

I prefer “Global Warming” rather than “Climate Change”, because “Climate Change” does not specify the direction of the change.

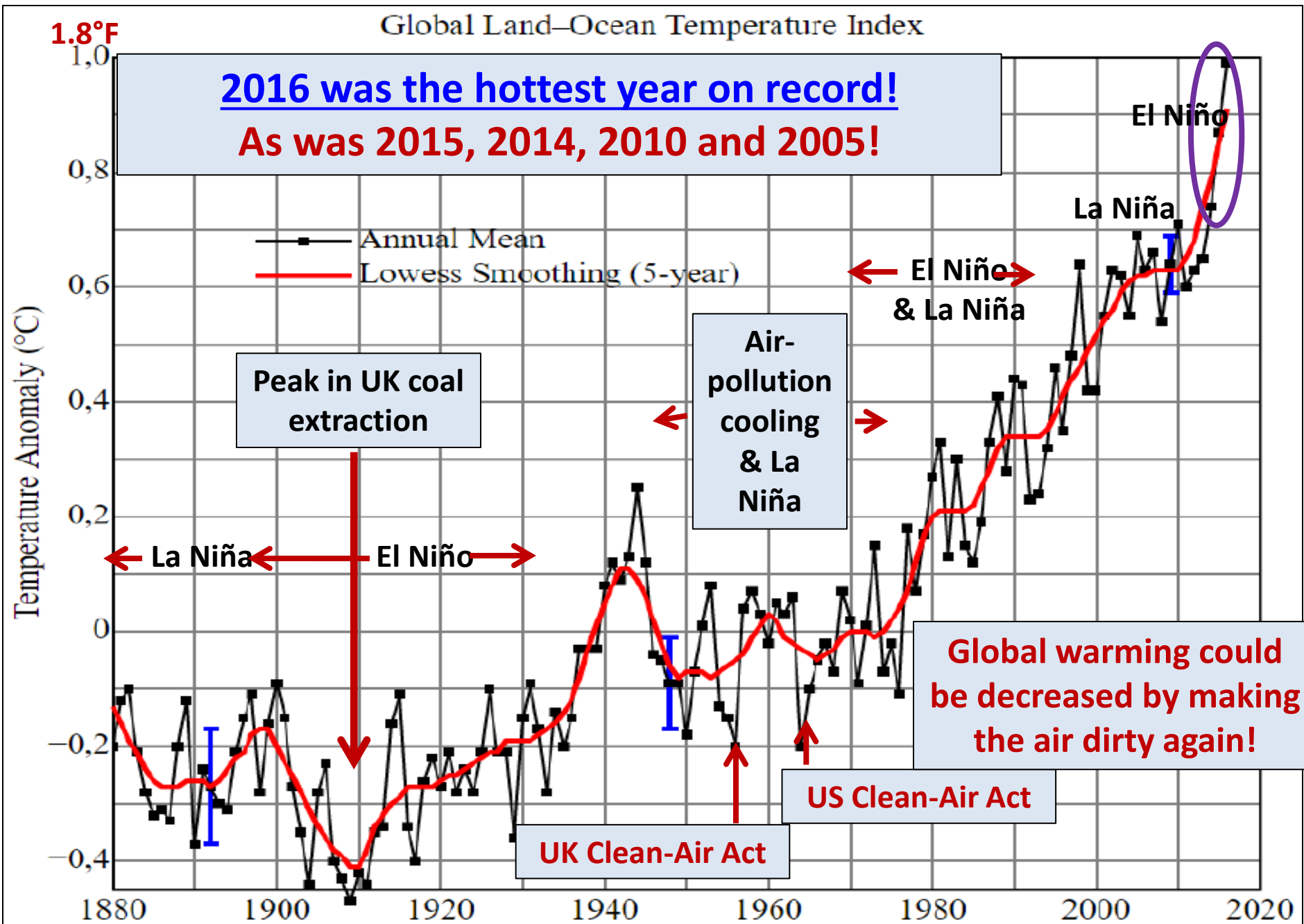
Global Warming

<http://tinyurl.com/GlobalWarmingRoper>

L. David Roper
roperld@vt.edu

Discovery of Global Warming: <http://www.aip.org/history/climate/>

El Niño increases global warming & La Niña decreases global warming.

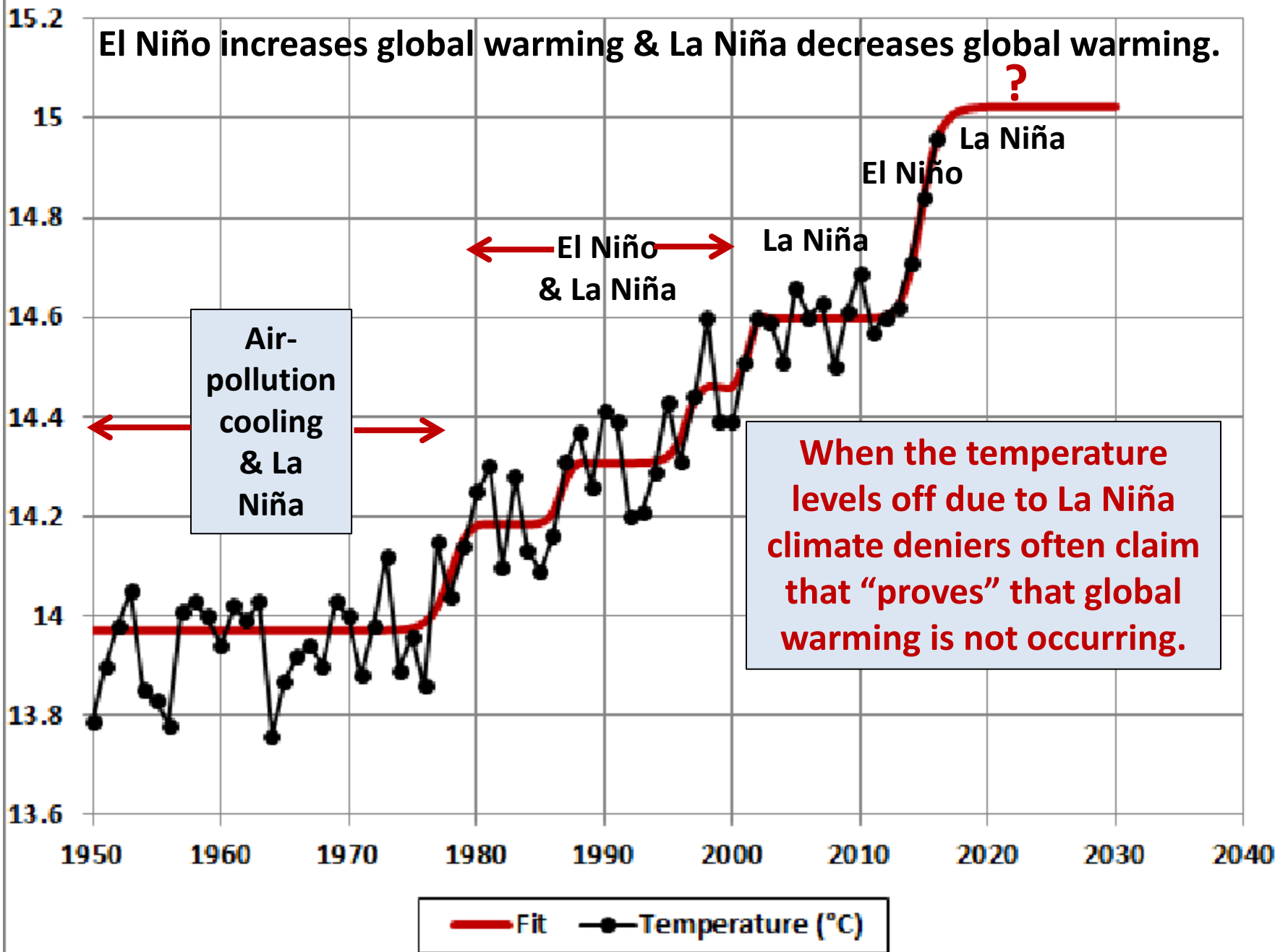


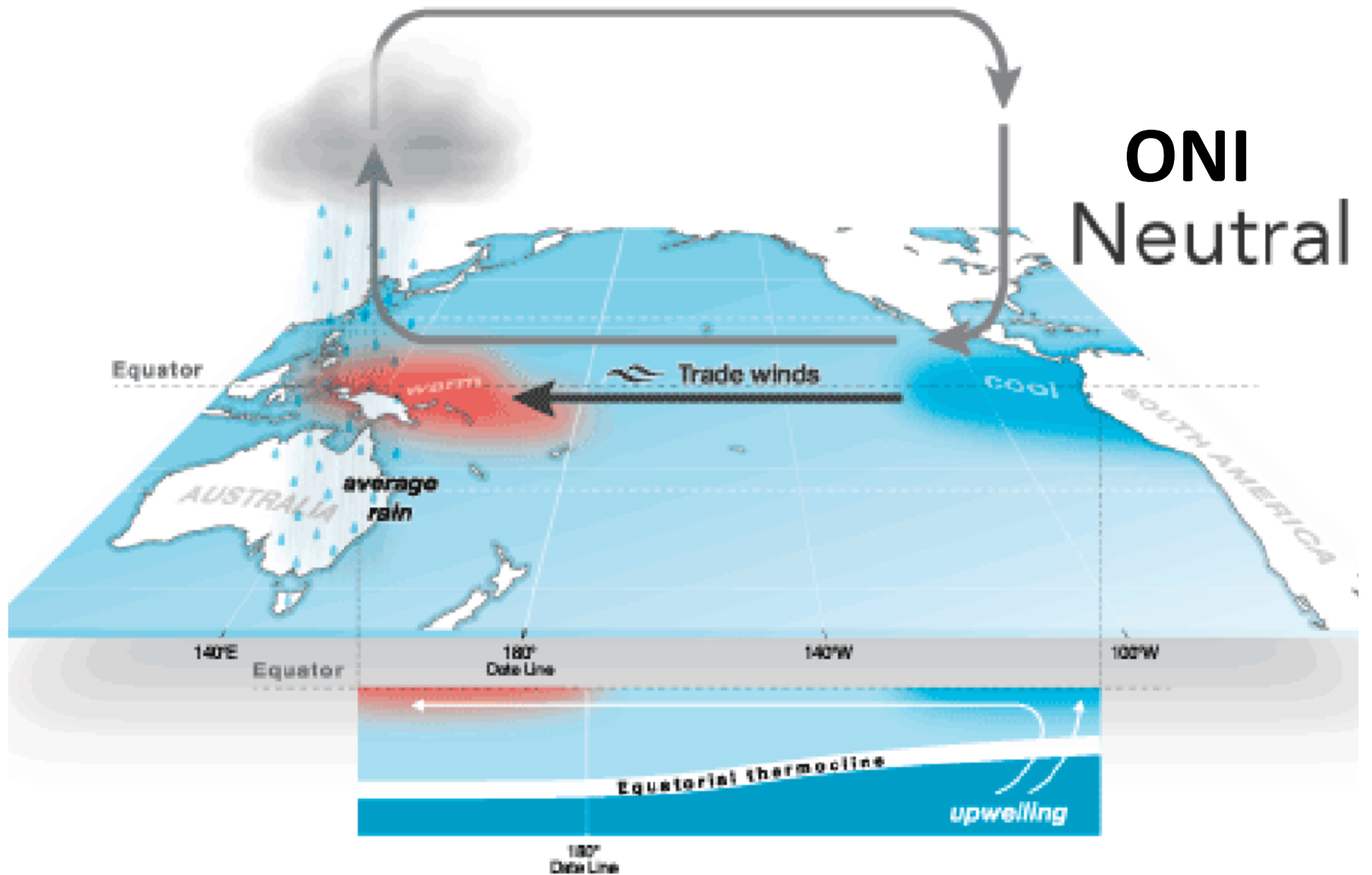
Pacific-Ocean **El Niño**/**La Niña**

Oceanic Niño Index (**ONI**)

- **La Niña** is **cooling** of Pacific-Ocean surface.
- **El Niño** is **heating** of Pacific-Ocean surface.
- Each lasts several months and occurs 3-10 years.
- **La Niña** involves upwelling of cold deep water.
- **El Niño** reduces the upwelling of cold deep water.
- **La Niña reduces** global warming.
- **El Niño increases** global warming less than La Niña reduces it.

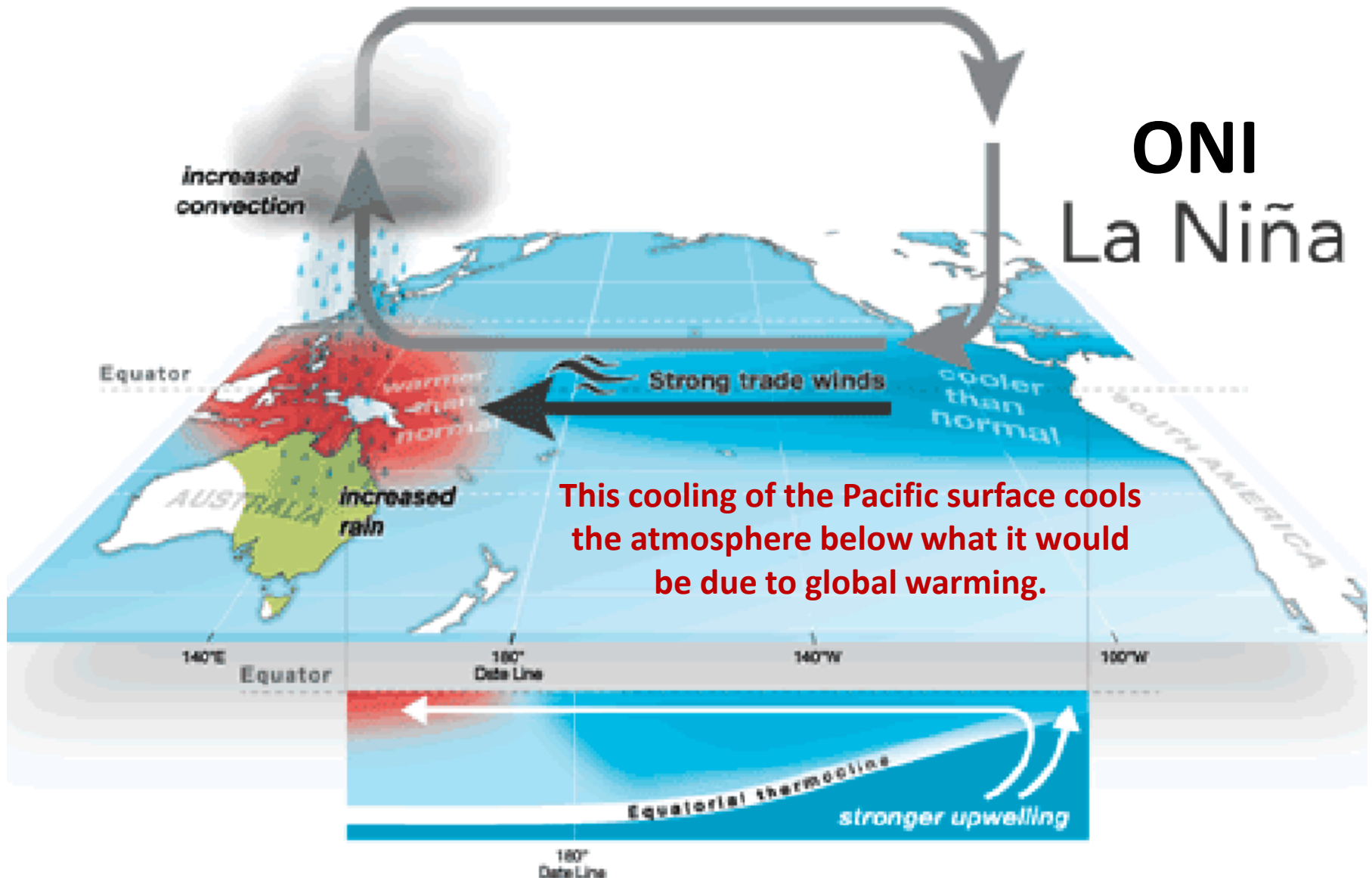
Global Temperature Average (°C)



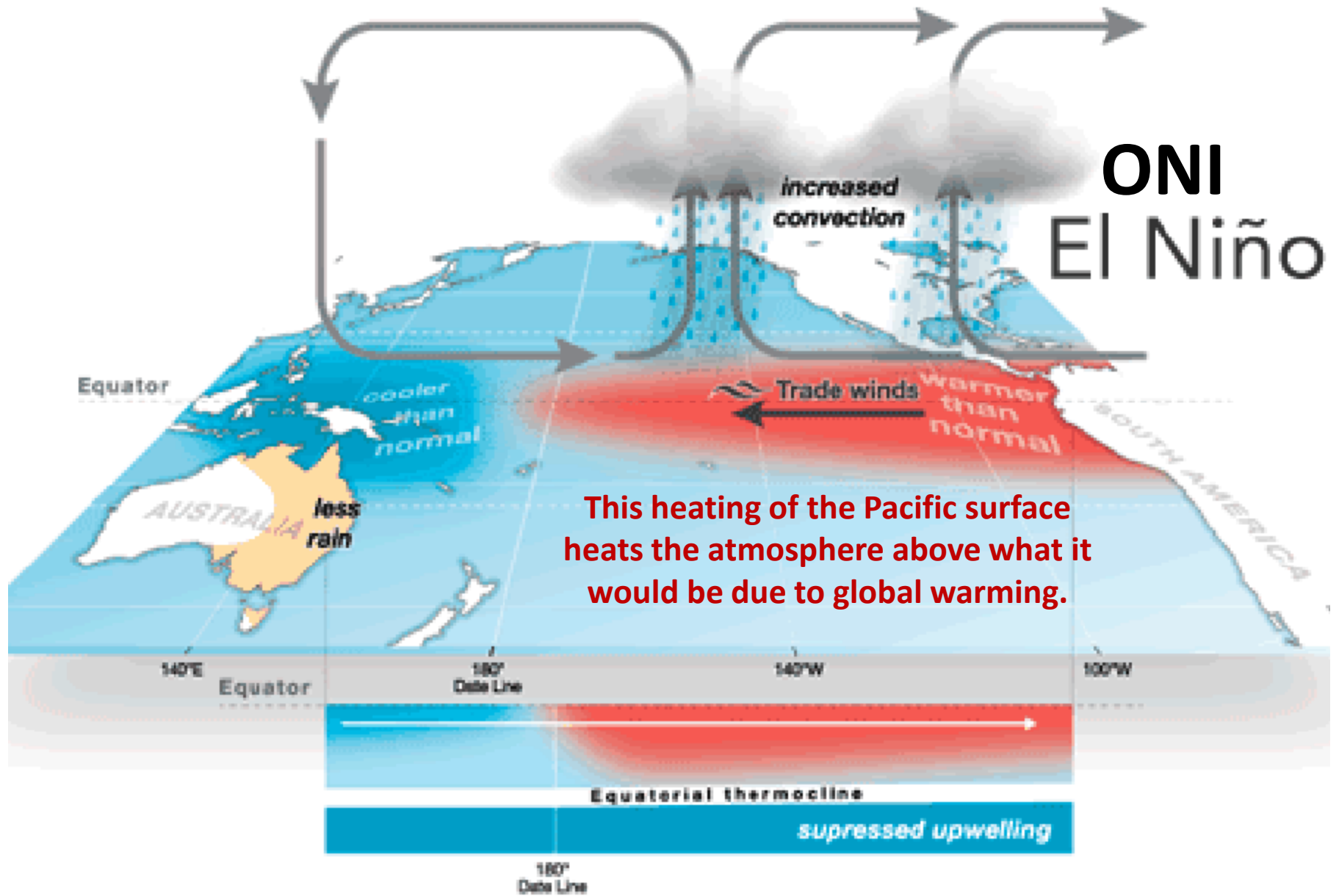


Neutral ONI involves some upwelling of cold deep water.

ONI La Niña

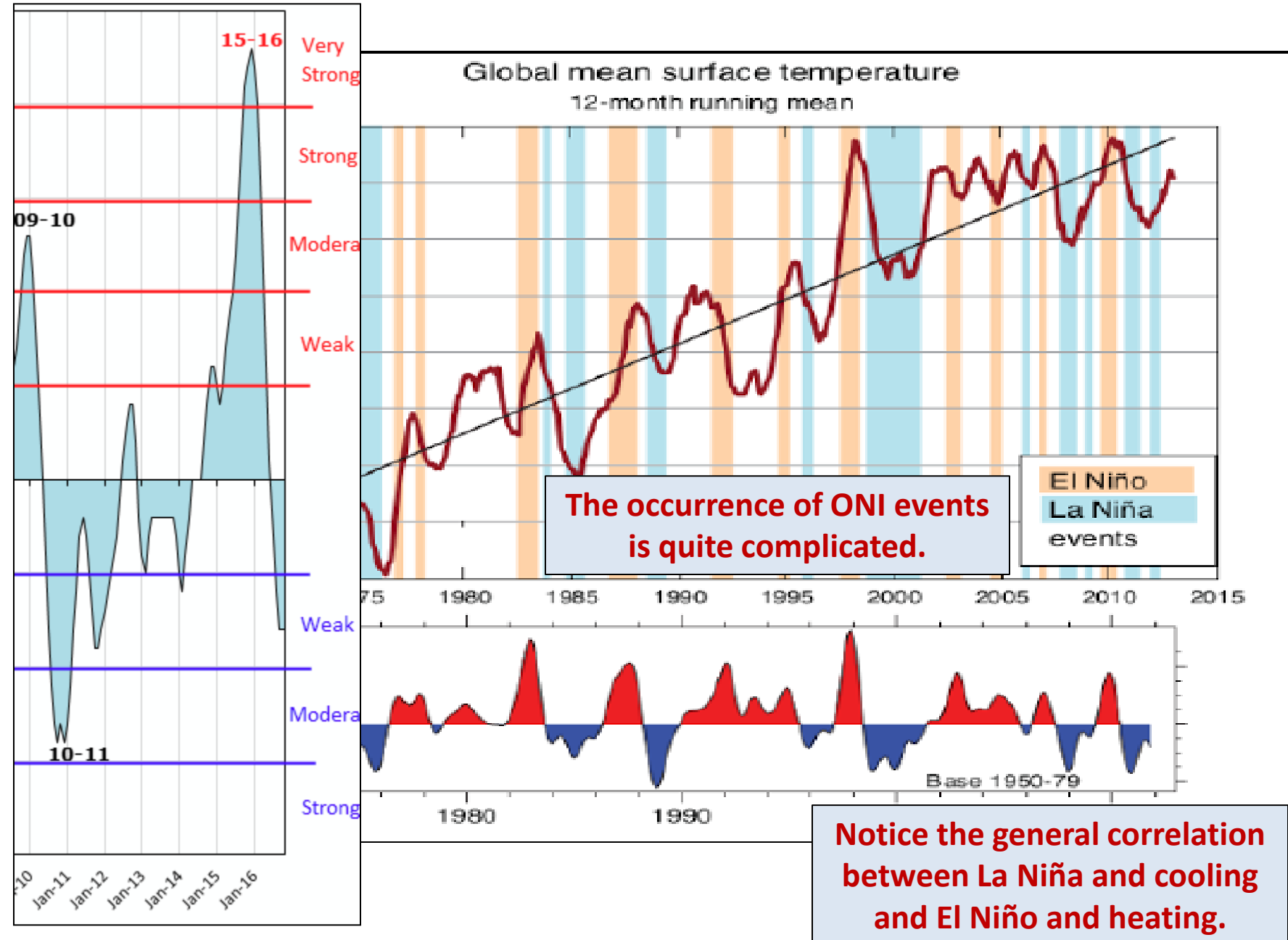


La Niña ONI involves strong upwelling of cold deep water.

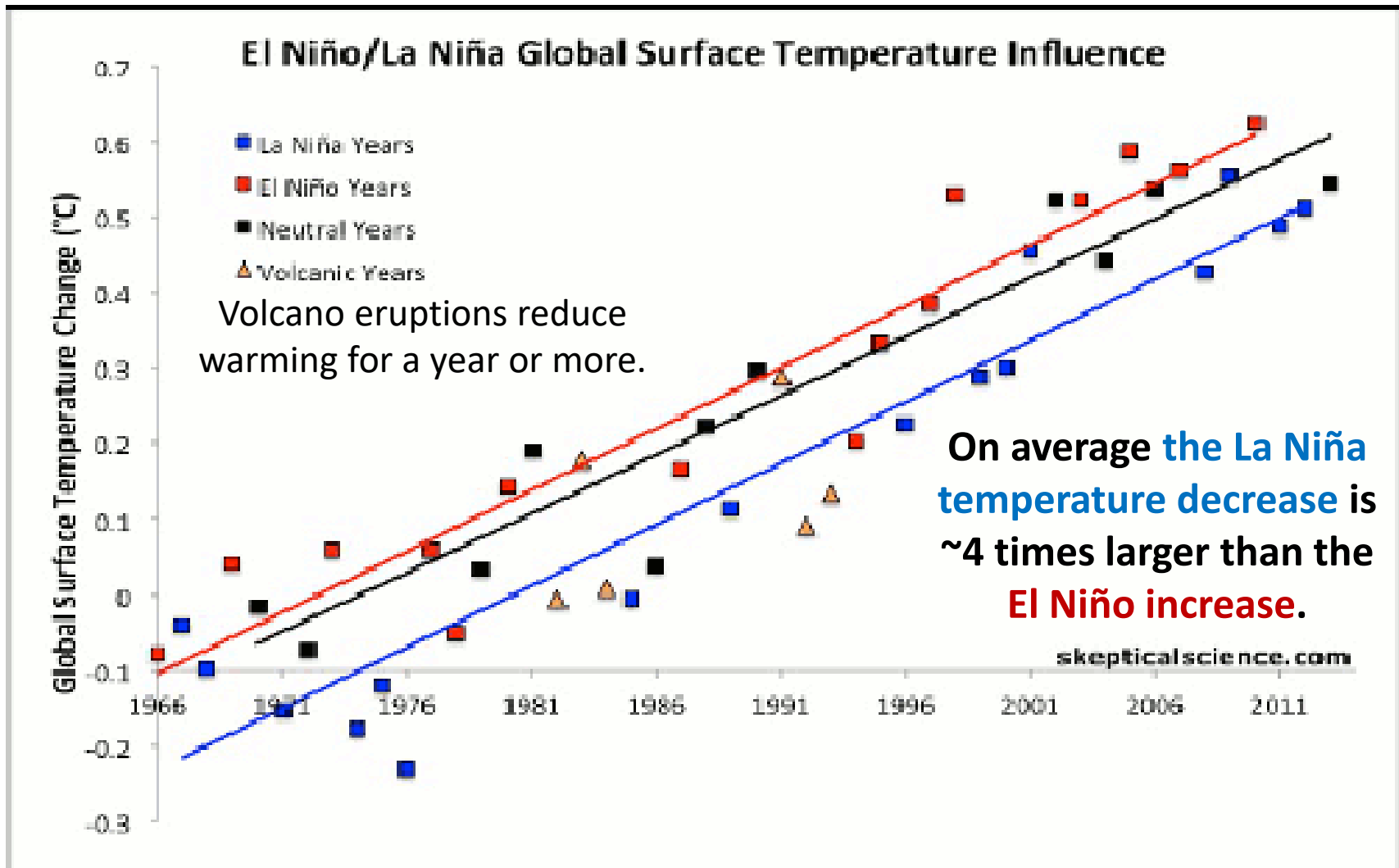


El Niño ONI involves suppressed upwelling of cold deep water.

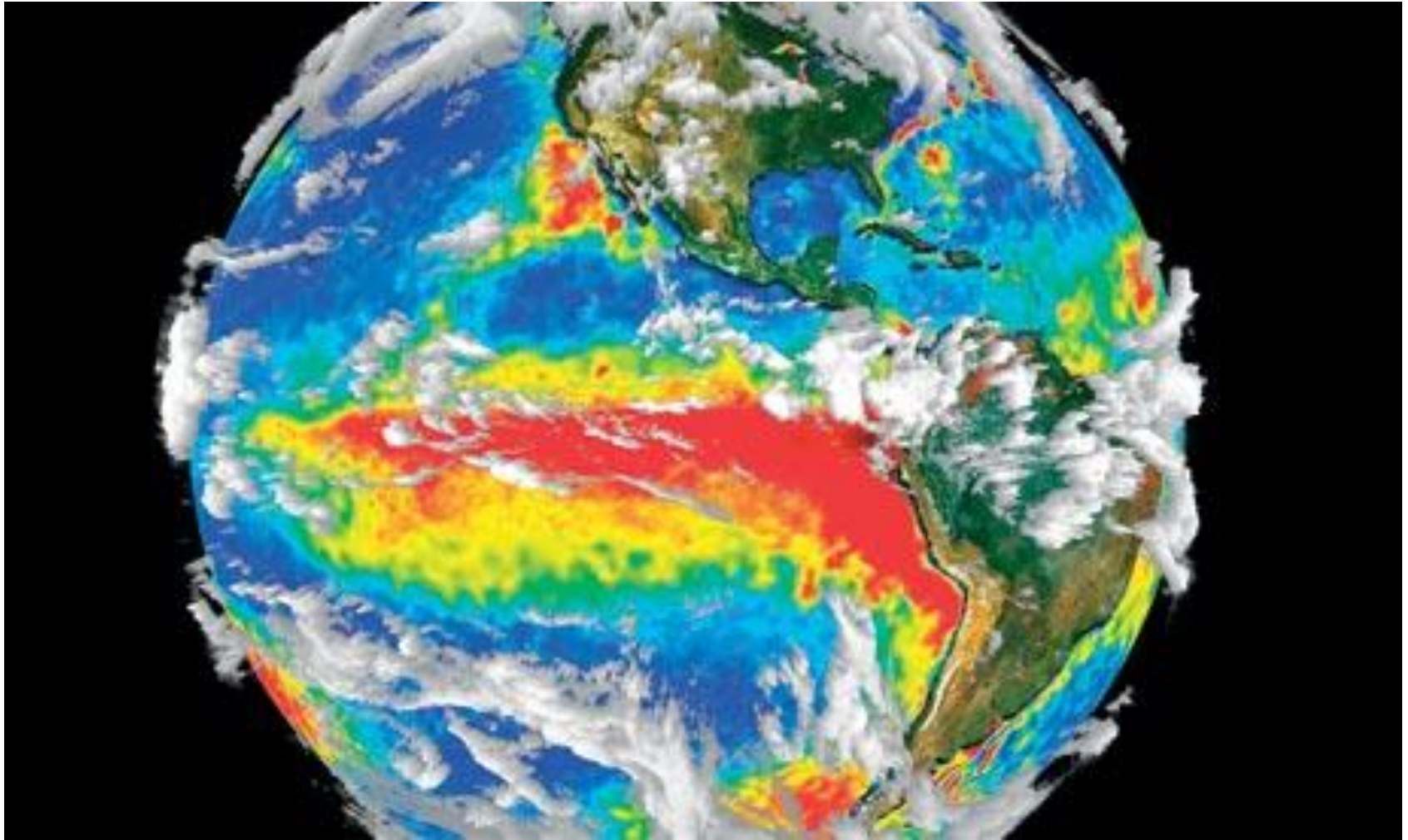
El Niño/La Niña Effects on Earth Temperature



El Niño/La Niña Effects on Earth Temperature



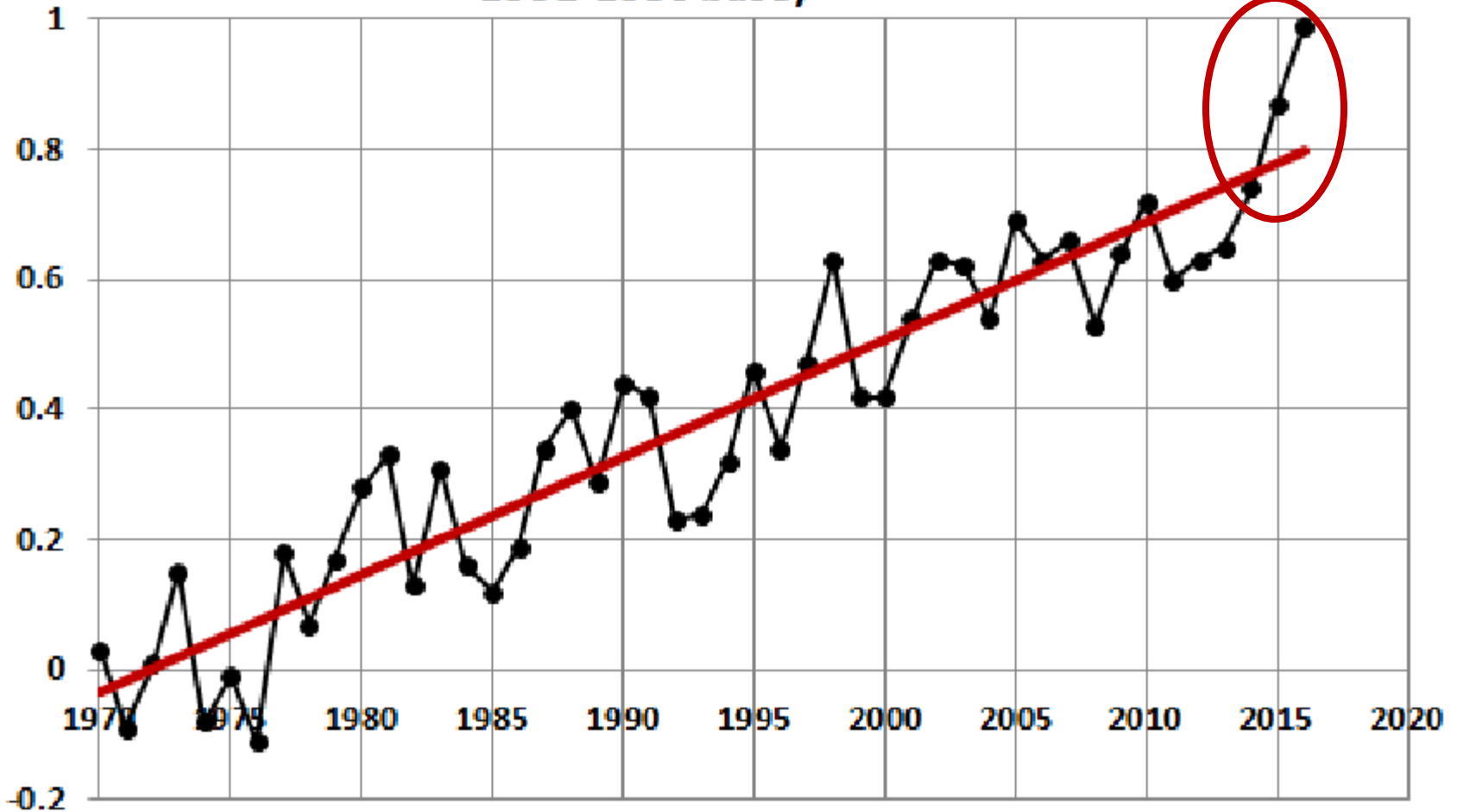
Typical El Niño Event



El Niño causes greater **surface temperature**, especially in eastern Pacific.
La Niña causes greater **deep ocean temperature**; the heat sinks into the deep western Pacific.

Recent Rapid Temperature Rise!

