

# **Contemporary Issues Regarding Climate Change and Solutions**

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**Geologist/Paleoclimatologist**

**Tuesday September 26<sup>th</sup> , 2017**

# Contemporary Issues Regarding Climate Change and Solutions

- **Introductions**
- **Books / website recommendations**
- **The difference between weather and climate**
  - **Climate system: feedbacks, cycles and self-regulation (climate, not government)**
  - **What determines Earth's climate**
- **Next week's field trip to Ice Core lab at Federal Center**
- **Topics to discuss October 10, 17, 24, 31**

# INTRODUCTIONS – Part 1

- **Lattina Adams: classroom assistant, liaison to me/OLLI**
  - **Logistics: bathrooms, breaks, no open containers**
  - **Lattina Adams [LATTINA@gmail.com](mailto:LATTINA@gmail.com)**
  - **303-564-3937**
  
- **Paul Belanger:**
  - **[PEBelanger@glassdesignresources.com](mailto:PEBelanger@glassdesignresources.com)**
  - **c. 303-249-7966; h 303-526-7996**

# INTRODUCTIONS – part 2

## Introduction:

- Yourself – what brought you here
- Paul
- <http://denverclimatestudygroup.com/> (OLLI tab)
- Web page - 10 year history; Resume in “About” tab
- Facebook -  
<https://www.facebook.com/denverclimatestudygroup/>

# Three books to consider:

- **Simple succinct Summary:**

- [What We Know About Climate Change \(Boston Review Books\)](#) by Kerry Emanuel (Nov 30, 2012)

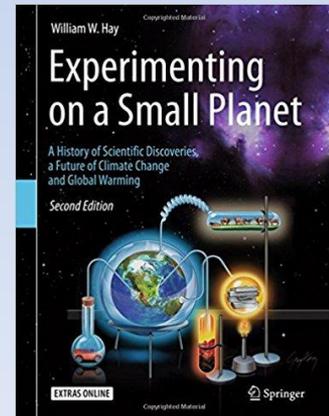
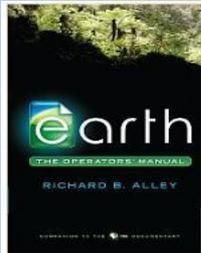
- **Intermediate Level Book:**

- [Earth: The Operators' Manual](#) by [Richard B. Alley](#) (Apr 18, 2011)

<http://earththeoperatorsmanual.com/>

- **More comprehensive book:**

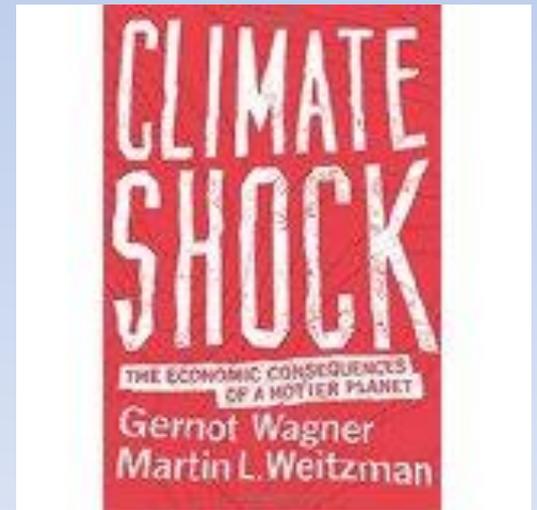
[Experimenting on a Small Planet: A History of Scientific Discoveries, a Future of Climate Change and Global Warming](#) 2nd ed. 2016 Edition



# Another book to consider:

- **Economics:**

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



# THE BIG PICTURE

- Sustainability:

- Population
- Resources
- Energy
- World stability
- Conflict
- **Climate change**
- Weather
- Pestilence
- Etc. – very complex



CLIMATE-RELATED

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# Weather



can change within  
a few minutes or hours!



# Climate



takes very long time  
to change!



TAKE AWAY: This is Weather



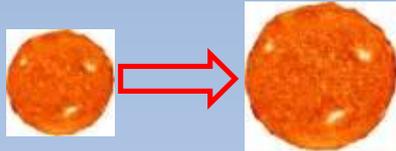
This is NOT Climate Change

Chair of the [Senate Environment Committee](#)

# What determines Earth's climate

- Primary Influences (3):

1. **SOLAR input:**



0.9% less  
100 My ago

& sunspots



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

# What determines Earth's climate TODAY:

- **The Sun**
- **Orbital parameters aka Milankovitch**
- **Greenhouse Gases (GHGs)**

# The Sun

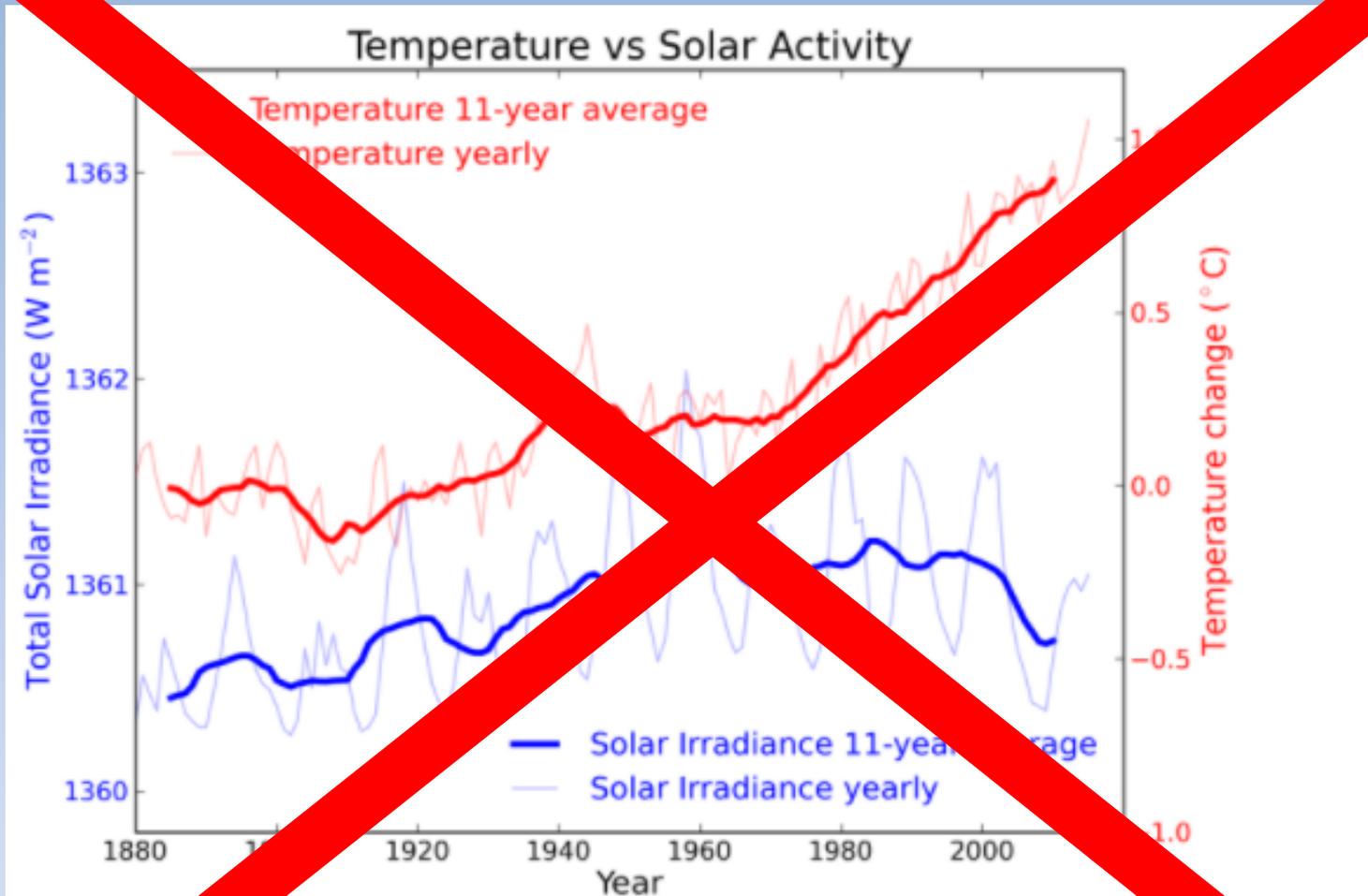
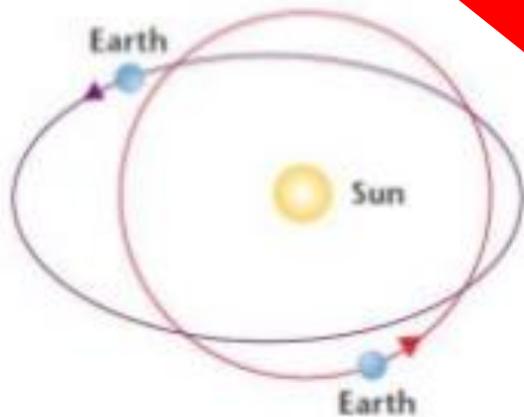


Figure 1: Annual global temperature change (thin light red) with 11 year moving average of temperature (thick dark red). Temperature from NASA GISS. Annual Total Solar Irradiance (thin light blue) with 11 year moving average of TSI (thick dark blue). TSI from 1880 to 1978 from Krivova et al 2007. TSI from 1979 to 2015 from PMOD (see the PMOD index page for data updates).

