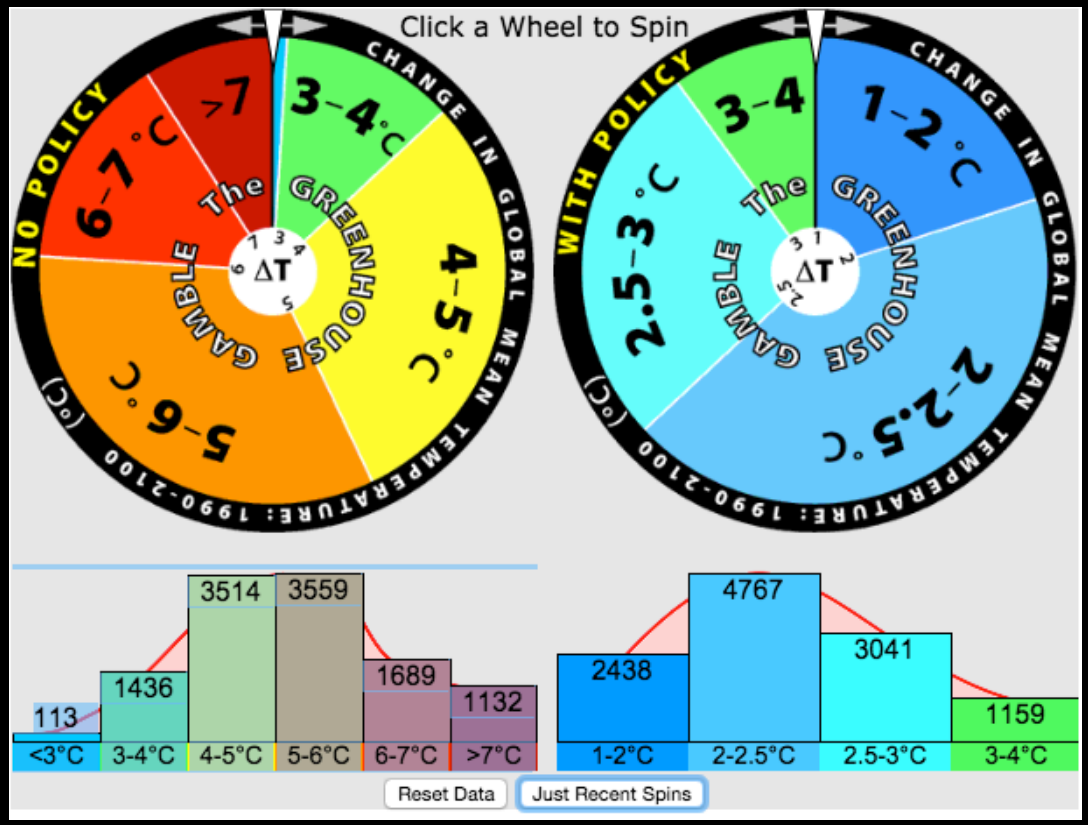
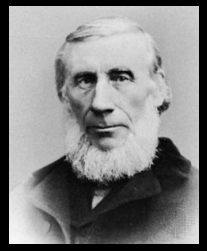
Climate Changes. Do Policies?



Ankur Desai
Dept of Atmospheric & Oceanic Sciences
University of Wisconsin-Madison

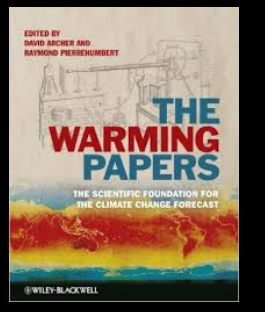
Nov 11, 2015. Public Affairs 850

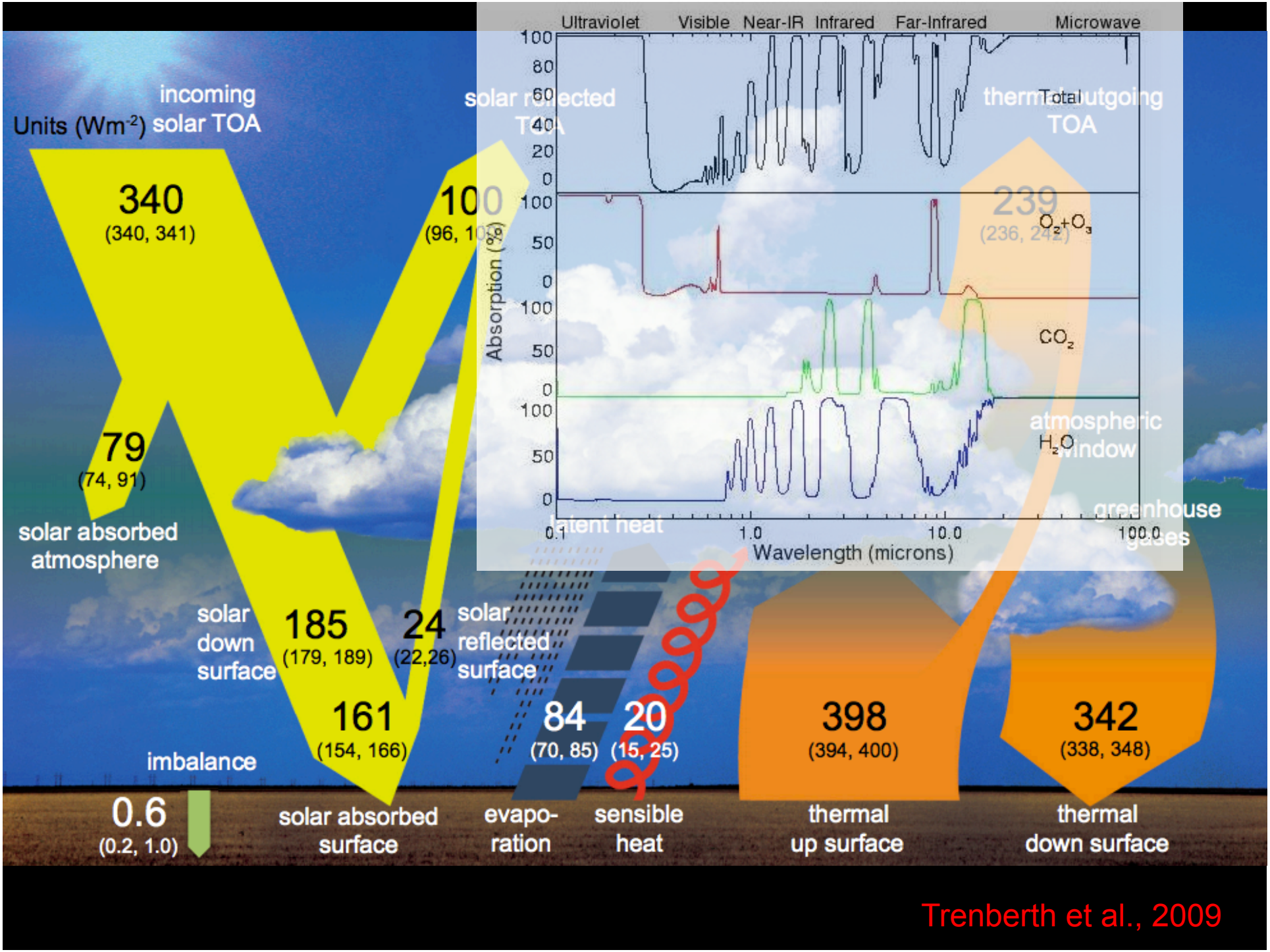


- Planetary (inc. Earth) temperature is determined by interaction of sunlight warming Earth's surface, and "greenhouse" gases that absorb infrared radiation (Fourier 1824, Tyndall 1861)

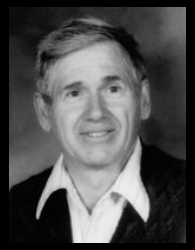
- CO_2 is a greenhouse warming gas and emitted from coal, oil, gas (Arrhenius 1896)

- Oceans can only take up a fraction of CO_2 produced by combustion (Revelle 1957)





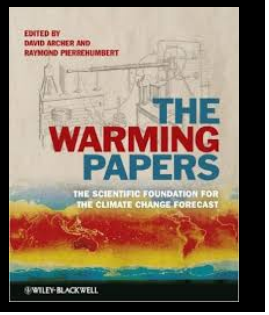
Trenberth et al., 2009

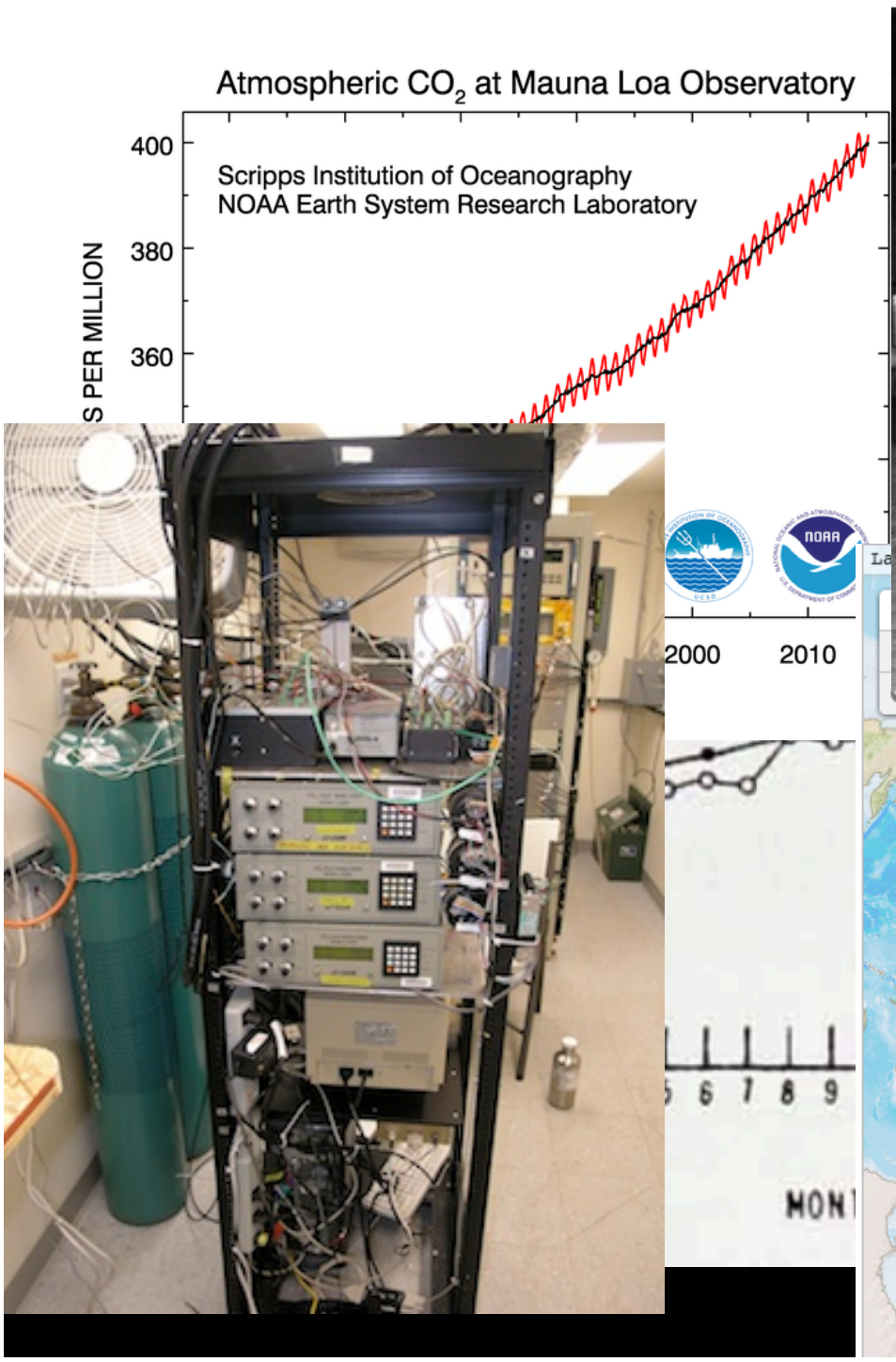


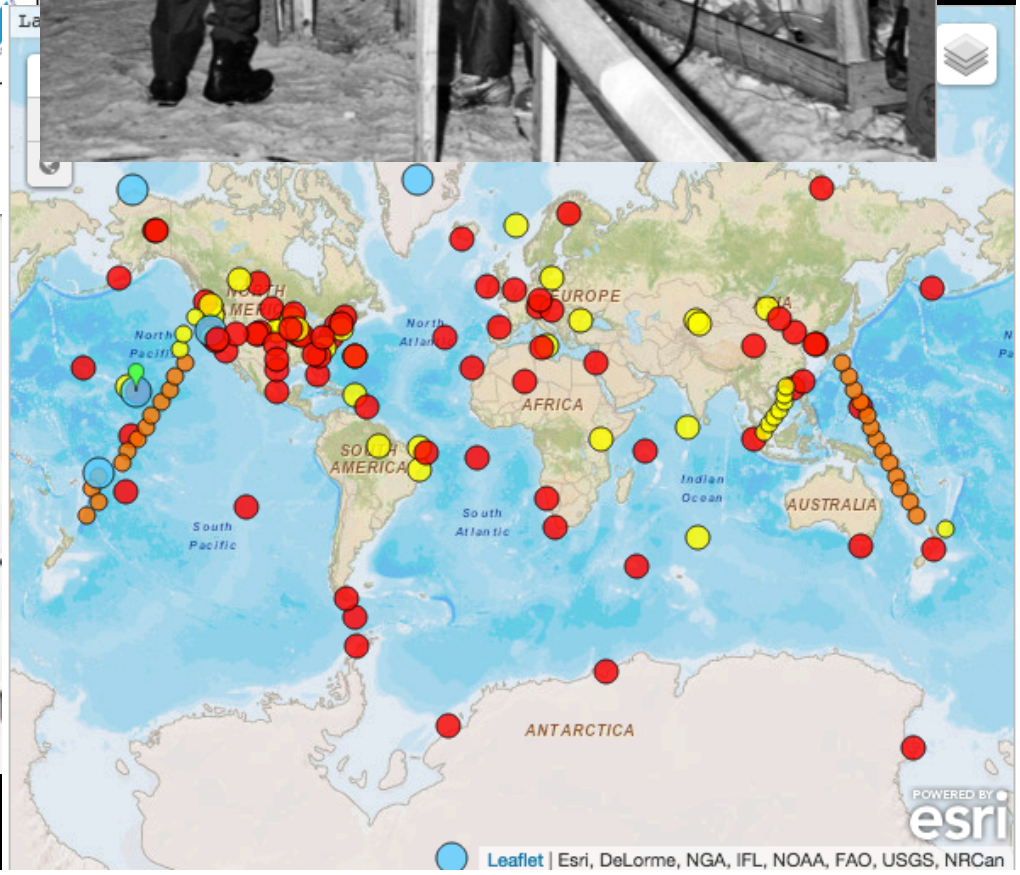
- Atmospheric CO_2 increasing ~ 2 ppm/yr from fossil fuel combustion, with 50% going into land and ocean sinks (Keeling 1960, Tans 1990)

