

# Who will flourish in the Anthropocene?

Bob Raynolds

Oct 2015

[bobraynolds@yahoo.com](mailto:bobraynolds@yahoo.com)



**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

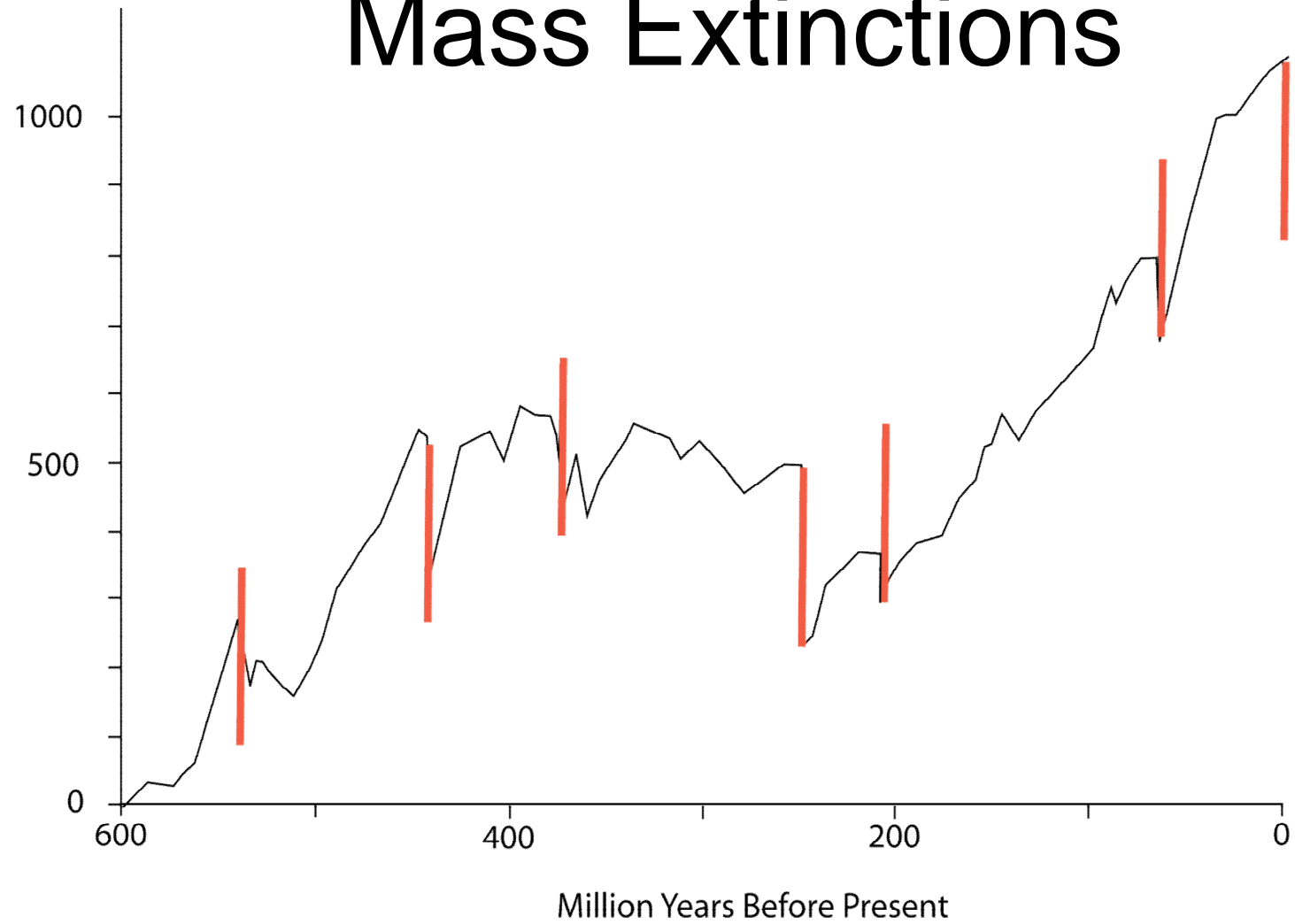


Jon Berkeley

AMERICAN MUSEUM OF NATURAL HISTORY



# Mass Extinctions



Diversity of marine families

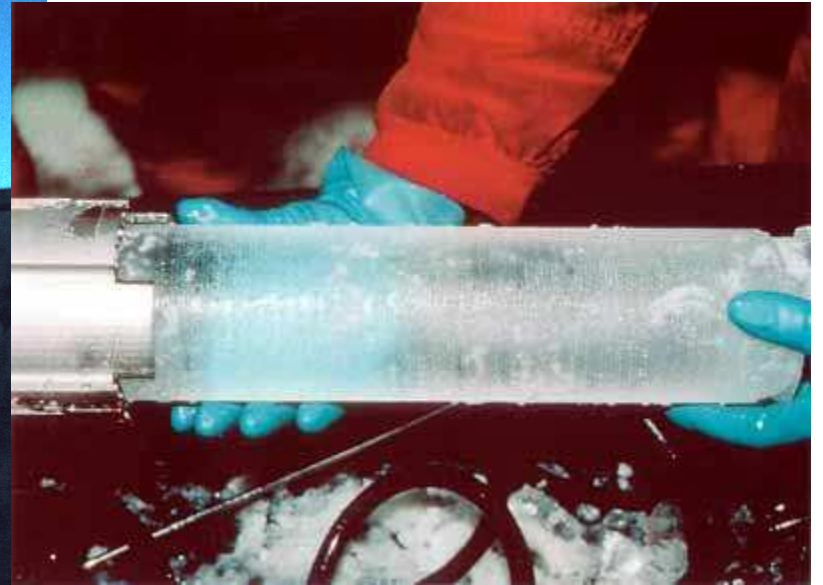
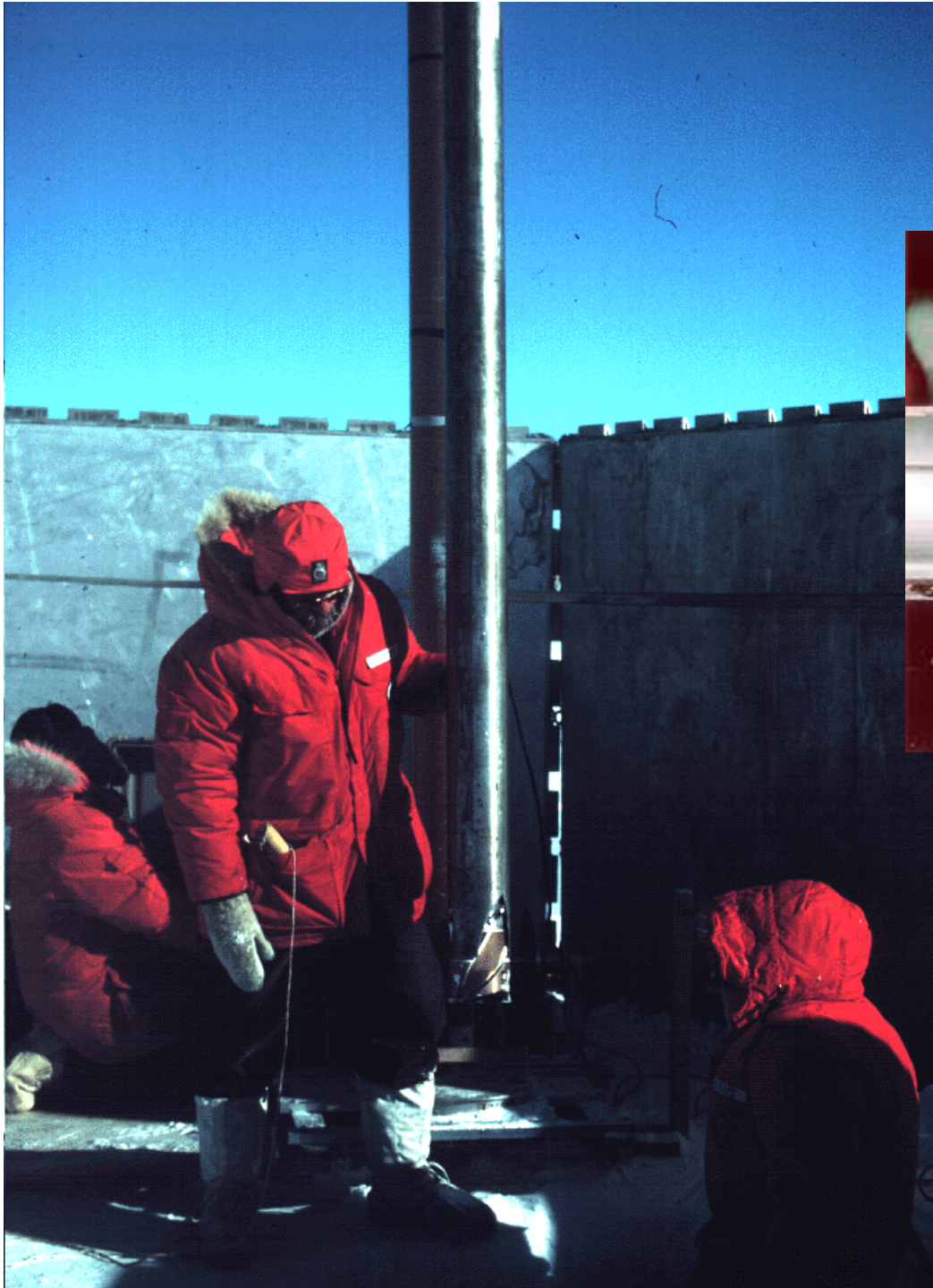
Raup, 1986

