What is the Anthropocene?

Bob Raynolds

March 2019

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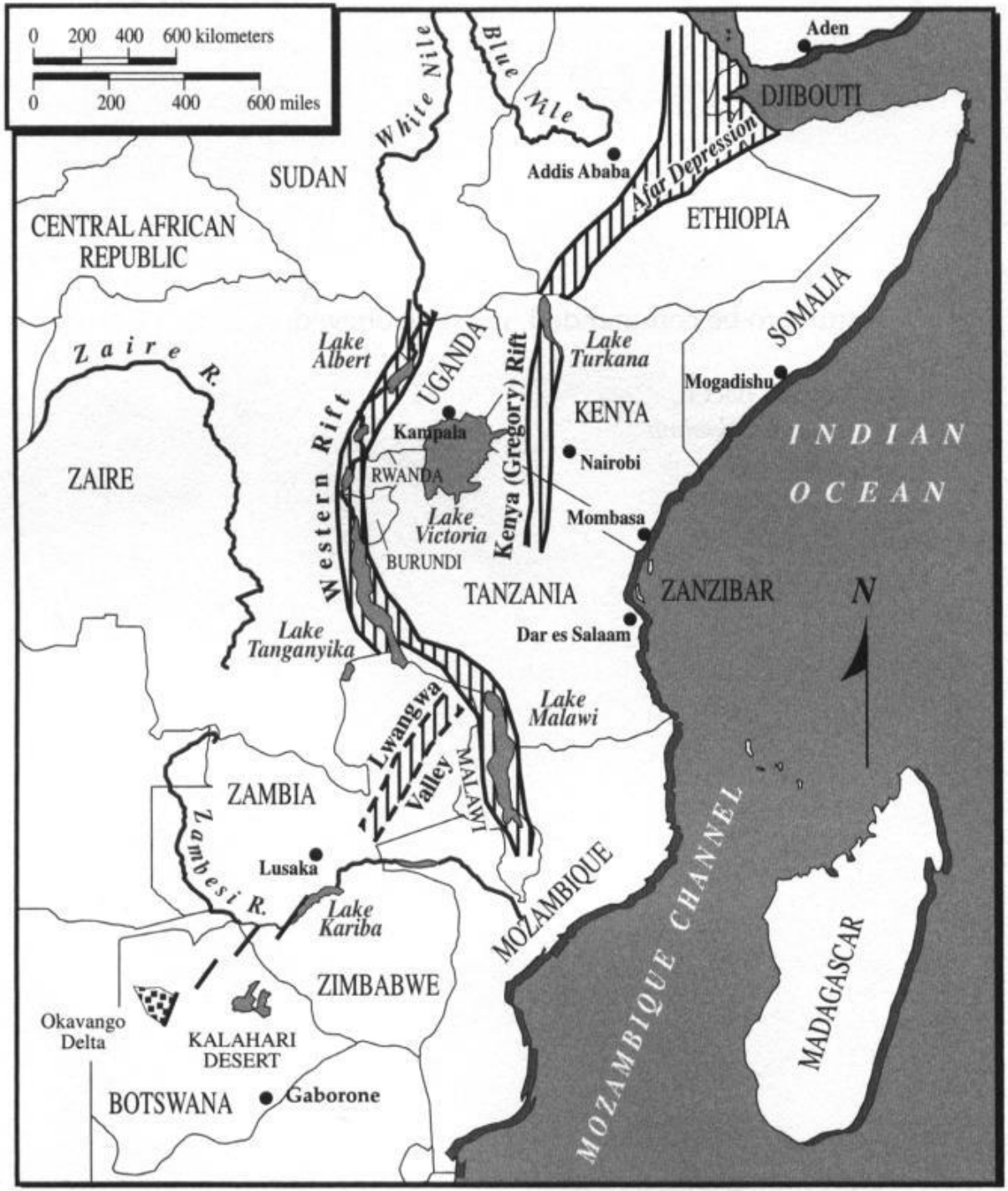
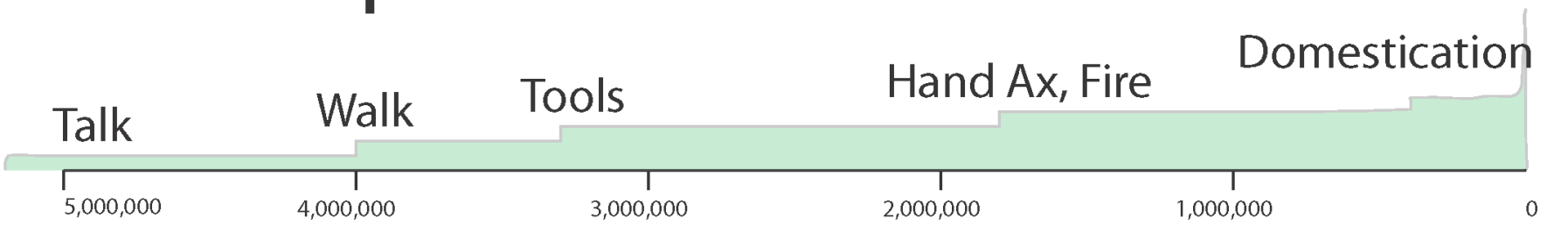
Geologists study the Earth

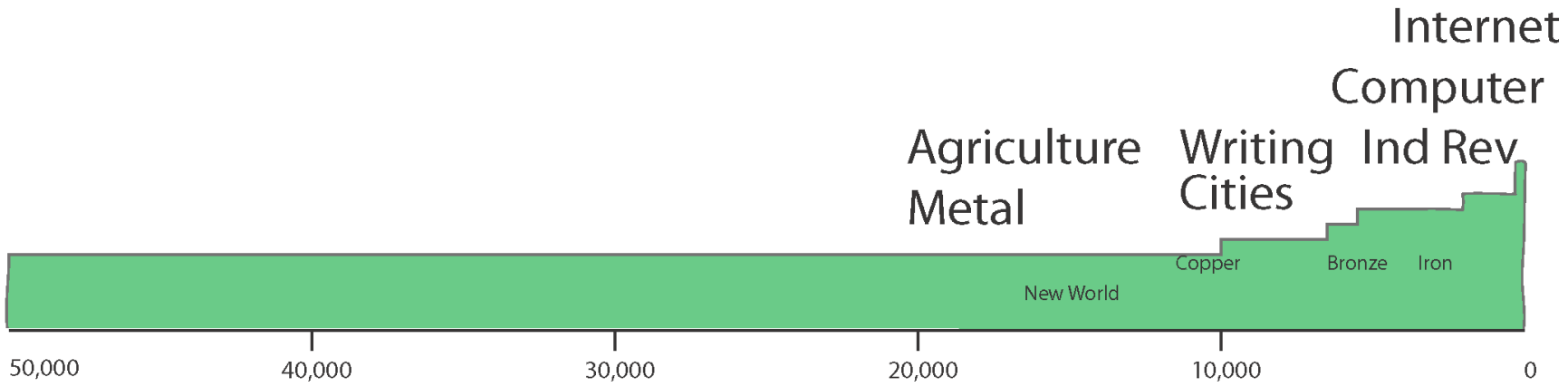
Elevation Data
of Africa
Digital Chart of the World
DCW Hydrology
ETOPO5 Ocean Data
Plate Carree
Meters
Feet
Elevations
map compliments of
NASA

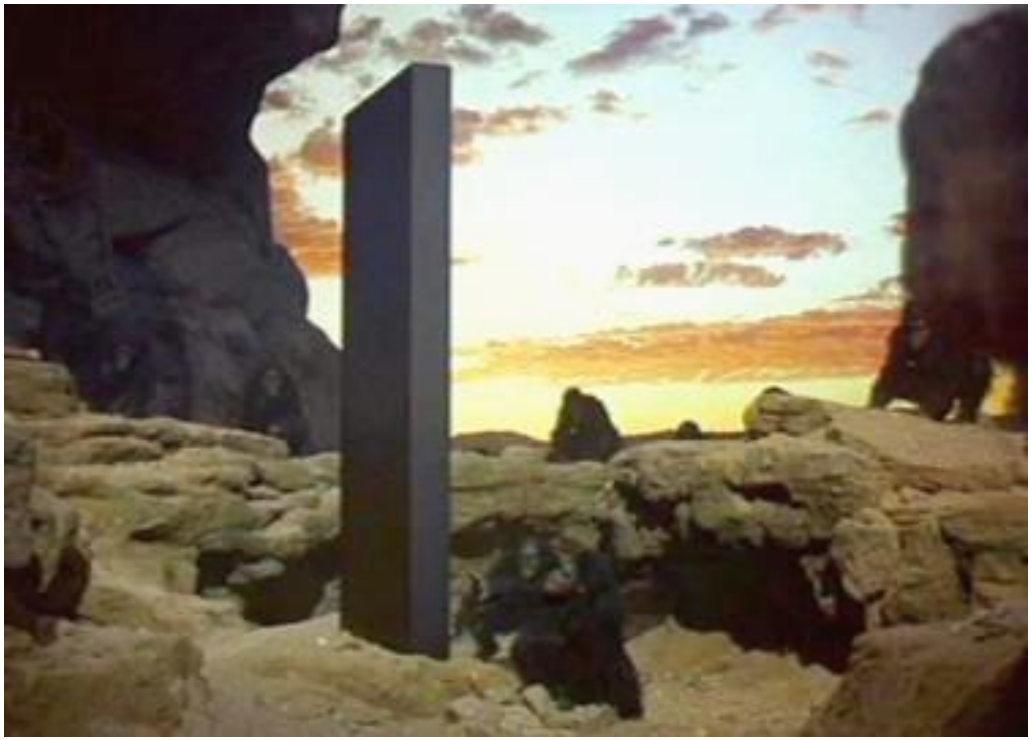


From Scholz (1997

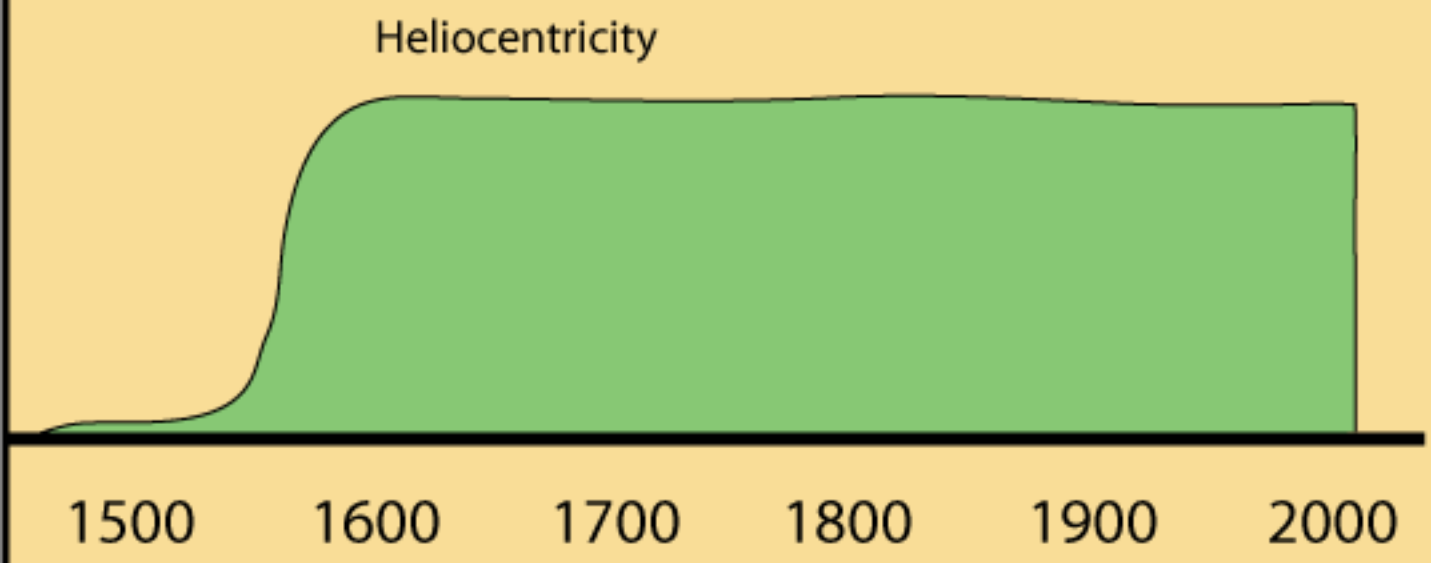
Our path


Talk
Walk
Tools
Hand Ax, Fire
Domestication
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0


Internet
Computer
Agriculture
Writing
Ind Rev
Metal
Cities
Copper
Bronze
Iron
New World
50,000
40,000
30,000
20,000
10,000
0