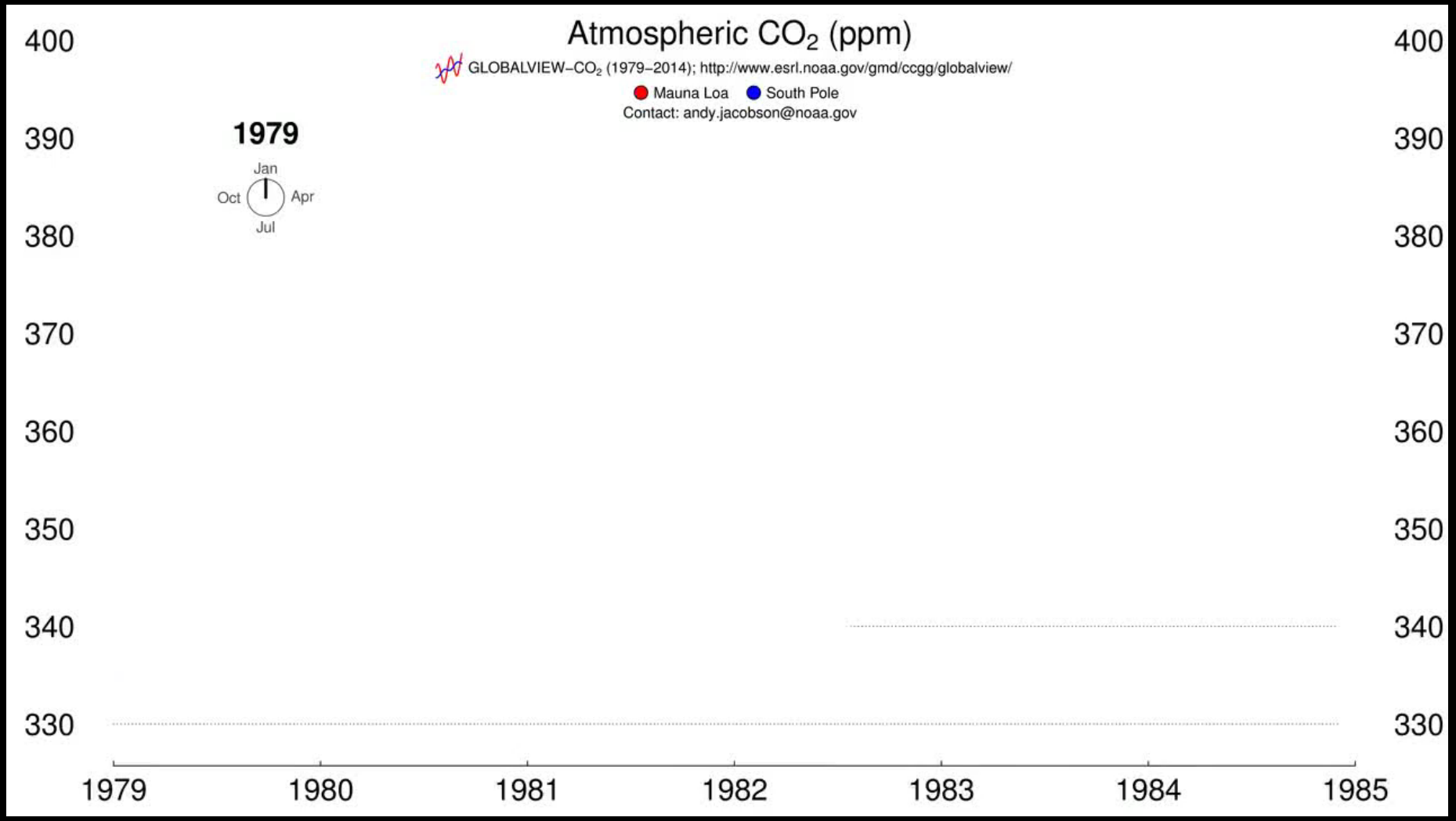
- Short and long term observed warming patterns are linked to greenhouse gases (Callendar 1938, Mann 1999)

- Significant warming in the 20th century is mostly explained by atmospheric CO_2 (Manabe 1967, Hansen 1984)

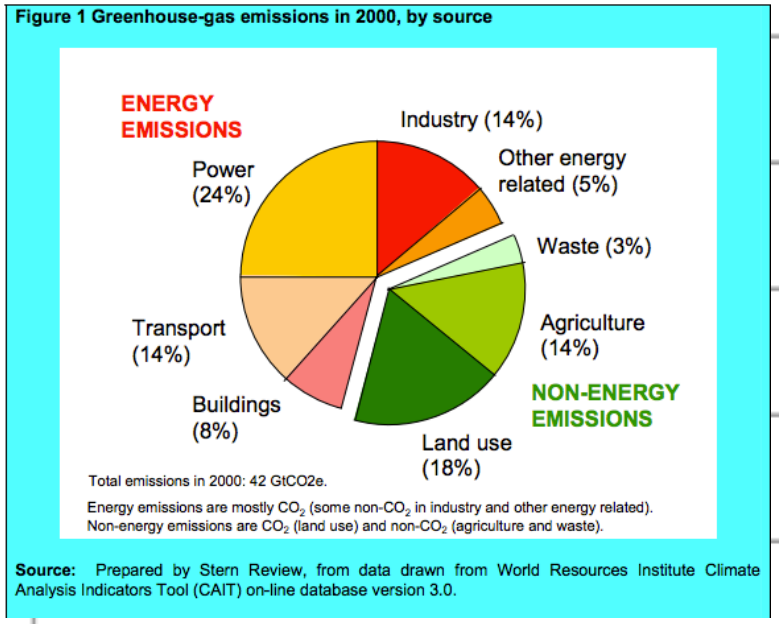



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
400
380
360
S PER MILLION
2000
2010
MON


EUROPE
AFRICA
AUSTRALIA
ANTARCTICA
Indian Ocean
South Pacific
South Atlantic
Leaflet | Esri, DeLorme, NGA, IFL, NOAA, FAO, USGS, NRCan


Atmospheric CO_2 (ppm)
GLOBALVIEW–CO_2 (1979–2014); http://www.esrl.noaa.gov/gmd/ccgg/globalview/
Mauna Loa
South Pole
Contact: andy.jacobson@noaa.gov
1979
Jan
Oct
Apr
Jul
400
390
380
370
360
350
340
330
1979
1980
1981
1982
1983
1984
1985

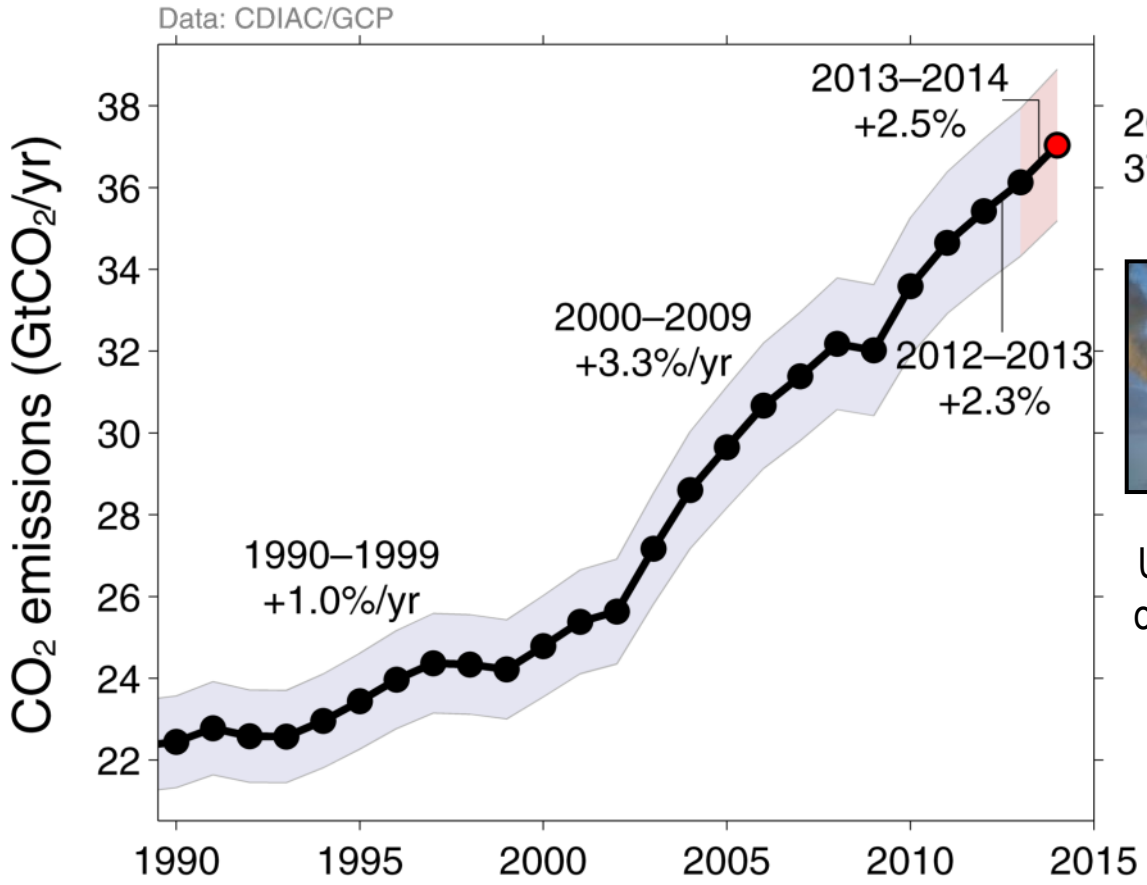
World Energy Consumption



Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 36.1 ± 1.8 $GtCO_2$ in 2013, 61% over 1990

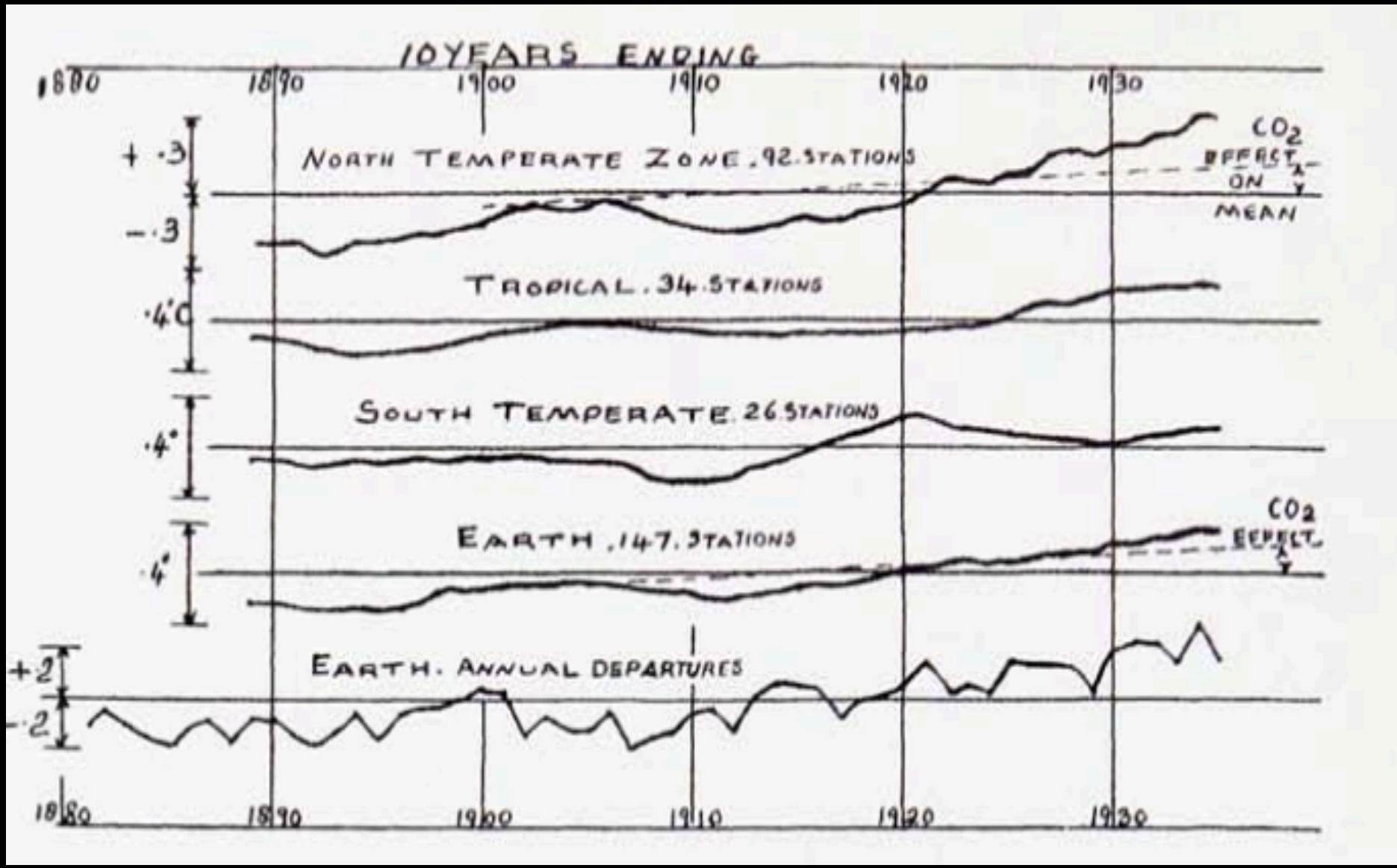
- Projection for 2014 : 37.0 ± 1.9 $GtCO_2$, 65% over 1990



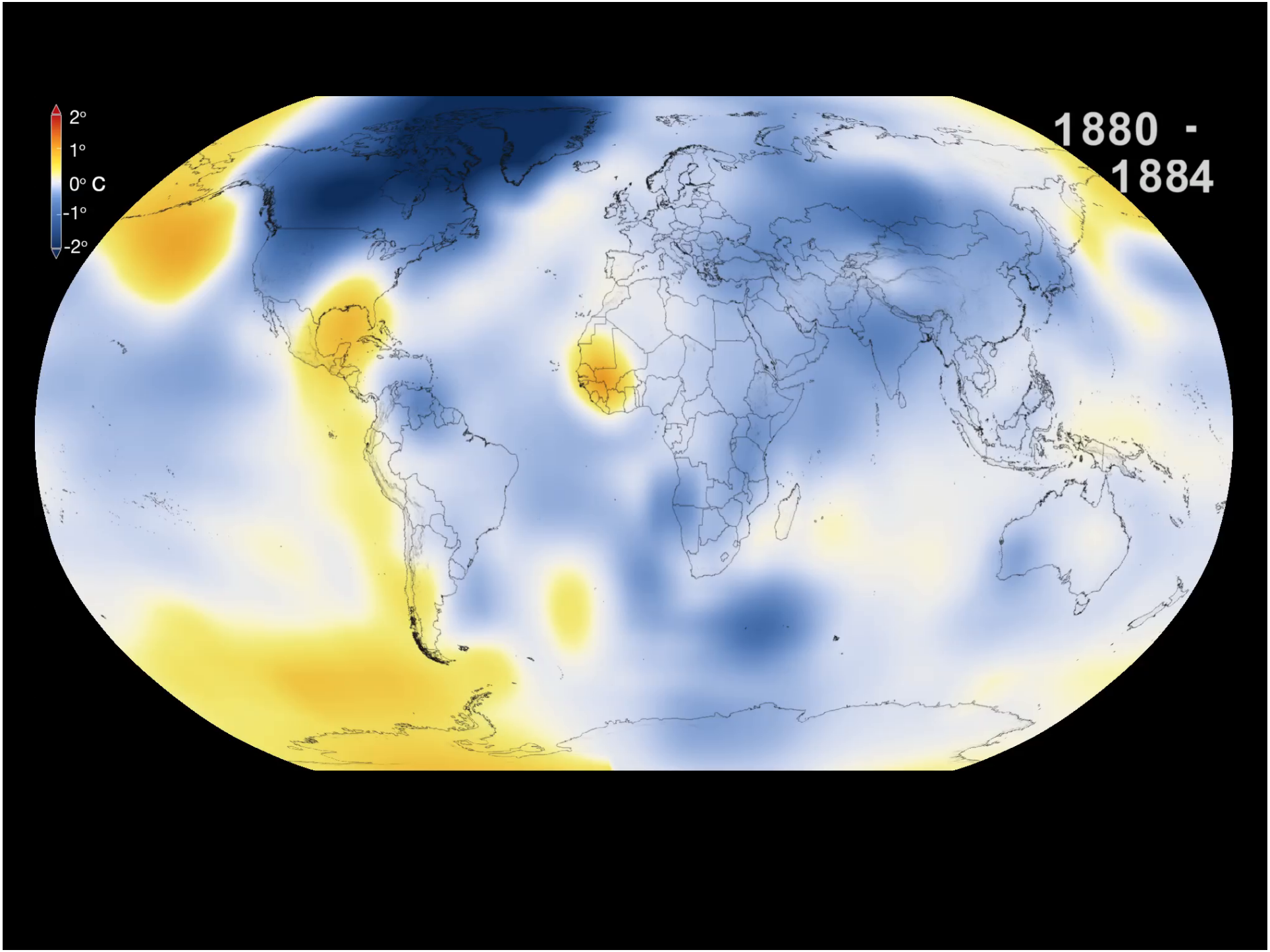
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