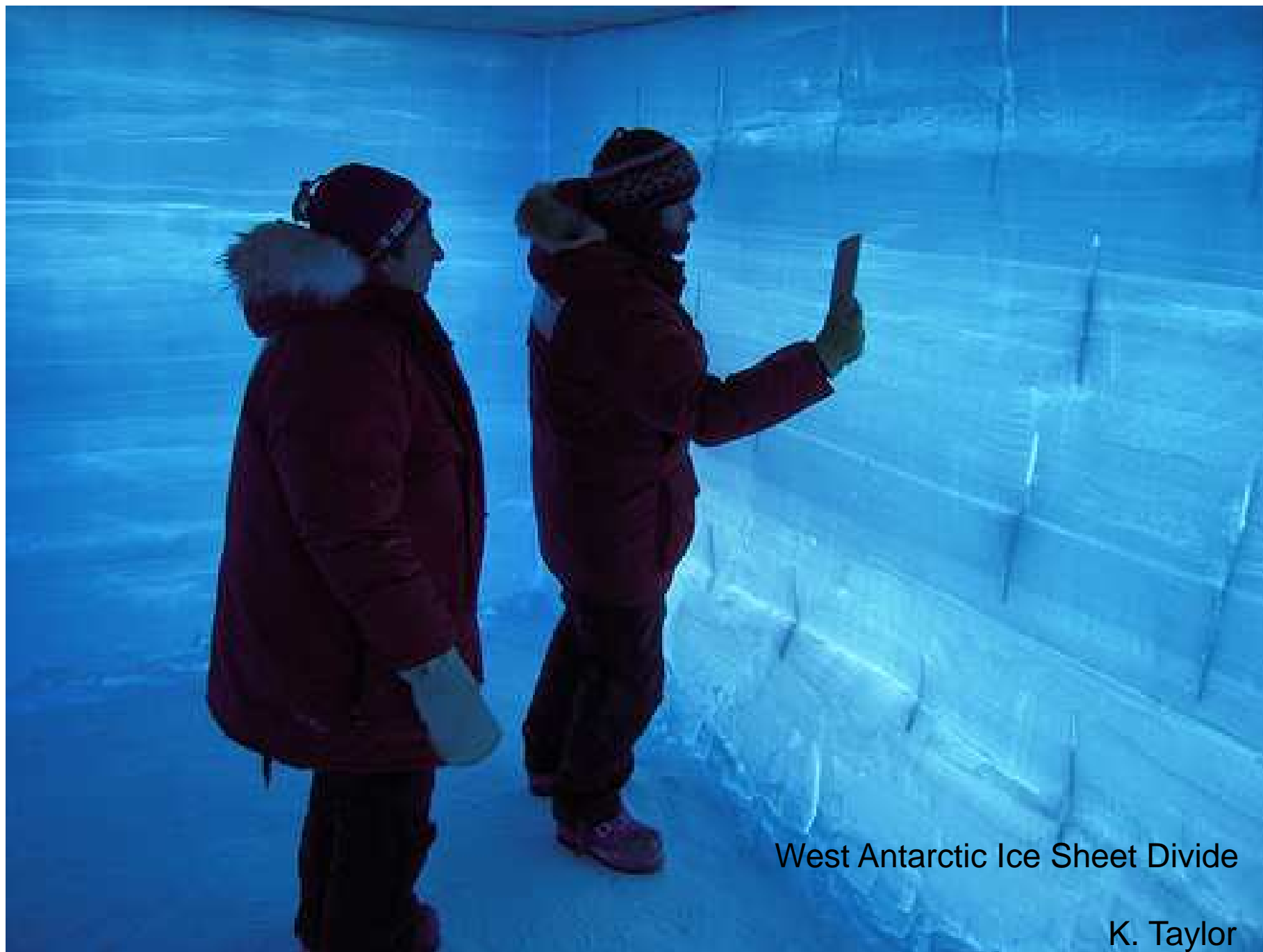


The data are in the strata

Changes are Happening

ICE





West Antarctic Ice Sheet Divide

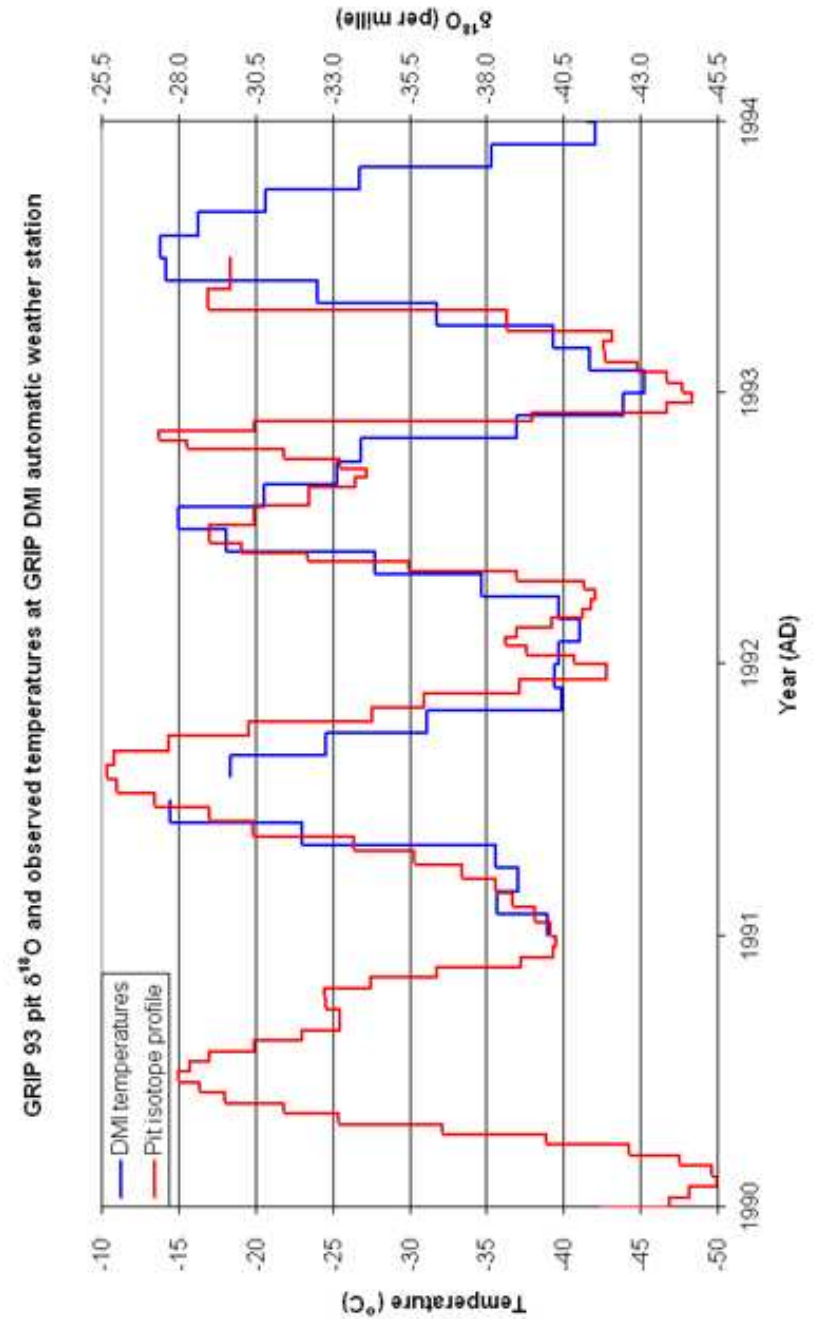
K. Taylor

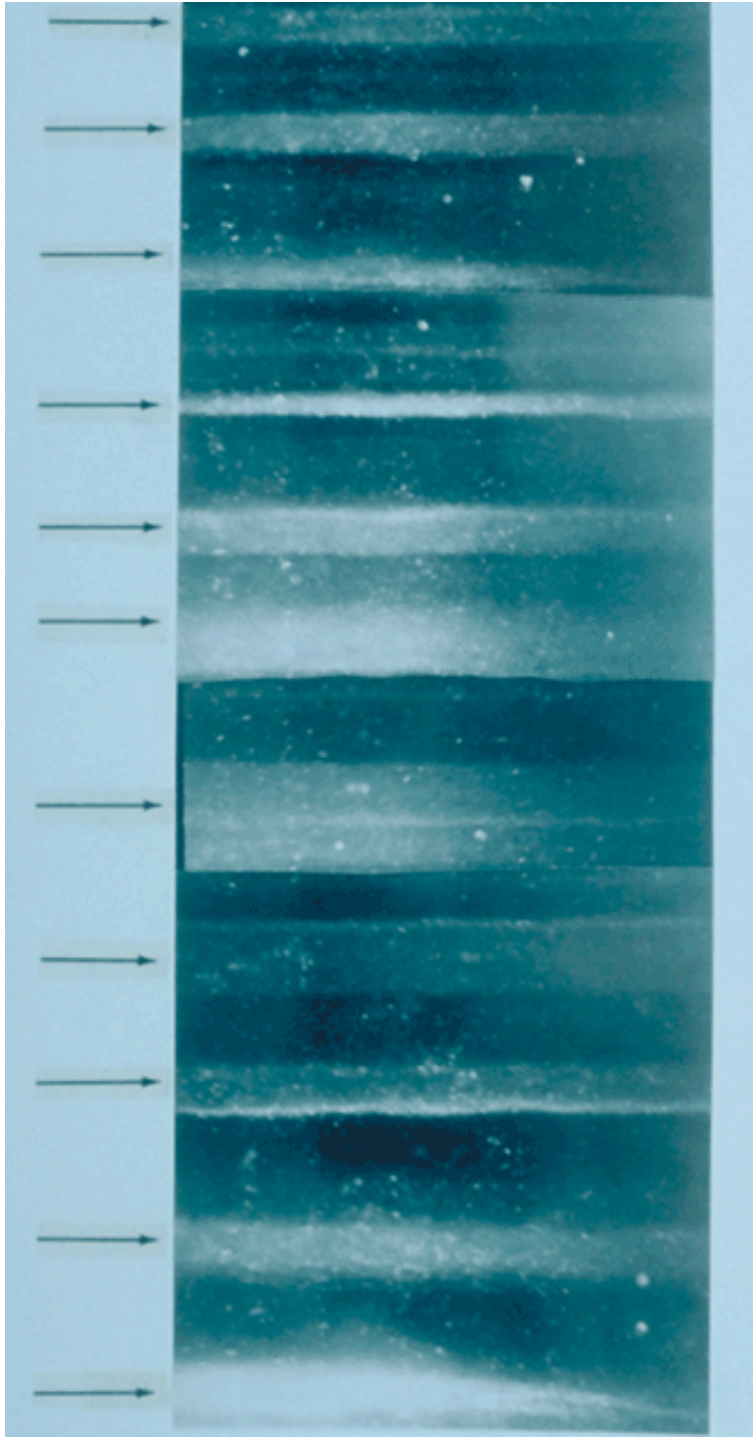