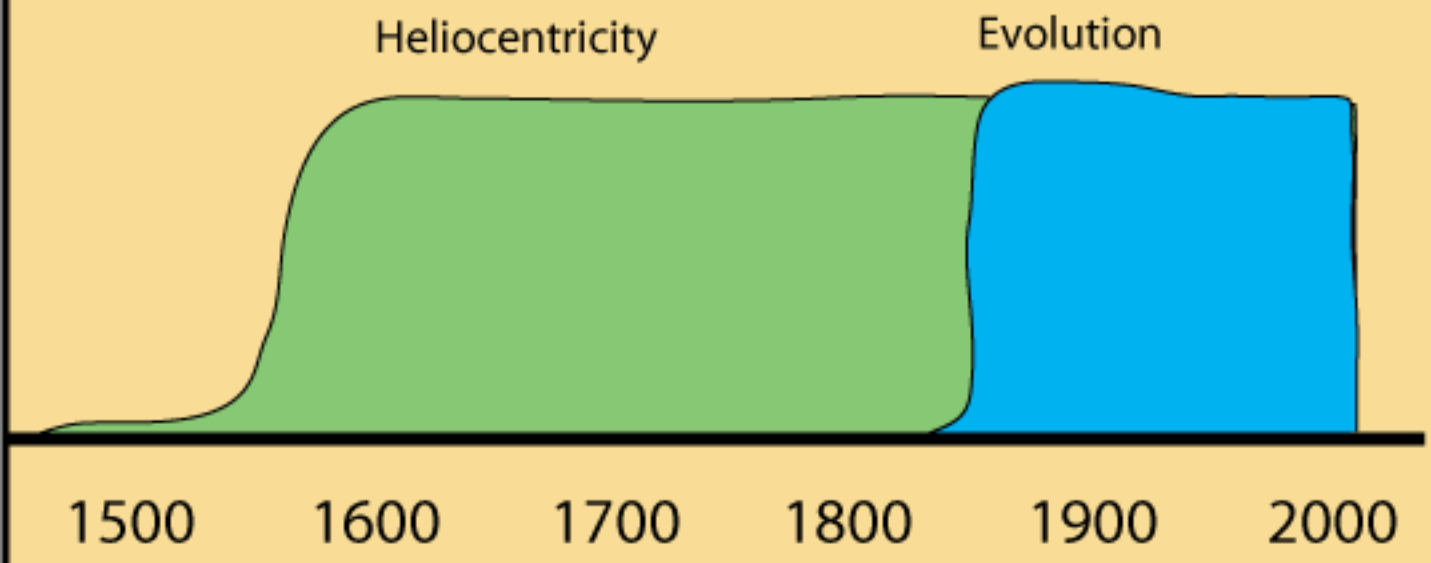


PARADIGM SHIFTS



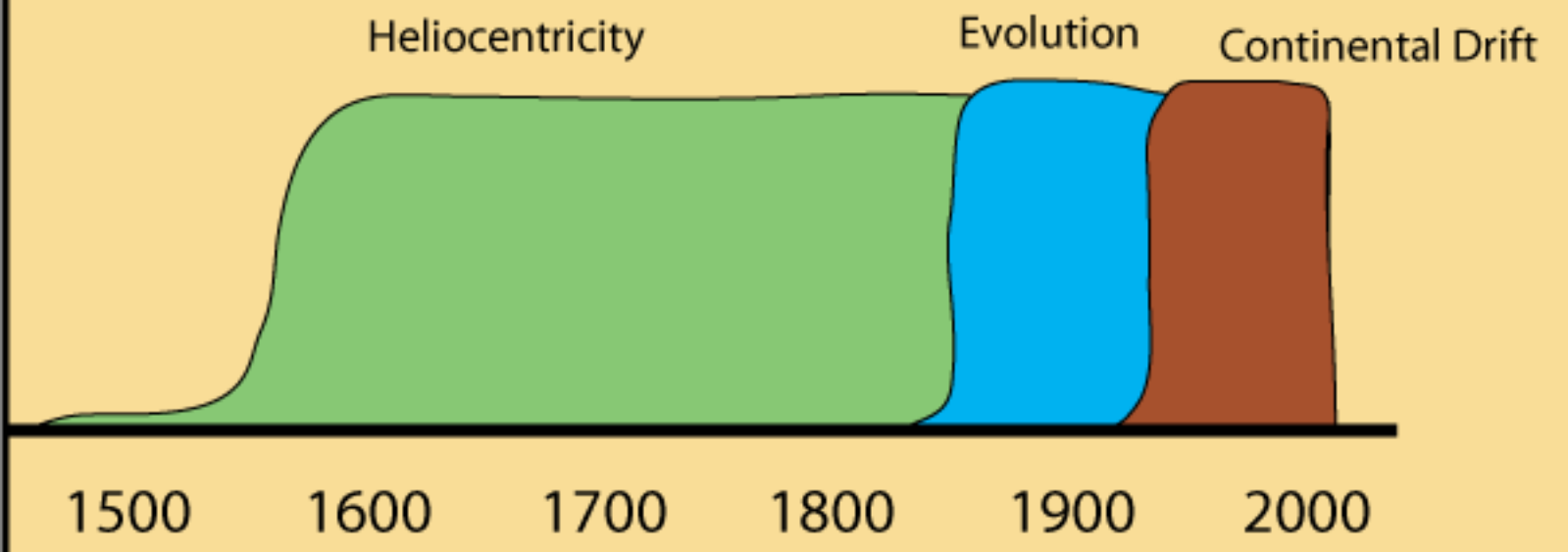
Copernicus, 1543

PARADIGM SHIFTS



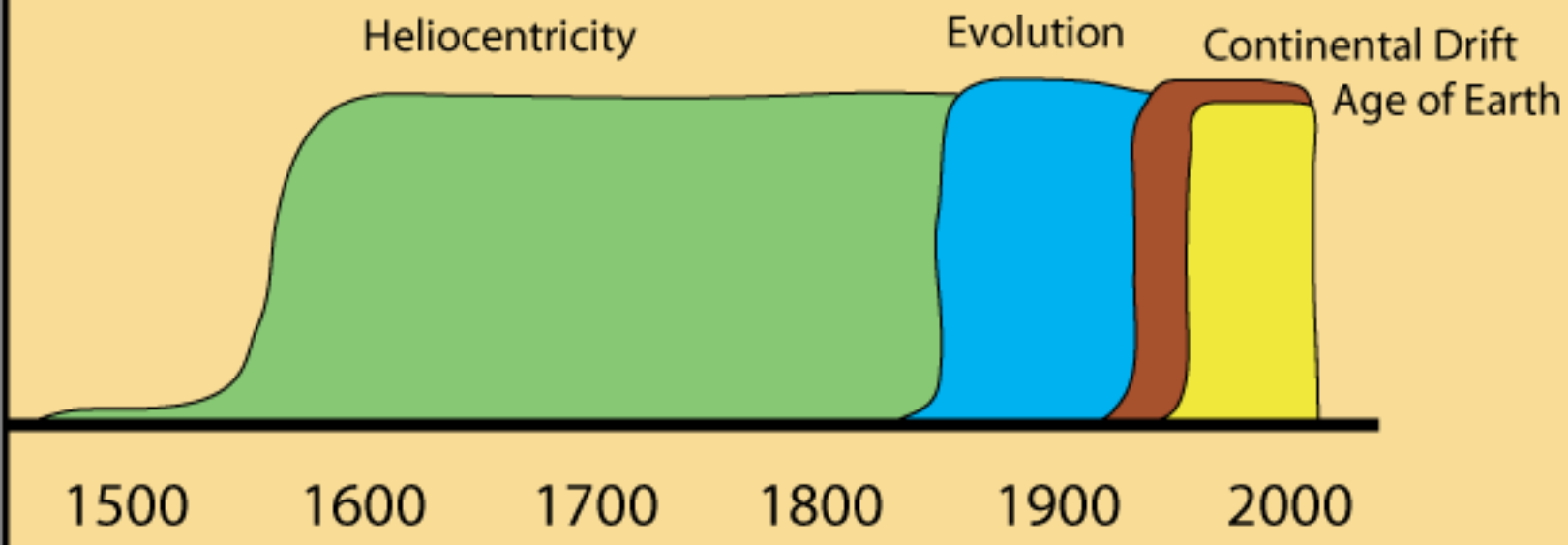
Darwin and Wallace, 1858

PARADIGM SHIFTS



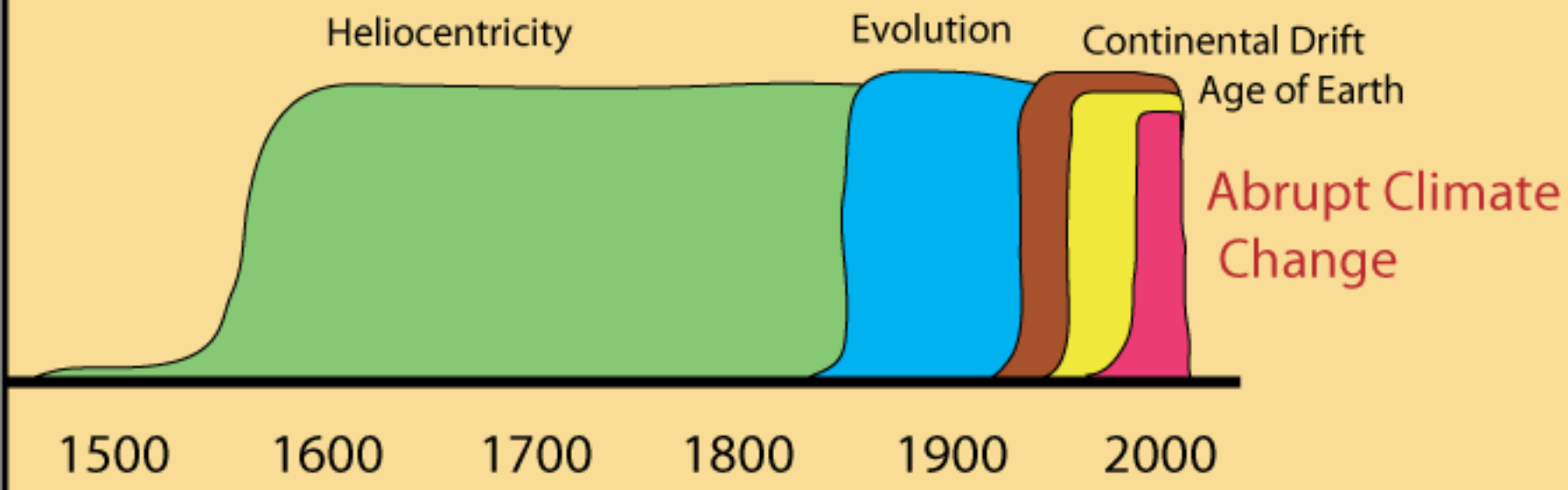
Alfred Wegener, 1915

PARADIGM SHIFTS

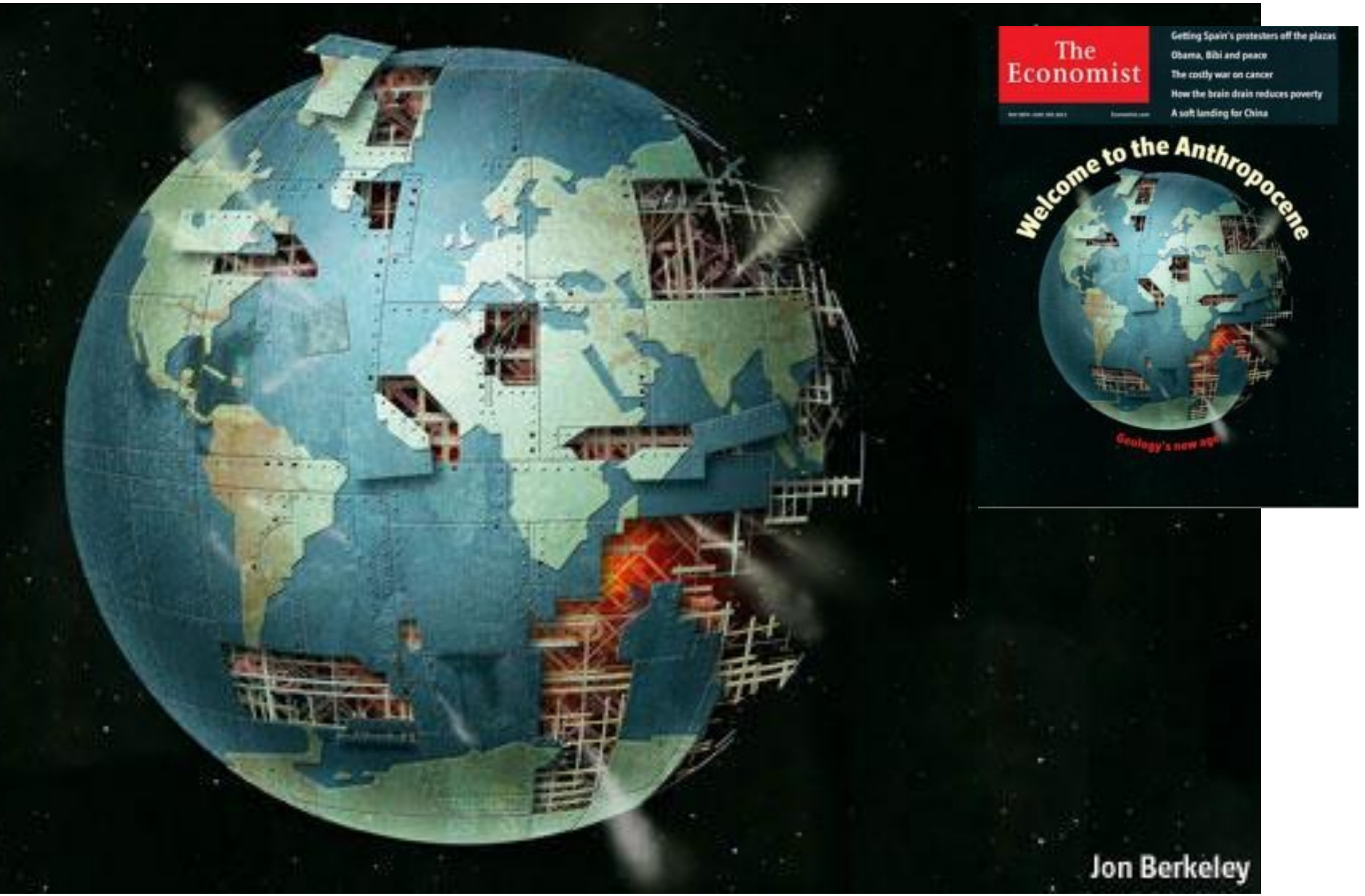


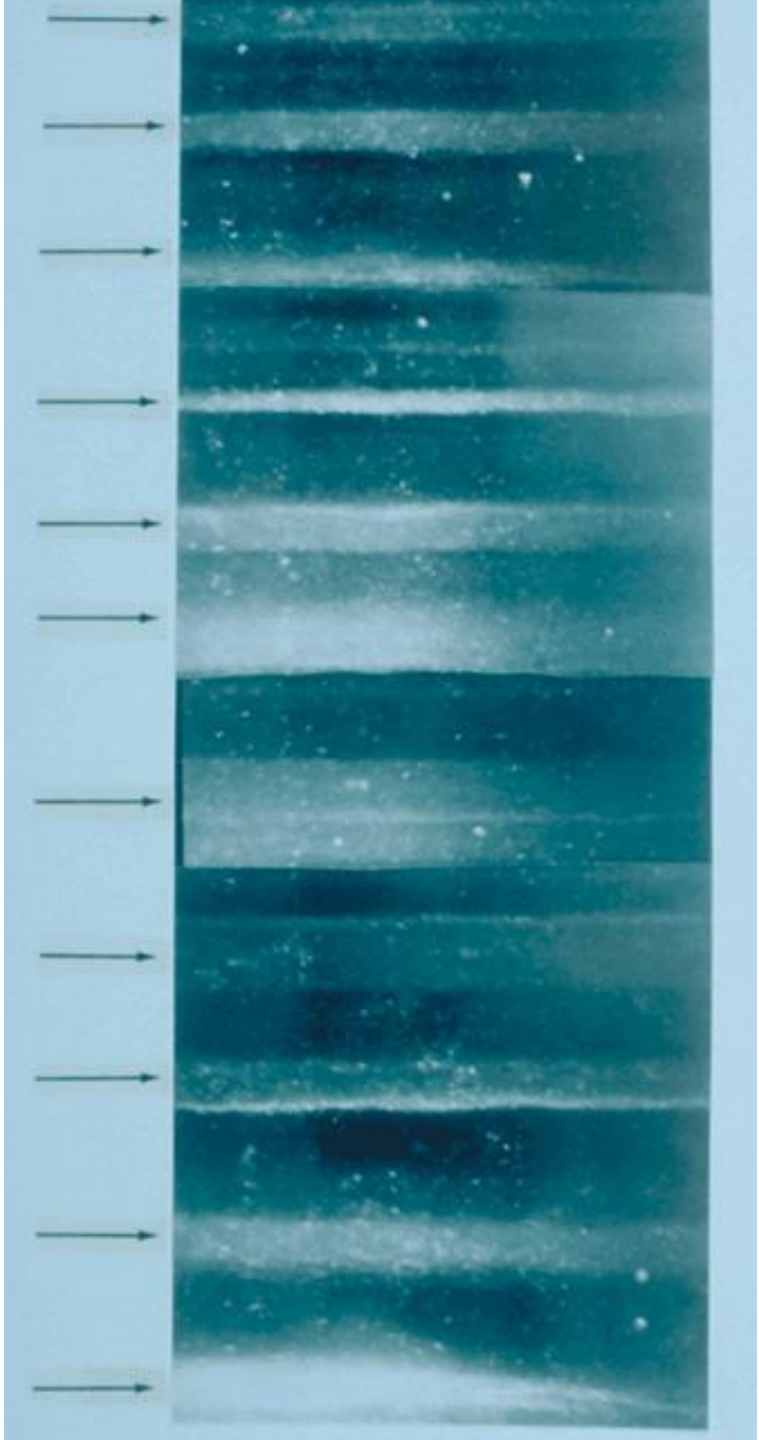
Arthur Holmes, 1927

PARADIGM SHIFTS



Ice Cores, 1992-1993


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



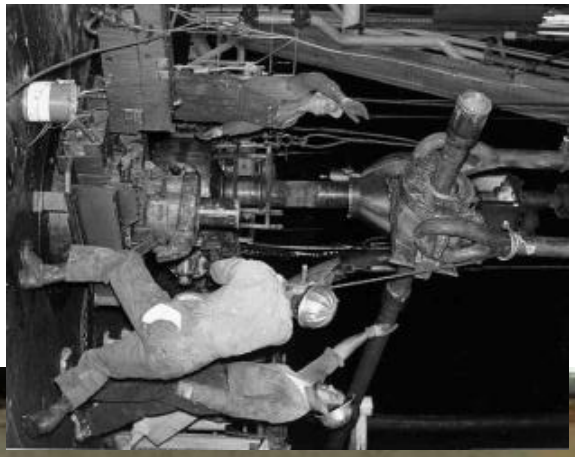
Stratified Ice

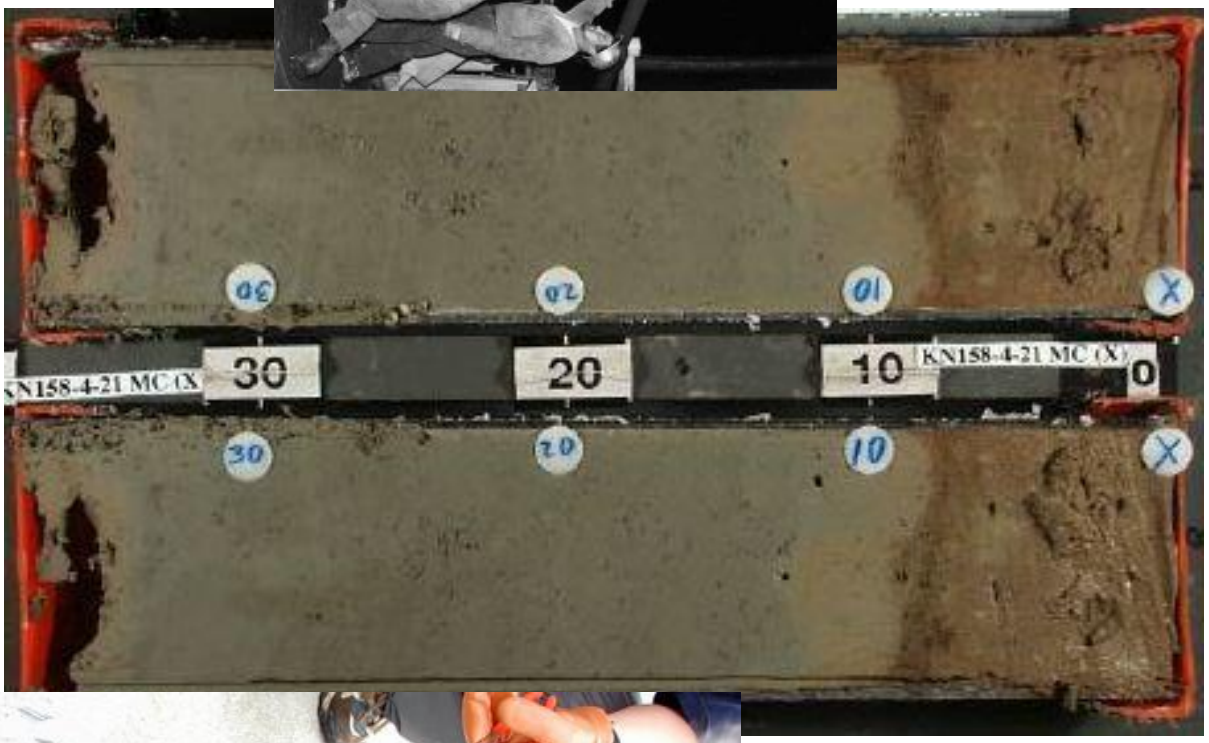
The pale bands are summer, the dark bands winter.

5 Cm

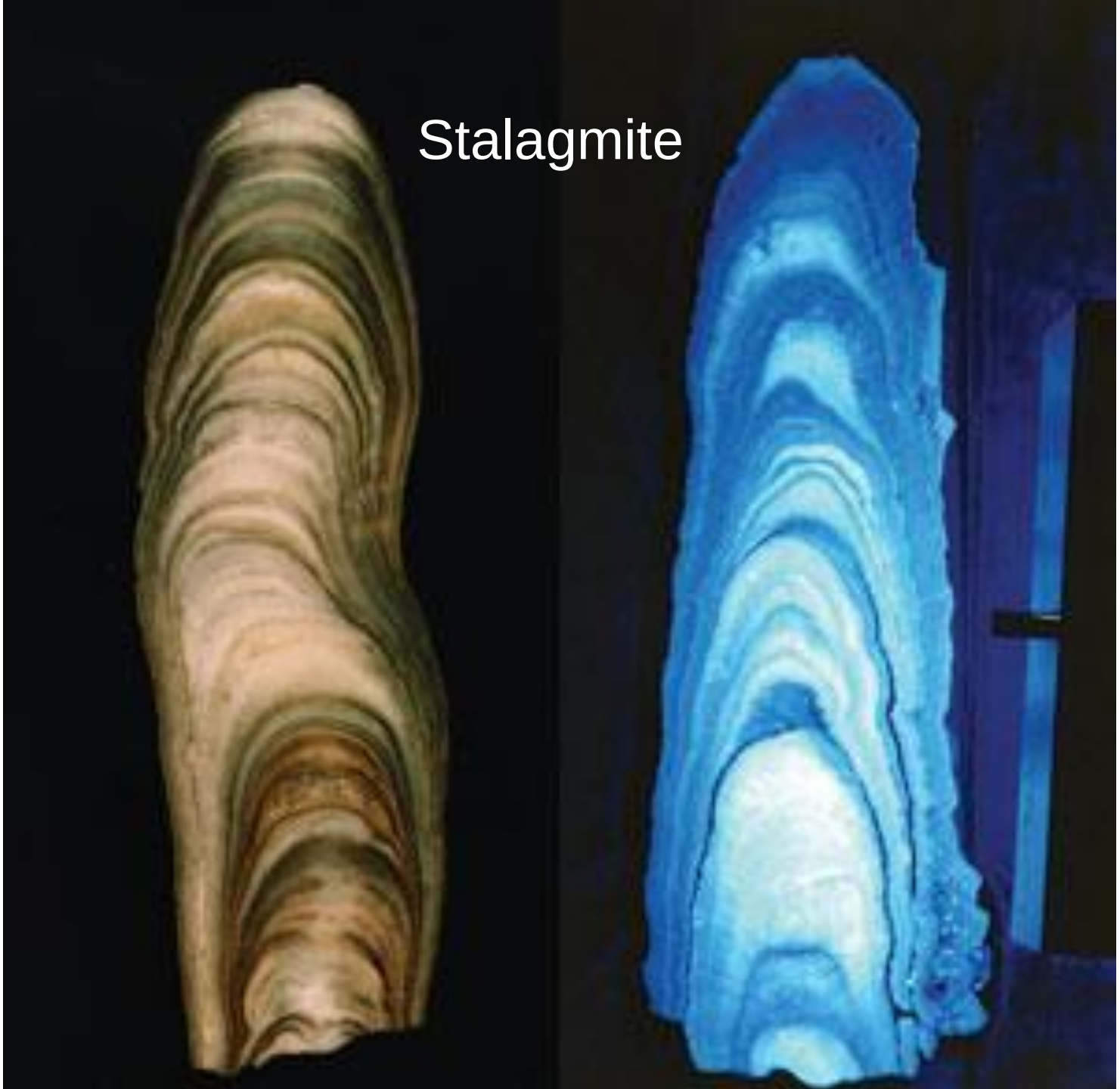
GISP 2 Core, 1855 meters

Wikipedia




KN158-4-21 MC (X
30
20
10
KN158-4-21 MC (X)
0

Stalagmite

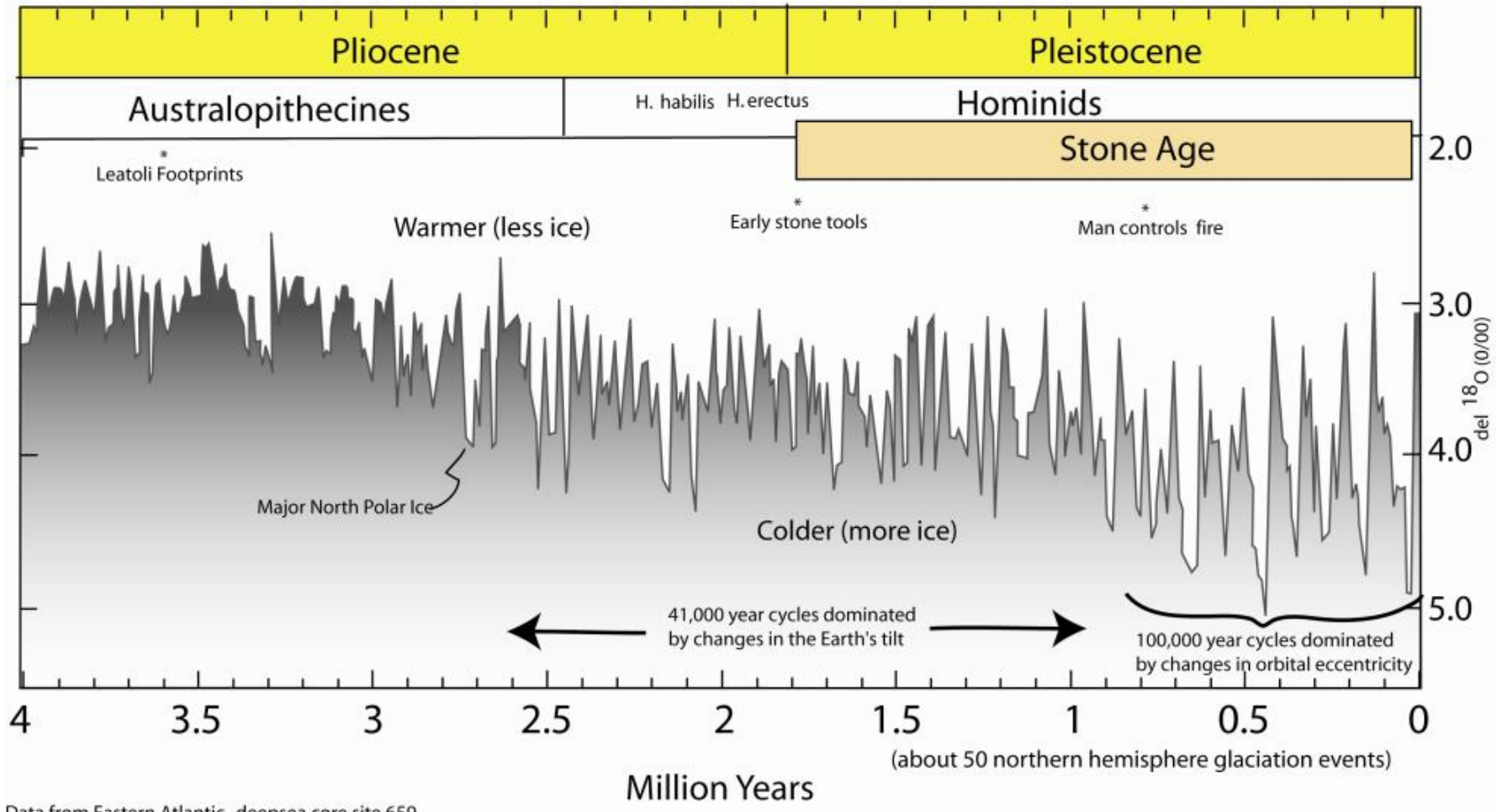


Paul Williams

UV Light

4,000,000 years

Deep Sea Core



Data from Eastern Atlantic, deepsea core site 659

Zachos et al., Science, 2001

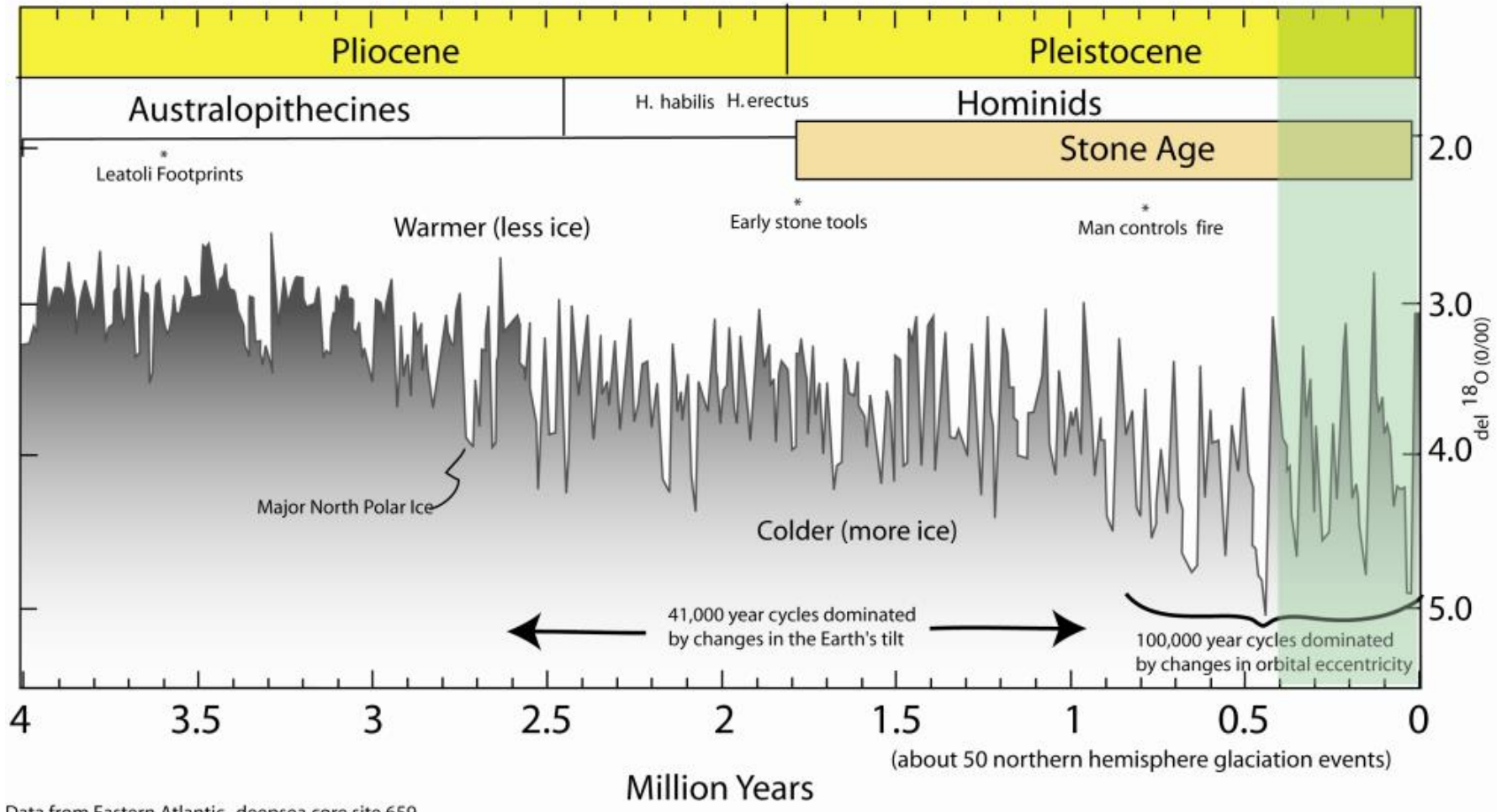
Proportion of $^{18}O/^{16}O$ in calcite of fossil shells.

