Weather and Climate

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Week 8 March: 5th , 2019

PART B

- LECTURE 23: PREDICTION AND PREDICABILITY
- LECTURE 24: THE IMPERFECT FORECAST
- CLIMATE CHANGE

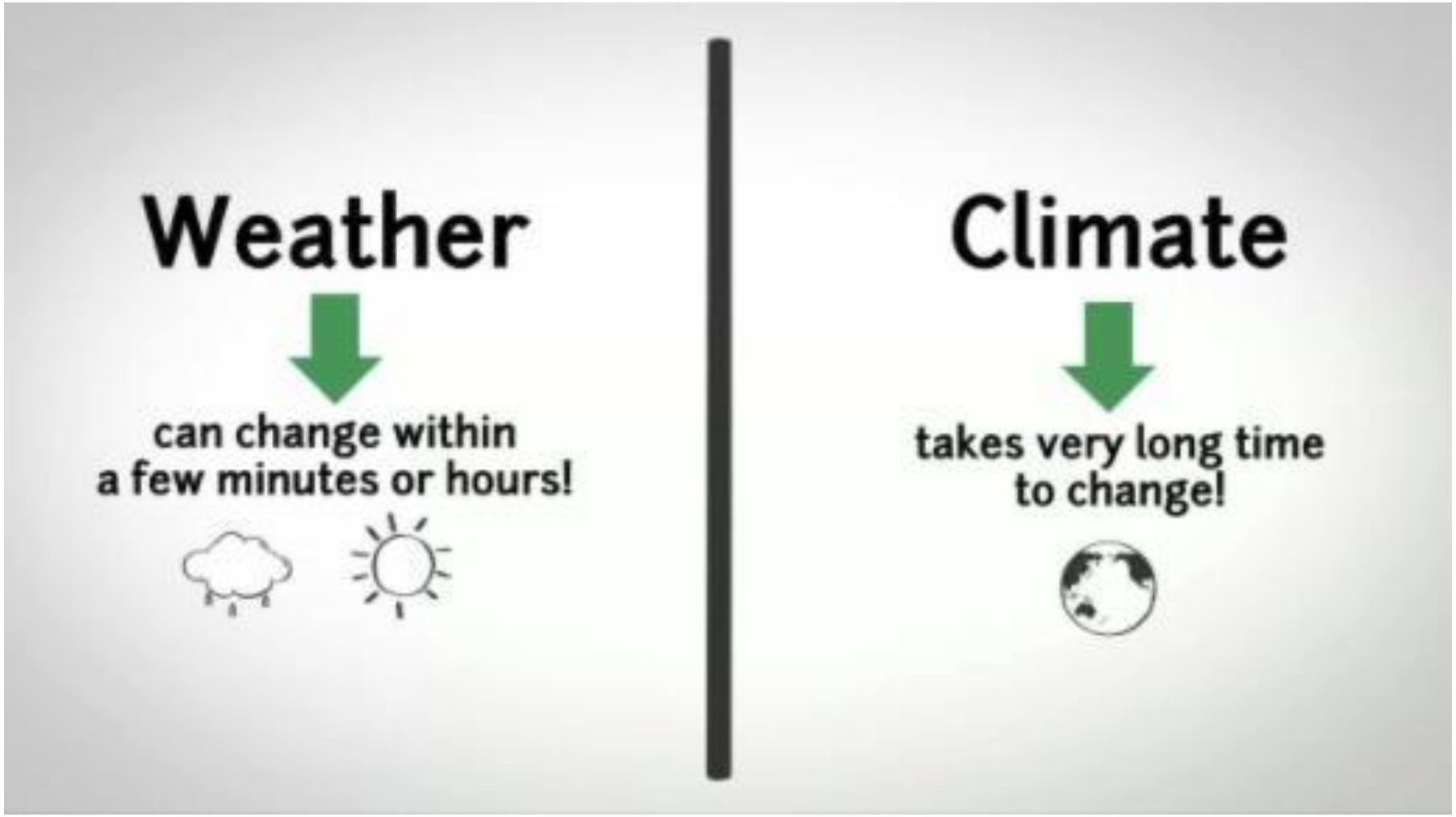
So What is Climate Change

Weather vs. Climate

- **Weather:** consists of the short-term (minutes to months) changes in the atmosphere.
  - temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.
- **Climate:** long-term averages of daily weather.
  - The statistics of weather

https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Weather vs. Climate



So what's the issue today – what's the big deal? It's always changed?

…in the bigger picture of things it's about our sustainability

- Climate change is only one part to the bigger picture: **SUSTAINABILITY**
  - Climate change
  - Population
  - Resources limits
  - Limits to growth
  - Economics
  - Energy
  - Environment
  - Ethics
  - Habitat loss; ecological impacts
  - ETC.

So let’s look at our history of Discovery and Understanding

1820s - Greenhouse gas analogy

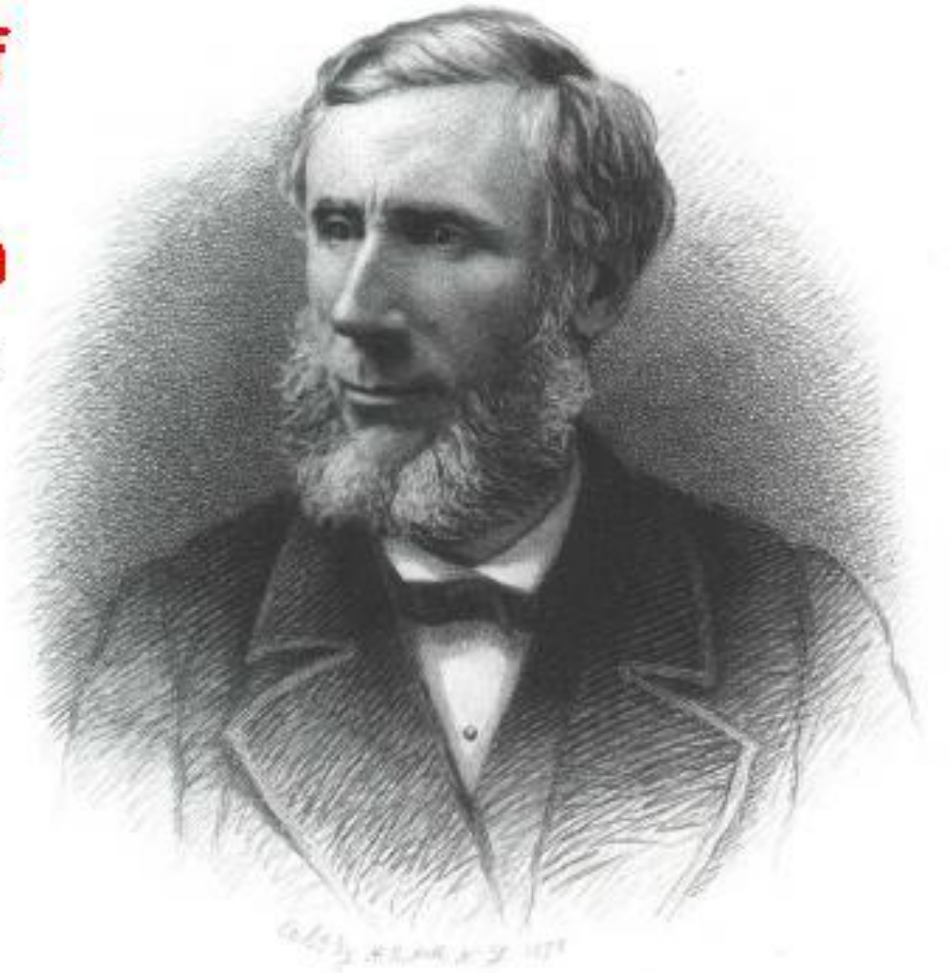
1820's – Joseph Fourier

- Showed that solar heat alone isn't enough to explain Earth's warm climate
- Coined the "Greenhouse" analogy

From Where has all the carbon gone: Scott.Denning@ColoState.edu

1860's – John Tyndall

- First direct measurements of the absorption of infrared radiation by CO_2 gas in the laboratory
- CO_2 absorbs IR the wavelengths emitted by Earth



From Where has all the carbon gone: Scott.Denning@ColoState.edu

1890's – Svante Arrhenius

- Measured IR absorption by the Earth's atmosphere
- Showed doubling CO_2 would warm global average temperature by 3 Celsius

From Where has all the carbon gone: Scott.Denning@ColoState.edu

Well then what? …sort of disappeared off the radar!

A 100 PLUS YEARS WENT BY:

- We had 2 World Wars
- We wanted a breather / recovery

Discovery: Paleoceanography & Paleoclimate

Then in the 1950s, 1960s and 1970s we studied the science of climate change through ocean cores, mapping and stable isotopes. A few examples:

- The sun changes: luminosity, sunspots
- Relationship of climate change to Milankovitch cycles/Orbital parameters
- Ice core data in the 1990s; rediscovery and understanding of Green House Gases (GHGs)
- Yet 1975: Wally Broecker raised concerns; others too: Bill Ruddiman:
  — Wally Broecker's ebook – **What Drives Glacial Cycles Broecker**
  — Wally Broecker's 1975 paper **BroeckerScience1975 Are we on the brink of a pronounced GLOBAL WARMING**
- 1990s-2000s – International Panel on Climate Change (IPCC) reports

- Bipartisan agreement went the way of becoming a political issue vs. science

Scientific Discoveries & Observations

- We found out about Snow Ball Earth Episodes before O_2 dominated our atmosphere
- We found out that most of Earth History has been a Hot-House Earth with Episodes of Glaciation
- We found out that we are currently in an Interglacial of one of those Ice-House / Glaciated episodes
- We found out that atmospheric gases are very important in moderating our climate
- We found out that our current emissions of GHGs is:
  - Nearly unprecedented – not unlike the PETM (Paleocene-Eocene Thermal Maximum) https://en.wikipedia.org/wiki/Paleocene%E2%80%93Eocene_Thermal_Maximum
  - It's causing ocean acidification, fisheries, marine life
  - It threatens our coastal cities with sea level rise
  - It threatens our sustainability:
    - Extreme weather events: floods, droughts, wildfires, farming challenges
  - It will lead to mass migrations and refugees problems

Scientific Discoveries & Observations

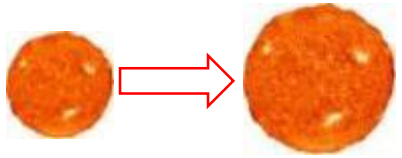
Earth History – deep time to present

- From Jim Keller - How we evolved to have O_2 in our Atmosphere:
  - https://earthsky.org/earth/when-where-earths-o2-oxygen-rise-began?utm_source=EarthSky+News&utm_campaign=ecbfc8e82e-EMAIL_CAMPAIGN_2018_02_02_COPY_01&utm_medium=email&utm_term=0_c643945d79-ecbfc8e82e-395269909
- Other links from Earth's Climate; Past, Present and Future: Concerns and solutions:
  - From SNOWBALL EARTH, to HOTHOUSE EARTH to today's Glacial/Interglacials: Particularly week 2 – see these slides: https://denverclimatestudygroup.com/wp-content/uploads/2019/01/Belanger-OLLI-EASTCLIMATE-week2-slides.pdf

So – WHAT Controls Climate

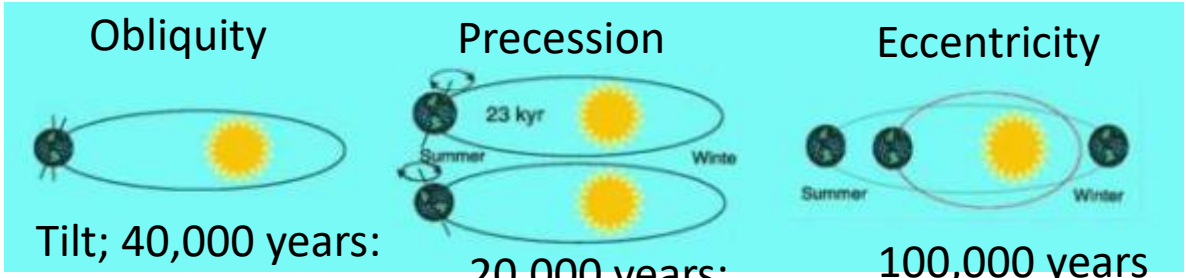
What determines Earth's climate

- **Primary Influences (3):**
  1. **SOLAR input:**



0.9% less
100 My ago

& sunspots



Tilt; 40,000 years:
21.5 – 24.5 degrees

20,000 years:
summer season

100,000 years
400,000 years

  2. **Greenhouse Gases (GHGs)**
     (gases that absorb radiation in or out)

  3. **Albedo**
     (reflectivity:30-85%)

- **Feedbacks:** INTERNAL dynamics and responses
  - e.g. higher water vapor in atm. due to heating of atm

