

Who will flourish in the Anthropocene?

Bob Raynolds

April 2017

bobraynolds@yahoo.com

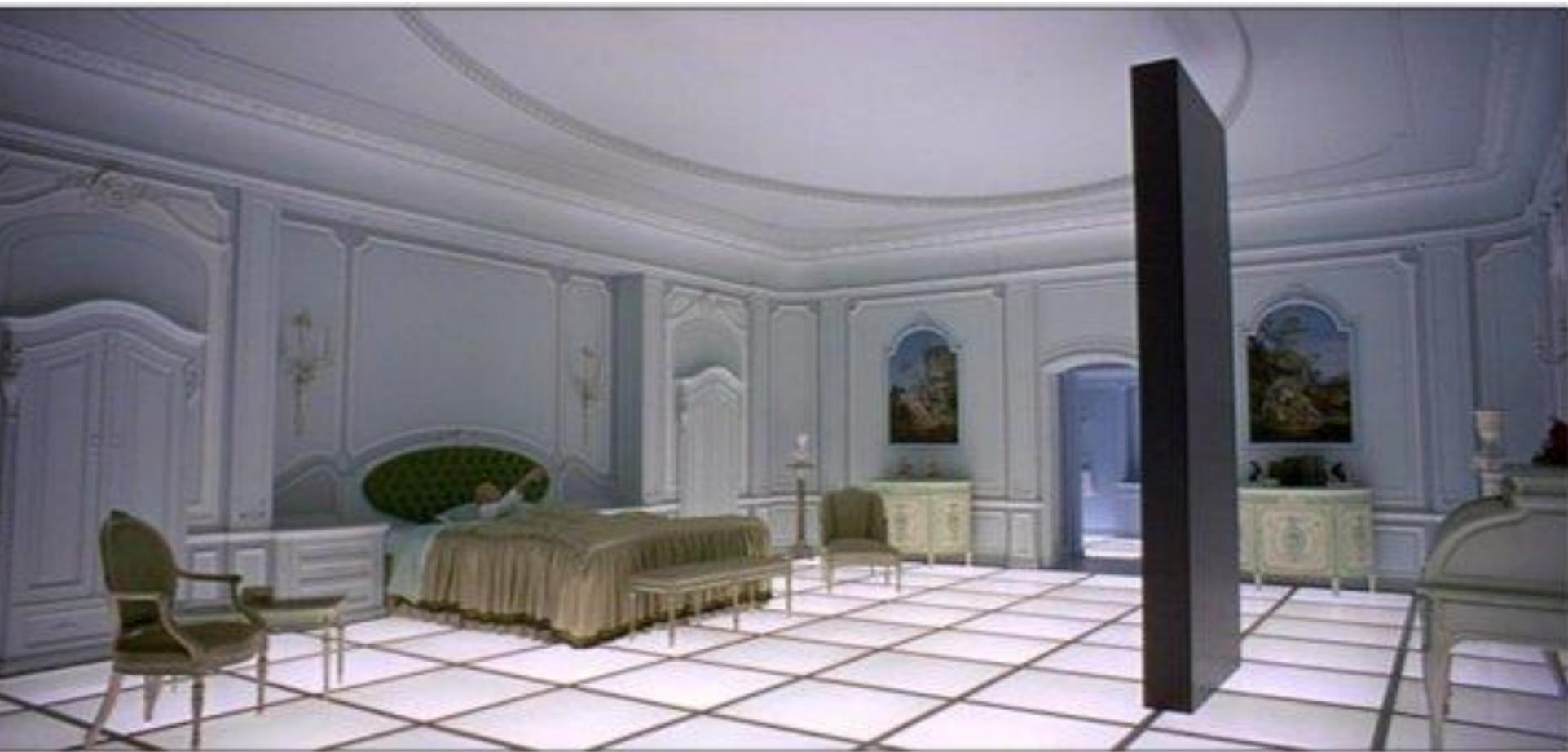
Thomas Cole The Course of the Empire 1836













**The
Economist**

ISSN 0950-0804

economist.com

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

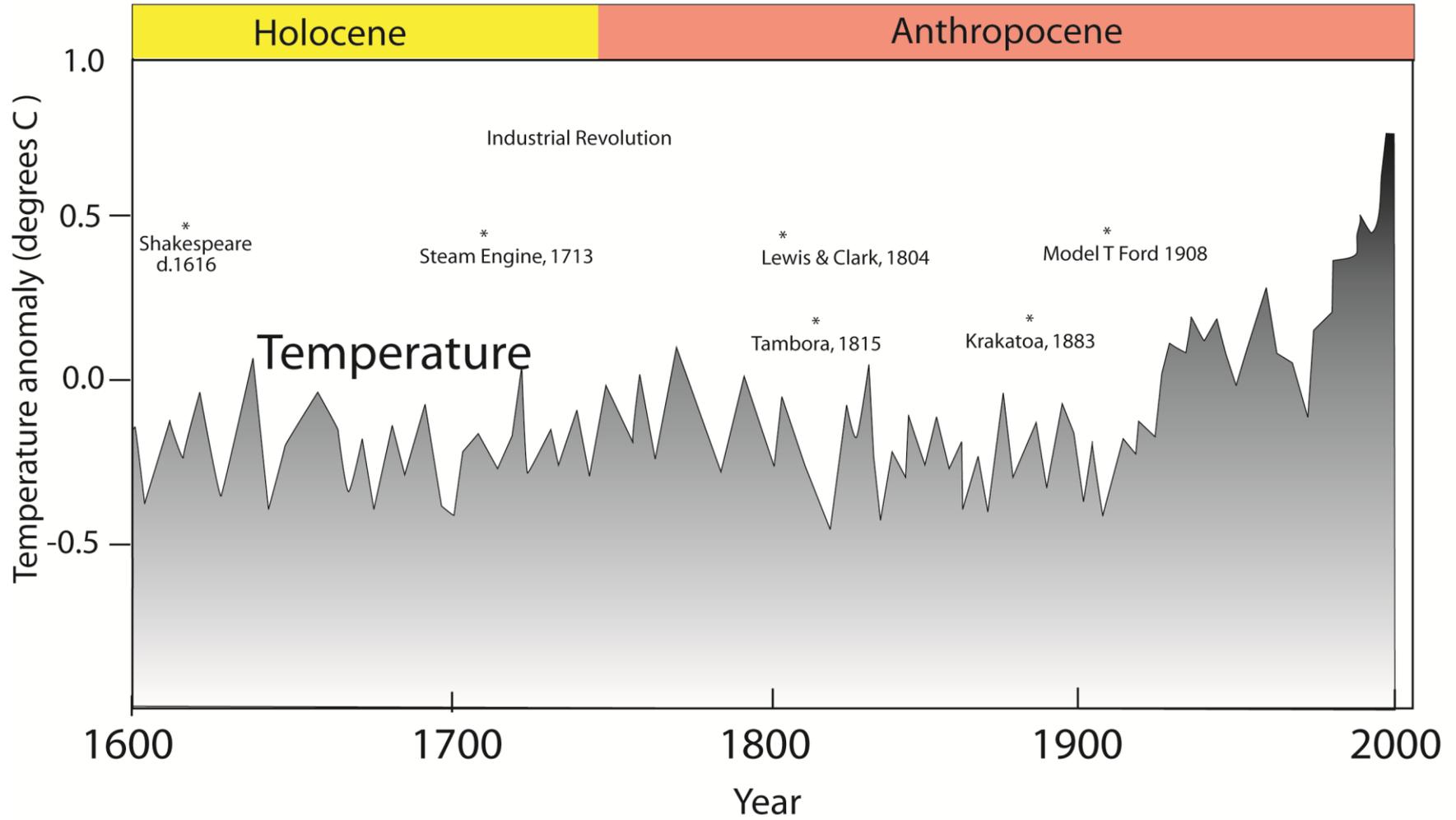


Geology's new age

Jon Berkeley

400 Years

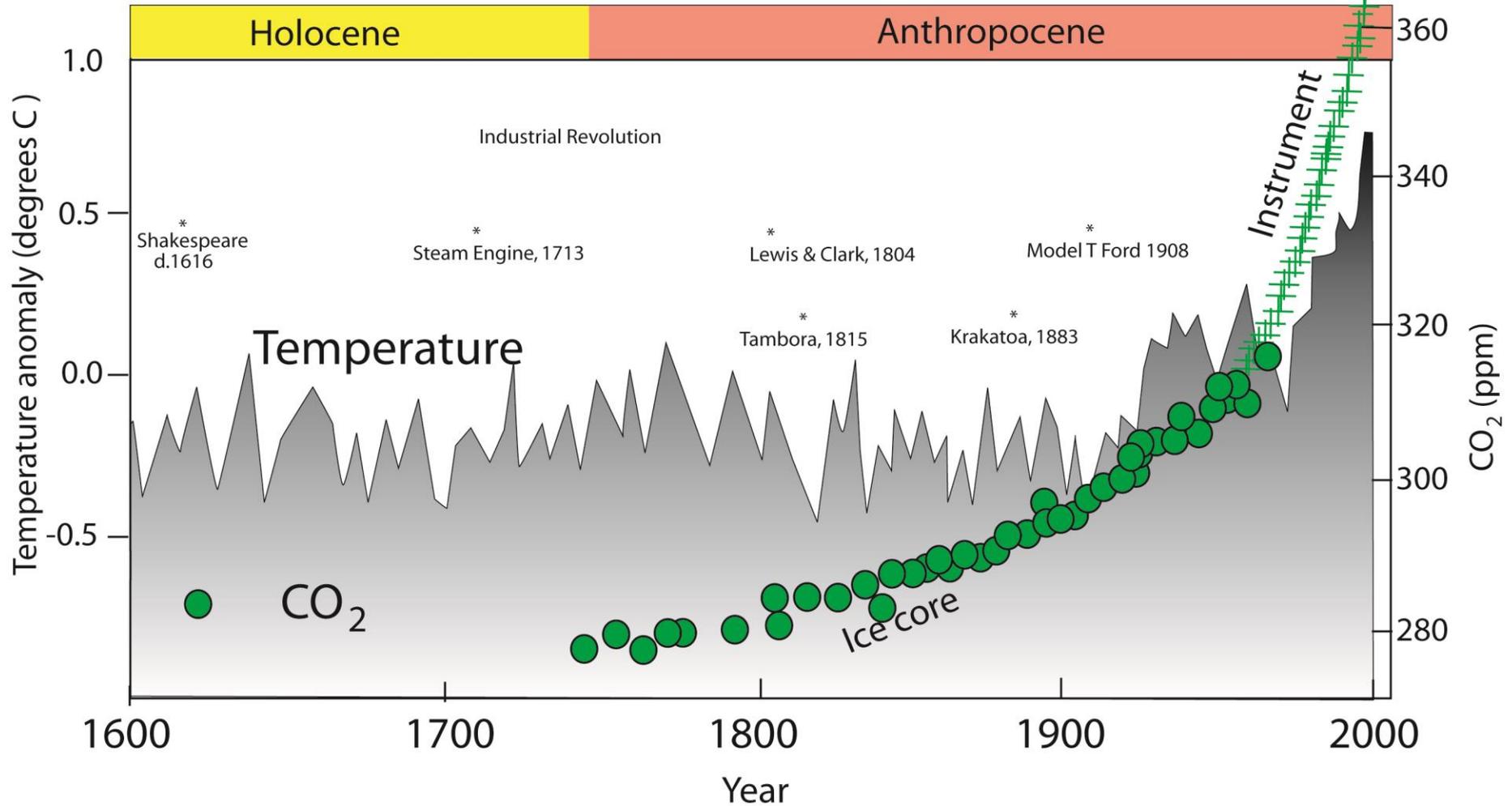
Temp: tree rings and ice cores



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

400 Years

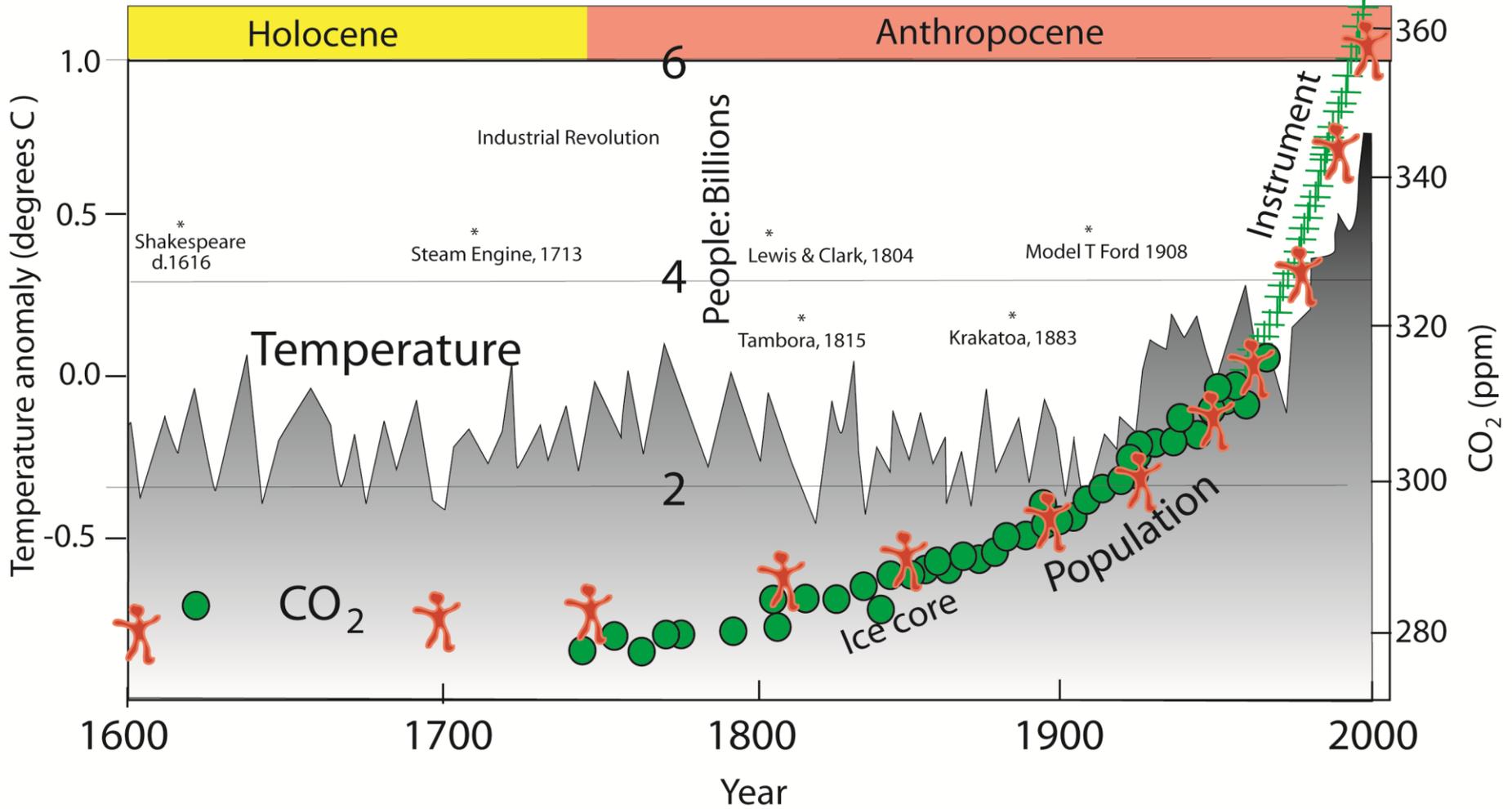
Temp: tree rings and ice cores
CO₂: ice cores and measurements



Temperature: Mann et al., 1999, Geophysical Research Letters
CO₂: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

400 Years

Temp: tree rings and ice cores
CO₂: ice cores and measurements



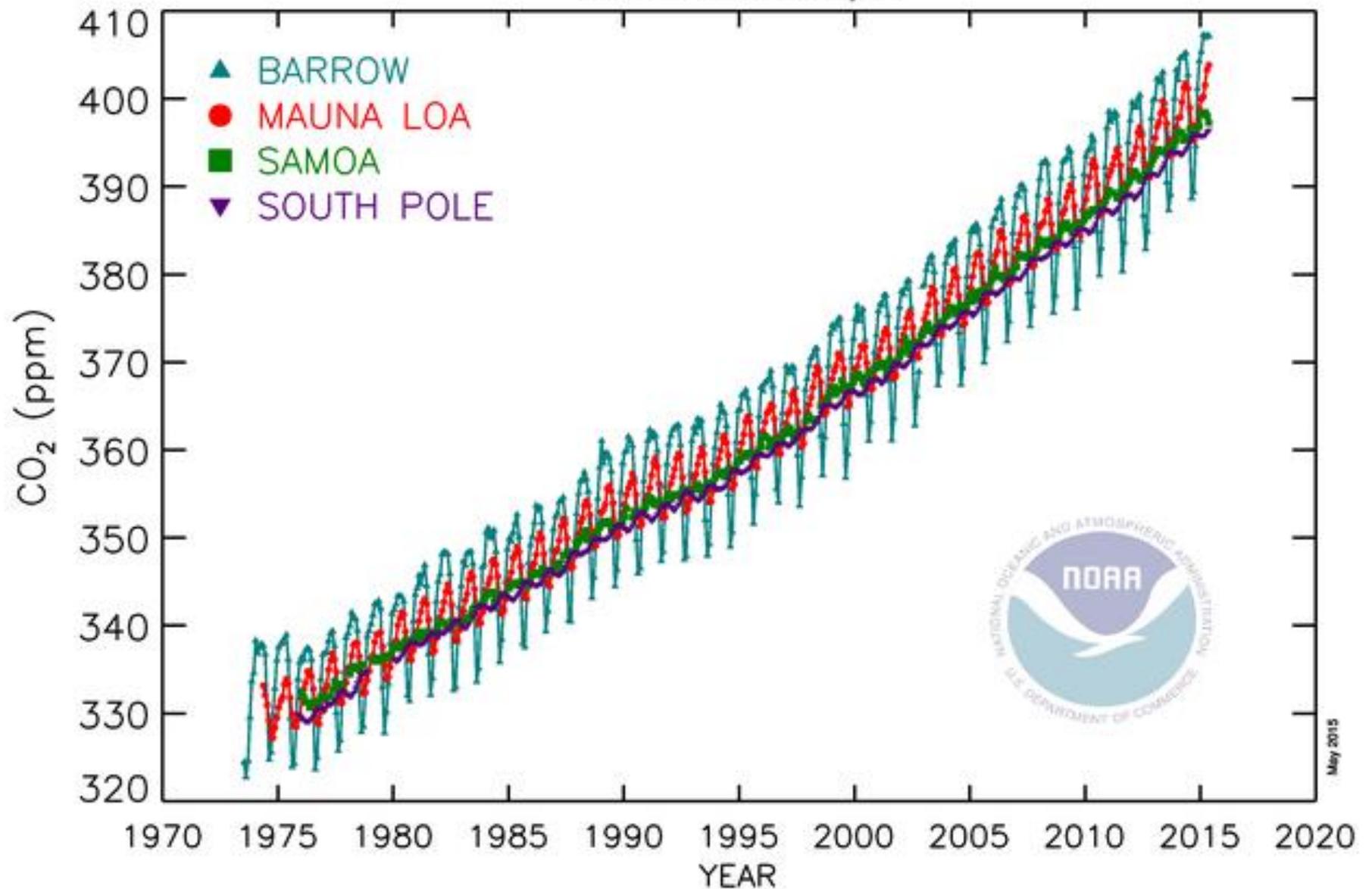
Temperature: Mann et al., 1999, Geophysical Research Letters

CO₂: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

 Population: UN

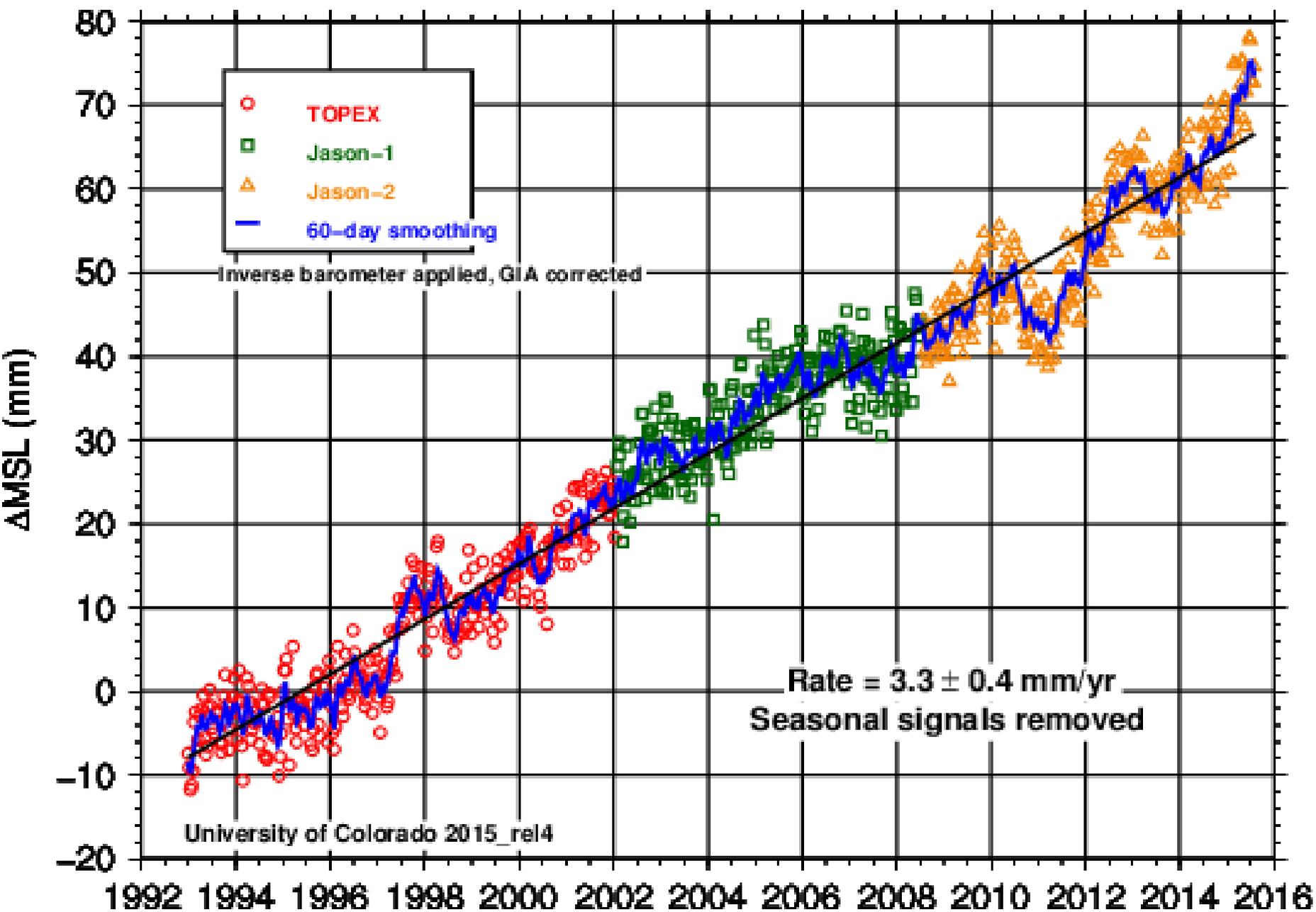
Monthly Mean Carbon Dioxide

NOAA ESRL Carbon Cycle



May 2015

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/>.





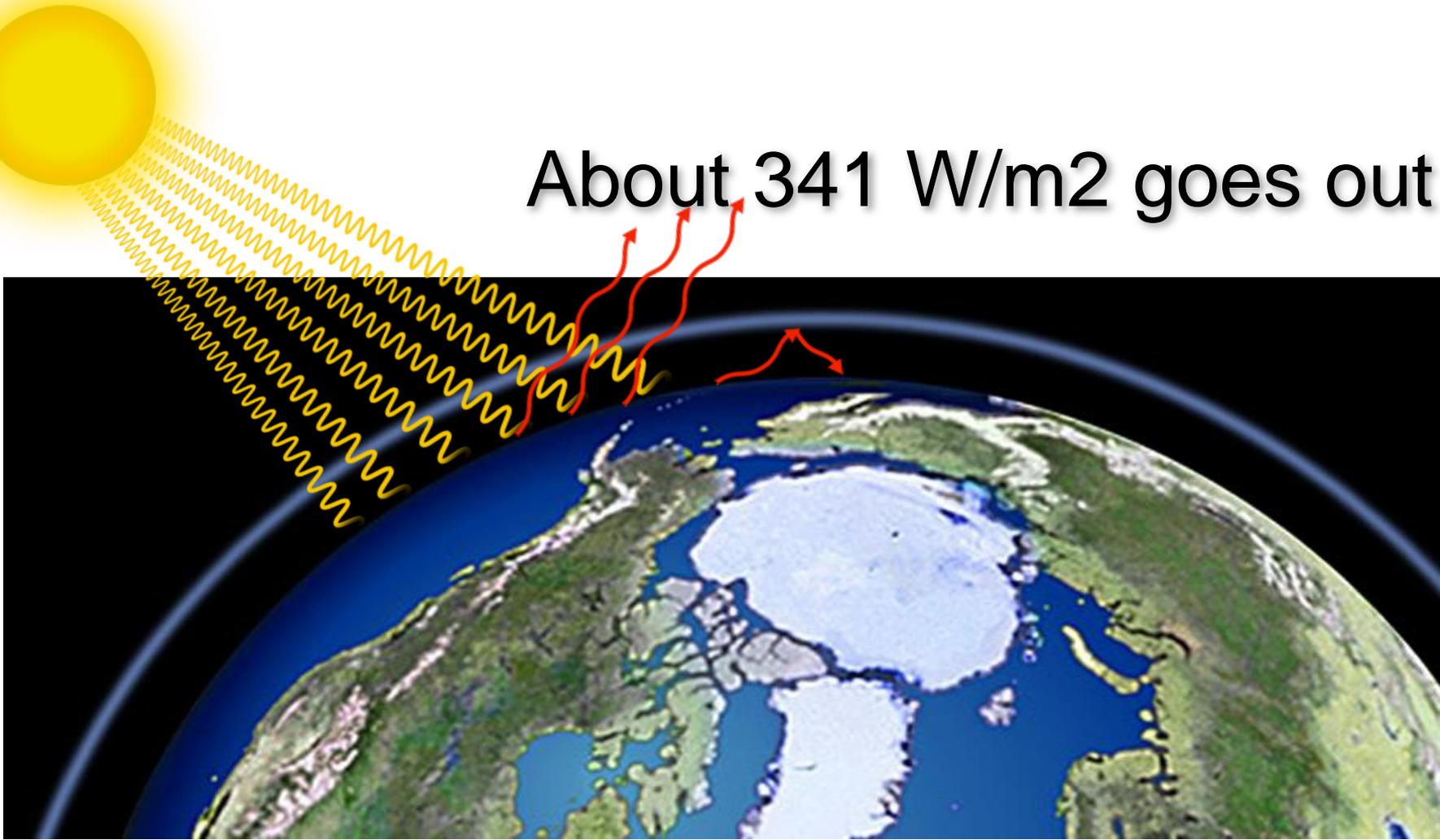
Number 234 in a series of DITSEL "how to" ...