Higher ^{18}O indicates more ice volume hence is also a good proxy for seal level.

RR Aug 12, 2006

4,000,000 years

Deep Sea Core



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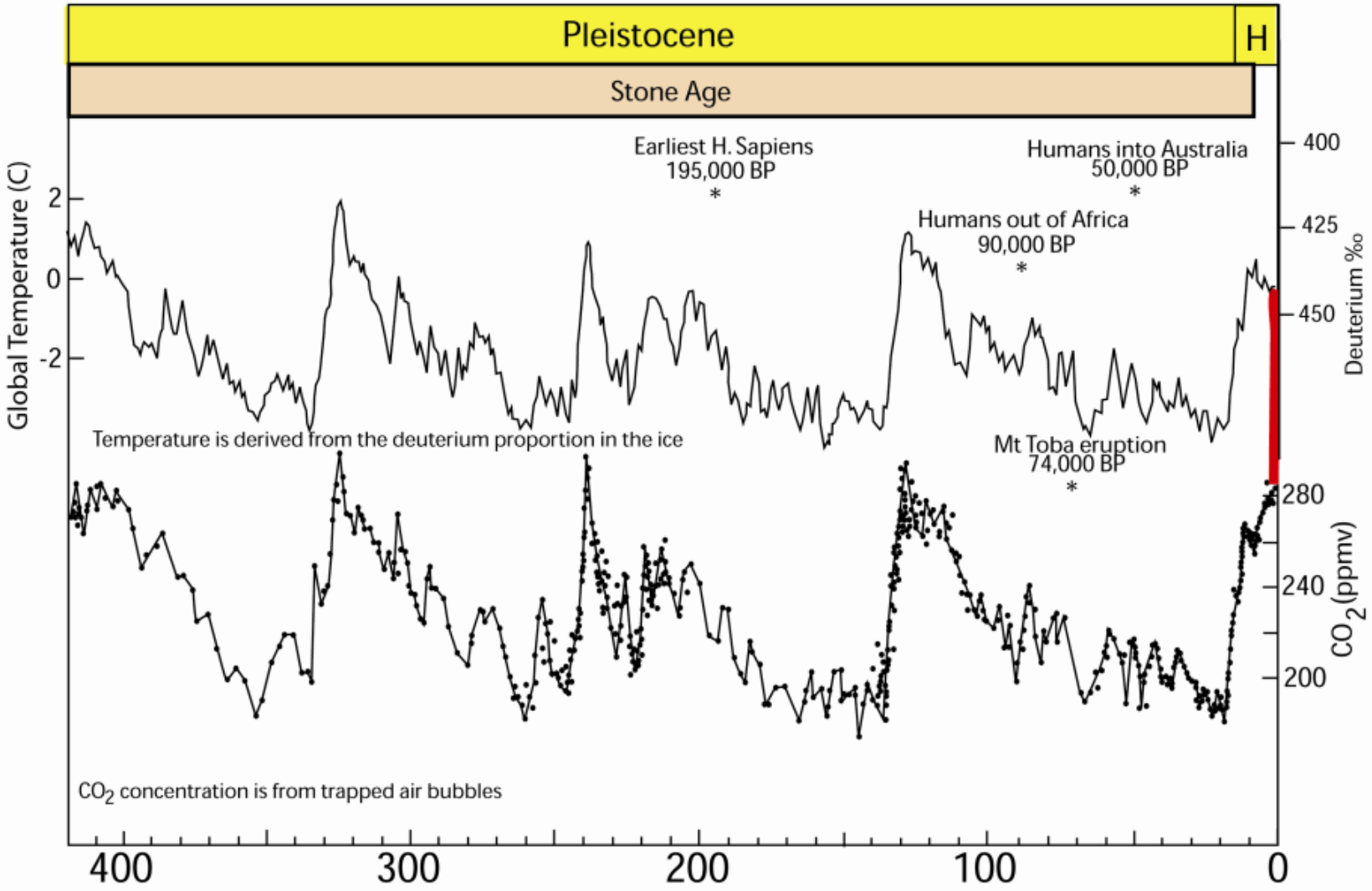
RR Aug 12, 2006

400,000 years

Antarctic Ice Cores



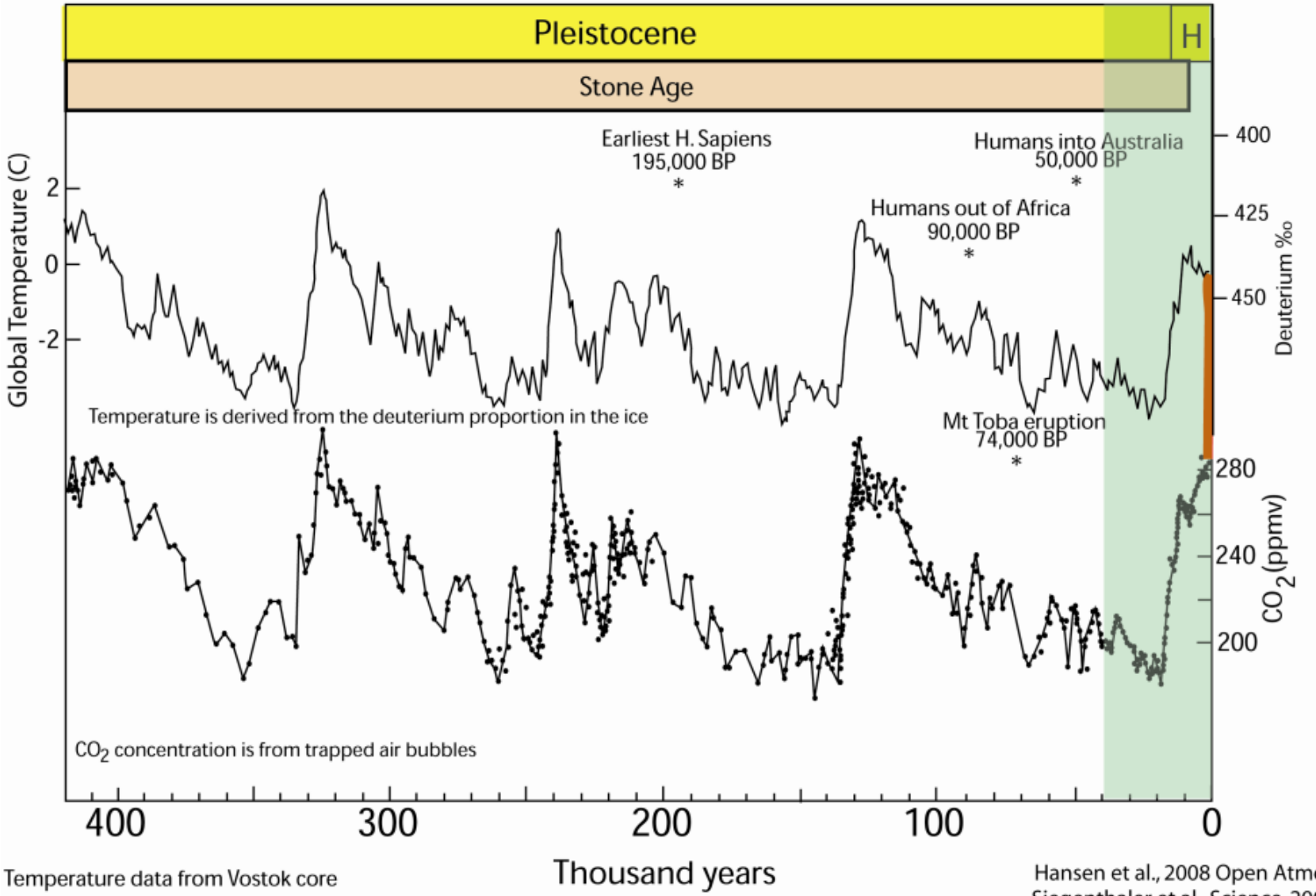
Temperature data from Vostok core
CO_2 data from four ice cores

Hansen et al., 2008 Open Atmos. Sci
Siegenthaler et al., Science, 2005

RR 30 March, 2009

400,000 years

Antarctic Ice Cores



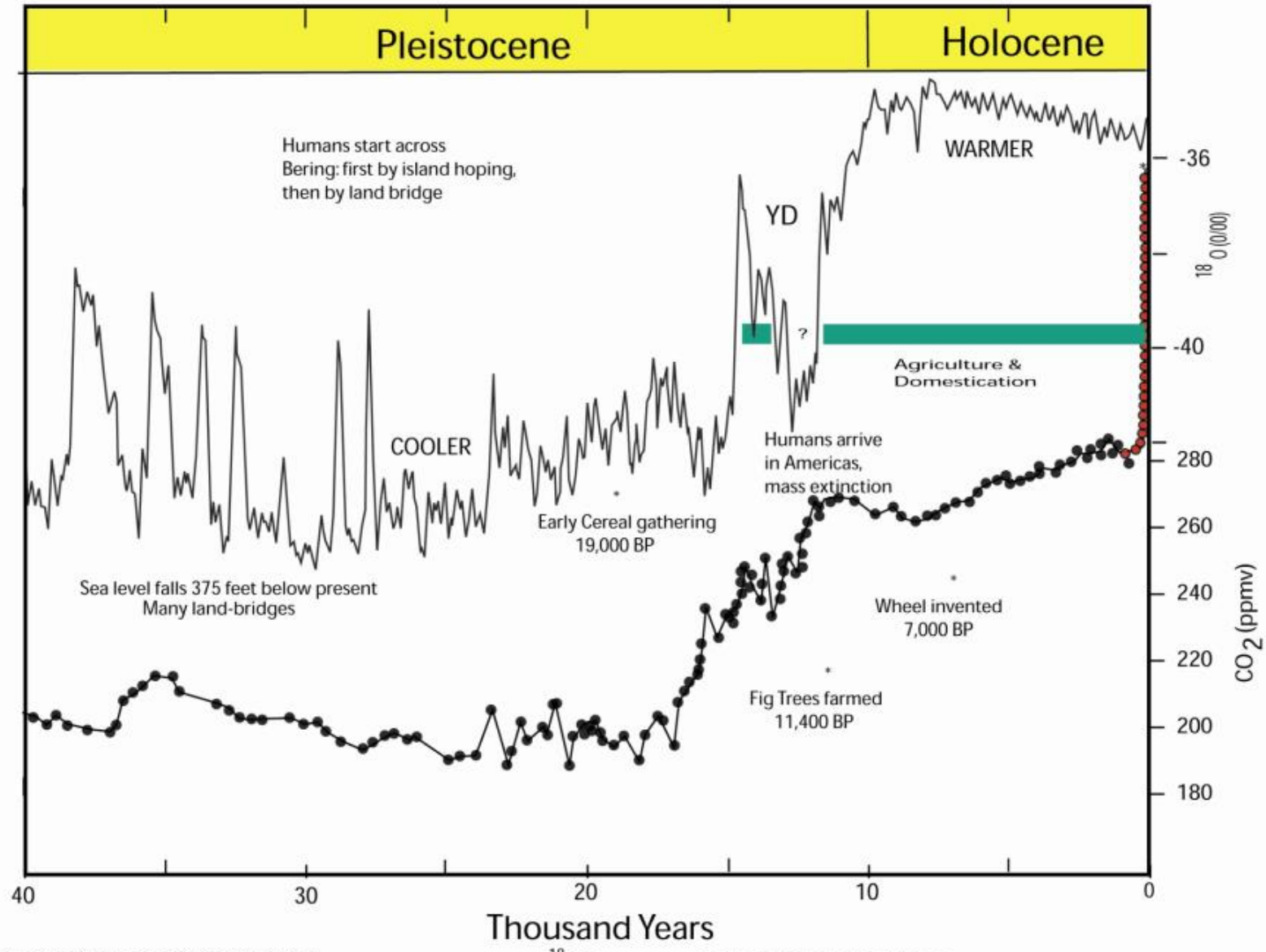
Temperature data from Vostok core
CO_2 data from four ice cores

Hansen et al., 2008 Open Atmos. Sci
Siegenthaler et al., Science, 2005

RR 30 March, 2009

40,000 years

Greenland Ice Core, NGRIP



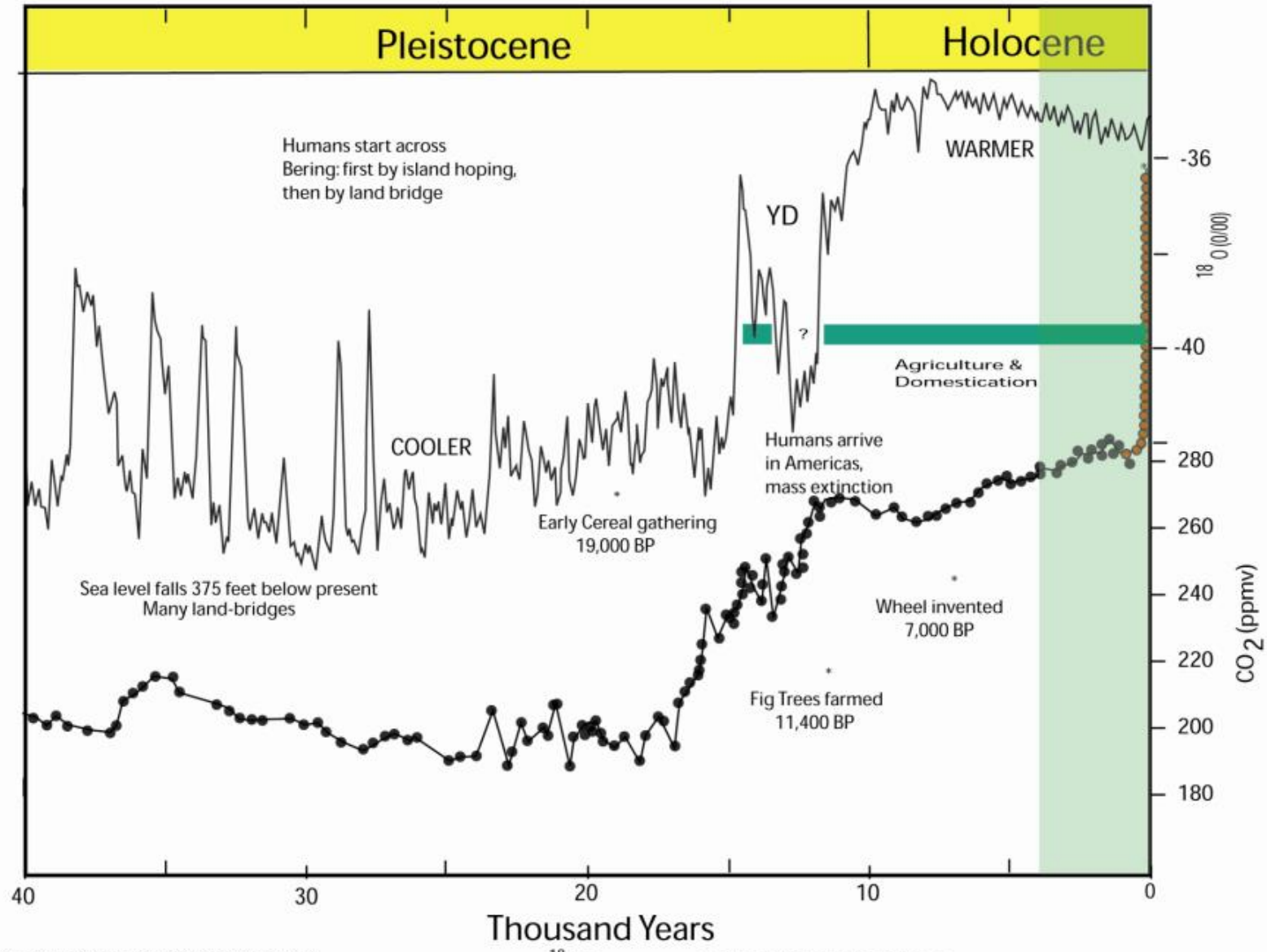
Early cereal: Tano and Willcox, 2006, Science 311:1886
First fig: Kislev et al., 2006, Science 312:1372

^{18}O: Svensson et al., 2006, QSR 25:3258-3267 fig. 2
CO_2: NOAA: www.climate.unibe.ch/clim_recon/images/CO2_60-0k_big.gif

RR 16 Feb, 2007

40,000 years

Greenland Ice Core, NGRIP



Early cereal: Tano and Willcox, 2006, Science 311:1886
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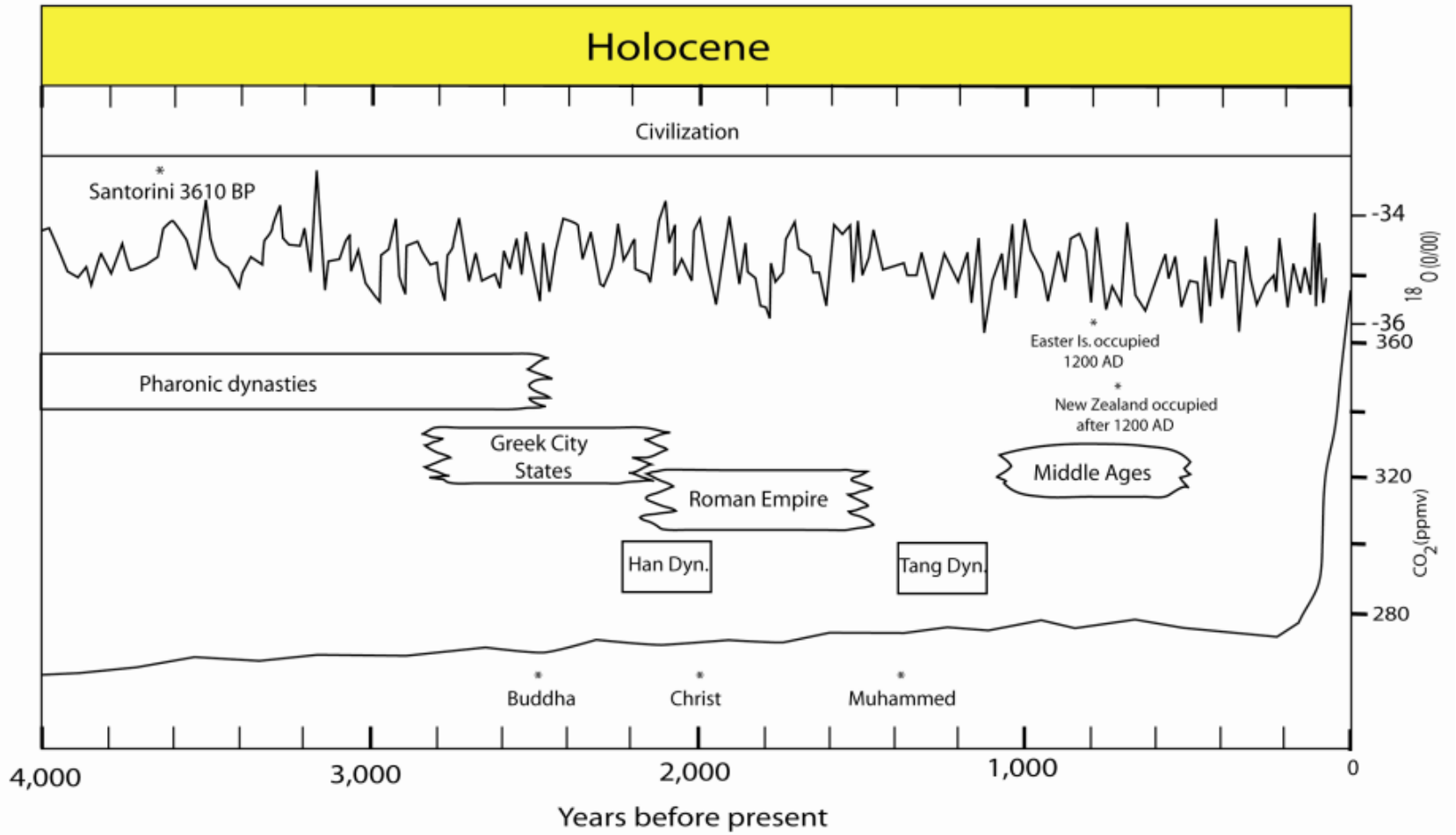
^{18}O: Svensson et al., 2006, QSR 25:3258-3267 fig. 2
CO_2: NOAA: www.climate.unibe.ch/clim_recon/images/CO2_60-0k_big.gif

RR 16 Feb, 2007

4,000 years

Greenland ice core, GISP-2



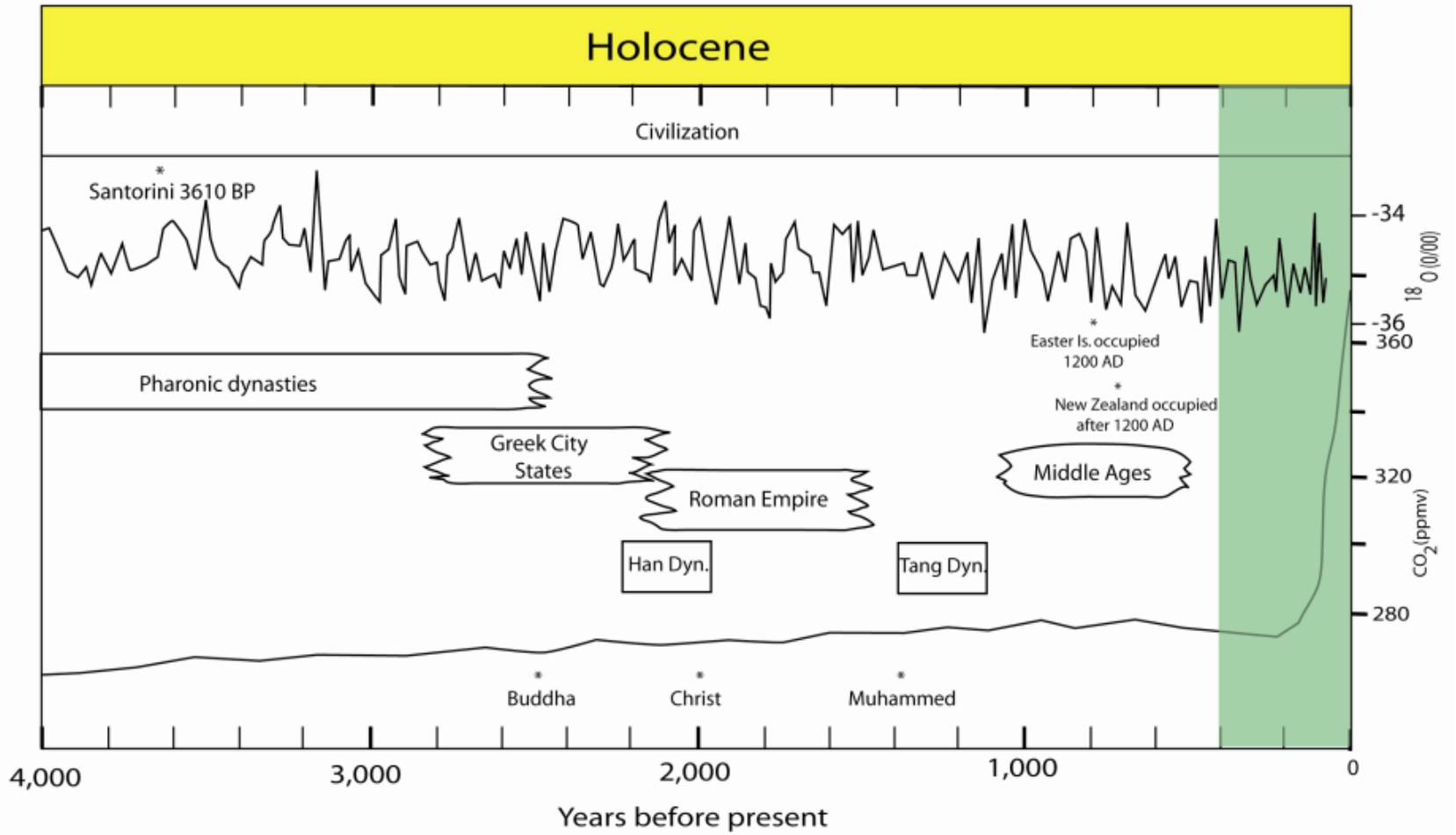
Oxygen isotope: www.gisp2.sr.unh.edu/DATA/Obrien
CO2: NOAA.gov/pub/data/paleo/icecore/greenland/summit/gisp2/isotopes and Mauna Loa measurments.