## Snow Pit Stratigraphy

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





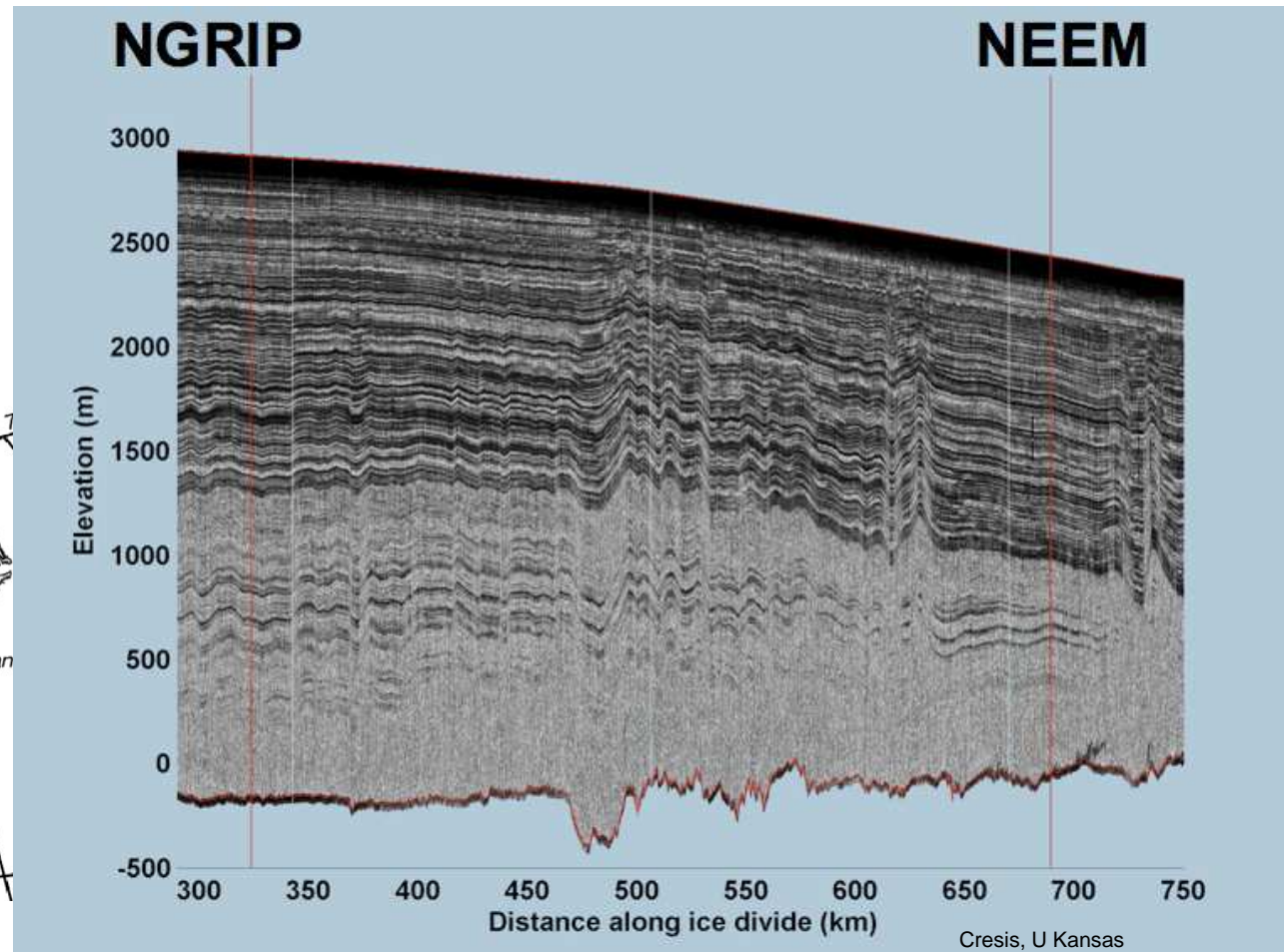
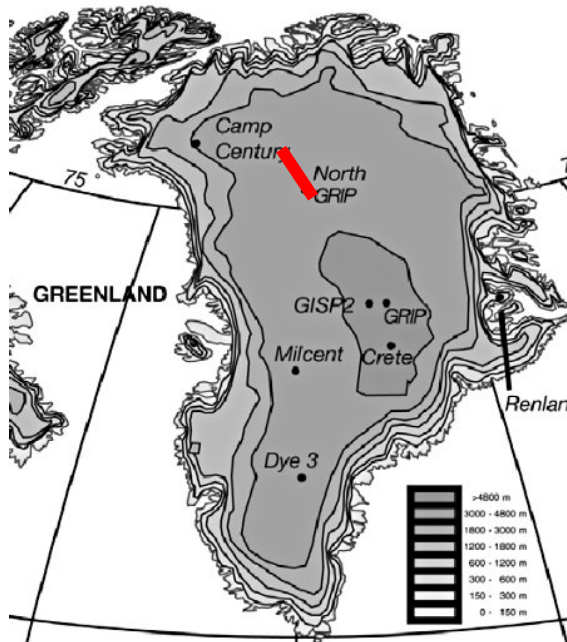
# Stratified Ice

The pale bands are summer, the dark bands winter.