Global Temperature Anomaly (°C)
1951-1980 base)



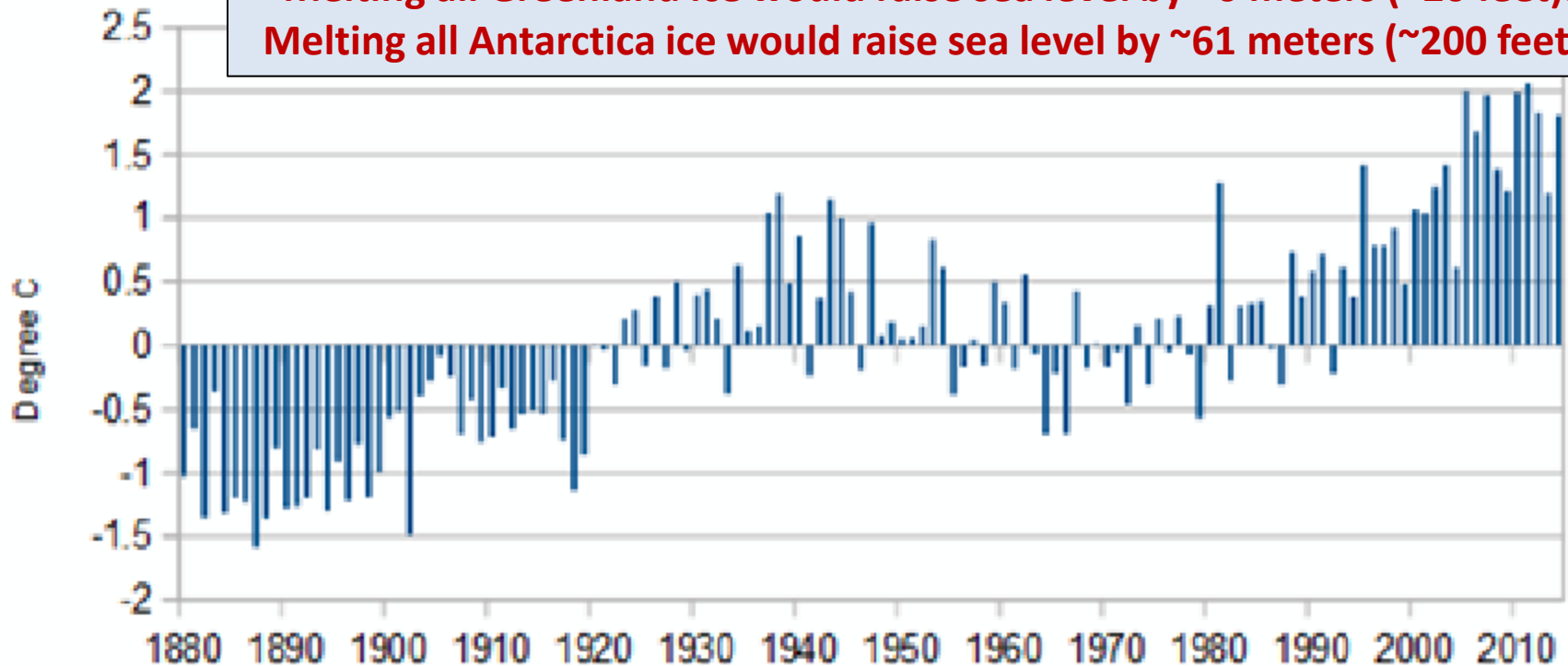
● Average — Linear (Average)

Arctic Temperature

GISS LOTI Annual Temperature Anomalies : 1880 to 2014

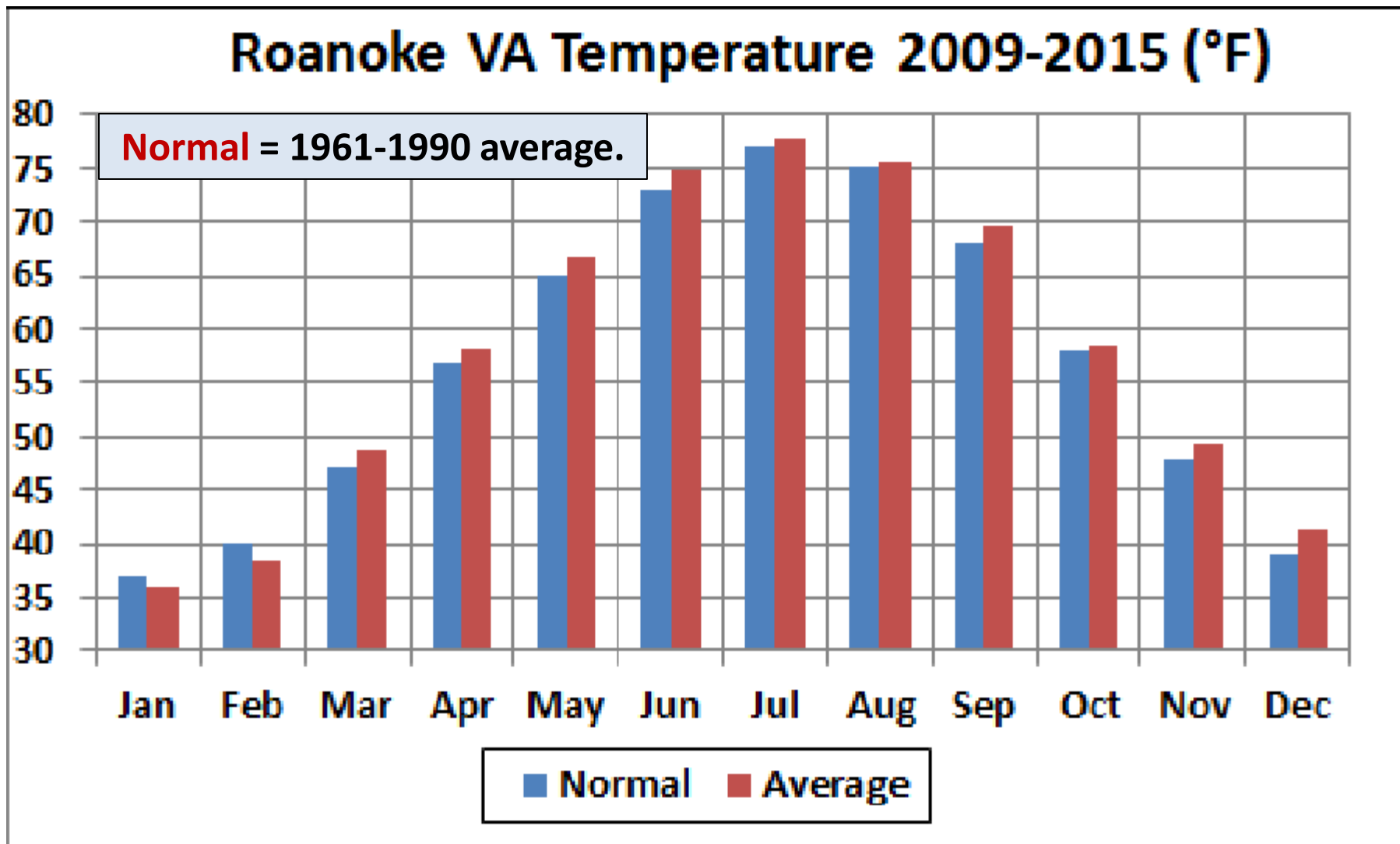
64N - 90N

Melting all Greenland ice would raise sea level by ~6 meters (~20 feet).
Melting all Antarctica ice would raise sea level by ~61 meters (~200 feet).



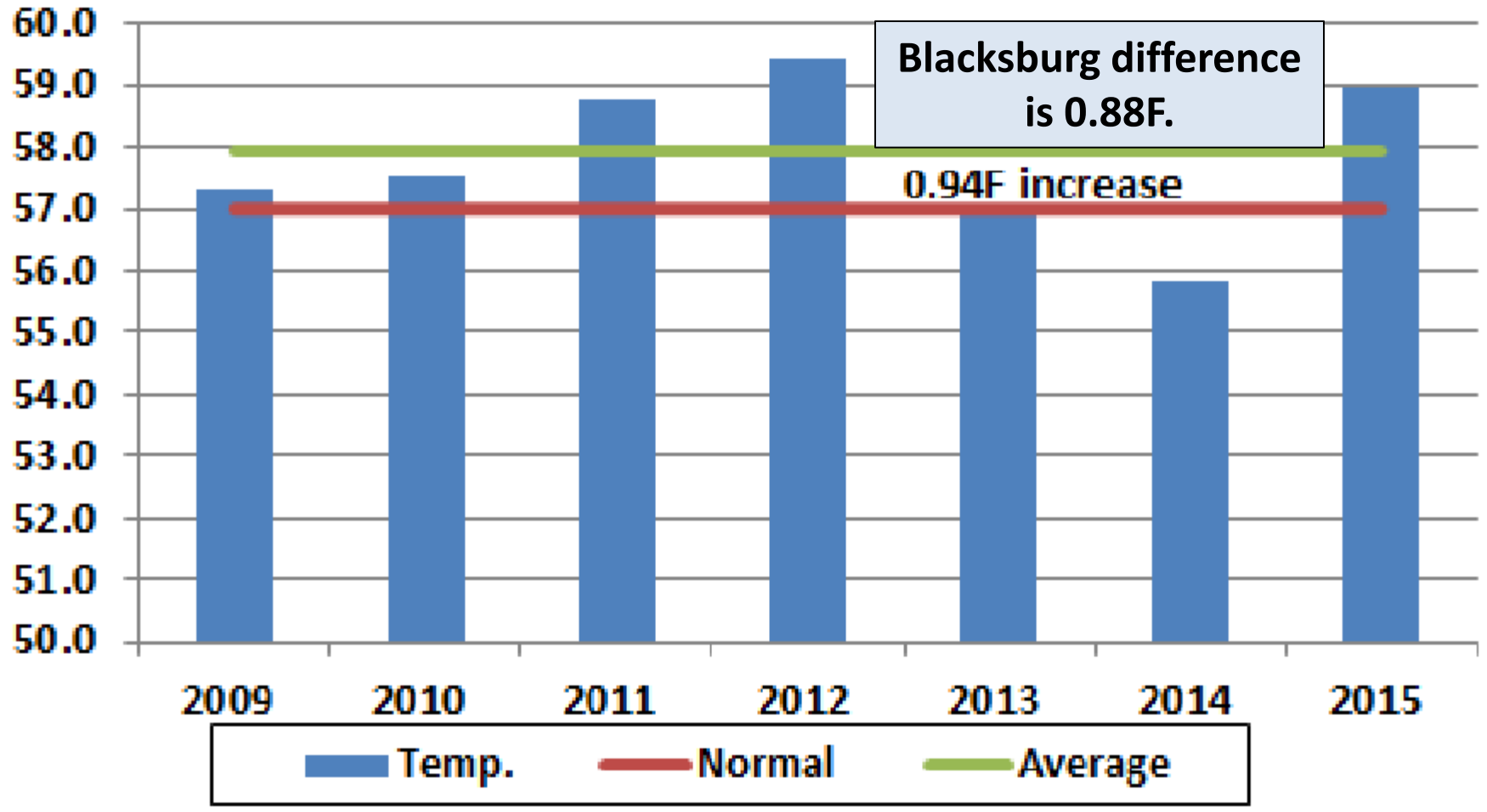
The Earth temperature rise is ~1.2°C (2.2°F) since 1880.
The Arctic rise is ~3°C (5.4°F) since 1880!

What about Roanoke, Virginia?



It looks like the **yearly average temperature** is slightly higher than **normal**.
So, let's calculate it.

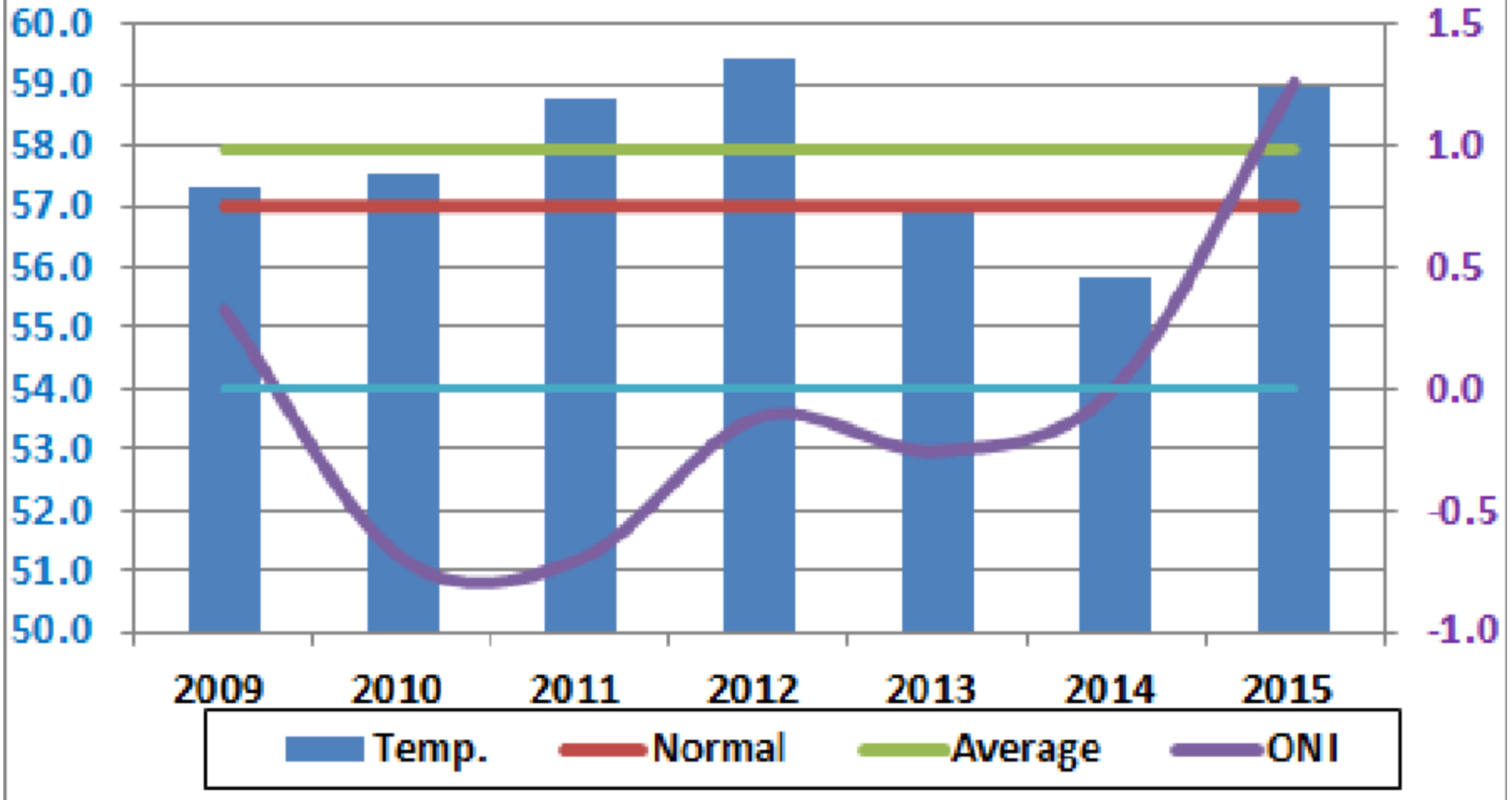
Roanoke VA Temperature 2009-2015 (°F)



Average is larger than **normal** (1961-1990 average),
as expected by Global Warming.

What about ONI?

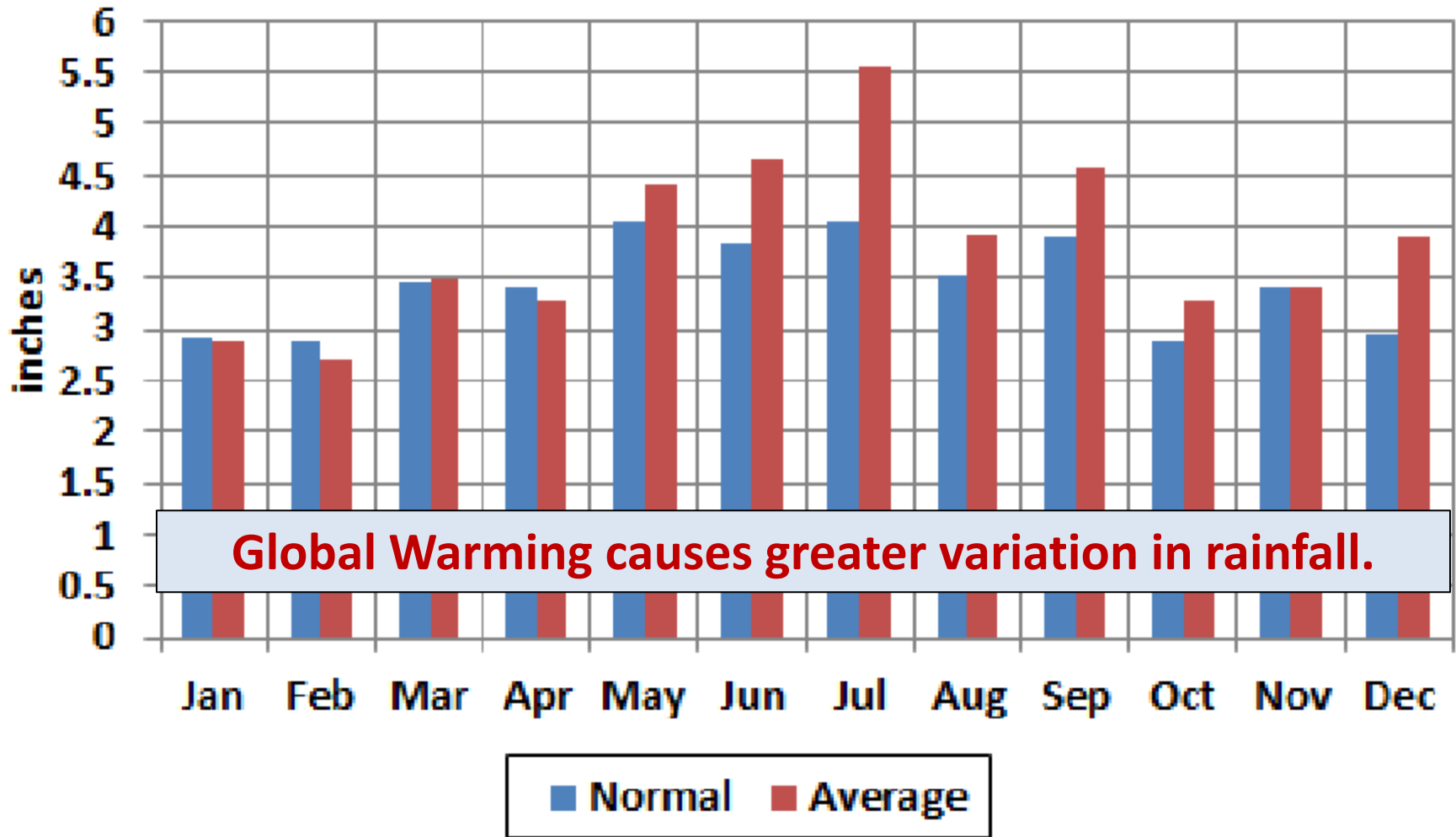
Roanoke VA Temperature 2009-2015 (°F)



**La Niña (negative ONI) dominates over this time period,
so Global Warming should be reduced.**

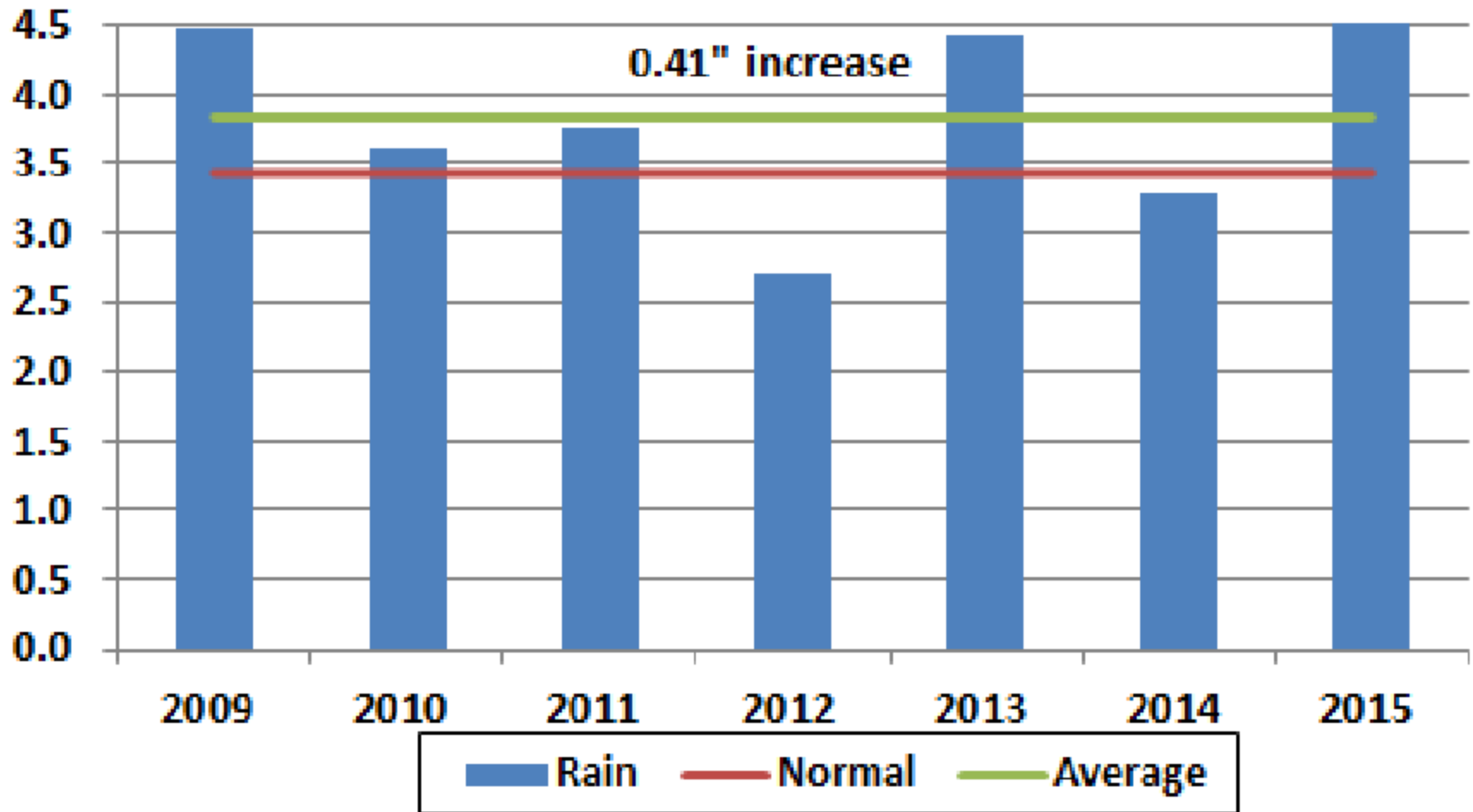
However, it does occur!

Roanoke VA Rain 2009-2015 (F)



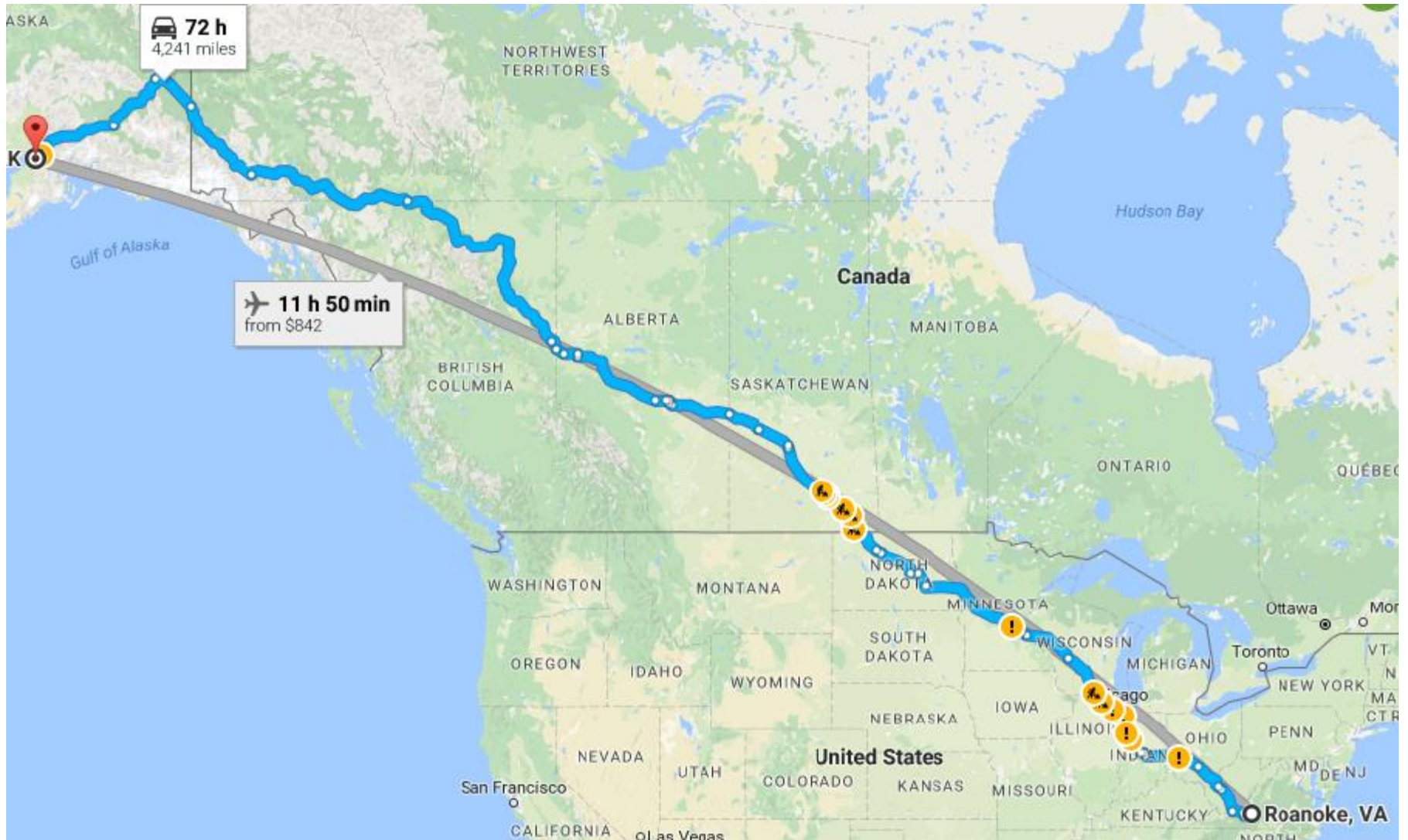
Normal = 1961-1990 average.

Roanoke VA Rain 2009-2015 (inches)

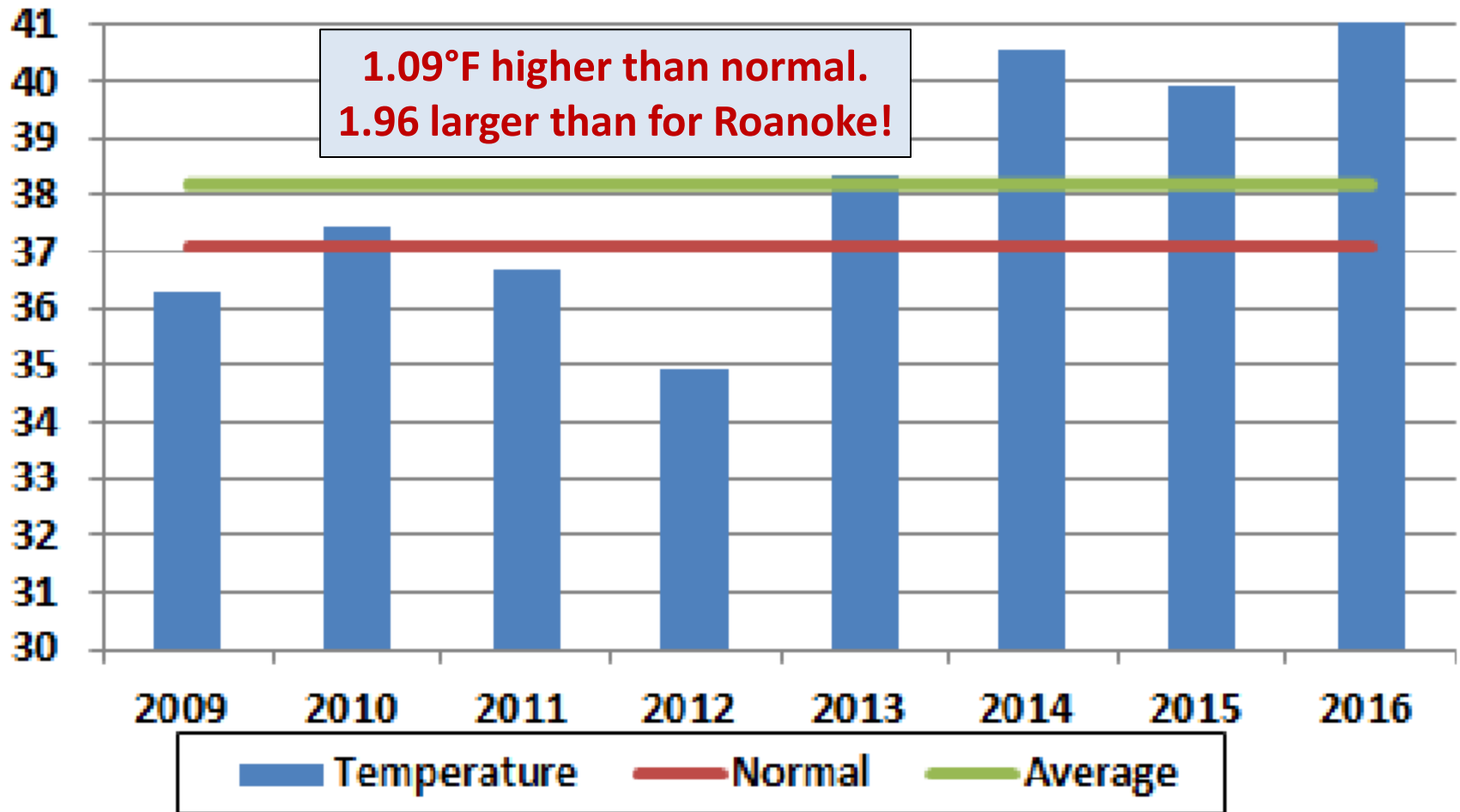


More rain than normal is consistent with Global Warming.

What about Anchorage, Alaska?

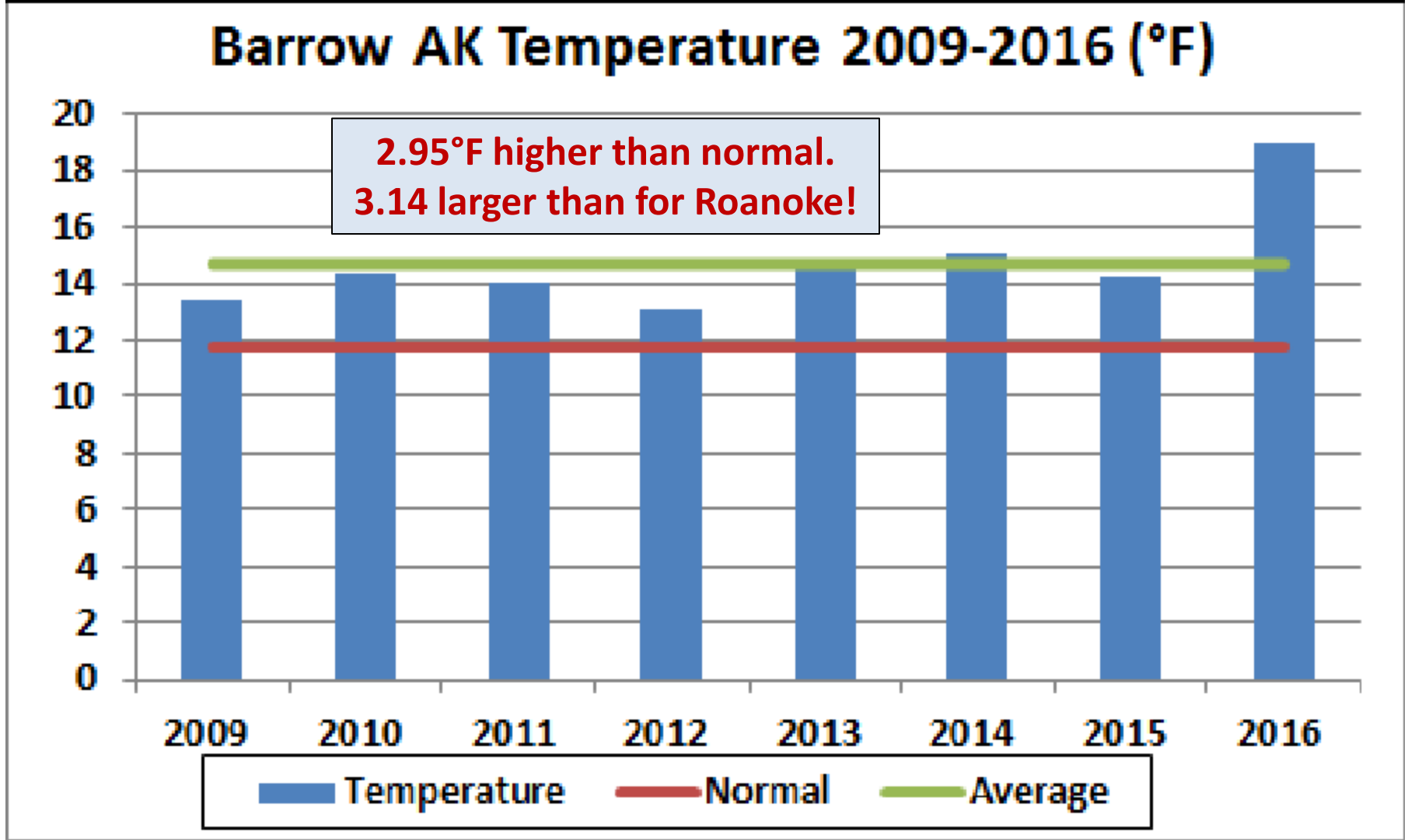


Anchorage Temperature 2009-2016 (°F)



Normal = 1961-1990 average.

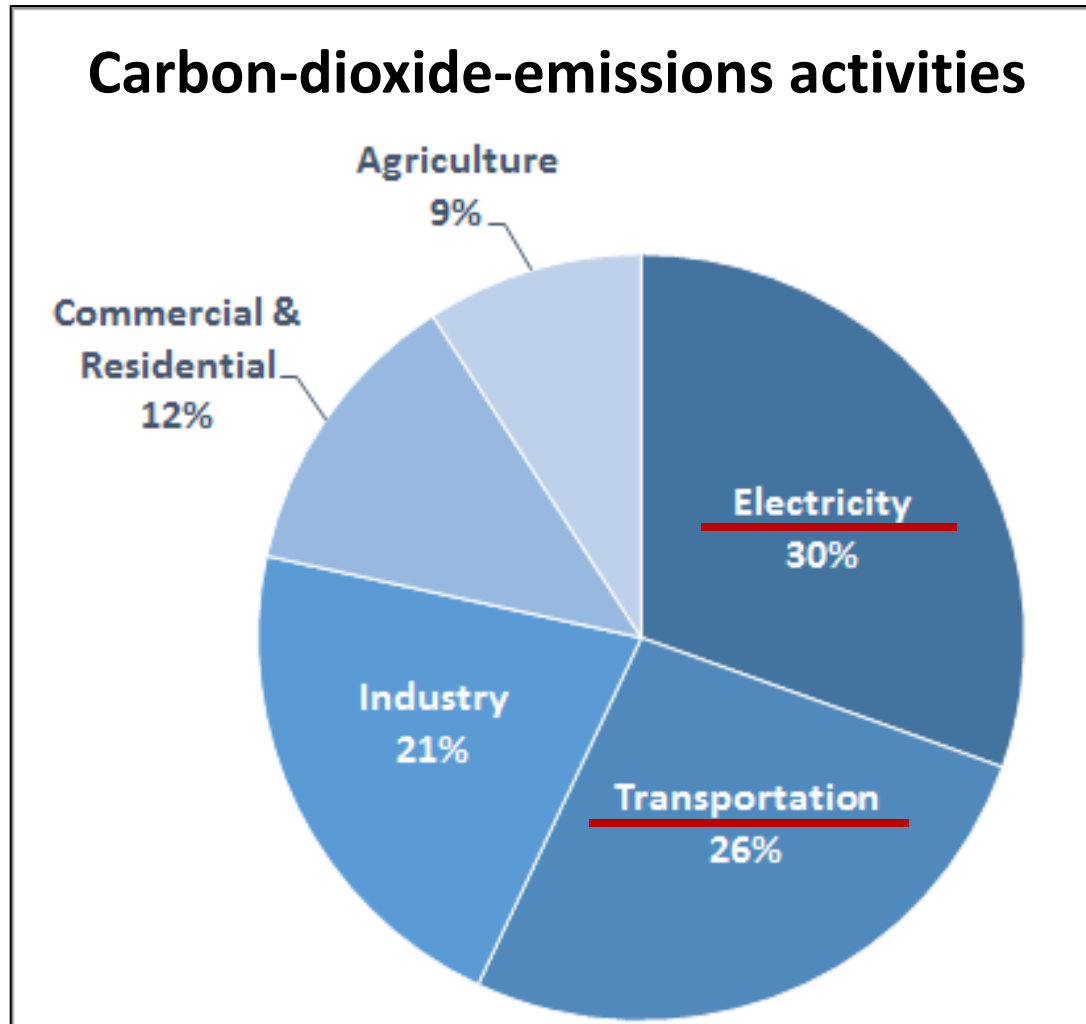
What about Barrow, Alaska?



Anchorage AK to Barrow AK is north 720 miles by air.
There is no road!