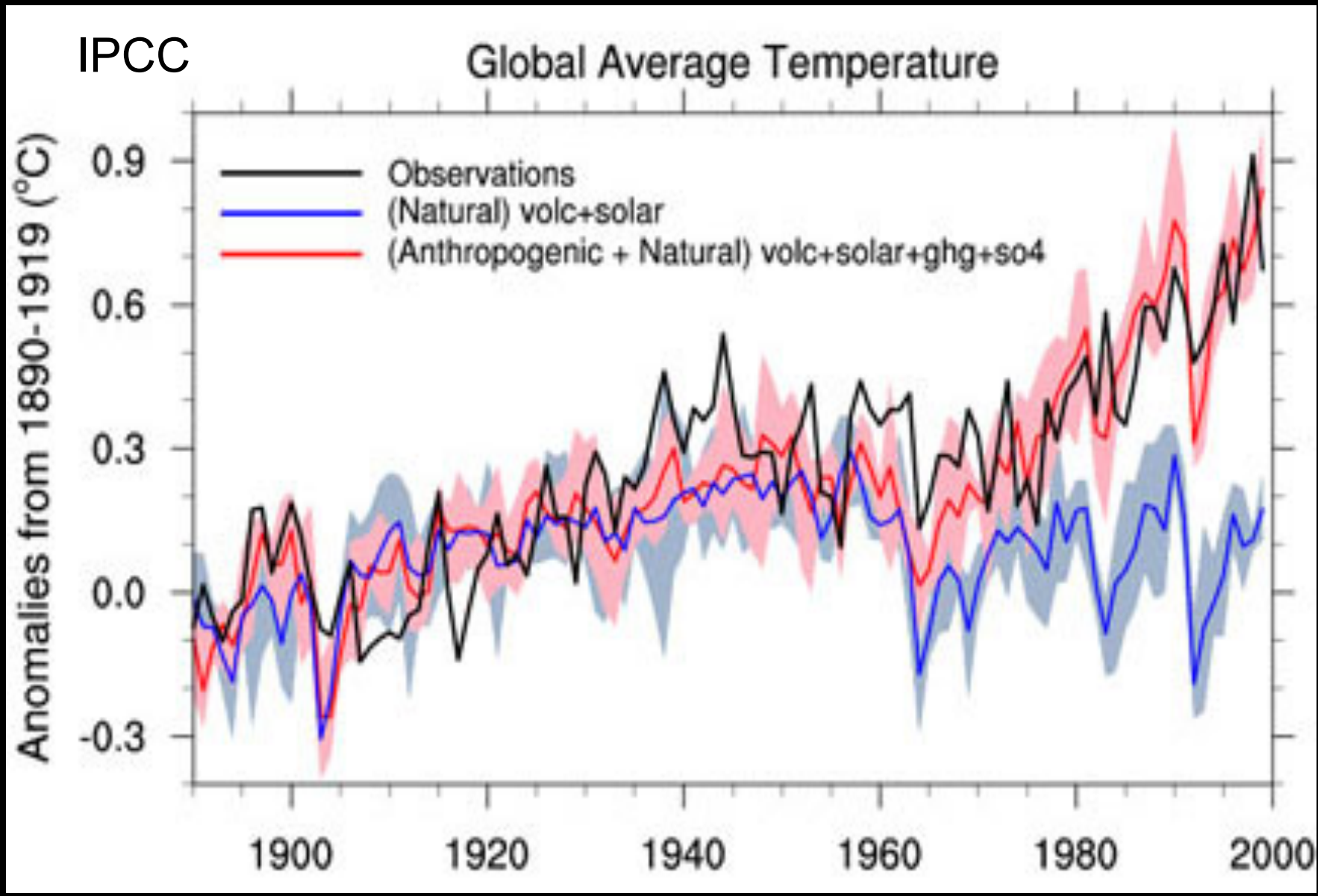
Estimates for 2011, 2012, and 2013 are preliminary

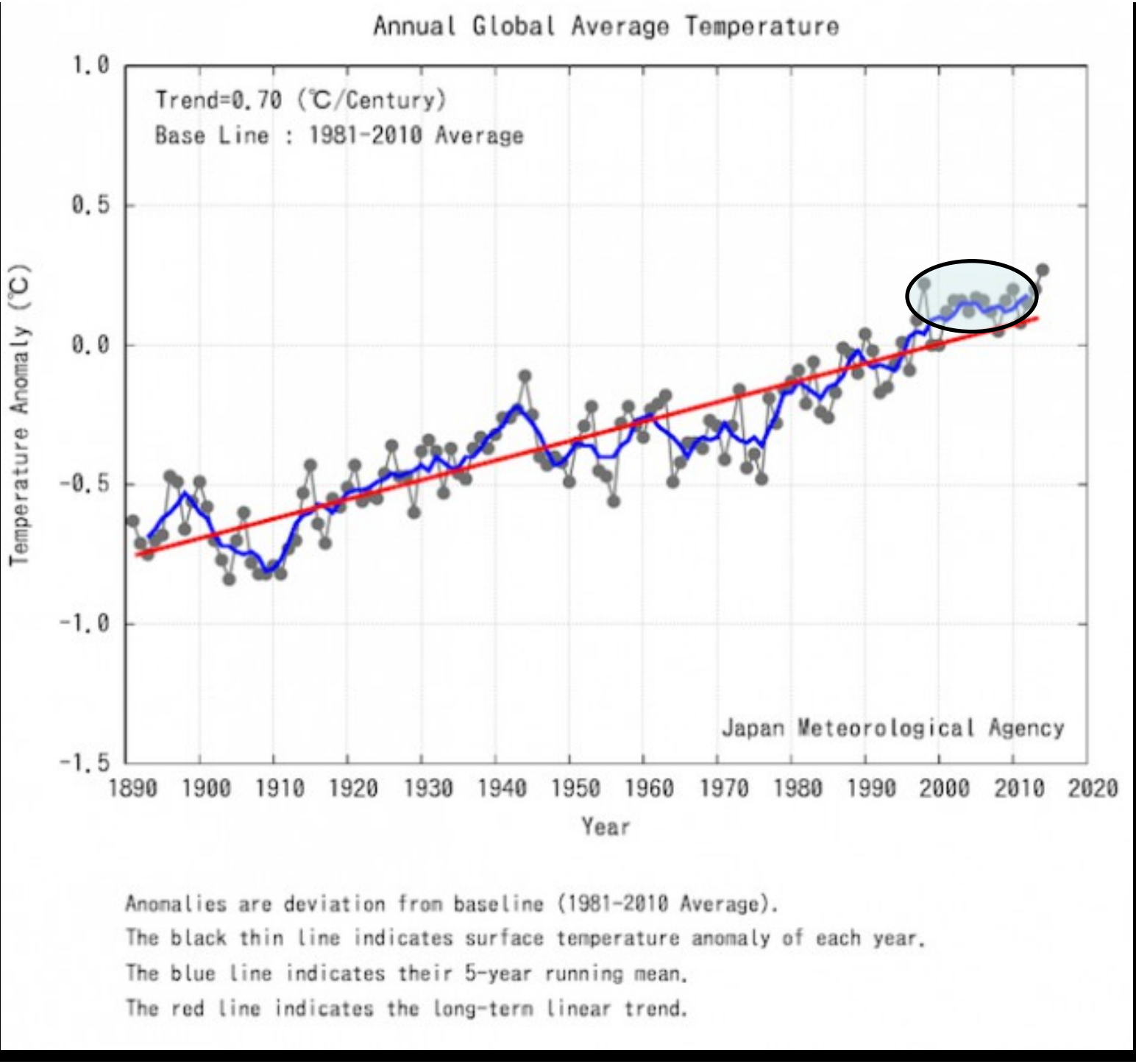
Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014

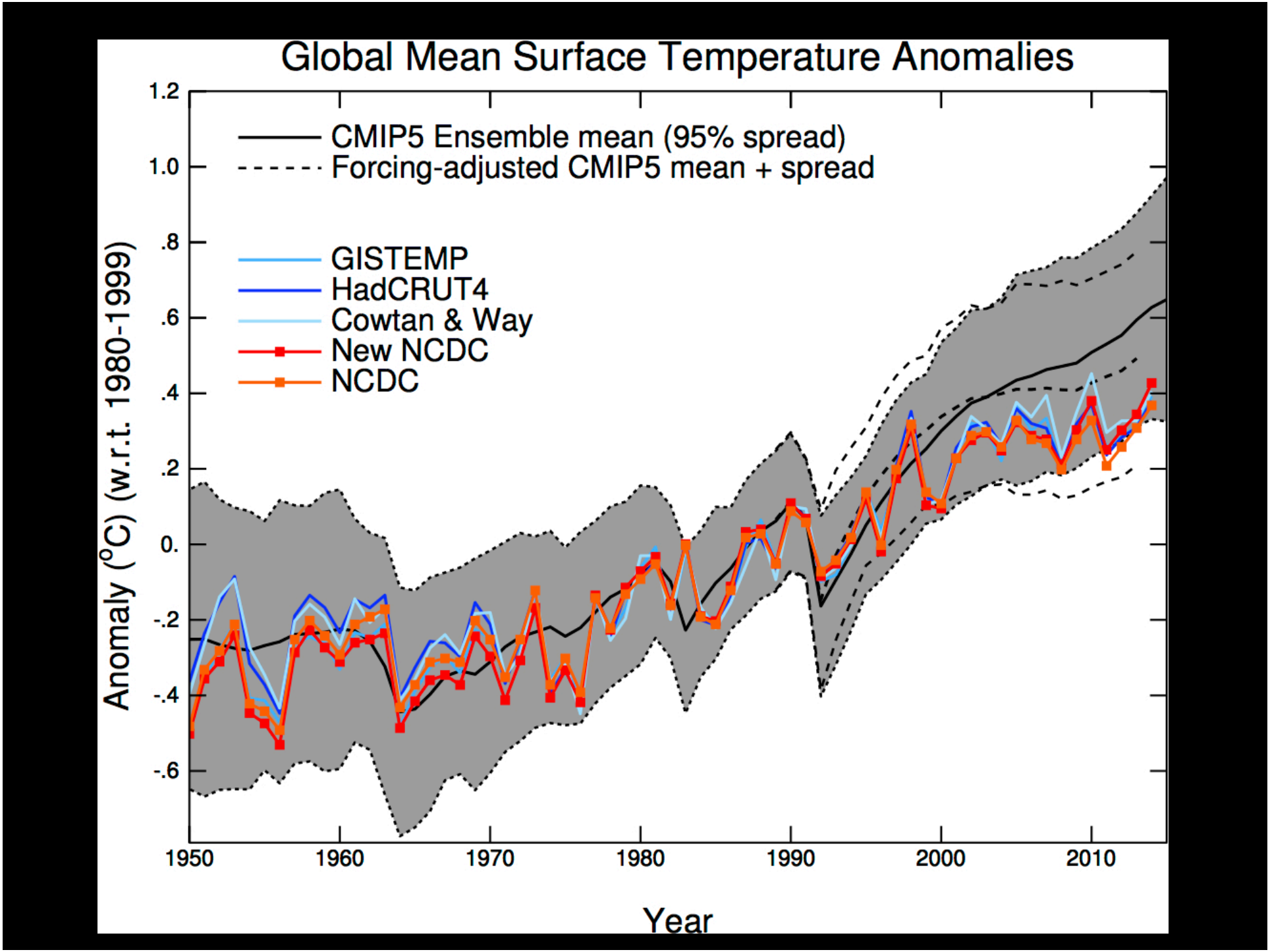


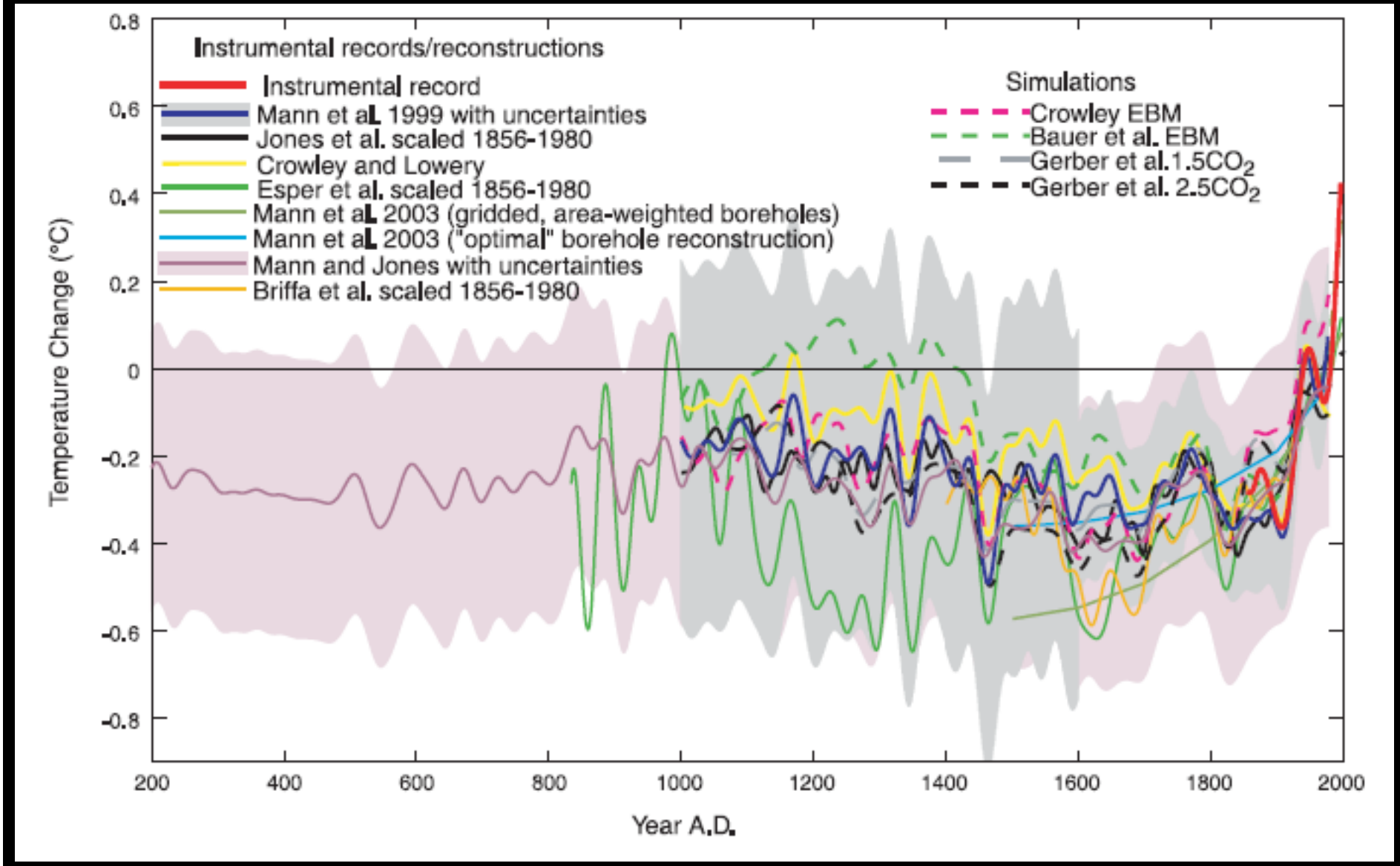
Callendar, 1938


2°
1°
0° C
-1°
-2°
1880 -
1884


IPCC
Global Average Temperature
Anomalies from 1890-1919 (°C)
0.9
0.6
0.3
0.0
-0.3
Observations
(Natural) volc+solar
(Anthropogenic + Natural) volc+solar+ghg+so4
1900
1920
1940
1960
1980
2000


Annual Global Average Temperature
Trend=0.70 (℃/Century)
Base Line : 1981-2010 Average
Temperature Anomaly (℃)
1.0
0.5
0.0
-0.5
-1.0
-1.5
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Japan Meteorological Agency
Anonalies are deviation fron baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-tern linear trend.