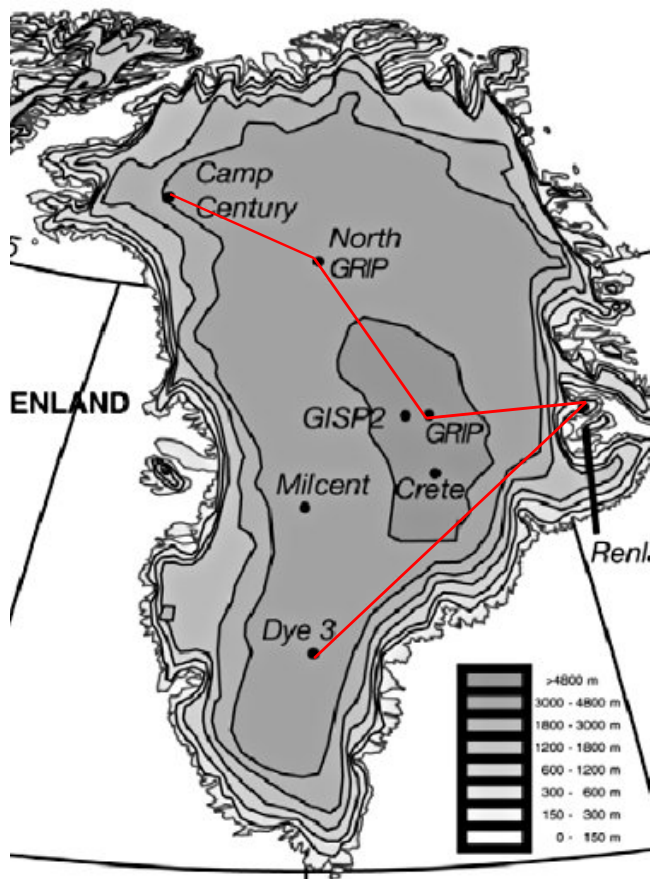


5 Cm

GISP 2 Core, 1855 meters

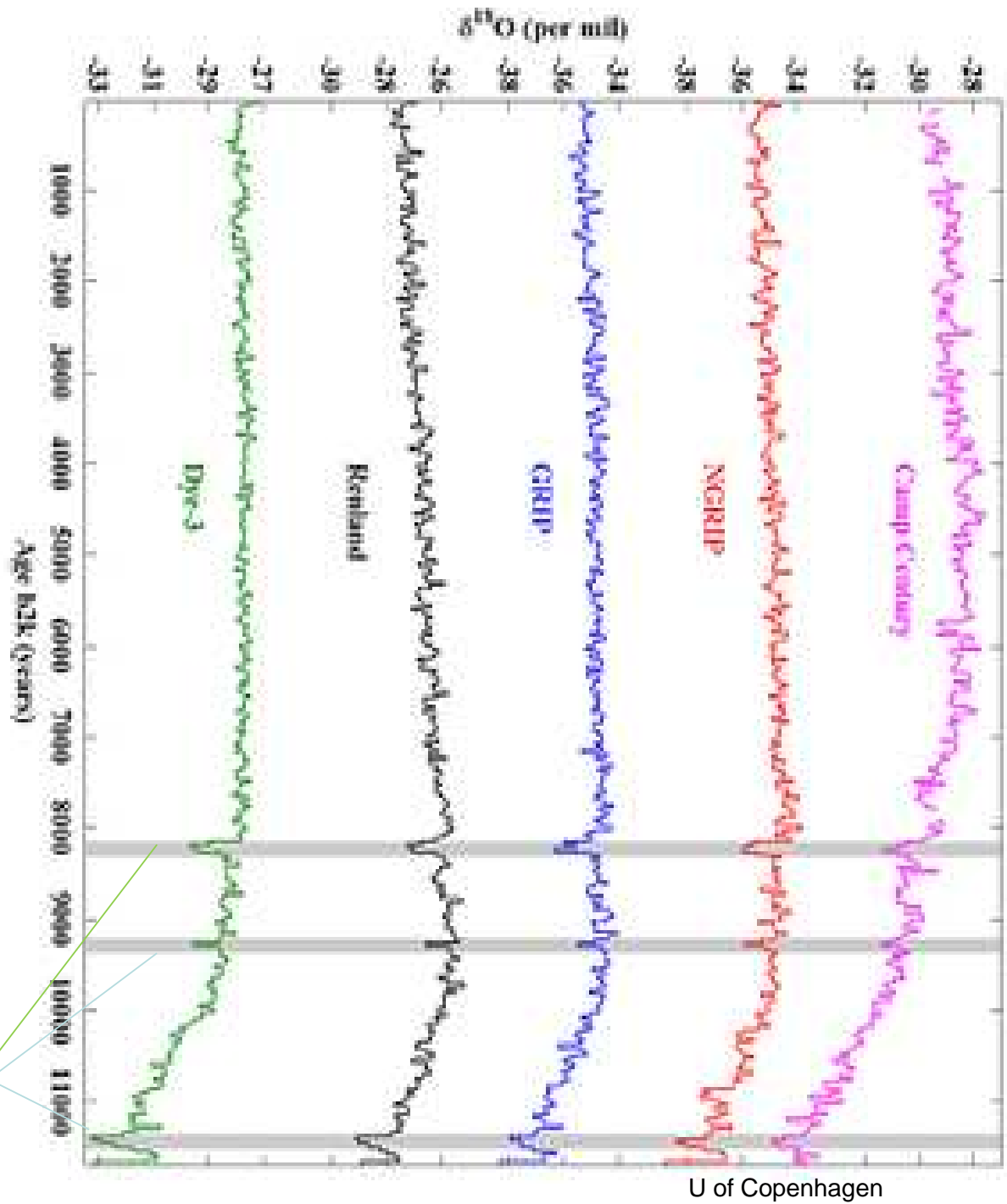


Character of radar reflectors in northern Greenland



## Holocene ice correlations across Greenland