Long-term Carbon Cycle: rocks

Two generalized reactions…

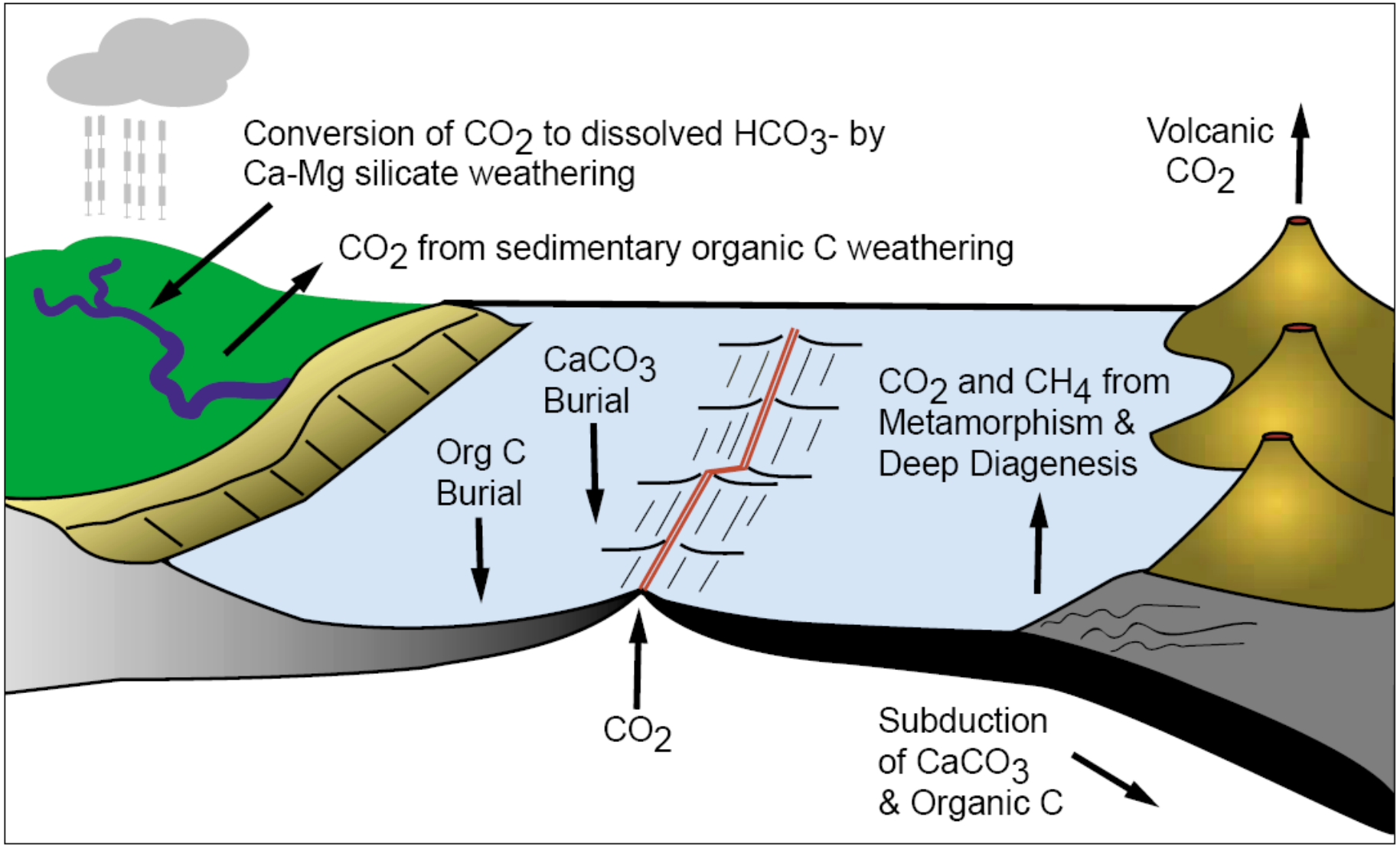
Photosynthesis/Respiration

$$CO_2 + H_20 \leftrightarrow CH_2O + O_2$$

Weathering/Precipitation

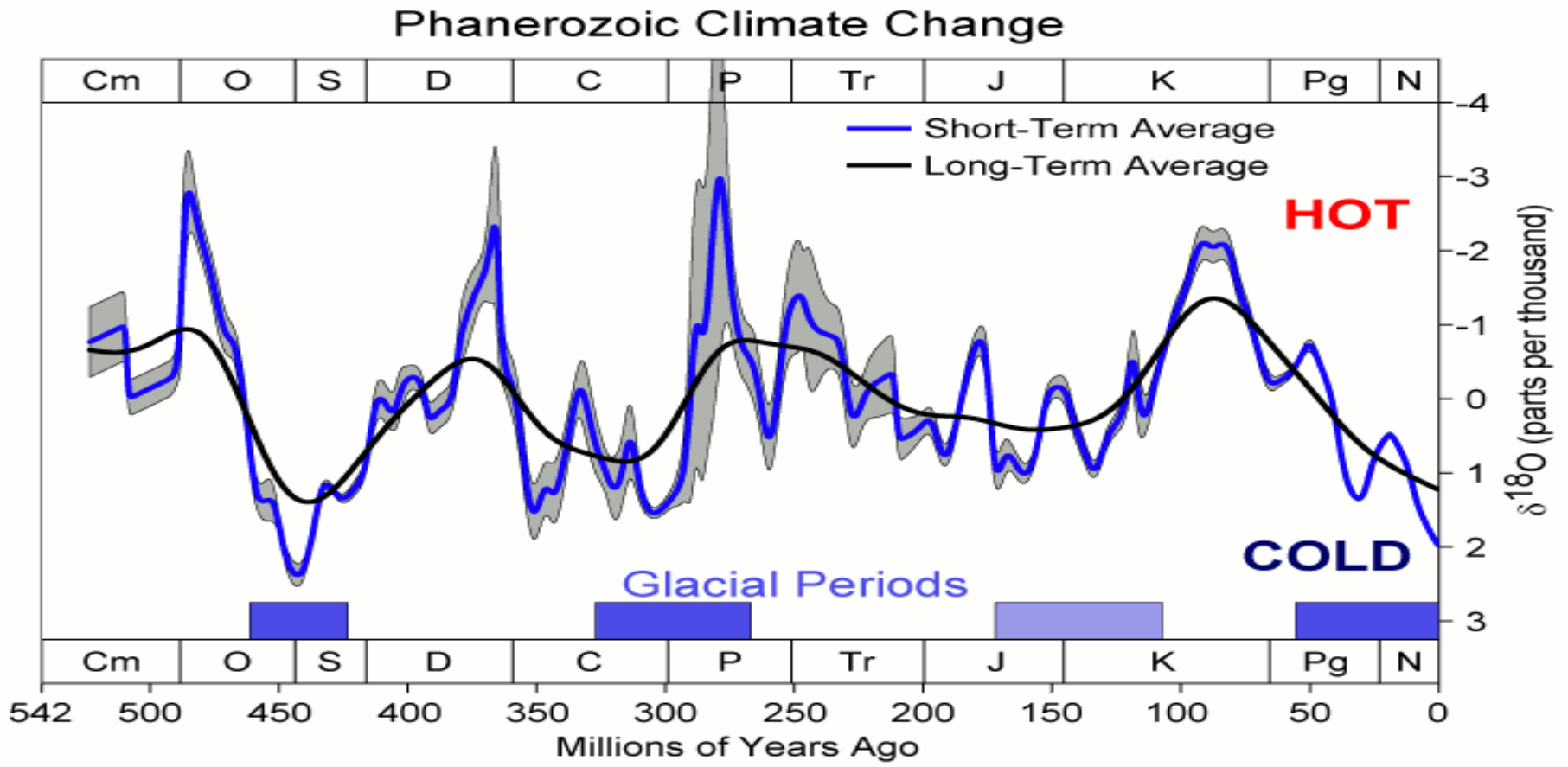
$$CO_2 + CaSiO_3 \leftrightarrow CaCO_3 + SiO_2$$

Long-term carbon cycle: *rocks*

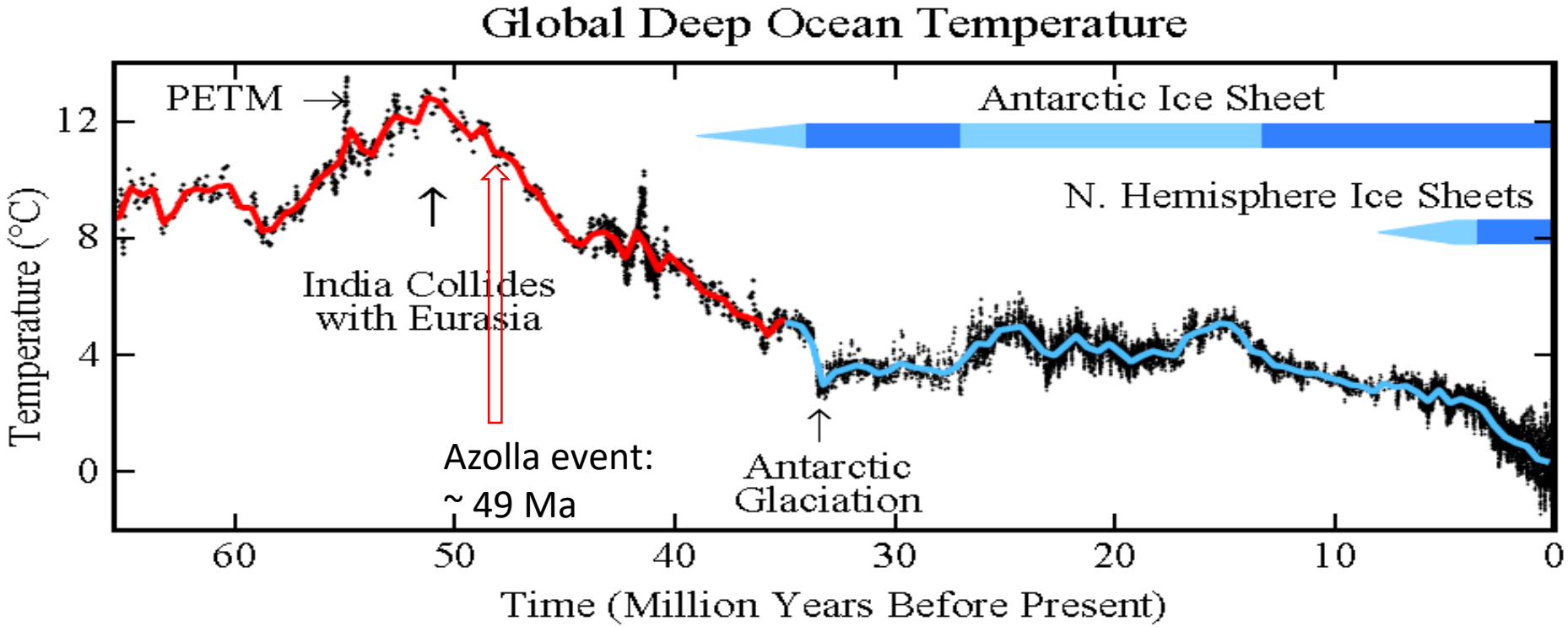


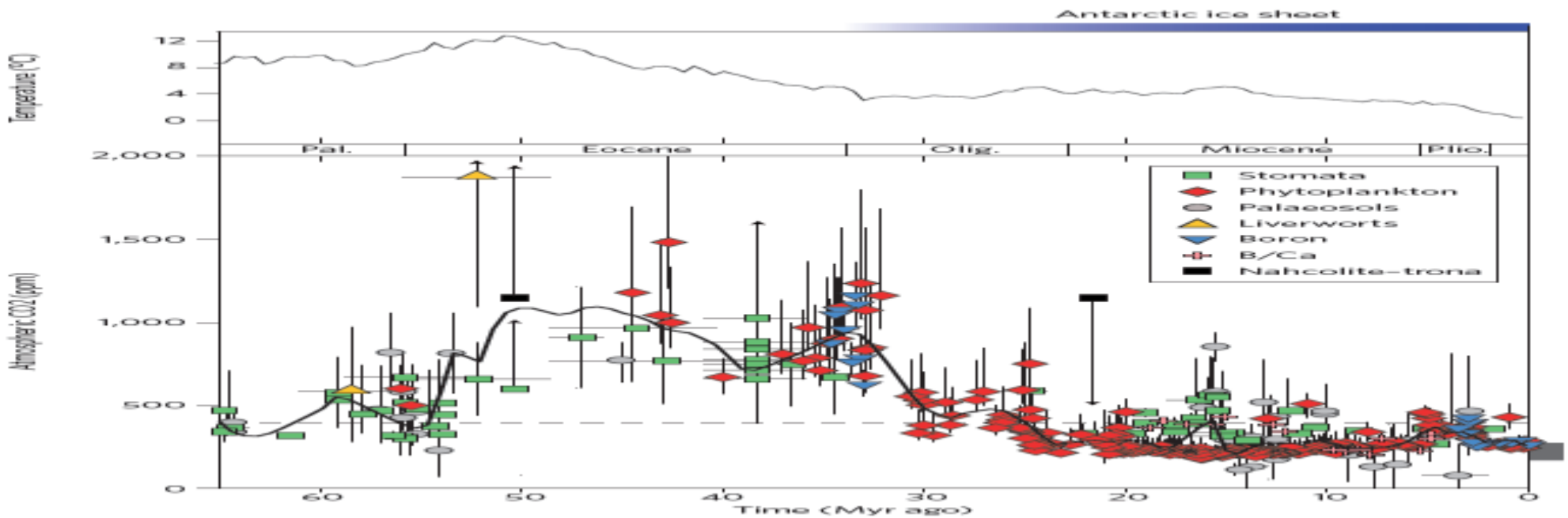
Berner, 2001

Scientific Discoveries & Observations



PALEOZOIC | MESOZOIC | CENOZ


Global Deep Ocean Temperature
PETM
India Collides with Eurasia
Azolla event:
~ 49 Ma
Antarctic Glaciation
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
Temperature (°C)
Time (Million Years Before Present)


Antarctic ice sheet
Pal.
Eocene
Olig.
Miocene
Plio.
Stomata
Phytoplankton
Palaeosols
Liverworts
Boron
B/Ca
Nahcolite–trona
Time (Myr ago)

Greenhouse Gases (GHGs)

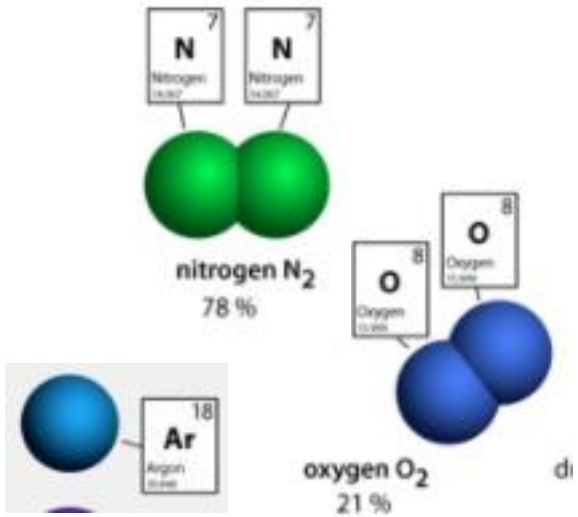
Let's look at our atmosphere

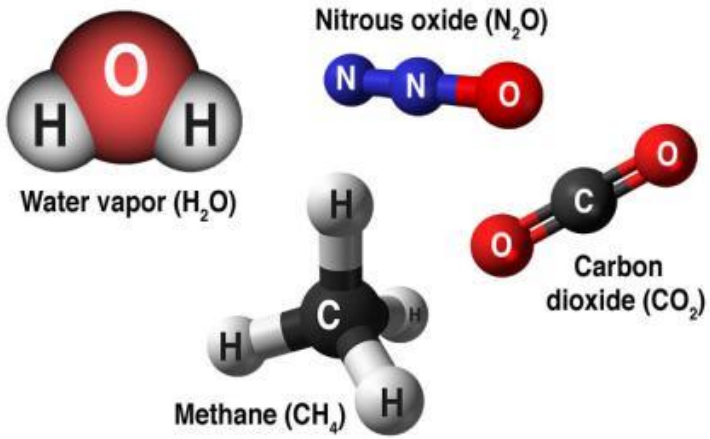
DOMINATED BY NON-GHGs:

- N_2 = 78%
- O_2 = 21%
- Ar = 0.93%

GHGs:

- CO_2 = -.408%
- H_20 = variable
- Other: CH_4, CFCs, O_3, etc.





GREENHOUSE GASES (GHGs)

- Water – H_2O – the amount is a feedback of temperature held in by the “blanket” of other GHGs
- Carbon dioxide - CO_2
- Methane - CH_4
- Ozone - O_3
- Nitrous oxide- N_2O
- others

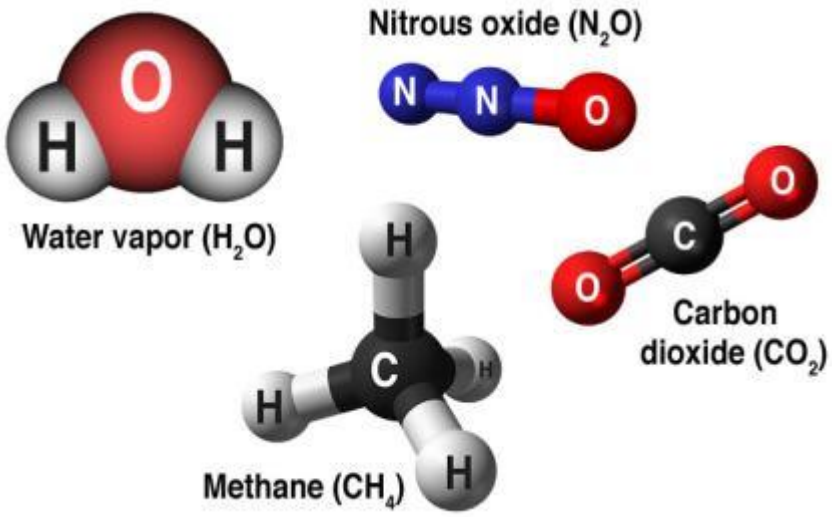


Table 1 Specific humidity of a kilogram of air (at average sea level pressure)

Temp. (°C)	Temp. (°F)	Grams of water vapor per kg of air (g/kg)
-40	-40	0.1
-35	-31	0.2
-30	-22	0.3
-25	-13	0.51
-20	-4	0.75
-10	14	1.8
0	32	3.8
5	41	5
10	50	7.8
15	59	10
20	68	15
25	77	20
30	86	27.7
35	95	35
40	104	49.8

What is the volume of 1 kg of air?

Answer: 0.8562 m^3

(95 cm x 95 cm x 95 cm)

TAKE AWAY:

Water vapor in the atmosphere
~ DOUBLES WITH EVERY +10^{o}C

How GHGs Blanket the Earth

Blanket Earth:

- **NASA –Global Climate Change Cause:** http://climate.nasa.gov/causes/

Denial 101x - Video includes First handout Global warming:

- https://www.youtube.com/watch?v=aqkGoCglp_U&feature=youtu.be

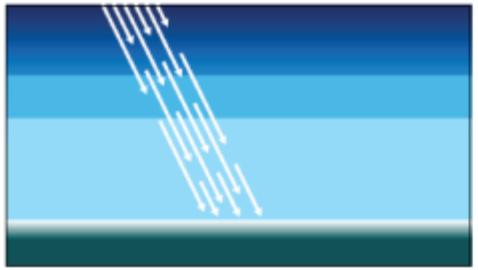
Denial 101x - Second handout – Increasing Greenhouse Effect:

- https://www.youtube.com/watch?v=we8VXwa83FQ

Increasing GHGs 1 of 3

DENIAL101x - 3.3.2.1 - Animation 1 v3

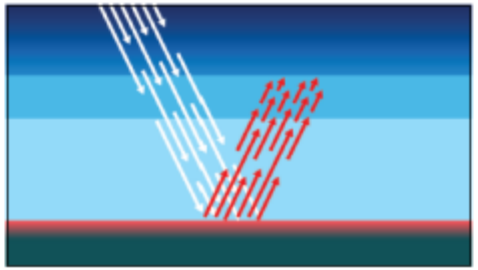
1 — 5 sec



Voice Over:
Greenhouse gases let sunlight through to warm the surface.

Visual: White arrows continually move into the Earth's surface. Earths surface glows white.

2 — 3 sec



Voice Over:
The surface then glows with infrared light.

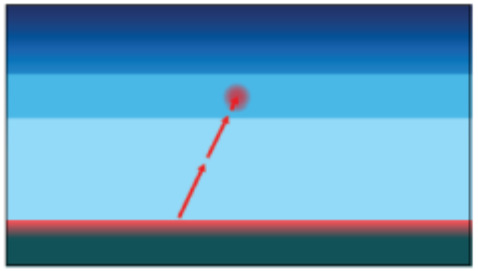
Visual:
Earths surface glows red. Red arrows move away from the ground reducing in speed as they move through the greenhouse gas.

3 — 4 sec

Voice Over:
Our eyes aren't tuned to its frequency so it's invisible to us.

Visual:
All arrows and glows disappear.

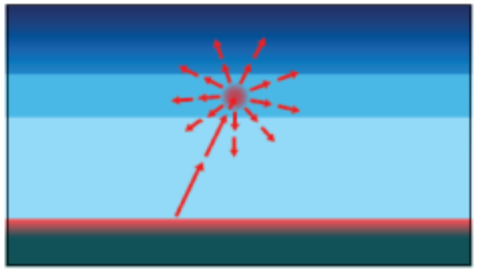
4 — 7 sec



Voice Over:
But greenhouse gases absorb some of this infrared. At the same time, they glow with their own infrared.

Visual:
Glow reappears and a single arrow continually moves up from the ground in the greenhouse gas. The a small section of the greenhouse gas glows where the arrow collides.

