

Who will flourish in the Anthropocene?

Bob Raynolds

April 2017

bobraynolds@yahoo.com

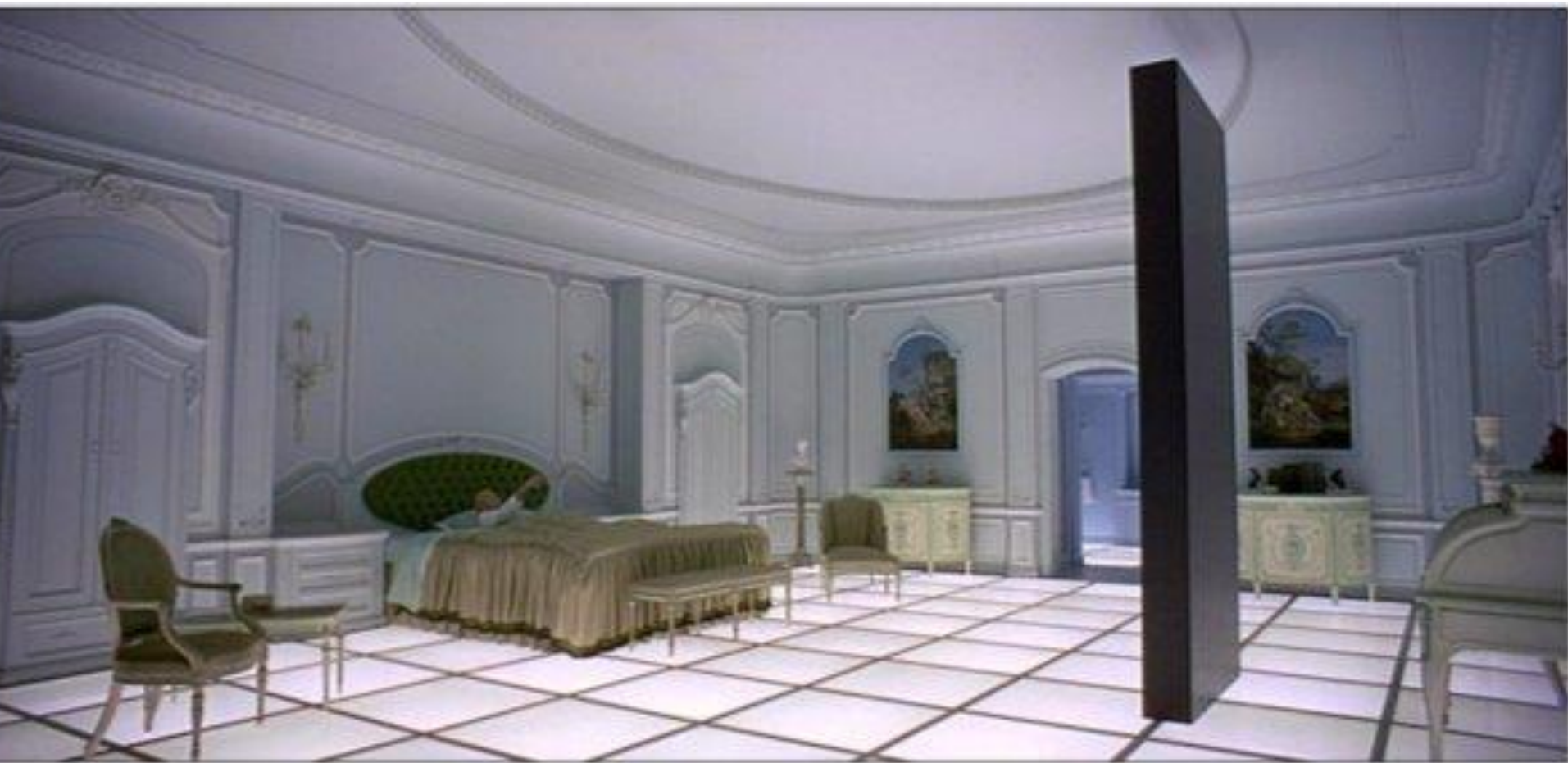
Thomas Cole The Course of the Empire 1836













The Economist

ISSN 0013-061X

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

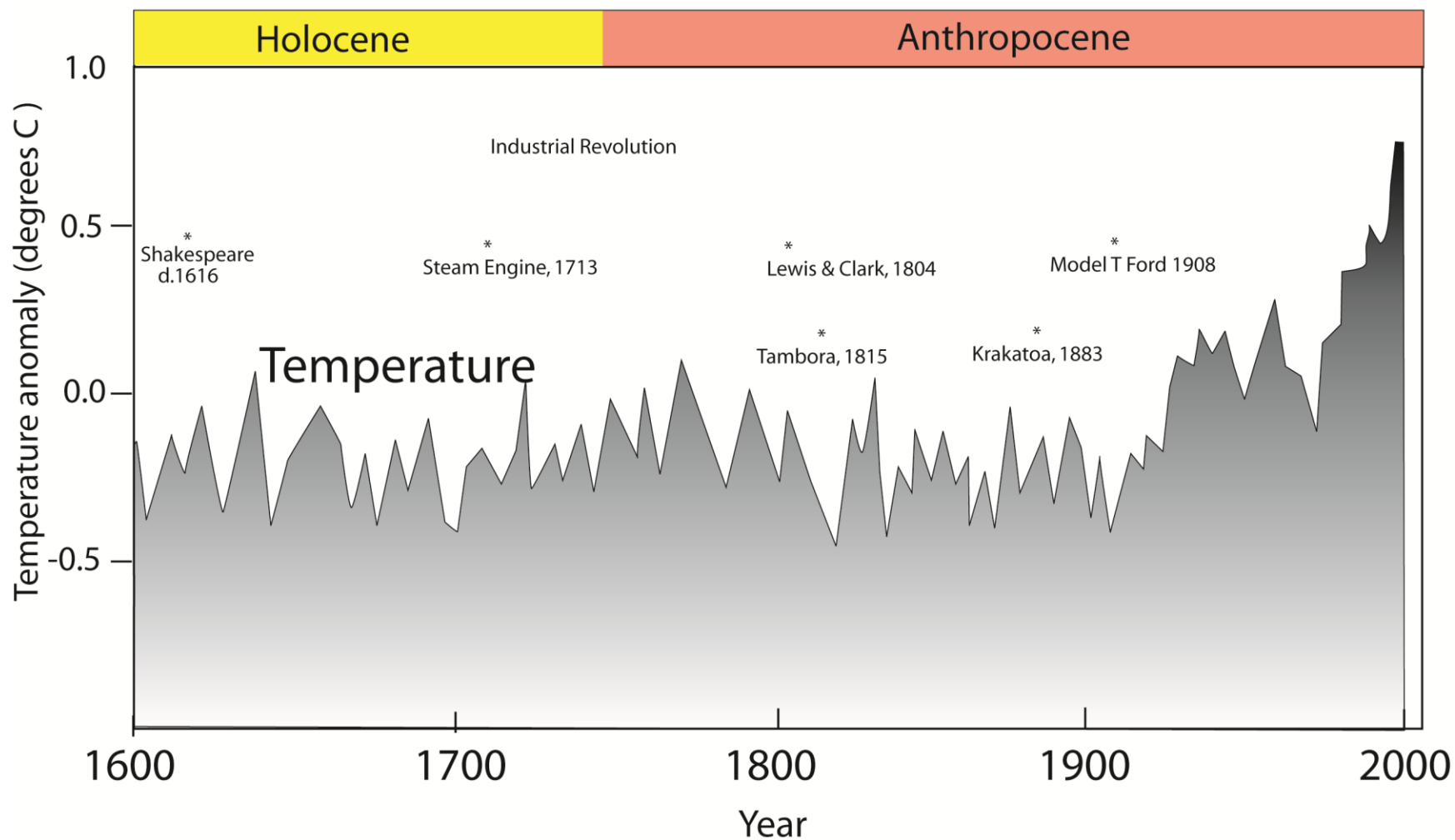


Geology's new age

Jon Berkeley

400 Years

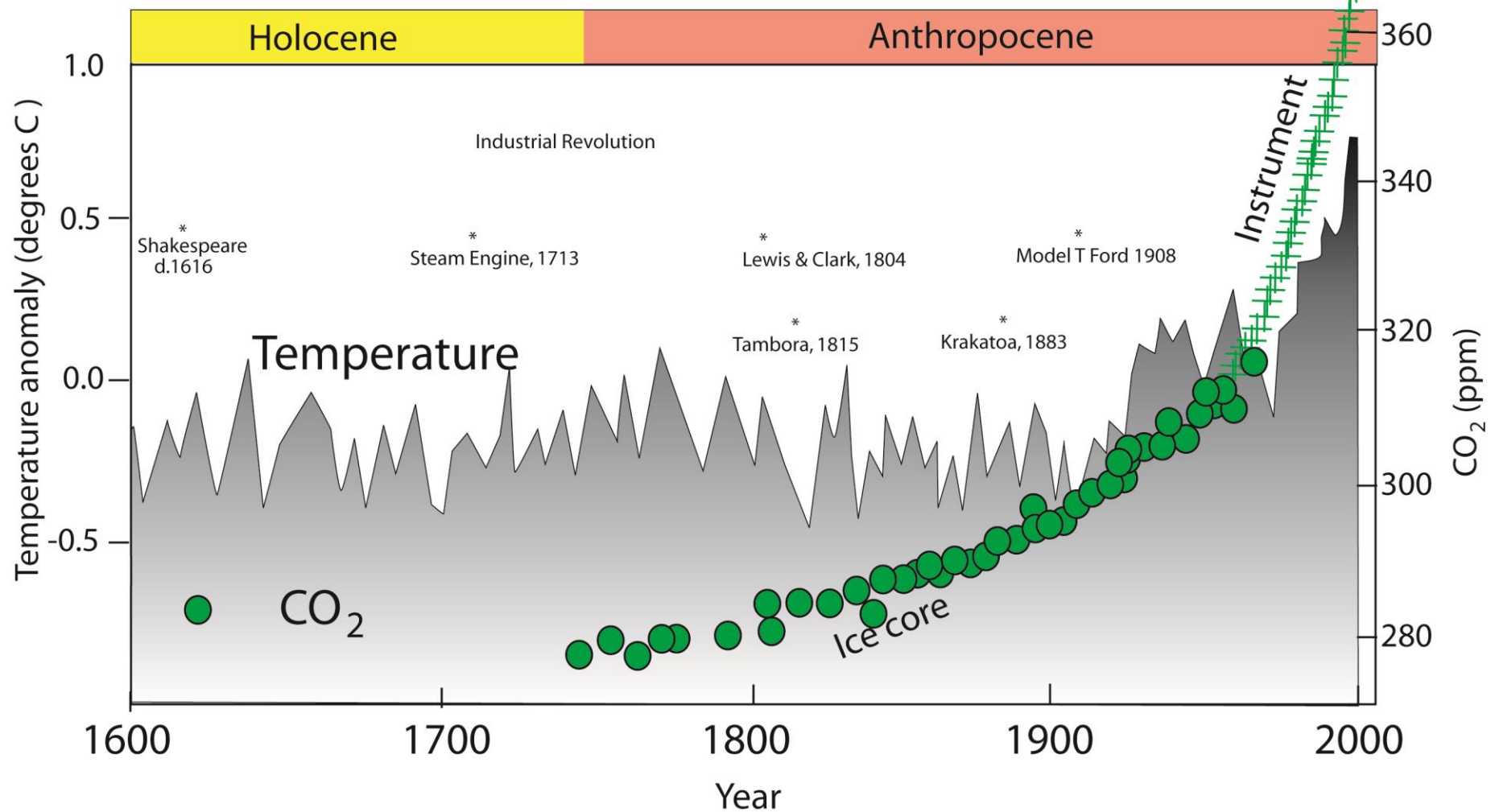
Temp: tree rings and ice cores



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

400 Years

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

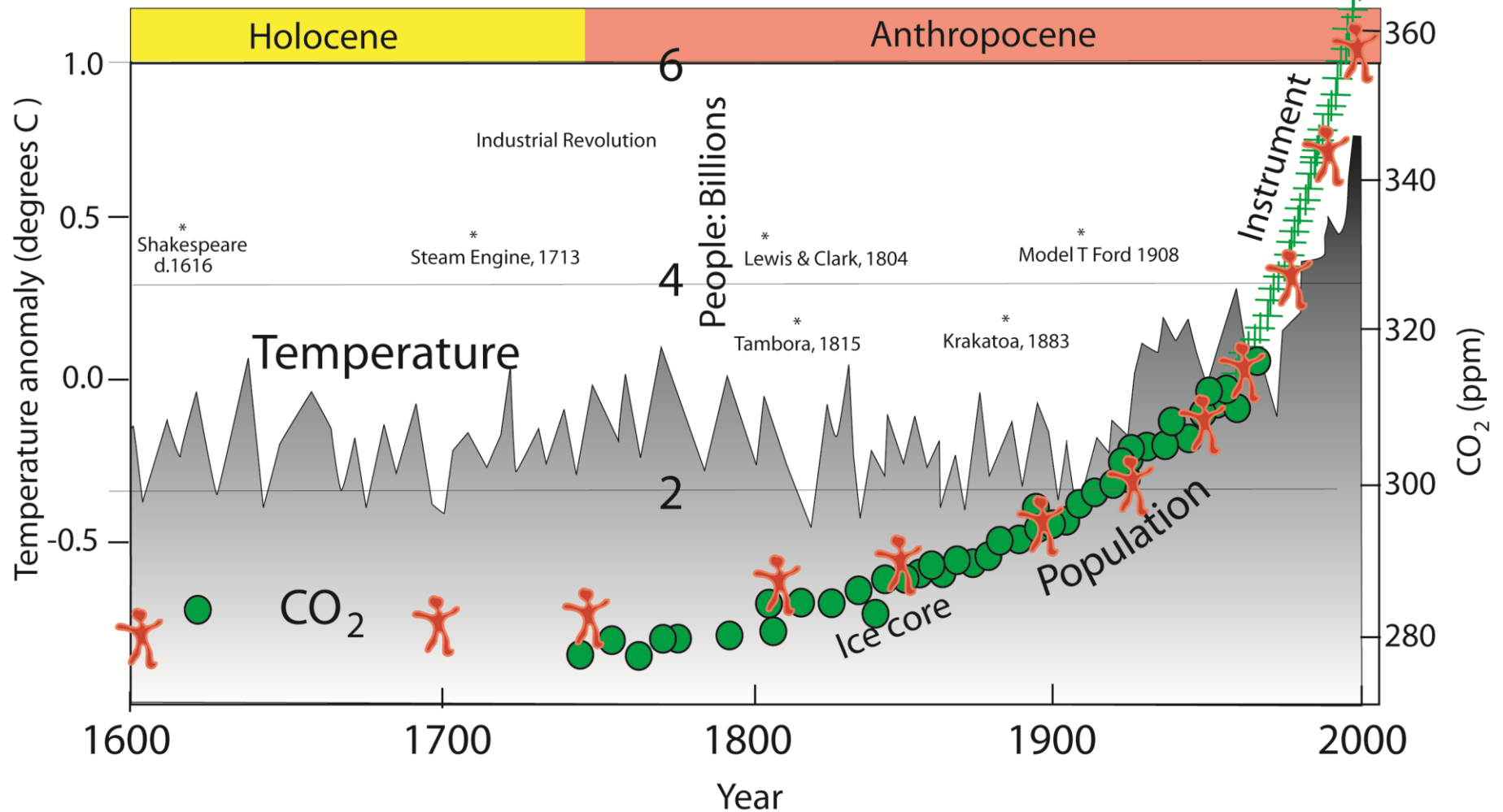


Temperature: Mann et al., 1999, Geophysical Research Letters

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

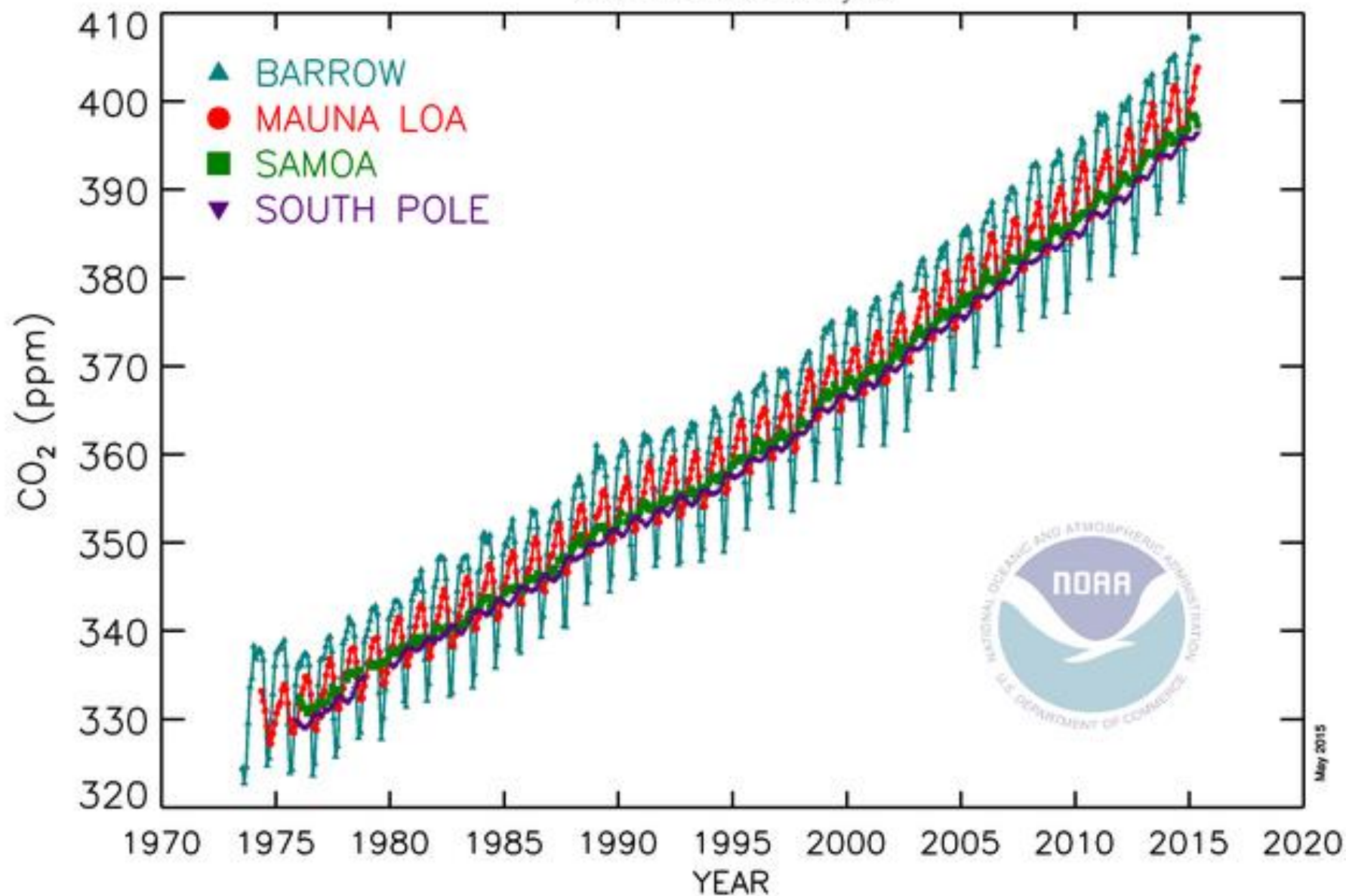
CO₂: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12



Population: UN

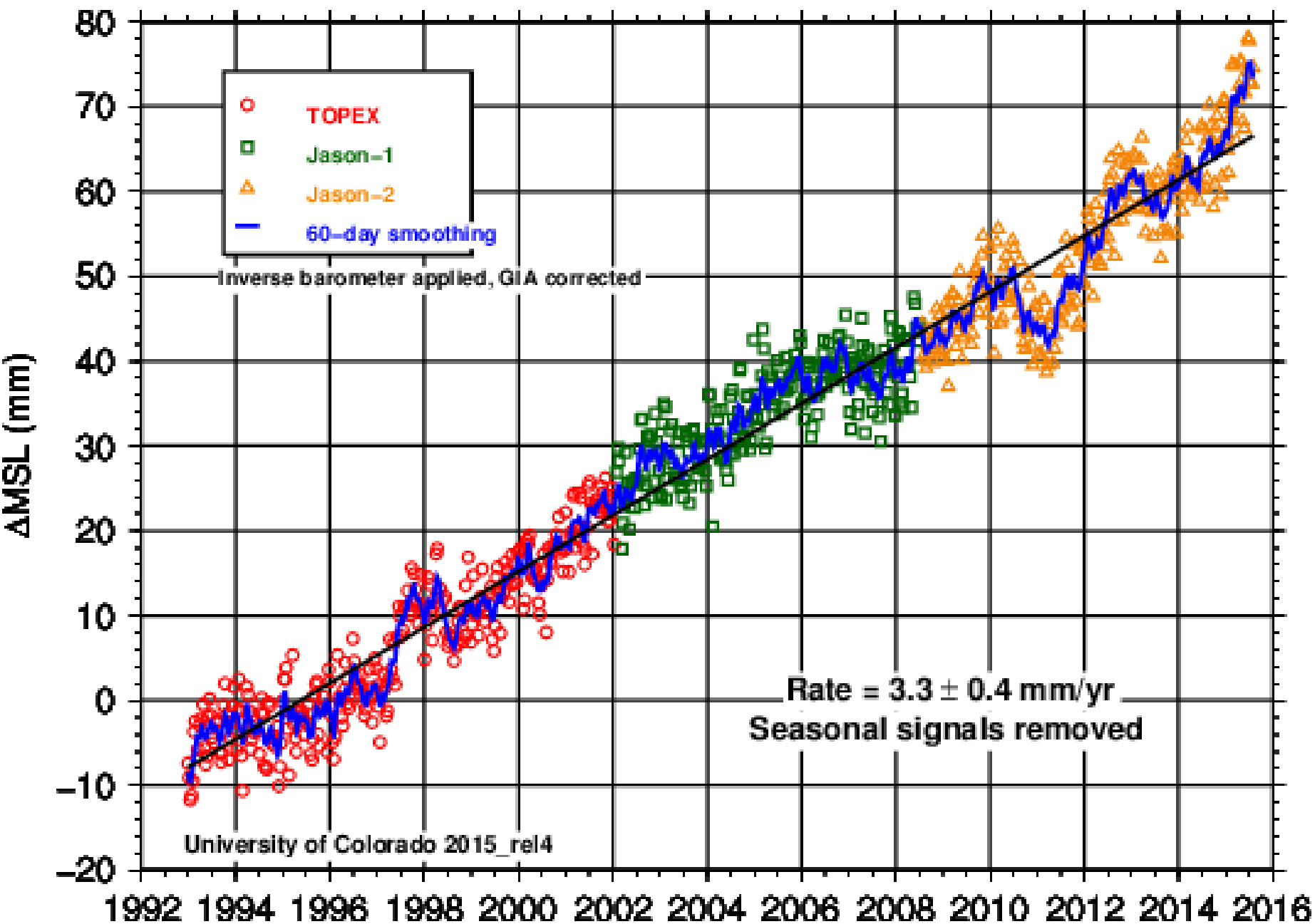
Monthly Mean Carbon Dioxide

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/>.





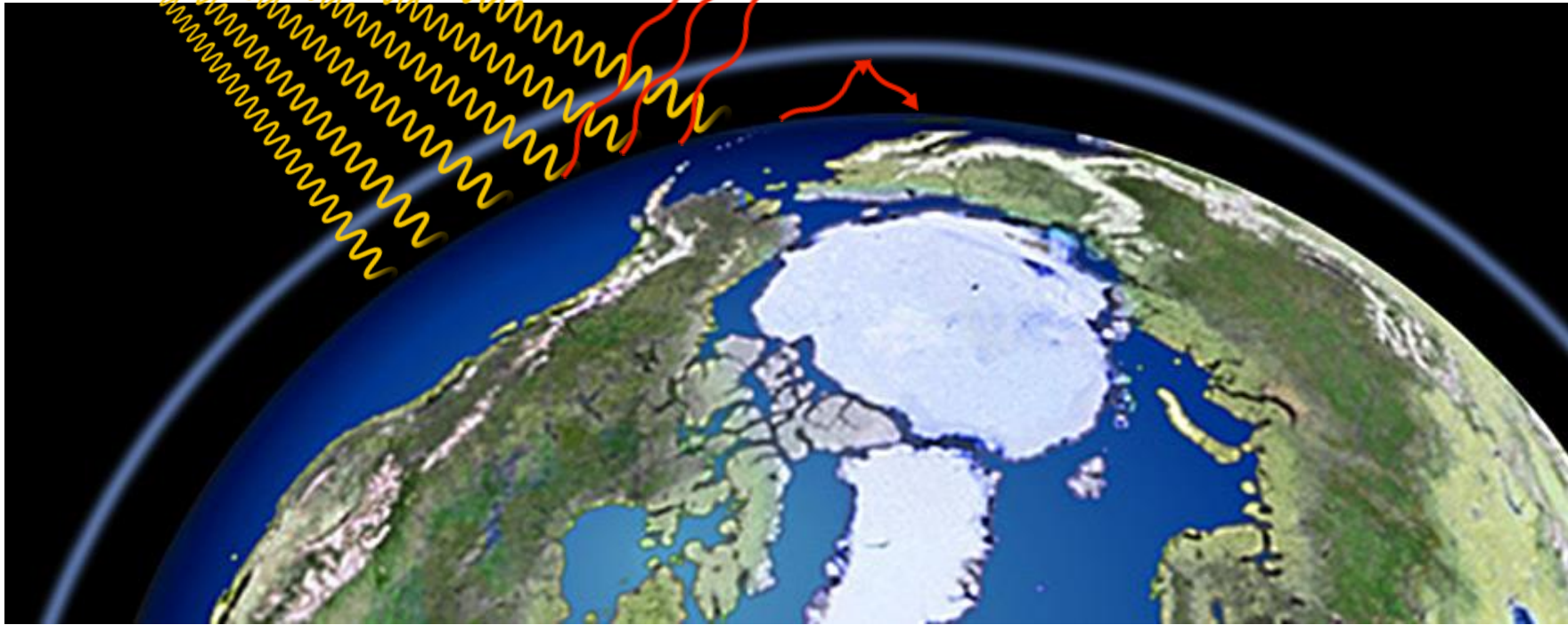
GLOBAL
WARMING
READY

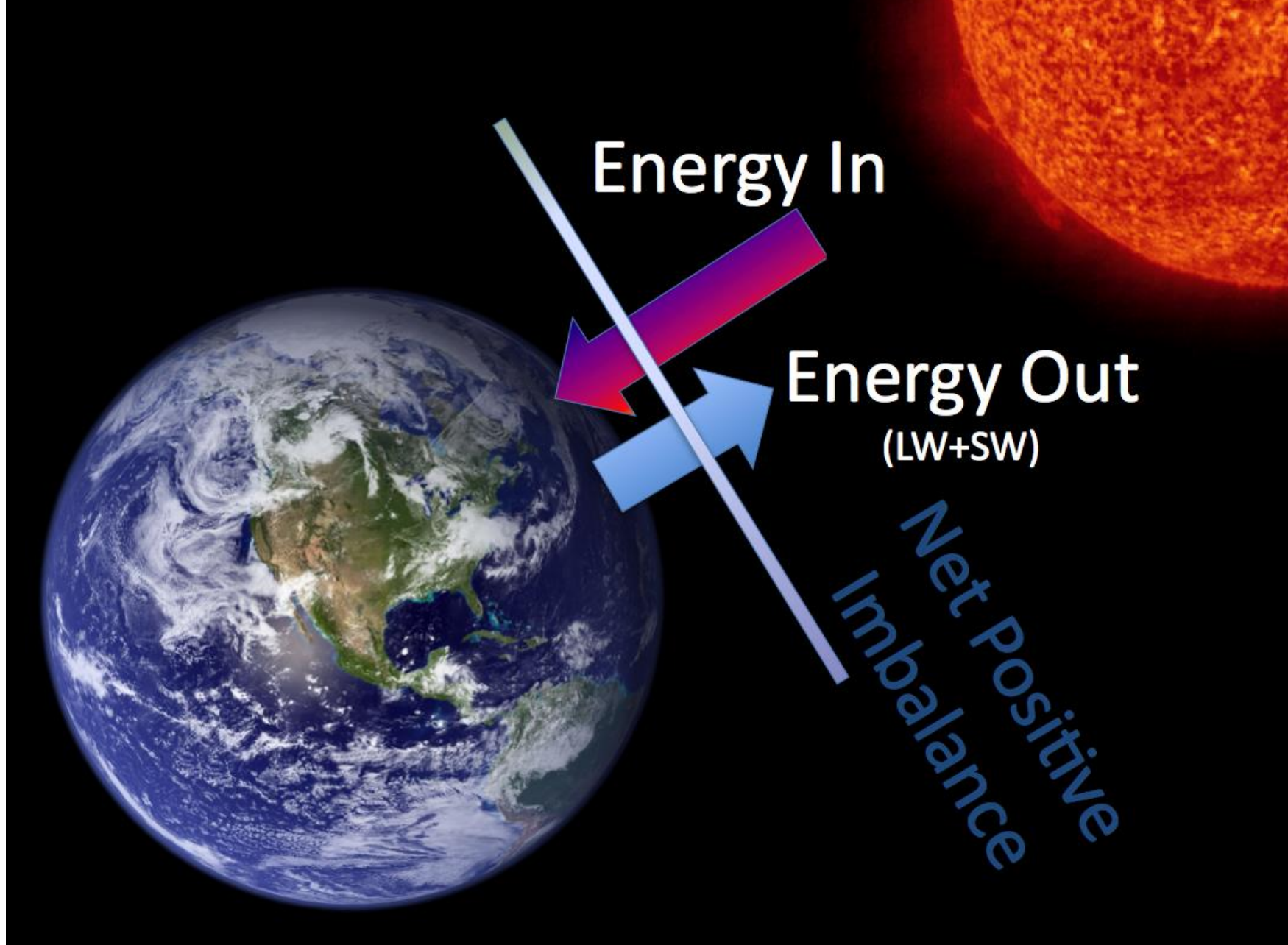
Number 234 in a series of DISEL "How to" guides