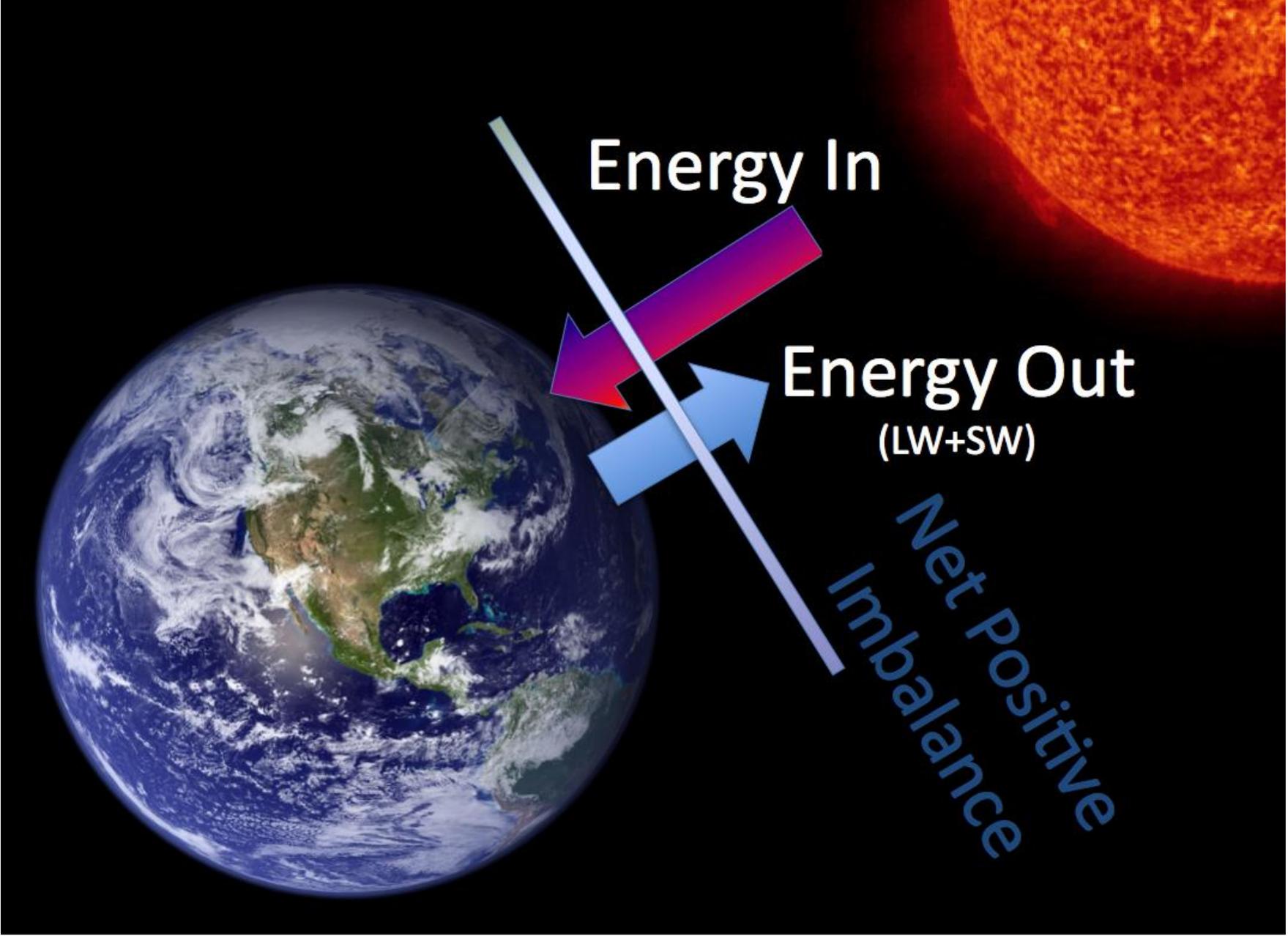
View our ... Union Sq, San Francisco Post 50

GLOBAL
WARMING
READY

About 342 w/m² comes in

About 341 W/m² goes out





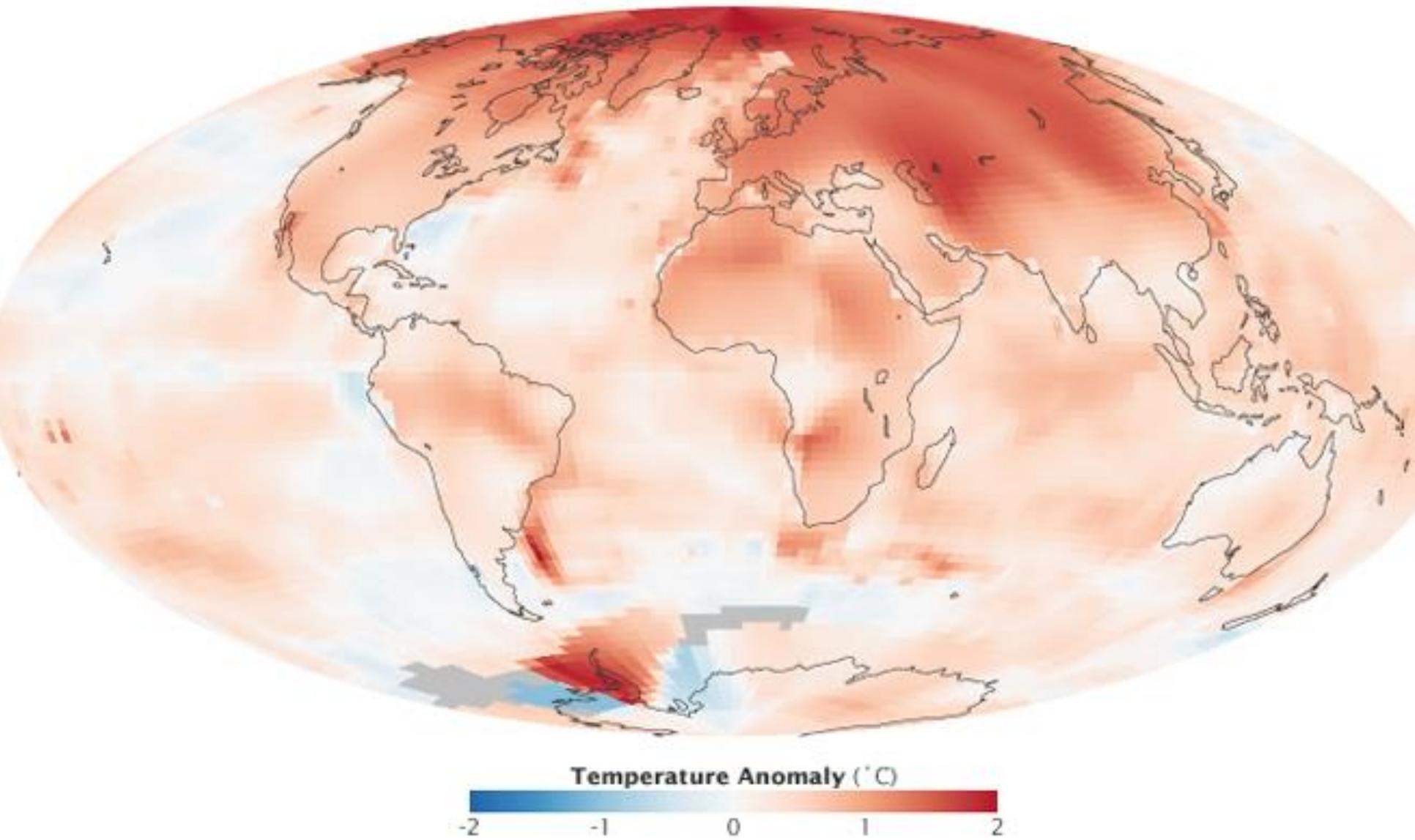
Energy In

Energy Out
(LW+SW)

Net Positive
Imbalance

Change in temperature

2000-2009 vs. 1951-1980



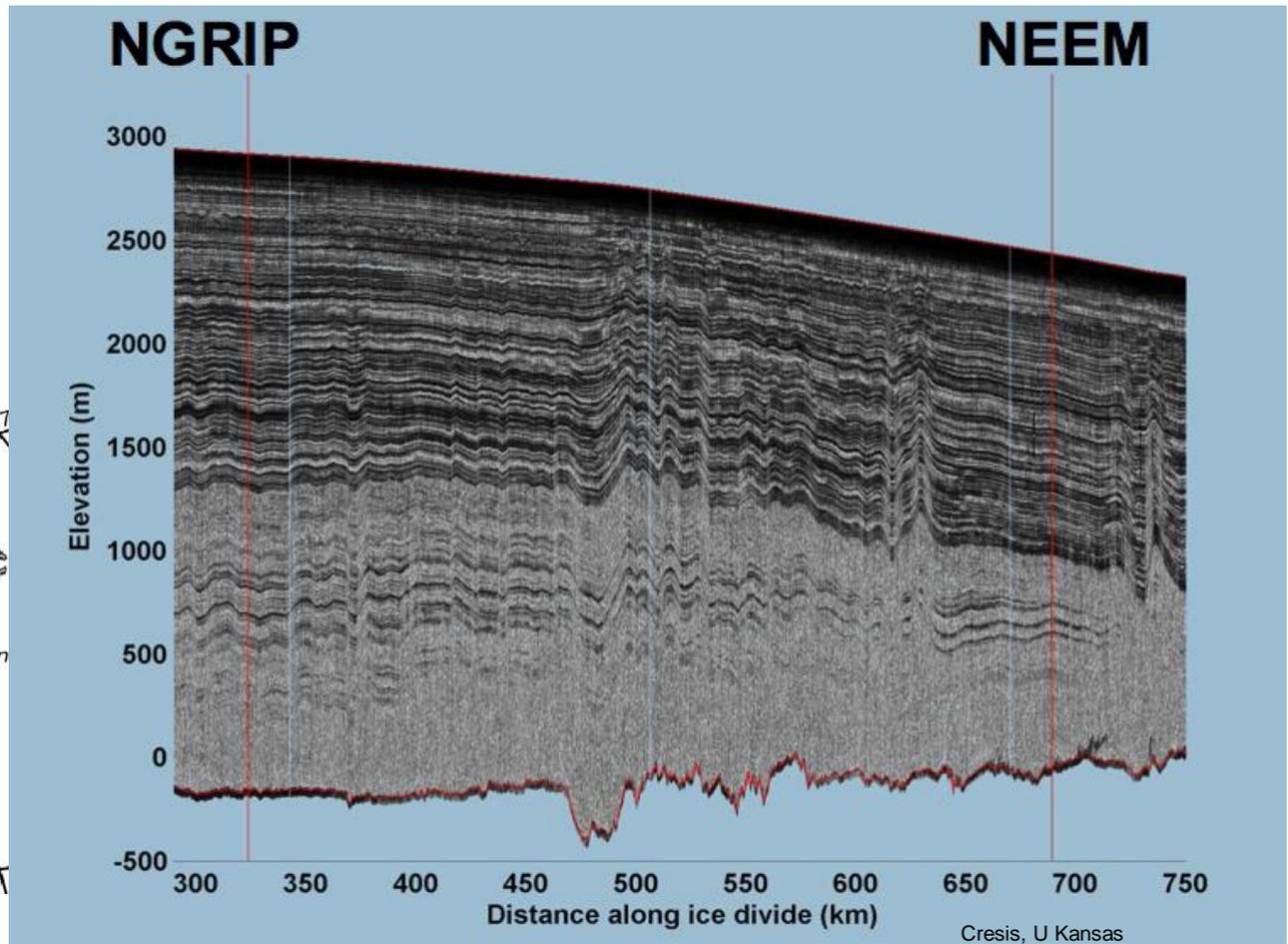
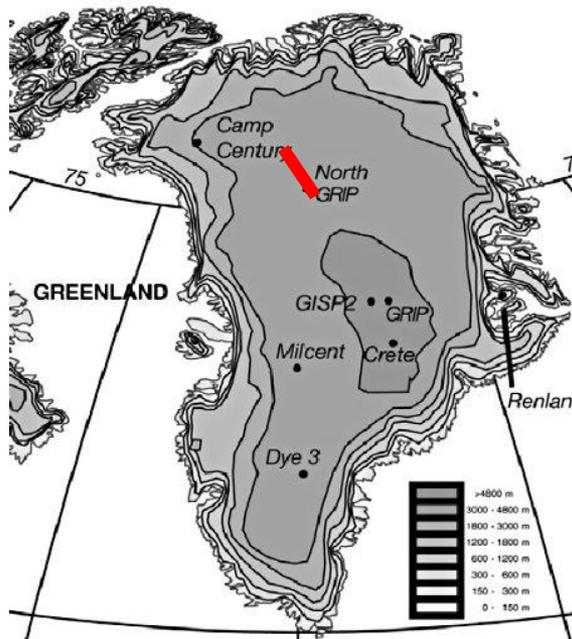
Stratified Ice

The pale bands are summer, the dark bands winter.



5 Cm

GISP 2 Core, 1855 meters



Character of radar reflectors in northern Greenland

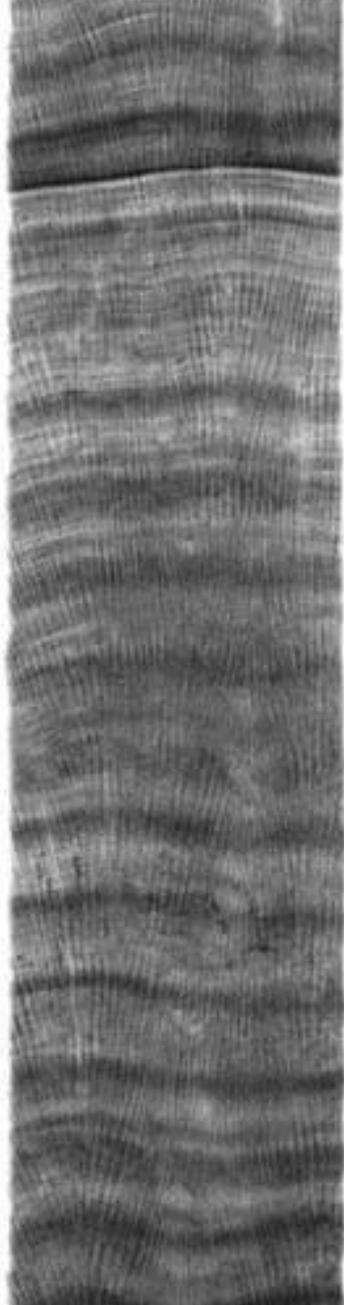


Stalagmite

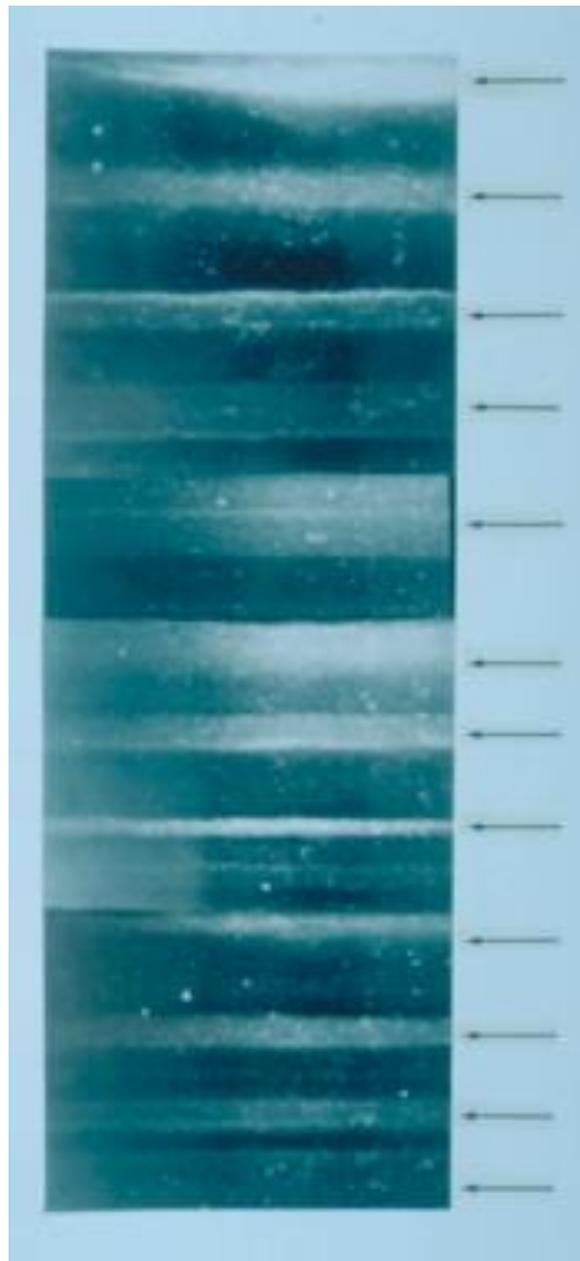


UV Light

Photo: AlMS



Coral, Australia

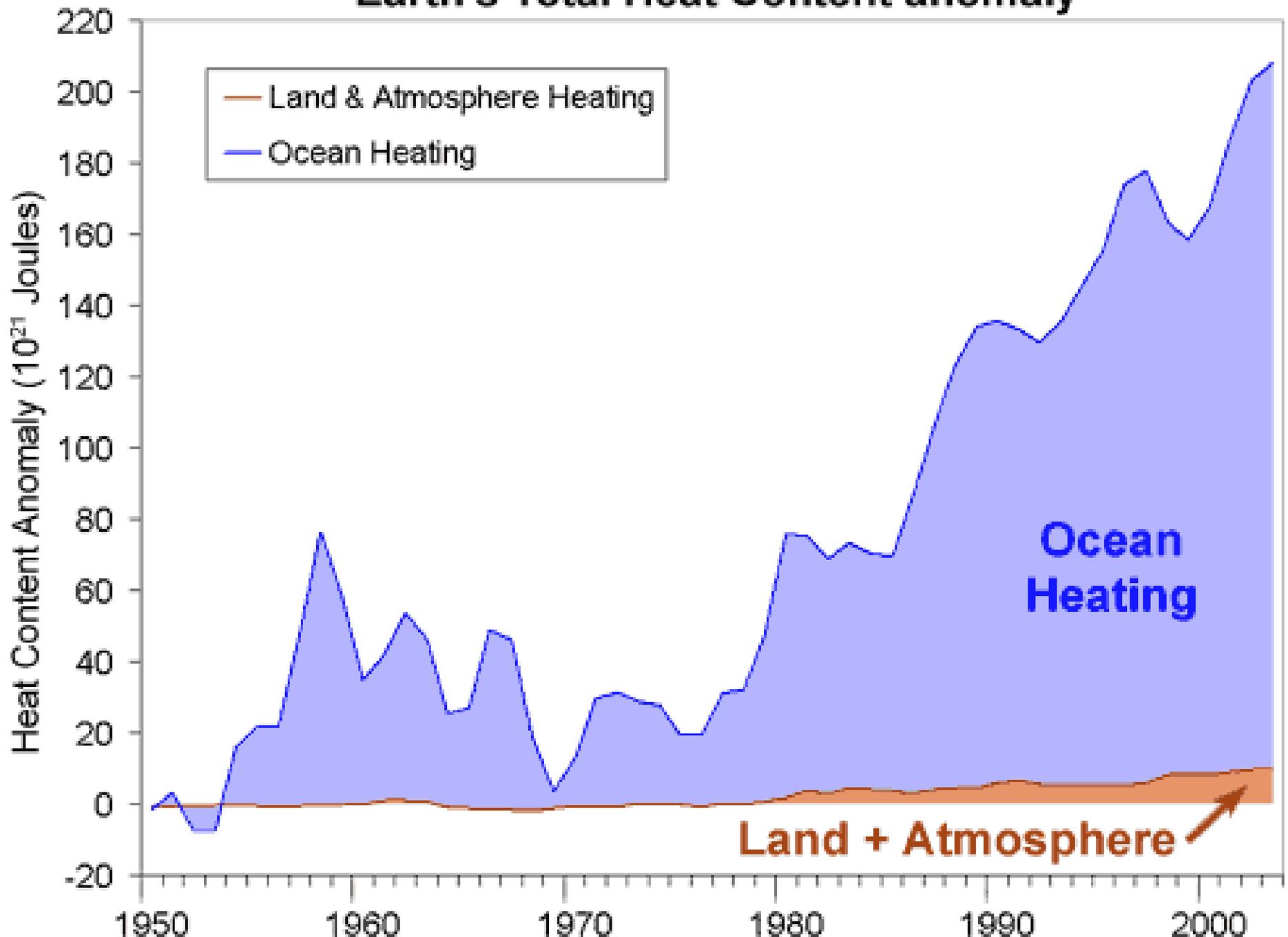


Ice, Greenland



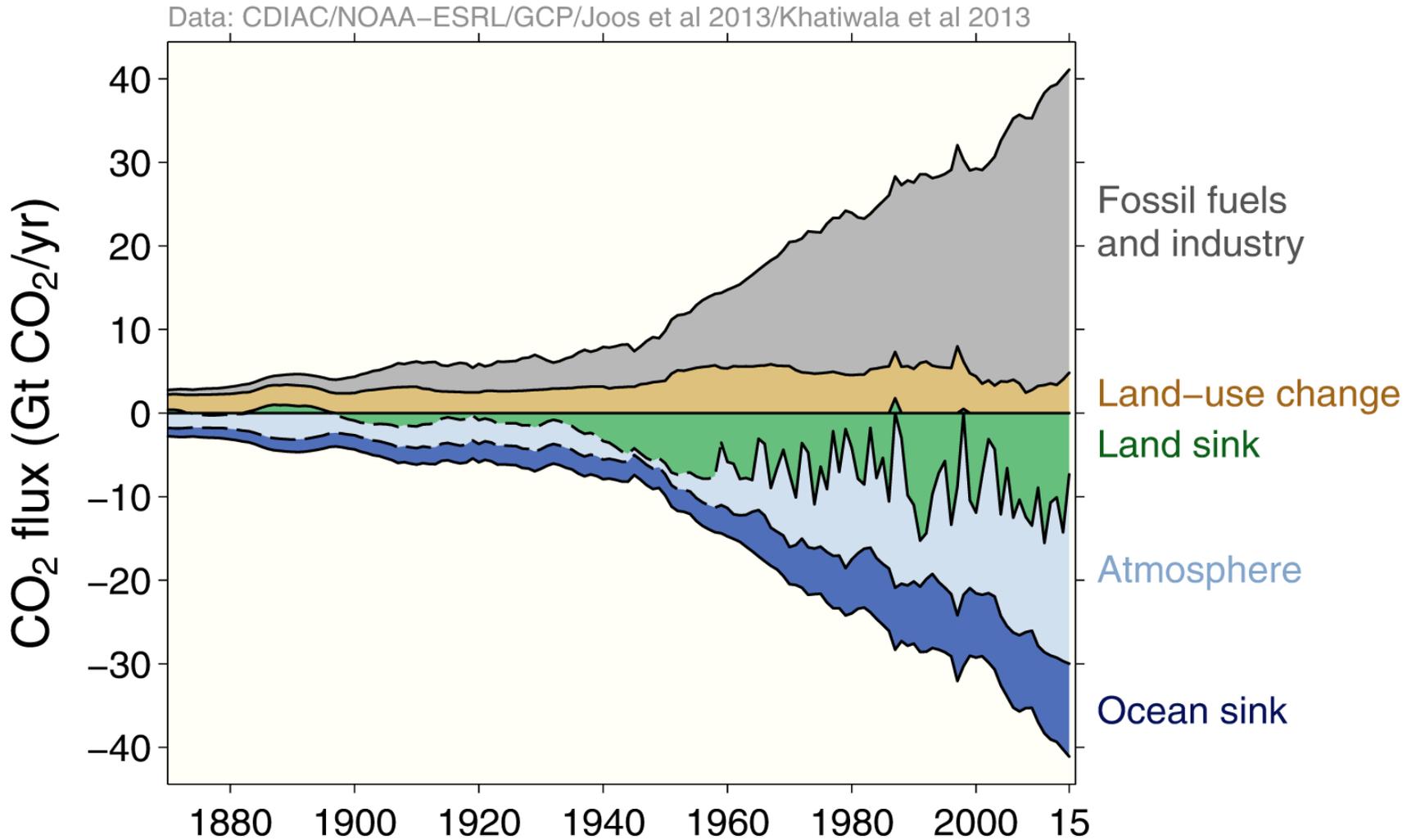
Lake Sediments, Turkey

Earth's Total Heat Content anomaly

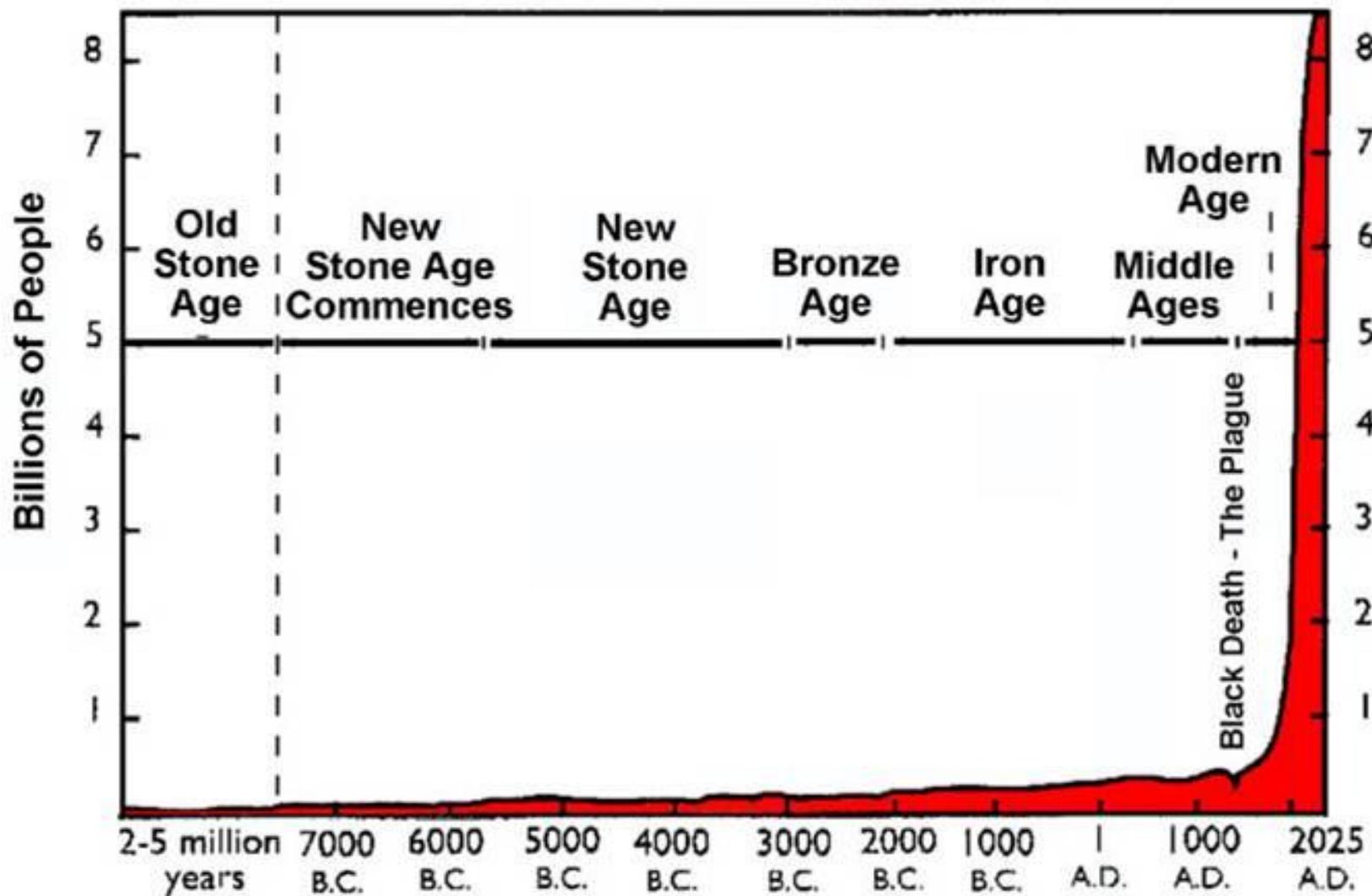


The

by

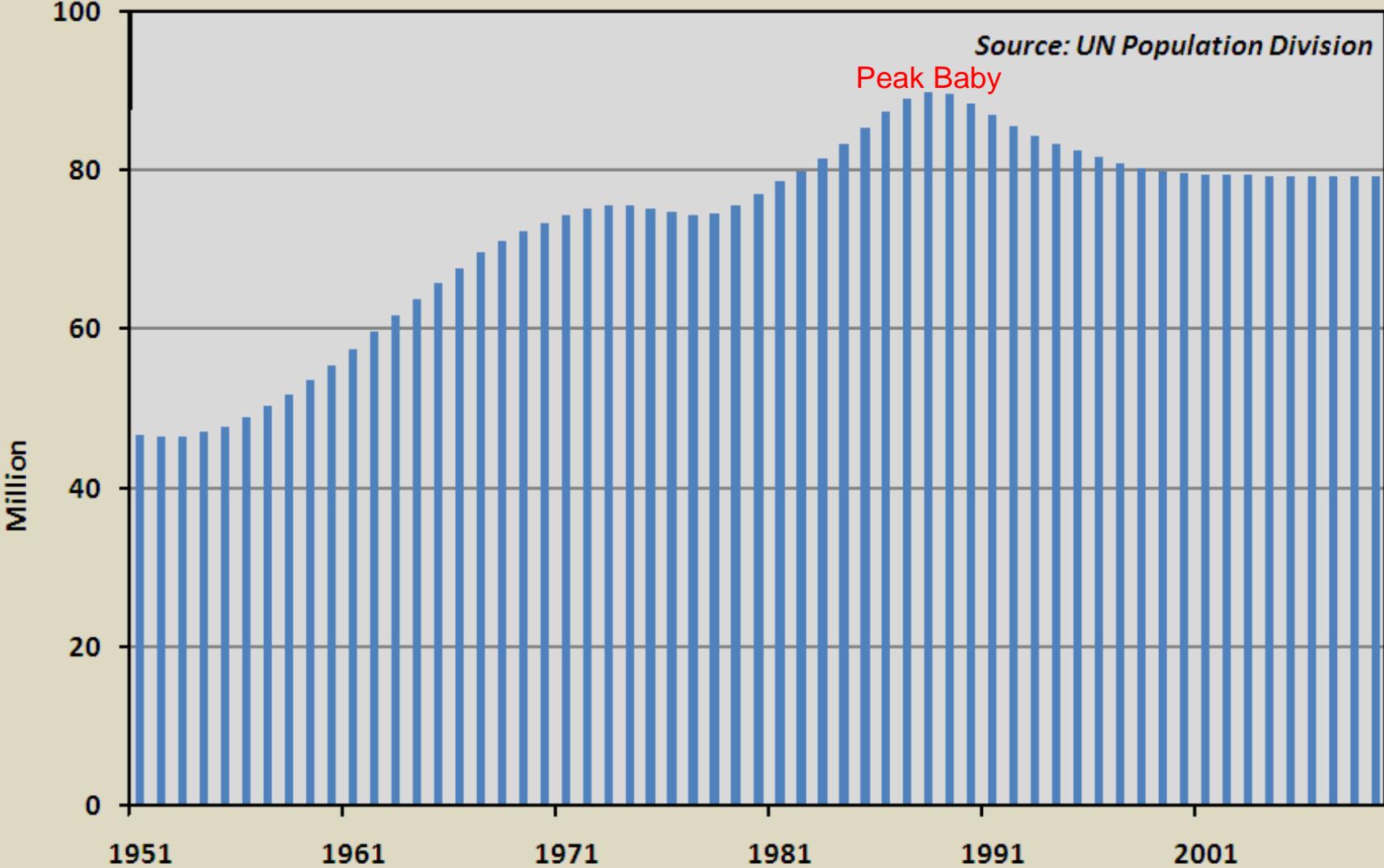


World Population Growth Through History

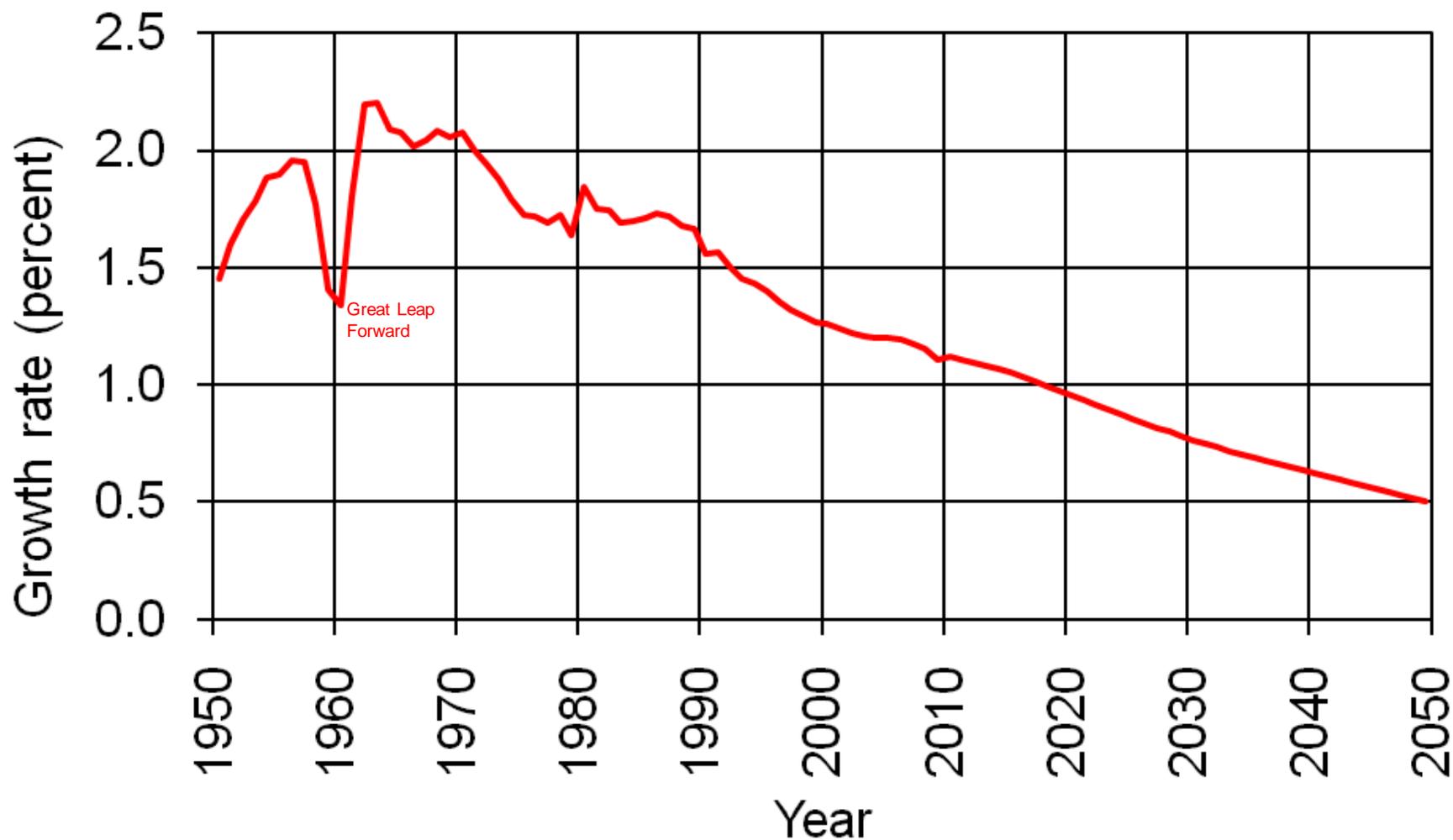


From "World Population: Toward the Next Century," copyright 1994 by the Population Reference Bureau