RR 16 Feb., 2007

Easter Is. NZ: Hunt and Lipo, 2006, Science 311:1603

4,000 years

Greenland ice core, GISP-2



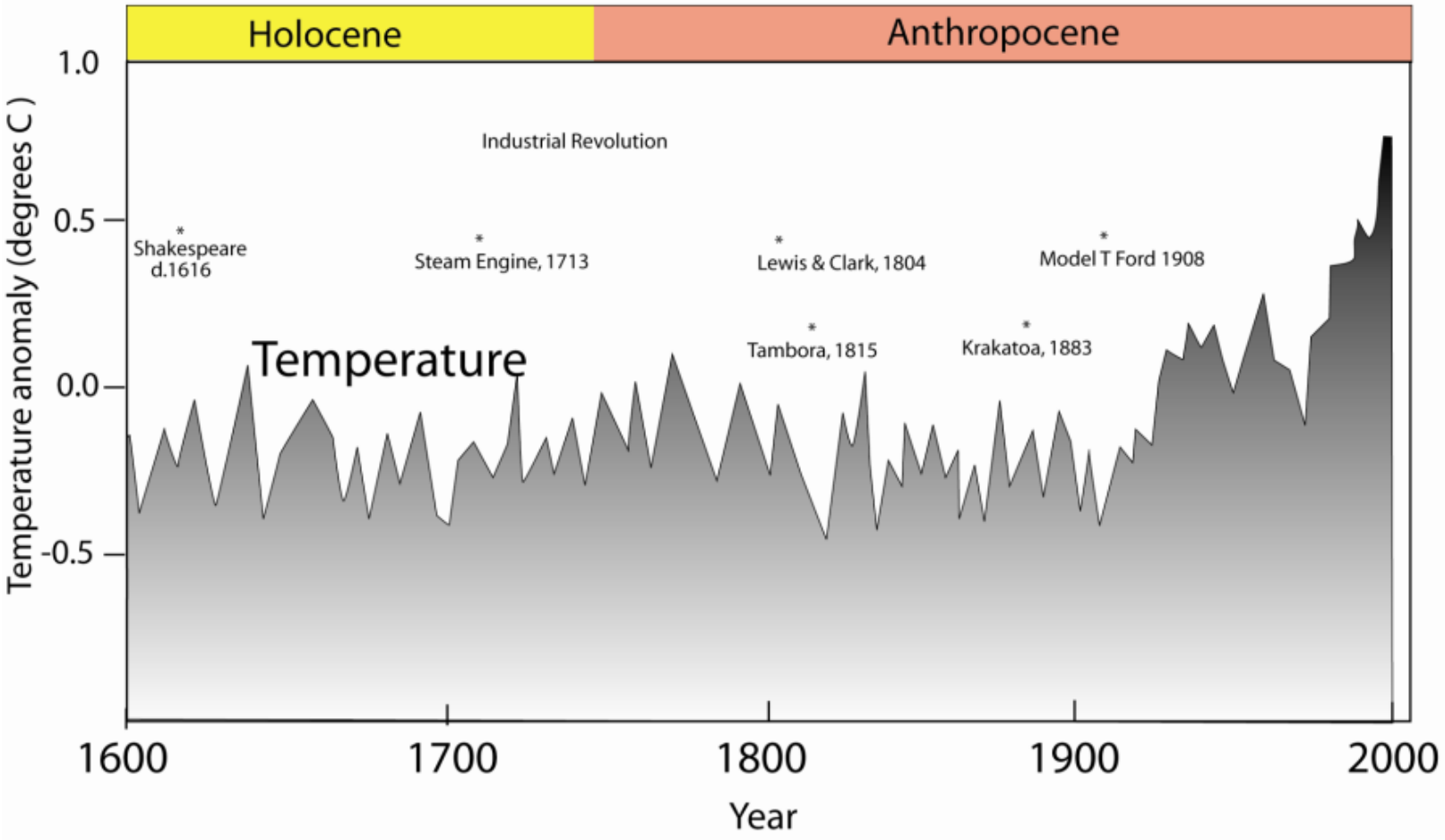
Oxygen isotope: www.gisp2.sr.unh.edu/DATA/Obrien
CO2: NOAA.gov/pub/data/paleo/icecore/greenland/summit/gisp2/isotopes and Mauna Loa measurments.

RR 16 Feb., 2007

Easter Is. NZ: Hunt and Lipo, 2006, Science 311:1603

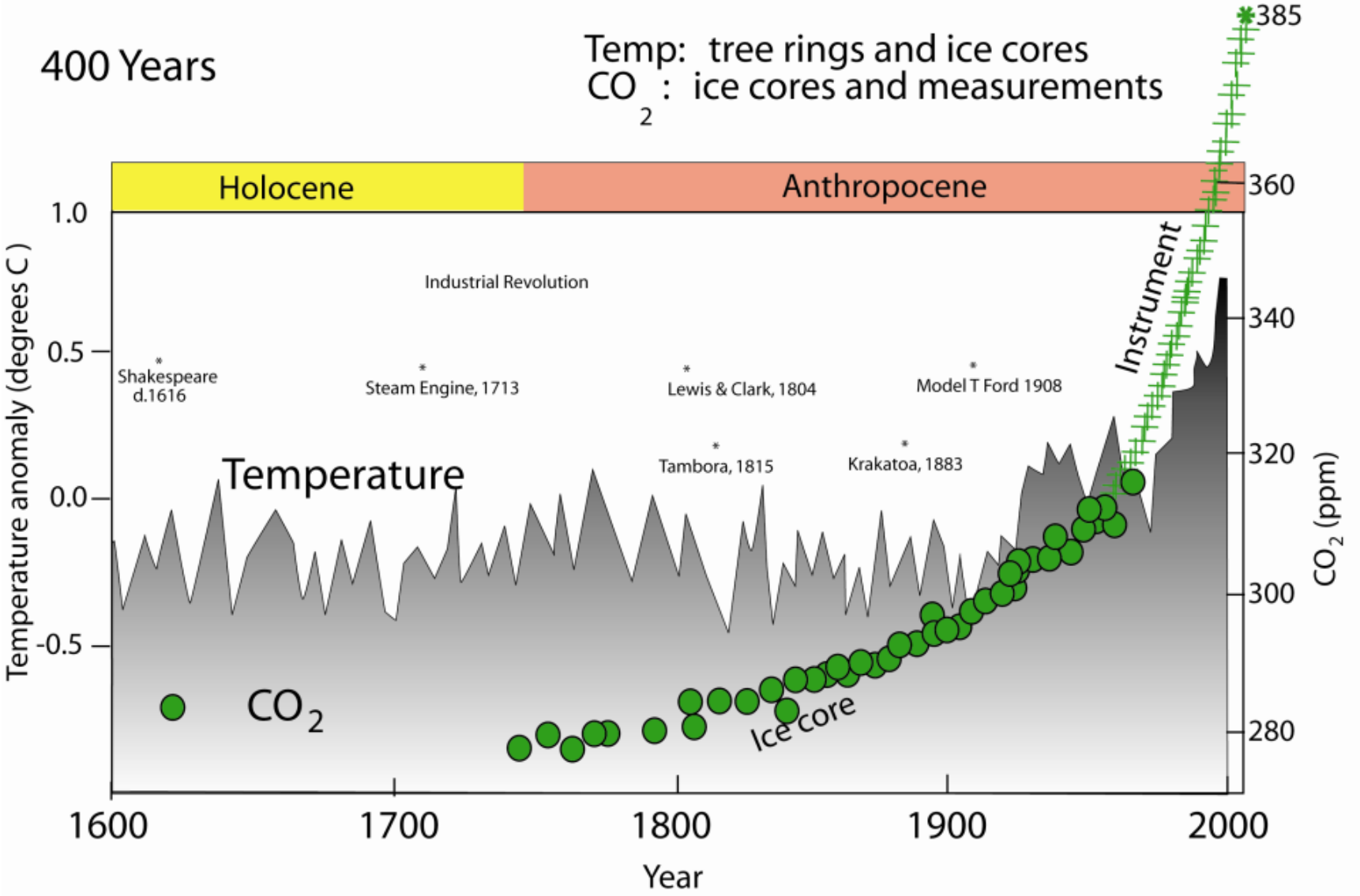
400 Years

Temp: tree rings and ice cores



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

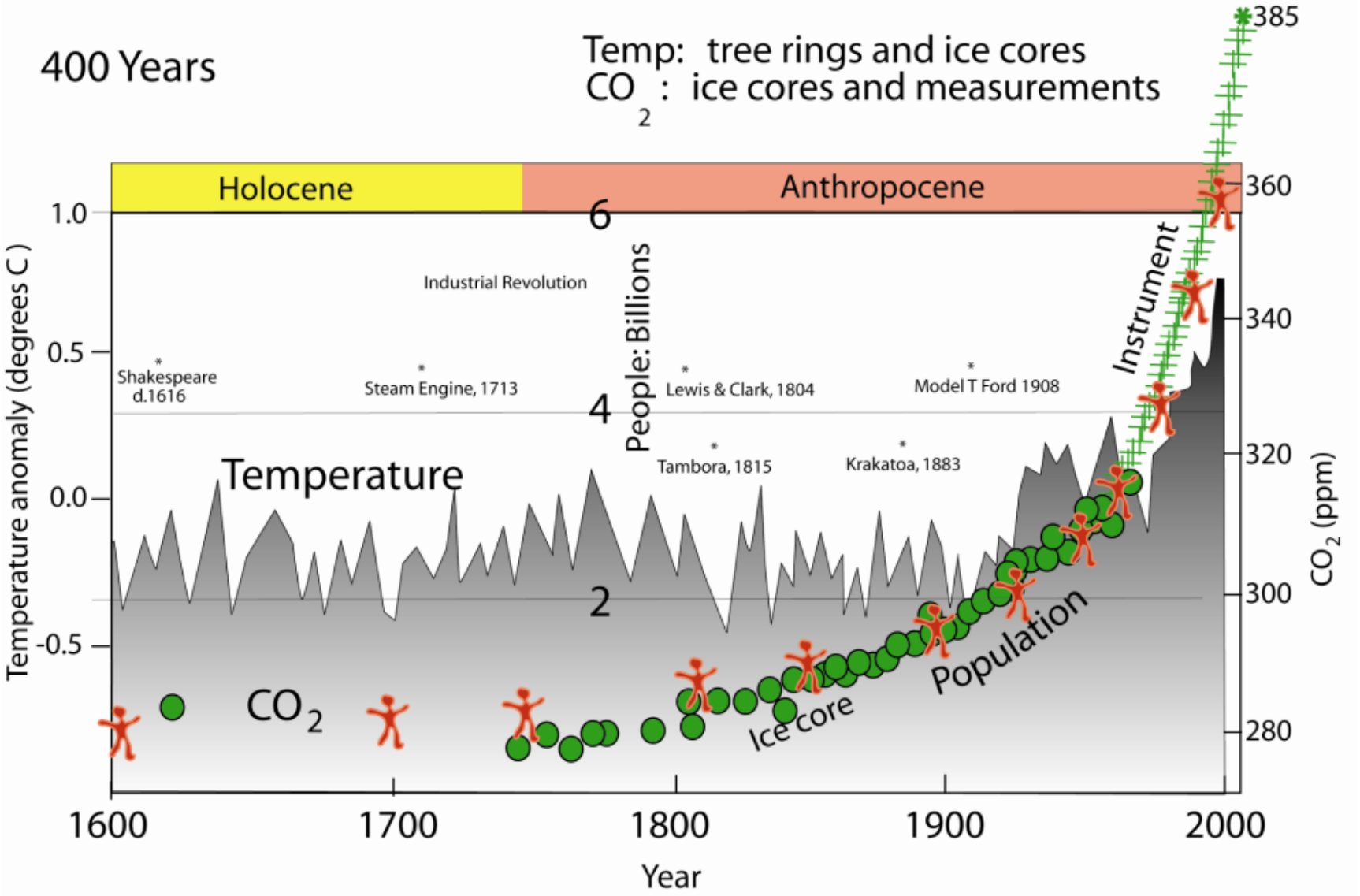
RR 6 Jan 2007



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

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

RR 6 Jan 2007

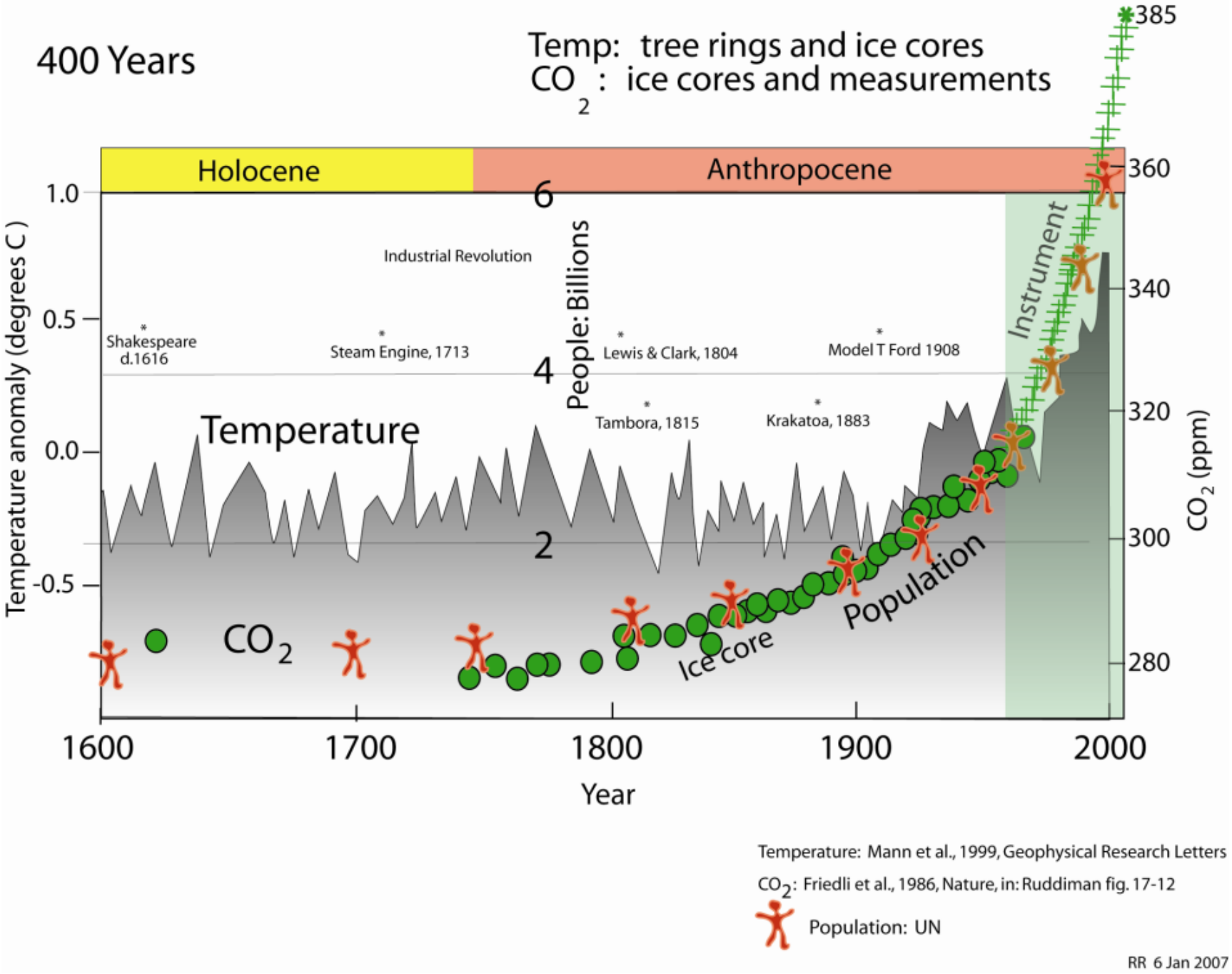


Temperature: Mann et al., 1999, Geophysical Research Letters

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

Population: UN

RR 6 Jan 2007



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

D = 12,756 20 Km

D = 7.5 cm
Skin = ca. 0.1 mm

GLOBAL MONTHLY MEAN CO_2

Dave Keeling

PARTS PER MILLION

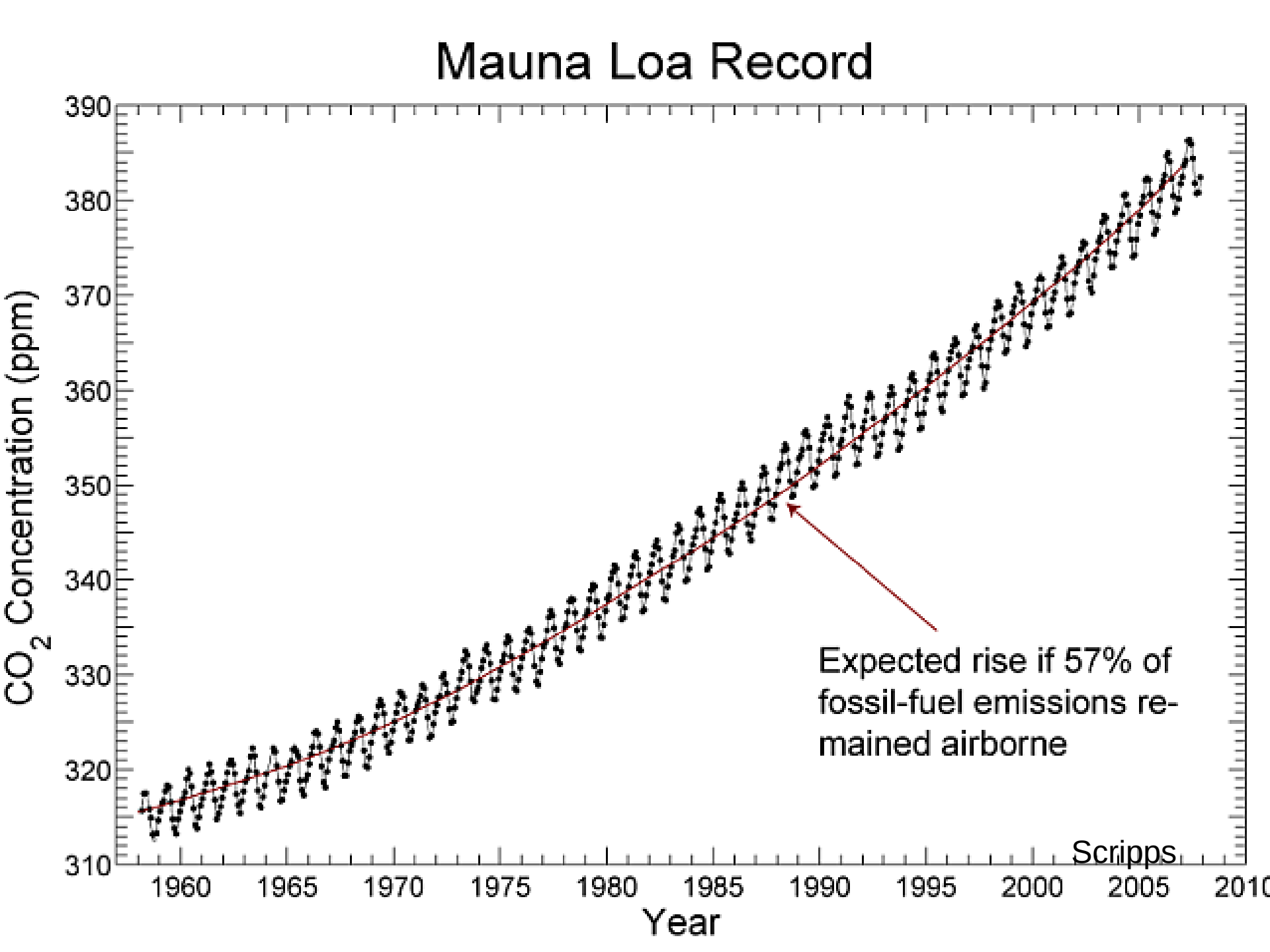
420
400
380
360
340
320

1980
1990
2000
2010
2020

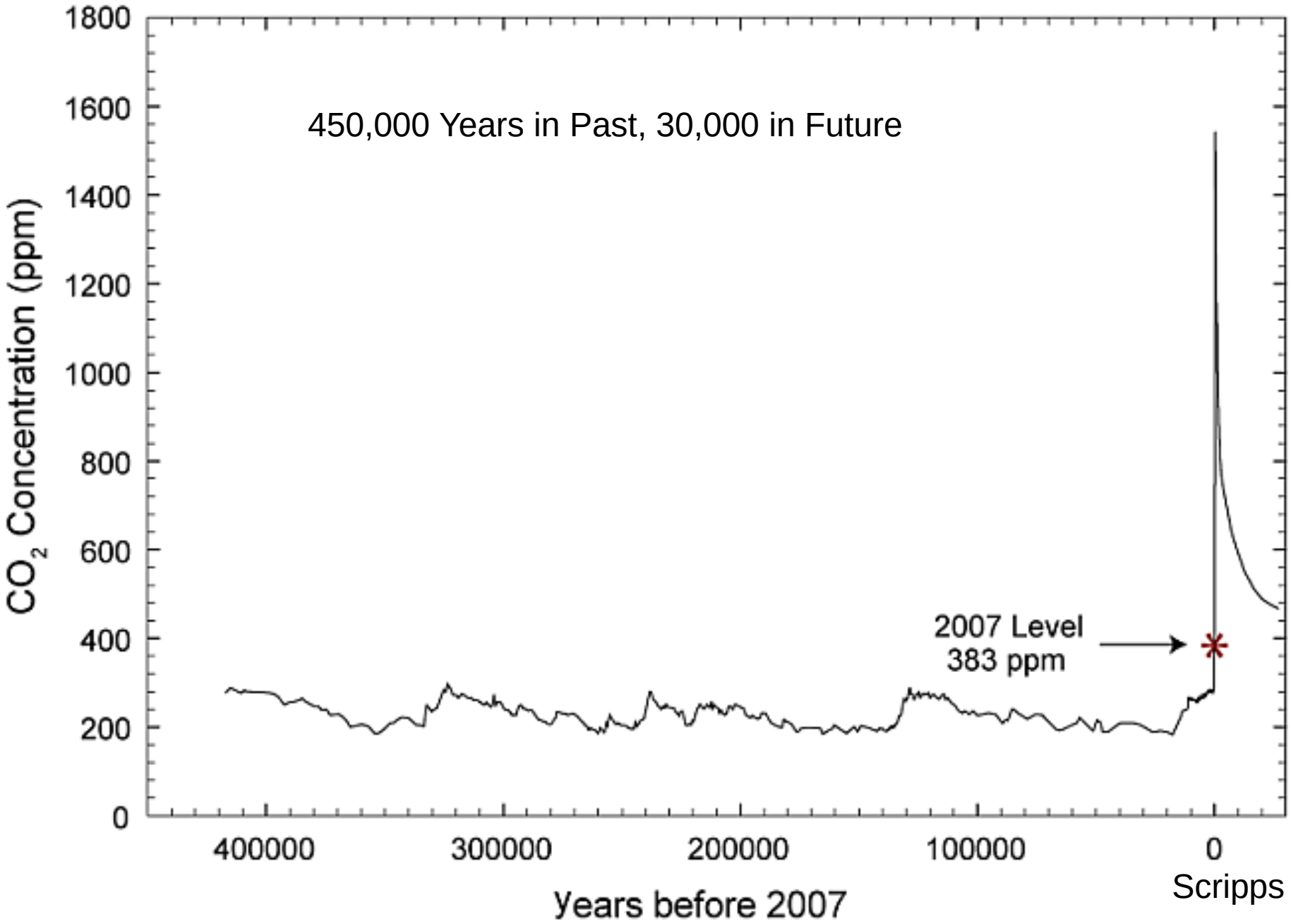
YEAR

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

January 2018


Mauna Loa Record
390
380
370
360
350
340
330
320
310
CO_2 Concentration (ppm)
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Expected rise if 57% of fossil-fuel emissions remained airborne
Scripps

