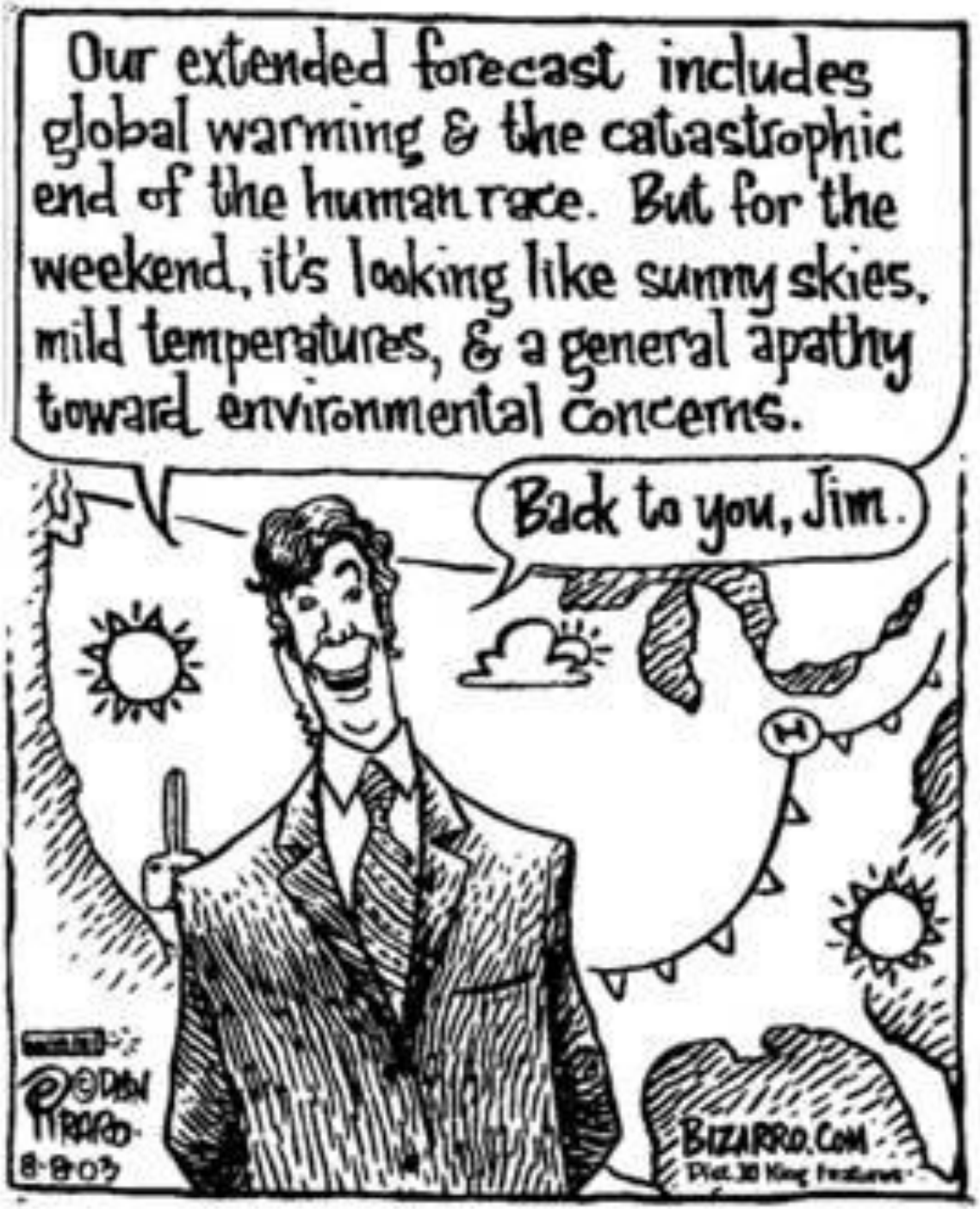
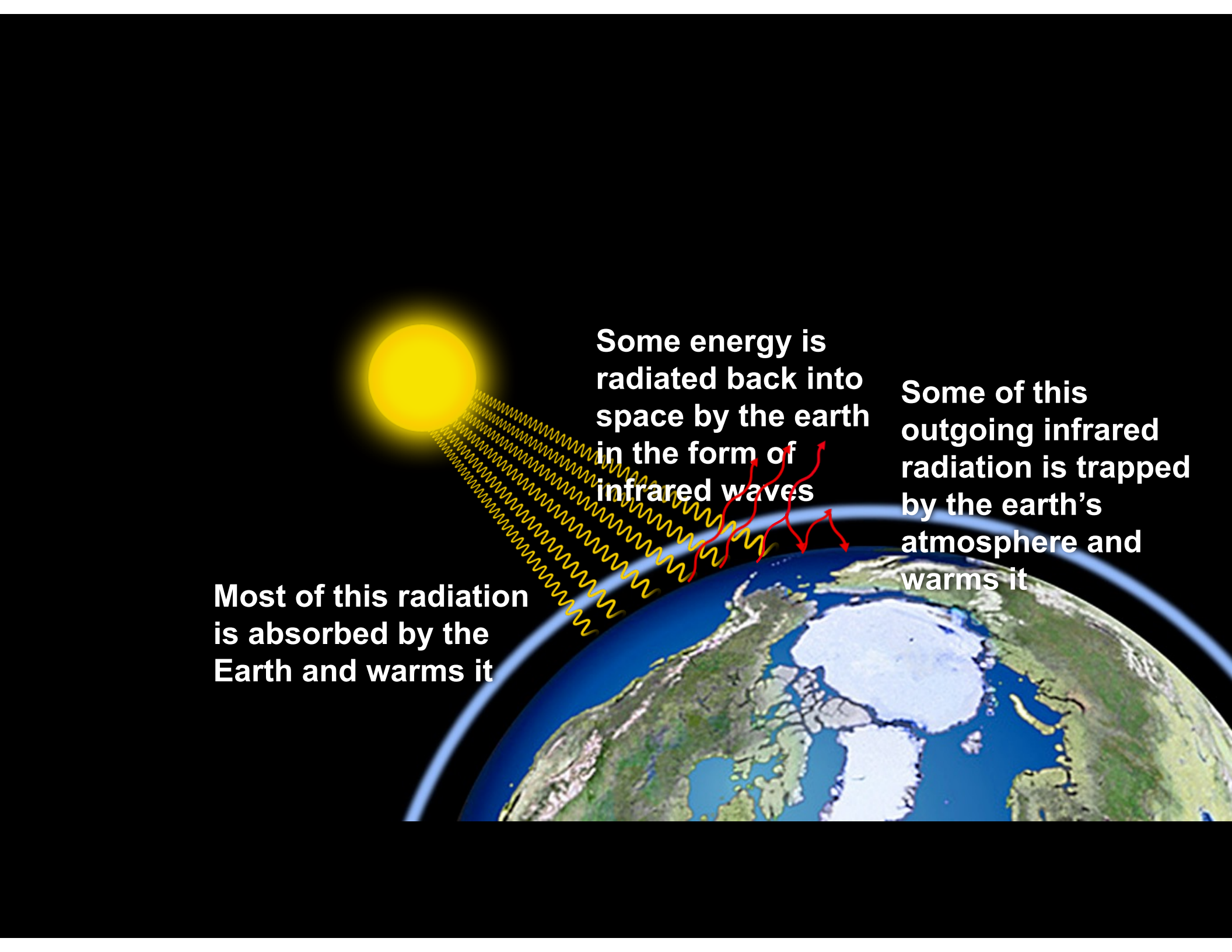
Human Population 2018

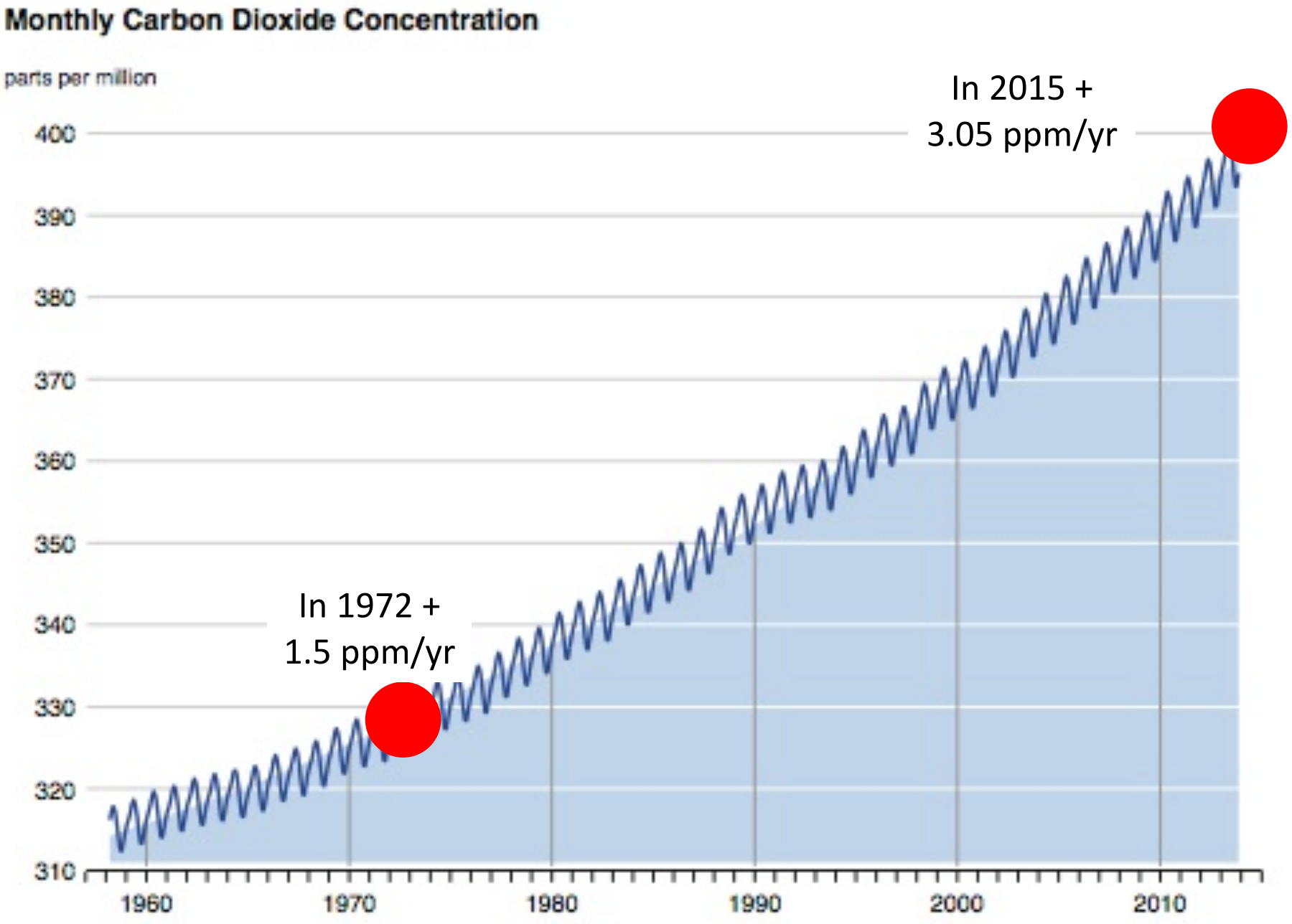
Lecture 9
Climate change

BIZARRO Dan Piraro

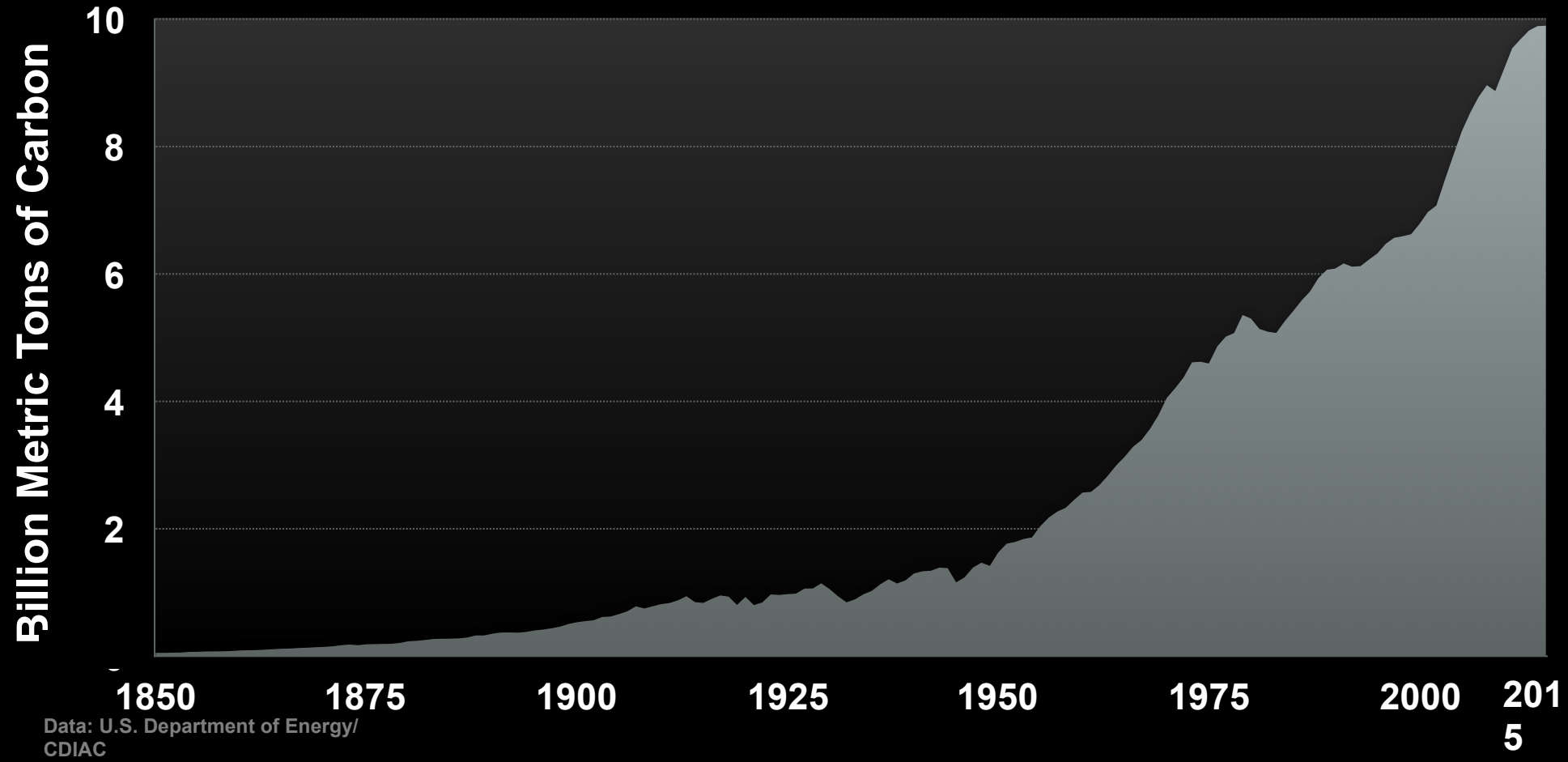



Some energy is radiated back into space by the earth in the form of infrared waves
Some of this outgoing infrared radiation is trapped by the earth's atmosphere and warms it
Most of this radiation is absorbed by the Earth and warms it