Figure 2. Annual Addition to World Population, 1951–2009

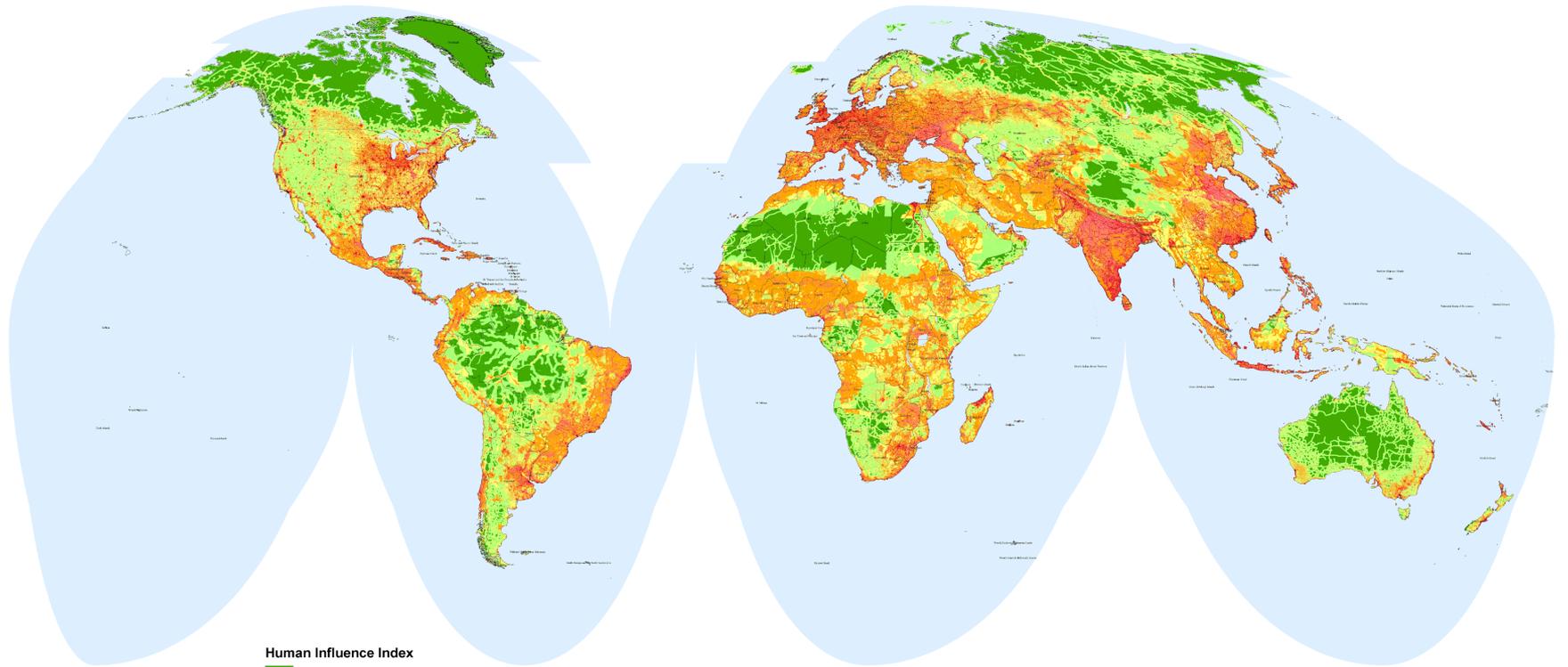


World Population Growth Rates: 1950-2050

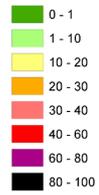


Source: U.S. Census Bureau, International Data Base, June 2011 Update.

Map of Human Footprint



Human Influence Index

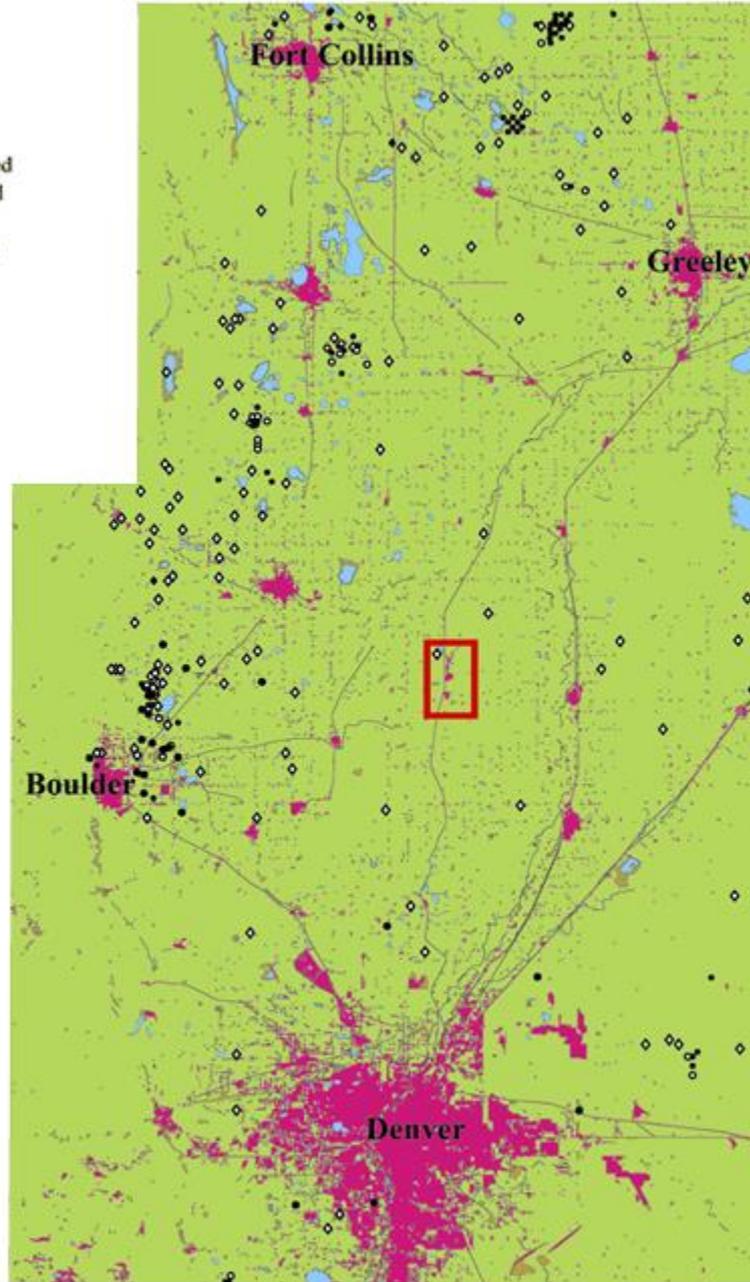


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1960

- Developed
- Vegetated
- Water
- ◇ Gas Well
- Oil Well

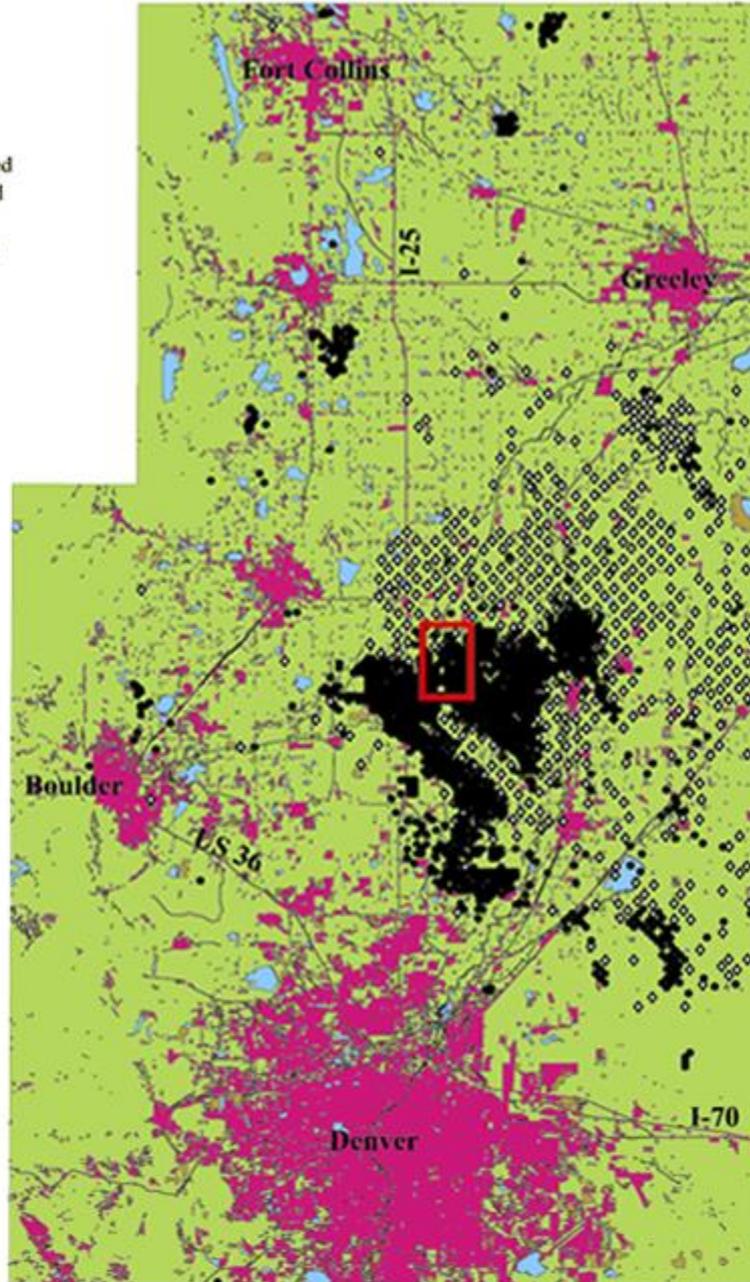


U

USGS

1980

- Developed
- Vegetated
- Water
- Gas Well
- Oil Well

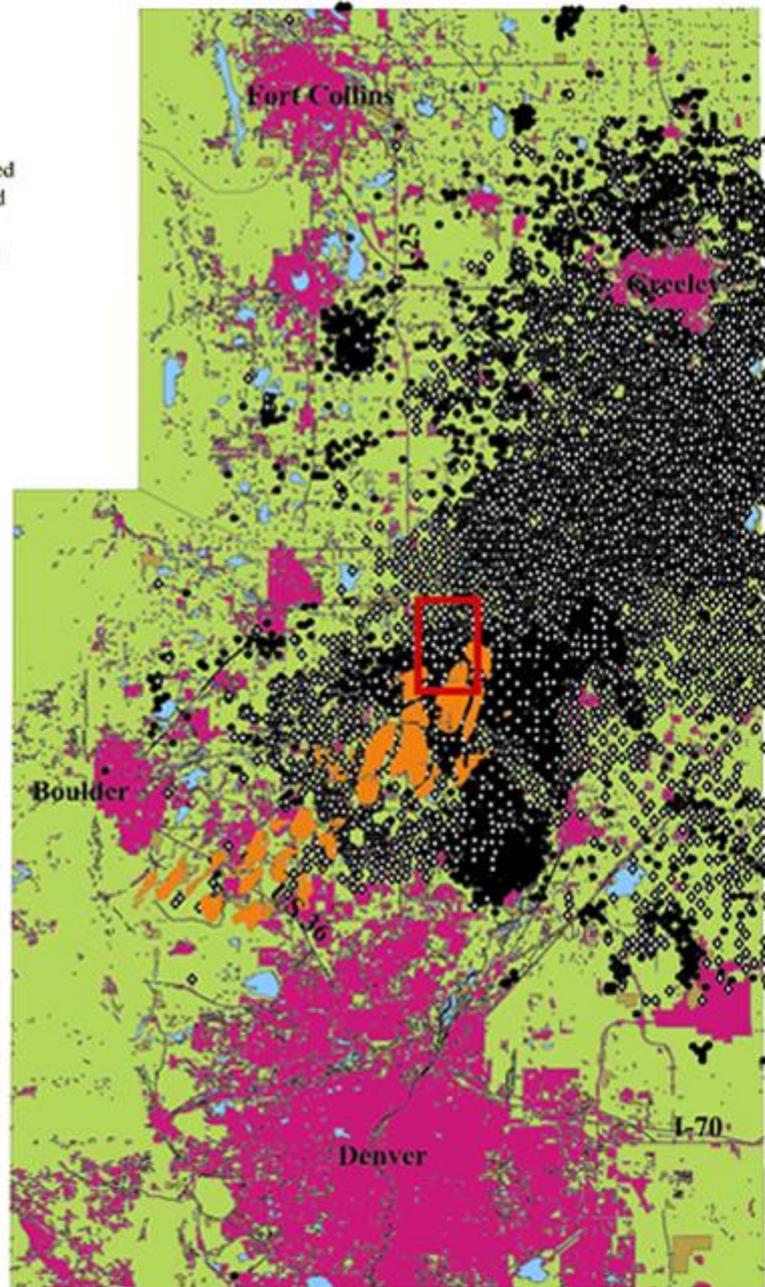


U

USGS

2000

- Developed
- Vegetated
- Water
- ◇ Gas Well
- Oil Well



U

USGS

Jonah Field, Wyoming August 1994



4881 ft

© 2010 Google
Image U.S. Geological Survey

©2010 Google™

Imagery Dates: Aug 25, 1994 - Sep 5, 1994

lat 42.452560° lon -109.709765° elev 7253 ft

Eve alt 27512 ft

Jonah Field, Wyoming August 2006



Image © 2010 DigitalGlobe
© 2010 Google

© 2010 Google

4881 ft

Imagery Date: Aug 14, 2006

lat 42.452560° lon -109.709765° elev 7253 ft

Eye alt 27512 ft

9/5/1998

N

Ln 8 N

Rd N 109

17

Rd N 108

Sept 1998

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

8/29/2003

N

Ln 8 N

Rd N 109

Rd N 108

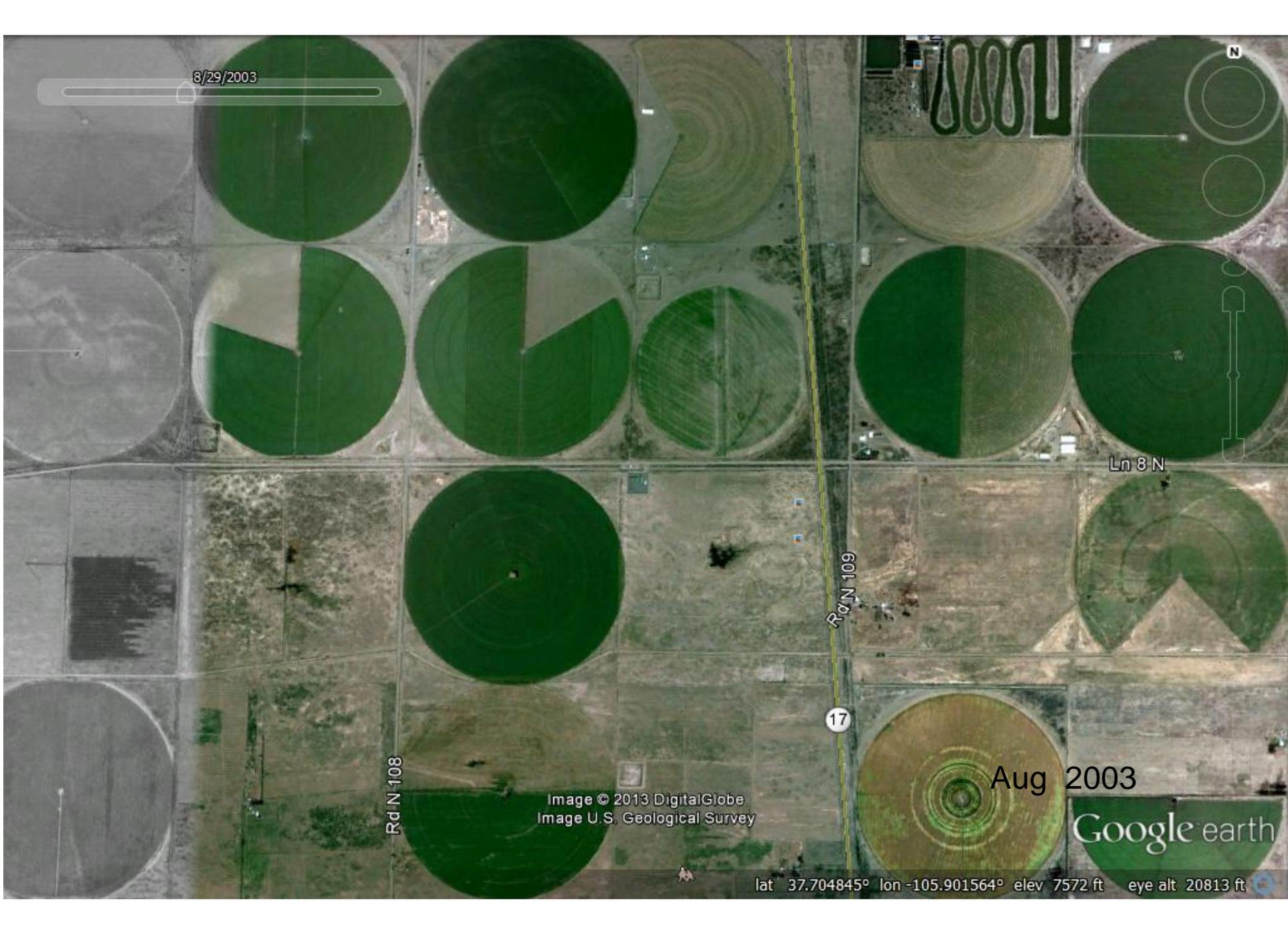
17

Aug 2003

Image © 2013 DigitalGlobe
Image U.S. Geological Survey

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

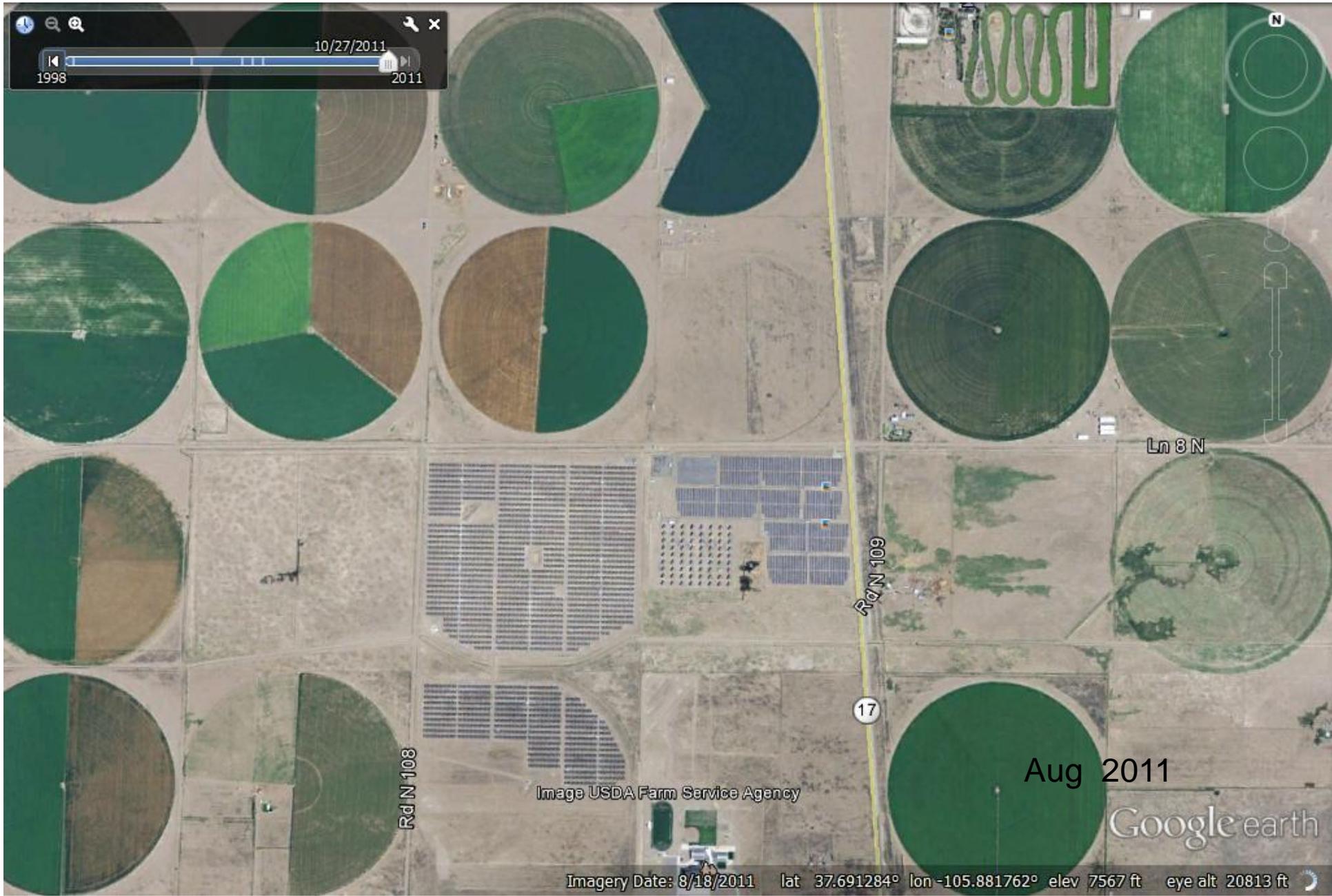
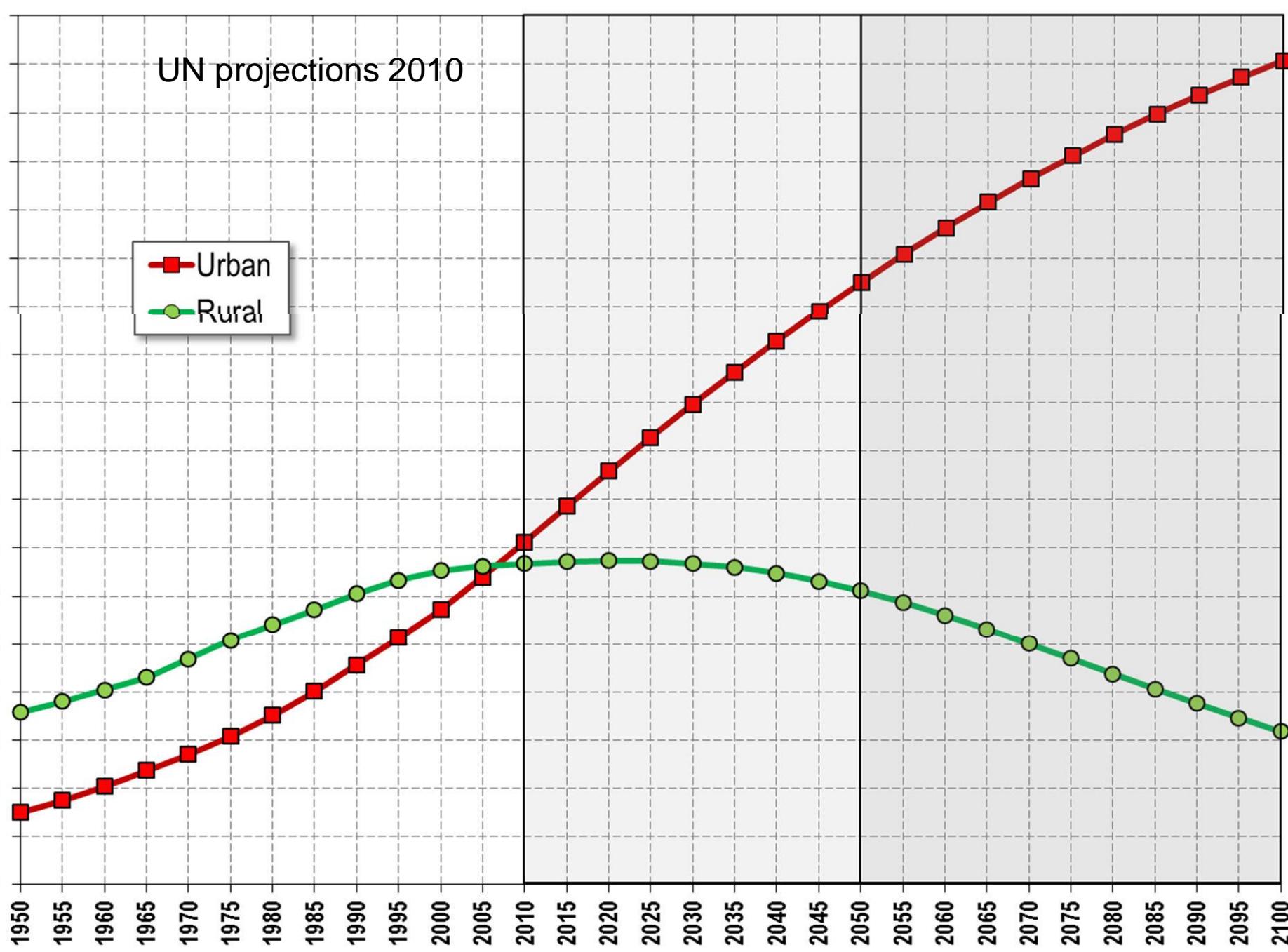
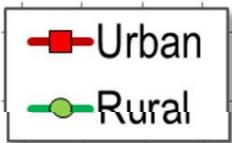


