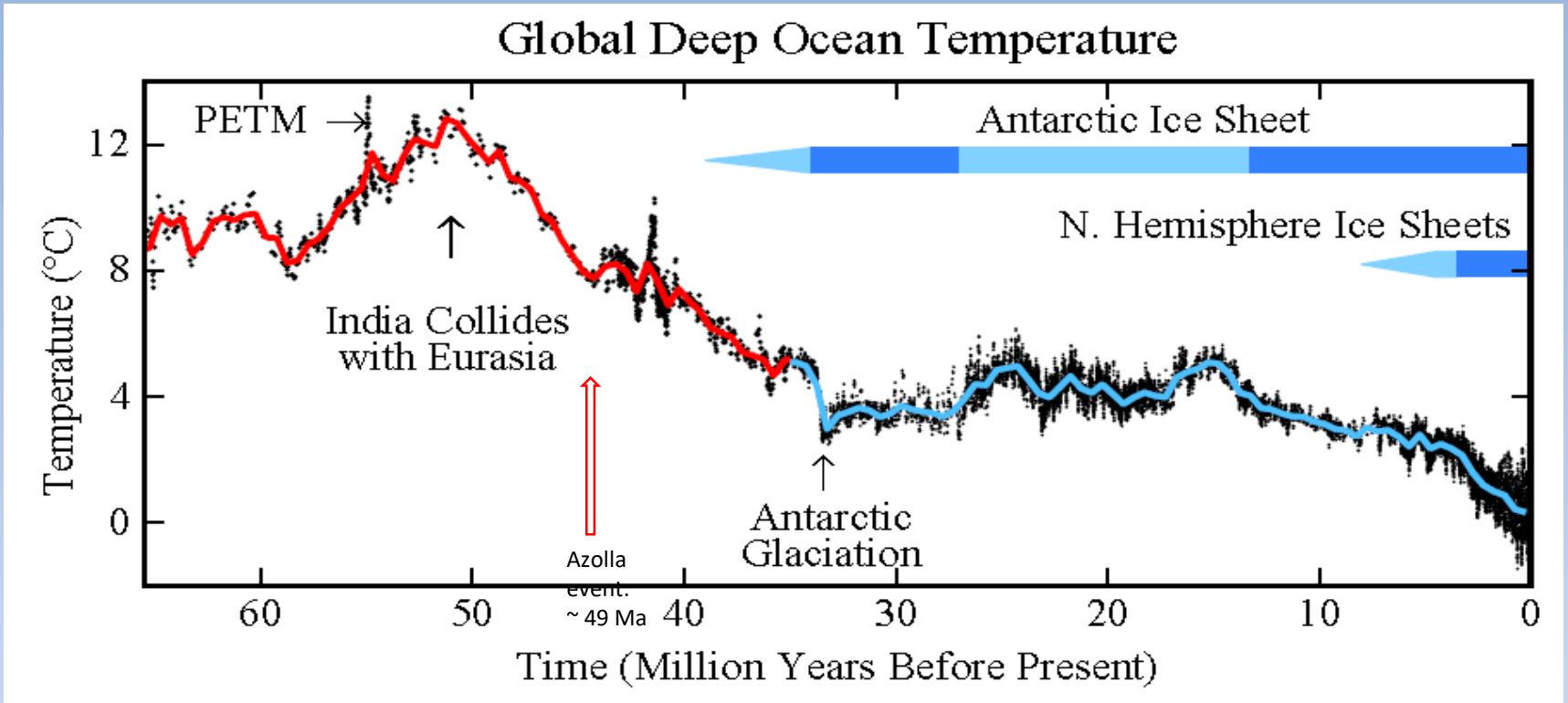
Contemporary Issues Regarding Climate Change and Solutions

Paul Belanger, Ph.D.,
Geologist/Paleoclimatologist

Tuesday October 10th , 2017:

- **Follow up to NICL**
- **Contemporary events**
- **Population**

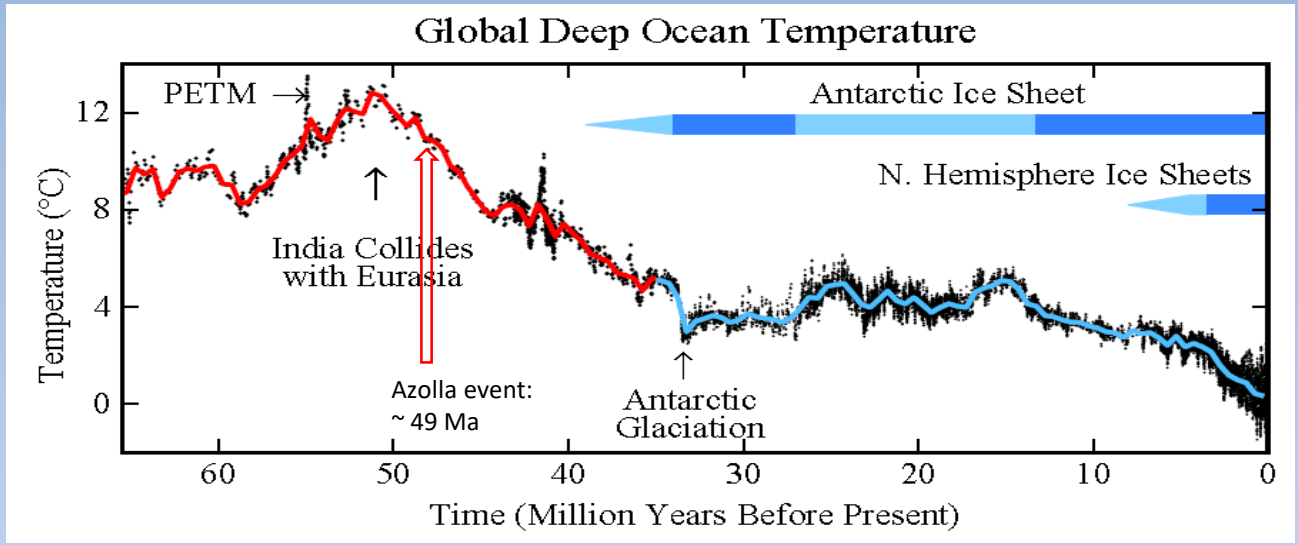
Follow-up to NICL

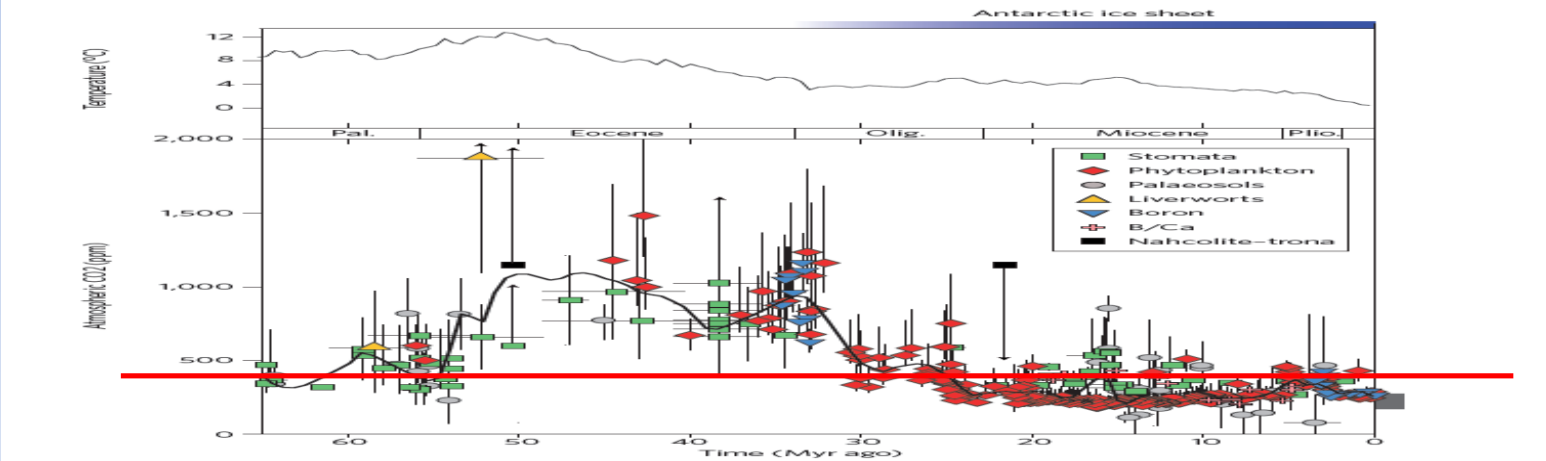


50 million years ago (50 MYA) Earth was ice-free.

Atmospheric CO_2 amount was of the order of 1000 ppm 50 MYA.

Atmospheric CO_2 imbalance due to plate tectonics ~ 10^{-4} ppm per year.


Global Deep Ocean Temperature
PETM
India Collides with Eurasia
Azolla event: ~ 49 Ma
Antarctic Glaciation
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
Temperature (°C)
Time (Million Years Before Present)


Antarctic ice sheet
Temperature (°C)
Pal.
Eocene
Olig.
Miocene
Plio.
Stomata
Phytoplankton
Palaeosols
Liverworts
Boron
B/Ca
Nahcolite-trona
Atmospheric CO2 (ppm)
Time (Myr ago)

Long-term Carbon Cycle: rocks

Two generalized reactions…

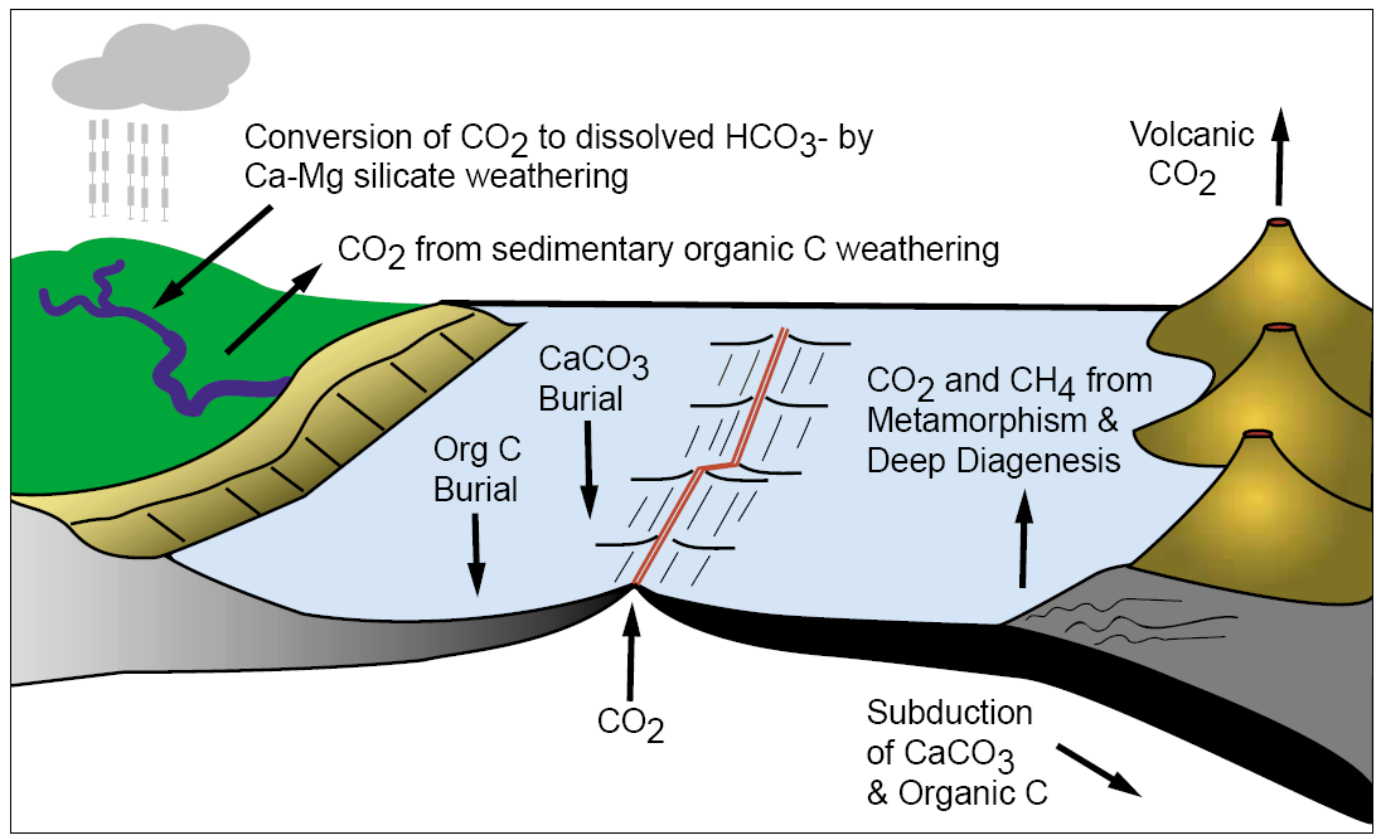
Photosynthesis/Respiration

$$CO_2 + H_20 \leftrightarrow CH_2O + O_2$$

Weathering/Precipitation

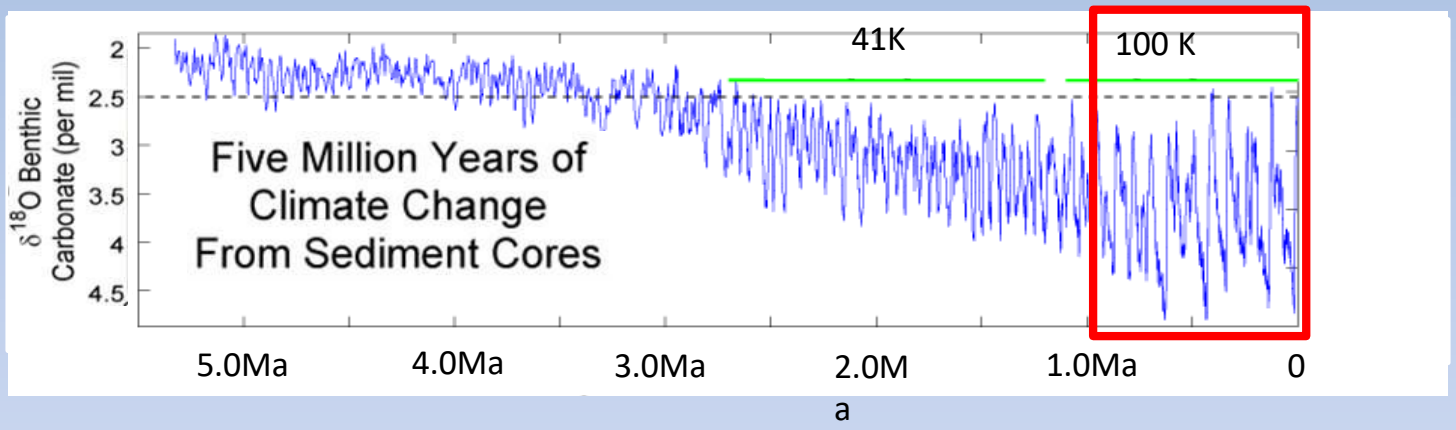
$$CO_2 + CaSiO_3 \leftrightarrow CaCO_3 + SiO_2$$