The Biggest Sources of Greenhouse Gases
THAWING PERMAFROST
COAL MINING
COAL PLANTS
AIR TRANSPORT
OIL PRODUCTION
INDUSTRIAL PROCESSES
CROP BURNING
FERTILIZATION
FOREST BURNING
INDUSTRIAL AGRICULTURE
LAND TRANSPORTATION
LANDFILLS
Melcher


Monthly Carbon Dioxide Concentration
parts per million
400
390
380
370
360
350
340
330
320
310
1960
1970
1980
1990
2000
2010
In 2015 +
3.05 ppm/yr
In 1972 +
1.5 ppm/yr

Global Carbon Emissions from Fossil Fuels



Data: U.S. Department of Energy/ CDIAC

The energy trapped by man-made global warming pollution is now "… equivalent to exploding

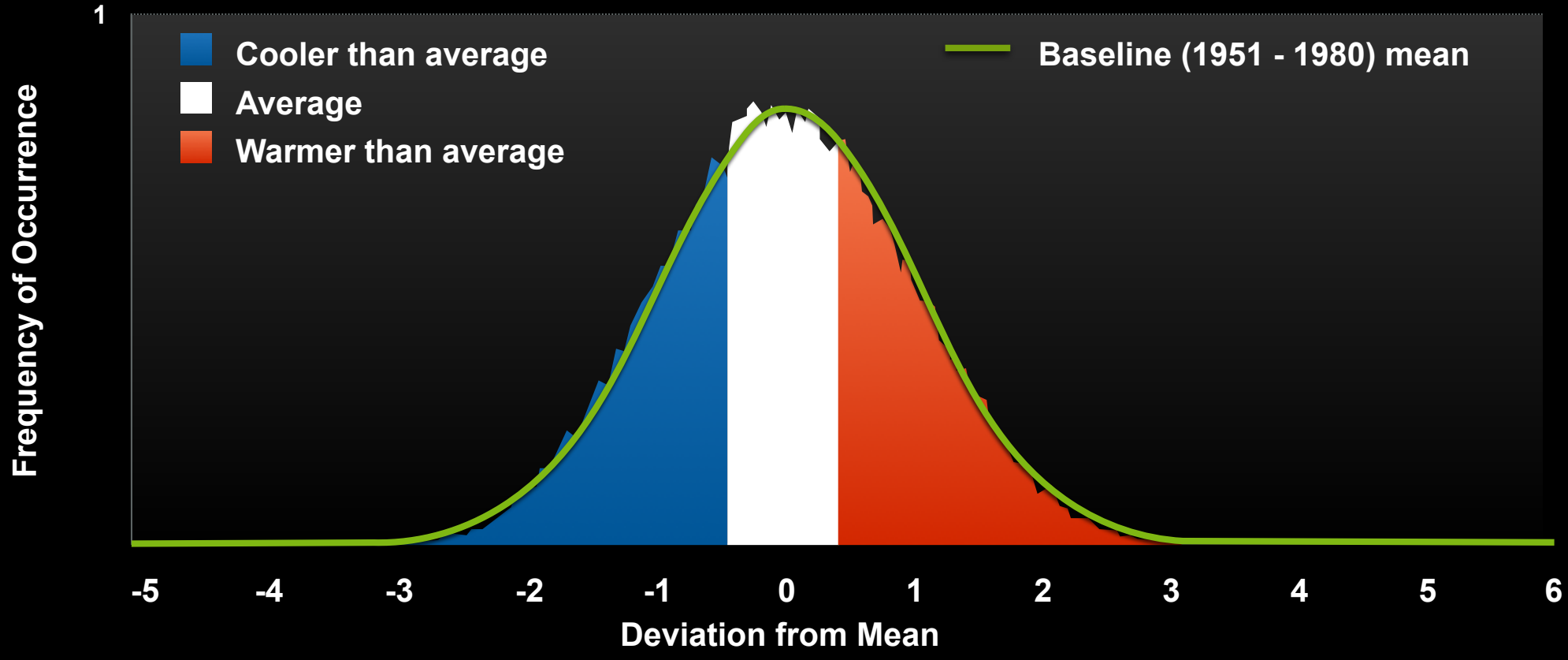
400,000

Hiroshima atomic bombs per day 365 days per year."

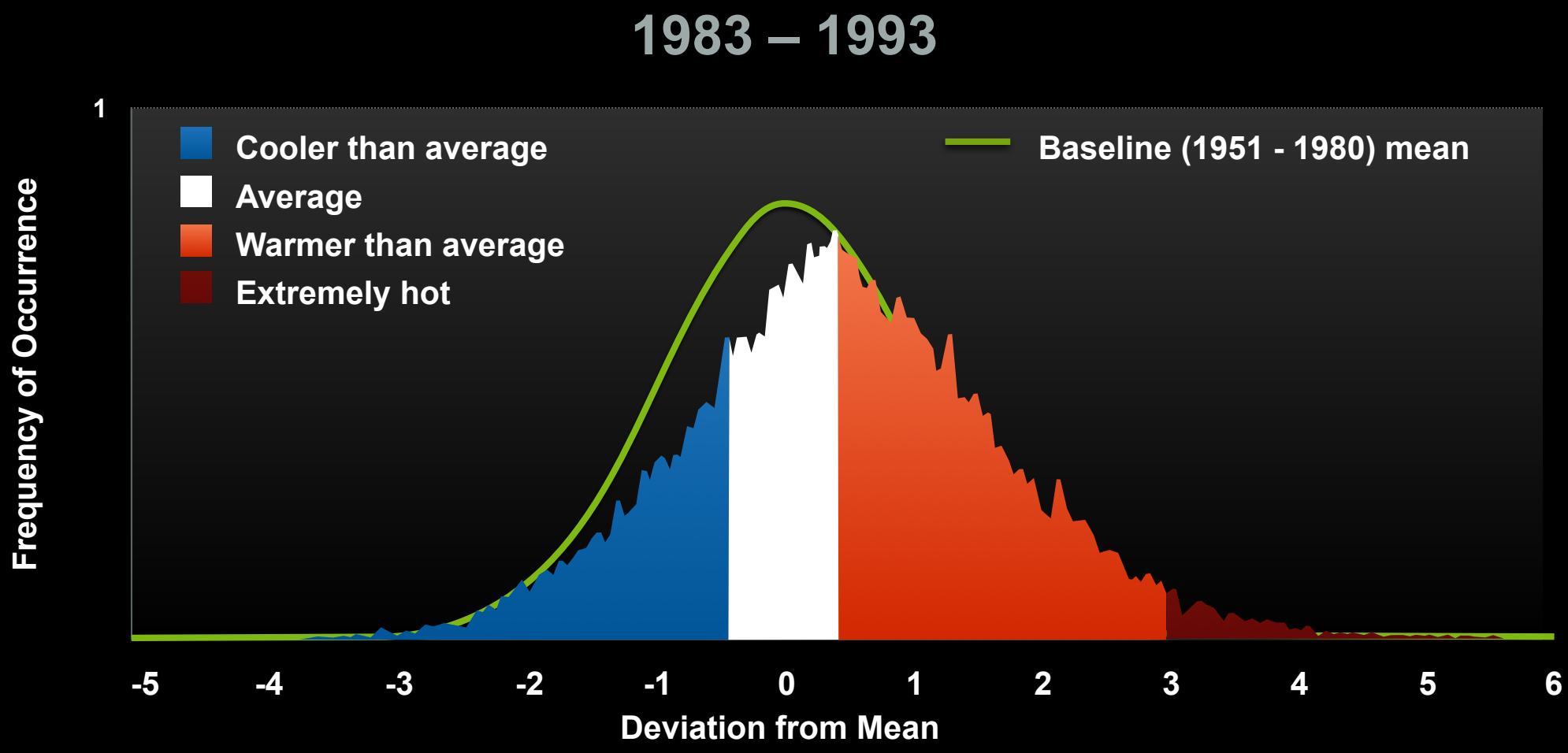
James Hansen
Former Director, NASA Goddard Institute for Space Studies