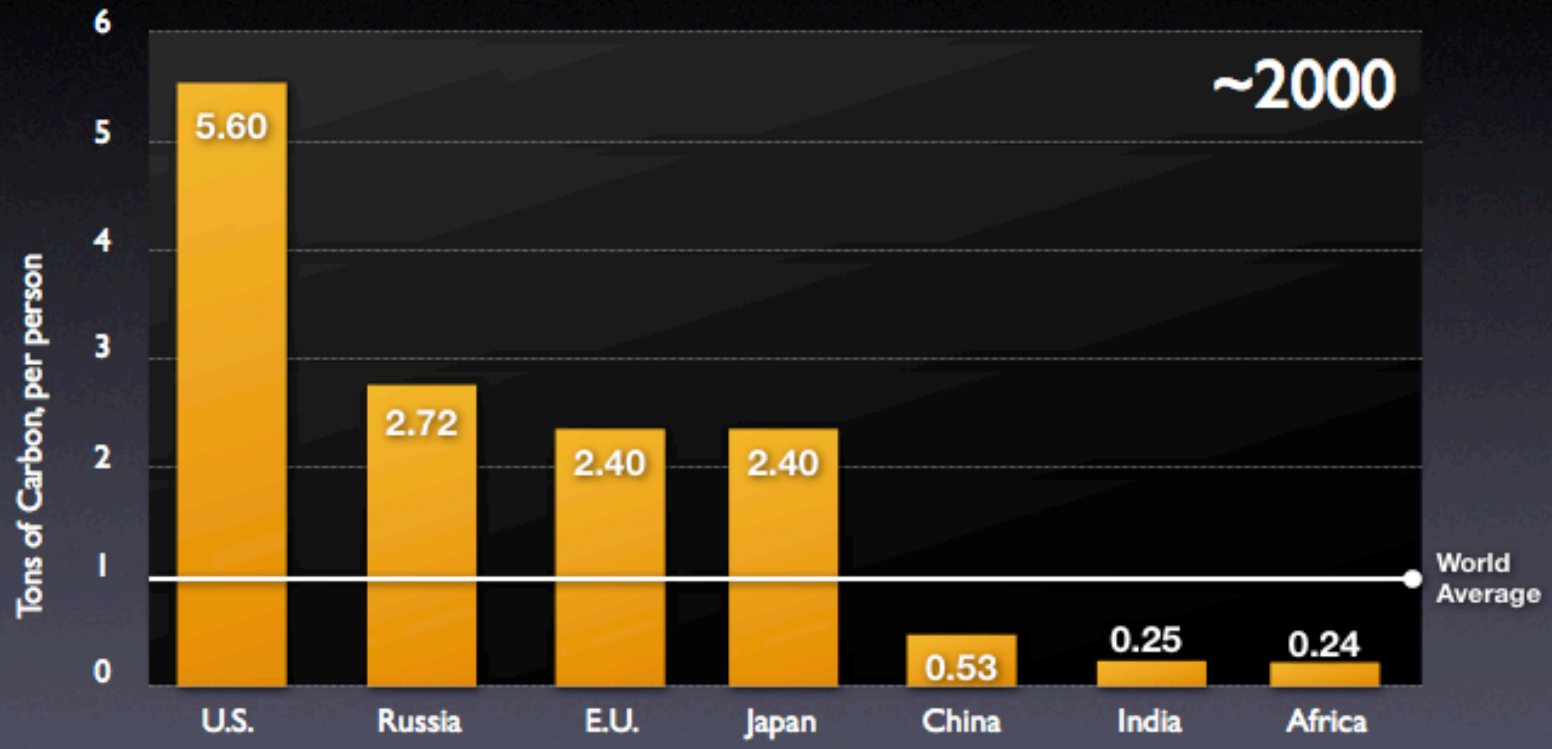

Global Mean Surface Temperature Anomalies
CMIP5 Ensemble mean (95% spread)
Forcing-adjusted CMIP5 mean + spread
GISTEMP
HadCRUT4
Cowtan & Way
New NCDC
NCDC
Anomaly (°C) (w.r.t. 1980-1999)
1.2
1.0
.8
.6
.4
.2
0.
-.2
-.4
-.6
1950
1960
1970
1980
1990
2000
2010
Year



Mann et al., 2003, EOS

- US per capita fossil fuel emissions exceed most of the world (DOE, GCP). China total emissions now exceeds the US (IEA).
- Climate projections show a 3 C +/- 1.5 C response to doubling of CO_2 by 2100 with the primary uncertainty in range of emissions (IPCC 1990, 1995, 2001, 2007, 2013)
- Modest warming (0-2 C) creates both winners and losers; warming above 2C or 550 ppm, losers > winners; warming above 4C, mostly losers (WMO, ExxonMobil, Stern Review, World Bank, NCA, WICCI, DOD 1979-present)

Carbon Emissions *per Person*



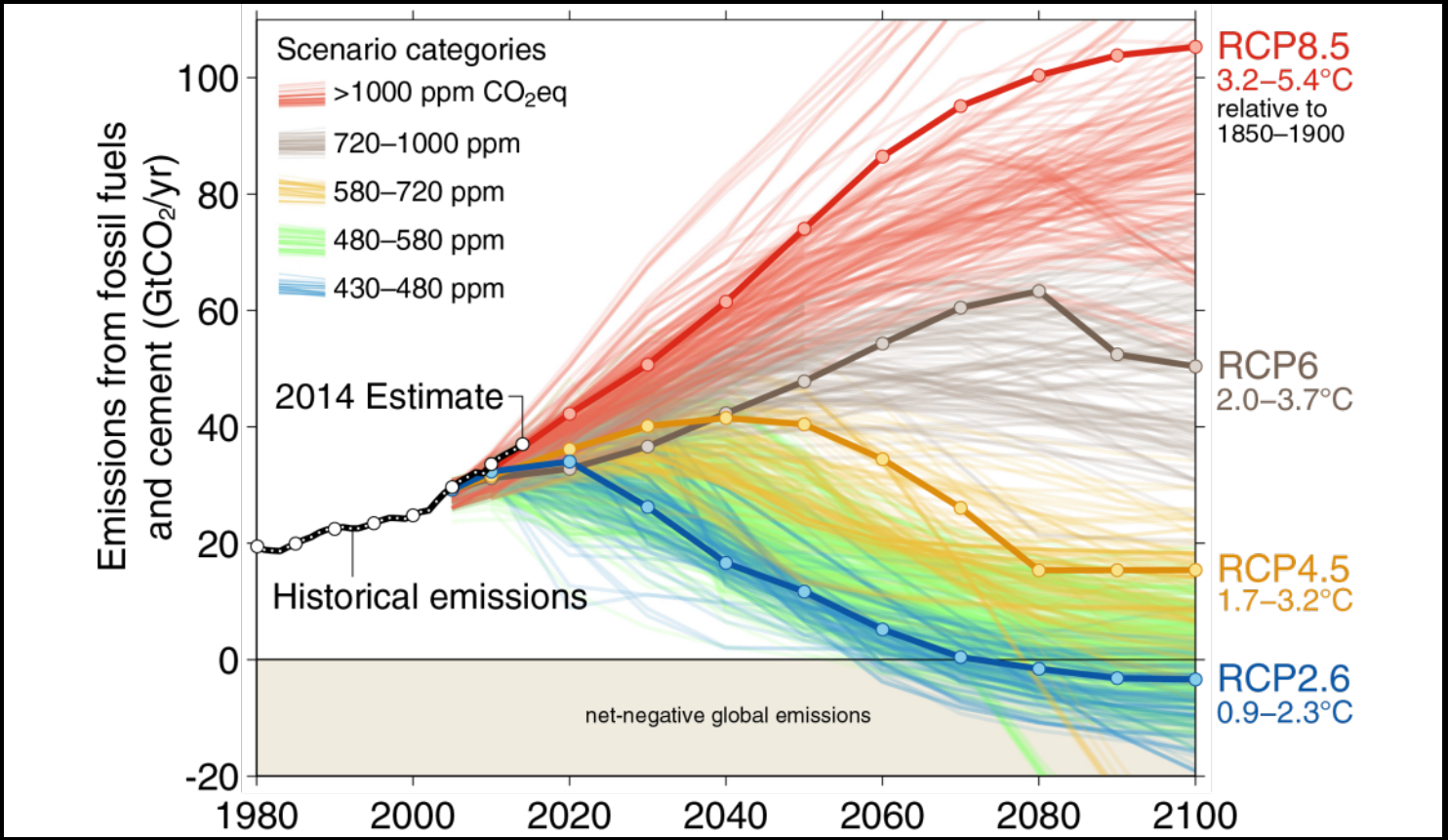
Center for Sustainability and the Global Environment (SAGE)
University of Wisconsin, Madison

Image: Gore

Observed Emissions and Emissions Scenarios

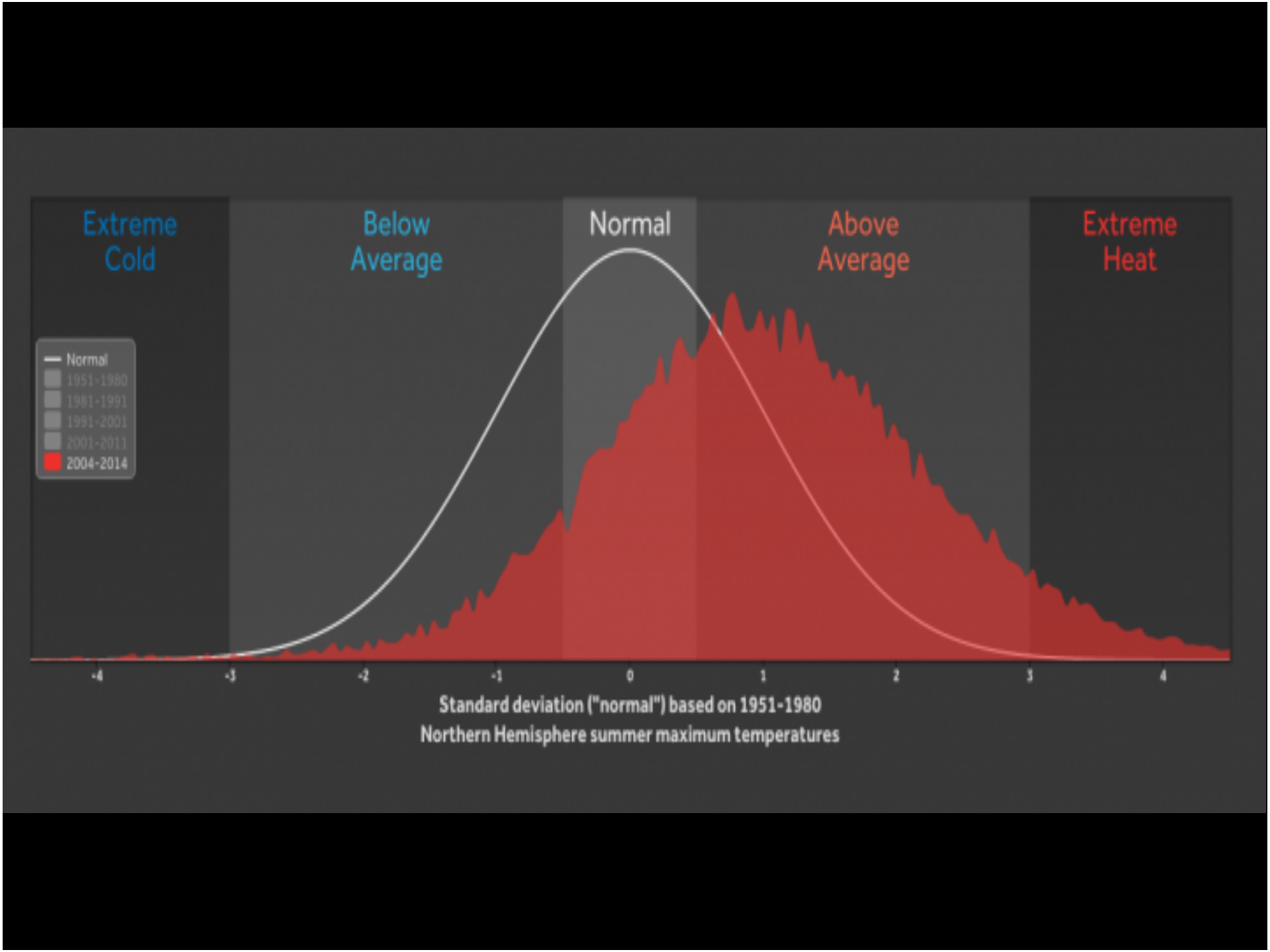
Emissions are on track for 3.2–5.4ºC "likely" increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2ºC