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

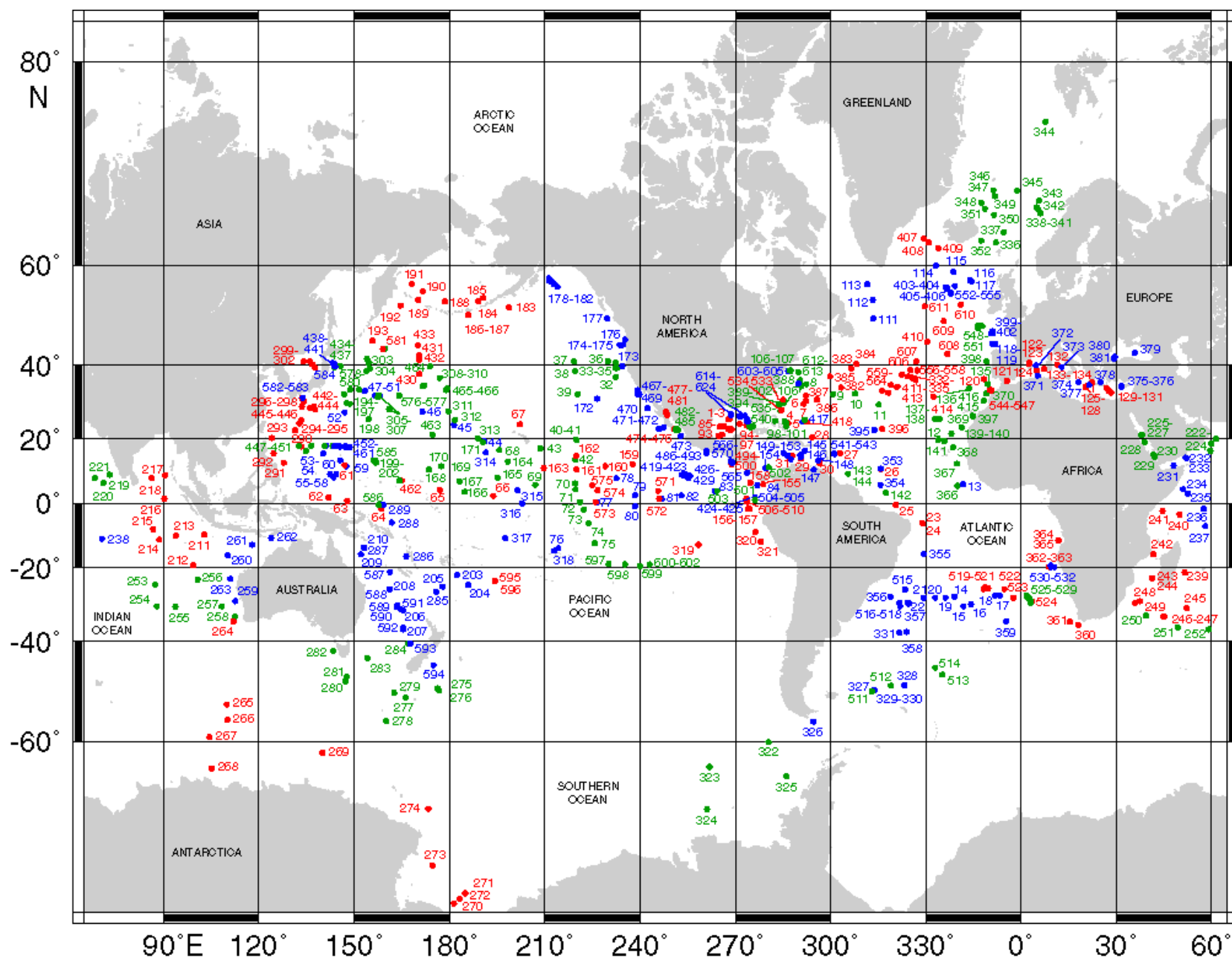




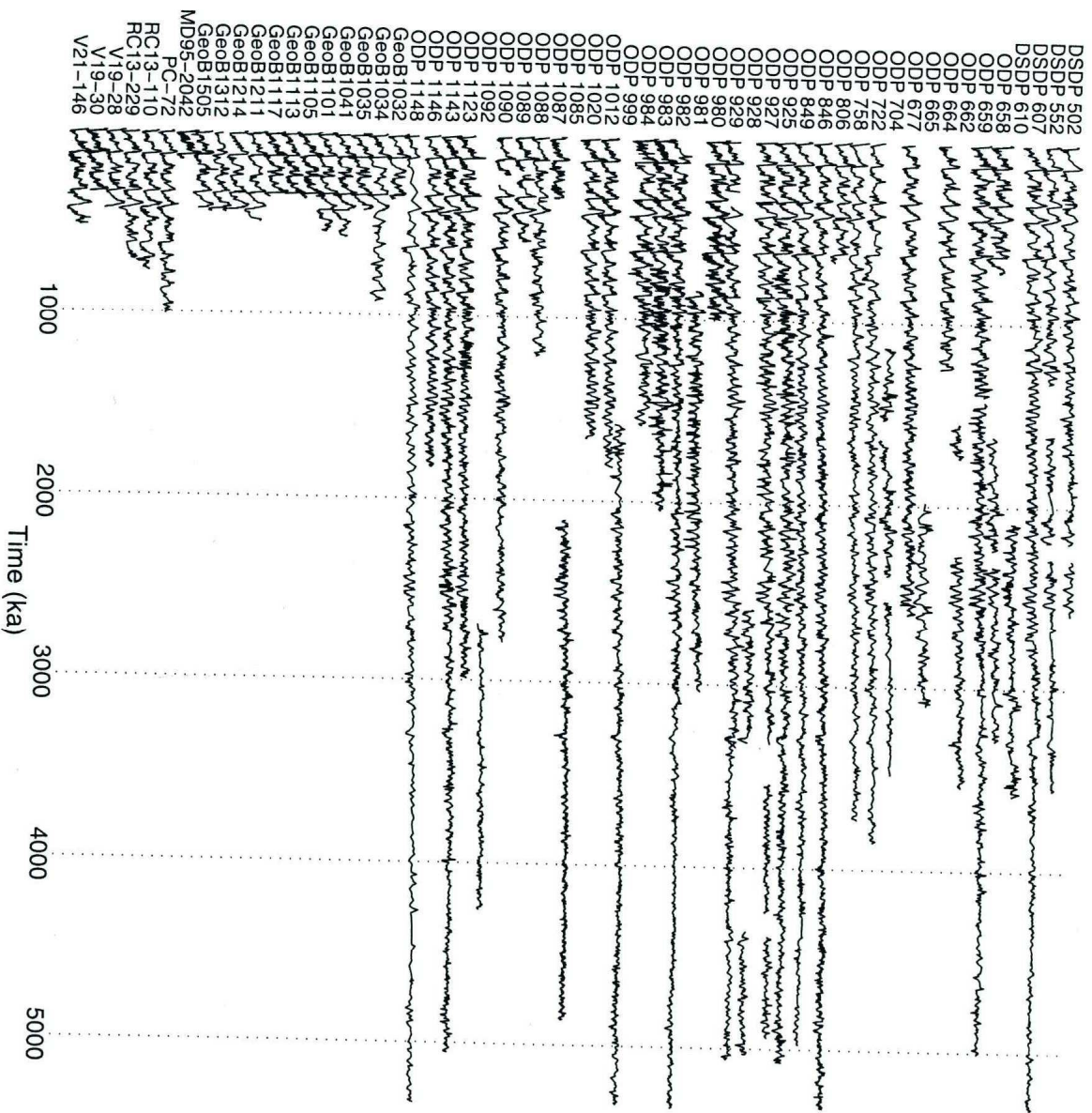
Changes are Happening

MUD

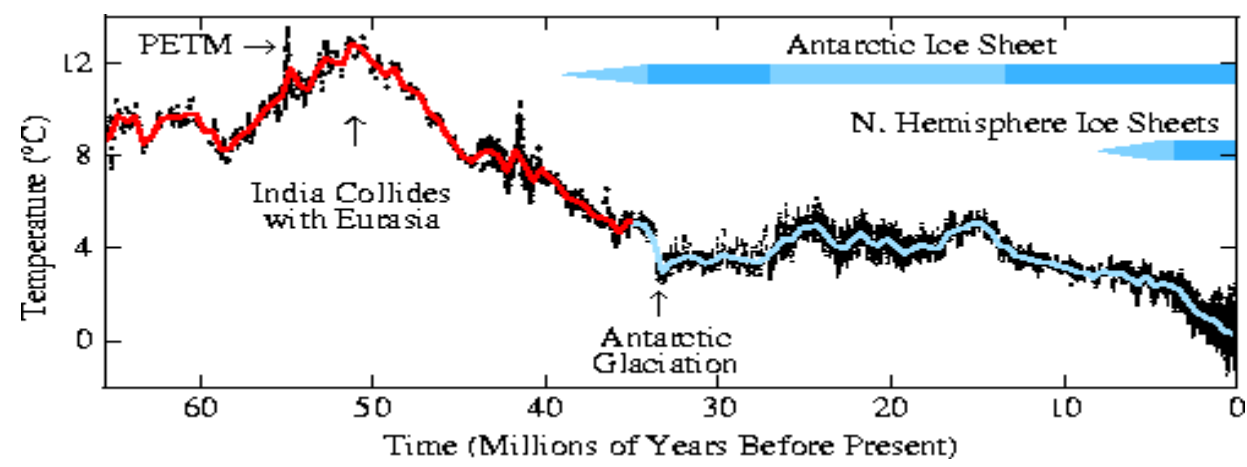
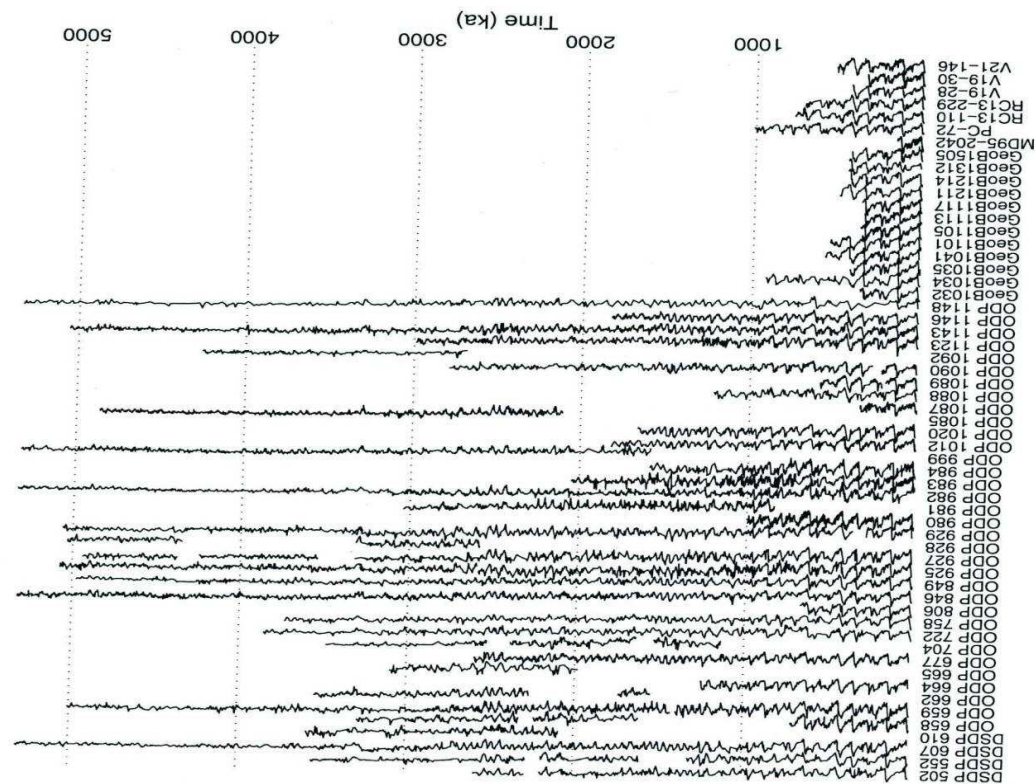