Long-term carbon cycle: *rocks*

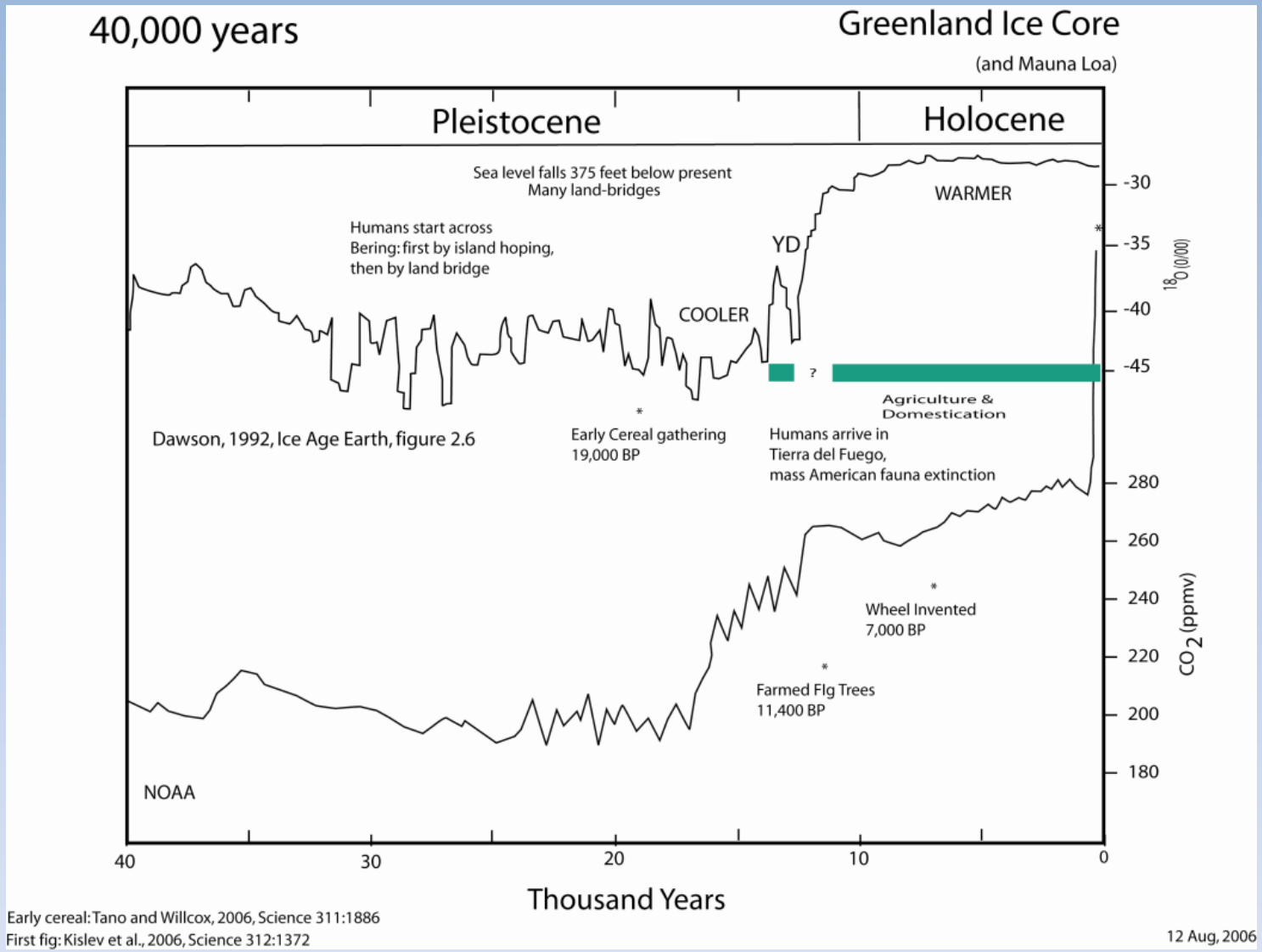


Berner, 2001

Climate Changes from Ocean Sediment Cores, since 5 Ma. Milankovitch Cycles

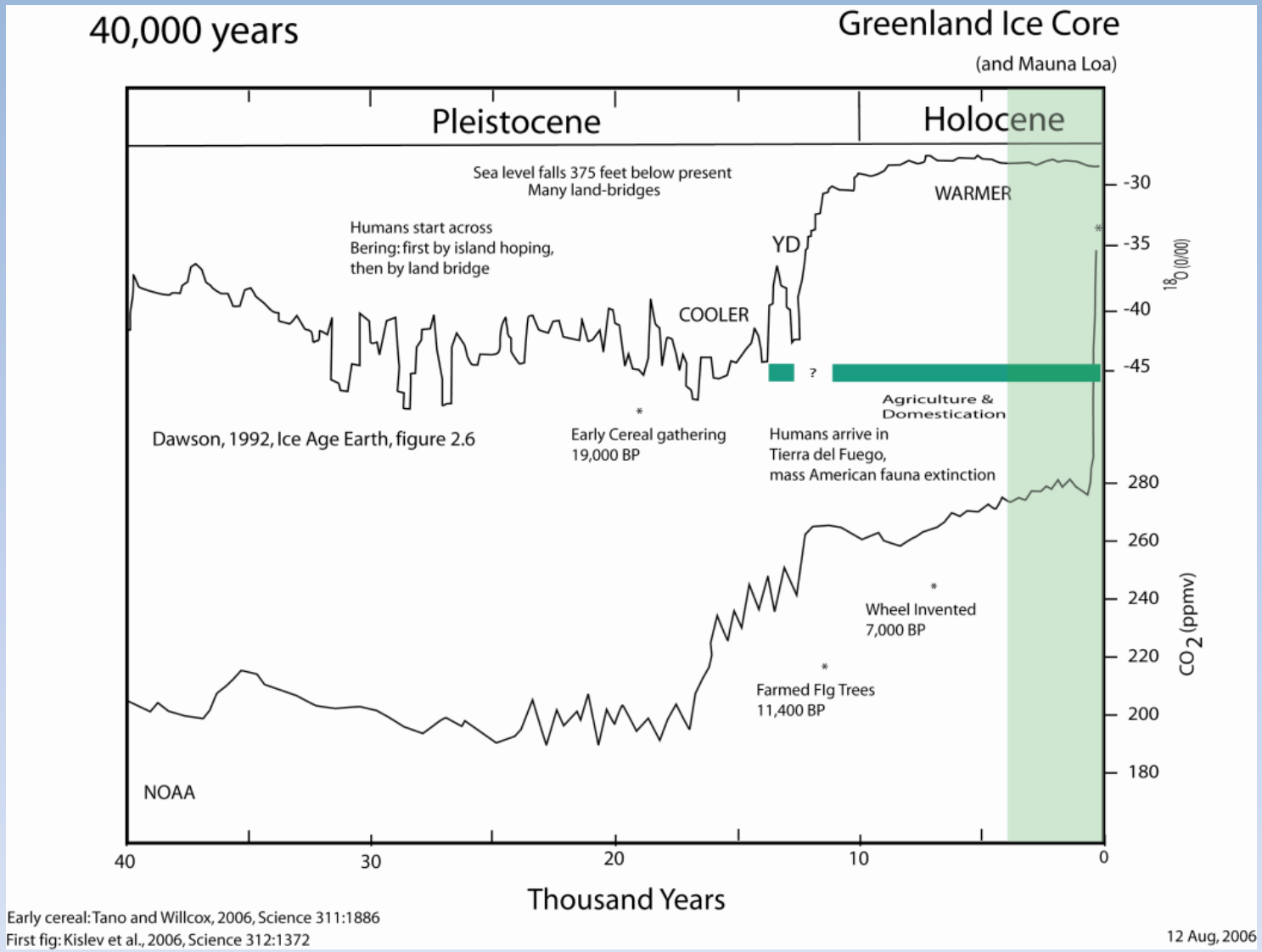


When CO_2 levels get below ~400-600 ppm Orbital parameters become more important than CO_2



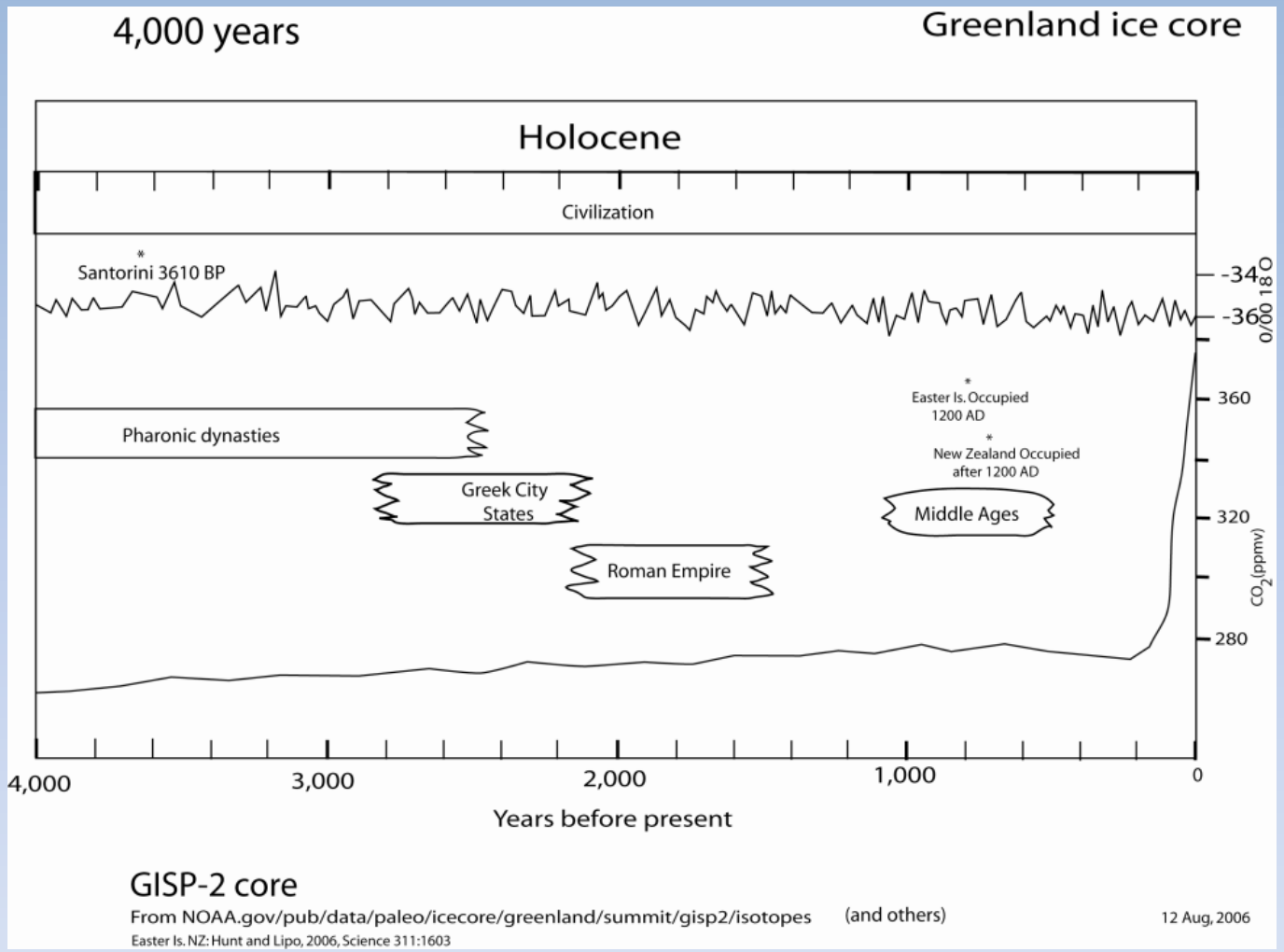
Early cereal: Tano and Willcox, 2006, Science 311:1886
First fig: Kislev et al., 2006, Science 312:1372

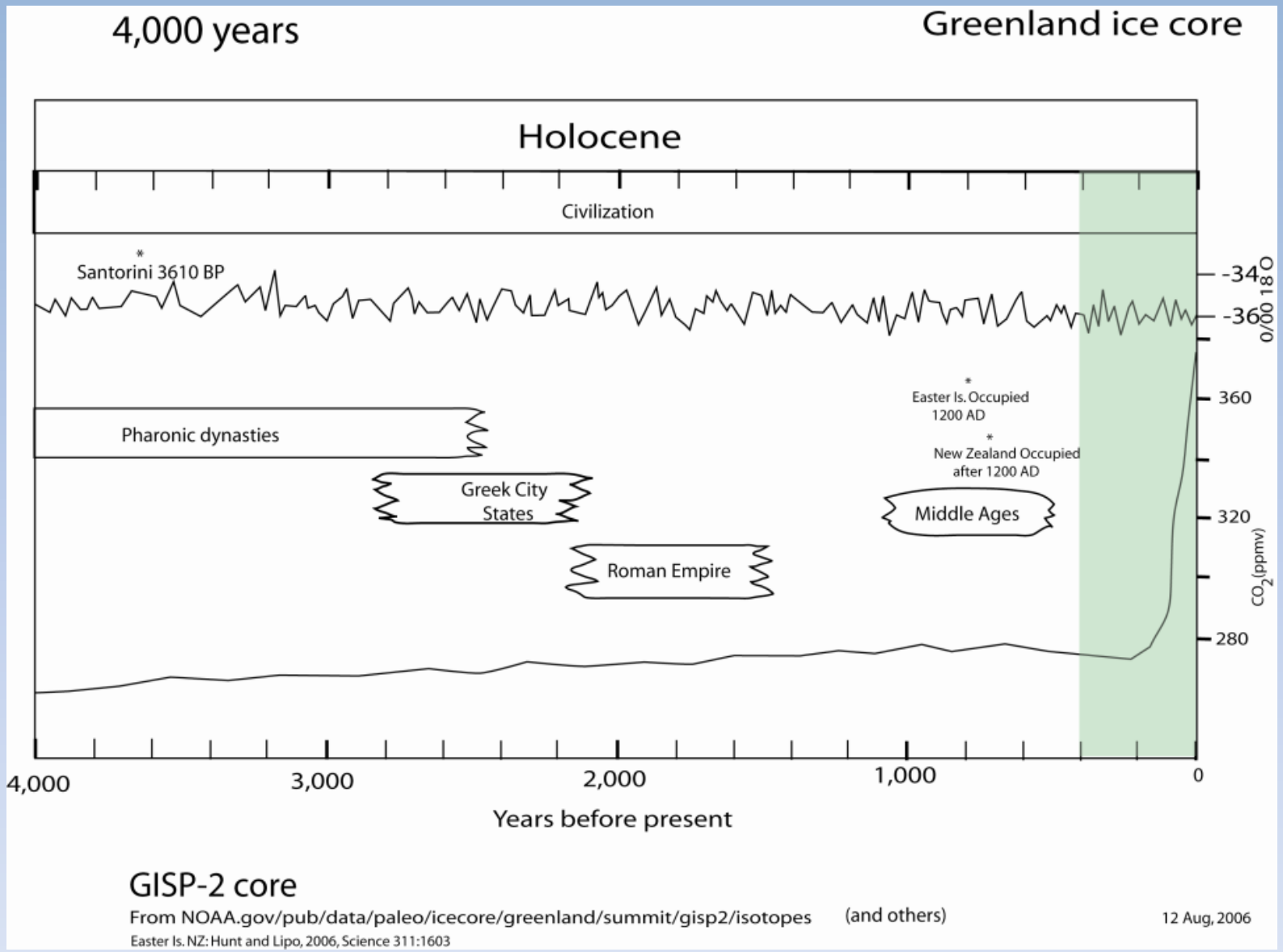
12 Aug, 2006

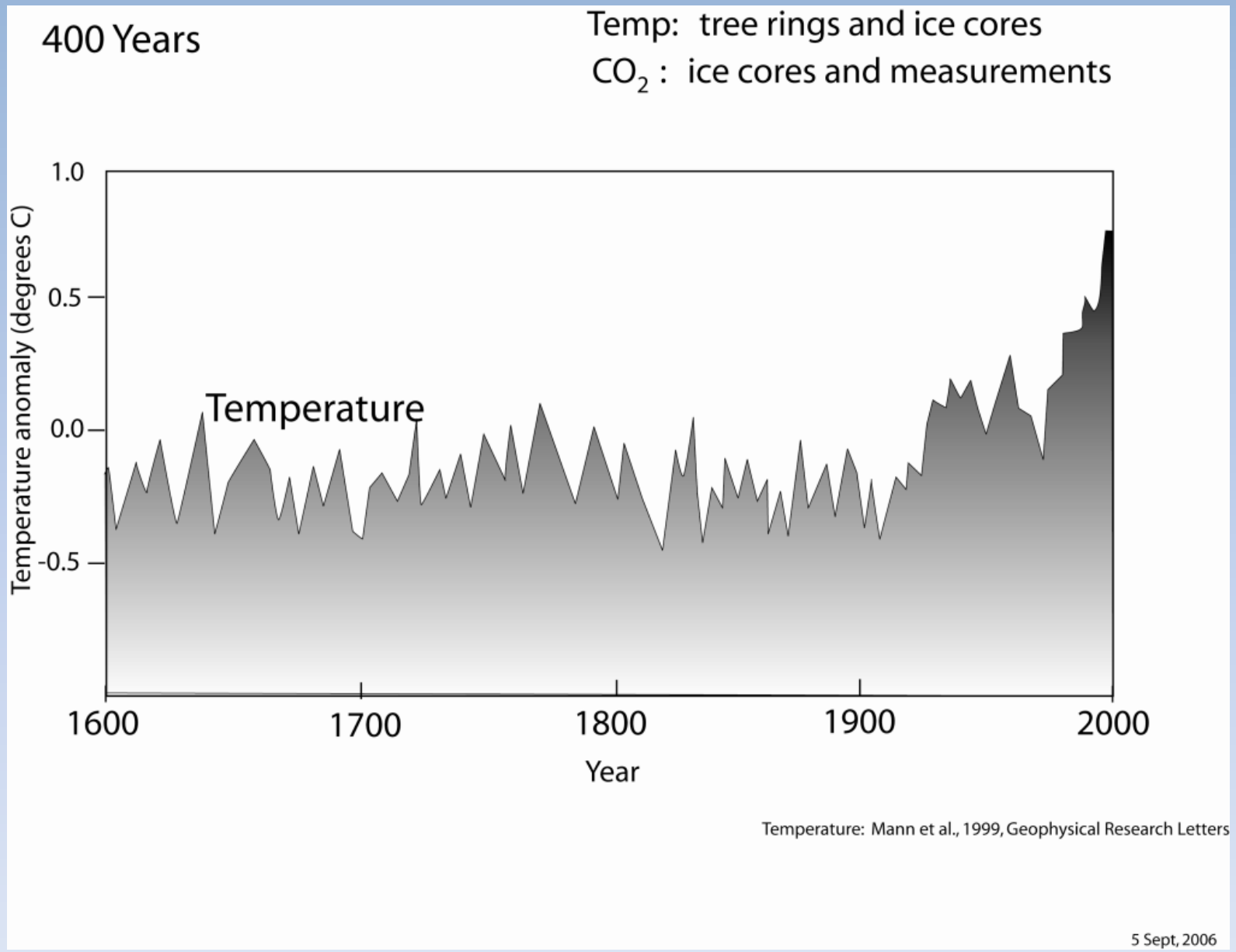


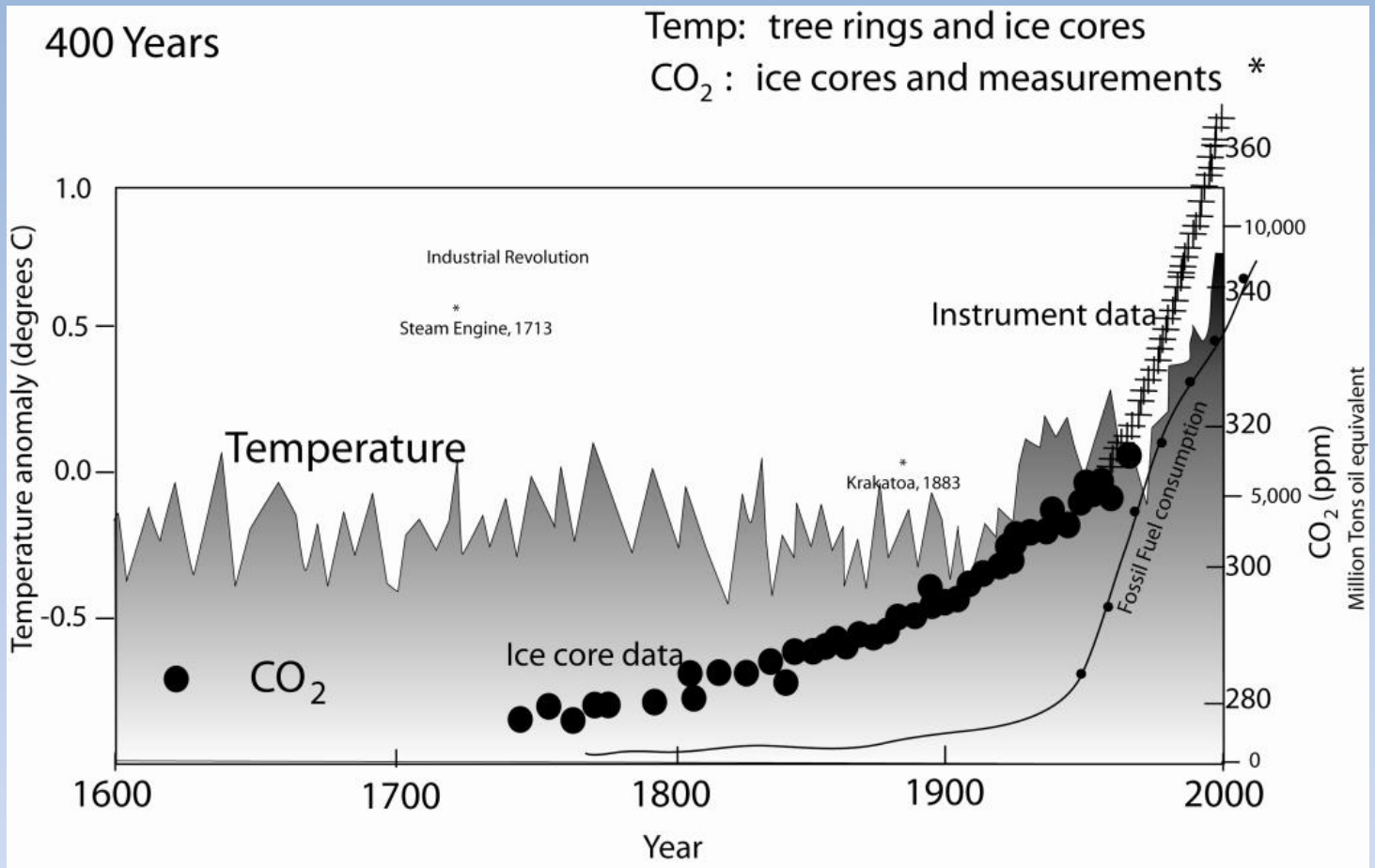
Early cereal: Tano and Willcox, 2006, Science 311:1886
First fig: Kislev et al., 2006, Science 312:1372

12 Aug, 2006


4,000 years
Greenland ice core
Holocene
Civilization
Santorini 3610 BP
-34
-36
0/00 18O
Easter Is. Occupied
1200 AD
New Zealand Occupied
after 1200 AD
Pharonic dynasties
Greek City
States
Middle Ages
Roman Empire
360
320
280
CO2 (ppmv)
4,000
3,000
2,000
1,000
0
Years before present
GISP-2 core
From NOAA.gov/pub/data/paleo/icecore/greenland/summit/gisp2/isotopes
(and others)
12 Aug, 2006
Easter Is. NZ: Hunt and Lipo, 2006, Science 311:1603


4,000 years
Greenland ice core
Holocene
Civilization
Santorini 3610 BP
-34
-36
o/oo 18O
Easter Is. Occupied
1200 AD
New Zealand Occupied
after 1200 AD
Pharonic dynasties
Greek City
States
Middle Ages
Roman Empire
360
320
280
CO2(ppmv)
4,000
3,000
2,000
1,000
0
Years before present
GISP-2 core
From NOAA.gov/pub/data/paleo/icecore/greenland/summit/gisp2/isotopes
(and others)
12 Aug, 2006
Easter Is. NZ: Hunt and Lipo, 2006, Science 311:1603