Causes of Global Warming

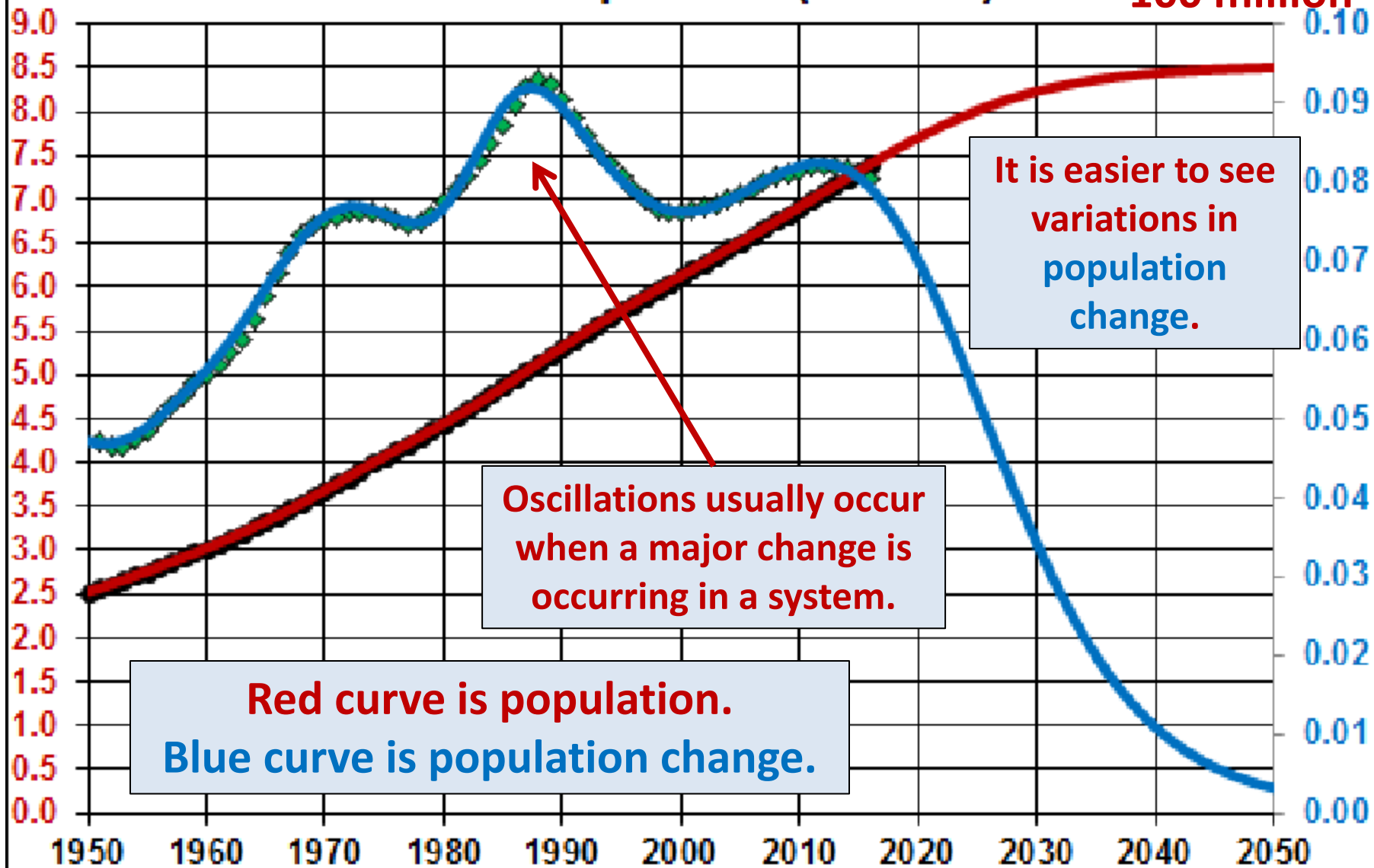
Too many people is basic cause!



We need renewable electrical energy & electric transport!

World Population (billions)

100 million



Red curve is population.
Blue curve is population change.

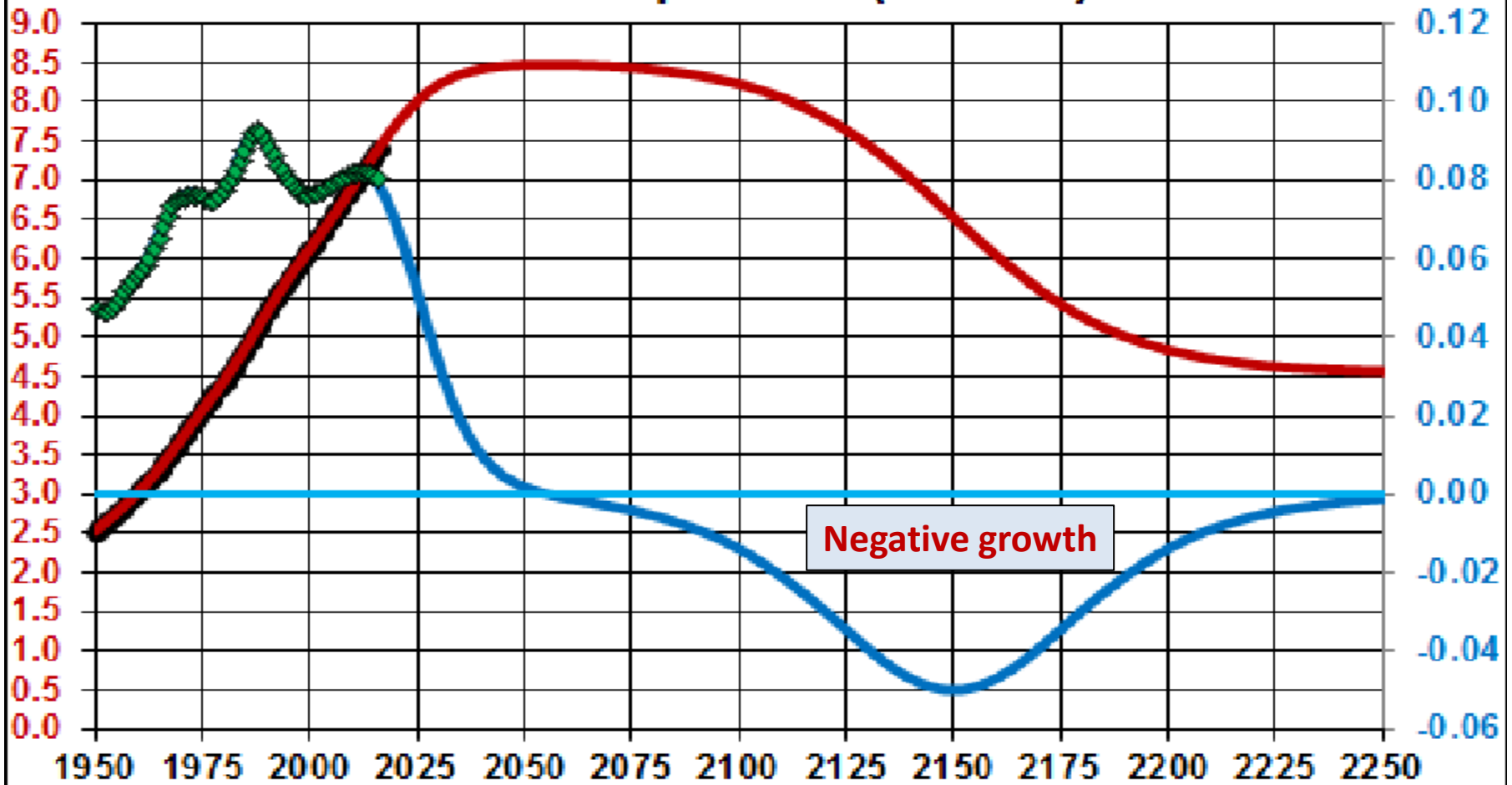
Oscillations usually occur
when a major change is
occurring in a system.

It is easier to see
variations in
population
change.

● Population ● Pop Change — Fit Pop — Fit Pop Change

**Much better would be for this to occur,
if it occurred by human choice not by disaster!**

World Population (billions)



Negative growth

Birth control should be free worldwide!

● Population — Fit Pop — Fit Pop Change ◆ Pop Change

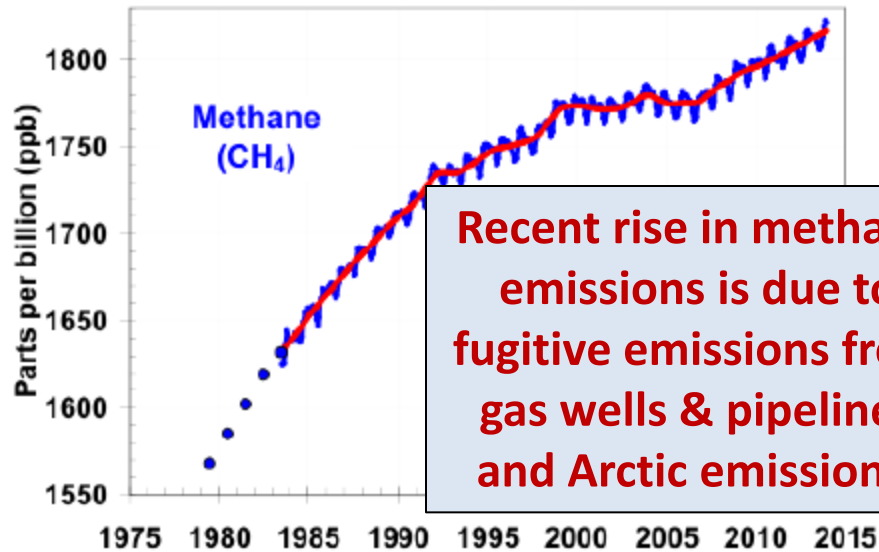
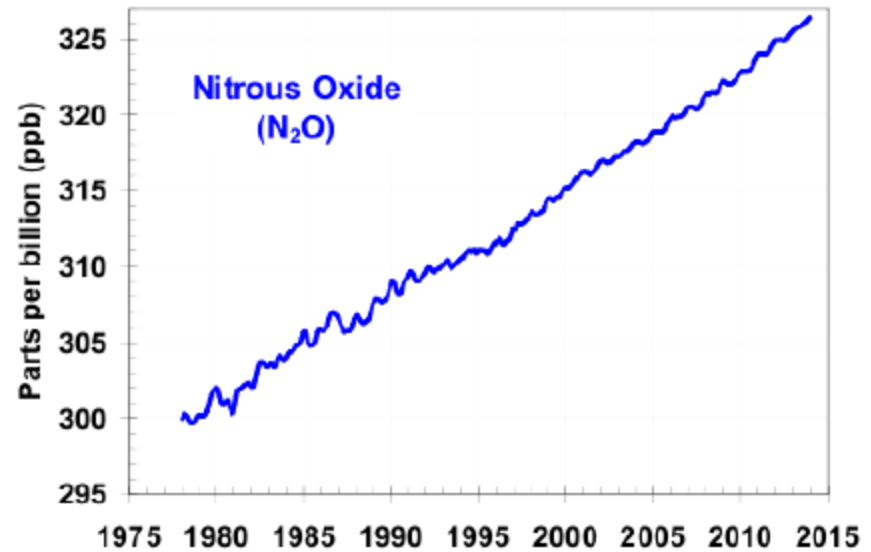
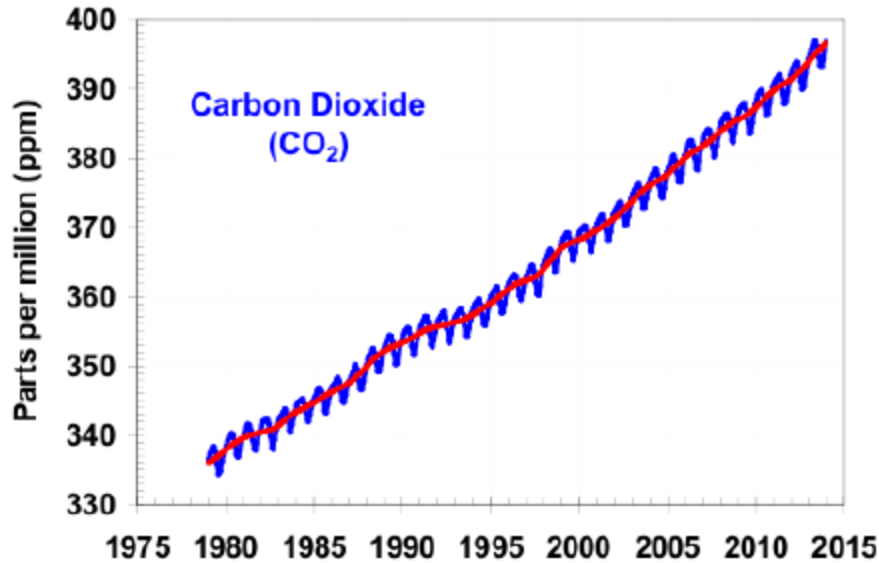
Effect of Carbon in Atmosphere

- **Earth would be covered with ice (-18°C or -0.4°F)** if there were no carbon in the atmosphere (**currently 0.04%**). Instead it is **15°C or 59°F**.
- Venus is very hot (**462°C or 864°F**) because of **96% CO₂** in a very dense atmosphere. Without carbon it would be **-53°C or -63°F**, because its clouds reflect 90% of solar energy.
- Extra carbon in the atmosphere (**currently 0.04%**) due to industrial revolution makes the Earth warmer.
- Burning fossil fuels puts carbon in the atmosphere.
- Burning coal puts about twice the carbon into the atmosphere as does burning natural gas.
 - **However methane leaks in gas drilling and pipelines make natural gas global-warming effect about the same as coal.**

Greenhouse Gases (GHG)

- **Carbon dioxide** (Global-Warming Potential = **GWP = 1**).
Lifetime in atmosphere = ~1000 years.
- **Methane** (**GWP = ~85** in 20 years & **~32** in 100 years).
Lifetime in atmosphere = 12 years.
Reacts with oxygen to produce water & **carbon dioxide**.
- **Ozone** (**GWP = ~1000**).
Lifetime in lower atmosphere = ~21 days.
- **Nitrous oxide** (**GWP = ~300** in 100 years).
Lifetime in atmosphere = ~121 years.
- **Halocarbons** (many of them which have variable GWP and lifetimes in atmosphere)
- **Water vapor** is a major cause of GW (Lifetime in atmosphere = ~9 days) **Warming of atmosphere increases it and it ~doubles the effect of other GHGs.**

Greenhouse Gases' Emissions that Cause Global Warming



Recent rise in methane emissions is due to fugitive emissions from gas wells & pipelines and Arctic emissions.

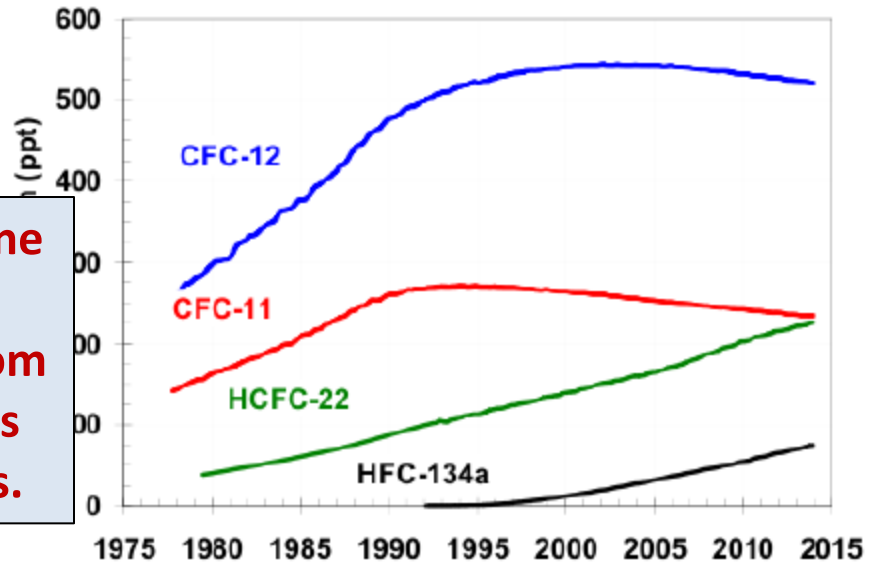
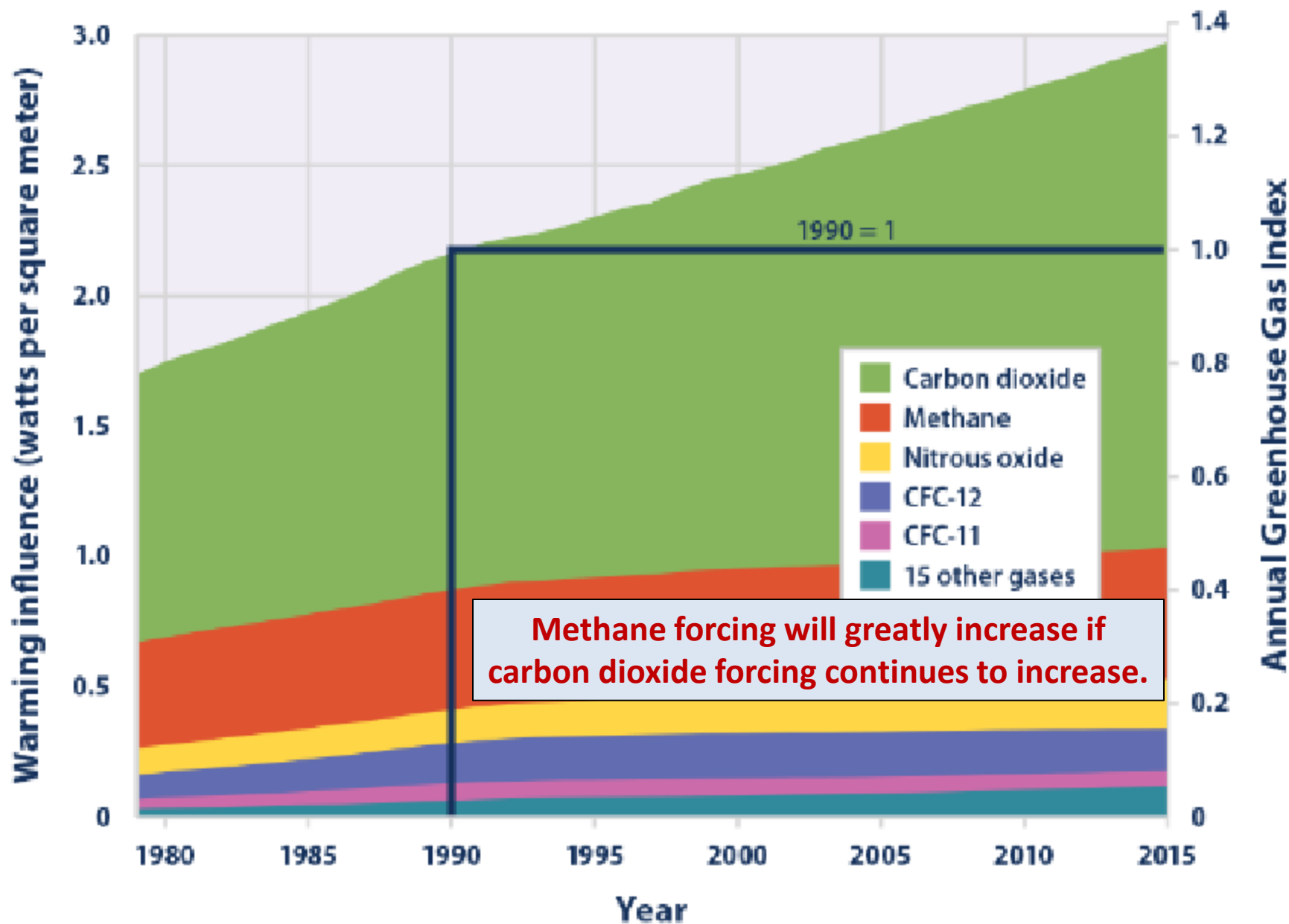
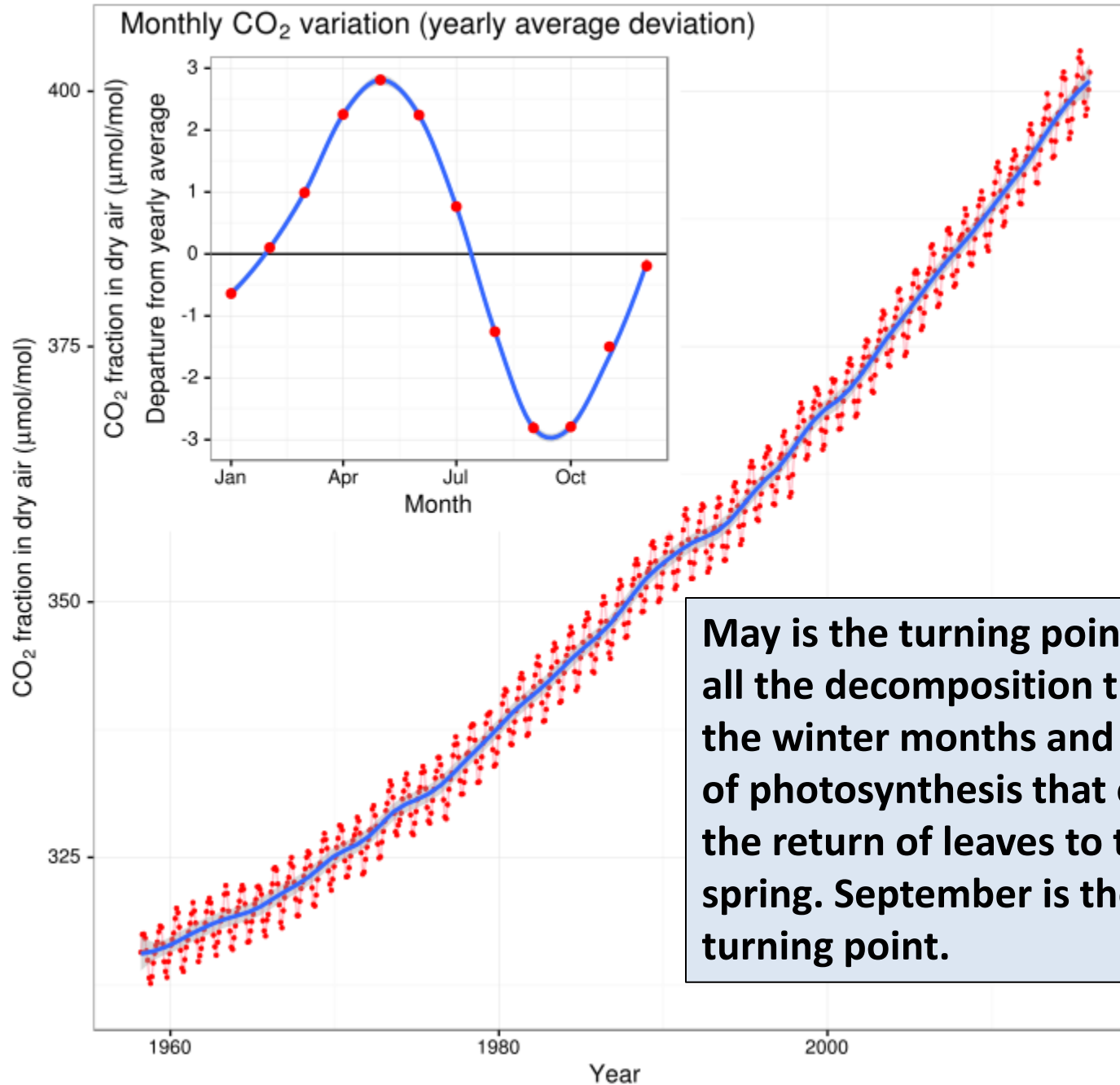


Figure 1. Radiative Forcing Caused by Major Long-Lived Greenhouse Gases, 1979-2015



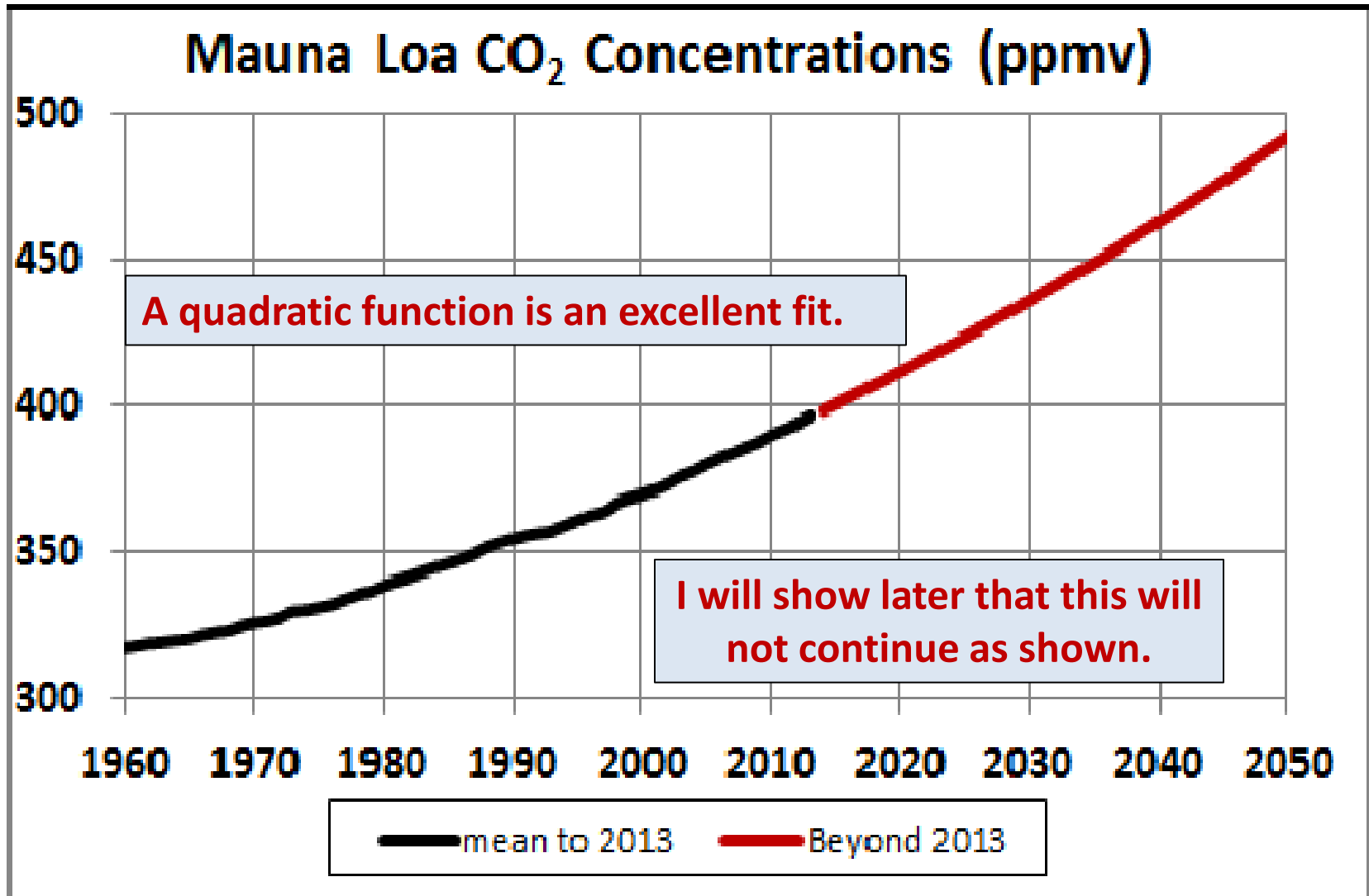
Mauna Loa monthly mean CO₂ concentration 1958-2015



**Above
400 ppmv
in 2016.**

May is the turning point between all the decomposition throughout the winter months and the burst of photosynthesis that occurs with the return of leaves to the trees in spring. September is the opposite turning point.

CO₂ Concentration Projection



It's a complicated relationship, but the most important part of it is this: When there is a rise in the temperature, more CO₂ is released into the atmosphere.

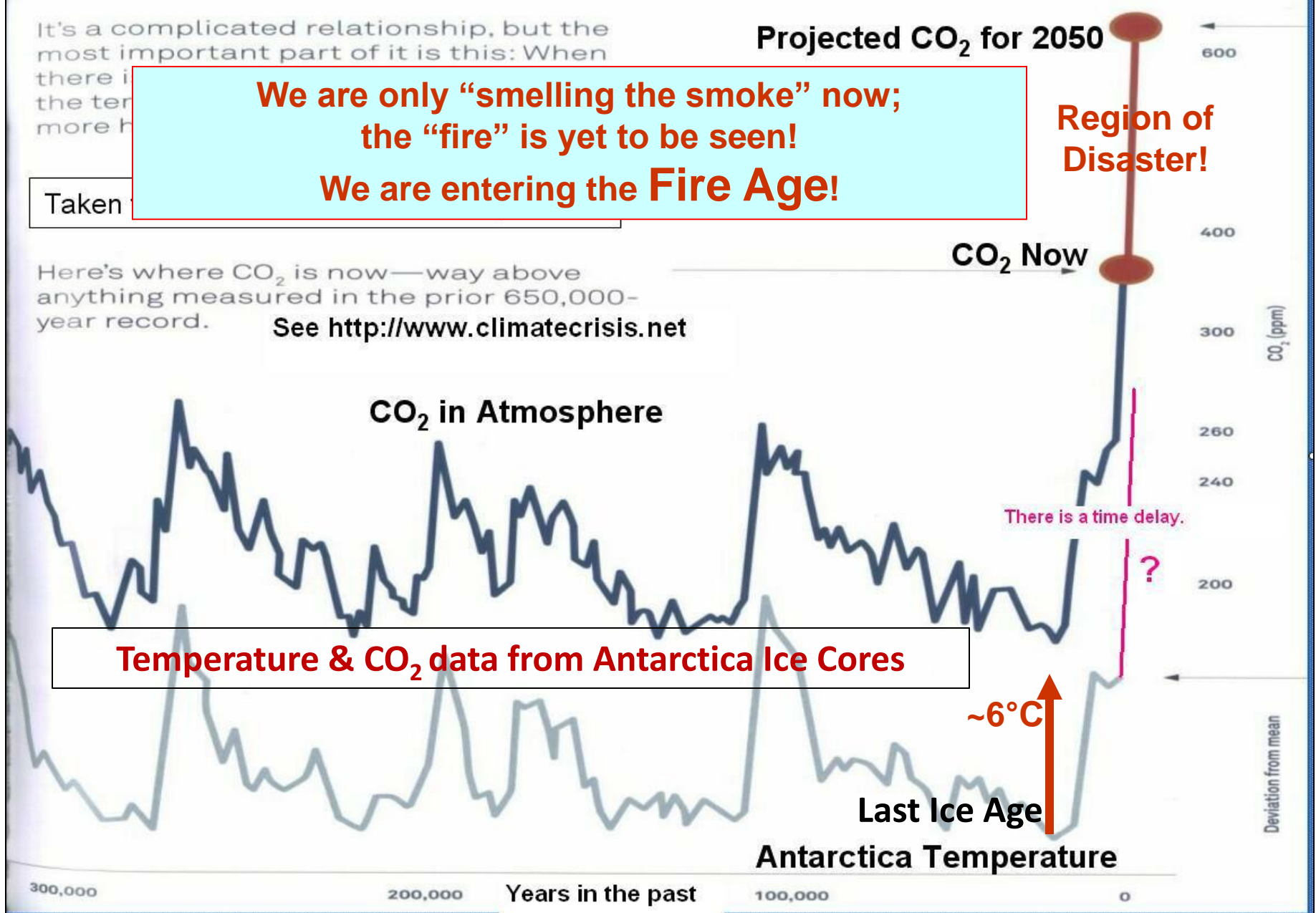
Projected CO₂ for 2050

We are only "smelling the smoke" now;
the "fire" is yet to be seen!
We are entering the **Fire Age!**

Region of Disaster!

Taken

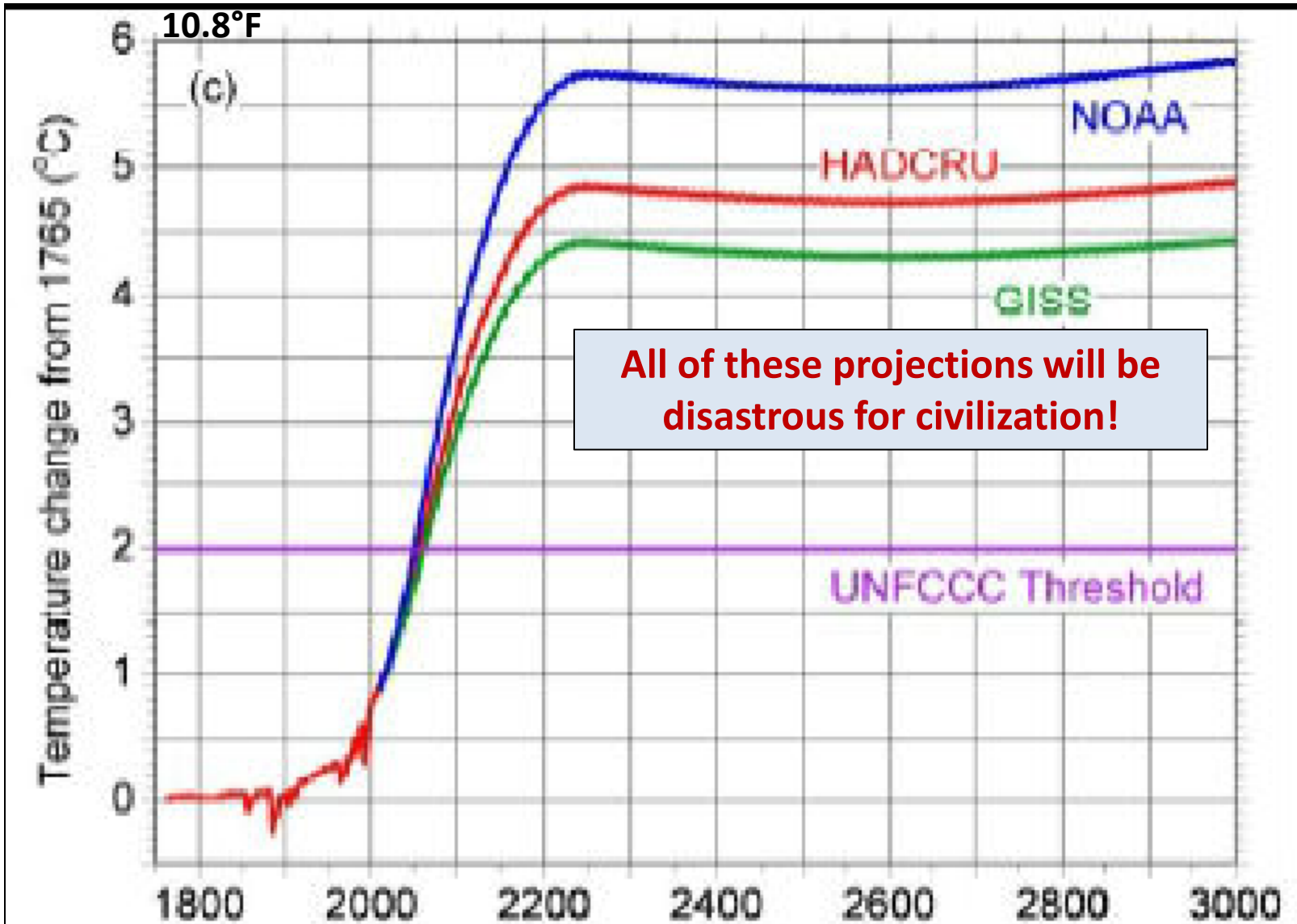
Here's where CO₂ is now—way above anything measured in the prior 650,000-year record. See <http://www.climatecrisis.net>



Temperature & CO₂ data from Antarctica Ice Cores

Temperature & CO₂ are mutually reinforcing (positive feedback).

Global Temperature Rise since 1765 for three models.



Global Warming is a Mathematical Problem

- **Climate Sensitivity Equation** (How much does temperature rise due to doubling CO₂ in atmosphere.)
- Amount of carbon-dioxide in atmosphere
- Residing time of carbon-dioxide in atmosphere
- Positive mutual feedback between carbon-dioxide in atmosphere & average earth temperature
- Positive mutual feedback between moisture in atmosphere & average earth temperature
- Positive mutual feedback between sea-ice melting & average Earth temperature
- **Positive mutual feedback between methane release from Arctic tundra and continental shelves & average earth temperature**
- Positive and negative feedbacks between clouds due to increased evaporation & average earth temperature
- Negative feedback between dust/aerosol in atmosphere due to droughts and winds & average earth temperature

Occasional large volcano eruptions can lower earth temperature for a few years.
Collision of a large asteroid or comet with the earth can lower temperature.

