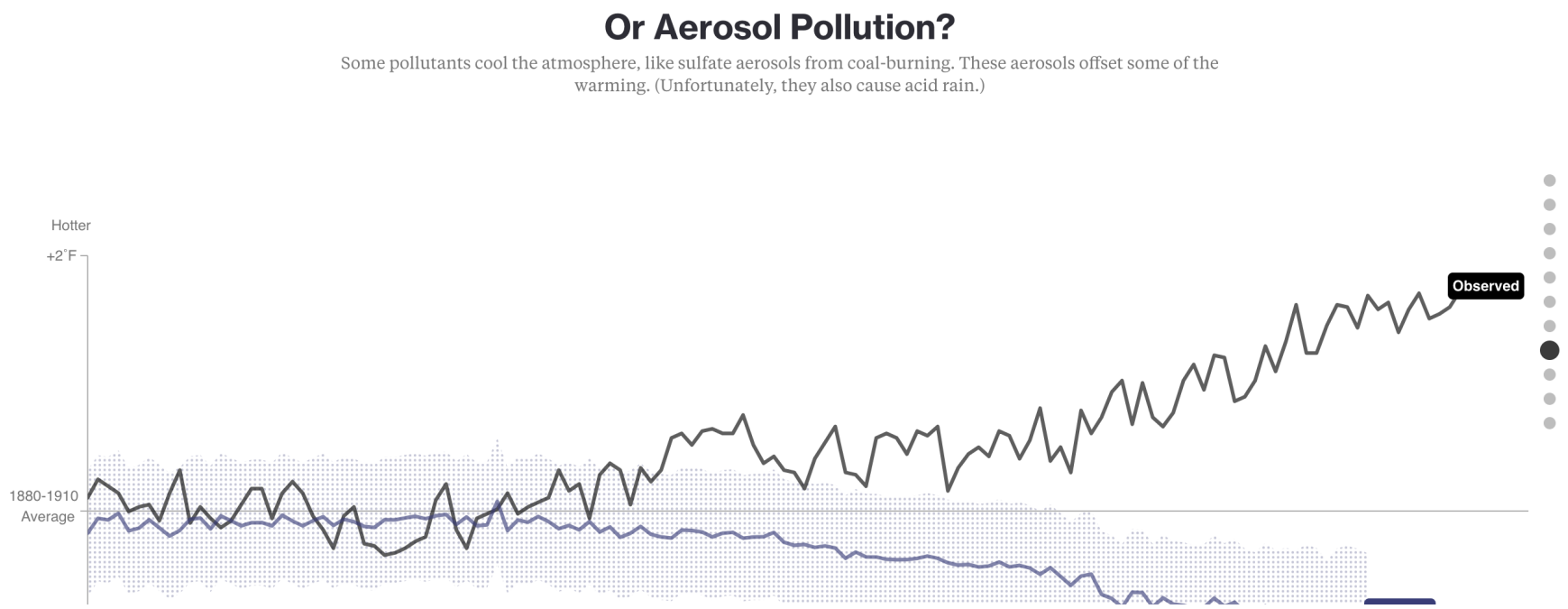
Deforestation? (should be slight cooling!)