400 Years
Temp: tree rings and ice cores
CO_2 : ice cores and measurements
1.0
0.5
0.0
-0.5
Temperature anomaly (degrees C)
Temperature
1600
1700
1800
1900
2000
Year
Temperature: Mann et al., 1999, Geophysical Research Letters
5 Sept, 2006

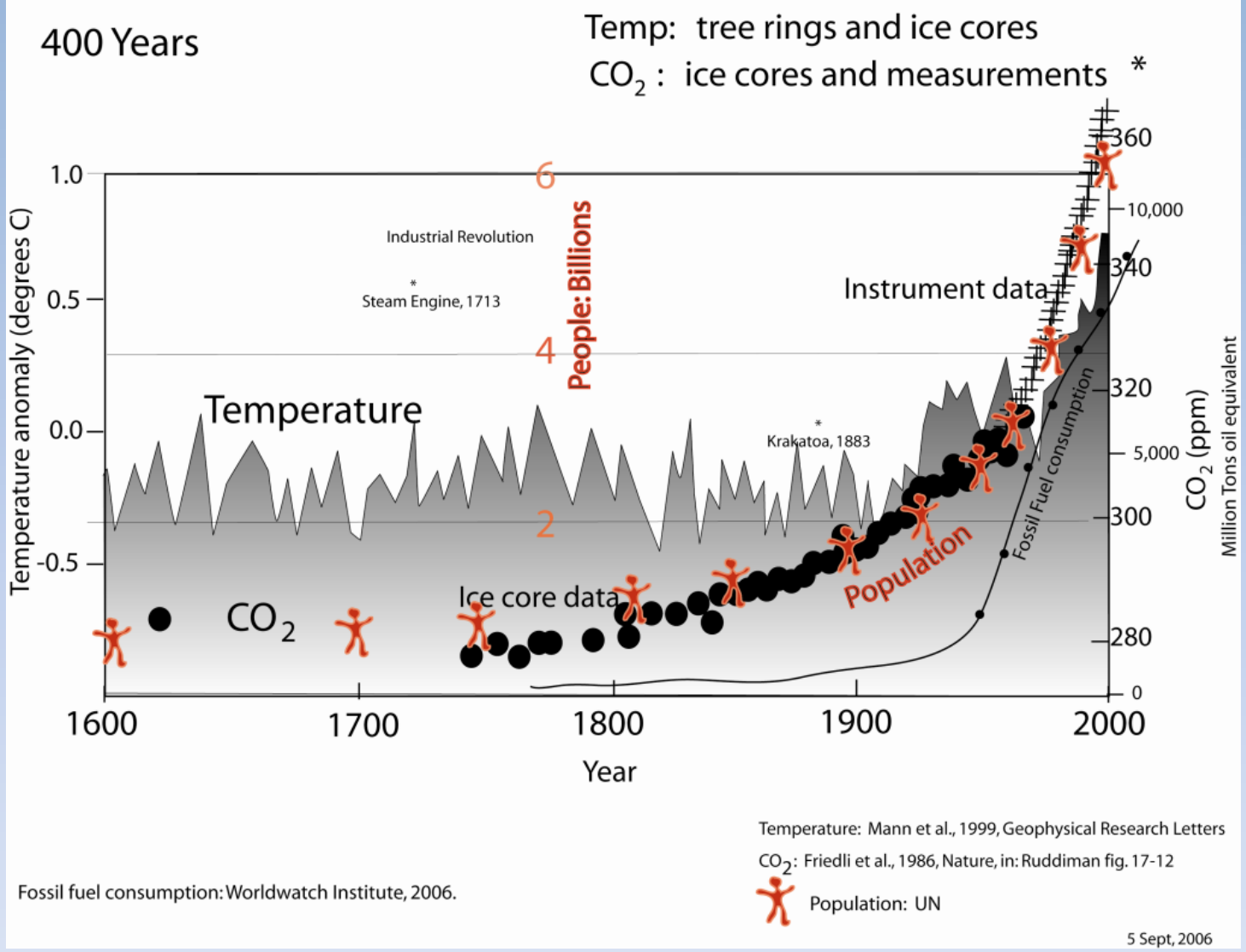


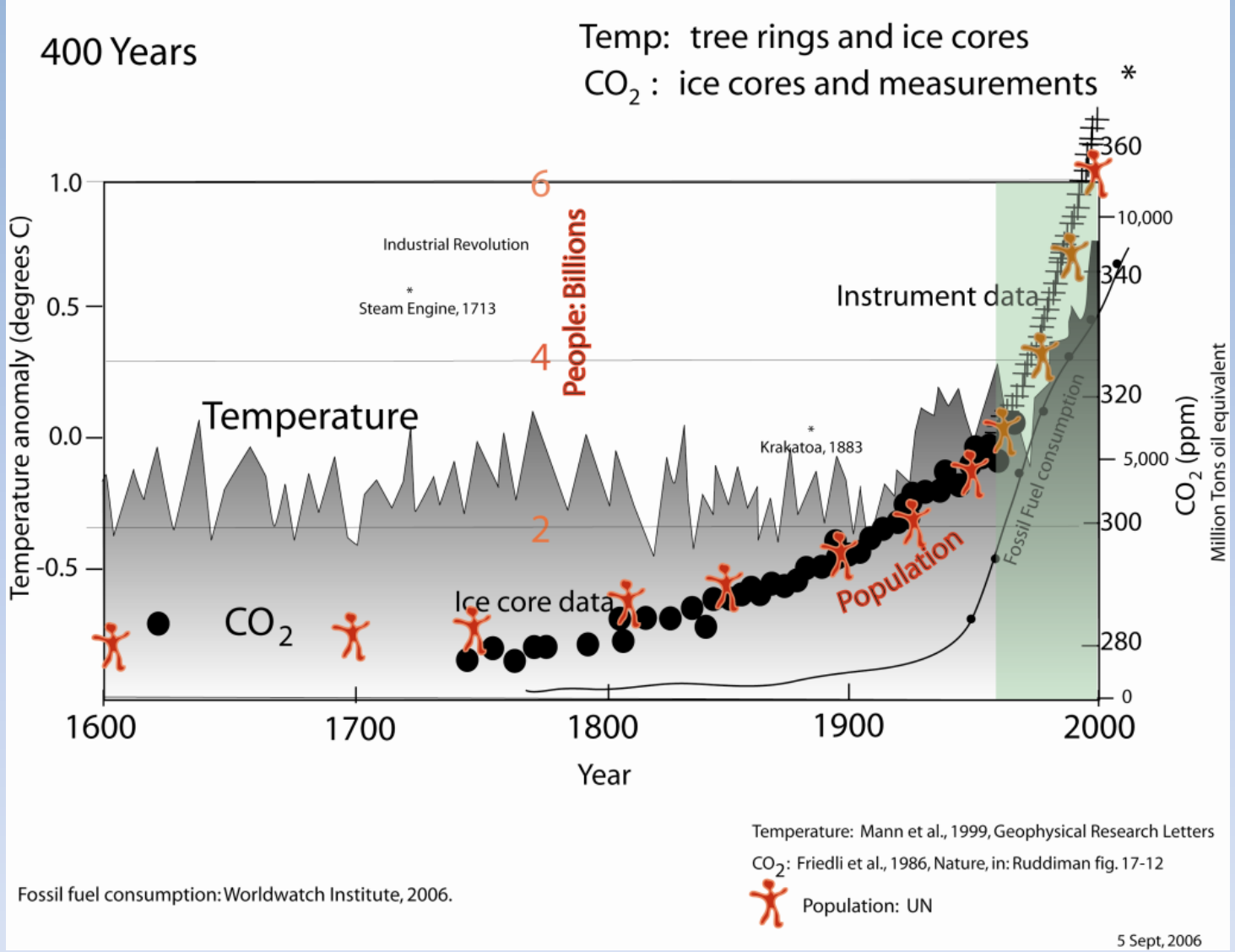
Temperature: Mann et al., 1999, Geophysical Research Letters

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

Fossil fuel consumption: Worldwatch Institute, 2006.

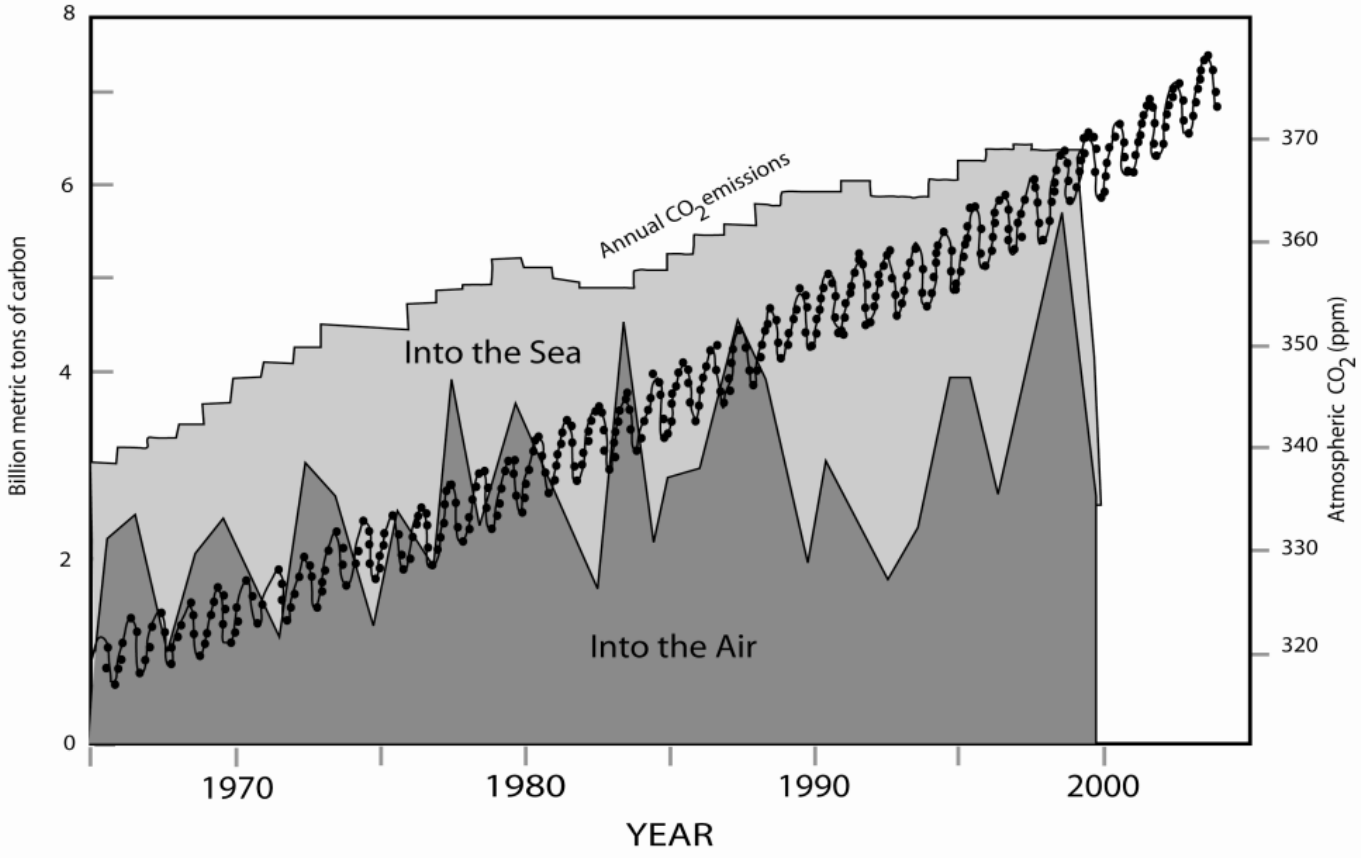
5 Sept, 2006


400 Years
Temp: tree rings and ice cores
CO_2 : ice cores and measurements *
Temperature anomaly (degrees C)
1.0
0.5
0.0
-0.5
1600
1700
1800
1900
2000
Year
6
4
2
People: Billions
Industrial Revolution
*
Steam Engine, 1713
Temperature
CO_2
Ice core data
*
Krakatoa, 1883
Instrument data
Population
Fossil Fuel consumption
360
340
320
300
280
0
10,000
5,000
CO_2 (ppm)
Million Tons oil equivalent
Temperature: Mann et al., 1999, Geophysical Research Letters
CO_2: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12
Population: UN
Fossil fuel consumption: Worldwatch Institute, 2006.
5 Sept, 2006


400 Years
Temp: tree rings and ice cores
CO_2 : ice cores and measurements *
Temperature anomaly (degrees C)
1.0
0.5
0.0
-0.5
Industrial Revolution
*
Steam Engine, 1713
Temperature
CO_2
Ice core data
*
Krakatoa, 1883
6
4
2
People: Billions
Instrument data
Population
Fossil Fuel consumption
1600
1700
1800
1900
2000
Year
360
340
320
300
280
0
10,000
5,000
CO_2 (ppm)
Million Tons oil equivalent
Temperature: Mann et al., 1999, Geophysical Research Letters
CO_2: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12
Population: UN
Fossil fuel consumption: Worldwatch Institute, 2006.
5 Sept, 2006

40 Years

CO_2 emitted by man and CO_2 in the Atmosphere

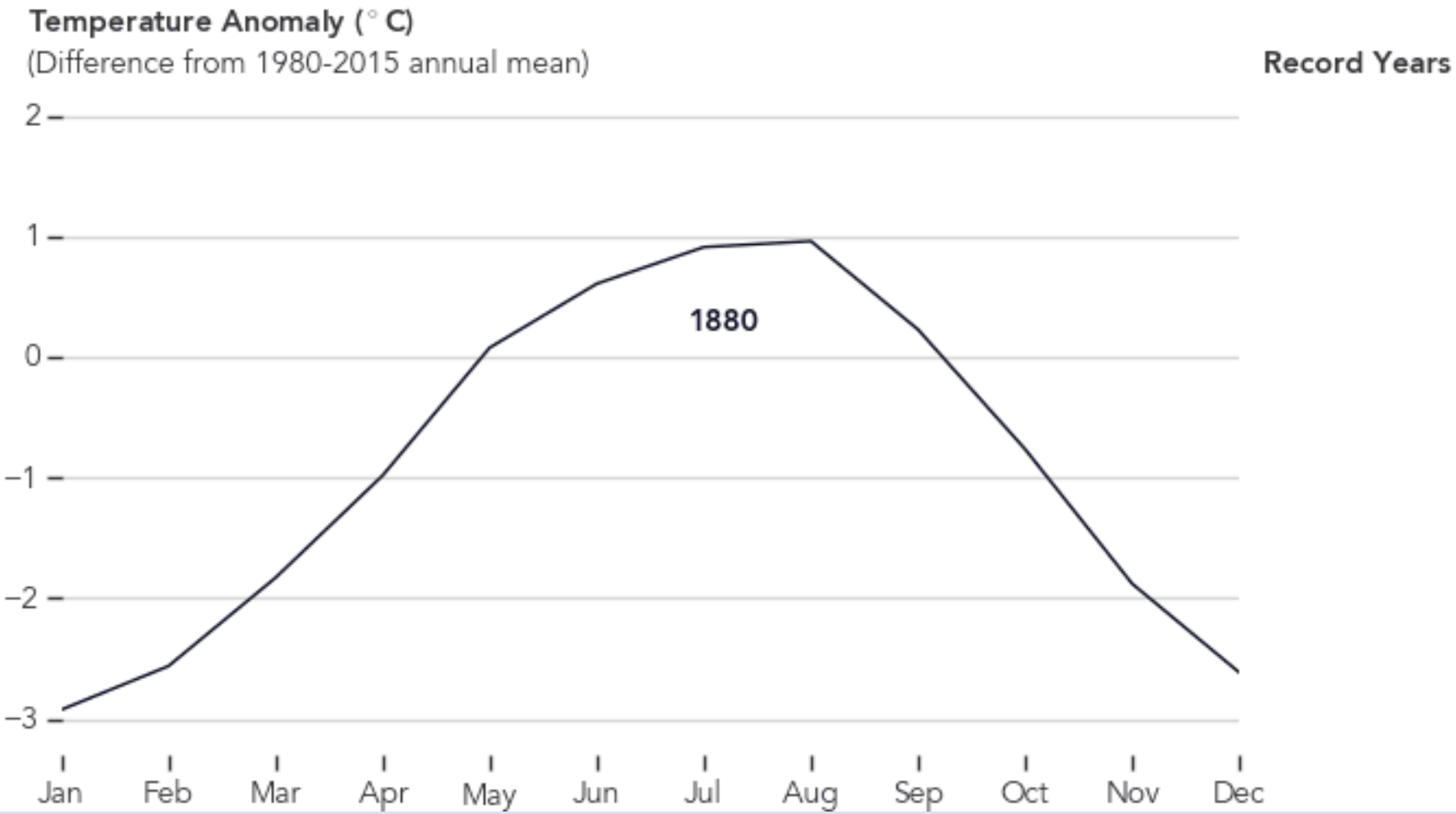


Fossil fuel emission: www.grida.no/climate/ipcc_tar/wg1/fig3-3.htm

CO_2 : Mauna Loa, Scripps, NOAA

25 August, 2006

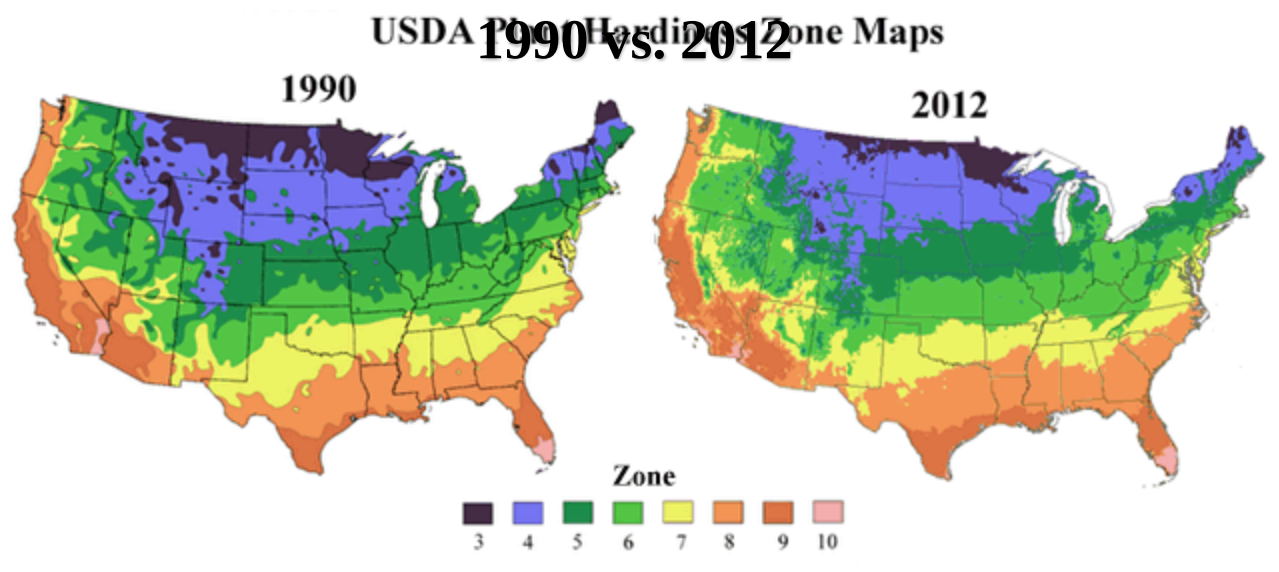
Seasonal change 1880-2016 (NASA)



Goddard Institute for Space Studies

Plants and Animals are Responding to a Warming Climate

1990 vs. 2012



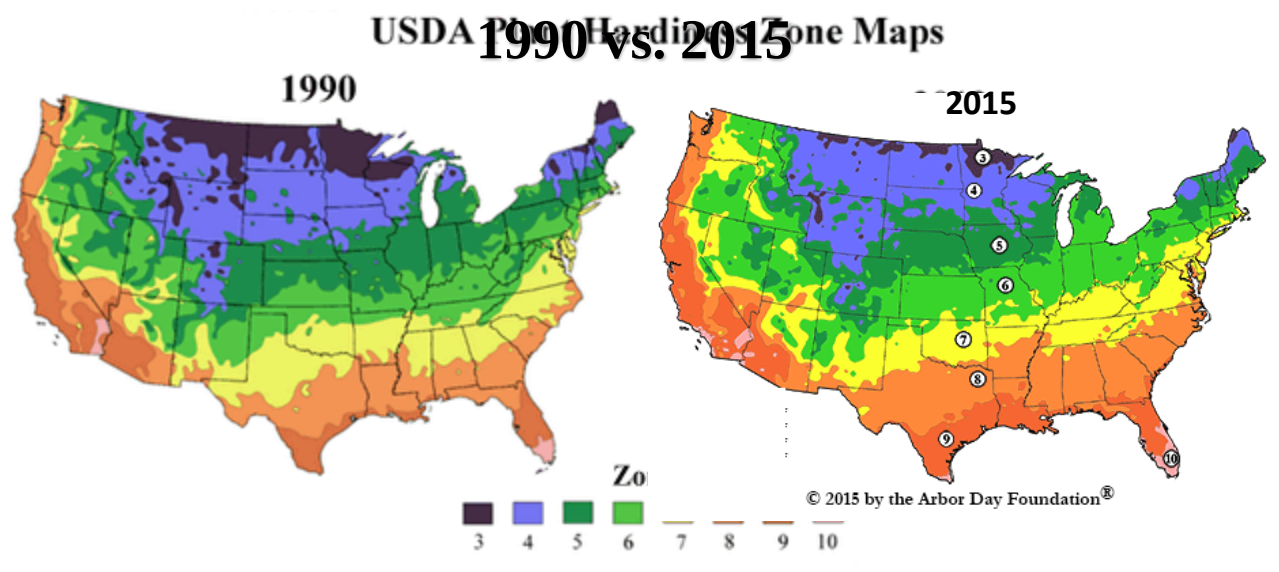
Spring is springing forward: Spring events, like bird and butterfly migrations, flower blooming times, and frog mating, have been advancing by about three days per decade over the past 30 years.

Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

https://www.arborday.org/media/zones.cfm

Plants and Animals are Responding to a Warming Climate

1990 vs. 2015

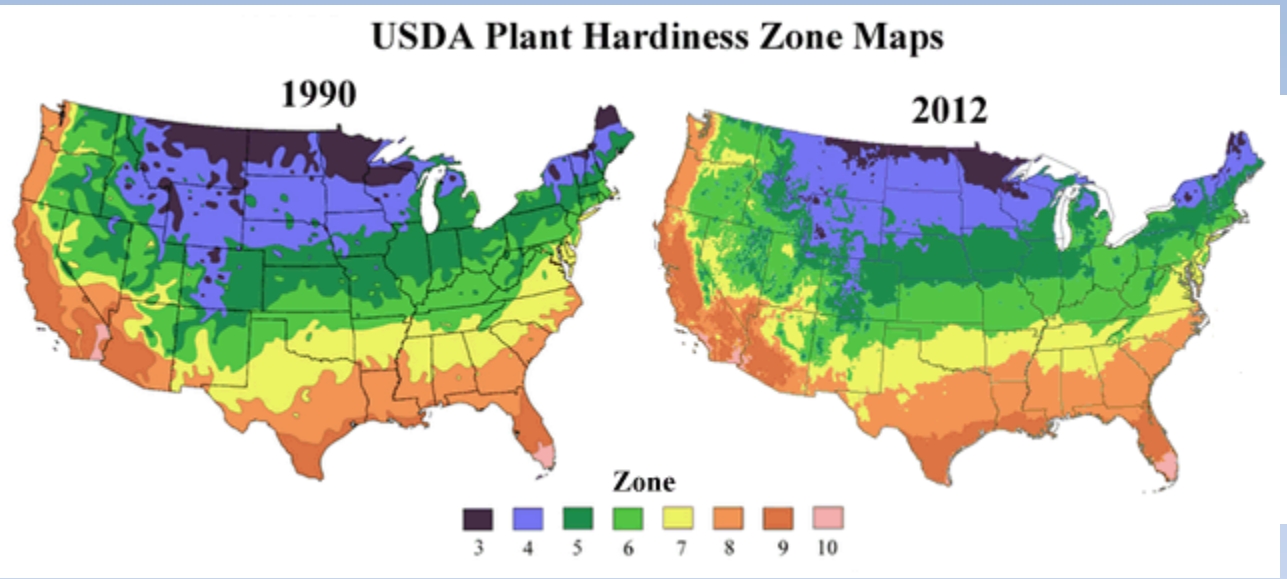


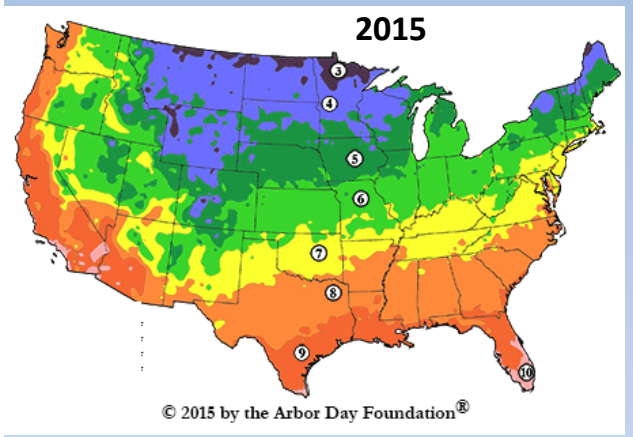
Spring is springing forward: Spring events, like bird and butterfly migrations, flower blooming times, and frog mating, have been advancing by about three days per decade over the past 30 years.

Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

https://www.arborday.org/media/zones.cfm

Plants and Animals are Responding to a Warming Climate
1990 vs. 2012





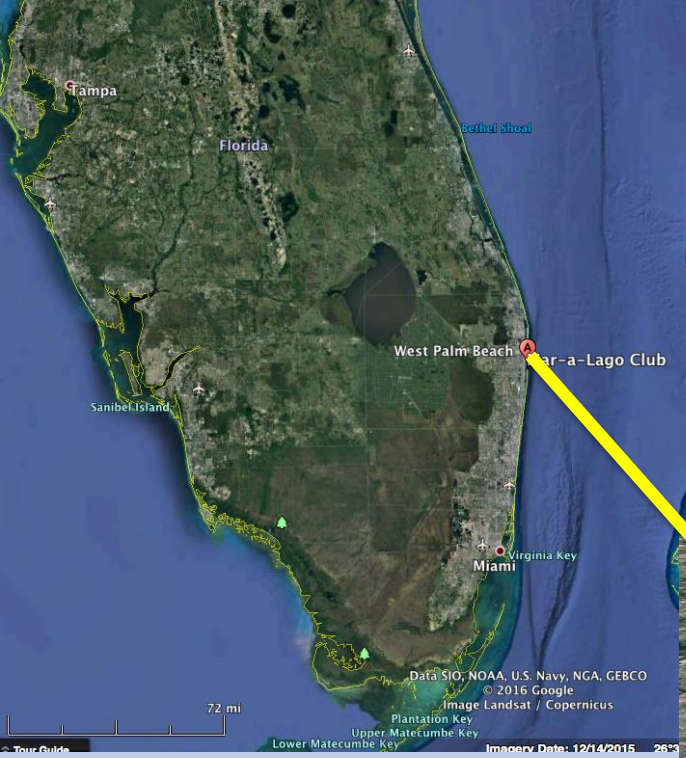
Spring is springing forward: Spring events, like bird and butterfly migrations, flower blooming times, and frog mating, have been advancing by about three days per decade over the past 30 years.

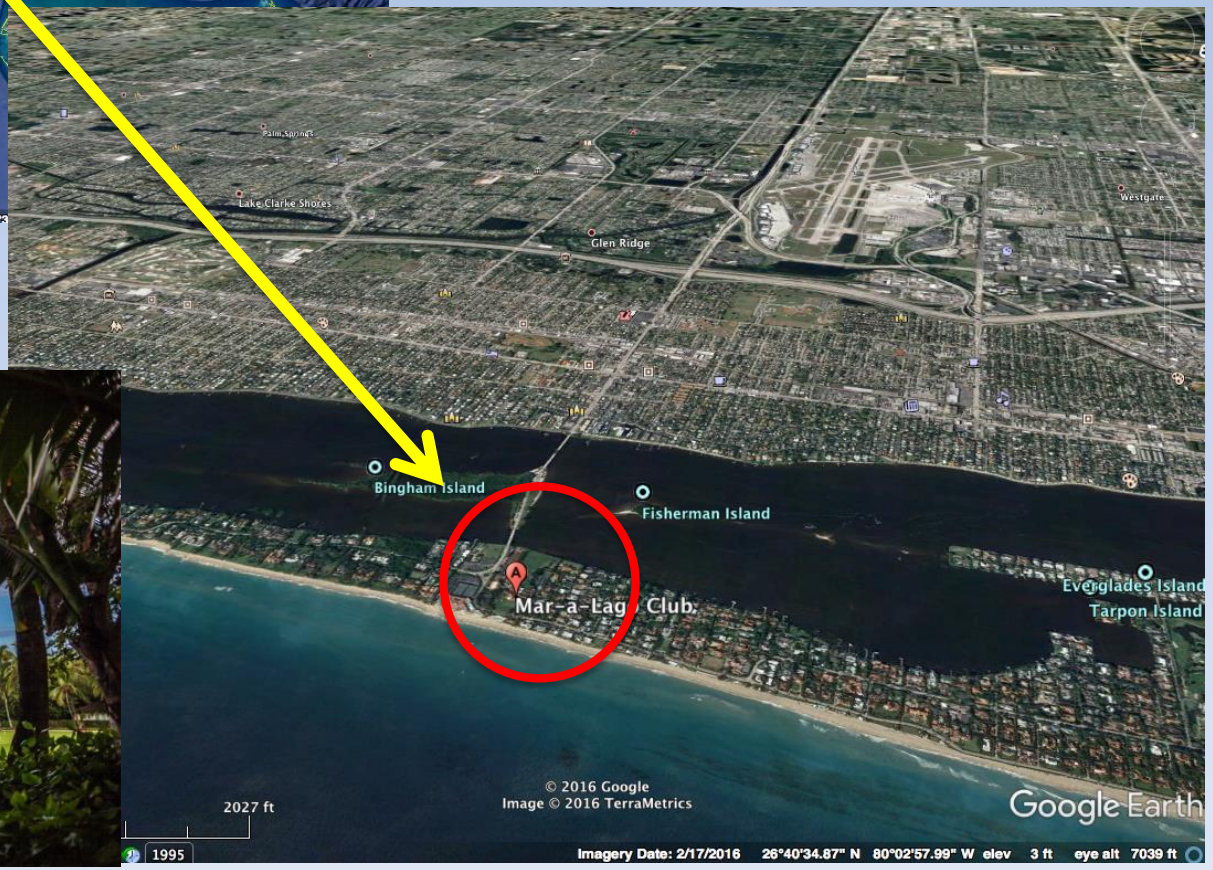
Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

https://www.arborday.org/media/zones.cfm

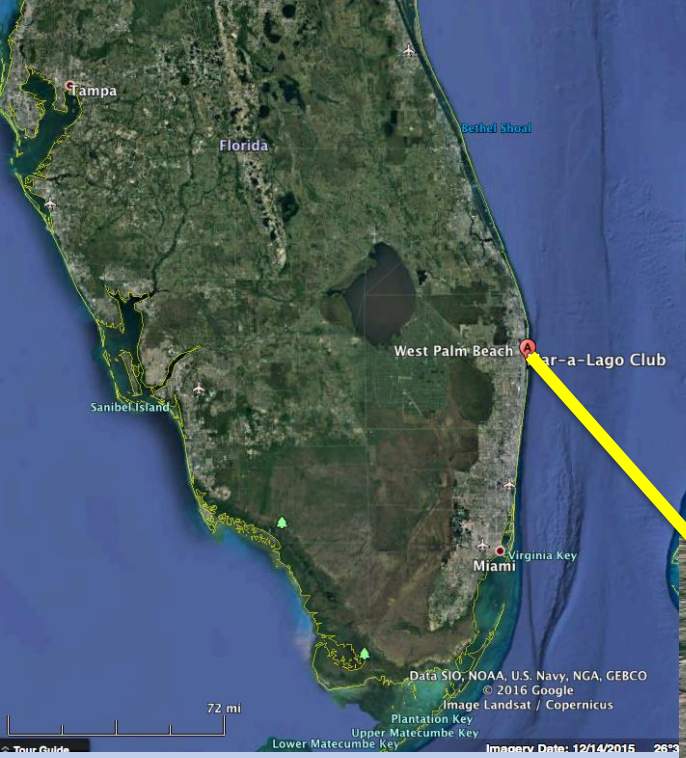
Global Impacts → Rising sea level is affecting coasts worldwide

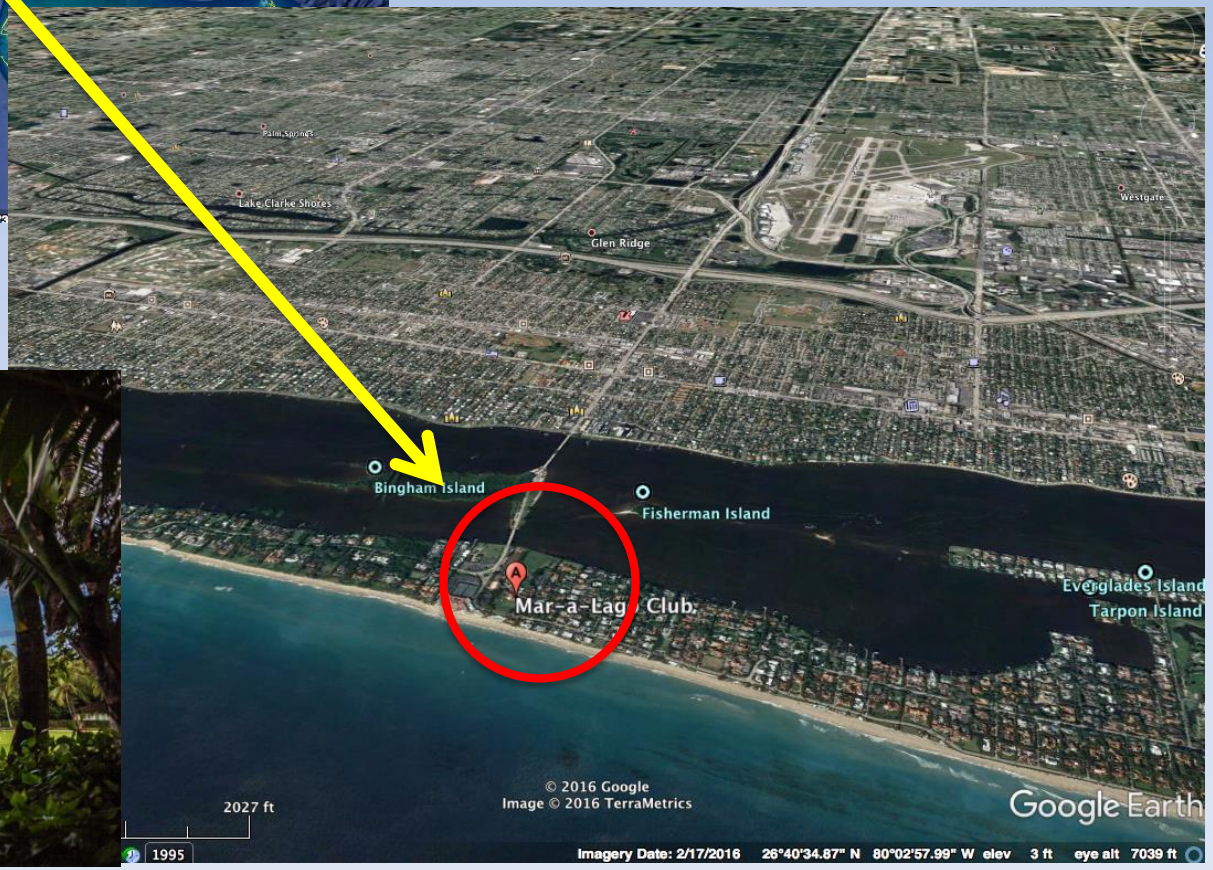
Mar-a-Lago Resort
West Palm Beach





Mar-a-Lago Resort
West Palm Beach





nature climate change

ARTICLES

PUBLISHED ONLINE: 27 MARCH 2017 | DOI: 10.1038/NCLIMATE3252

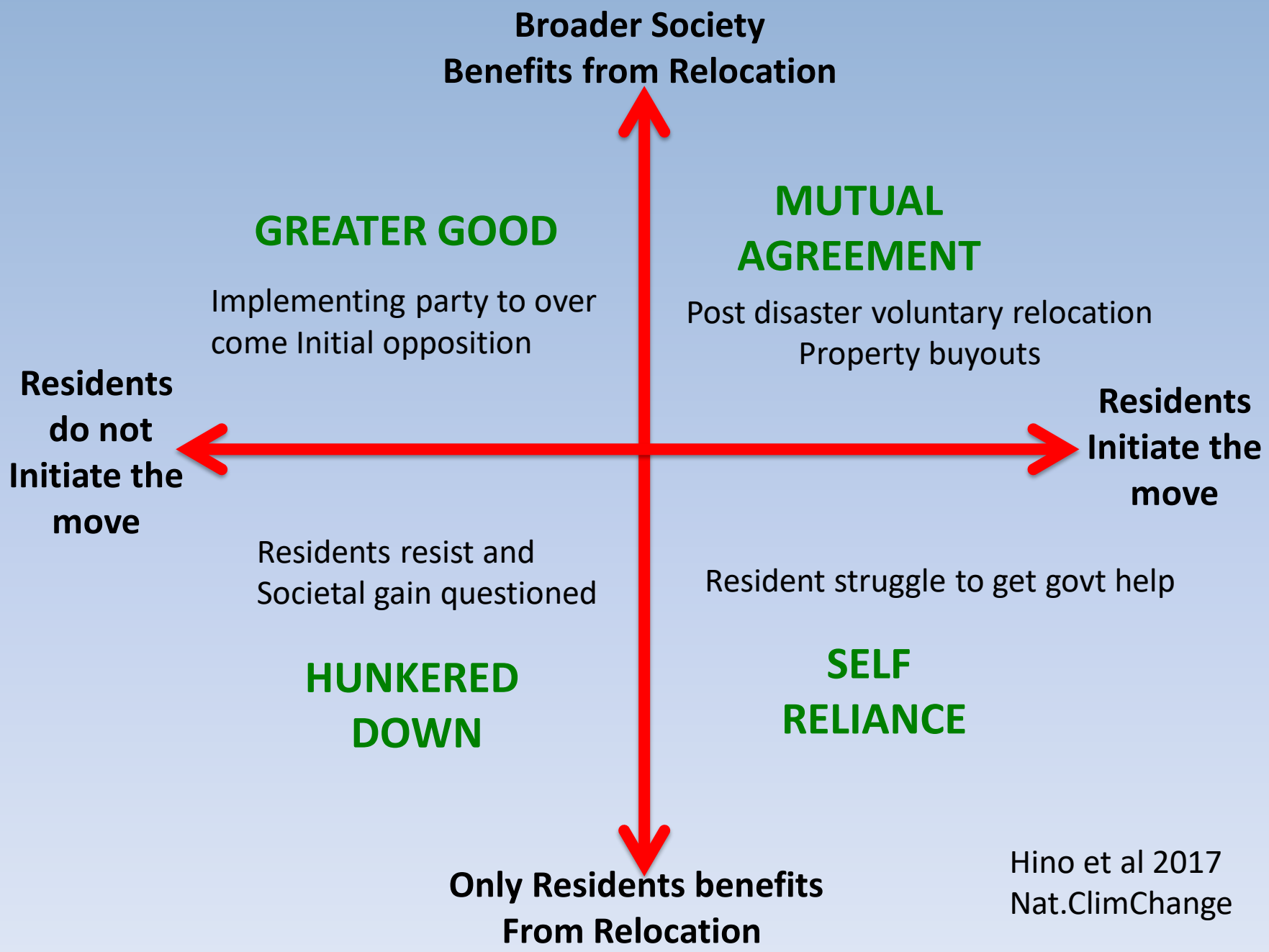
Managed retreat as a response to natural hazard risk

Miyuki Hino[1*], Christopher B. Field[2] and Katharine J. Mach[3]

the application of coastal zone management designed to move existing and planned development out of the path of eroding coastlines and coastal hazards

Miami skyline Today

One River Point Miami Luxury condos – to be built



Hino et al 2017
Nat.ClimChange

Table 1 | Projected populations at risk of sea-level rise by 2100.