New York, Manhattan, Union Sq, San Francisco Post 36

About 342 w/m² comes in

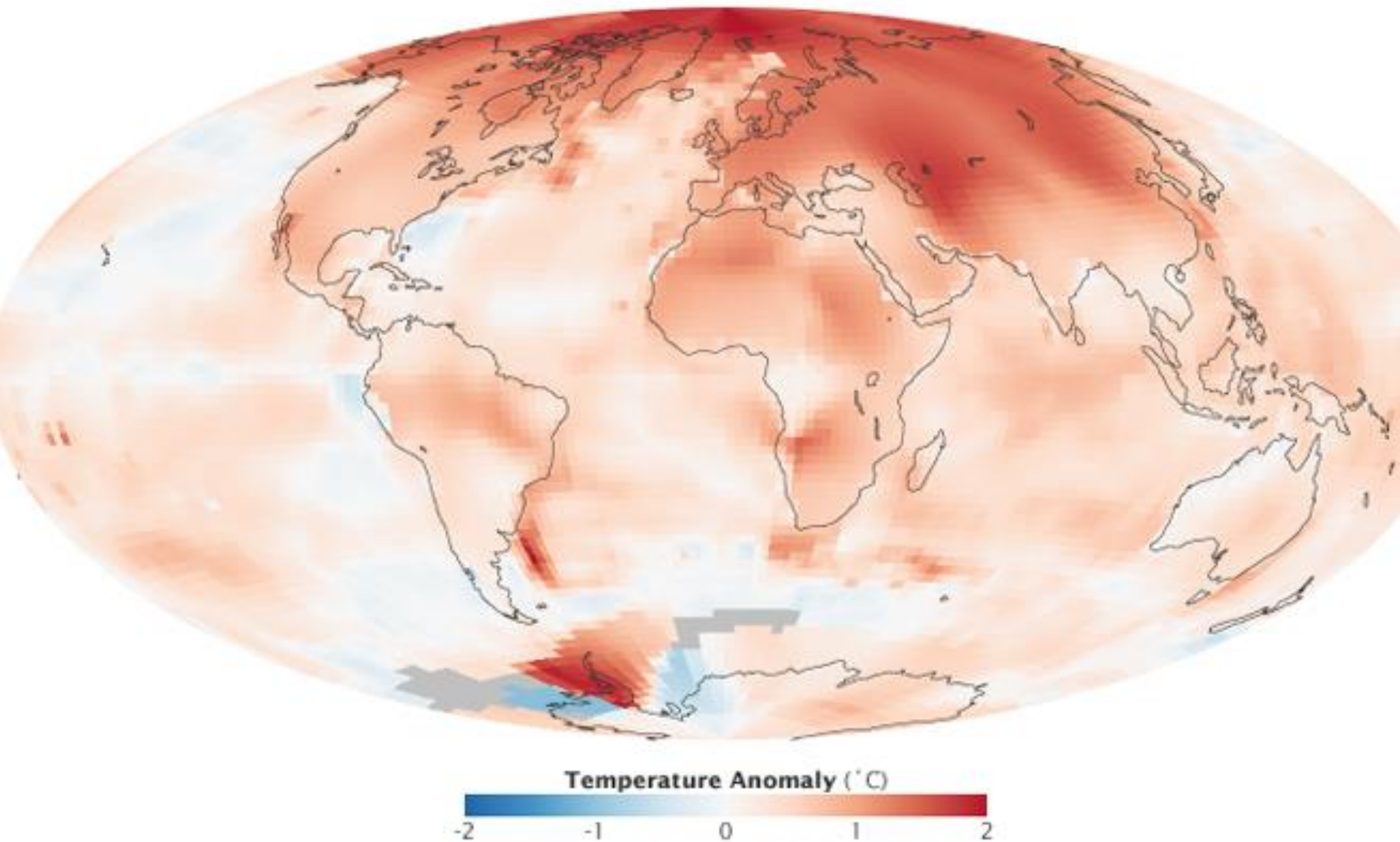
About 341 W/m² goes out





Change in temperature

2000-2009 vs. 1951-1980



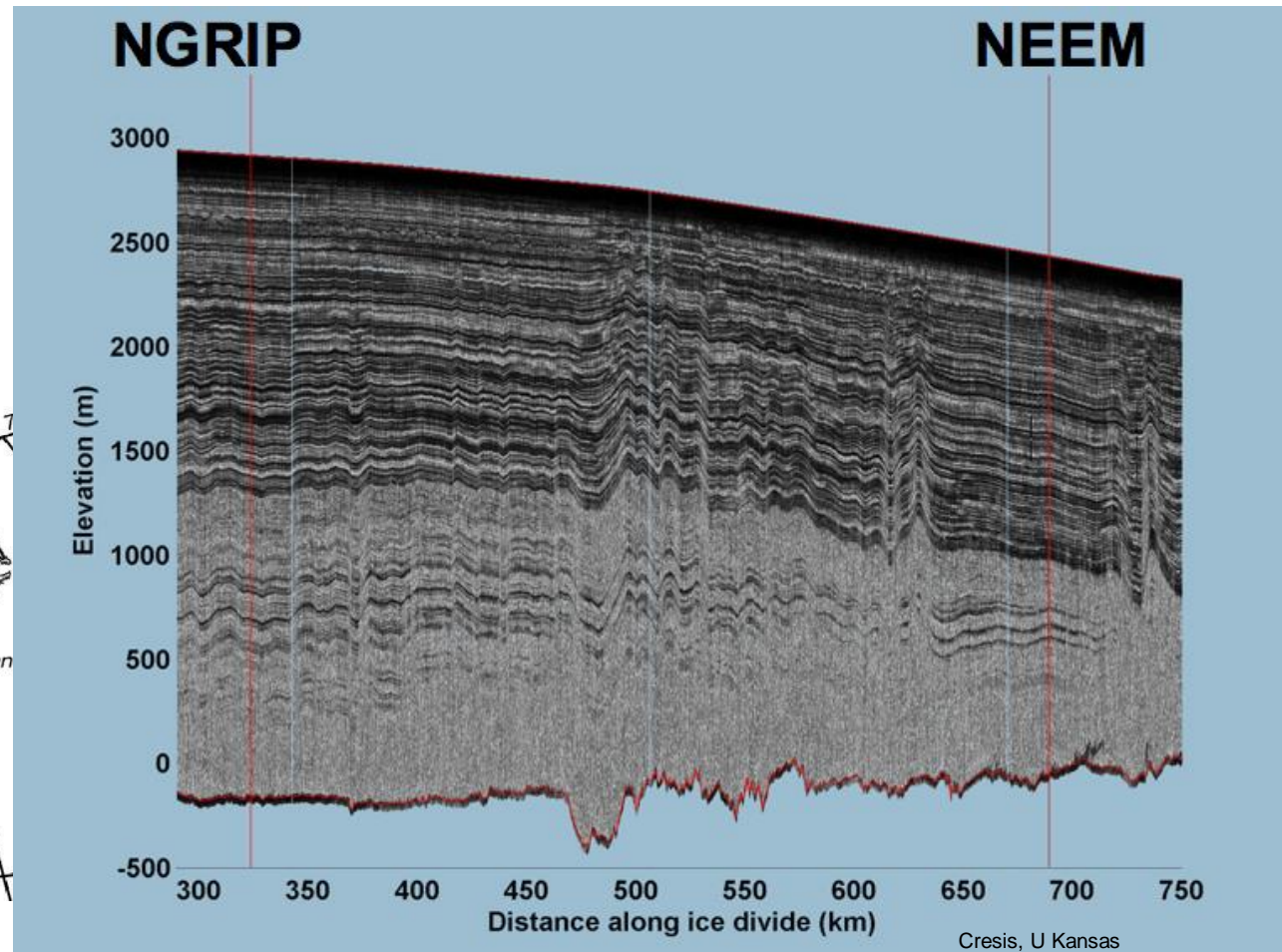
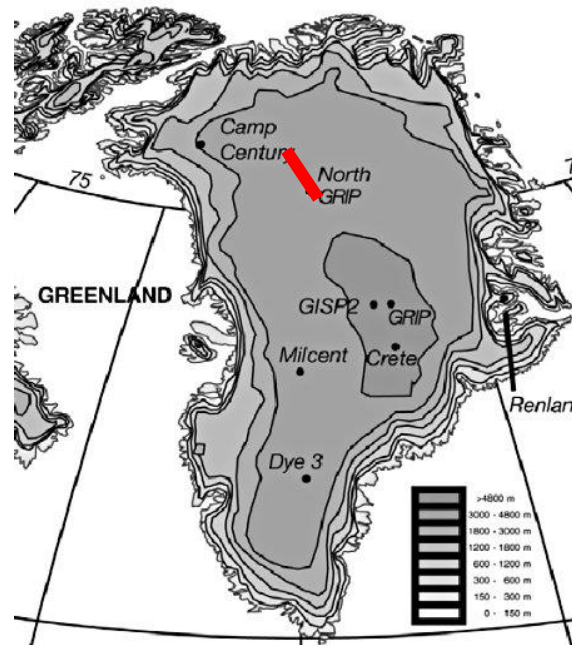
Stratified Ice

The pale bands are summer, the dark bands winter.



5 Cm

GISP 2 Core, 1855 meters



Character of radar reflectors in northern Greenland

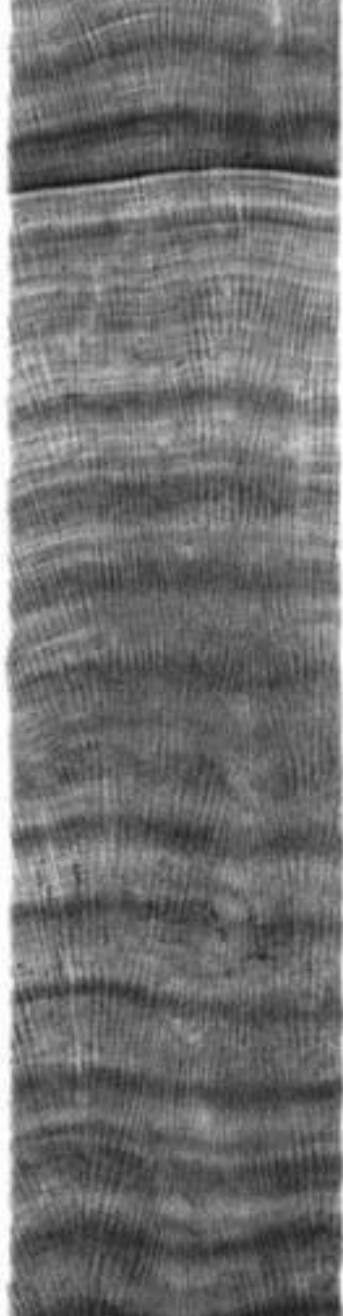


Stalagmite

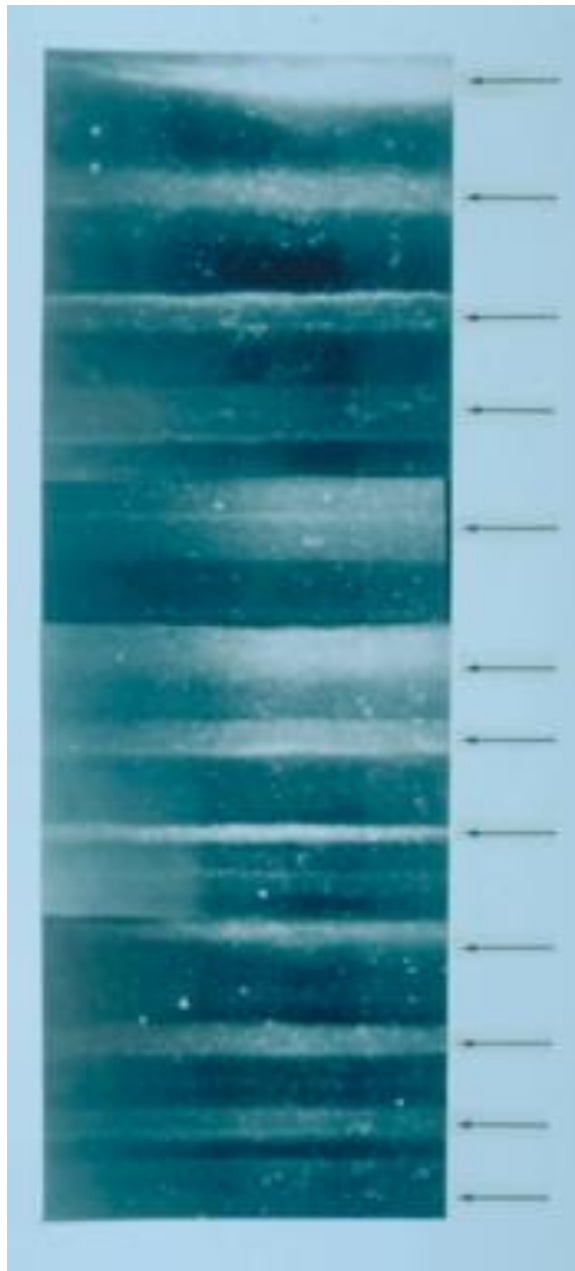


UV Light

Photo: Alamy



Coral, Australia

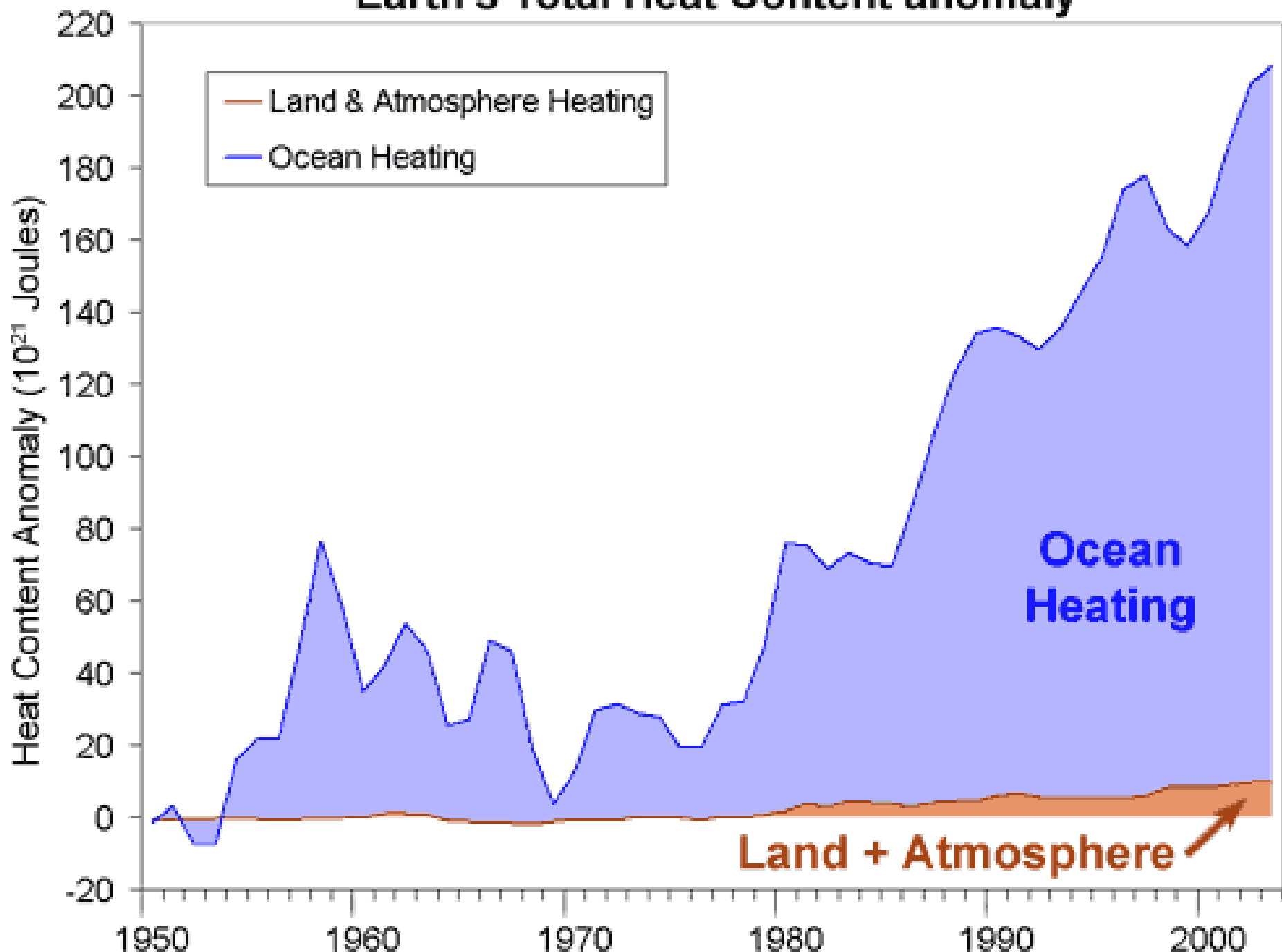


Ice, Greenland



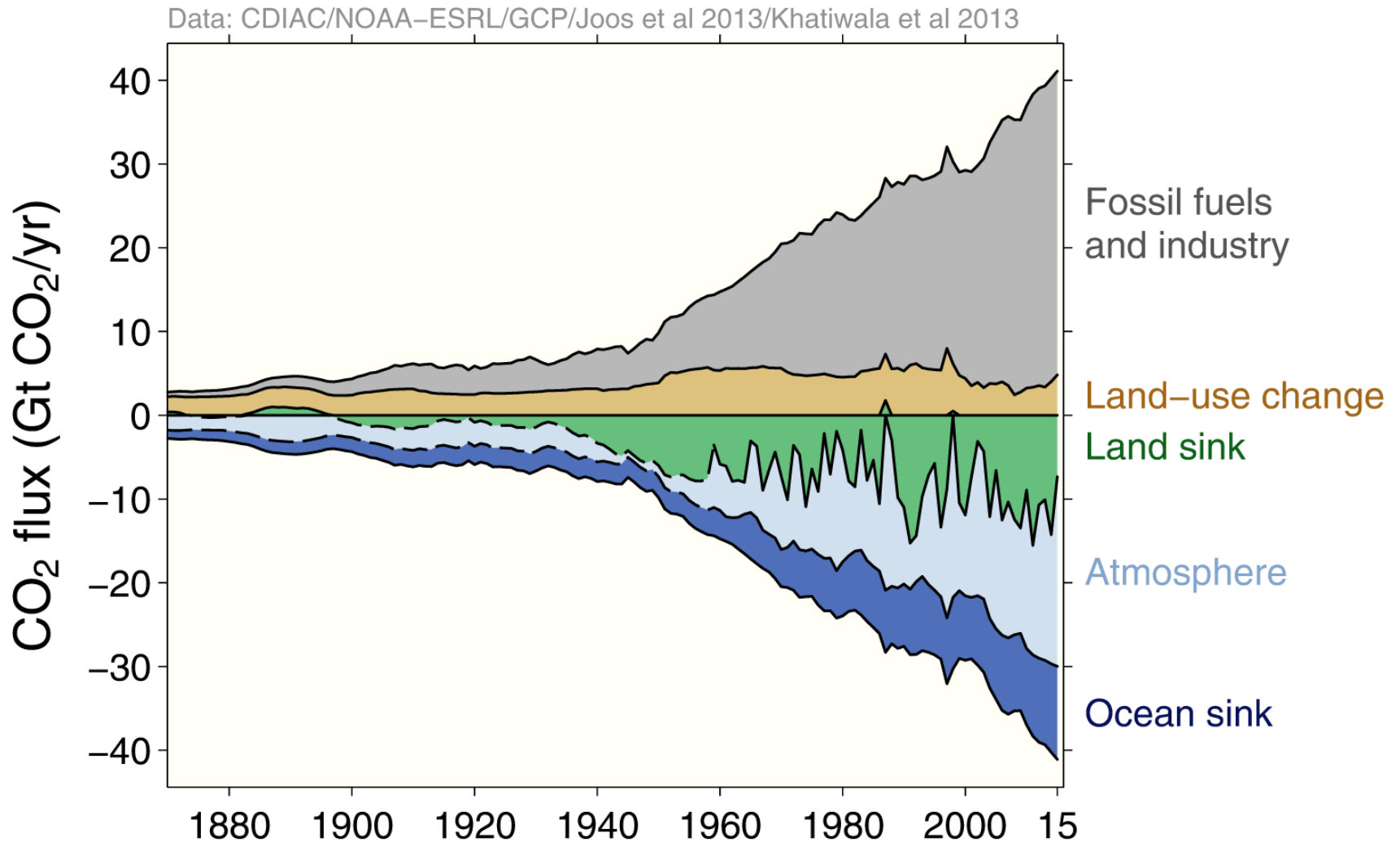
Lake Sediments, Turkey

Earth's Total Heat Content anomaly

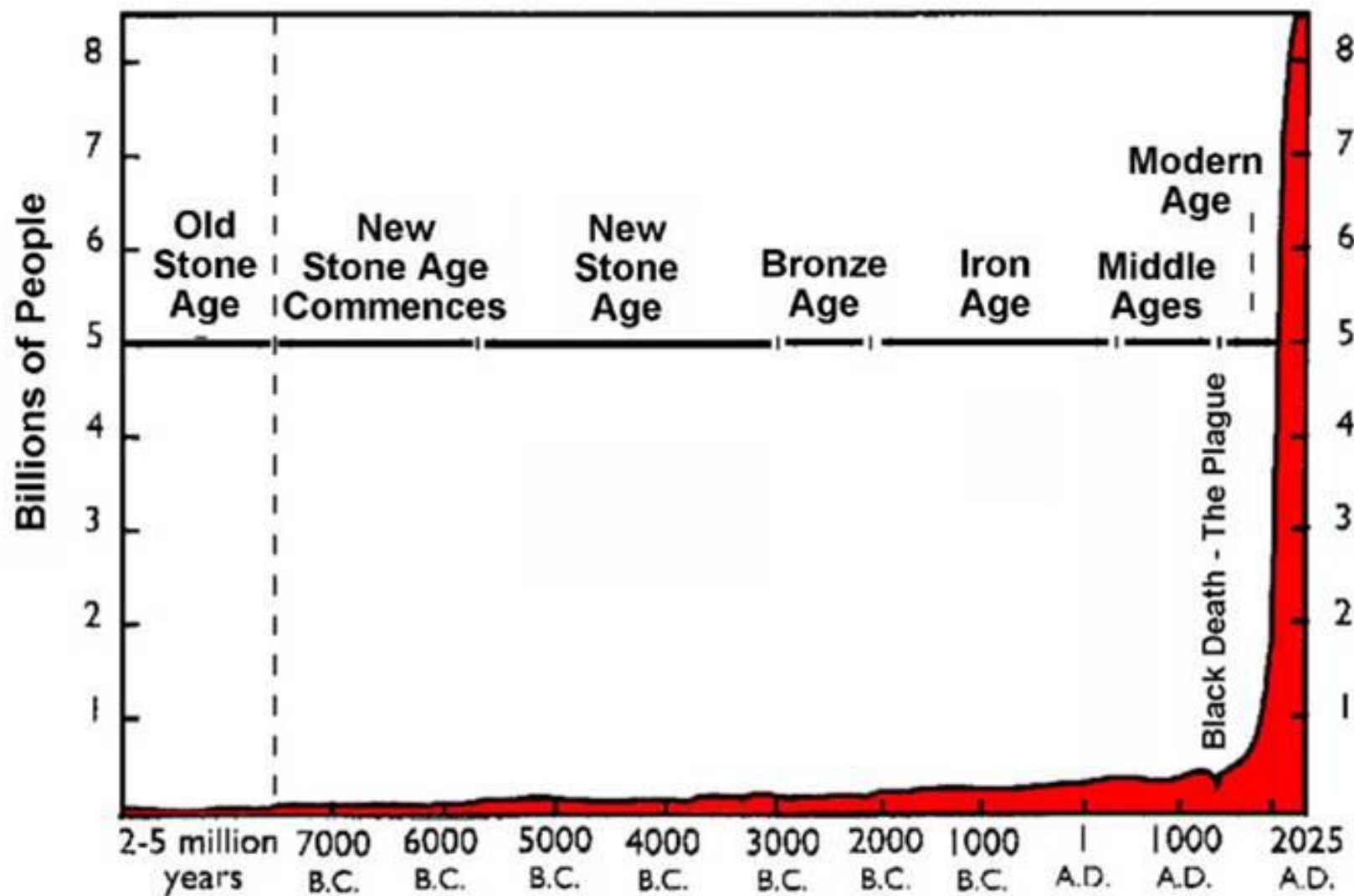


The

by

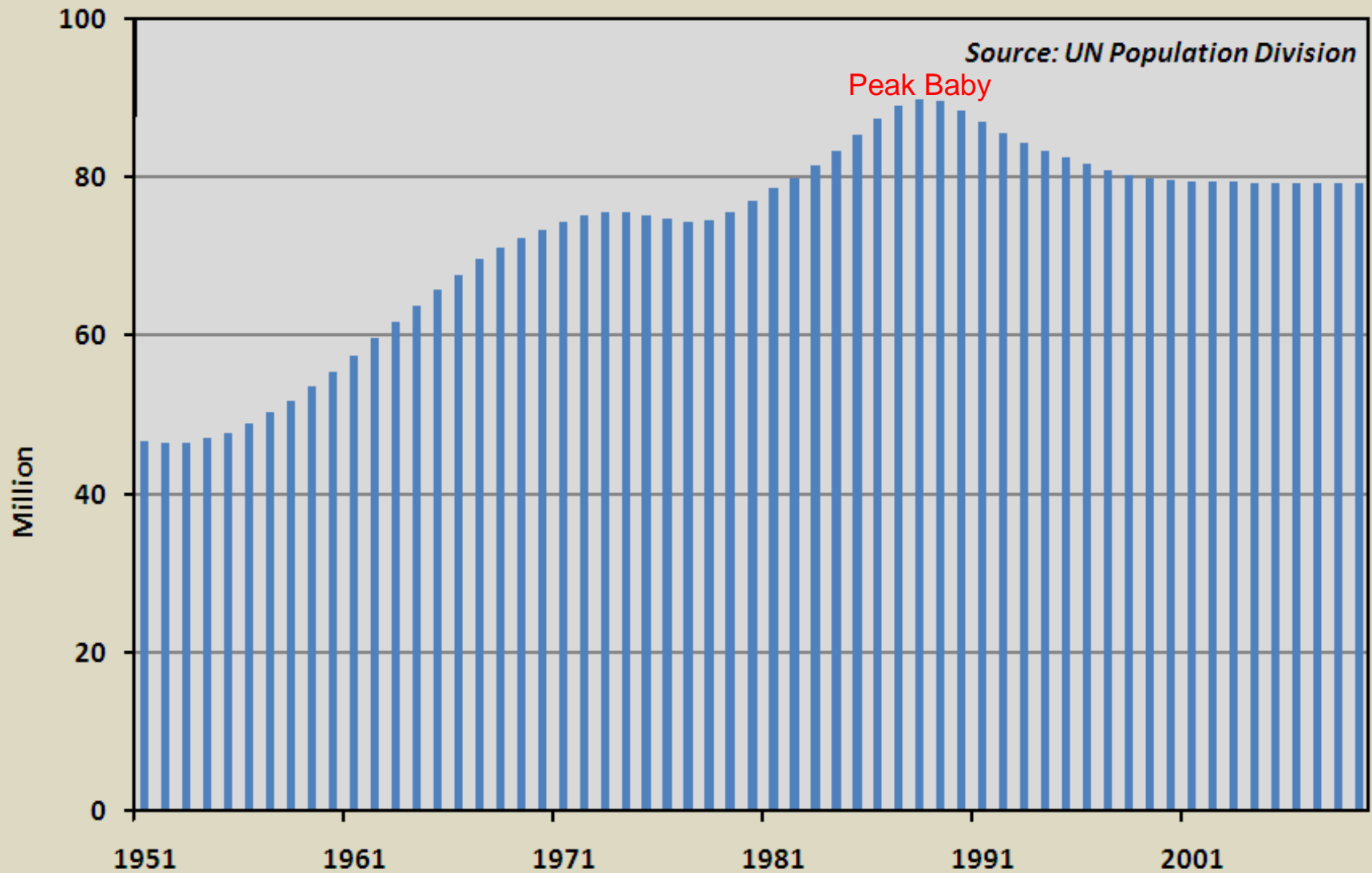


World Population Growth Through History

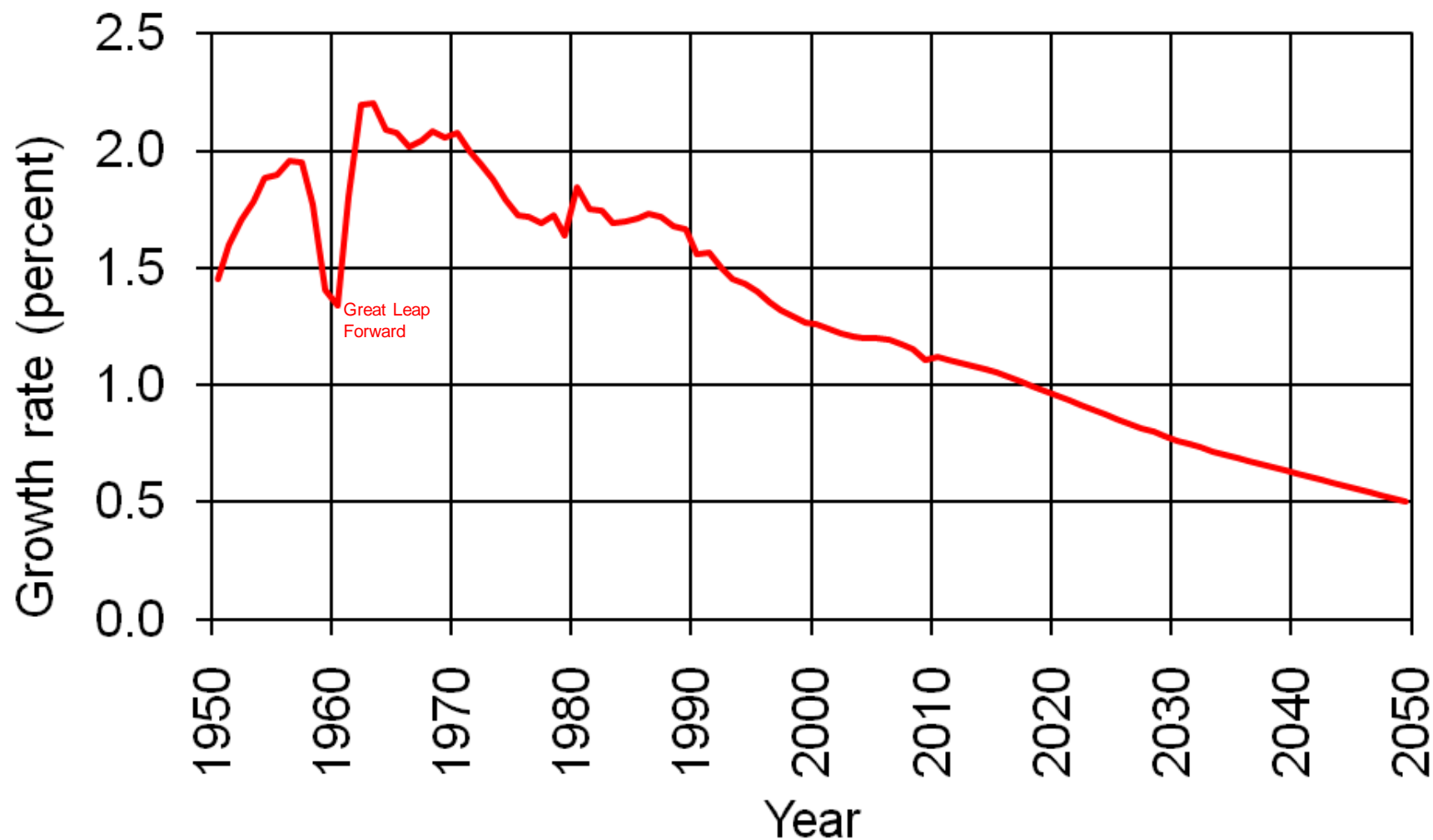


From "World Population: Toward the Next Century," copyright 1994
by the Population Reference Bureau

