

Earth's Climate: Past, Present and Future
OLLI Central Spring 2016 -
week 7 & week 8 (May 18th)
Paul Belanger

Solutions – part B

1. Economics
 - of doing nothing (solely adapting) vs. the economics of mitigation
 - Actuality: it WILL be a combination
2. Capitalism, GDP/growth based economics vs. “Herman Daly” economics (no-growth/steady-state)
3. Solutions? Paradigm shift? From we can't/too expensive to WE CAN
4. There is promise, but at what cost? (One might be surprised).
 - Energy
 - Mitigation – Agricultural revolution/biofuels: Biochar for Carbon Dioxide Removal (CDR)

Solutions – part B continued

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
http://denverclimatestudygroup.com/?page_id=28
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

Earth's Climate: Past, Present and Future

Solutions – part B

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

SEE February 15, 2016 discussion on EEE tab:

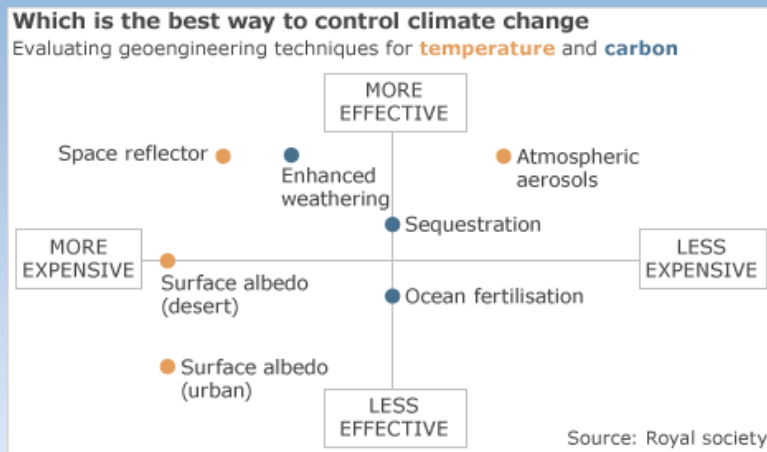
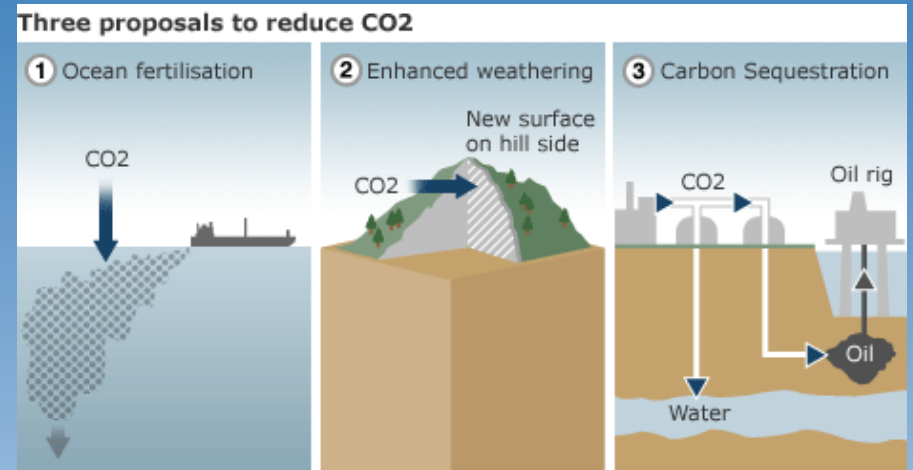
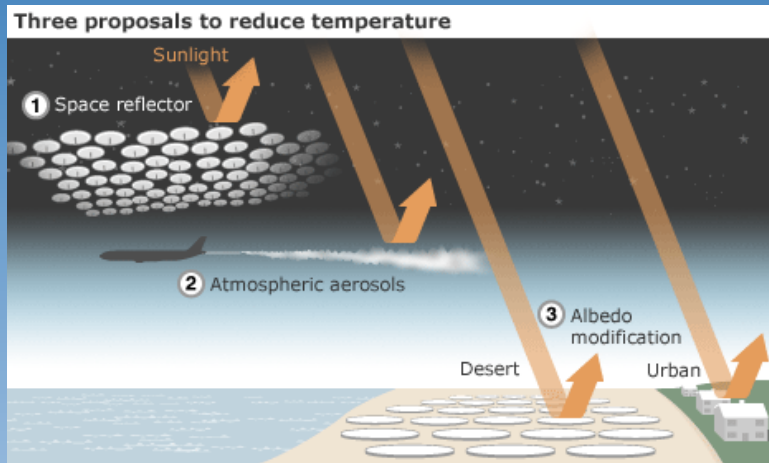
http://denverclimatestudygroup.com/?page_id=683

- **NAS Climate Intervention: Preface and links ([Click here](#)); detailed reports below:**
 - **NATIONAL ACADEMY OF SCIENCES ONLINE: *CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH* (2015), AT [HTTP://WWW.NAP.EDU/READ/18988](http://www.nap.edu/read/18988);**
 - **AND *CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION* (2015), AT [HTTP://WWW.NAP.EDU/READ/18805](http://www.nap.edu/read/18805).**

AR5; WGIII Mitigation

- [WGIII_AR5_Presentation](#) or in [PDF format](#)
- [wg3_ar5_summary-for-policymakers_approved](#)
- **Video – the geoengineering dilemma 4.5**
7.3 minutes <https://www.futurelearn.com/courses/climate-change-challenges-and-solutions/1/steps/3297>
- **Are Ideas to cool the planet realistic**
<http://news.bbc.co.uk/2/hi/technology/8338853.stm>

SRM VS. CDR



Mitigation and adaptation – 7.1 3.35 minutes

Earth's Climate: Past, Present and Future

Solutions – part B

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. CDR: Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
http://denverclimatestudygroup.com/?page_id=28
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

Biochar

- Definition: <https://en.wikipedia.org/wiki/Biochar>
- Biochar tab: http://denverclimatestudygroup.com/?page_id=28





2. Carbon Dioxide Removal (CDR)



- <https://en.wikipedia.org/wiki/Biochar>:

“**Biochar** is [charcoal](#) used as a [soil amendment](#). Like most charcoal, biochar is made from [biomass](#) via [pyrolysis](#). Biochar is under investigation as an approach to [carbon sequestration](#) to produce [negative carbon dioxide emissions](#).^[1] Biochar thus has the potential to help mitigate [climate change](#) via carbon sequestration.^{[2][3]} Independently, biochar can increase [soil fertility](#) of [acidic soils](#) (low pH soils), increase agricultural productivity, and provide protection against some foliar and soil-borne diseases.^[4] Furthermore, biochar reduces pressure on [forests](#).^[5] Biochar is a stable solid, rich in [carbon](#), and can endure in soil for thousands of years.^[1]”

Cool Planet - @ 9:00 minutes

- https://youtu.be/JPIsYZLU_sM?t=535



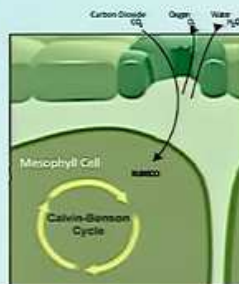
Rapid Growth C4 Plants Can Capture 10X CO₂

C3

- Trees
- Shrubs
- Flowers



Soybeans

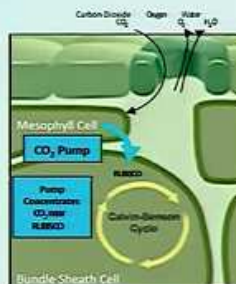


C4

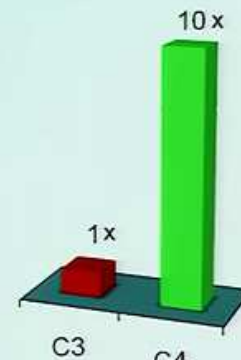
- Corn
- Switchgrass
- Sugarcane



Sorghum



Carbon Capture



C3

C4

Photosynthesis Cycles
Source: Wikipedia

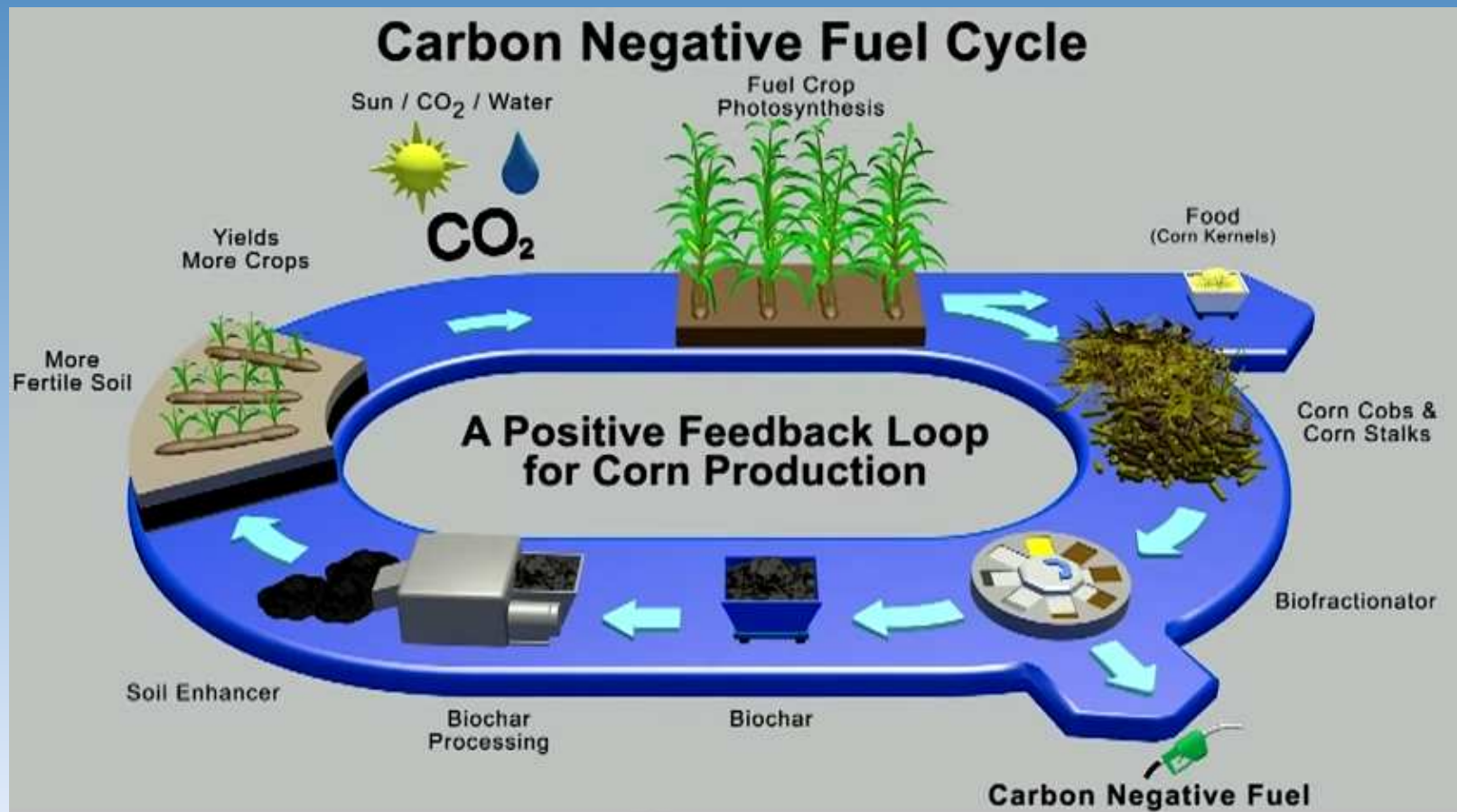
C4 plants have a more efficient system of processing CO₂ than C3 plants

Source: Taub, D. Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants. Nature (2010)
Source: Wikipedia, C4 carbon fixation, WEB, http://en.wikipedia.org/wiki/C4_plants (2011)