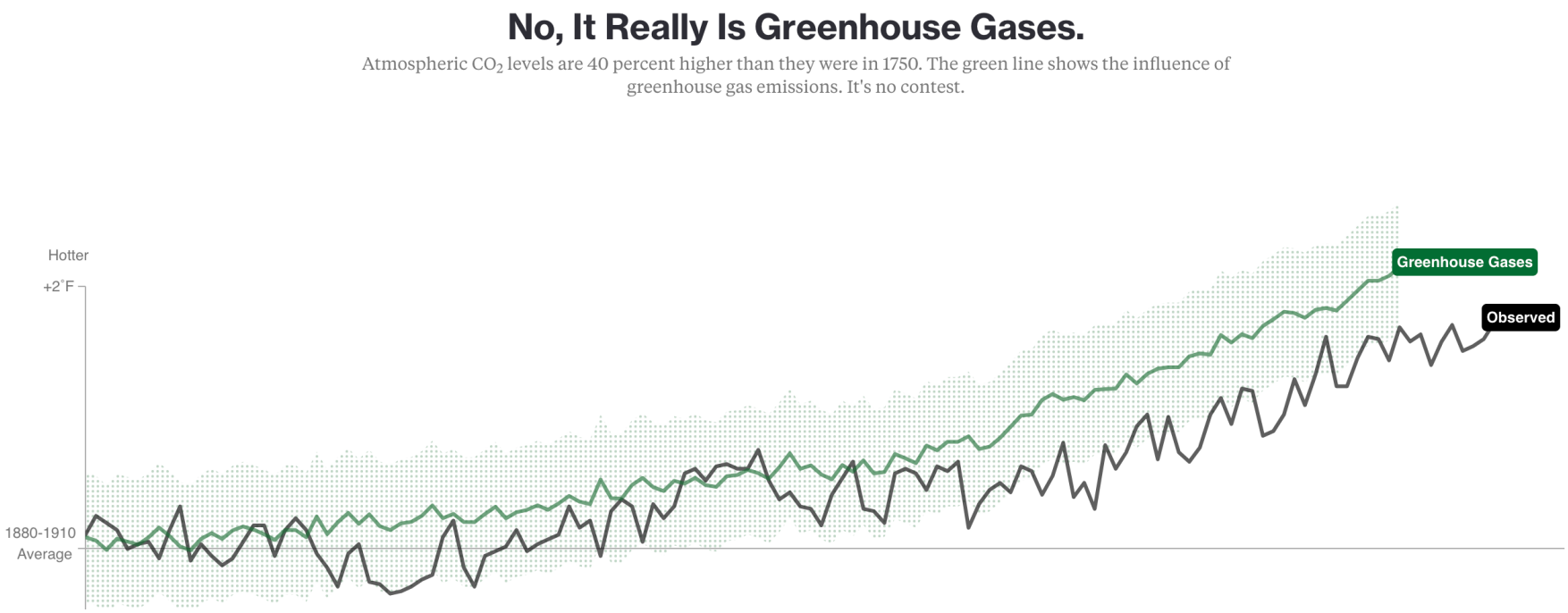
Ozone doesn’t work either…

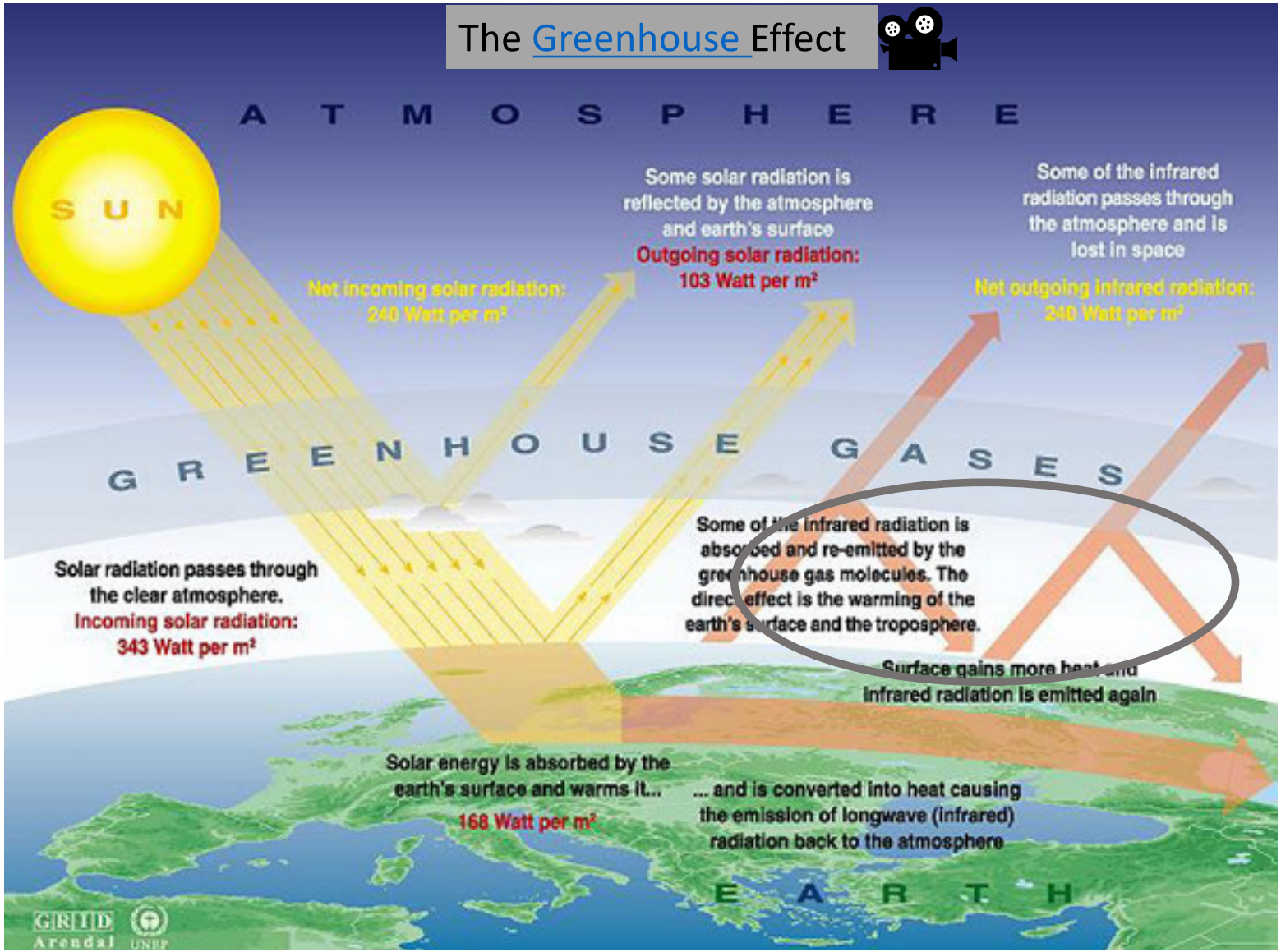


Aerosols may actually be ‘hiding’ the warming

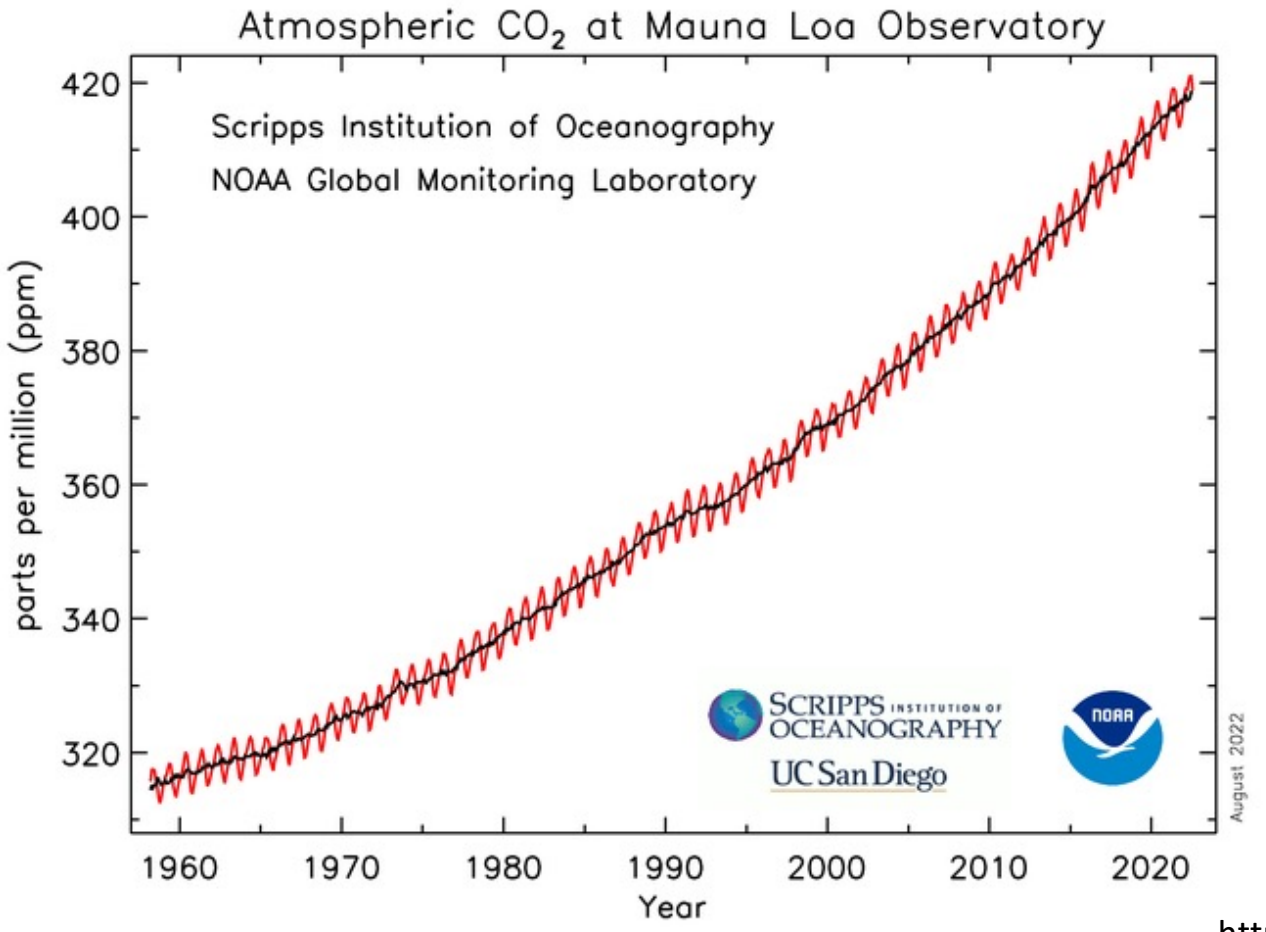


Human-produced greenhouse gases (primarily CO_2)




The Greenhouse Effect
ATMOSPHERE
SUN
Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m²
Net incoming solar radiation: 240 Watt per m²
GREENHOUSE GASES
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
Surface gains more heat and infrared radiation is emitted again
Solar energy is absorbed by the earth's surface and warms it...
168 Watt per m²
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
EARTH
GRID Arendal
UNEP

Mauna Loa Curve or “Keeling Curve”