# Milankovitch Cycle



**Eccentricity** Earth encounters more variation in the energy that it receives from the sun when Earth's orbit is more elongated than it does when Earth's orbit is more circular.

100,000 years  
40,000 - 50,000 years



**Tilt** The tilt of Earth's axis varies between 22.2° and 24.5°. The greater the tilt angle is, the more solar energy the poles receive.

41,000 years



**Precession** A gradual change, or "wobble," in the orientation of Earth's axis and the relationship between Earth's tilt and eccentricity.

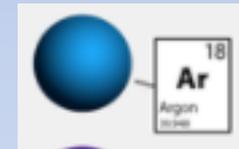
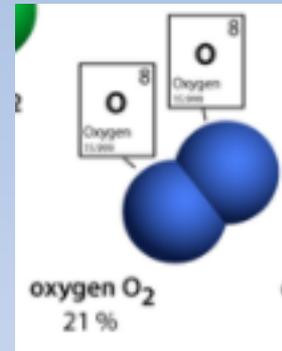
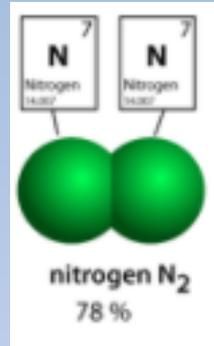
19 – 24,000 years

Thus it leaves it to Greenhouse Gases

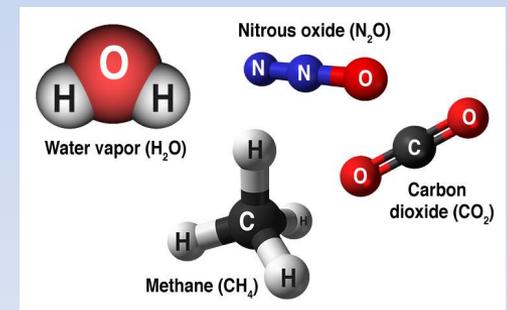
And so we will explore this a little further

# Let's look at our atmosphere

- N<sub>2</sub> = 78%
- O<sub>2</sub> = 21%
- Ar = 0.93%

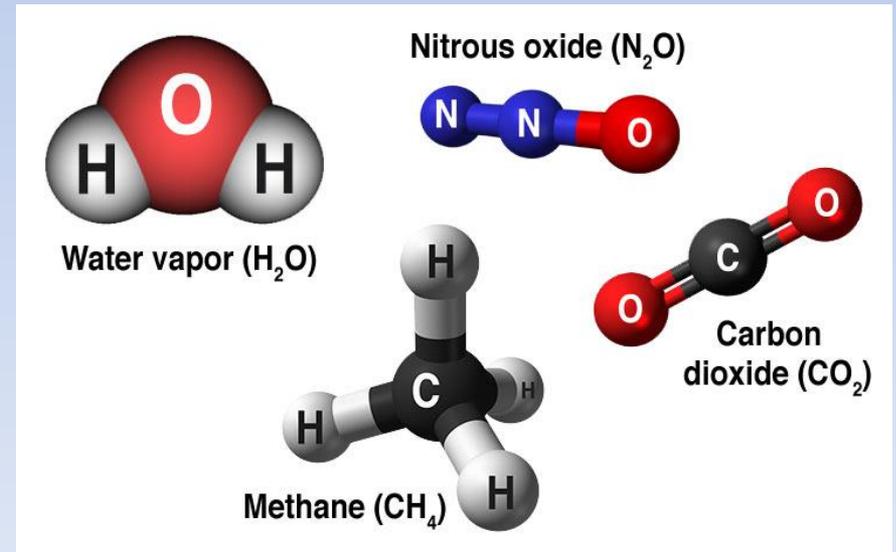


- CO<sub>2</sub> = .0408%
- H<sub>2</sub>O = variable
- Other: CH<sub>4</sub>, CFCs, O<sub>3</sub>, etc.



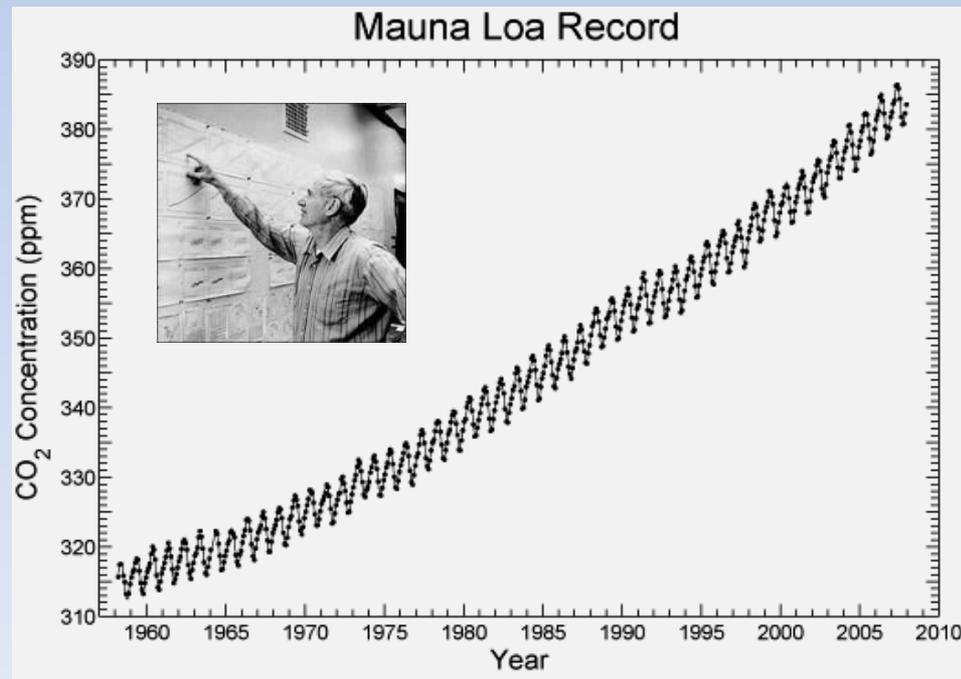
# GREENHOUSE GASES (GHGs)

- Water –  $\text{H}_2\text{O}$  – the amount is a feedback of temperature held in by the “blanket” of other GHGs
- Carbon dioxide -  $\text{CO}_2$
- Methane -  $\text{CH}_4$
- Ozone -  $\text{O}_3$
- Nitrous oxide-  $\text{N}_2\text{O}$
- others