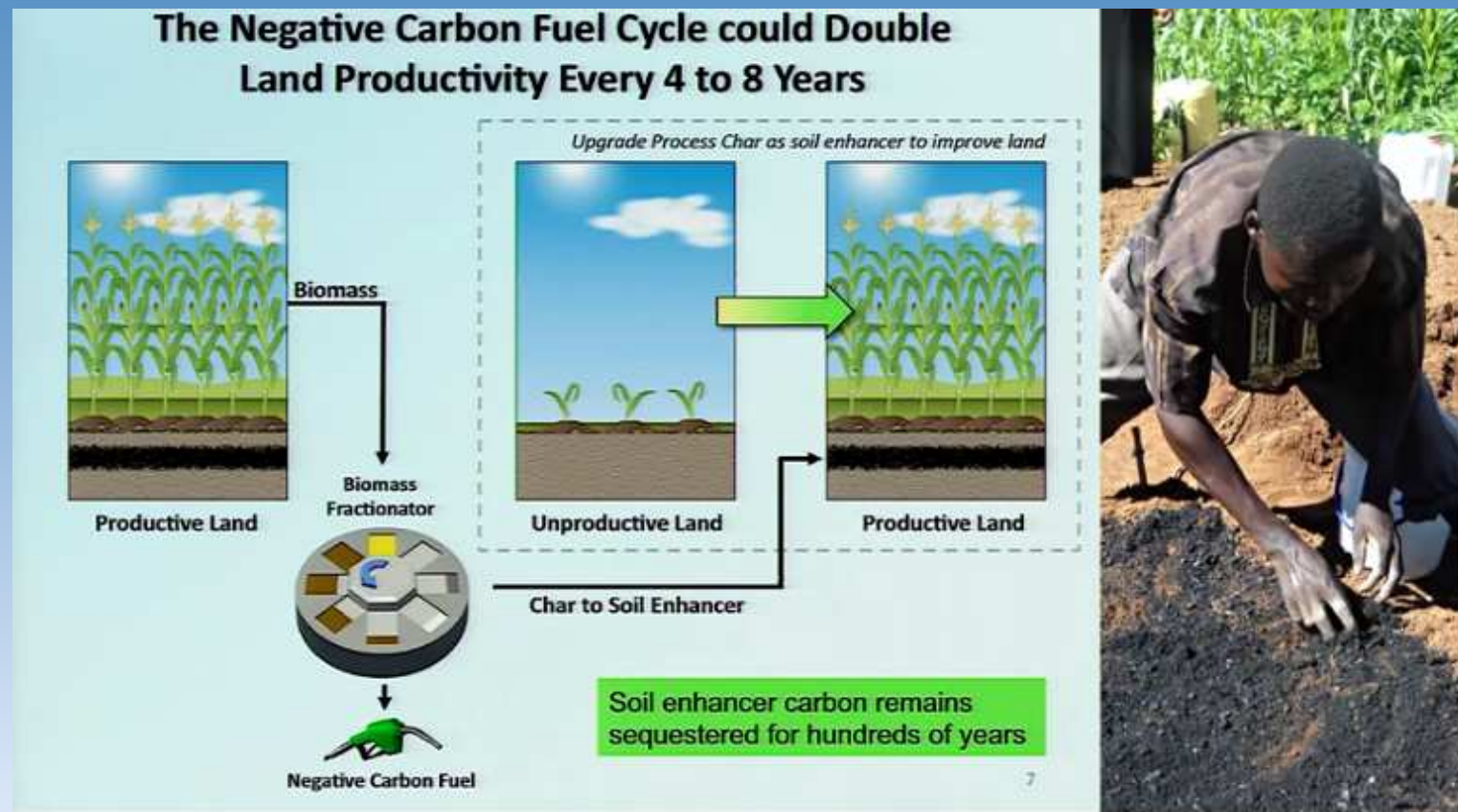


- About C3, C4 and Cam Photosynthesis and Plants:
- Photosynthetic efficiency: http://en.wikipedia.org/wiki/Photosynthetic_efficiency
- C3 carbon fixation: http://en.wikipedia.org/wiki/C3_carbon_fixation
- C4 carbon fixation: http://en.m.wikipedia.org/wiki/C4_carbon_fixation
- Summary table comparison: <http://www.cropsreview.com/types-of-photosynthesis.html>
- C3 C4 CAM Photosynthesis video: https://www.youtube.com/watch?v=Yg_pdXzWXVA

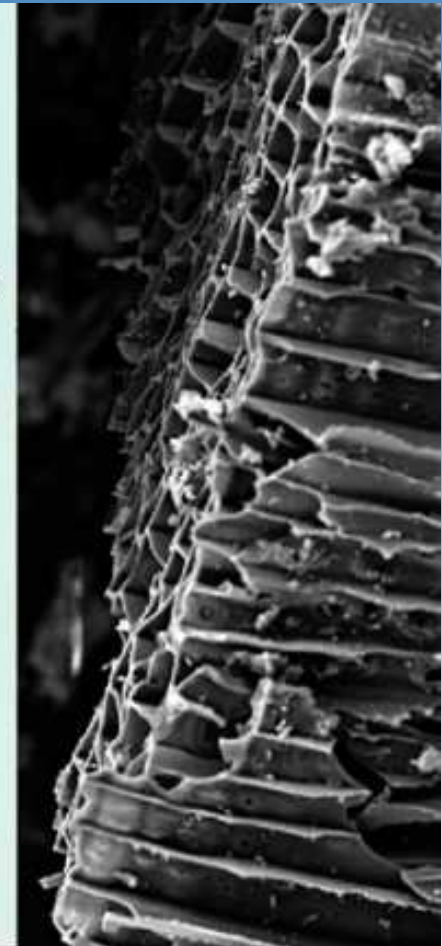
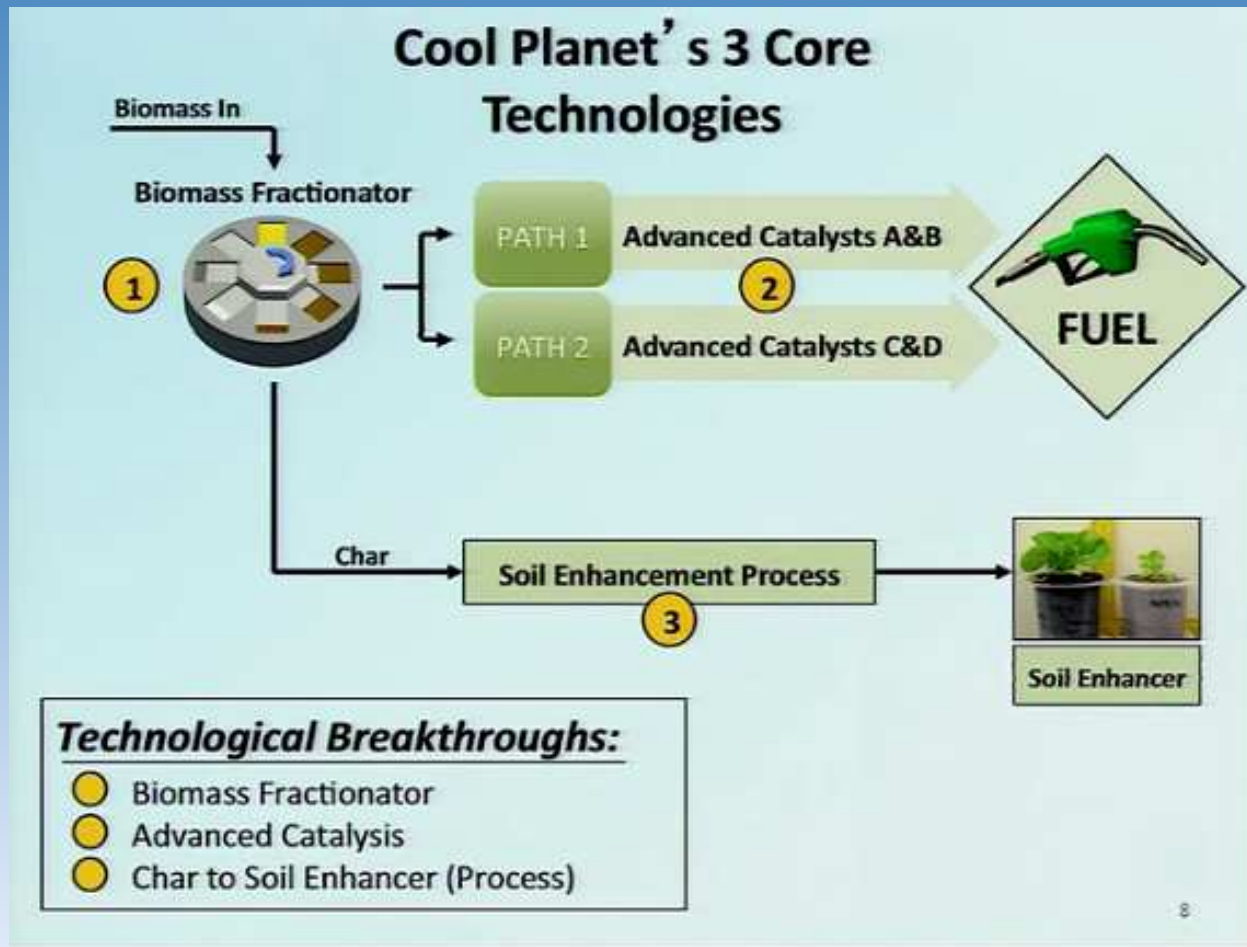
Carbon negative fuel cycle: Biochar and biofuels



Soil Enhancement



3 Core Technologies:





Current Plans to Deploy the Negative Carbon Fuel Cycle



Commercial Plants - 50 million gallons a year
(2,000 plants worldwide – developed world)

Google
ventures



Constellation

ConocoPhillips



NORTH BRIDGE
venture partners

Shea Ventures



Global Village Plants - 1 million gallons a year
(100,000 plants worldwide – emerging world)

As suggested by:

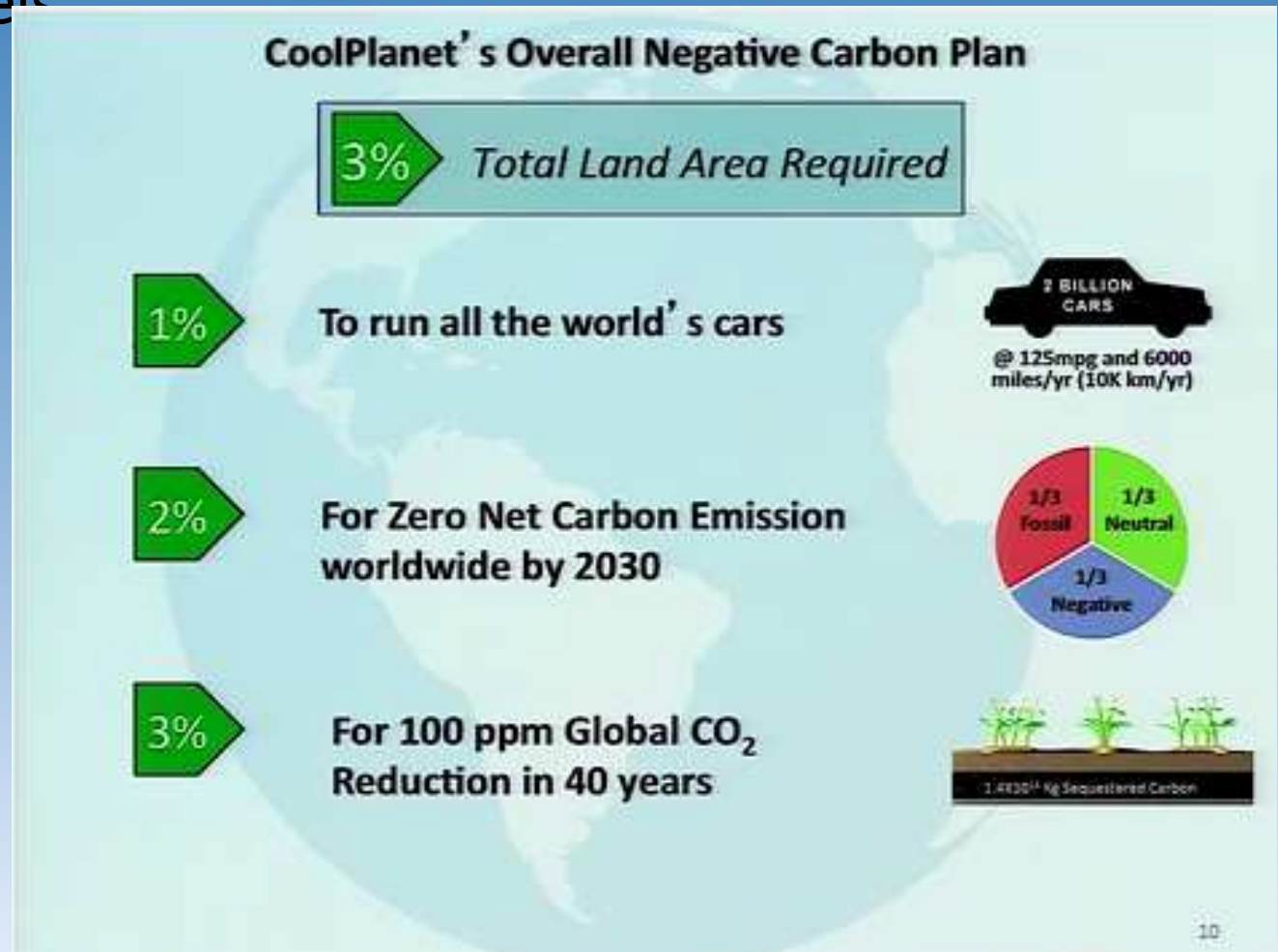
google.org

Up to 8X gain in village income by
increasing energy & food production
while bringing the village into
the information society



CARBON NEGATIVE BENEFITS:

- Sequester CO₂
- create Biofuels



Bio-energy with carbon capture and storage BECCS

Bio-energy with carbon capture and storage

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

Earth's Climate: Past, Present and Future

Solutions – part B

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

National Renewable Energy Lab: NREL

- <http://www.nrel.gov/>
- [OSHER 10.14.15](#)

Earth's Climate: Past, Present and Future

Solutions – part A

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

SOLUTIONS

Carbon fee/dividend:

- citizensclimatelobby.org/ccl-applauds-republican-resolution-calling-for-action-on-climate-change/
- <http://citizensclimatelobby.org/>
- Facebook:
 - CCI – national: <https://www.facebook.com/CitizensClimateLobby/?fref=ts>
 - CCL-Colorado: <https://www.facebook.com/CitizensClimateLobbyDenverChapter/>

5. Geoengineering:

- Solar Radiation Management (SRM) and
- Carbon Dioxide Removal (CDR)

6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:

7. Efficiency – the single quickest way to reduce:

- What NREL is doing: Efficiency, Solar, wind, other

8. Other strategies:

- CCL – carbon fee/dividend
- Cap and trade?