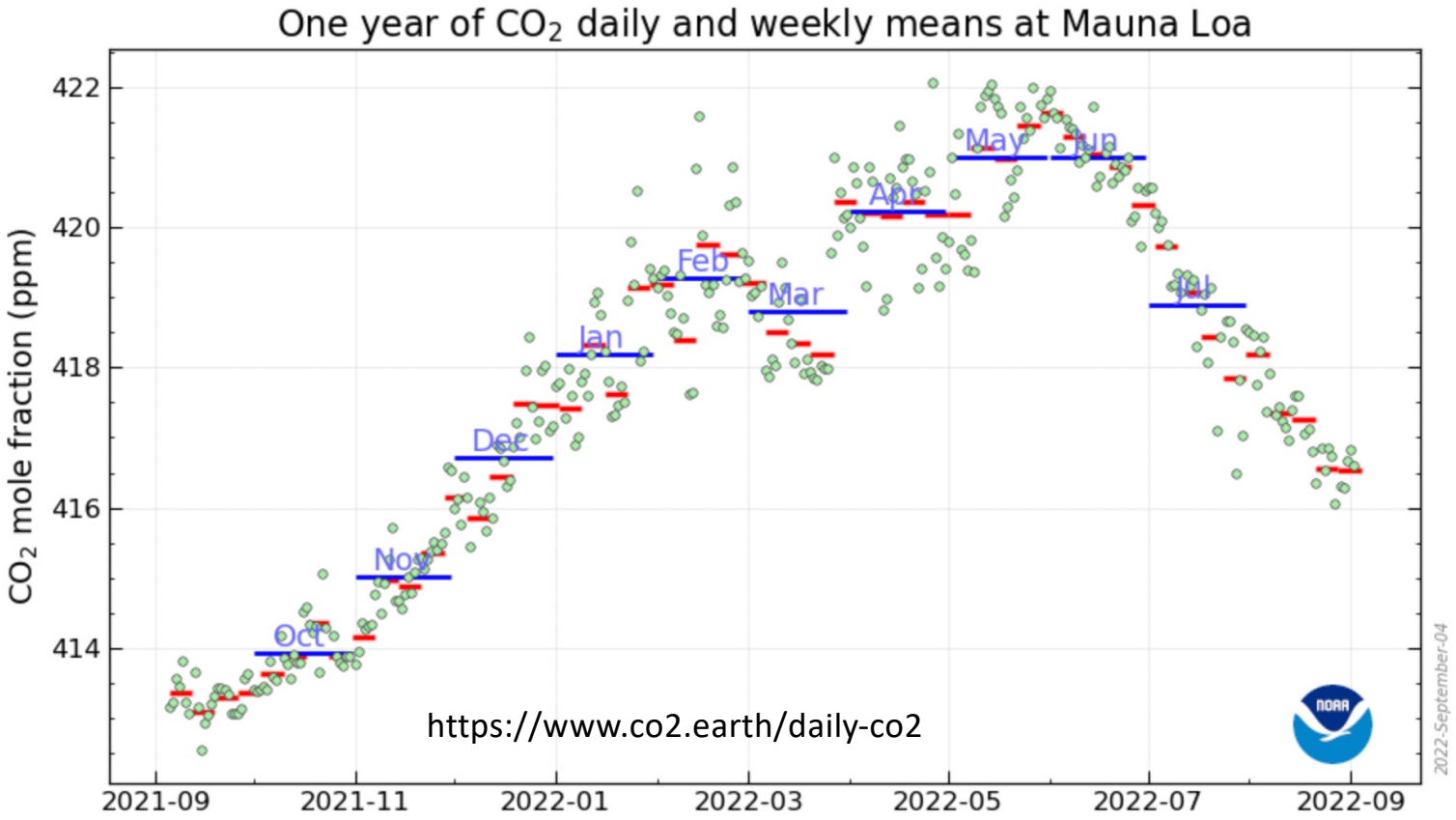


Dr Charles Dave Keeling, measuring atm. CO_2 since 1958 (-2005)

Medal of Science 2001

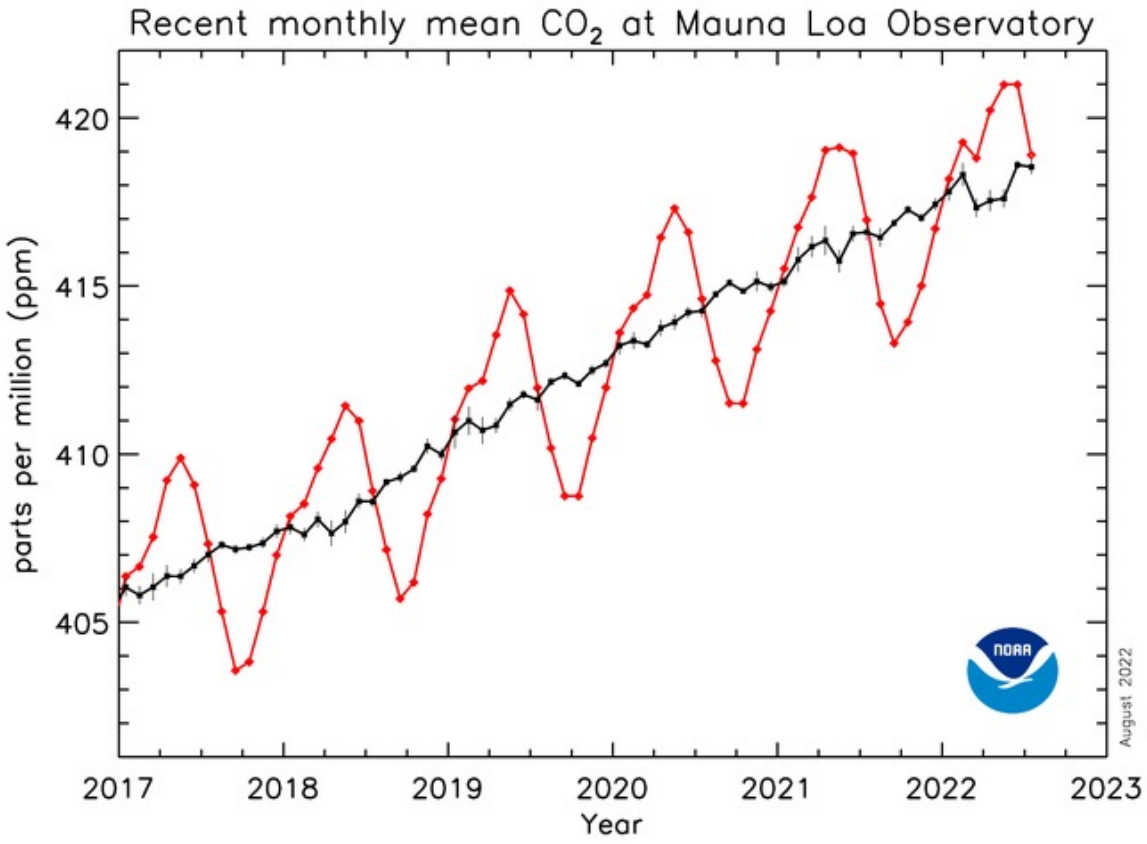
https://keelingcurve.ucsd.edu/

Mauna Loa Curve or “Keeling Curve”



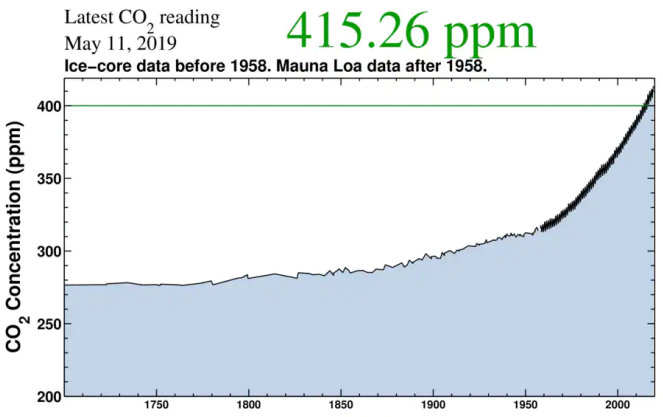
Preliminary weekly (red line), monthly (blue line) and daily (green points) averages at Mauna Loa for the last year.