HAUER ET AL., 2017

State	CURRENT POPULATIONS		PROJECTED POPULATIONS			
	0.9 m SLR in 2100	1.8 m SLR in 2100	0.9 m SLR in 2100	±	1.8 m SLR in 2100	±
AL	20,914	32,775	38,238	7,801	57,303	11,584
CA	227,677	504,595	472,248	98,343	1,046,757	208,343
CT	34,980	82,922	53,566	7,189	128,048	17,947
DC	1,391	3,167	2,005	410	4,629	948
DE	24,251	43,262	44,597	7,708	76,836	14,061
FL	593,207	2,743,086	1,221,837	236,103	6,057,419	1,216,806
GA	50,837	96,727	93,036	18,683	178,787	37,263
LA	412,648	678,151	846,203	263,827	1,361,792	292,676
MA	67,540	303,649	103,552	13,329	427,549	57,669
MD	54,226	110,009	92,584	14,730	188,624	31,624
ME	9,085	18,492	15,230	1,848	29,028	3,574
MS	25,974	41,469	50,385	10,254	76,901	16,721
NC	90,538	165,760	163,260	27,210	297,917	52,013
NH	4,795	8,948	8,670	1,131	15,432	2,024
NJ	174,822	482,180	308,662	47,436	827,449	137,272
NY	110,865	505,359	198,257	32,543	901,366	159,124
OR	7,425	15,499	12,754	1,903	25,614	4,163
PA	5,692	16,593	9,939	1,858	27,427	5,659
RI	9,171	23,429	14,875	1,646	36,546	3,977
SC	91,394	204,039	163,492	38,527	374,395	86,058
TX	93,092	214,364	173,025	45,306	405,423	106,301
VA	96,622	248,600	181,130	38,072	475,871	102,952
WA	22,753	53,279	43,436	7,229	94,139	16,040
Tot	2,229,898	6,596,356	4,310,981	923,086	13,115,252	2,584,797

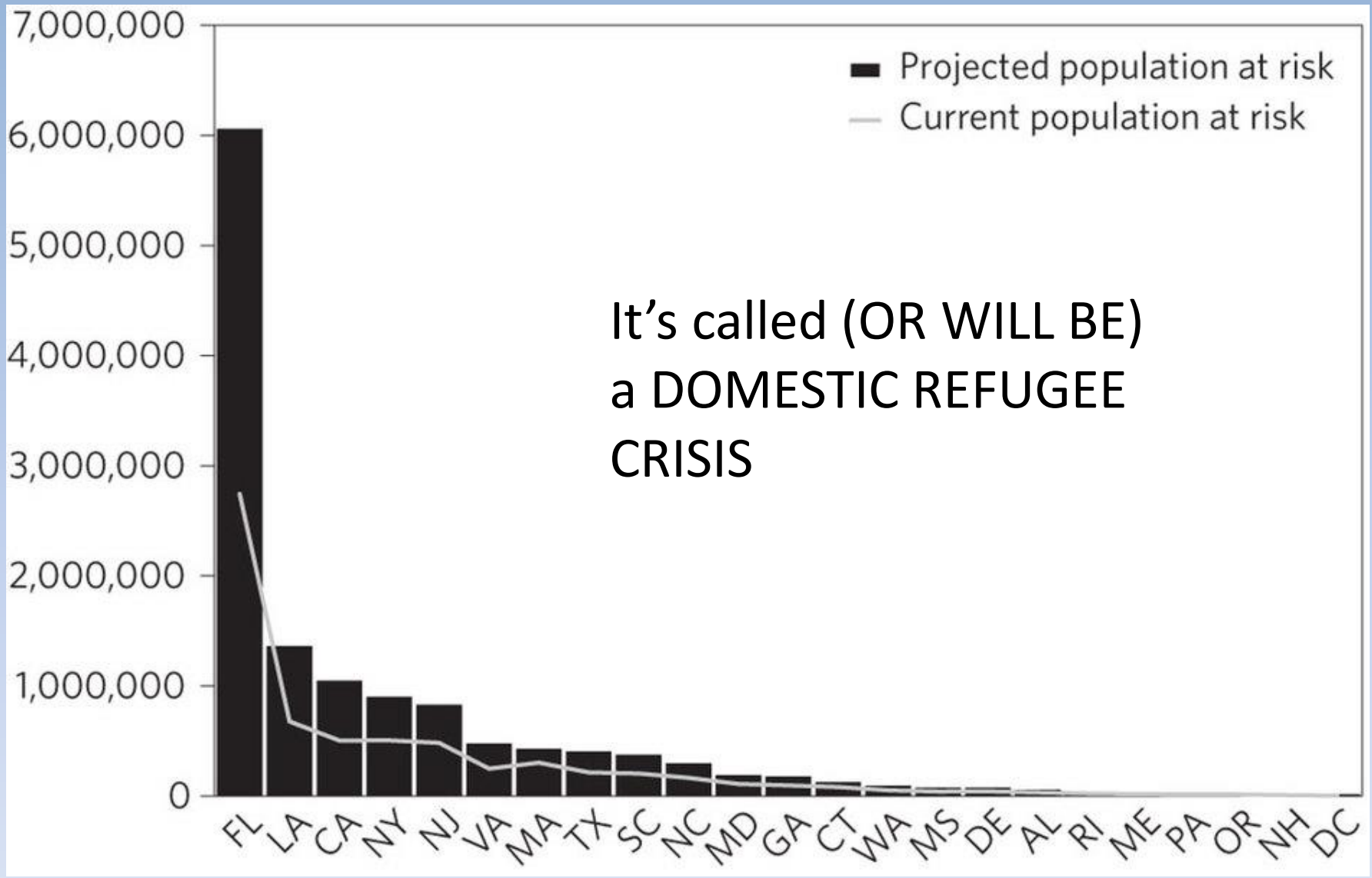
We considered only census block groups and counties expected to experience any inundation under 1.8 m of sea-level rise in 2100. ± values are the 90th percentile from the projection values.

2.23 MILLION
0.9 m SLR 2100

6.6 MILLION
1.8 m SLR 2100

4.3 MILLION
0.9 m SLR 2100

13.1 MILLION
1.8 m SLR 2100



It's called (OR WILL BE)
a DOMESTIC REFUGEE
CRISIS

HAUER ET AL., 2017

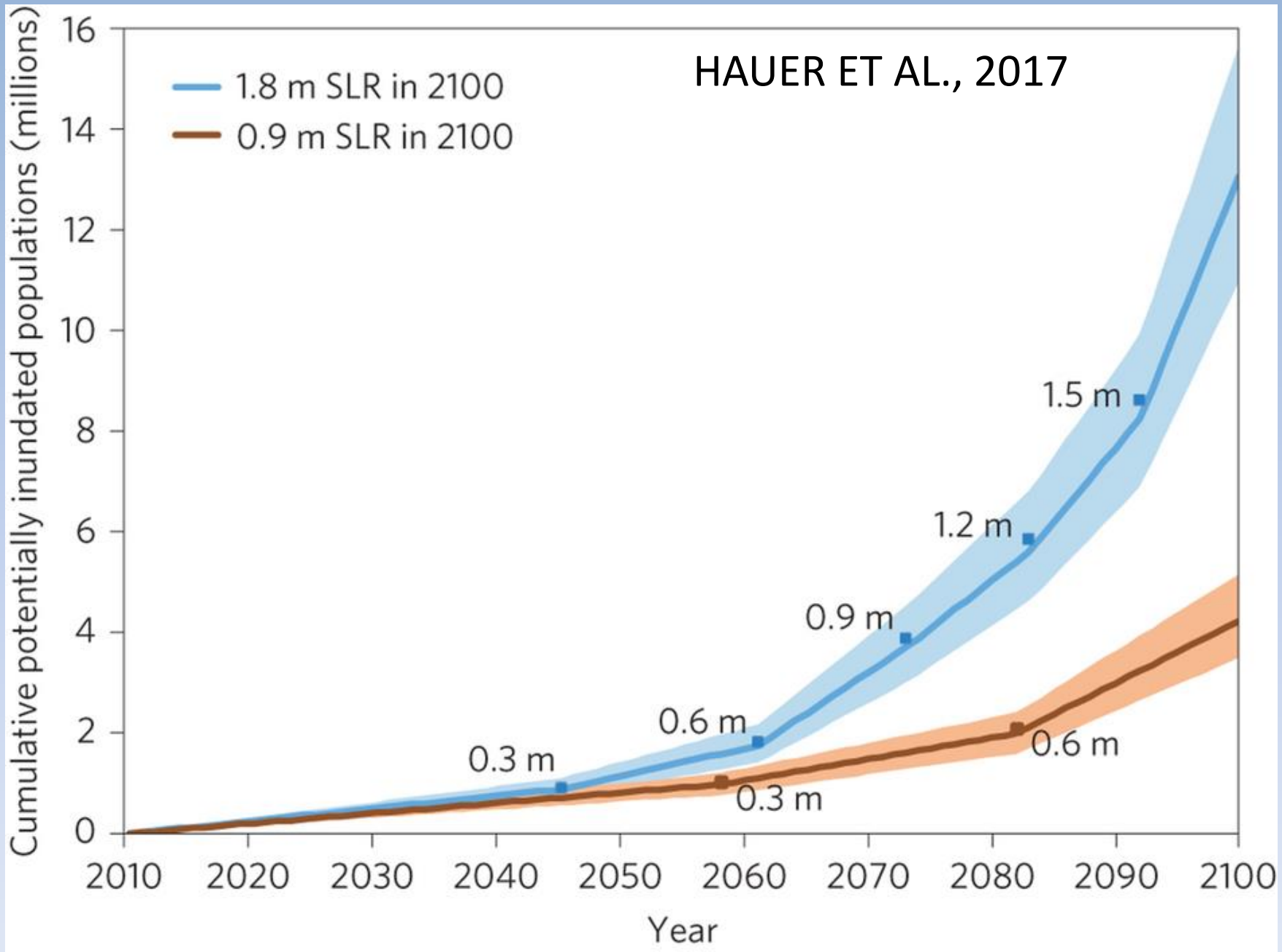

In the Garages of Miami

New Policies Needed: Plan for Managed Retreat (even though unthinkable)

Hino et al. 2017 NatClimChange

- Evaluate financial constraints to rebuild after natural disasters
- Drive self-reliance into community planning
- Develop comprehensive governance framework for communities and agencies to shift work from protection in place to community relocation.
- Requires sensitivity to place attachment, heritage and social dimensions of decision-making

First graders today will be 40 years old by 2050 when sea level could be 3 feet higher.


HAUER ET AL., 2017
1.8 m SLR in 2100
0.9 m SLR in 2100
Cumulative potentially inundated populations (millions)
0
2
4
6
8
10
12
14
16
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
0.3 m
0.6 m
0.9 m
1.2 m
1.5 m
0.3 m
0.6 m

“THERE IS SUCH A THING AS BEING **TOO LATE.** AND WHEN IT COMES TO **CLIMATE CHANGE,** THAT **HOUR IS ALMOST UPON US.**”

President Obama
Anchorage AK
August 2015

The Urgency of Now

"We are now faced with the fact that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there "is" such a thing as being too late. This is no time for apathy or complacency. This is a time for vigorous and positive action."

------ Martin Luther King Jr

"Don't relax. Don't feel good about yourselves.
See how *bad* it is, and then make it good.
And feel good about *that.*"
Gov. Jerry Brown 4/20/17

Take Home Points

Models still underestimate rates and magnitude of change in parts of Earth system

Geologic evidence from the Arctic and Antarctic show that Greenland and West Antarctic ice sheets are much more sensitive to forcings then thought.

Plan for Managed Retreat (though unthinkable now)

- **Evaluate financial constraints to rebuild after natural disasters**
- **Drive self-reliance into community planning**
- **Educate K to Gray!***

Politicians debating climate change: SLOW LEARNERS

Contemporary events

- We had snow!
- We had to shovel or snow-blow
- Or use a green-plow!

1. A low-carbon footprint snowplow

2. Another low-carbon footprint snowplow

TODAY

- Where's the moral compass regarding human health
- It doesn't even make economic sense; no utilities are building new coal plants in the U.S.

EPA CHIEF

Pruitt: "War on coal is over"

Groups denounce override of Obama rules by White House

By Michael Biesecker and Adam Beam
The Associated Press

Solar Decathlon

- Through Sunday: 61st and Pena –
- A-line rail stop
- https://www.solardecathlon.gov/
- Thursday, Oct. 12–Sunday, Oct. 15, 2017: 11 a.m.–7 p.m

https://www.solardecathlon.gov/


DSC00459.JPG


DSC00460.JPG


DSC00461.JPG


DSC00462.JPG


DSC00463.JPG


DSC00464.JPG


DSC00465.JPG


DSC00466.JPG


DSC00467.JPG


DSC00468.JPG


DSC00469.JPG


DSC00470.JPG


DSC00471.JPG


DSC00472.JPG


DSC00473.JPG


DSC00474.JPG


DSC00475.JPG


DSC00476.JPG


DSC00477.JPG


DSC00478.JPG


DSC00479.JPG


DSC00480.JPG


DSC00481.JPG


DSC00482.JPG

Citizens Climate Lobby

- October 14, Sat 1030 AM. CCL Golden monthly meeting at Abrusci's Fire & Wine, 2200 Youngfield St, back room.

Colorado Renewable Energy Society:

https://www.cres-energy.org/

Colorado Renewable Energy Society – YouTube of selected talks:

https://www.youtube.com/channel/UCr81EUb2qVJVfmmlJMxEHVw

Changes are Happening

POPULATION

THE BIG PICTURE

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

CLIMATE-RELATED

Earth

Human Population = 7.3 B

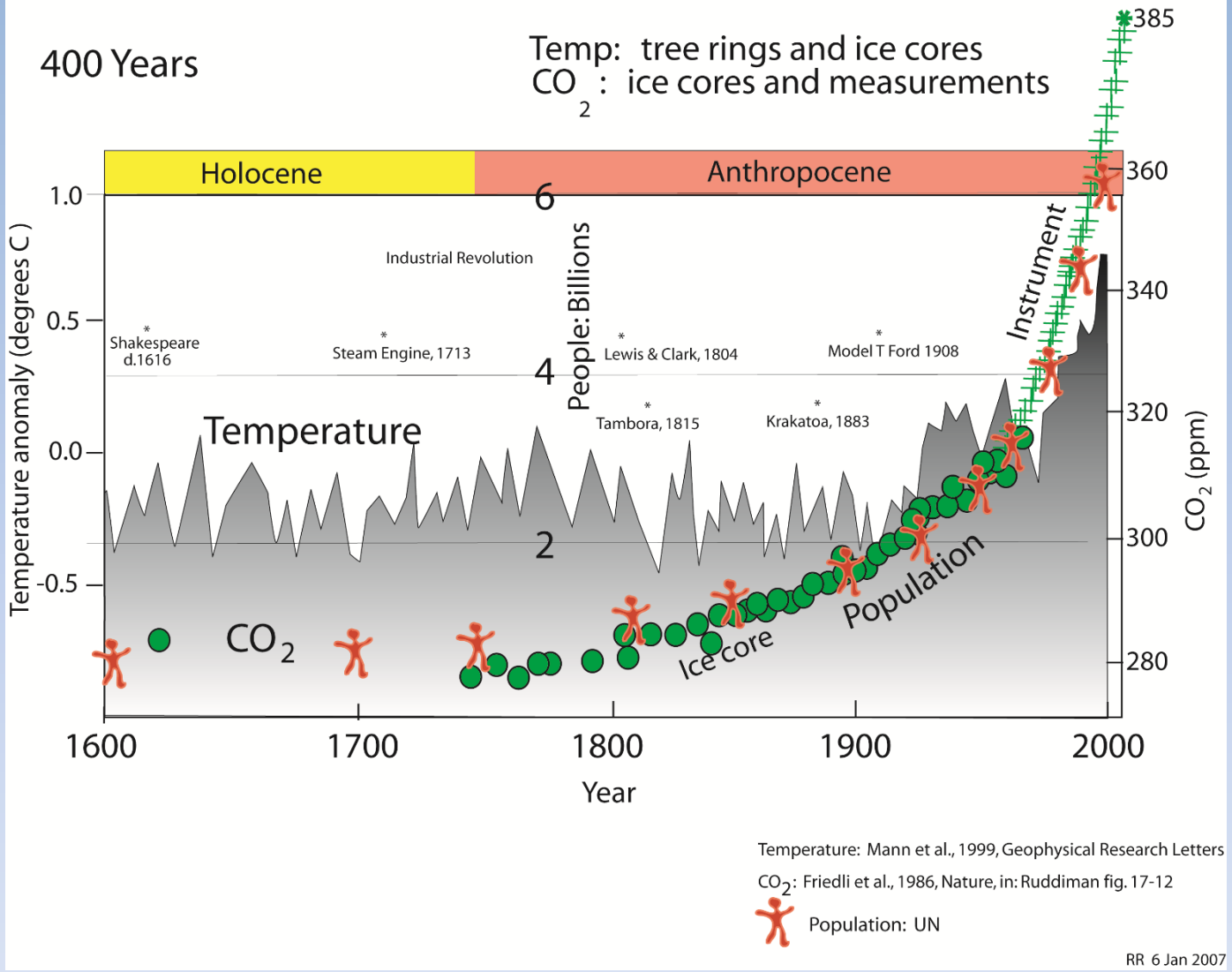
Annual Electricity Demand = 23,300 TWh

Annual CO2 Emissions = 32.2 Gt

Fraction of GHG Emissions from Energy Use ≈ 68%

Gt C = Gt CO2/3.67
(mass 44/mass 12 C)
32.7/3.67 = 8.91 Gt C

Museums, Zoos and Your Children will save the World



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

CO_2: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

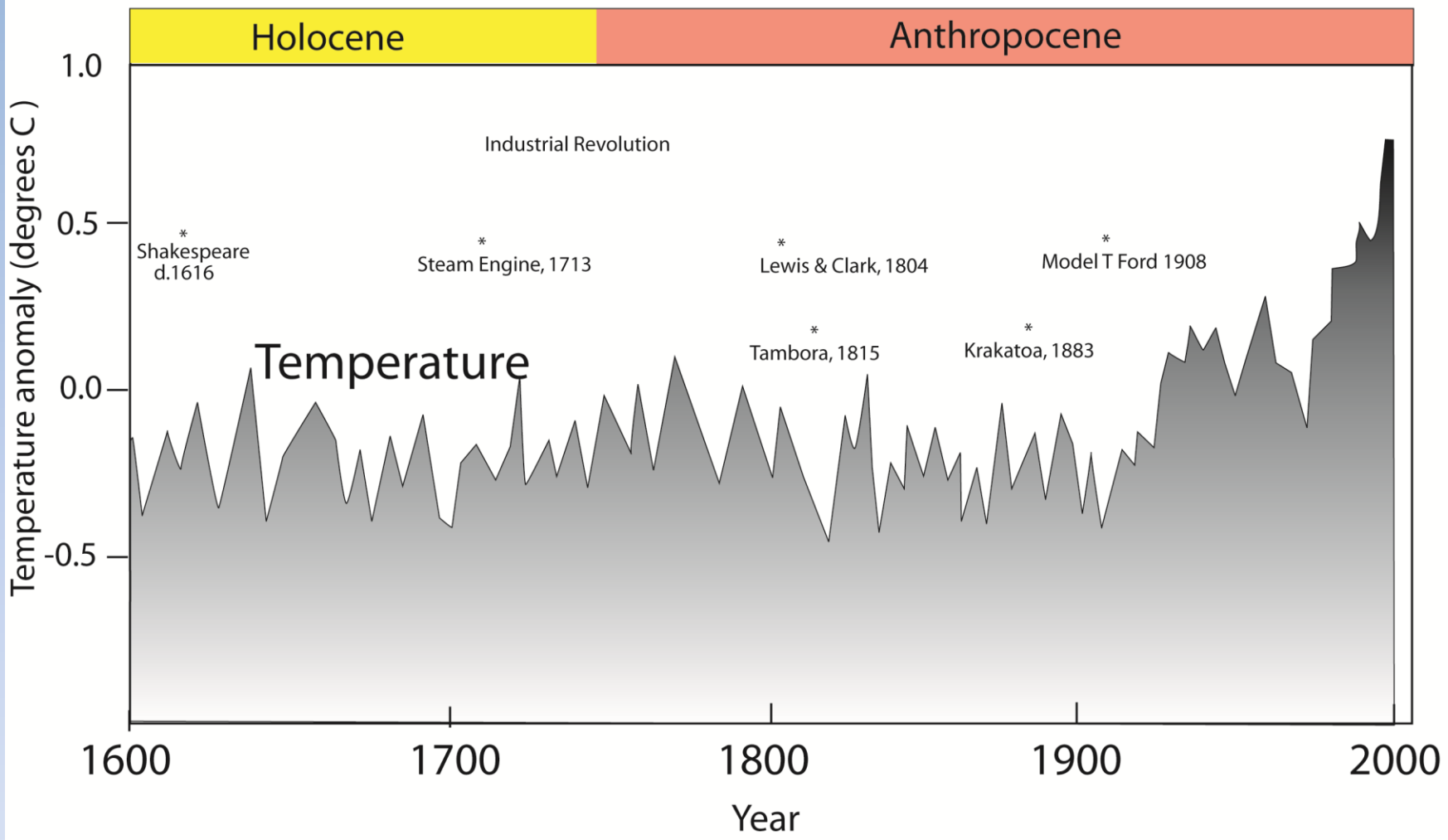
Population: UN

RR 6 Jan 2007

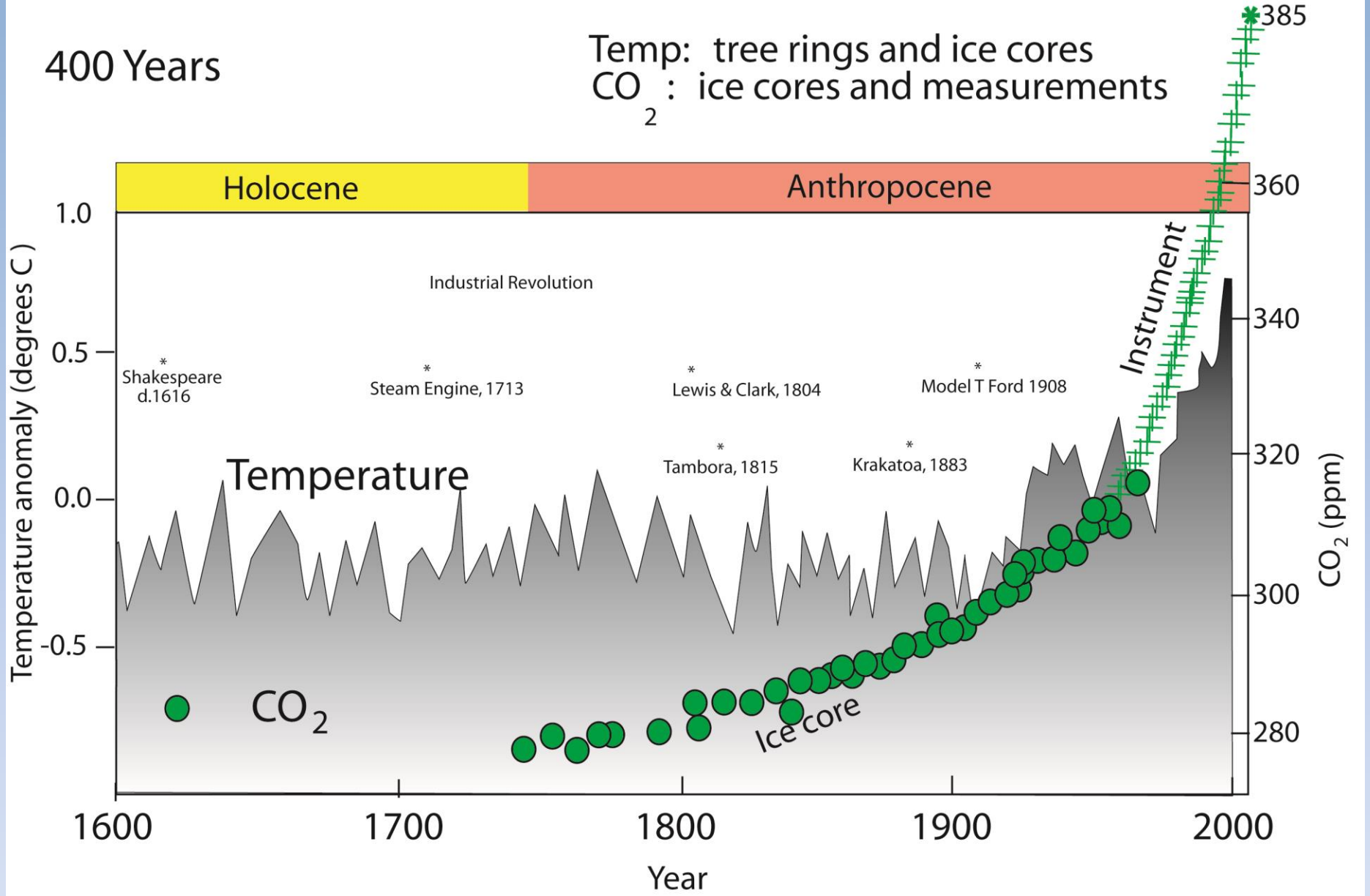

The Economist
Getting Spain's protesters off the plazas
Obama, Bibi and peace
The costly war on cancer
How the brain drain reduces poverty
A soft landing for China
Welcome to the Anthropocene
Jon Berkeley

400 Years

Temp: tree rings and ice cores

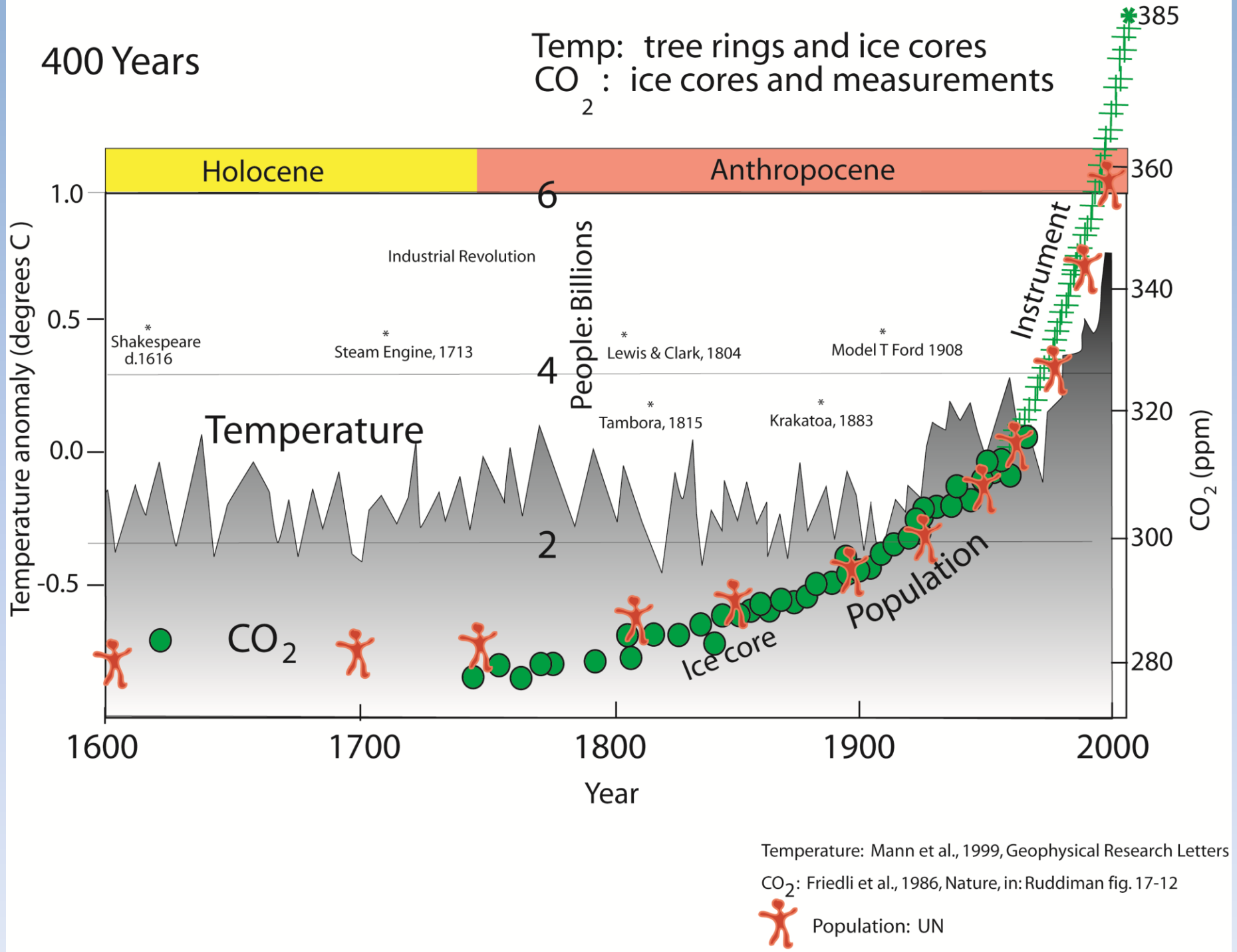


Temperature: Mann et al., 1999, Geophysical Research Letters



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

CO_2: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12



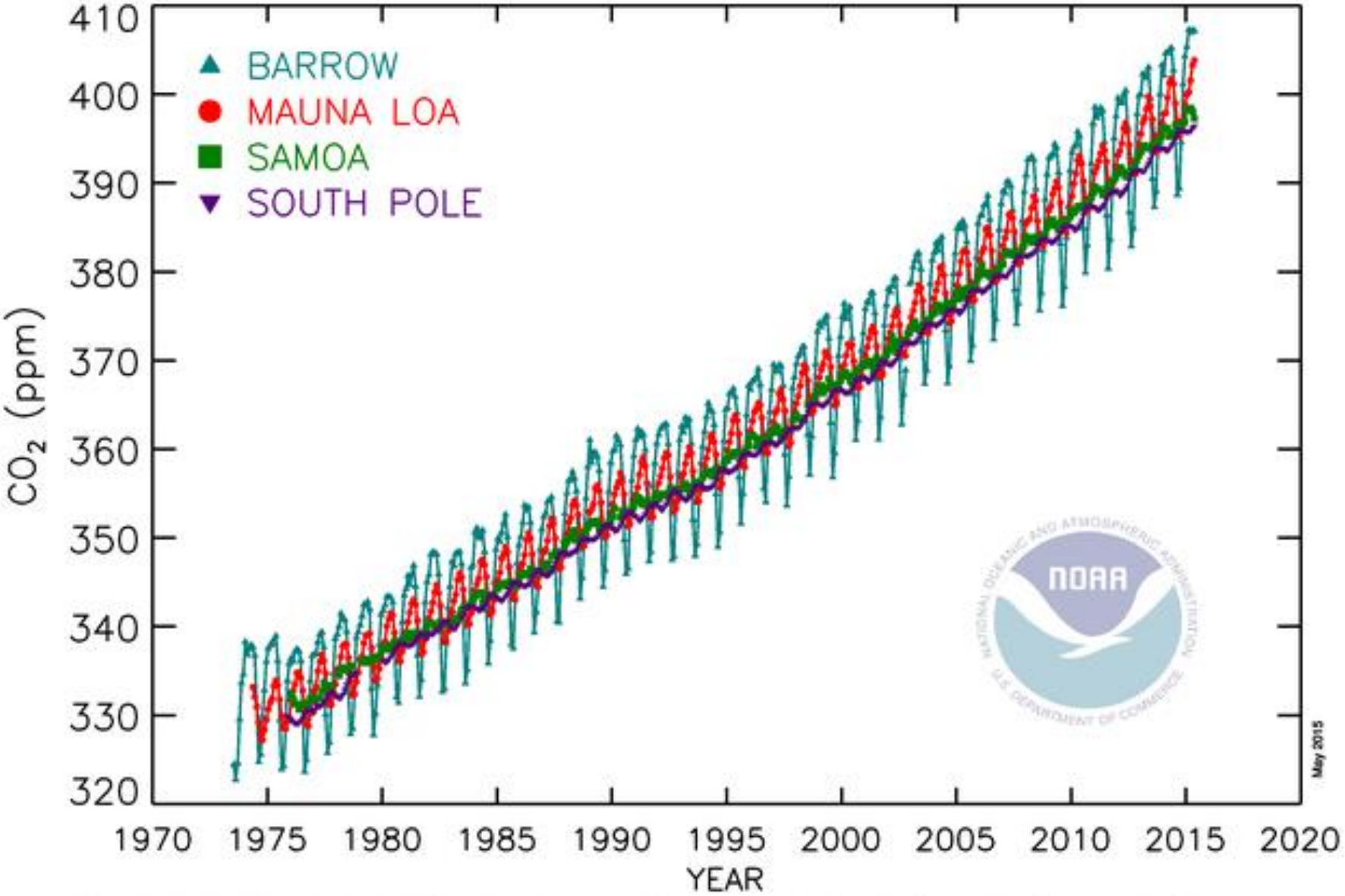
Temperature: Mann et al., 1999, Geophysical Research Letters

CO_2: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

Population: UN

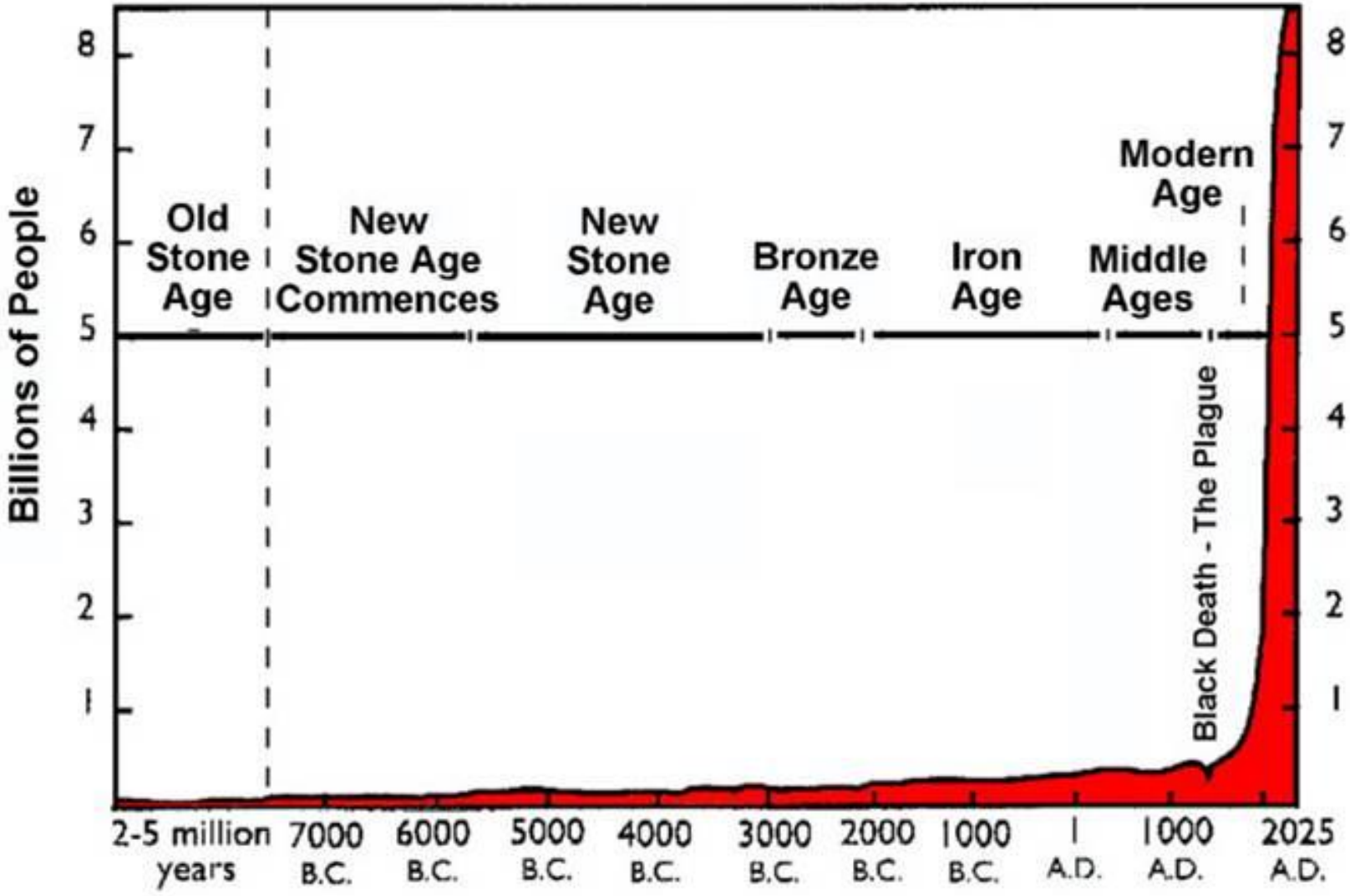
Monthly Mean Carbon Dioxide

NOAA ESRL Carbon Cycle



Atmospheric carbon dioxide mixing ratios determined from the continuous monitoring programs at the 4 Baseline Observatories. Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.

World Population Growth Through History



Fertility rate
vs.
Zero Population Growth

- Total Fertility Rate: https://en.wikipedia.org/wiki/Total_fertility_rate
  - The **total fertility rate** (**TFR**), sometimes also called the **fertility rate**, **absolute/potential natality**, **period total fertility rate** (**PTFR**) or **total period fertility rate** (**TPFR**) of a population is the average number of children that would be born to a woman over her lifetime if:
  - She were to experience the exact current age-specific fertility rates (ASFRs) through her lifetime, and
  - She were to survive from birth through the end of her reproductive life.[1]
  - It is obtained by summing the single-year age-specific rates at a given time.