Image USDA Farm Service Agency

Aug 2011

Google earth

UN projections 2010





Doug Wheelock, ISS NASA Nov 2, 2010

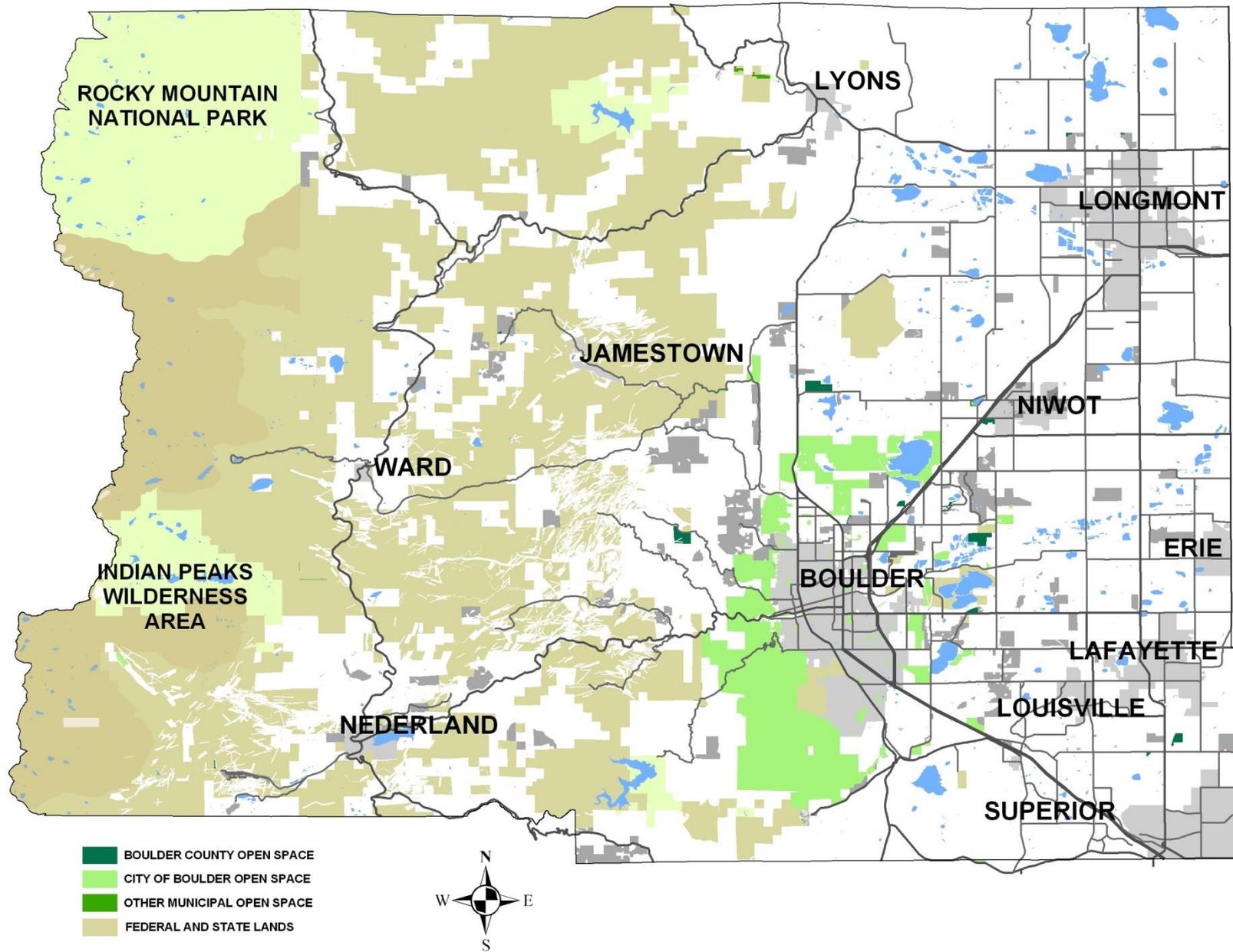


Doug Wheelock, ISS NASA Jan 31, 2010

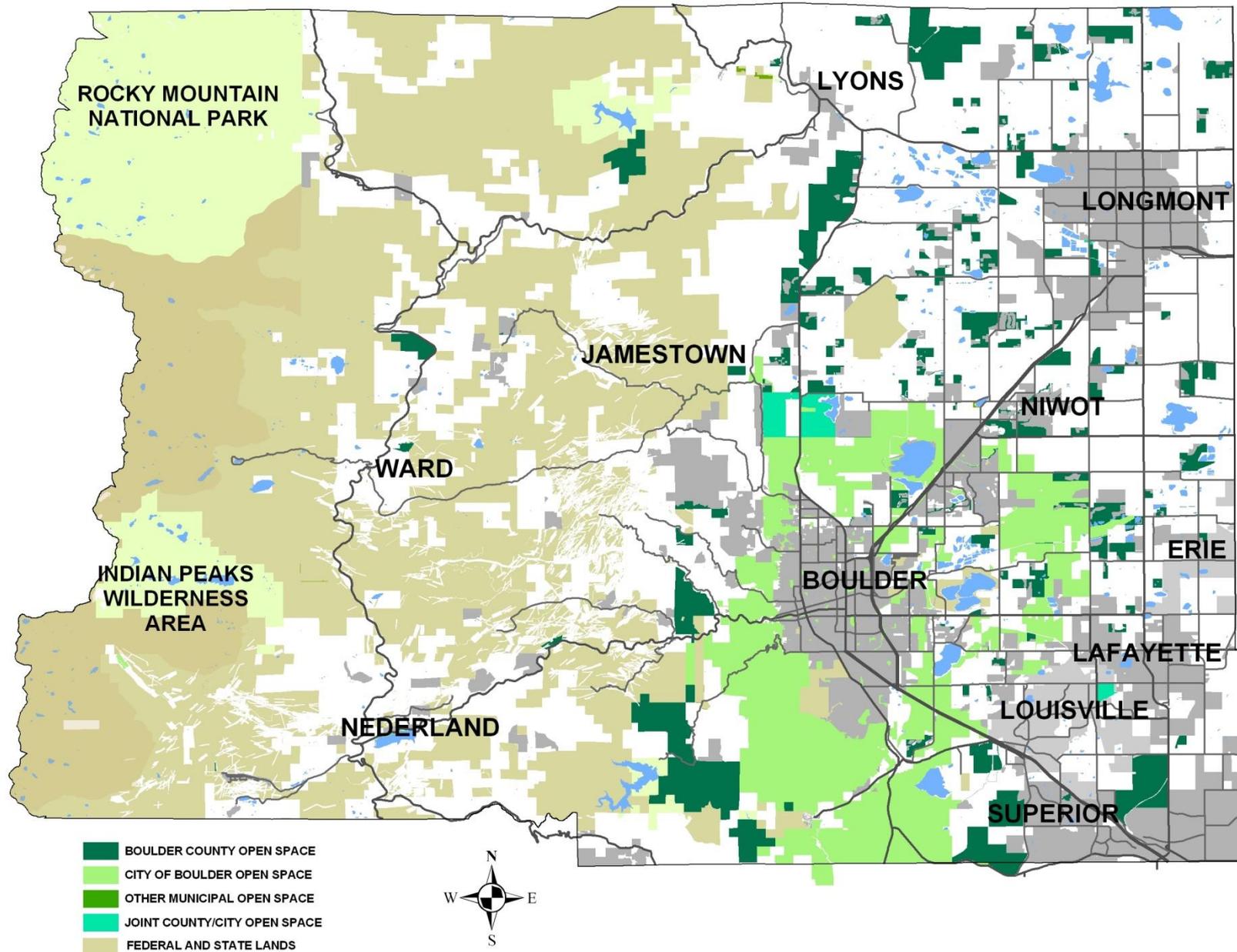


Doug Wheelock, ISS NASA Aug 22, 2010

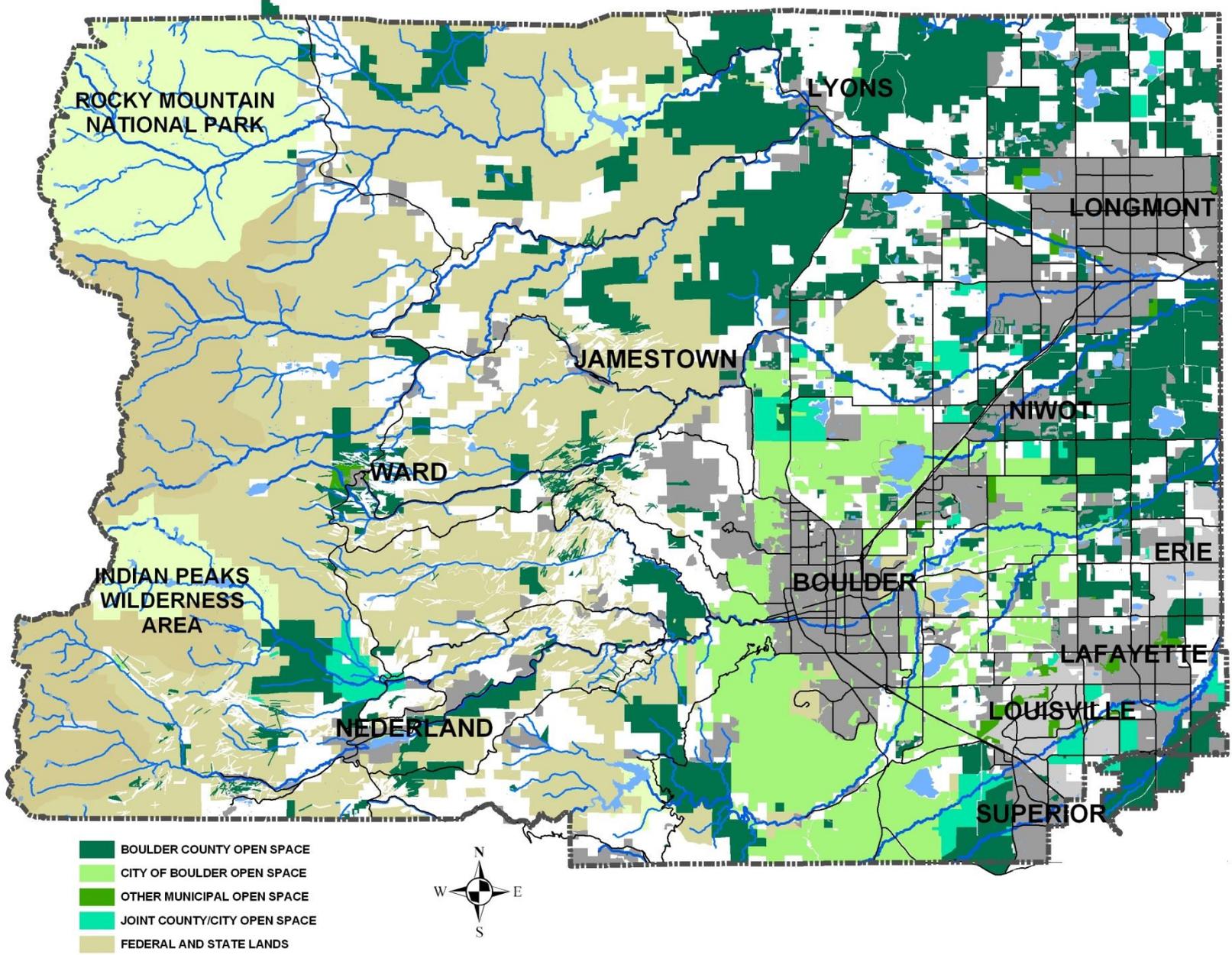
Open Space 1975



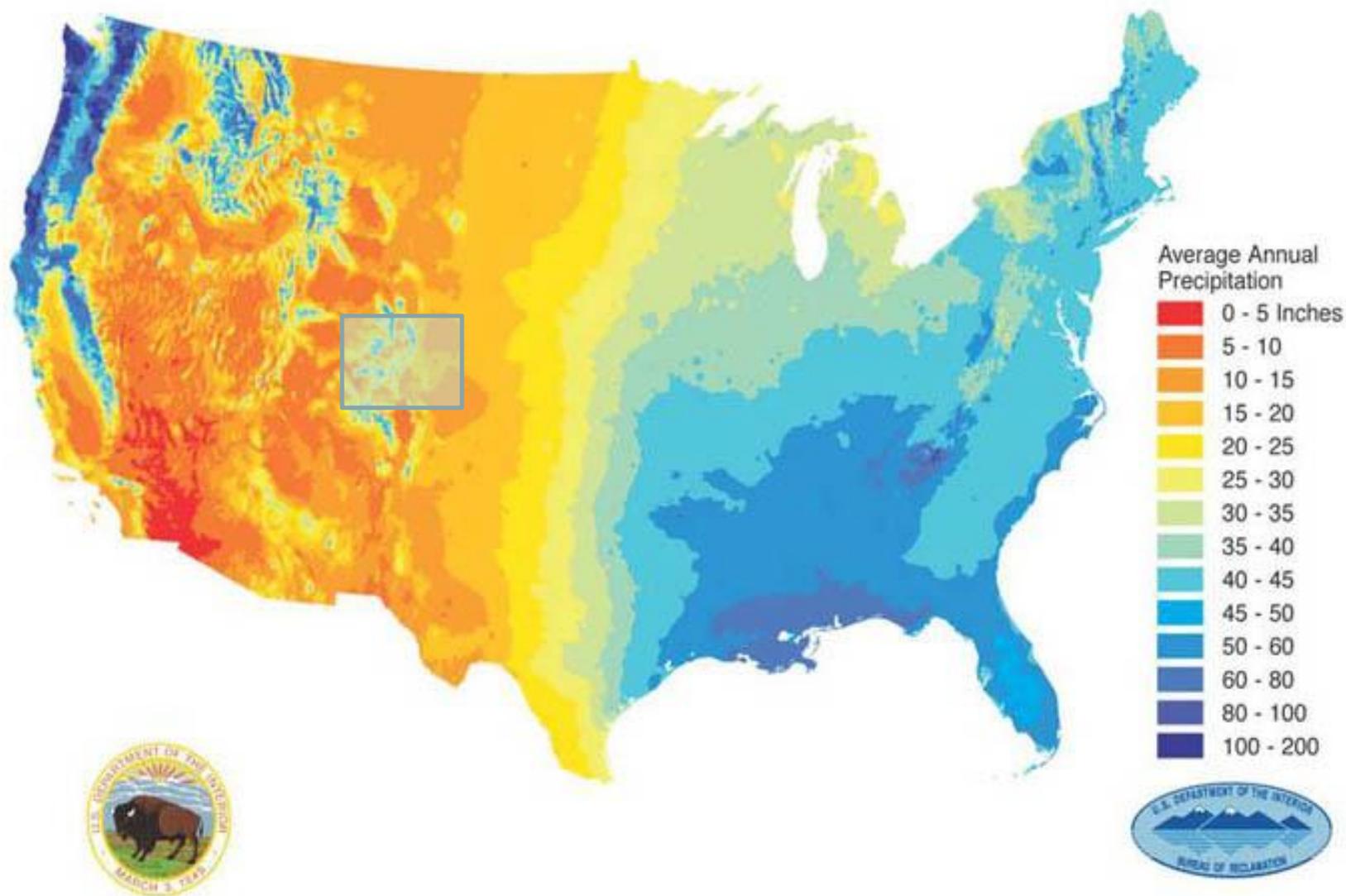
Open Space 1994



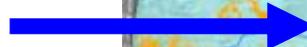
Open Space 2007



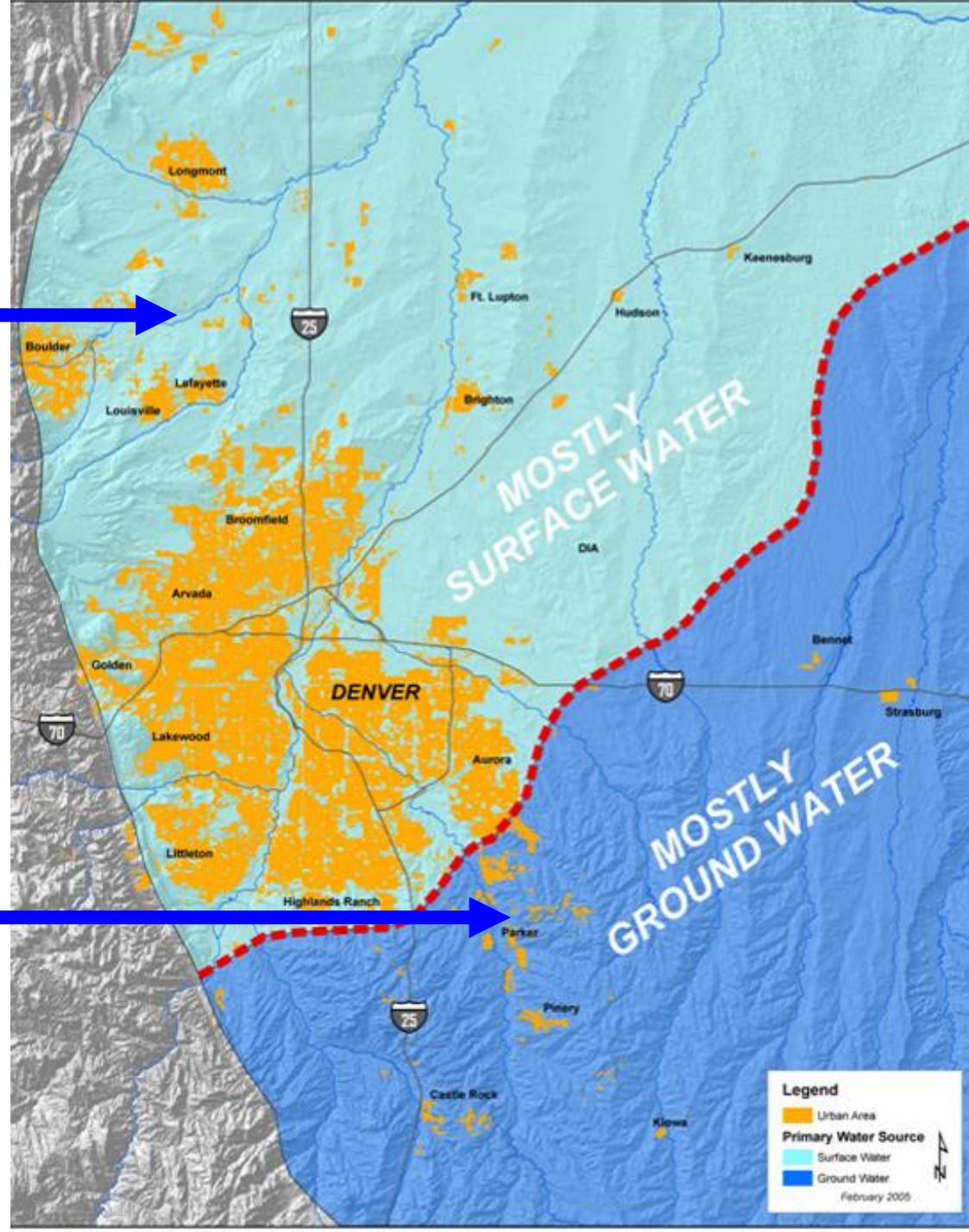
Average Inches of Annual Precipitation in the United States 1961-1990



Climate
dependent
(drought)

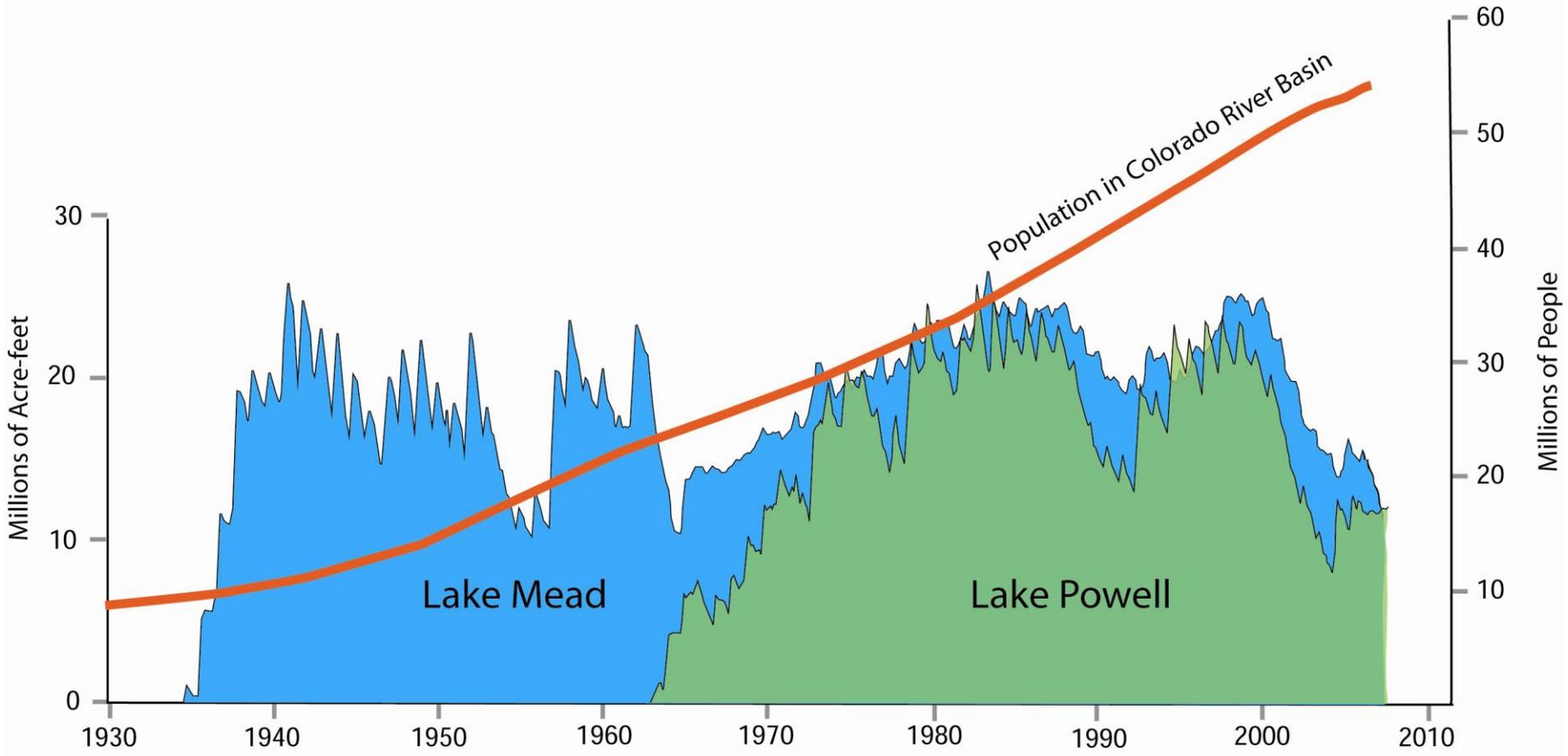


Aquifer
dependent
(finite resource)





Water Storage and Population in the Colorado River System



Modified after Western Water Assessment 2008









קולחי אילת

11

מי קולחין

השתיה אסורה !