9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

IN SUMMARY

1. The world has been getting better
2. **Changes** are happening; **WE NEED TO CHANGE:**
 - 25+ Ways to Reduce Your Carbon Footprint:
<http://cotap.org/reduce-carbon-footprint/>
3. We need to support science and new technologies

25 charts and maps that show the world is getting much, much better

- <http://www.vox.com/2014/11/24/7272929/charts-thankful>

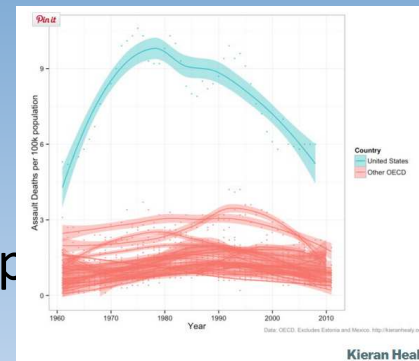
So – let's not regress; let's continue to improve our world and transition to a new future: A NEW NORMAL

There are few, if any, historical examples of civilizations consciously making sacrifices on behalf of descendants two or more generations removed.

- In that regard **we need a social paradigm shift**
- Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

1. ECONOMIC PROGRESS: Extreme poverty has fallen
2. Hunger is falling
3. Child labor in decline
4. More leisure time
5. Income spent on food has plummeted in US
6. Health care: life expectancy is rising
7. Child Mortality is down
8. Death in childbirth is rarer
9. People are getting taller
10. More people have access to malaria bednets

11. Guinea worm is almost eradicated
12. Teen births in US are down
13. As is smoking
14. War is on the decline
15. Homicide rates are down in Europe
16. And the US too
17. Violent crime declining
18. Rapidly reduced the supply of nuclear weapons
19. More countries are democracies
20. More people going to school longer



- 21. Literacy is up as well
- 22. US unsheltered homeless declined nearly 32% since 2007
- 23. Moore's law is still going (# transistors on a chip doubling) i.e. greater computer power
- 24. Access to internet increasing
- 25. Solar power is getting cheaper

Who will flourish in the Anthropocene?

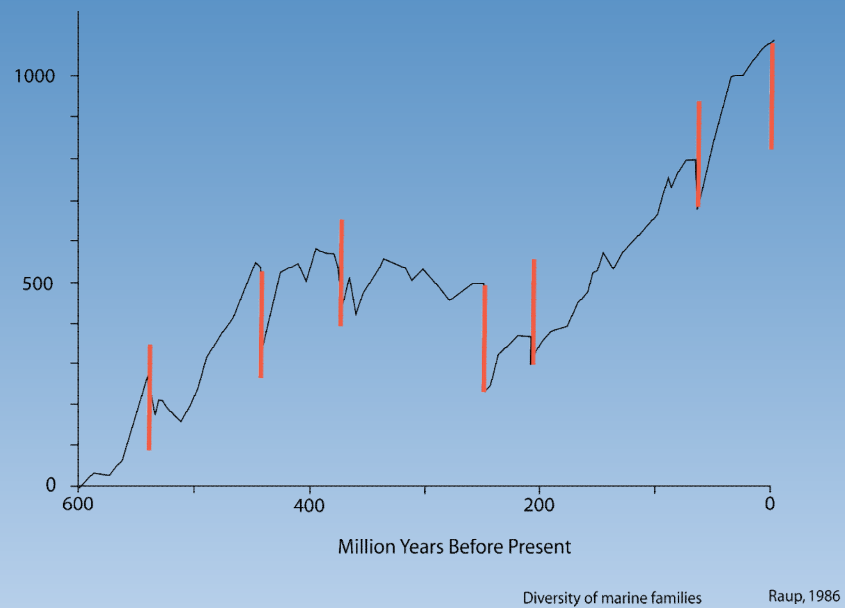


Changes ARE happening

- SEE Bob Raynolds week 6 presentation:

http://denverclimatestudygroup.com/?page_id=1375

Mass Extinctions



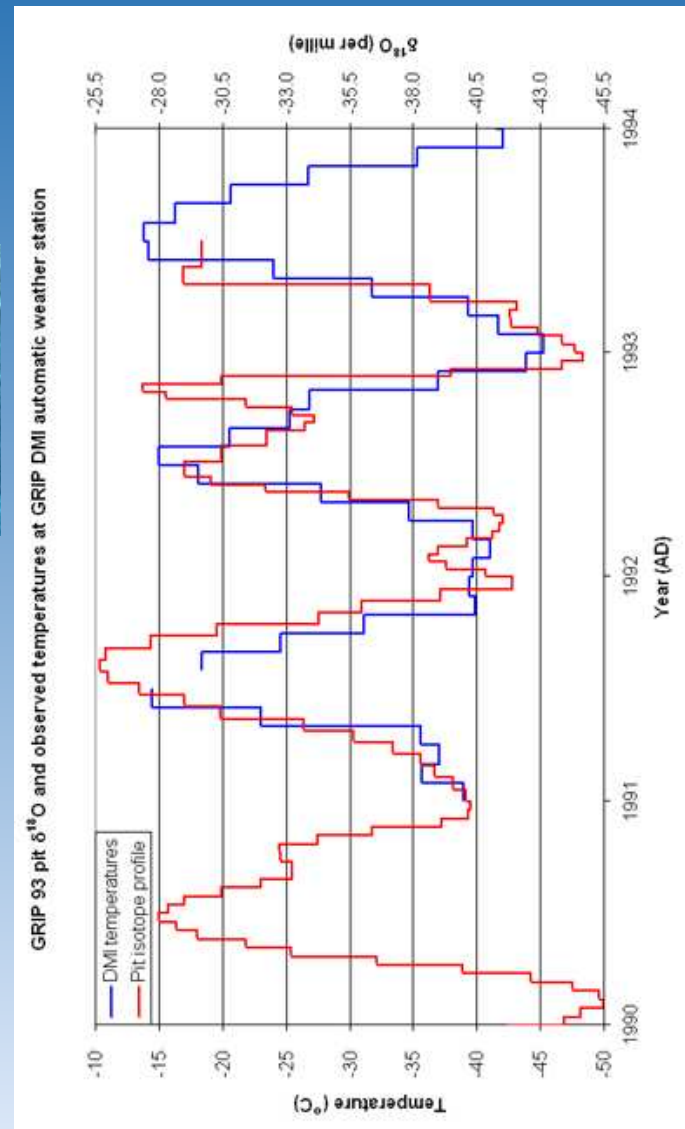
Changes are Happening

ICE



Snow Pit Stratigraphy

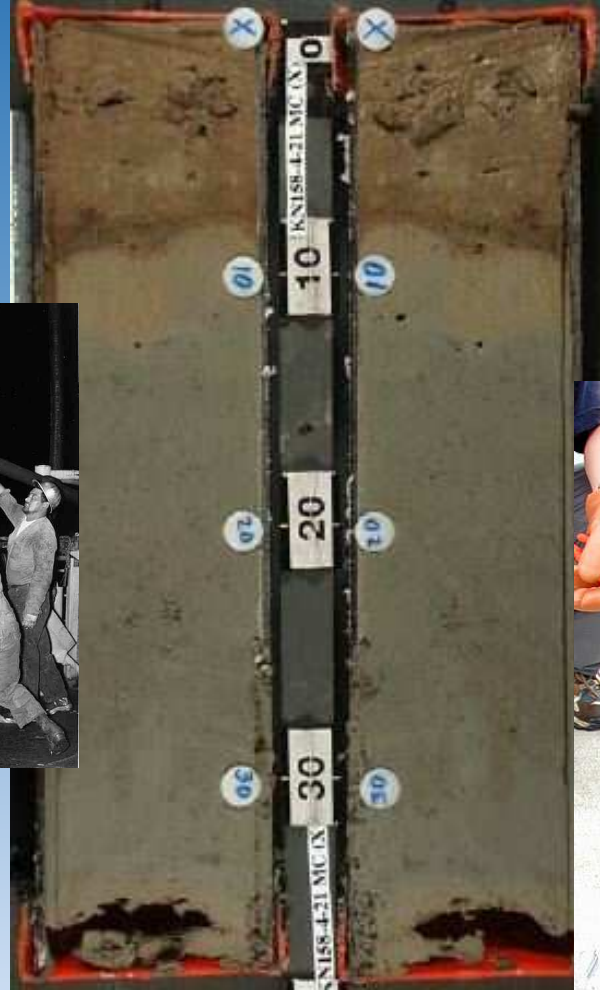
Temperature and Isotope Correlations
from Snow Pit at GRIP site, Greenland