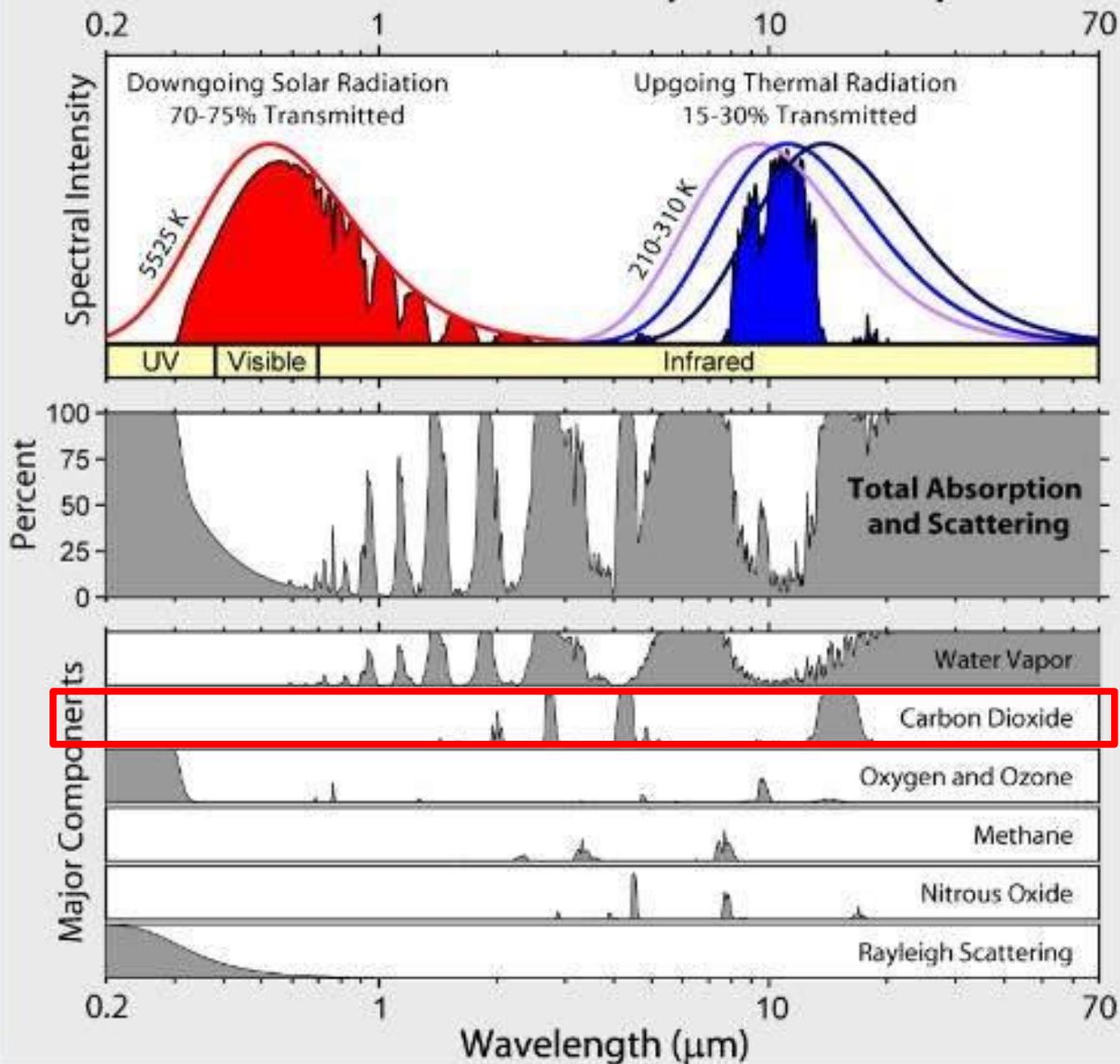


# EMISSIONS FROM HUMAN ACTIVITIES LARGELY TO BLAME

- 40% increase in CO<sub>2</sub>
- Dead carbon altering atmospheric C<sup>14</sup>
- That Carbon is more negative/enriched in C<sup>12</sup>



# Radiation Transmitted by the Atmosphere



# FOR THERE TO HAVE NO CLIMATE CHANGE

Energy in (Visible)

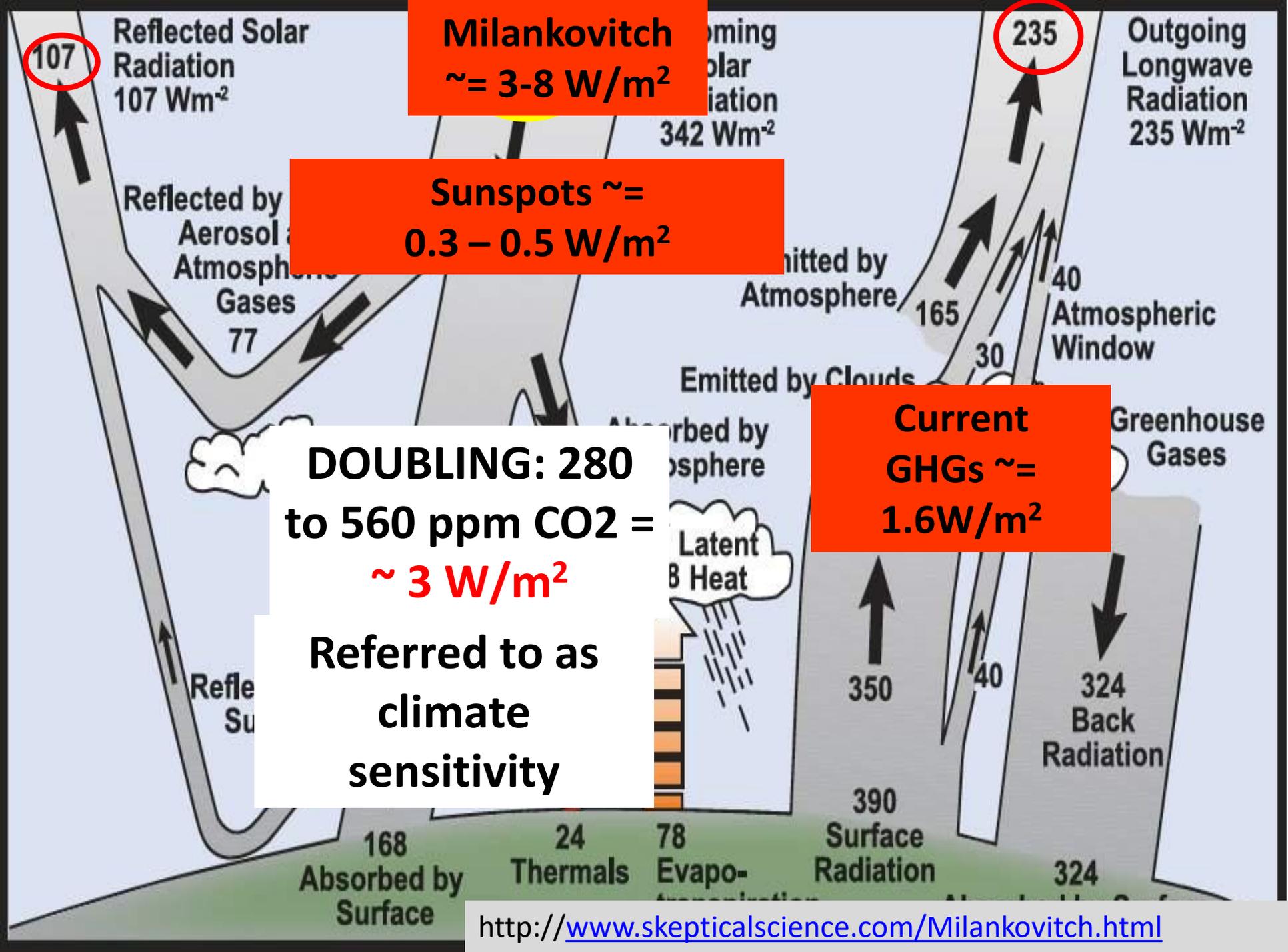
=

Energy out (infrared)

- Relatively stable last 10,000 years
- GHGs Now Changing our climate – but at an unprecedented rate
  - Threatens our sustainability as DO other factors:
    - Population
    - Sea level rise
    - Extreme weather
    - Resources (Energy, food)
    - Ocean acidification

# IF EARTH'S HEAT BUDGET CHANGES WE HAVE EITHER:

- COOLING or
- WARMING



**Milankovitch**  
 $\approx 3-8 \text{ W/m}^2$

**Sunspots**  $\approx$   
 $0.3 - 0.5 \text{ W/m}^2$

**Current GHGs**  $\approx$   
 $1.6 \text{ W/m}^2$

**DOUBLING: 280 to 560 ppm CO<sub>2</sub> =**  
 $\approx 3 \text{ W/m}^2$   
 Referred to as  
 climate  
 sensitivity

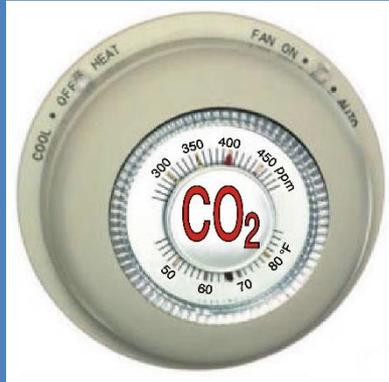
The  $\text{CO}_2$  greenhouse gas effect is concentrated  
The most potent greenhouse gas is  $\text{H}_2\text{O}$  - vapor  
in the polar regions !!!