Summer Temperatures Have Shifted

1951 – 1980

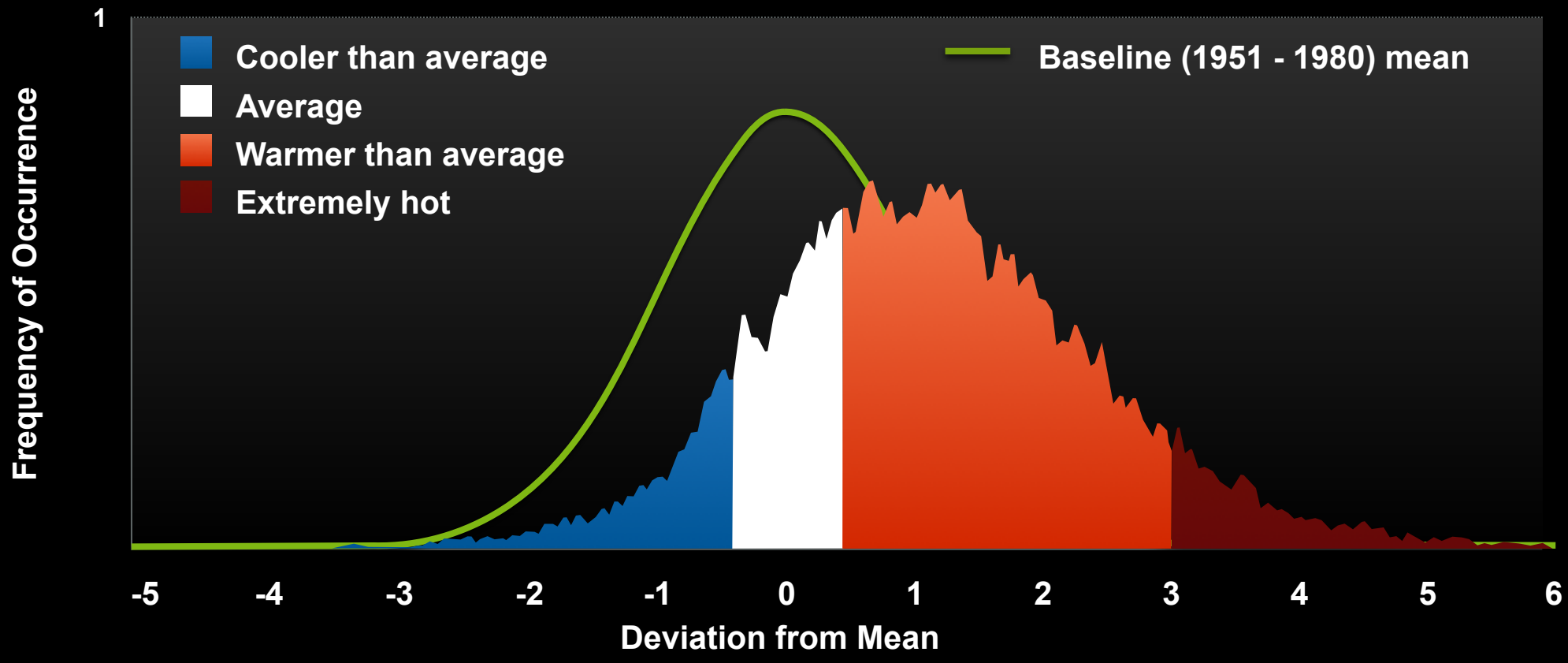


Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016



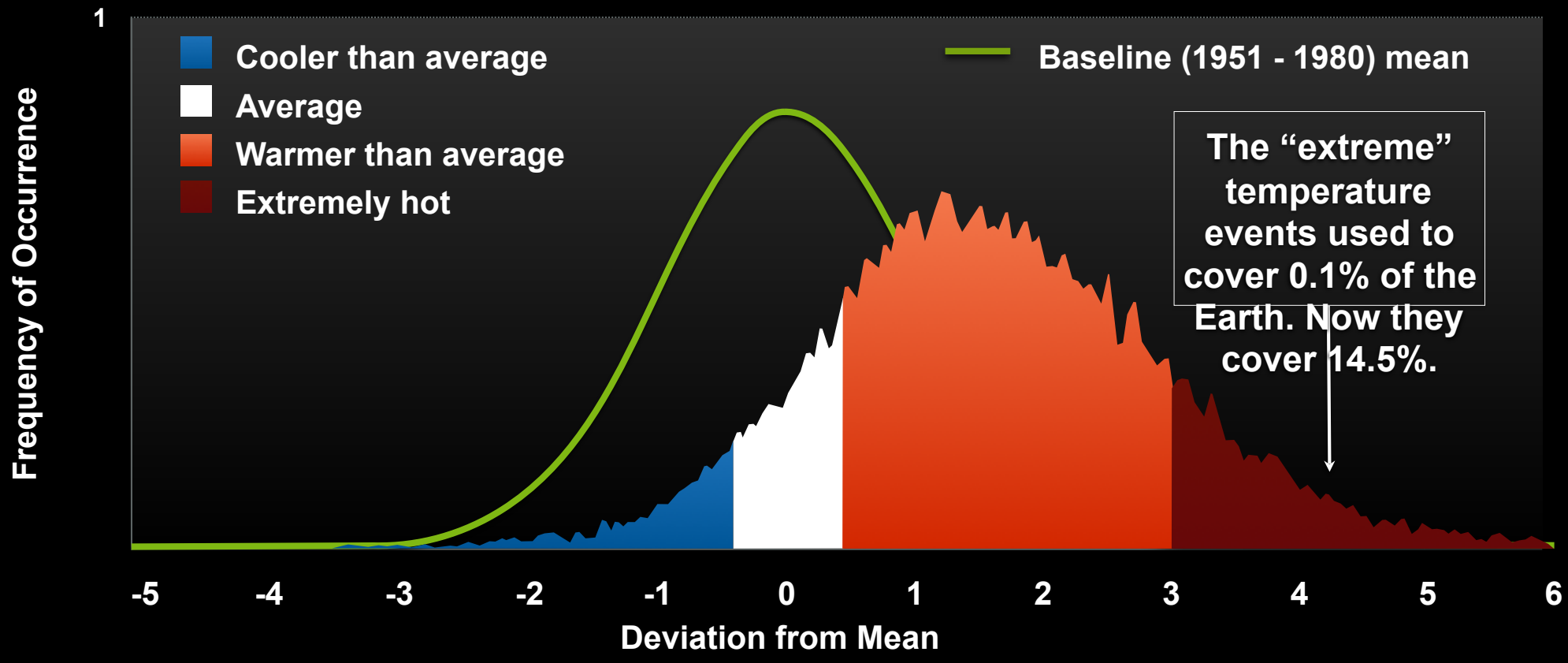
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

1994 – 2004



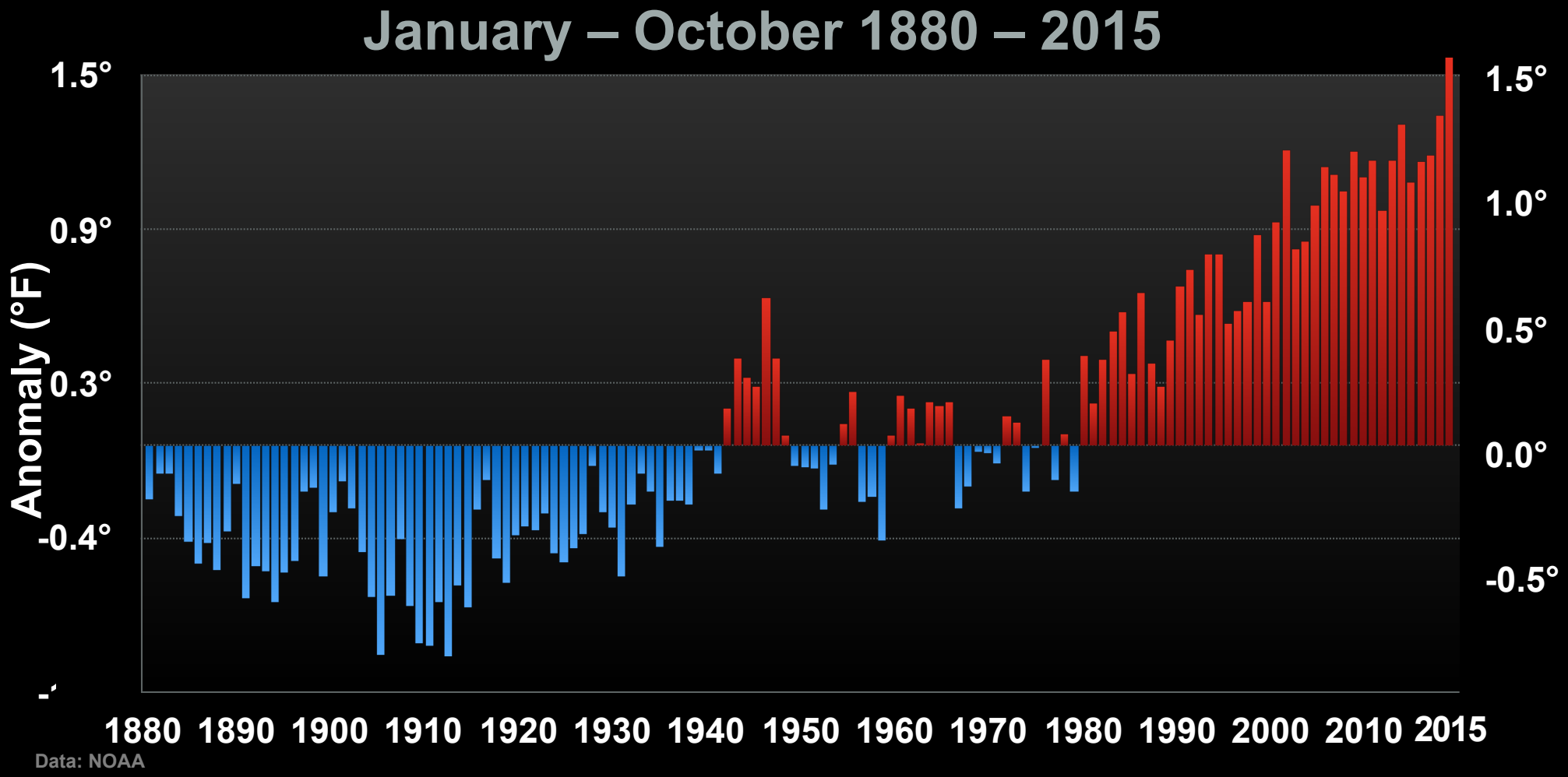
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

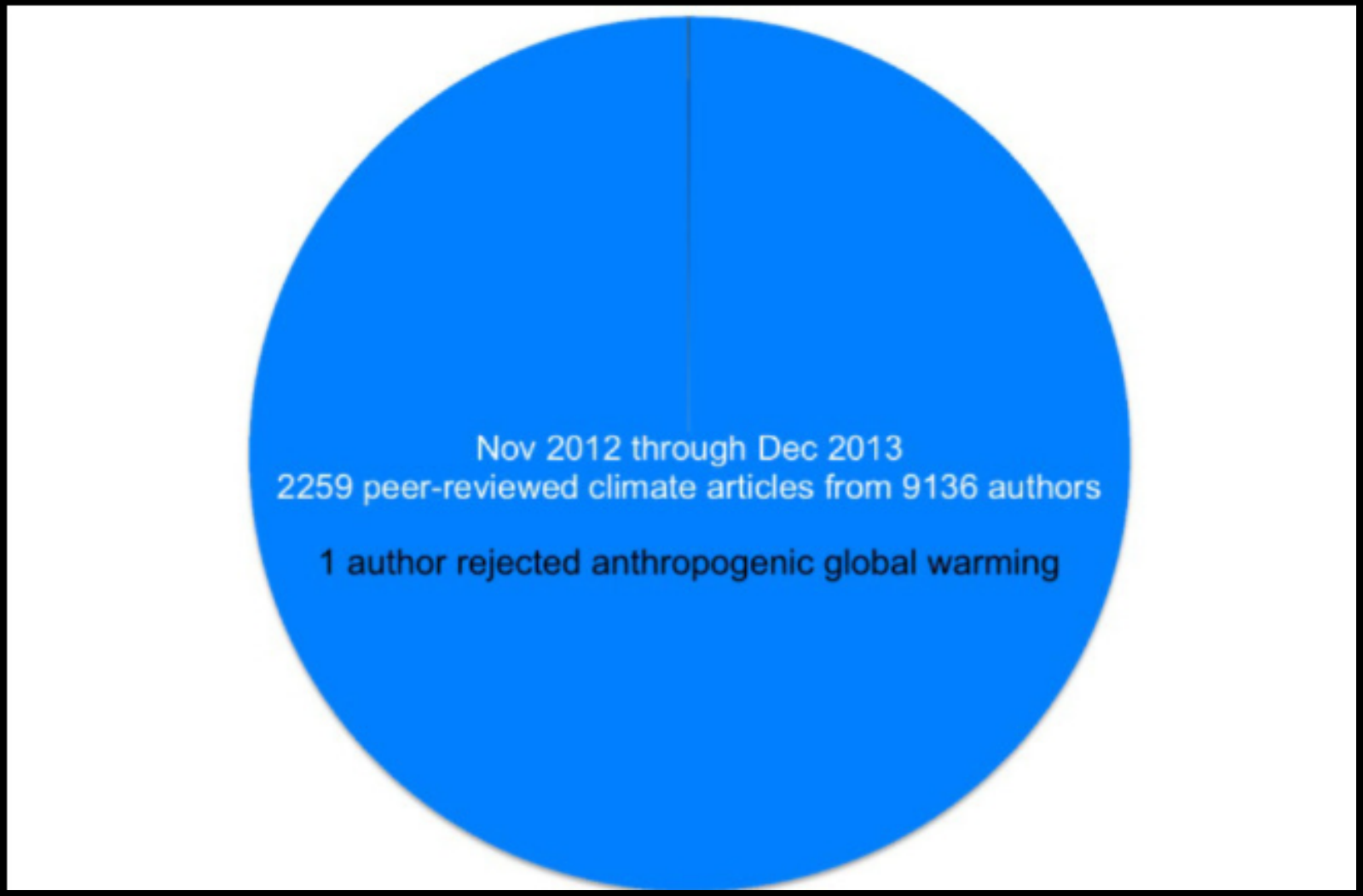
2005 – 2015



Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

Global Surface Temperature – Departure from Average




Nov 2012 through Dec 2013
2259 peer-reviewed climate articles from 9136 authors
1 author rejected anthropogenic global warming

The Hottest Year Ever Measured…

16 of the 17 Hottest Years on Record Have Occurred Since the Year 2001

2016 2015 2014 2010 2005 2007 2013 2009

2012 2006 1998 2002 2003 2011 2004 2001

Data: NASA/GISS

The heat index in Bandar Mahshahr, Iran reached

165° F

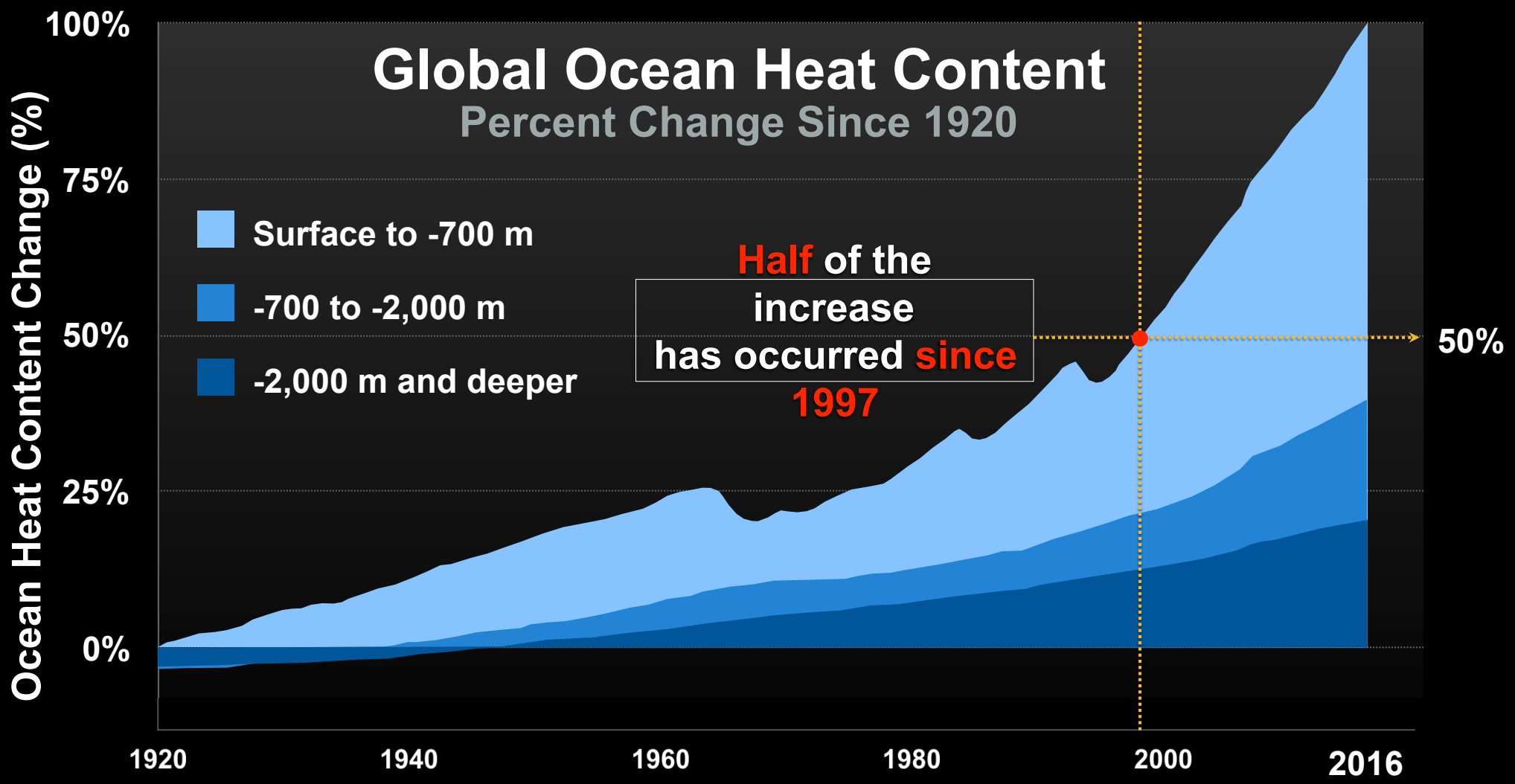
(74° C) on July 31, 2015

The tiny nation of Kiribati will soon be underwater

news.vice.com/article/doomed-by-climate-change-kiribati-wants-migration-with-dignity

© 2015 AP Photo/Ajit Solanki

93% of the extra **Heat** trapped by manmade global warming pollution goes into the **Ocean**



Adapted by permission from Macmillan Publishers Ltd: Nature Climate Change, *Industrial-era global ocean heat uptake doubles in recent decades*, Figure 4, copyright 2016.