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

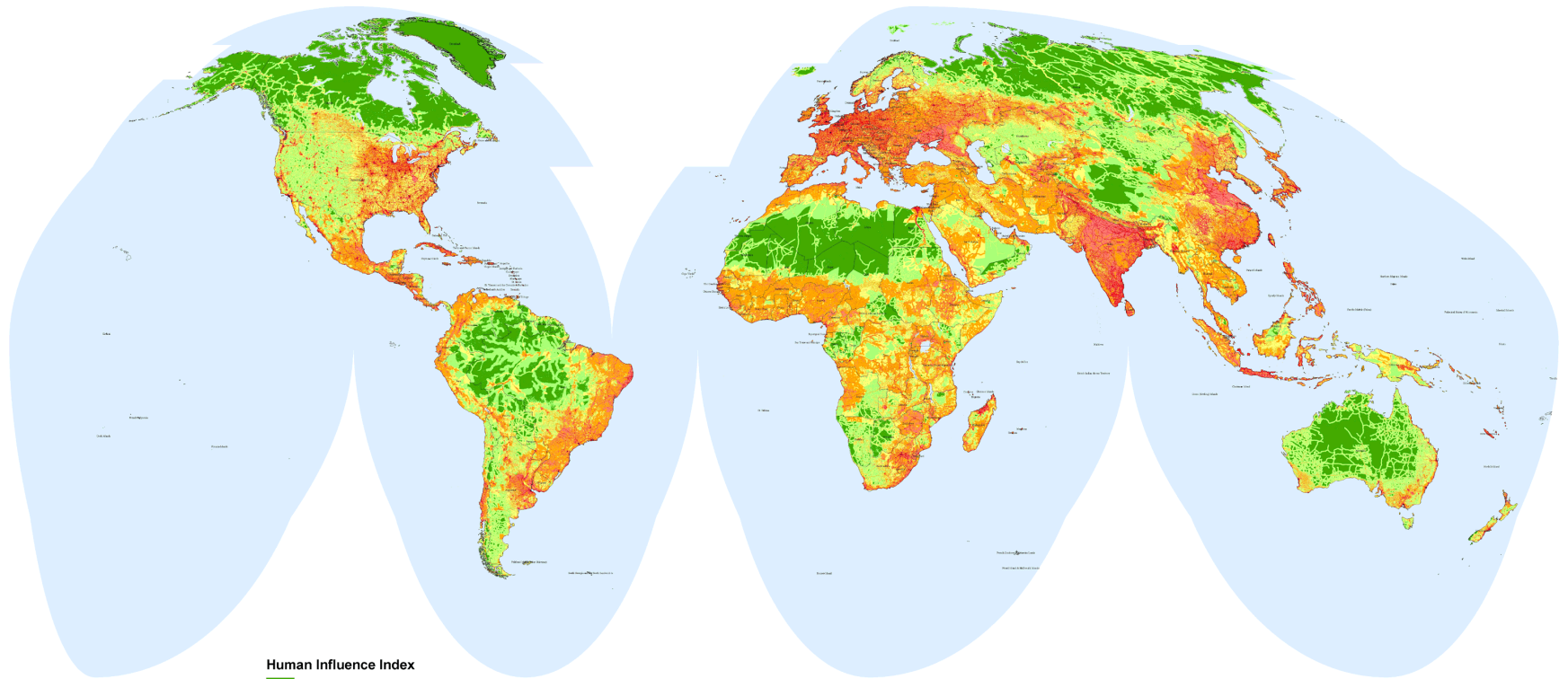


World Population Growth Rates: 1950-2050

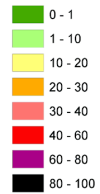


Source: U.S. Census Bureau, International Data Base, June 2011 Update.

Map of Human Footprint



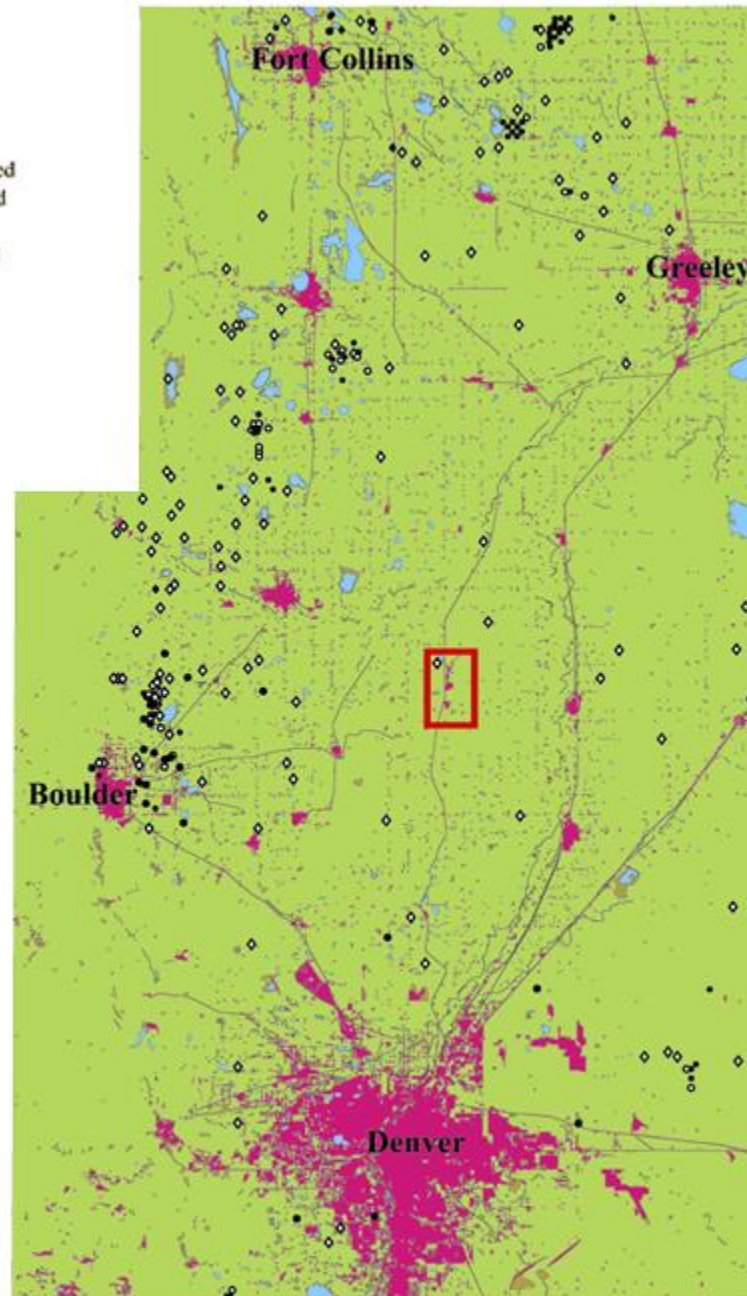
Human Influence Index



© 2009 ESRI. All rights reserved.

1960

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

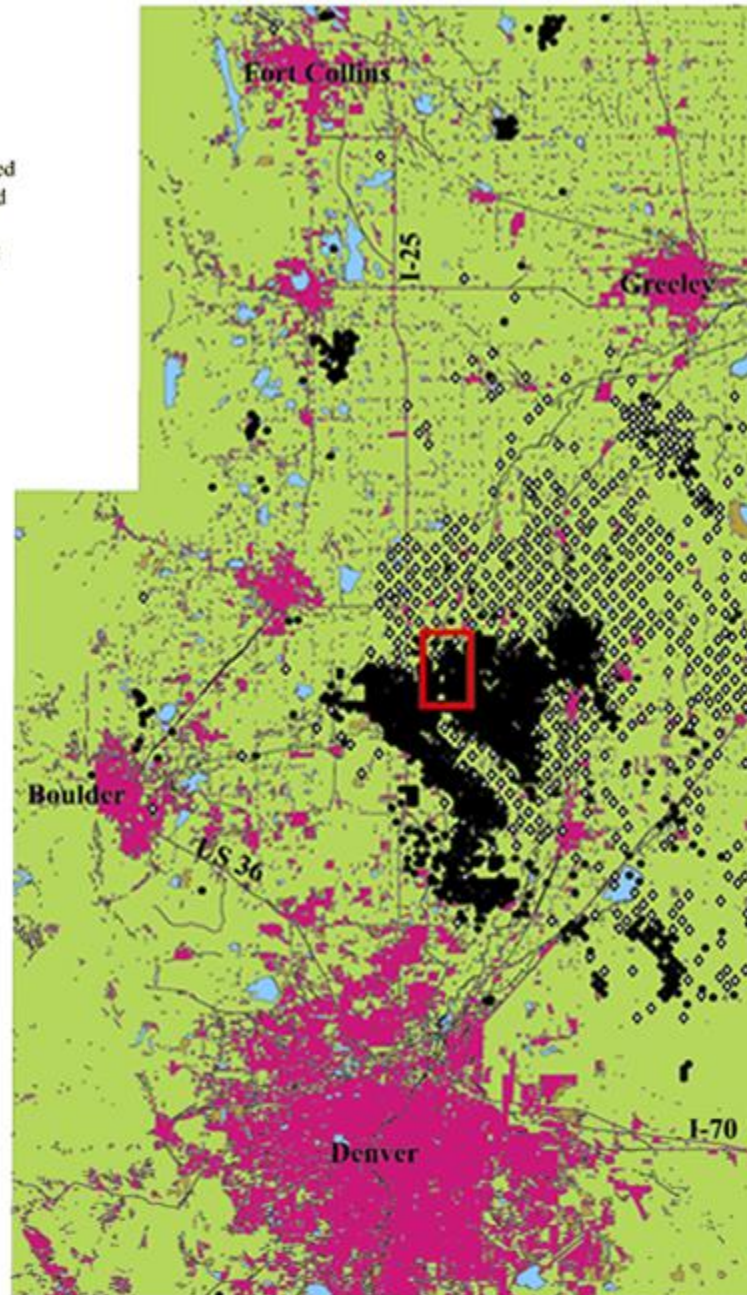


U

USGS

1980

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

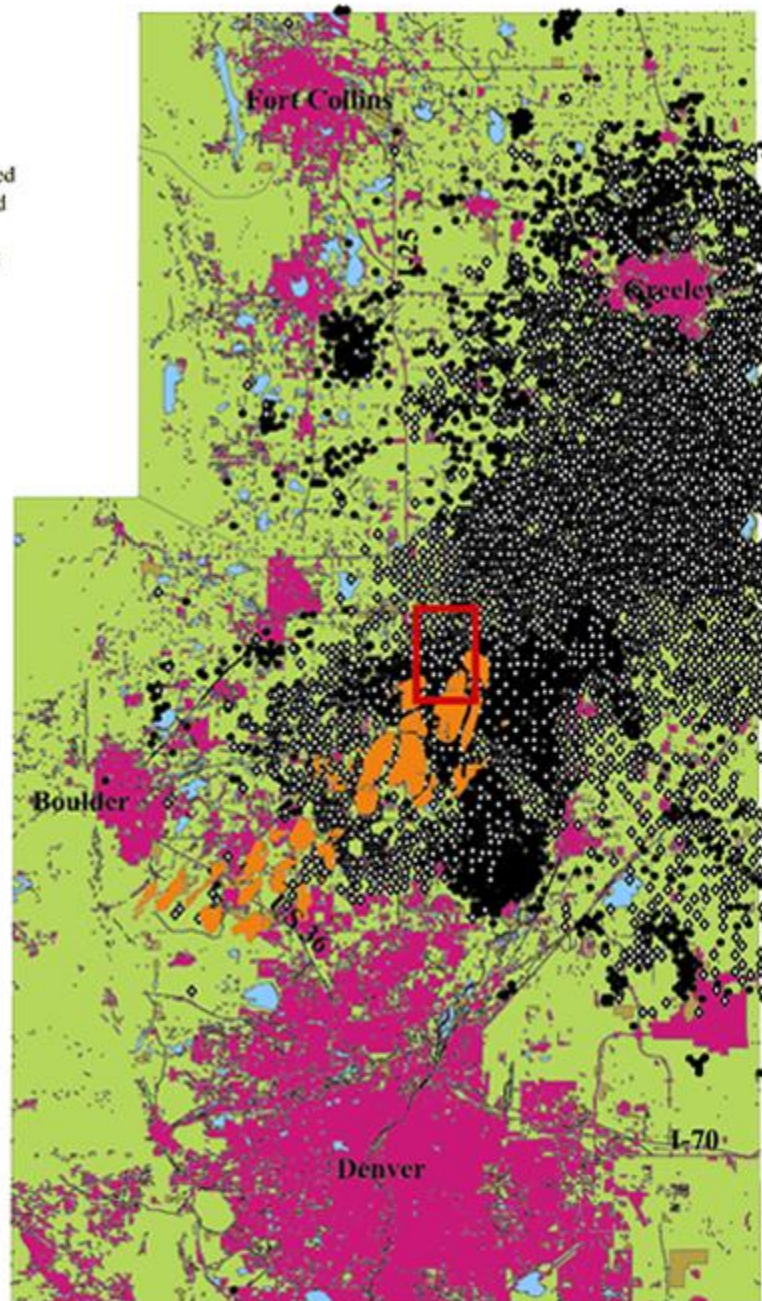


U

USGS

2000

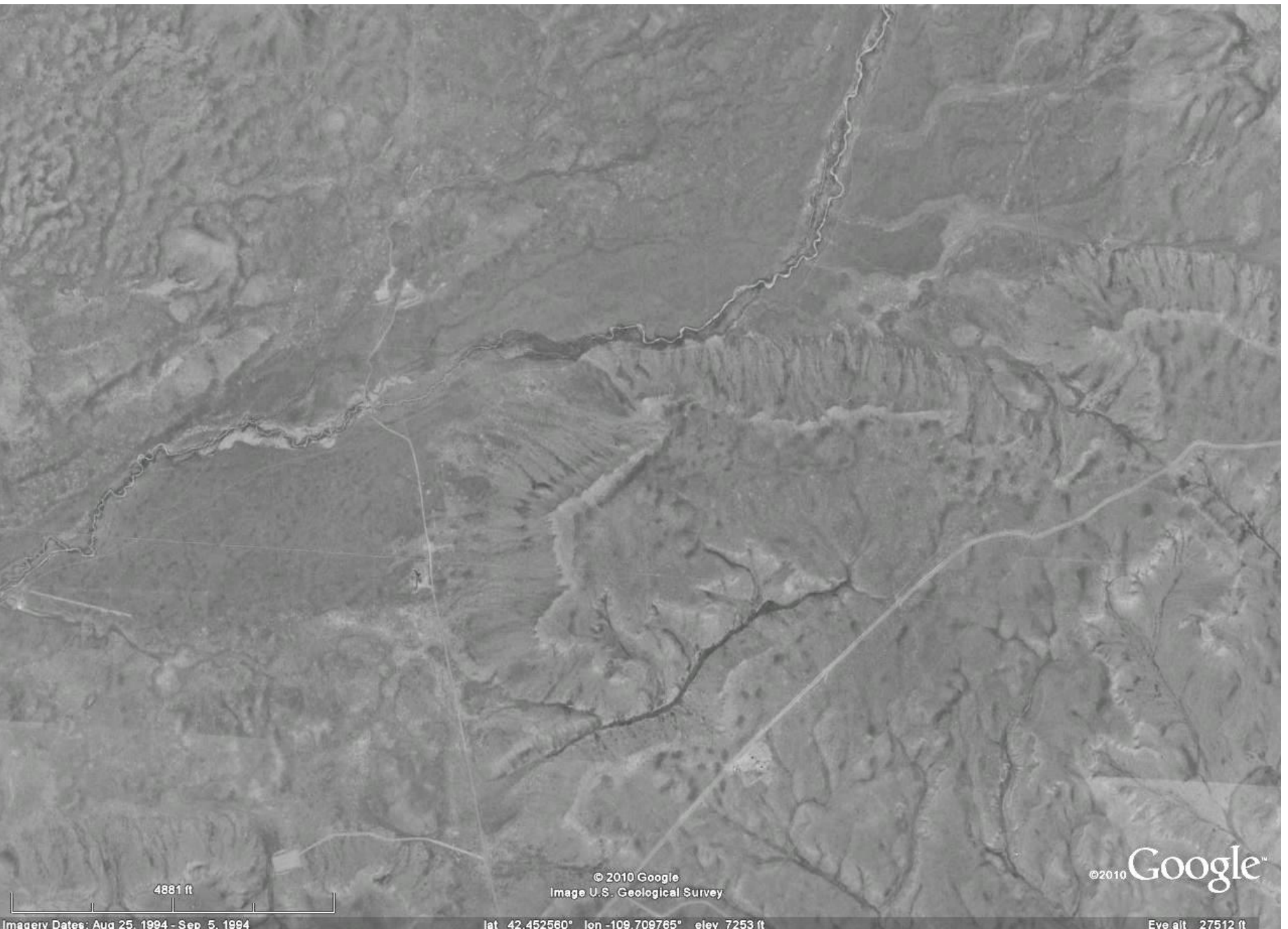
- Developed
- Vegetated
- Water
- Gas Well
- Oil Well



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



9/5/1998

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

Ln 8 N

Rd N 109

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

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

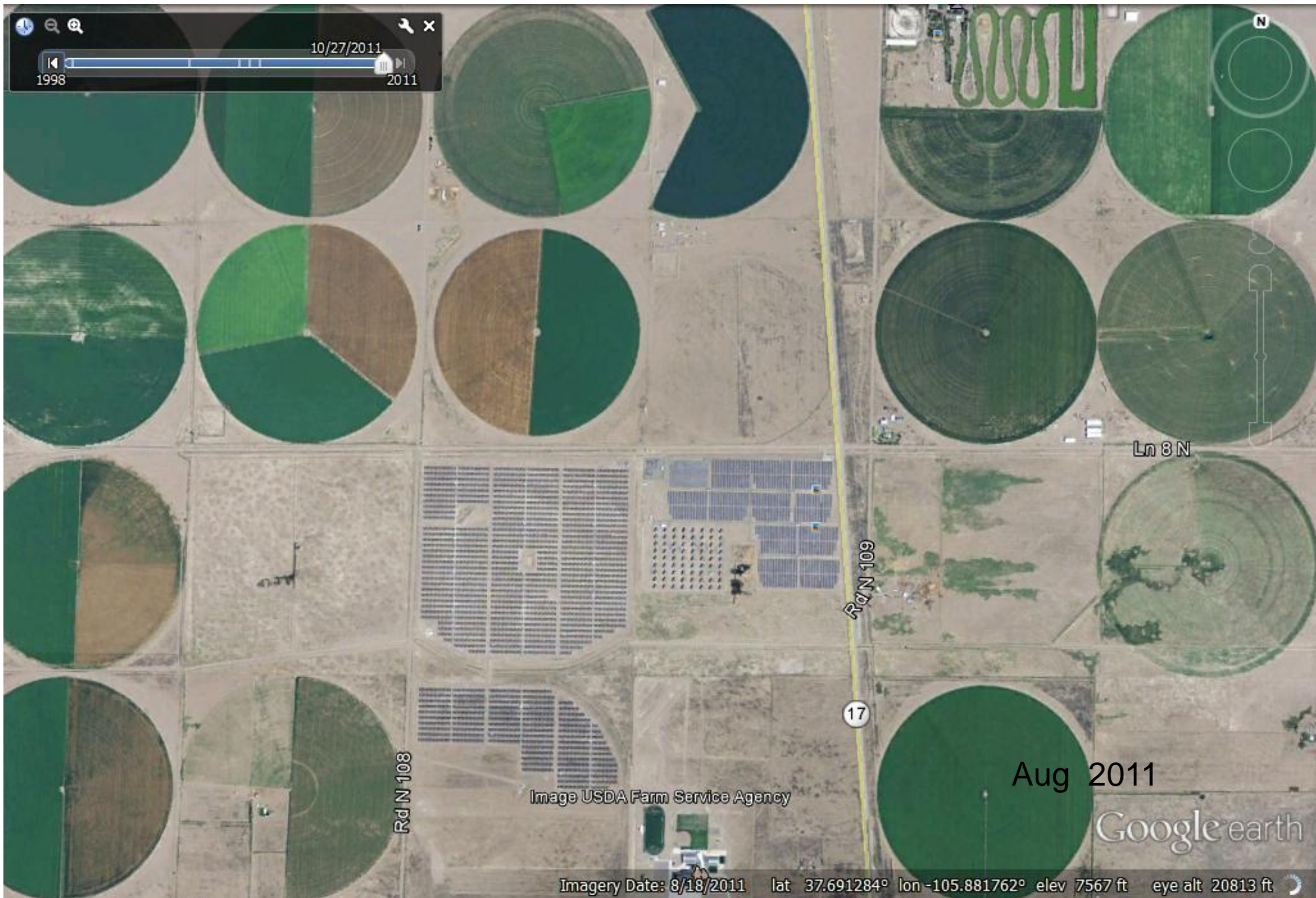
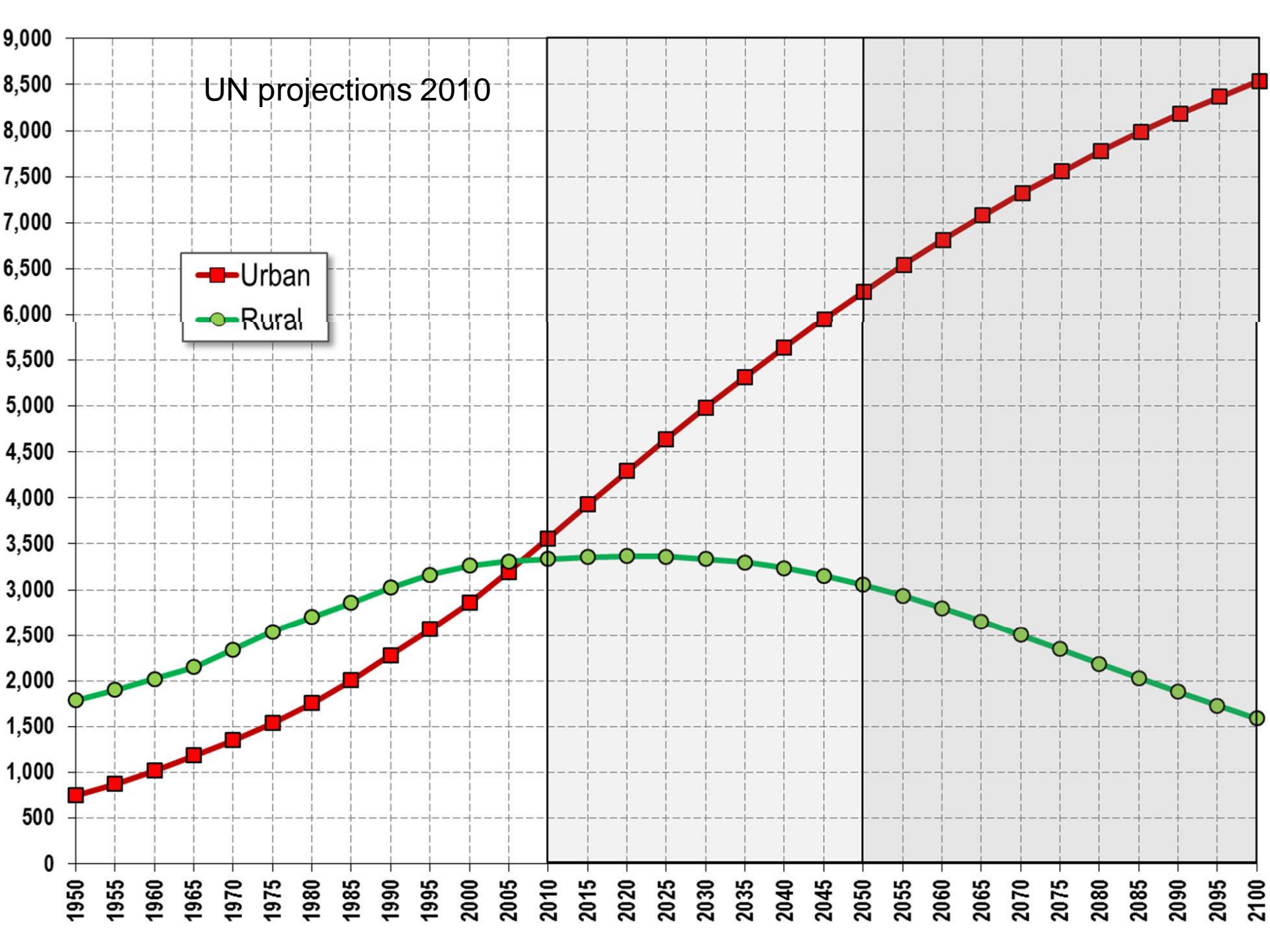


Image USDA Farm Service Agency

Aug 2011

Google earth

Imagery Date: 8/18/2011 lat 37.691284° lon -105.881762° elev 7567 ft eye alt 20813 ft