Particularly in the  
Arctic!  
The large  $\text{H}_2\text{O}$   
greenhouse effect  
is controlled by  
temperature –  
 $\text{H}_2\text{O}$  saturation doubles  
with every  
 $10^\circ\text{C}$  increase  
 $\text{CO}_2$  and other  
Greenhouse gases  
are evenly distributed  
throughout the  
atmosphere  
As a result it is  
concentrated in  
the lower atmosphere  
of the tropics

# RESULTS:

- Greater warming at High Latitudes
- Reduction Arctic sea ice
- Melting glaciers
- Rising sea levels
- Average temperature increases
- Earlier springs / earlier snow melt
- Ocean acidification



Human  
Activity



Warmer Air,  
Warmer Water  
(Global Warming)

More Water Vapor  
and Clouds

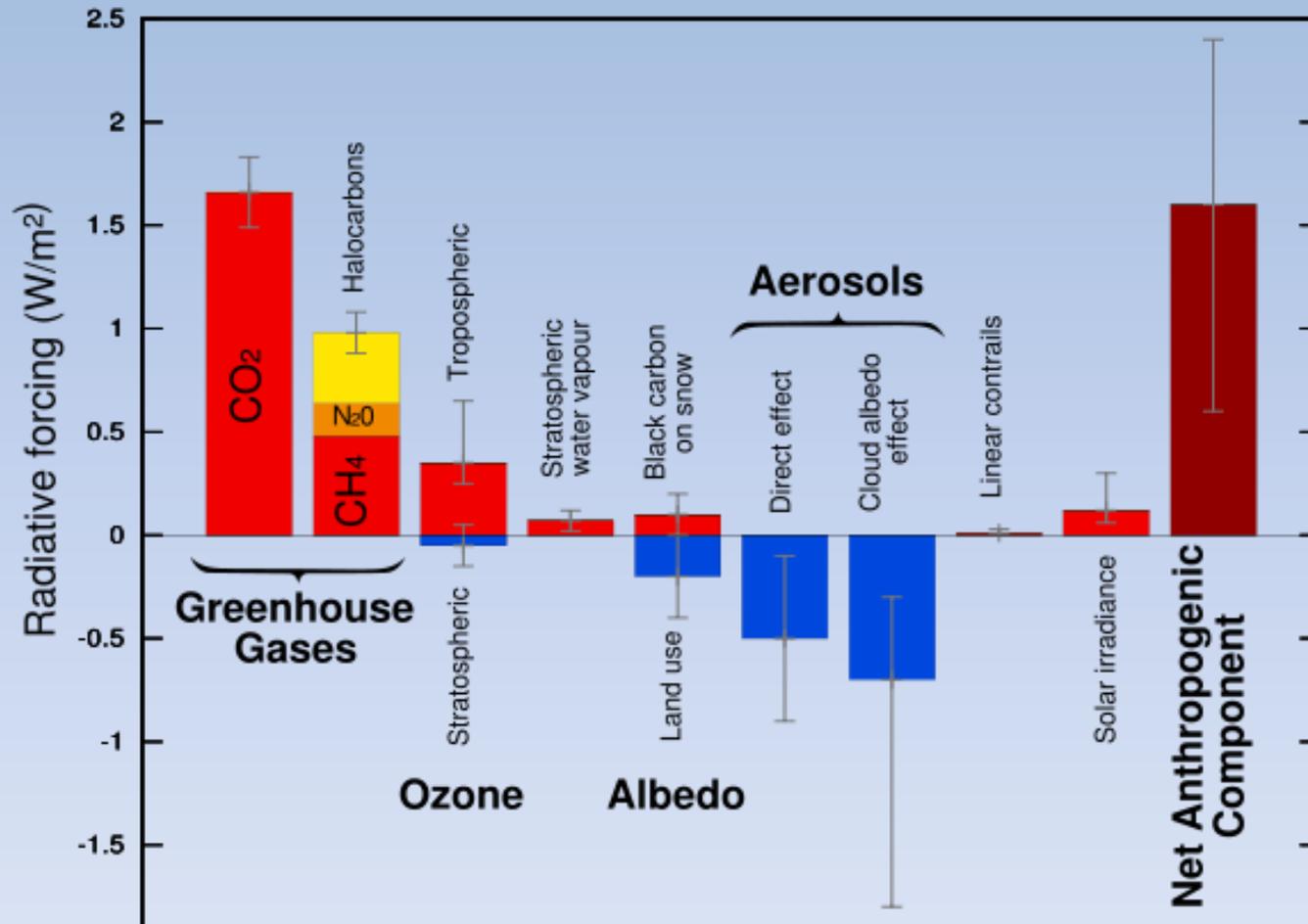


Atmosphere  
Biosphere  
Hydrosphere  
Cryosphere  
(Climate Change)