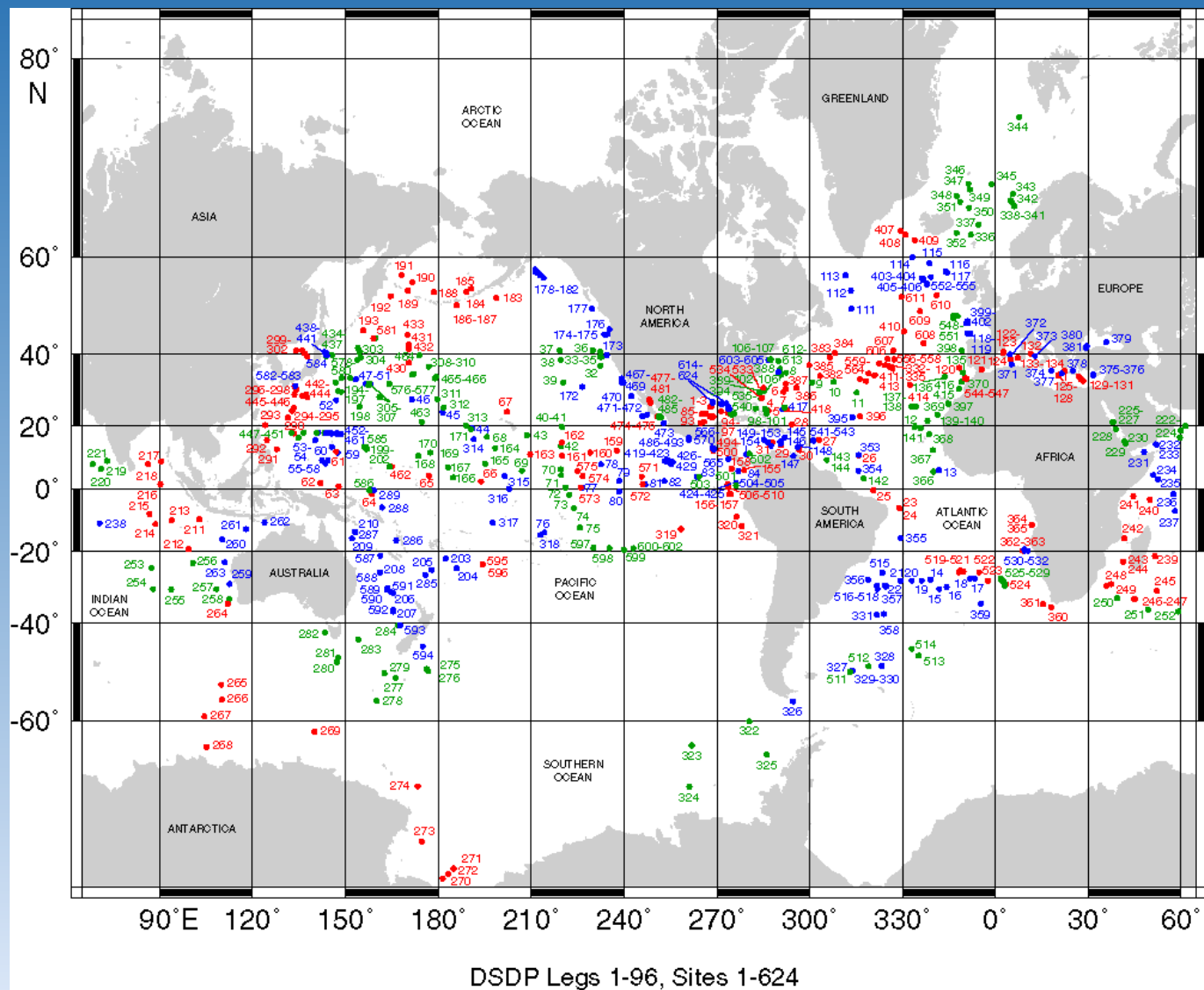


U of Copenhagen

Changes are Happening

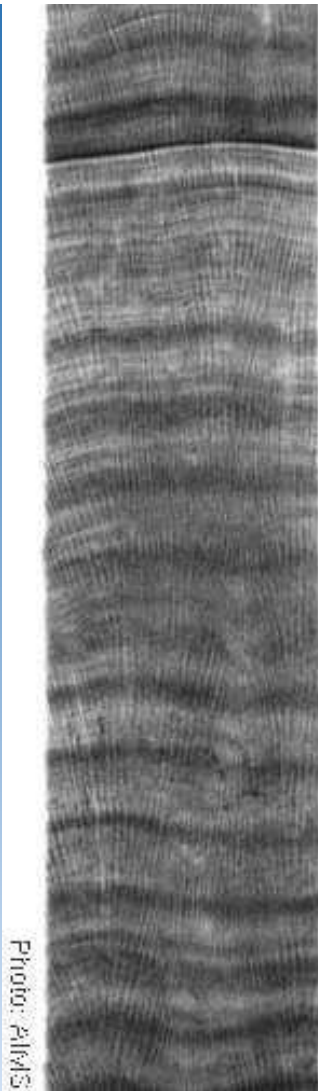
MUD



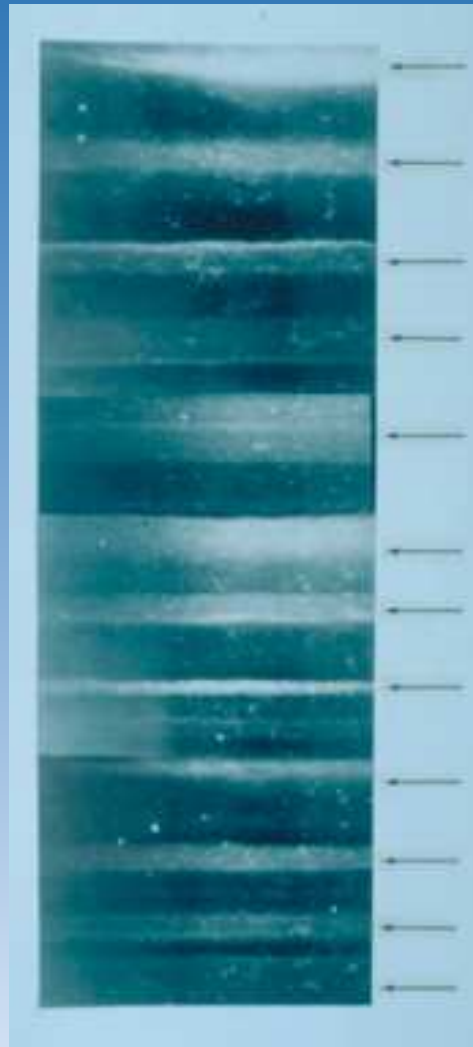


Changes are Happening

Caves and Reefs



Coral, Australia



Ice, Greenland

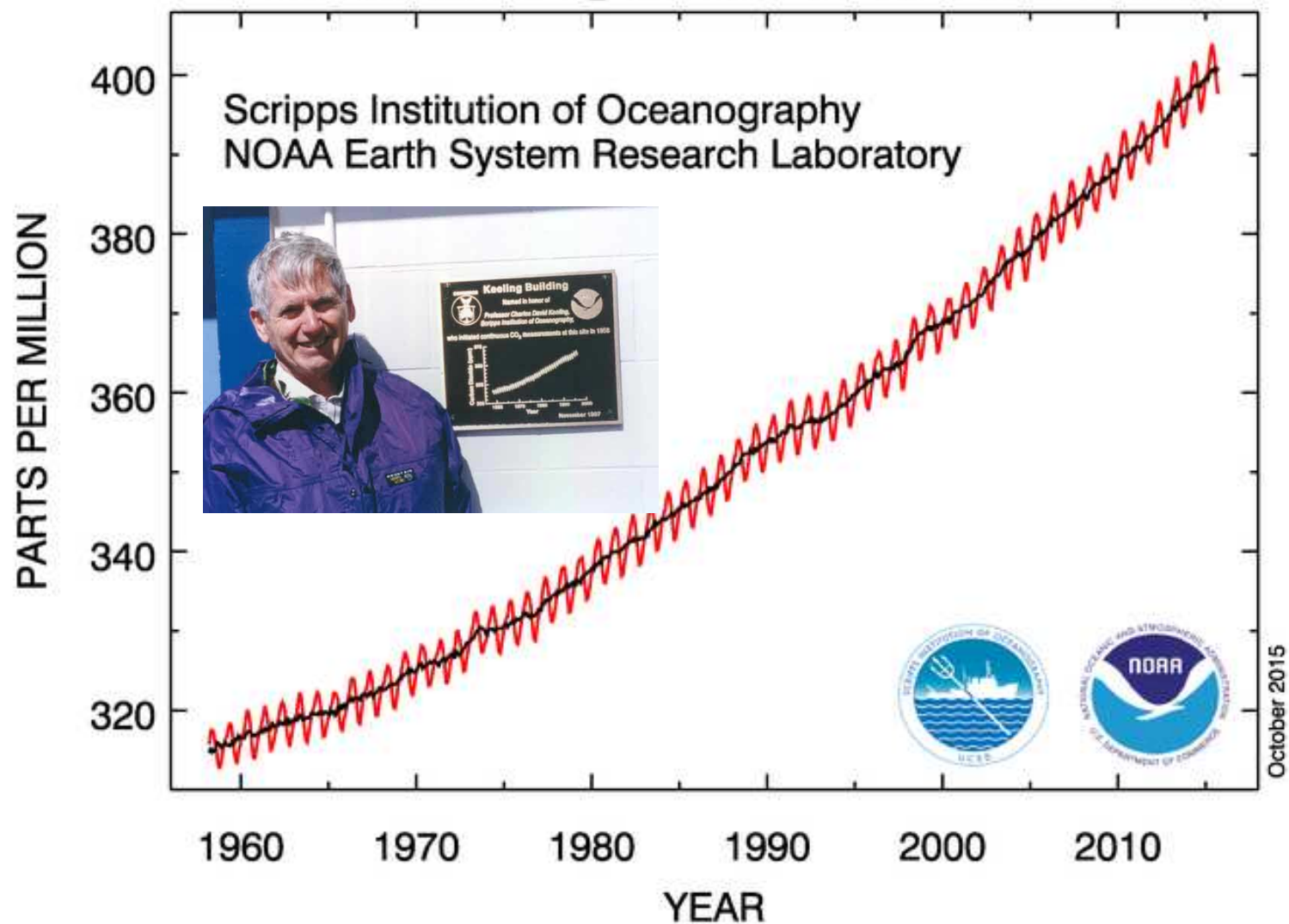


Lake Sediments, Turkey

Changes are Happening

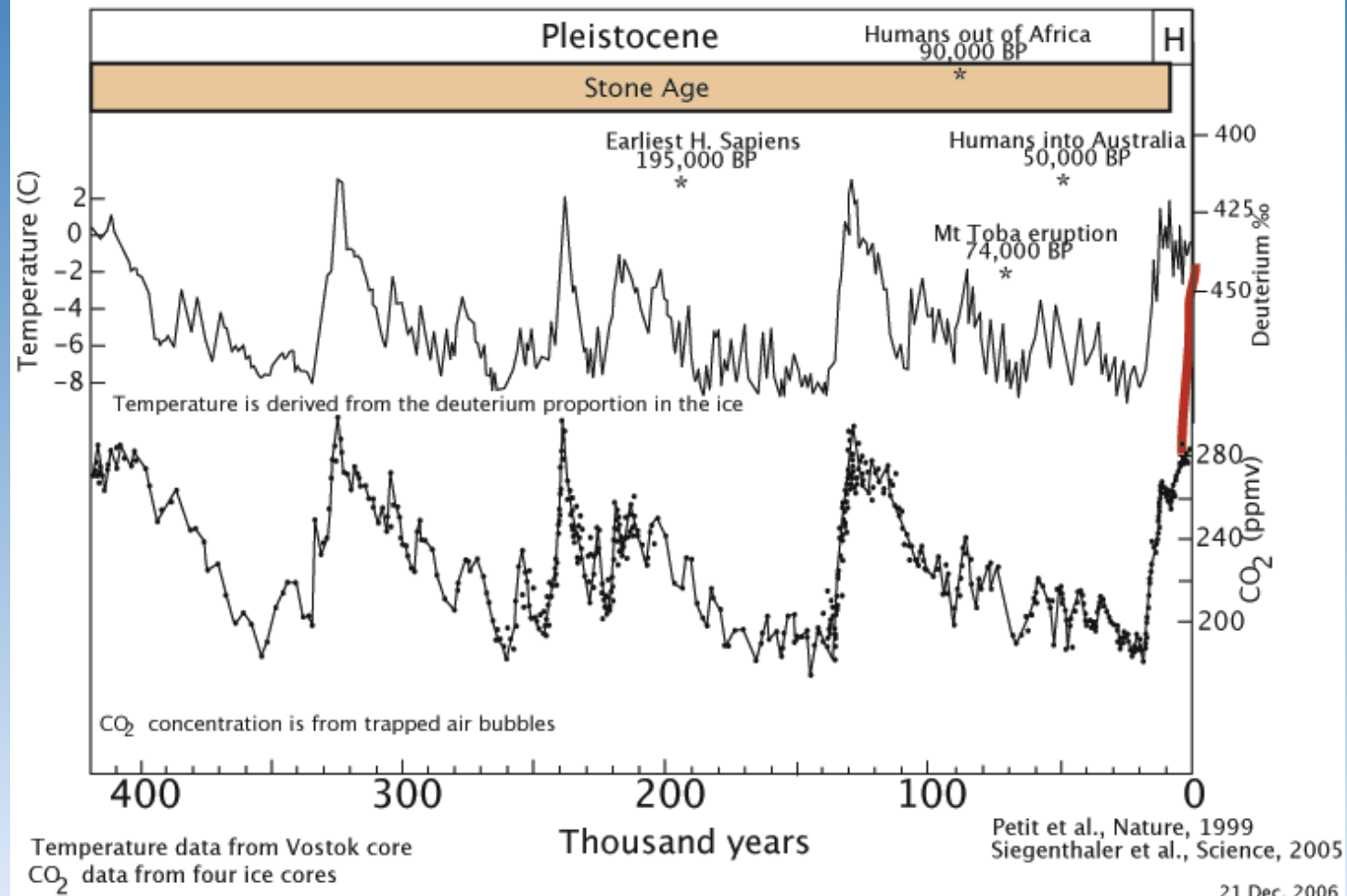
AIR

Atmospheric CO₂ at Mauna Loa Observatory



400,000 years

Antarctic Ice Cores