Climate Sensitivity Equation

$$\underline{dT = S \ln(C_f/C_i)/\ln(2)}$$
 where

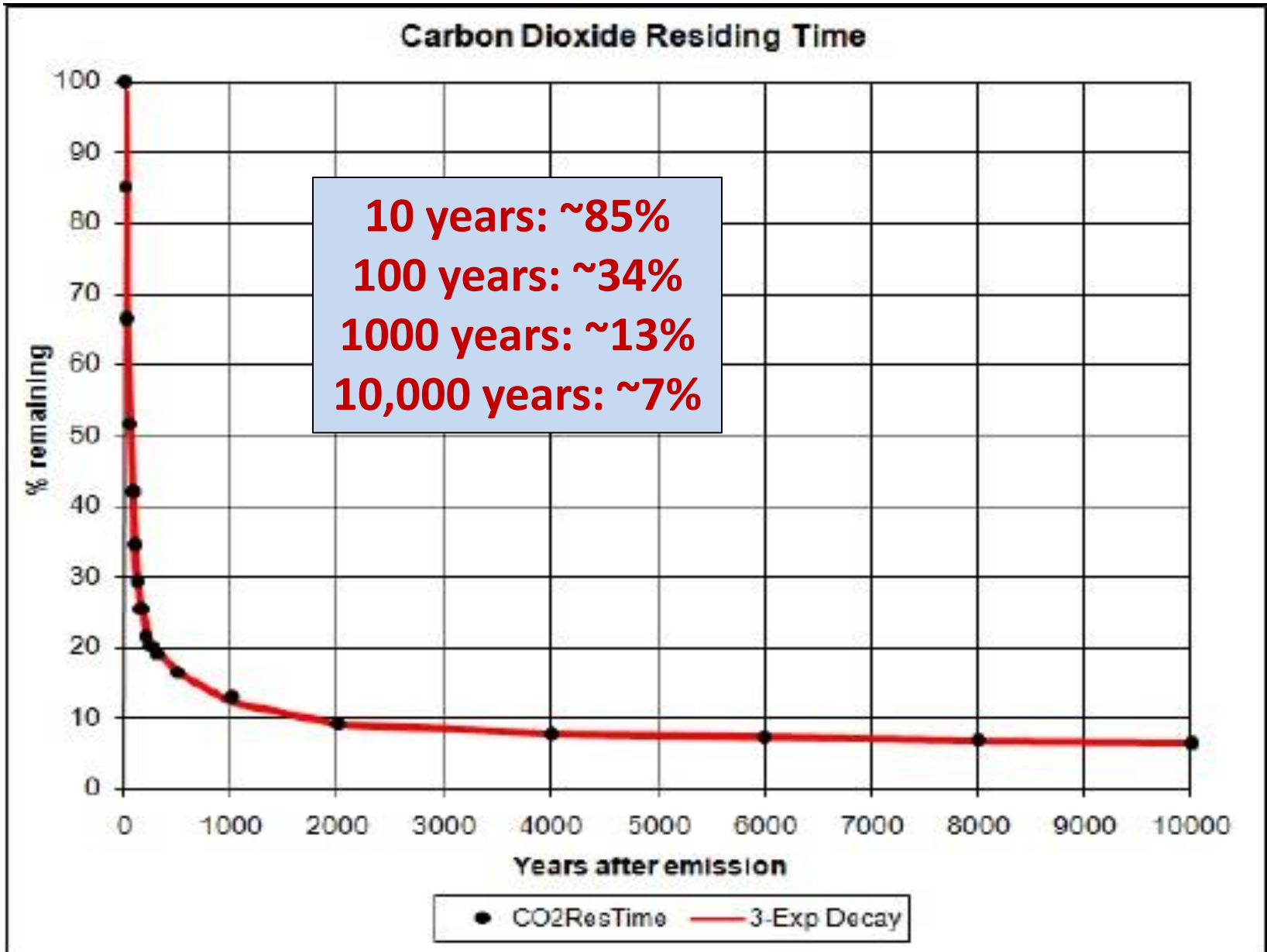
- dT = average Earth temperature change due to emitting CO_2 into the atmosphere.
- S = climate sensitivity = temperature when CO_2 doubled
- C_f = final CO_2 concentration
- C_i = initial CO_2 concentration
- First stated by Svante Arrhenius in **1896!**
- $S = 3^\circ\text{C}$ (5.4°F) for short-term positive feedbacks, determined by studying recent global warming. (**Recent study indicates $S = 4^\circ\text{C}$.**)
- $S = 6^\circ\text{C}$ (10.8°F) for long-term positive feedbacks, determined by studying ice cores back $\sim 500,000$ years.

Svante Arrhenius first reported Global Warming in 1896!

CO₂ concentration History & Future

- ~**285 ppmv** in year 1700
- ~**400 ppmv** in year 2016: increase ratio ~1.4, not quite doubled since 1700
- dT = ~**1.5°C** (~2.7°F) to ~**2.9°C** (~5.2°F) eventual temperature beyond year 1700 **if CO₂ remained at 400 ppmv & no other GHGs & no triggered feedbacks**
- **Add other GHGs**: dT = ~**2.5°C** (~4.5°F) to ~**4°C** (~7.2°F) since year 1700
- **Future increases in GHGs** could cause dT = ~**6°C** (~10.8°F) since year 1700.
- **Time delay of ~1500 years**, so stopping emitting GHGs into atmosphere now will not stop Global Warming for a long time.

CO₂ Stays in Atmosphere for a Long Time!



Changes to Global Warming (GW) besides GHGs

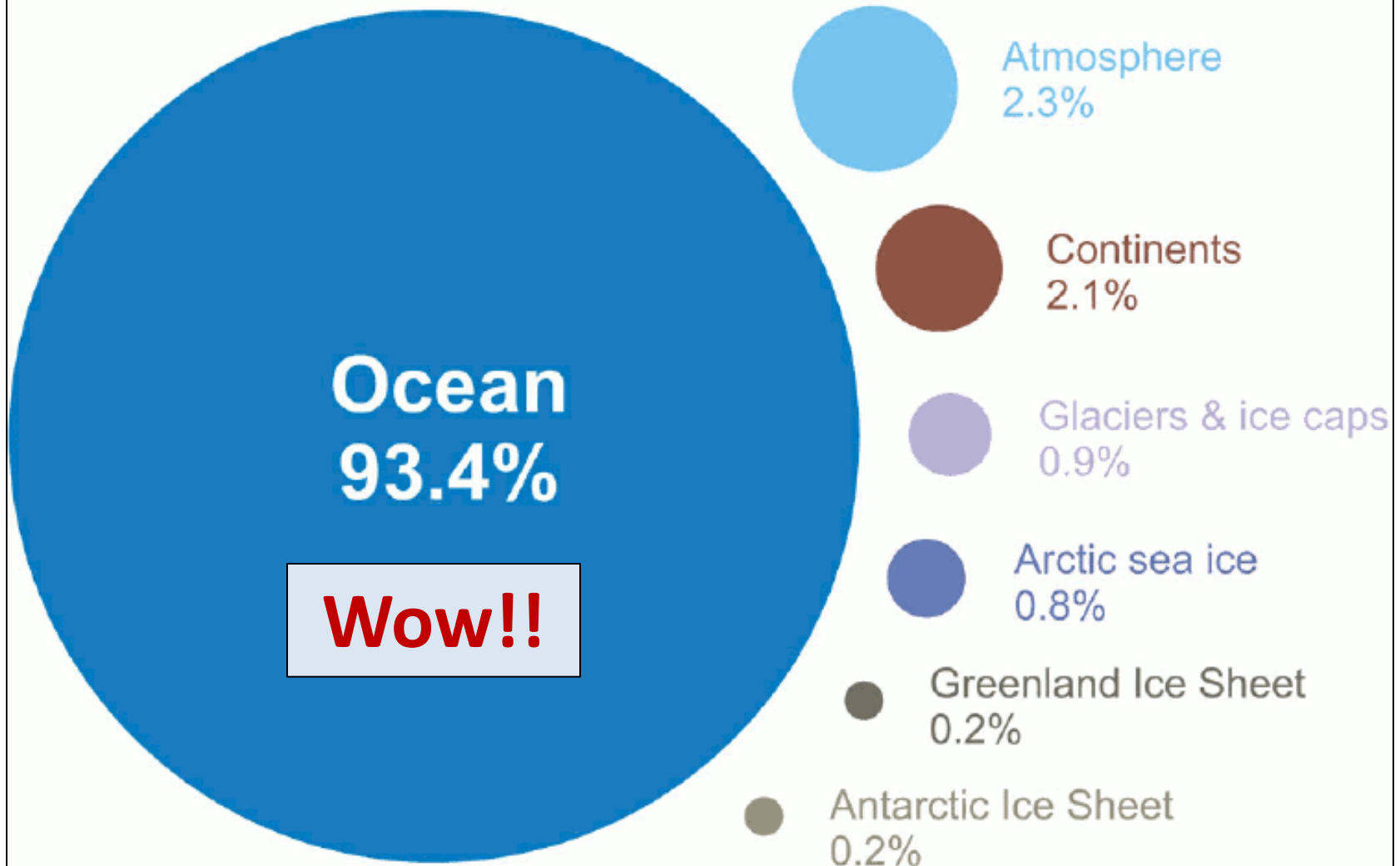
- **Deforestation** cancels the trees absorbing CO₂.
- **Aerosols and particulates** in the atmosphere reduce GW. (Geoengineering is proposed to put aerosols into the atmosphere. They are detrimental to human health and reside only a few years in atmosphere.)
- **Geoengineering** proposals to reduce the sunlight striking the Earth (unintended side effects?) See ***Hack the Planet*** book.
- High temperature **melting Arctic sea** ice reveals dark water to absorb much more solar energy than does ice, causing increased GW.
- High temperature causes **release of methane from Arctic permafrost and continental shelves (triggered feedback)**.

Climate Models

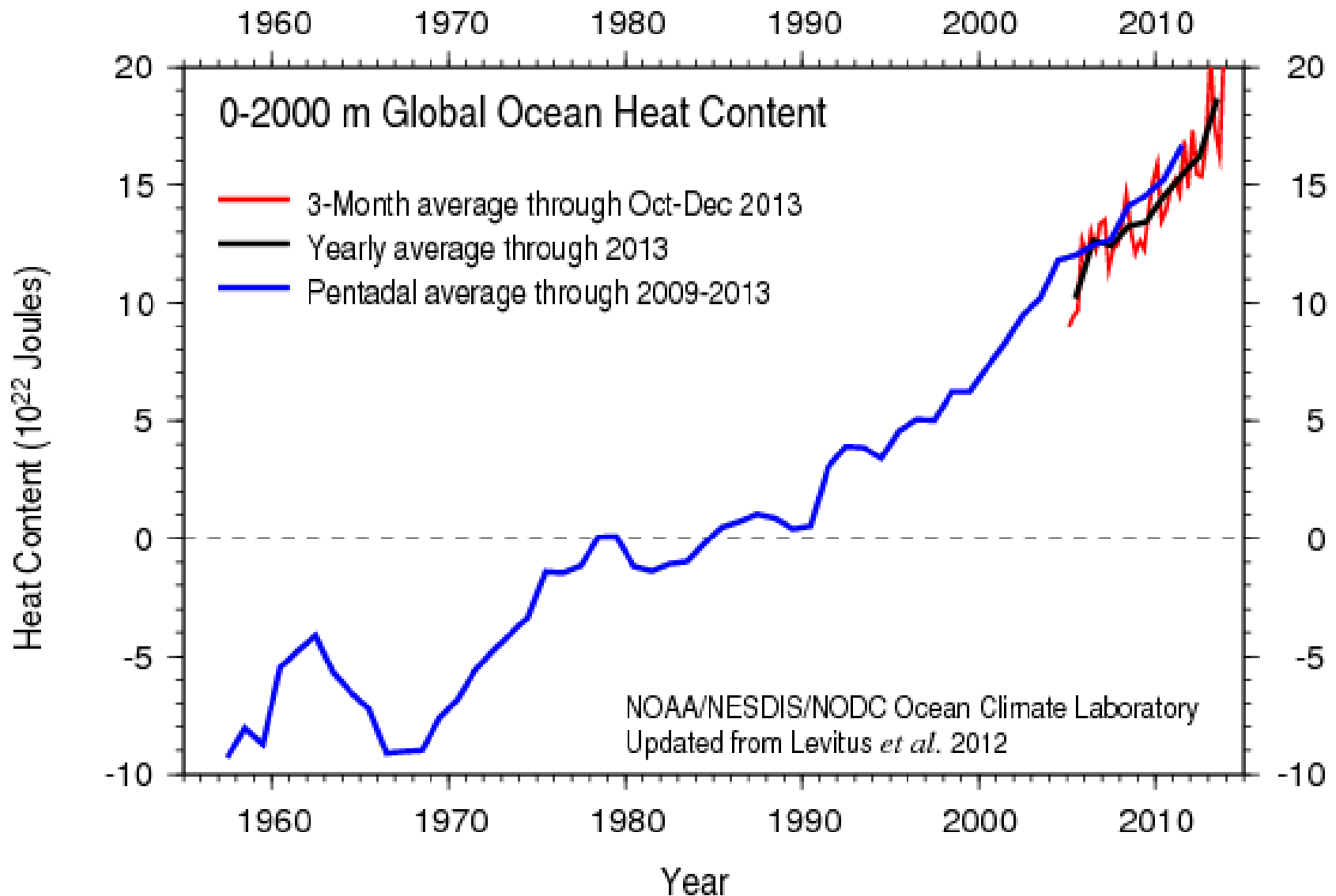
- Atmosphere of Earth divided into a large 3-dimensional grid to a particular height
- Surface of Earth divided into a large 2-dimensional grid
- Oceans of Earth divided into a large 3-dimensional grid to a particular depth
- Incoming solar energy at all wavelengths
- Outgoing energy from the Earth
- GHGs in atmosphere
- Intake of GHGs into the oceans
- Heat and mass transfer between the grid elements
- Instruments, including satellites, measuring climate variables
- Large supercomputers doing the climate calculations
- There are several major models that give similar results. An average of ~15 models' predictions is used.
- **Copious Earth data show larger current global warming effects than the models calculate. So, yes, the models are “wrong”, but in a bad direction!**

Ocean heat will transfer heat to atmosphere slowly over time after carbon emissions are stopped.

Where Global Warming is Going



Ocean Heat Content Increase

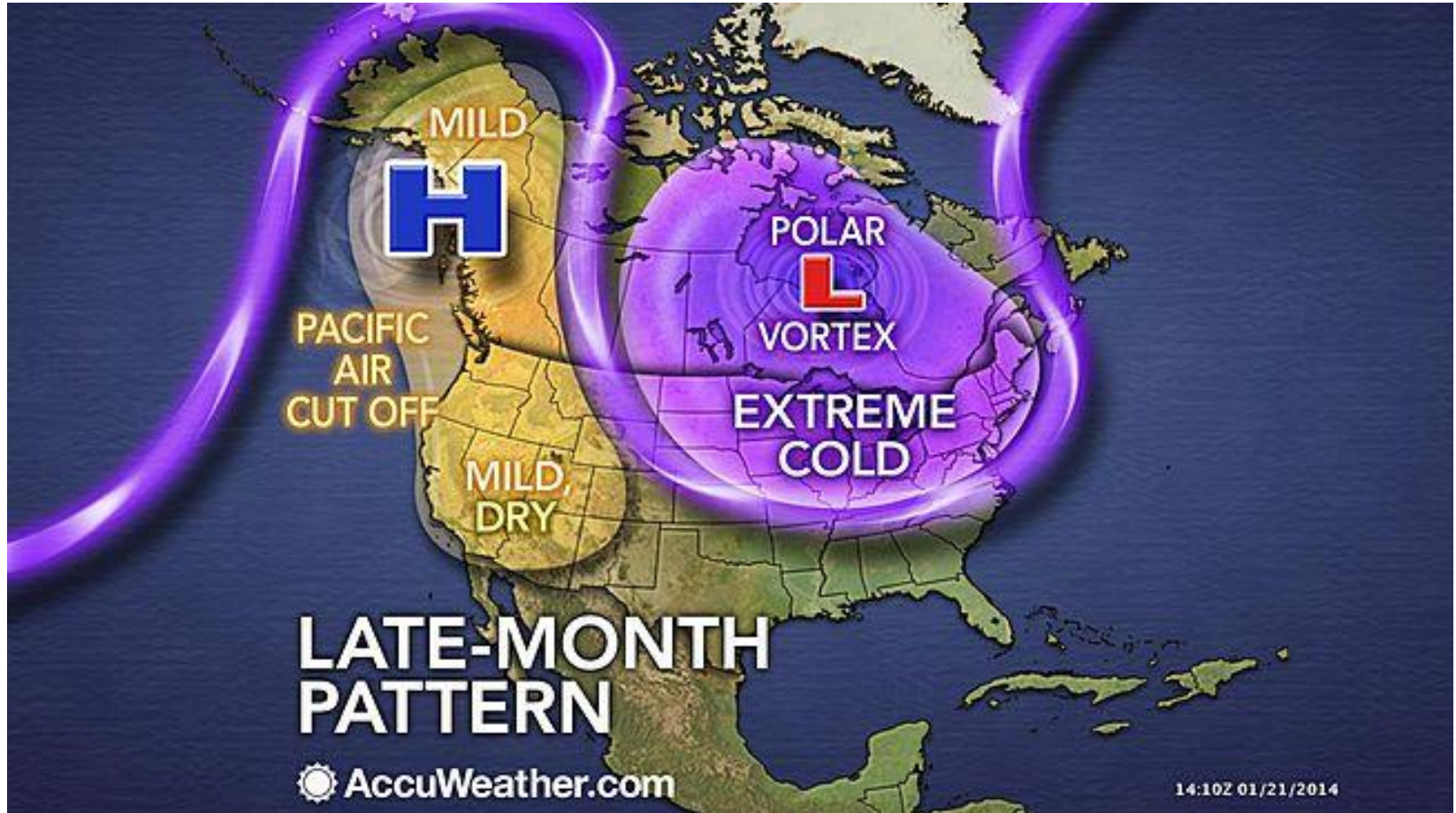


Oceans are heating faster than the atmosphere.

Extreme Storms

- **Polar vortex**: fast counterclockwise winds around the Arctic
- Arctic warming more than temperate areas, such as US, reduces the temperature differential, which weakens the **Polar Vortex**.
- **Weakened Polar Vortex** causes undulations in the Jet Stream, **pulling warm air from western US into Arctic and cold air from the Arctic into eastern US**.
- Collision of Arctic cold air with south Pacific, south Atlantic and Gulf of Mexico warm moist air causes **extreme storms** with high precipitation in eastern United States, which deprives western United States of precipitation, causing extreme droughts and subsequent **forest fires**.
- U.S. storm damage cost was **2.5 times** more for 2011-2015 compared to 1980-2010.

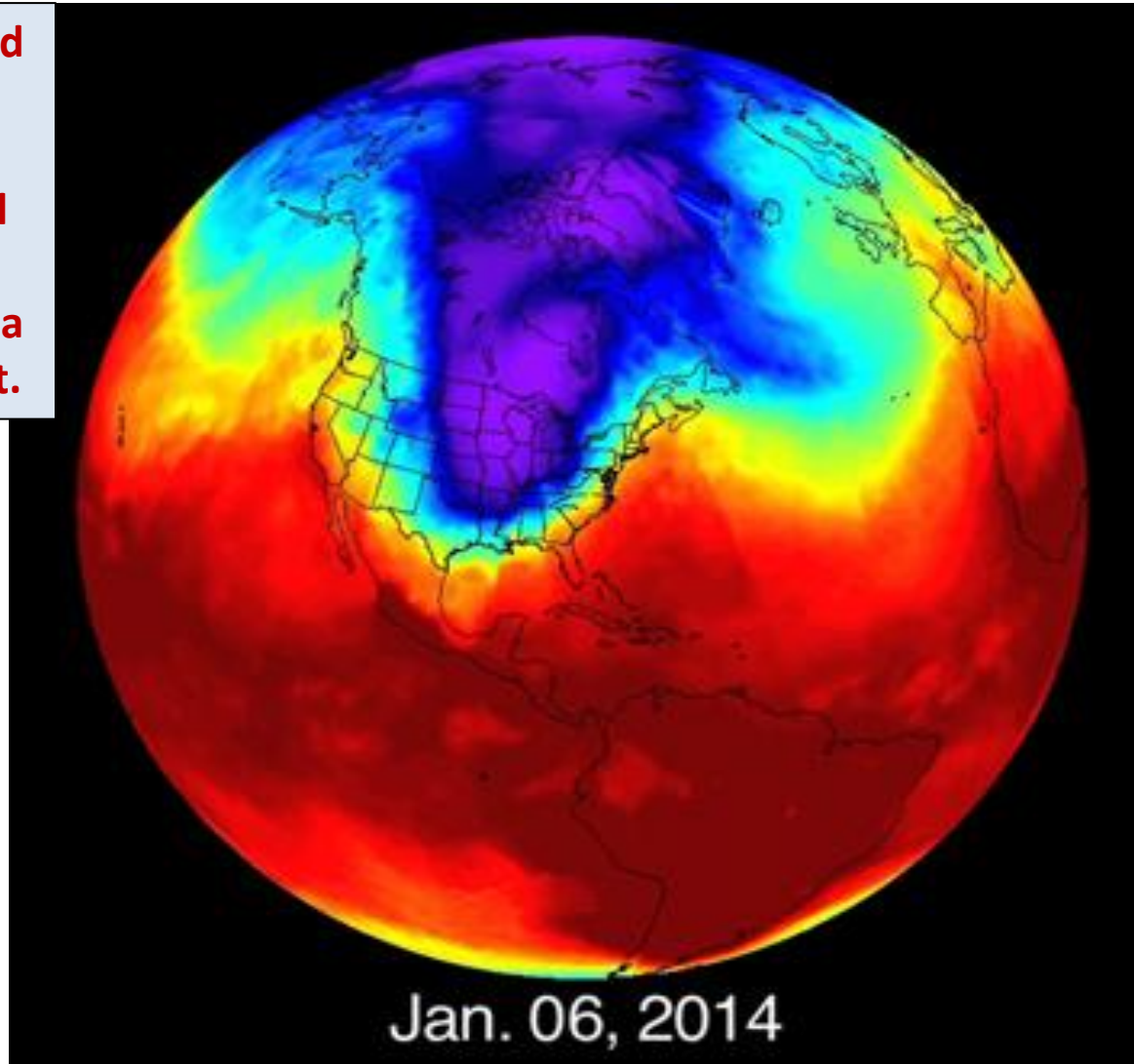
Jet Stream late January 2014



Heating in the Arctic weakens the Polar Vortex that circulates counterclockwise around the polar region, causing it to deform and push warm air into the Arctic and cold air into eastern North America.

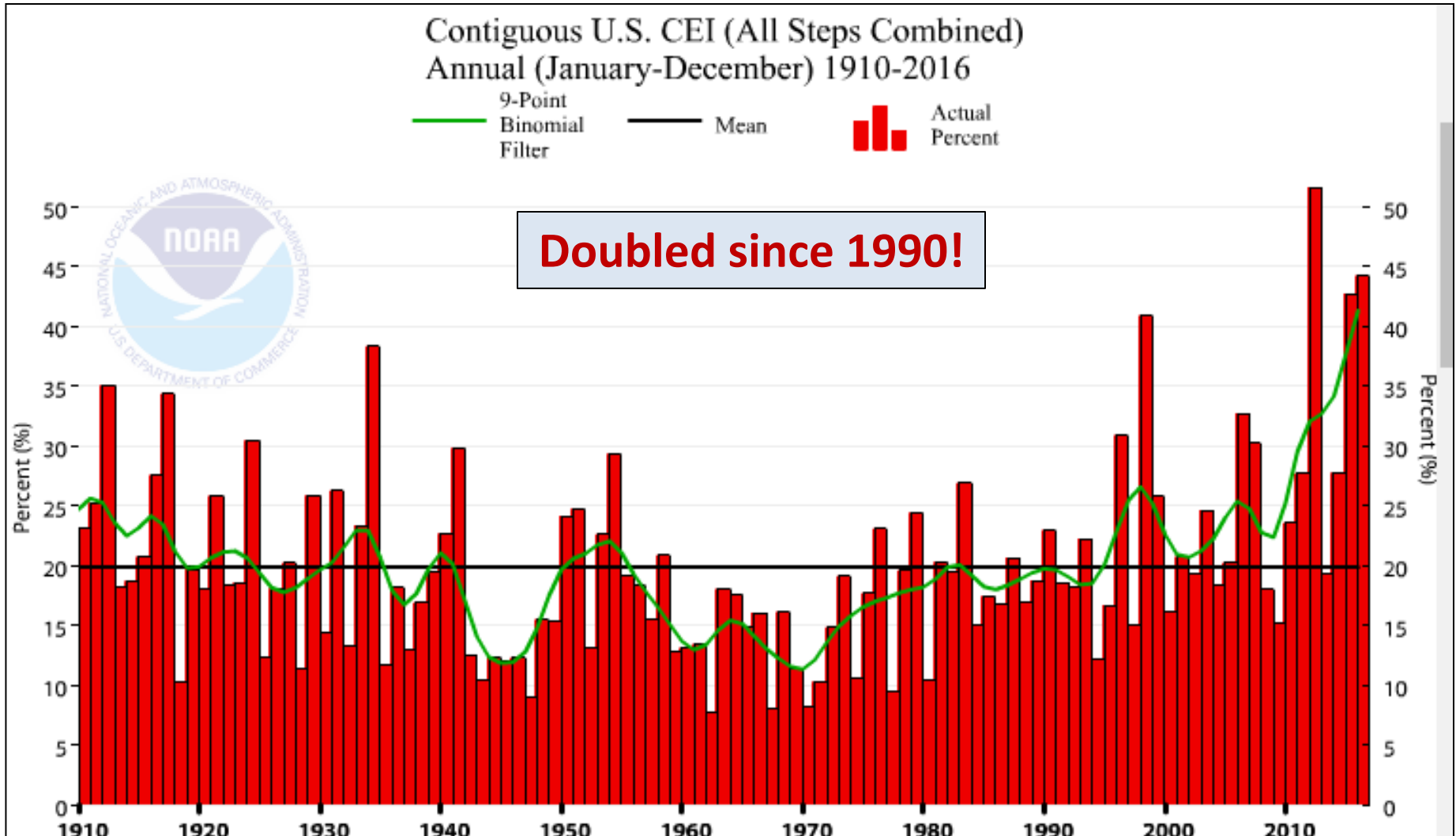
Earth Temperatures 6 January 2014

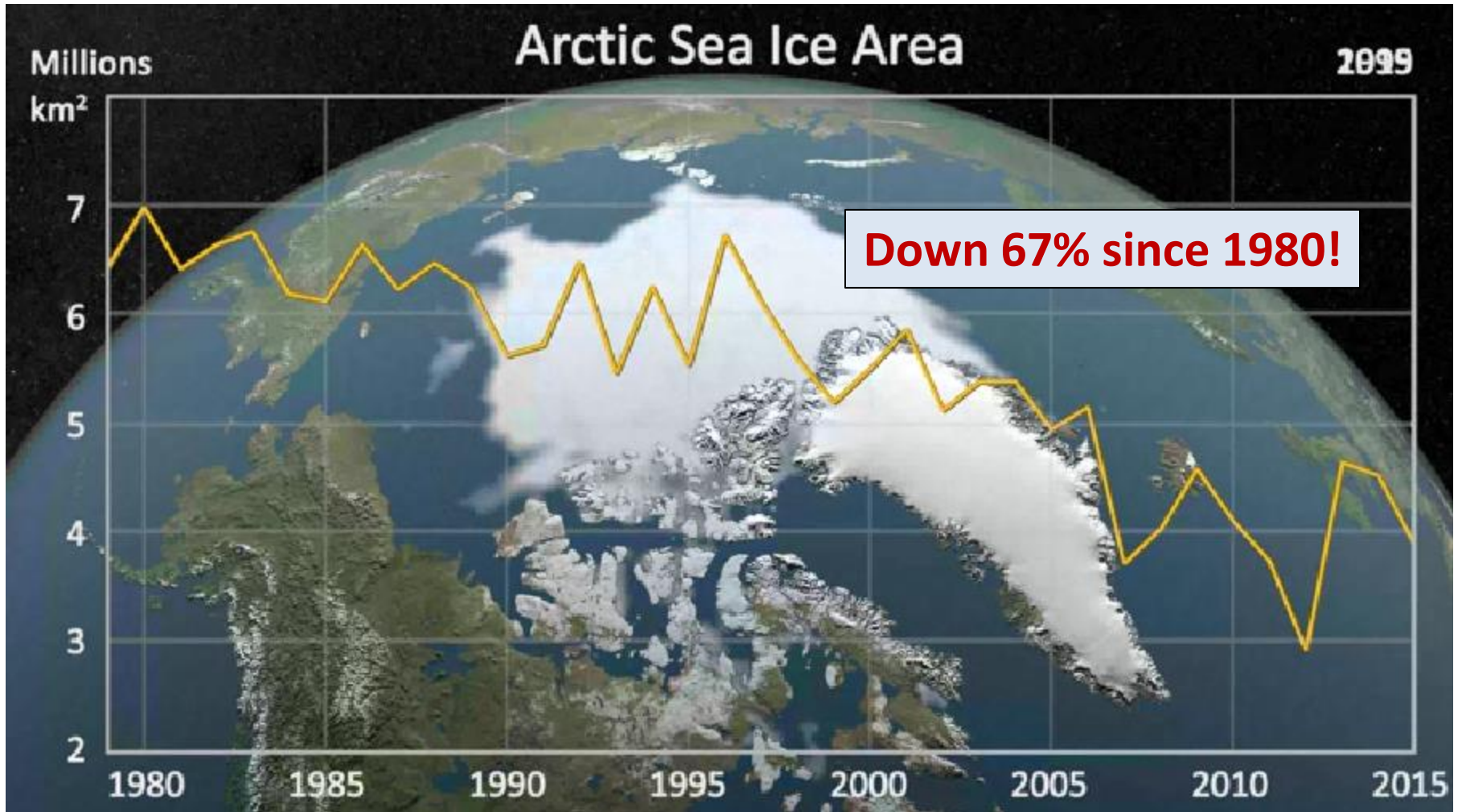
Severe winter cold spells in eastern U.S. do NOT invalidate Global Warming! In fact, many are a consequence of it.



Western Hemisphere Northern View

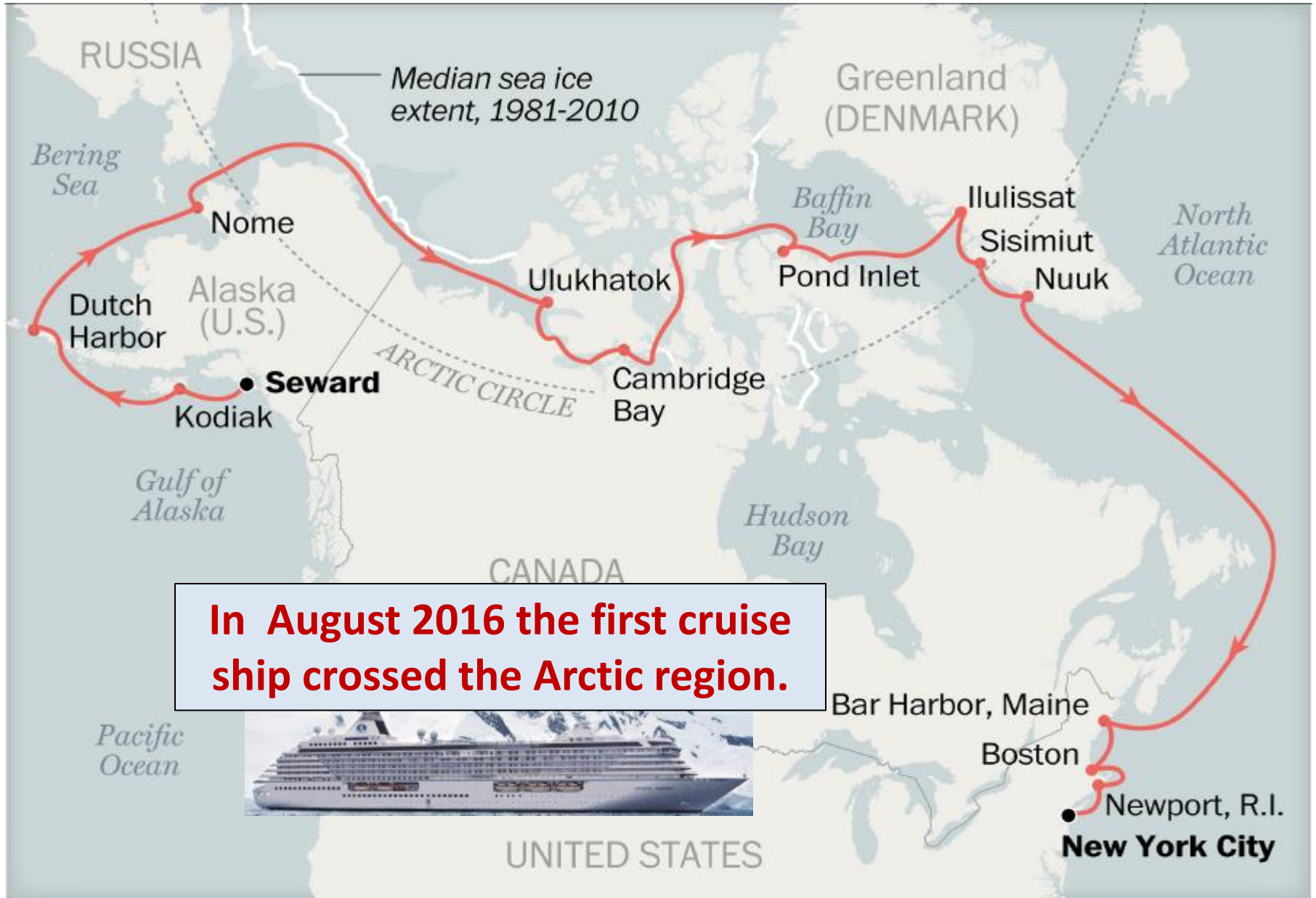
NOAA Extreme-Storms Index for U.S.





[“The Arctic will be reliably free of sea ice in the summer by the middle of the century.”](#)
Melting sea ice does not raise sea level, but heating ocean water does.

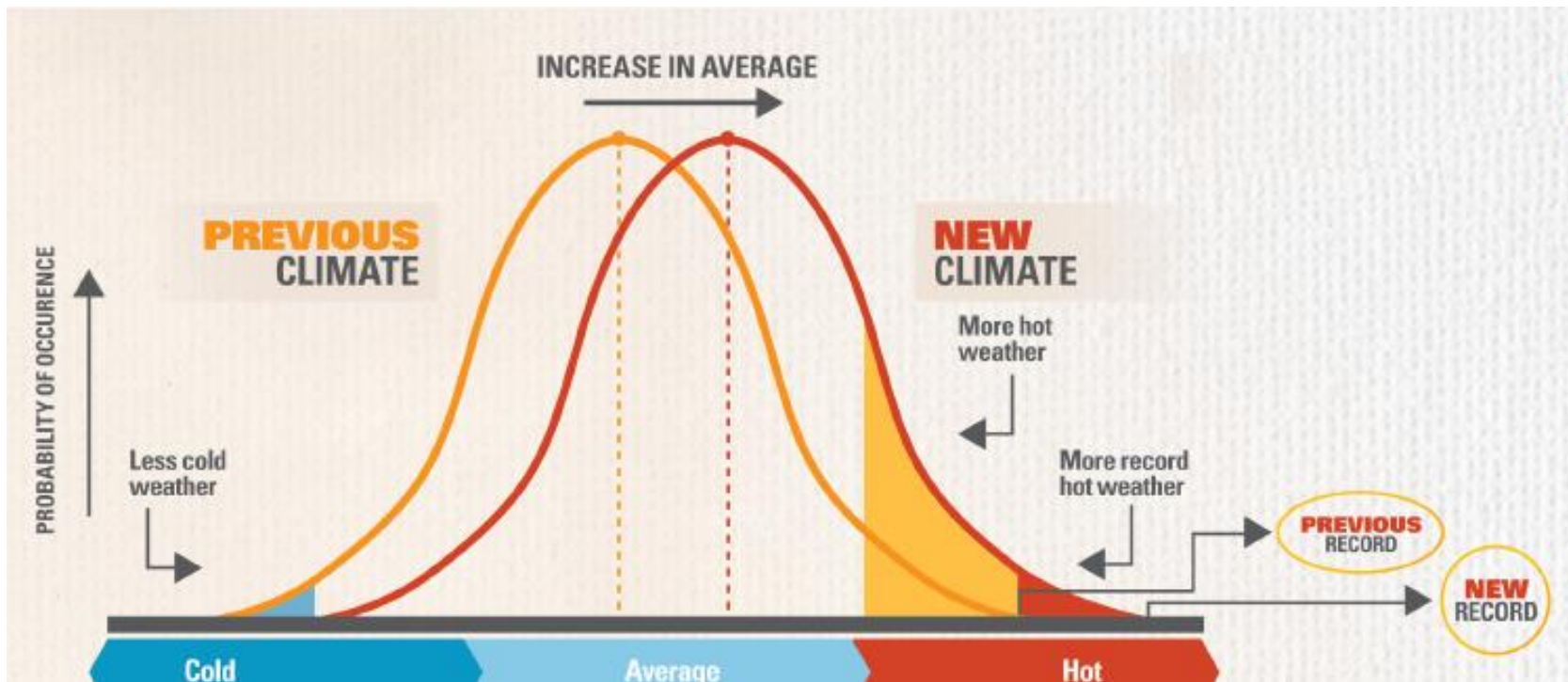
Exploiting the Arctic Sea



Exploiting the Arctic Sea

- UN is assessing Russian, Danish and Canadian claims to own large portions of the Arctic seabed.
- China is investing in mines in Greenland.
- Petroleum companies are looking for Arctic seabed reserves of natural gas and oil.
- Large companies plan to expand fishing into the Arctic.
- Countries will probably want to dump wastes into the Arctic Sea.