Business-As-Usual Projection

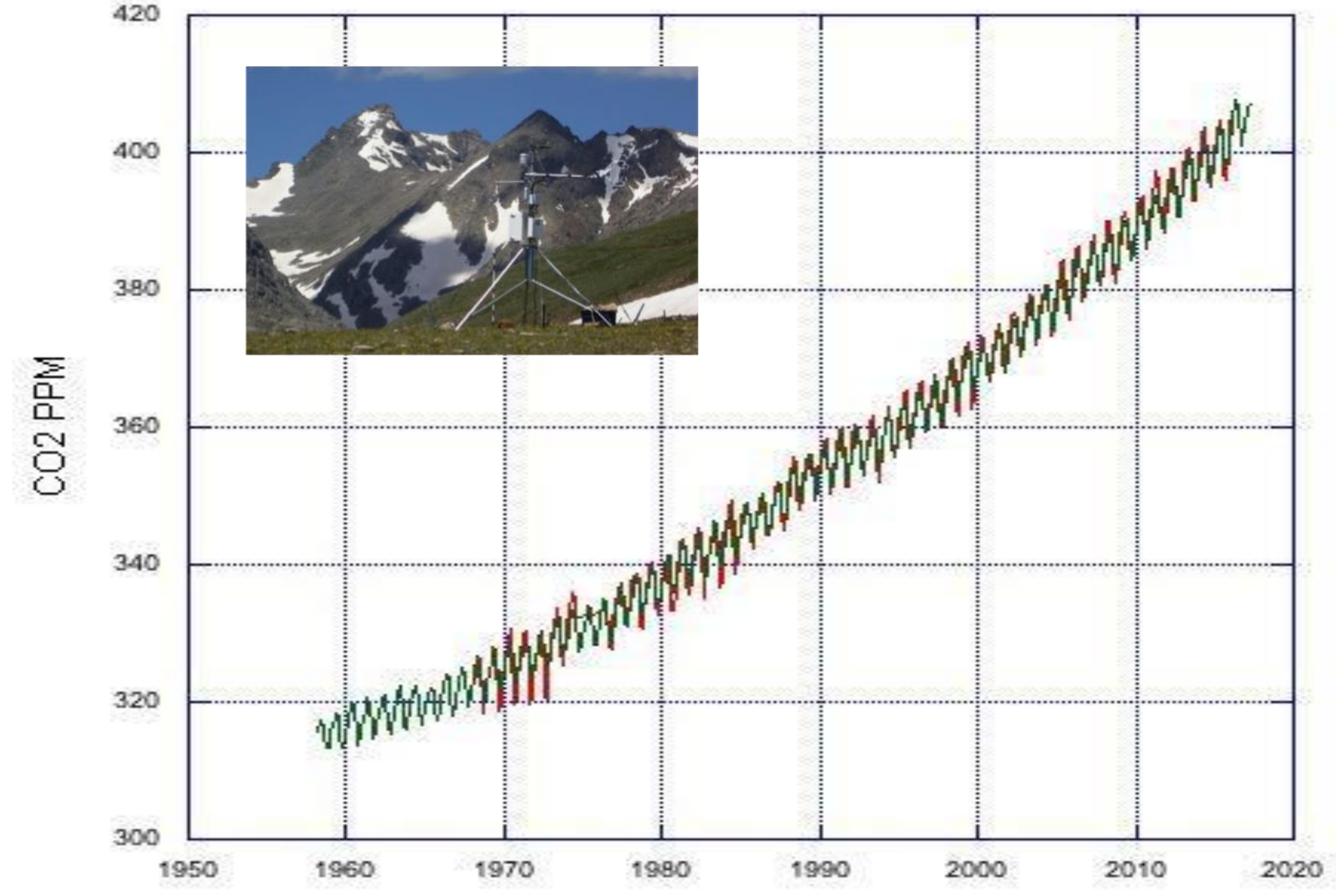


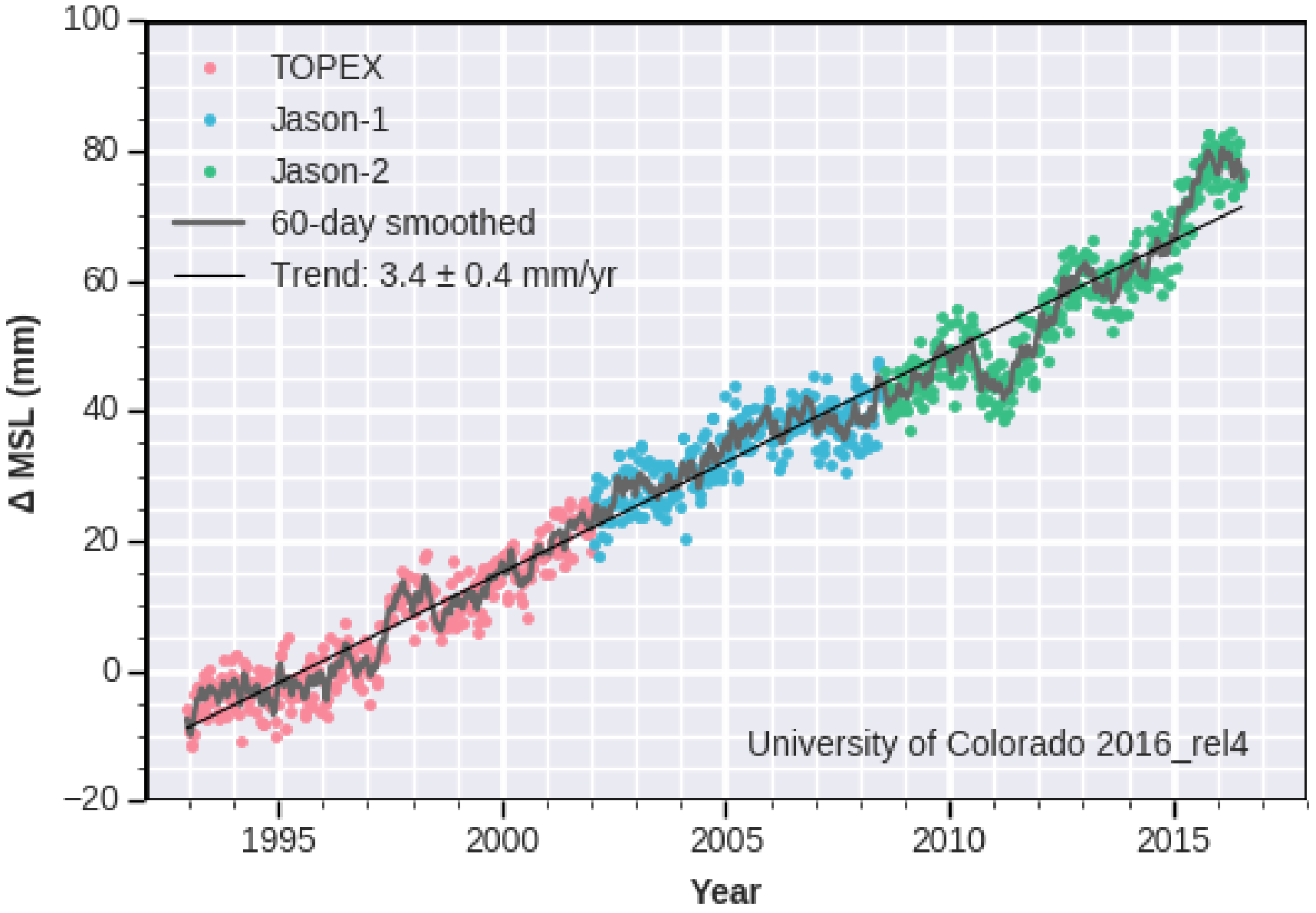
Scripps

NWR CO2
MLO CO2

Mauna Loa since 1958
Niwot Ridge since 1967

Allen Best, Mt Times News

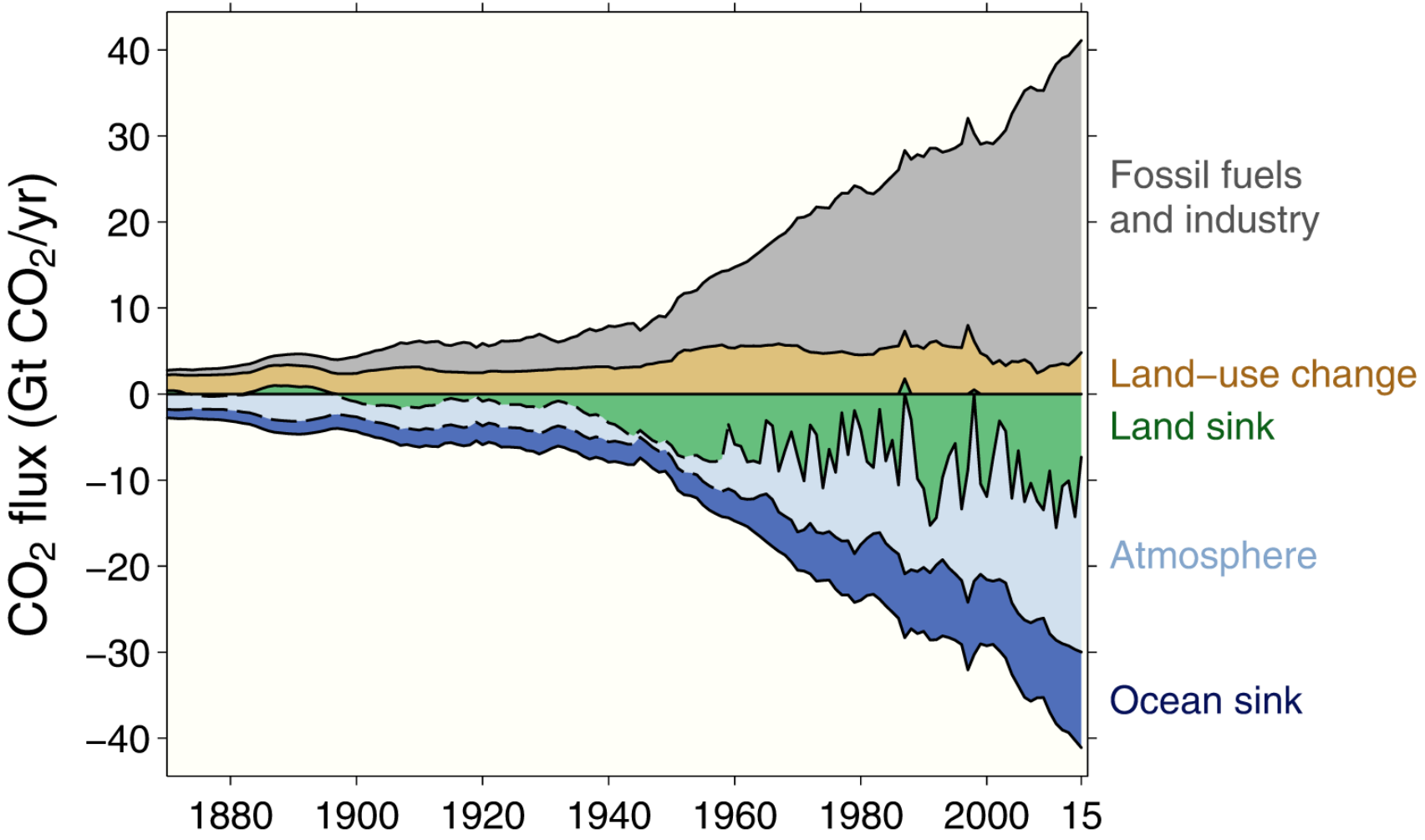



TOPEX
Jason-1
Jason-2
60-day smoothed
Trend: 3.4 ± 0.4 mm/yr
University of Colorado 2016_rel4
Δ MSL (mm)
Year
100
80
60
40
20
0
−20
1995
2000
2005
2010
2015

Global carbon budget

The

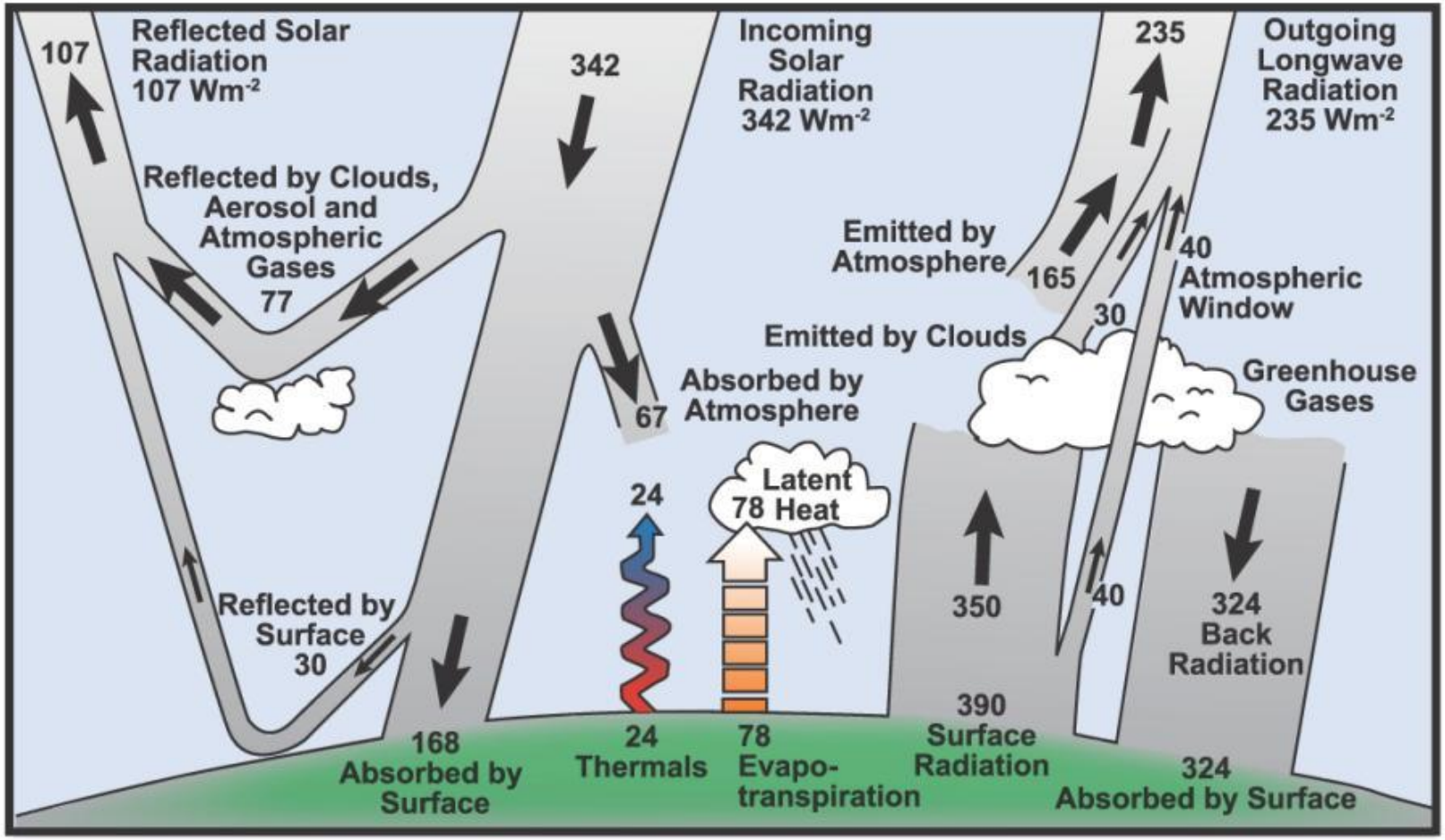
Data: CDIAC/NOAA–ESRL/GCP/Joos et al 2013/Khatiwala et al 2013



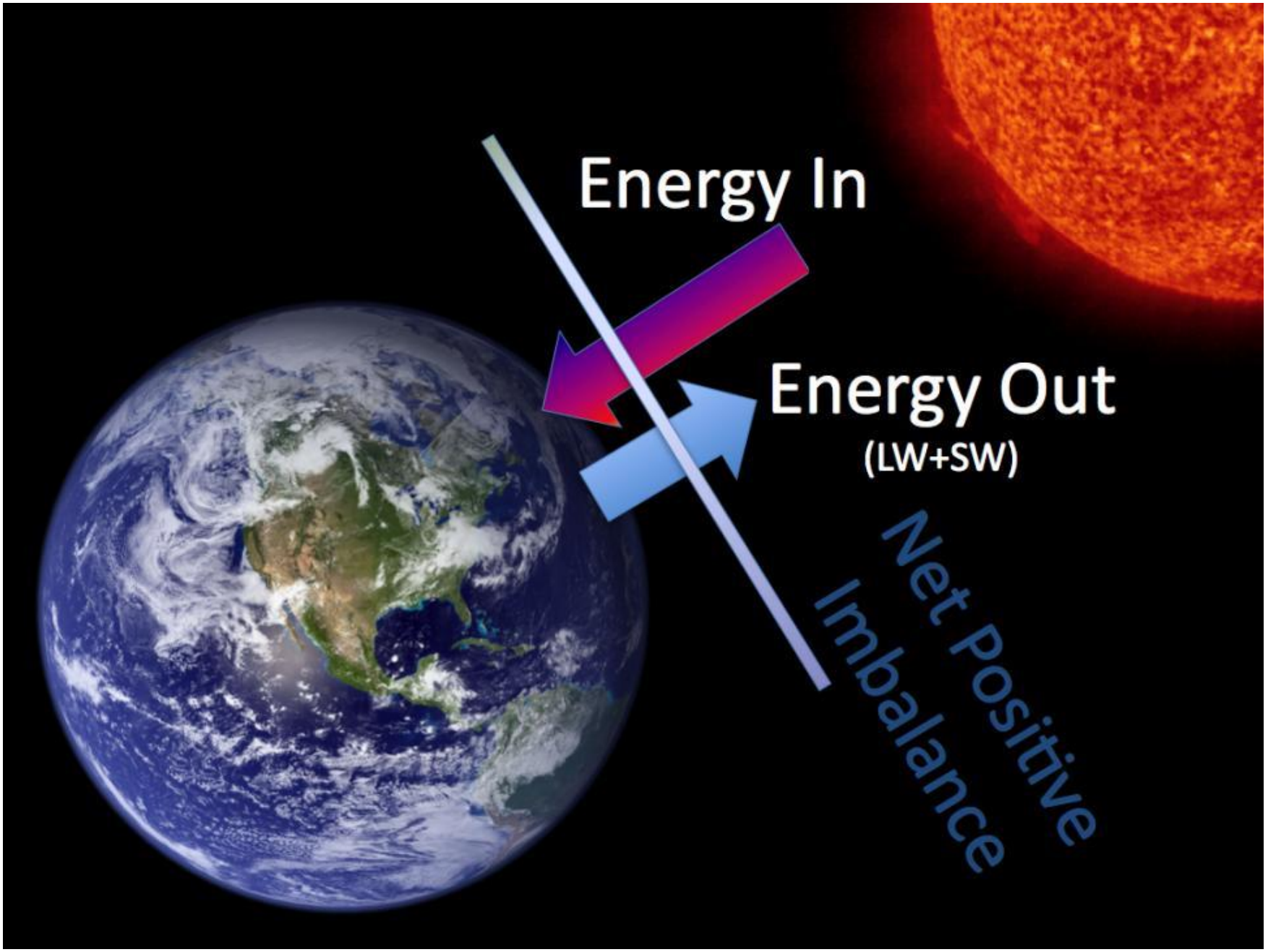
Global Carbon Project

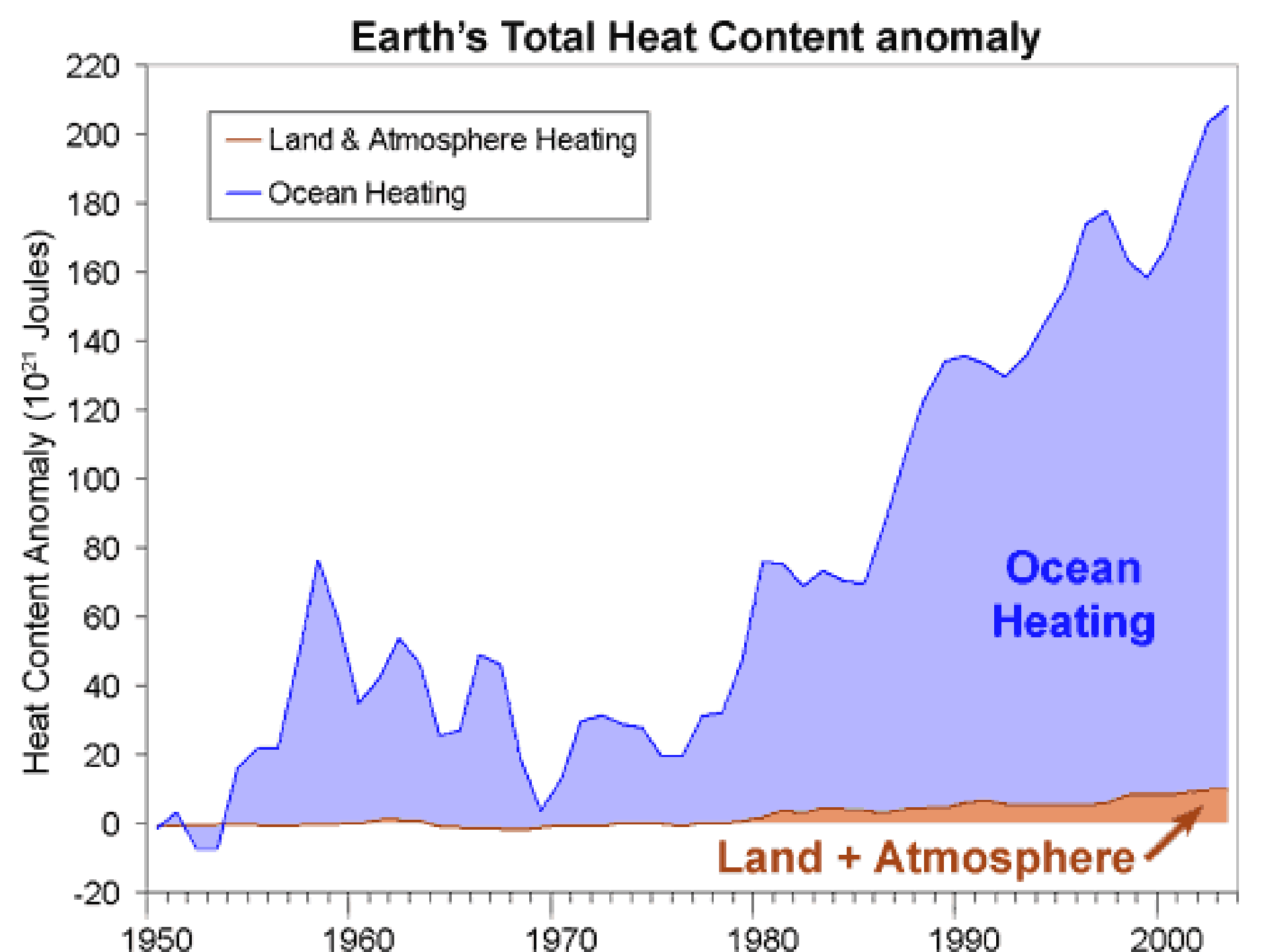
Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