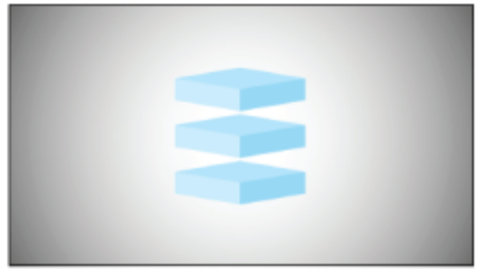
5 — 8 sec



Voice Over:
They glow in all directions, and the part of the glow that goes up can be absorbed by greenhouse gases further up in the atmosphere.

Visual:
Arrows are emitted from the glow in the greenhouse gas.

6 — 3 sec



Voice Over:
It's useful to think of the atmosphere as layers.

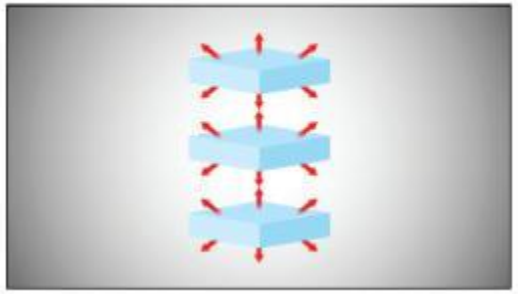
Visual:
Cut to new scene showing layers of atmosphere.

animation by Daniel Greenup, University of Queensland for Denial101x

Increasing GHGs 2 of 3

DENIAL101x - 3.3.2.1 - Animation 1 v3

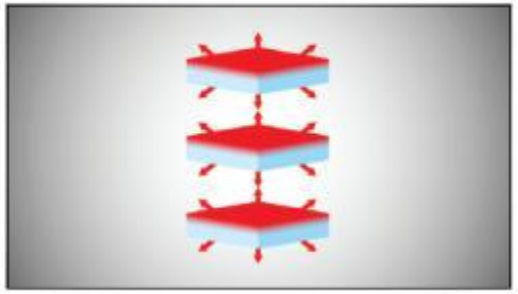
7 — 4 sec



Voice Over:
Each layer of the atmosphere has a greenhouse glow in every direction.

Visual:
Layers separate more and arrows are emitted.

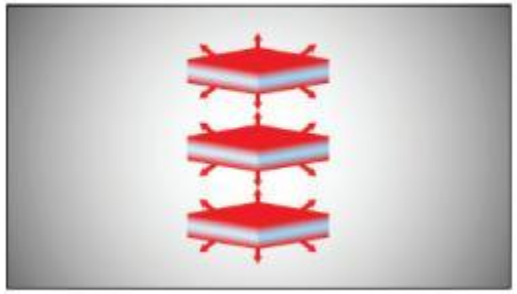
8 — 5 sec



Voice Over:
Meanwhile, each layer absorbs some of the infrared glow that comes from the layer above,

Visual:
Top of layers glow.

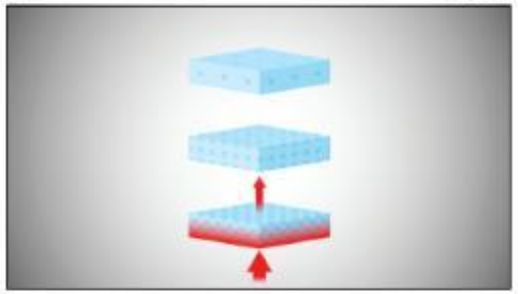
9 — 3 sec



Voice Over:
and some from the layer below.

Visual:
Bottoms of layers start glowing.

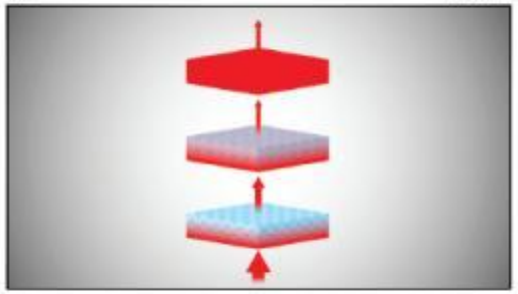
10 — 9 sec



Voice Over:
Low down in the atmosphere, the air is thicker than higher up. Each layer has enough greenhouse gas to absorb much of the infrared going through it.

Visual:
Glow and arrows are removed. Dots appear in layers to indicate air thickness. A new arrows moves through the bottom layer and reduce in size. The bottom of the layer glows.

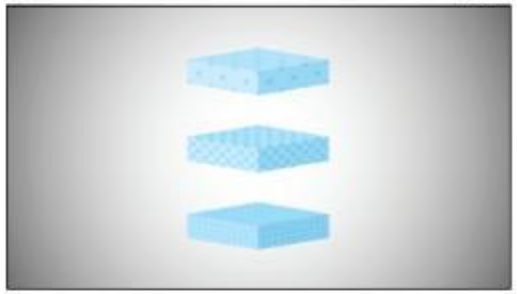
11 — 11 sec



Voice Over:
Higher up in the atmosphere, the air gets thinner. That's why it's harder to breathe at the top of a mountain. Each layer doesn't have enough greenhouse gas to fully trap passing infrared.

Visual:
Arrows move through all of the layers reducing in size.

12 — 9 sec



Voice Over:
Burning coal, oil and gas releases carbon dioxide, a greenhouse gas. Stirred by the winds, it mixes through the atmosphere.

Visual:
Arrows and glows are removed and extra dots appear in each layer.

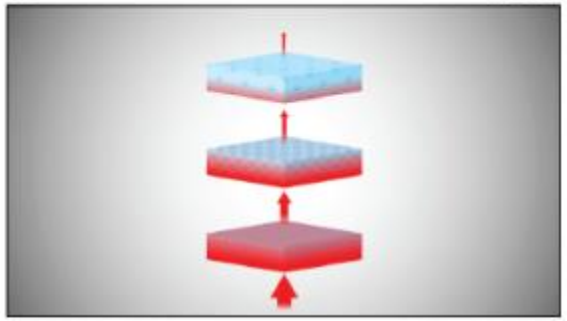
animation by Daniel Greenup, University of Queensland for Denial101x

Increasing GHGs 3 of 3

DENIAL101x - 3.3.2.1 - Animation 1 v3

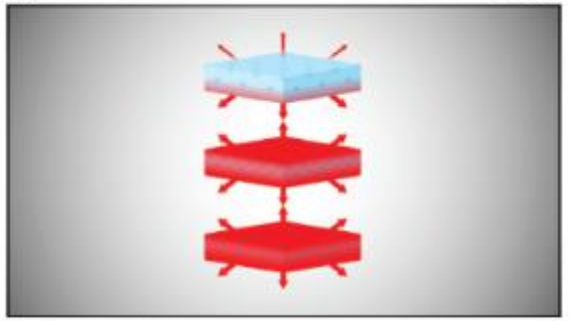
3 of 3

13 10 sec



Voice Over:
The biggest effect is high up where the air is thinner. This is where infrared previously escaped to space. Adding more greenhouse gases captures this infrared.

14 9 sec

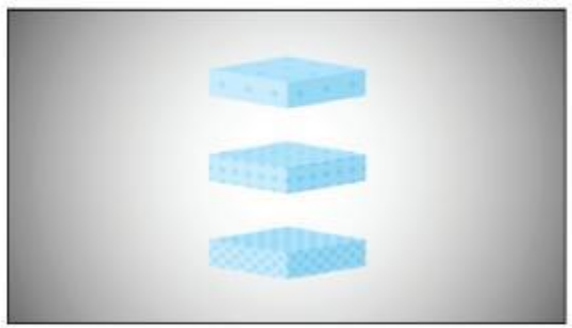


Voice Over:
This upper layer now glows a little more brightly. A little more heat is recycled back into the atmosphere. This is how adding more greenhouse gases makes us warmer.

DENIAL101x - 3.3.2.1 - Animation 2 v2

1 of 1

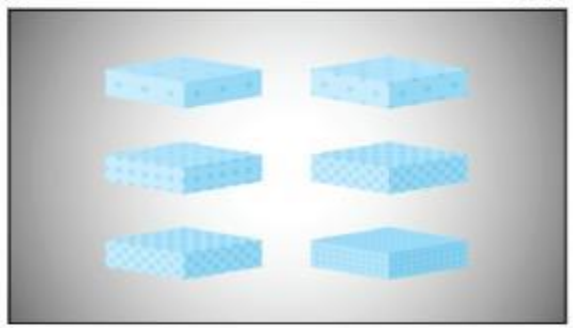
1 9 sec



Voice Over:
In the upper layers of the atmosphere, the greenhouse effect isn't saturated. The concentration of greenhouse gases is a lot less than in Angstrom's tube.

Visual:
Layers of atmosphere appear.

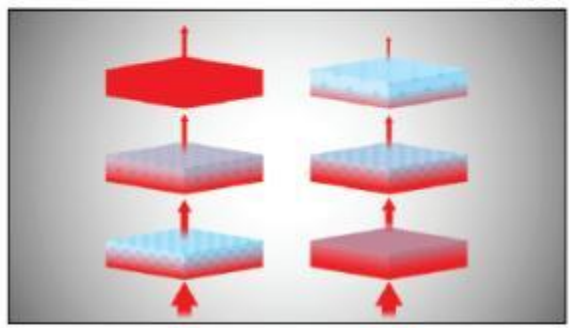
2 6 sec



Voice Over:
Adding greenhouse gases blocks the infrared's escape path to space.

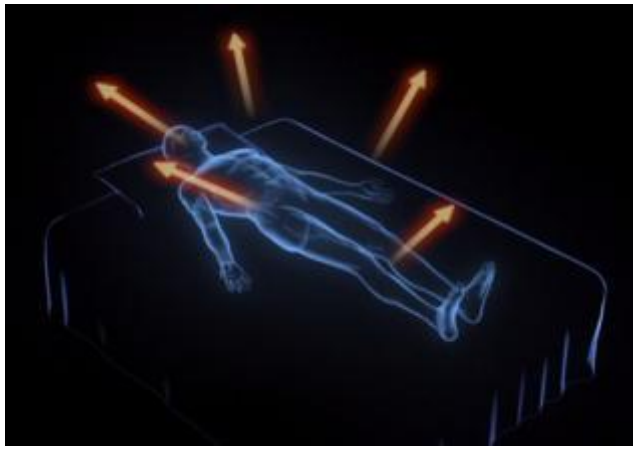
Visual:
Layers of atmosphere and greenhouse gases appear.

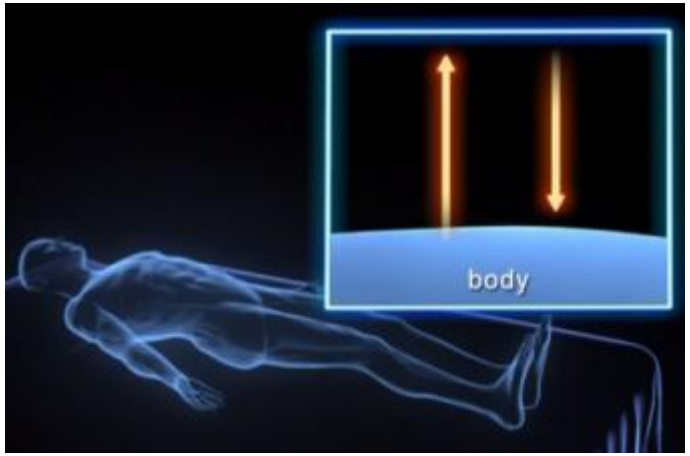
3 8 sec



Voice Over:
Some of the infrared that used to escape to space has now been trapped. The layer's greenhouse glow sends some of it back down to warm us up.

Visual:
Arrows move through layers.

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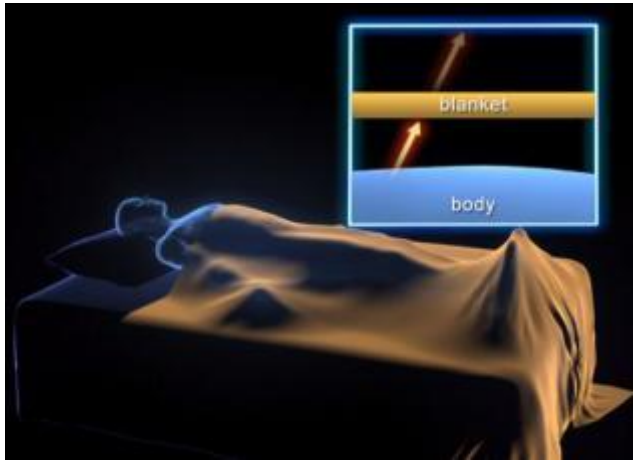
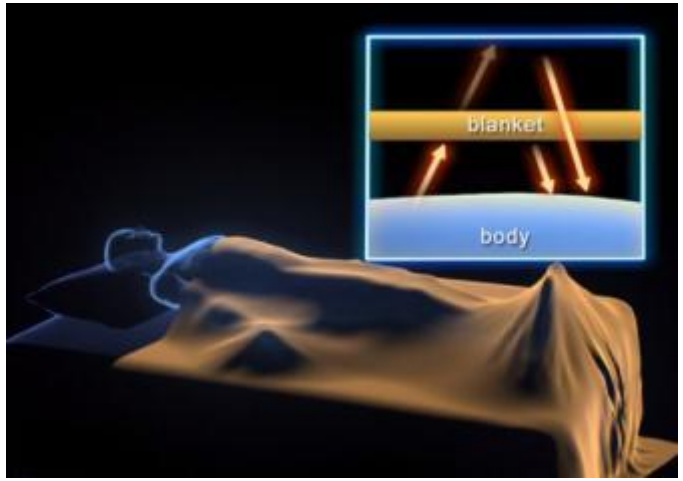

blanket
body


blanket
body

The CO_2 greenhouse gas effect is concentrated in the polar regions ! ! !

The Earth and its atmosphere

The Earth and its atmosphere H_2O - Vapor

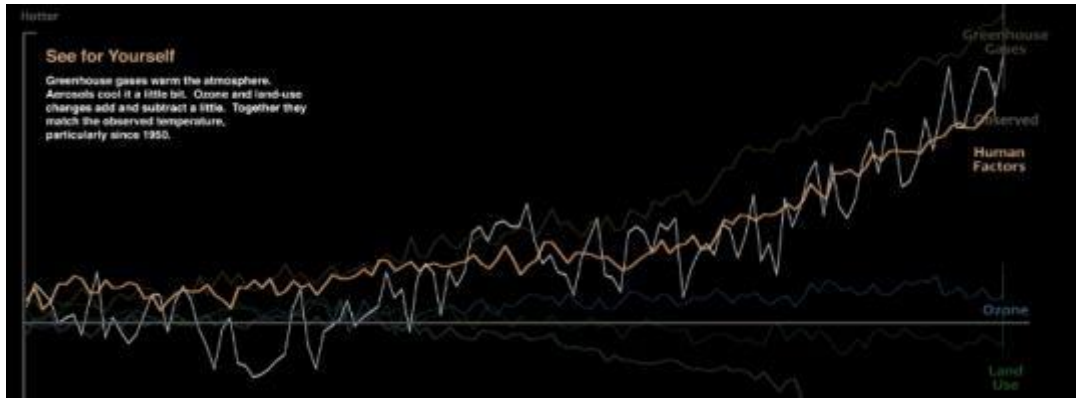
The large H_2O greenhouse effect is controlled by temperature – H_2O saturation doubles with every 10° C Increase

CO_2 and other Greenhouse gases are evenly distributed throughout the atmosphere

As a result it is concentrated in the lower atmosphere of the tropics

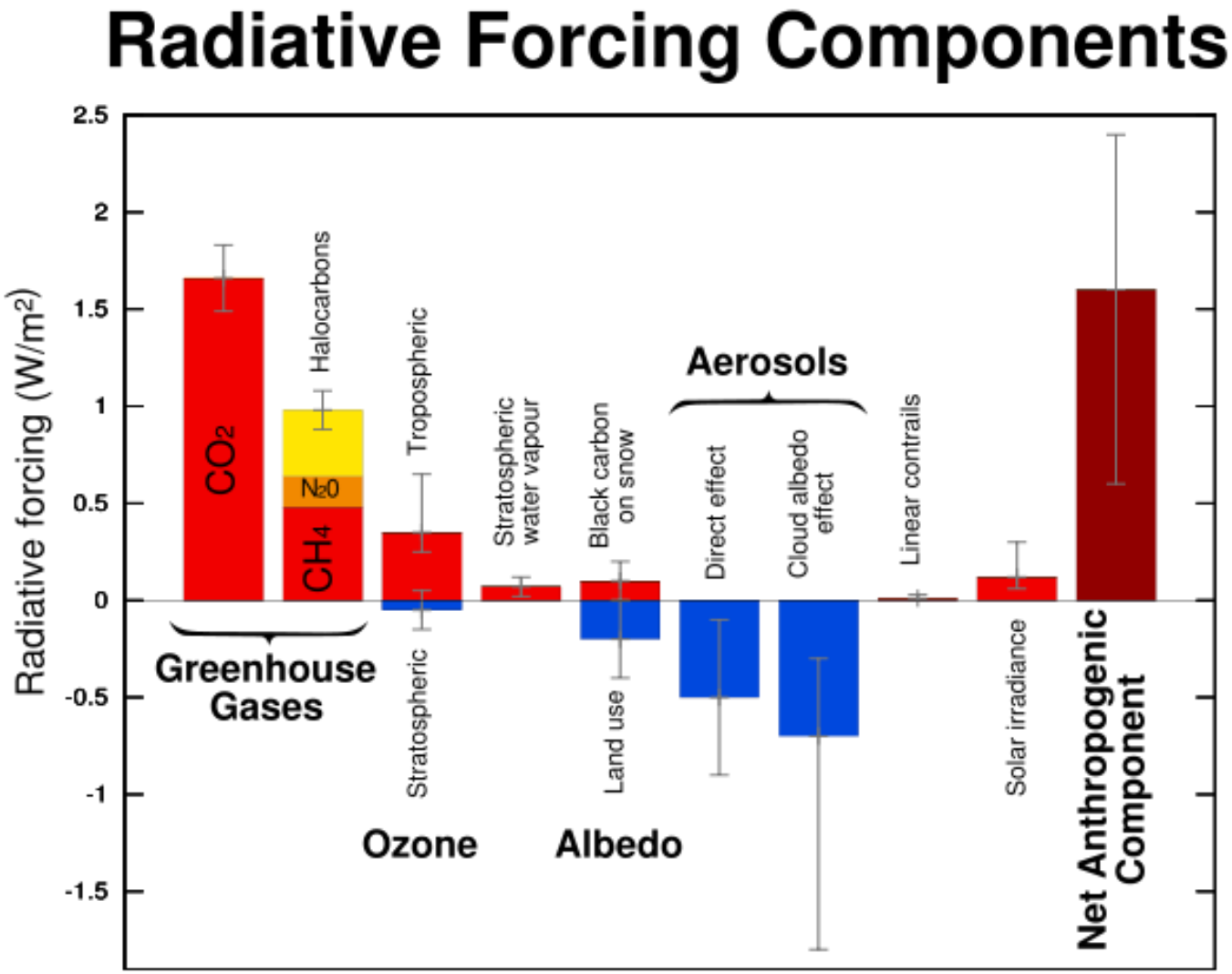
Particularly in the Arctic!