So the downpours get bigger

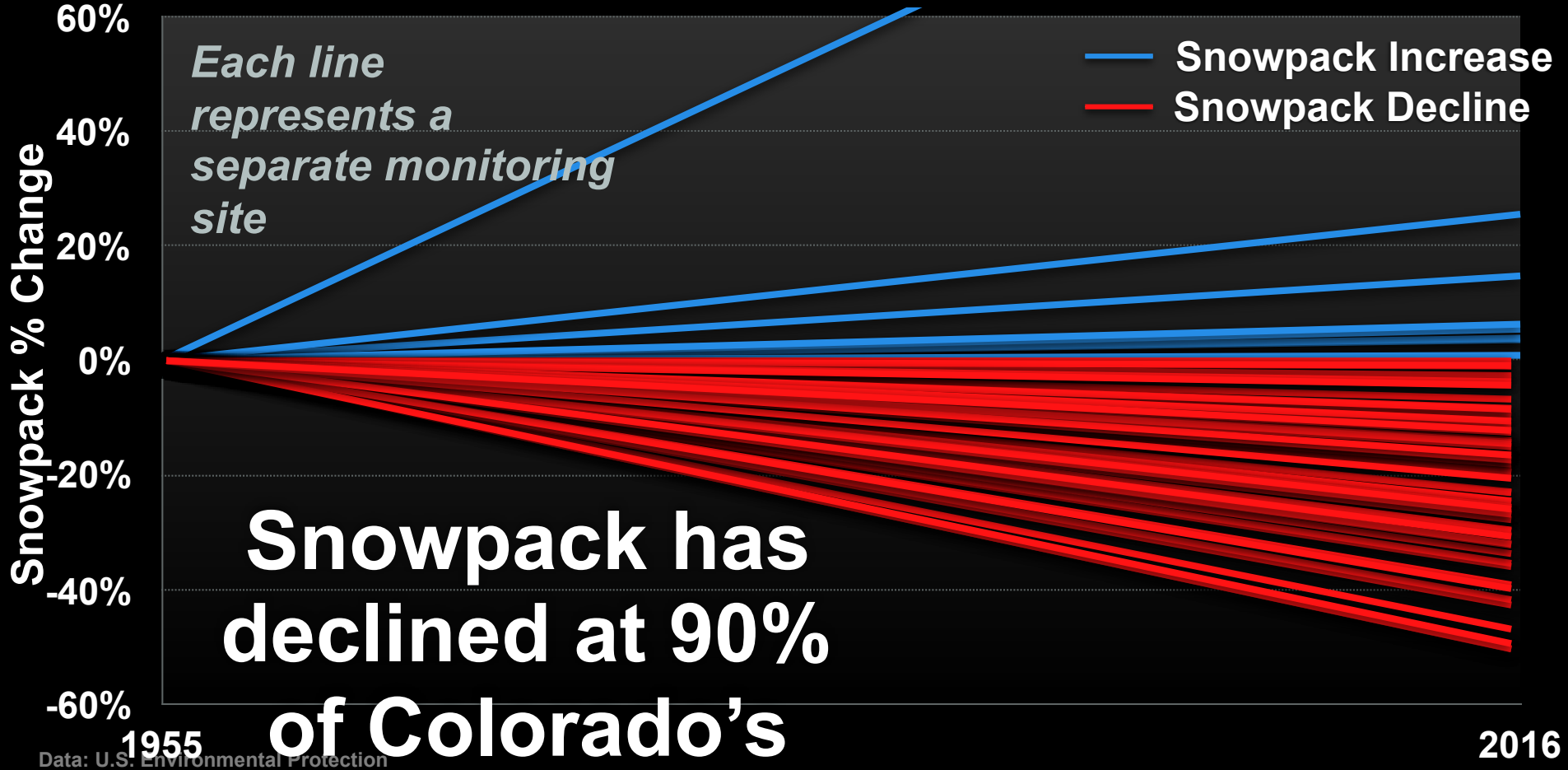
© 2010 Sean R. Heavey

Phoenix, Arizona
July 18, 2016
© 2016 Chopperguy Photographer Jerry Ferguson and Pilot Andrew Park

© 2016 AP Photo/Sakchai Lalit

Maharashtra State, India
May 10, 2016
Over 400 farmers in Maharashtra committed suicide in the first four months of 2016, due mainly to pressures from the ongoing regional drought.
© 2016 AP Photo/Manish Swarup