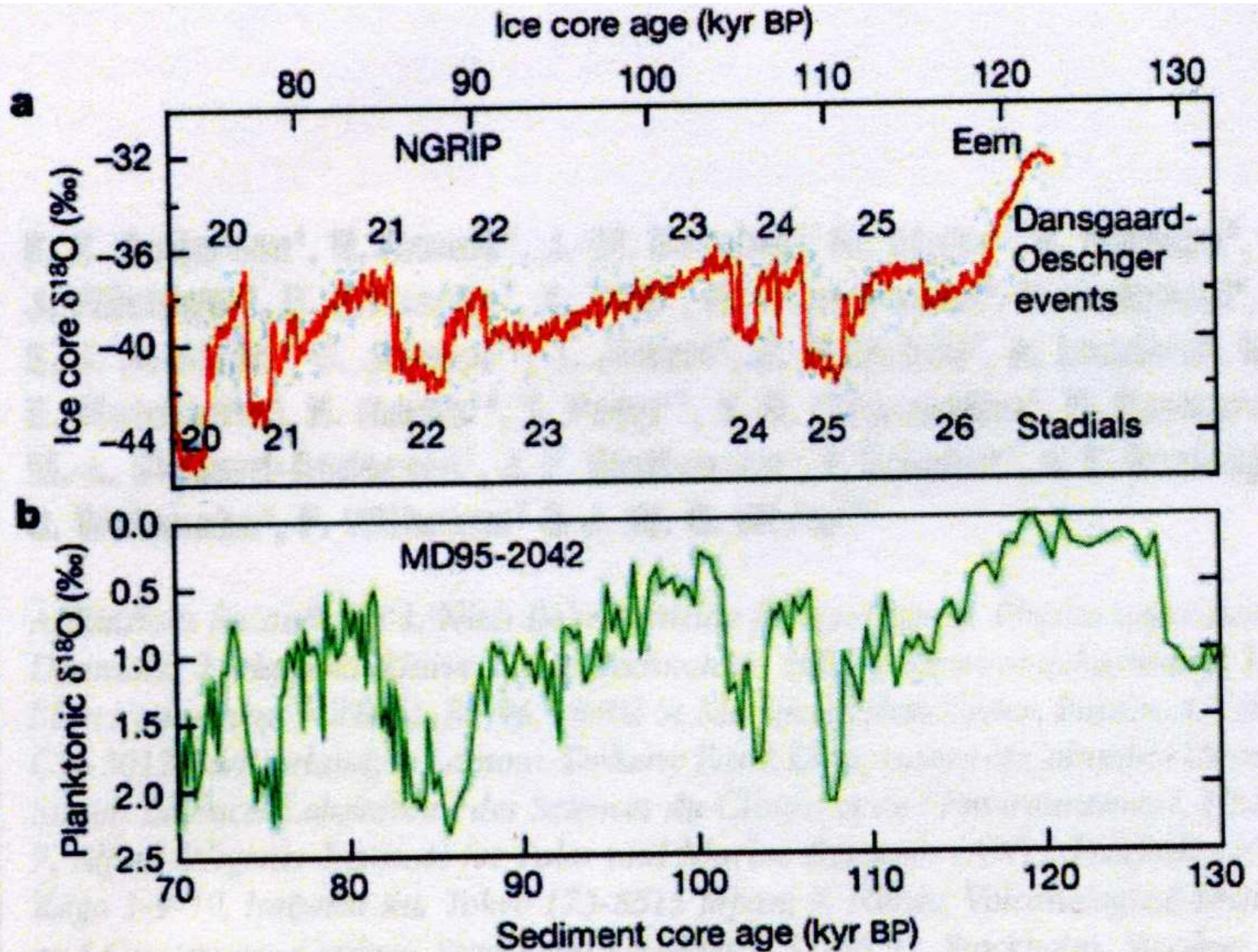


DSDP Legs 1-96, Sites 1-624









Ice to Mud Correlation

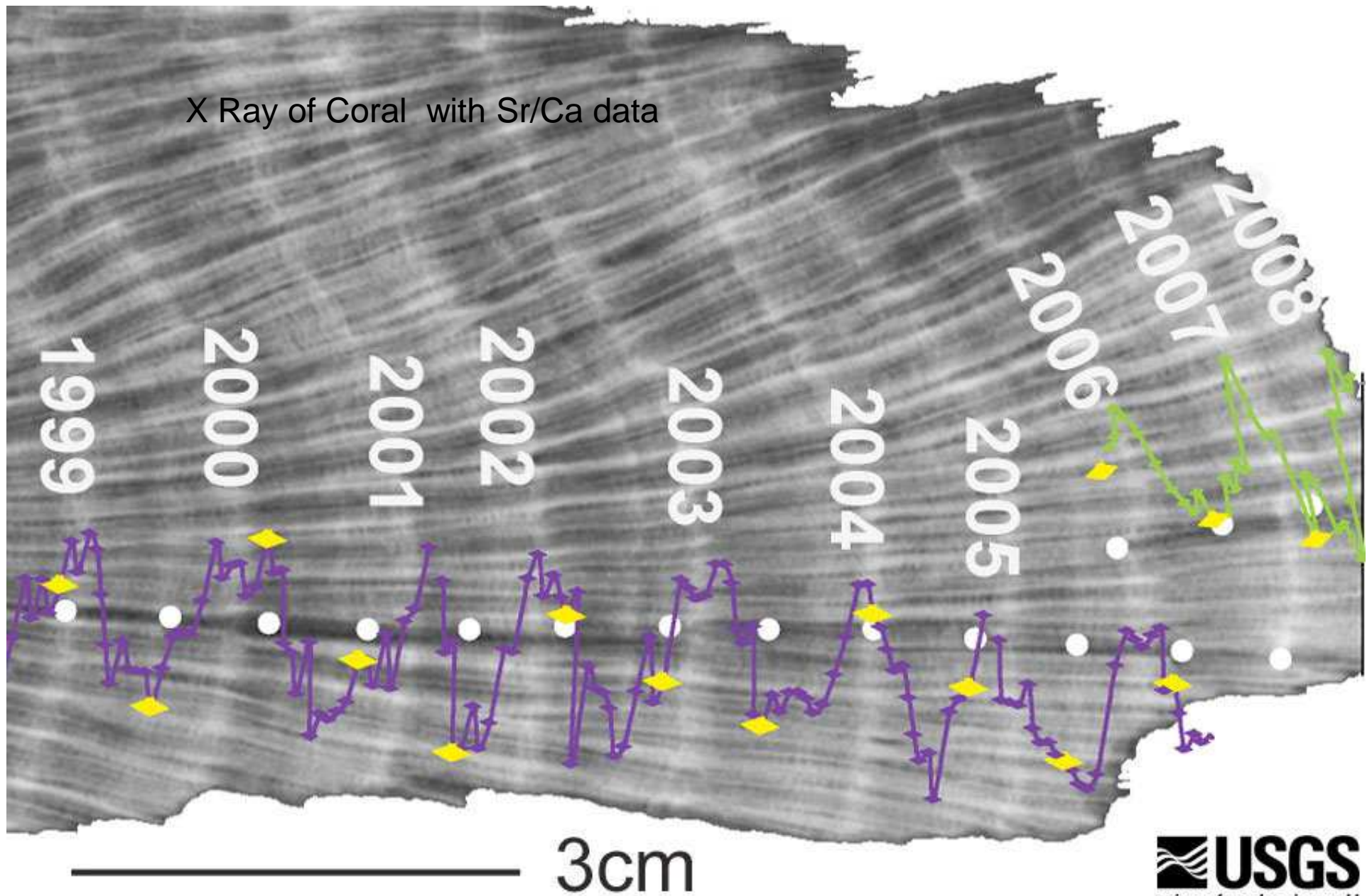
Greenland to off-shore Spain

Changes are Happening

Caves and Reefs



X Ray of Coral with Sr/Ca data



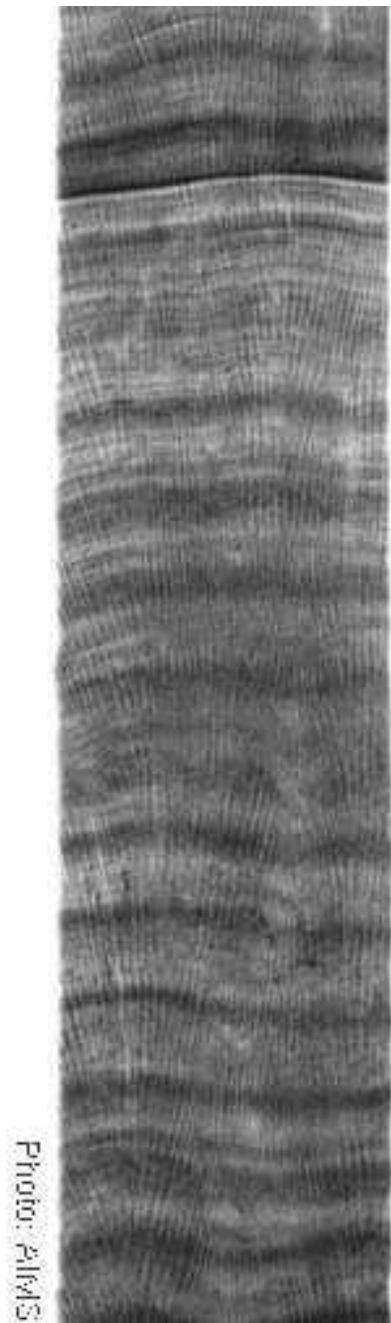


# Stalagmite

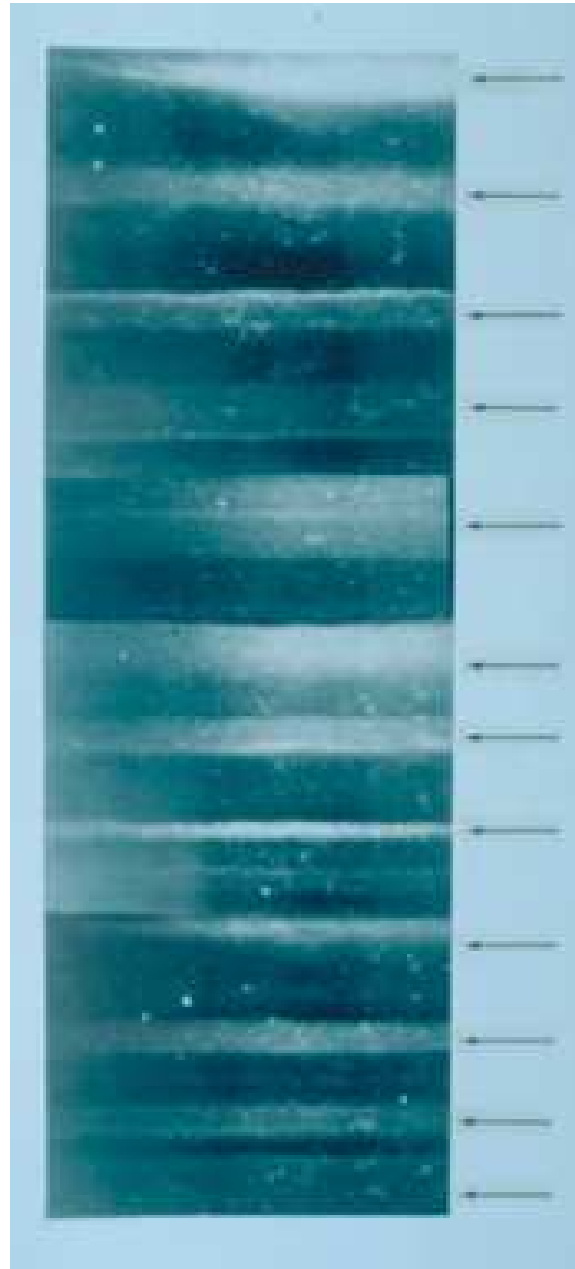


Paul Williams

UV Light



Coral, Australia



Ice, Greenland



Lake Sediments, Turkey

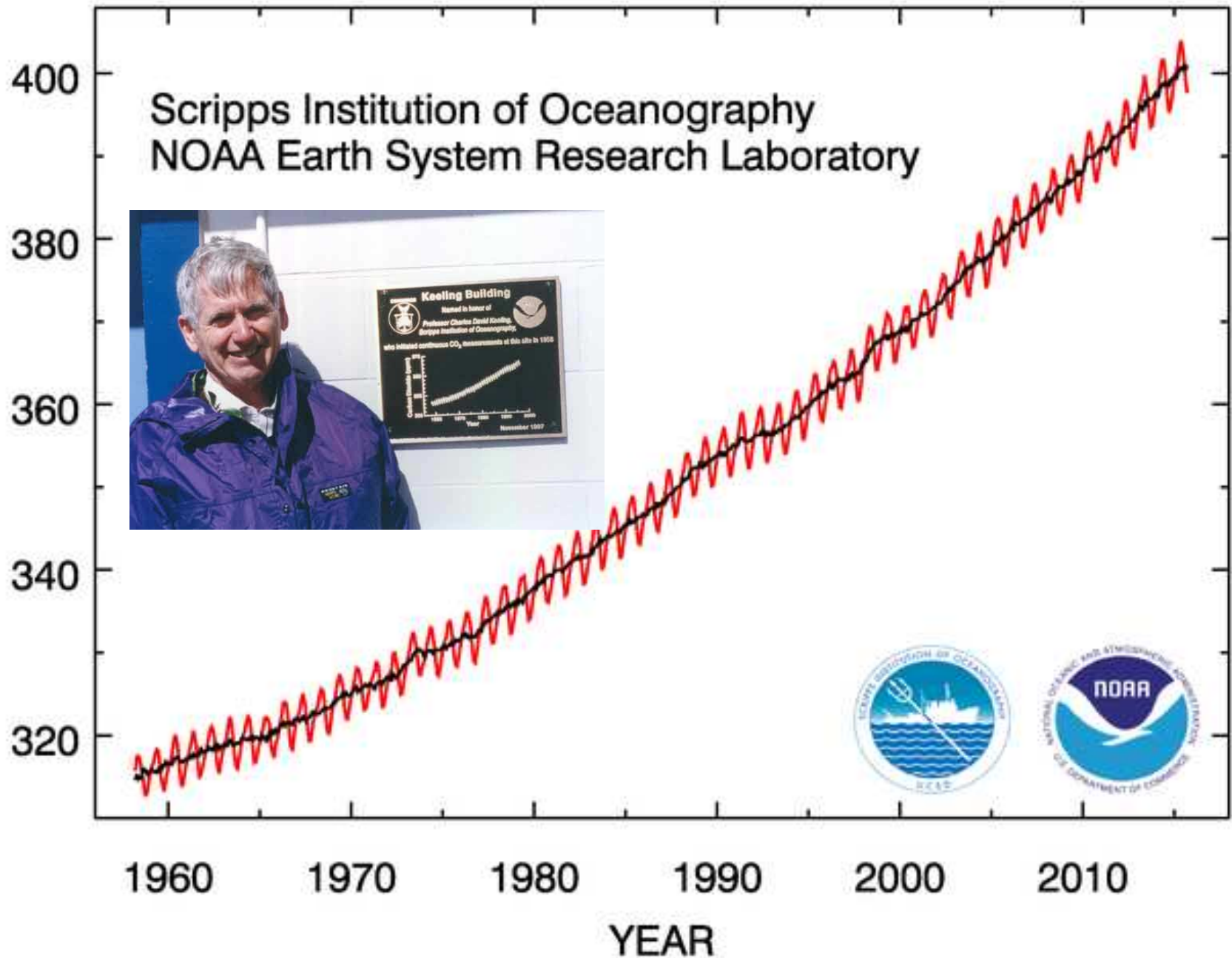
Changes are Happening

AIR