# GLOBAL WARMING CONCERNS

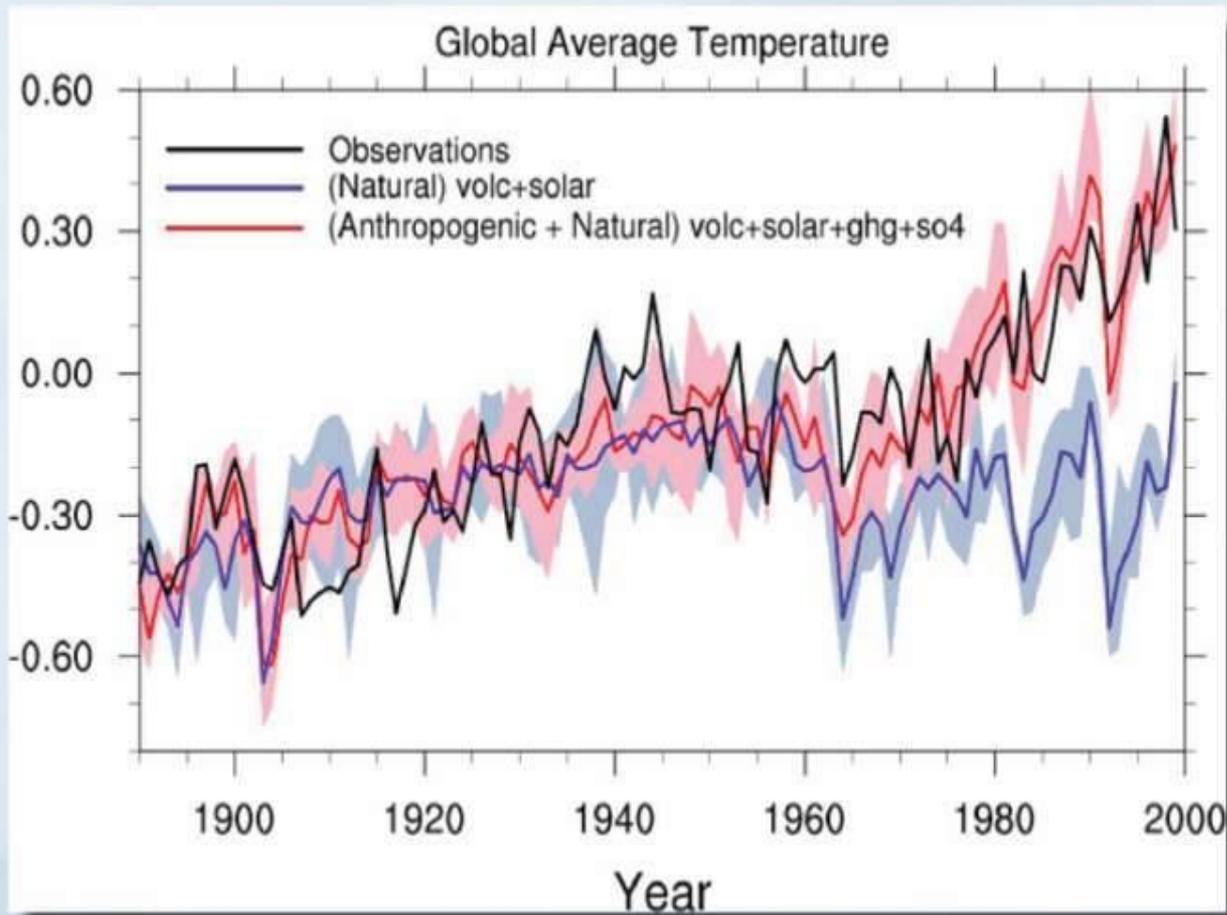
## Radiative Forcing Components



Incoming Solar irradiance:  $342 W/m^2$

IPCC, 2007

# Simulations of the 20th century: Time



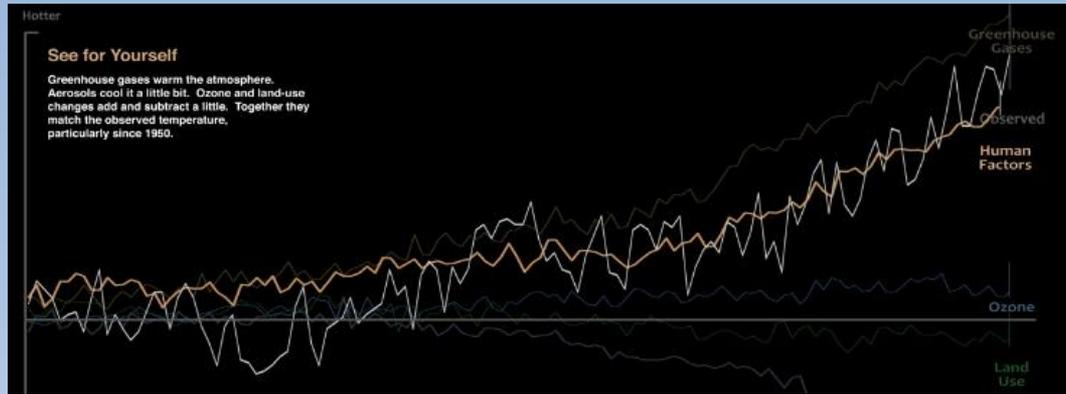
All forcings

Natural only

Meehl et al. 2004



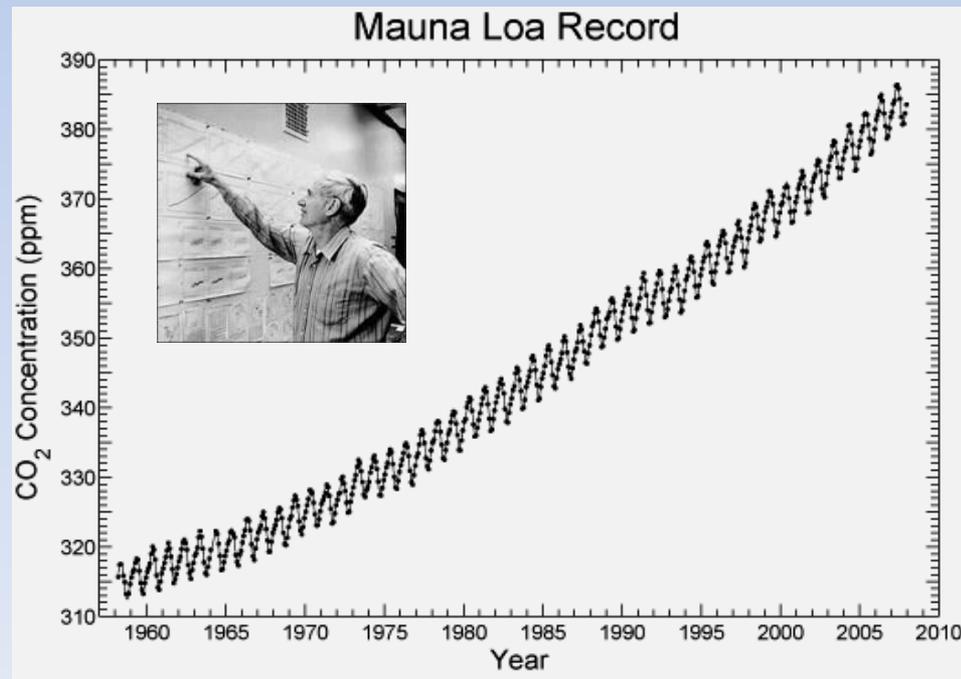
# How global warming stacks up



- <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.

# 3: EMISSIONS FROM HUMAN ACTIVITIES LARGELY TO BLAME

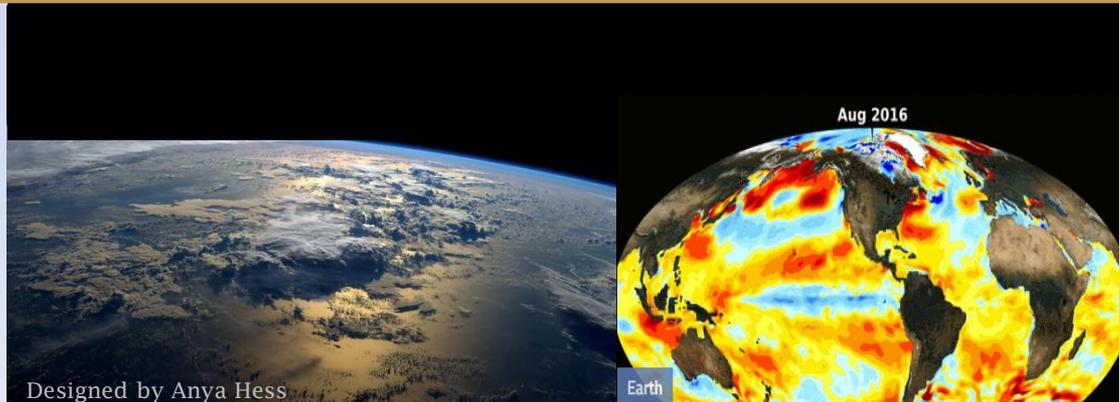
- 40% increase in CO<sub>2</sub>
- Dead carbon altering atmospheric C<sup>14</sup>
- That Carbon is more negative/enriched in C<sup>12</sup>