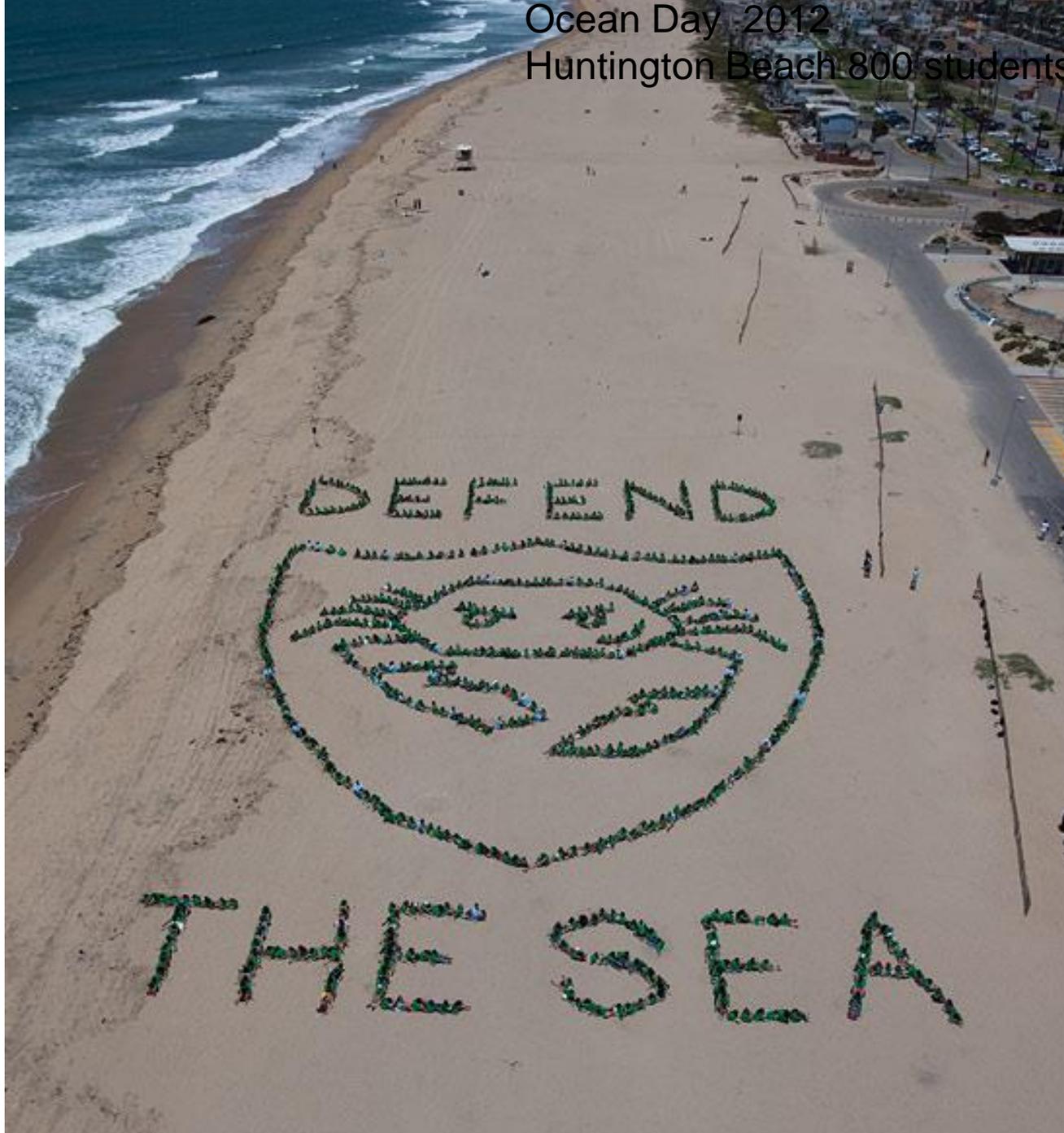




Tijuana River



Ocean Day 2012
Huntington Beach 800 students

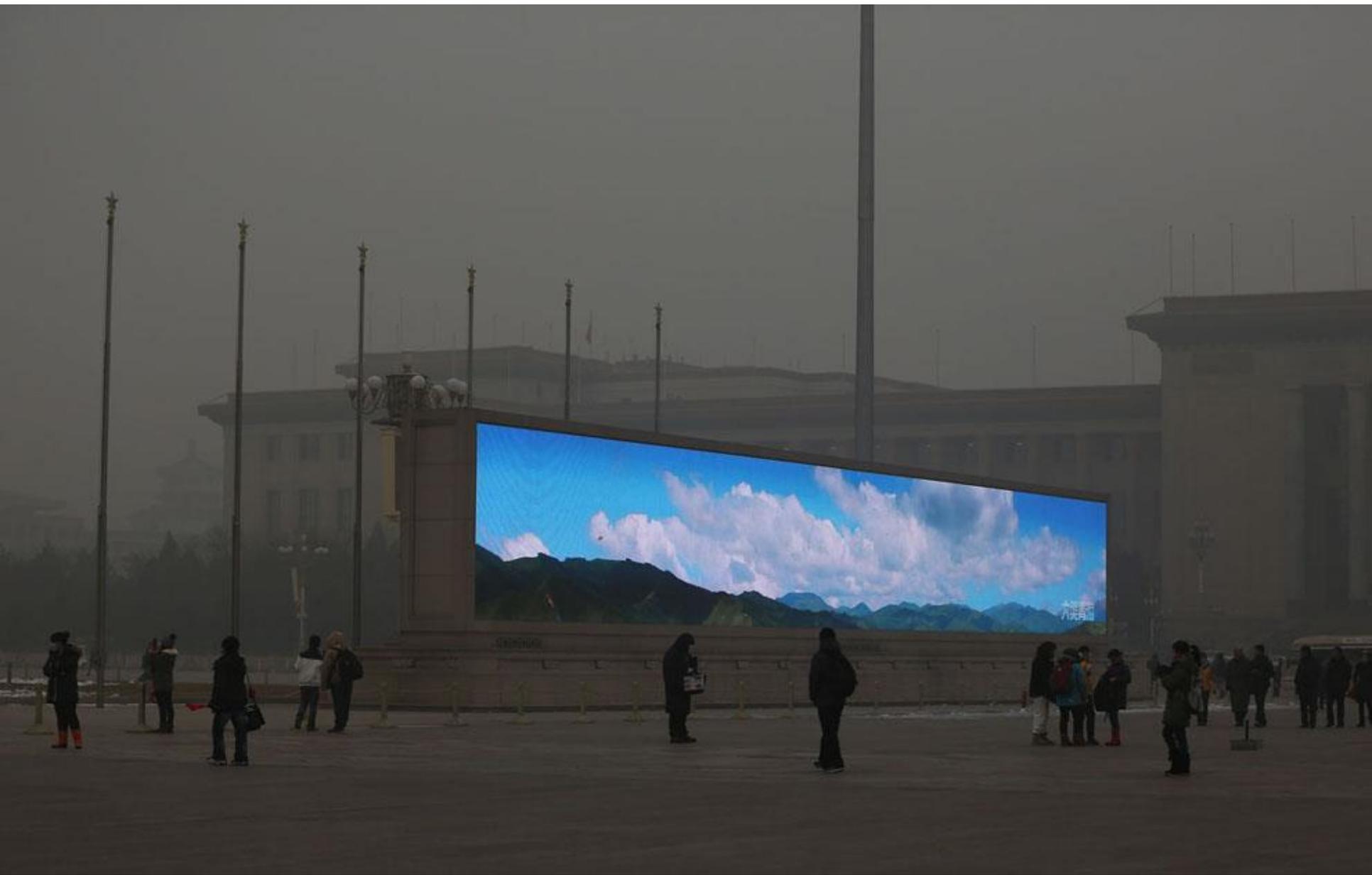




Ocean Day
Dockweiler Beach, LA
5000 students



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



Museums, Zoos and Your Children will save the World



facebook

December 2010

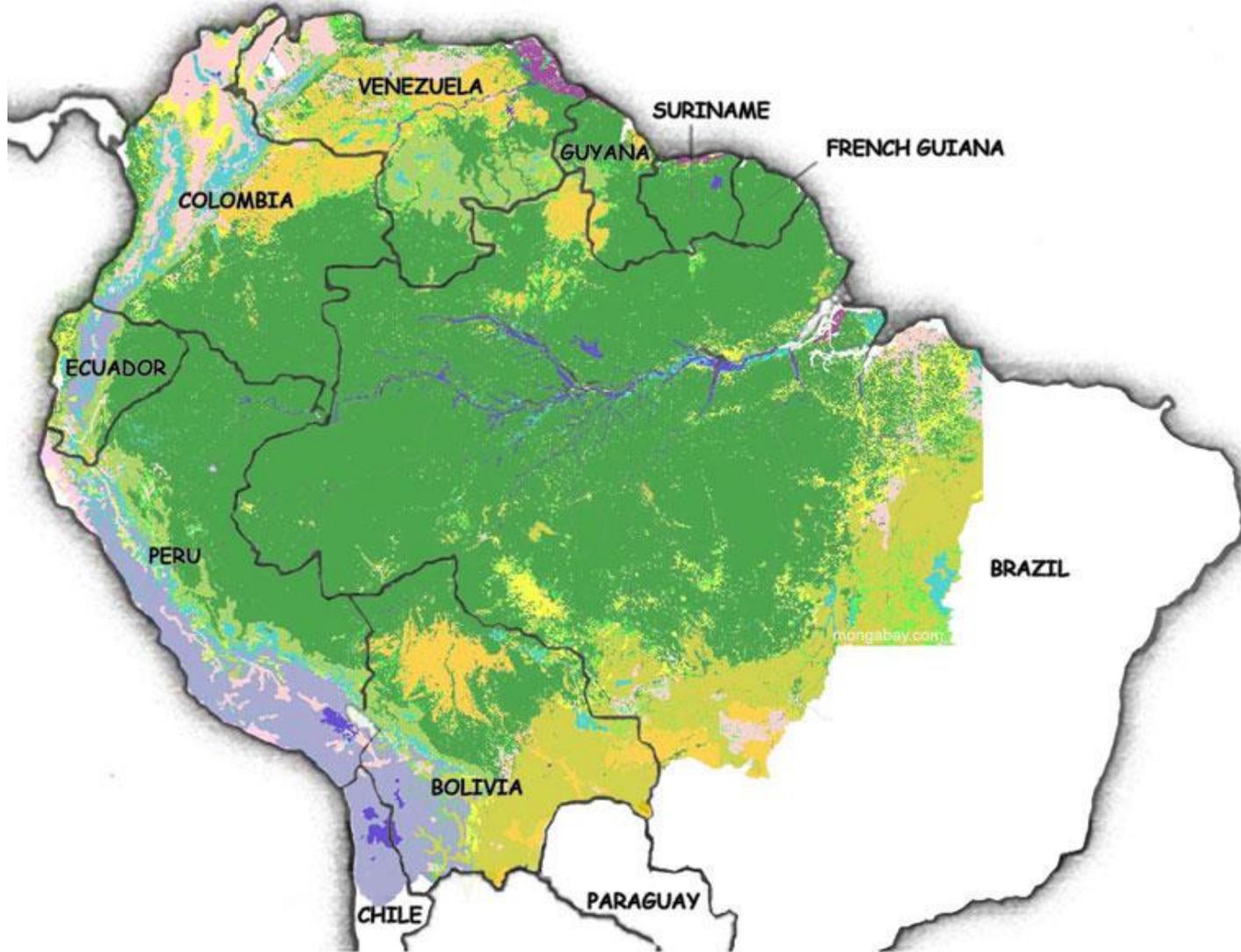






Neft Dashlari, oily rock

Off Baku, Caspian Sea



mongabay.com

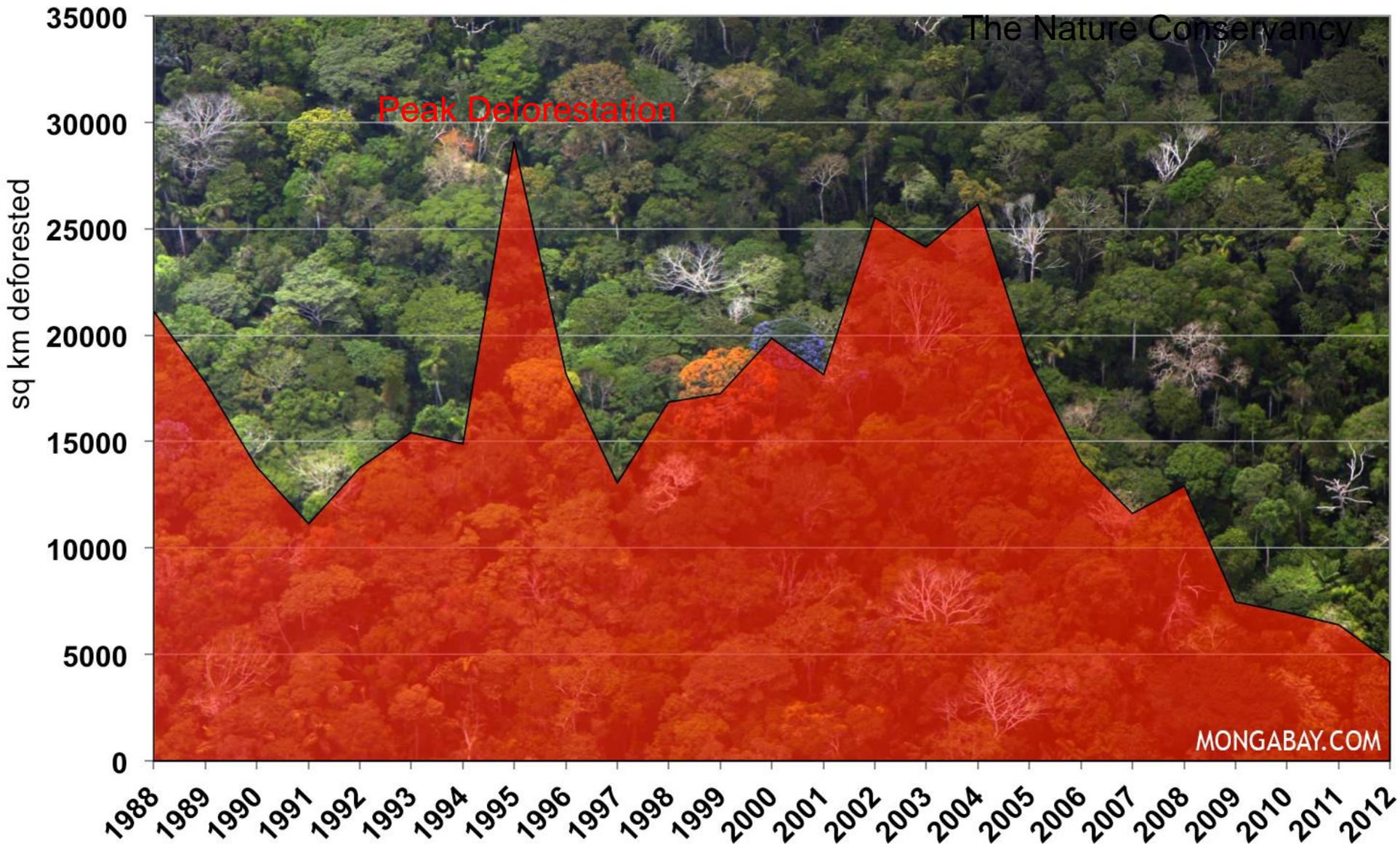
- Lowland moist forest
- Mangrove and coastal swamp forest
- Sub-montane forest
- Montane forest
- Fragmented forest
- Converted forest

- Inland water

- Savannah woodlands
- Grasslands
- Subdesertic vegetation
- Montane mosaics
- Seasonally flooded grasslands
- Agricultural mosaics
- Subdesertic vegetation

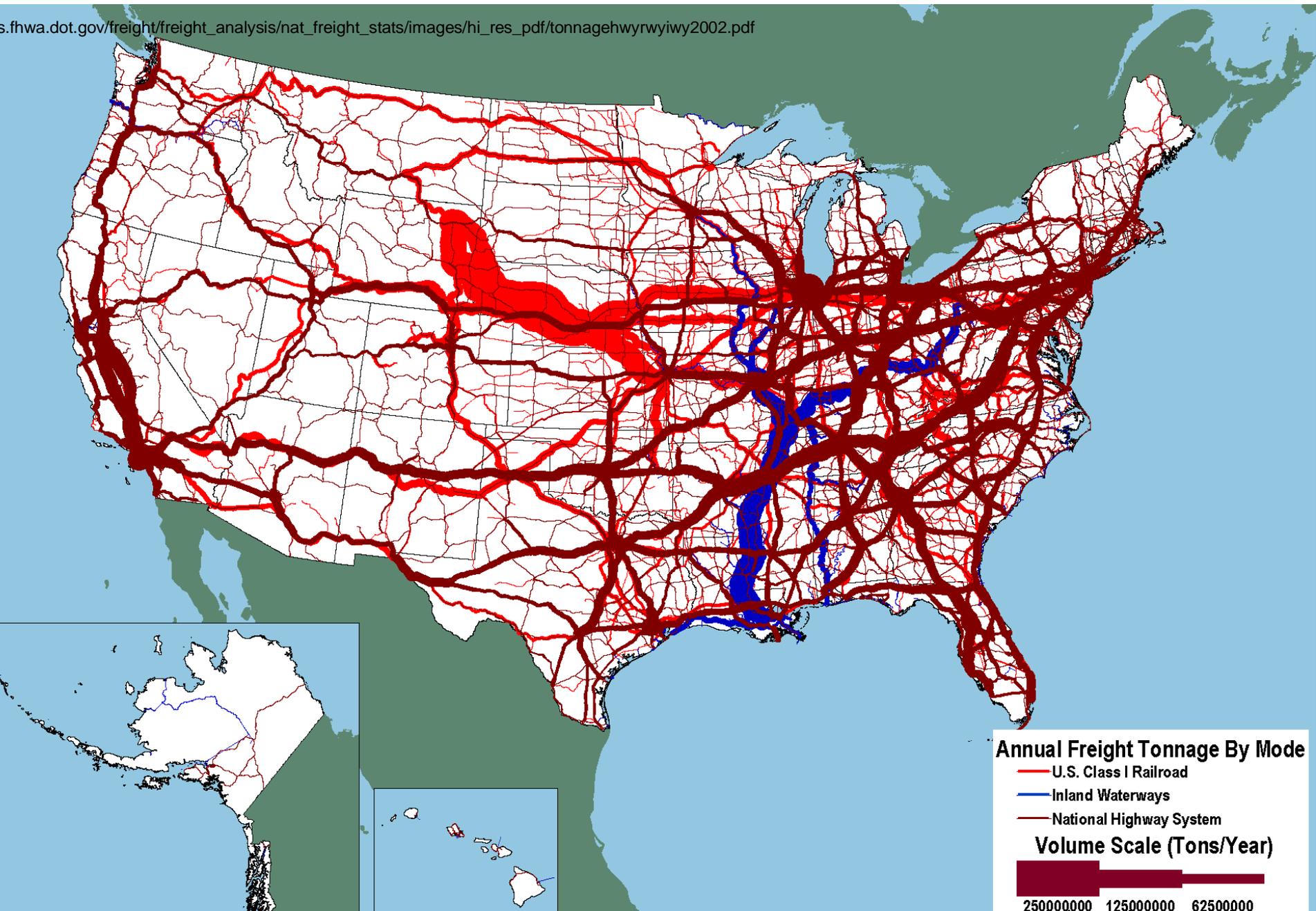
Based on the Vegetation Map of Tropical South America, H.D. Eva et al. (1999) TREES Publications Series, European

Deforestation in the Brazilian Amazon, 1988-2012



Tonnage on Highways, Railroads and Inland Waterways: 2002

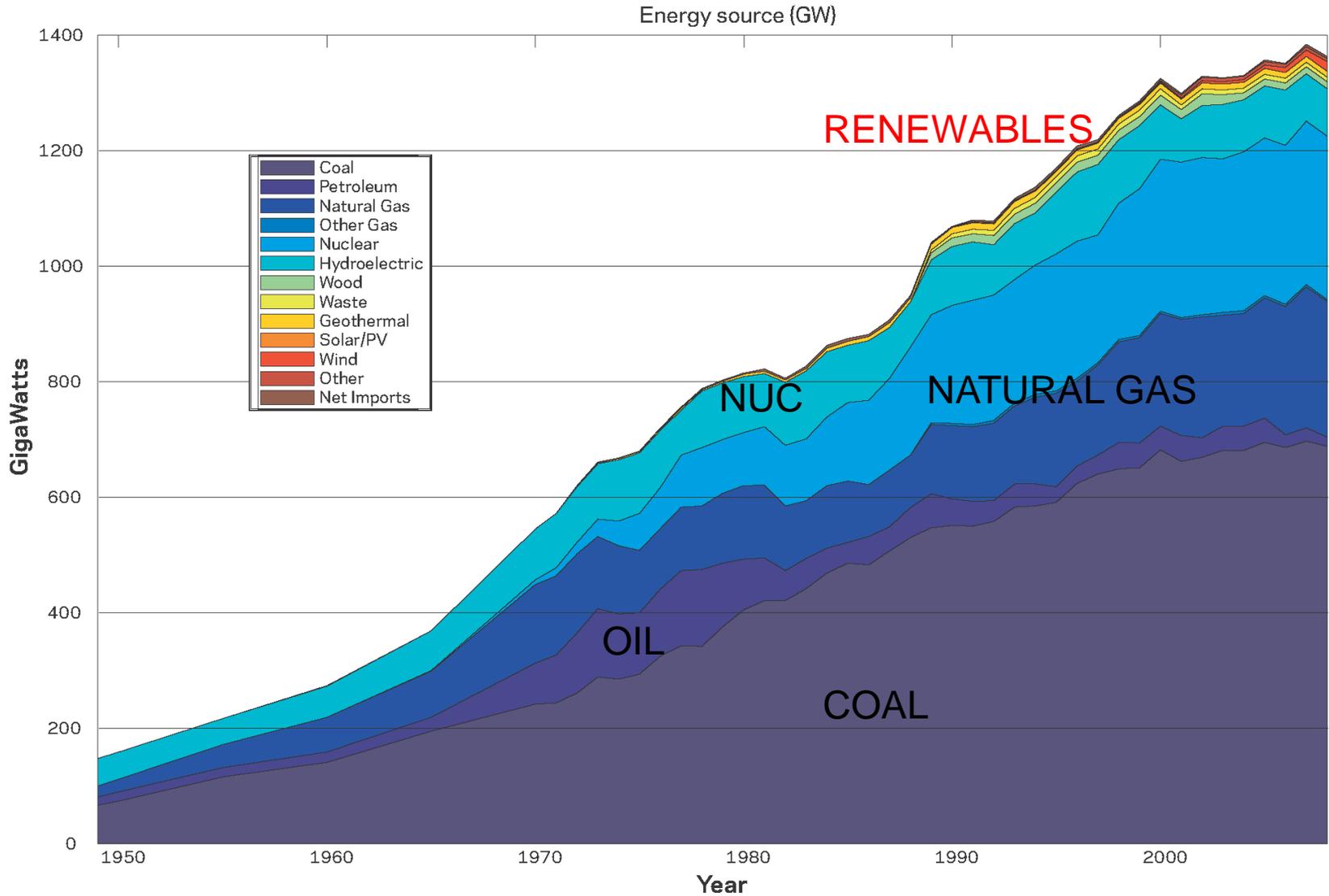
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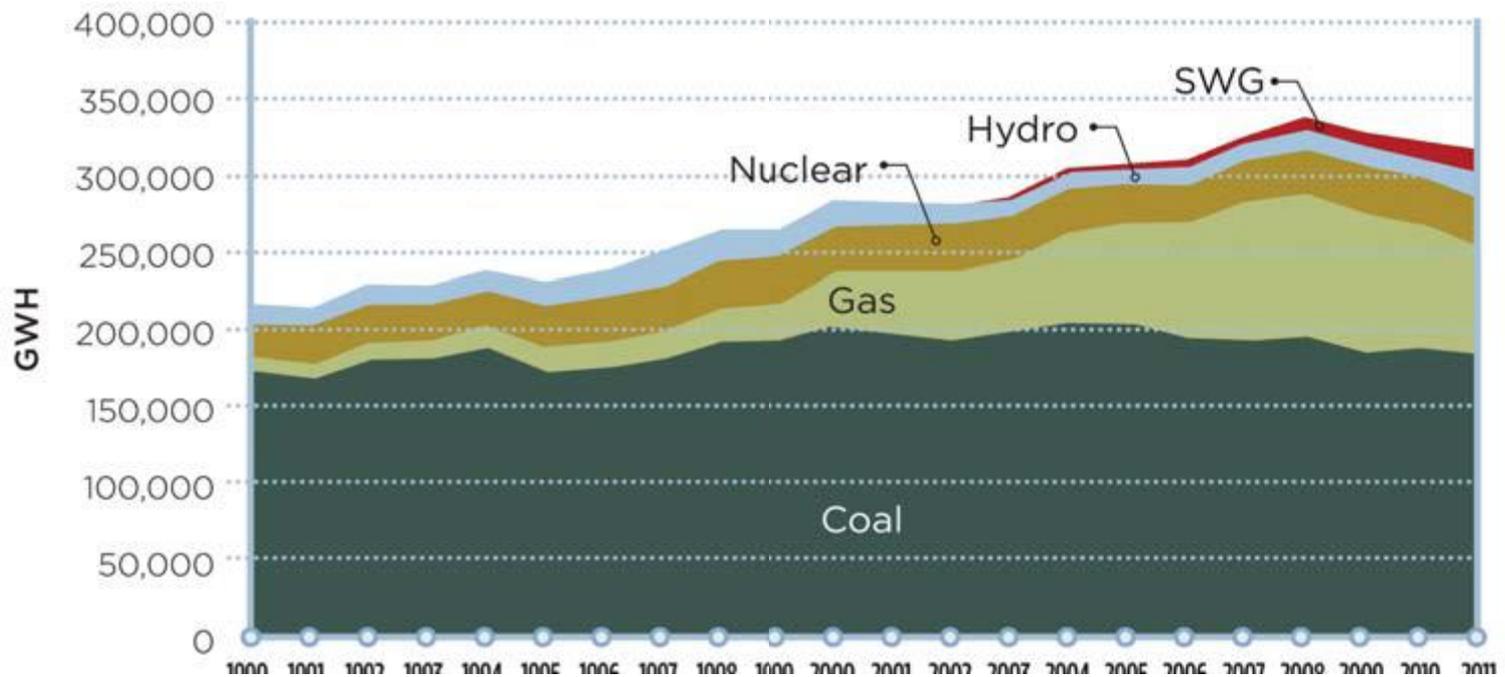


Courtesy of <http://www.peabodyenergy.com/>

Historical US electricity production, by generation source.



ROCKY MT REGION



Mountain West power generation by fuel type

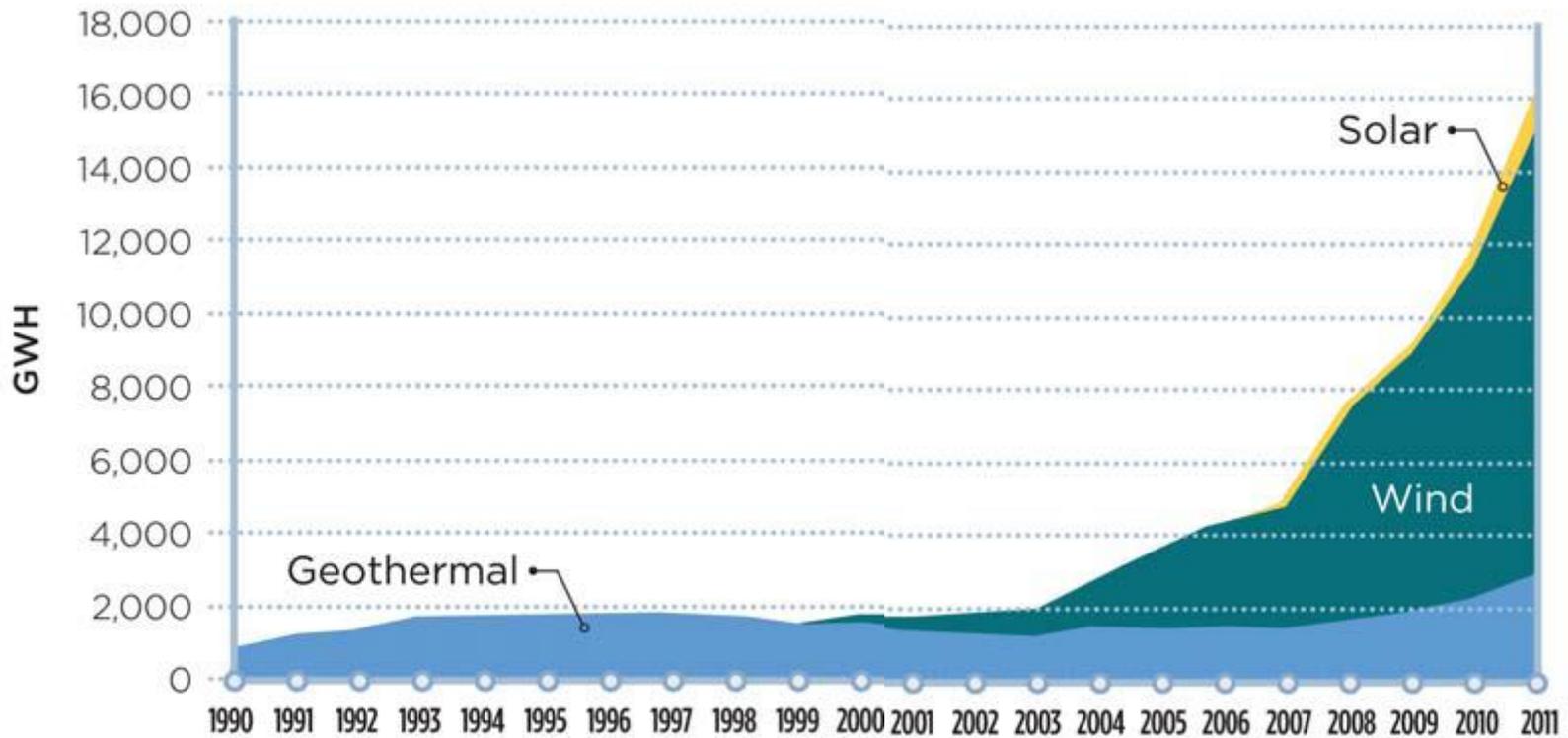


Figure 8. *Central Station Renewable Energy Generation in the Mountain West*

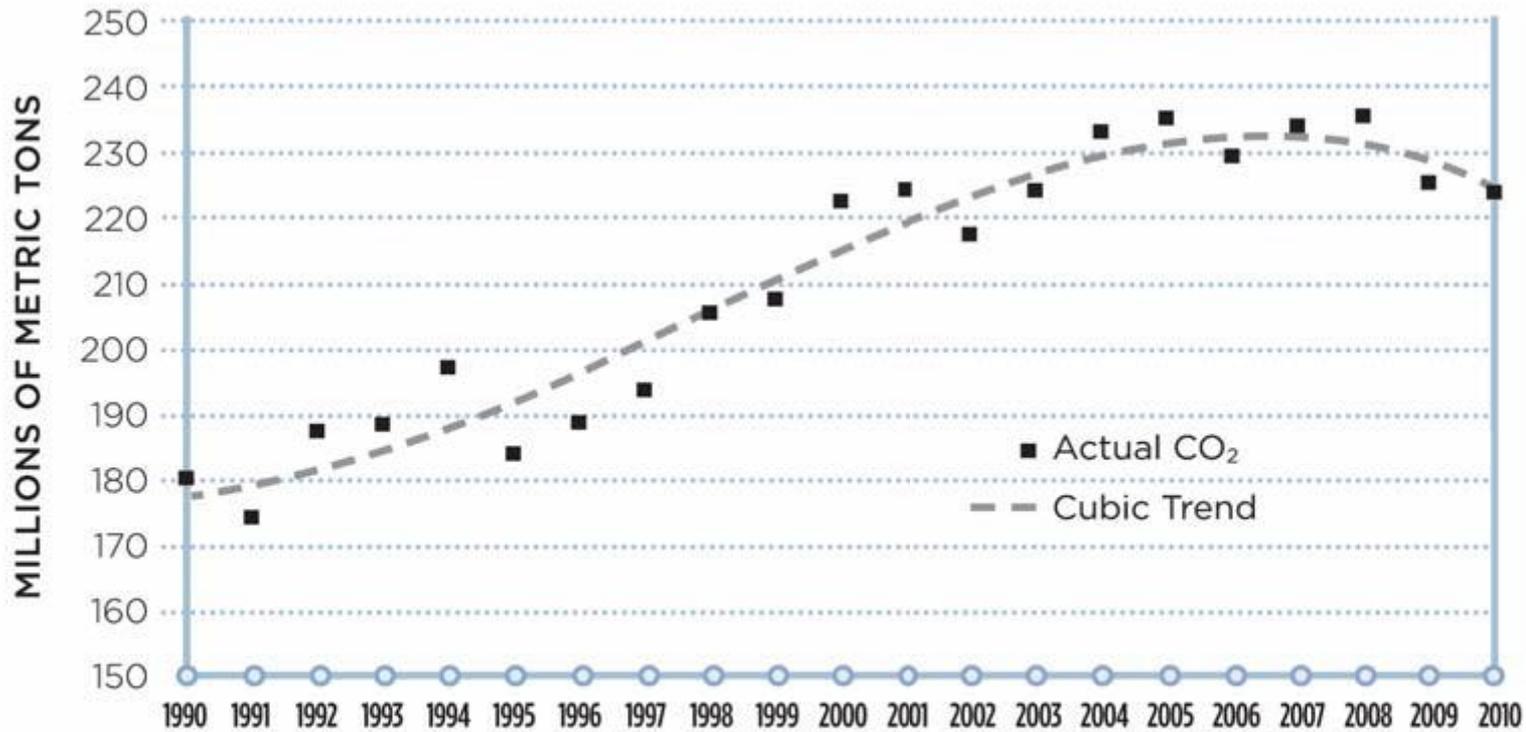
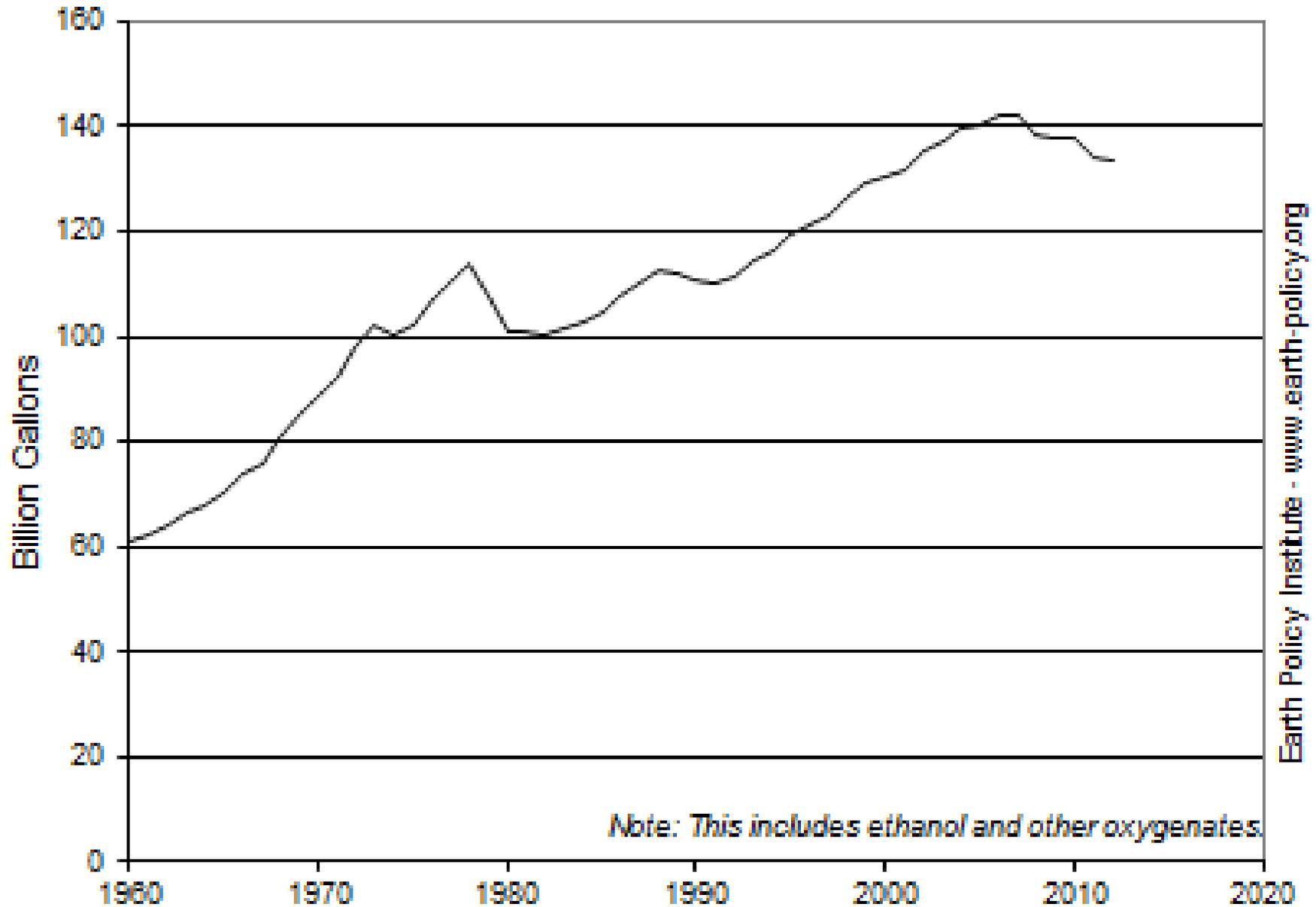


Figure 1. *CO₂ Emissions from the Electric Power Sector in the Mountain West*

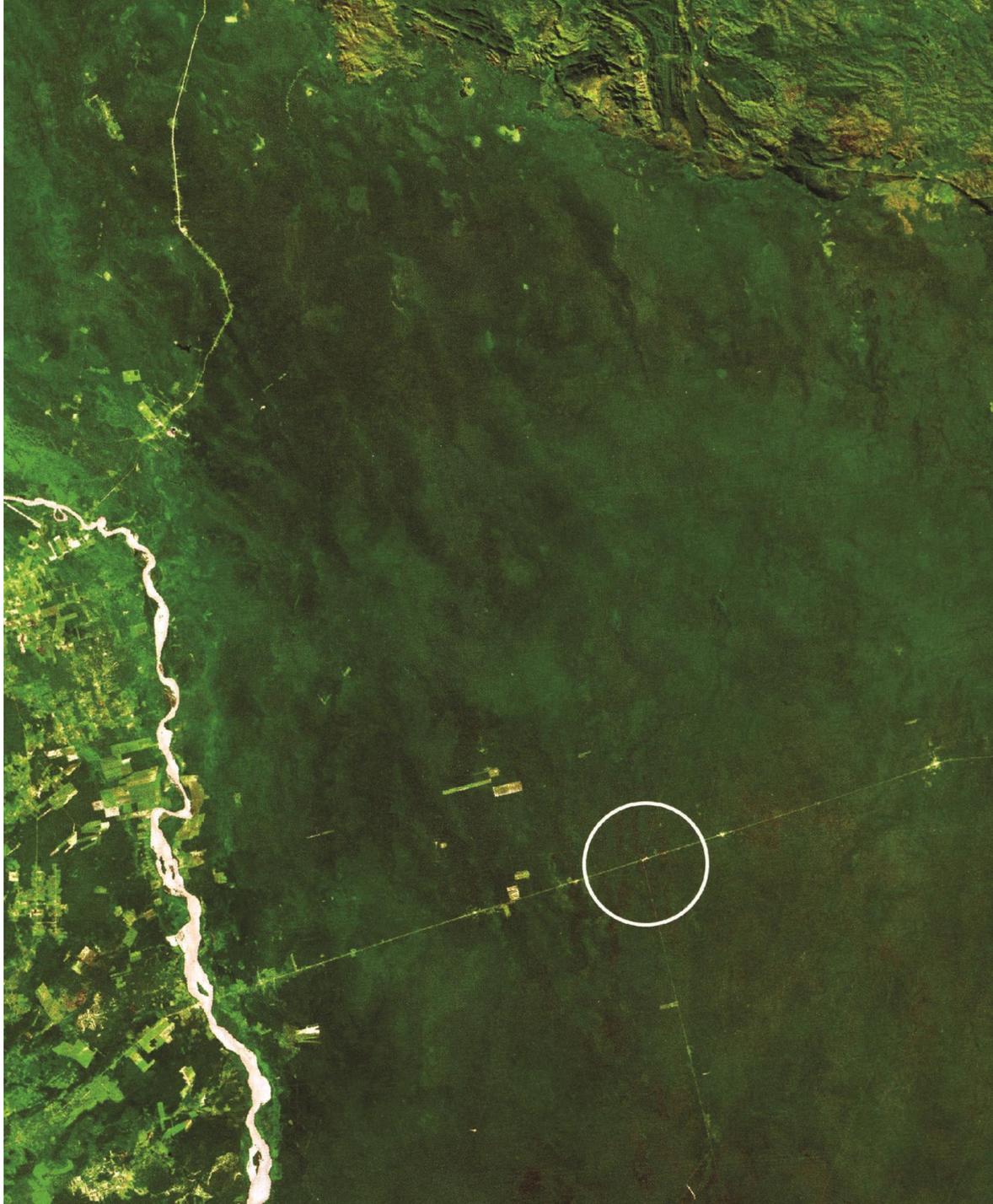
U.S. Motor Gasoline Consumption, 1960-2012



Note: This includes ethanol and other oxygenates.