# Atmospheric CO<sub>2</sub> at Mauna Loa Observatory

Scripps Institution of Oceanography  
NOAA Earth System Research Laboratory

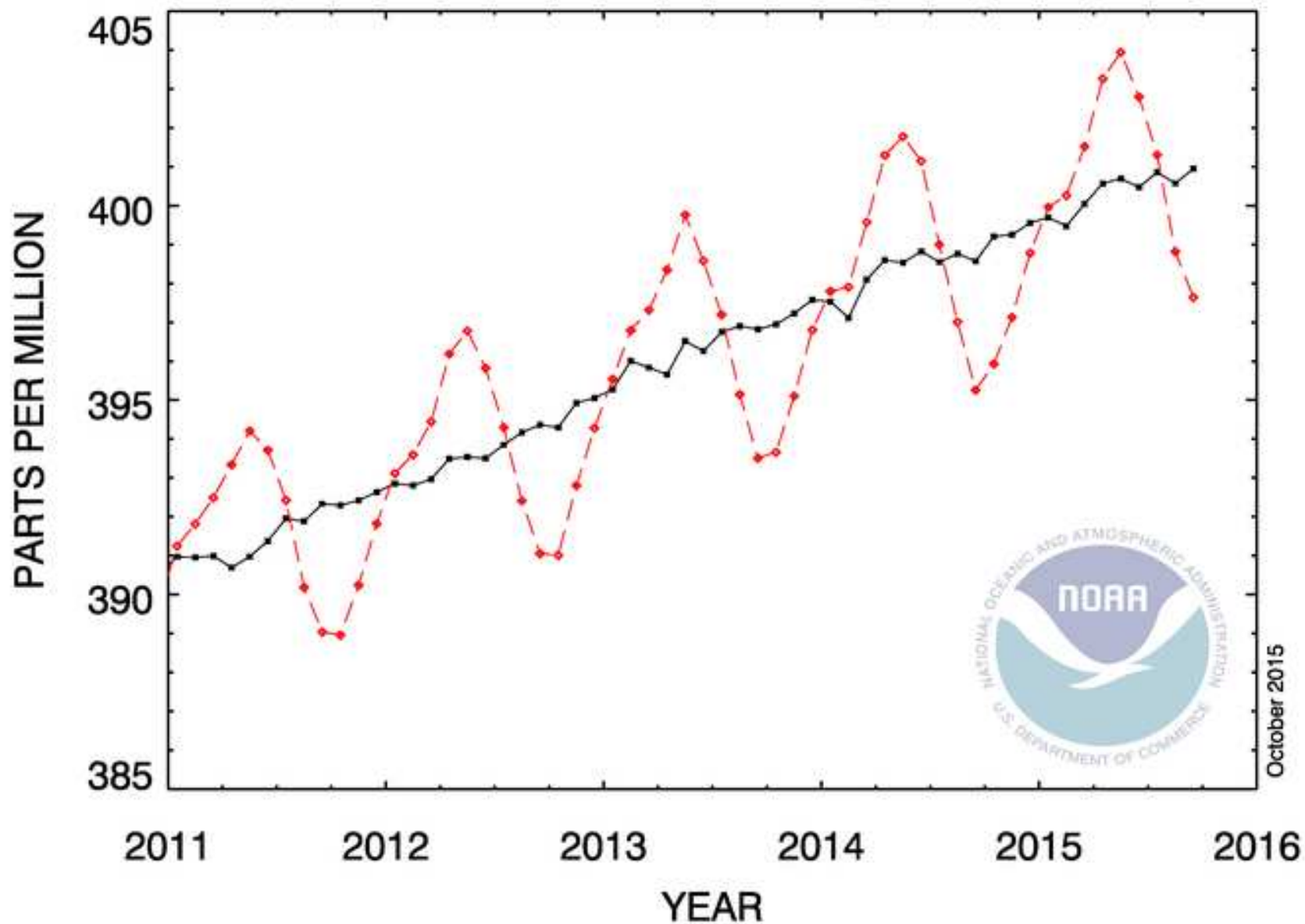
PARTS PER MILLION



October 2015

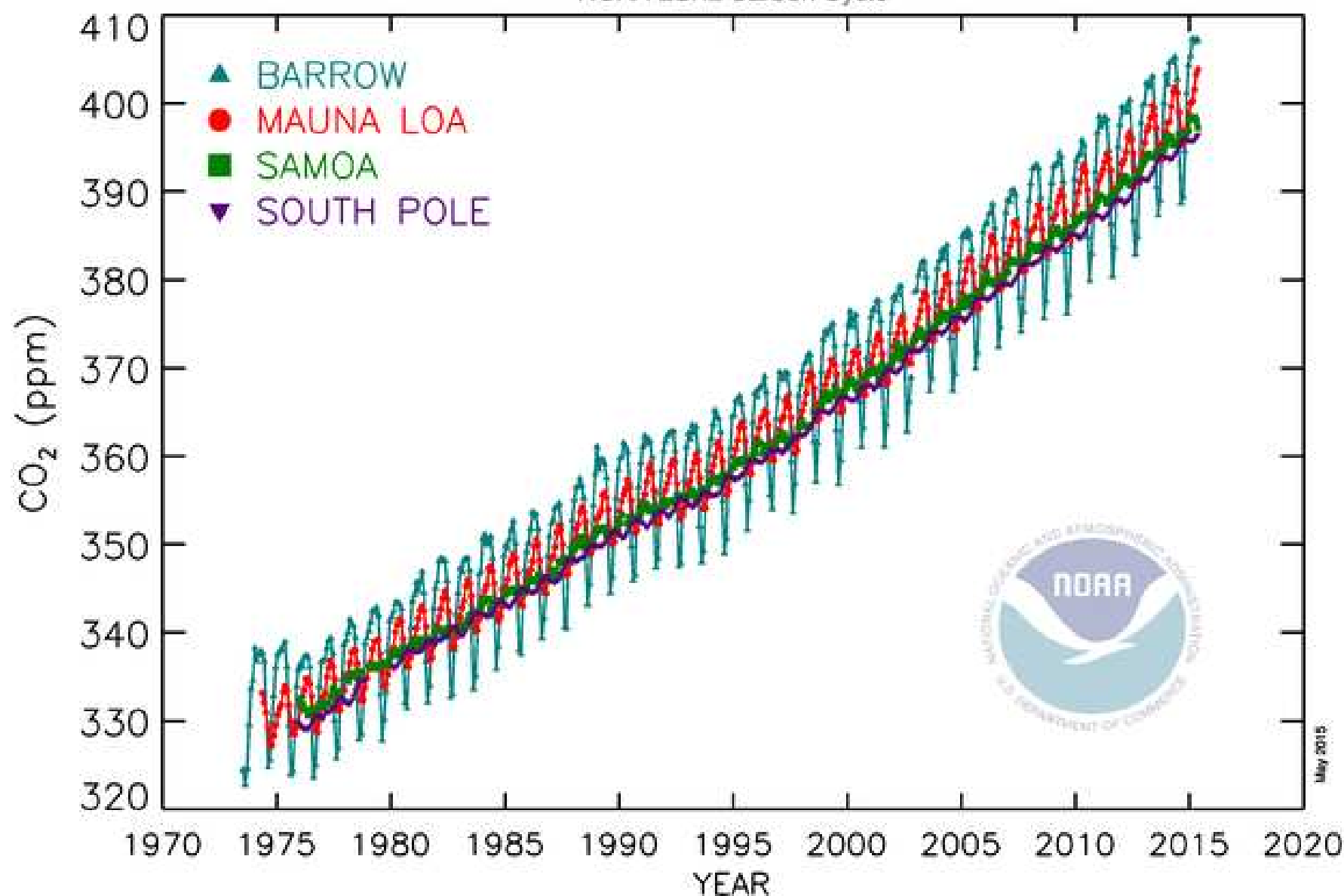


## RECENT MONTHLY MEAN CO<sub>2</sub> AT MAUNA LOA



# Monthly Mean Carbon Dioxide

NOAA ESRL Carbon Cycle

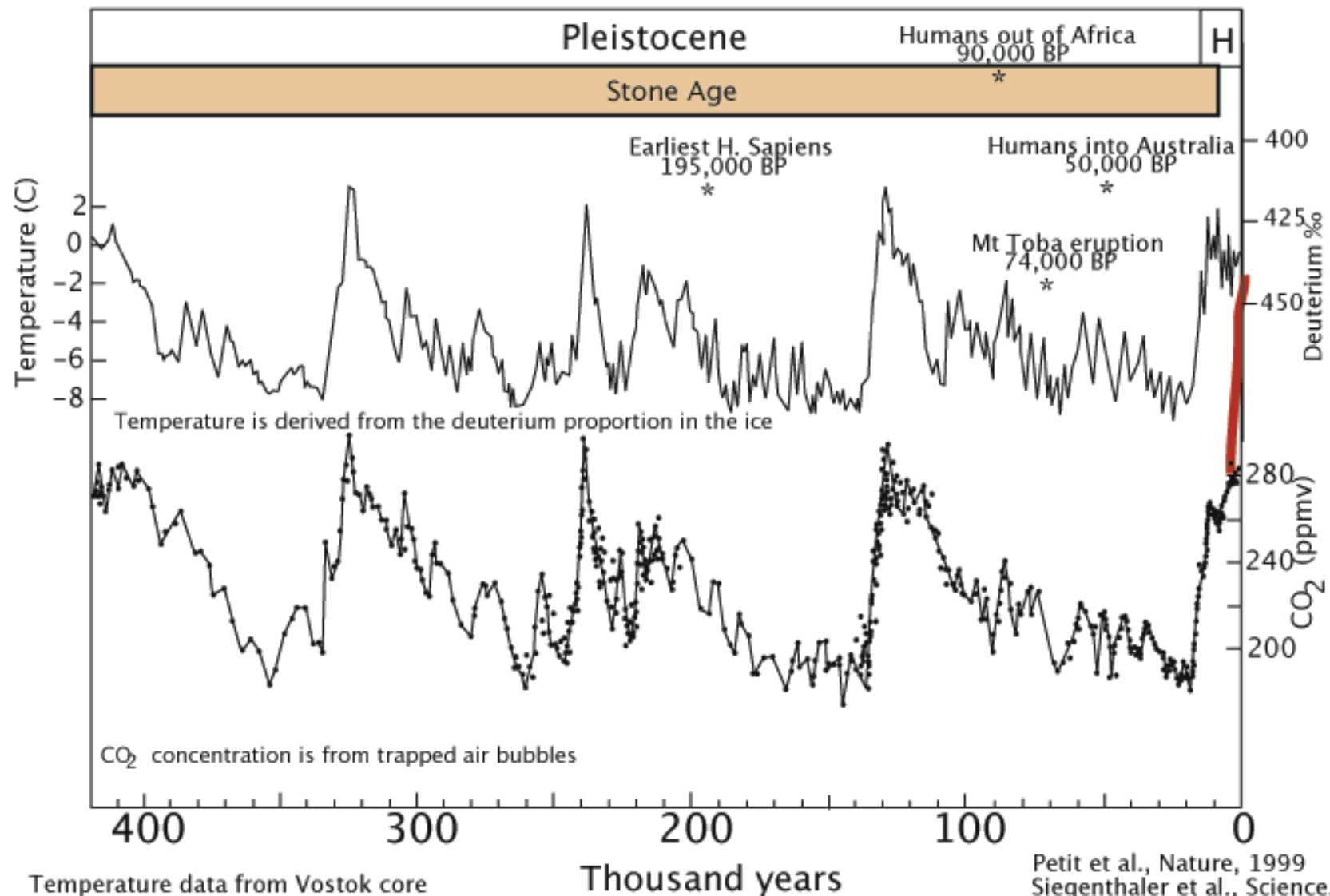


May 2015

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) 497-6878, [pieter.tans@noaa.gov](mailto:pieter.tans@noaa.gov), <http://www.esrl.noaa.gov/gmd/ccgg/>.