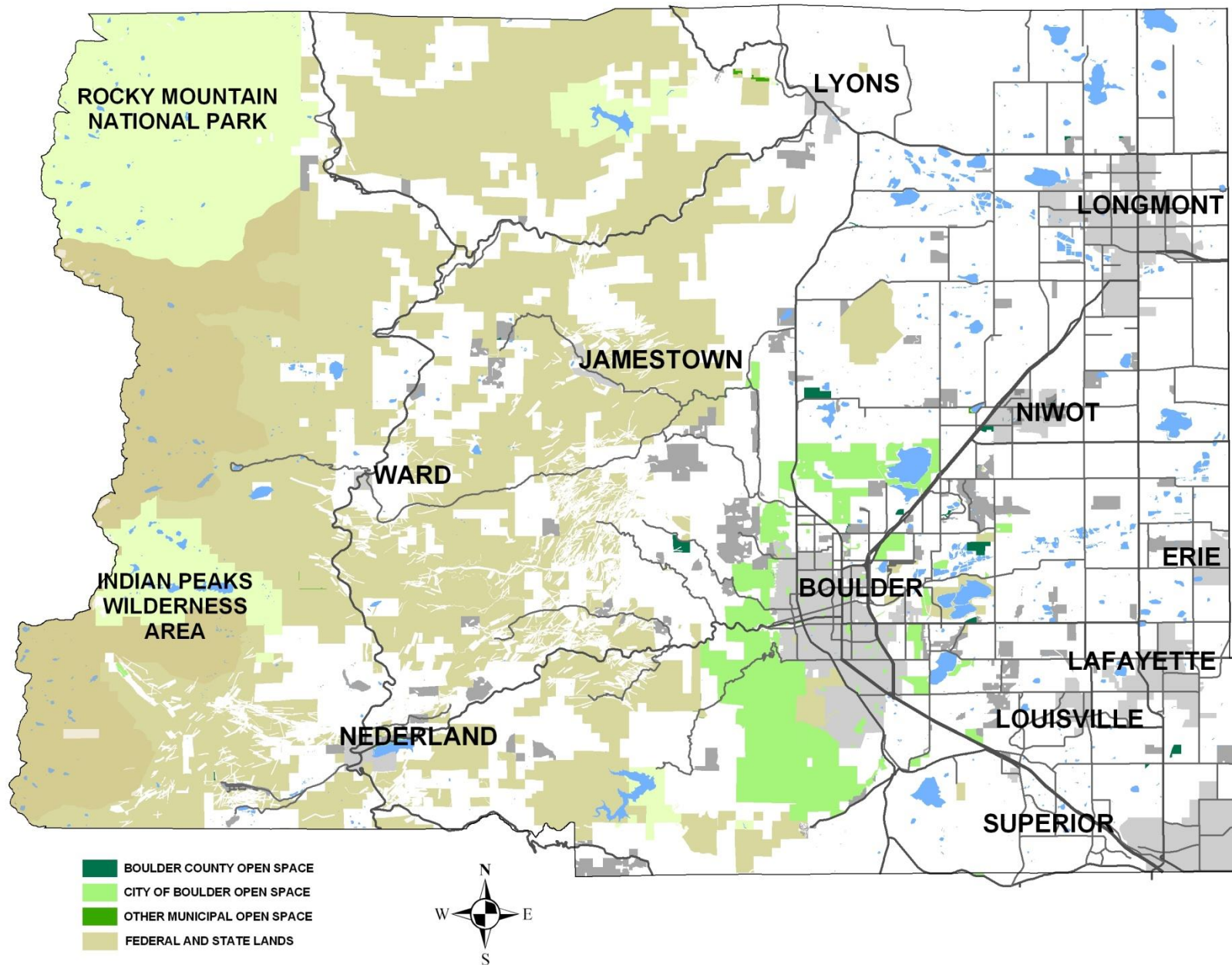
Doug Wheelock, ISS NASA Nov 2, 2010



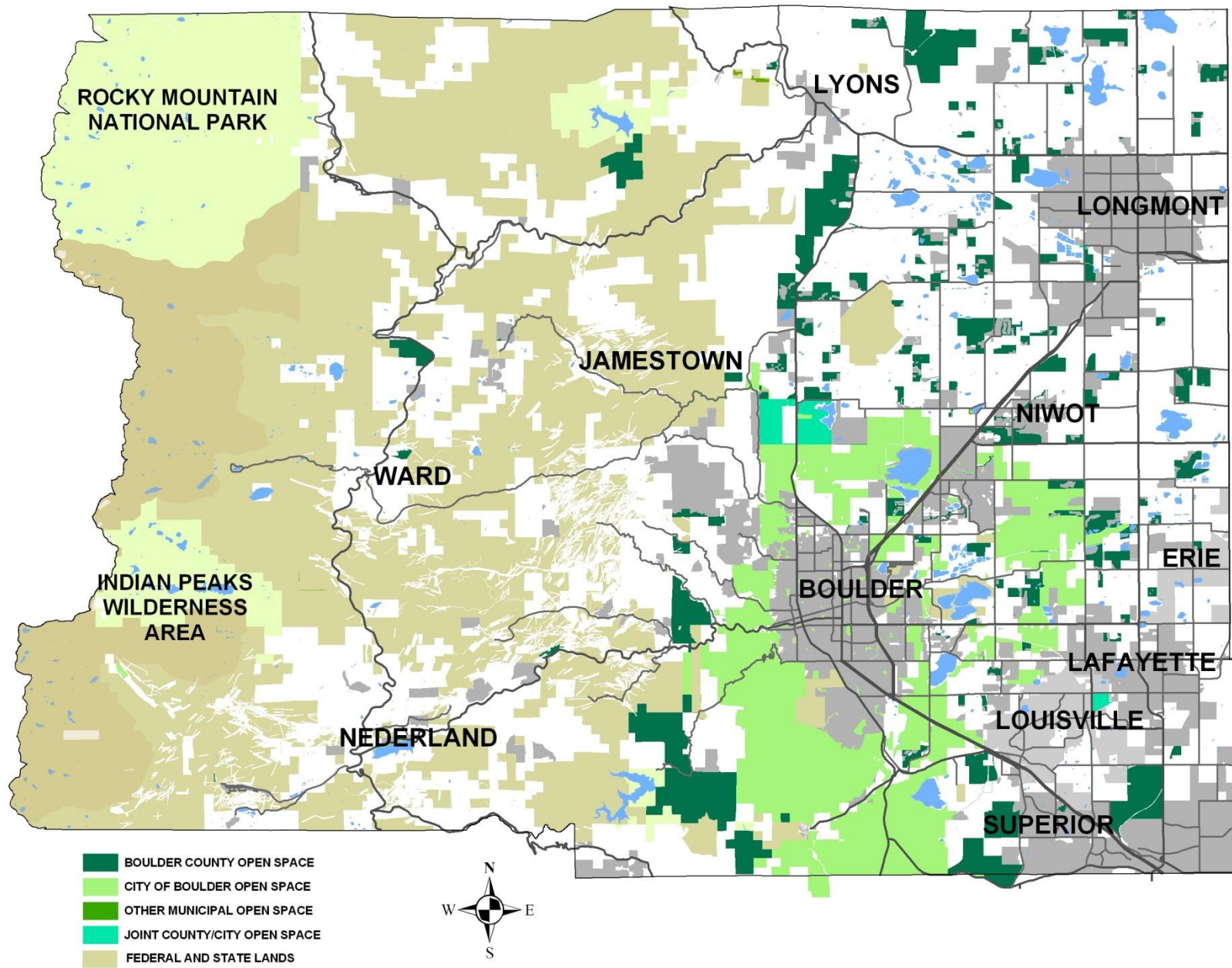
Doug Wheelock, ISS NASA Jan 31, 2010



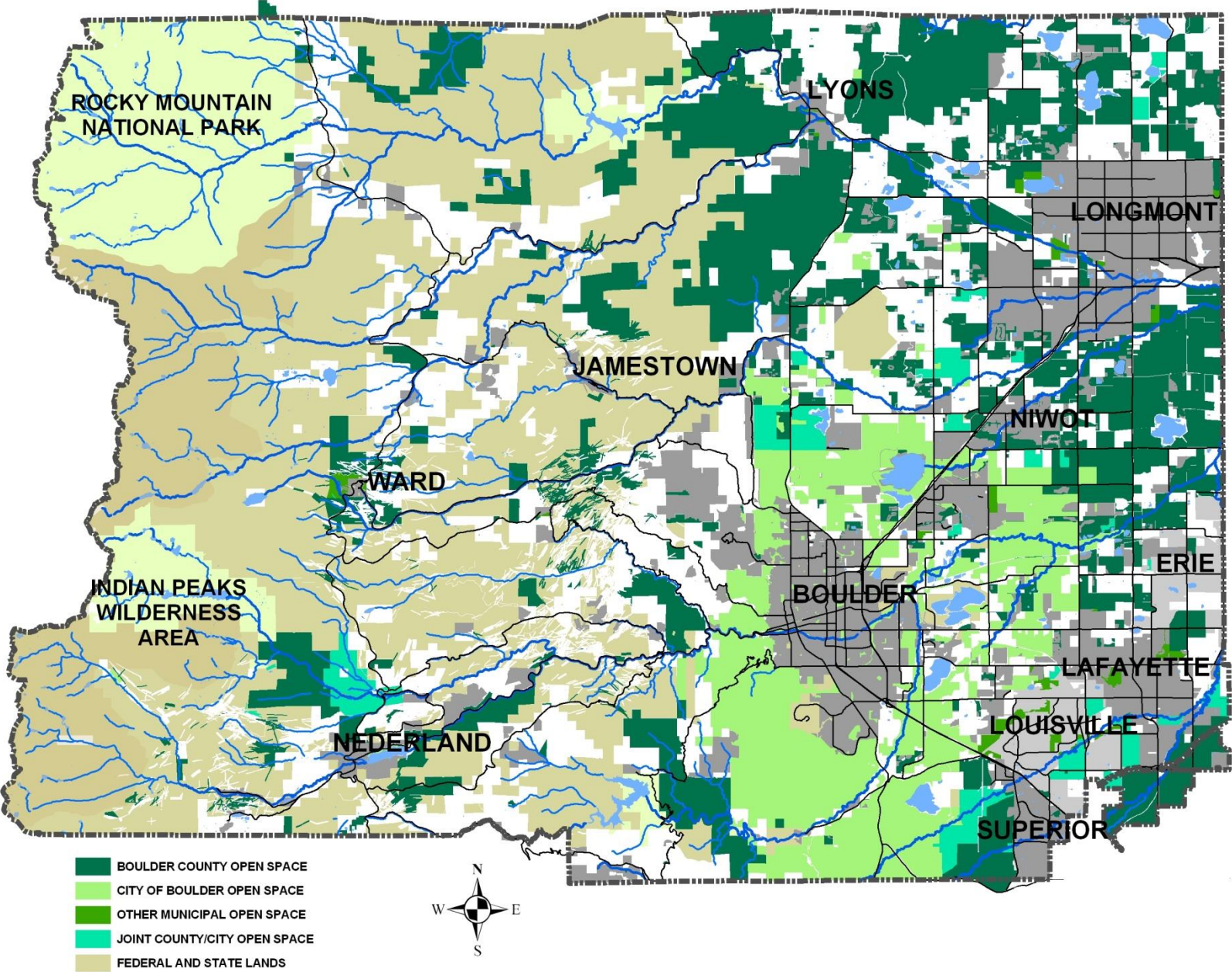
Open Space 1975



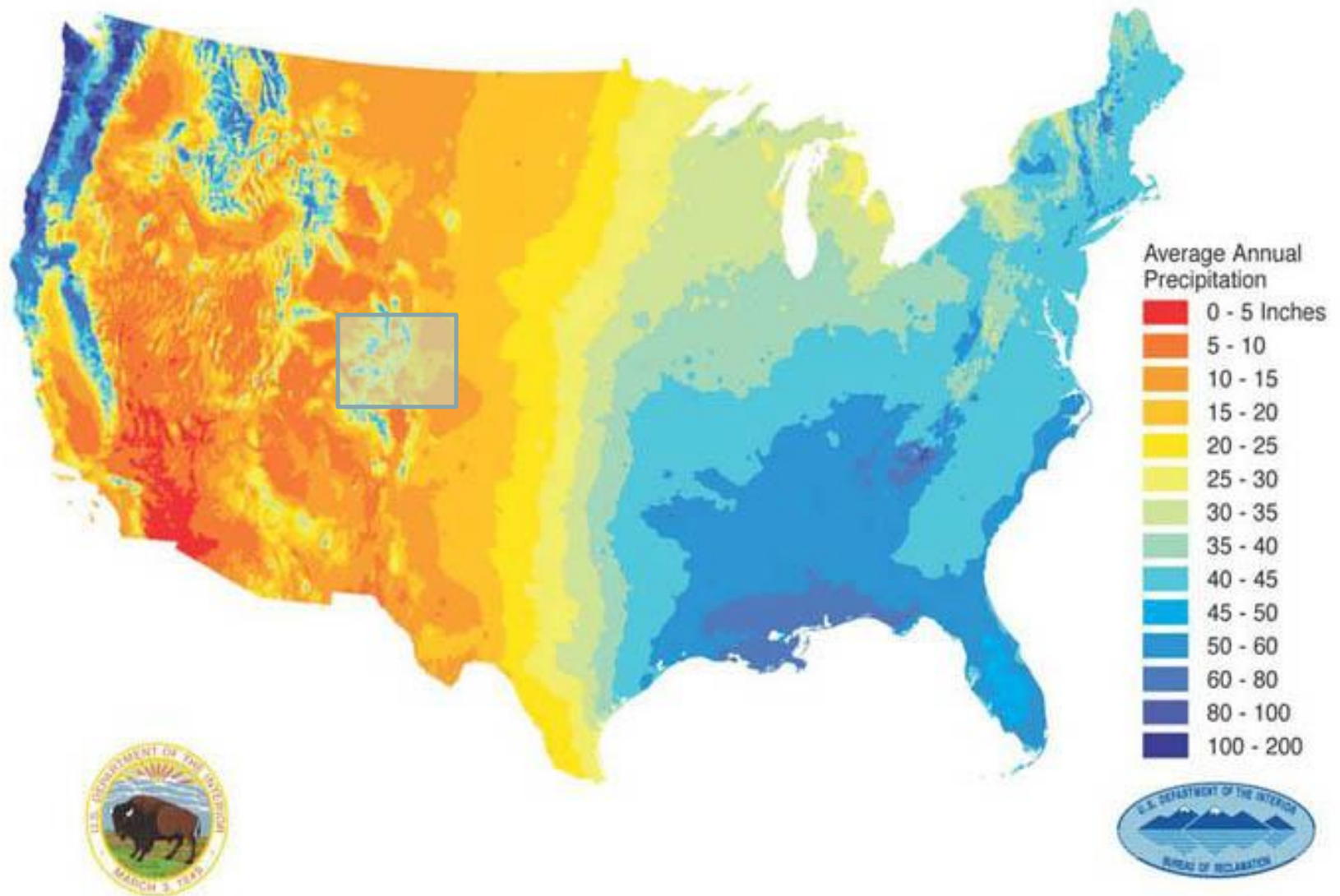
Open Space 1994



Open Space 2007

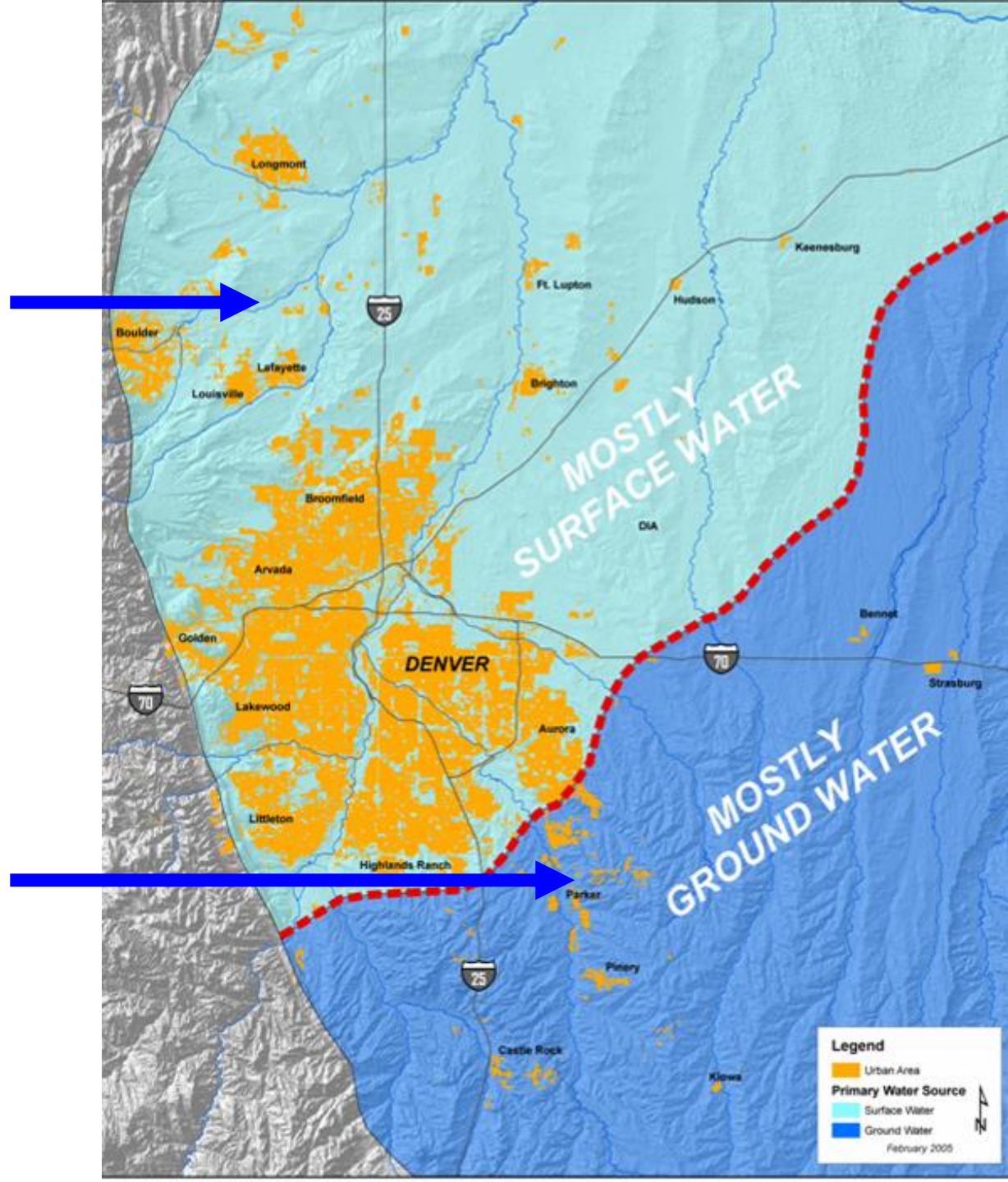


Average Inches of Annual Precipitation in the United States 1961-1990



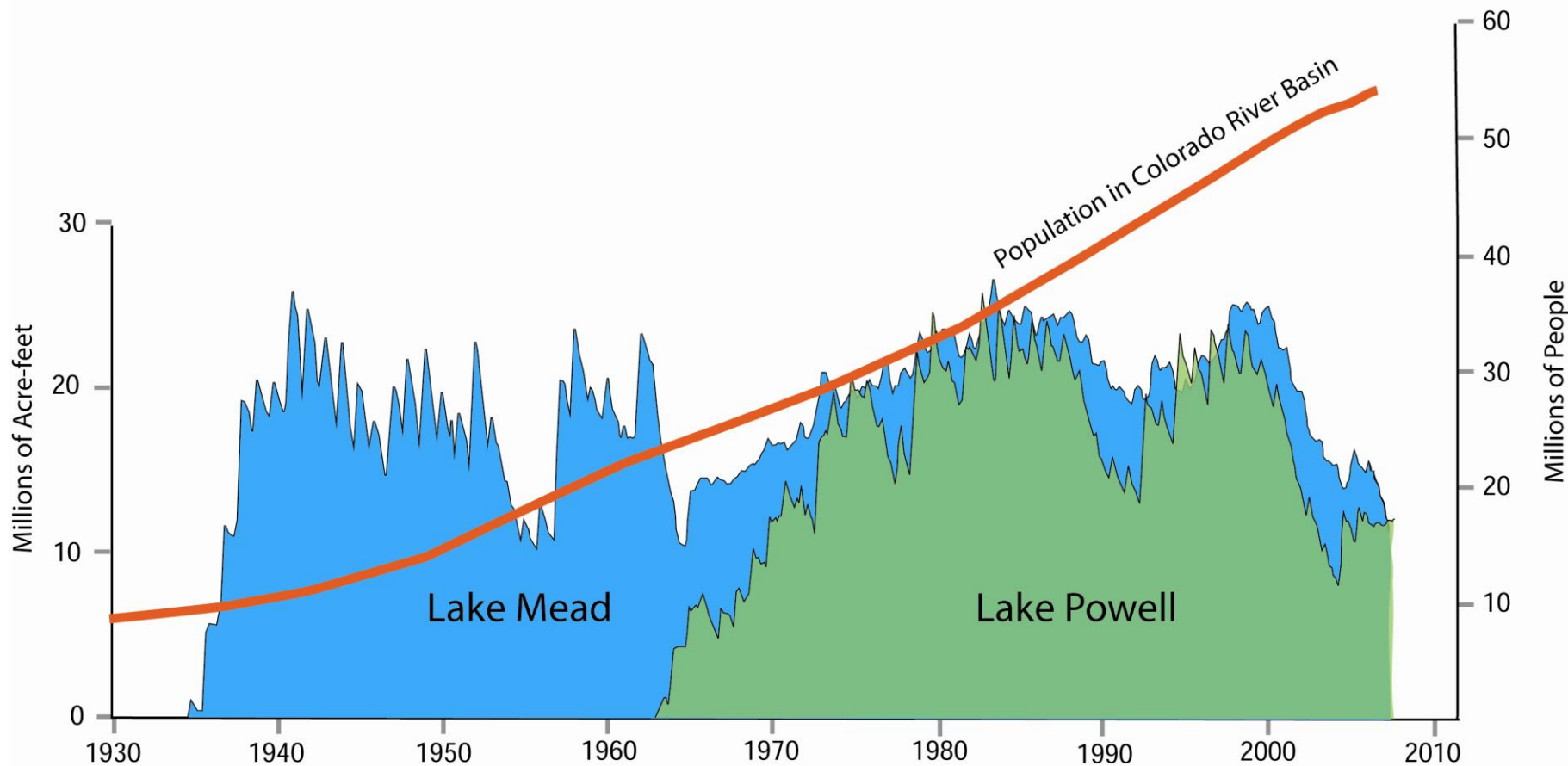
Climate
dependent
(drought)

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



RobertStock.com



Museums, Zoos and Your Children will save the World



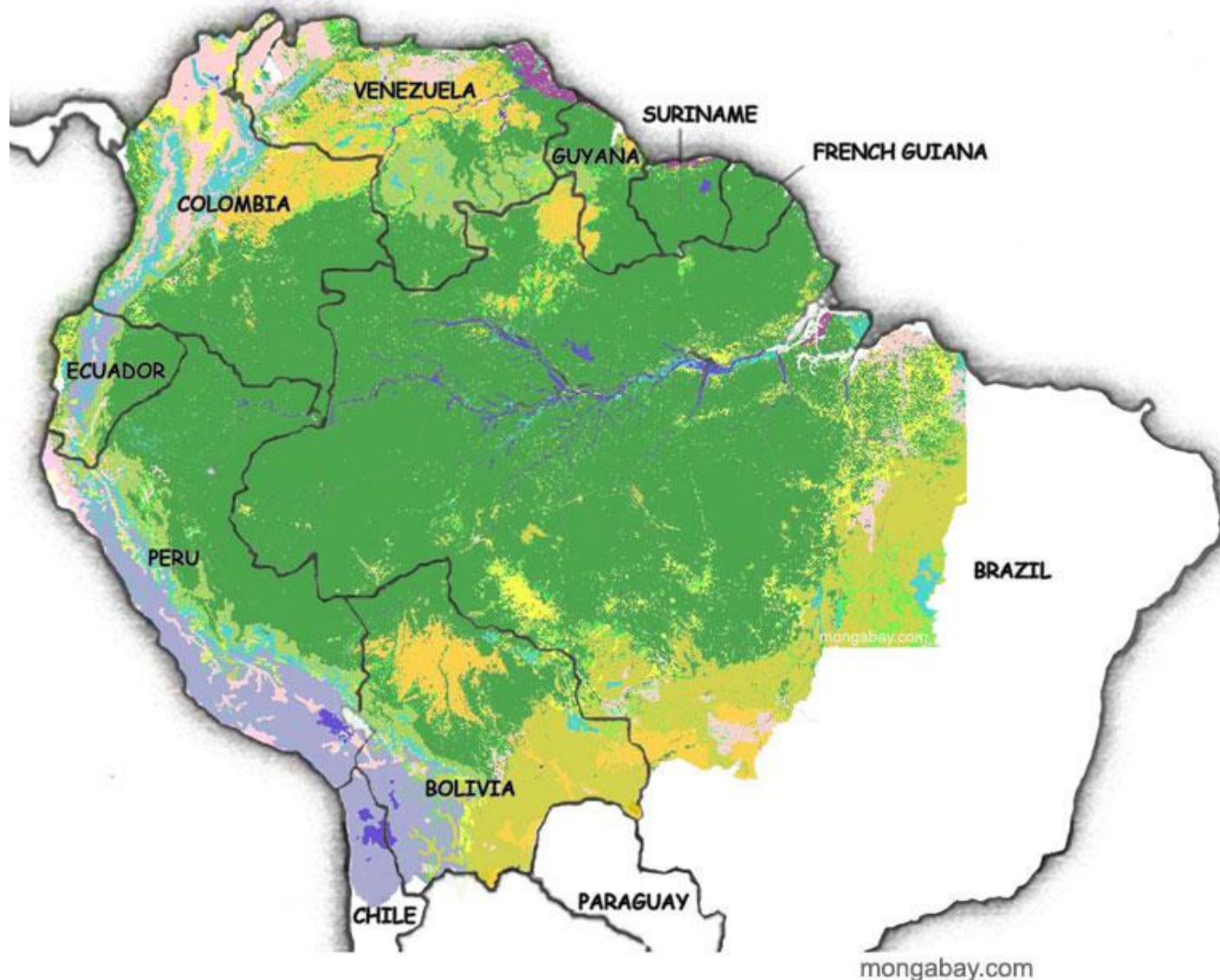






Neft Dashlari, oily rock

Off Baku, Caspian Sea



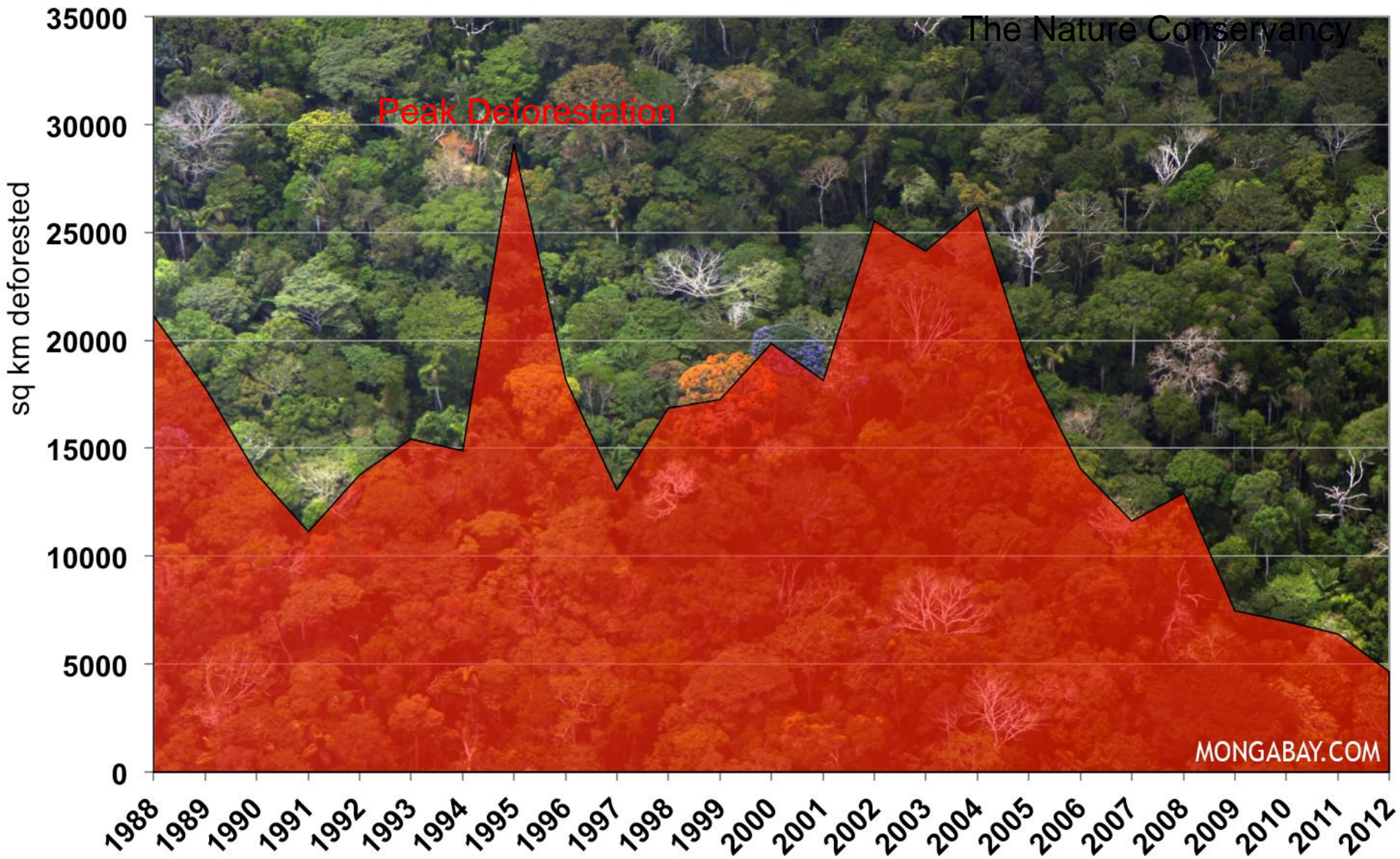
- Lowland moist forest
- Mangrove and coastal swamp forest
- Sub-montane forest
- Montane forest
- Fragmented forest
- Converted forest