How global warming stacks up



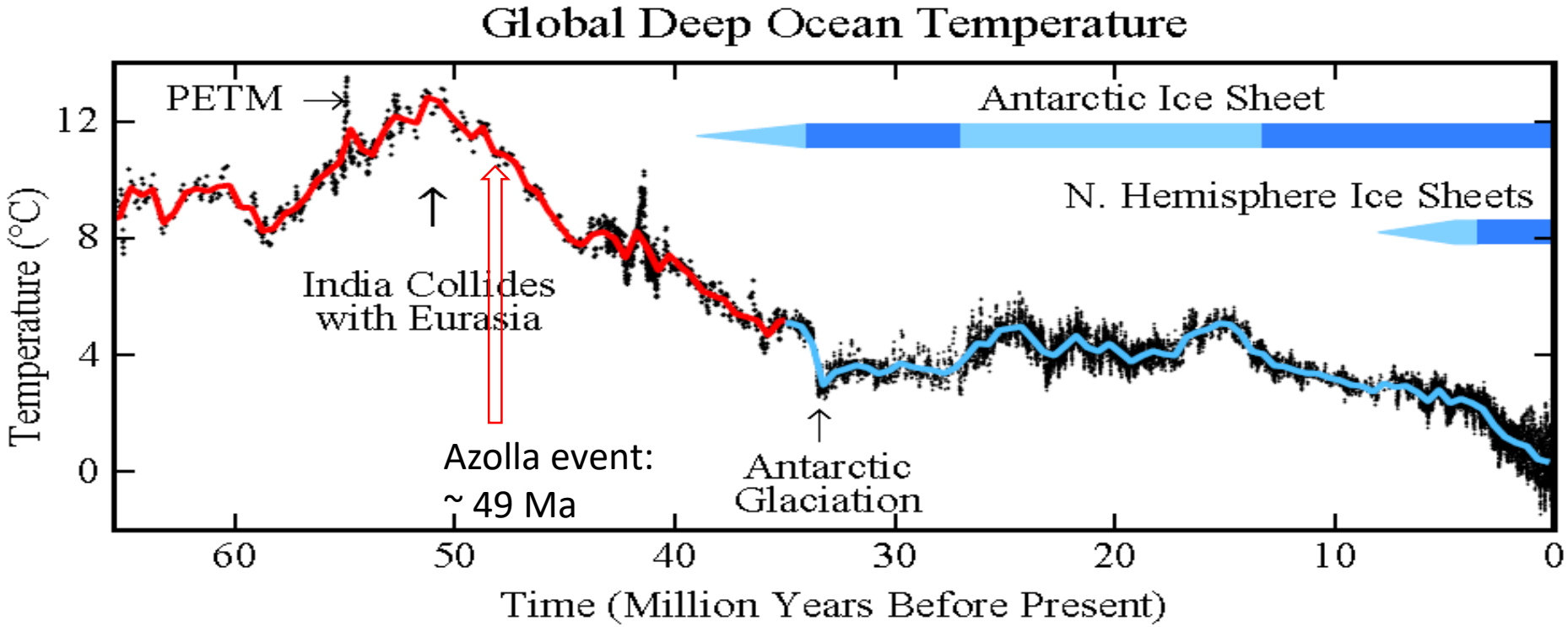
- https://www.youtube.com/watch?v=-gHUHoqBn-Y
- Published on Sep 15, 2016
- Skeptics of manmade climate change offer various natural causes to explain why the Earth has warmed 1.4 degrees Fahrenheit since 1880. But can these account for the planet's rising temperature? Watch to see how much different factors, both natural and industrial, contribute to global warming, based on findings from NASA's Goddard Institute for Space Studies.

GLOBAL WARMING CONCERNS



Incoming Solar irradiance: 342 W/m^2

IPCC, 2007


Global Deep Ocean Temperature
PETM
India Collides with Eurasia
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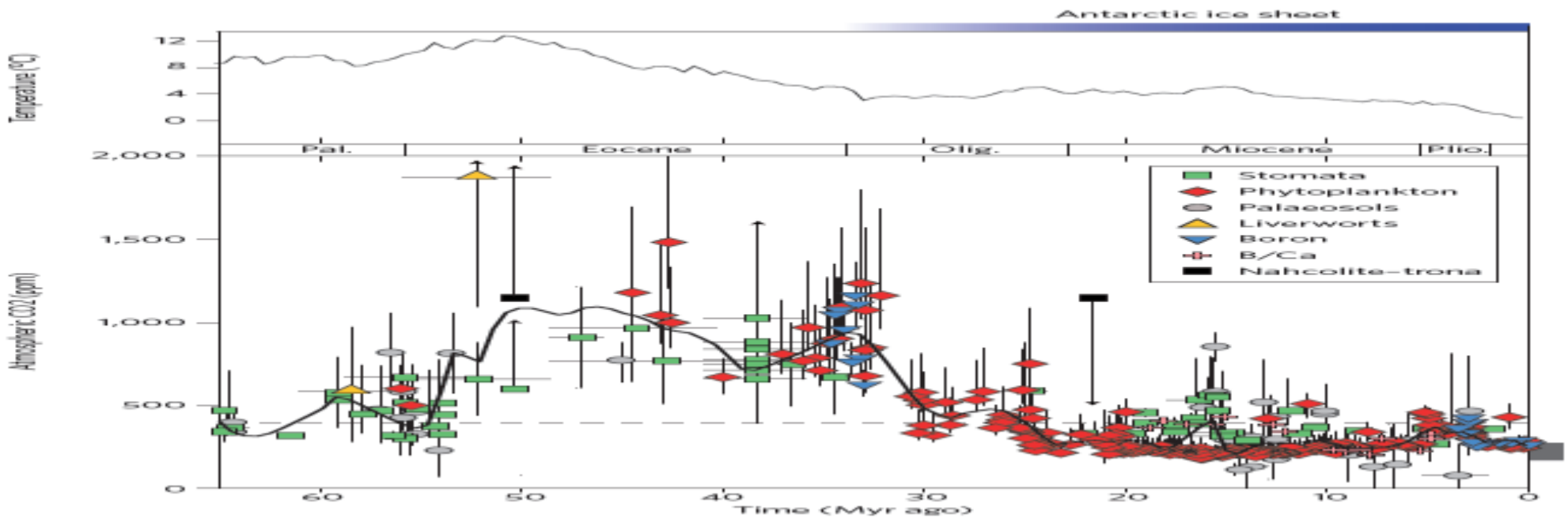
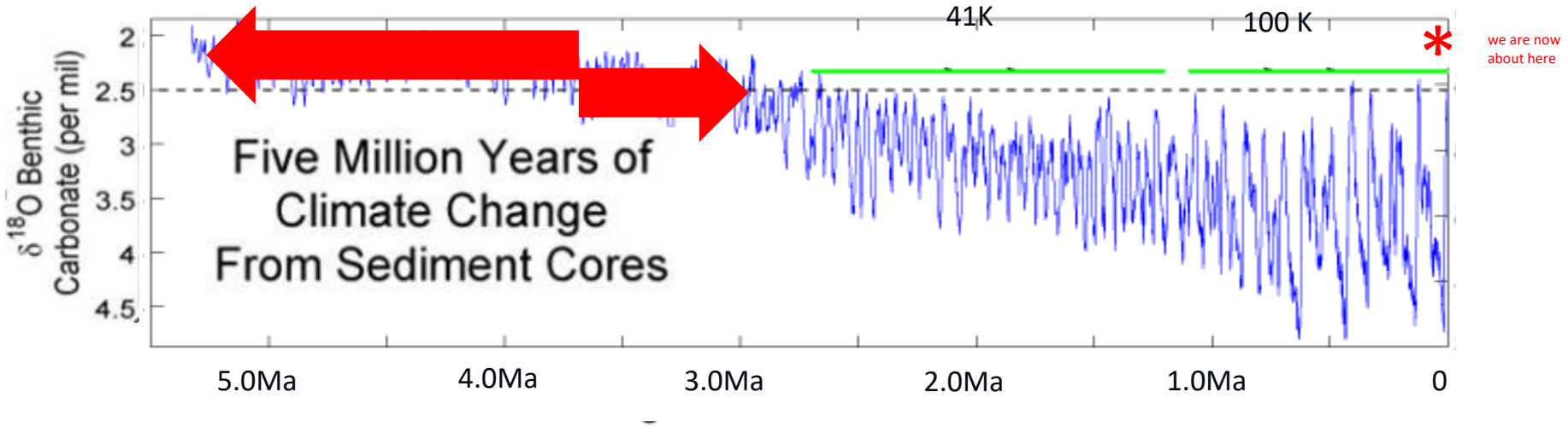
Temperature (°C)
Time (Million Years Before Present)


Antarctic ice sheet
Pal.
Eocene
Olig.
Miocene
Plio.
Stomata
Phytoplankton
Palaeosols
Liverworts
Boron
B/Ca
Nahcolite–trona
Time (Myr ago)

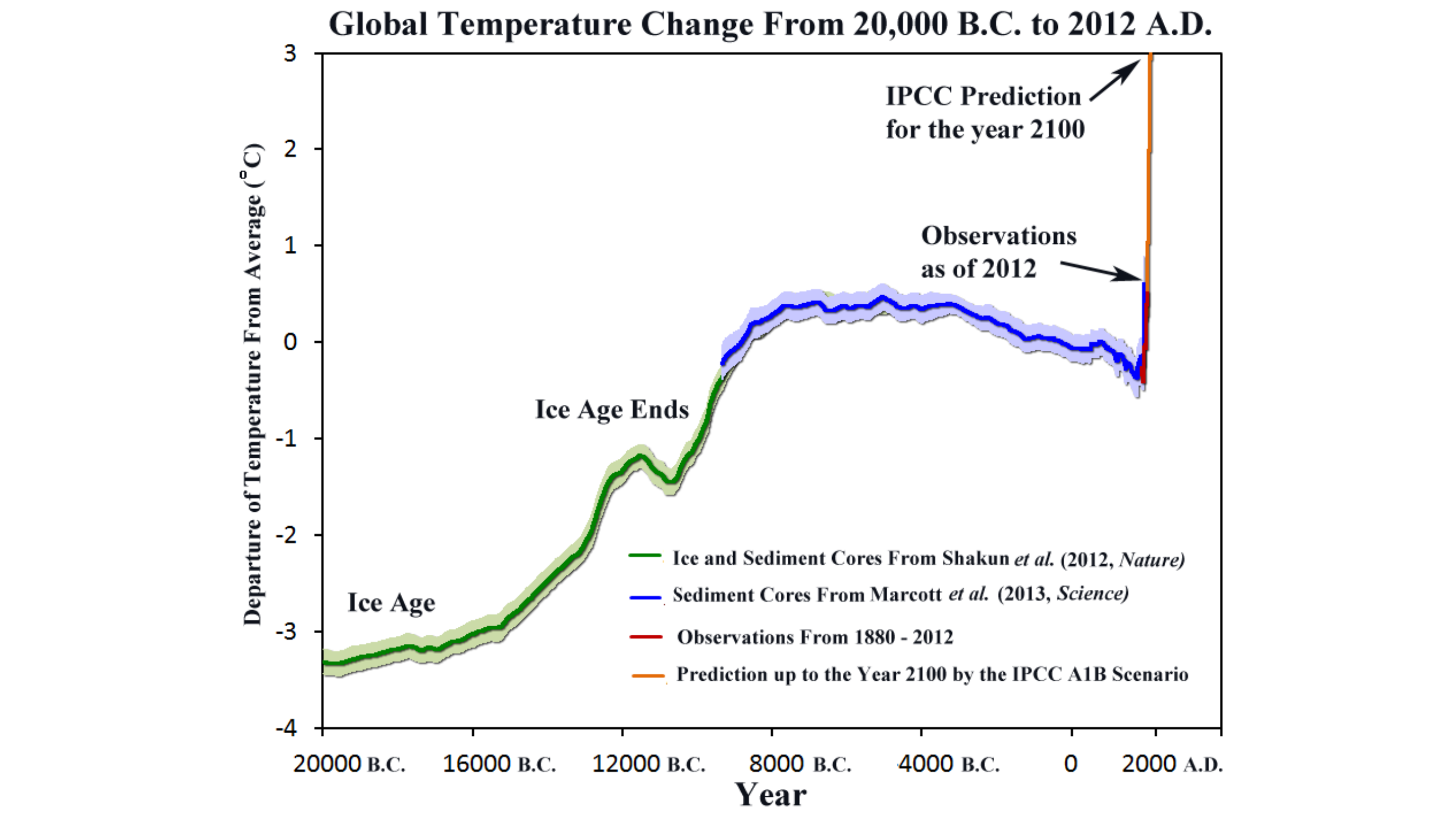
Climate Changes from Ocean Sediment Cores, since 5 Ma. Milankovitch Cycles

the last time inferred temperatures will have been this high – once equilibrium is reached, will have been 3-5 million years ago or more



When CO_2 levels get below ~400-600 ppm Orbital parameters become more important than CO_2

IT’S REALLY HAPPENING – AT AN ACCELERATED PACE


Global Temperature Change From 20,000 B.C. to 2012 A.D.
Departure of Temperature From Average (°C)
3
2
1
0
-1
-2
-3
-4
IPCC Prediction
for the year 2100
Observations
as of 2012
Ice Age Ends
Ice Age
Ice and Sediment Cores From Shakun et al. (2012, Nature)
Sediment Cores From Marcott et al. (2013, Science)
Observations From 1880 - 2012
Prediction up to the Year 2100 by the IPCC A1B Scenario
20000 B.C.
16000 B.C.
12000 B.C.
8000 B.C.
4000 B.C.
0
2000 A.D.
Year

2/3 rds of that since 1970

Climate Connections
click on link for more

Worrisome first quarter of 2017 climate trends

The year is off to a toasty start globally ... and not in a comforting way for those concerned about another year of high temperatures, sea ice record lows at both Poles, and mounting risks to coral reefs.