Extreme Heat



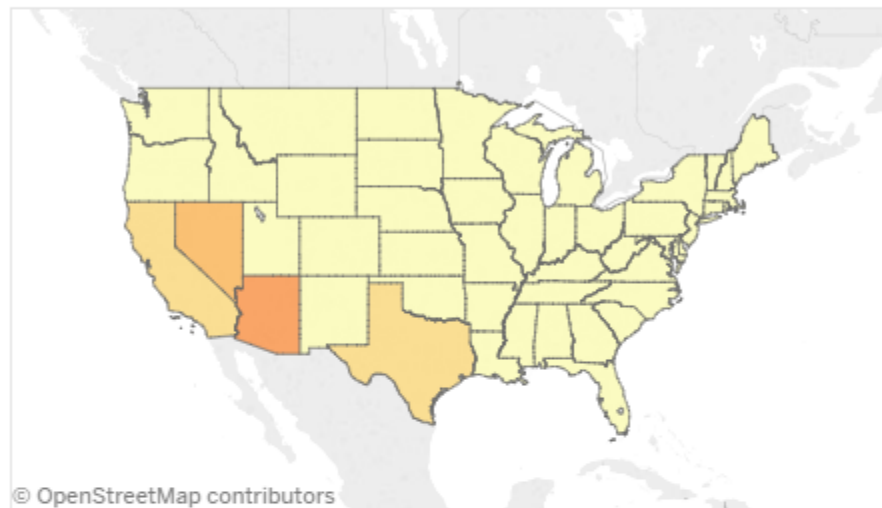
There will still be cold weather, but not as much as before.

The number of days above 95 °F (35 °C) will rise dramatically in many parts of the United States if climate change continues unabated

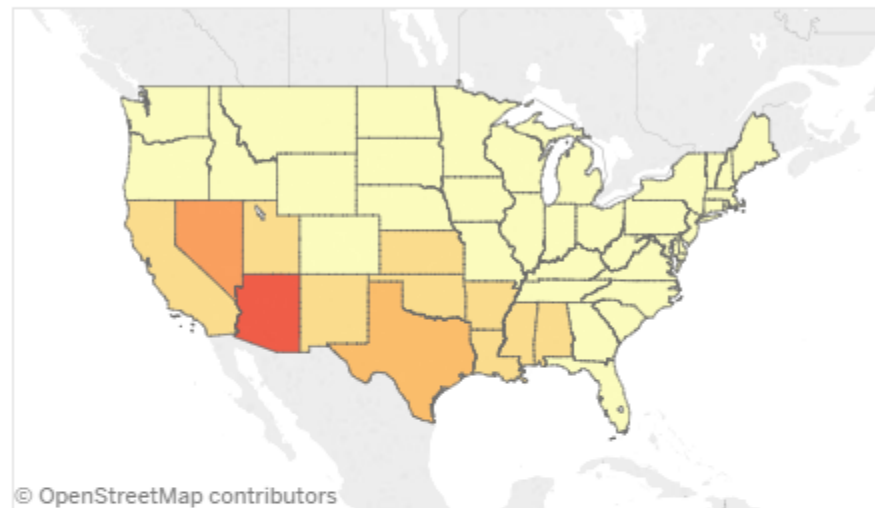
Yellow->red colors 30 to 180 days/year

AZ: 179; TX: 135; NV: 127
FL: 108; CA: 72; VA: 60
CO: 59; NY: 30; MI: 27
MA: 26; WA: 22; ME: 15

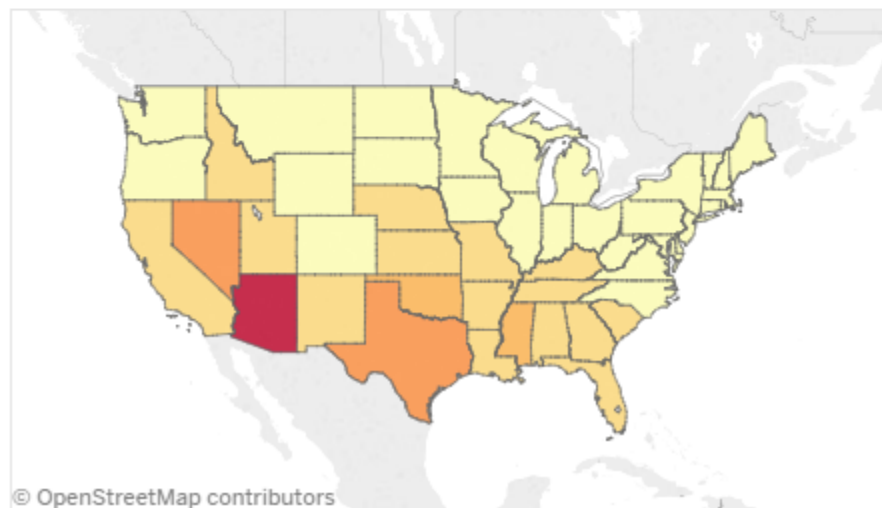
1981-2010



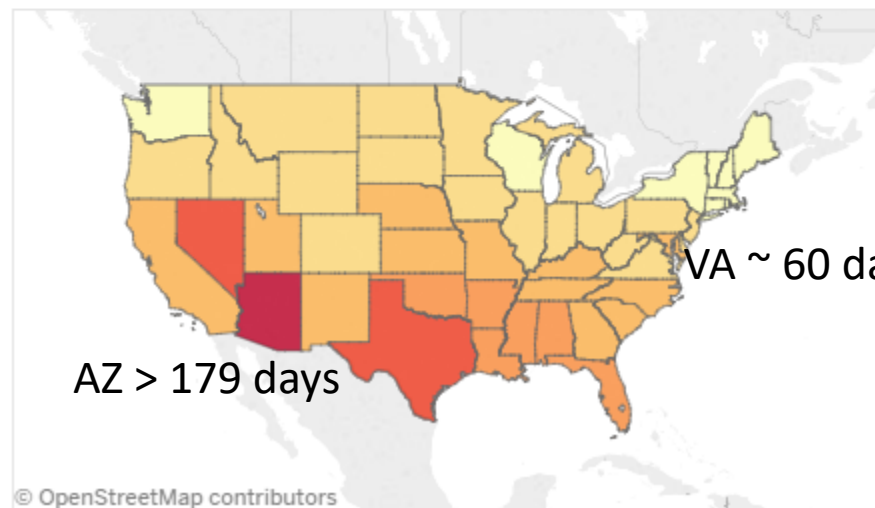
2020-2039



2040-2059



2080-2099 Most of U.S. > 60 days

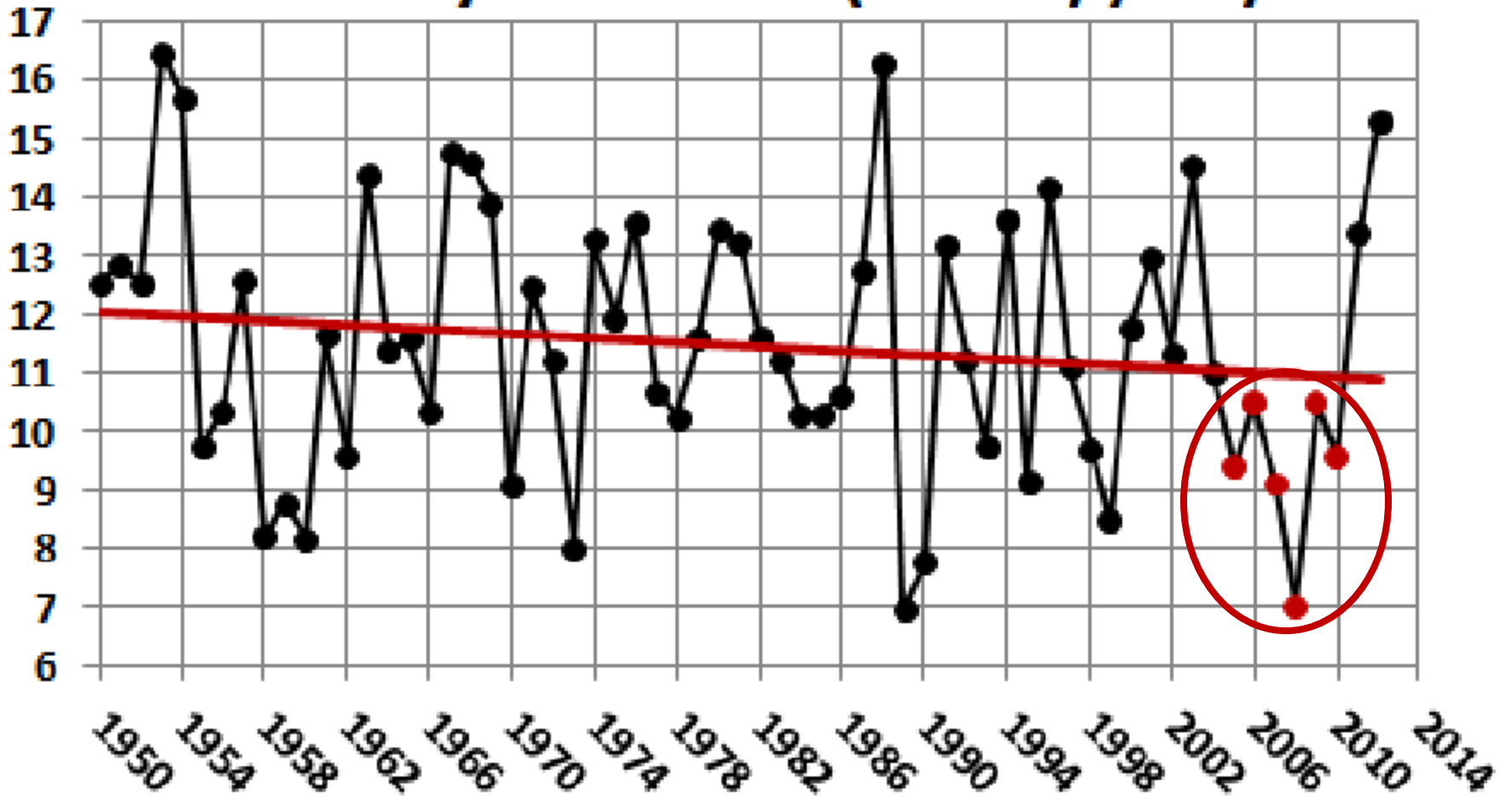


Droughts and Floods

- **Higher temperatures evaporate more moisture into the atmosphere.**
- **Westerly winds (from the west) move the moisture from western U.S. to eastern U.S.**
- **The dry west gets dryer and the wet east gets wetter.**
- **Forest fires become more prevalent in the west because of lack of moisture.**
- **The rare large rains in the west cause floods because the trees and vegetation have burned to ashes.**
- **The increased rapid rainfall in the east causes more floods.**

2005-2010 Drought in Syria was a major factor in the rebellion.

Syria Rainfall (inches/year)

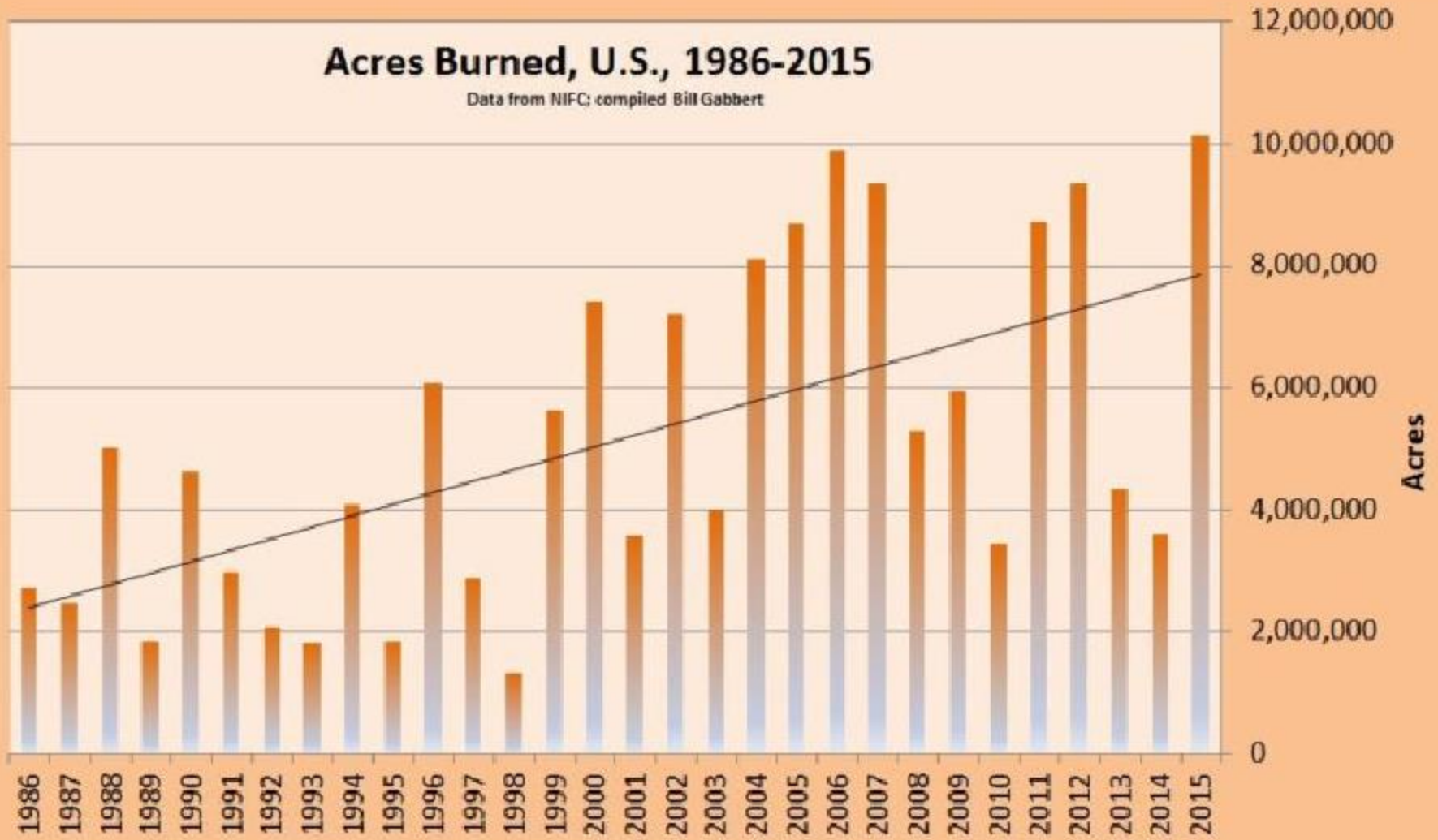


This is one of the reasons the U.S. military is studying global warming.

U.S. forest acres burned increased over a factor of 3 in 30 years!

Acres Burned, U.S., 1986-2015

Data from NIFC; compiled Bill Gabbert



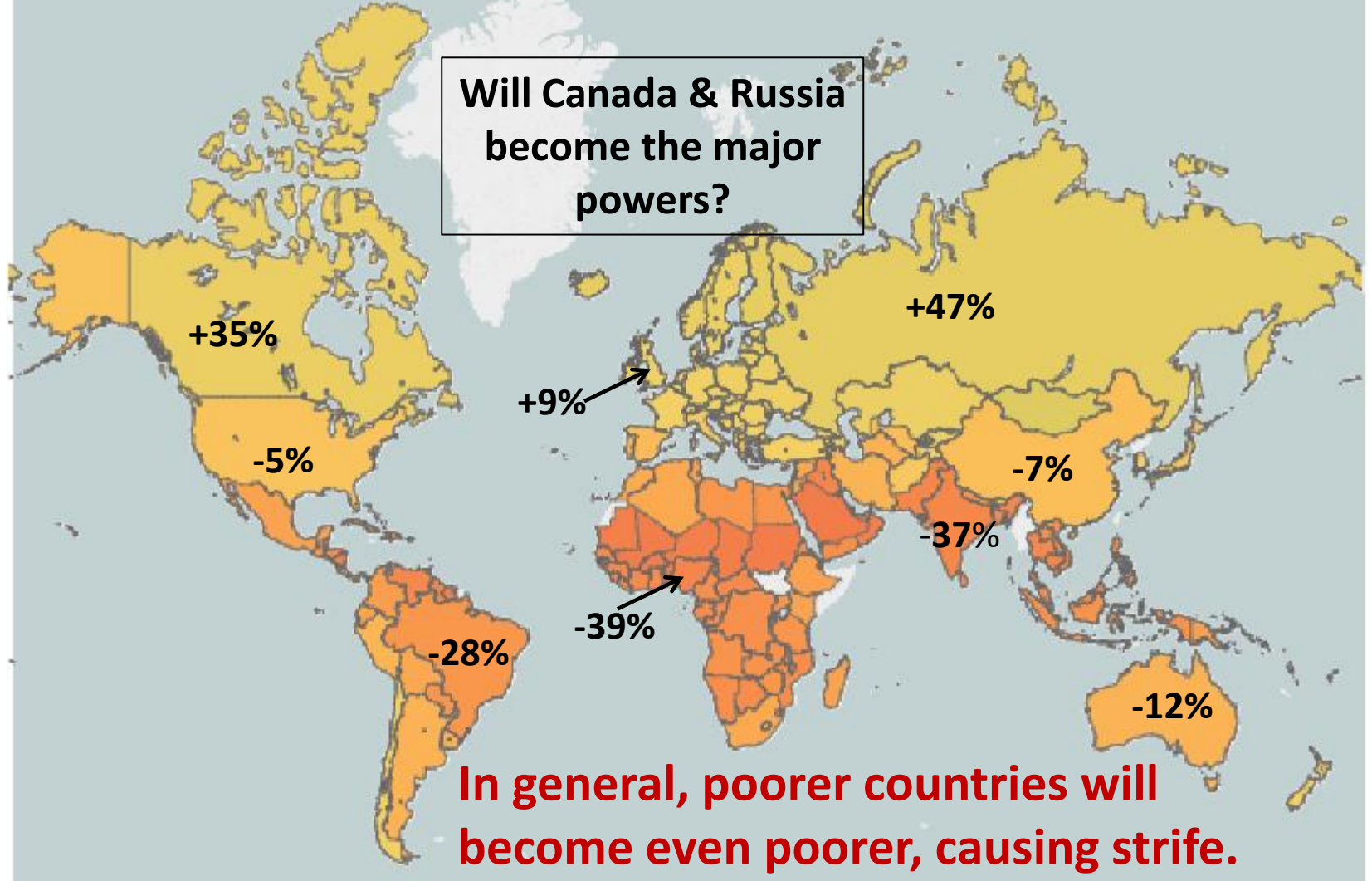
Hotter Days Will Drive Global Inequality

Percent Change GDP - 2050

Red->orange colors +50% to -50% GDP change

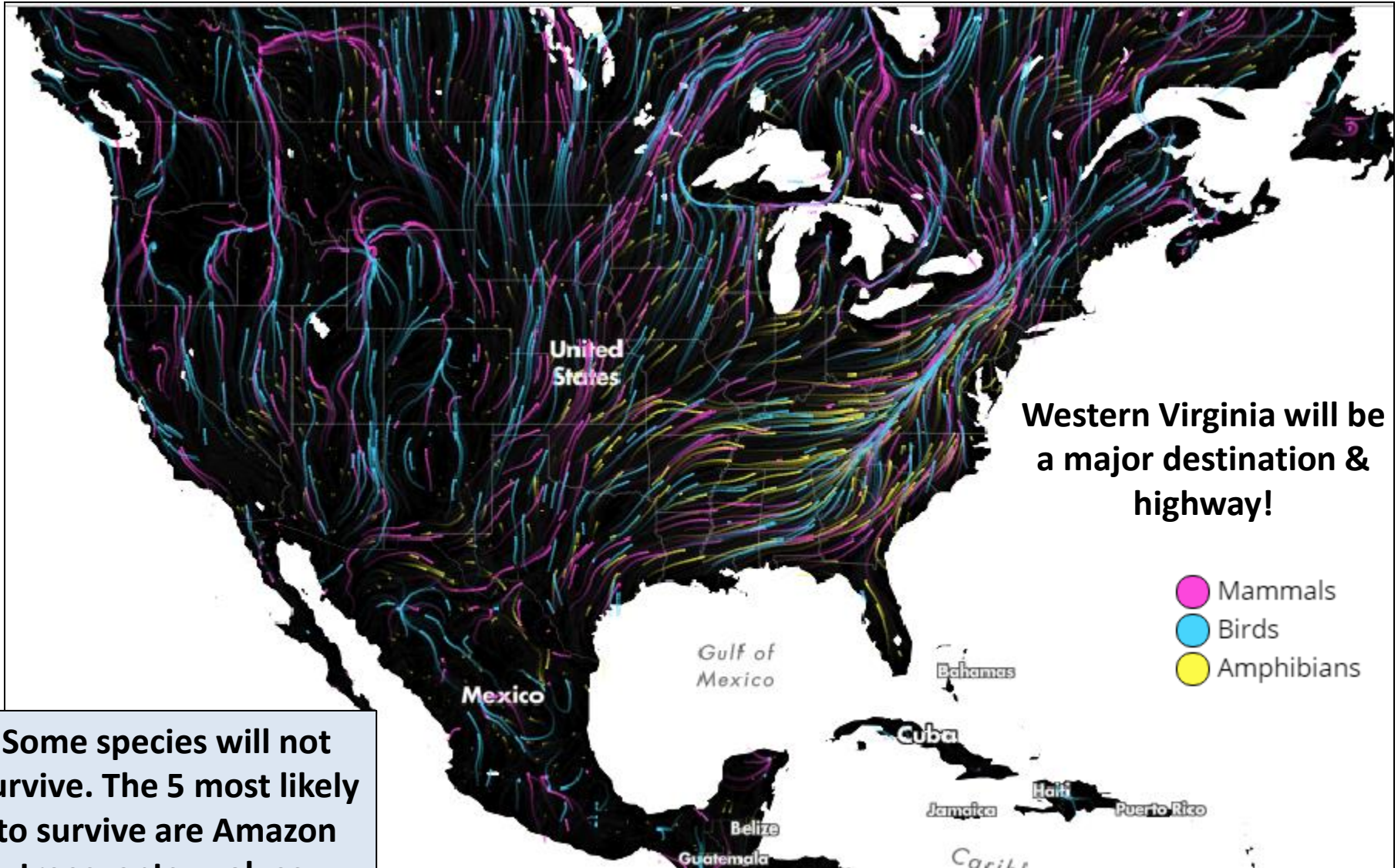
Will Canada build a wall to keep U.S. citizens out?

Will Canada & Russia
become the major
powers?



In general, poorer countries will become even poorer, causing strife.

Where animals will move to new homes because of global warming:



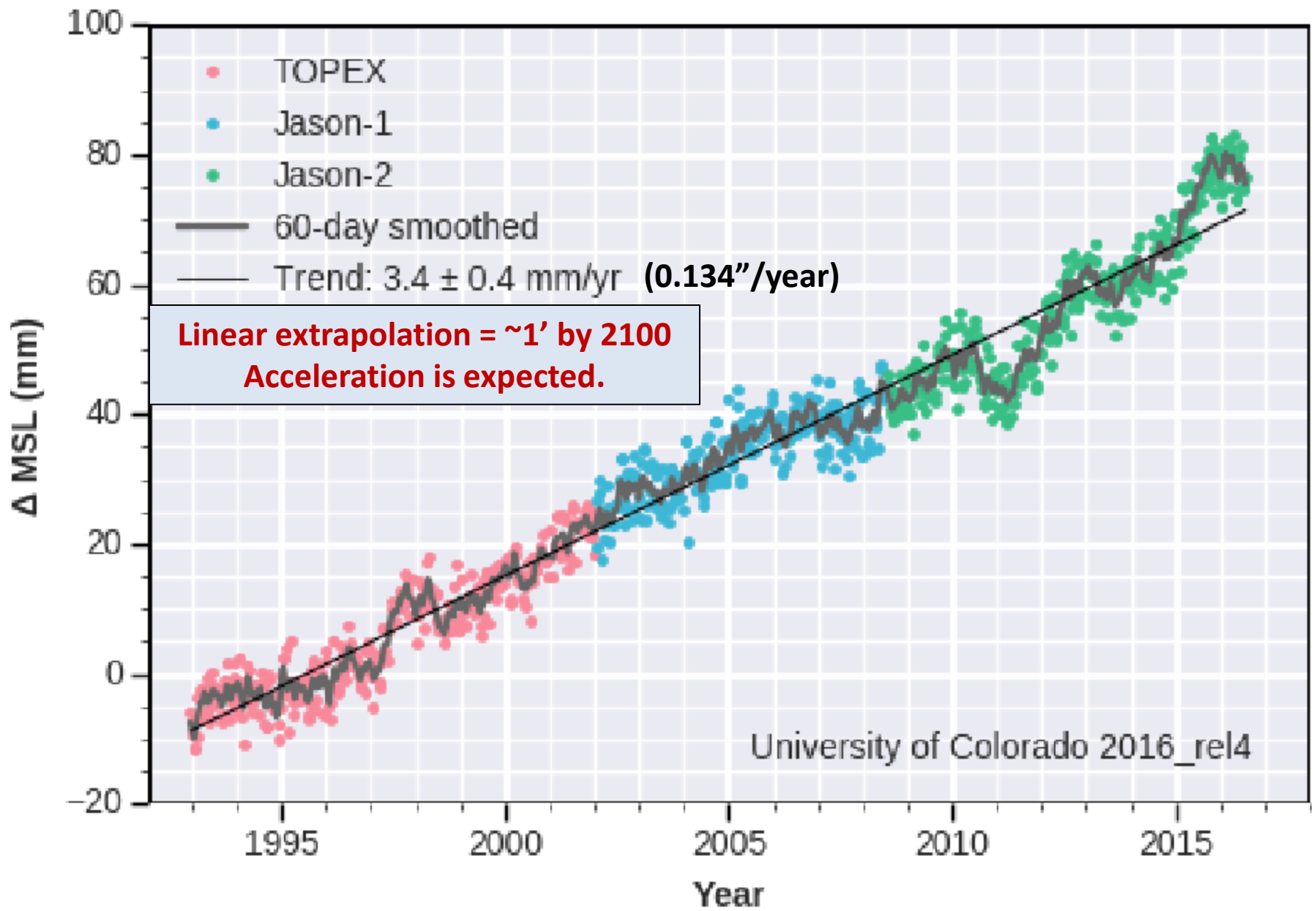
Western Virginia will be a major destination & highway!

- Mammals
- Birds
- Amphibians

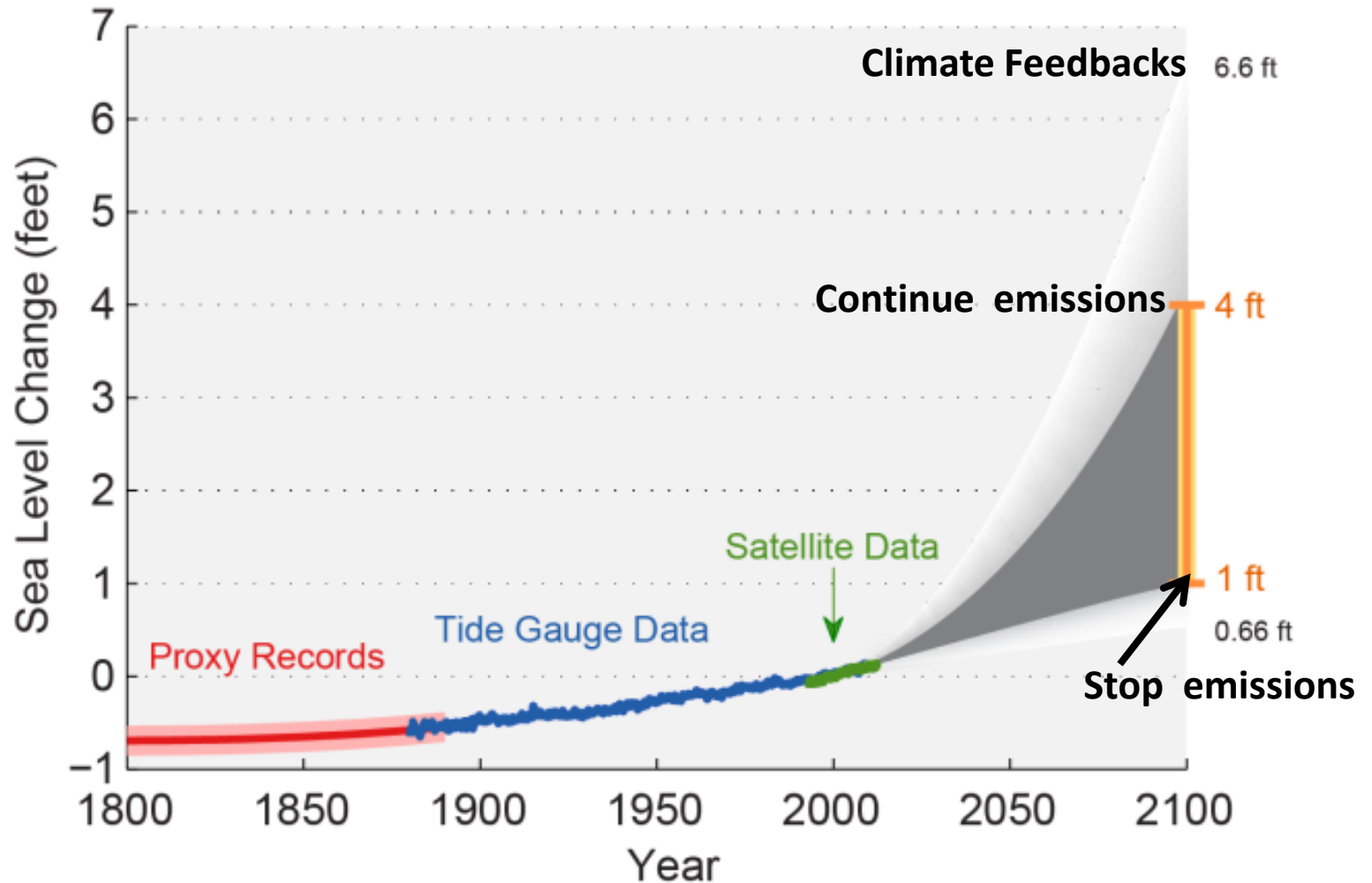
Some species will not survive. The 5 most likely to survive are Amazon trees, ants, wolves, coyotes & cockroaches.

Sea-Level Rise

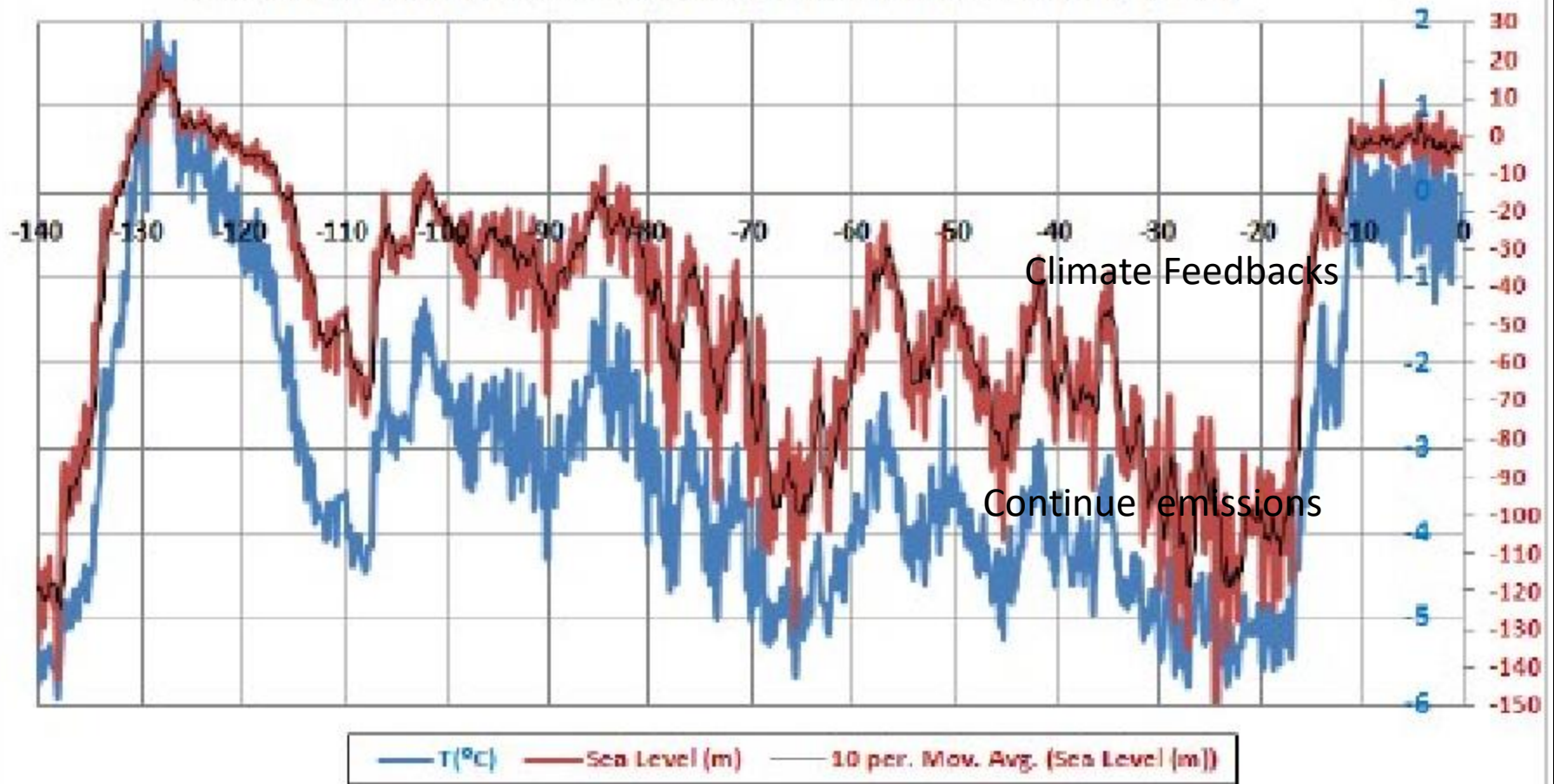
- Melting Arctic sea ice indicates moderate sea-level rise because warm water occupies more volume than cold water (**thermal expansion**).
- **Melting ice on land**, such as Greenland and Antarctica, can cause great sea-level rise. If all the ice on Greenland melted, sea level would rise by **~7 meters (23 feet)**. If all the ice on Antarctica melted sea level would rise by **~60 meters (197 feet)**.
- Predictions for sea-level rise by year 2100 range from **0.5 meters (1.64 feet)** to **5 meters (16.4 feet)**.



Past and Projected Changes in Global Sea Level



Average Temperature & Sea Level Relative to 1990



- This shows the **temperature** and **sea level** over the last **130,000 years**.
- We are in the current **Holocene interglacial** at the extreme right.
- **20,000 years ago** was the **last glacial maximum** with **temperature ~6°C (10.8°F)** below 1990 and **sea level 130 meters (427 ft)** below 1990.
- **130,000 years ago** was the **Eemian interglacial** with **temperature ~2°C (3.6°F)** above 1990 and **sea level 20 meters (66 ft)** above 1990.
- Many climate scientists say we are in a new era called the “**Anthropocene**”.

16 U.S. Cities Under Water by 2100

- Miami FL
- Fort Lauderdale FL
- Boston MA
- New York City NY
- Atlantic City NJ
- Honolulu HI
- New Orleans LA
- Galveston TX
- Sacramento CA
- San Diego CA
- Los Angeles CA
- Charleston SC
- Virginia Beach VA
- Norfolk VA
- Seattle WA
- Savannah GA

Global Warming and Insurance

- Rise in sea level will increase risk of storm surges.
- Extreme storms will have more high winds and tornados.
- Extreme storms will cause more floods.
- Insurance companies plan to increase rates to keep their profits up as disasters increase.
- Insurance companies are promoting storm-resistant buildings and clean and efficient uses of energy.
- Global warming could bankrupt the insurance industry.

Global Warming Effects on Oceans

- 20%-40% of CO₂ emitted into the atmosphere is dissolved in the oceans.
- This lowers the pH of the oceans making them more acidic. ~30% decrease since Industrial Revolution began.
- CO₂ in oceans prevents production of calcium carbonate to form shells for shelled sea life. Sea water must be saturated with carbonate ions for shells to form and remain intact.
- CO₂ threatens the food chains in the oceans because shelled sea life occurs at many links in the chains.
- Coral bleaching destroys species that live on them.
- Fish migrate toward the poles disrupting fisheries.