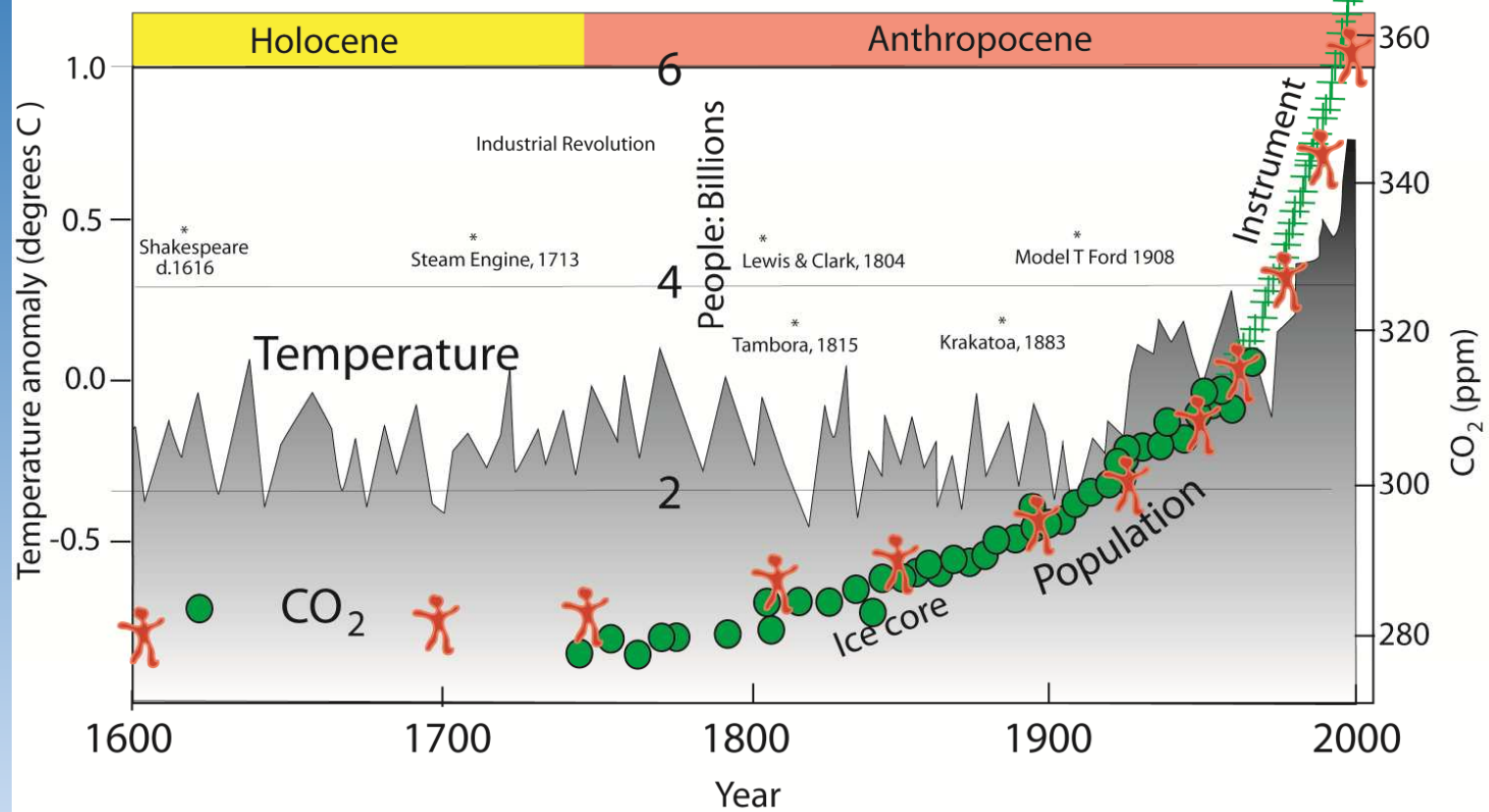


Changes are Happening

POPULATION

400 Years

Temp: tree rings and ice cores
CO₂: ice cores and measurements



Temperature: Mann et al., 1999, Geophysical Research Letters

CO₂: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

Population: UN

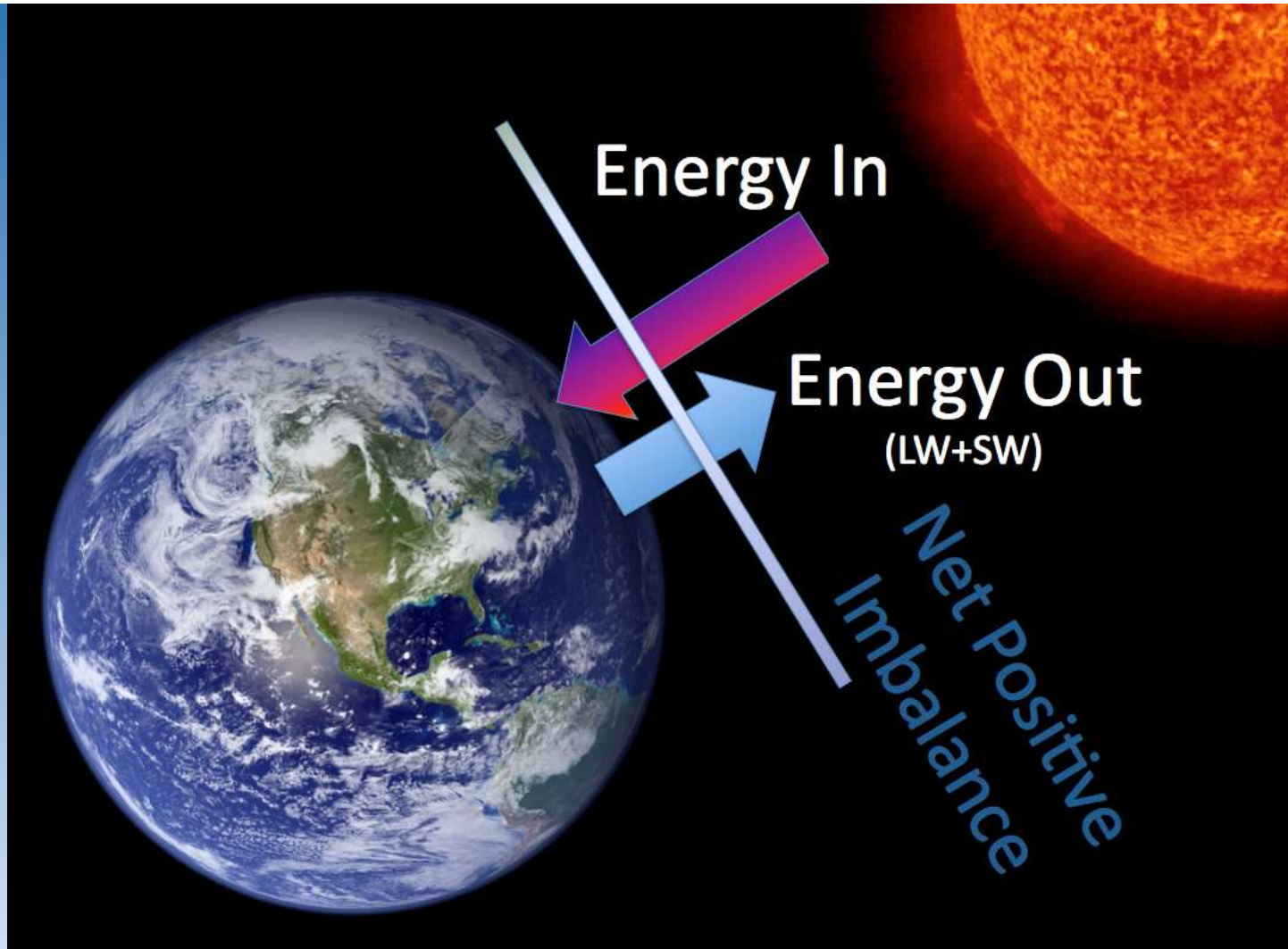
Changes are Happening

GLOBAL WARMING

About 342 w/m² comes in

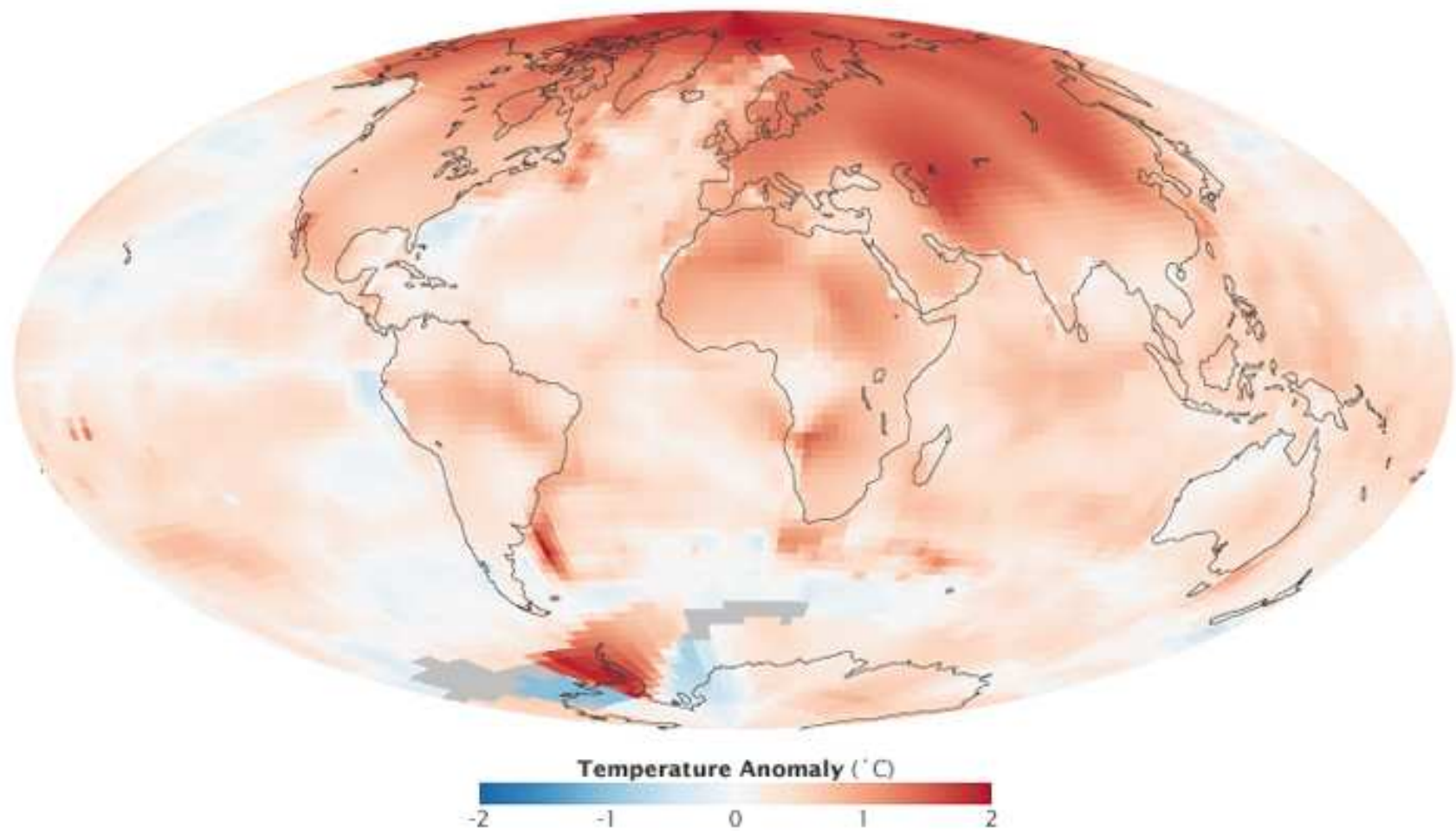
About 341 W/m² goes out