Source: EIA

Bolivia



1975

Bolivia

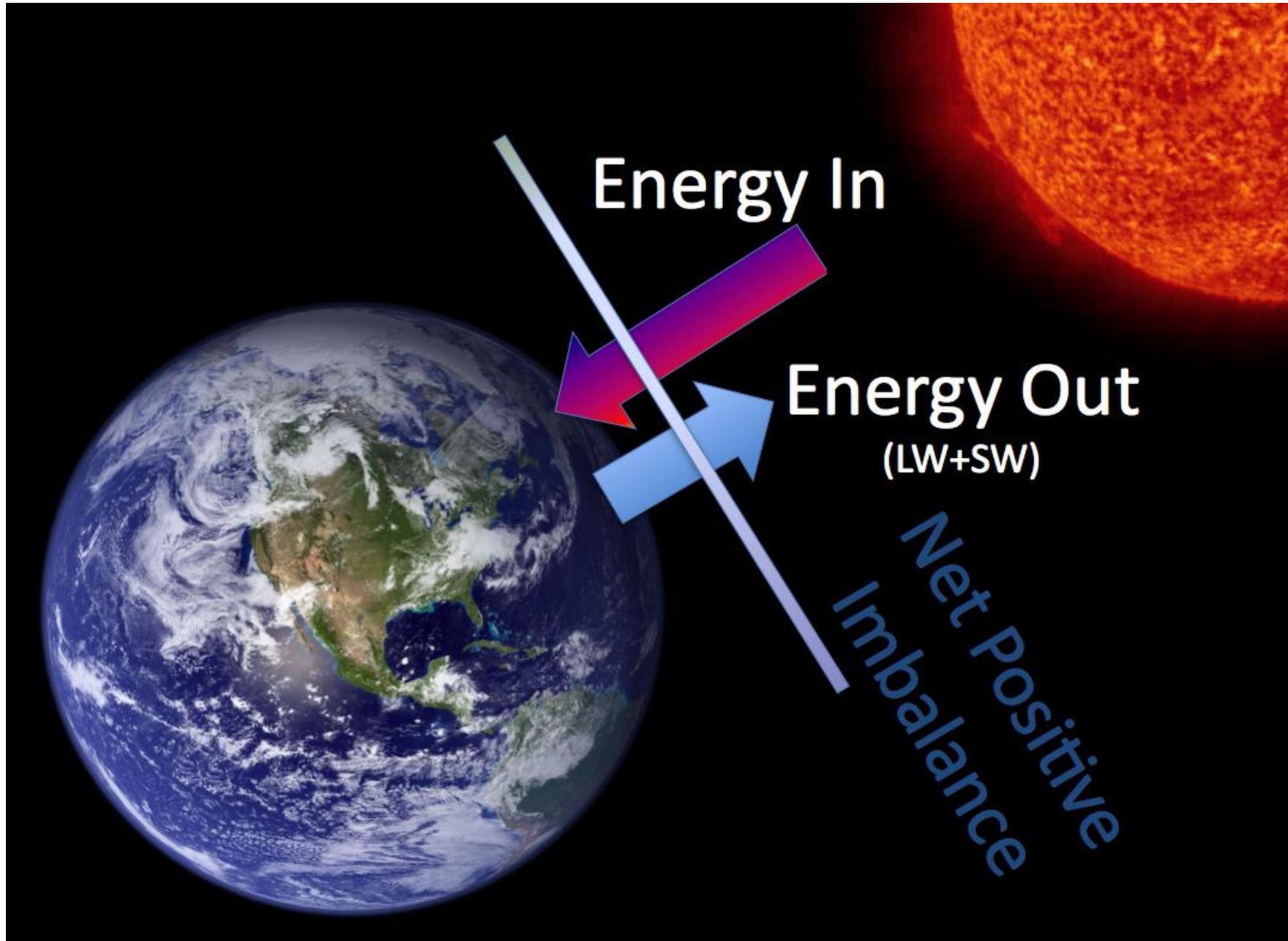


2003



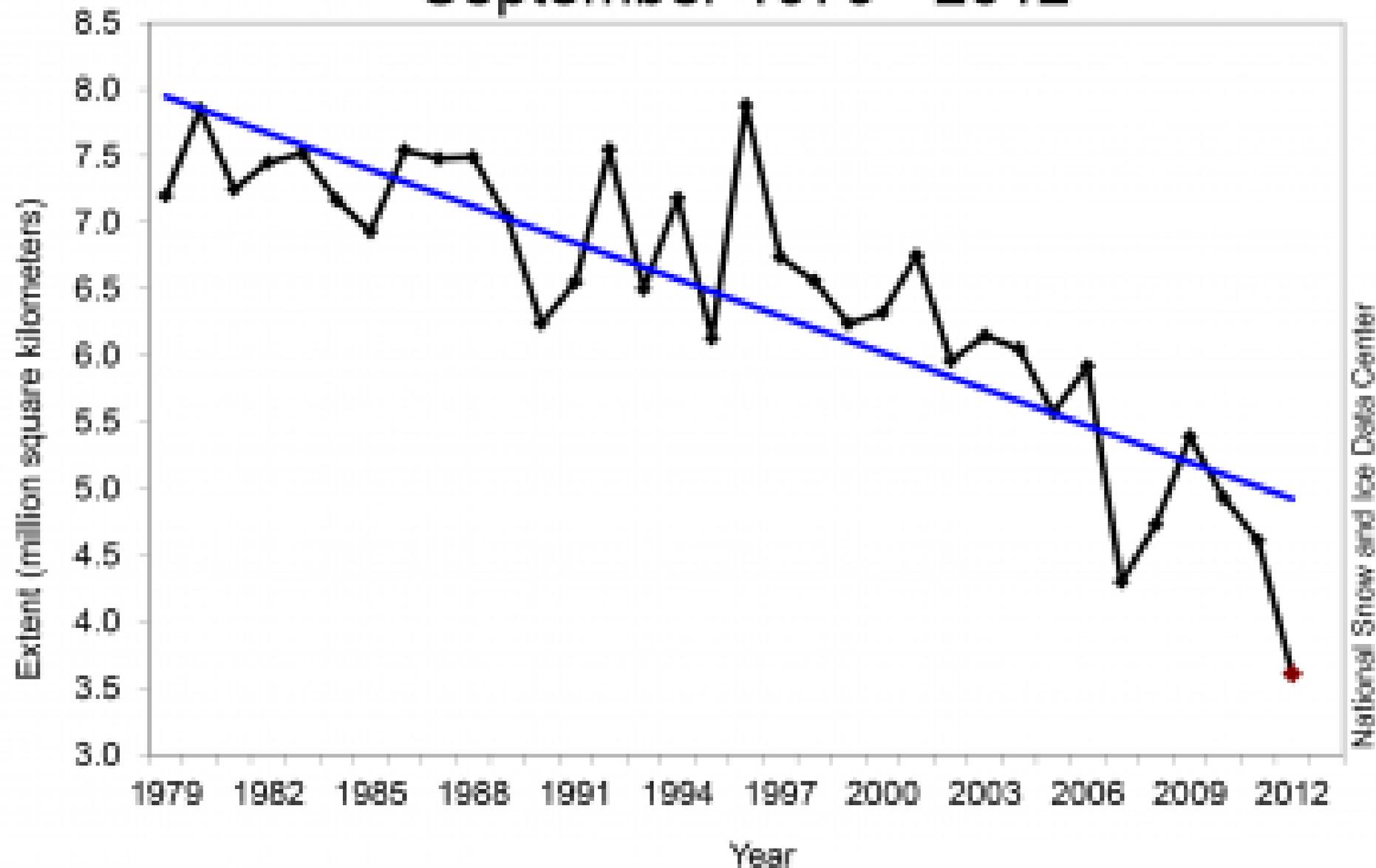
Chores on the Steiner family farm, Illinois; Lee News Service, 2/2013

THE PAST IS YOUR FUTURE





Average Monthly Arctic Sea Ice Extent September 1979 - 2012



Geologists study the Earth



I HEAR HOOFBEATS

Fate of the penultimate tree, Ethiopia



Fate of the penultimate tree, Ethiopia



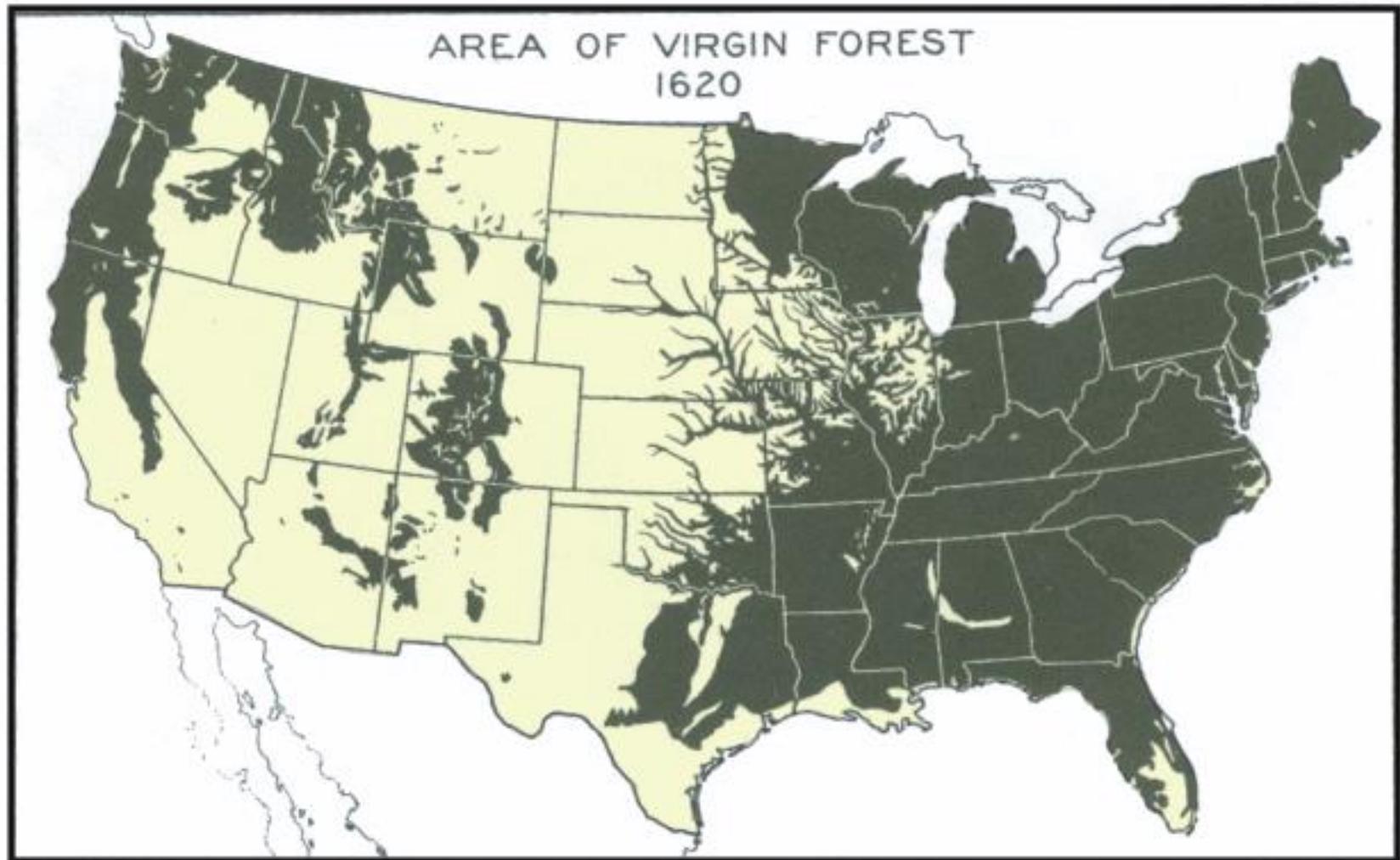


Figure 12.2 "Area of virgin forest," United States, 1620. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)

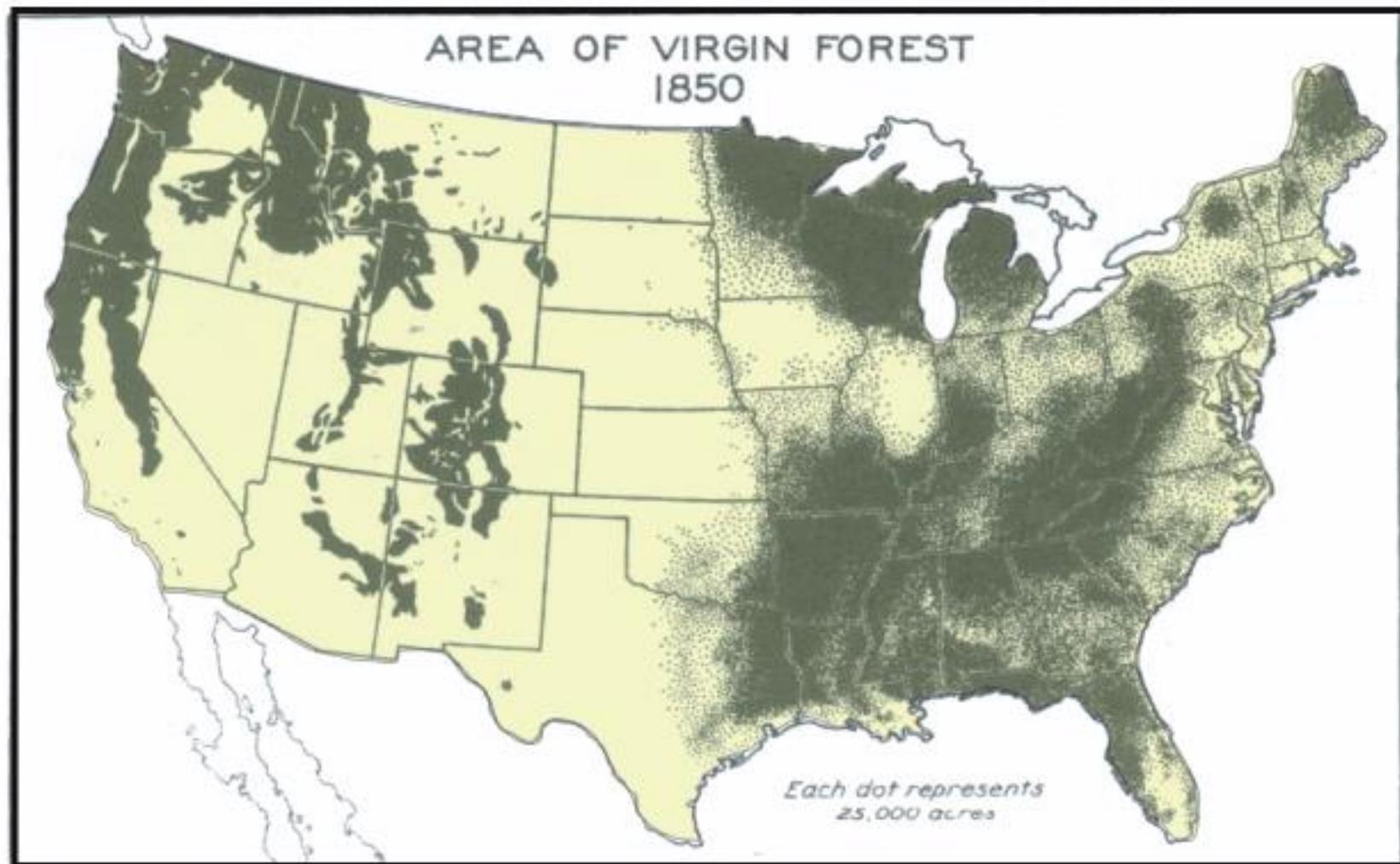


Figure 12.3 “Area of virgin forest,” United States, 1850. (Source: W. B. Greeley, “The Relations of Geography to Timber Supply,” *Economic Geography* 1 [1925]: 4–5.)

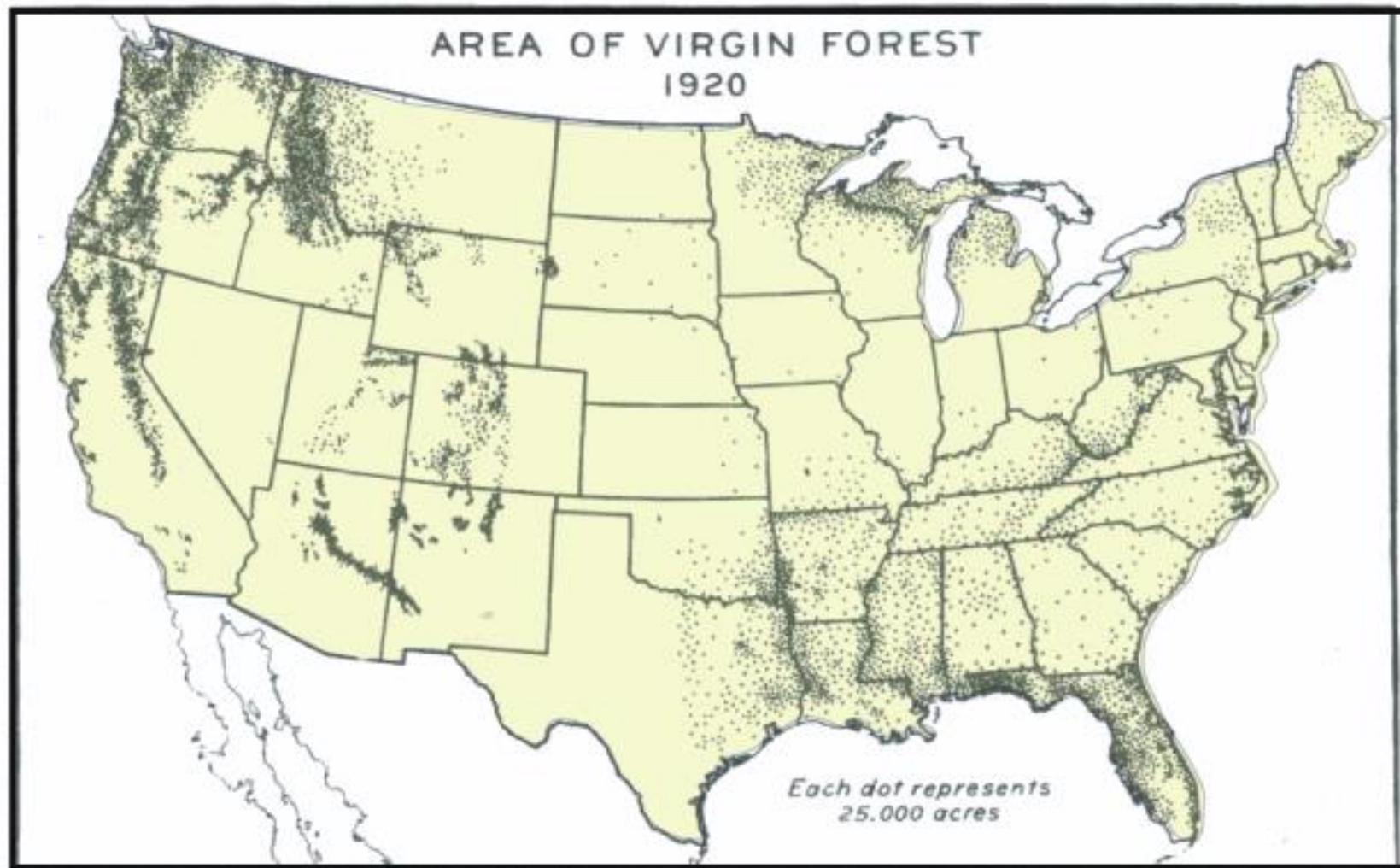


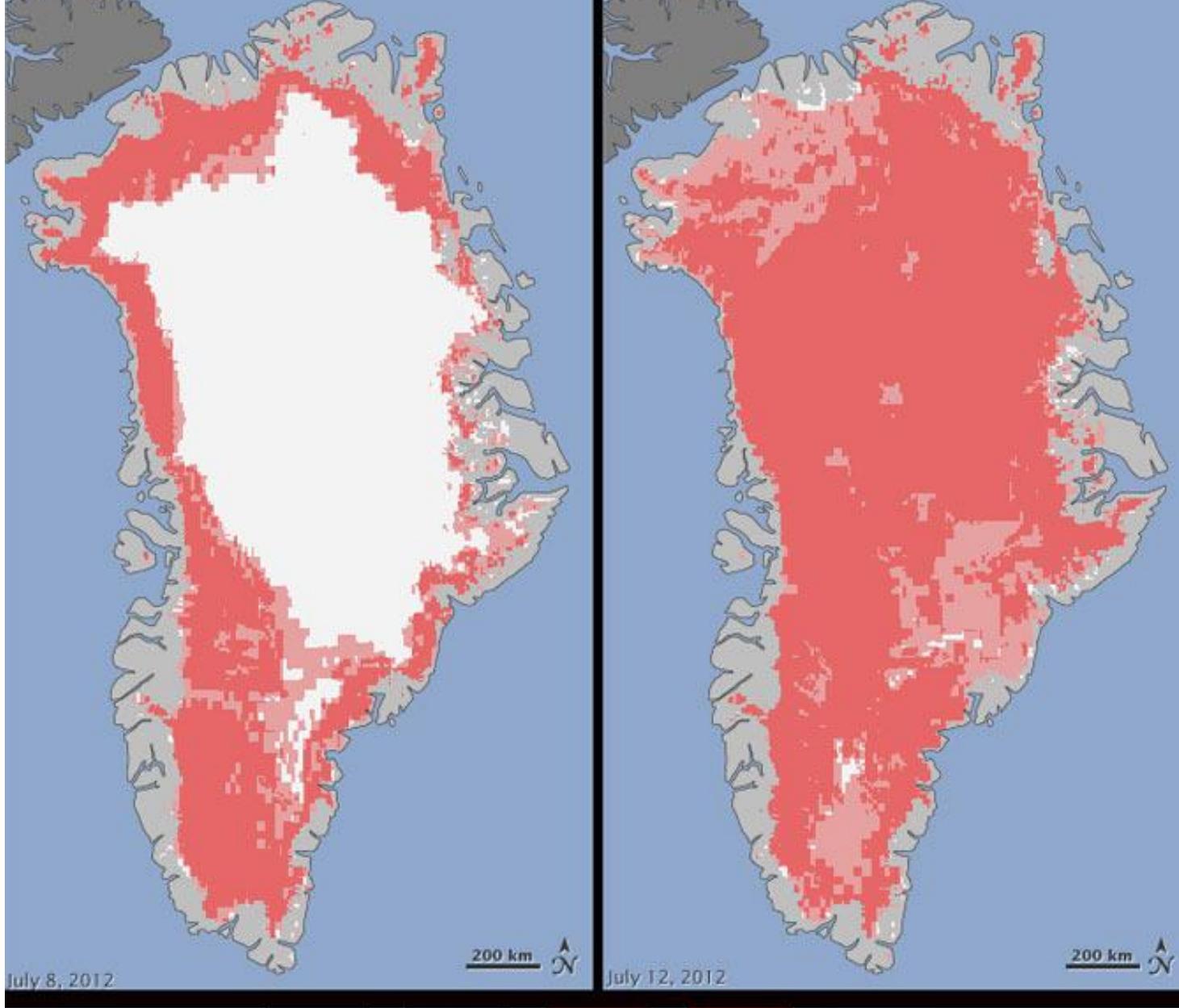
Figure 12.4 "Area of virgin forest," United States, 1920. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)



We need to move away from
WOE IS ME and SHAME ON YOU

To: Let's learn about this challenge,
Let's see if we can fix this....