Earth's Annual and Global Mean Energy Balance

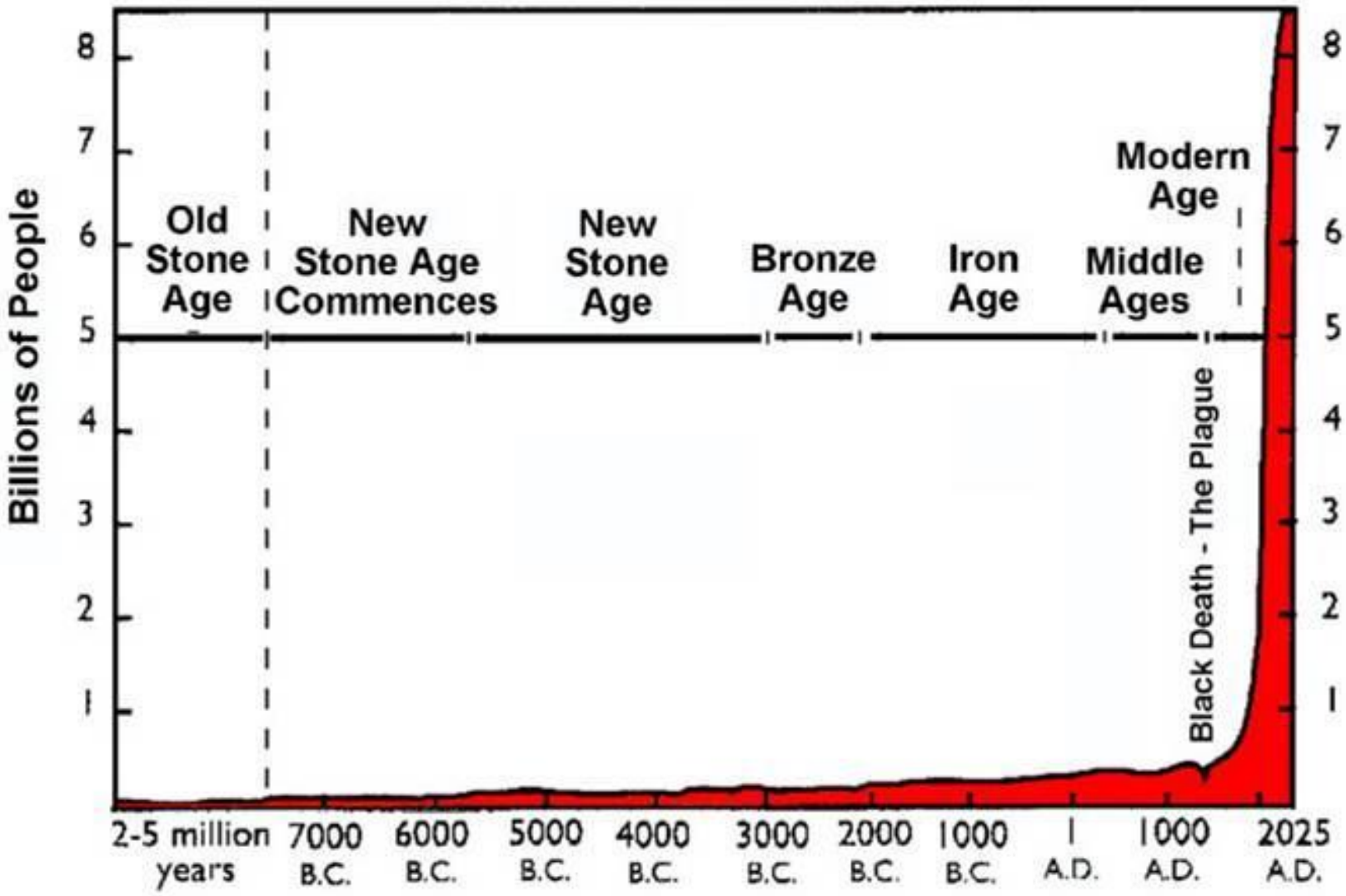


IPCC Climate Change 2007, The Physical Science Basis page 96


Energy In
Energy Out
(LW+SW)
Net Positive
Imbalance


Earth's Total Heat Content anomaly
Land & Atmosphere Heating
Ocean Heating
Heat Content Anomaly (10^{21} Joules)
220
200
180
160
140
120
100
80
60
40
20
0
-20
1950
1960
1970
1980
1990
2000
Ocean Heating
Land + Atmosphere

World Population Growth Through History



From "World Population: Toward the Next Century," copyright 1994 by the Population Reference Bureau

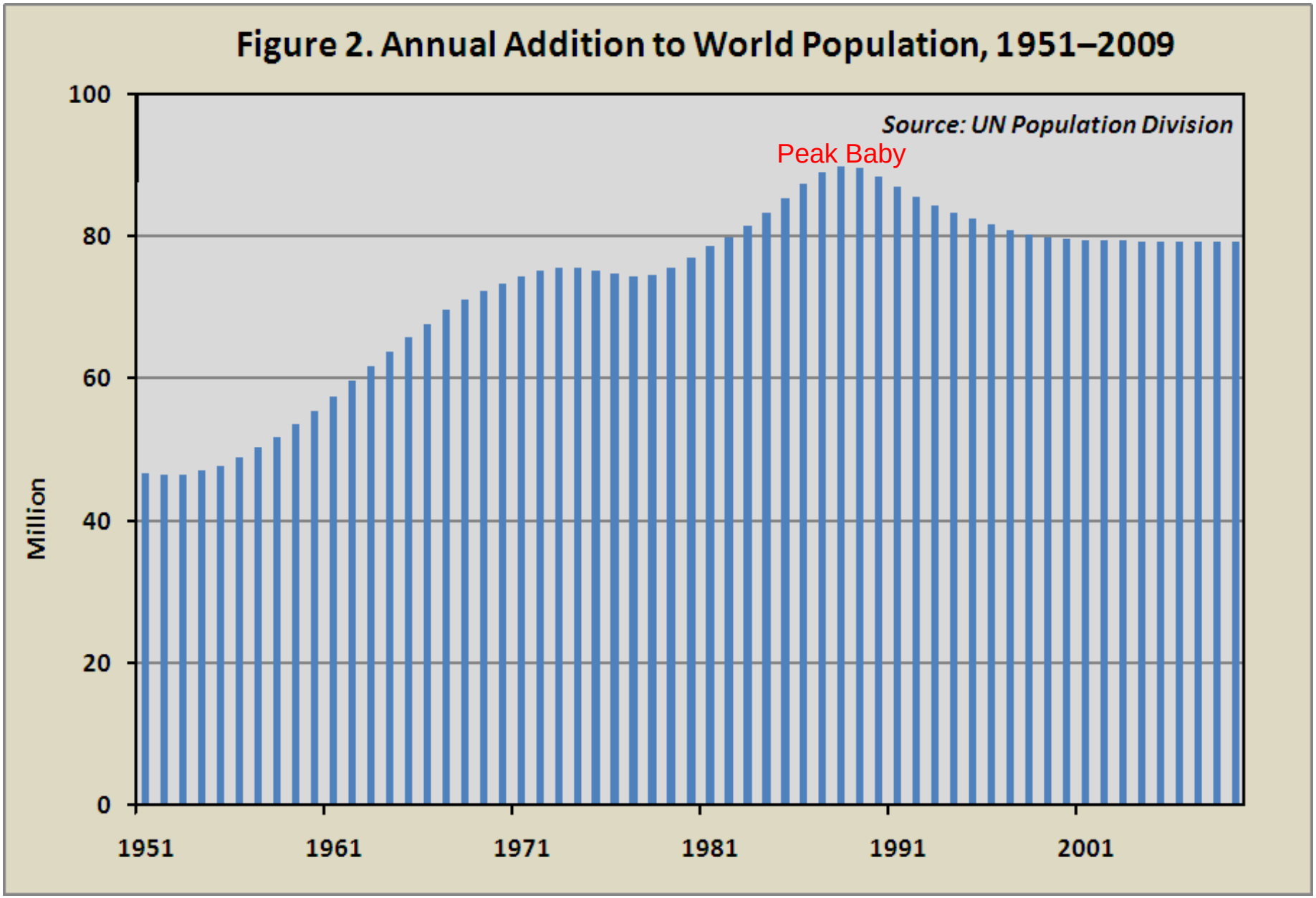
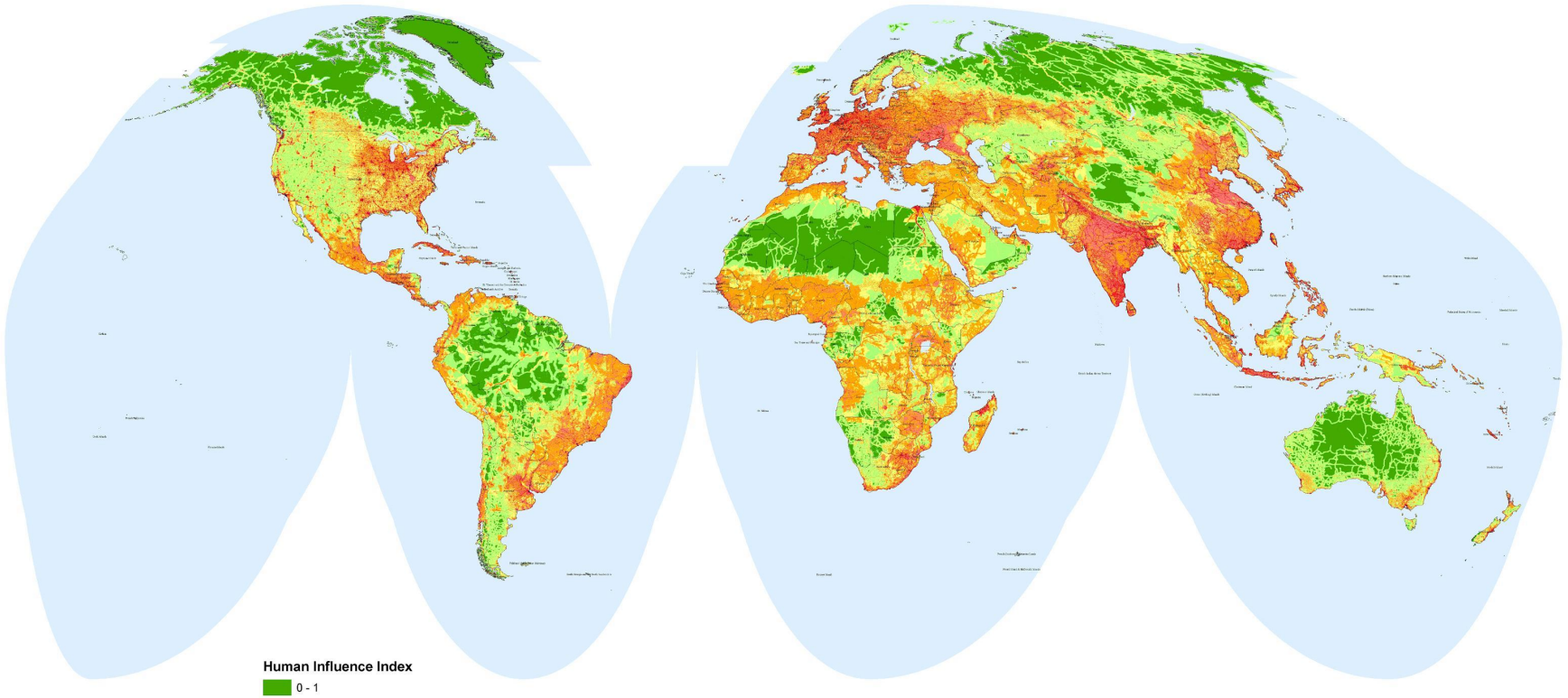


Figure 2. Annual Addition to World Population, 1951–2009
Source: UN Population Division
Peak Baby
Million
100
80
60
40
20
0
1951
1961
1971
1981
1991
2001

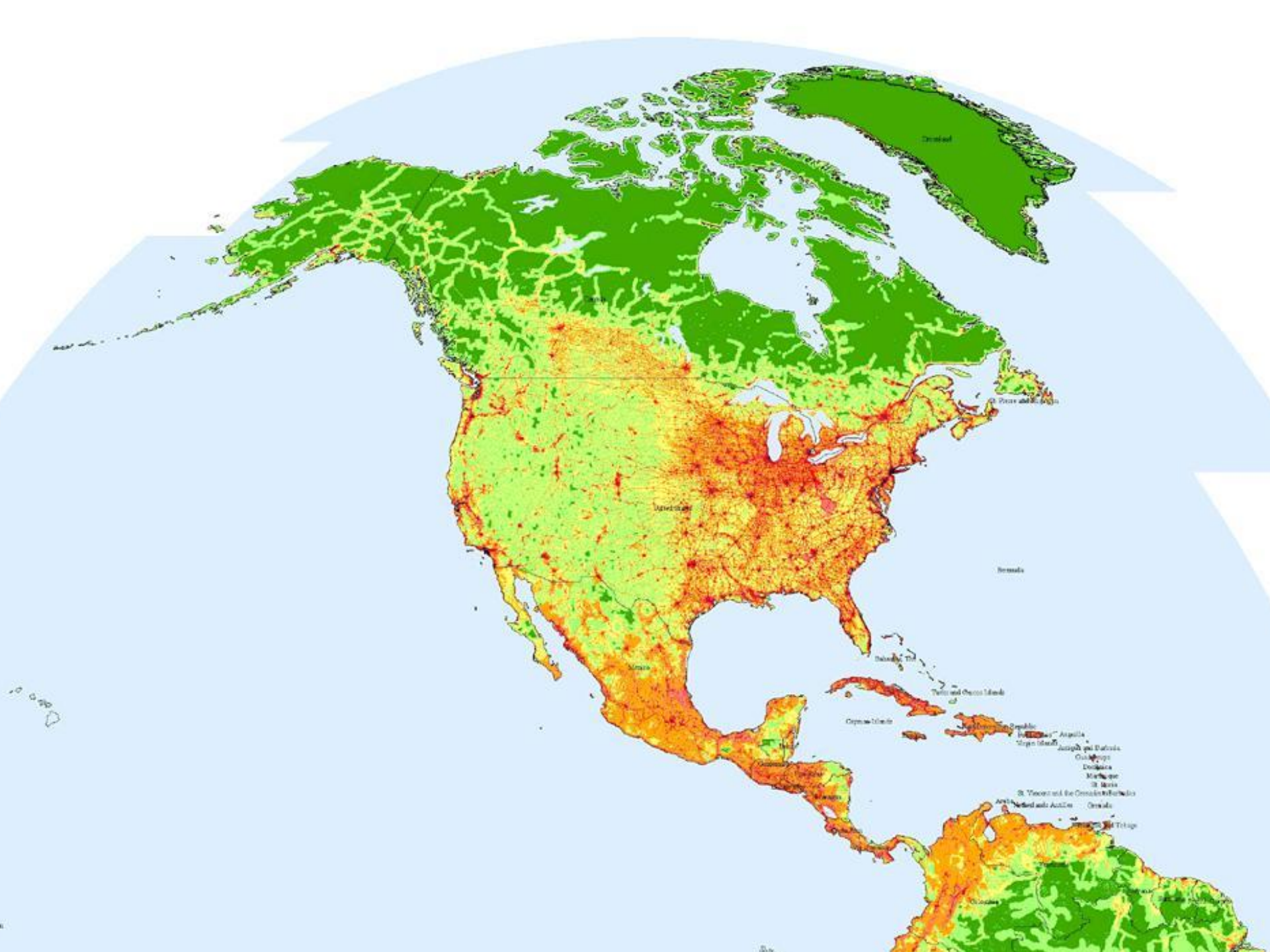
Map of Human Footprint



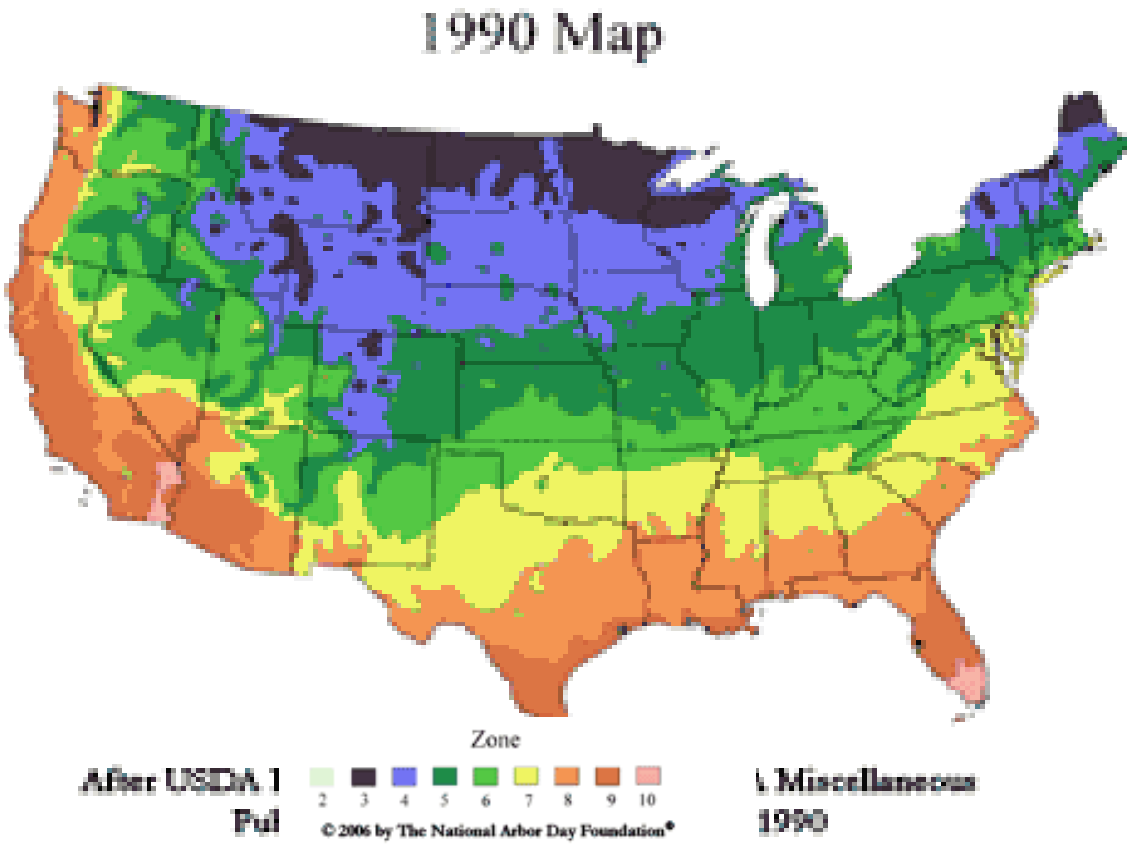
Human Influence Index

- 0 - 1
- 1 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 60
- 60 - 80
- 80 - 100