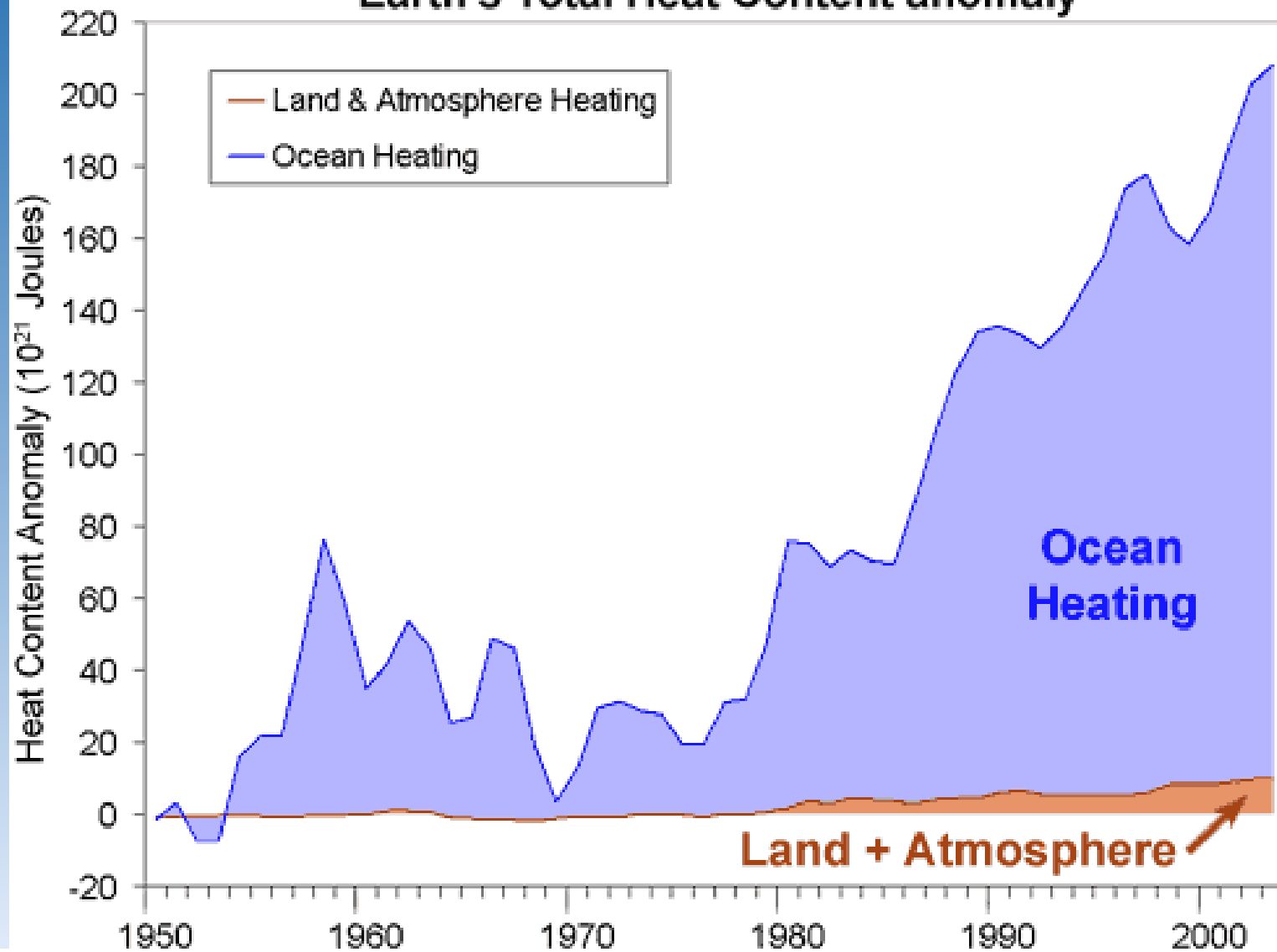


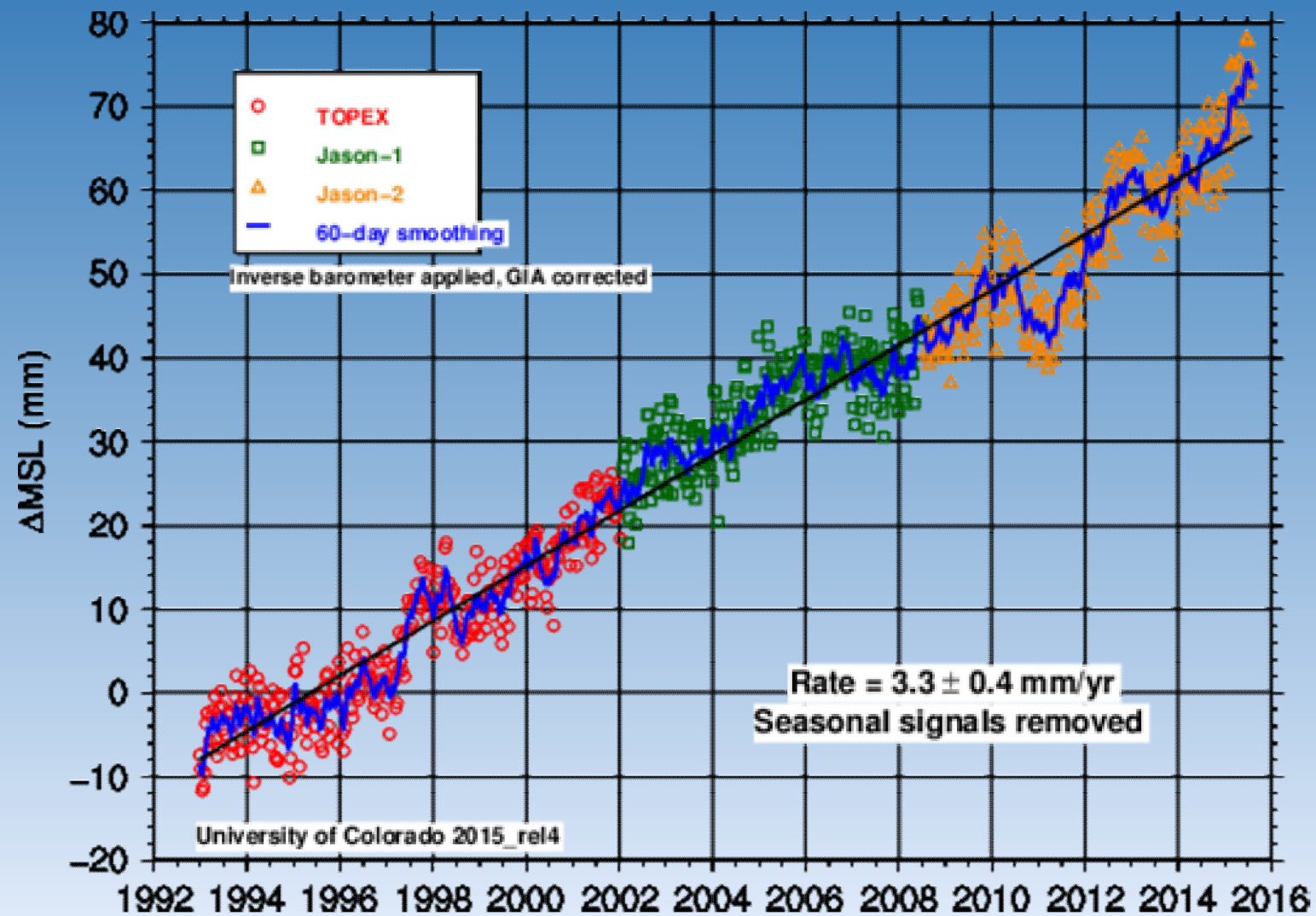
Change in temperature

2000-2009 vs. 1951-1980

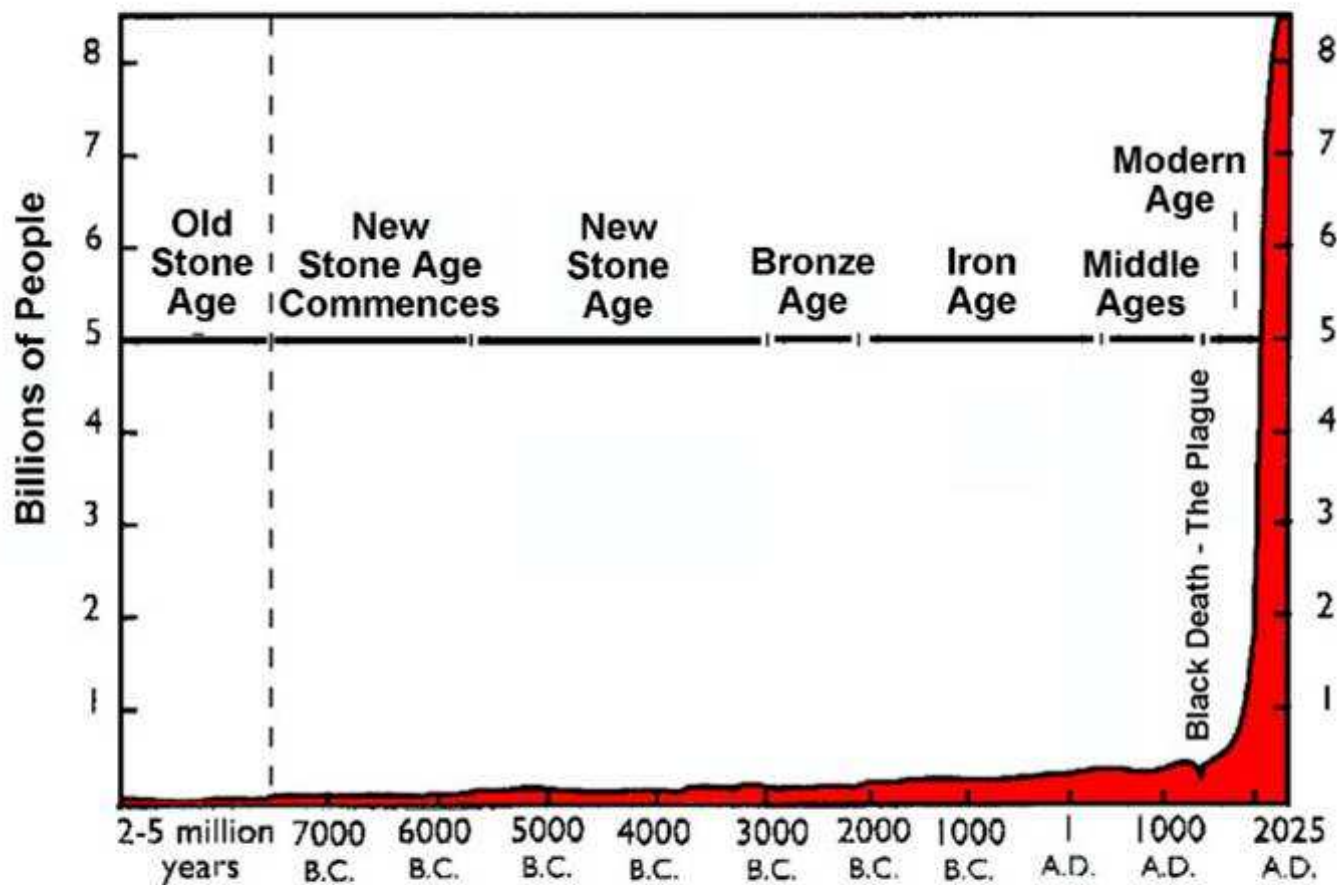


Earth's Total Heat Content anomaly



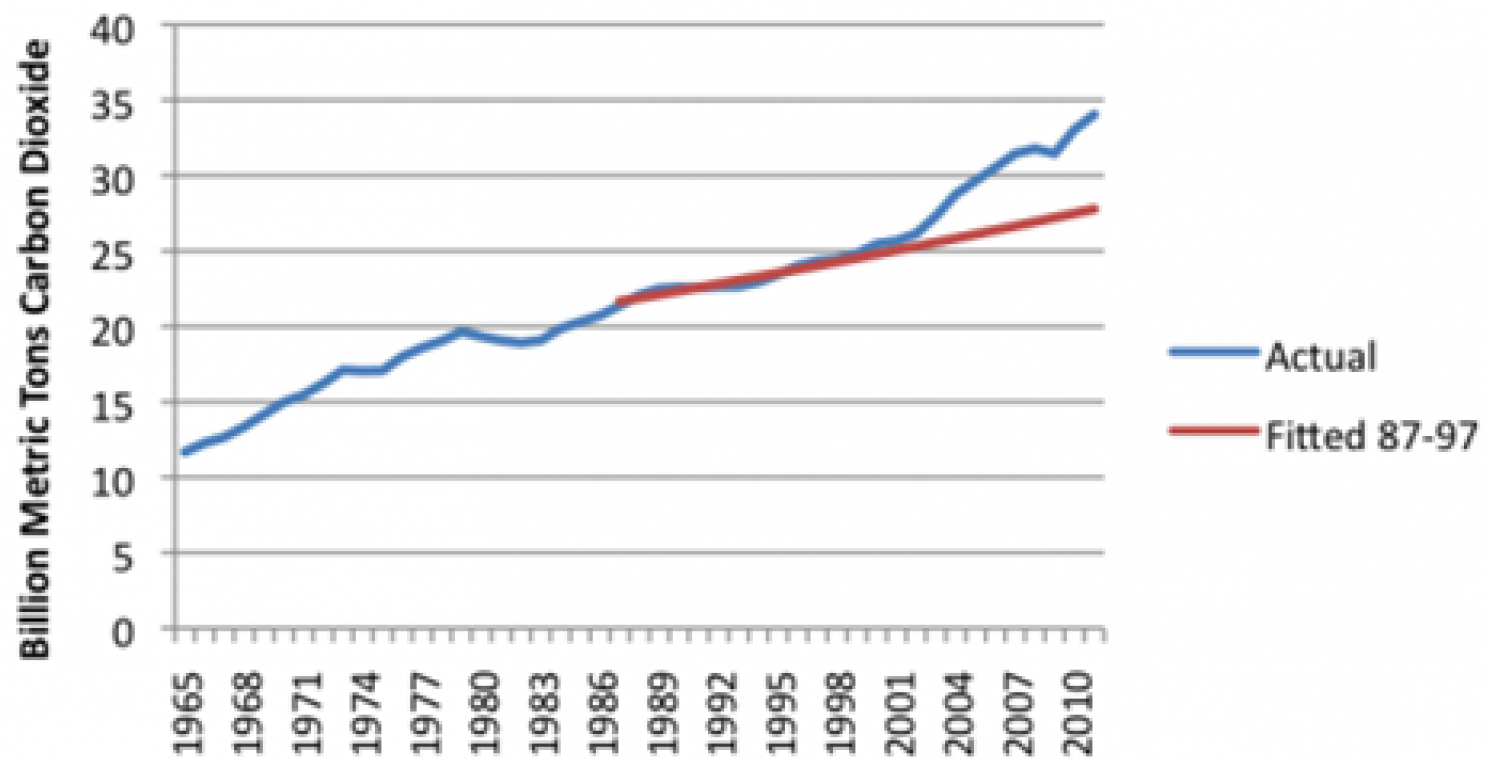


World Population Growth Through History



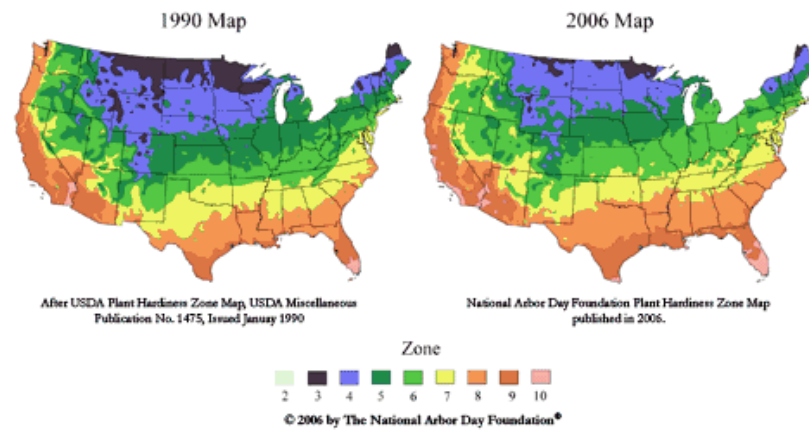
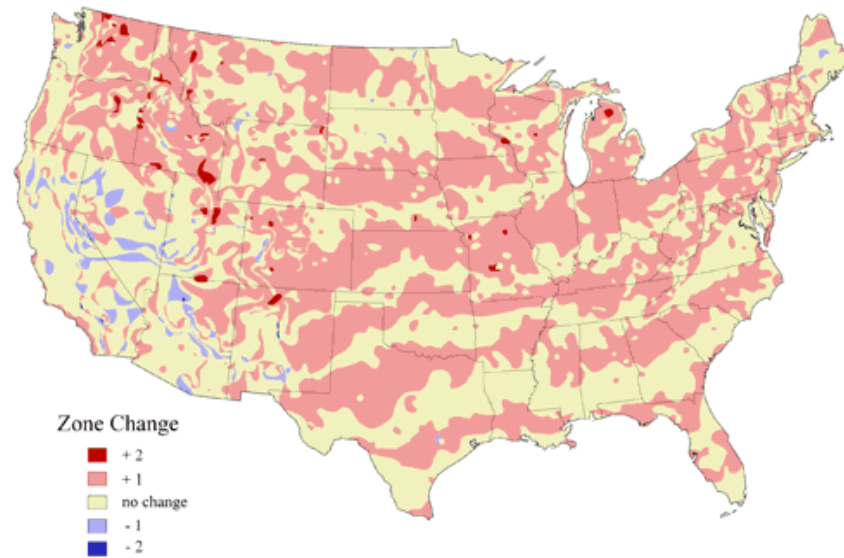
From "World Population: Toward the Next Century," copyright 1994
by the Population Reference Bureau