# *Adapting to our Changing Climate*

*Global warming:*

*The Consequences of  
turning up that  
thermostat*



# Floods

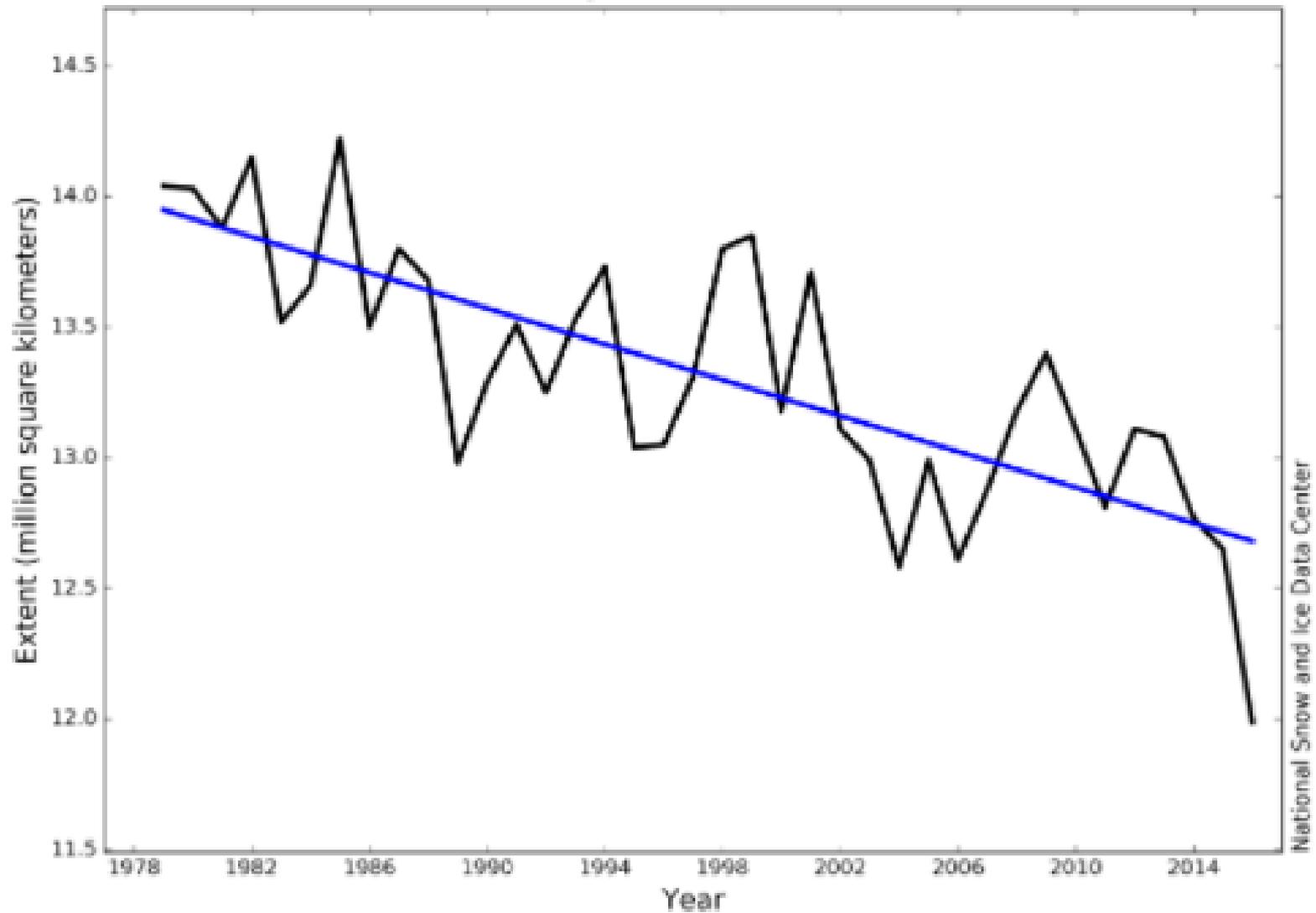
Drought

# Wildfires

# Pollution

**Not Attributable to climate change  
But is related to our fossil fuel burning  
that is causing climate change**

# Average Monthly Arctic Sea Ice Extent May 1979 - 2016

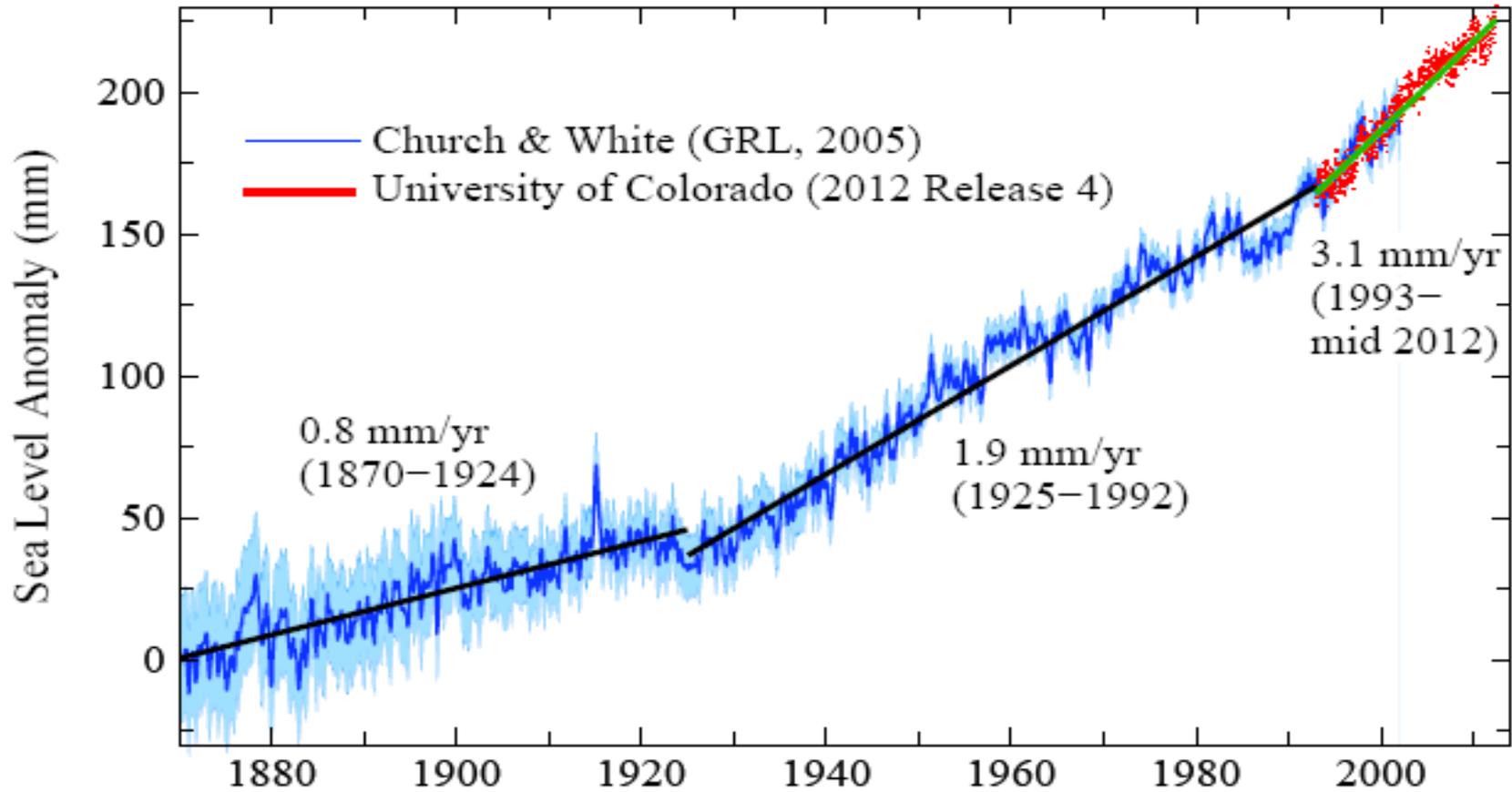


For more see: <http://www.skepticalscience.com/melting-ice-global-warming.htm>

<http://nsidc.org/arcticseaicenews/2016/06/>

# 14: HOW FAST IS SEA LEVEL RISING?

Global Mean Sea Level Change

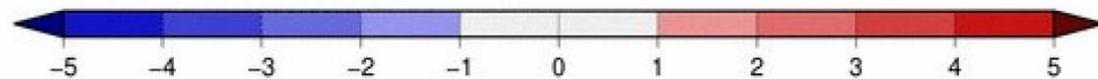
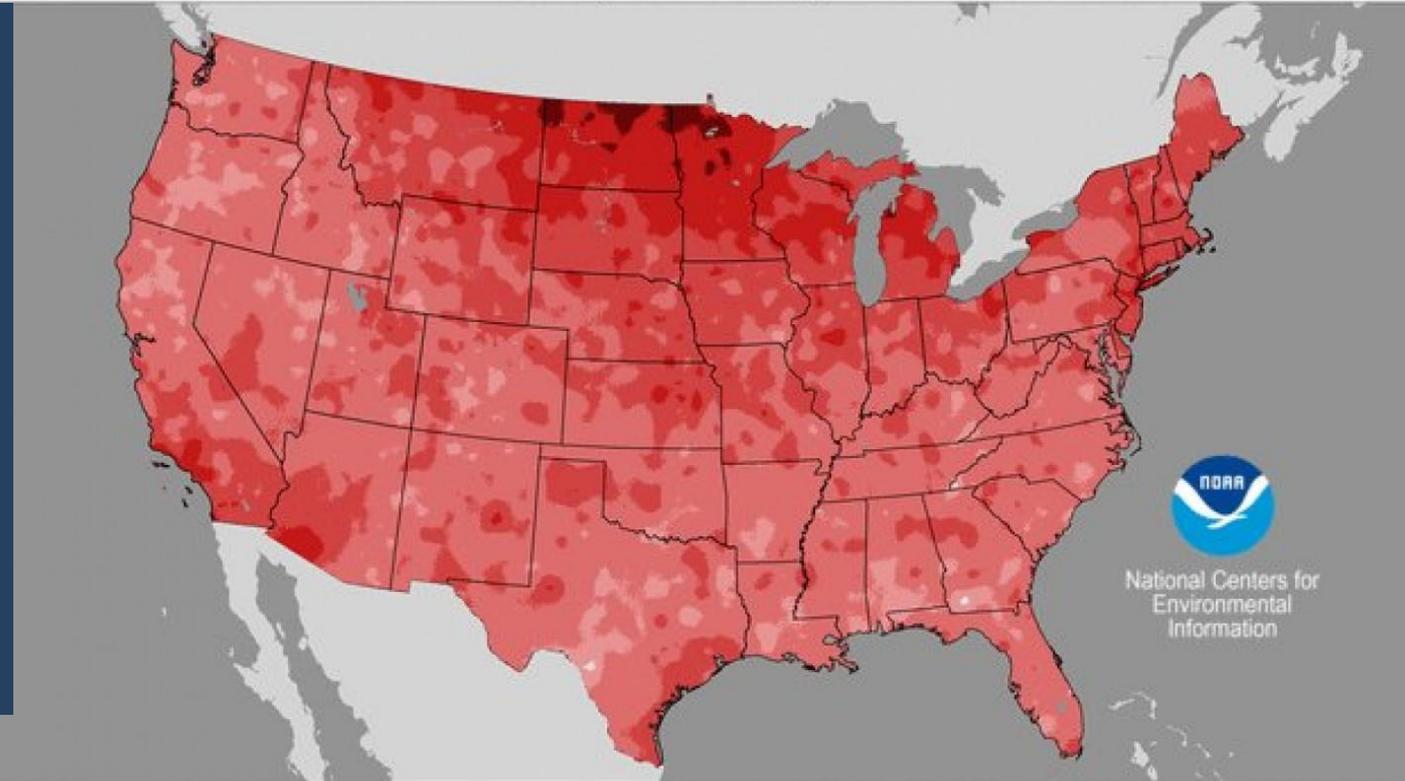


Blue: Sea level change from tide-gauge data (*Church J.A. and White N.J., Geophys. Res. Lett. 2006; 33: L01602*)

Red: Univ. Colorado sea level analyses in satellite era (<http://www.columbia.edu/~mhs119/SeaLevel/>).