Triggering **Rapid** Climate Change

- Drastic rapid climate events have occurred in the past.
- **Climatology is not yet able to predict which and when drastic rapid events will be triggered.**
- Rapid melting of ice on Greenland and Antarctica can cause rapid sea-level rise.
- One possible trigger event that may be underway is rapid massive release of the powerful **GHG methane** in the Arctic and on the continental shelves, which greatly accelerates global warming.

Position Statements Acknowledging Human-Induced Climate Change (mid-2015)

American Academy of Pediatrics
American Association for the Advancement of Science (AAAS)
American Chemical Society
American College of Preventive Medicine
American Geophysical Union
American Institute of Biological Sciences
American Institute of Physics
American Medical Association
American Meteorological Society
American Physical Society
American Public Health Association
American Quaternary Association
American Society for Microbiology
Australian Coral Reef Society
Australian Medical Association
Australian Meteorological and Oceanographic Society
Canadian Foundation for Climate and Atmospheric Sciences
Canadian Meteorological and Oceanographic Society
Ecological Society of America
European Academy of Sciences and Arts
European Federation of Geologists
European Geosciences Union
European Physical Society
European Science Foundation
Federation of Australian Scientific and Technological Societies
Geological Society of America
Geological Society of Australia
Geological Society of London
Institute of Biology (UK)
Institute of Professional Engineers New Zealand

Institution of Engineers Australia
InterAcademy Council
International Association for Great Lakes Research
International Council of Academies of Engineering and Technological Sciences
International Union for Quaternary Research
International Union of Geodesy and Geophysics

National Academies of: Australia, Belgium, Brazil, Cameroon Royal Society of Canada, the Caribbean, China, Institut de France, Ghana, Leopoldina of Germany, of Indonesia, Ireland, Accademia nazionale delle scienze of Italy, India, Japan, Kenya, Madagascar, Malaysia, Mexico, Nigeria, Poland, Royal Society of New Zealand, Russian Academy of Sciences, Senegal, South Africa, Sudan, Royal Swedish Academy of Sciences, Tanzania, Turkey, Uganda, The Royal Society of the United Kingdom, the United States, Zambia, and Zimbabwe.

National Association of Geoscience Teachers

Network of African Science Academies (The science academies of Cameroon, Ghana, Kenya, Madagascar, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, as well as the African Academy of Sciences)

Royal Meteorological Society (UK)
World Federation of Public Health Associations
World Meteorological Organization

Mitigating Global Warming

- The only sure way to mitigate global warming is for humans to **quit burning fossil fuels**, especially coal and unconventional fossil fuels such as tar-sands oil.
- Currently, although extraction of crude oil and natural gas for the world is expected to peak within the next decade, **coal extraction for the world is expected to peak at year ~2050! That would be disastrous!**
- We need to greatly accelerate replacing energy from fossil fuels with **renewable energy**, such as wind, solar and biodiesel made from algae and transform our means of transportation to **electric trains, electric cars and biodiesel trucks and airplanes.**

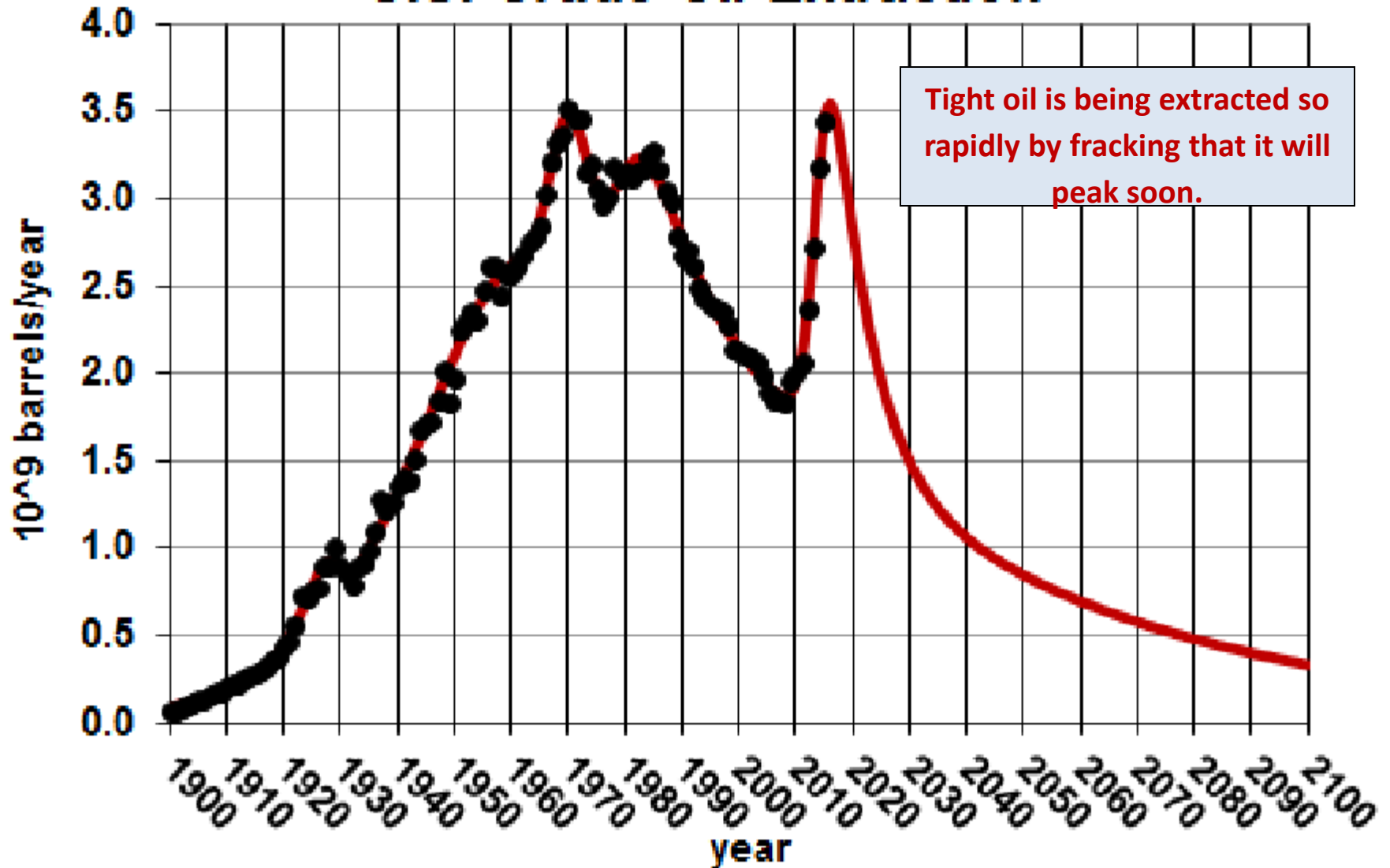
Global Warming Due to Burning Fossil Fuels

Fuel	CO ₂ emitted (g/10 ³ J)
Natural gas	~50
Gasoline	~67
Coal	~90

However, methane emissions from drilling and pipelines make using natural gas for energy as bad as coal for causing global warming!

US Crude-Oil Boom & Coming Bust

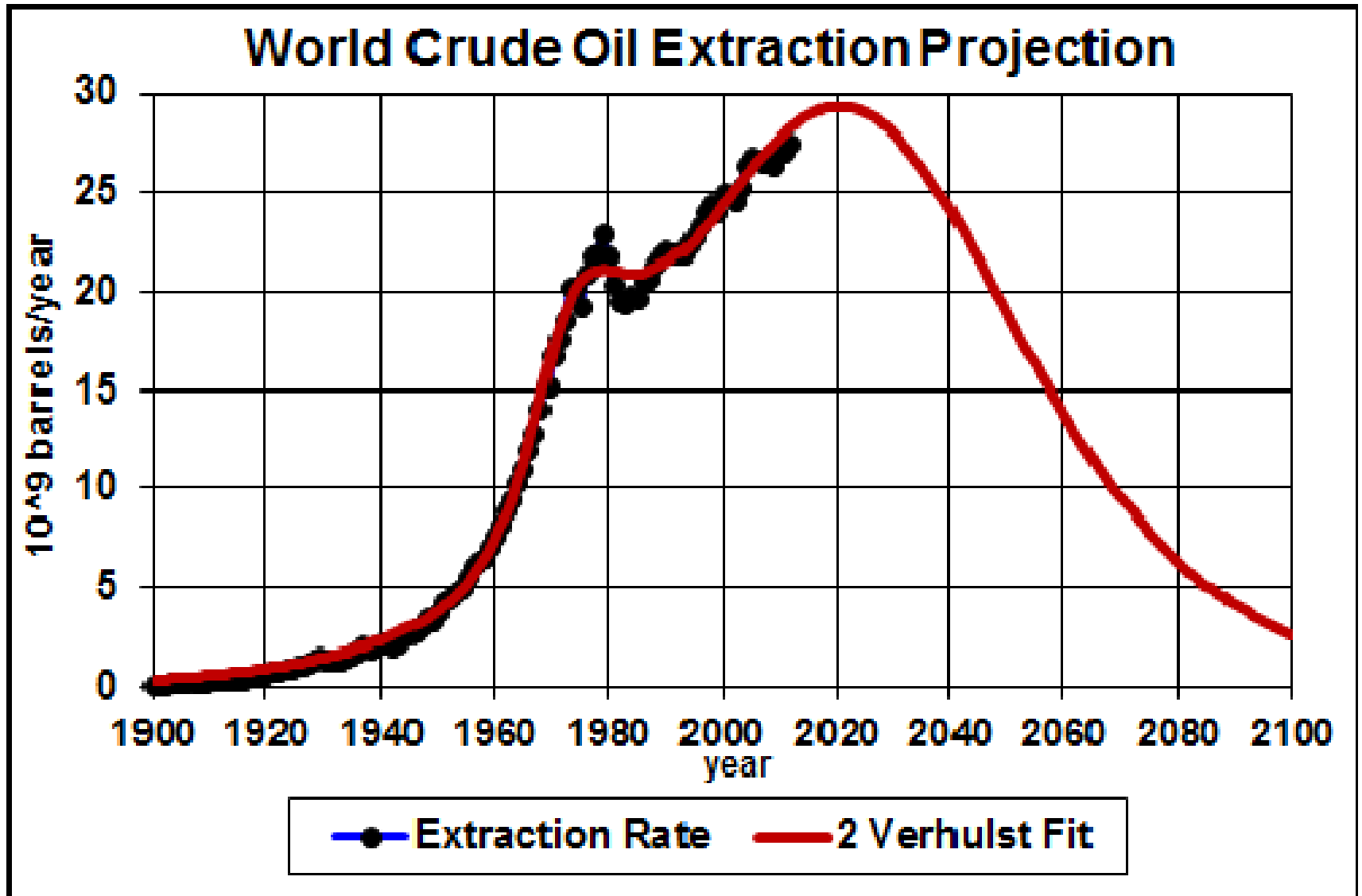
U.S. Crude Oil Extraction



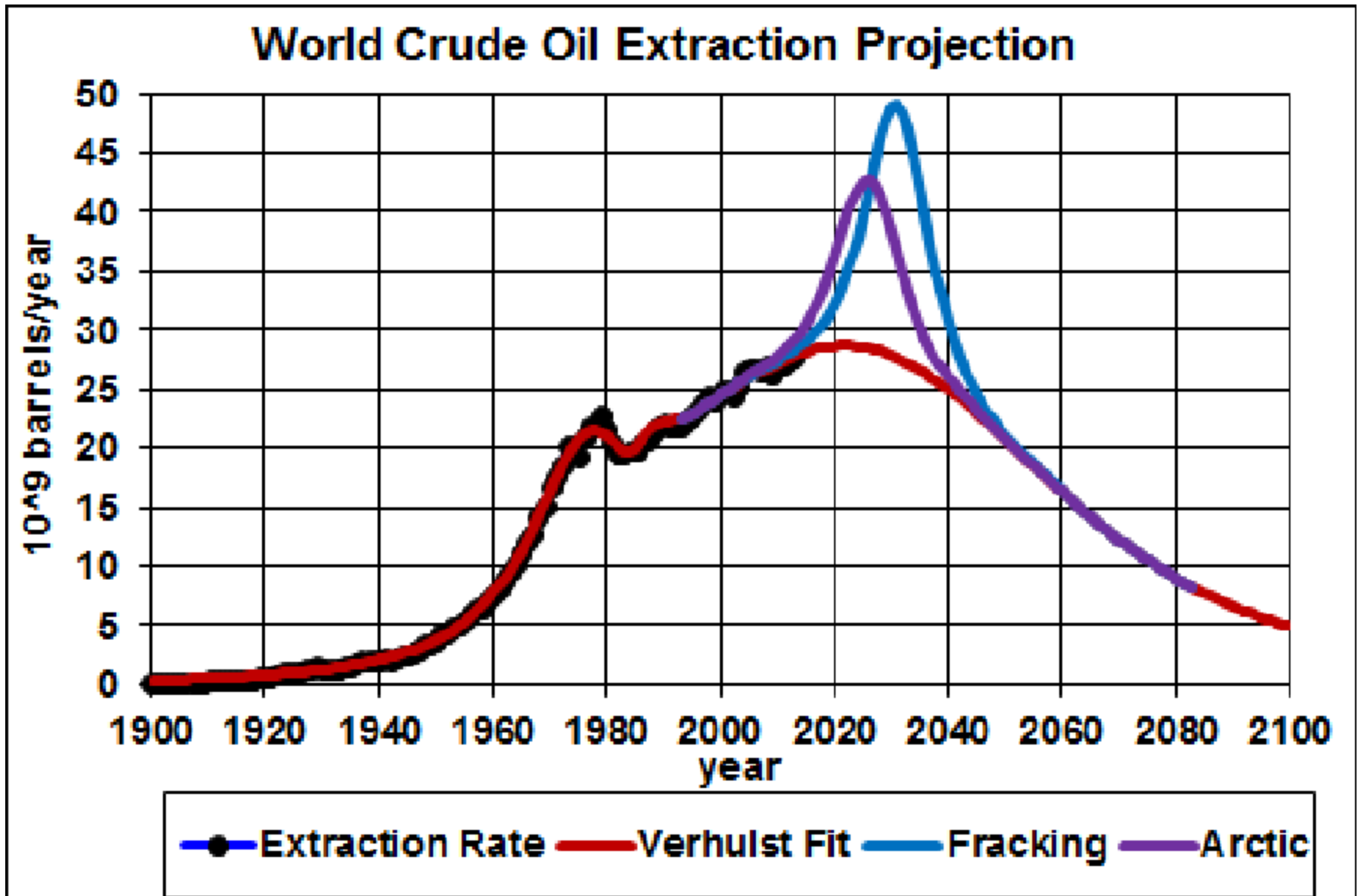
Tight oil is being extracted so rapidly by fracking that it will peak soon.



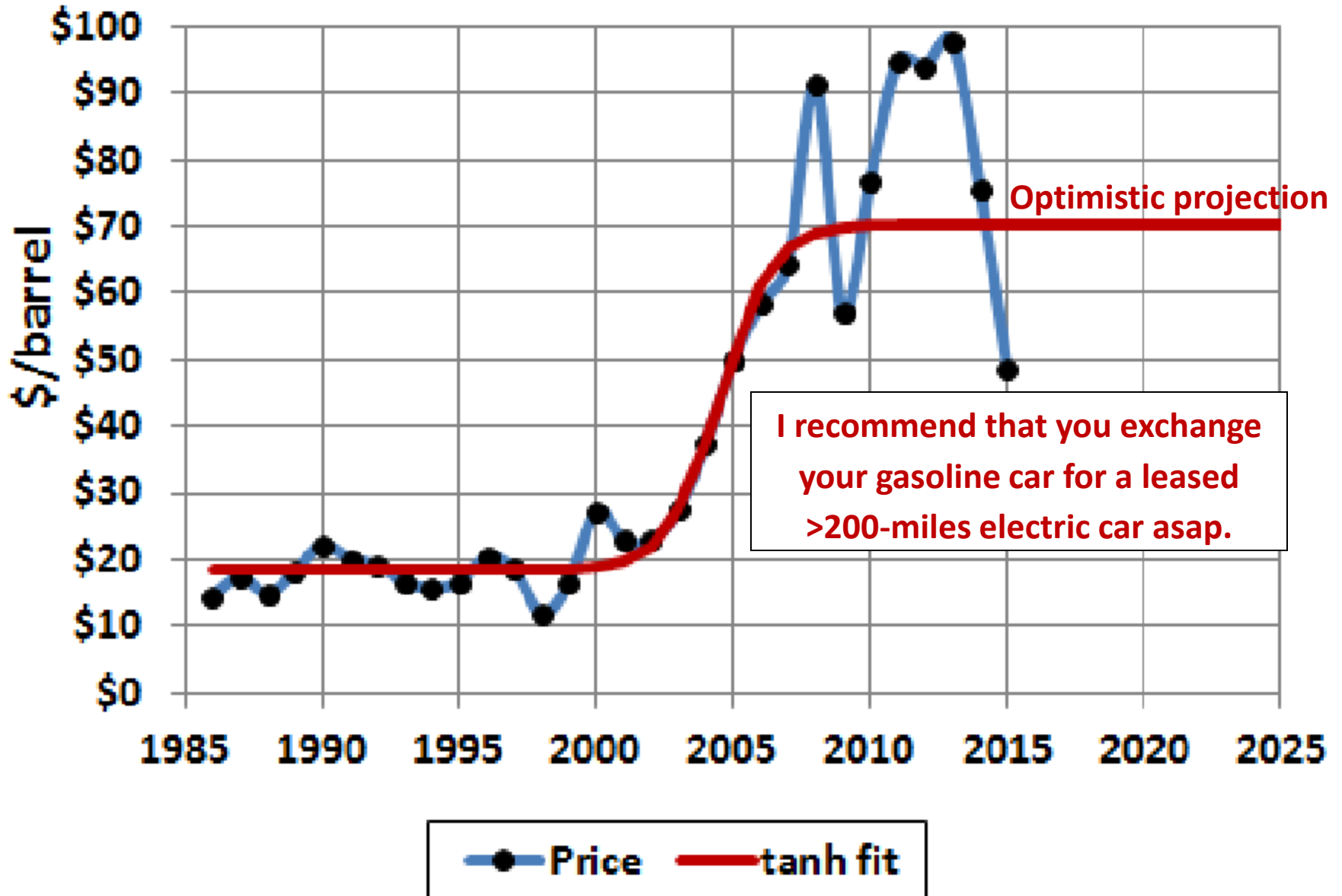
World Extraction of Conventional Crude Oil



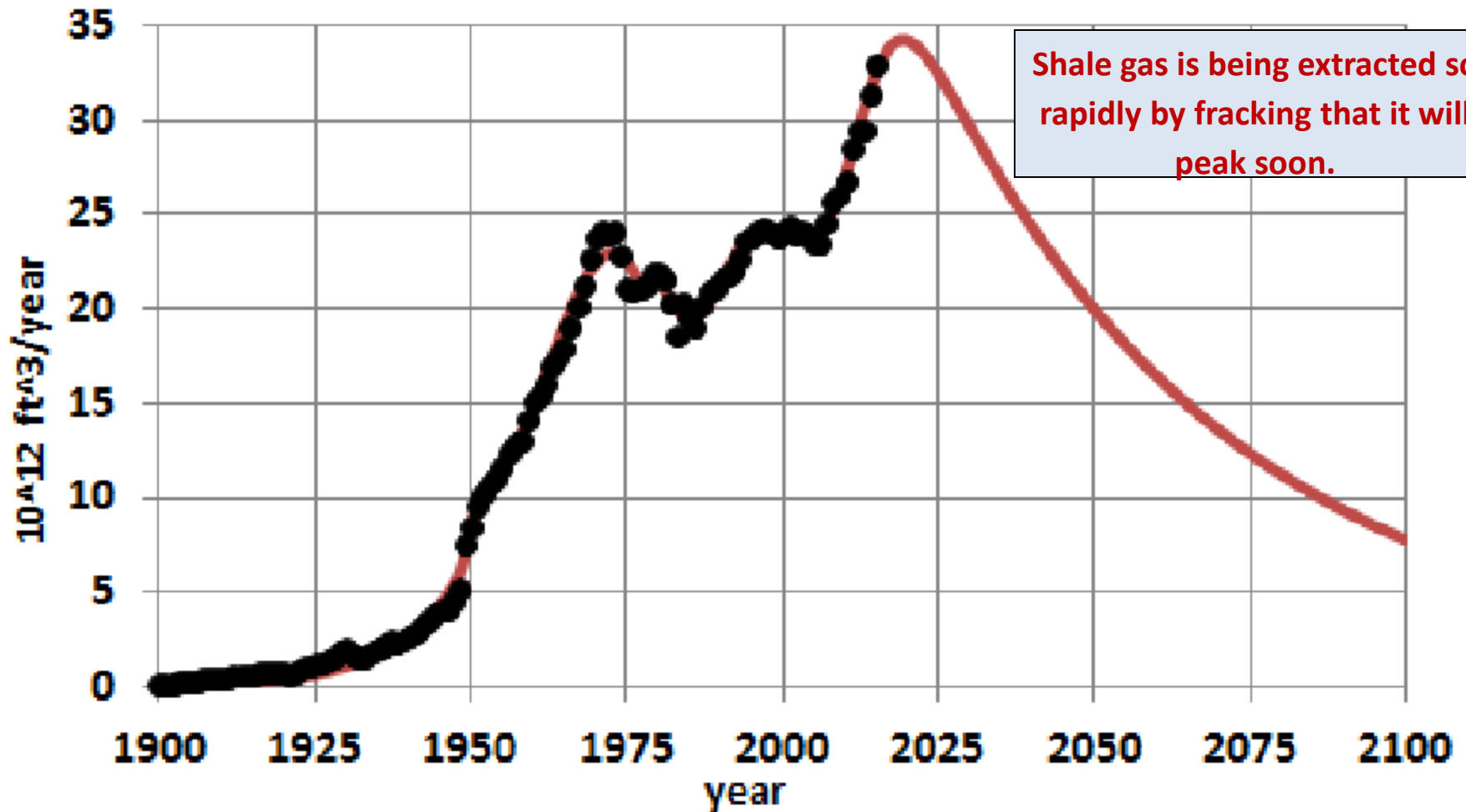
What if the world extracts crude oil by fracking and/or extracts it in the Arctic after the ice melts?



Crude-Oil Price



United States Natural-Gas Extraction

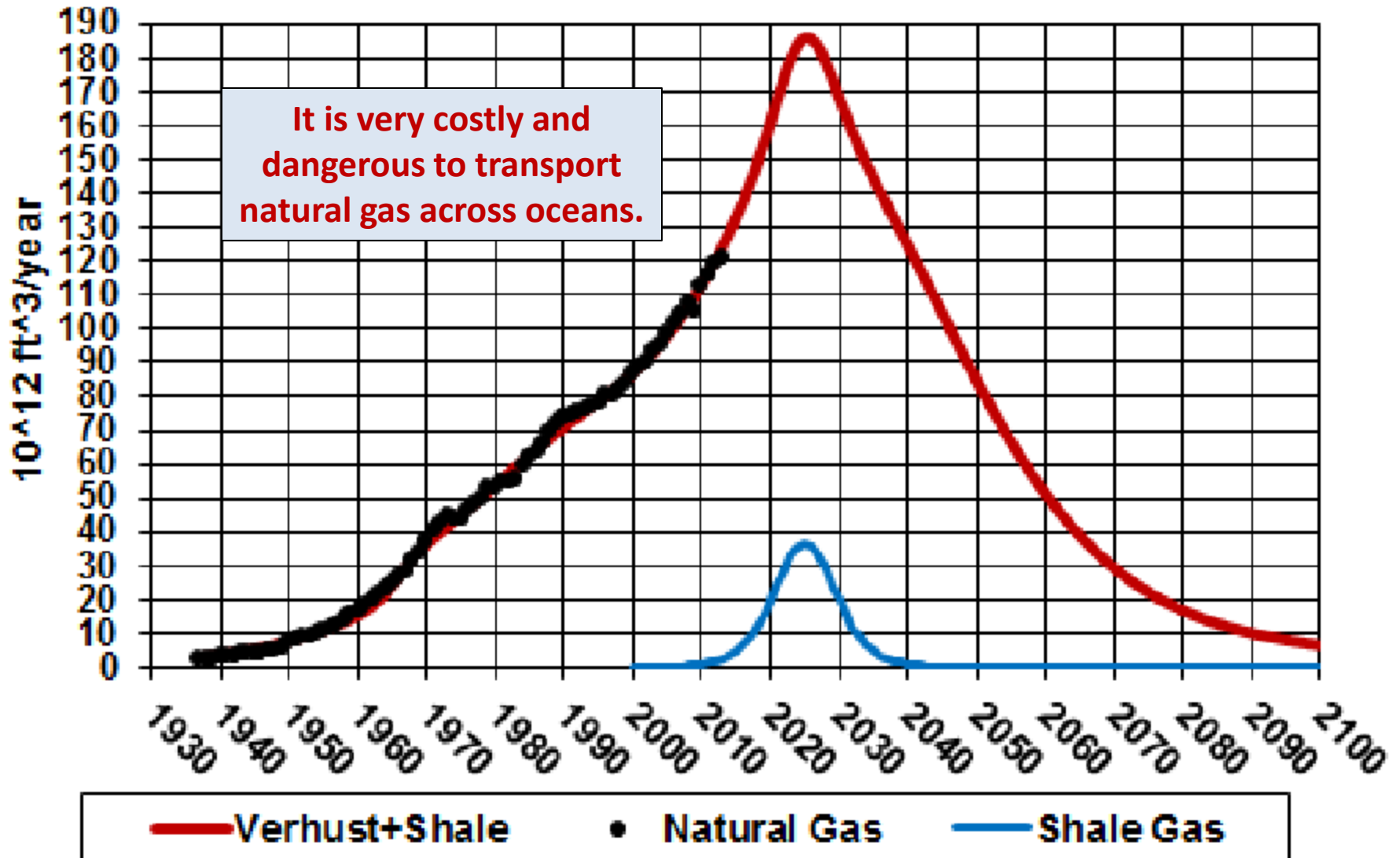


Shale gas is being extracted so rapidly by fracking that it will peak soon.

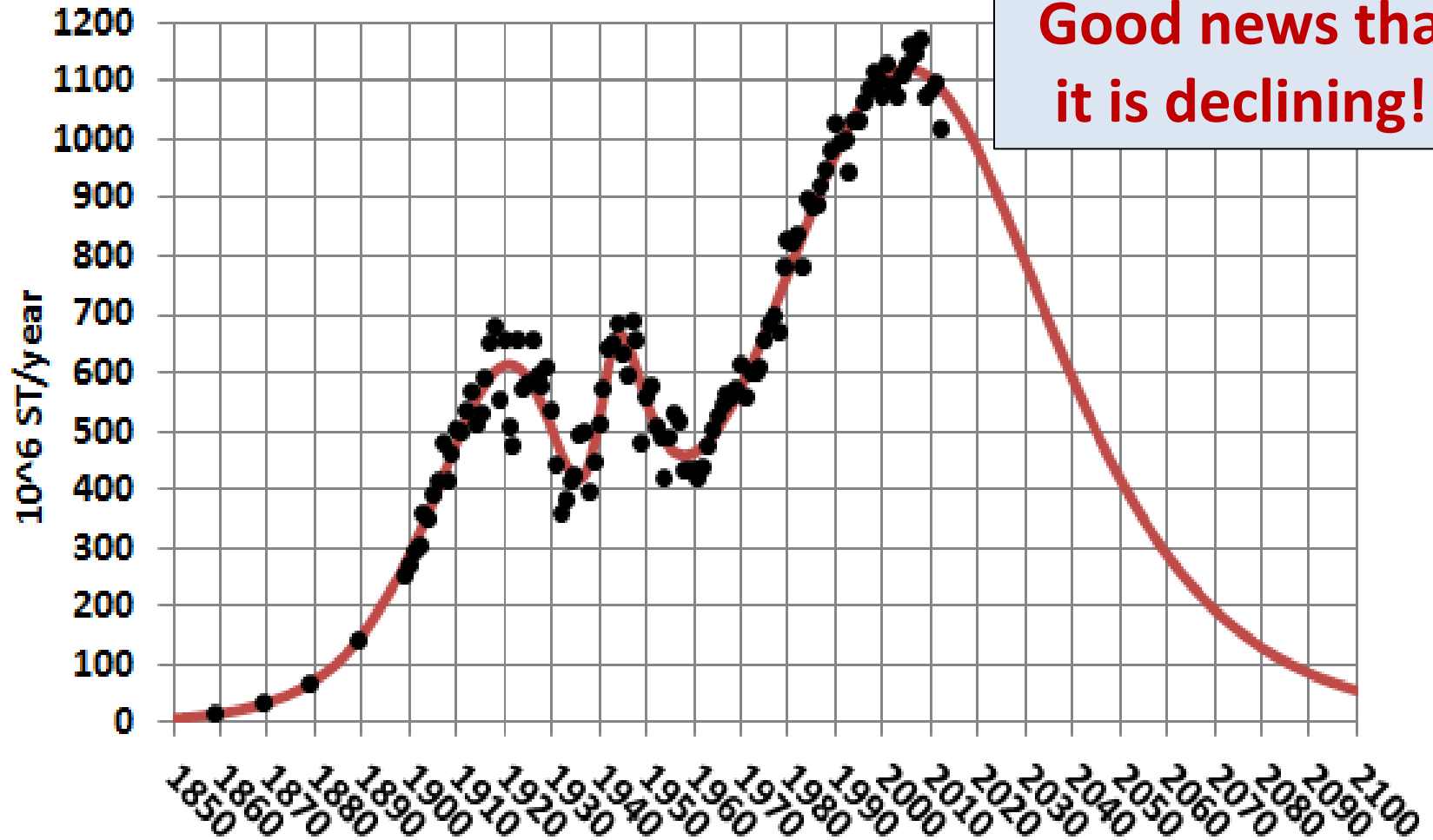
● Extracted

— Fit

World Natural-Gas Extraction



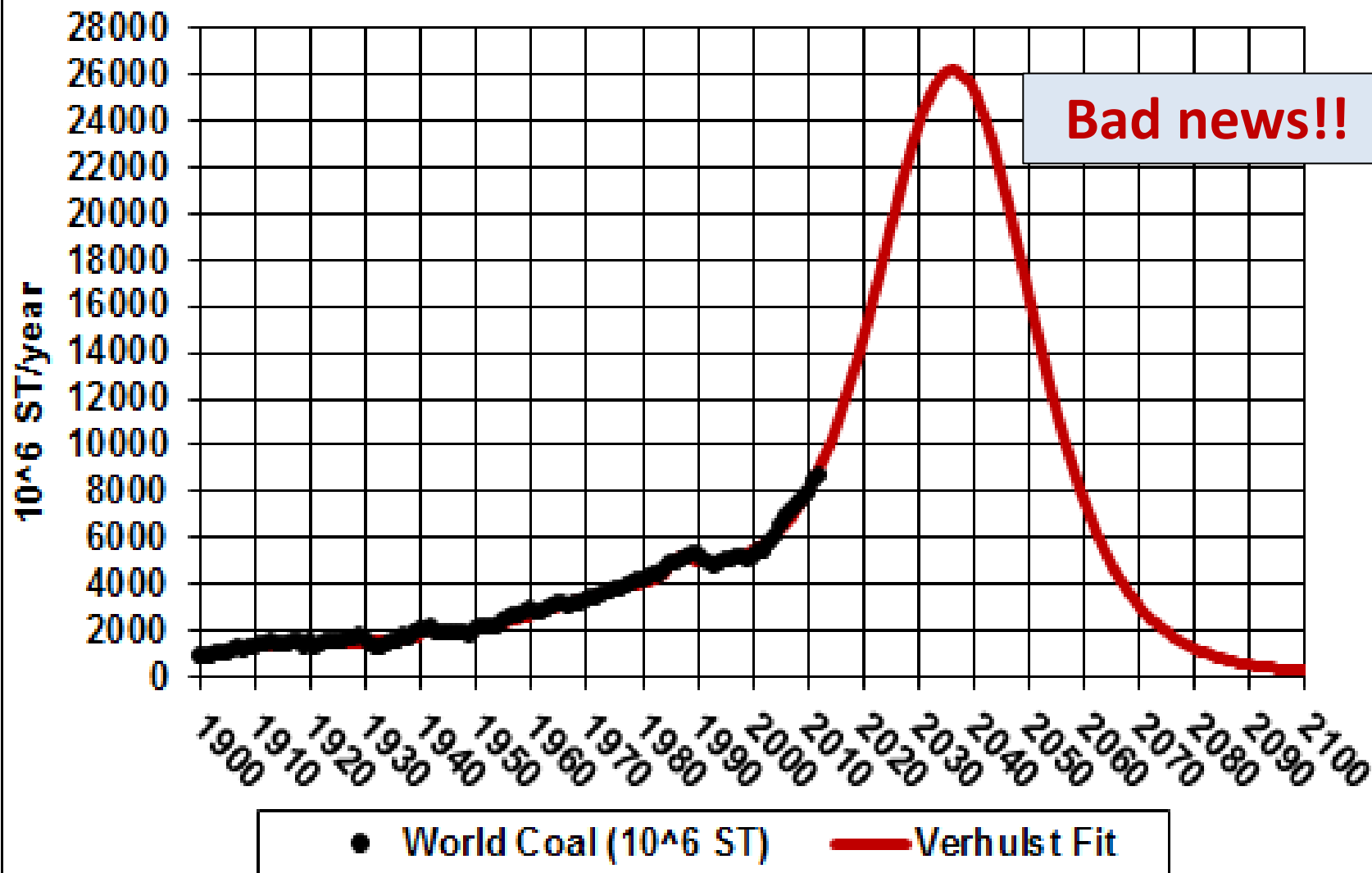
US Coal Extraction



**Good news that
it is declining!!**

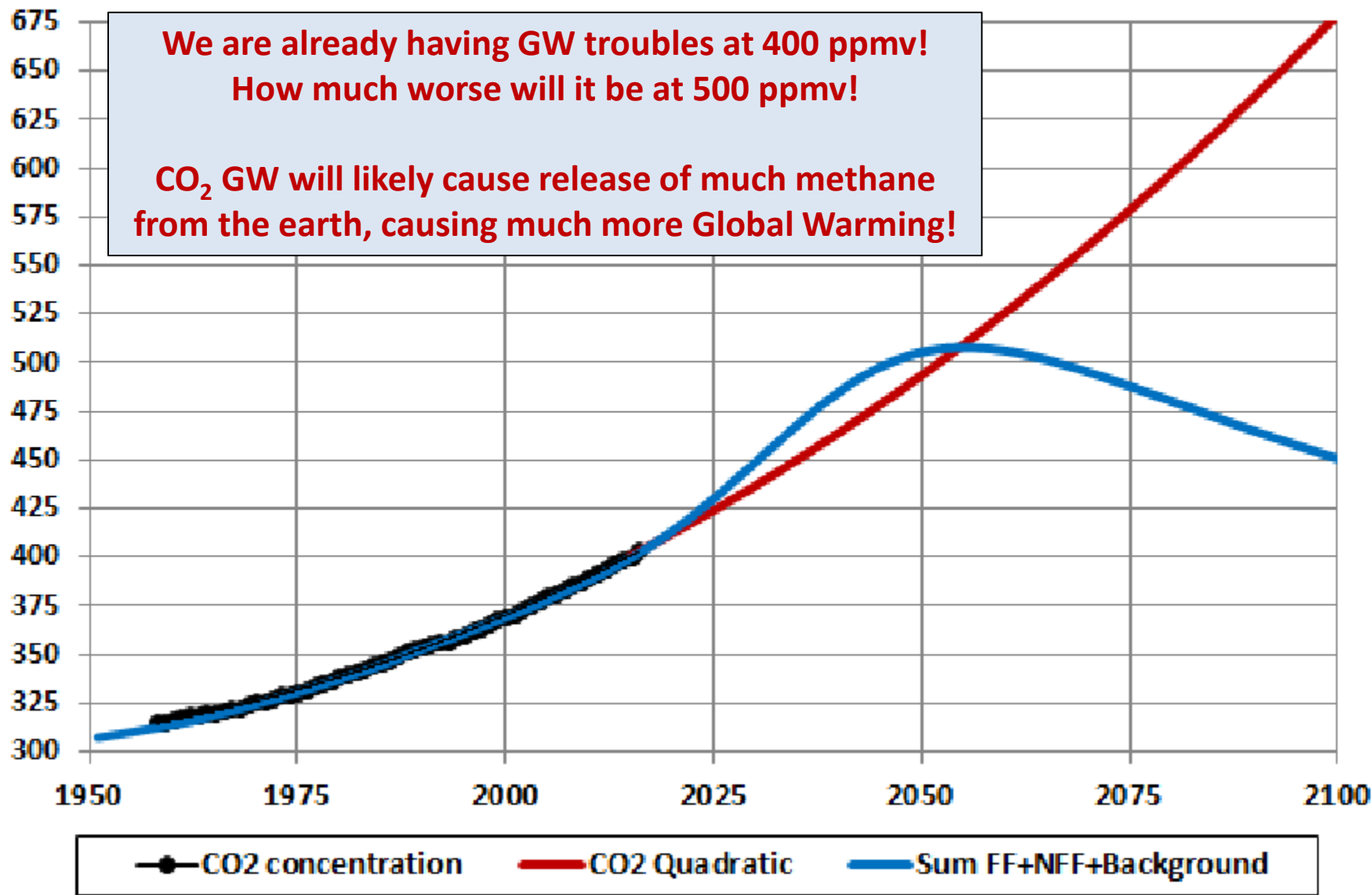
• Extraction Rate — 3 peaks

World Coal Extraction



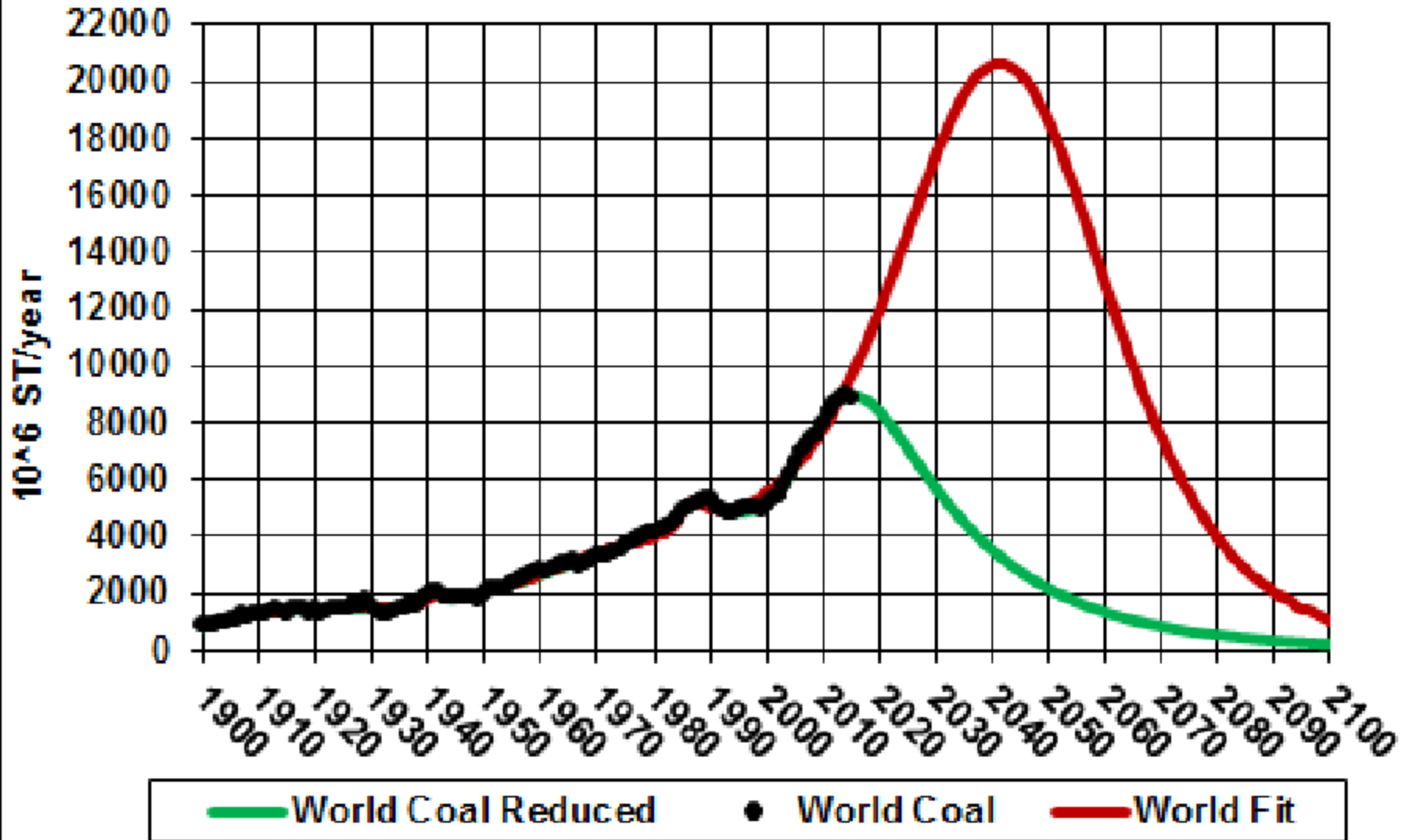
However, Bank of America and Deutsche Bank are committed to end financing of coal mining and coal-fired power plant construction; and coal plants are shutting down.