World Fossil Fuel Carbon Dioxide Emissions



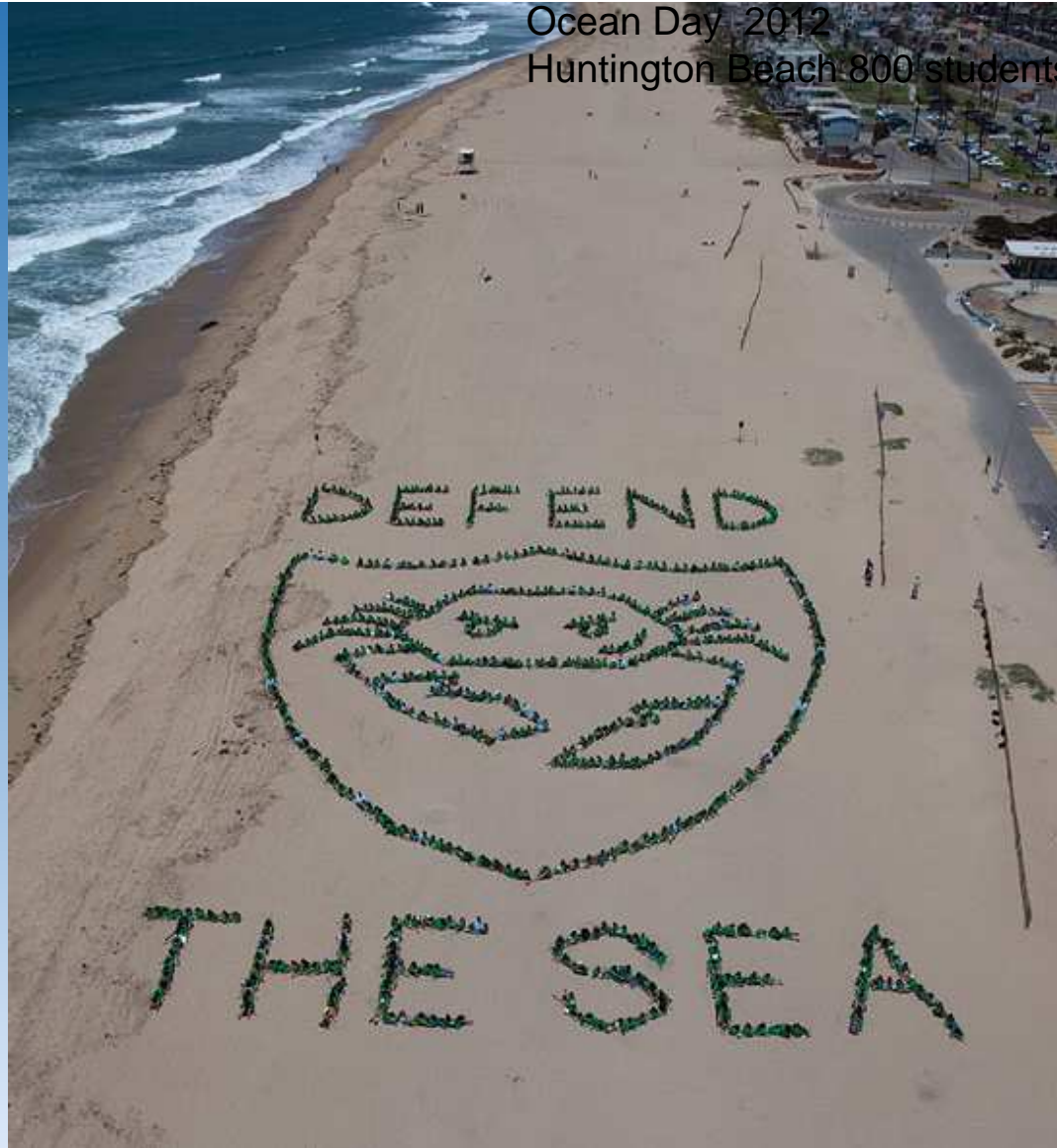
BP, 2012;

Differences between 1990 USDA hardiness
zones and 2006 arborday.org hardiness
zones reflect warmer climate



POWER OF THE PEOPLE

Ocean Day 2012
Huntington Beach 800 students





Ocean Day
Dockweiler Beach, LA
5000 students

Museums, Zoos and Your Children will save the World



Neil deGrasse Tyson – if I were in charge, I wouldn't be in charge – I would want to inform

- <https://www.facebook.com/techinsider/videos/428602874004741/>



How do we advance if we don't believe in Science?

When we don't believe:

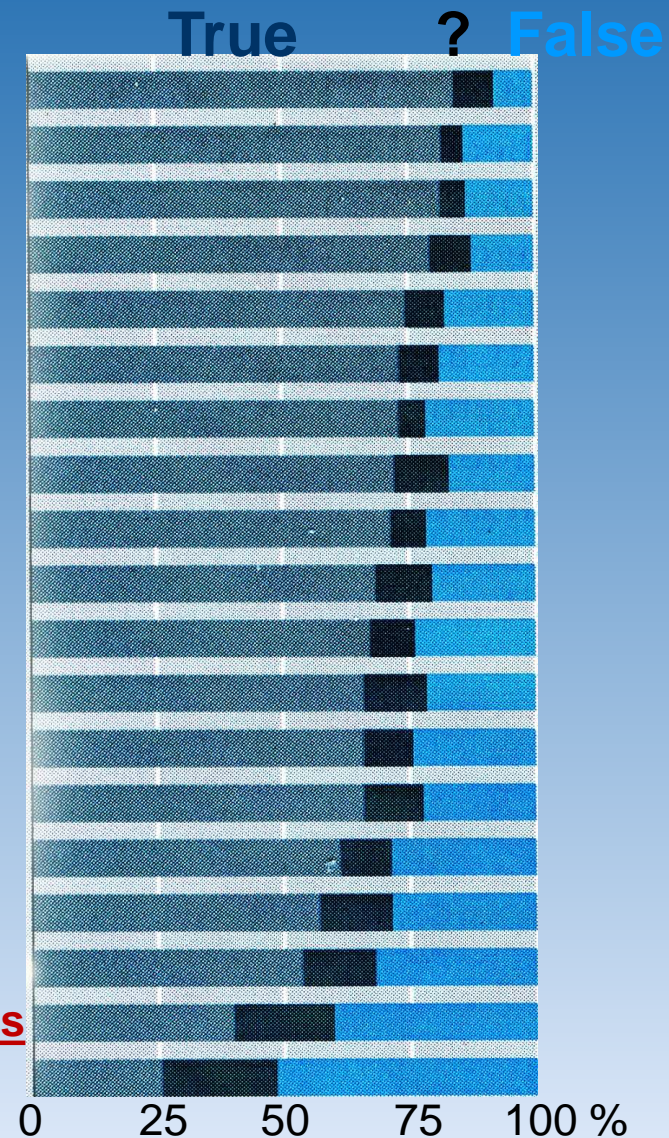
- In evolution?
- In climate change?

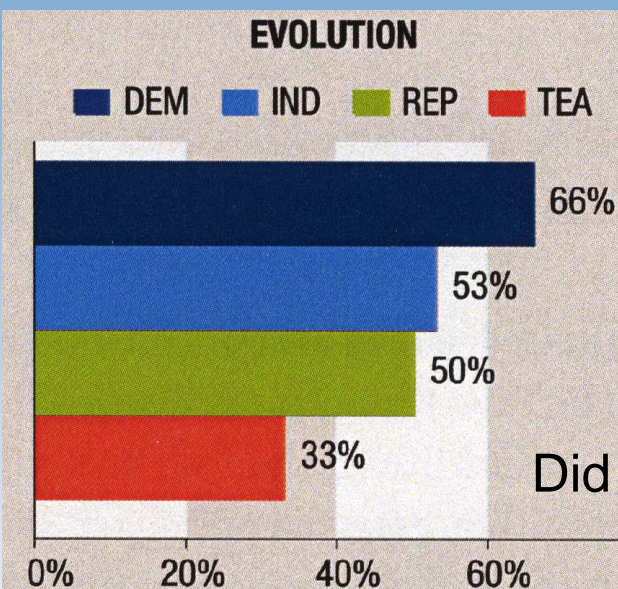
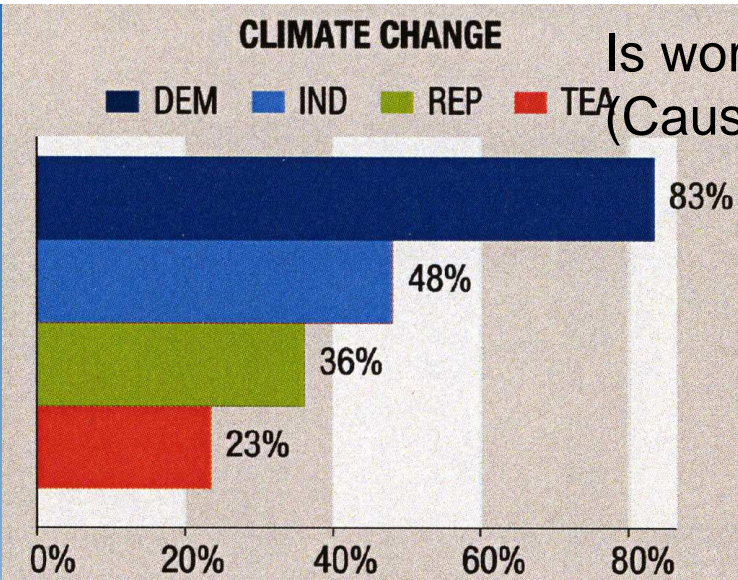
Public acceptance of evolution

Poll by New Scientist, 2006

(2012 Gallup poll found 49% of U.S. responders reject evolution, and another 35% accept it only as divinely steered to produce us)

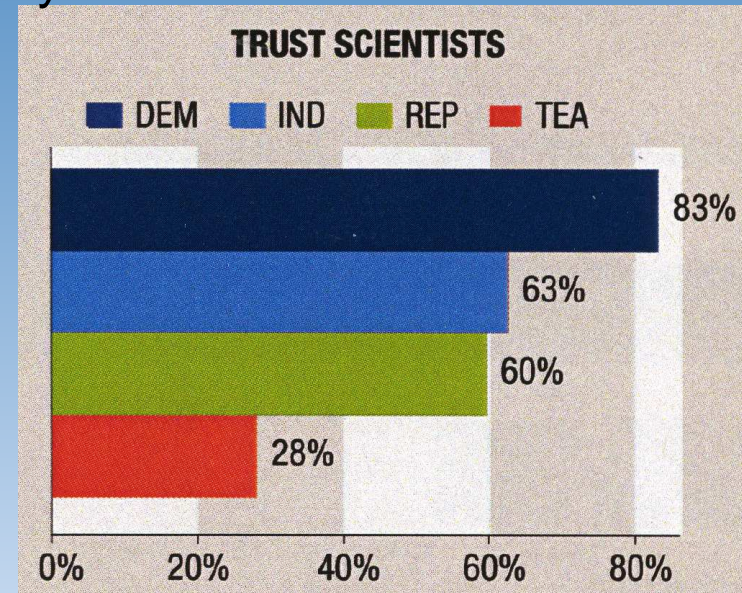
Iceland
Denmark
Sweden
France
Britain
Norway
Belgium
Spain
Germany
Italy
Netherlands
Hungary
Luxembourg
Ireland
Switzerland
Austria
Greece
United States
Turkey





New Hampshire poll,
UNH-Carsey Inst., 2014

Do you trust data from scientists?



(L.C. Hamilton, 2014)

CLIMATE

Ted Cruz: 'Climate Change Is Not Science. It's Religion.'

BY [SAMANTHA PAGE](#)  OCT 30, 2015 11:28AM



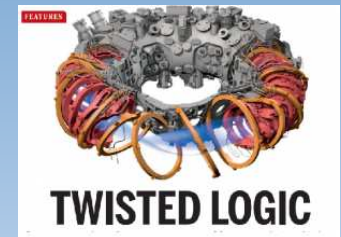
IN SUMMARY

1. The world has been getting better
2. Changes are happening
3. We need to support science and new technologies

WE NEED TO SUPPORT GAME CHANGERS; IN PARTICULAR:

1. ENERGY – NON-CARBON sources:

- FUSION: COMPACT FUSION OF LOCKHEED ([CLICK HERE](#))
- OR NEW GERMAN REACTOR ([CLICK HERE](#))
- SOLAR, OTHER NUCLEAR, MODERN GRID, ETC.