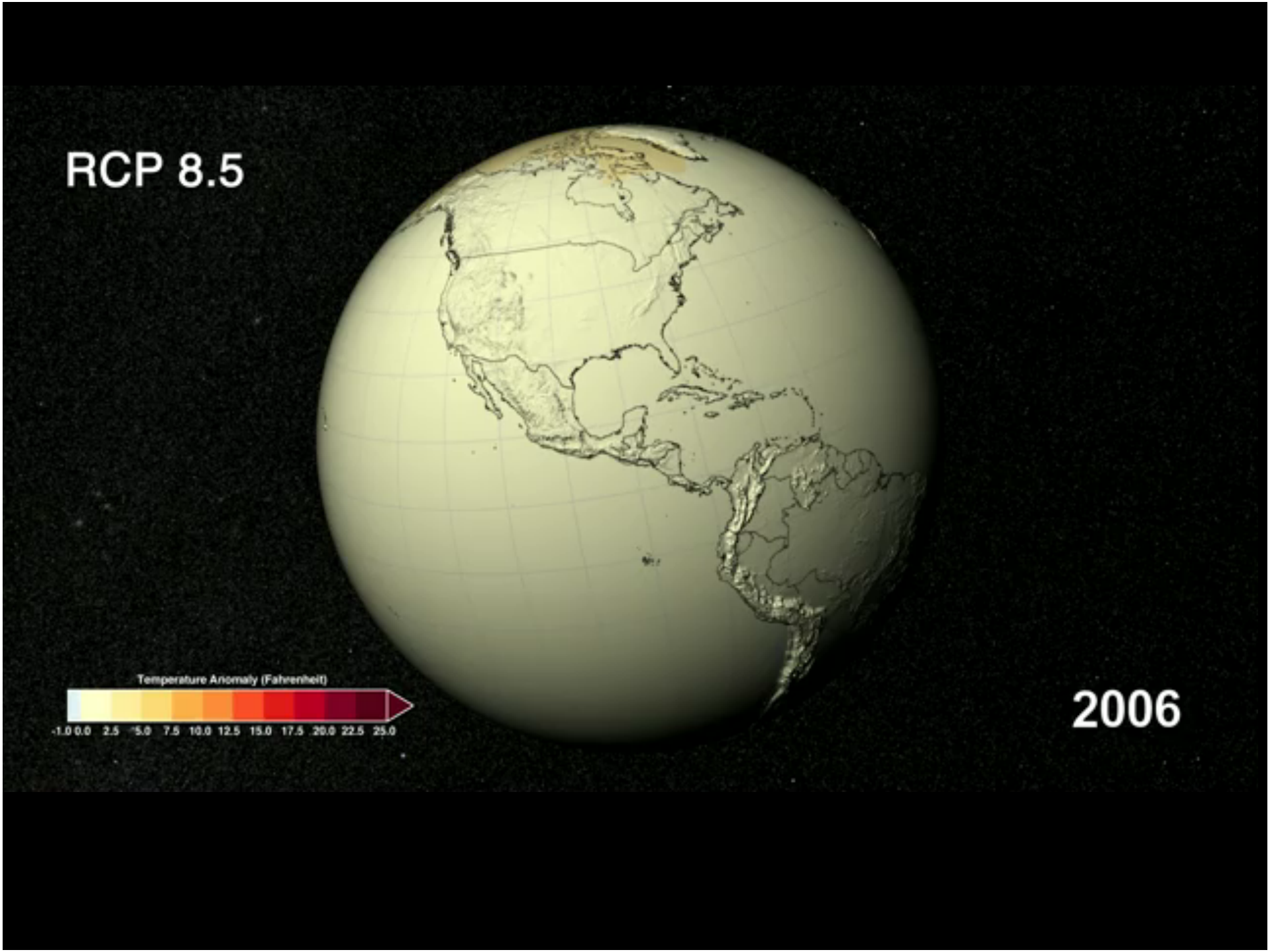
Data: CDIAC/GCP/IPCC/Fuss et al 2014

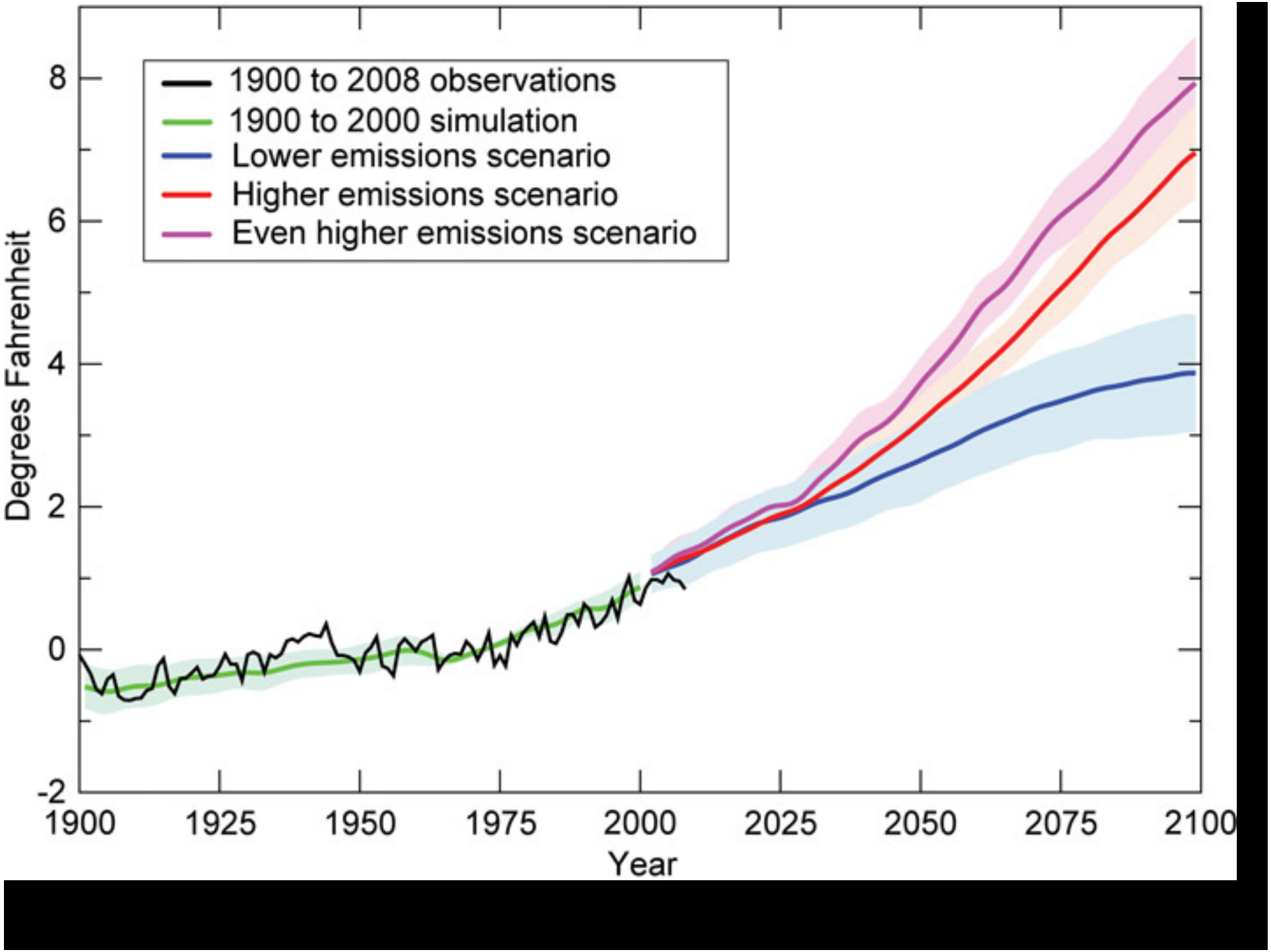


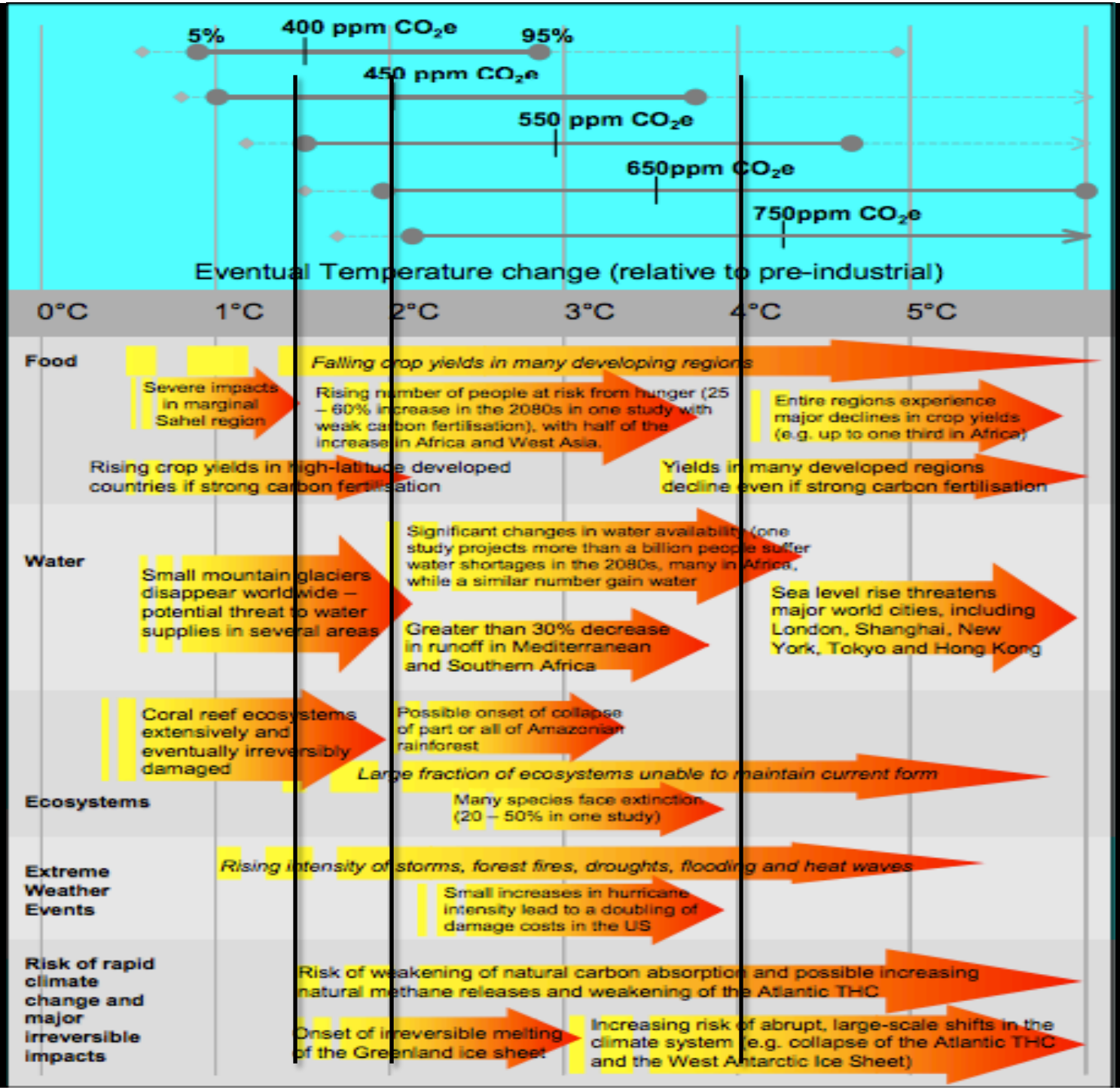
Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

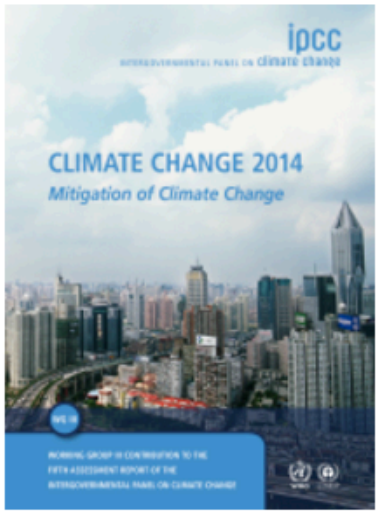
Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014

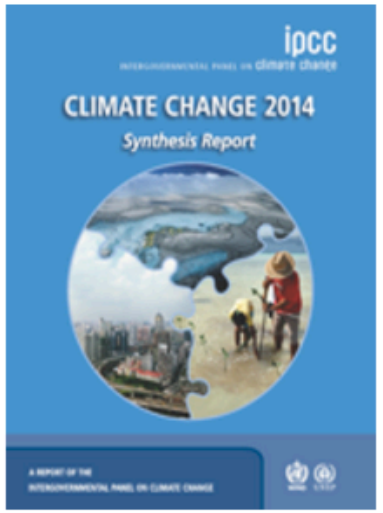

Extreme Cold
Below Average
Normal
Above Average
Extreme Heat
Normal
1951-1980
1981-1991
1991-2001
2001-2011
2004-2014
-4
-3
-2
-1
0
1
2
3
4
Standard deviation ("normal") based on 1951-1980
Northern Hemisphere summer maximum temperatures

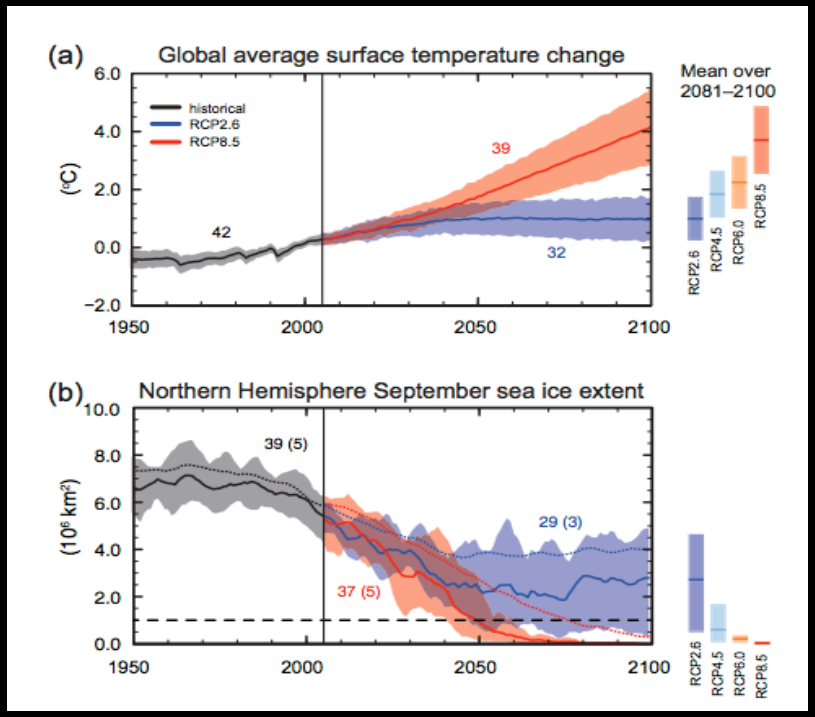

RCP 8.5
Temperature Anomaly (Fahrenheit)
<1.0 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0
2006


1900 to 2008 observations
1900 to 2000 simulation
Lower emissions scenario
Higher emissions scenario
Even higher emissions scenario
Degrees Fahrenheit
8
6
4
2
0
-2
1900
1925
1950
1975
2000
2025
2050
2075
2100
Year

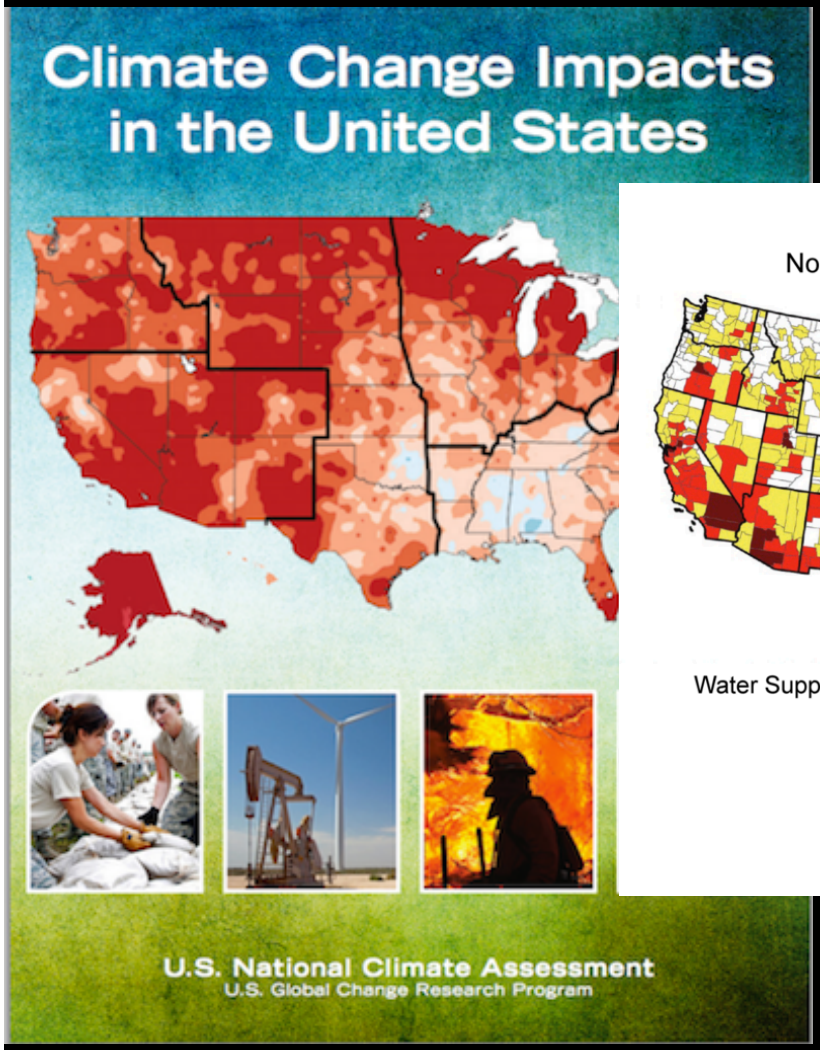

5%
400 ppm CO_2e
95%
450 ppm CO_2e
550 ppm CO_2e
650ppm CO_2e
750ppm CO_2e
Eventual Temperature change (relative to pre-industrial)
0°C
1°C
2°C
3°C
4°C
5°C
Food
Falling crop yields in many developing regions
Severe impacts in marginal Sahel region
Rising number of people at risk from hunger (25 – 60% increase in the 2080s in one study with weak carbon fertilisation), with half of the increase in Africa and West Asia.
Entire regions experience major declines in crop yields (e.g. up to one third in Africa)
Rising crop yields in high-latitude developed countries if strong carbon fertilisation
Yields in many developed regions decline even if strong carbon fertilisation
Water
Significant changes in water availability (one study projects more than a billion people suffer water shortages in the 2080s, many in Africa, while a similar number gain water
Small mountain glaciers disappear worldwide – potential threat to water supplies in several areas
Sea level rise threatens major world cities, including London, Shanghai, New York, Tokyo and Hong Kong
Greater than 30% decrease in runoff in Mediterranean and Southern Africa
Ecosystems
Coral reef ecosystems extensively and eventually irreversibly damaged
Possible onset of collapse of part or all of Amazonian rainforest
Large fraction of ecosystems unable to maintain current form
Many species face extinction (20 – 50% in one study)
Extreme Weather Events
Rising intensity of storms, forest fires, droughts, flooding and heat waves
Small increases in hurricane intensity lead to a doubling of damage costs in the US
Risk of rapid climate change and major irreversible impacts
Risk of weakening of natural carbon absorption and possible increasing natural methane releases and weakening of the Atlantic THC
Onset of irreversible melting of the Greenland ice sheet
Increasing risk of abrupt, large-scale shifts in the climate system (e.g. collapse of the Atlantic THC and the West Antarctic Ice Sheet)