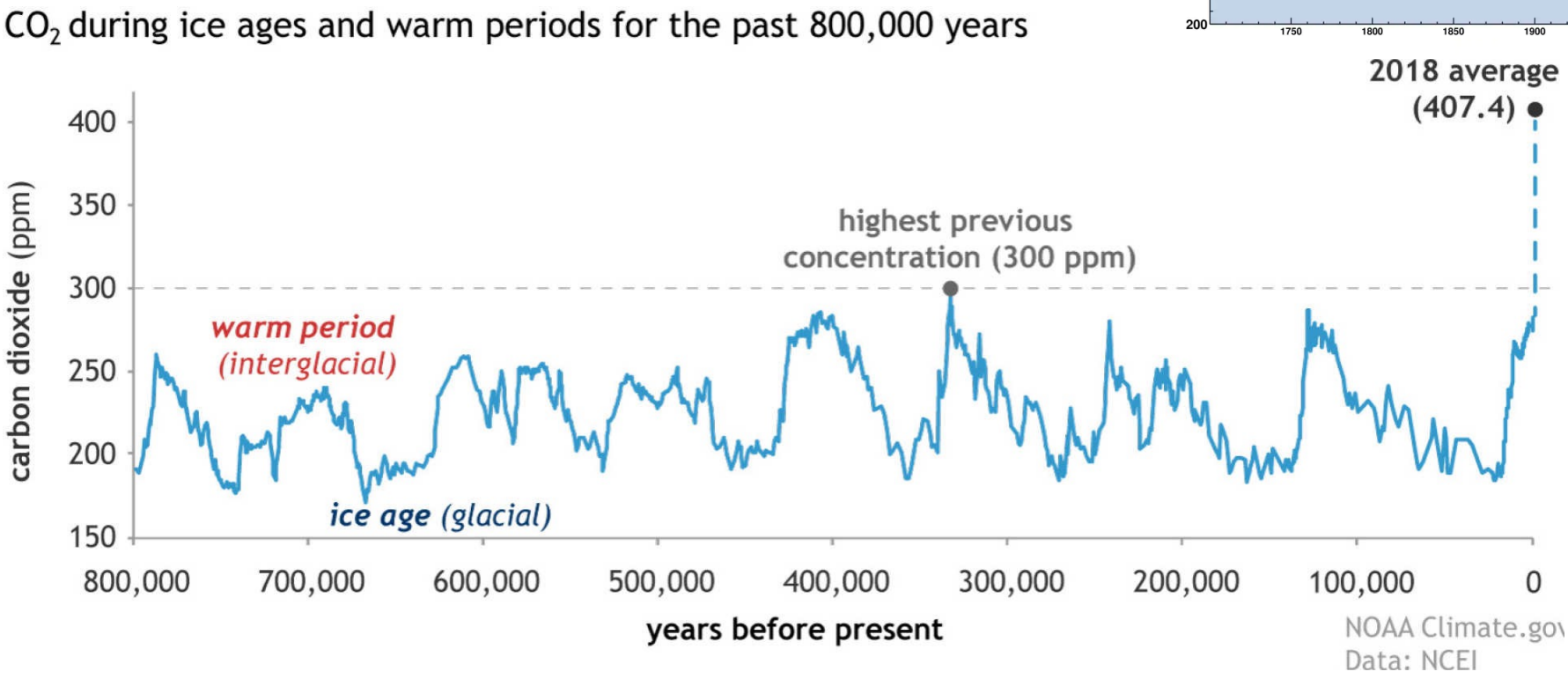
Mauna Loa Curve or “Keeling Curve”



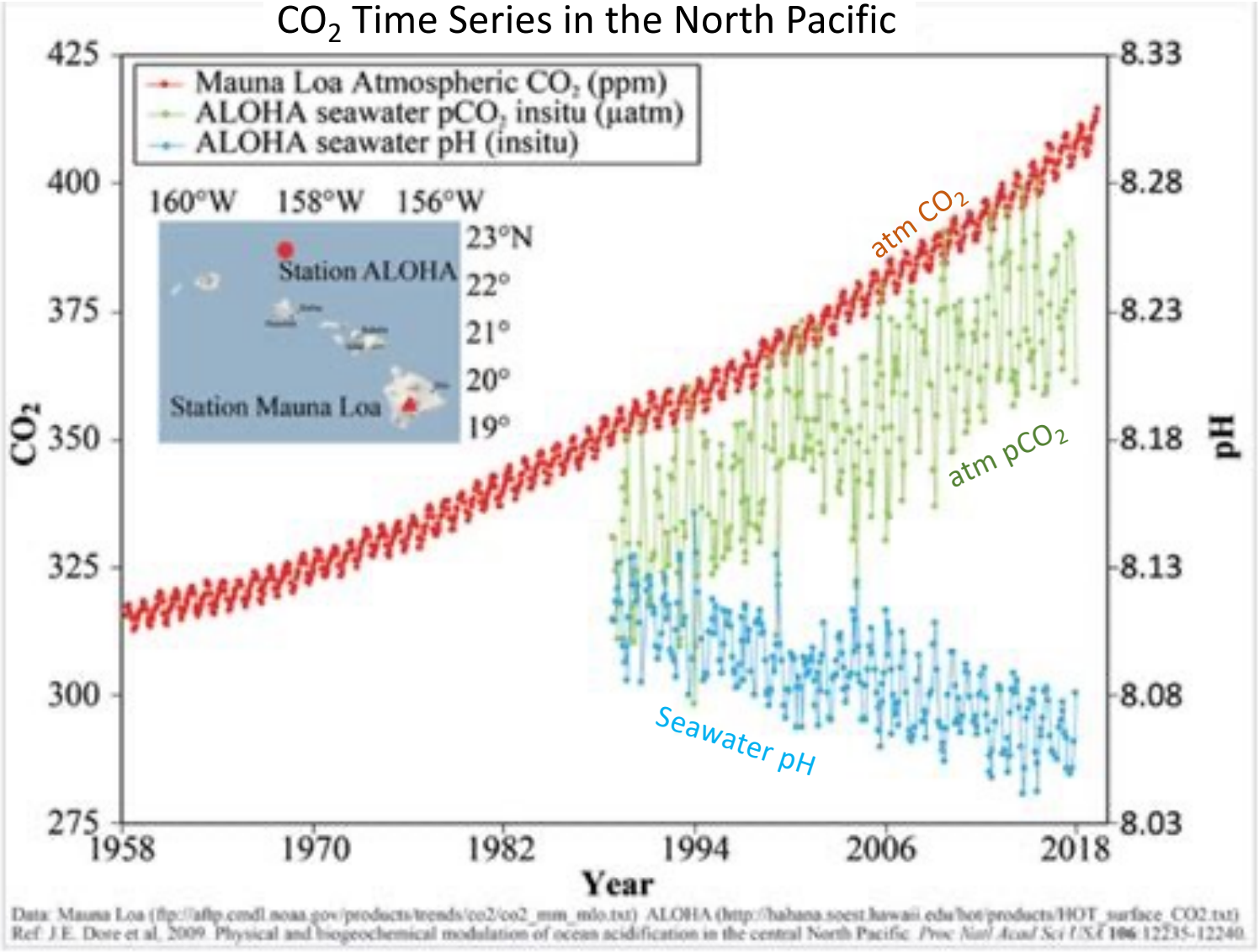
What’s causing the oscillation?