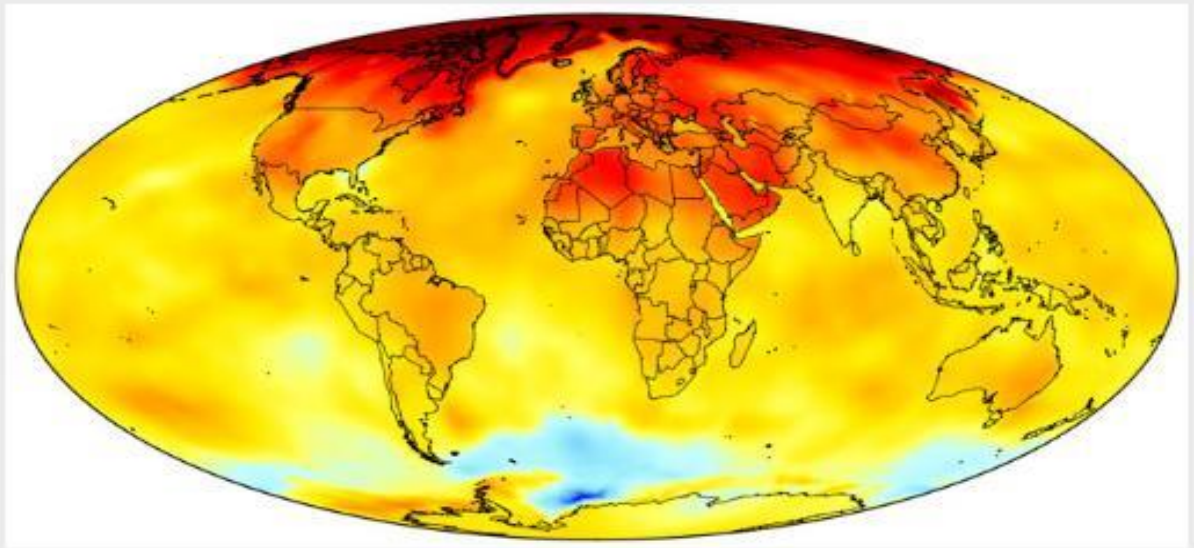
By Zeke Hausfather

Thursday, April 27, 2017

TOPICS
Oceans, Polar Ice, Science

Recent Posts

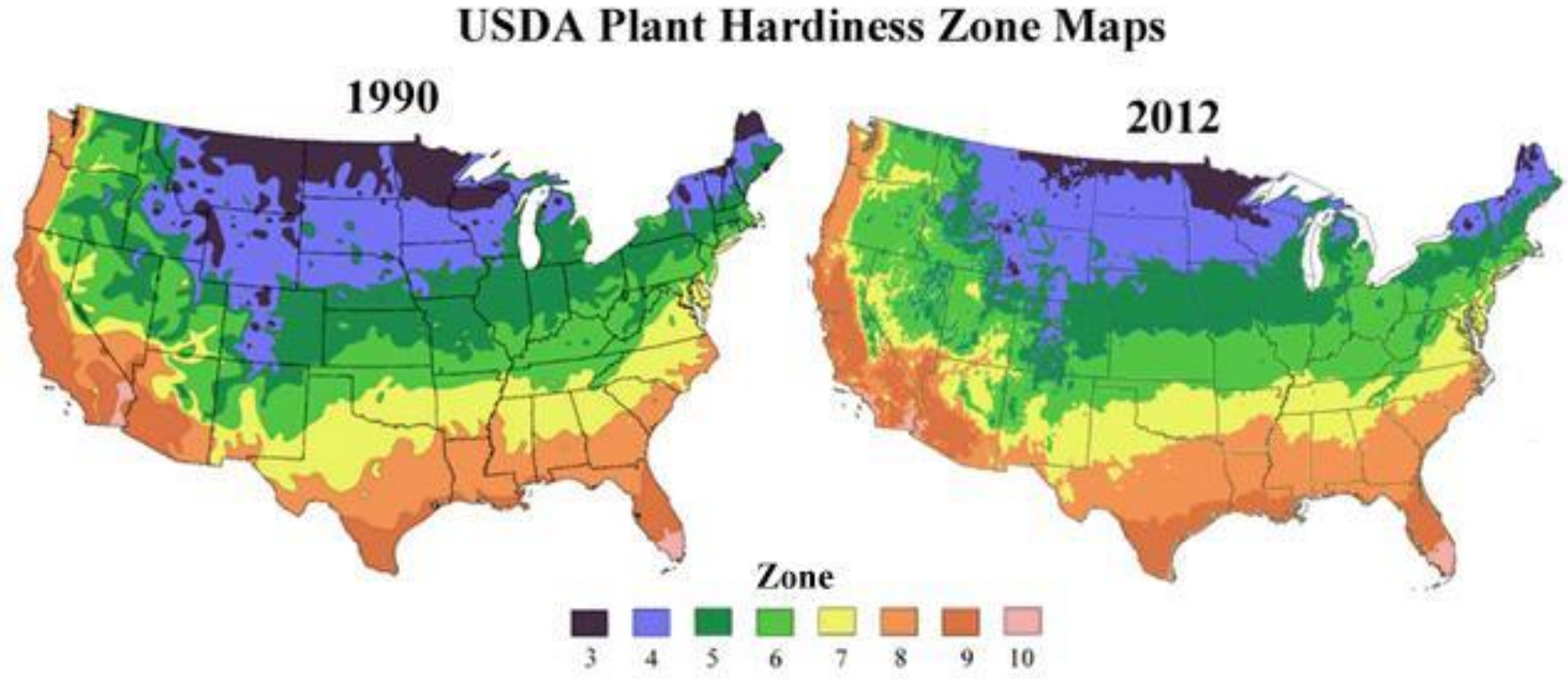
- Reversing climate change
- Columnist: 'Swamped' coastal Louisiana
- Georgia island confronts 'blue



With the first quarter of 2017 now past, the year is shaping up to be one of climate extremes: high temperatures, low sea ice, and coral bleaching.

https://www.yaleclimateconnections.org/2017/04/worrisome-first-quarter-of-2017-climate-trends/

Plants and Animals are Responding to a Warming Climate
1990 vs. 2012

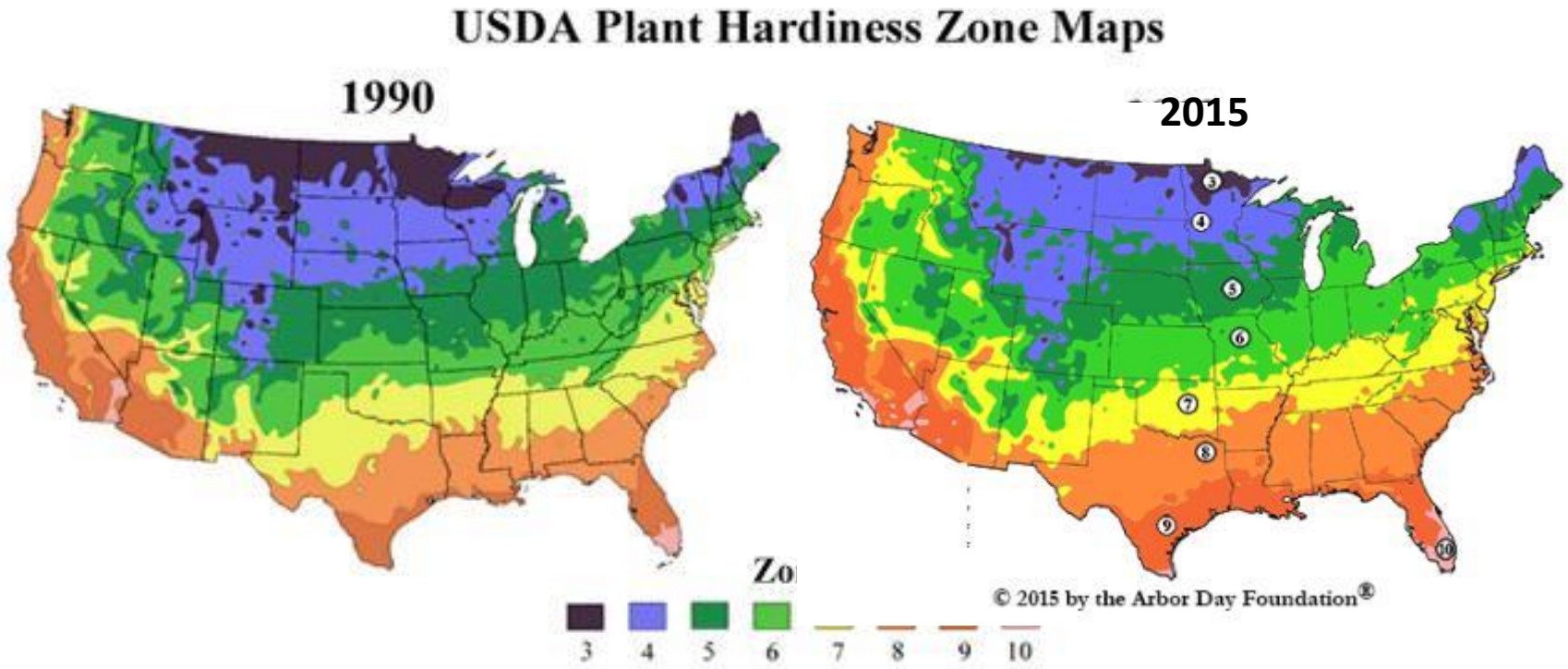


Spring is springing forward: Spring events, like bird and butterfly migrations, flower blooming times, and frog mating, have been advancing by about three days per decade over the past 30 years.

Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

https://www.arborday.org/media/zones.cfm

Plants and Animals are Responding to a Warming Climate
1990 vs. 2015



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Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

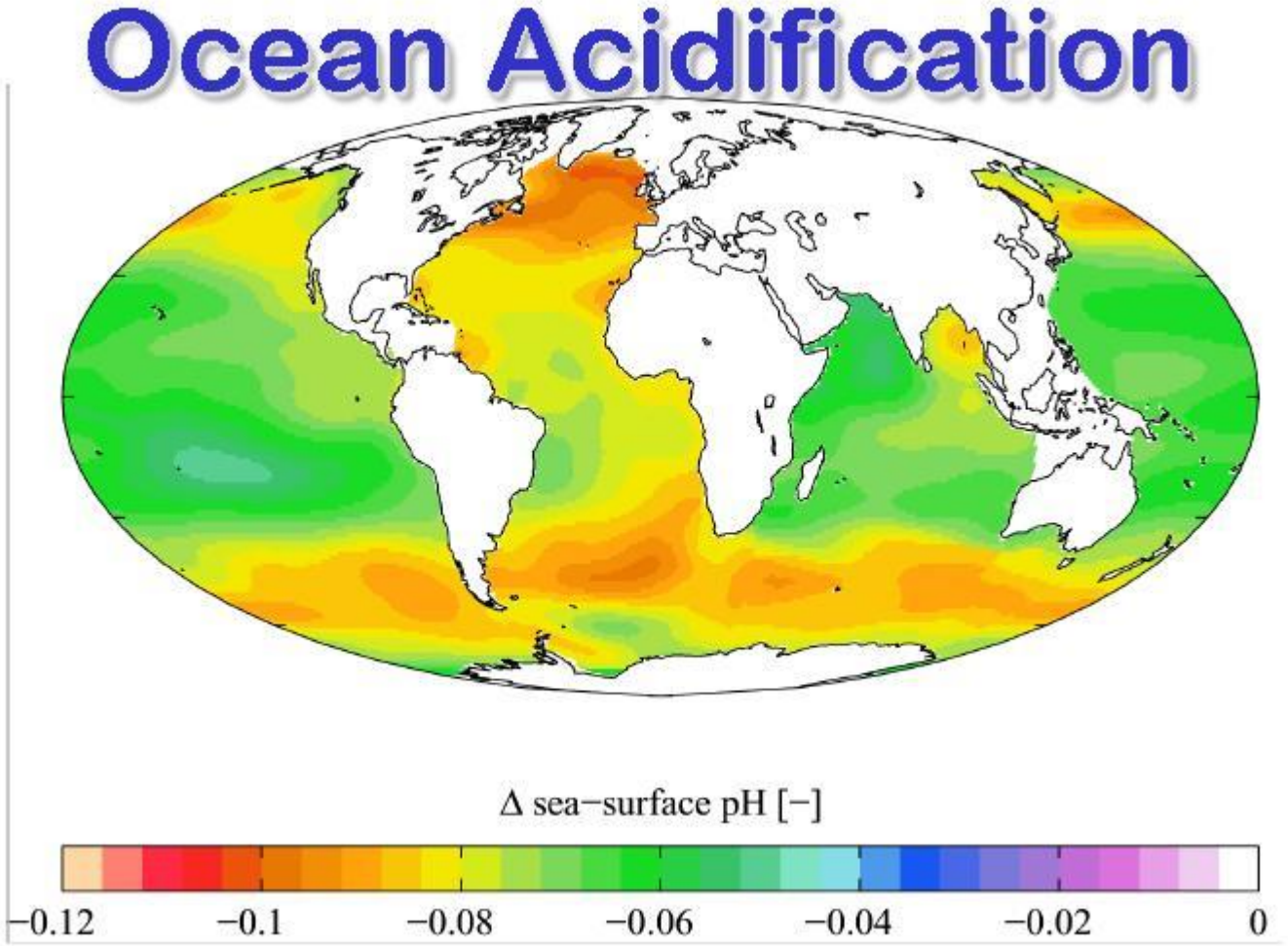
https://www.arborday.org/media/zones.cfm

CONSEQUENCES:

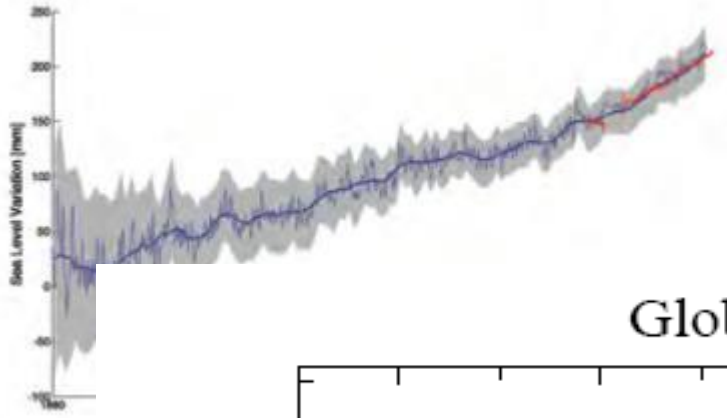
- It’s causing ocean acidification, fisheries, marine life
- It threatens our coastal cities with sea level rise
- Extreme weather events: floods, droughts, wildfires, farming challenges
- It will lead to It threatens our sustainability:
- species extinctions, mass migrations and refugees problems

- …and more
- …i.e. our sustainability and way of life

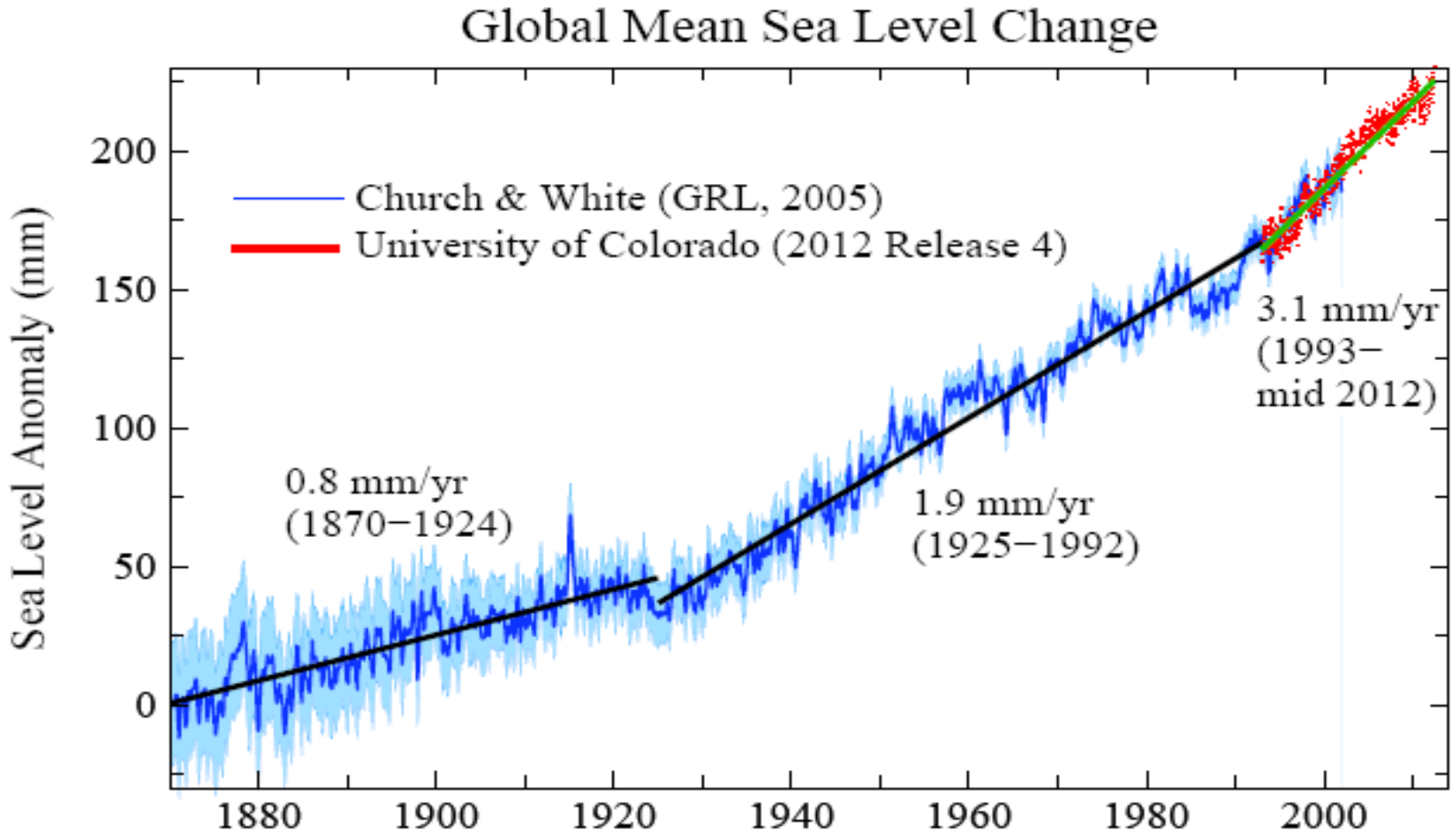
Ocean Acidification
What's will be its impact on the food chain?



From Where has all the carbon gone: Scott.Denning@ColoState.edu



14: HOW FAST IS SEA LEVEL RISING?



Blue: Sea level change from tide-gauge data *(Church J.A. and White N.J., Geophys. Res. Lett. 2006; 33: L01602)*
Red: Univ. Colorado sea level analyses in satellite era *(http://www.columbia.edu/~mhs119/SeaLevel/)*.