Trends in Colorado April Snowpack, 1955 – 2016

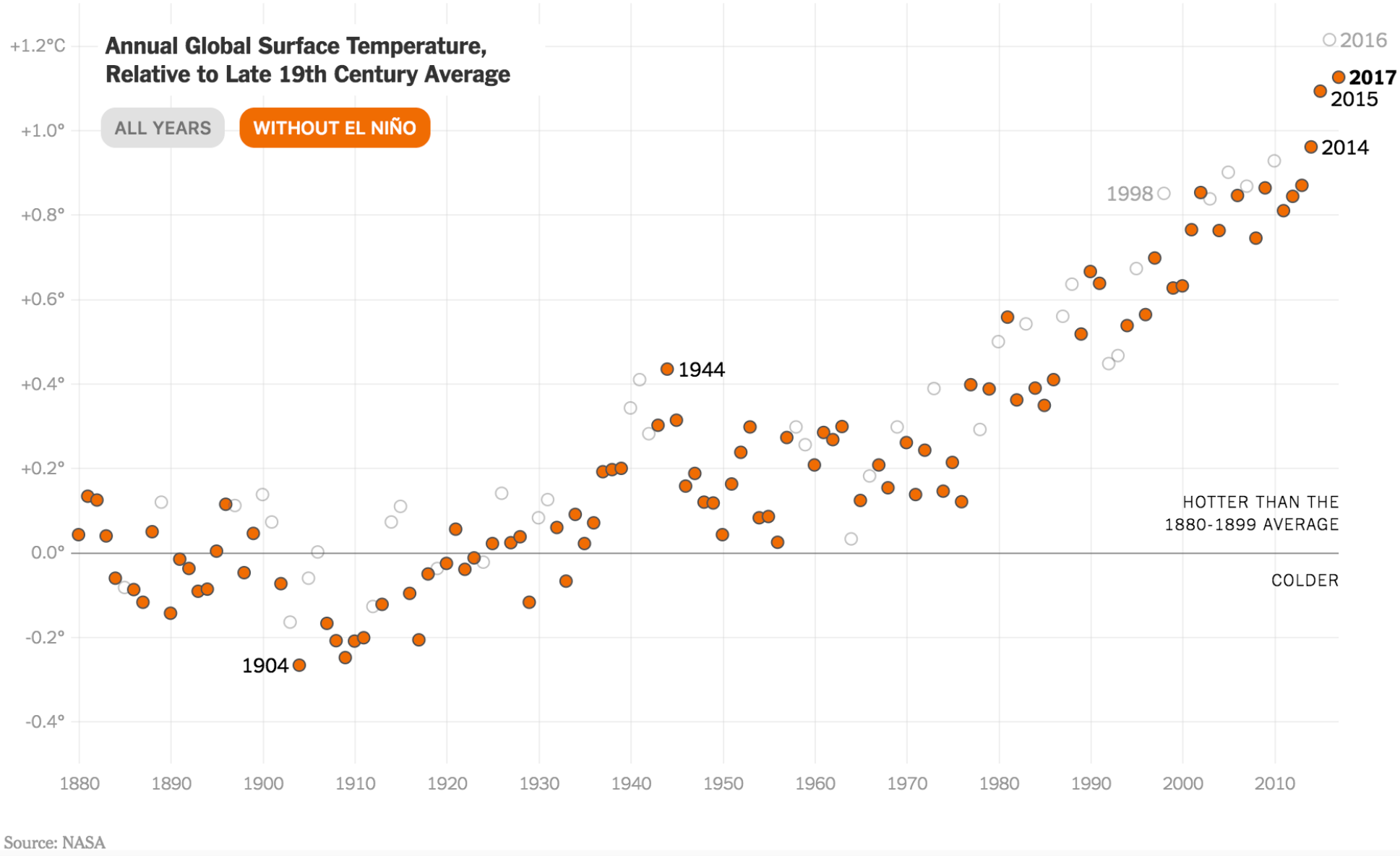


Data: U.S. Environmental Protection Agency

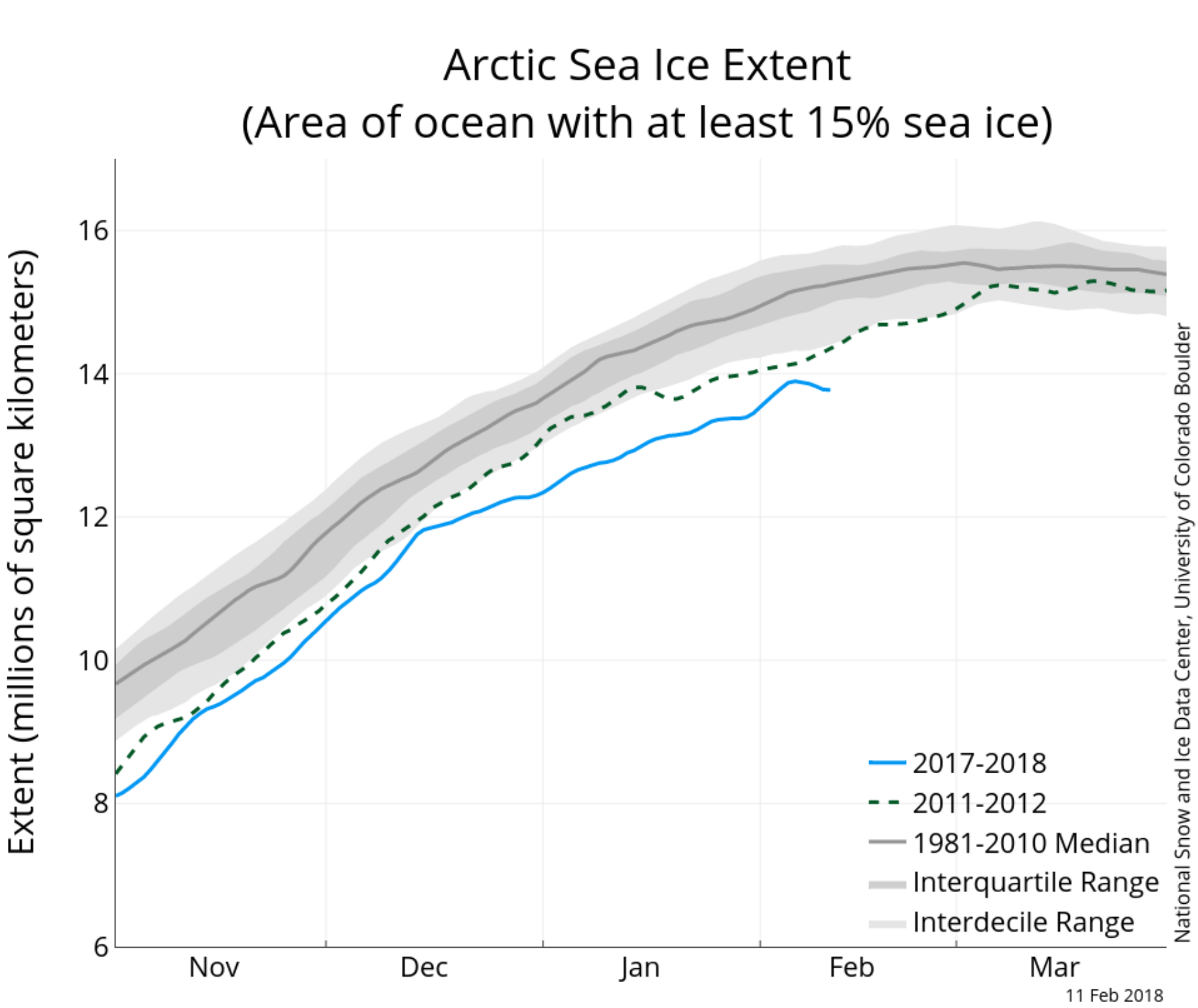
Pine-borer beetle damage

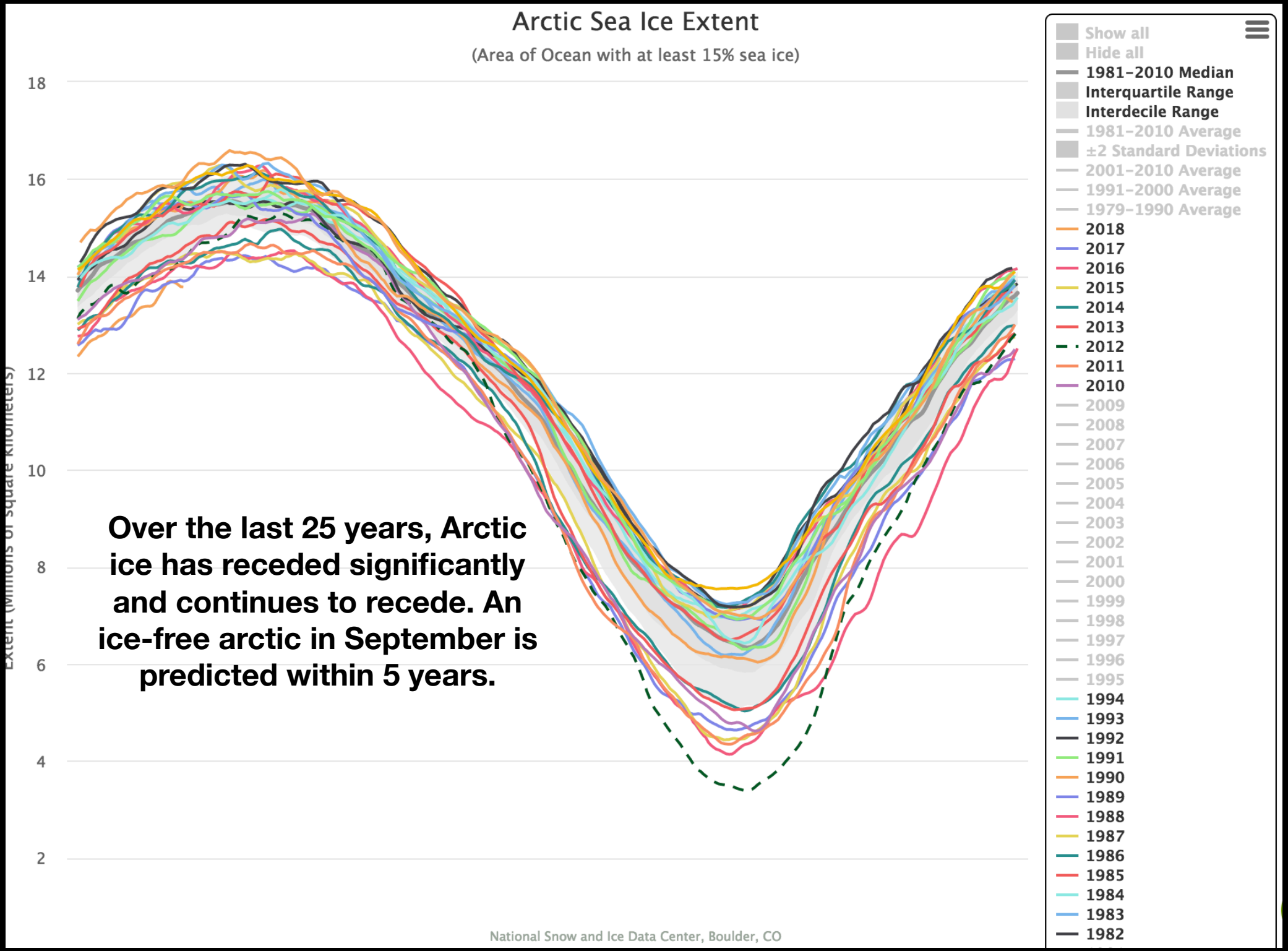
© 2008 AP Photo/Colorado State Forest Service, Jen Chase

Near Granby, Colorado


Annual Global Surface Temperature,
Relative to Late 19th Century Average
ALL YEARS
WITHOUT EL NIÑO
+1.2°C
+1.0°
+0.8°
+0.6°
+0.4°
+0.2°
0.0°
-0.2°
-0.4°
2016
2017
2015
2014
1998
1944
1904
HOTTER THAN THE
1880-1899 AVERAGE
COLDER
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Source: NASA


Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
16
14
12
10
8
6
Nov
Dec
Jan
Feb
Mar
2017-2018
2011-2012
1981-2010 Median
Interquartile Range
Interdecile Range
National Snow and Ice Data Center, University of Colorado Boulder
11 Feb 2018


Arctic Sea Ice Extent
(Area of Ocean with at least 15% sea ice)
Extent (Millions of Square Kilometers)
18
16
14
12
10
8
6
4
2
Over the last 25 years, Arctic ice has receded significantly and continues to recede. An ice-free arctic in September is predicted within 5 years.
National Snow and Ice Data Center, Boulder, CO
Show all
Hide all
1981–2010 Median
Interquartile Range
Interdecile Range
1981–2010 Average
±2 Standard Deviations
2001–2010 Average
1991–2000 Average
1979–1990 Average
2018
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
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2002
2001
2000
1999
1998
1997
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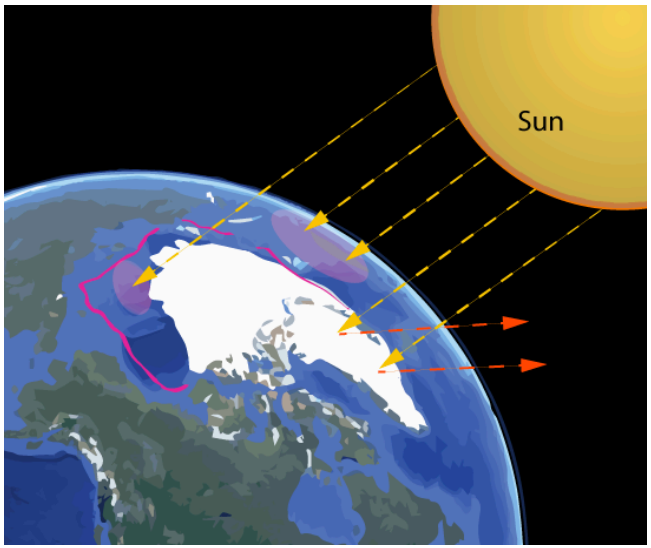
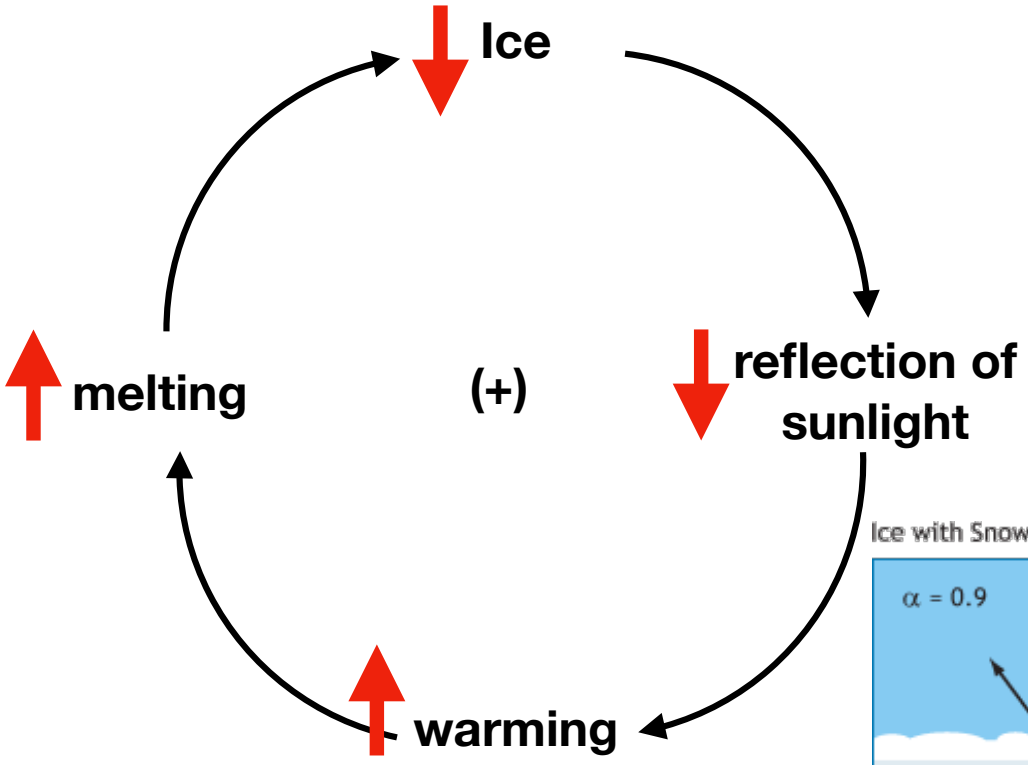
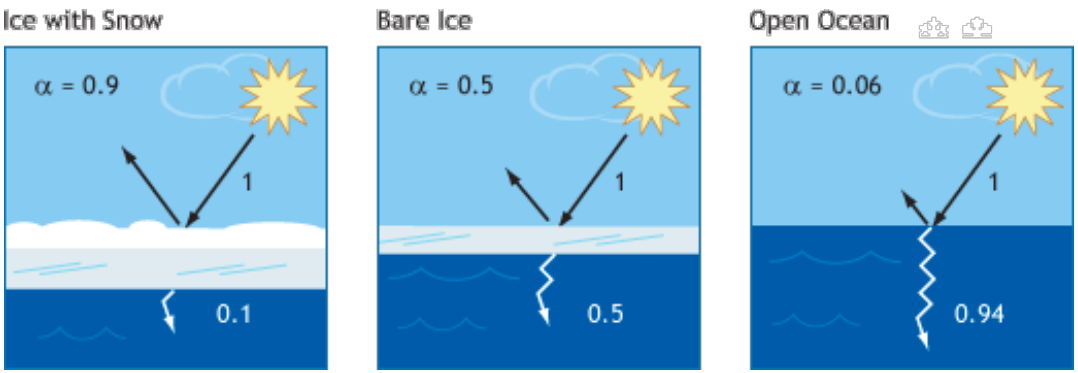
1984
1983
1982

Positive feedback effects of arctic ice decline.

Ice albedo effect. Ice reflects more light than the open ocean.

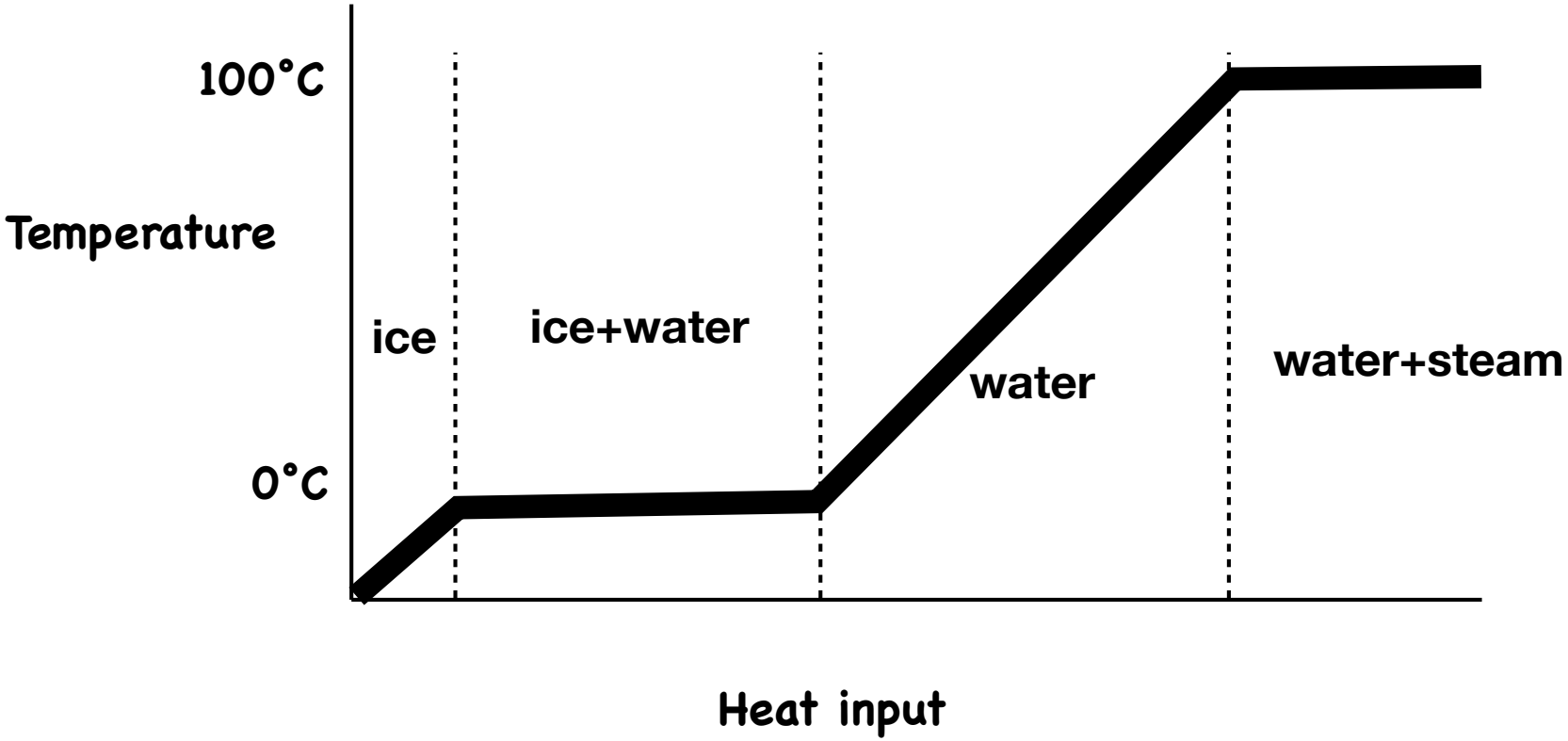






Positive feedback effects of arctic ice decline.

Heat of fusion of water is 79.72 cal/g. Heat capacity of liquid water is 1.0 cal/deg/g. Therefore the amount of heat that it took to melt one g of ice will heat the meltwater from 0°C to 80°C.



Positive feedback effects of arctic ice decline.

Methane (CH_4) is stored in permafrost under the ocean as caged gas, or clathrate. As the ocean warms, the clathrates melt, releasing the CH_4 gas, which bubbles up to the surface. CH_4 has a much higher (150x) greenhouse gas potential than CO_2, and has a half-life in the atmosphere of decades.

The East Siberian Sea sediments contain 100 to 1000x more carbon than all of the methane currently in the atmosphere.