[CO_2] through time



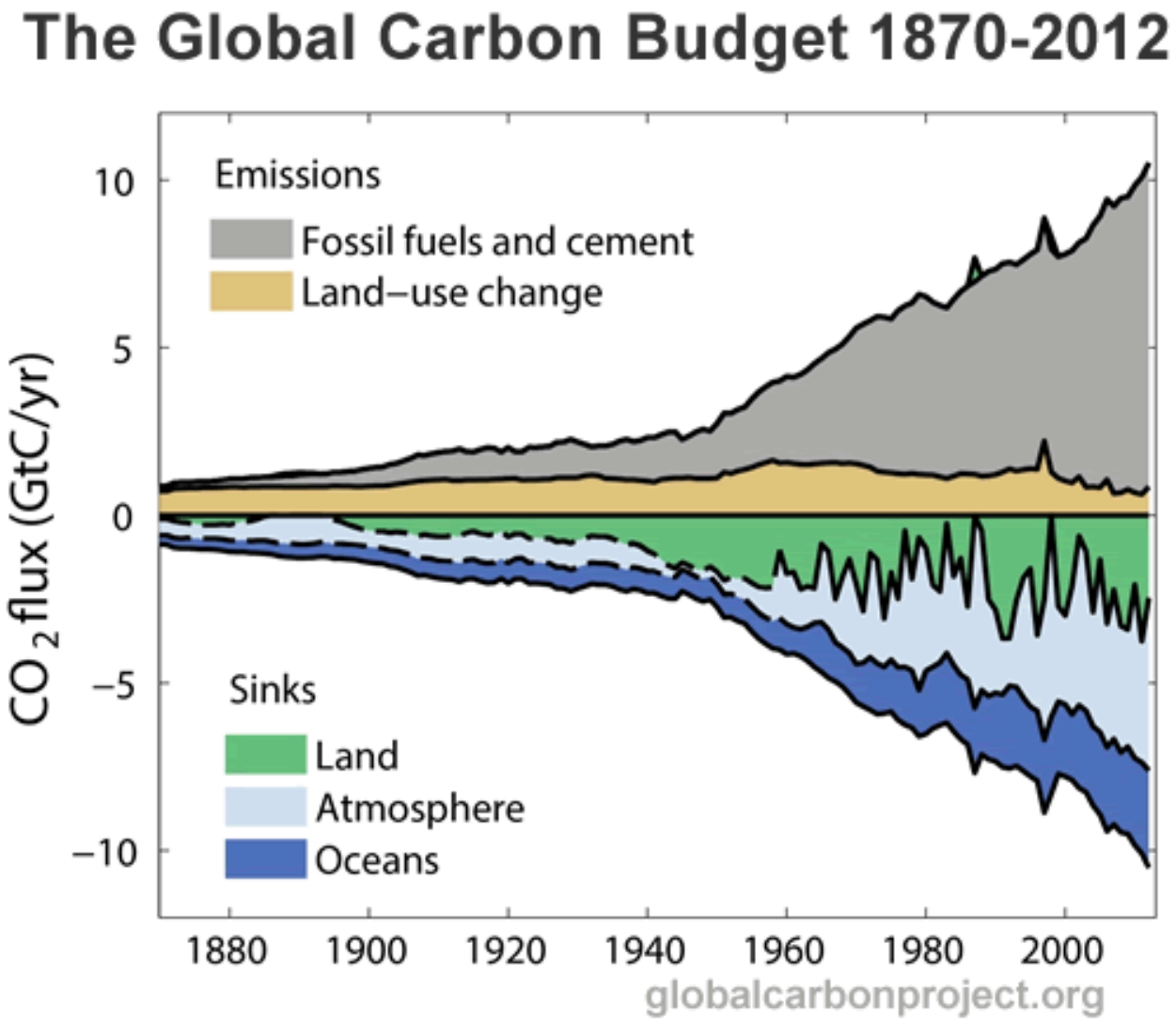


CO_2 Time Series in the North Pacific

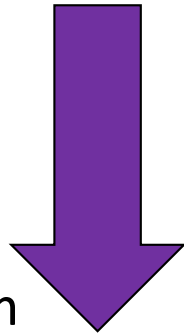


Data: Mauna Loa (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt) ALOHA (http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt)
Ref: J.E. Dore et al. 2009. Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proc Natl Acad Sci USA* **106**:12235-12240.