CIESIN/WCS Last of the Wild Project 2002

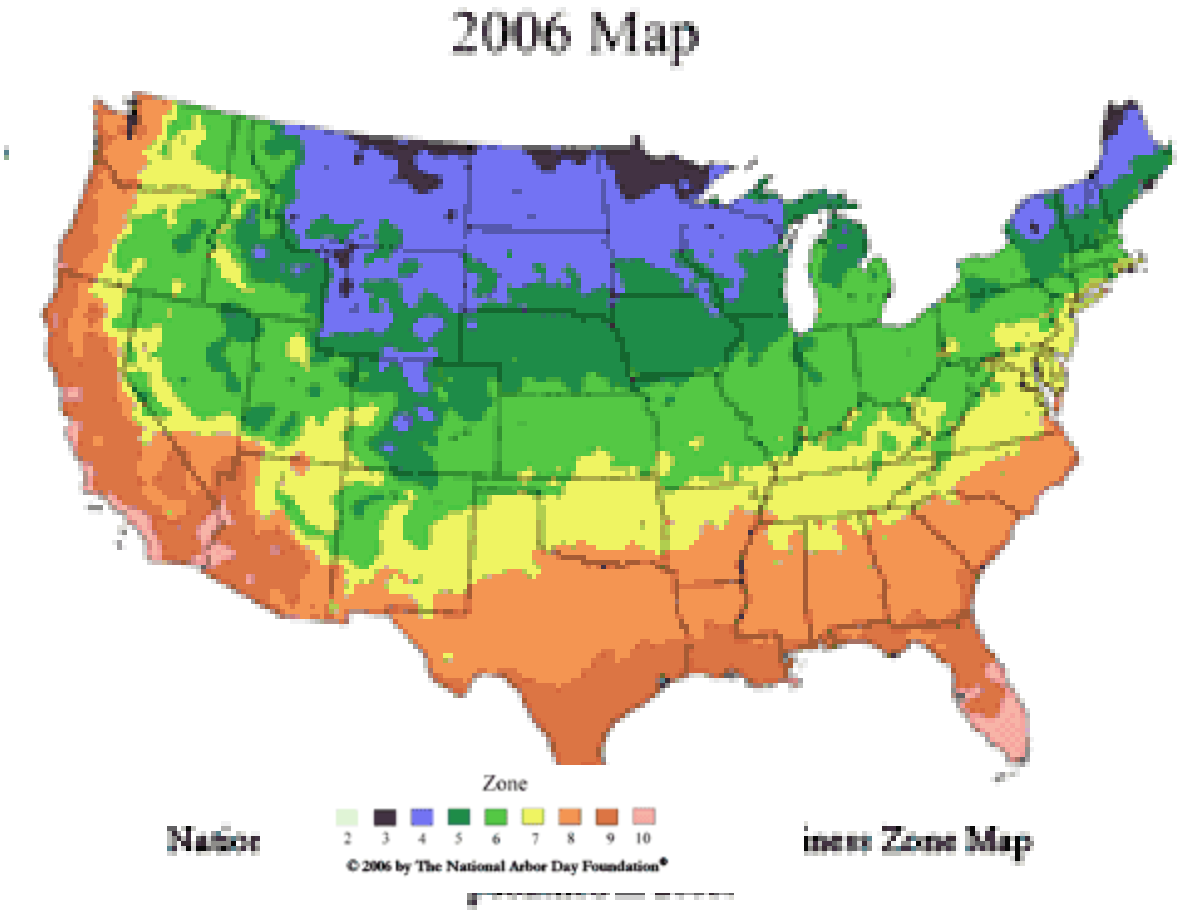

Greenland
Bermuda
Turks and Caicos Islands
Cayman Islands
Anguilla
Antigua and Barbuda
Dominica
Martinique
St. Lucia
St. Vincent and the Grenadines/Barbados
Netherlands Antilles
Grenada

1990 USDA Hardiness Zones



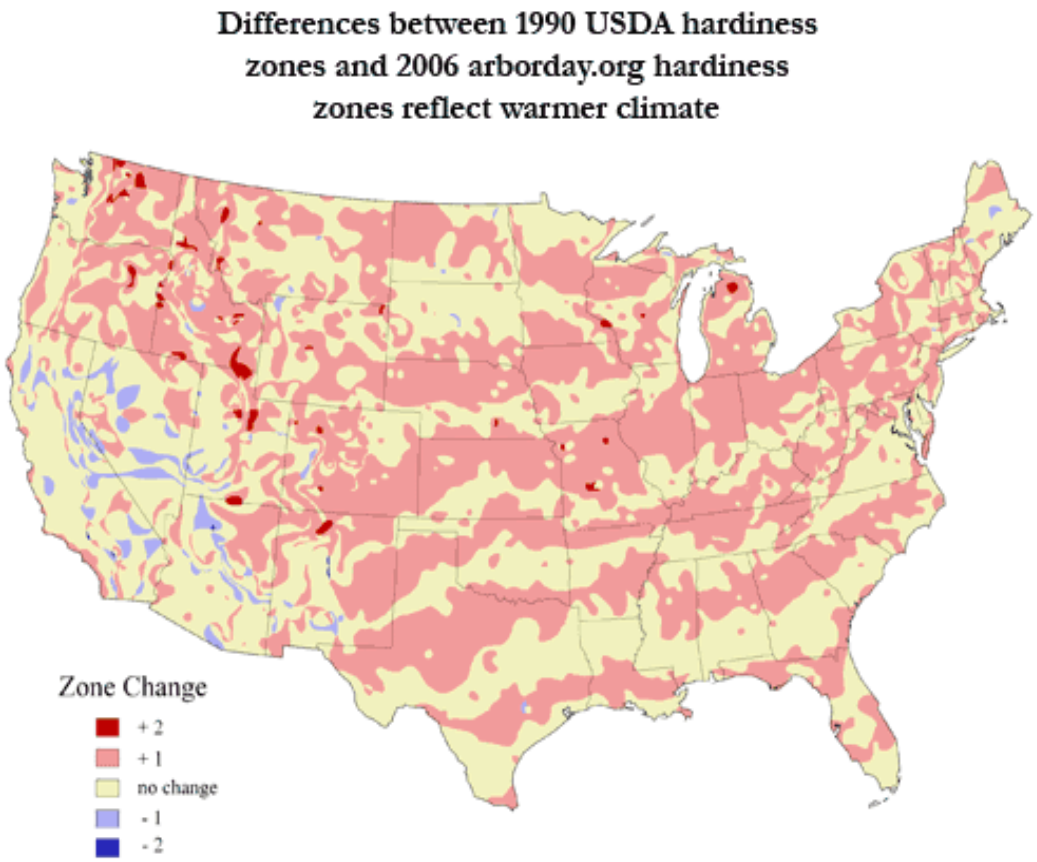
http://www.arborday.org/media/map_change.cfm

2006 Arborday.org Hardiness Zones



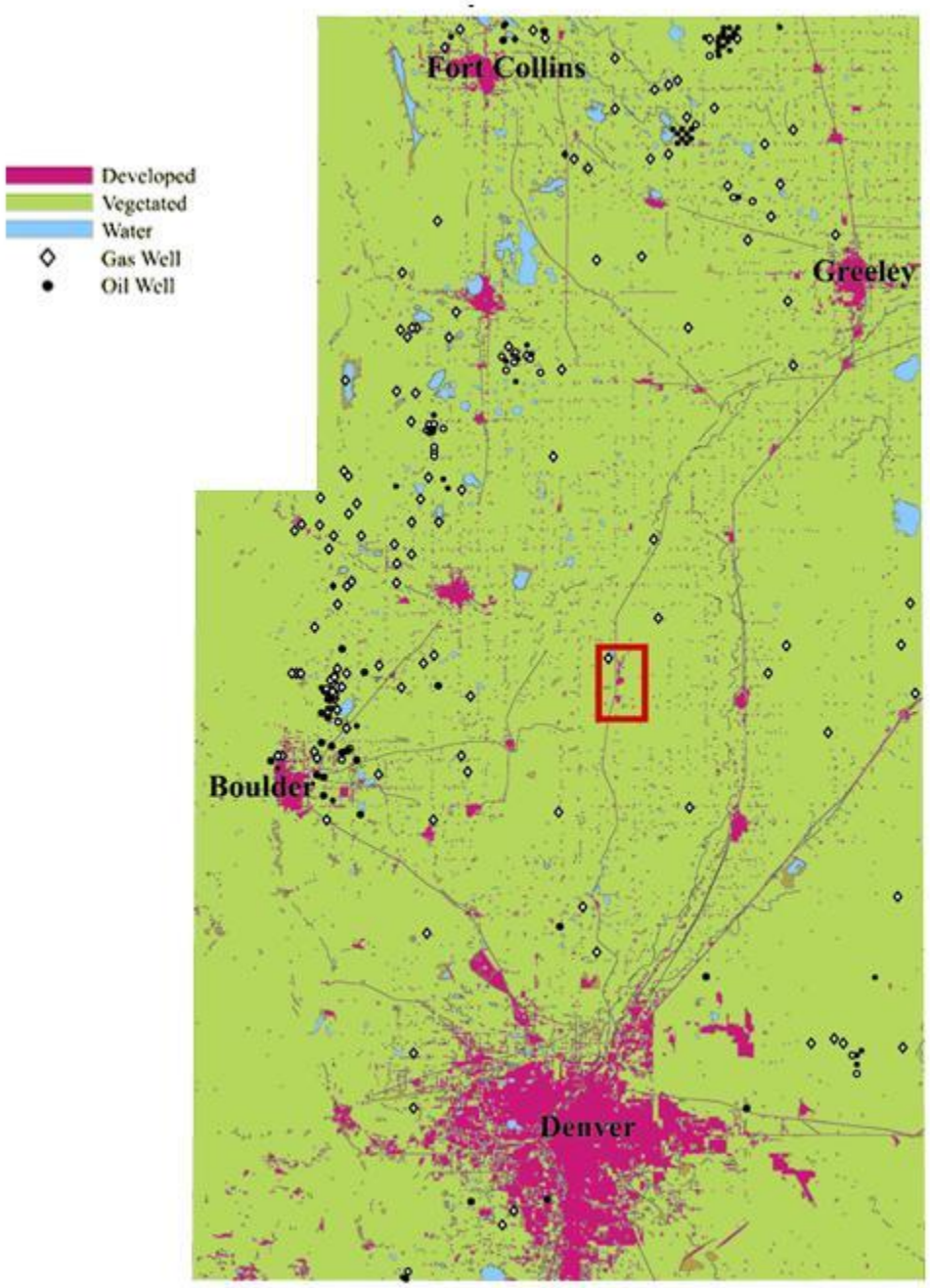
http://www.arborday.org/media/map_change.cfm