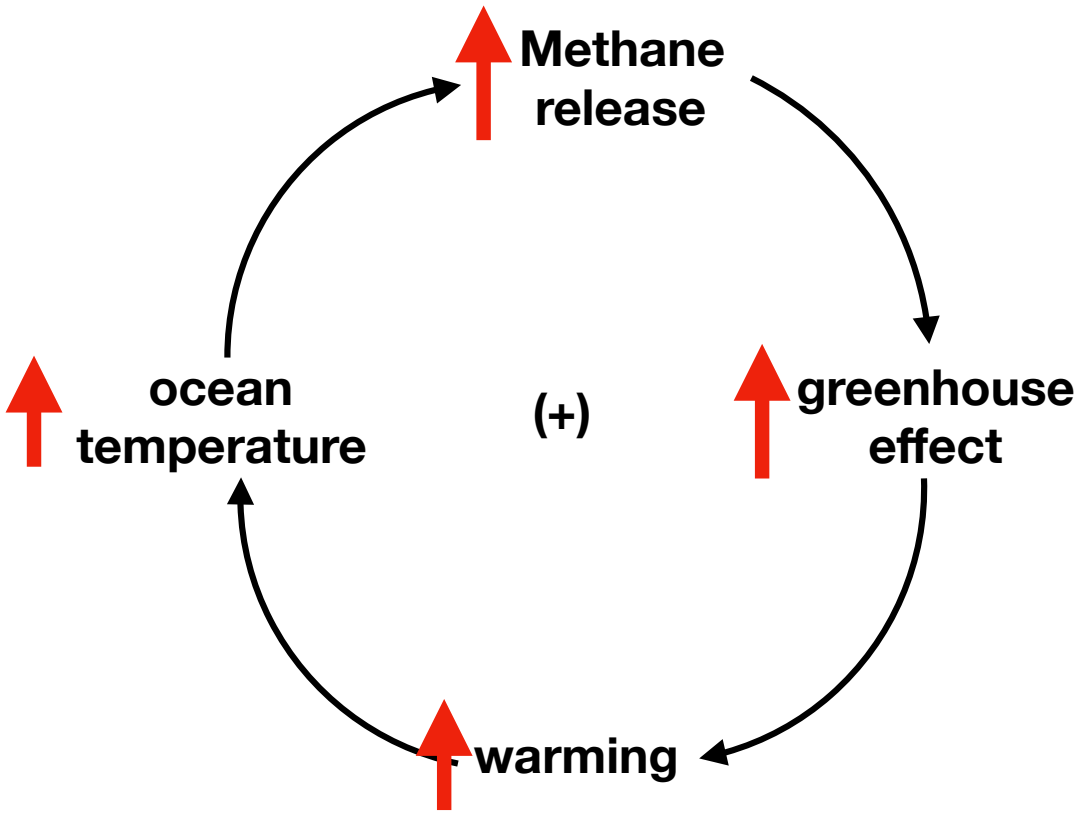
https://youtu.be/FPdc75epOEw

Shakhova, N., Semiletov, I., Salyuk, A., Yusupov, V., Kosmach, D., & Gustafsson, Ö. (2010). Extensive methane venting to the atmosphere from sediments of the East Siberian Arctic Shelf. *Science*, *327*(5970), 1246-1250.

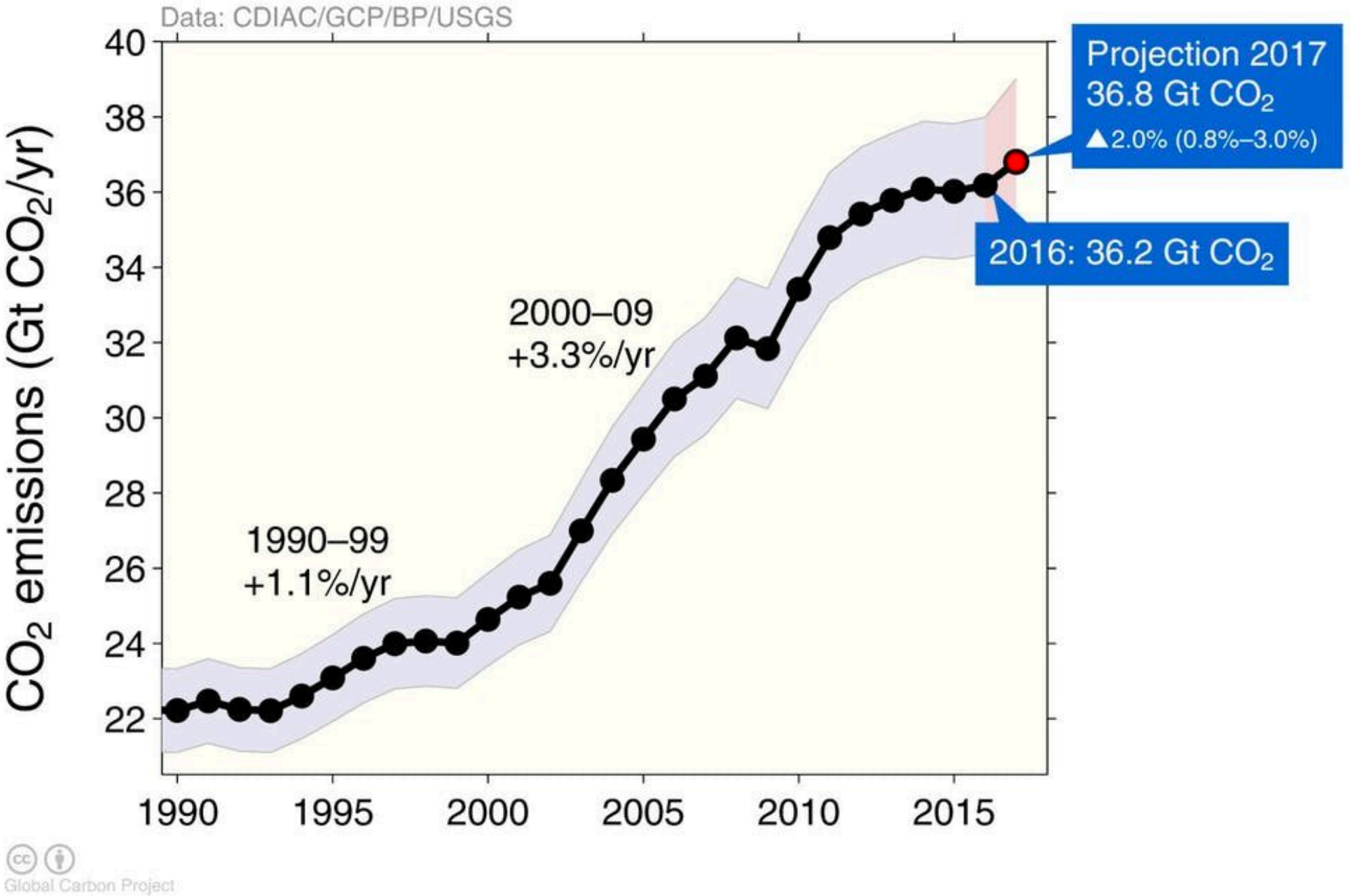
rctic Methane Emergency: Methane released by the Gigaton!

https://youtu.be/FPdc75epOEw?t=42m46s

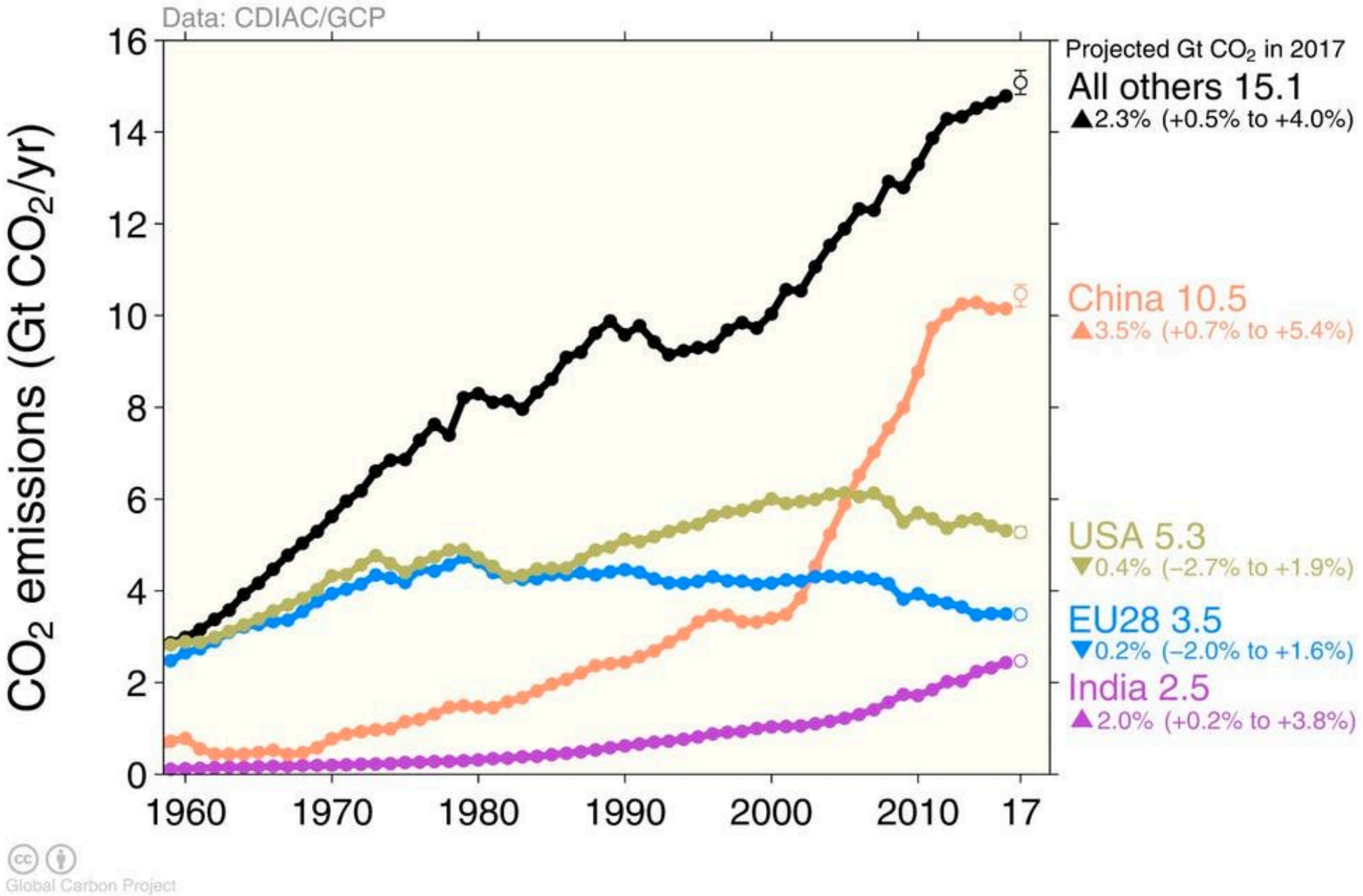
Positive feedback effects of arctic ice decline.



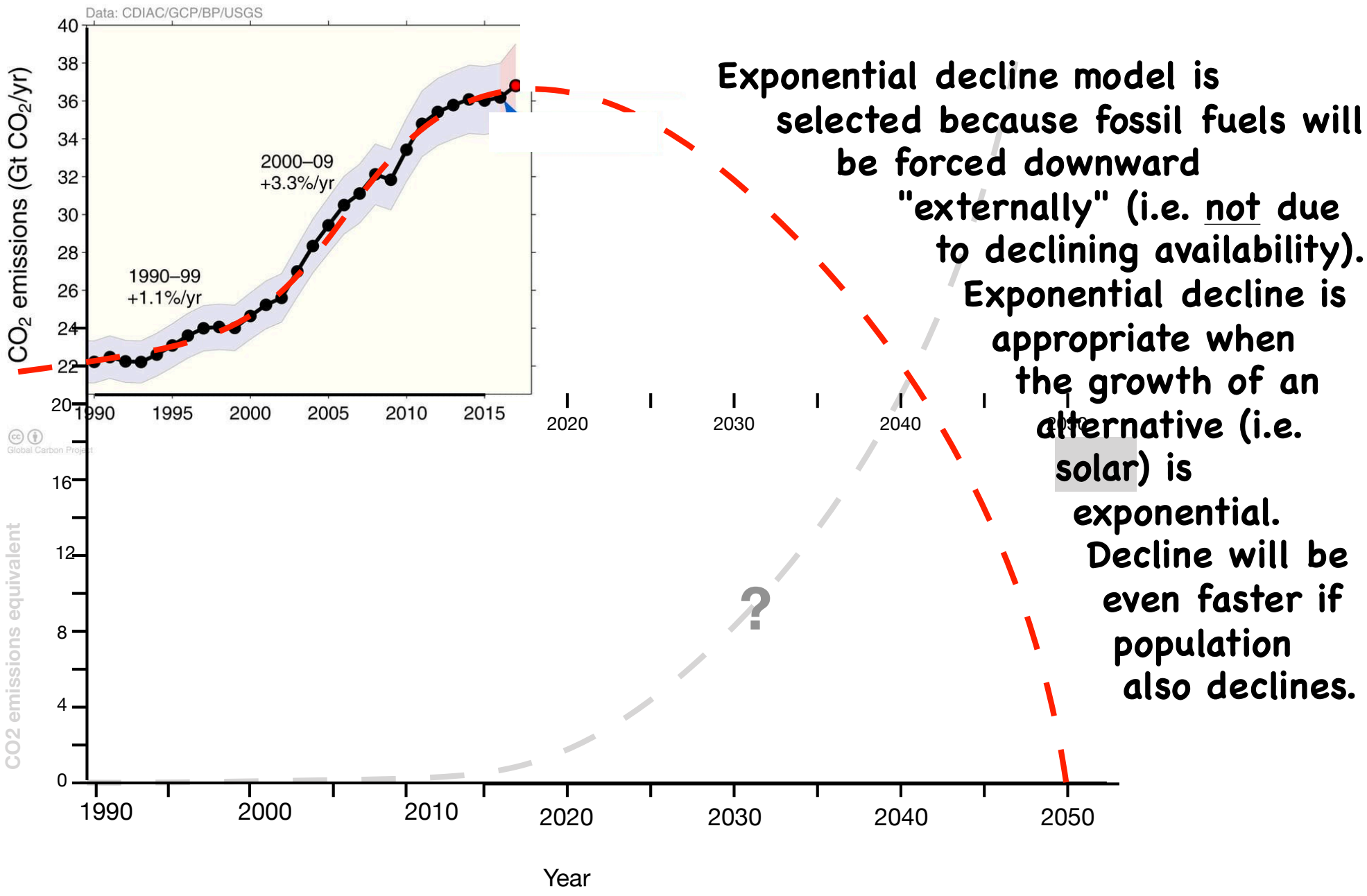
Isa there any good news? Yes!