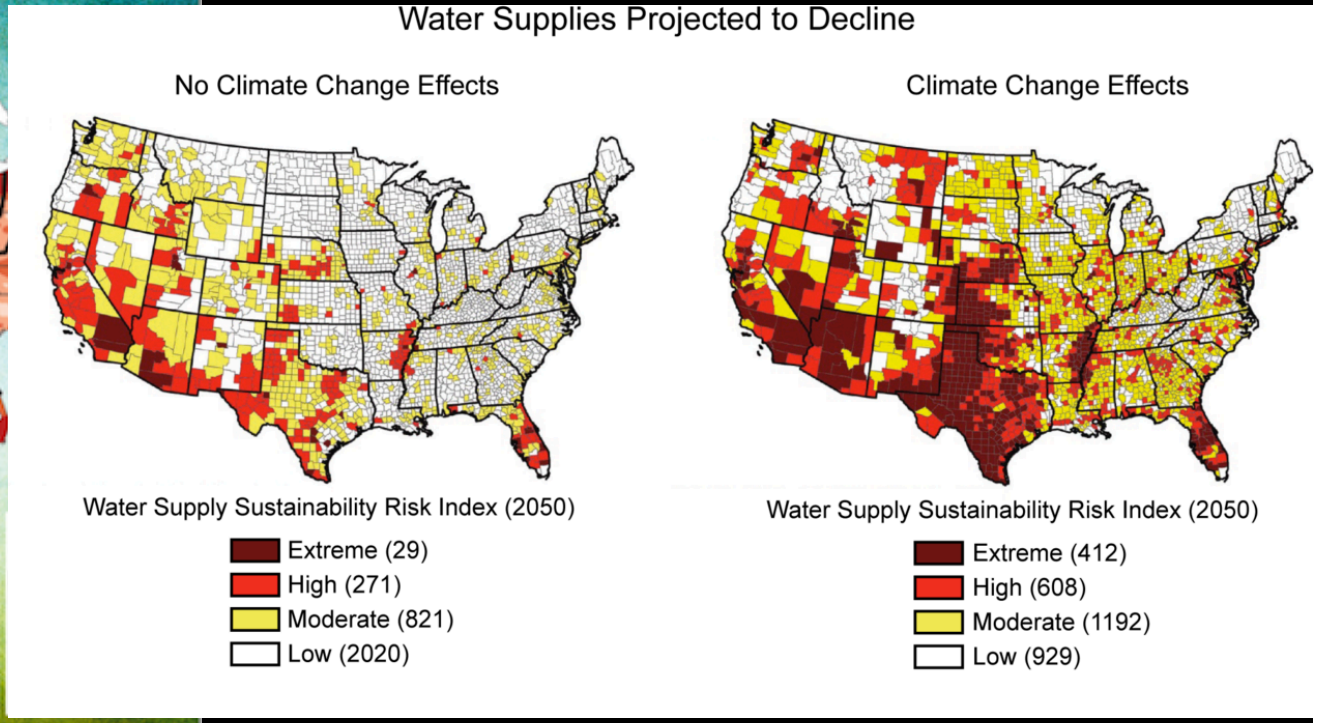






https://www.ipcc.ch/report/ar5/

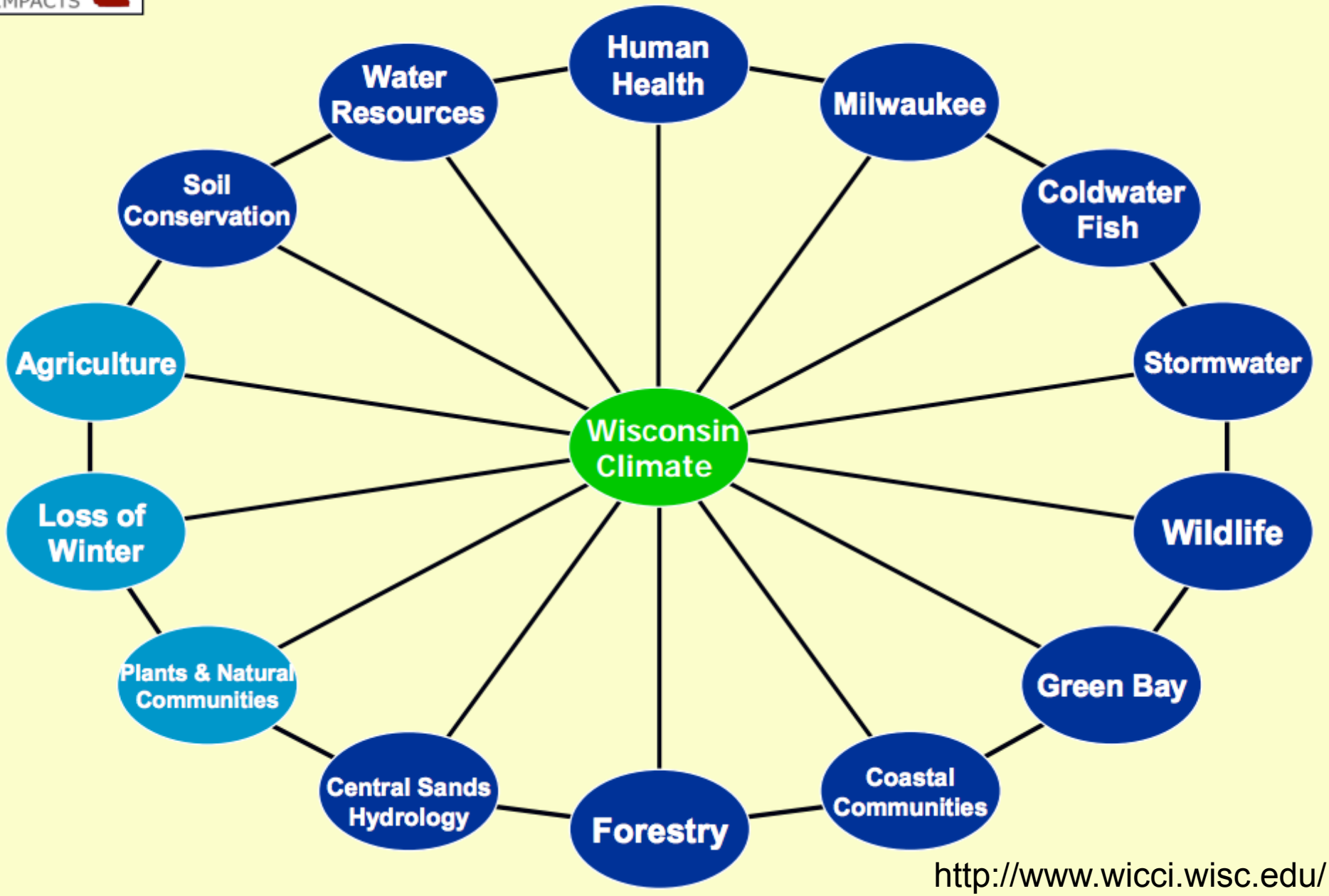




http://nca2014.globalchange.gov/

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Current & Developing Working Groups



http://www.wicci.wisc.edu/

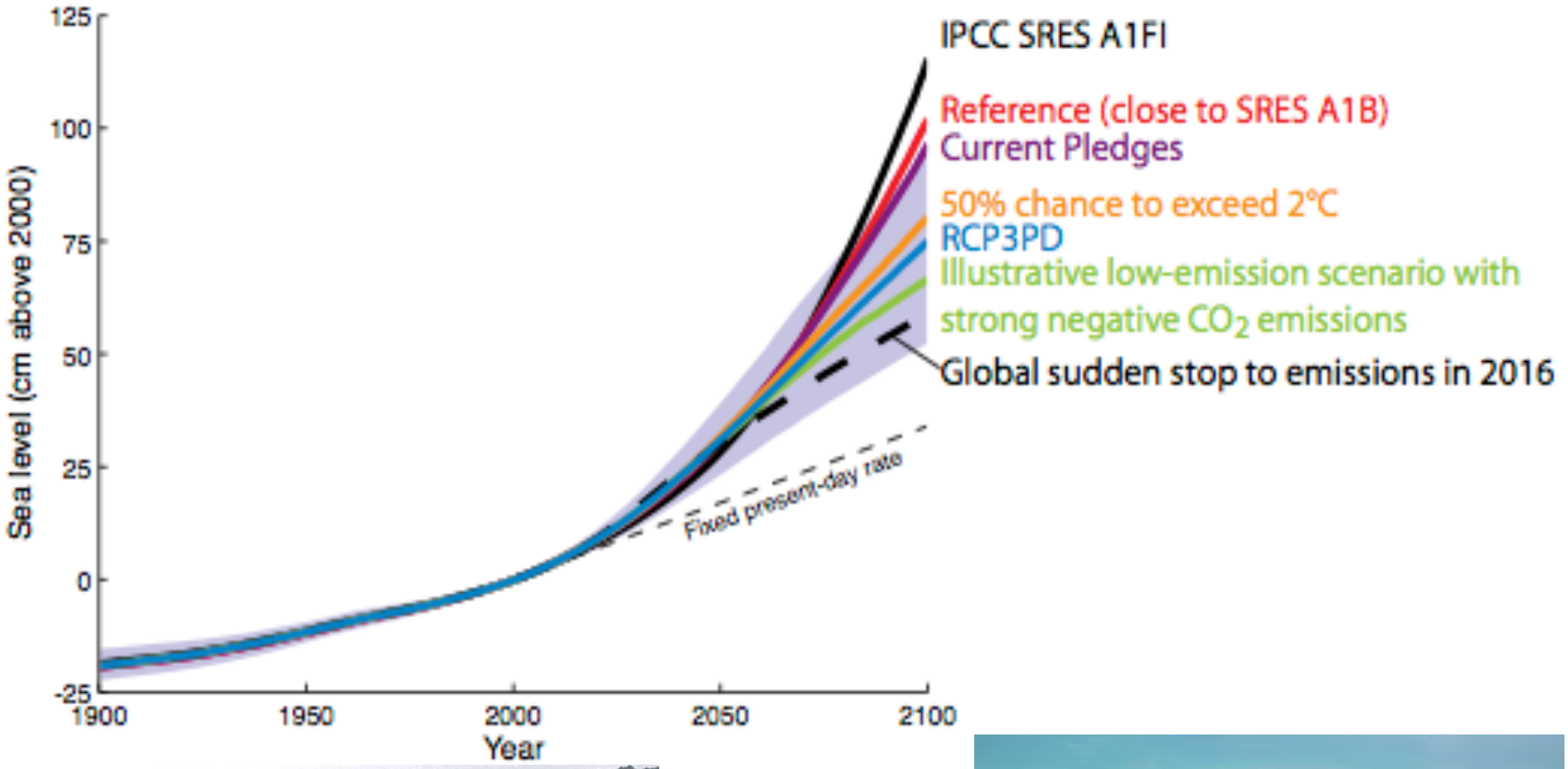
What Are The Options?

- Adaptation

- Mitigation

What Are The Options?

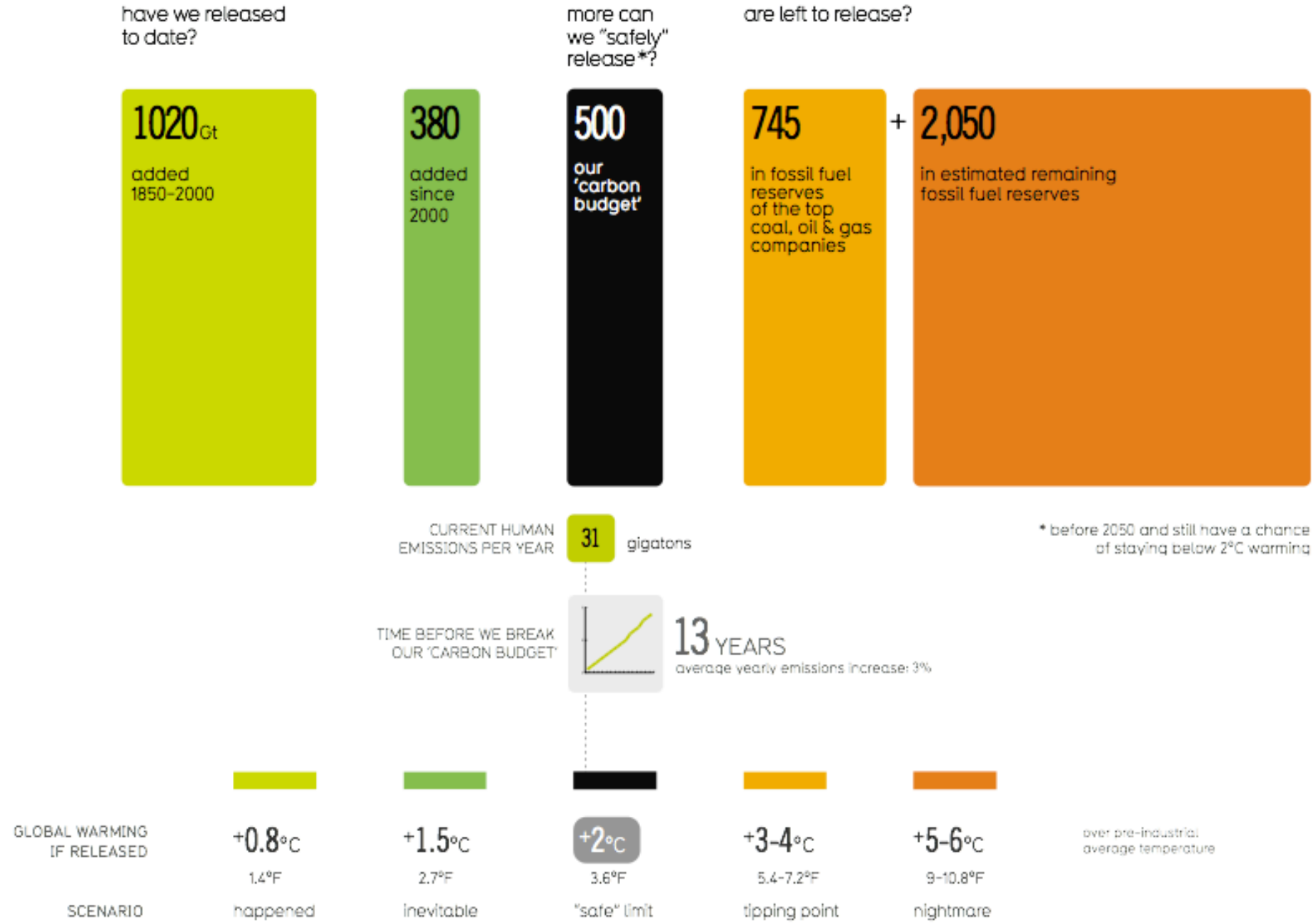
- Adaptation
  - Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  - Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)
- Mitigation



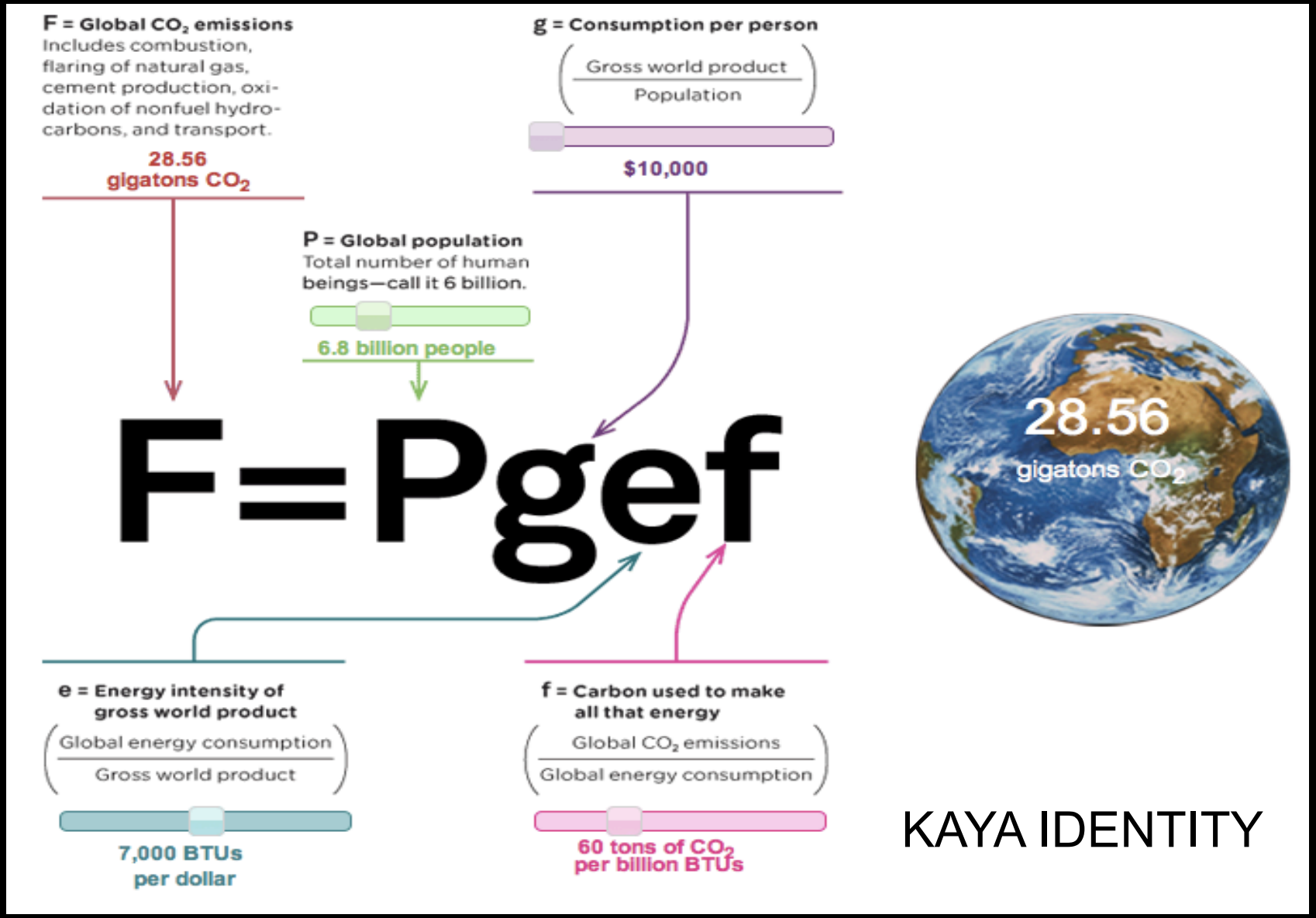
Maarten van Aalst / World Bank

What Are The Options?