EXTREME WEATHER EVENTS AND COSTS

- floods,
- droughts,
- wildfires,
- farming challenges

Refugee problems

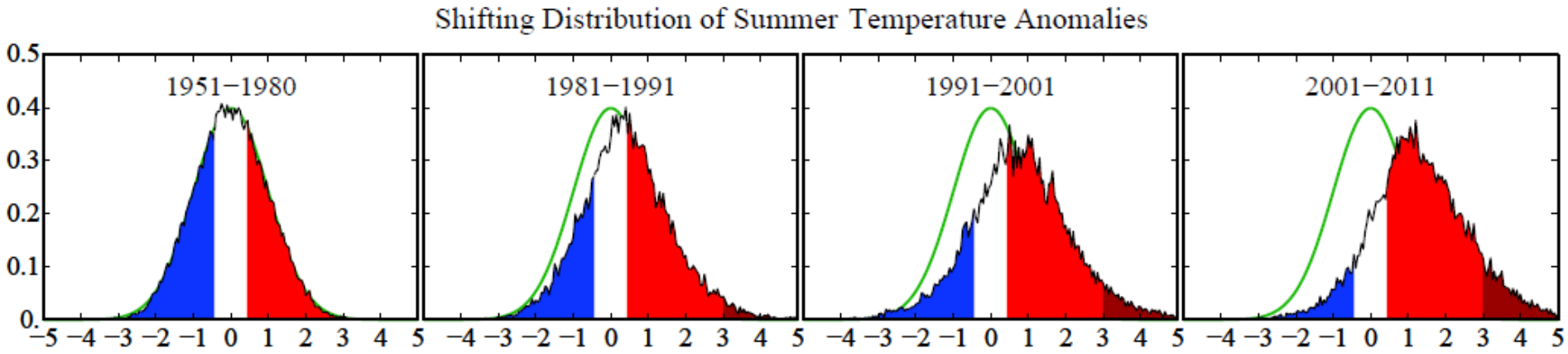
Re-iterating - Global Warming Results:

- Greater warming at High Latitudes:
  - Due to CO_2 being more important as a GHG
  - Increase in H_2O over time as average temperature increases
- Reduction Arctic sea ice changing albedo (reflectivity)
- Melting glaciers changing albedo
- Rising sea levels
- Average temperature increases also changes amount of moisture in atmosphere
- Earlier springs / earlier snow melt
- Ocean acidification

Loaded Climate Dice: global warming is increasing extreme weather events.

Extreme summer heat anomalies now cover about 10% of land area, up from 0.2%.

This is based on observations, not models.



Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land in units of local standard deviation (horizontal axis). Temperature anomalies in the period 1951-1980 match closely the normal distribution ("bell curve", shown in green), which is used to define cold (blue), typical (white) and hot (red) seasons, each with probability 33.3%. The distribution of anomalies has shifted to the right as a consequence of the global warming of the past three decades such that cool summers now cover only half of one side of a six-sided die, white covers one side, red covers four sides, and an extremely hot (red-brown) anomaly covers half of one side.
Source: Hansen, J., Sato, M., and Ruedy, R., Proc. Natl. Acad. Sci., 2012.

So What can WE do?

More Water Vapor
and Clouds

Warmer Air,
Warmer Water
(Global Warming)

Atmosphere
Biosphere
Hydrosphere
Cryosphere
(Climate Change)

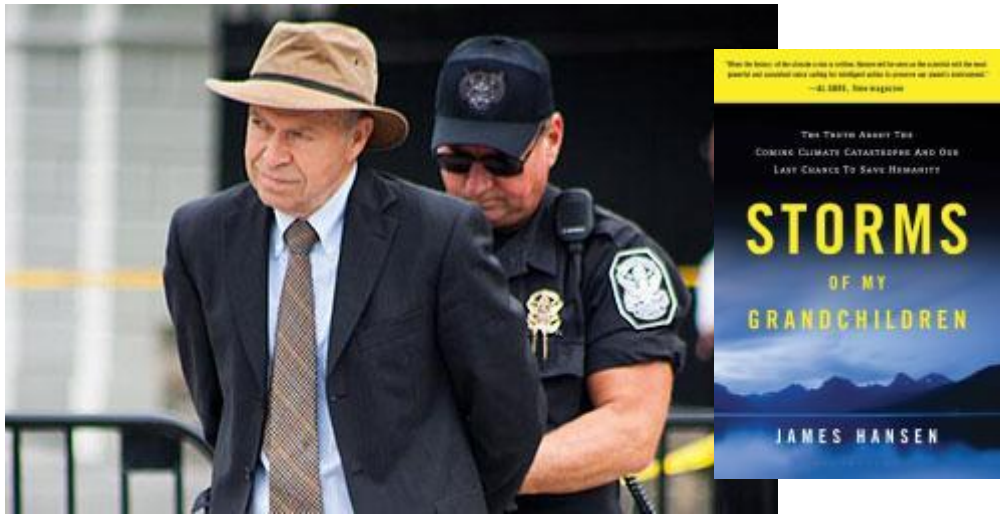
HUMAN RESPONSES
Personal
Family, Friends, Neighbors
Town and City
State
National
International

Courtesy Phil Nelson

60 MINUTES, March 3rd/19: The climate change lawsuit that could stop the U.S. government from supporting fossil fuels

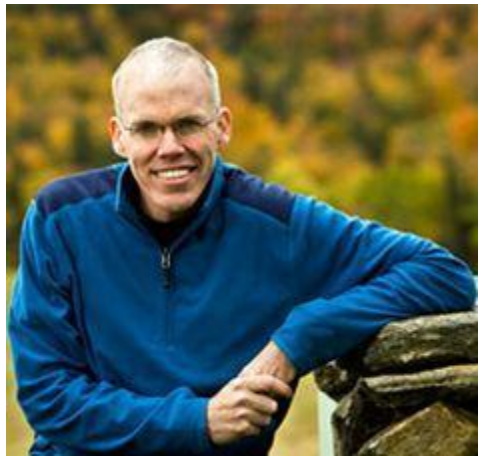
- Mel Mandell: comment
- YouTube – 13 minutes https://www.cbsnews.com/news/juliana-versus-united-states-the-climate-change-lawsuit-that-could-stop-the-u-s-government-from-supporting-fossil-fuels-60-minutes/
- 37 second snip: https://www.cbsnews.com/video/lawsuit-could-put-u-s-governments-role-in-climate-change-on-trial/

Jim Hansen, Bill McKibben among others: activists



Jim Hansen

https://en.wikipedia.org/wiki/James_Hansen
http://www.columbia.edu/~jeh1/



BILL MCKIBBEN
AUTHOR.EDUCATOR.ENVIRONMENTALIST.

https://350.org/

March 24, 2017

Common Dreams | Colorado Youth Score Decisive Legal Victory Against Fracking Industry

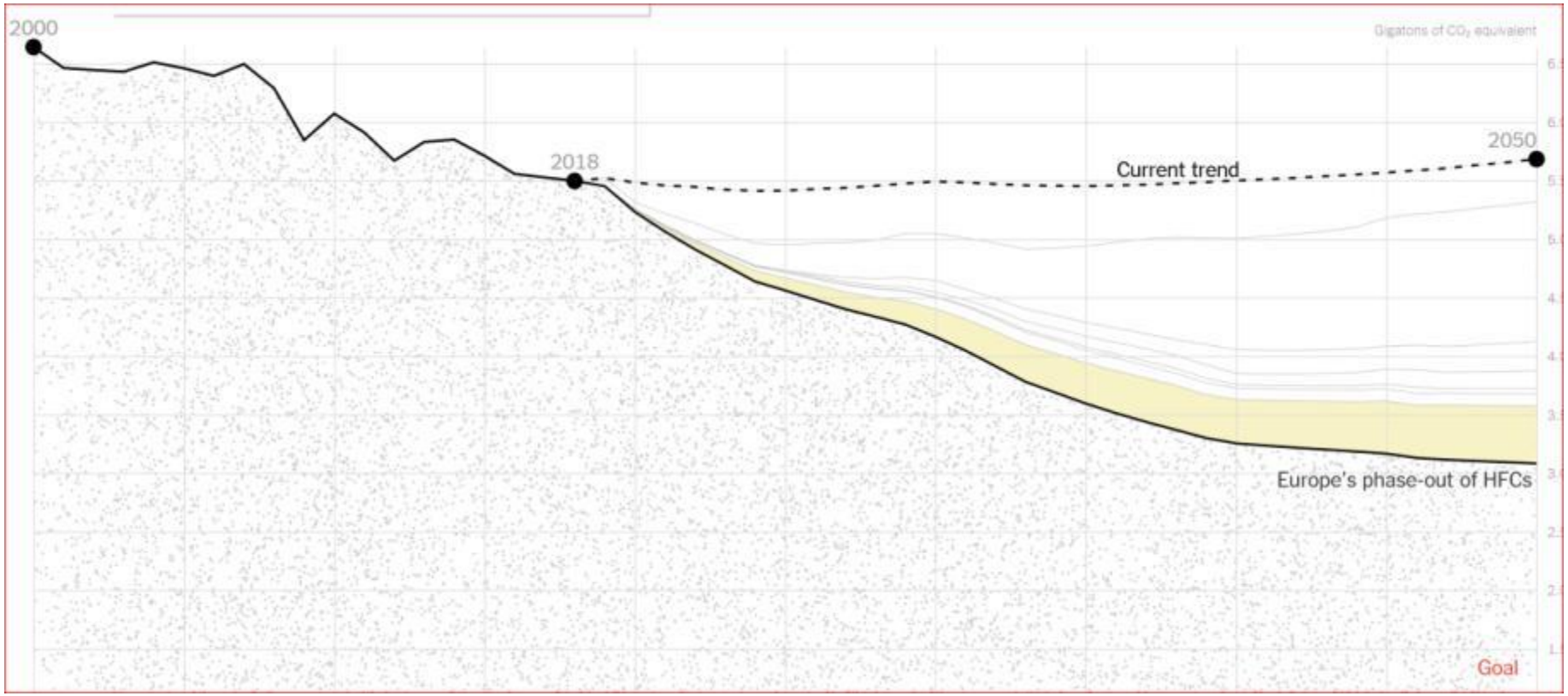
Xiuhtezcatl Martinez, 16-year-old plaintiff and youth director of the Boulder-based Earth Guardians,

https://www.ourchildrenstrust.org/news

Most don’t have a geologic perspective

- It’s the rate of change
- It’s about our sustainability
- Our limits to growth

Solutions - Adoption of 7 policies



- https://www.nytimes.com/interactive/2019/02/13/climate/cut-us-emissions-with-policies-from-other-countries.html?smid=fb-nytimes&smtyp=cur&fbclid=IwAR13rNqUxYrKOomsaKQKotuuYQ1SBUK_lIddhZbL0E9lNp70f9NHhuy8_Nw

Adoption of 7 policies

- **Carbon tax:** The tax on coal, oil and natural gas starts at $7.50 per ton of carbon dioxide in 2020 and reaches $37.50 per ton by 2033. This is based on the rates and schedule for British Columbia's carbon tax, which began in 2008. …
- **Clean electricity standard:** This policy is partly modeled after existing state-level standards. It requires utilities to increase the amount of electricity they produce from carbon-free sources — including wind, solar, nuclear, hydro, geothermal and biomass — until they reach 100 percent clean electricity in 2050. For comparison, California is steadily increasing its clean electricity requirements to 100 percent by 2045, while New York has announced a 2040 goal.
- **Electric vehicle push:** Rather than model Norway's specific set of electric vehicle tax incentives, this scenario assumes that the United States makes a push to match the rapid recent growth in Norway's electric vehicle sales over the next eight years. (Between 2011 and 2018, electric vehicles and plug-in hybrids went from 1.6 percent of new sales in Norway to 49 percent.) After 2027, ….
- **Industrial efficiency standards:** The industrial efficiency gains are based on a 2016 Department of Energy study …..
- **Building codes:** This policy reduces energy use in new homes and buildings. In 2016, the California Energy Commission calculated that the state's stricter building codes would reduce energy-use intensity by 29 percent for residential buildings and 13 percent for commercial …..
- **Methane standards:** Canada's methane rules aim to reduce emissions from oil and gas operations 40 to 45 percent below 2012 levels by 2025. …
- **HFC phaseout:** This….

Why it’s not enough

PAST: MONDAY March 26TH: CO2 Removal and Nature Conservancy presentation by Betsy Neely + What is and the Need for Biochar by Paul Belanger

slides and links added below

Handout: 2018.03.26x Nat Climate Solutions Forum handout half-page

Part A: Why PRICING IS NOT ENOUGH & WHY WE NEED SEQUESTRATION! – Paul Belanger

- Pptx: TROUBLE LOADING contact me pebelanger@glassdesignresources.com if copy desired
- Pdf: 2018.03.26 Belanger-why pricing is no enough EEEF

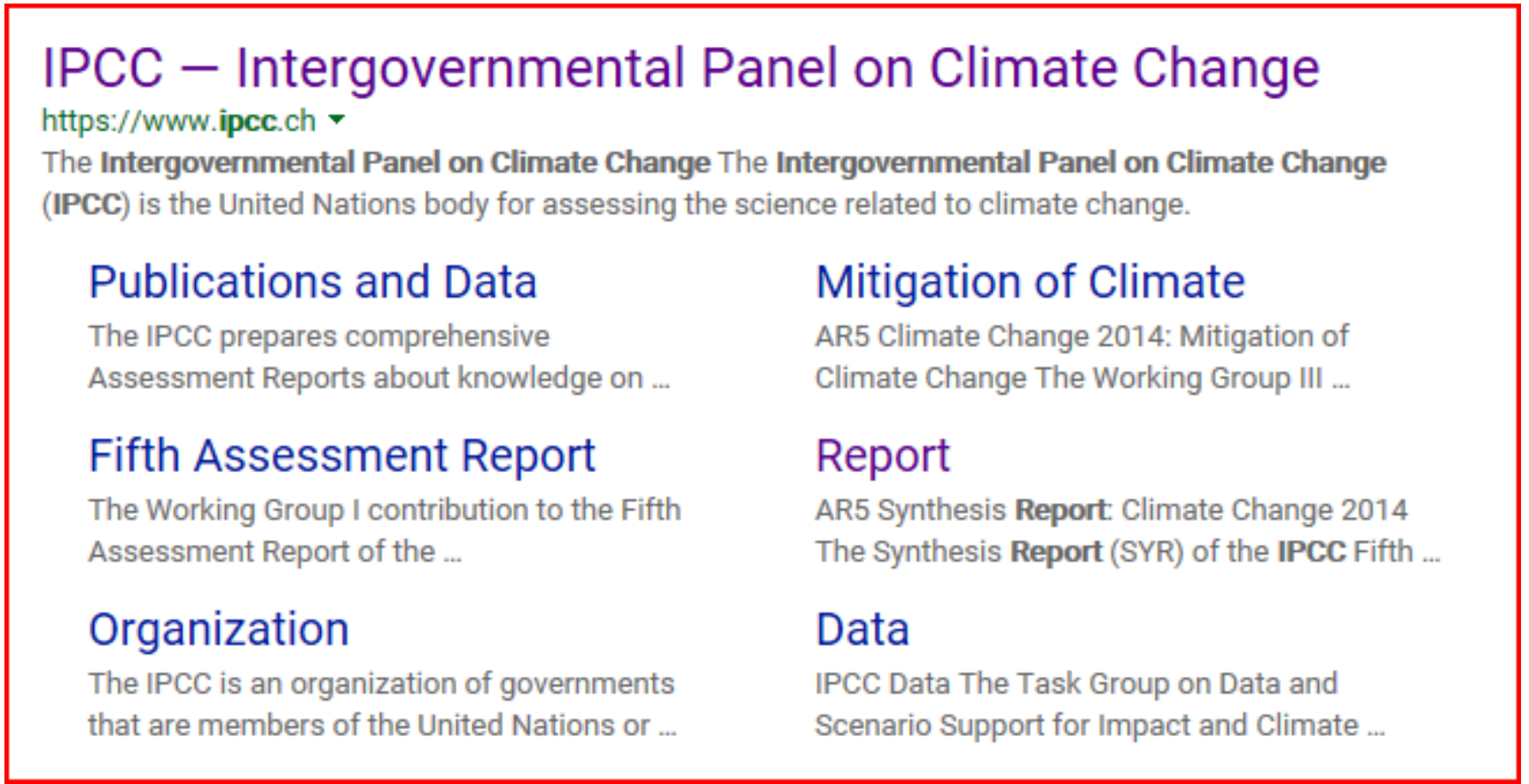
Part B: NATURAL CLIMATE SOLUTIONS – Betsy Neely