Where's all the CO_2 going?



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."

Temperature

Solubility

Temperature

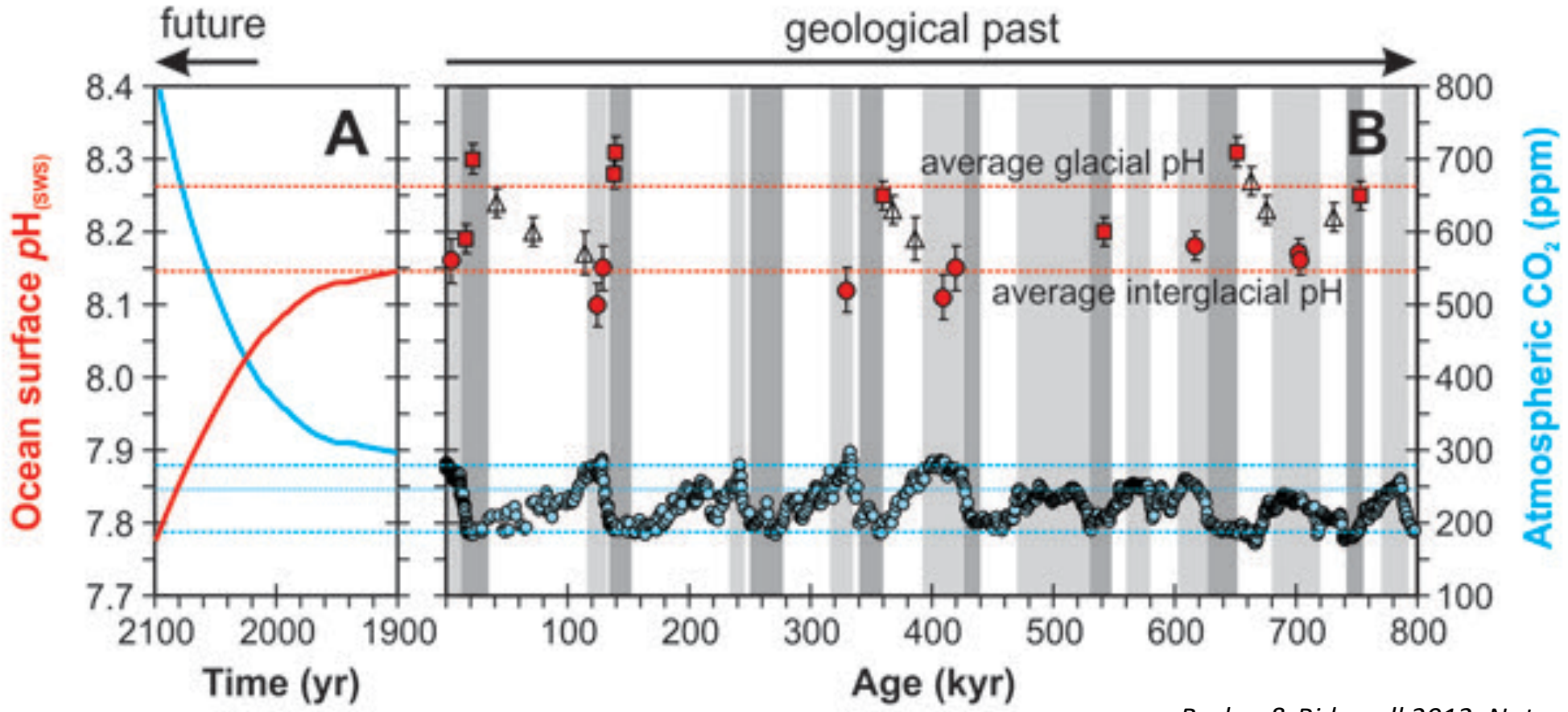
Stratification

Mixing

"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

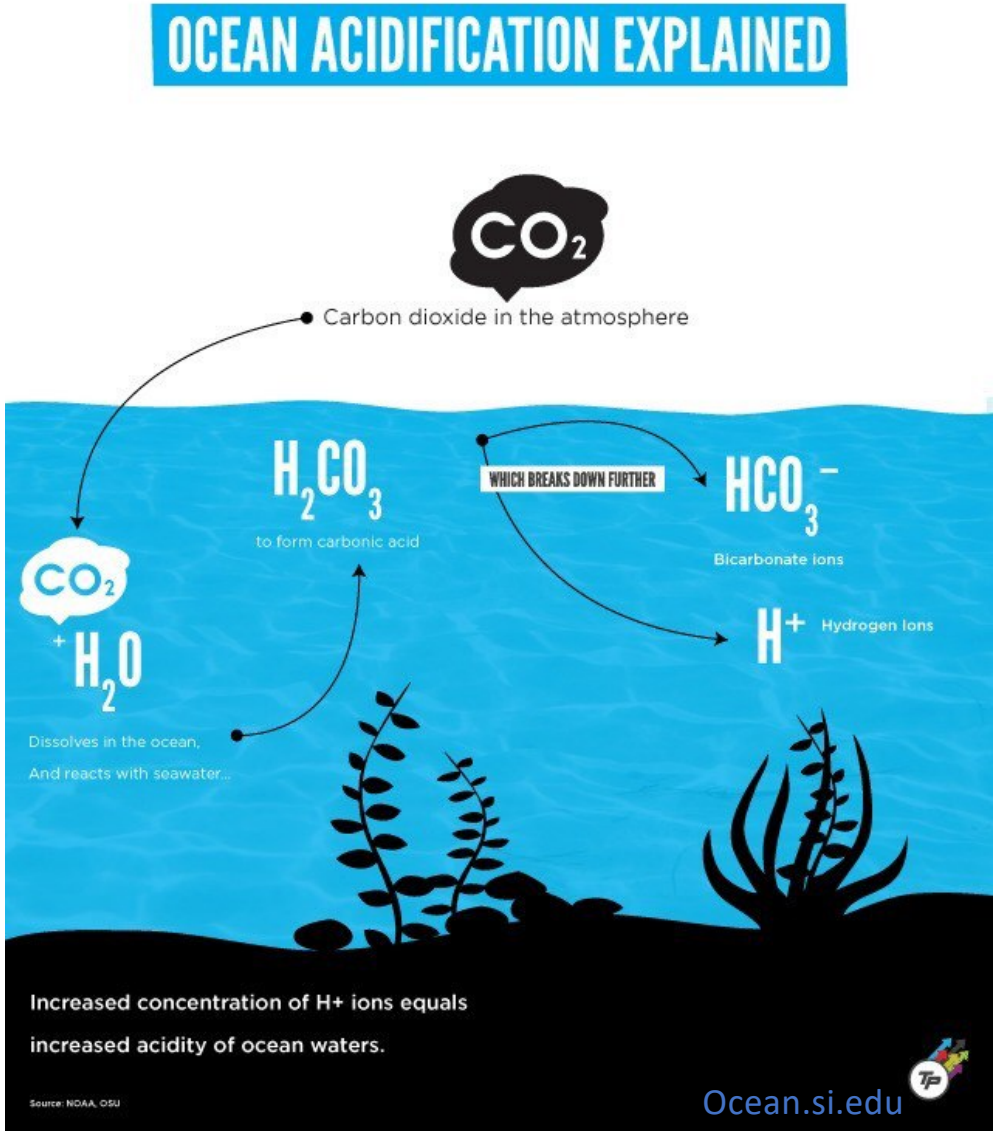
Trivia! In humans, normal blood pH is 7.35 to 7.45