Differences Between 1990 and 2006 = Reflect Warmer Climate



http://www.arborday.org/media/map_change.cfm

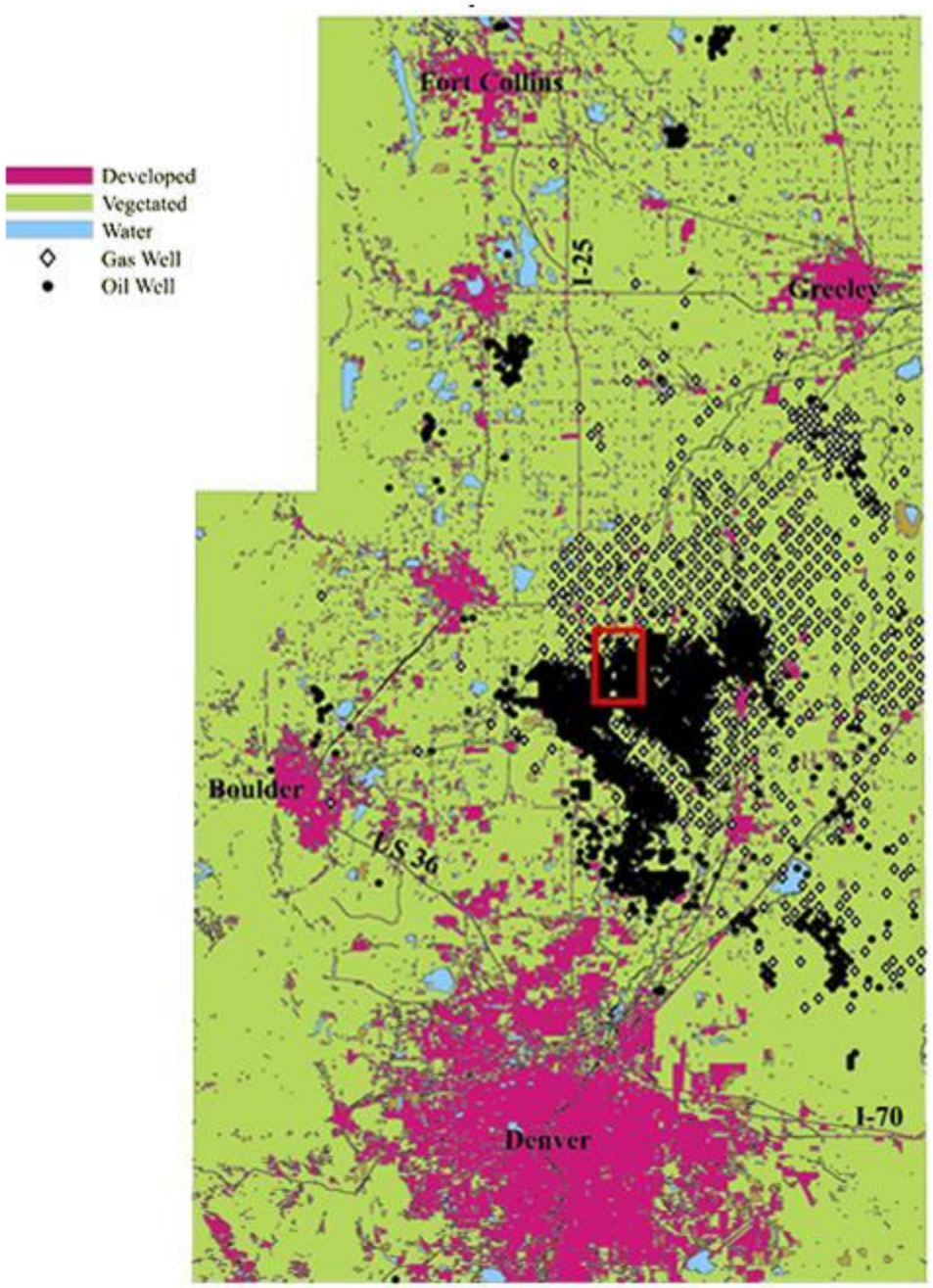
1960


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

U

USGS

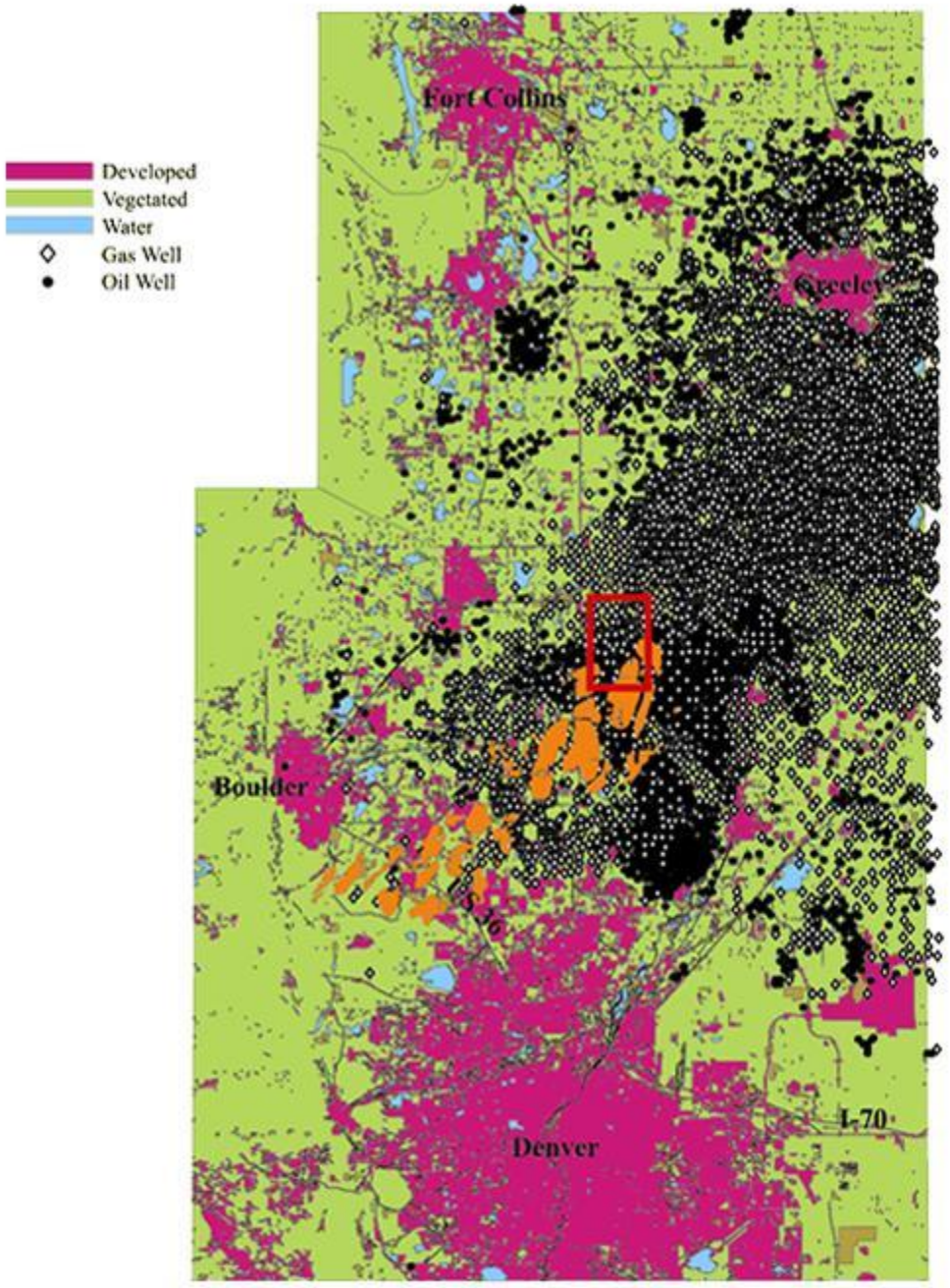
1980


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

U

USGS

2000


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

U

USGS

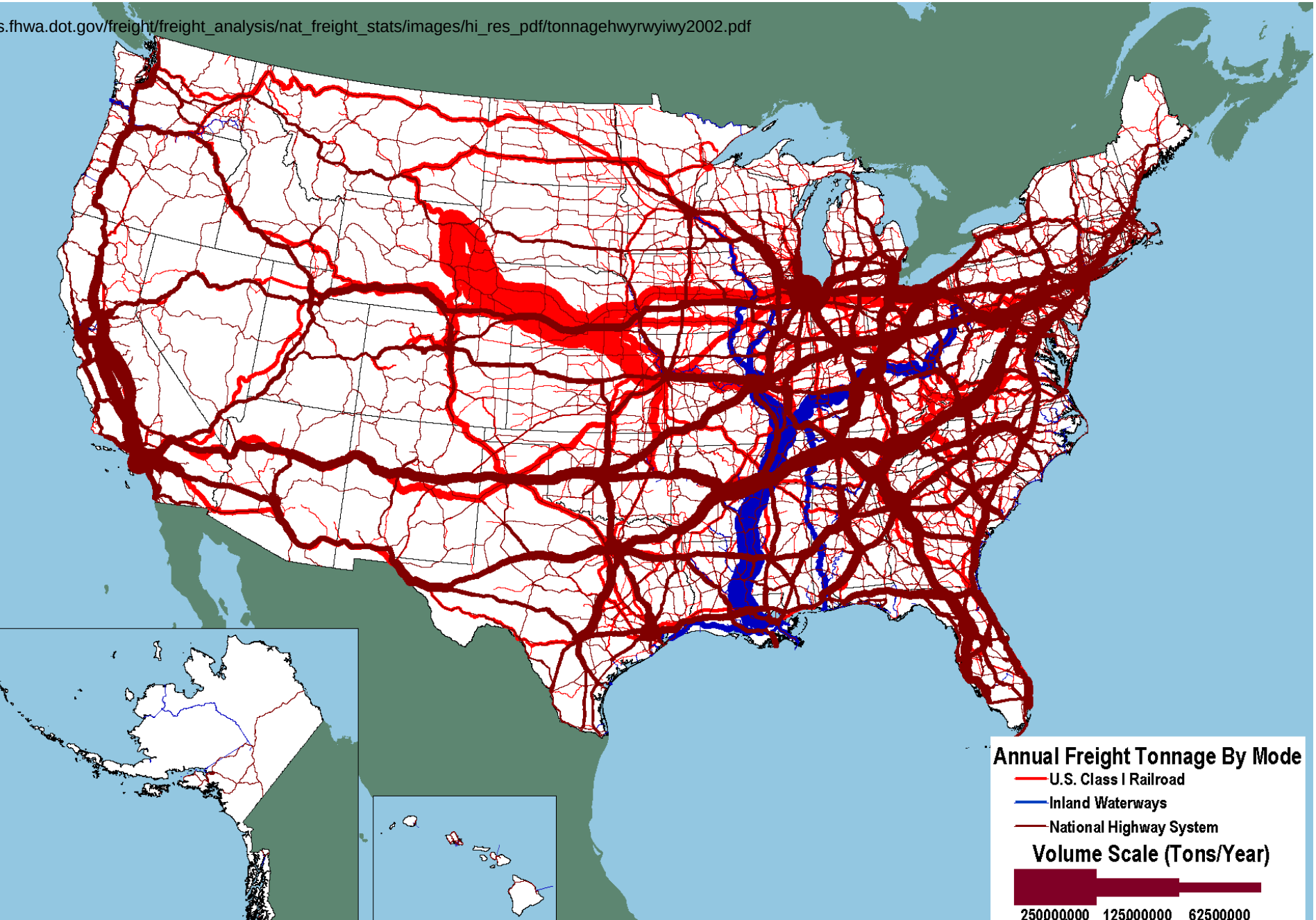
http://www.fs.fed.us/r2/bark-beetle/

US Forest Service

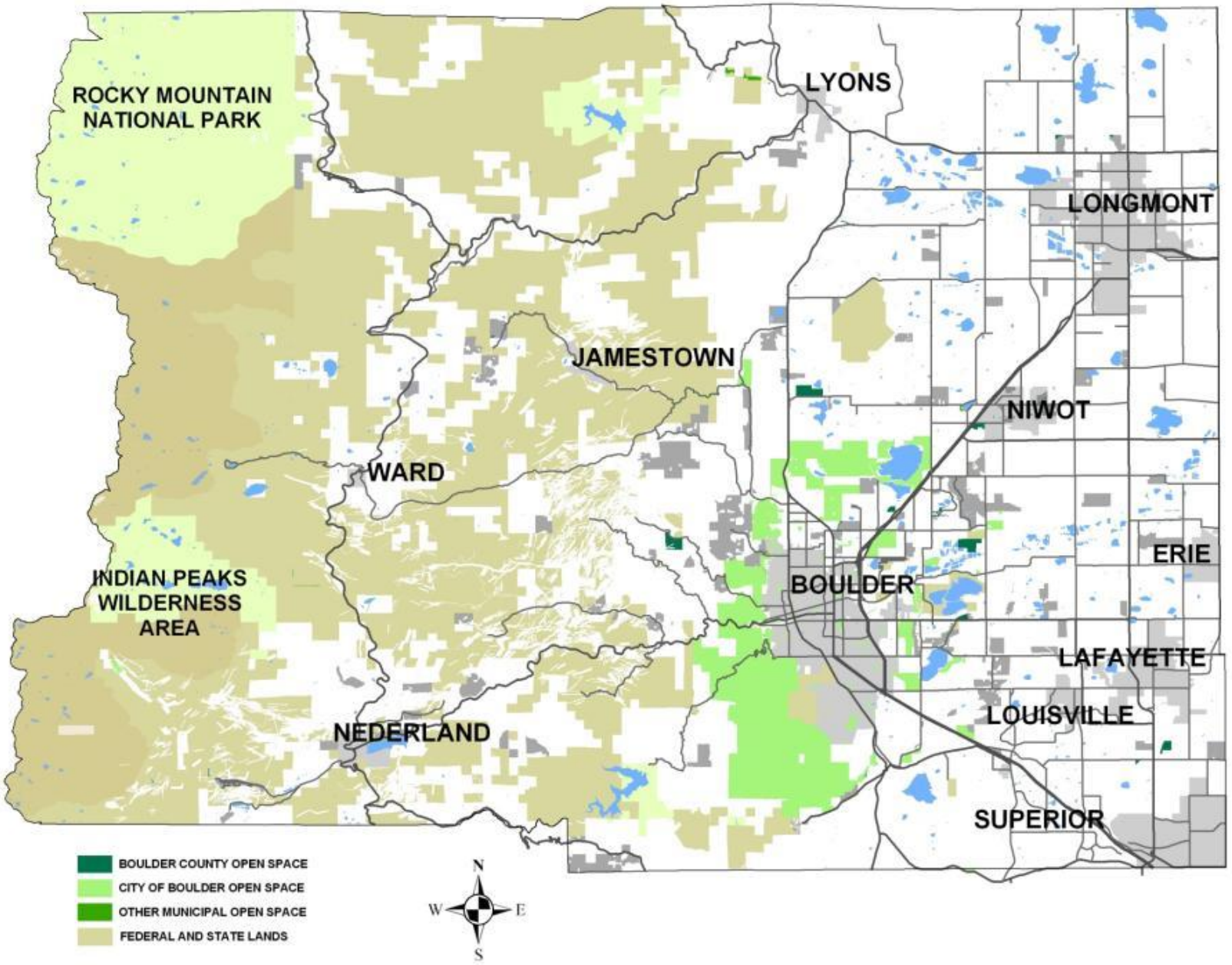
http://www.fs.fed.us/r2/bark-beetle/

US Forest Service

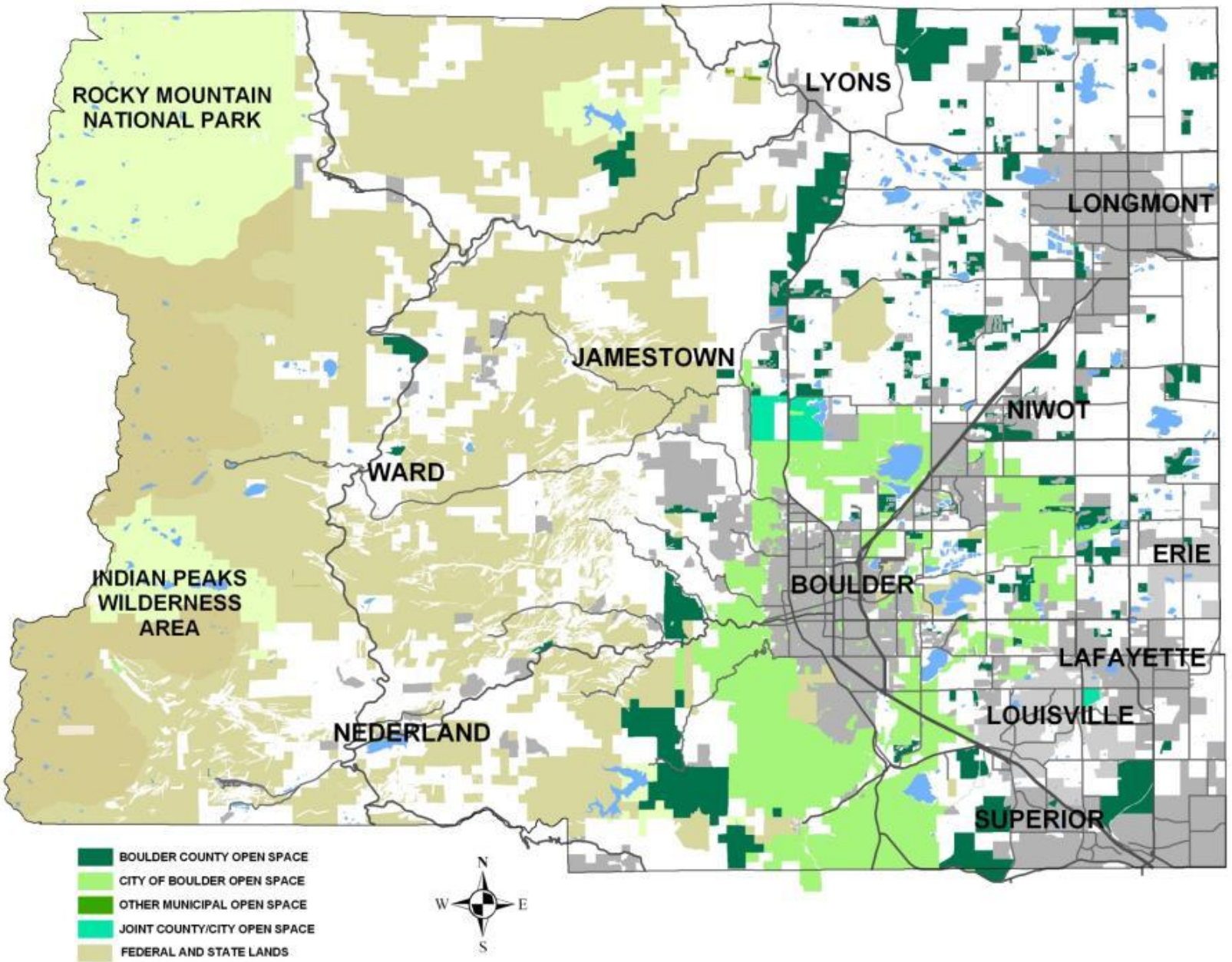
Tonnage on Highways, Railroads and Inland Waterways: 2002



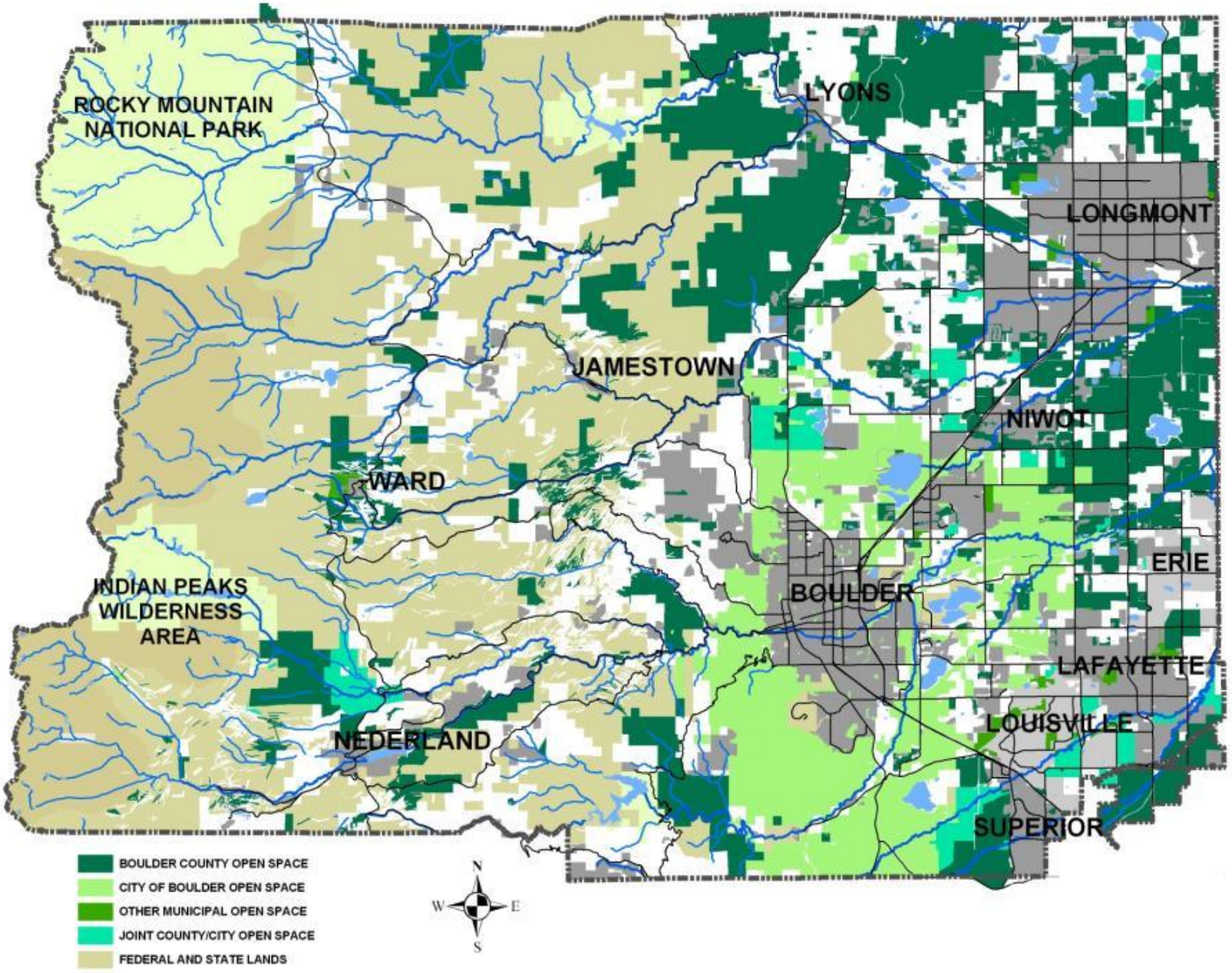
Open Space 1975



Open Space 1994



Open Space 2007



קולחי אילת
11
מי קולחין
השתיה אסורה !

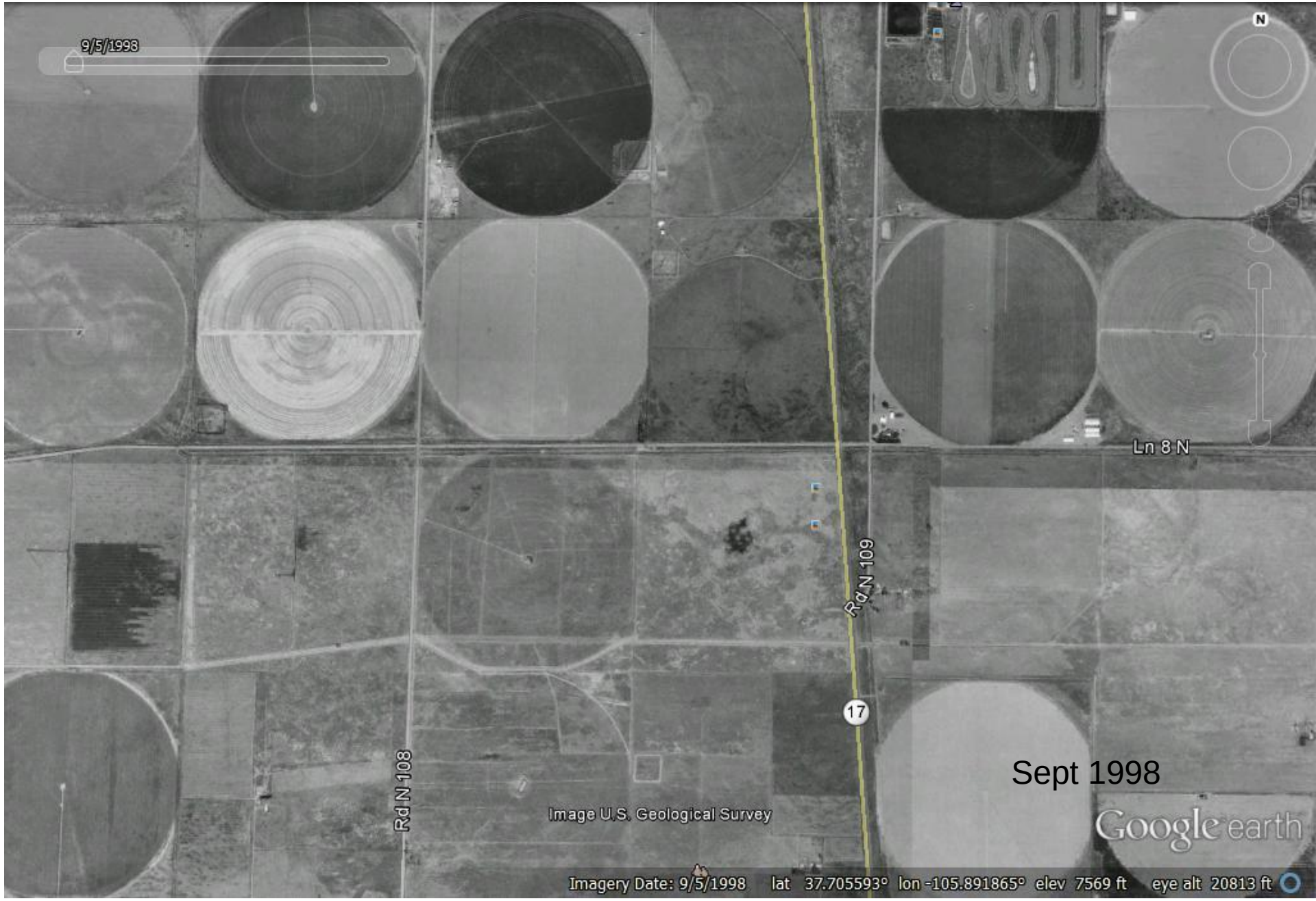
John Williamson Jan 2013, Beijing airport

Beijing Feng Li/ Getty 23 Jan 2013 Atlantic Monthly

Ng Han Guan, Tiananmen Square, Jan 29, 2013

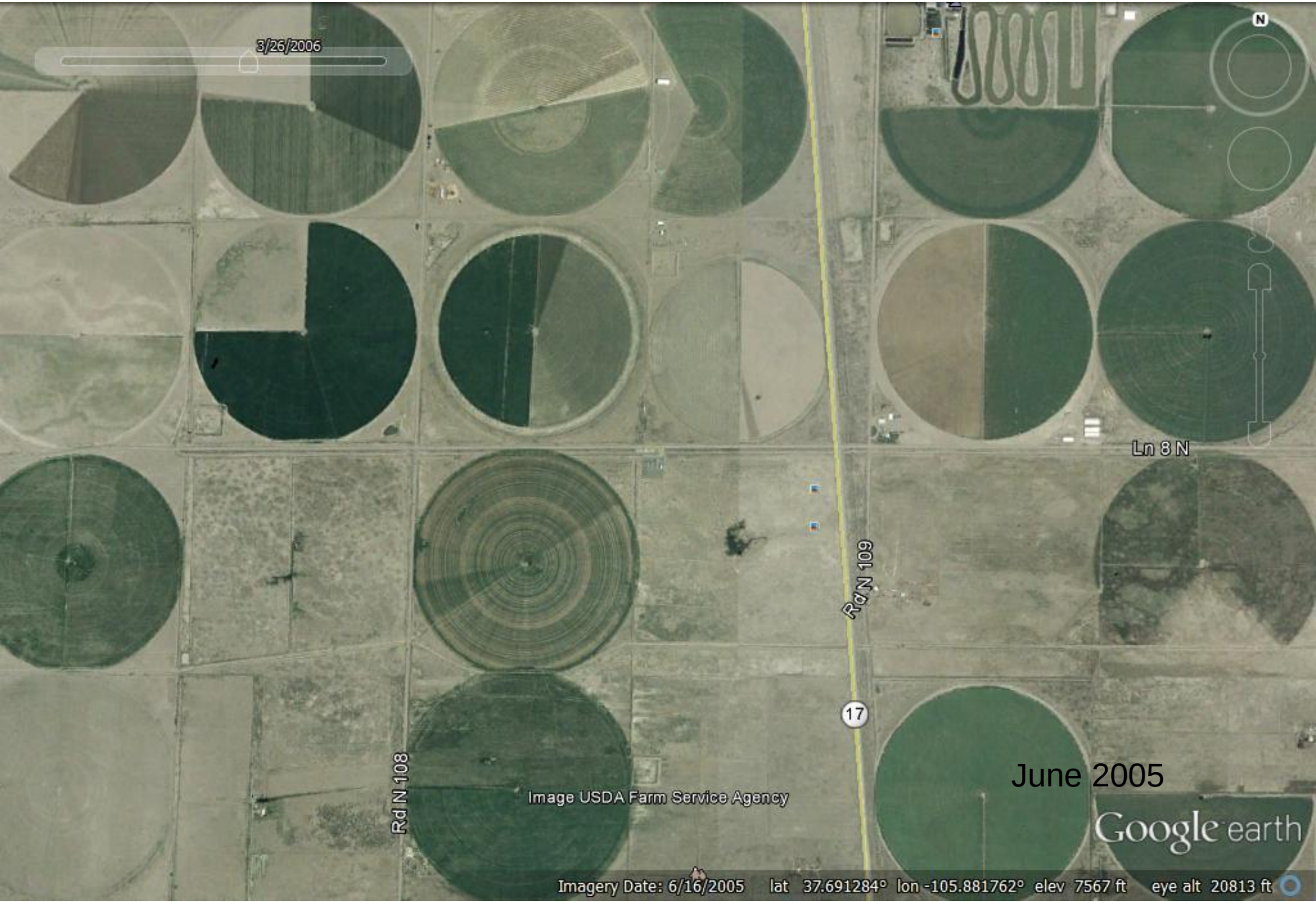
29 Nov 2001 G Asakawa Denver Post

RobertStock.com


9/5/1998
N
Ln 8 N
Rd N 109
17
Rd N 108
Image U.S. Geological Survey
Google earth
Imagery Date: 9/5/1998 lat 37.705593° lon -105.891865° elev 7569 ft eye alt 20813 ft

Sept 1998

8/29/2003
N
Ln 8 N
Rd N 109
17
Rd N 108
Image © 2013 DigitalGlobe
Image U.S. Geological Survey
Aug 2003
Google earth
lat 37.704845° lon -105.901564° elev 7572 ft eye alt 20813 ft

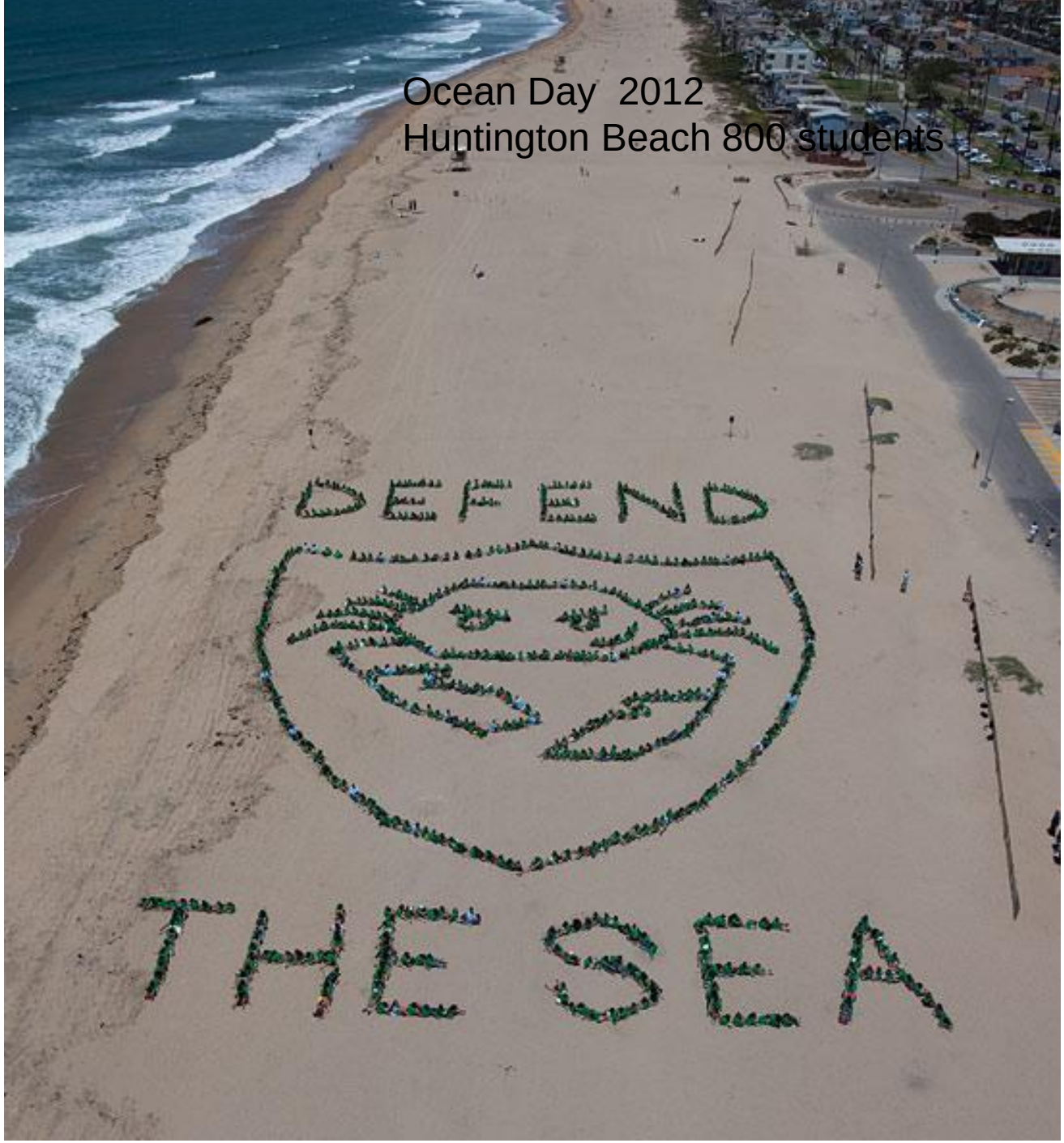

3/26/2006
N
Ln 8 N
Rd N 109
17
Rd N 108
Image USDA Farm Service Agency
June 2005
Google earth
Imagery Date: 6/16/2005 lat 37.691284° lon -105.881762° elev 7567 ft eye alt 20813 ft

10/27/2011
1998
2011
Ln 8 N
Rd N 109
17
Rd N 108
Image USDA Farm Service Agency
Aug 2011
Google earth
Imagery Date: 8/18/2011 lat 37.691284° lon -105.881762° elev 7567 ft eye alt 20813 ft

Tijuana River

World Ocean Day is

8 June



Ocean Day 2012
Huntington Beach 800 students

Ocean Day 2012
Dockweiler Beach, LA
5000 students

Students will save the World

GLOBAL
WARMING
READY

Tianjin Eco City, China
Kepcorp.com

Four riders of the apocalypse:

- Conquest
- War
- Famine
- Death

Population
Biodiversity
Climate
Energy Supply
Water Supply
Food Supply

A Durer, 1498

Thomas Cole The Course of the Empire 1836

Thomas Cole The Course of the Empire 1836

Thomas Cole The Course of the Empire 1836

Thomas Cole The Course of the Empire 1836

I HEAR HOOFBEATS

Worldend.info

Atmospheric CO_2 at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

PARTS PER MILLION

400
380
360
340
320

1960
1970
1980
1990
2000
2010

YEAR

October 2015