- Inland water

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

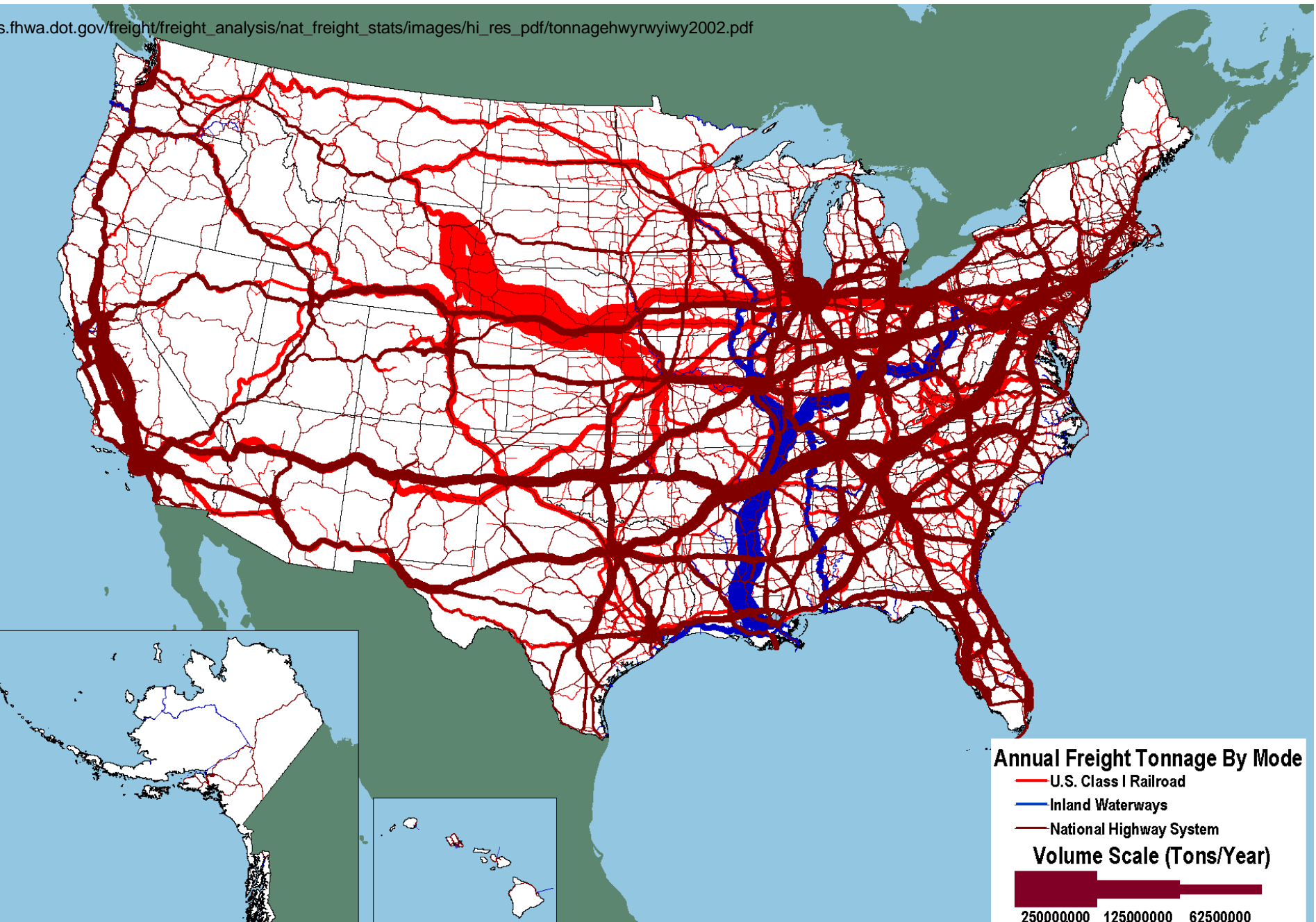
Based on the Vegetation Map of Tropical South America,
H.D. Eva et al. (1999) TREES Publications Series, European

Deforestation in the Brazilian Amazon, 1988-2012



Tonnage on Highways, Railroads and Inland Waterways: 2002

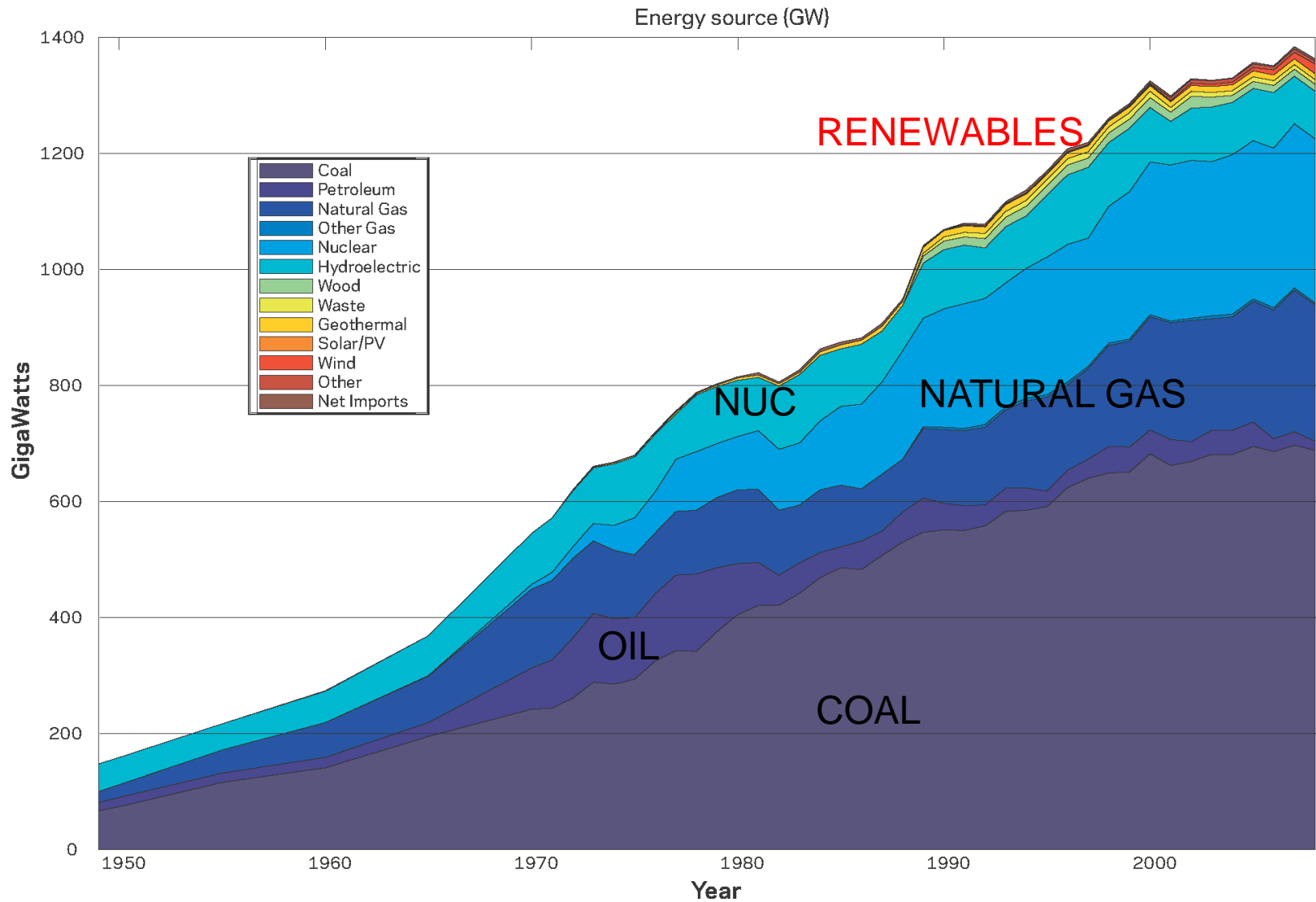
s.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/images/hi_res_pdf/tonnagehwyrwywy2002.pdf



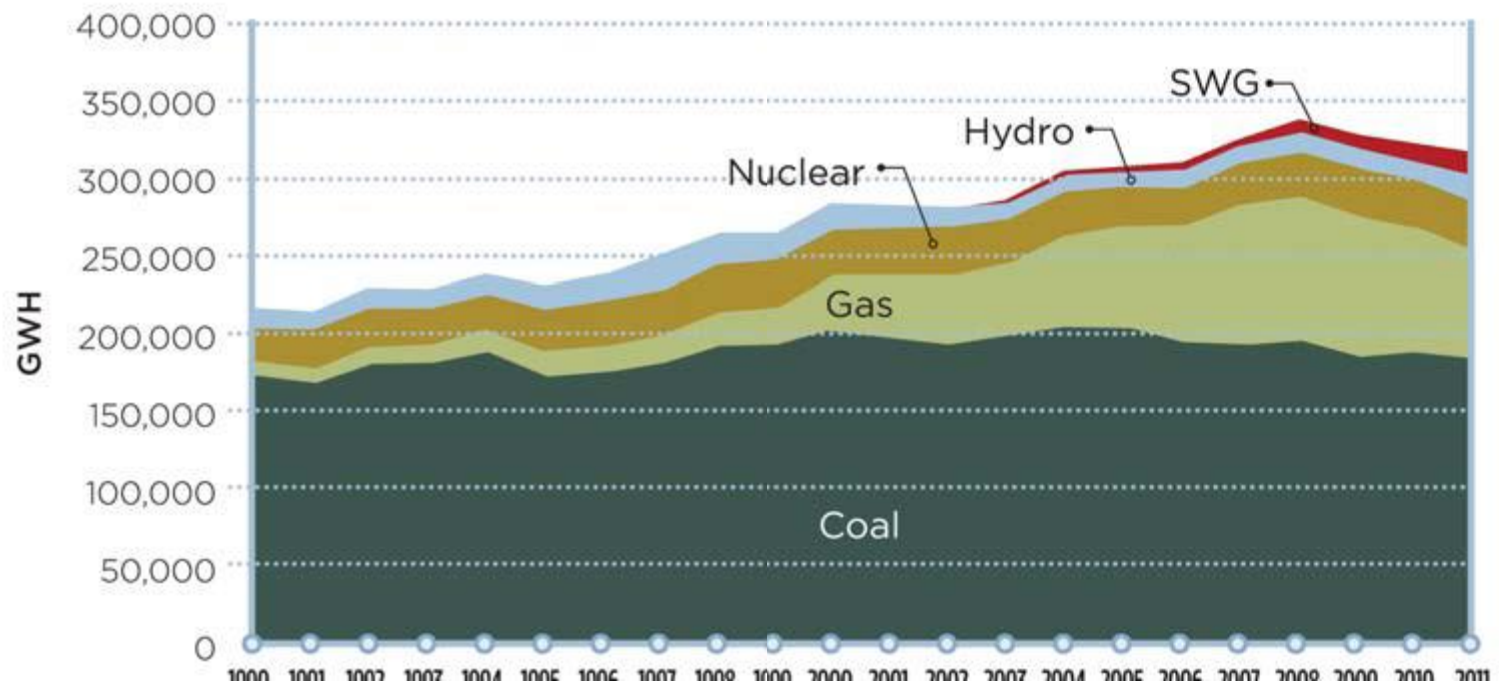


Courtesy of <http://www.peabodyenergy.com/>

Historical US electricity production, by generation source.



ROCKY MT REGION



Mountain West power generation by fuel type

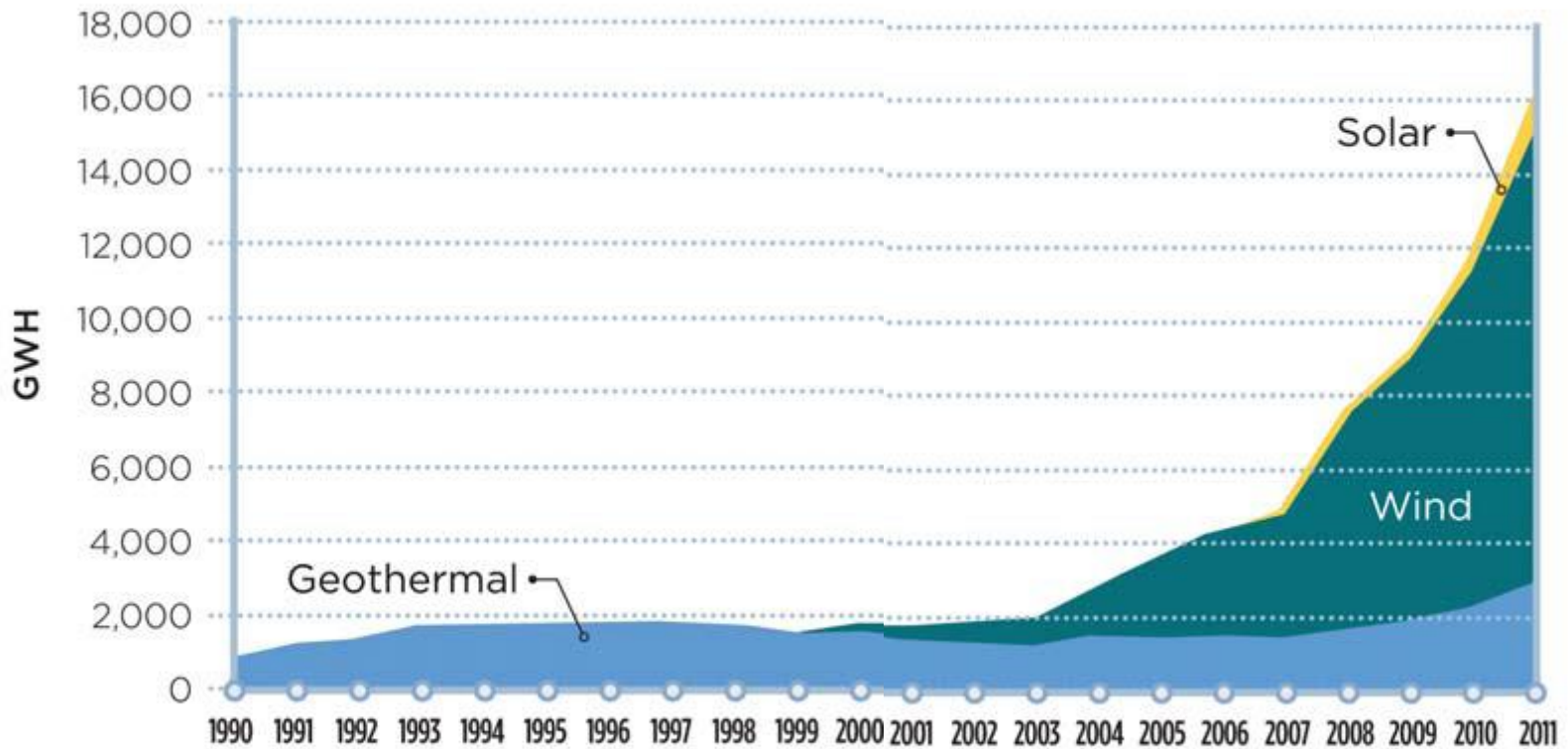


Figure 8. *Central Station Renewable Energy Generation in the Mountain West*

WESTERN RESOURCE ADVOCATES

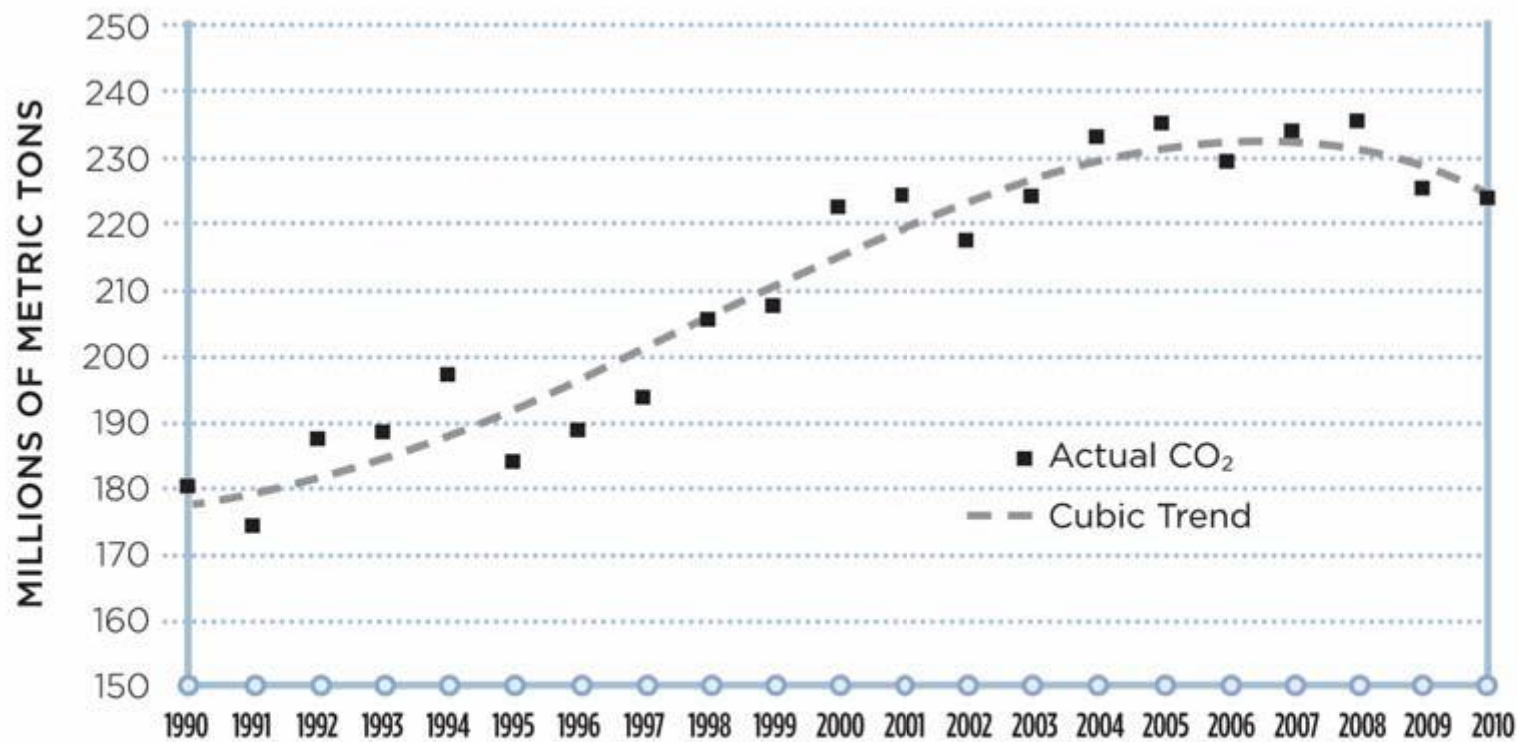
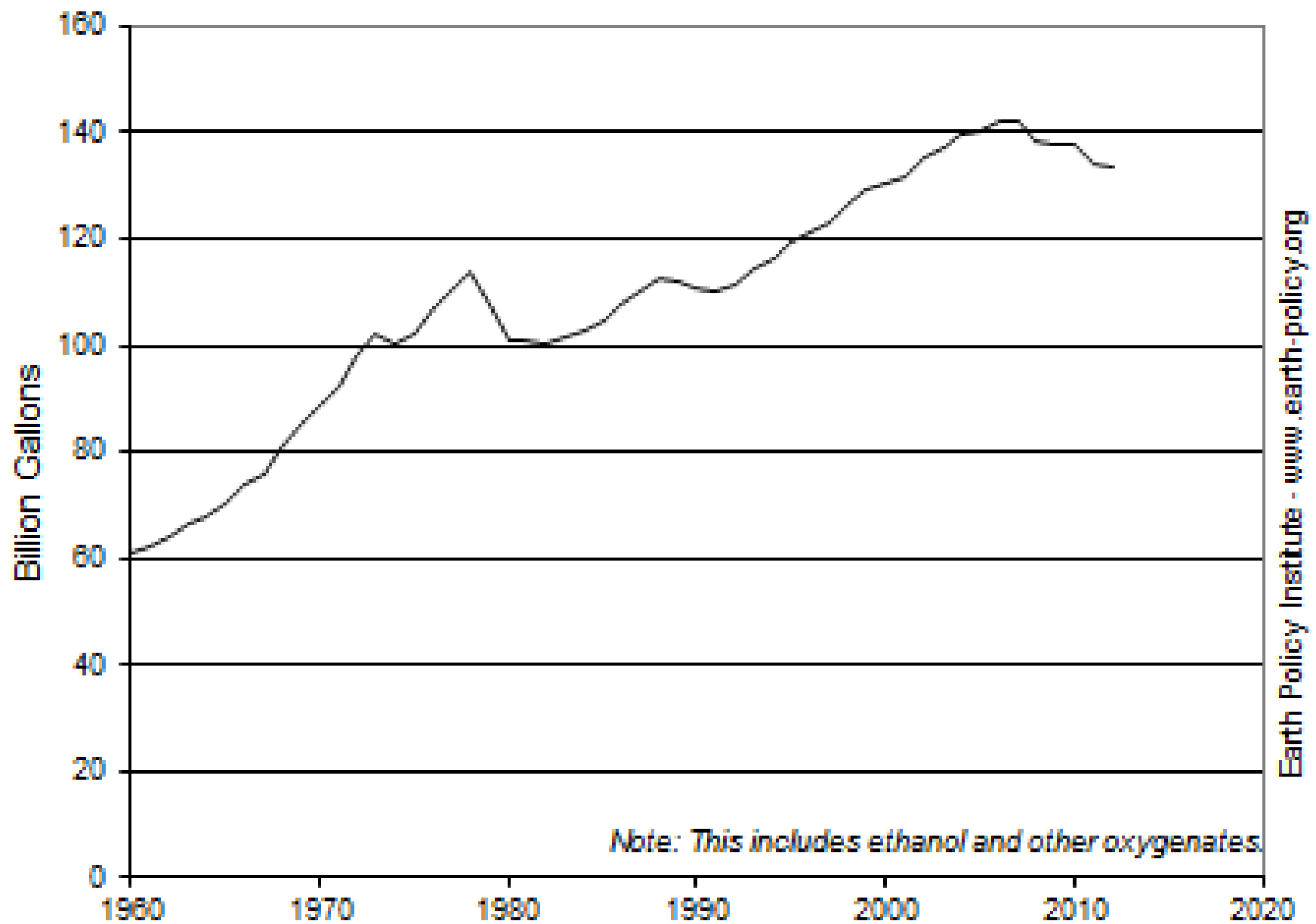


Figure 1. *CO₂ Emissions from the Electric Power Sector in the Mountain West*

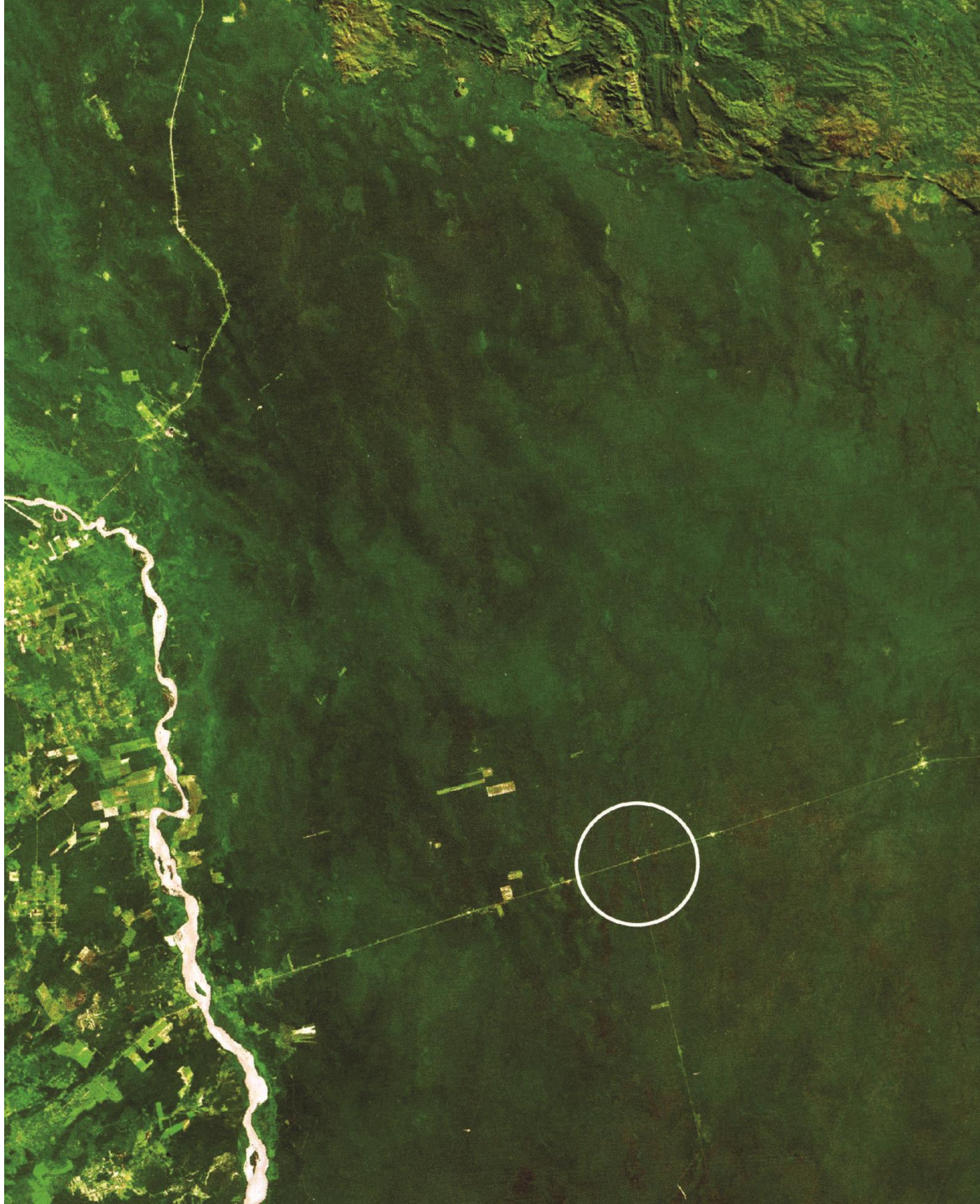
U.S. Motor Gasoline Consumption, 1960-2012



Note: This includes ethanol and other oxygenates.