*How great a contribution can **nature itself**—e.g., forests, grasslands, wetlands, etc.—make to storing and reducing global carbon emissions?*

https://denverclimatestudygroup.com/?page_id=683

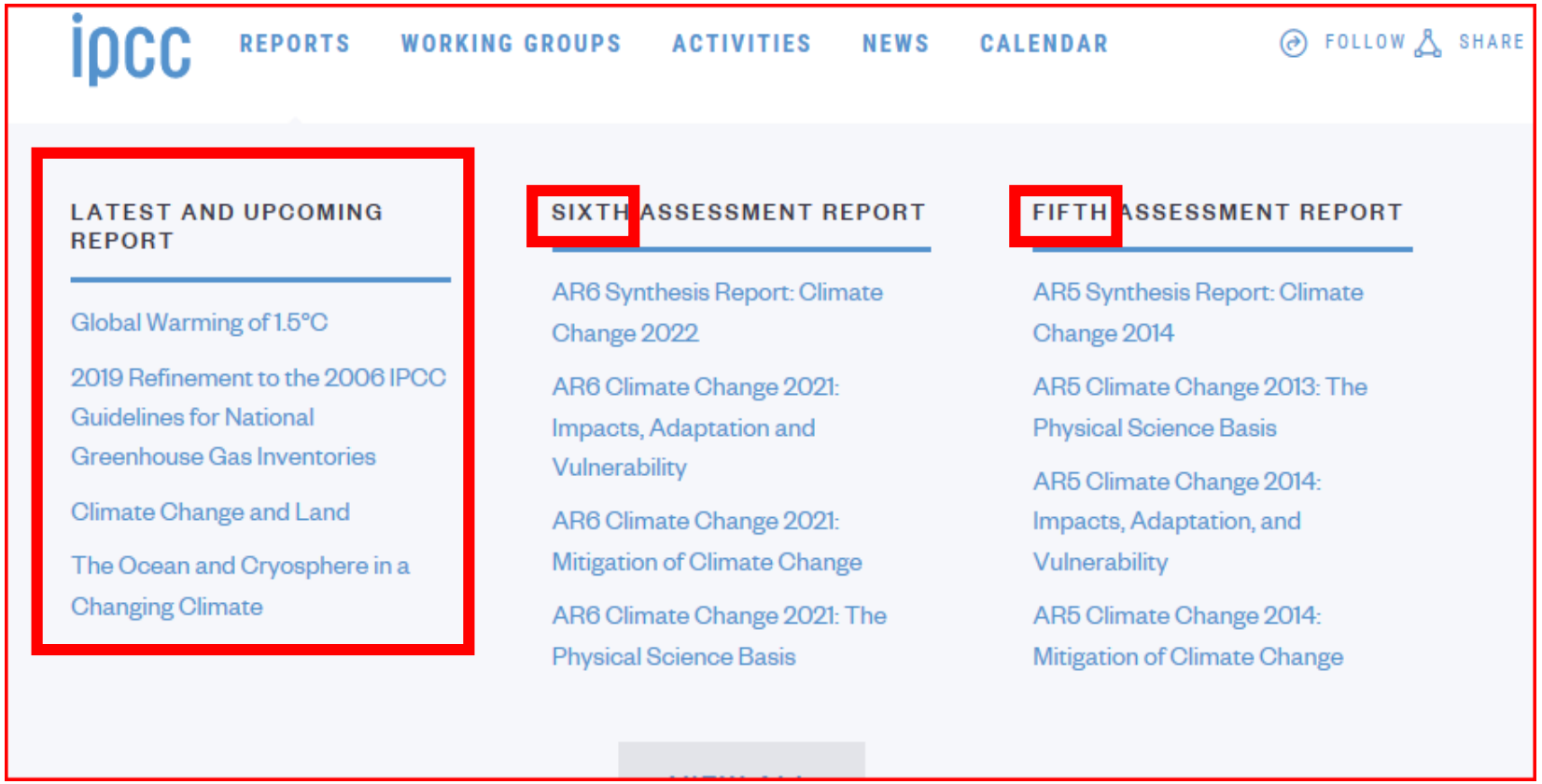
IPCC — Intergovernmental Panel on Climate Change

[IPCC — Intergovernmental Panel on Climate Change](https://www.ipcc.ch/) -- https://www.ipcc.ch/



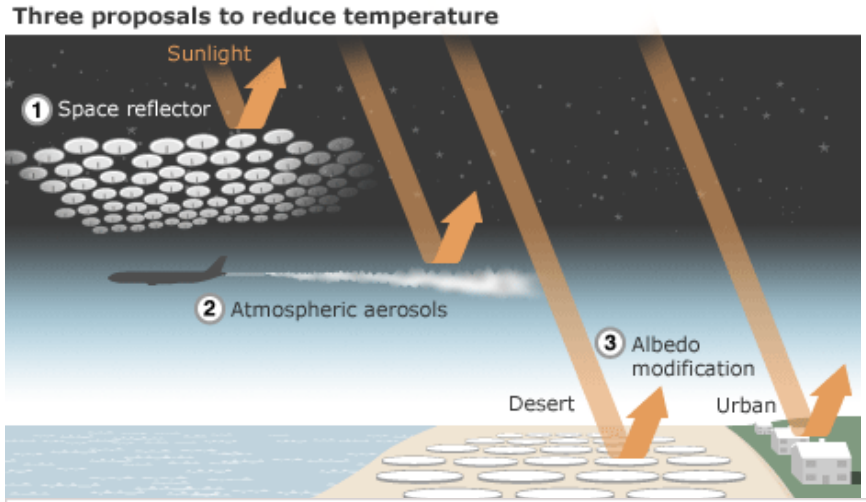
IPCC REPORTS

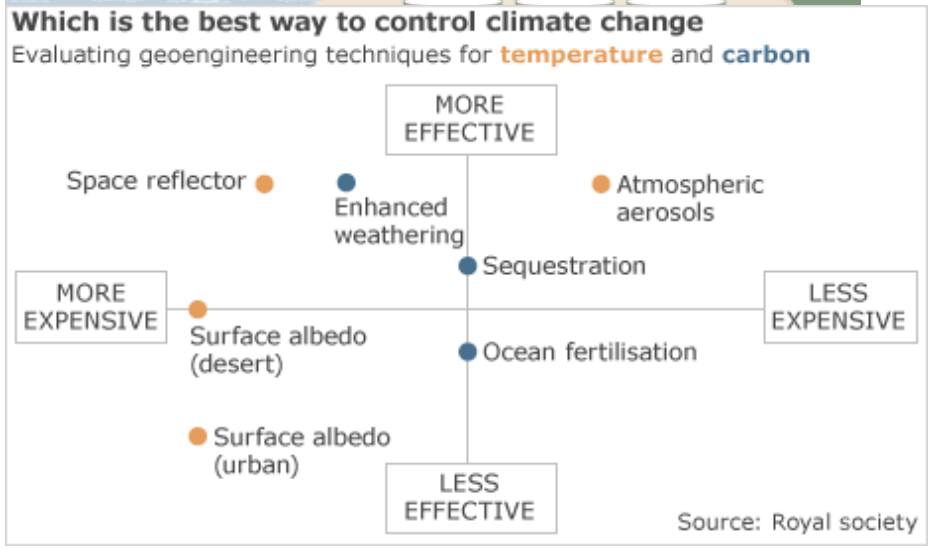
Assessment reports (AR #) with 3 working groups:

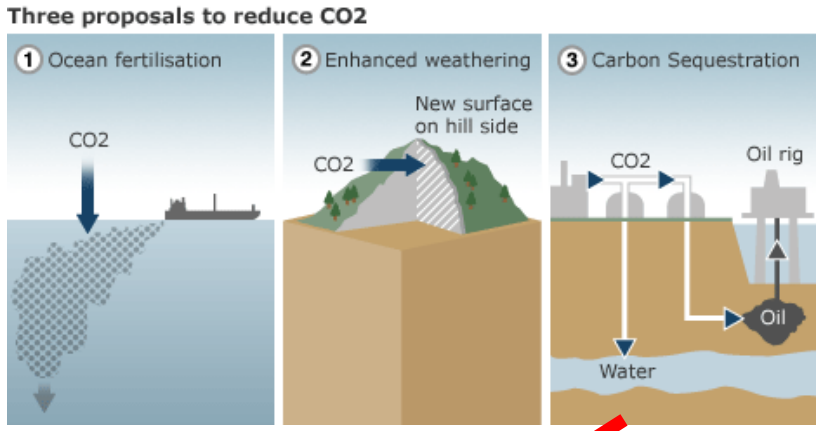


IPCC — Intergovernmental Panel on Climate Change -- https://www.ipcc.ch/

Solar Radiation Management vs. Carbon dioxide Removal (SRM VS. CDR)





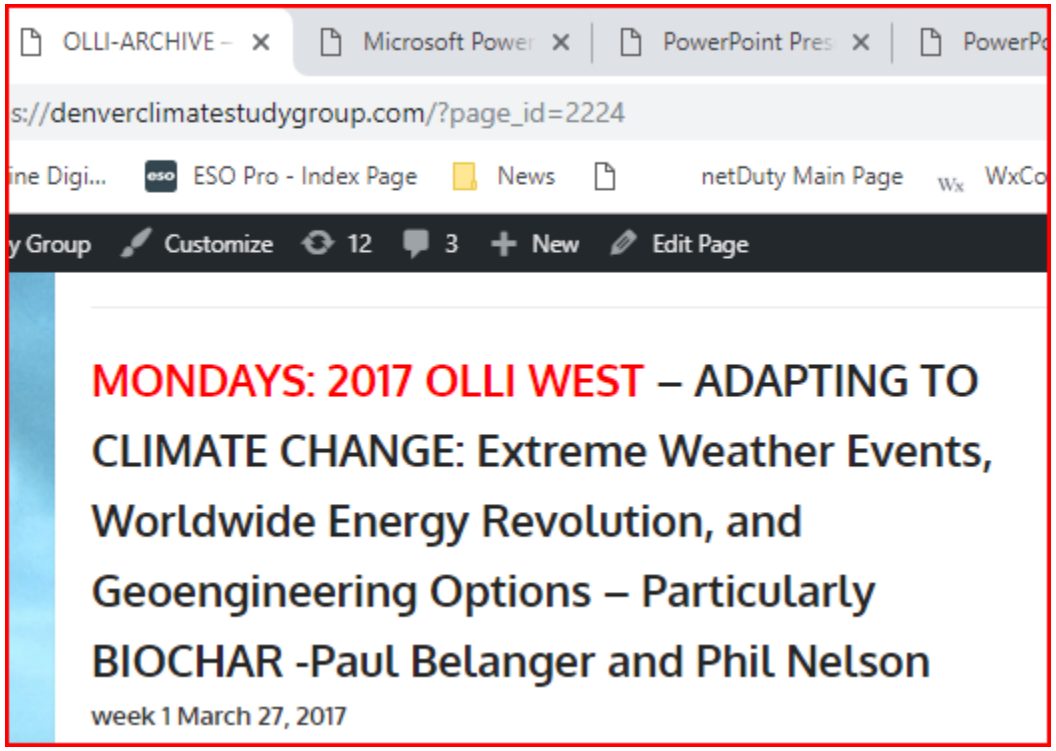


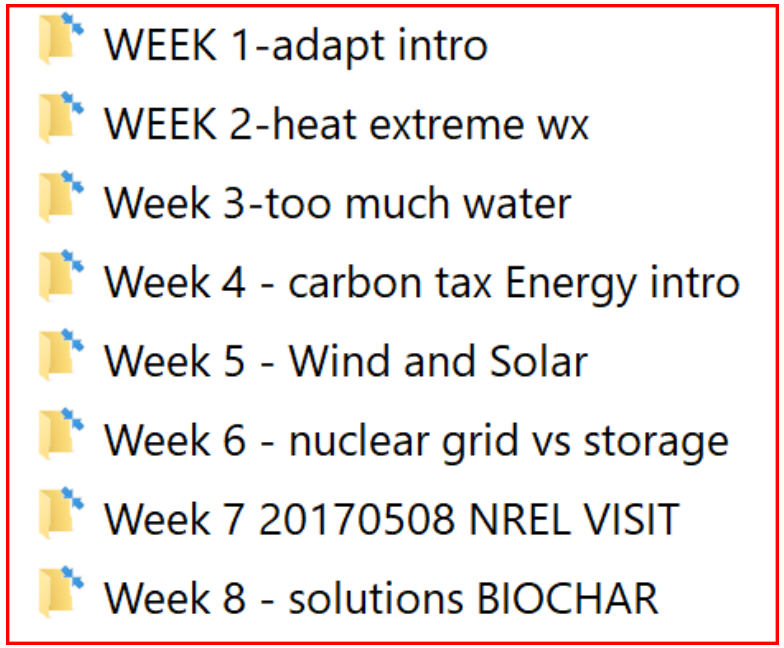
Biochar & Beccs

- https://en.wikipedia.org/wiki/Biochar
- https://en.wikipedia.org/wiki/Bio-energy_with_carbon_capture_and_storage

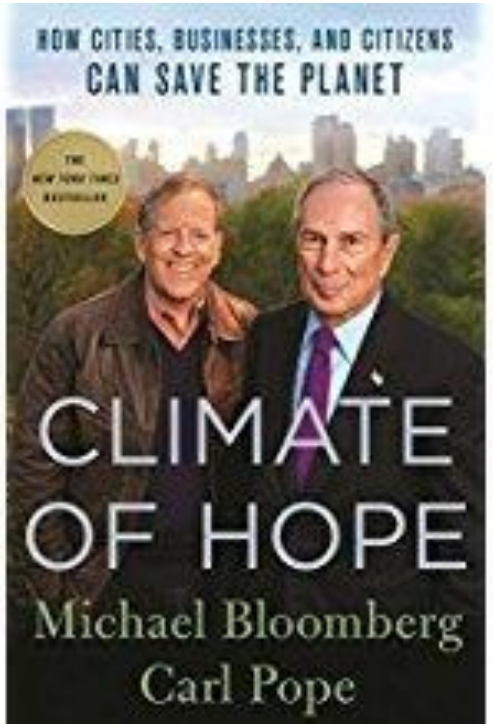
OLLI West – Spring 2017

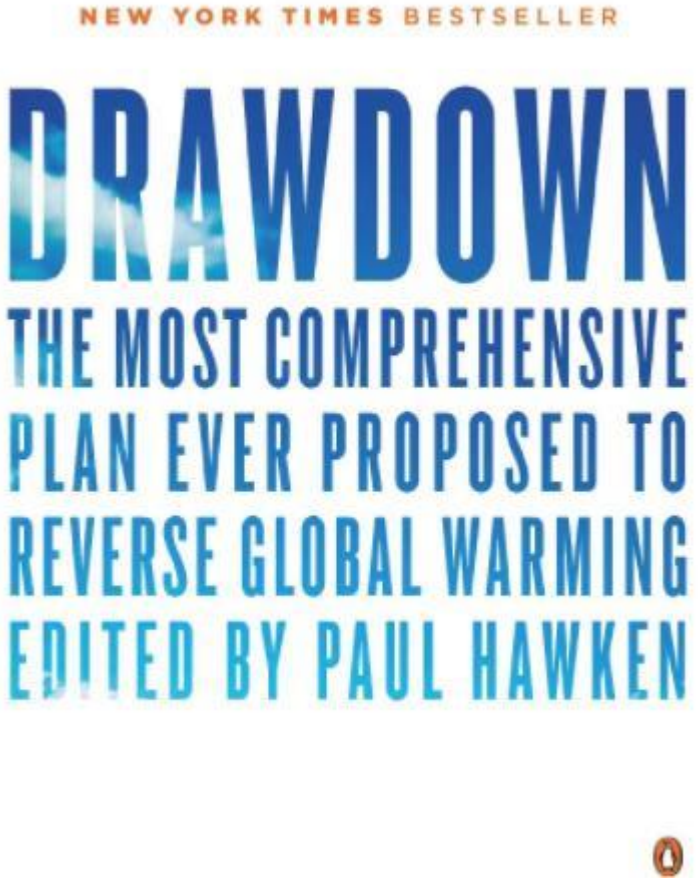
- Spent 6 of the 8 weeks on solutions
- https://denverclimatestudygroup.com/?page_id=2224





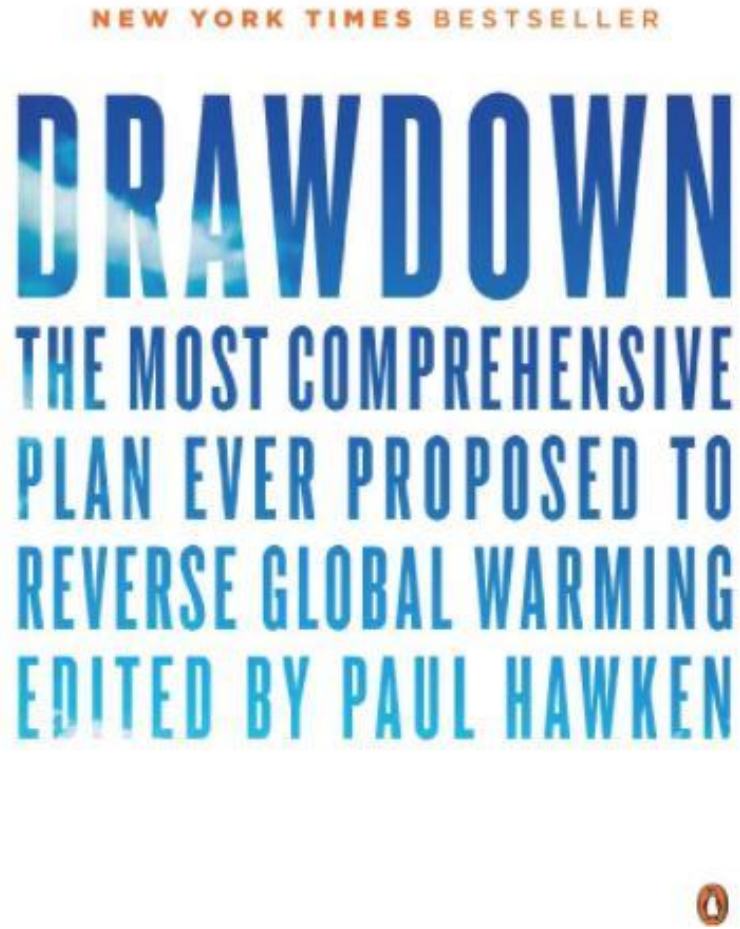
- READ:
  Climate of Hope – Solutions Drawdown – and associated web pages