https://phys.org/news/2017-11-fossil-fuel-emissions-high-unexpected.html

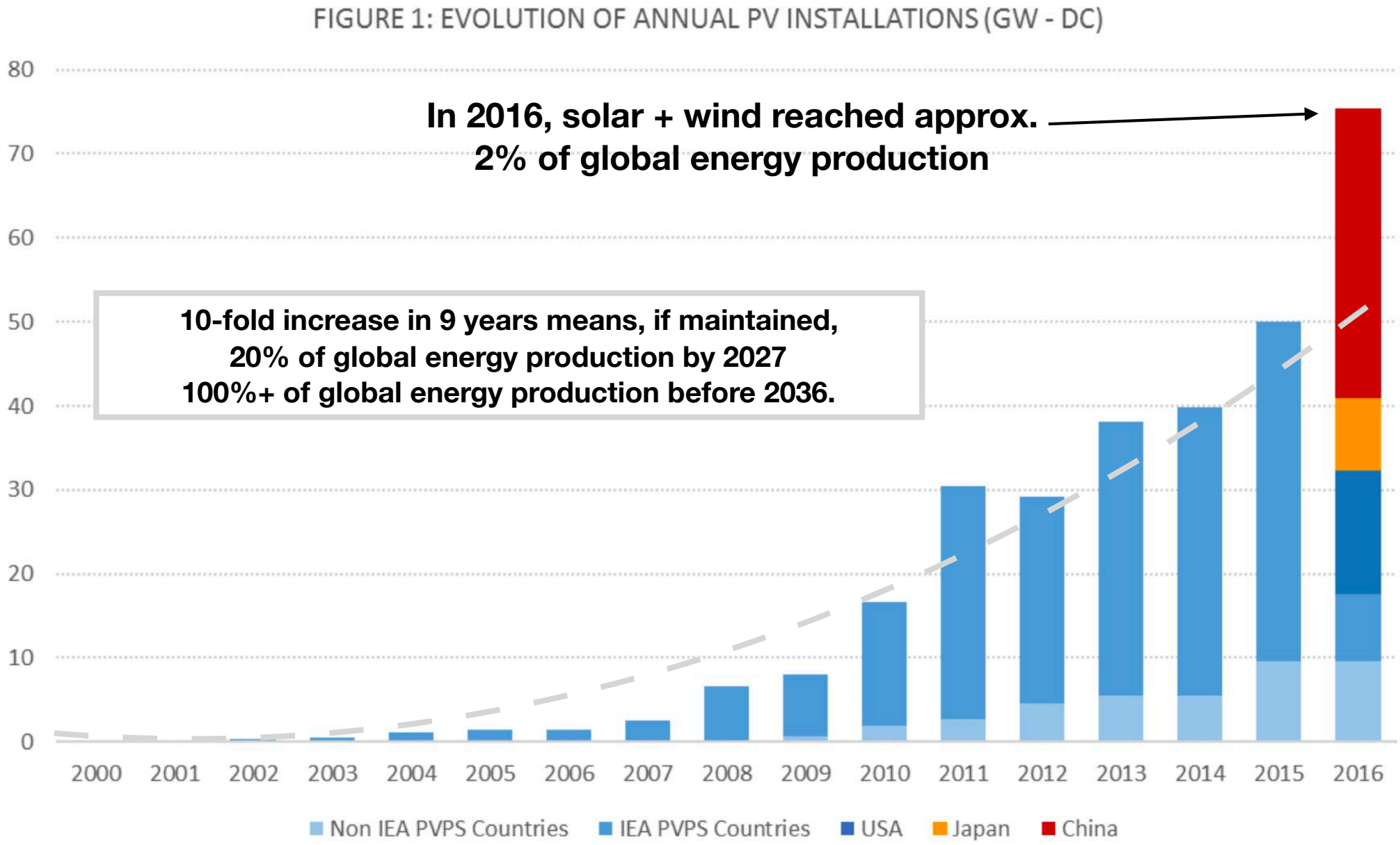

Data: CDIAC/GCP
CO_2 emissions (Gt CO_2/yr)
16
14
12
10
8
6
4
2
0
1960
1970
1980
1990
2000
2010
17
Projected Gt CO_2 in 2017
All others 15.1
▲2.3% (+0.5% to +4.0%)
China 10.5
▲3.5% (+0.7% to +5.4%)
USA 5.3
▼0.4% (–2.7% to +1.9%)
EU28 3.5
▼0.2% (–2.0% to +1.6%)
India 2.5
▲2.0% (+0.2% to +3.8%)
Global Carbon Project

Hypothetical model for emissions goal of zero in 2050



Exponential decline model is selected because fossil fuels will be forced downward "externally" (i.e. not due to declining availability). Exponential decline is appropriate when the growth of an alternative (i.e. solar) is exponential. Decline will be even faster if population also declines.

The rise of renewables!



https://www.greentechmedia.com/articles/read/iea-global-installed-pv-capacity-leaps-to-303-gw#gs.oEbQcfY

“Wind turbine service technician” is forecast to be the fastest-growing job category in the U.S. through 2024

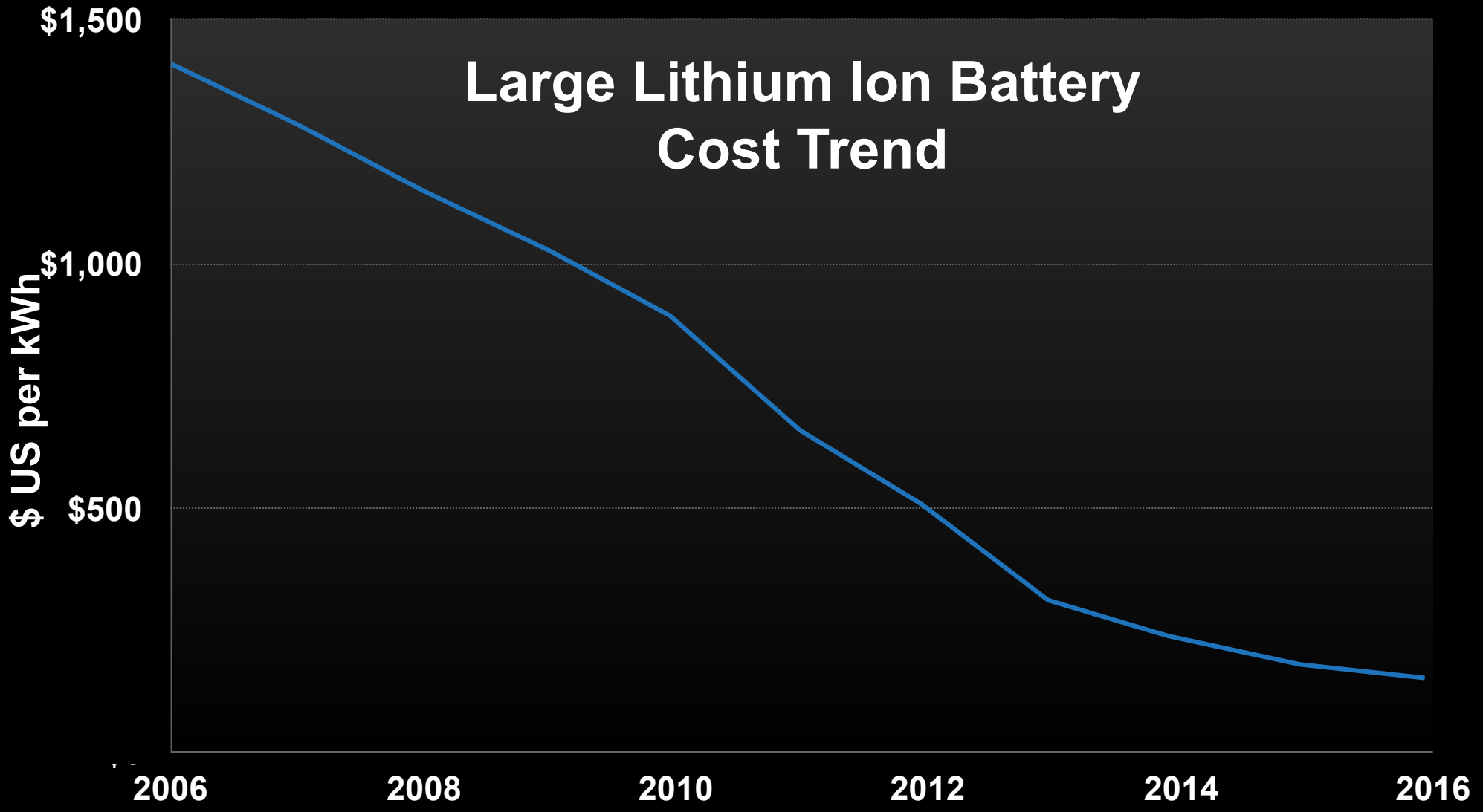
Colorado Highlands Wind Farm, Fleming, Colorado

Photo: © 2016 Matthew Staver/Bloomberg via Getty Images
Data: U.S. Bureau of Labor Statistics via Bloomberg

Some utilities in Texas are offering
free electricity at night
because wind energy is so abundant.

The U.S. now has 75 gigawatts of wind power installed, enough to power 20 million homes.
© 2014 Coty Giannelli
Akron Township, Michigan

Globally, wind could supply worldwide electricity consumption 40 times over



Source: Navigant and Bernstein estimates and analysis

Green Energy Progress

How Do Projections Compare With Reality?

2002 Projection

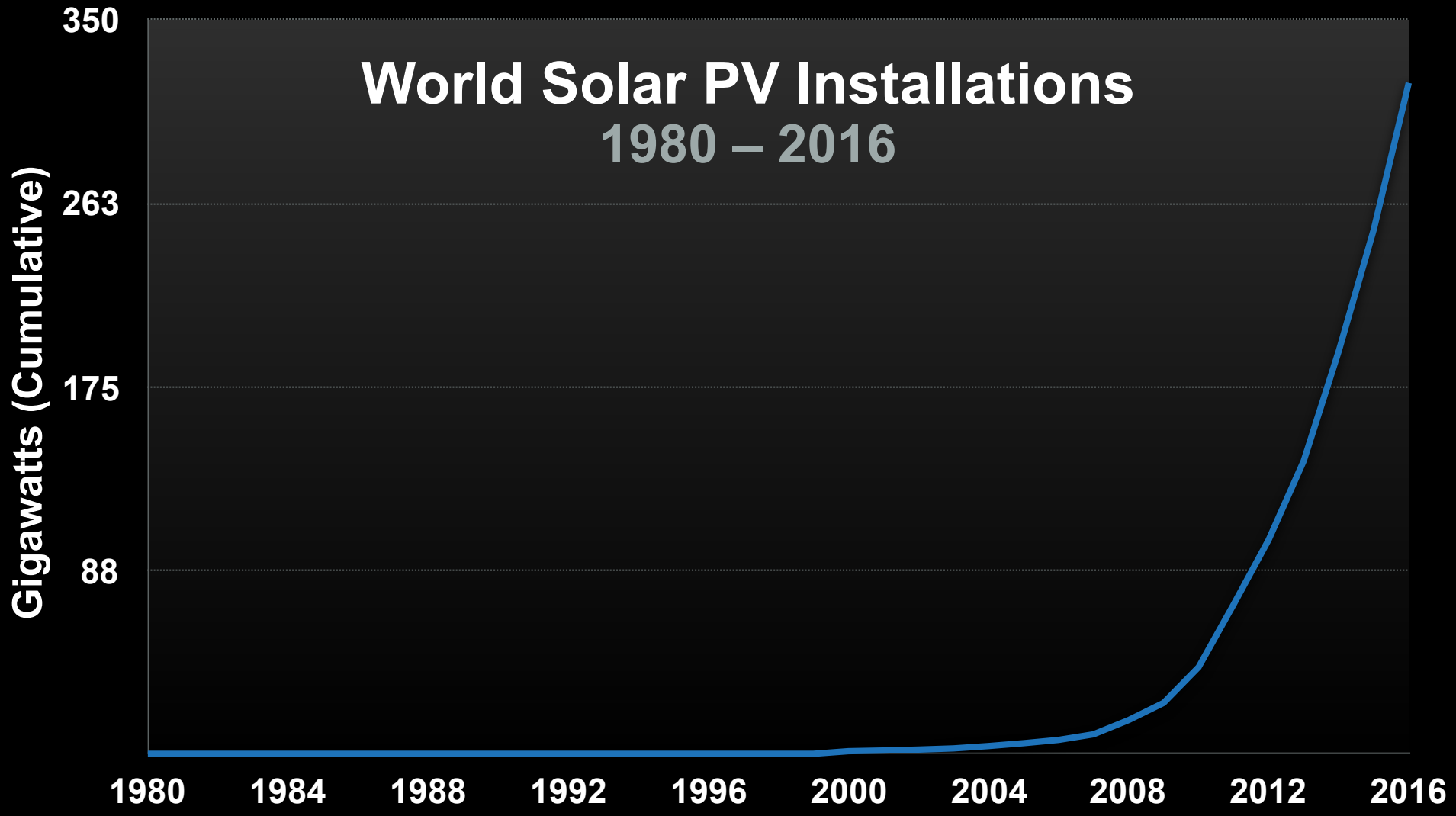
The solar energy market will grow 1 GW per year by 2010