# U.S. posts second-warmest year (2016) on record, breadth of warmth 'unparalleled' Washington Post, 9 Jan 2017

Mean Temperature Departures from Average  
January–December 2016  
Average Period: 20<sup>th</sup> Century



Created: Wed Jan 04 2017

Degrees Fahrenheit

Data Source: 5km Gridded (nClimGrid)

NOAA:

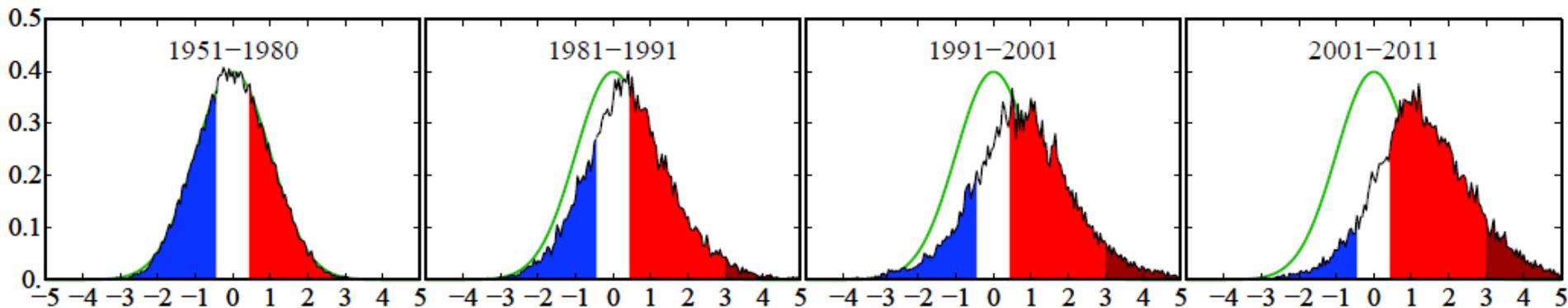
- “The breadth of the 2016 warmth is unparalleled in the nation’s climate history,”
- “No other year had as many states breaking or close to breaking their warmest annual-average temperature.”

**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.**

Shifting Distribution of Summer Temperature Anomalies

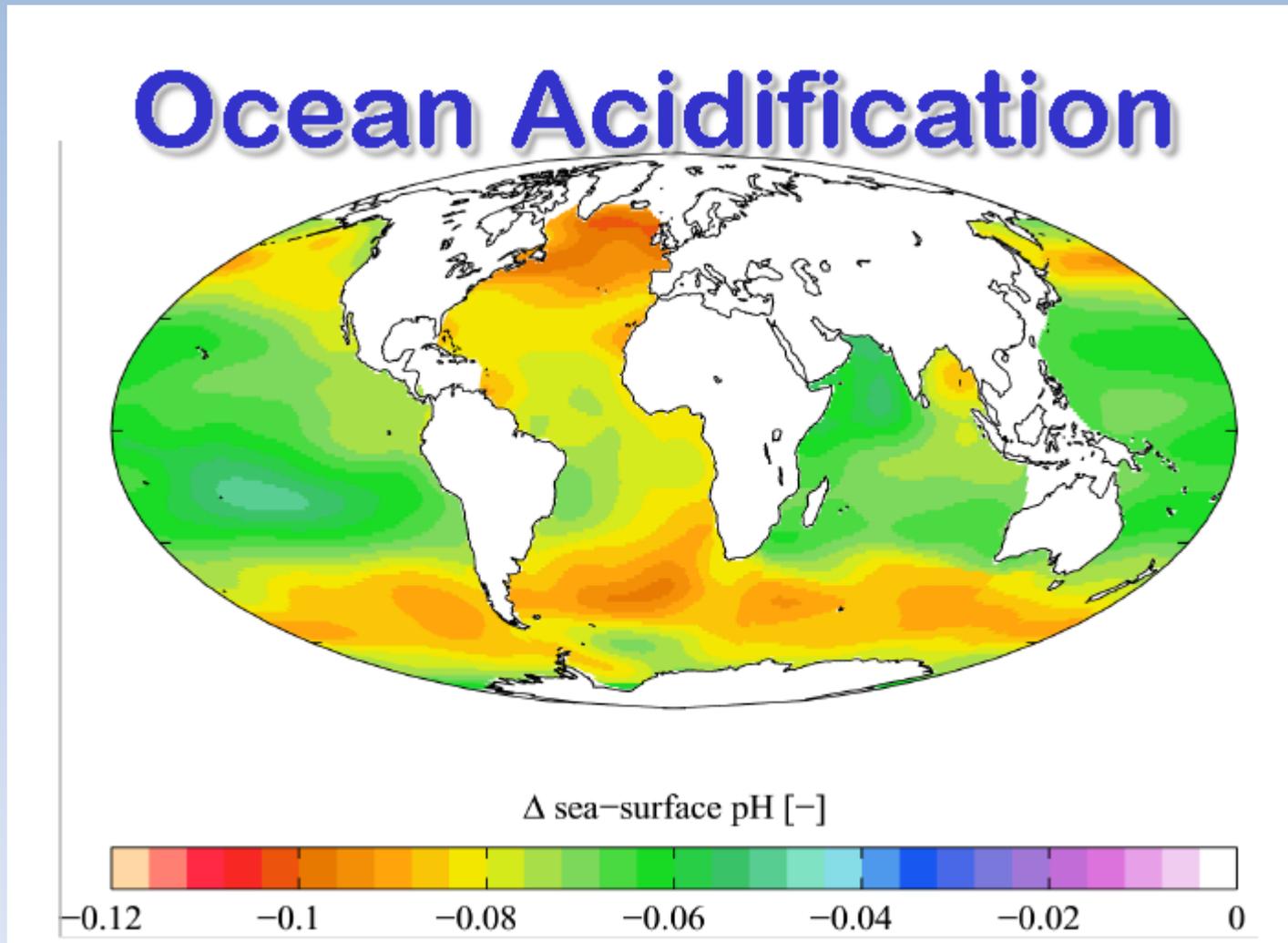


Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land in units of local standard deviation (horizontal axis). Temperature anomalies in the period 1951-1980 match closely the normal distribution ("bell curve", 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.*