Fertility rate
vs.
Zero Population Growth

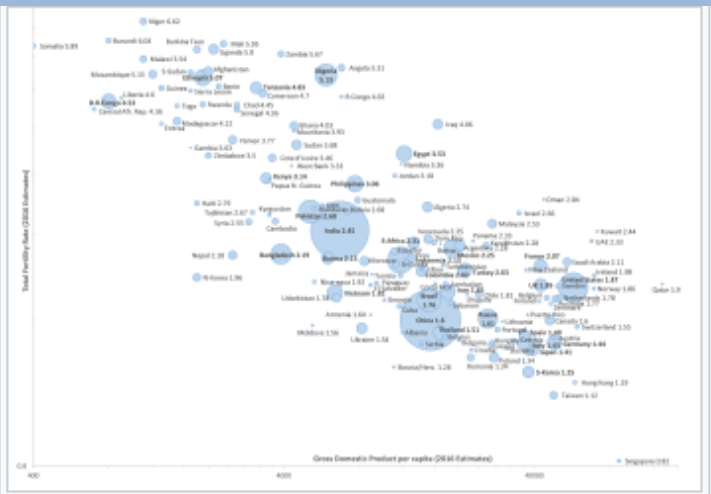
- **Zero population growth (ZPG): https://en.wikipedia.org/wiki/Zero_population_growth**
  - **Zero population growth**, sometimes abbreviated **ZPG** (also called the replacement level of fertility),[1] is a condition of demographic balance where the number of people in a specified population neither grows nor declines, considered as a social aim by some.[2] According to some, zero population growth, perhaps after stabilizing at some optimum population, is the ideal towards which countries and the whole world should aspire in the interests of accomplishing long-term environmental sustainability.[3] What it means by 'the number of people neither grows nor declines' is that births plus in-migrants equal deaths plus out-migrants.[4]

Replacement rates [edit]

Further information: Sub-replacement fertility

Replacement fertility is the total fertility rate at which women give birth to enough babies to sustain population levels.

If there were no mortality in the female population from birth to the end of the childbearing years, the replacement level of TFR would be very close to 2.0. The replacement fertility rate is indeed only slightly above 2.0 births per woman for most industrialized countries (2.075 in the UK, for example), but ranges from 2.5 to 3.3 in developing countries because of higher mortality rates, especially child mortality.[7] The global average for the replacement total fertility rate (leading to a stable global population) was 2.33 children per woman in 2003.[8]



Log-log graph of Total Fertility Rate (TFR) vs. GDP (PPP) per capita with population size shown as bubble area, for all countries having population greater than 2 million (2016 estimates; 30 largest countries bold)[4][5][6]

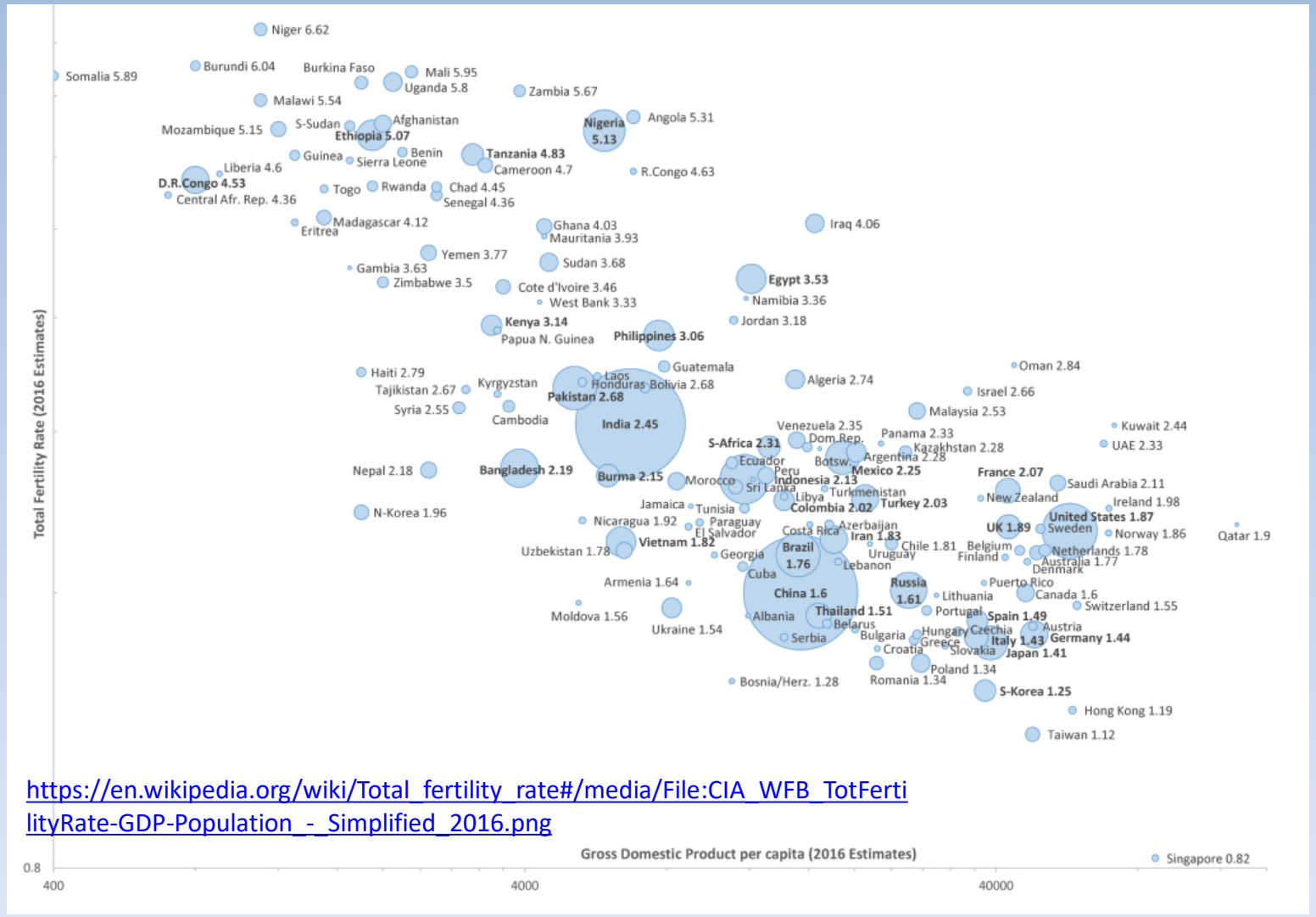
Lowest-low fertility [edit]

The term "lowest-low fertility" is defined as TFR at or below 1.3.[9] This is characteristic of some Eastern European, Southern European and East Asian countries.[10] In 2001, more than half of the population of Europe lived in countries with lowest-low TFR, but the situation has since slightly improved.[11]

Population-lag effect [edit]

A population that maintained a TFR of 3.8 over an extended period without a correspondingly high death or emigration rate would increase rapidly (doubling period ~ 32 years), whereas a population that maintained a TFR of 2.0 over a long time would decrease, unless it had a large enough immigration. However, it may take several generations for a change in the total fertility rate to be reflected in birth rate, because the age distribution must reach equilibrium. For example, a population that has recently dropped below replacement-level fertility will continue to grow, because the recent high fertility produced large numbers of young couples who would now be in their childbearing years.

Log-log graph of Total Fertility Rate (TFR) vs. GDP (PPP) per capita with population size shown as bubble area, for all countries having population greater than 2 million (2016 estimates; 30 largest countries bold)



https://en.wikipedia.org/wiki/Total_fertility_rate#/media/File:CIA_WFB_TotFertilityRate-GDP-Population_-_Simplified_2016.png

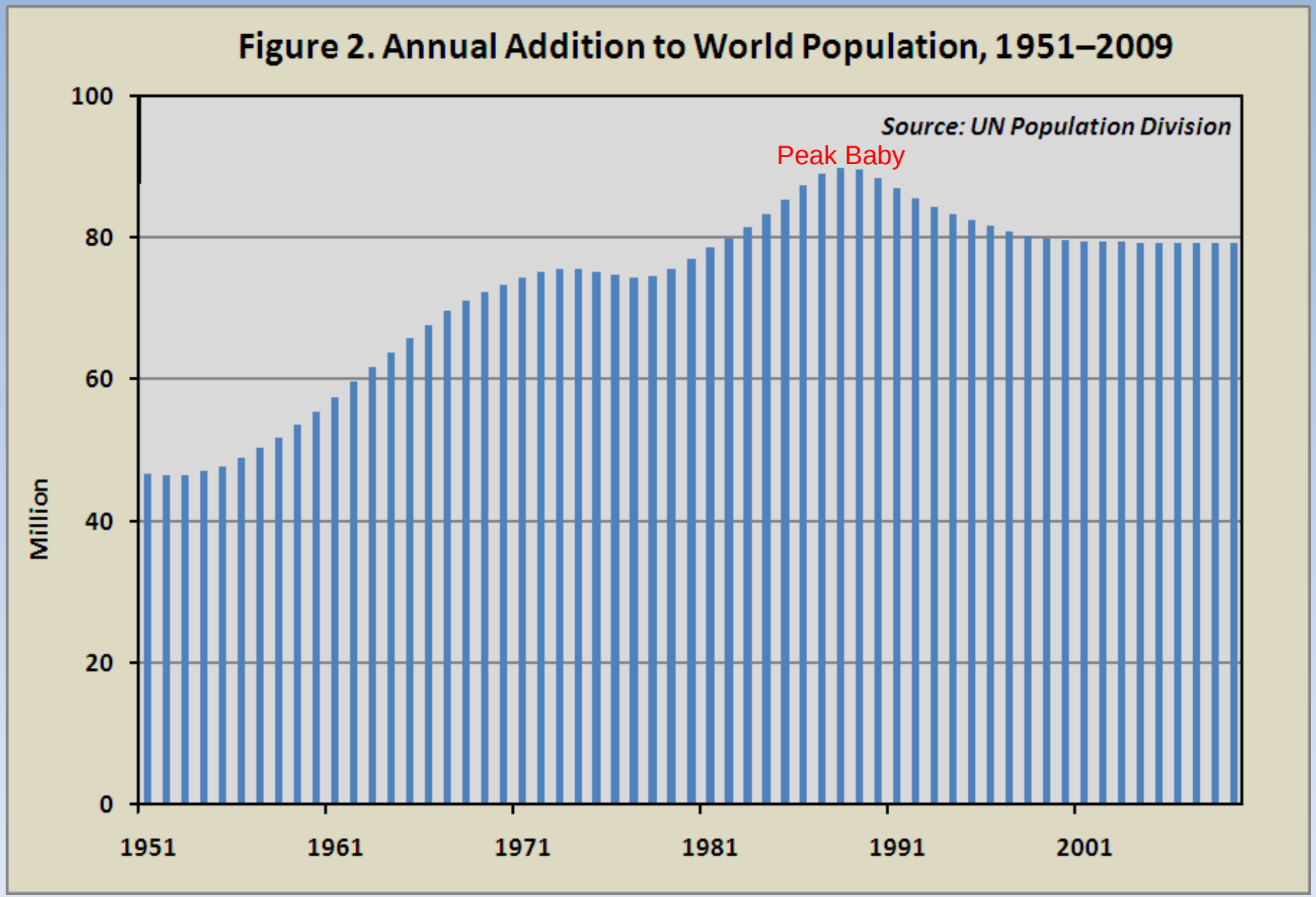
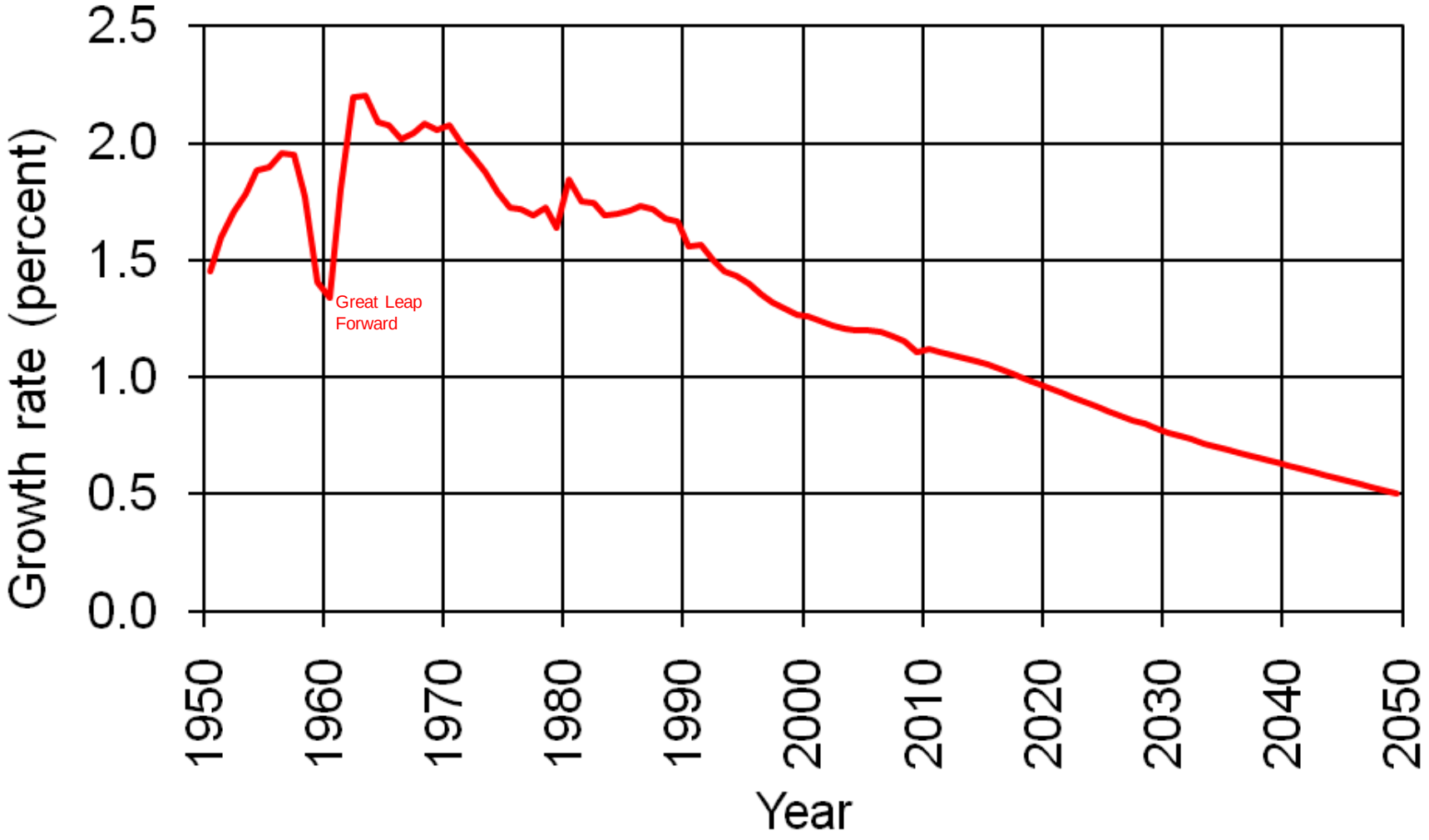


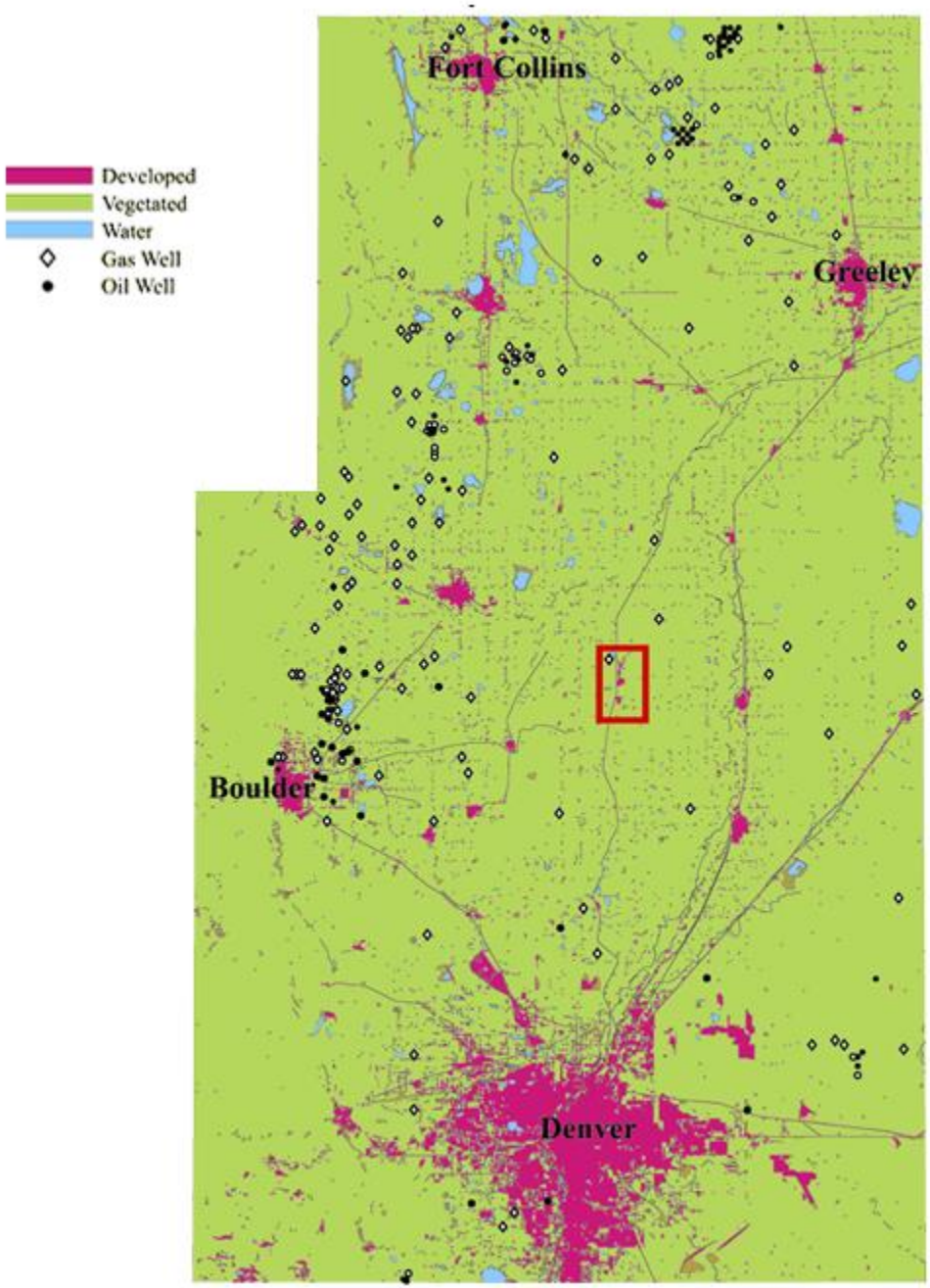
Figure 2. Annual Addition to World Population, 1951–2009
Source: UN Population Division
Peak Baby
Million
100
80
60
40
20
0
1951
1961
1971
1981
1991
2001

World Population Growth Rates: 1950-2050



Source: U.S. Census Bureau, International Data Base, June 2011 Update.