- Adaptation
  - Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  - Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)
- Mitigation
  - Economic (taxes, cap and trade, R&D)
  - Regulatory (treaties, bans, compacts, fuel/energy standards, public transit, voluntary agreements)
  - Societal (sustainable development, education)
  - Technological (CO_2 capture, geoengineering, green tech, alternative energy, energy efficiency)

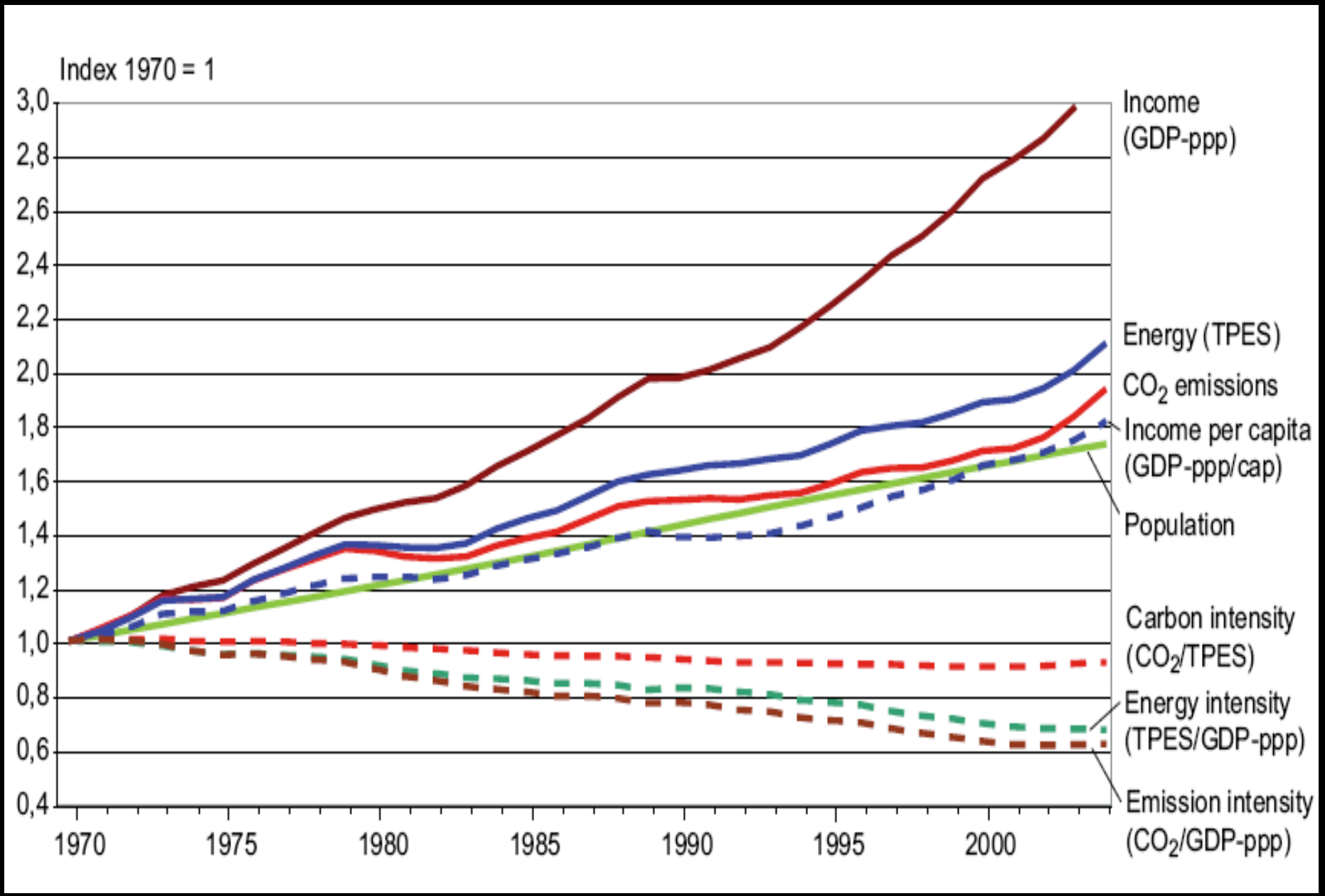


http://www.informationisbeautiful.net/2012/how-many-gigatons-of-co2/



KAYA IDENTITY

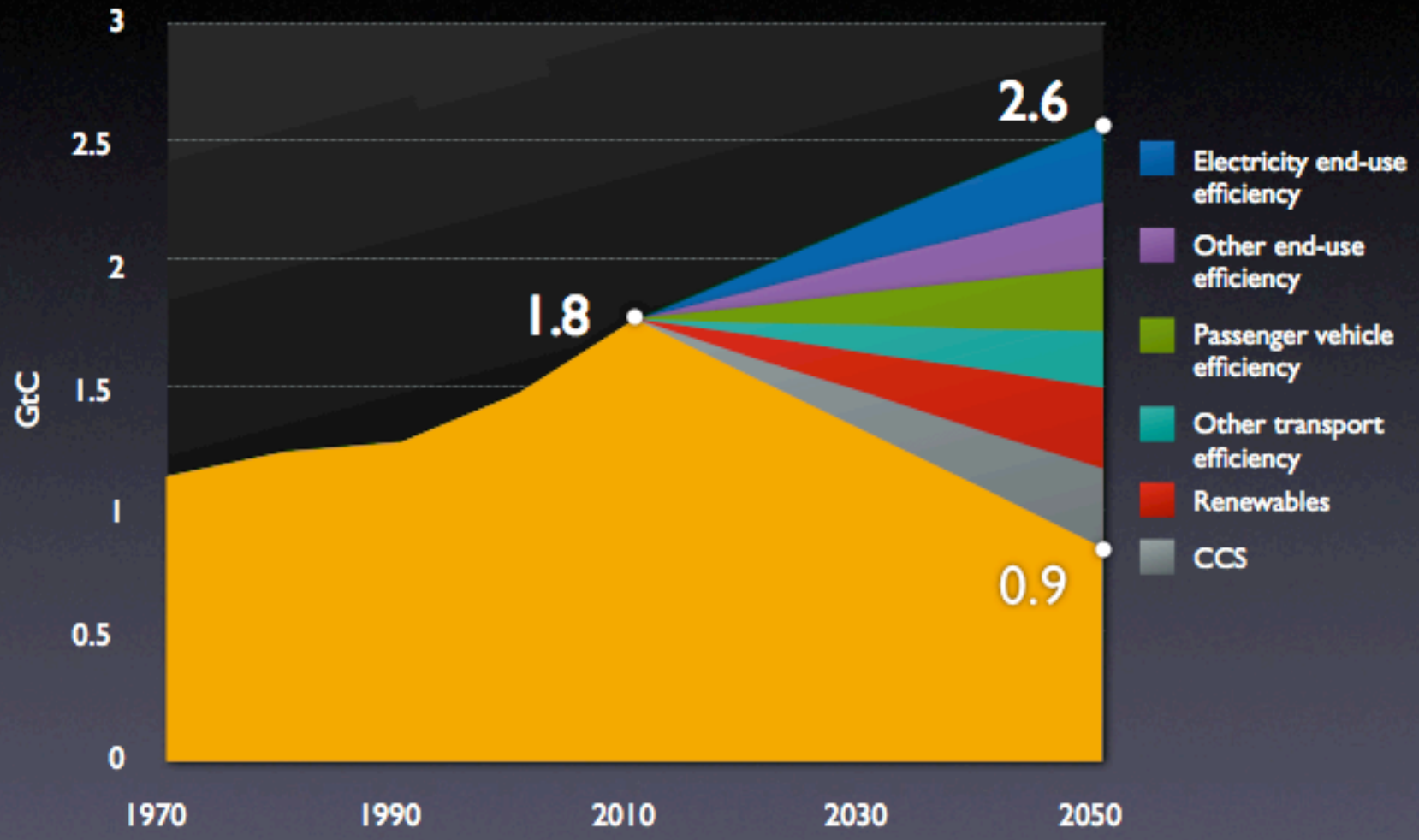
http://climatemodels.uchicago.edu/kaya/


Index 1970 = 1
3,0
2,8
2,6
2,4
2,2
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
1970
1975
1980
1985
1990
1995
2000
Income (GDP-ppp)
Energy (TPES)
CO2 emissions
Income per capita (GDP-ppp/cap)
Population
Carbon intensity (CO2/TPES)
Energy intensity (TPES/GDP-ppp)
Emission intensity (CO2/GDP-ppp)

U.S. Emissions

After Pacala and Socolow, 2004;
ARI CarBen3 Spreadsheet

- Carbon Capture & Storage



Why is climate policy so hard?

1990

SO, THIS CLIMATE CHANGE THING COULD BE A PROBLEM...

1995

CLIMATE CHANGE: DEFINITELY A PROBLEM.

2001

YEP, WE SHOULD REALLY BE GETTING ON WITH SORTING THIS OUT PRETTY SOON...

2007

LOOK, SORRY TO SOUND LIKE A BROKEN RECORD HERE...

2013

WE REALLY HAVE CHECKED AND WE'RE NOT MAKING THIS UP.

2019

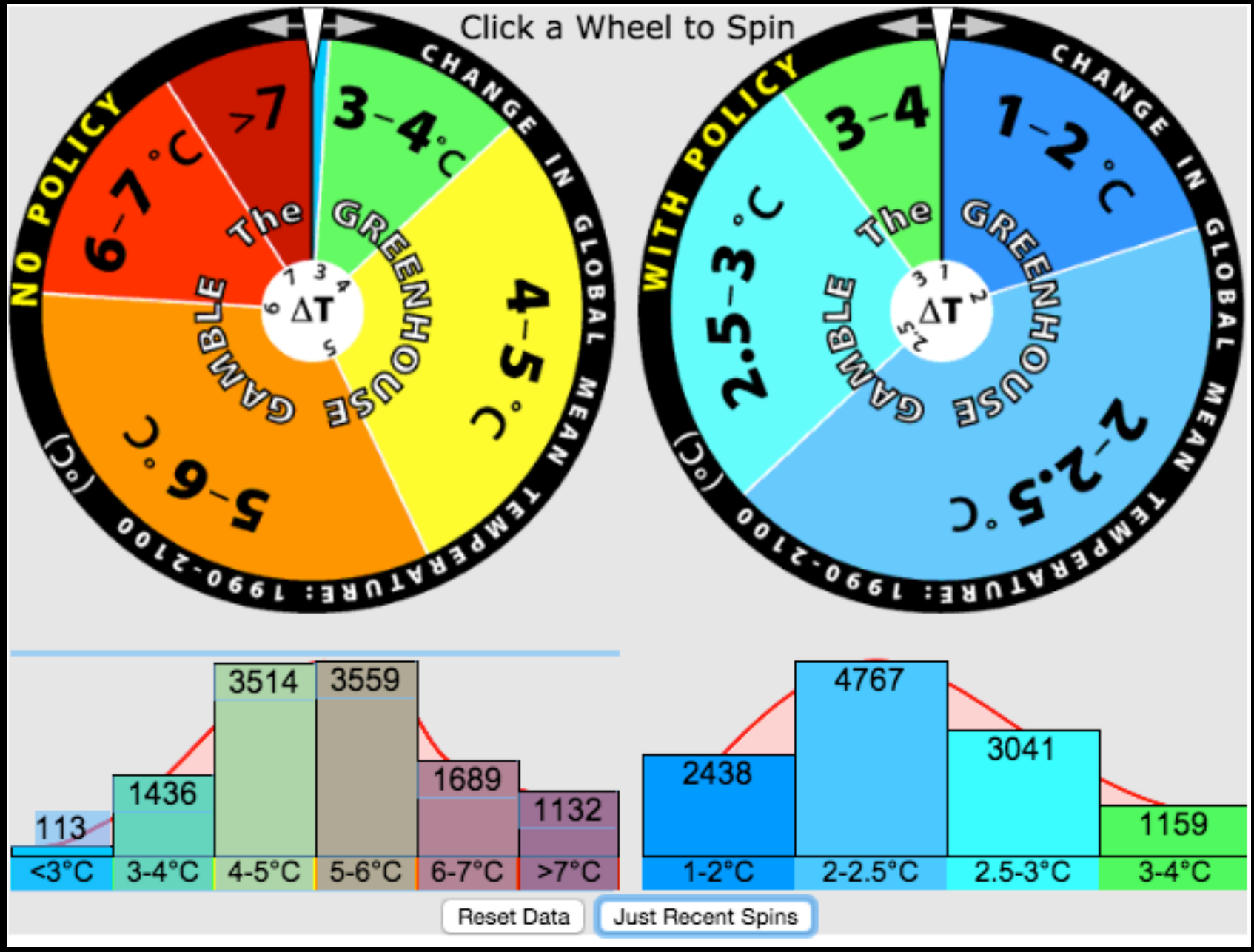
IS THIS THING ON?

TAP TAP TAP

KUDELKA. 28/9/13

- “I am not a scientist myself, but my best assessment of the data is that the world is getting warmer, that human activity contributes to that warming, and that policymakers should therefore consider the risk of negative consequences.”
  – Sept. 2012