# Ocean Acidification

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



# *Mitigating & Adapting to our Changing Climate*

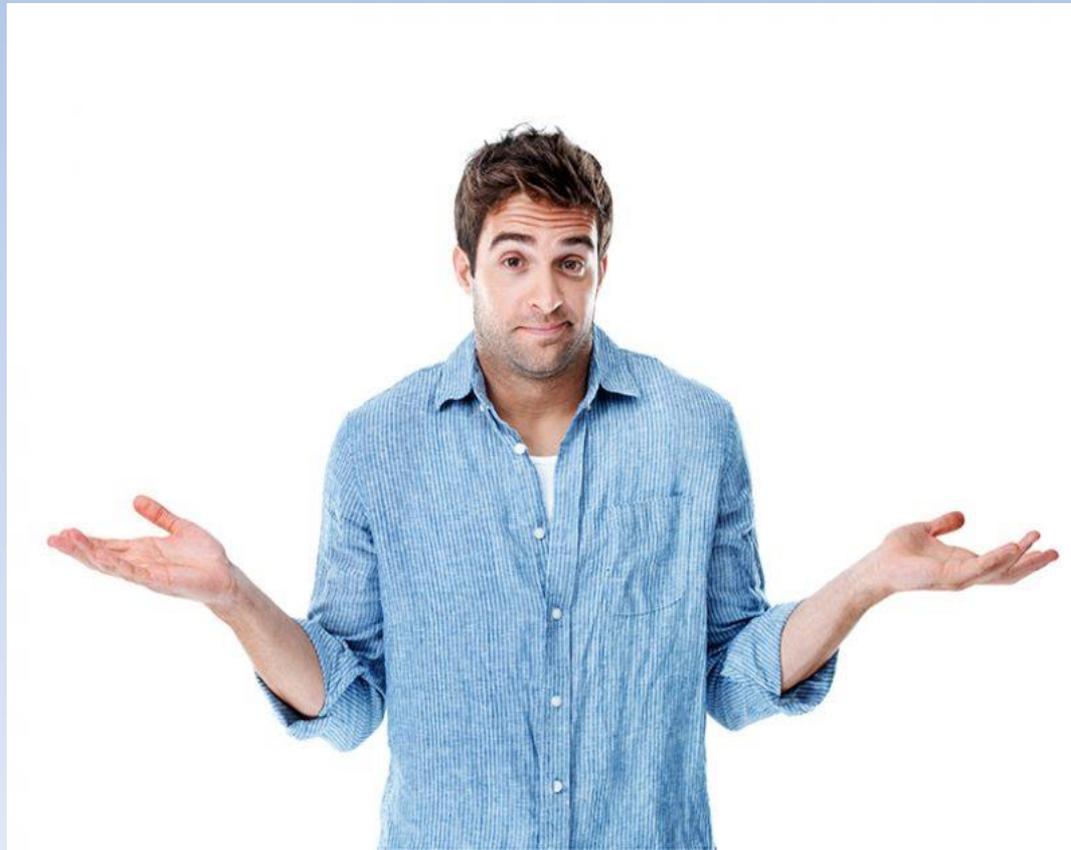
## **Solutions:**

- **Overcome our Inertia and Apathy**
  - Reduce Carbon Emissions in Electric Generation, Transportation and in Heating**
  - Carbon Dioxide Removal (CDR); Negative Emission Technology (NET); Greenhouse Gas Removal (GGR)**



# Part 2: Solutions

## How to Overcome our Inertia and Apathy



# The American Public and Climate Change

Yale Program on Climate Change Communication

Climate Change and the American Mind  
- November, 2016

- 70% believe global warming is occurring
- 55% understand it is caused by human activity
- **Only 5% believe anything can or will be done**

<http://climatecommunication.yale.edu/>

Kathleen Wells, Denver CCL, 2017

# APATHY / INERTIA

## WHY?

- IT'S too late
- It's too big a problem
- It's up to the government
- I'm not long for here anyway
- It's too expensive
- I'm too busy



<https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy>

# APATHY / INERTIA vs. good motives:

- IT'S our planet
- It's the right thing to do
- I CARE FOR FUTURE GENERATIONS!
- It's for our grandkids, or dogs or cats 😊
- I believe in promoting the best of human values by example



<https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy>

# SOLUTIONS TO APATHY

**#1 - CHANGE OUR WAY OF THINKING**

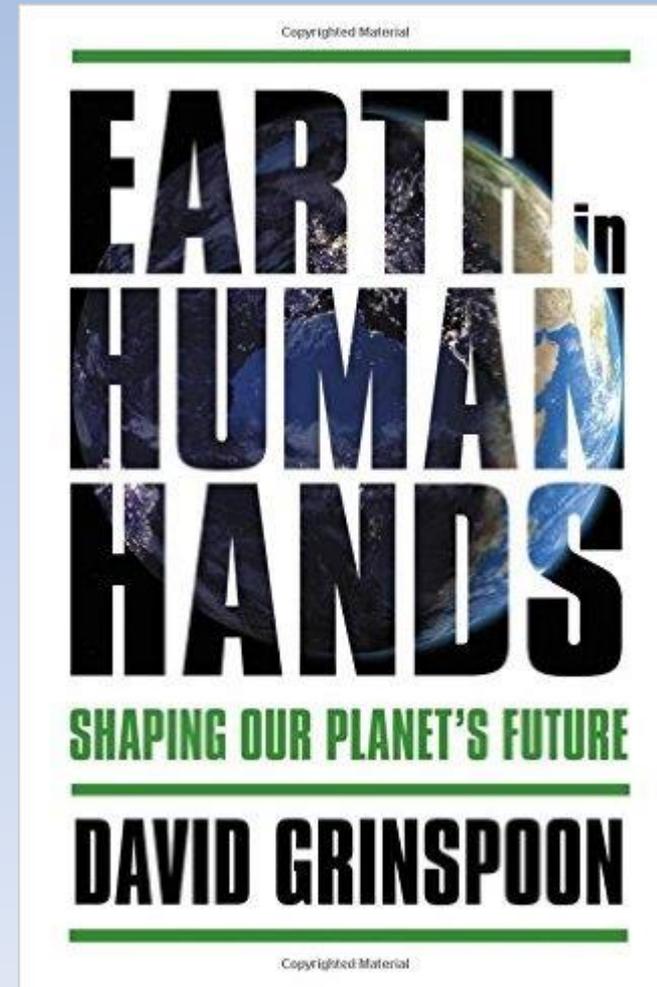
# Earth in human hands

- Kerry Emanuel, MIT Prof. Meteorology:
- “...there are few, if any, historical examples of civilizations consciously making sacrifices on behalf of descendants two or more generations removed”
- NEEDED CABINET POSTION:
  - **Secretary of the future**

# 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.

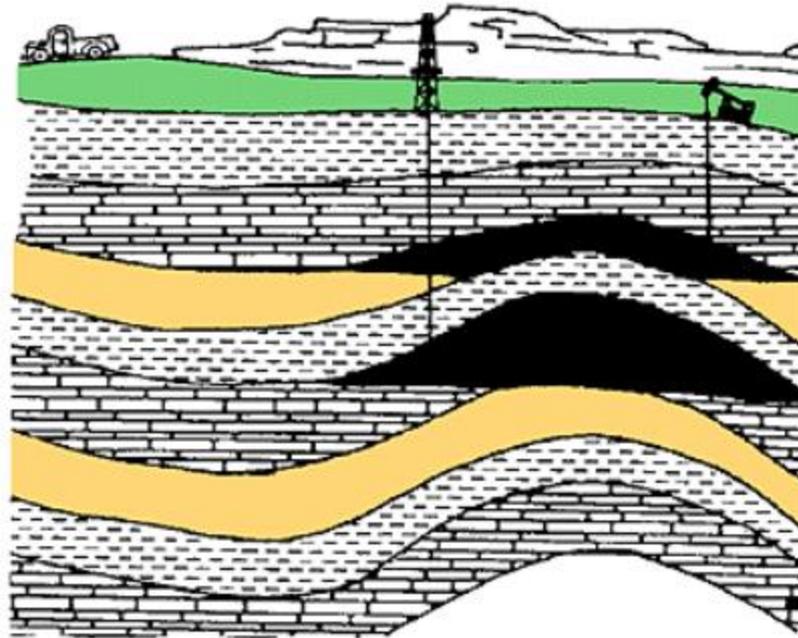
BTW – David Grinspoon will be at Conf. World Affairs (CWA), Boulder NEXT week of 4/8: <http://www.colorado.edu/cwa/>



# Fossil fuels: oil, gas, coal

- We owe a lot to fossil fuels
- It's only recently we've fully appreciated its consequences
- It's time for change!

## Fossil Fuels



Some of the stored solar energy in biomass can be **preserved in fossilized remains**

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# NATIONAL ICE CORE LAB:

<http://icecores.org/>

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**The Main Archive Freezer at the National Ice Core Laboratory**

Photo credit: National Ice Core Laboratory

# ICE CORE LAB

BE THERE 9:45

Lecture 10 to 11; BREAK AND 15-20 MINUTES IN MINUS 40 DEGREES  
STORAGE ROOM

BRING HAT, GLOVES, COAT



End of class slides September 26<sup>th</sup>, 2017



[https://i.kinja-img.com/gawker-media/image/upload/t\\_original/ihsllhptnm4vb7wuvvgq.jpg](https://i.kinja-img.com/gawker-media/image/upload/t_original/ihsllhptnm4vb7wuvvgq.jpg)