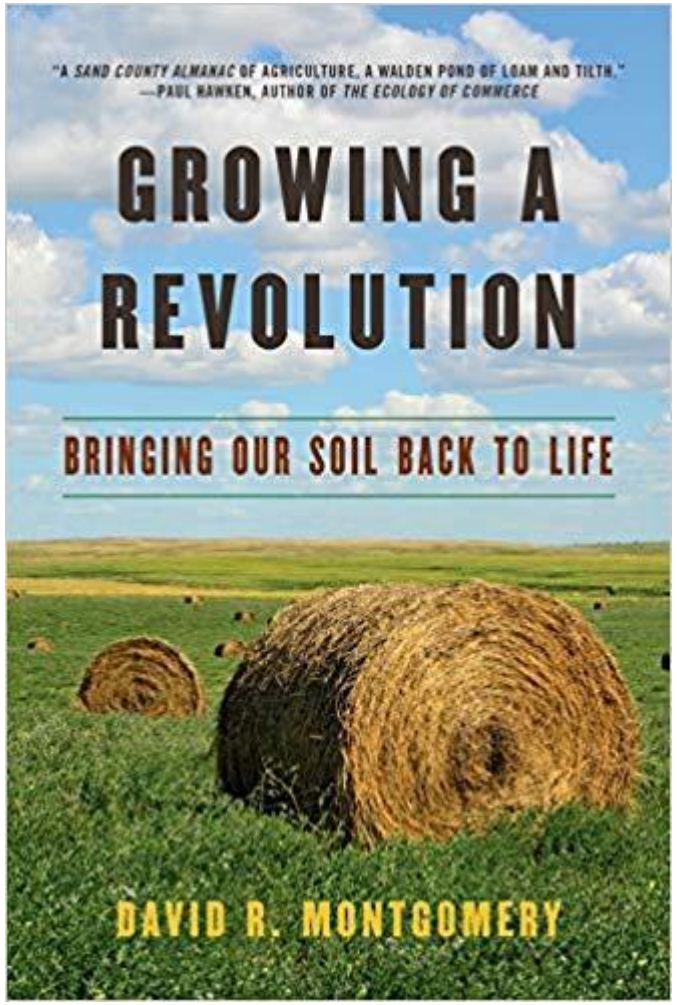
Drawdown

http://www.drawdown.org/solutions-summary-by-rank



- Drawdown video: 60 minutes with Paul Hawken: https://youtu.be/4XrFnK1RrLE

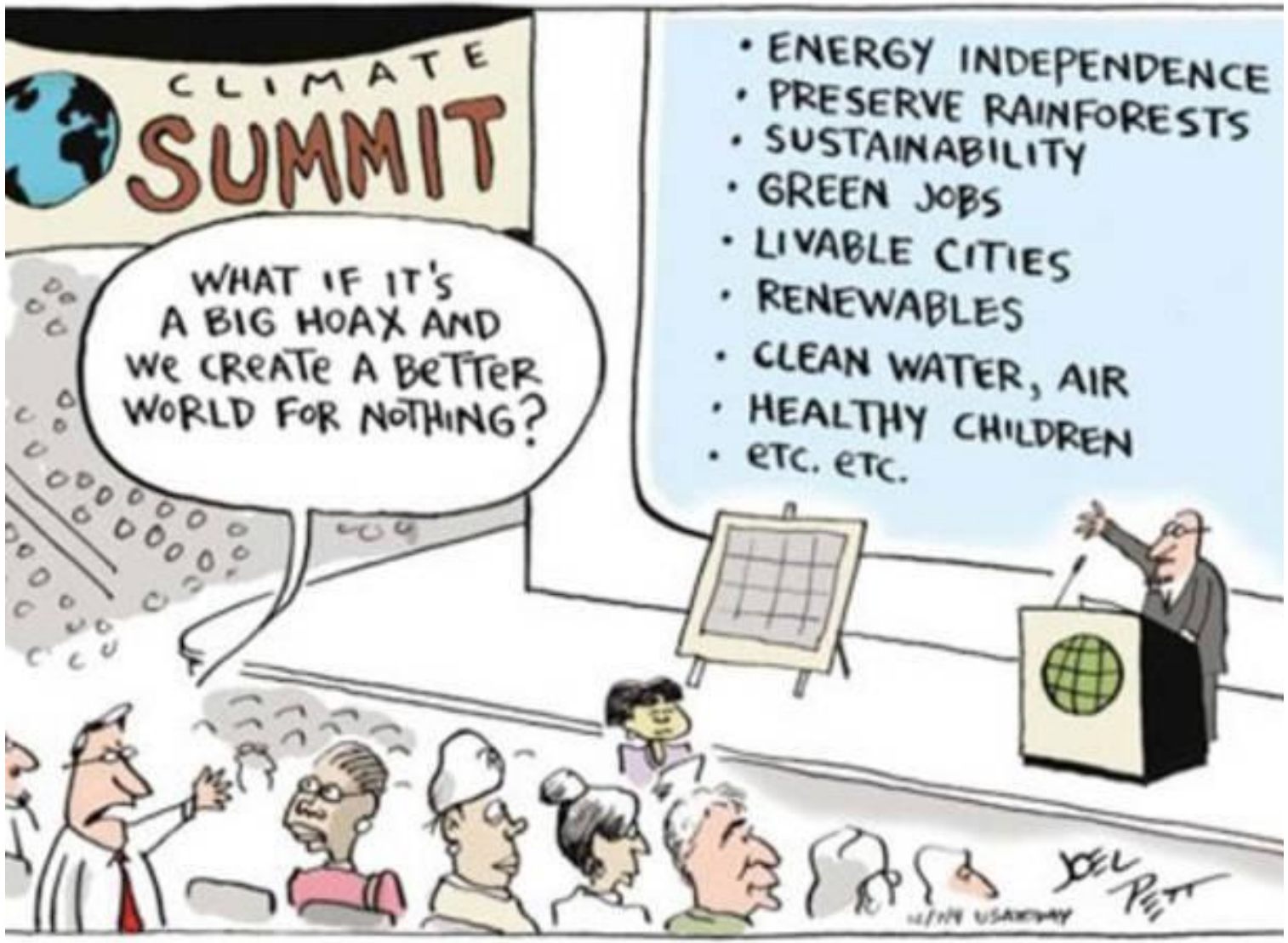
Soil Restoration: BIOCHAR and Other Short & Long-term practices



https://www.yesmagazine.org/issues/dirt

BIOCHAR PAGE:
https://denverclimatestudygroup.com/?page_id=28

What if?



Joel Pett

In closing

“ASK NOT WHAT YOU OUGHT TO DO, RATHER ASK WHAT YOU MUST DO!”
(attributed to a philosopher – please let me know who)

AND

For those that say “it can’t be done” I say: Stay out of the way of those that are DOING IT!

Web Links Energy/Other

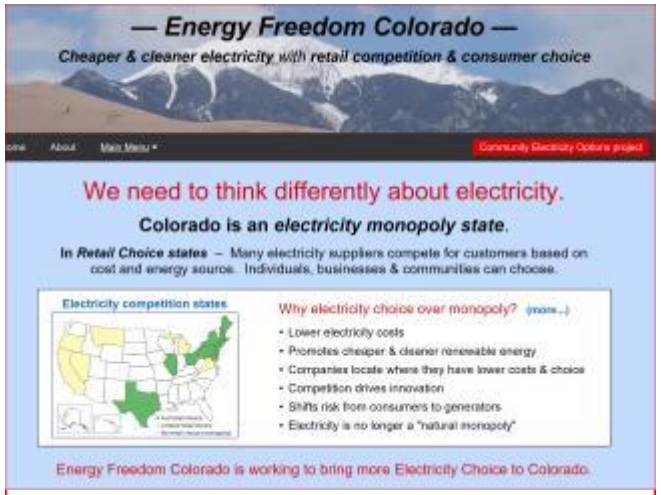
- **U.S. Energy Information Administration** https://www.eia.gov/
- **CRES** https://www.cres-energy.org/
  - YouTube https://www.youtube.com/channel/UCr81EUb2qVJVfmmlJMxEHVw
  - NREL Presentation: GREG WILSON https://www.youtube.com/watch?v=7CDPHxcnq4c&t=23s
  - Governor Ritter Presentation https://www.youtube.com/watch?v=agowW1QKwms&t=6s

- https://www.skepticalscience.com/
  - https://skepticalscience.com/How-Green-is-My-EV.html
- http://energyshouldbe.org/
  - Why Storage is Key for a Renewable Energy Future: https://www.youtube.com/watch?v=Yc_hULwykvQ&t=13s
  - Clean Energy through Open Electricity Markets: https://www.youtube.com/watch?v=seGwTKTm38A

Ken Regelson links

- EnergyFreedomCO.org
  - Innovation and lower costs through competition.

  Beginners, start here
  - The U.S. electricity system
  - Energy Freedom basics
  - Why restructure monopolies?
  - ***Terms and definitions***
- EnergyShouldBe.org - 100% Renewables
  - **Penguins & 100% Renewable Energy in 20 Years -** https://youtu.be/sRJquTFAGVU
  - **To Allow Lots of Renewables, Baseload Coal & Nuclear Must Go https://youtu.be/deWtgpheDJM**
  - **Modeling Electric Load & Renewables. Video and free spreadsheet model to download (scroll down for the link to the spreadsheet itself). (13 minutes) https://youtu.be/RVdJeAcuUZI**
  - others



Click Here for

General Audience Videos

Mildly Technical Videos

Technical Audience Videos

Newest Videos

Most Popular Videos

CRES YouTube Channel:

https://www.youtube.com/channel/UCr81EUb2qVJVfmmlJMxEHVw/videos

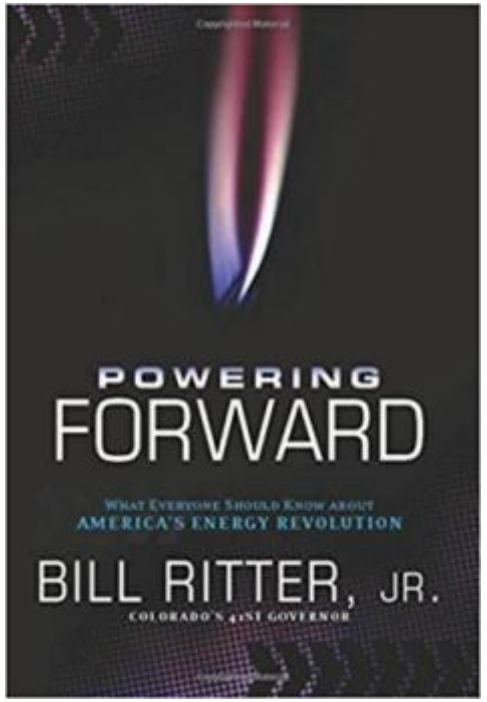
- Tony Seba: Clean Disruption - Energy & Transportation
  - https://youtu.be/2b3ttqYDwF0
- Ramping Up Solar to Power the World - Greg Wilson, NREL
  - https://youtu.be/7CDPHxcnq4c
- Driverless Cars and the Environment - Rutt Bridges, Futurist
  - http s://youtu.be/0BWJcpesr6A
- Bill Ritter - Powering Forward. The Clean Energy Revolution can't be stopped
  - https://youtu.be/agowW1QKwms
- Drawdown: 60 Minutes with Paul Hawken
  - https://www.youtube.com/watch?v=4XrFnK1RrLE
- Can Hydrogen Save our Energy System Mark Ruth, NREL
  - https://www.youtube.com/watch?v=4u93y-l0cwM&t=199s
- 100% Renewables: Let's Go! (Ken Regelson - 2/6/16)
  - https://youtu.be/xDBPE6ZUGXQ
- Why Storage is Key for a Renewable Energy Future
  - https://youtu.be/Yc_hULwykvQ

Links to active groups

- https://citizensclimatelobby.org/
- Fb -https://www.facebook.com/CitizensClimateLobbyDenverChapter/
- https://www.eldersclimateaction.org/
- Fb - https://www.facebook.com/eldersclimateaction/
- 100 solutions: https://www.ted.com/talks/chad_frischmann_100_solutions_to_climate_change

Powering Forward: …America's Energy Revolution

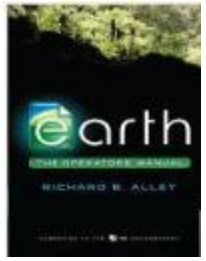
- **A historic energy revolution is underway in the United States & THE WORLD:**
  - **Wind, sunlight, and other sustainable resources**
  - **Power plants on their roofs**
  - **Entire communities are switching to 100 percent renewable energy; Hawaii has such a commitment!**
  - **Urgent need to prevent climate change is causing people around the planet to question their reliance on carbon-intensive oil, coal, and natural gas.**



Three books to consider:

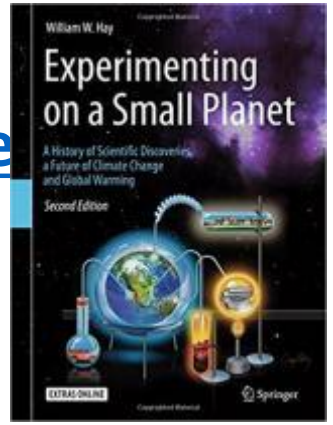
- **Simple succinct Summary:**
  - What We Know About Climate Change (Boston Review Books) by Kerry Emanuel (Nov 30, 2012)

- **Intermediate Level Book:**
  - Earth: The Operators' Manual by Richard B. Alley (Apr 18, 2011)
  - http://earththeoperatorsmanual.com/



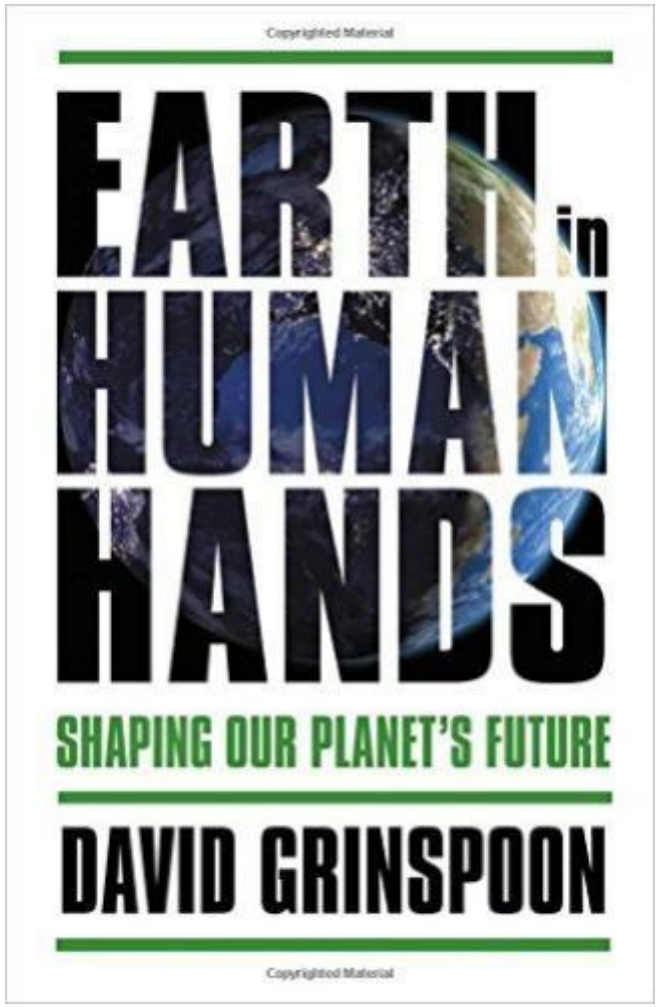
- **More comprehensive book:**

  Experimenting on a Small Planet: A History of Scientific Discoveries, a Future of Climate Change and Global Warming 2nd ed. 2016 Edition



We are a planet with brains

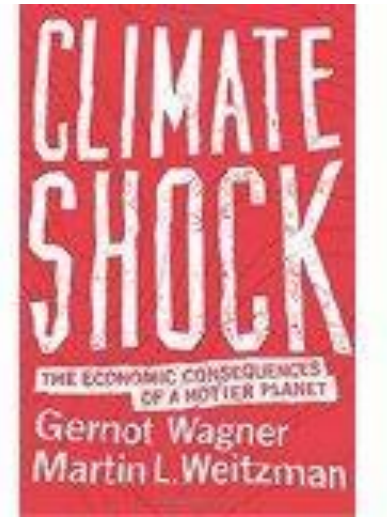
- Climate change is only the most visible of the modifications we've made--up until this point, inadvertently--to the planet.
- And our current behavior threatens not only our own future but that of countless other creatures.
- ….shows what a strange and novel development it is for a species to evolve to build machines, and ultimately, global societies with world-shaping influence.



BTW – David Grinspoon will be at Conf. World Affairs (CWA), Boulder NEXT week of 4/8: http://www.colorado.edu/cwa/

Another book to consider:

- **Economics:**
  - Climate Shock; the economic consequence of a hotter planet
  - by Gernot Wagner & Martin Weitzman



QUIZ

- What do you call it when a fast food hamburger hits your windshield?

…answer: A WINDSHIELD WHOPPER