Atmosphere CO₂ Concentration (ppmv)



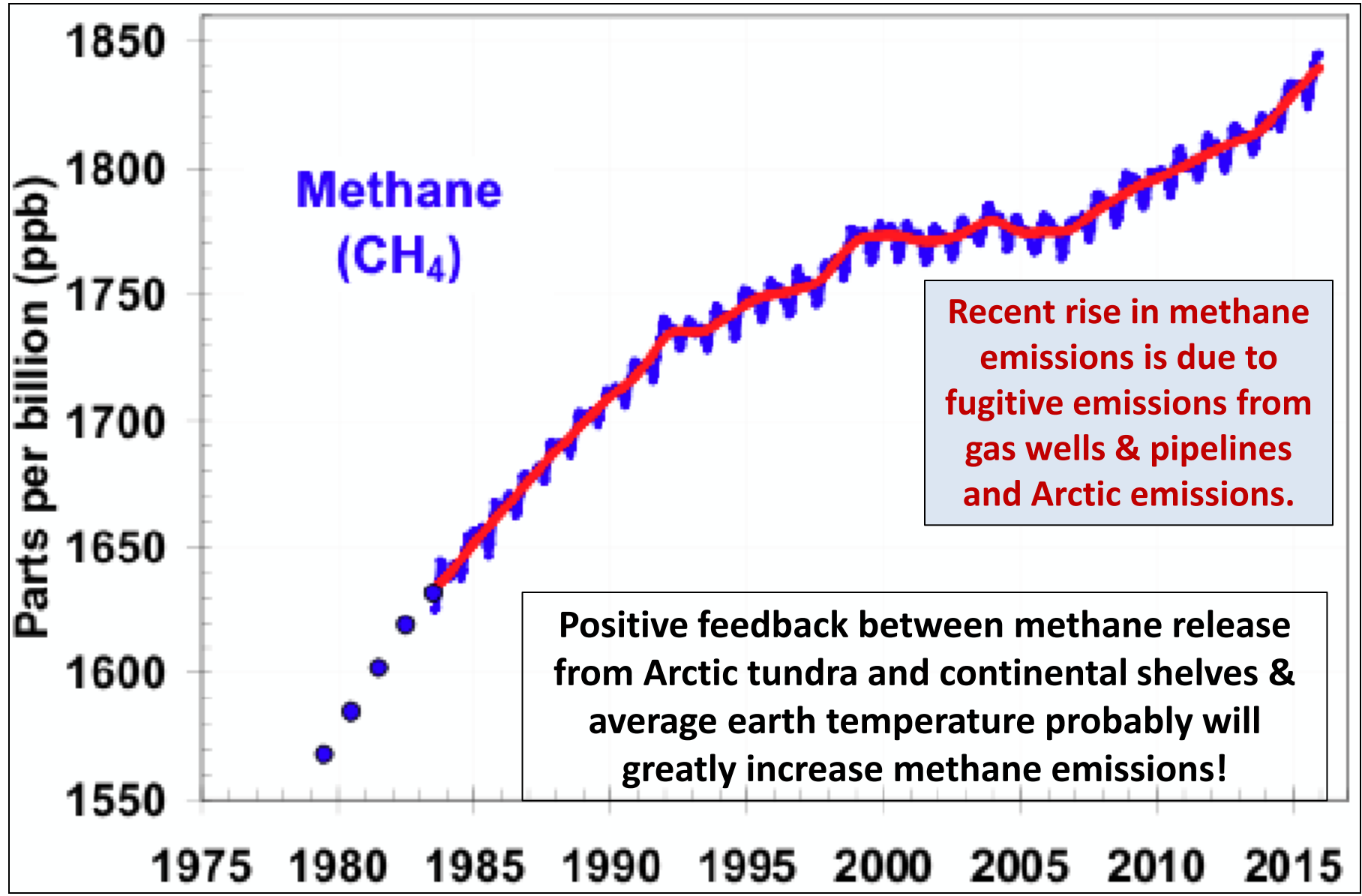
Red curve is quadratic data extrapolation into the future.
Blue curve is CO₂ concentration accounting for fossil-fuels depletion.

World Coal Extraction



This reduction in coal extraction would lower the CO₂ emissions peak from ~500 ppmv to ~425 ppmv and from year ~2050 to ~2030.

Methane (CH₄)

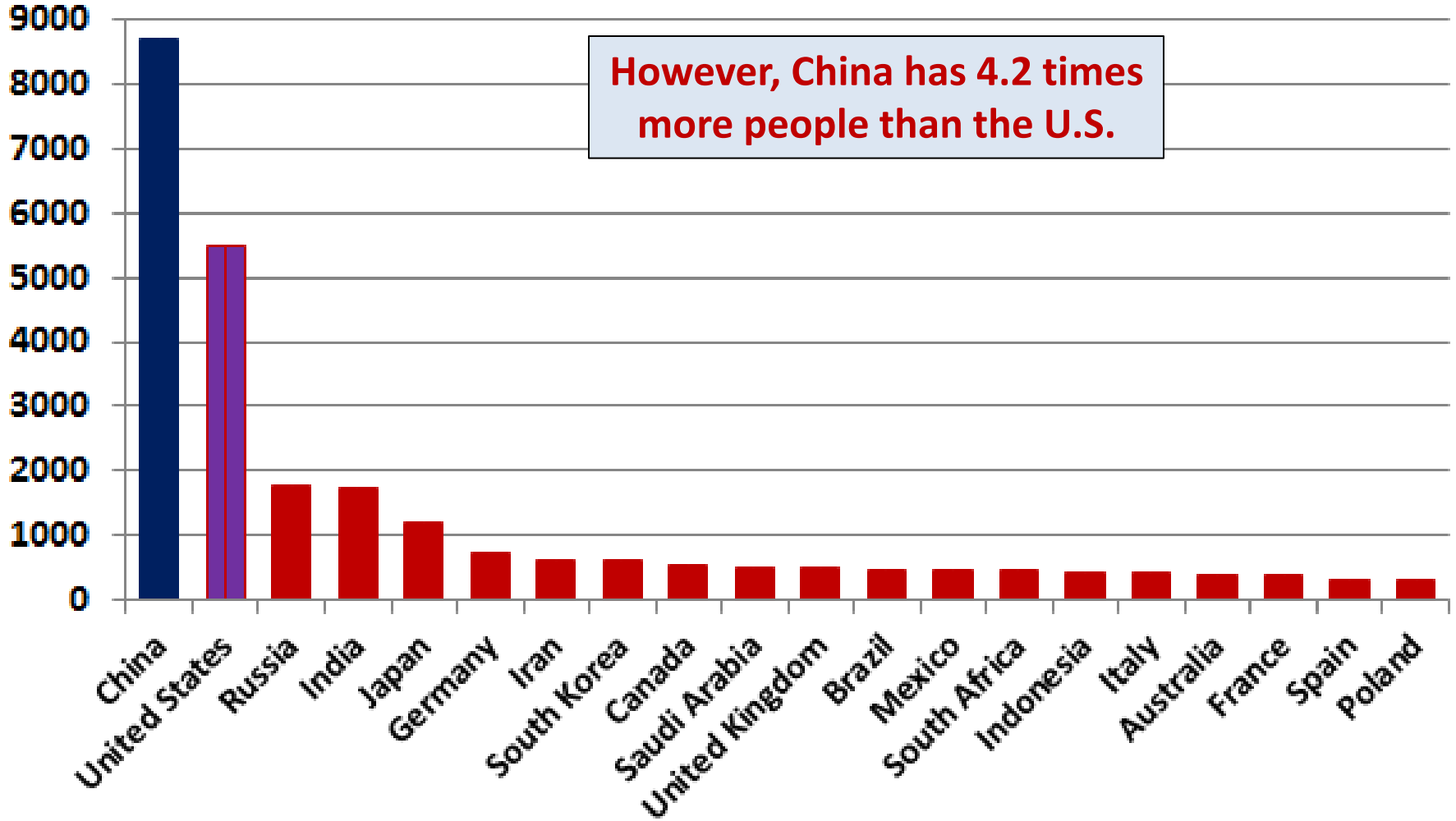


Recent rise in methane emissions is due to fugitive emissions from gas wells & pipelines and Arctic emissions.

Positive feedback between methane release from Arctic tundra and continental shelves & average earth temperature probably will greatly increase methane emissions!

1 tonne = 1.102 ton

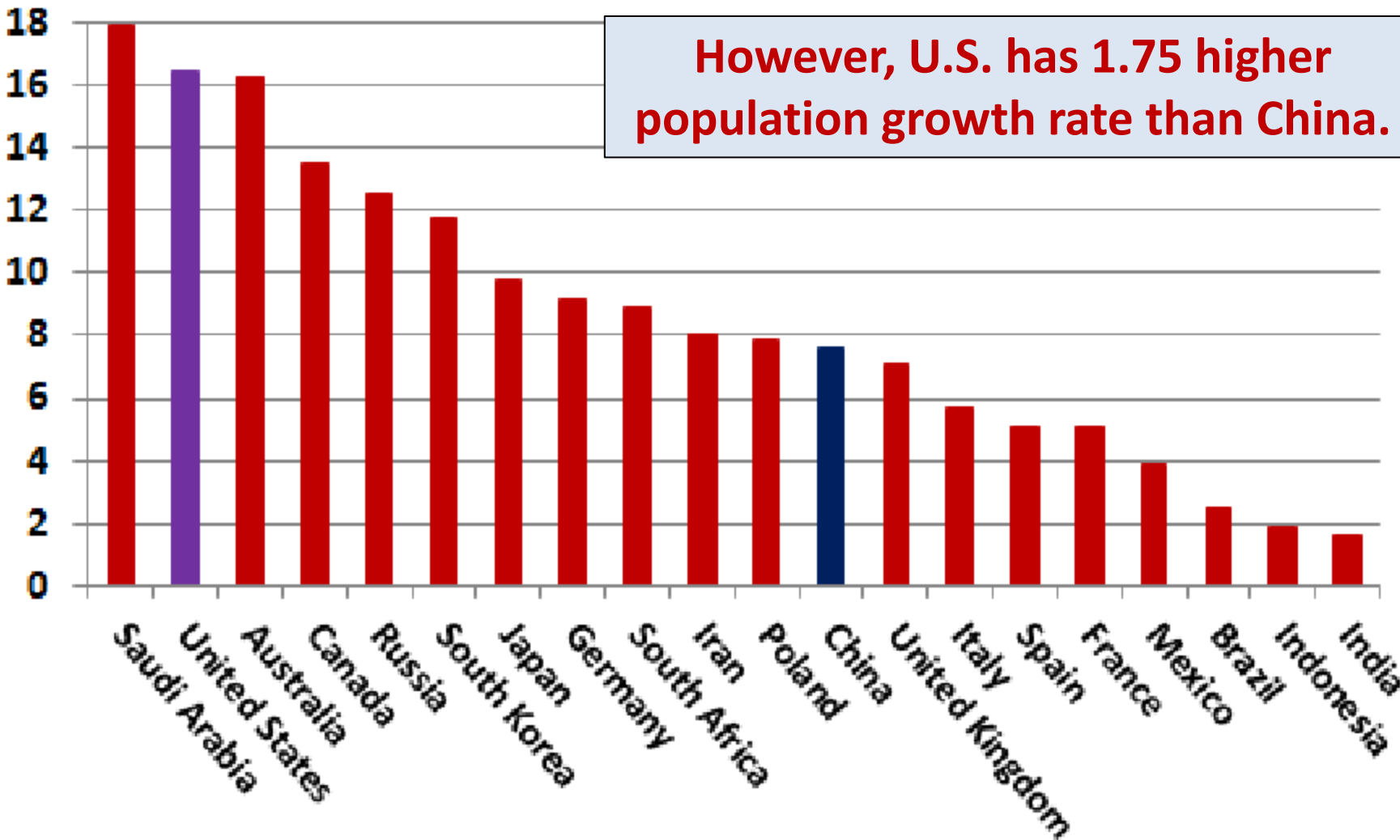
Total Carbon-Dioxide Emissions (10^6 tonnes)



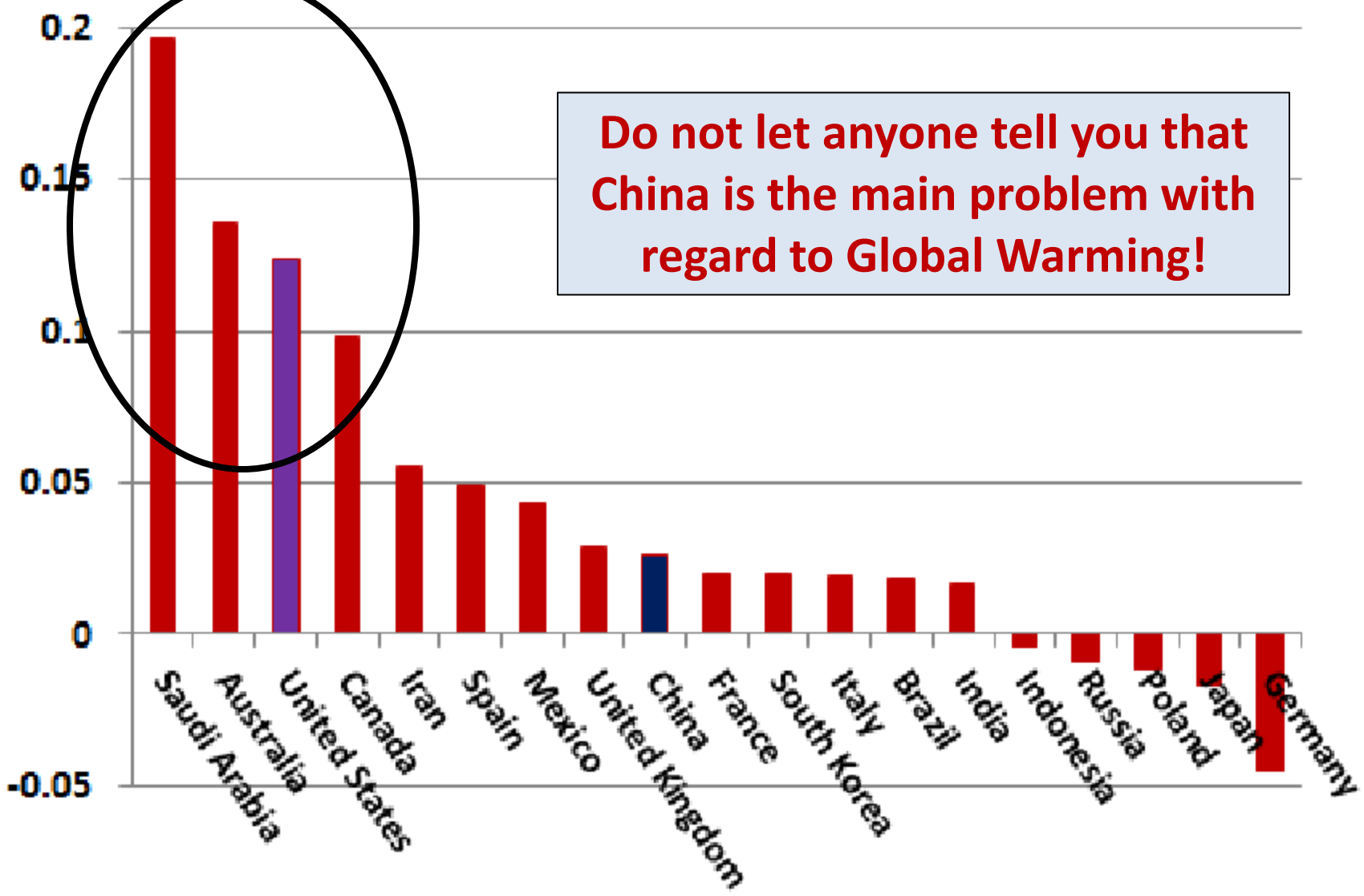
1 tonne = 1.102 ton

Per Capita Carbon-Dioxide Emissions (tonnes/person)

However, U.S. has 1.75 higher population growth rate than China.



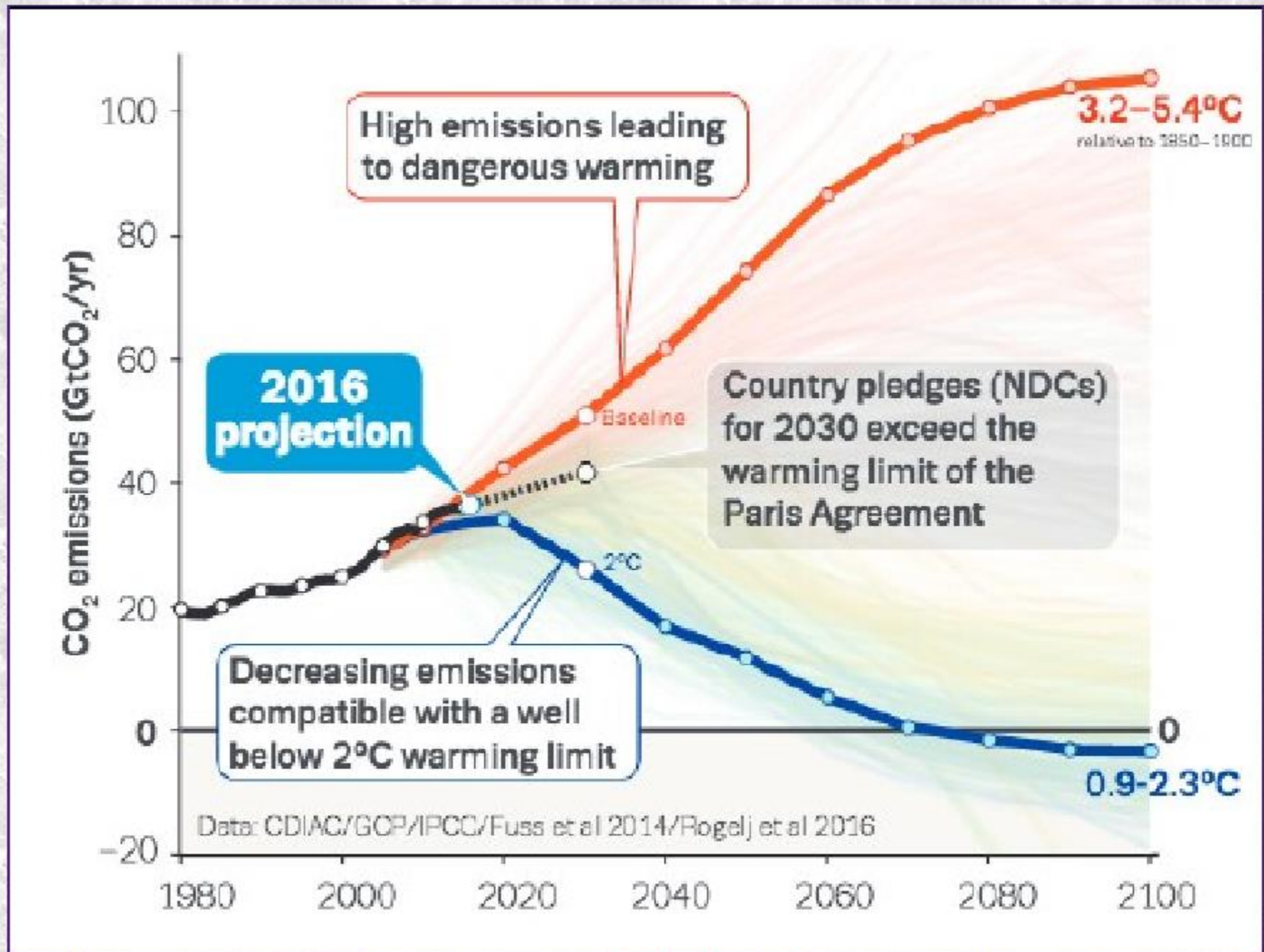
(% Population Growth) x (Per Capita Emissions)



Do not let anyone tell you that China is the main problem with regard to Global Warming!

Immediate Action Needed!

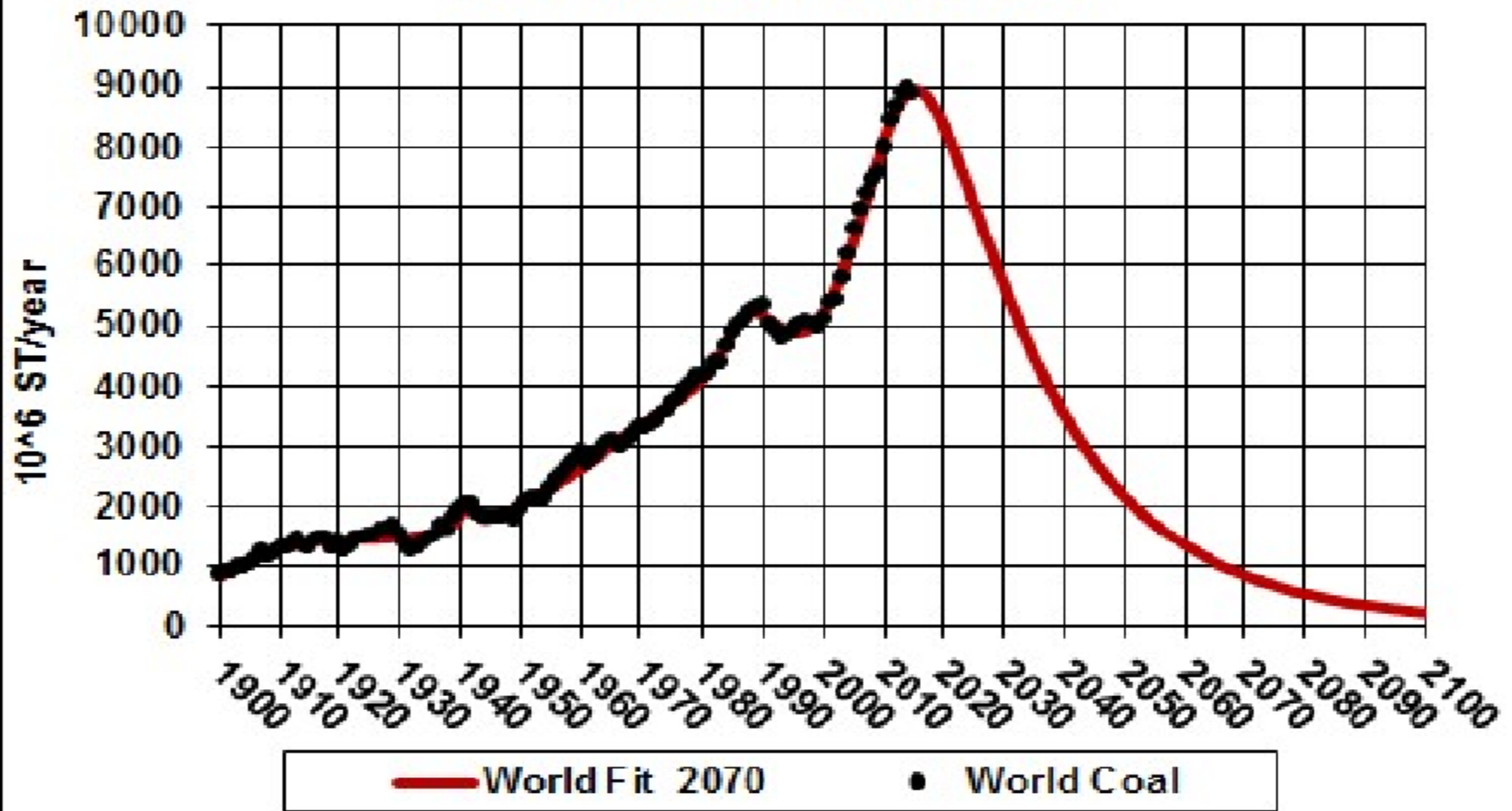
- Do not build any more coal power plants and stop current ones.
- Build distributed wind and solar energy and smart grid.
- Move to electric rail transportation for freight and mass people movement asap.
- Change personal transportation to electric vehicles and biofueled plug-in hybrid vehicles asap.
- Change trucks to fuel cells with hydrogen fuel made by solar.
- Make biofuels from non-food plants, such as algae and kudzu.
- Build all new buildings and remodel old buildings with high energy efficiency and with solar collectors and gardens on their roofs.
- Cover parking lots with solar panels and build community solar.
- Use petroleum and natural gas only for chemicals, not burning for fuel.
- Use coal to make carbon fibers to make vehicles lighter.



The y-axis is for CO₂ emissions; divide by 3.67 to get carbon emissions.

Reduce Global Coal Extraction!

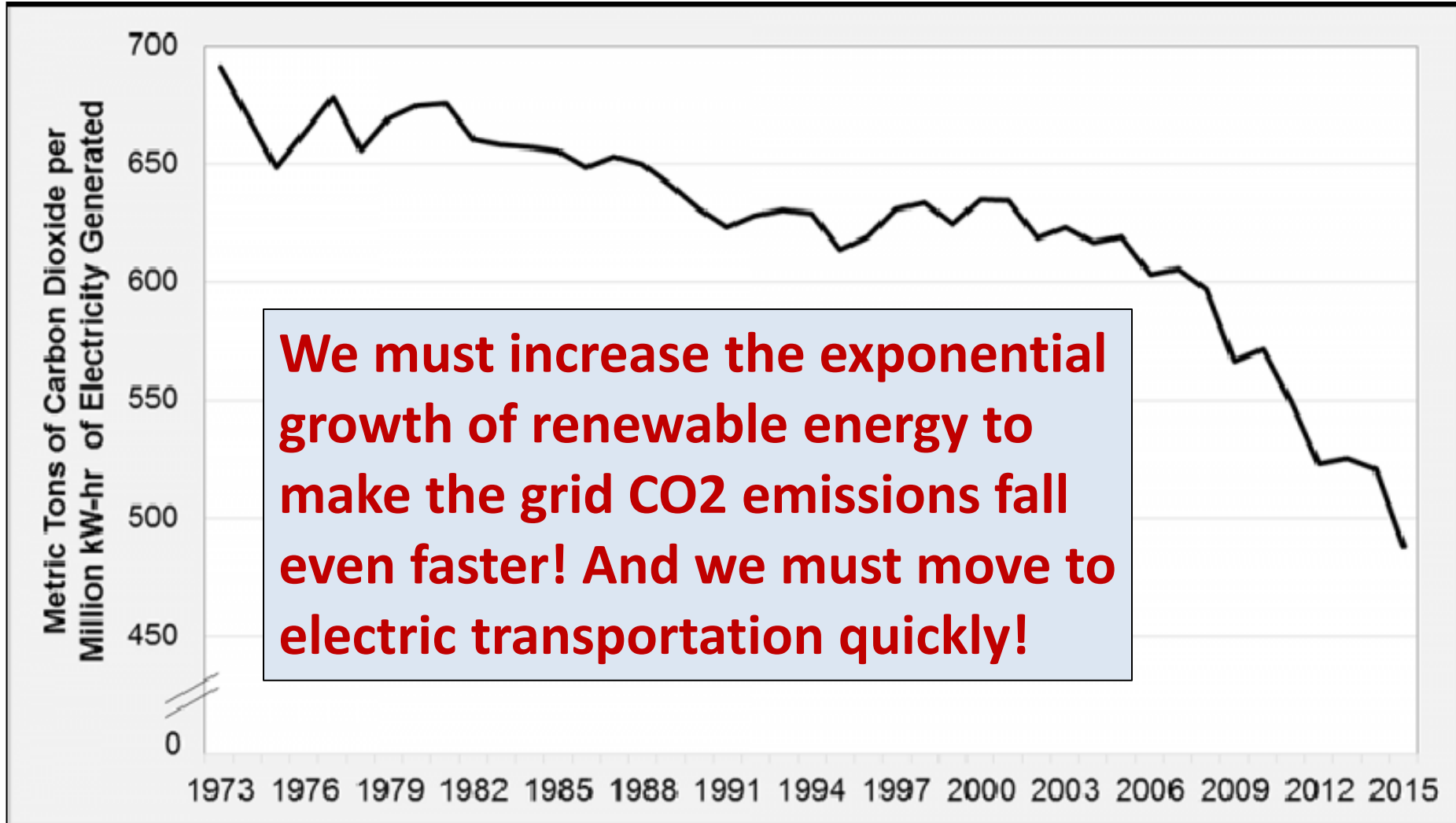
World Coal Extraction



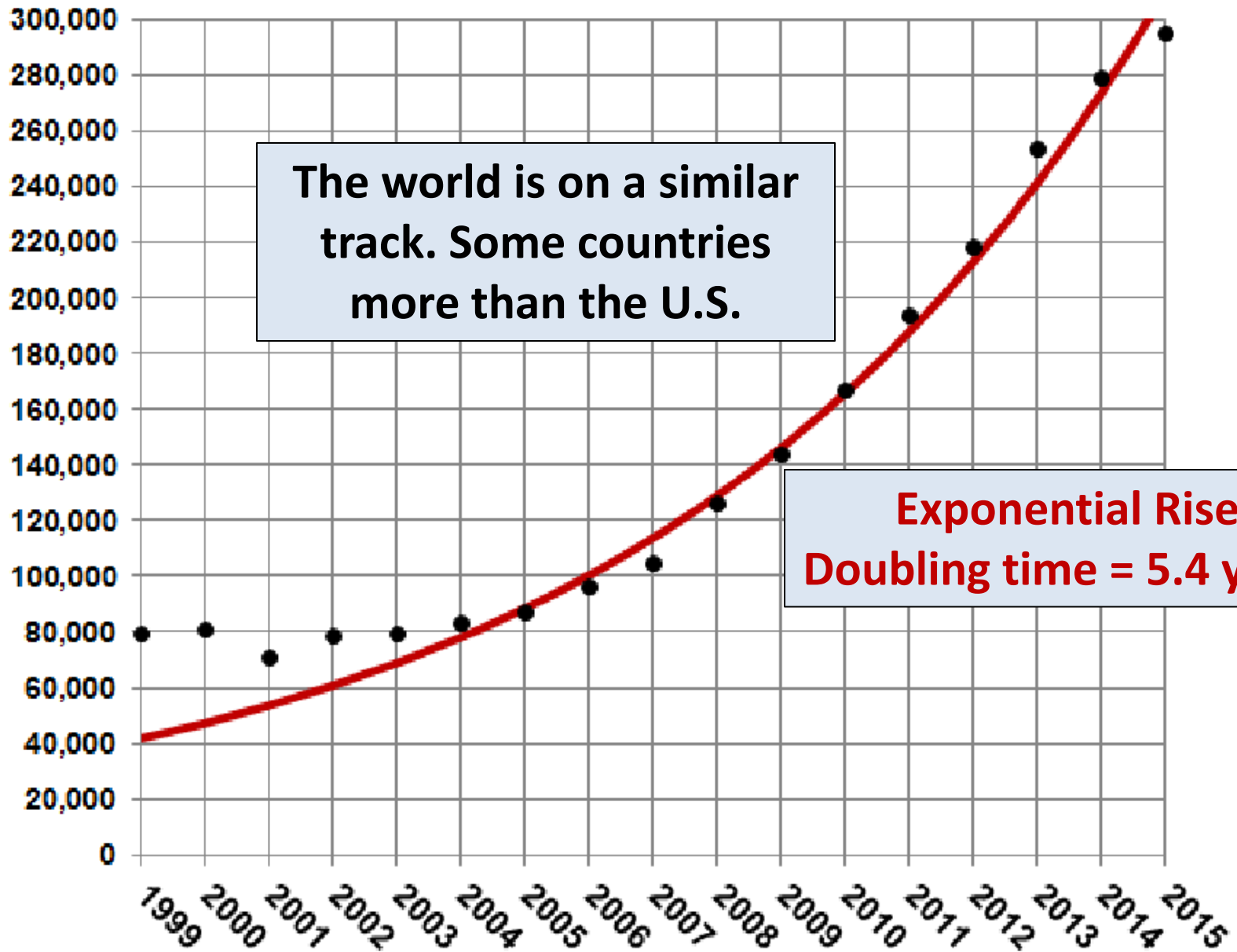
This curve reduces the recoverable reserves from 9.7×10^{11} ST to 2.2×10^{11} ST, causing stranded coal reserves of 7.5×10^{11} ST.

U.S. Reduced Grid CO₂ Emissions

Good News!