Paraphrased from Andy Revkin



NASA





5639 ft

Image © 2013 DigitalGlobe

Google earth

Imagery Date: 12/17/2012 lat 25.114659° lon 55.134648° elev -24 ft eye alt 24733 ft



4/19/2013



Bahrain

Image © 2013 DigitalGlobe

3770 ft

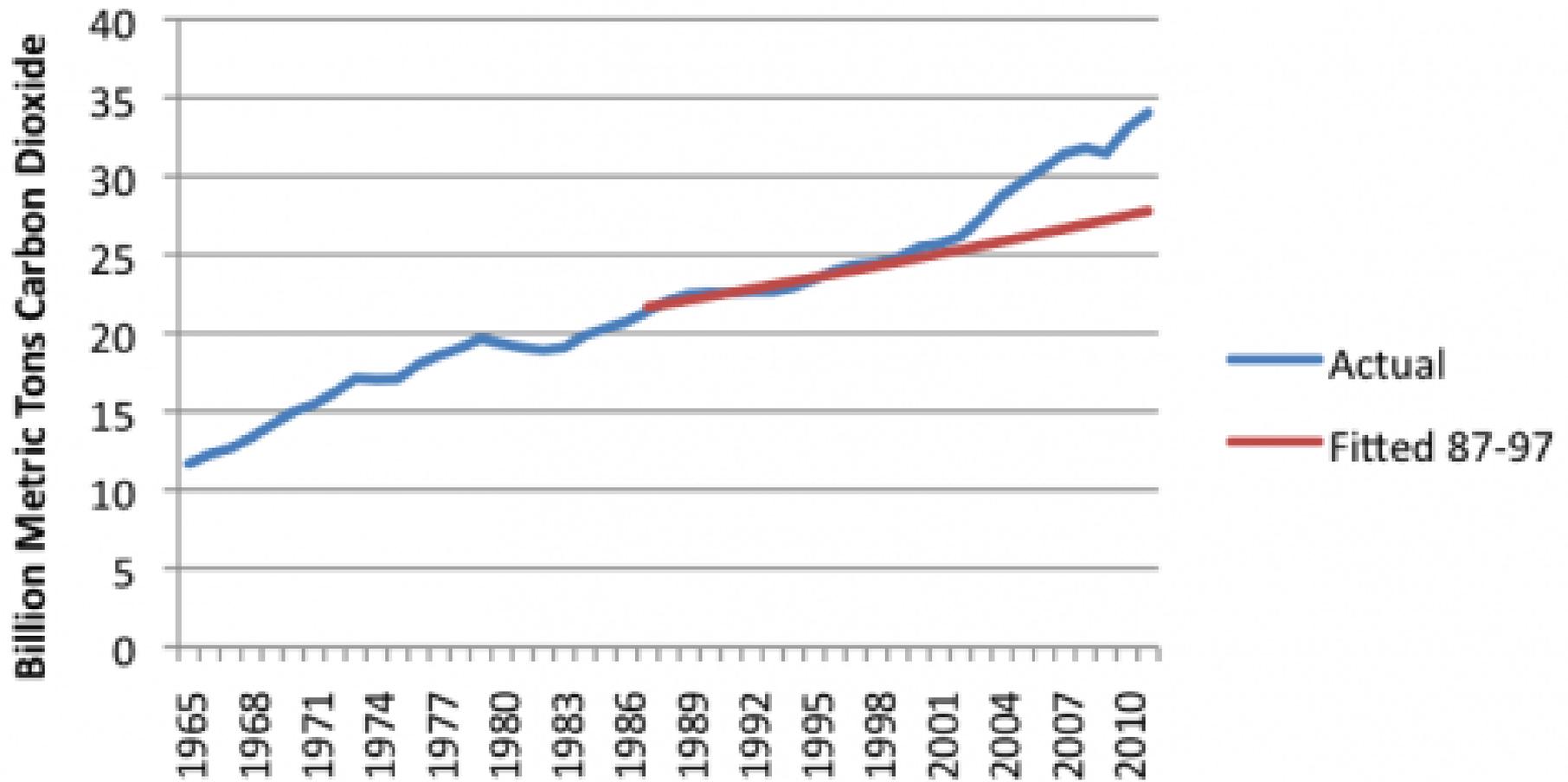
Google earth

Imagery Date: 7/3/2012 lat 25.840290° lon 50.603416° elev 0 ft eye alt 17313 ft

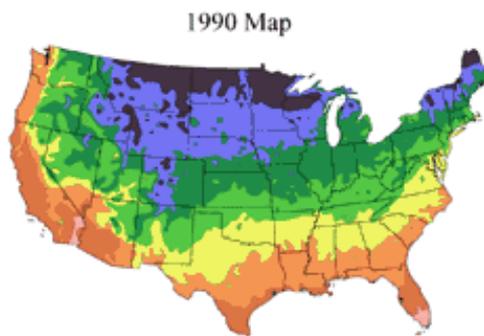
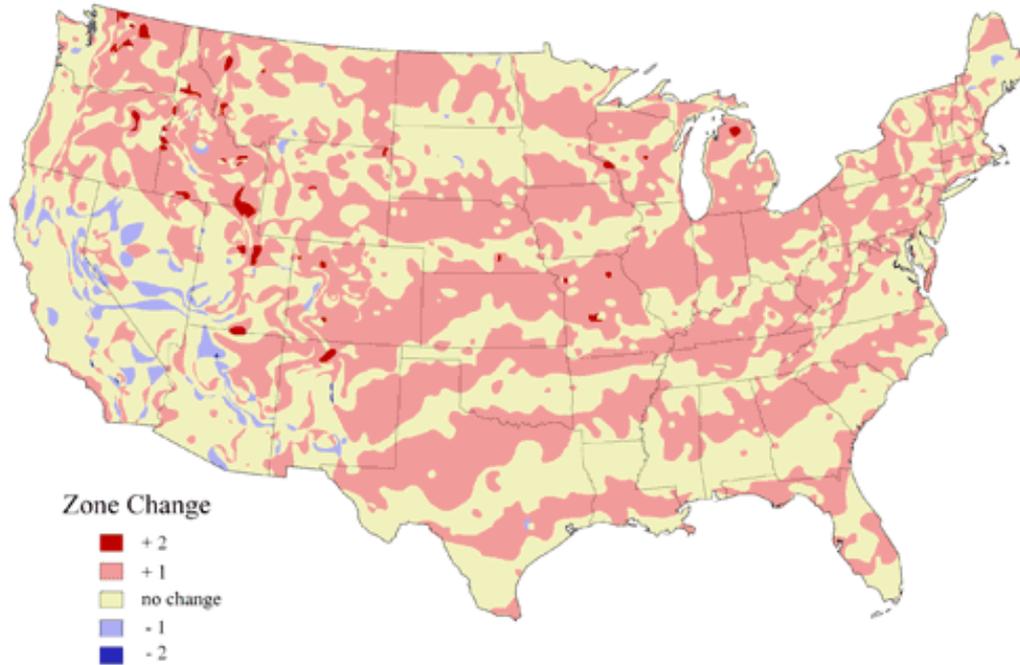




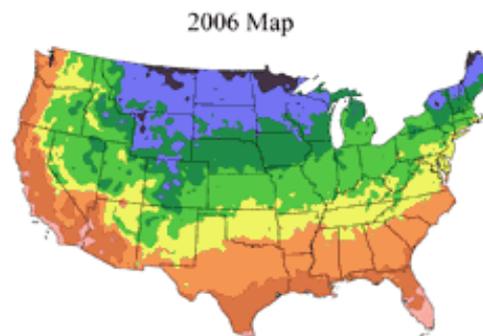
World Fossil Fuel Carbon Dioxide Emissions



Differences between 1990 USDA hardiness zones and 2006 arborday.org hardiness zones reflect warmer climate

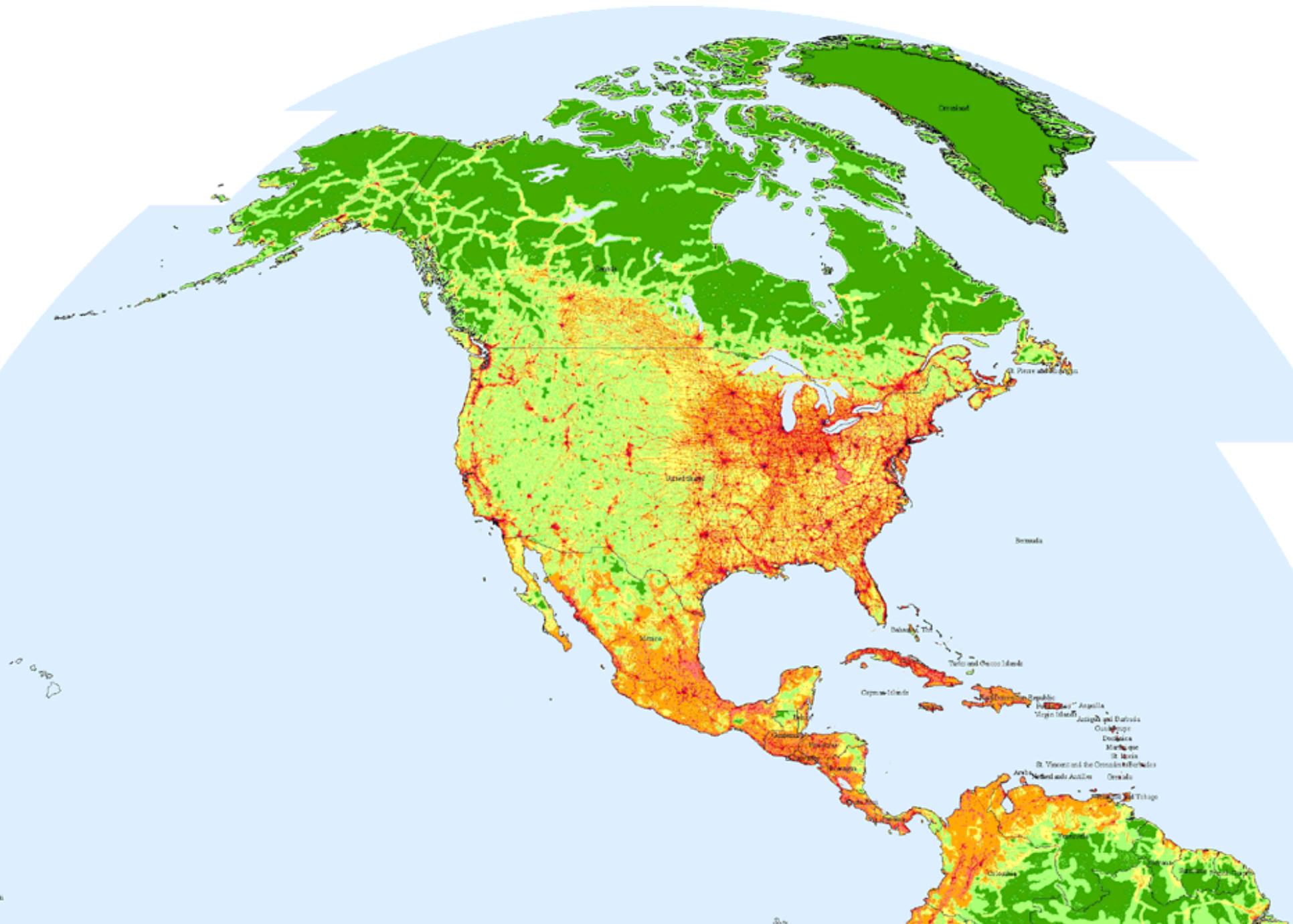


After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990



National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

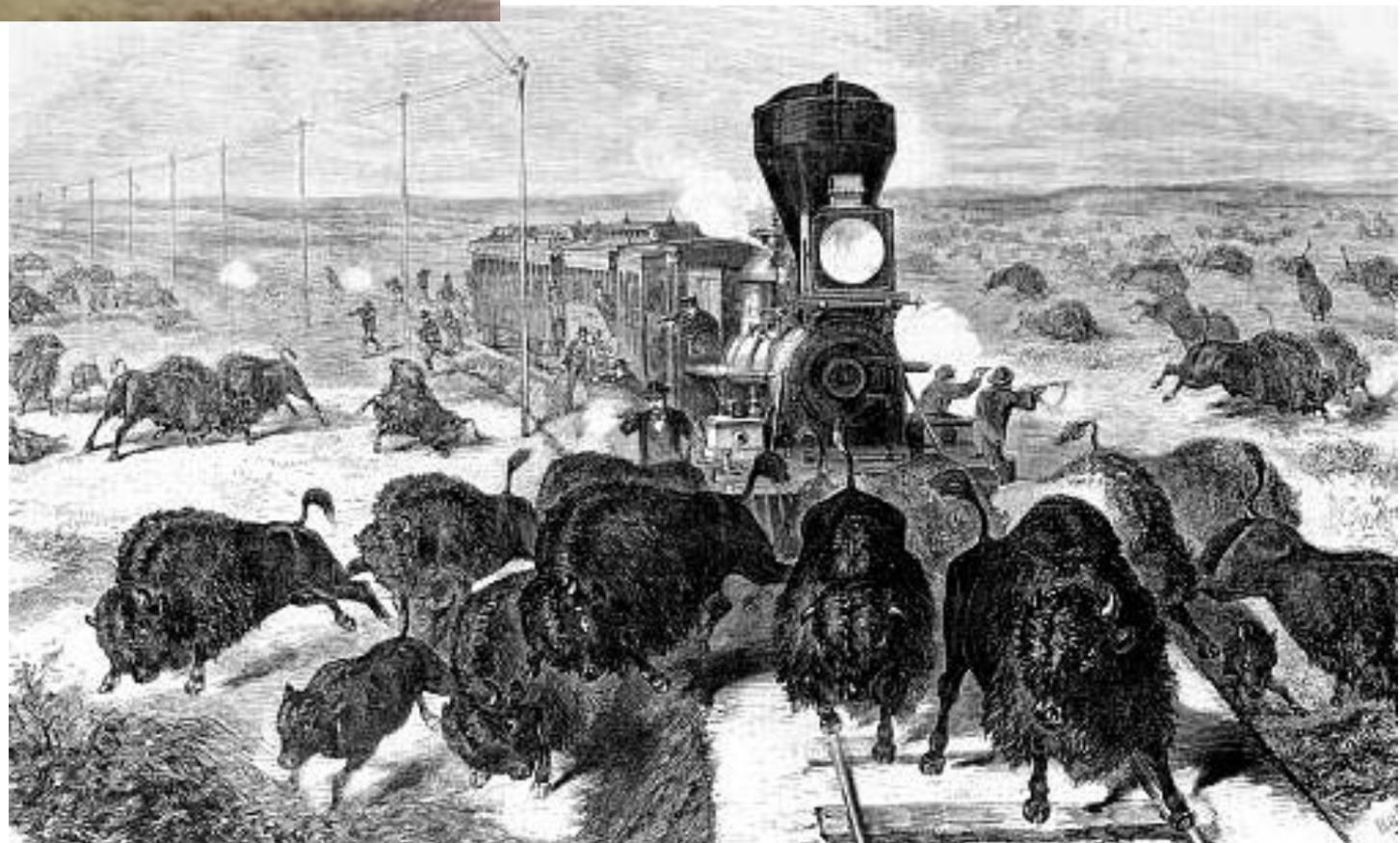






Among the Redwoods

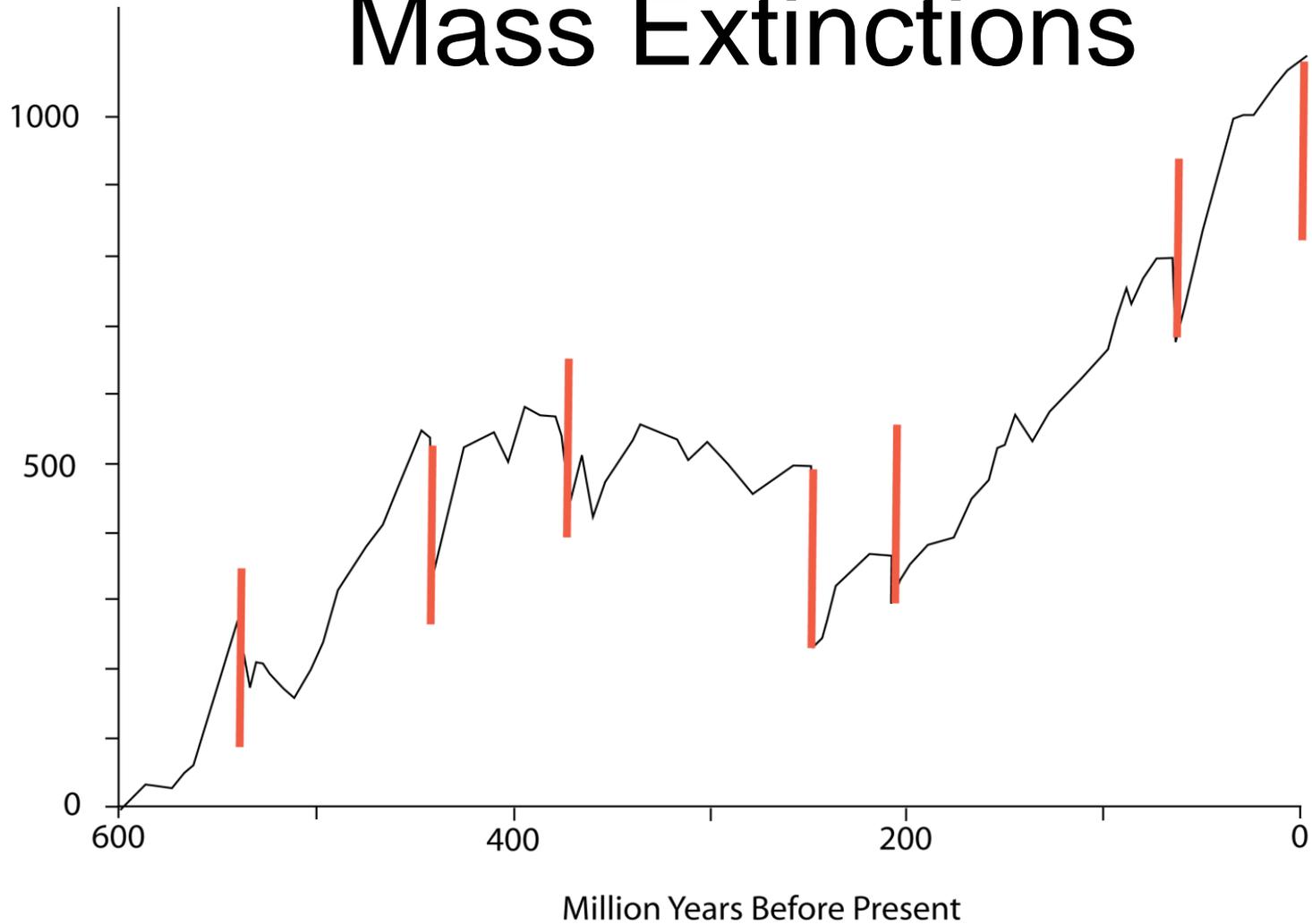
A.E. Ericson, ca. 1890



AMERICAN MUSEUM OF NATURAL HISTORY



Mass Extinctions



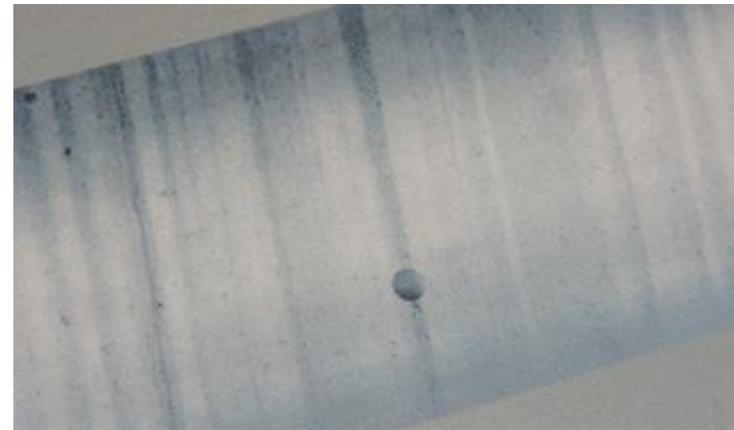
Diversity of marine families

Raup, 1986

The data are in the strata

Changes are Happening

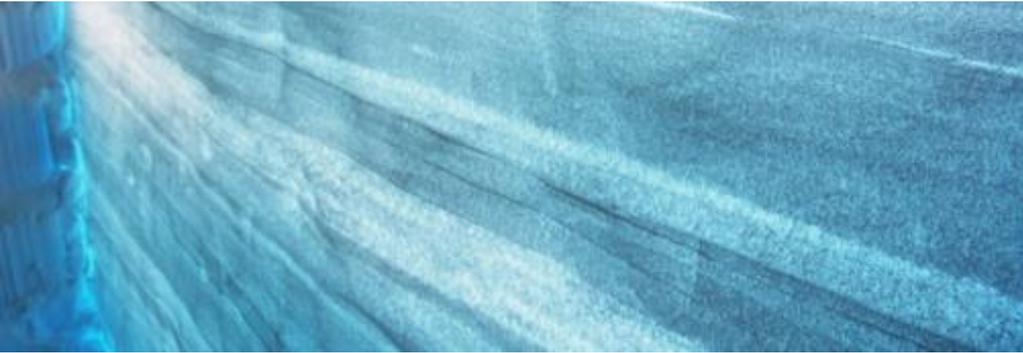
ICE





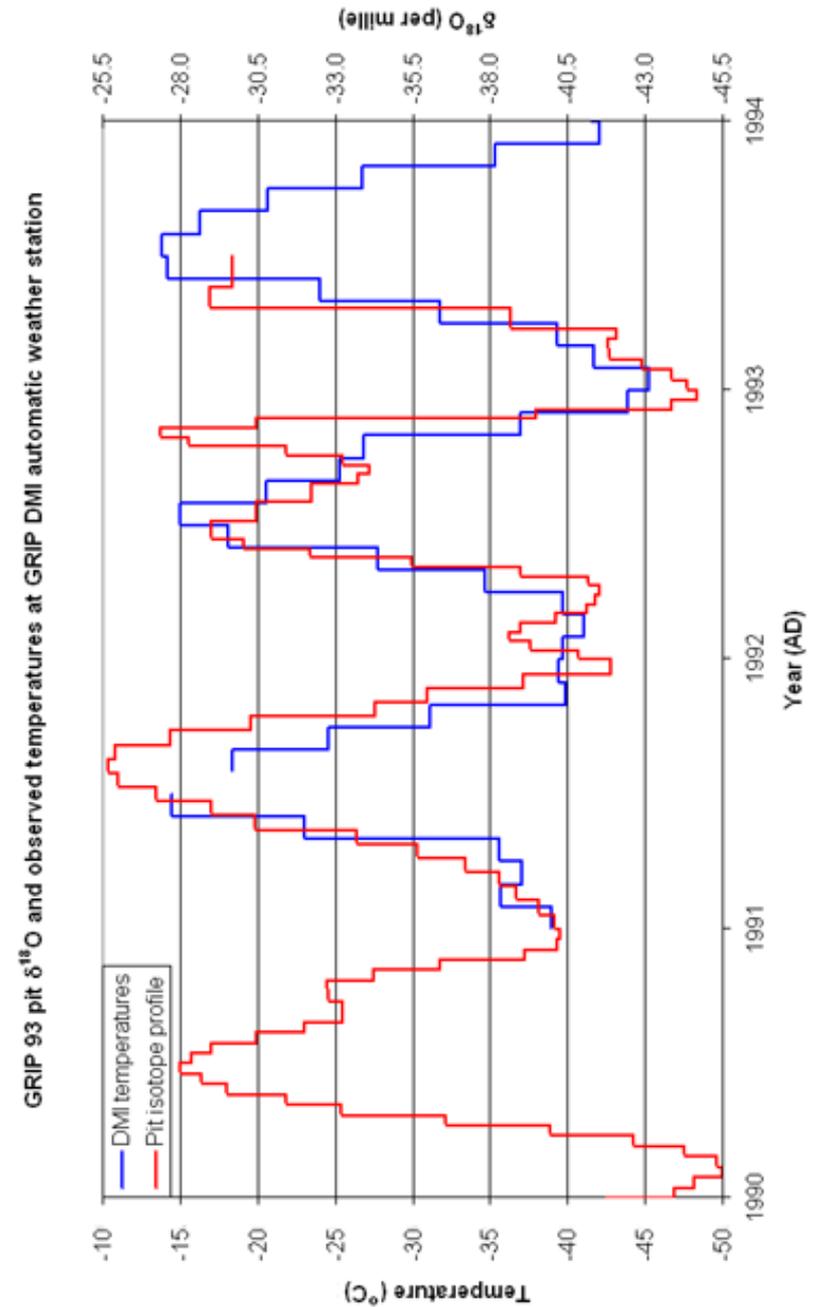
West Antarctic Ice Sheet Divide

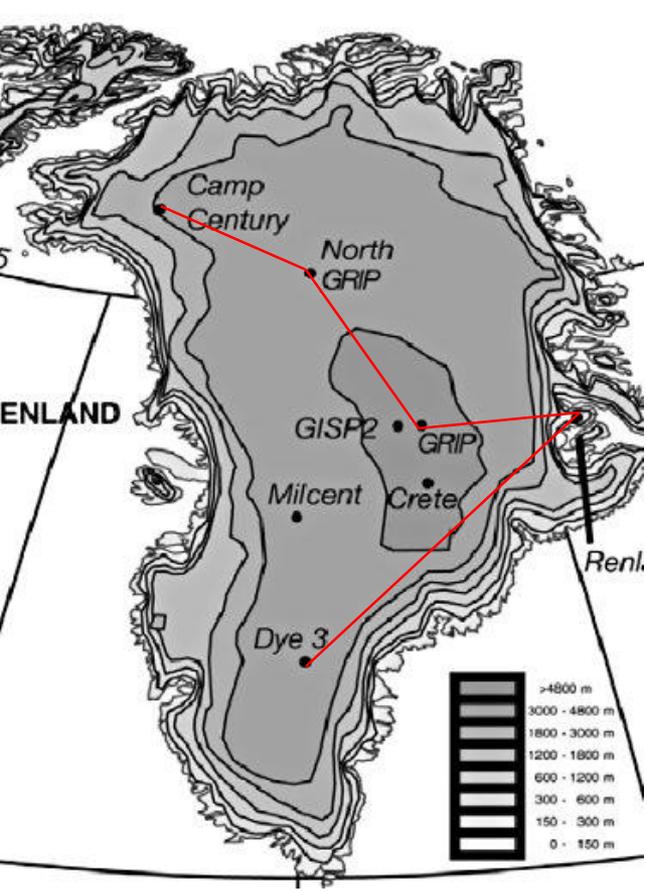
K. Taylor



Snow Pit Stratigraphy

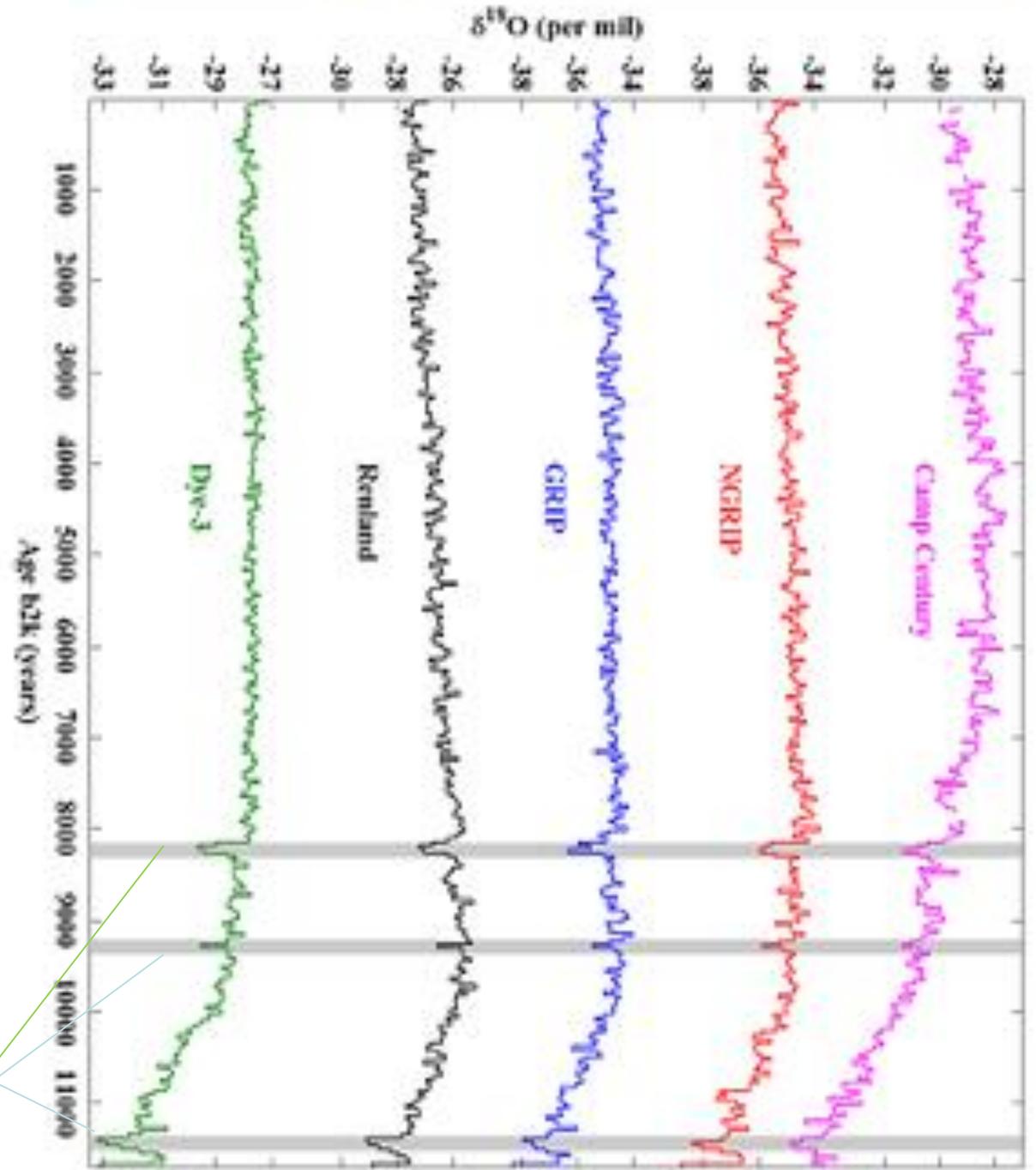
Temperature and Isotope Correlations from Snow Pit at GRIP site, Greenland