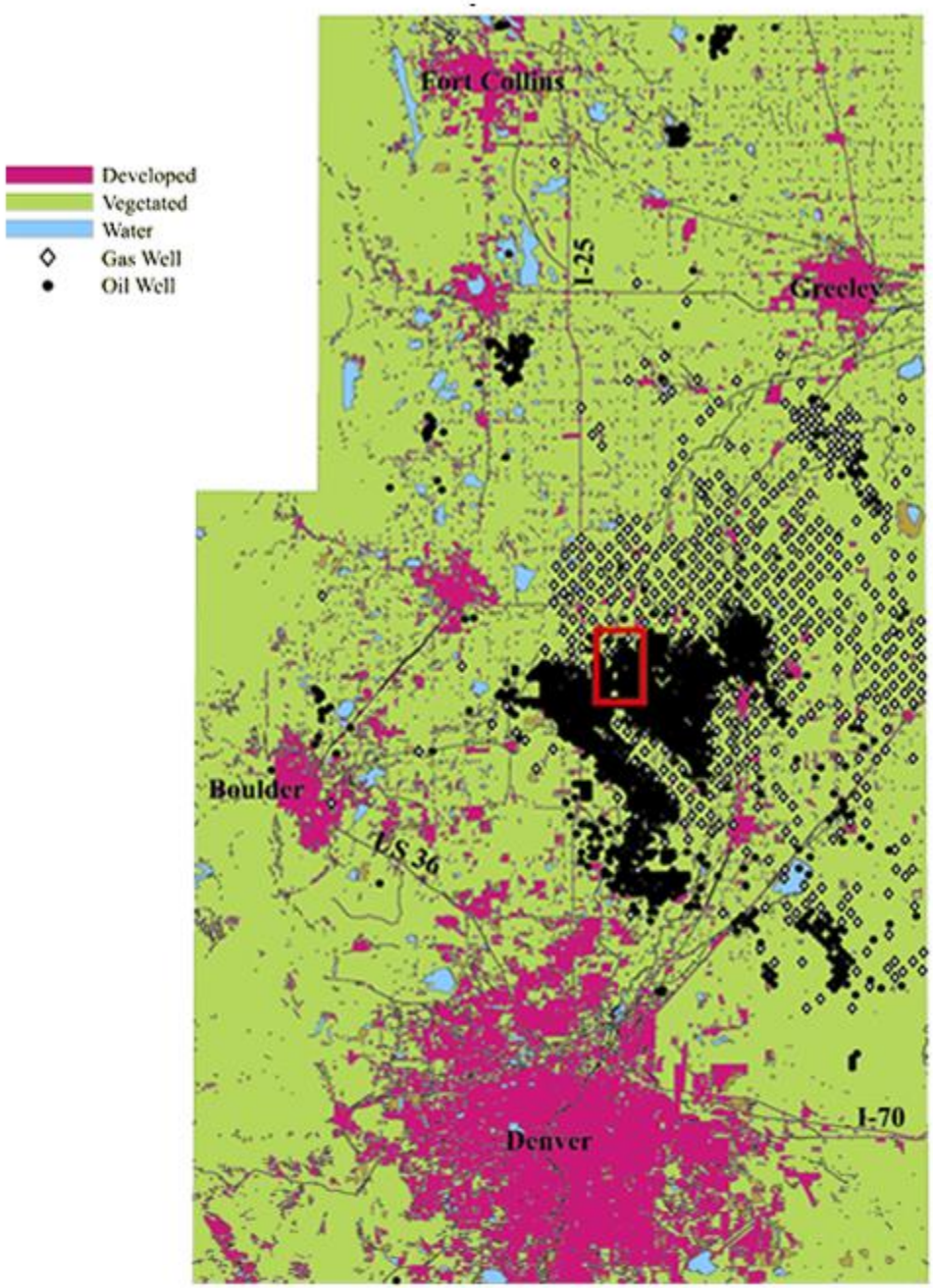
1960


Developed
Vegetated
Water
Gas Well
Oil Well
Fort Collins
Greeley
Boulder
Denver

U

USGS

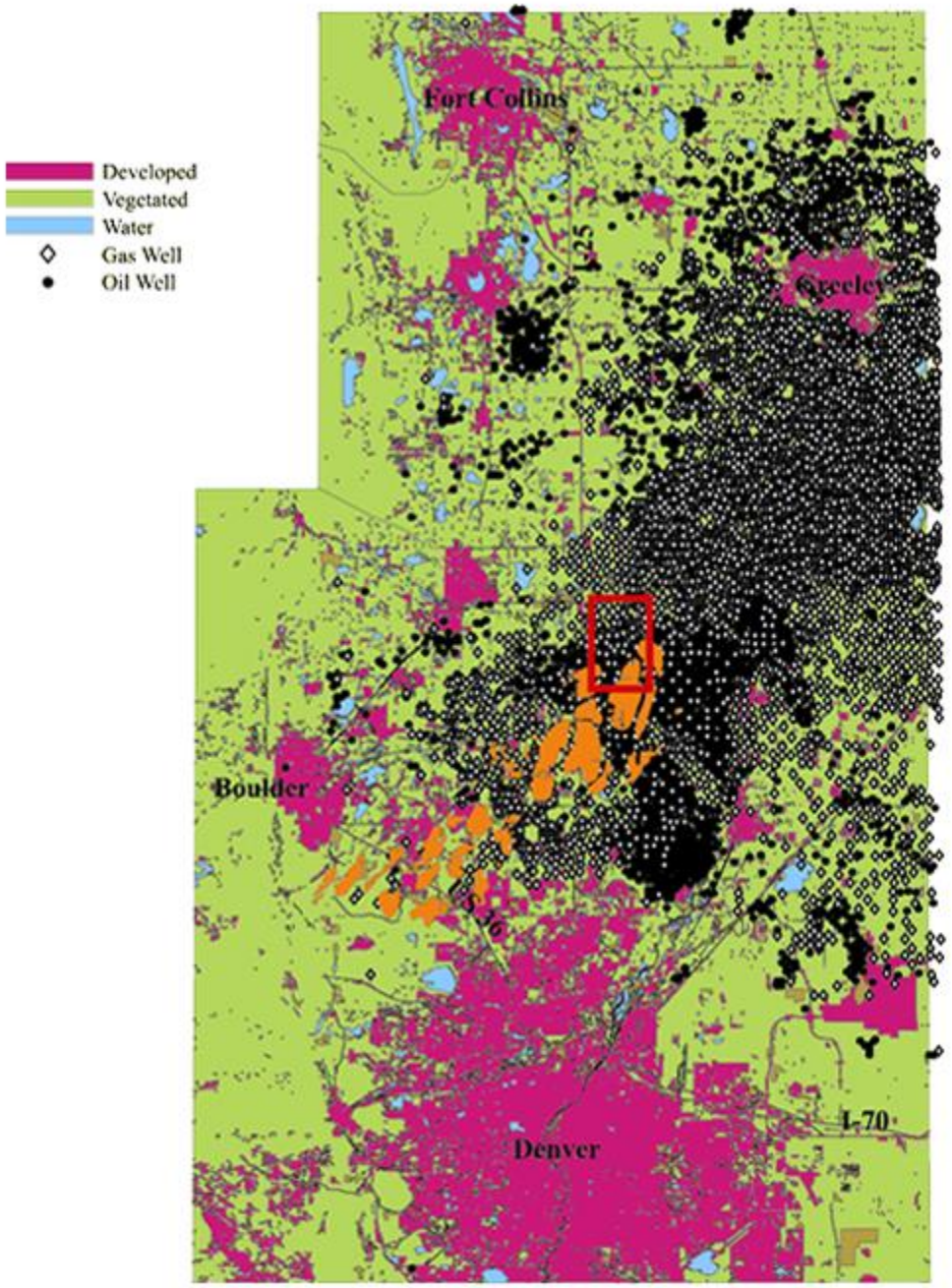
1980


Developed
Vegetated
Water
Gas Well
Oil Well
Fort Collins
I-25
Greeley
Boulder
US 36
Denver
I-70

U

USGS

2000

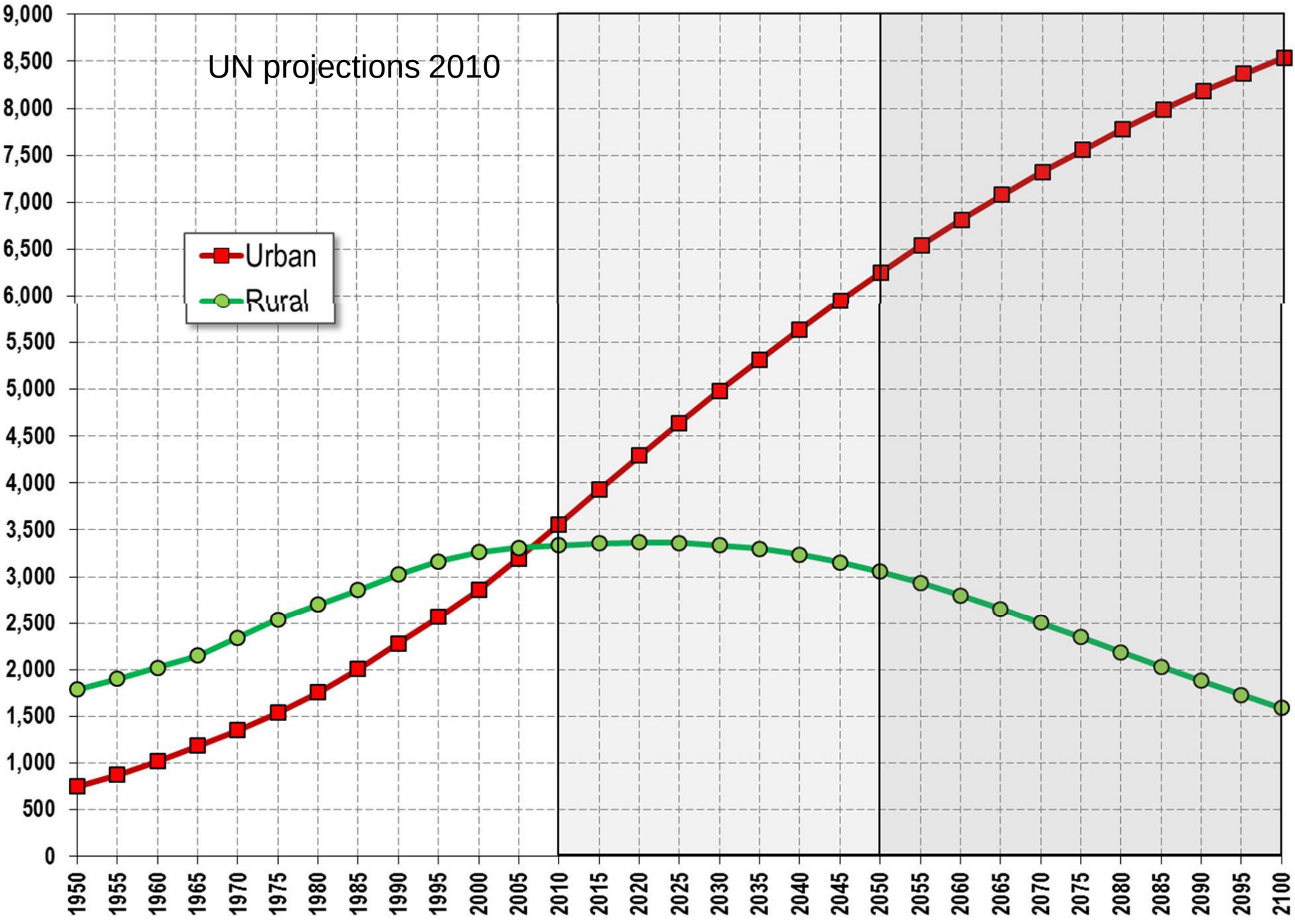

Developed
Vegetated
Water
Gas Well
Oil Well
Fort Collins
Greeley
Boulder
Denver
I-25
I-70

U

USGS

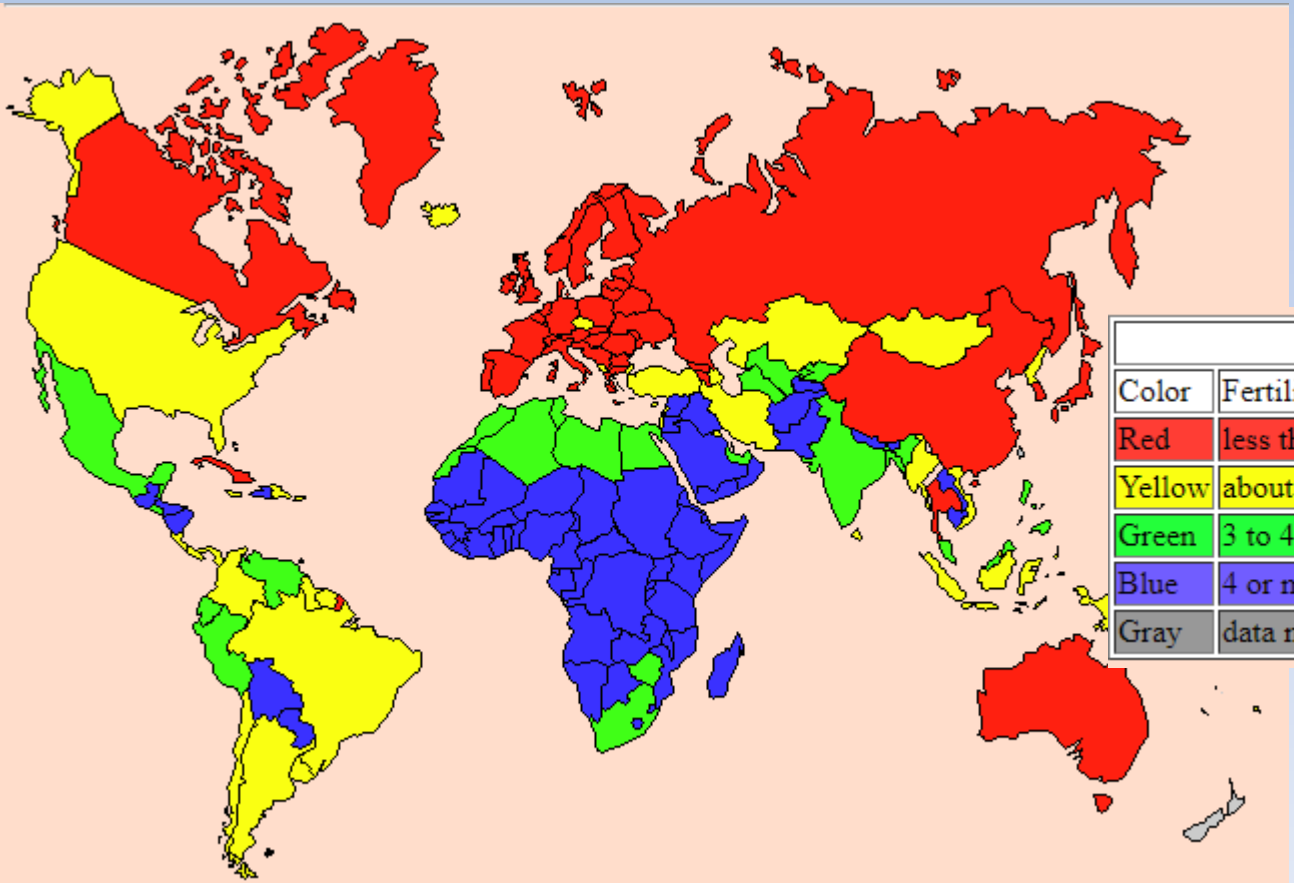
Jonah Field, Wyoming August 1994

Jonah Field, Wyoming August 2006


UN projections 2010
Urban
Rural
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095
2100

Fertility Rates (Children per Family) World Statistics

- http://www.pregnantpause.org/numbers/fertility.htm



Map Key		
Color	Fertility rate	Long-term impact
Red	less than 2	declining population
Yellow	about 2	stable population
Green	3 to 4	growing population
Blue	4 or more	rapidly growing population
Gray	data not available	

- 4 PDFs documents for you to peruse depending on your interest:
  - Science Mag June 30, 2017: Estimating economic damage from climate change in the United States
  - UN World Fertility Report: 2007: UN World Fertility Report 2007:compilation of key indicators of fertility, nuptiality, contraceptive use and population policies regarding childbearing for 192 countries referring mostly to two periods: the 1970s and the latest year for which data are available
  - UN World Fertility Report 2012: Report_WFR2012
  - World population stabilization unlikely this century: Science-2014-Lee-229-34

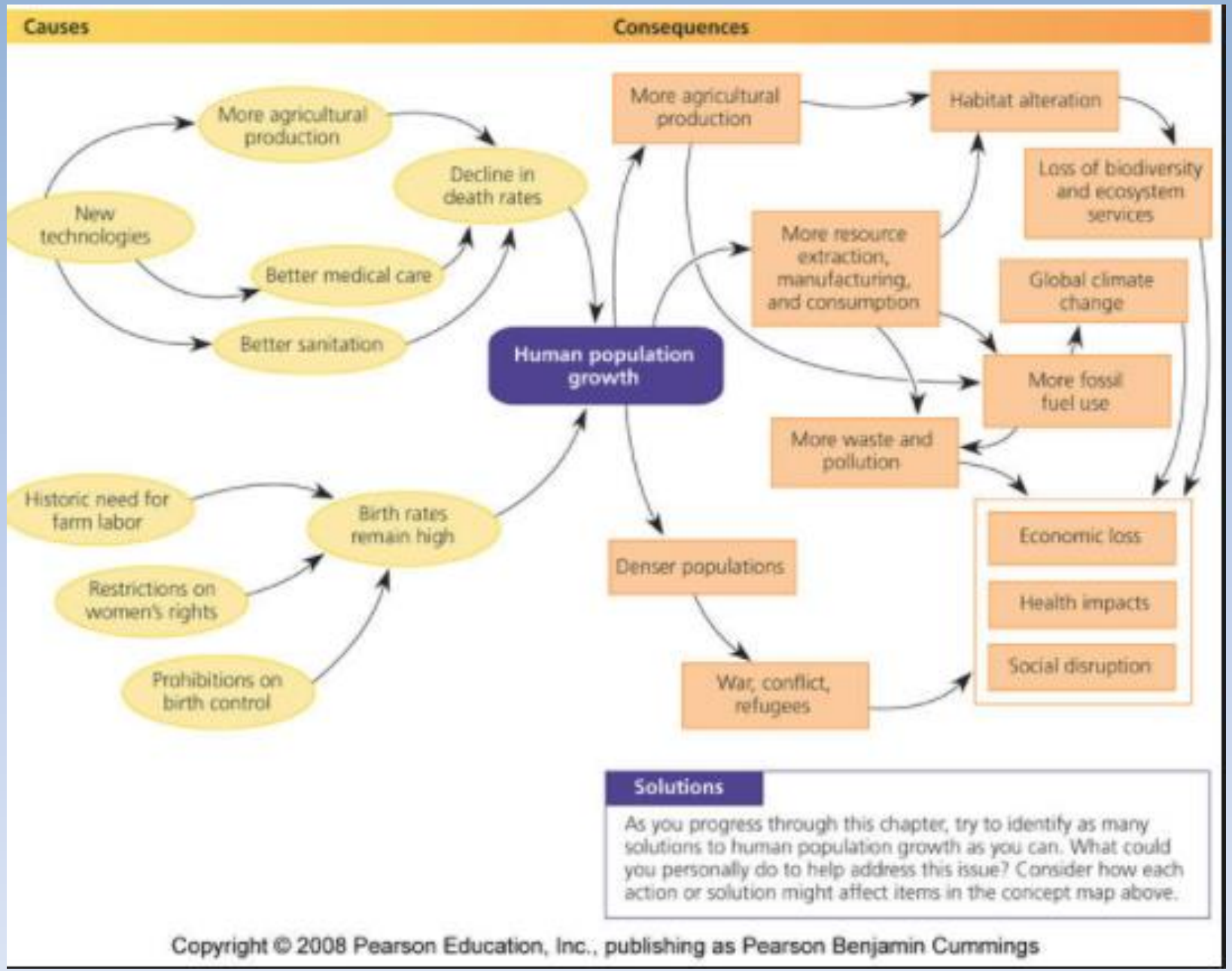
Science
AAAS

Is low fertility really a problem? Population aging, dependency, and consumption

Ronald Lee *et al.*

Science **346**, 229 (2014);
DOI: 10.1126/science.1250542

- ECONOMIC DEMOGRAPHY
- Is low fertility really a problem?
- Population aging, dependency, and consumption
- Ronald Lee,1* Andrew Mason,2,3* members of the NTA Network†
- Longer lives and fertility far below the replacement level of 2.1 births per woman are
- leading to rapid population aging in many countries. Many observers are concerned that
- aging will adversely affect public finances and standards of living. Analysis of newly
- available National Transfer Accounts data for 40 countries shows that fertility well above
- replacement would typically be most beneficial for government budgets. However,
- fertility near replacement would be most beneficial for standards of living when the
- analysis includes the effects of age structure on families as well as governments. And
- fertility below replacement would maximize per capita consumption when the cost of
- providing capital for a growing labor force is taken into account. Although low fertility will
- indeed challenge government programs and very low fertility undermines living
- standards, we find that moderately low fertility and population decline favor the broader
- material standard of living.



End of class slides October 10th , 2017

https://i.kinja-img.com/gawker-media/image/upload/t_original/ihsllhptnnm4vb7wuvgq.jpg