U.S. Electricity from Renewables (GWhours)

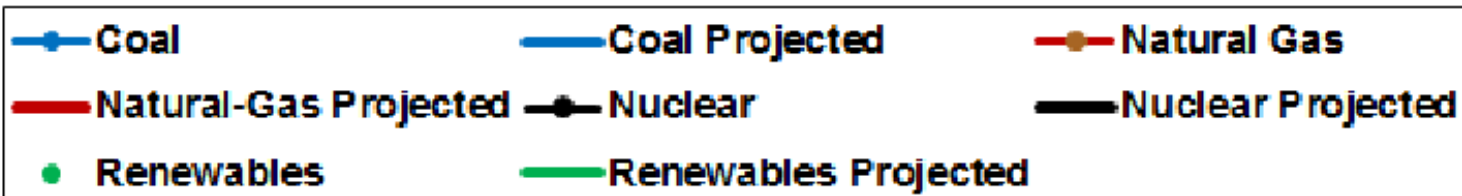
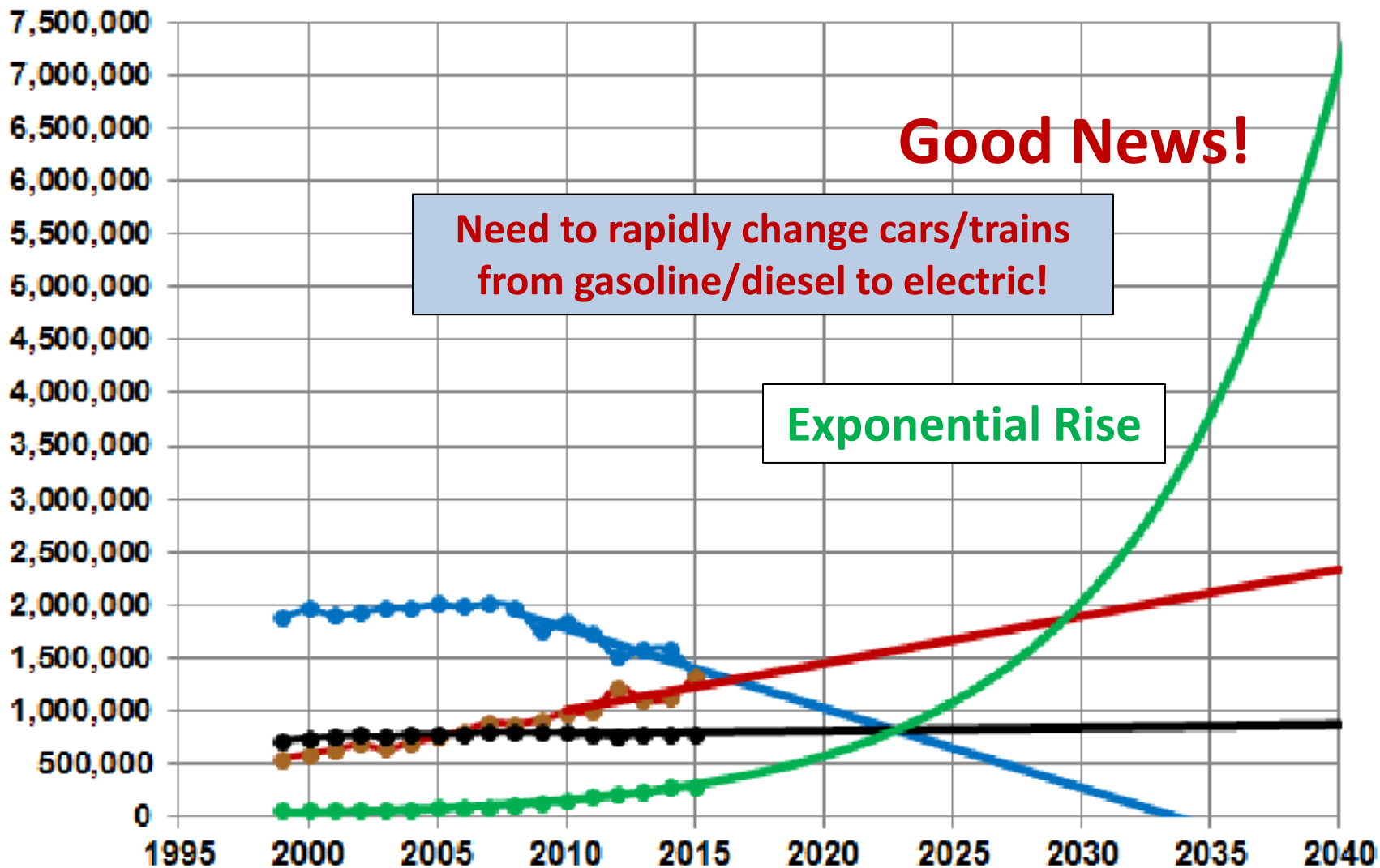


The world is on a similar track. Some countries more than the U.S.

Exponential Rise
Doubling time = 5.4 years

● Renewables — EXP Fit

U.S. Electricity Projection (GWhours)



Citizens' Climate Lobby

- Carbon Fee and Dividend
- Start with \$15/ton of CO₂-equivalent at entry point (CO₂, CH₄, N₂O, SF₆, etc.).
- Methane leakage fee after initial fee @20-year GWP charged to entities responsible for leakage.
- Fee increase of \$10/ton/year until CO₂e emissions are reduced to 10% of 1990 value.
- Emissions calculations will be done by U.S. Department of Energy.
- Fee will be collected by U.S. Treasury Department.

Citizens' Climate Lobby

- Dividend (Rebates)
- Equal monthly dividend for all persons above 18-years age.
- One-half dividend for persons under 18-years age.
- Dividends limited to two children per family.
- Total monthly dividends = total monthly carbon fees.
- Administered by U.S. Treasury Department.

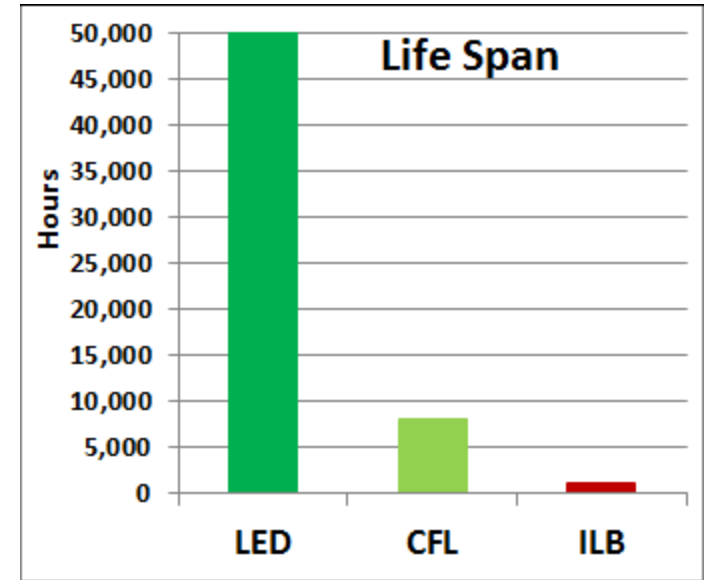
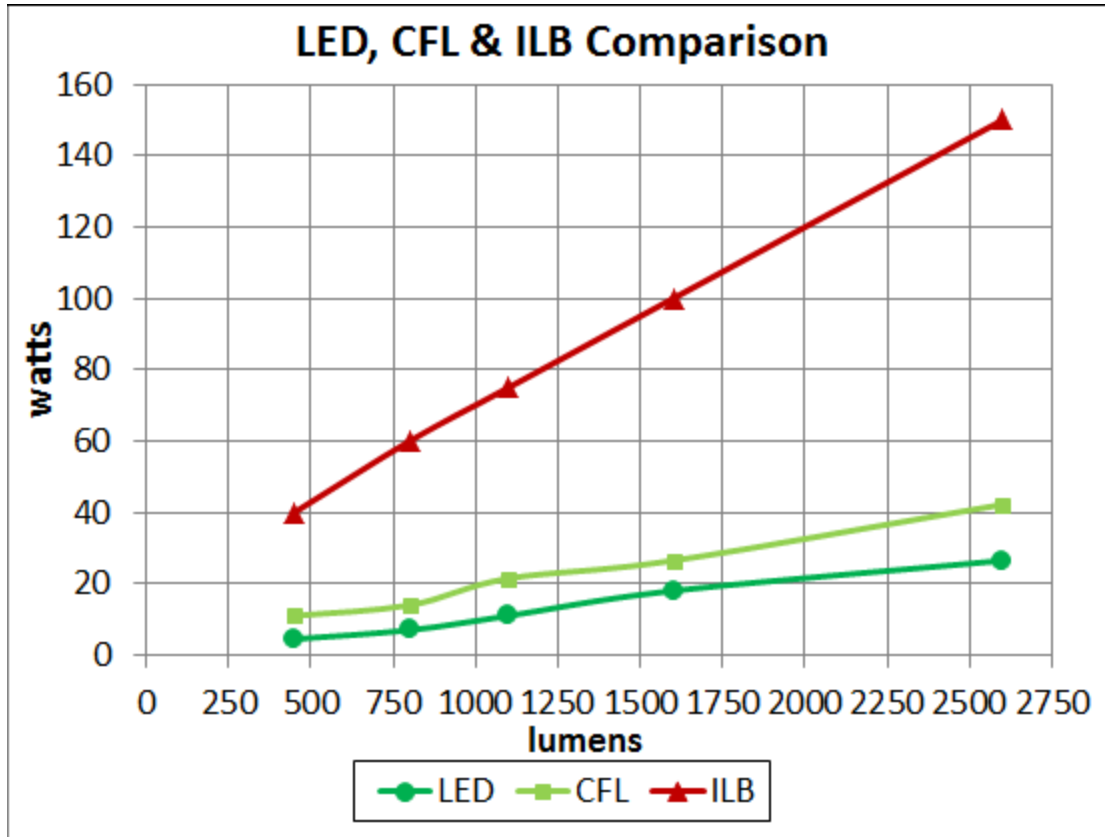
Citizens' Climate Lobby

- Tariffs and Rebates
- Tariffs on imports from countries without equivalent controls on emissions.
- Rebates to companies that export to countries without equivalent controls on emissions.
- U.S. State Department will determine the tariffs and rebates.

What Individuals can do

- Energy renovate your house and business.
- Install efficient heating and cooling.
- Change all lighting to LEDs. (7W = 60W-equivalent for \$1.50!)
- Install solar energy on your house and business .
- Lease a >200-miles electric car and promote fast charging.
- Advocate a fee for emitting carbon into the atmosphere.
- Advocate power companies to convert to renewable energy.
- Travel using less energy.
- Eat local food.
- Eat less meat.
- [Compost food and yard waste.](#)
- Don't drink carbonated drinks.
- Recycle everything possible.
- Donate items to thrift shops and ReStores for reuse.

Comparison of LED, CFL & ILB Bulbs



efficiency = lumens/watt

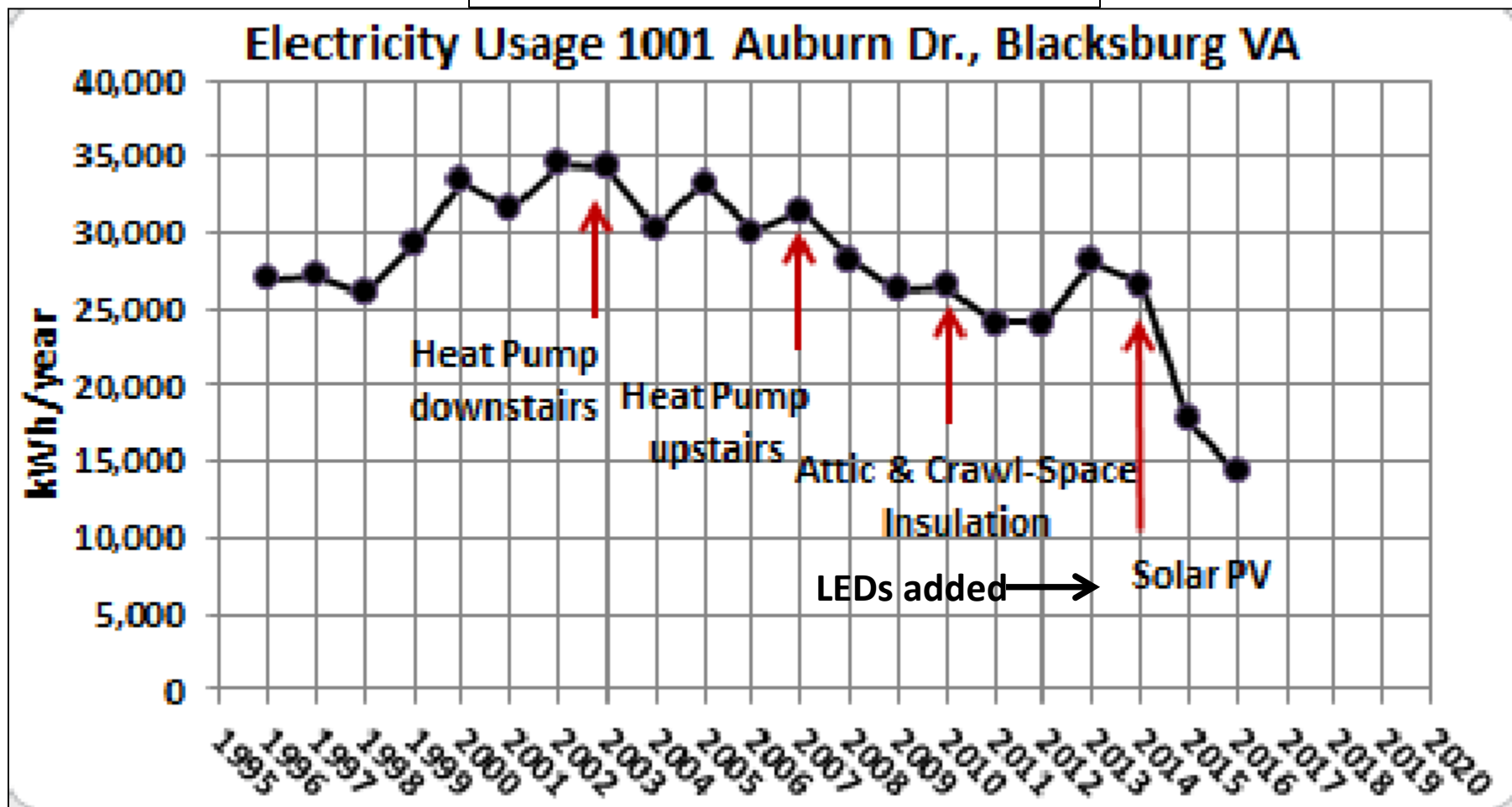
goodness = efficiency × life-span (lumens × hours/watt)

LED = 41 × ILB, CFL = 6.6 × ILB

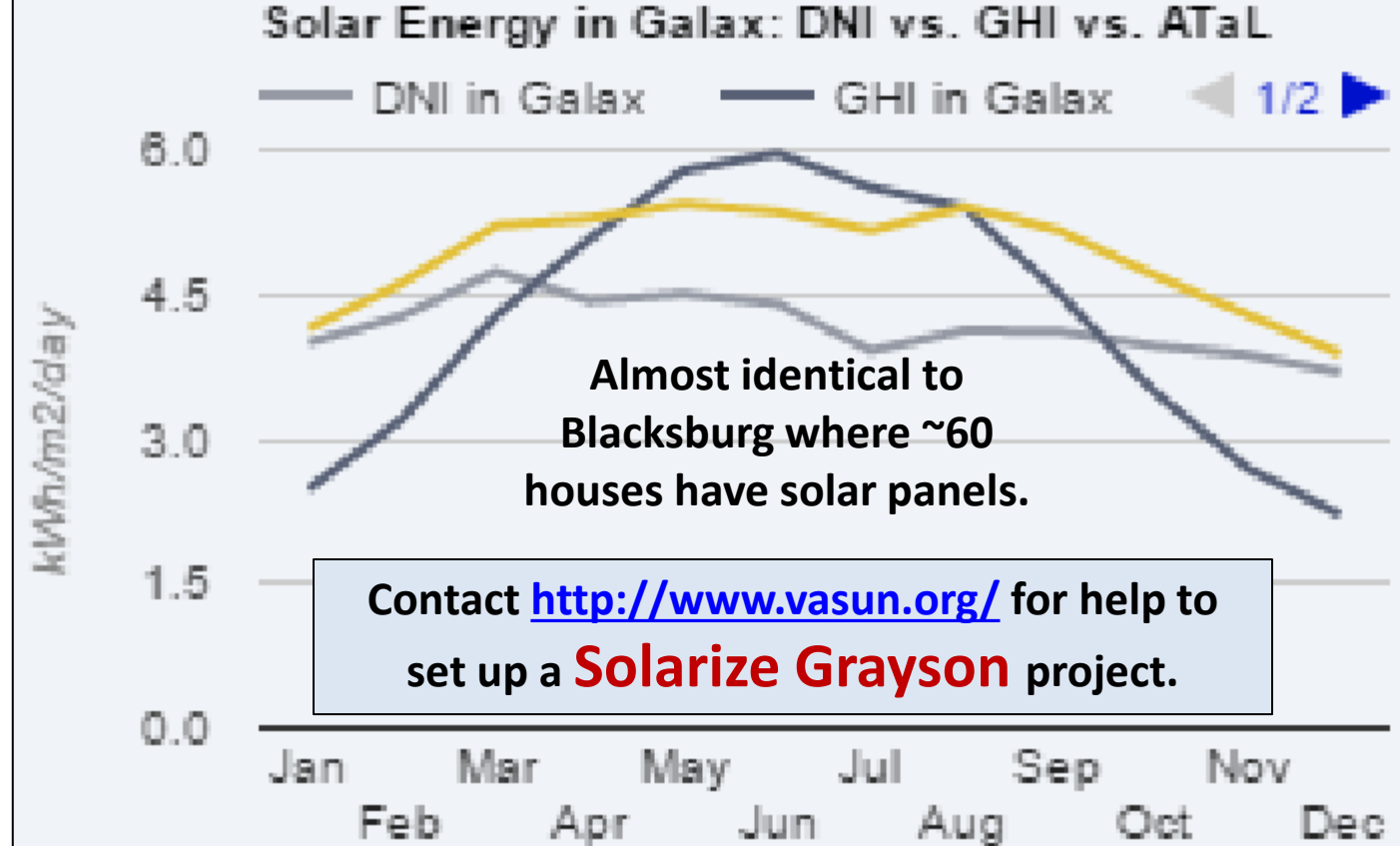
LEDs are available in White Light (2700K) & Daylight (5000K).

What my family is doing:

- Driving electric and hybrid cars
- Composting food and yard waste
- Recycling
- All LED light bulbs
- Solar PV on roof of house:



The installation of the 28 solar panels had a much larger effect than other changes.



- DNI = Direct Normal Irradiance (Horizontal surface)
- GHI = Global Horizontal Irradiance (Surface perpendicular to sun rays)
- **ATaL = Average Tilt at Latitude** (Surface tilted toward equator at current-latitude angle.)

Midsize >200-Miles BEVs in 2017-8

tinyurl.com/BoltEVManual

[Chevrolet Bolt EV](#) (238-miles)(2017)(\$37,500)



60-kWh battery
119 MPGe EPA
ECO: 140 MPGe
\$7,500 federal
tax credit

**Don't confuse the Chevy Bolt EV, a BEV,
with the Chevy Volt, a PHEV.**

Midsize >200-Miles BEVs in 2017-8

Tesla Model 3 (>215 miles)(2018)(\$35,000)



~55-kWh battery
15" horizontal &
Heads-Up displays

Often called Model ≡

I expect Tesla to increase the battery size to compete with the Chevy Bolt EV range.

Options:

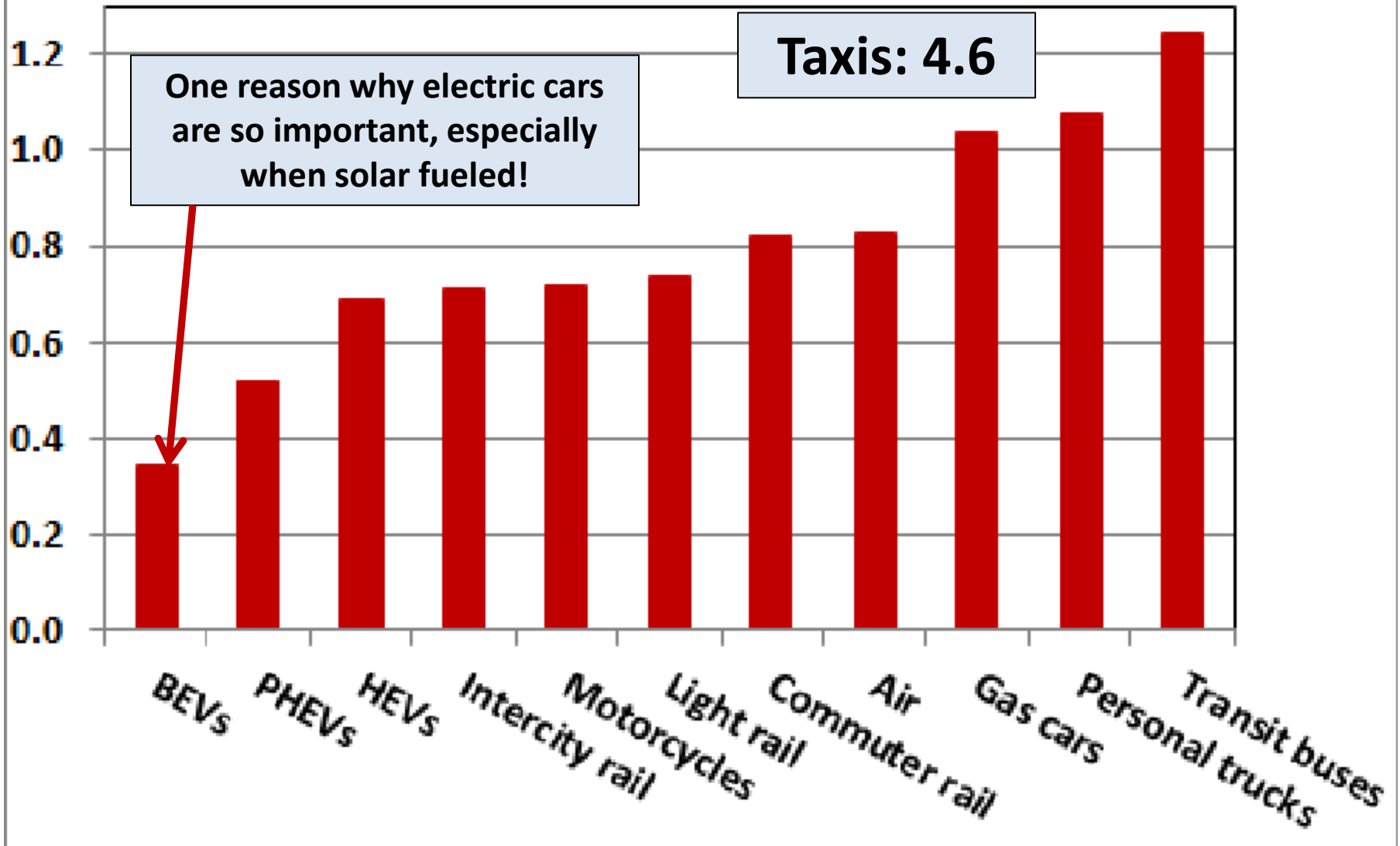
- Larger battery
- AWD
- Autopilot
- Glass roof
- Superchargers access

Establish a Grayson County electric-vehicles organization to encourage leasing BEVs or buying PHEVs.

Work with [Virginia Clean Cities](#) to get public charging stations in Grayson County.

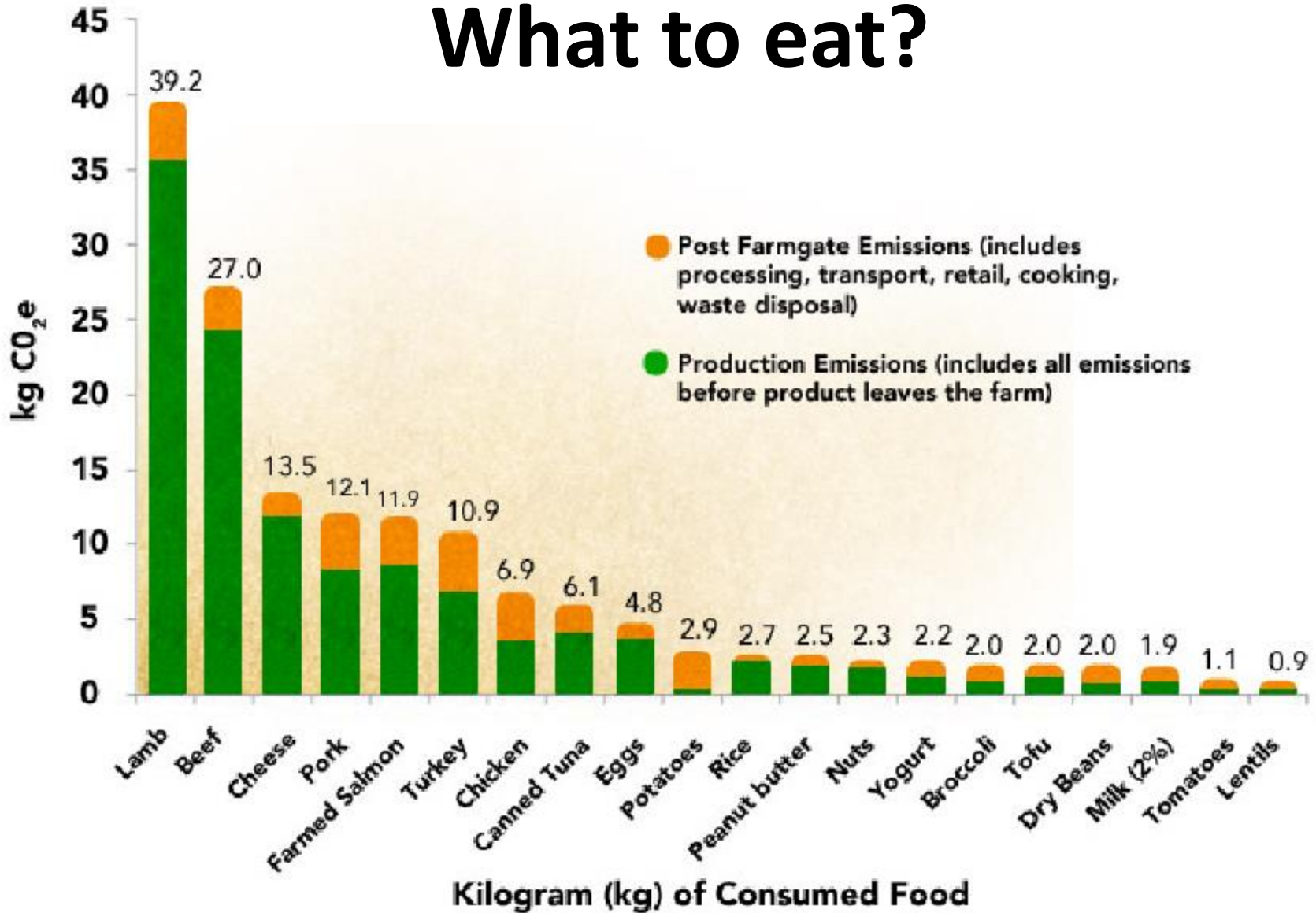
Passenger Travel Energy Use

kWh/passenger/mile



Agriculture causes ~9% of greenhouse gases.

What to eat?



UN Framework Convention on Climate Change

- Keep global temperature **below 2°C above pre-industrial value.**
- Pursue efforts to **limit the temperature rise below 1.5°C.**
- Nationally Determined Contributions to reduce carbon emissions to be reported regularly.
- Global analysis every 5 years of progress.
- 55 countries responsible for 55% of emissions have ratified the UNFCCC (Paris Agreement)(U.S. & China)

U.S. & China Cooperation on Climate Change

- Both ratified the Paris Agreement.
- **“China announced it was cancelling plans to build 103 new coal-fired plants. China is the world’s largest importer of coal, but even it is cutting back on fossil fuels and investing in renewables.”**
21 Jan 2017, The Roanoke Times
- Domestically transition to low-carbon economies.
- Pledge to increase use of renewable energy.
- Organized to increase cooperation to reduce climate change.

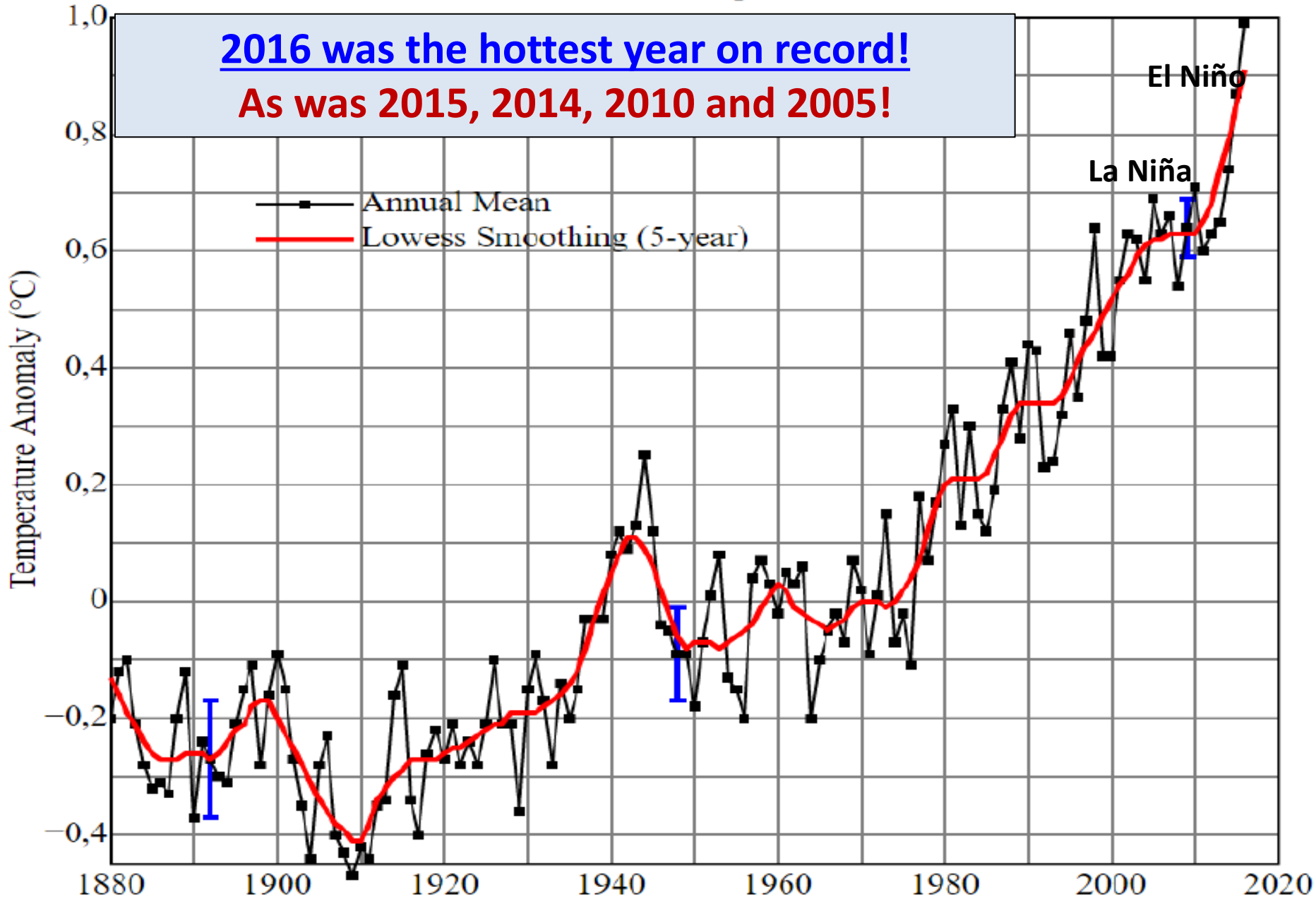
Global Warming may be the greatest challenge that humans have encountered in the last 10,000 years, and its effects will extend for many centuries!

Human-made Global Warming is challenging our *Homo-sapiens*-brain and society to **recognize the truth of climate science**, **make plans to mitigate Global Warming** and **put the plans into action**. We are having trouble doing all three.

The underlying problem is too many people wanting too many resources. Free global birth control is needed!

Global Land–Ocean Temperature Index

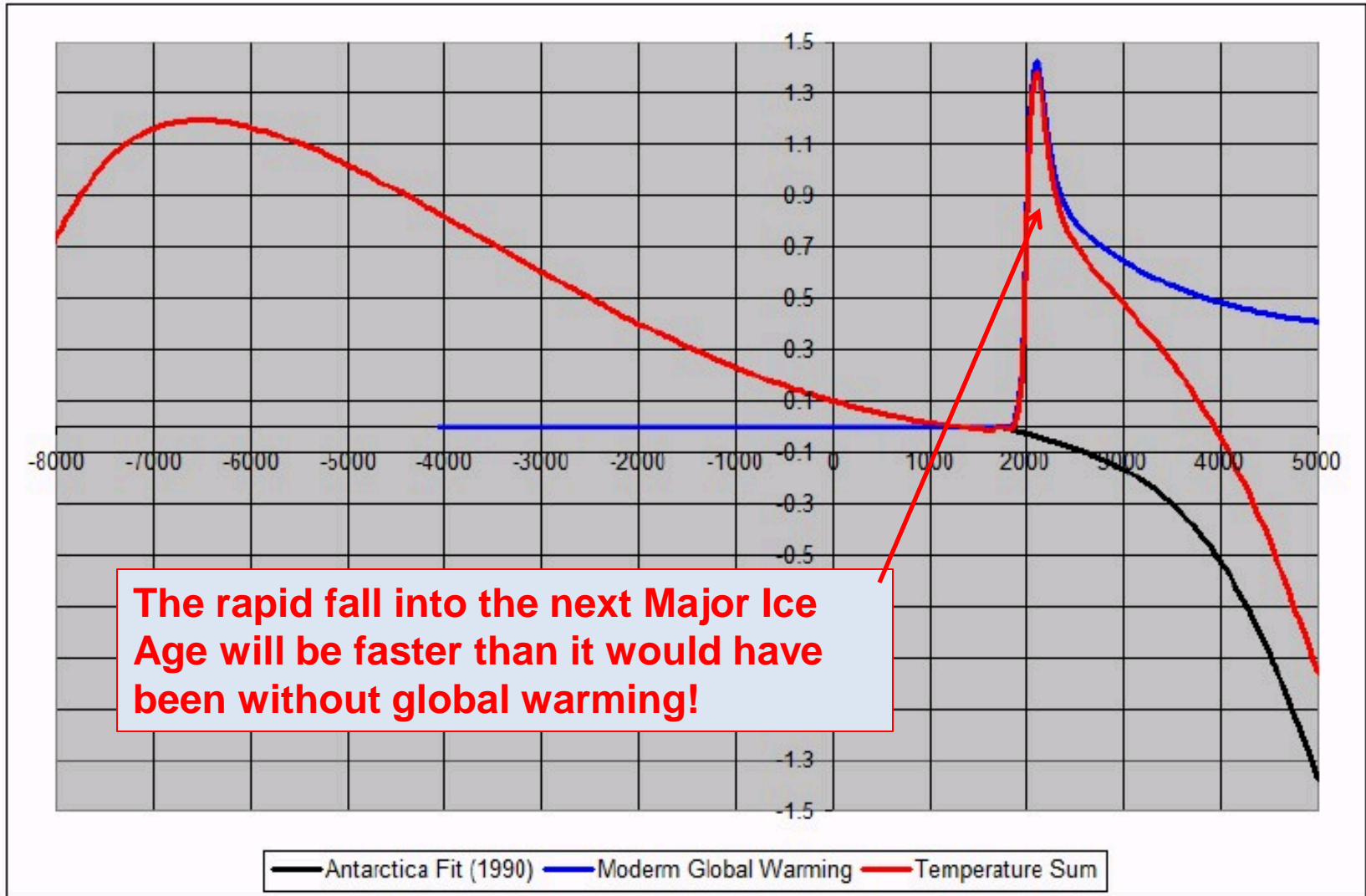
2016 was the hottest year on record!
As was 2015, 2014, 2010 and 2005!



Far Future

- Without global warming the global temperature would be dropping the Earth into the **next ~120,000-years ice age.**
- After fossil fuels are gone, the **temperature drop into the next major ice age will be faster** than it would have been without global warming.
- If a **nuclear war**, say between Pakistan and India, occurs or a large asteroid collides with the Earth, a “nuclear winter” may cause global cooling for a decade or longer and **may trigger the next ice age.**
- Should we be **storing the carbon dioxide due to burning fossil fuels** to release it later to slow down the entry into the next ice age?

Adding Modern Global Warming to Neolithic Global Warming and Fall into the Next Major Ice Age



Temperatures are normalized to 0 at year 1700.
Will probably be much more global warming than shown here.