a drop of 0.2 can lead to coma, even death



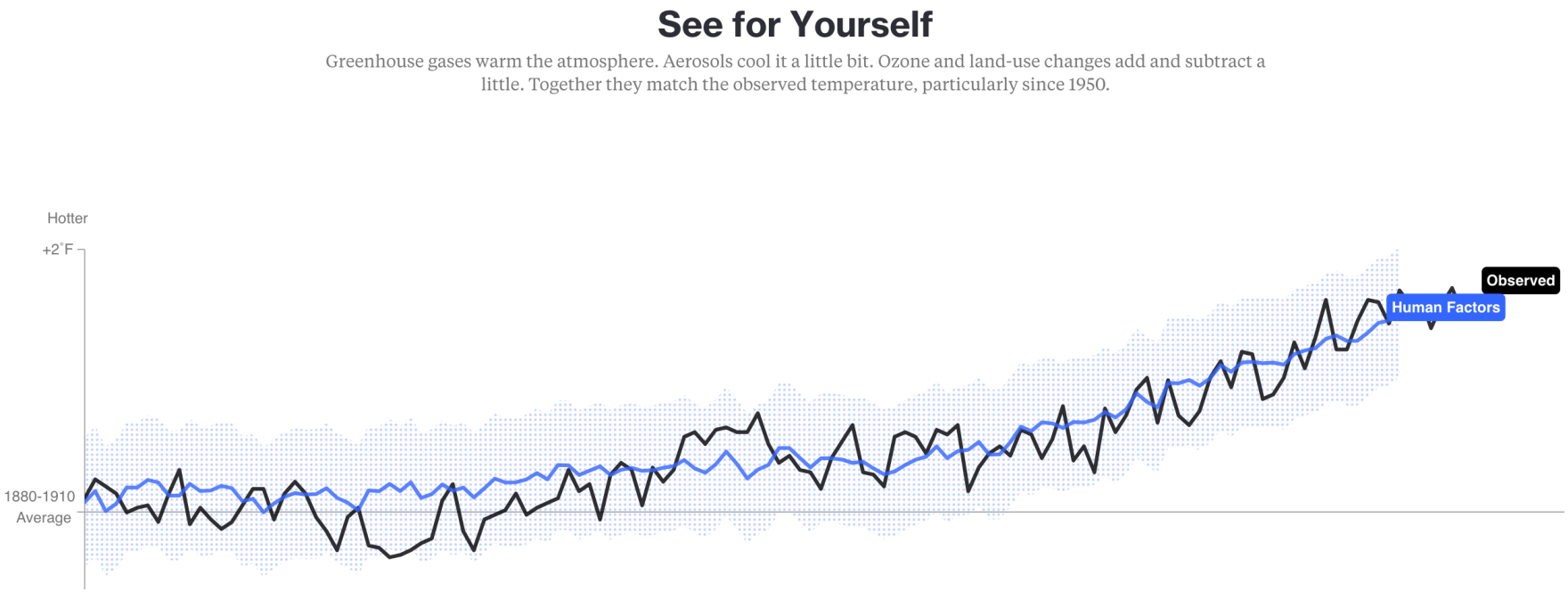
Barker & Ridgwell 2012, Nature

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 not



GHG + Deforestation + Aerosols + Ozone



What type of changes?

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