WE NEED TO SUPPORT GAME CHANGERS; IN PARTICULAR:



2. MITIGATION: BIOCHAR as a sequestration agent:

http://denverclimatestudygroup.com/?page_id=28

- *The potential for land-based biological CO2 removal to lower future atmospheric CO2 concentration-Tim Lenton, University of Exeter - [click here](#)*
- *Sustainable biochar to mitigate global climate change - [Woelf,](#)*

Gloom and Doom?

NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

IN SUMMARY

1. The world has been getting better
2. **Changes** are happening; **WE NEED TO CHANGE:**
 - 25+ Ways to Reduce Your Carbon Footprint:
<http://cotap.org/reduce-carbon-footprint/>
3. We need to support science and new technologies



Pixdaus

EXTRAS

Naomi Oreskes

Slides excerpted from:

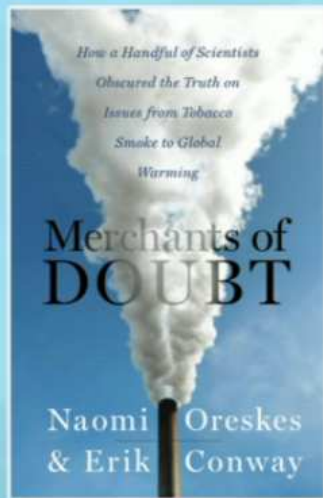
Changing Planet: Past, Present, Future
Lecture 4 – Climate Change: How Do We Know We're Not Wrong?
by Naomi Oreskes, PhD

<http://www.hhmi.org/biointeractive/climate-change-how-do-we-know-were-not-wrong>

<http://media.hhmi.org/hl/12Lect4.html>

Implicatory Denial

Rejection of climate science—like acid rain, ozone depletion, tobacco use—was not about science.



It was about its implications.

1. Free market capitalism had produced serious problems that the “invisible hand” was not solving.

2. The American way of life might need adjustment.

Catholic Church Rejected Galileo Because They Did Not Like the Implications

Not because his science wasn't right, but because it implied that the Catholic Church wasn't infallible



Dealing with Climate Change Will Require Big Decisions



Therefore, it is appropriate to turn a critical eye to the science to try to make sure it is not wrong.

Science Is Falsifiable

This means that if the claim is false, then that can be demonstrated by experiment and/or observation.



Example

Observation:
CO₂ levels are rising

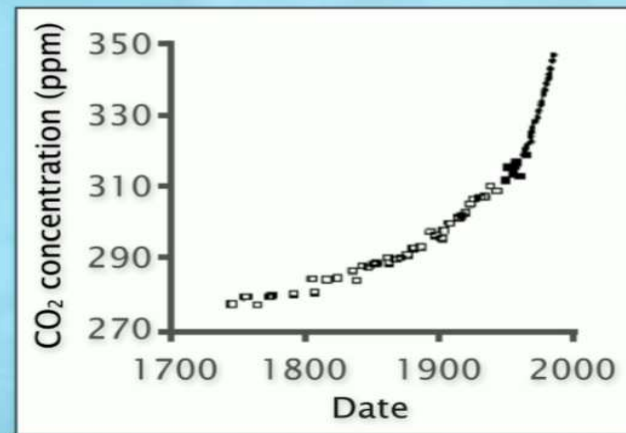
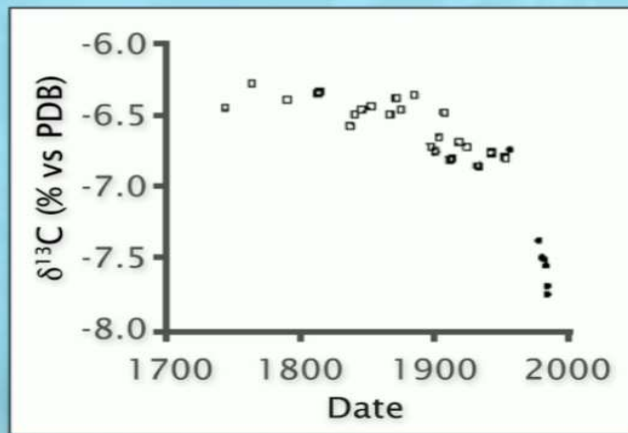
Hypothesis:
Volcanoes are the
source of that CO₂

How to test the hypothesis

Inorganic CO₂ from volcanoes are isotopically more positive; organic matter depleted in C¹³ = Fossil carbon is negative

“To claim otherwise:
Confused, ignorant or lying”

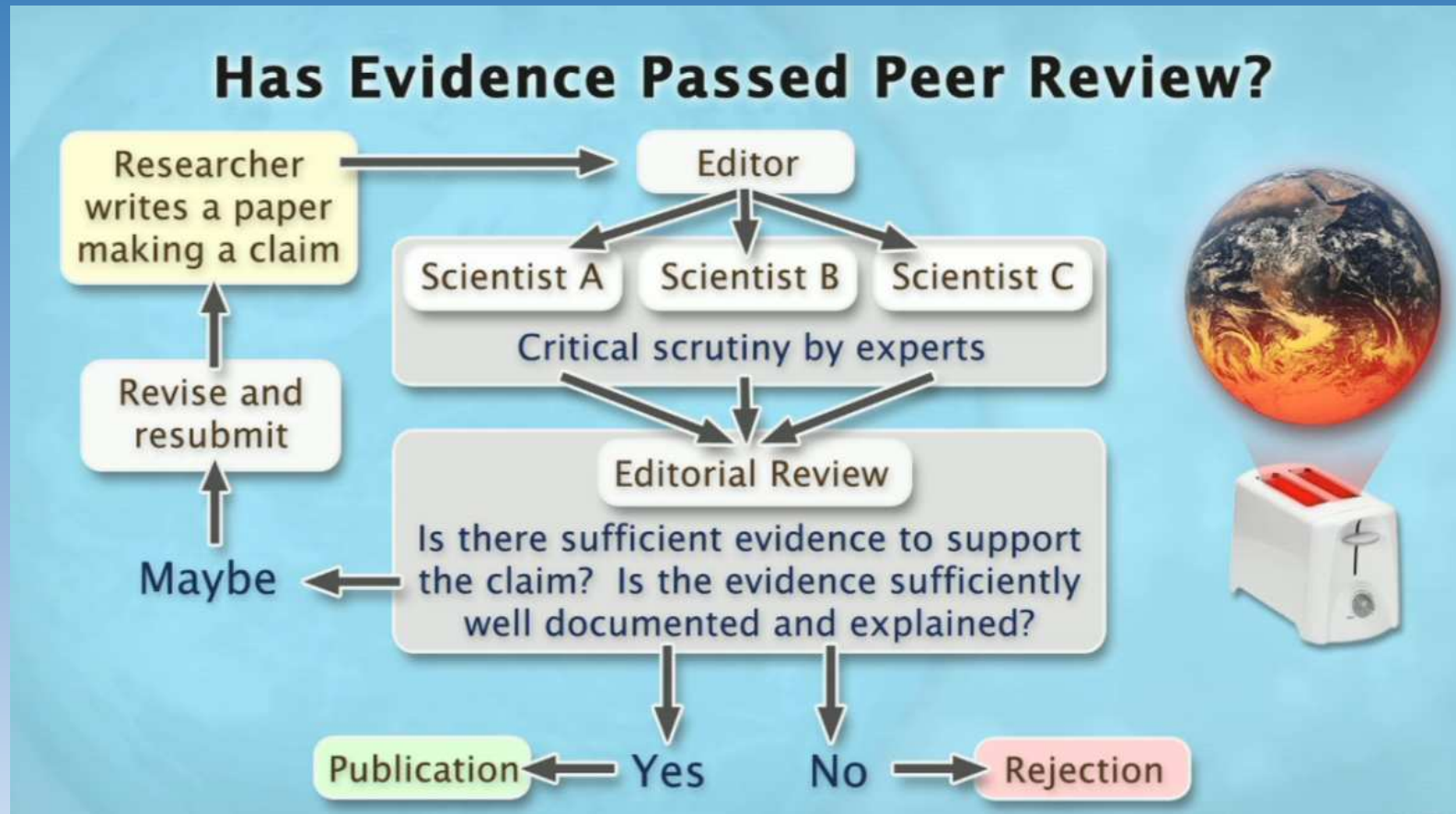
Data Clearly Show That CO₂ Increase Is Not from Volcanoes



HHMI

<http://media.hhmi.org/hl/12Lect4.html>

How peer review works



Intergovernmental Panel on Climate Change (IPCC)

Thousands of scientists

195 countries

Open process

An unprecedented level of review and inclusivity



Climate science has passed an unprecedented level of peer review.

<http://media.hhmi.org/hl/12Lect4.html>

Performance



Global climate model
geodesic grid

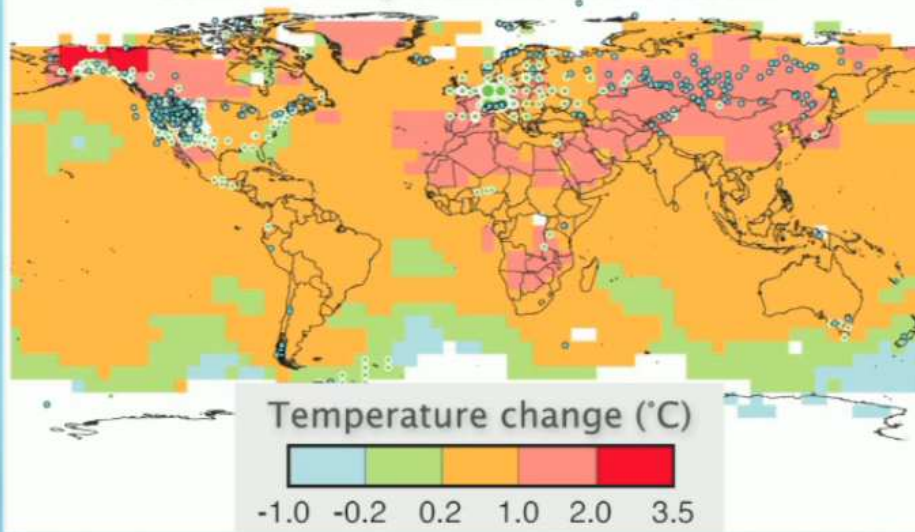
Climate models are extremely complex systems.

A good model should be consistent with what we see in the real world.

HHMI

IPCC Summary: A Vast Number of Observations Fit the Climate Models

Change in physical and biological systems and surface temperature 1970–2004



Global

Physical

765
significant
observed
changes

94%
significant
changes
consistent
with warming

Biological

28,671
significant
observed
changes

90%
significant
changes
consistent
with warming

Consensus



Review of 928 papers

75% supported the conclusion that anthropogenic climate change was under way

25% focused on paleoclimate or other technical aspects and took no position

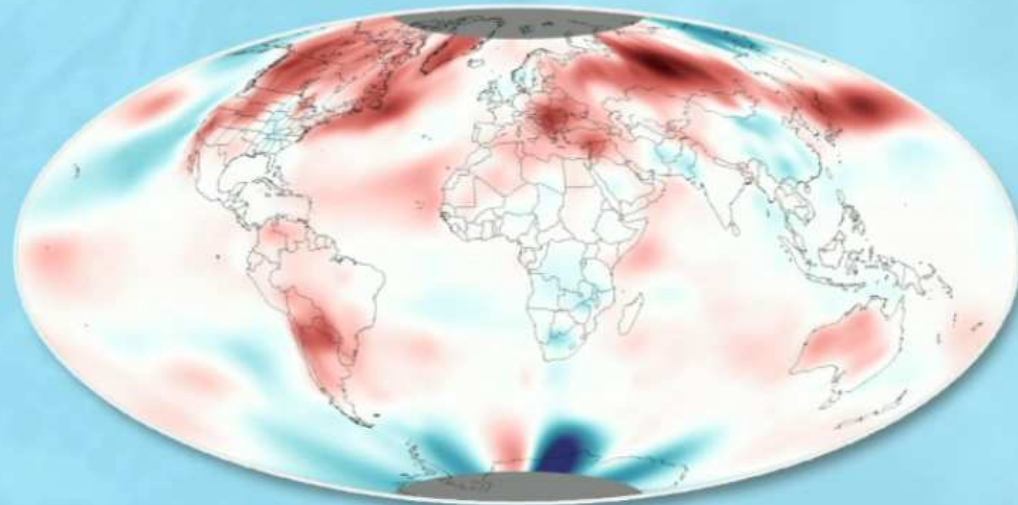
No peer-reviewed papers refuted the consensus view

HHMI

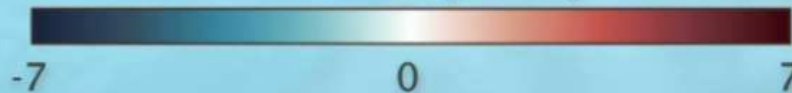
<http://media.hhmi.org/hl/12Lect4.html>

The Science Is Settled and Passes All the Tests That We Can Subject It To

The globe is
warming and
the climate
is changing.



Difference from average temperature (°F)



**The Debate Should Not Be About Whether
Climate Change Is Happening...**

...Rather, What Are We Going to Do About It?

HHMI