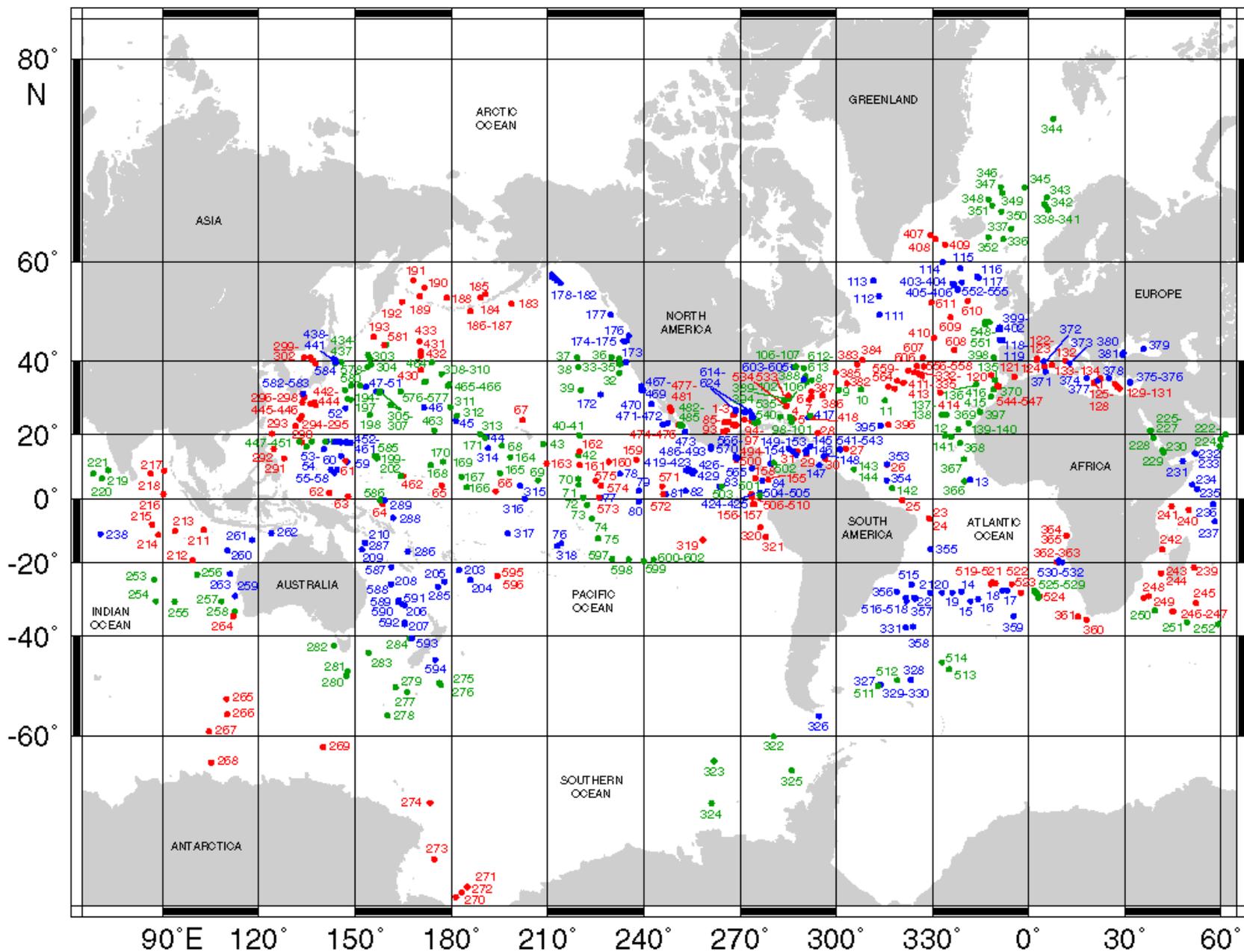
Holocene ice correlations across Greenland

The 3 cold intervals at 8.2, 9.3 and 11.4 Kyr are correlative across the northern hemisphere

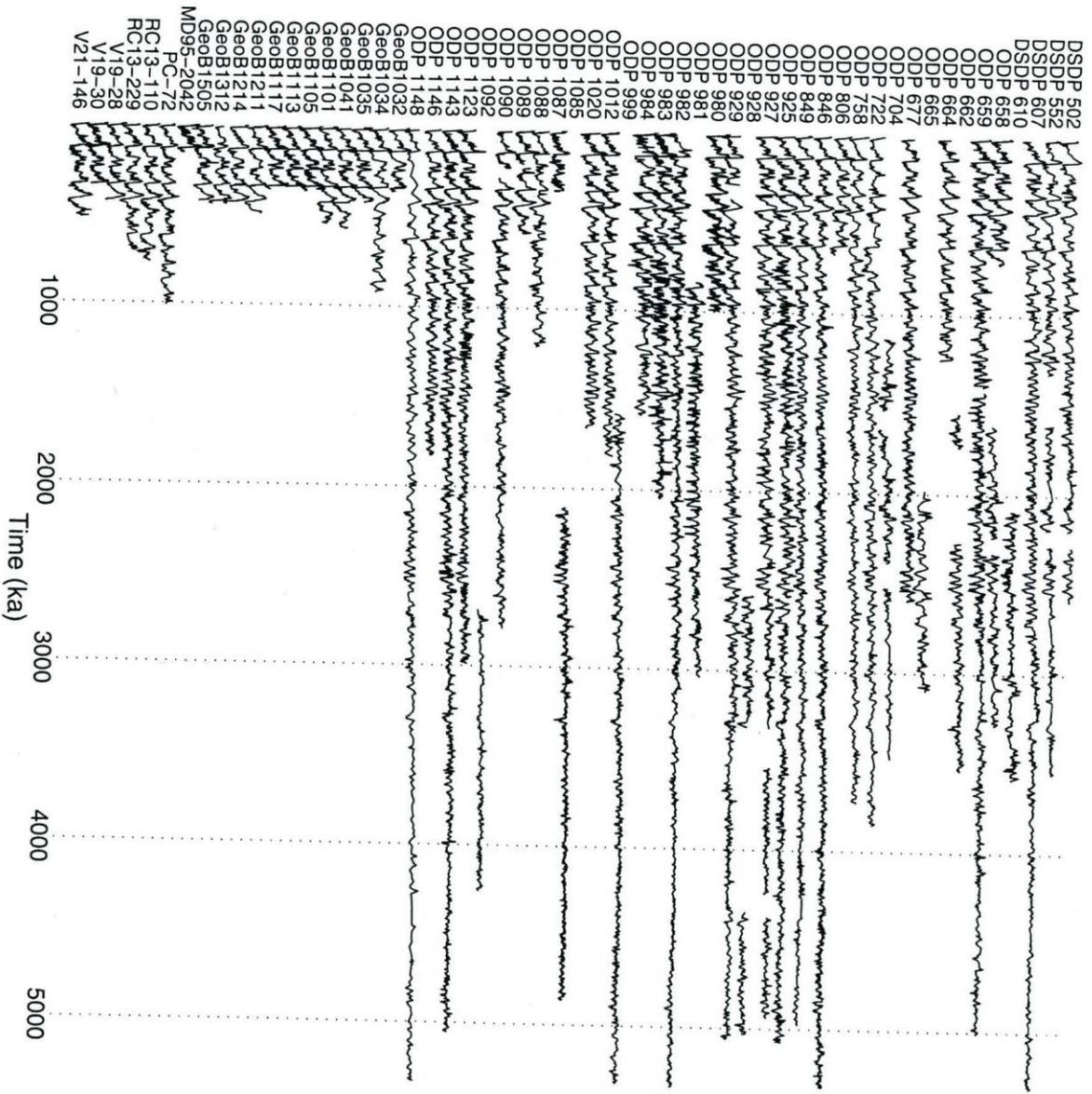


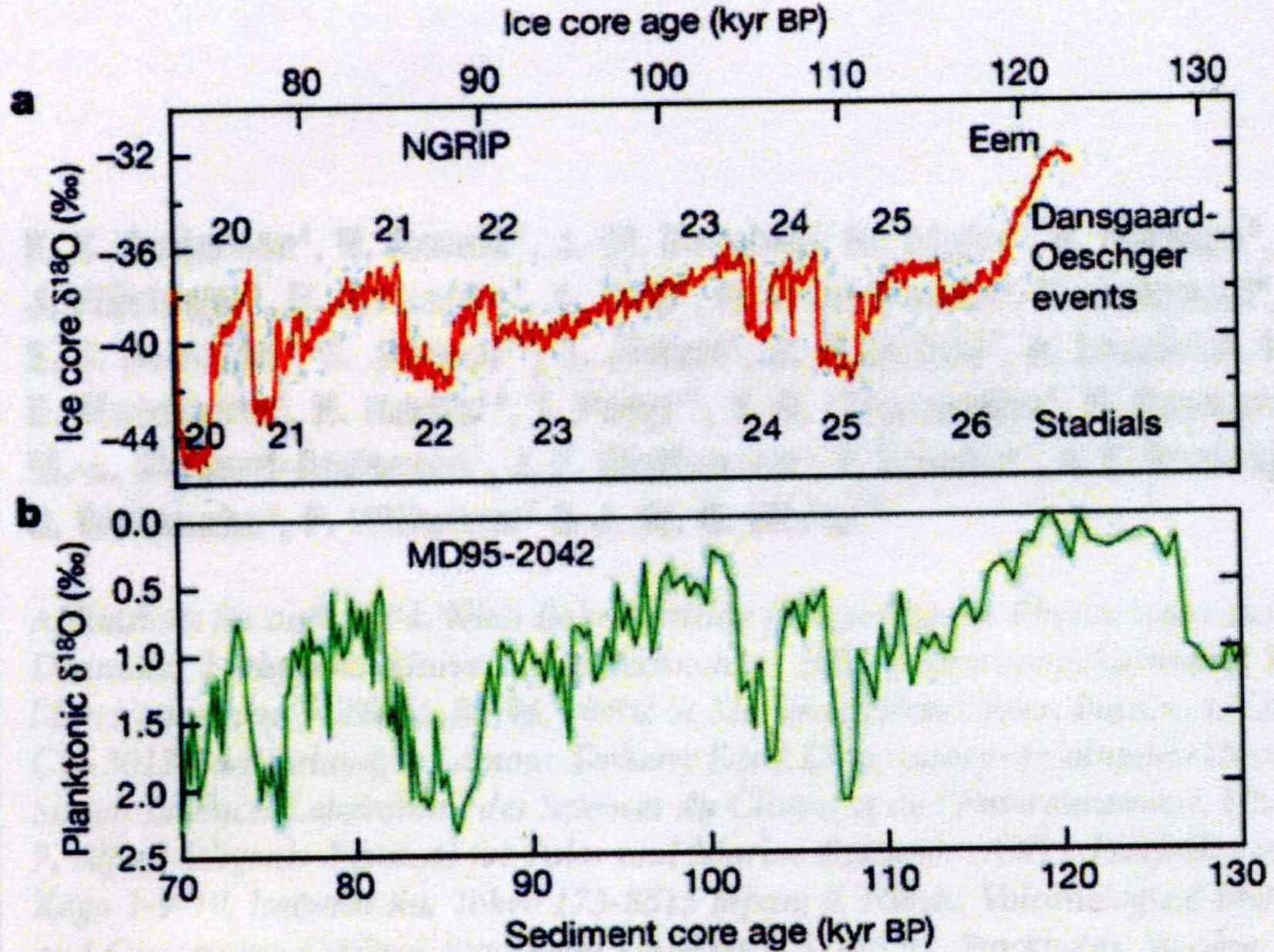
Changes are Happening

MUD



DSDP Legs 1-96, Sites 1-624





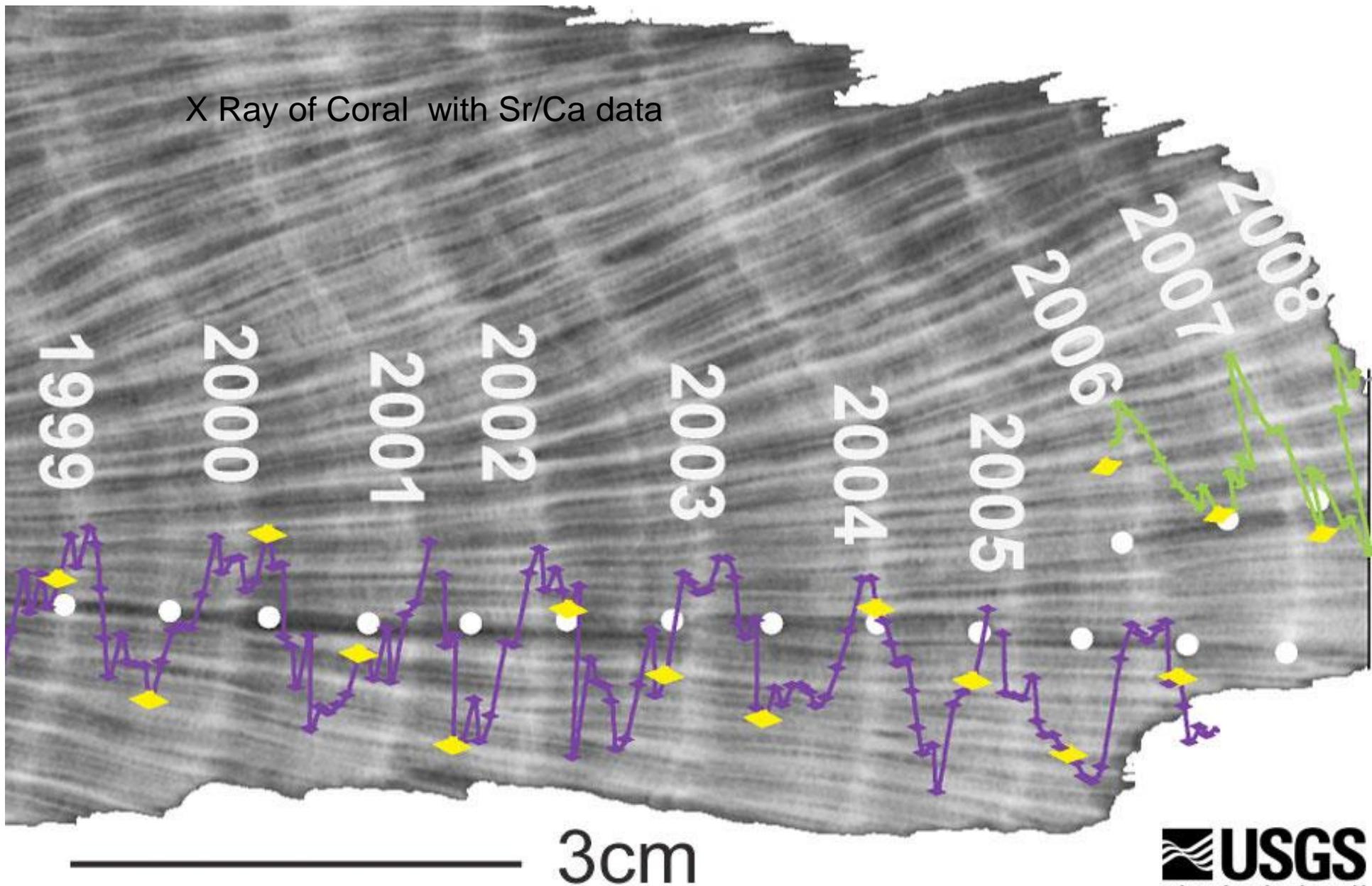
Ice to Mud Correlation

Greenland to off-shore Spain

Changes are Happening

Caves and Reefs

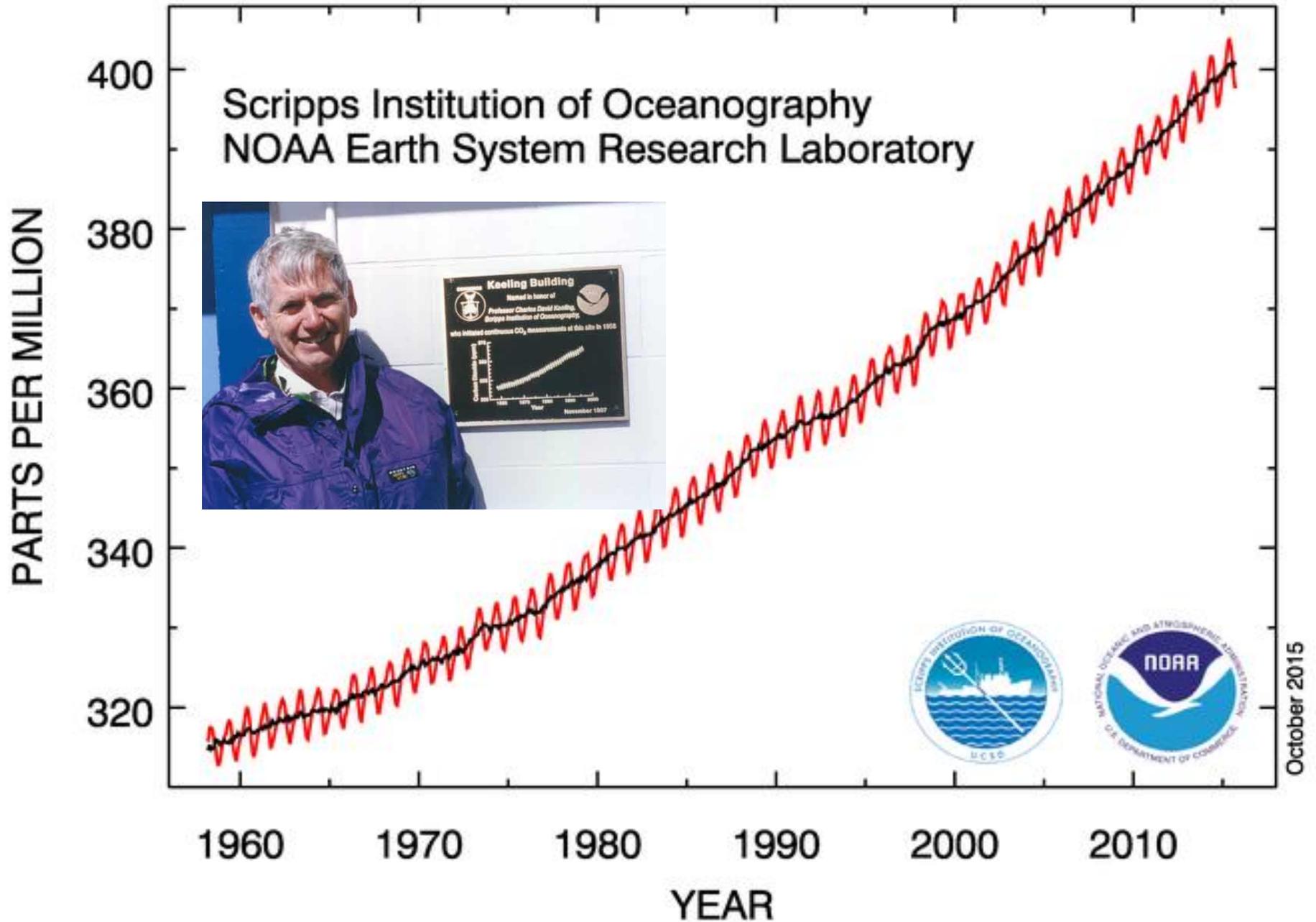
X Ray of Coral with Sr/Ca data



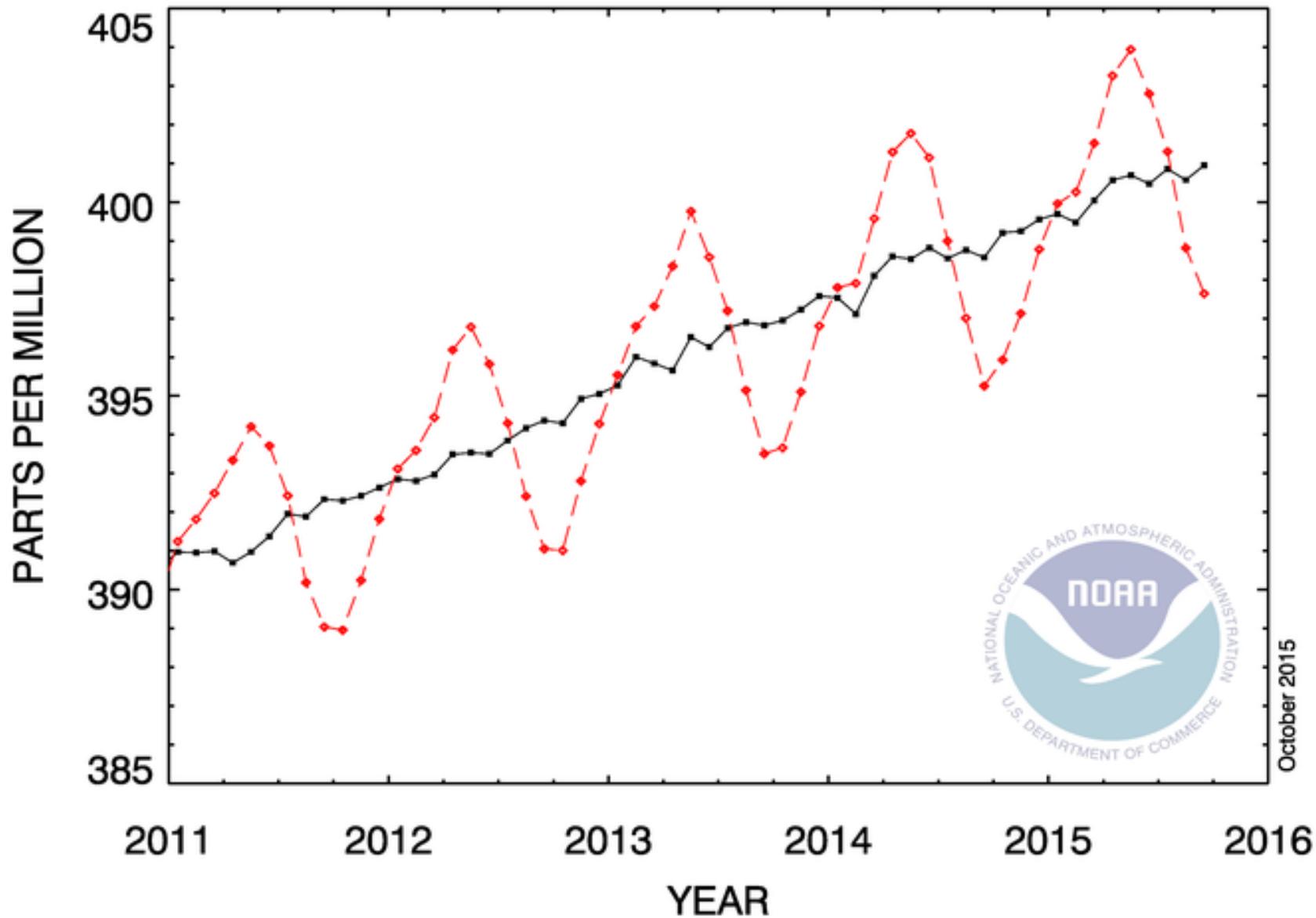
Changes are Happening

AIR

Atmospheric CO₂ at Mauna Loa Observatory



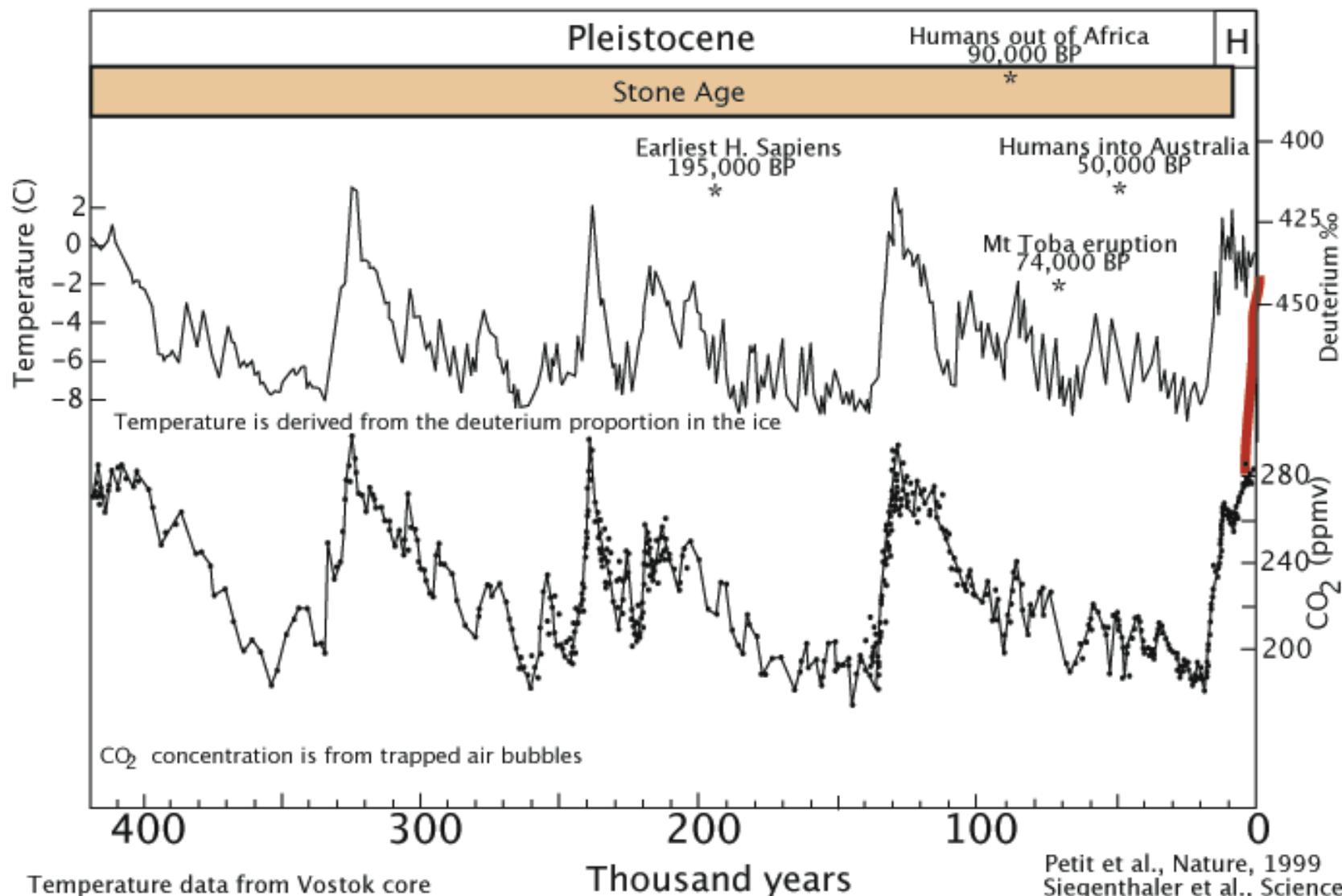
RECENT MONTHLY MEAN CO₂ AT MAUNA LOA



October 2015

400,000 years

Antarctic Ice Cores



Temperature data from Vostok core
CO₂ data from four ice cores

Petit et al., Nature, 1999
Siegenthaler et al., Science, 2005

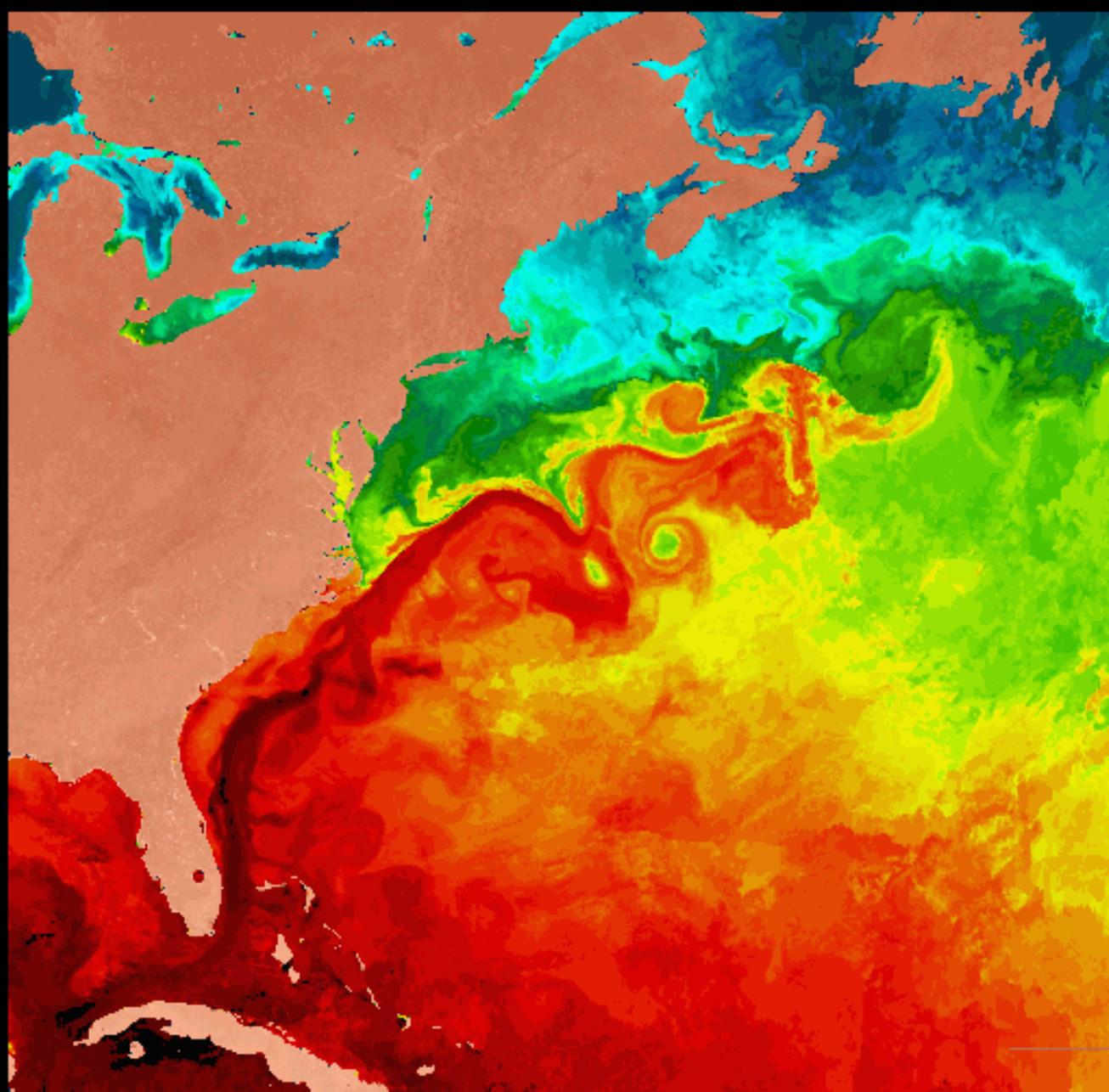
21 Dec, 2006

Heat capacity of air: 1005 J/kg/K

**Global Calculation of all air and ocean mass
Energy content in Joules/Degree Kelvin**



Heat capacity of ocean water: 3993 J/kg/K



Gulf-Stream and mesoscale eddies pictured on a color-enhanced NOAA/AVHRR image (downloaded from <http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/eastcoast.gif>).

1870



Pixdaus