Reality

The reality is that goal was exceeded by

77 x

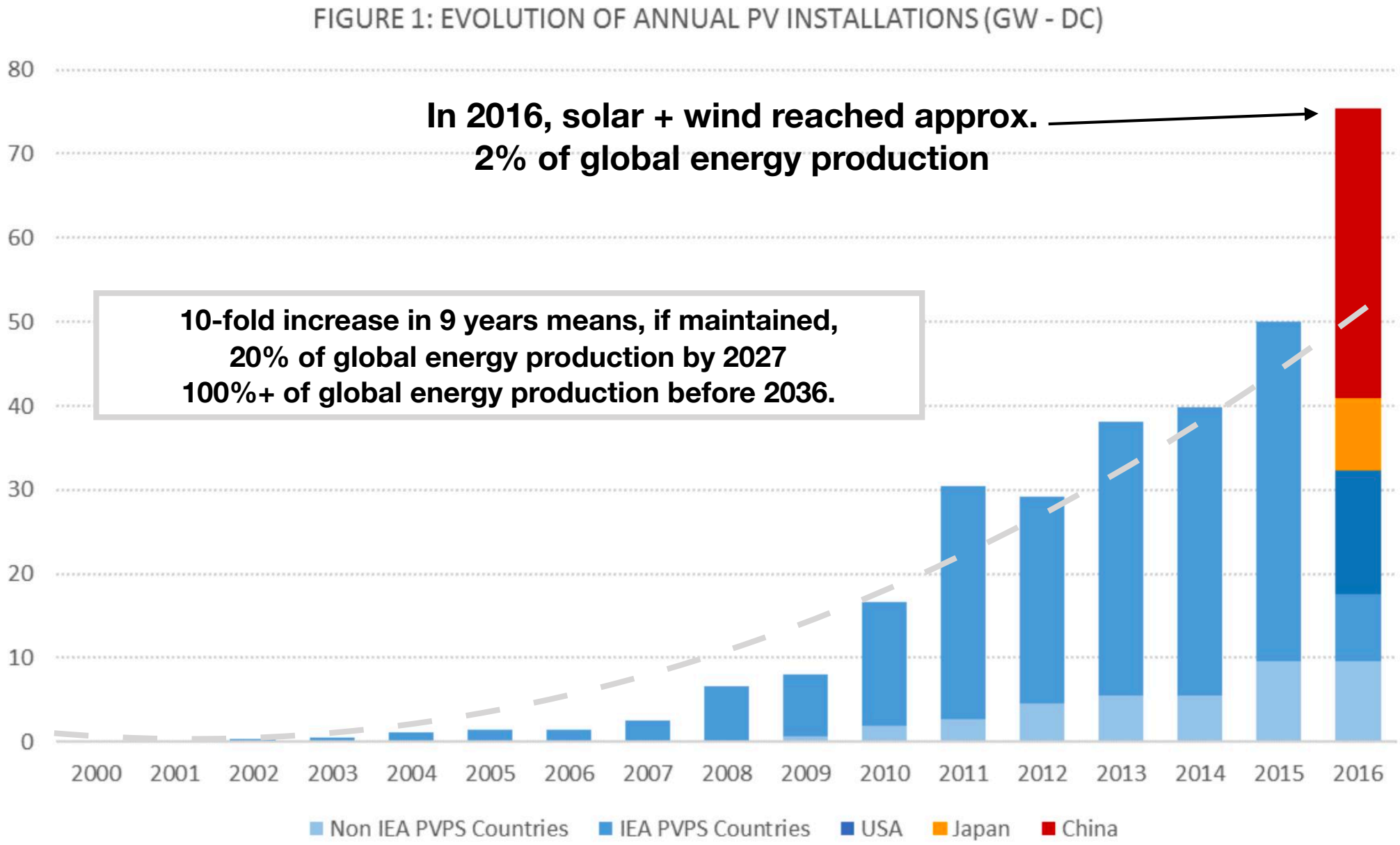
Data: Fresh-Energy; Bloomberg



Data: Earth Policy Institute/BP, *Statistical Review of World Energy* June 2014 (London: 2014).

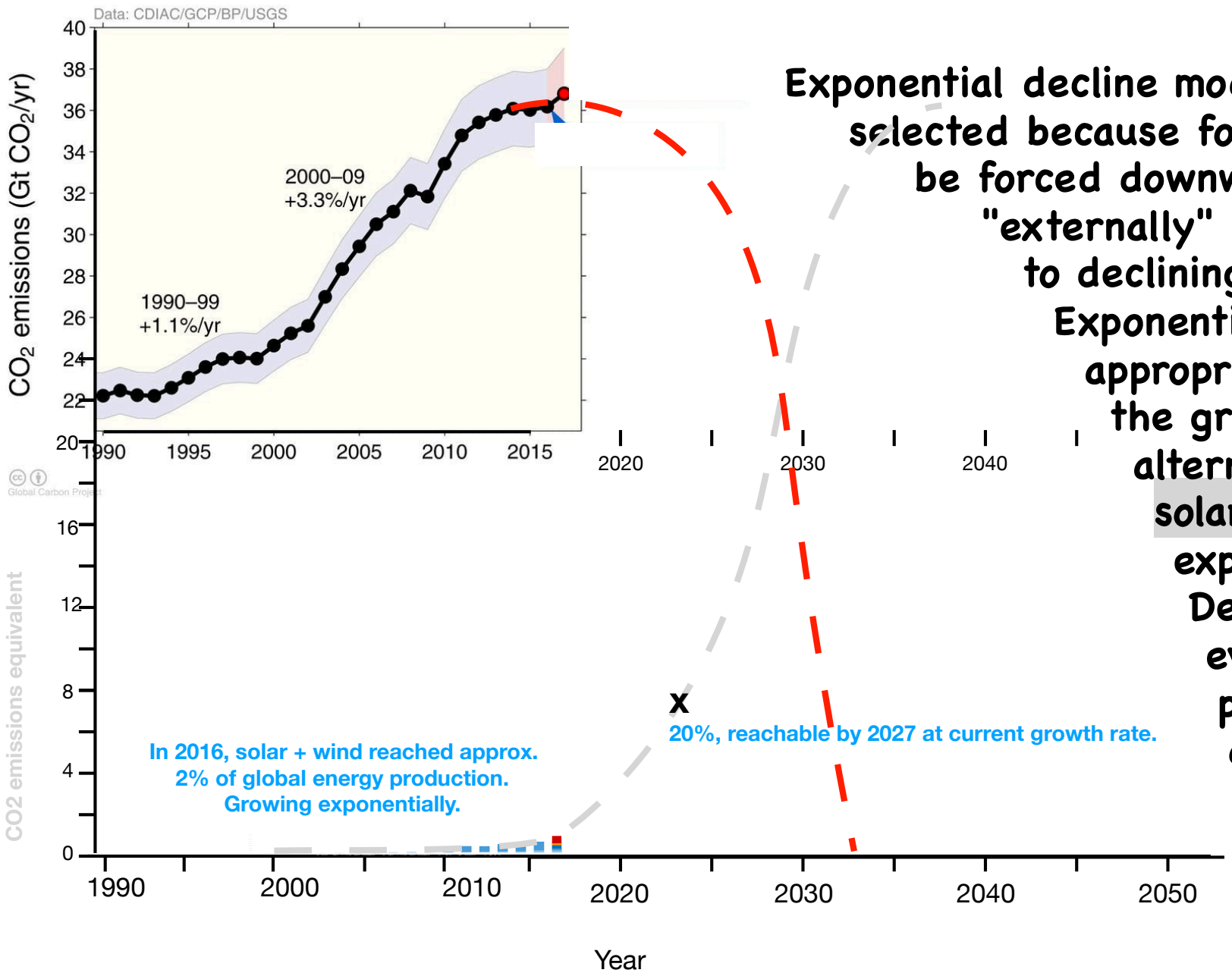
Fort Carson Army Base, Colorado
Source: U.S. Army

The rise of renewables!



https://www.greentechmedia.com/articles/read/iea-global-installed-pv-capacity-leaps-to-303-gw#gs.oEbQcfY

revised: Hypothetical model for emissions goal of zero in 2050



Exponential decline model is selected because fossil fuels will be forced downward "externally" (i.e. not due to declining availability). Exponential decline is appropriate when the growth of an alternative (i.e. solar) is exponential. Decline will be even faster if population also declines.

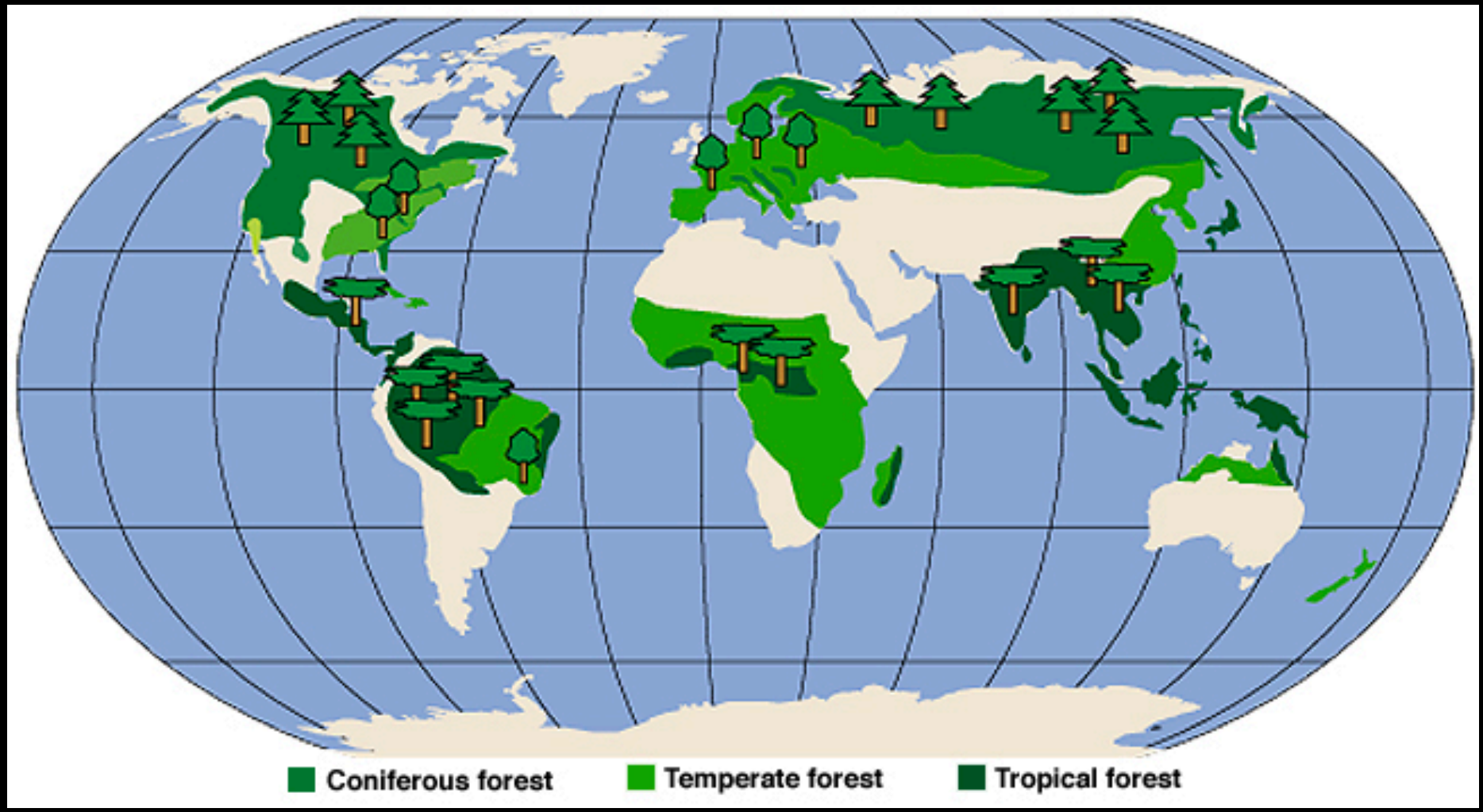
(This is an informal , back-of-the-envelope, model!)

Excess power could be used to sequester carbon!

Carbon capture

- https://youtu.be/5GBui1FRK78

Carbon capture!



I endorse these videos:

Anything by Paul Beckwith
paulbeckwith.net

Anything by Michael E Mann
http://www.realclimate.org/

Anything by James Hansen
http://www.columbia.edu/~jeh1/

More here: follow!
https://www.facebook.com/bio4961/

I do NOT endorse these videos:

It's Too Late To Stop Climate Change, WE ARE DEAD, Guy McPherson 18Nov2013
or anything by Guy MacPherson
https://www.youtube.com/watch?v=SQxYmVrSrcI

Arctic Death Spiral and the Methane Time Bomb
https://youtu.be/m6pFDu7lLV4?t=54m25s

A model for tree growth.

A tree growing in the open collects an amount of radiant energy roughly proportional to its leaf area. The JABOWA growth rate equation for a tree growing under optimum conditions has the form:

$$\delta(D^2H) = \mathrm{R} \cdot \mathrm{LA} \cdot \left(1 - \frac{DH}{D_{\max} H_{\max}}\right) \tag{1}$$

in which D is the dbh of the tree, H its height, with $D_{\max}$ and $H_{\max}$ being maximum values of these quantities for a given species, LA is the leaf area, and R is a constant. The equation states that the change in volume (D^2H) of a tree over a period of 1 year is proportional to the amount of sunlight which the tree receives, derated by a factor ($1 - DH/D_{\max}H_{\max}$) which takes some account of the energy required to maintain the living tissue. The right-hand side of eqn (1) is later multiplied by additional factors to take shading, climate, etc. into account. Values used in JABOWA version 1 for $D_{\max}$, $H_{\max}$ and other parameters are given in Table 1.

Botkin, D.B., Janak, J.F. and Wallis, J.R., 1972. Some ecological consequences of a computer model of forest growth. *The Journal of Ecology*, pp.849-872.