Source: EIA

Bolivia



1975

Bolivia

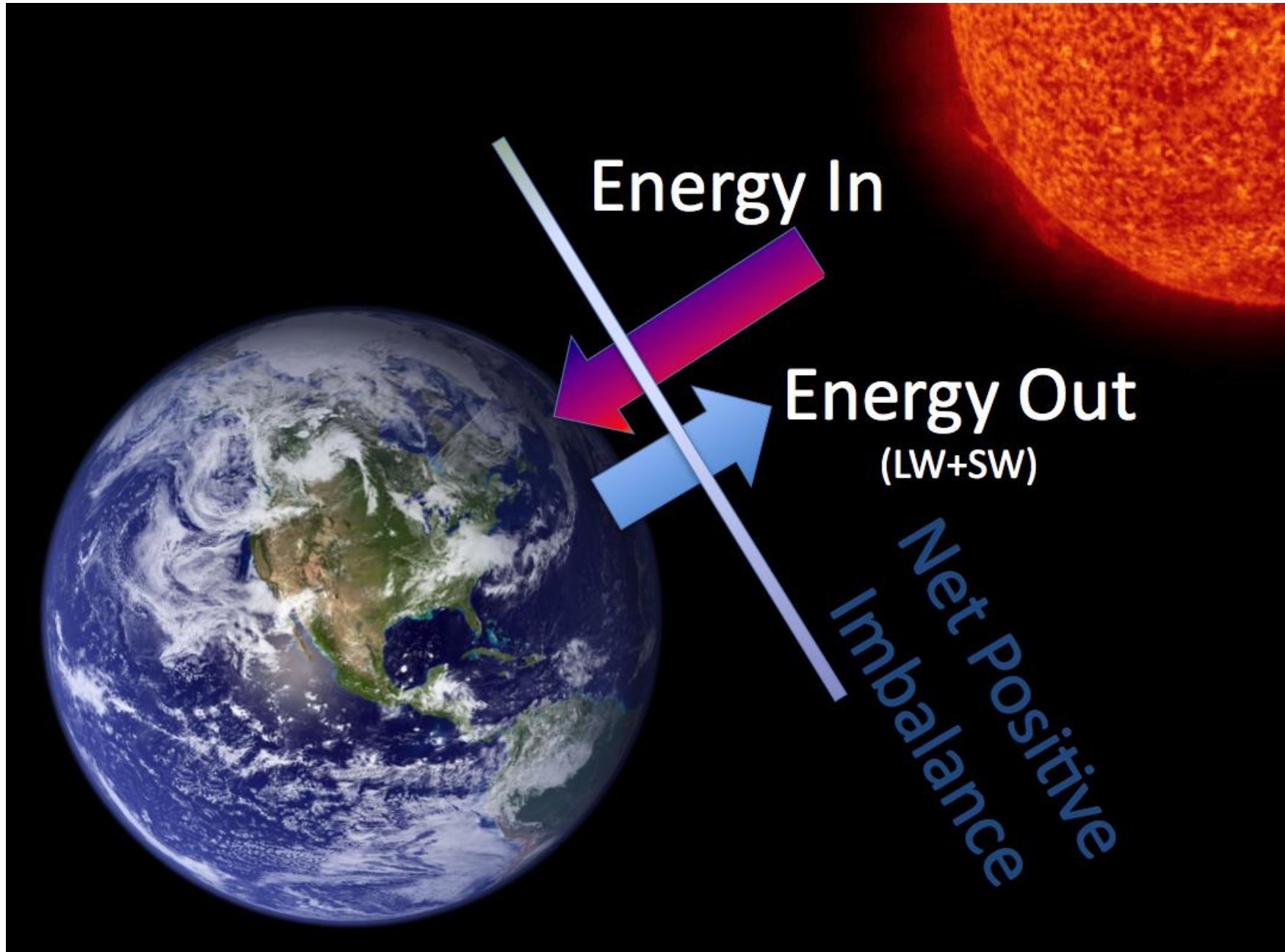


2003



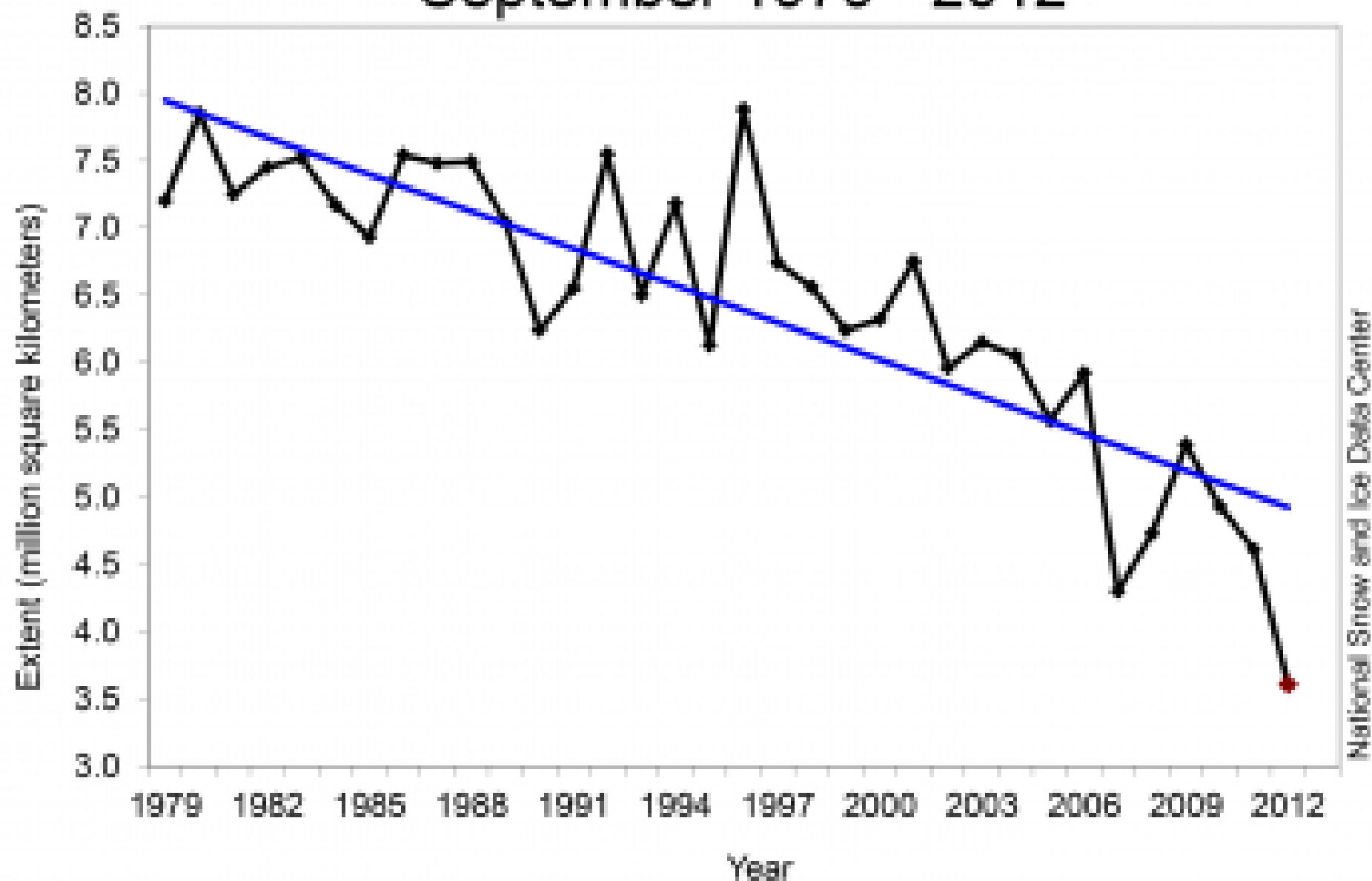
Chores on the Steiner family farm, Illinois; Lee News Service, 2/2013

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



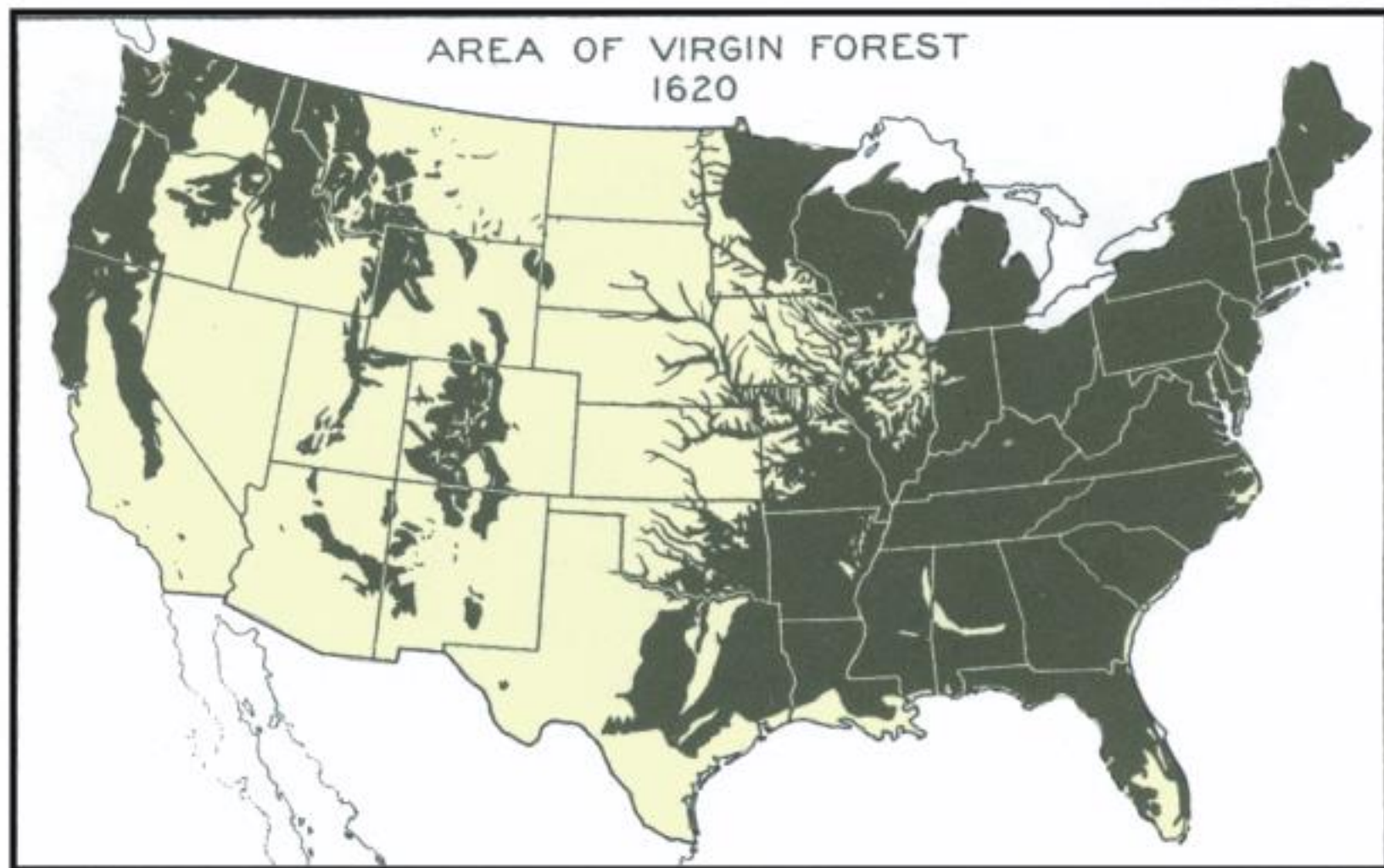


Figure 12.2 "Area of virgin forest," United States, 1620. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)

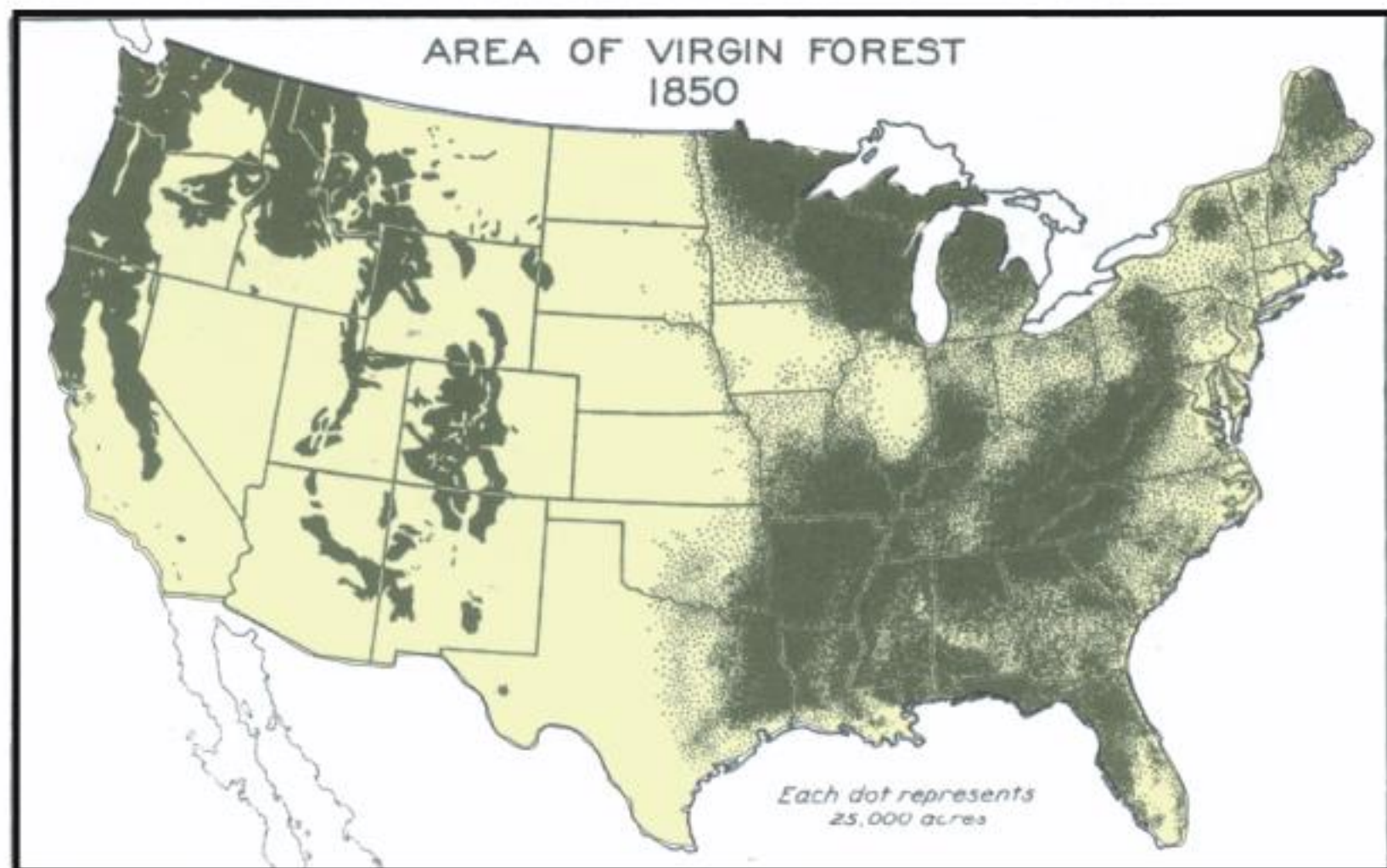


Figure 12.3 "Area of virgin forest," United States, 1850. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)

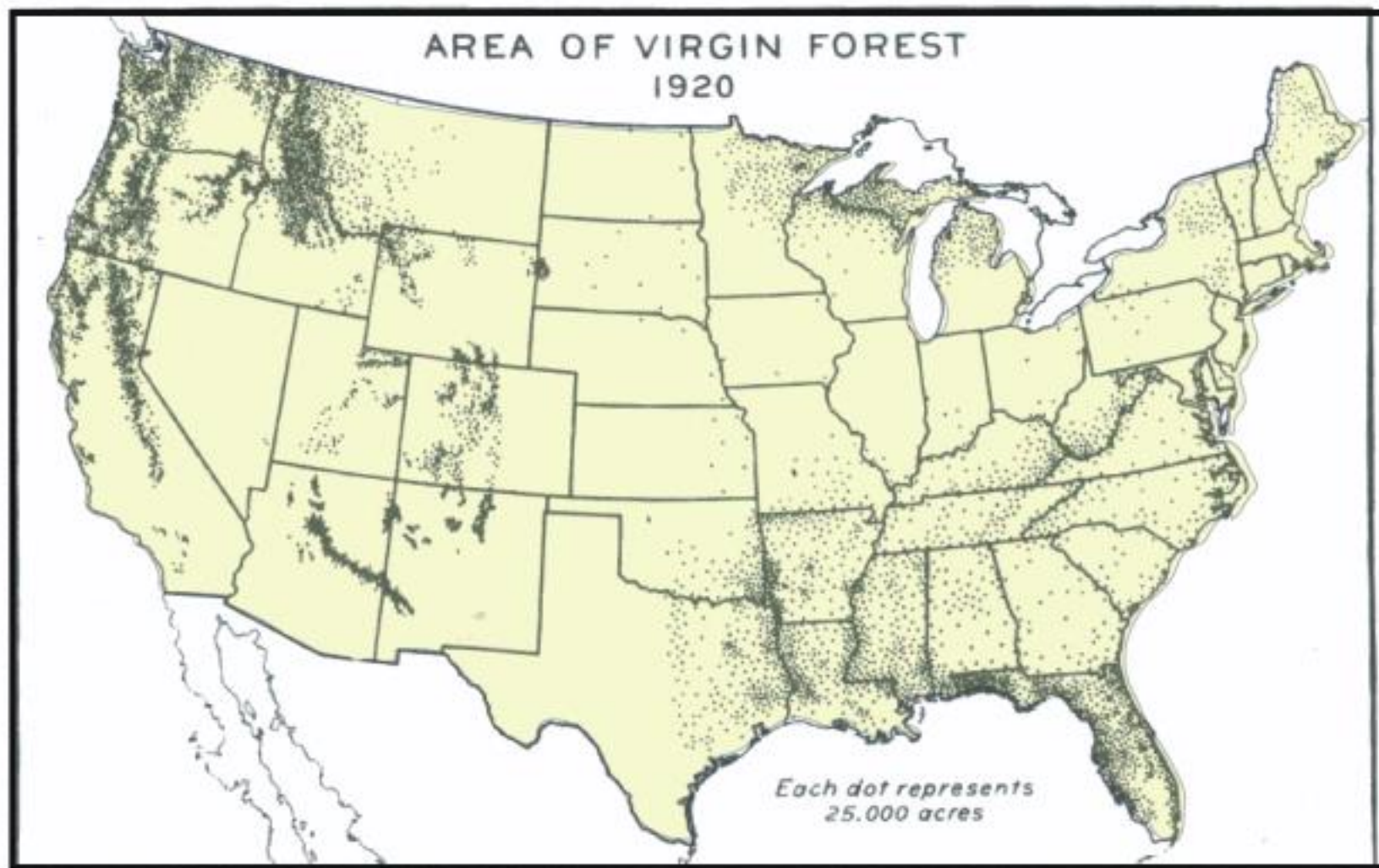
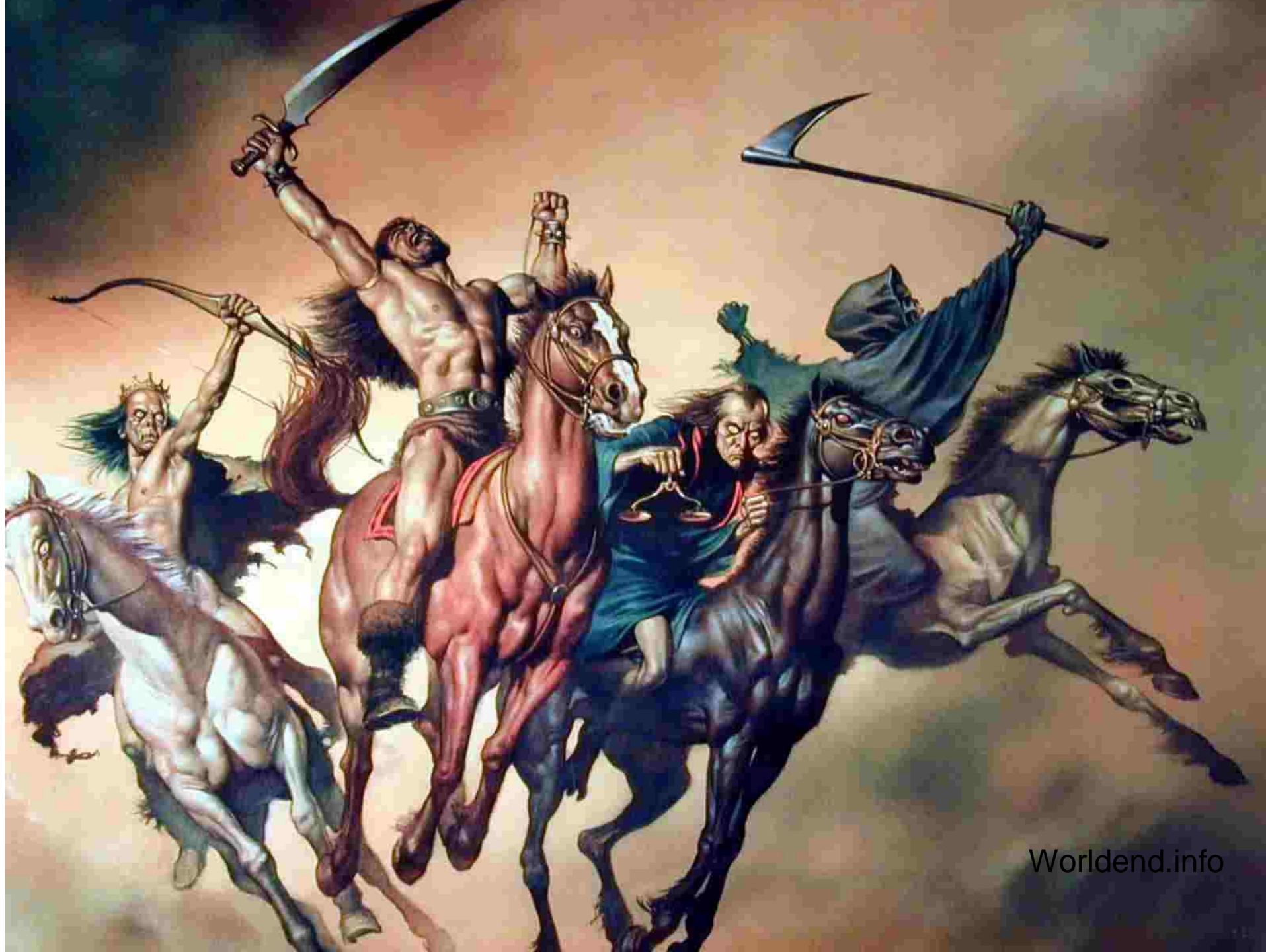


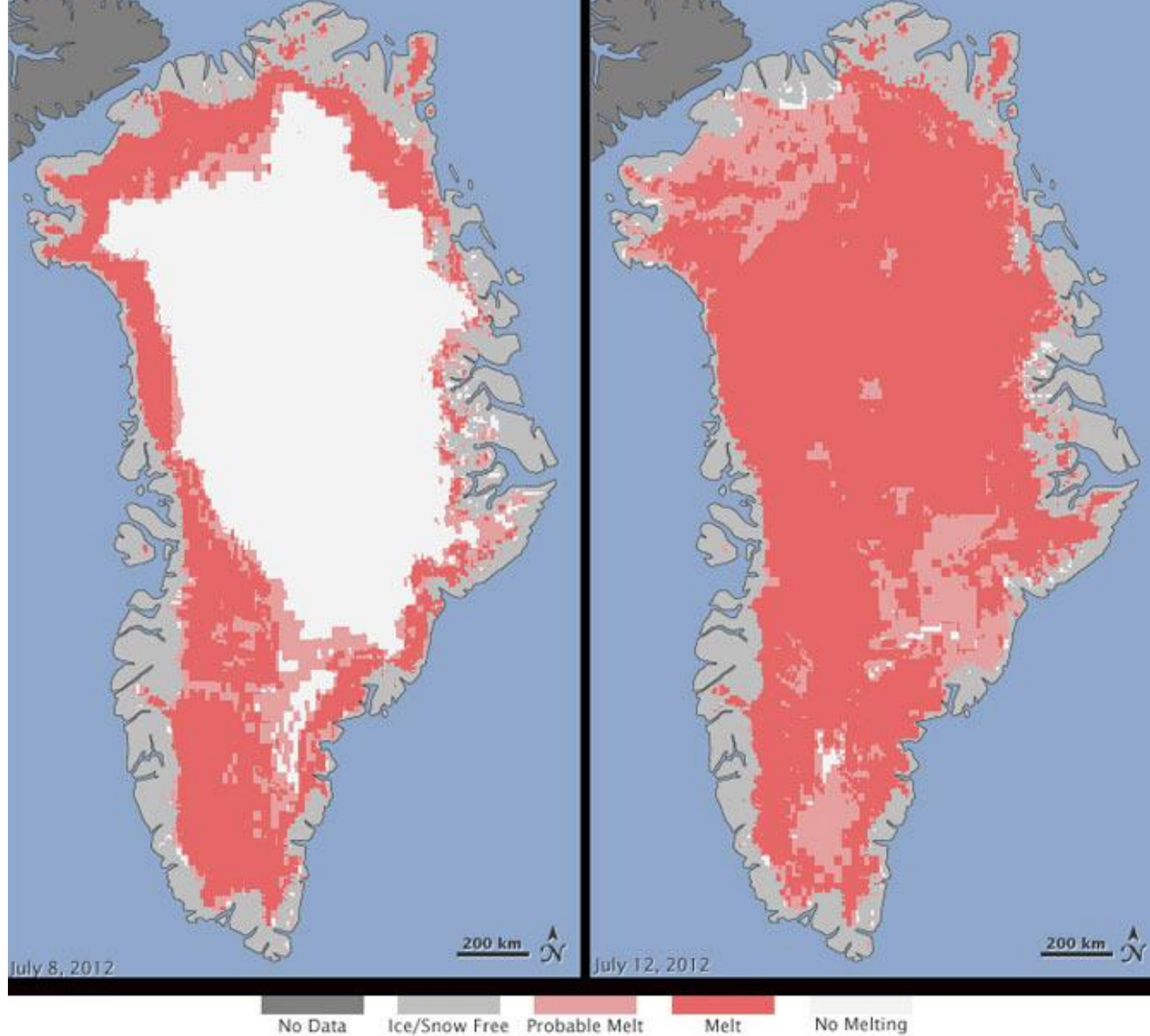
Figure 12.4 "Area of virgin forest," United States, 1920. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)



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

Google earth

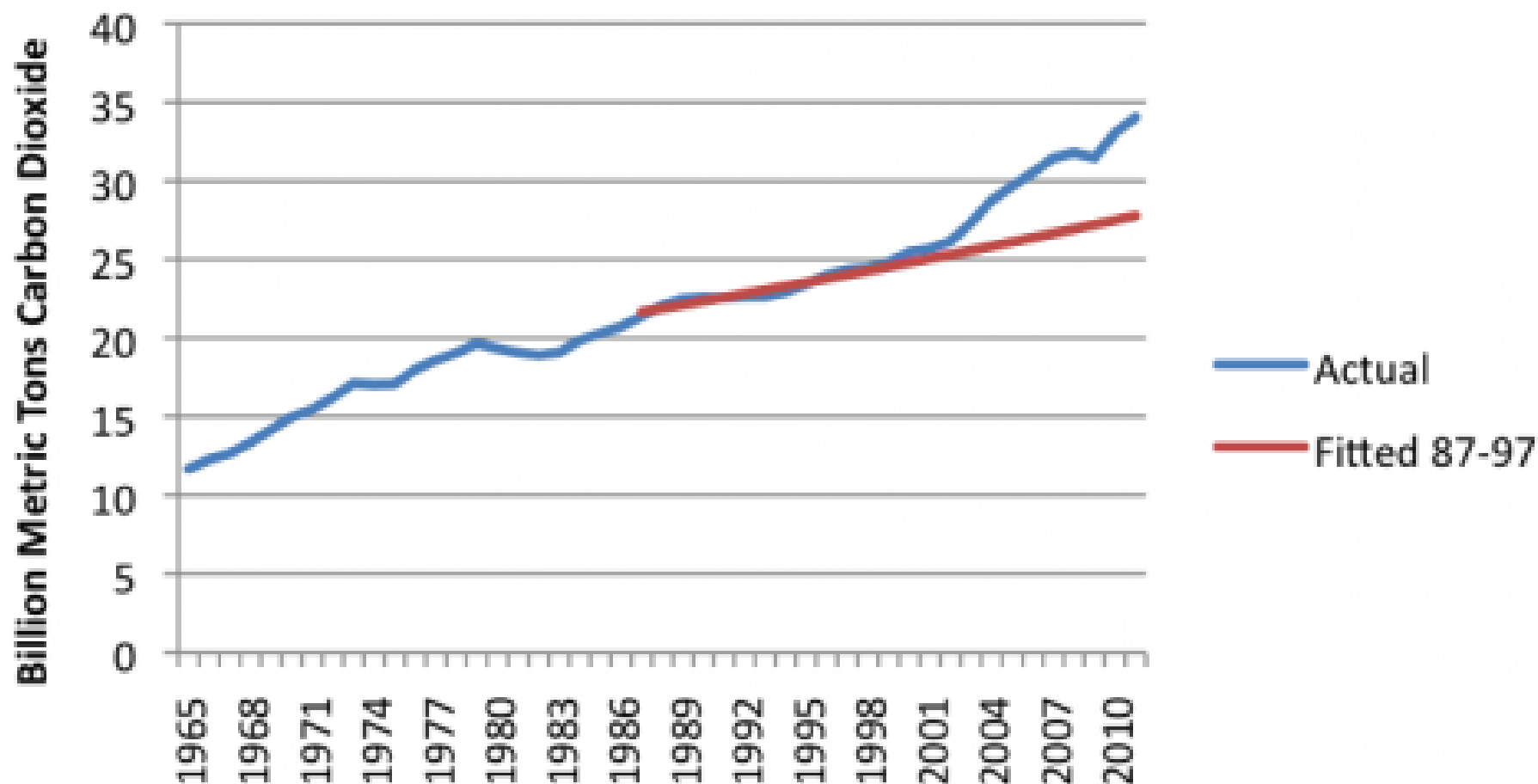
3770 ft

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

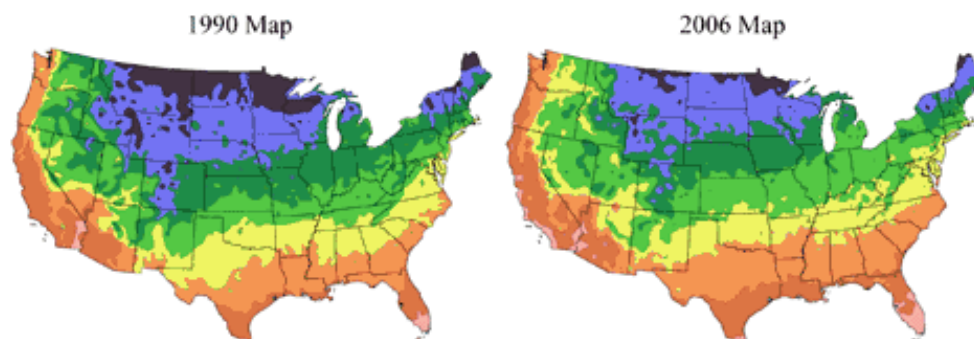
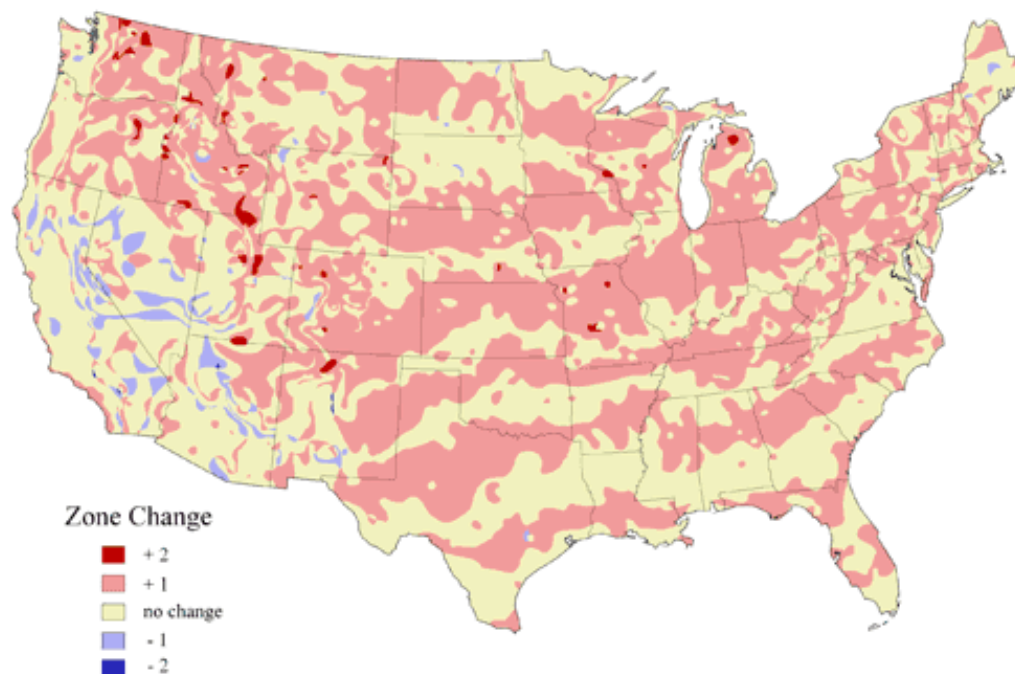