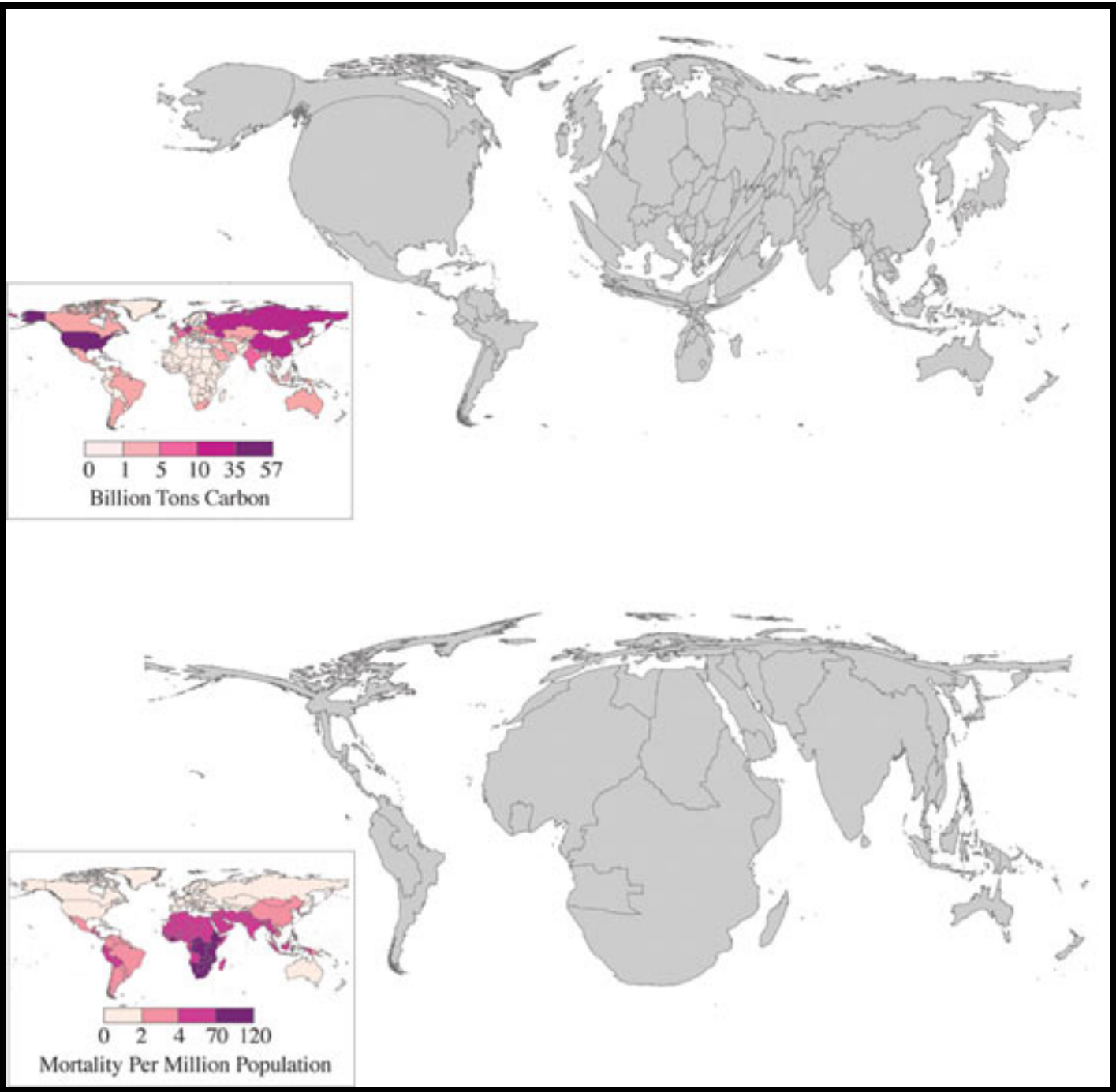
http://www.sciencedebate.org/debate12/

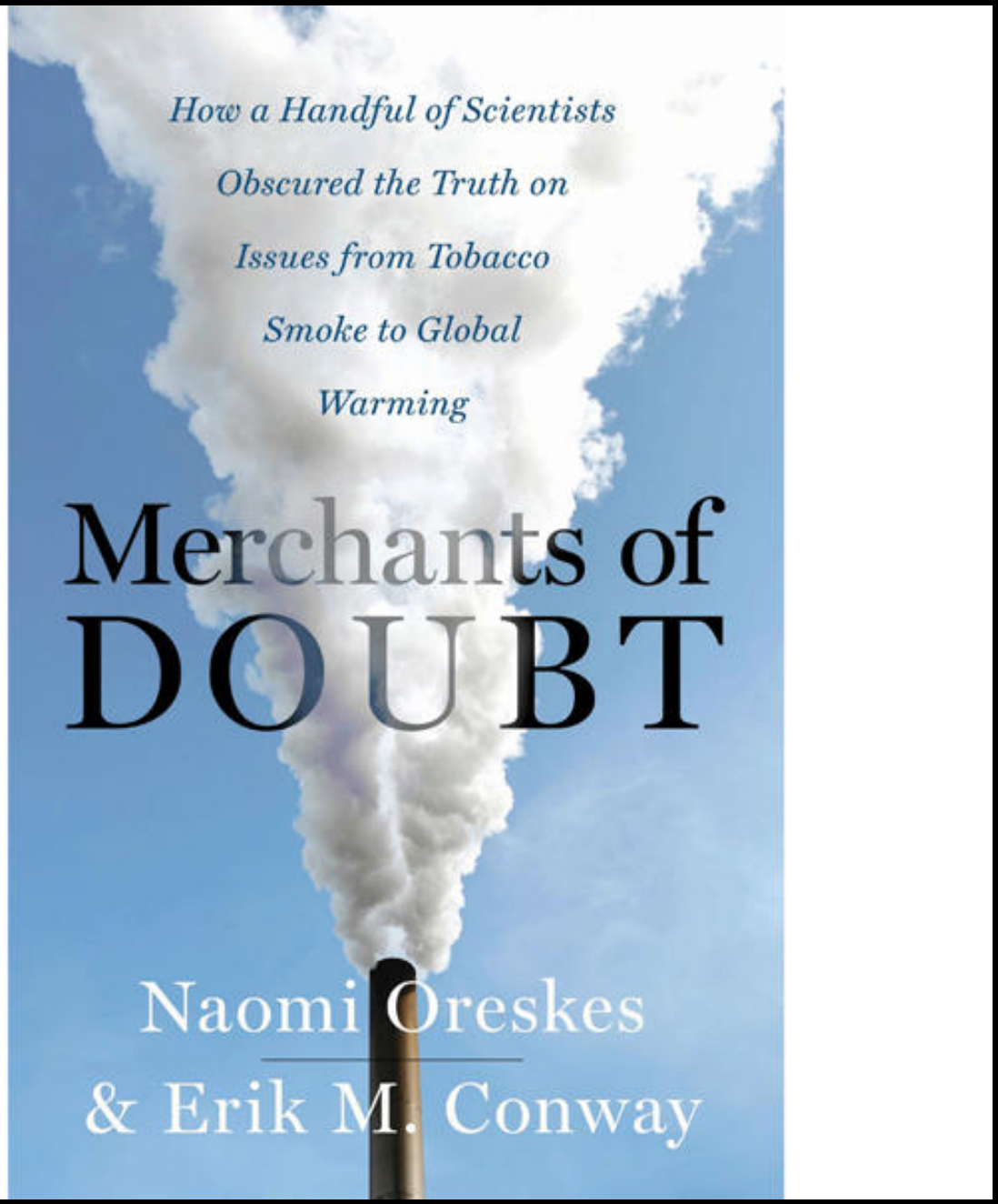


http://globalchange.mit.edu/focus-areas/uncertainty/gamble

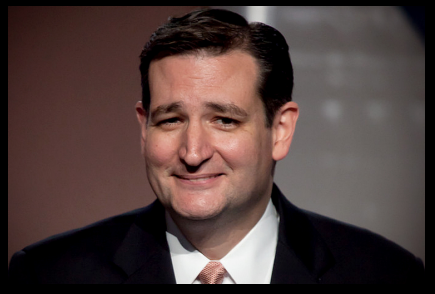
- “Higher temperatures and less-predictable weather would hurt poor farmers, most of whom live on the edge and can be devastated by a single bad crop. […] It would be a terrible injustice to let climate change undo any of the past half-century’s progress against poverty and disease—and doubly unfair because the people who will be hurt the most are the ones doing the least to cause the problem.”

Linkedin.com


0 1 5 10 35 57
Billion Tons Carbon
0 2 4 70 120
Mortality Per Million Population

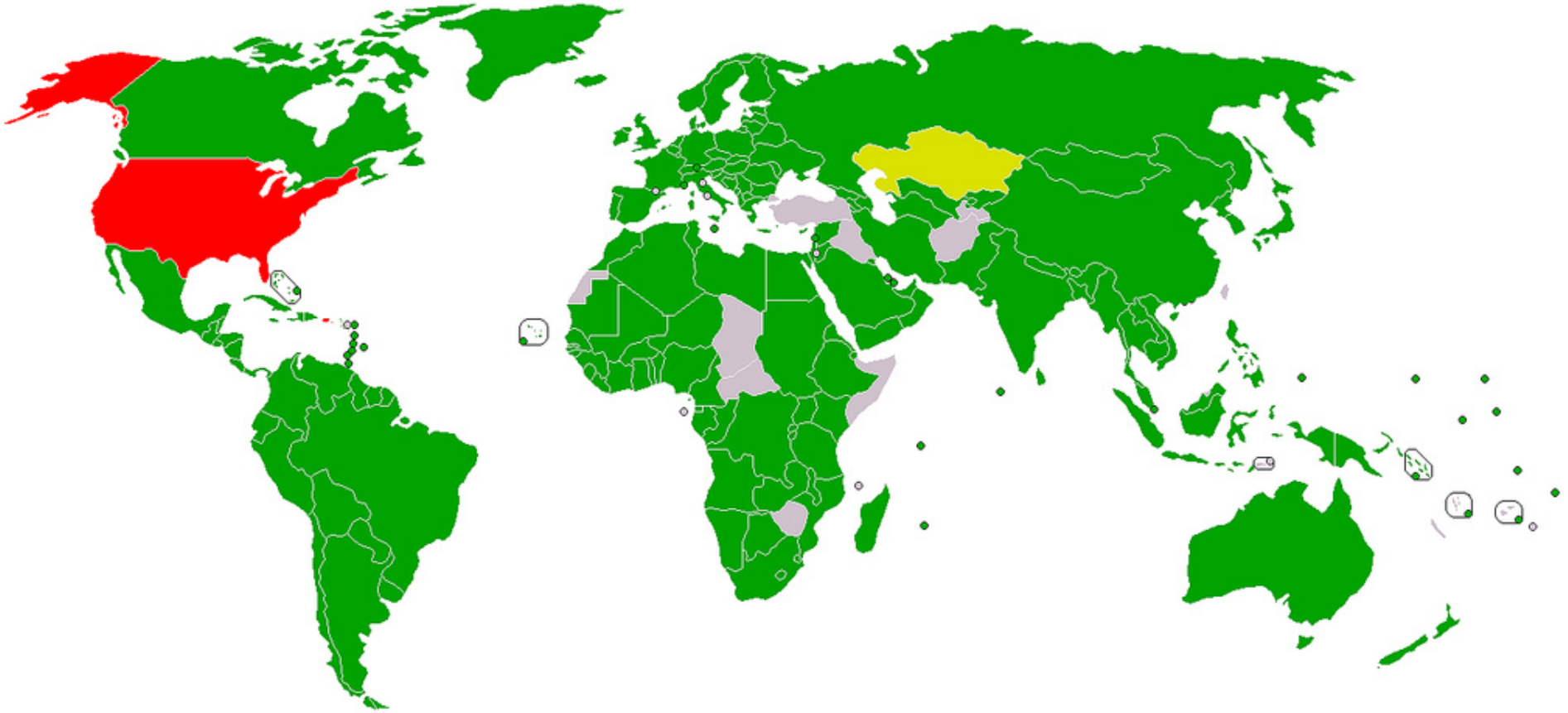

How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming
Merchants of DOUBT
Naomi Oreskes
& Erik M. Conway

- “If you look at global warming alarmists, they don't like to look at the actual facts and the data. The satellite data demonstrate that there has been no significant warming whatsoever for 17 years. […] I read this morning a Newsweek article from the 1970s talking about global cooling. And it said the science is clear, it is overwhelming, we are in a major cooling period... Now, the data proved to be not backing up that theory. So then all the advocates of global cooling suddenly shifted to global warming […] and the **solution interestingly enough was the exact same solution -- government control of the energy sector and every aspect of our lives.**”



Washington Post, 2 Aug 2015

UNFCCC and Kyoto Protocol

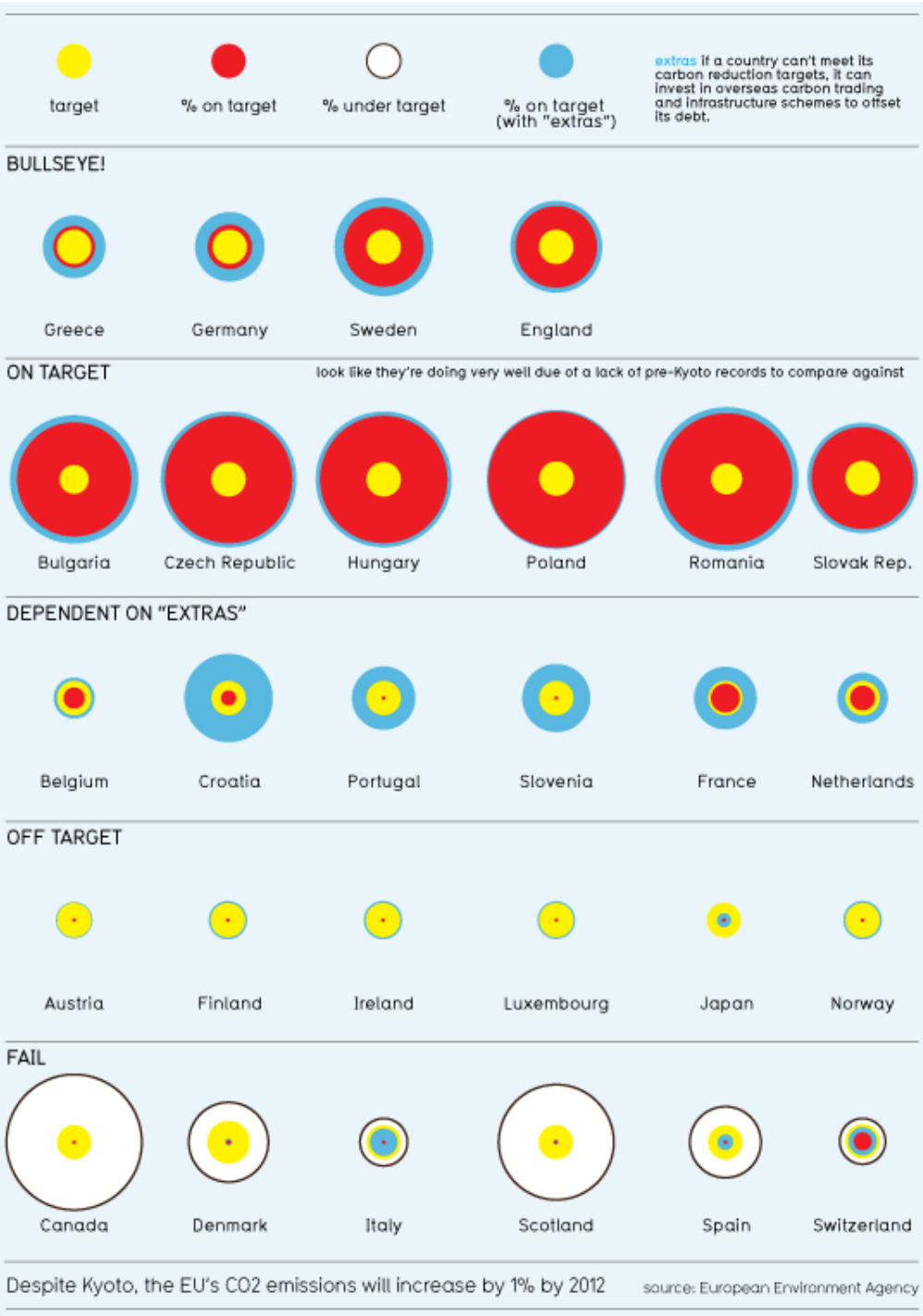


Signed and Ratified

Signed with intent to Ratify

Signed with no intent to Ratify

Non-Signatory



Global Treaties

- There is no international rules making body!
- Treaties are a game of incentives and disincentives to sign and to comply
- Individual countries weigh costs and benefits
- Compliance and monitoring are contentious issues

	Acid rain	Stratospheric ozone loss	Global warming
The Problem	Nox, SOX -> rain acidic -> corrosive to fish, lakes, roots/forest	High altitude ozone -> less uv -> less skin cancer CFCs	See preivous 45 slides
Costs/ benefits	Energy production Ecosystems -> food chain. forestry	CFC -> DuPont Skin cancer 100000:1	2C -> mix 4C -> bad for all 2:1 1:1
Solution(s)	CLRTAP – reduce NOX,SOX National regulation -> Clean Air Act,	Ban CFCs -> Vienna Convention, Montreal Protocol	Mitigate Who emits, who vulnerable not safe Players -> Co2 = everyone
Mechanism	1990 NAAQS Cap and Trade	Alternatives, payment to developing countries	Kyoto -> cap and trade , global/country Pay for damages, tech transfer

- “Power plants are the single biggest source of harmful carbon pollution that contributes to climate change. Until now, there have been no federal limits to the amount of carbon pollution plants dump in the air.”

CNN

Commitments from COP20

- China: carbon intensity in 2020 40% below 2005 (emissions still rise), peak carbon emissions 2030
- U.S.: 2025 26-28% emissions below 2005 (double earlier pace), 2050 83% below
- South Korea: 30% below business as usual by 2020 (emissions doubled 1990-2005)
- Russia: 25%
- Brazil: 38-42% below 2020 projection, half by deforestation reduction (REDD)
- Australia: 5-20% below 2000 by 2020
- India: carbon intensity 20% lower by 2020

The future?

- Climate scientists will continue to refine projections of future change and impacts in response to emissions and/or policy
- Global treaty progress will likely be slow, but there are successes in deforestation reduction, developing country support, and renewal energy infrastructure
- Bi- or Multi- lateral agreements (e.g., US-China) and within country “energy arms race” may end up having the biggest bang for buck
- Fossil fuel reserves are getting scarcer, but not running out anytime soon. Given lags in climate response, some level of adaptation is inevitable

DISCUSSION?