World Fossil Fuel Carbon Dioxide Emissions



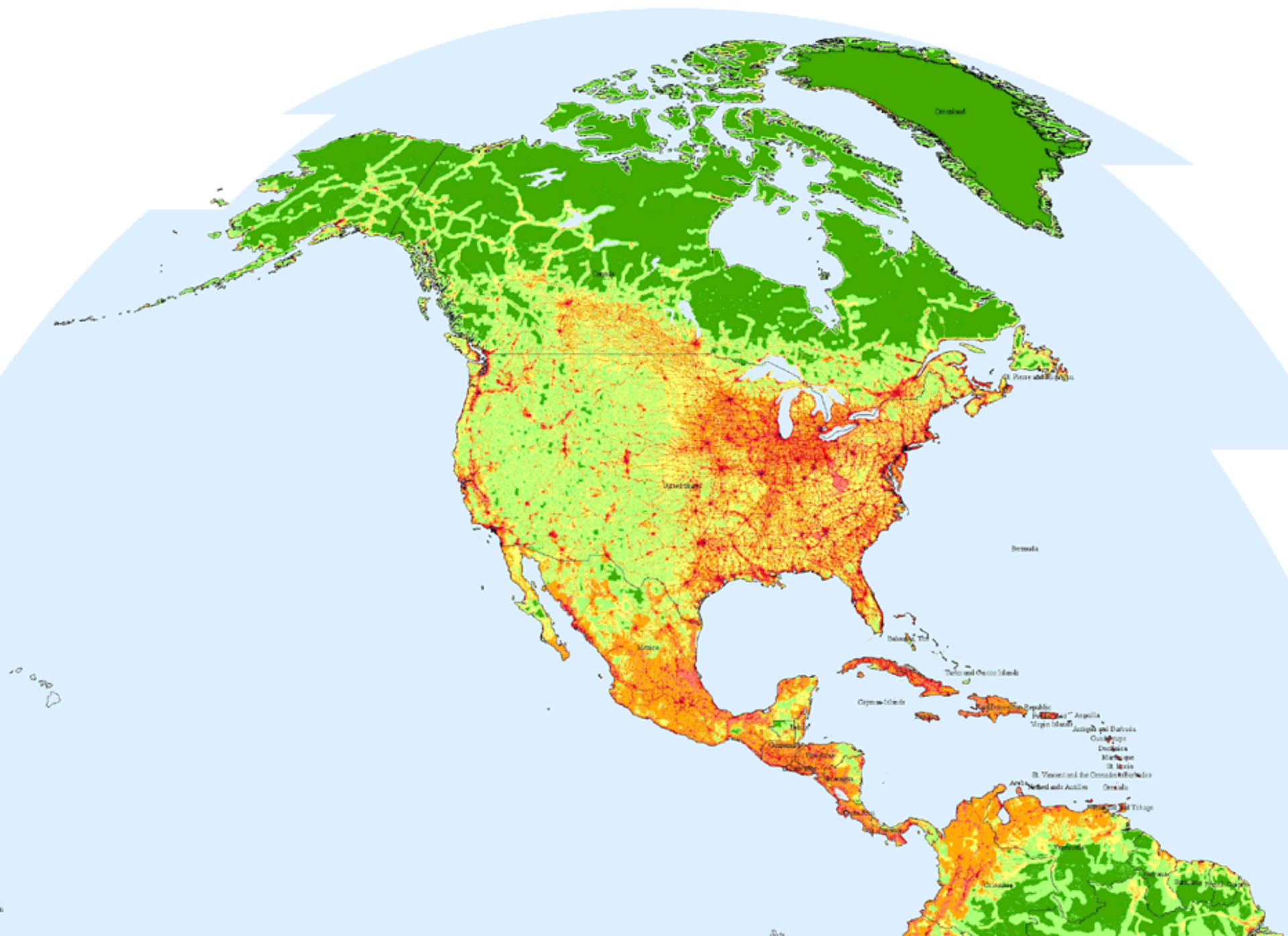
Differences between 1990 USDA hardiness
zones and 2006 arborday.org hardiness
zones reflect warmer climate



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.

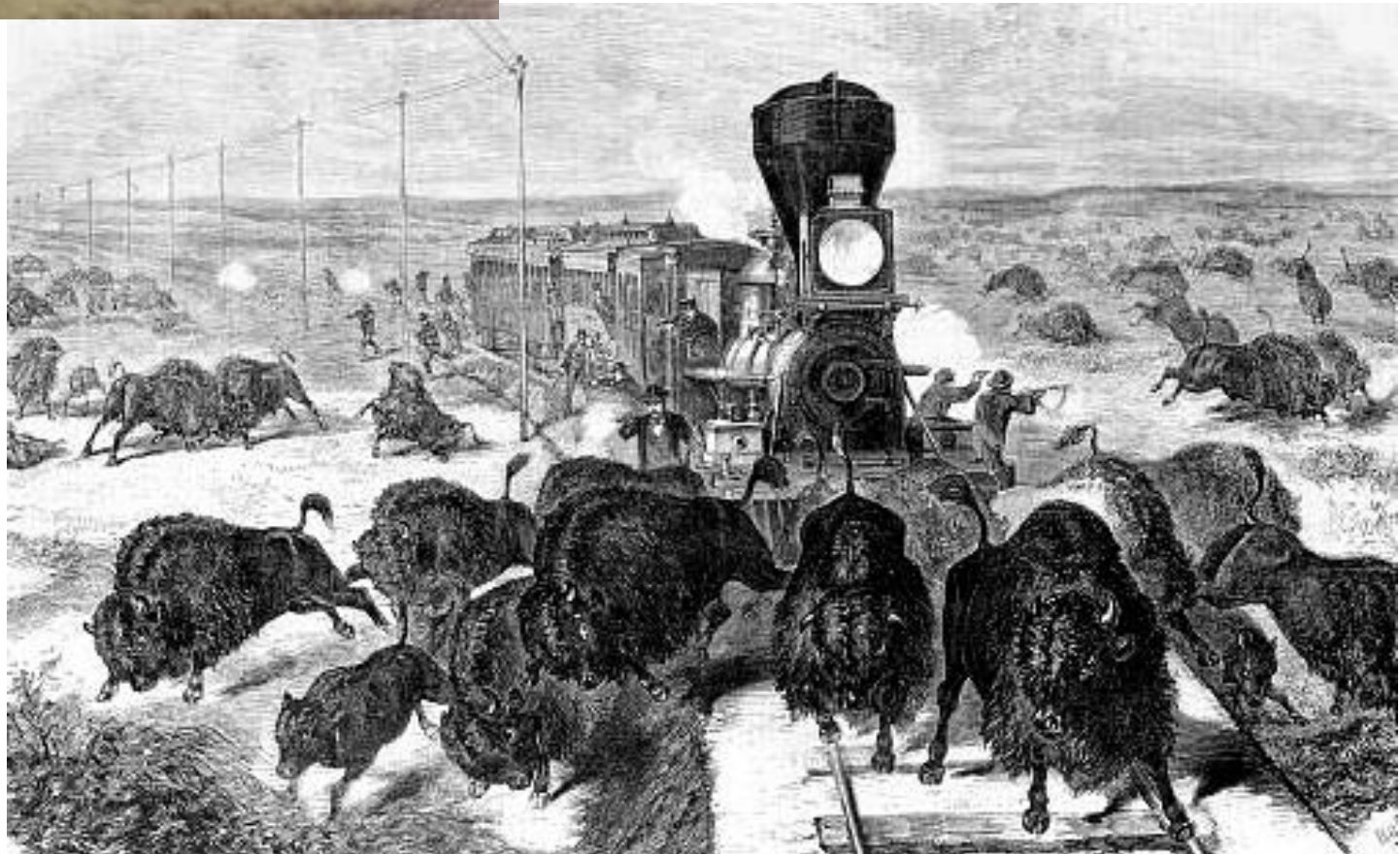






Among the Redwoods

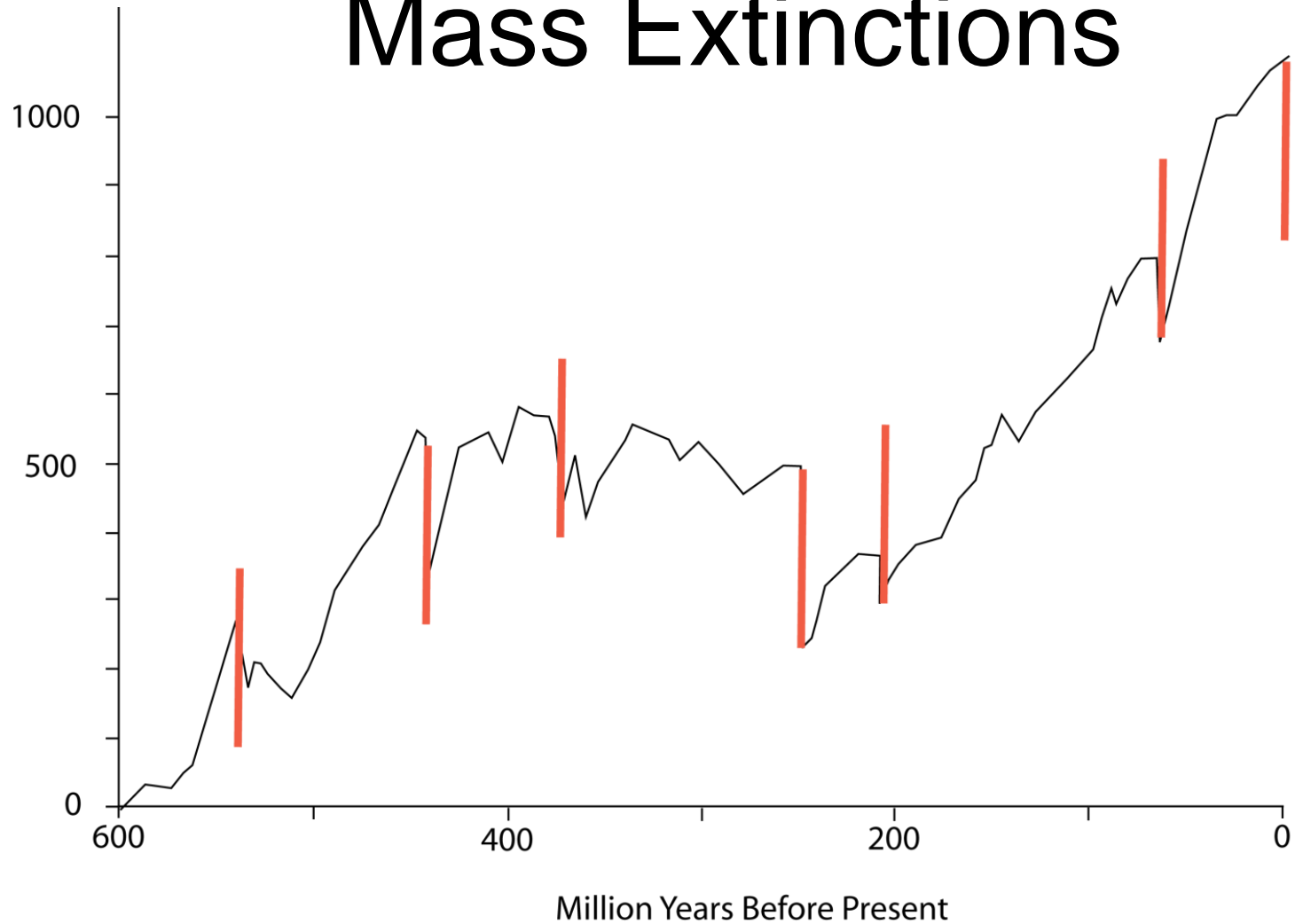
A.E. Ericson, ca. 1890



AMERICAN MUSEUM OF NATURAL HISTORY



Mass Extinctions



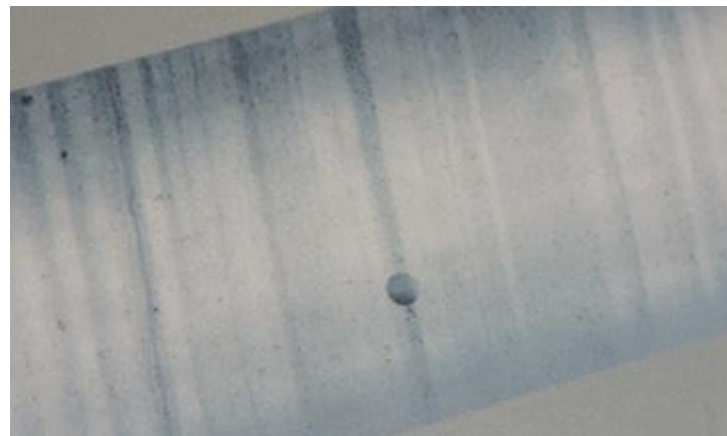
Diversity of marine families

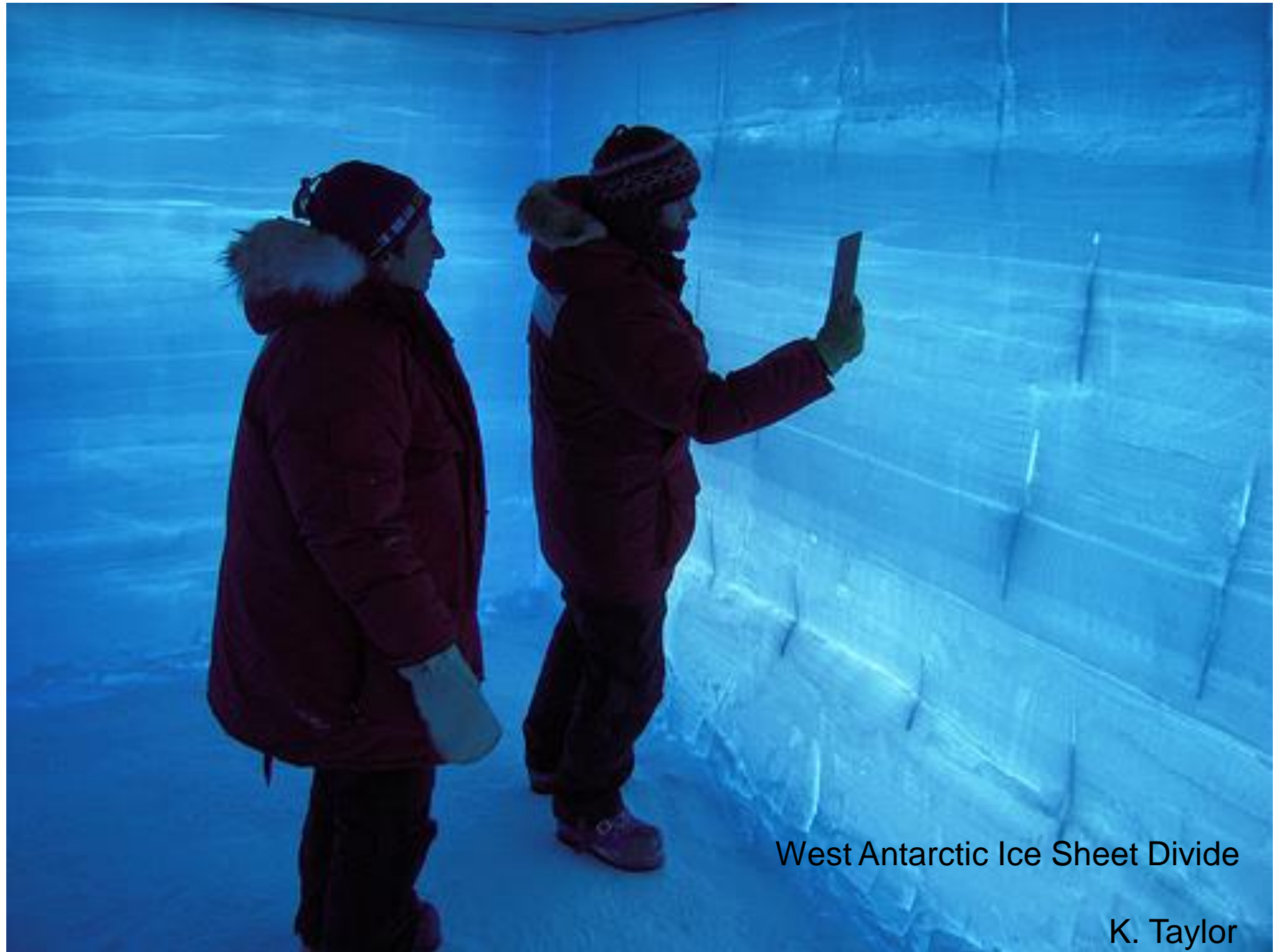
Raup, 1986

The data are in the strata

Changes are Happening

ICE





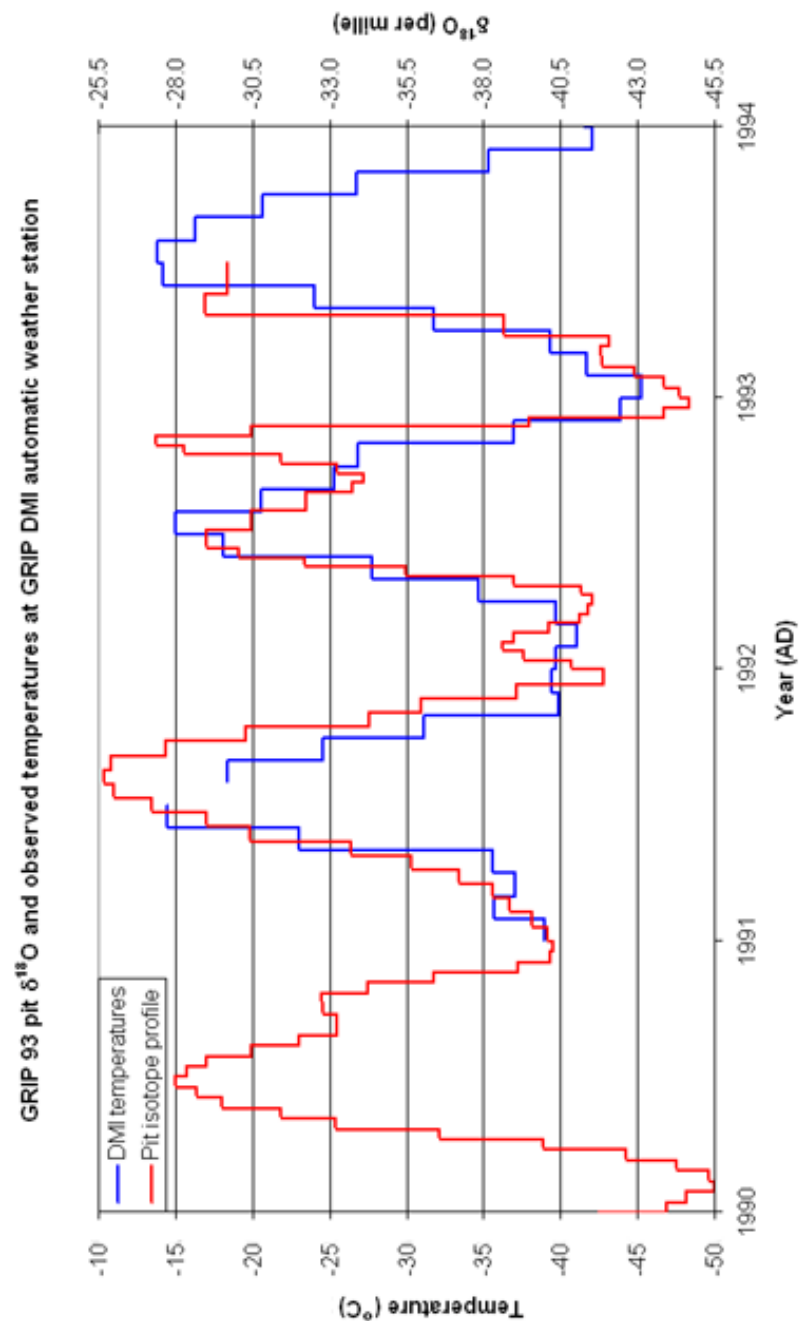
West Antarctic Ice Sheet Divide

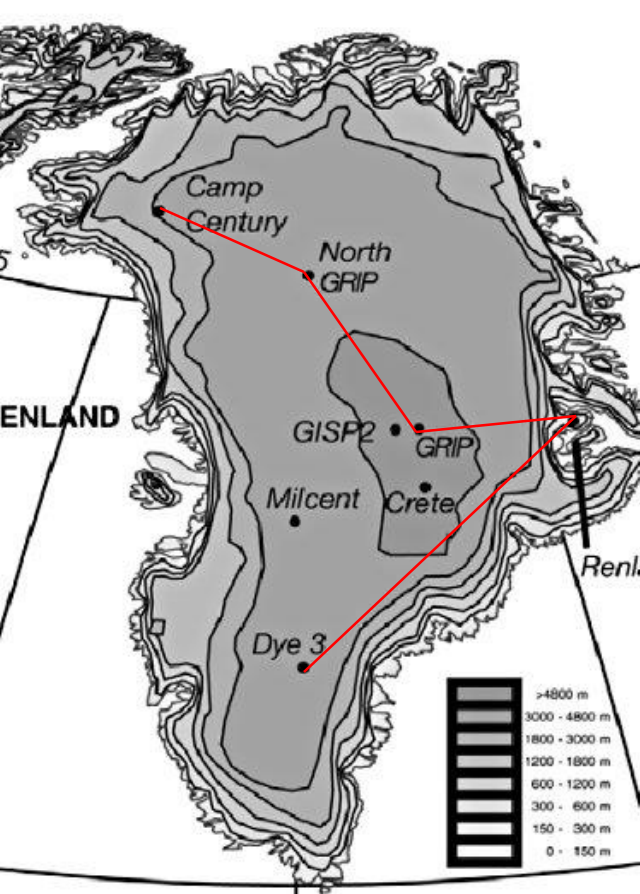
K. Taylor



Snow Pit Stratigraphy

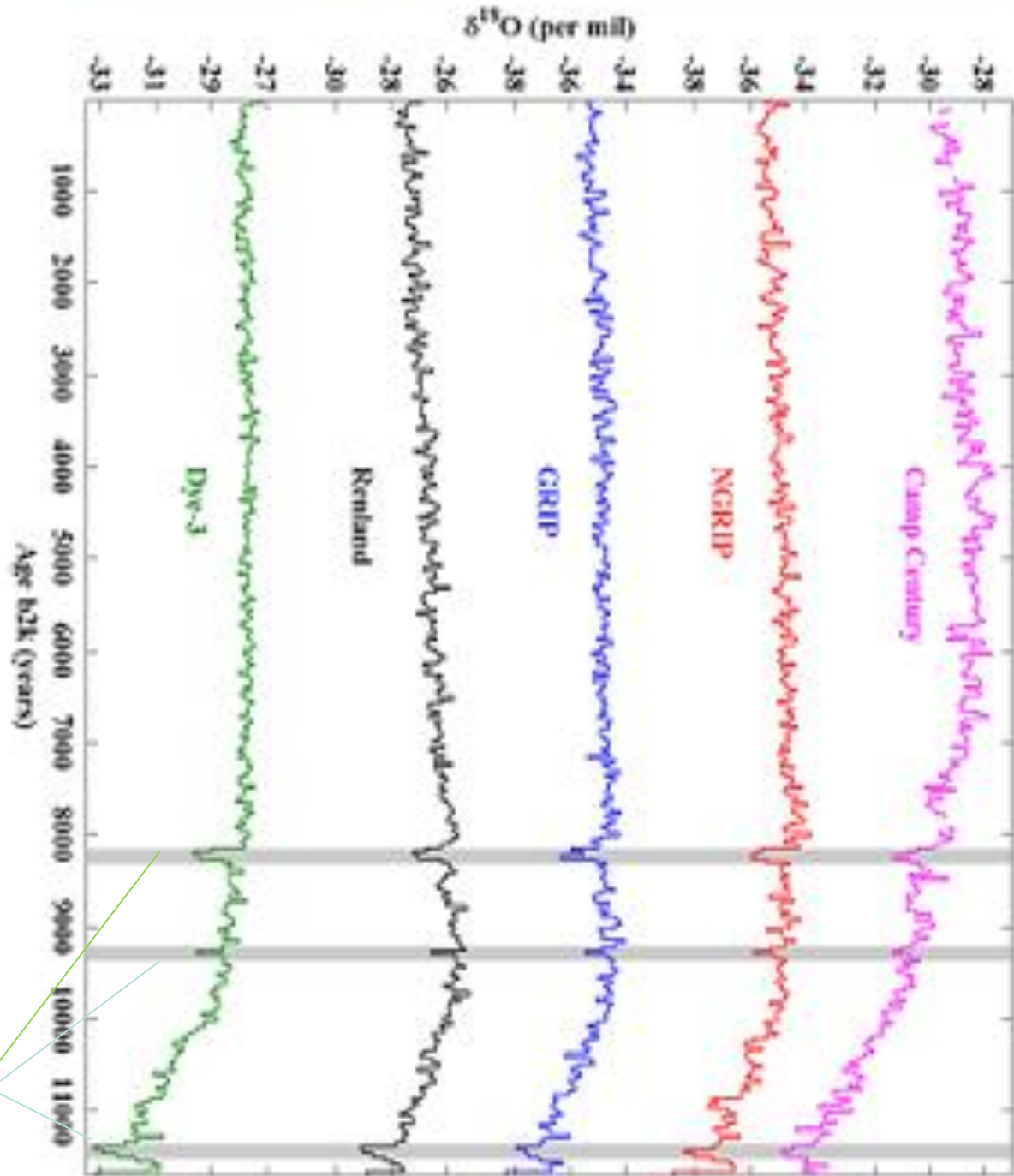
Temperature and Isotope Correlations
from Snow Pit at GRIP site, Greenland





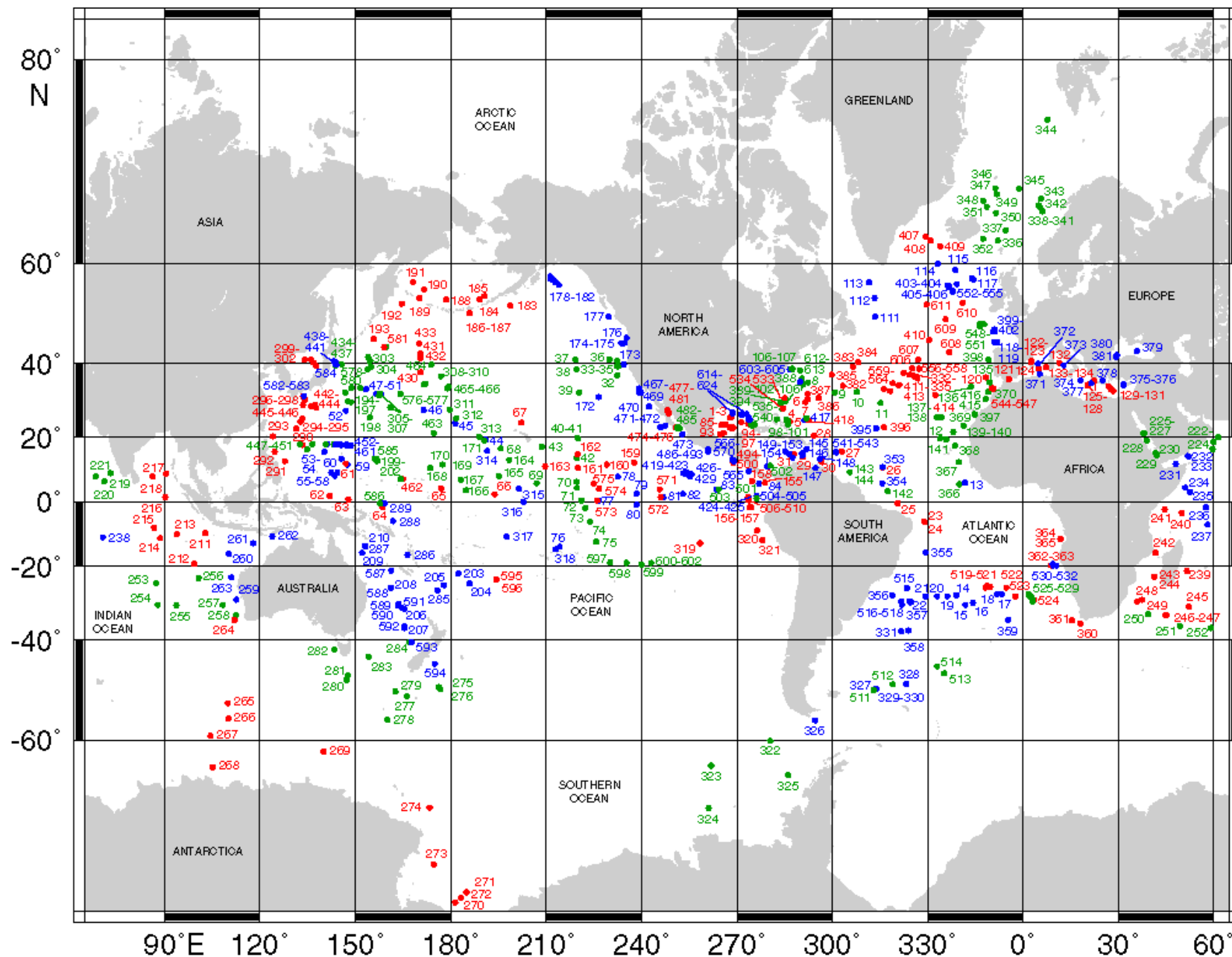
Holocene ice correlations across Greenland

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

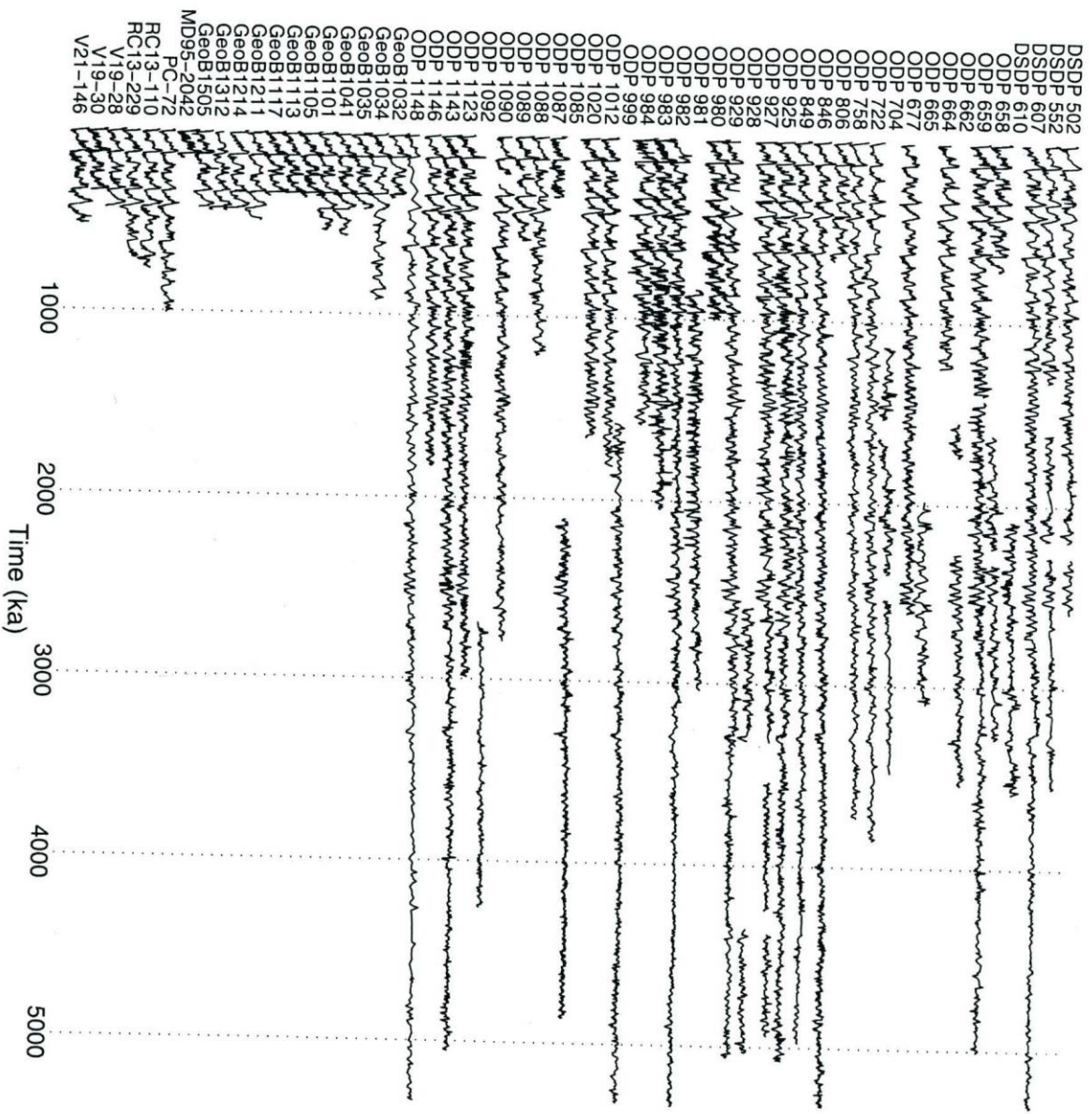


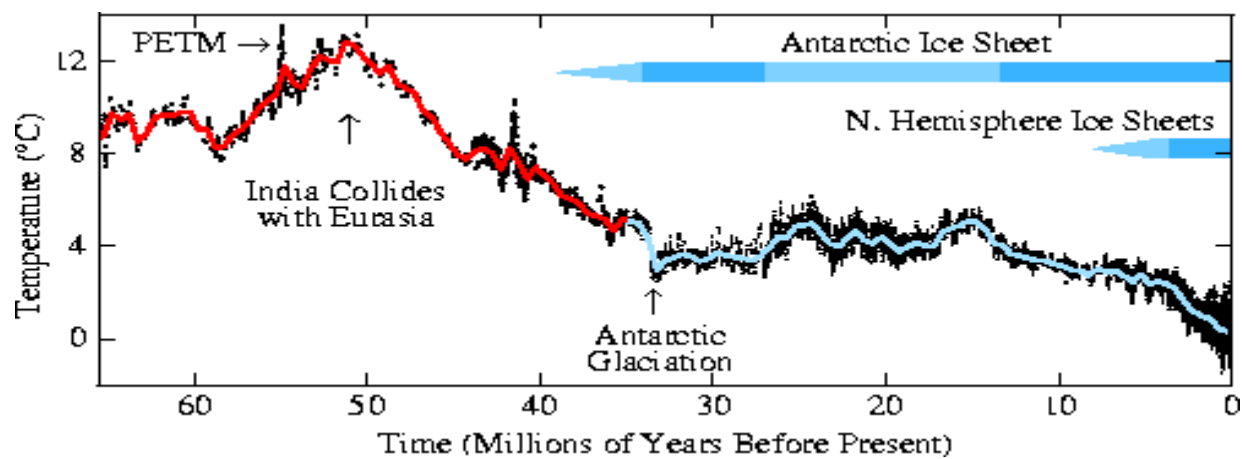
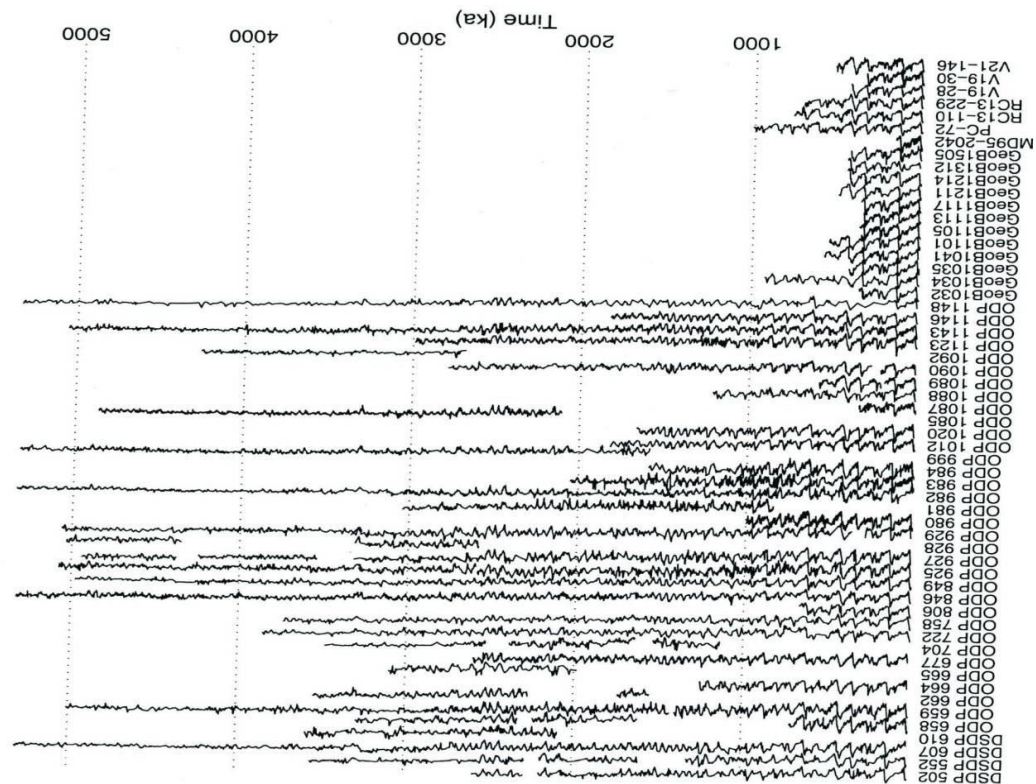
Changes are Happening

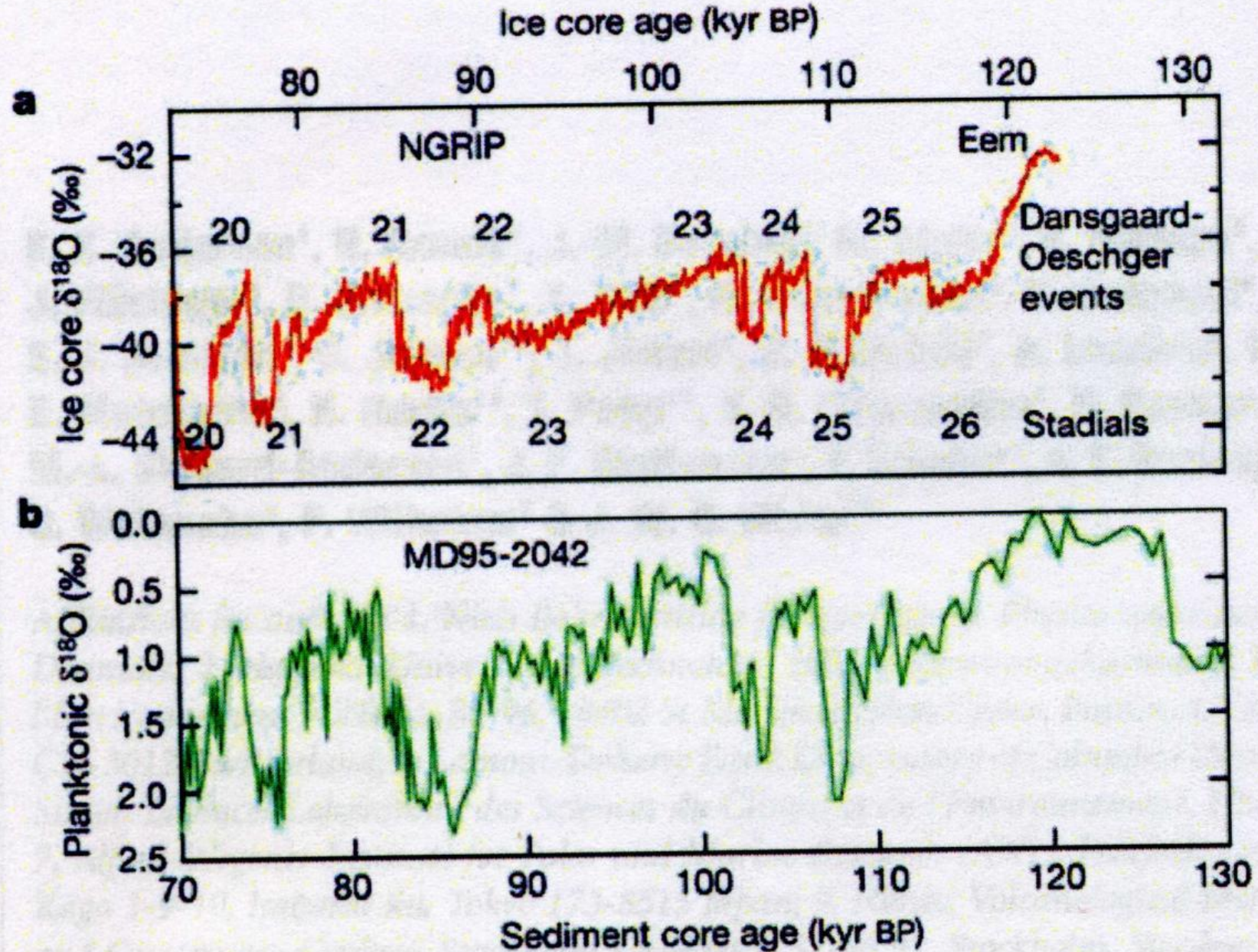
MUD



DSDP Legs 1-96, Sites 1-624







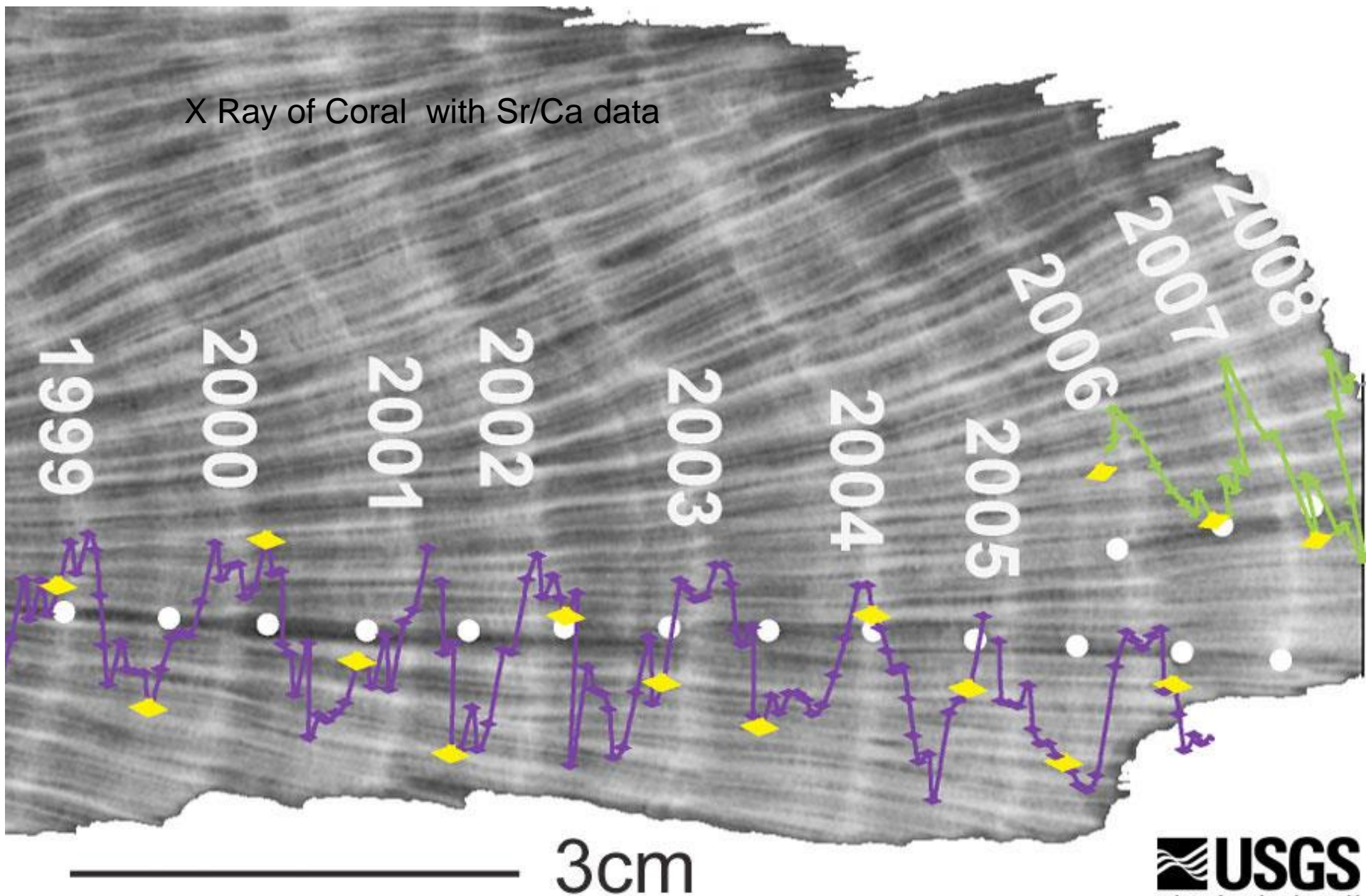
Ice to Mud Correlation

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

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory



PARTS PER MILLION

400
380
360
340
320

1960

1970

1980

1990

2000

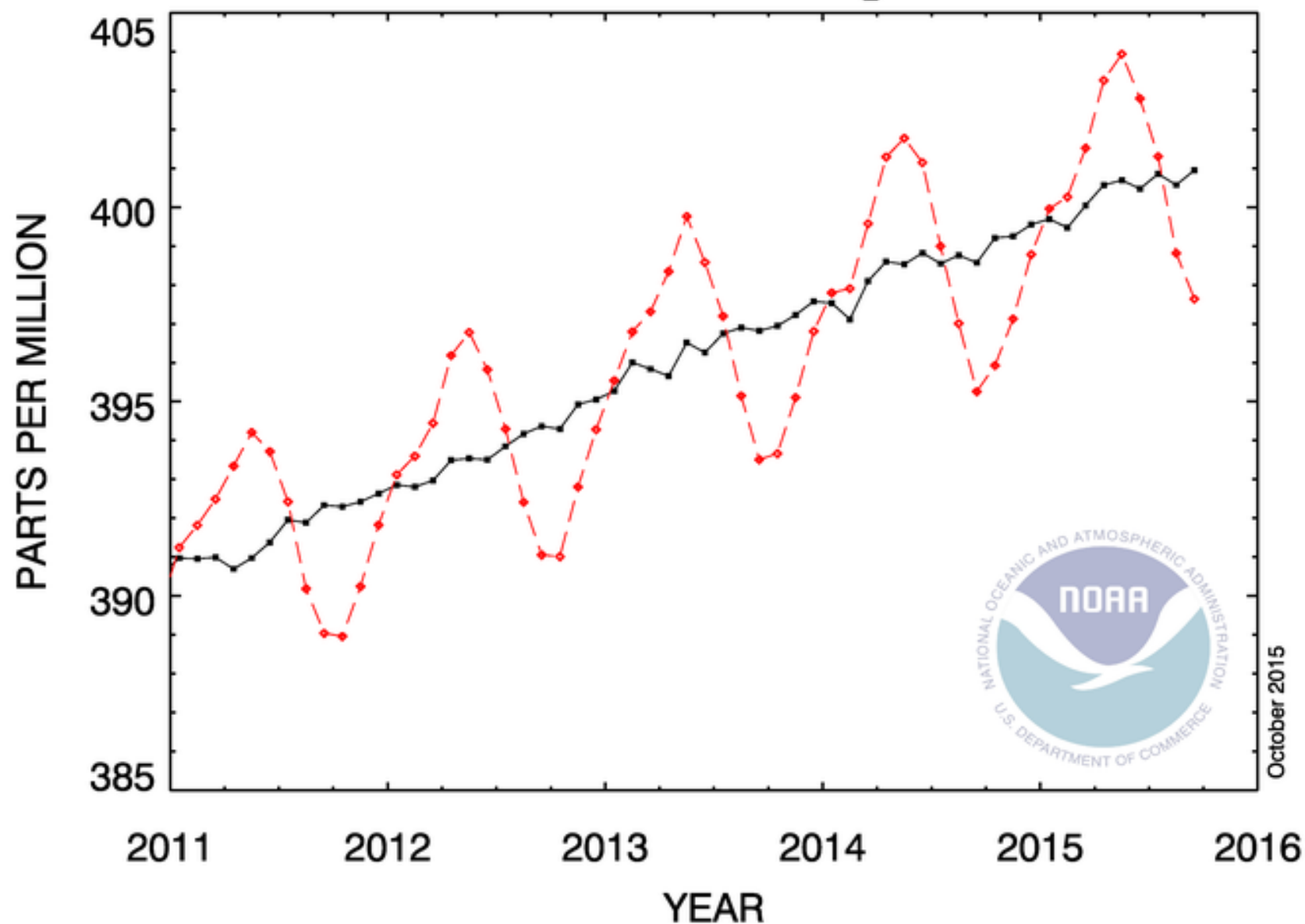
2010

YEAR



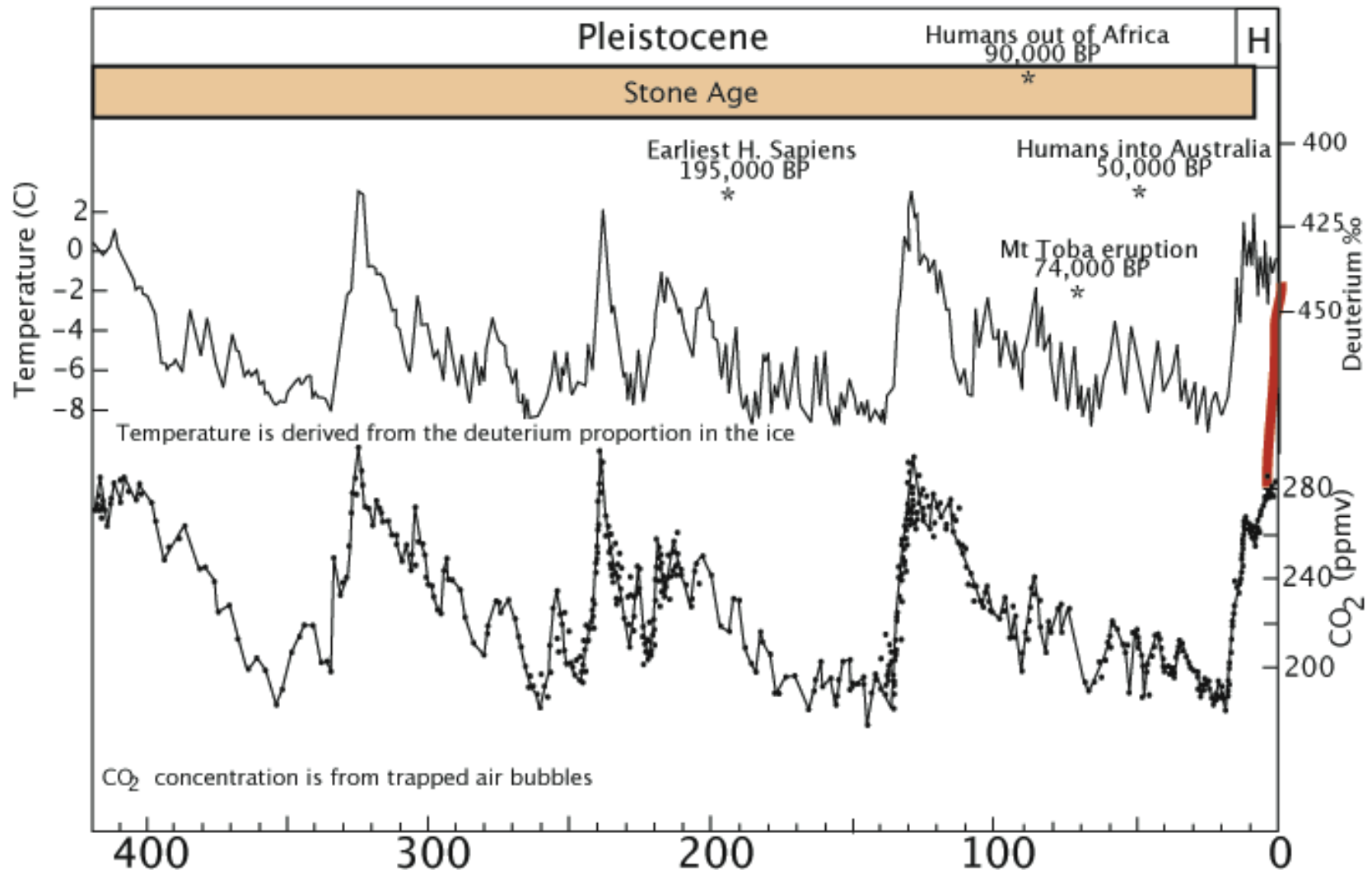
October 2015

RECENT MONTHLY MEAN CO₂ AT MAUNA LOA



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

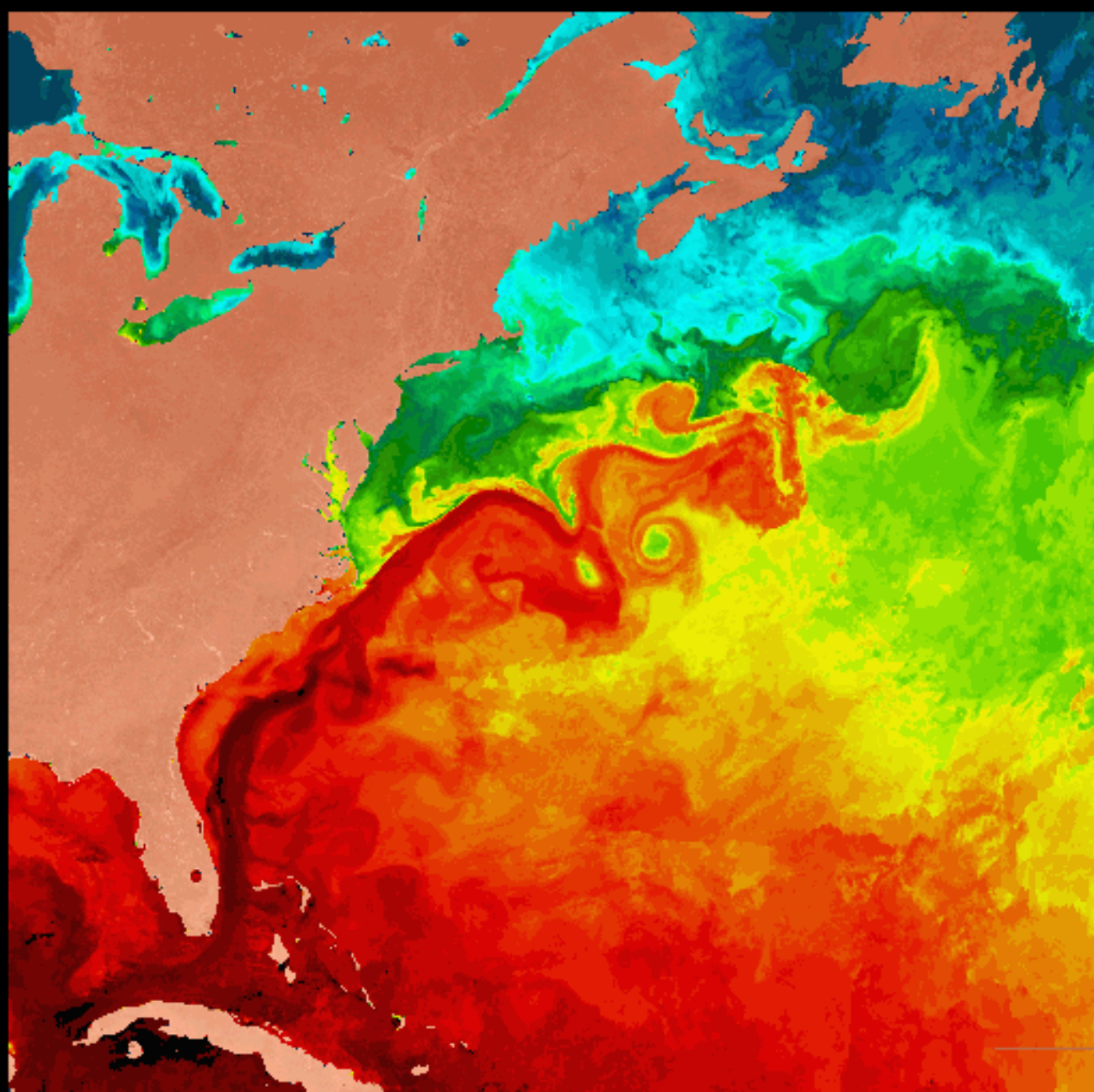
21 Dec, 2006

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>).

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