400,000 years

Antarctic Ice Cores



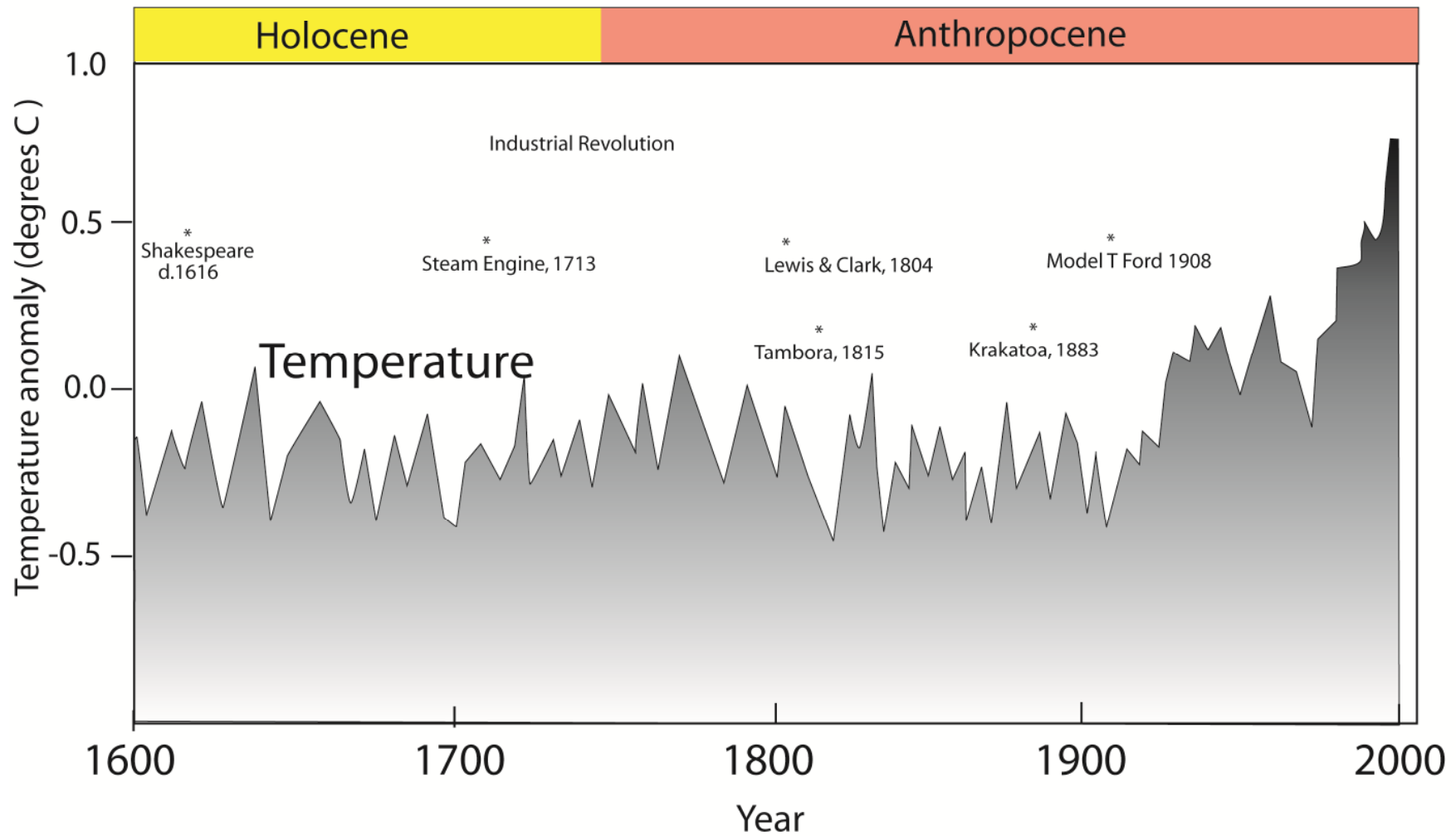
Temperature data from Vostok core  
CO<sub>2</sub> data from four ice cores

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

21 Dec, 2006

400 Years

Temp: tree rings and ice cores

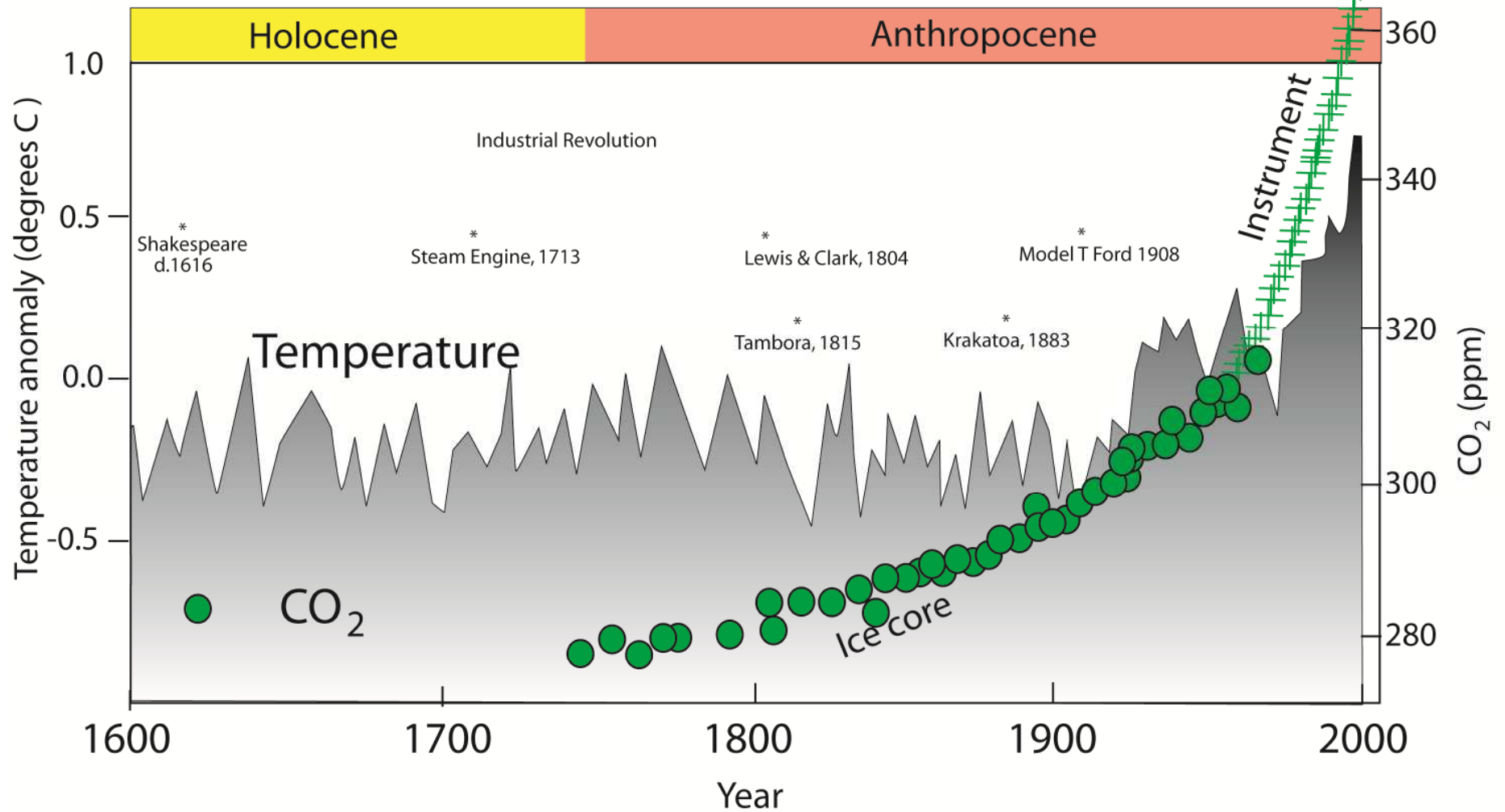


Temperature: Mann et al., 1999, Geophysical Research Letters



400 Years

Temp: tree rings and ice cores  
CO<sub>2</sub>: ice cores and measurements

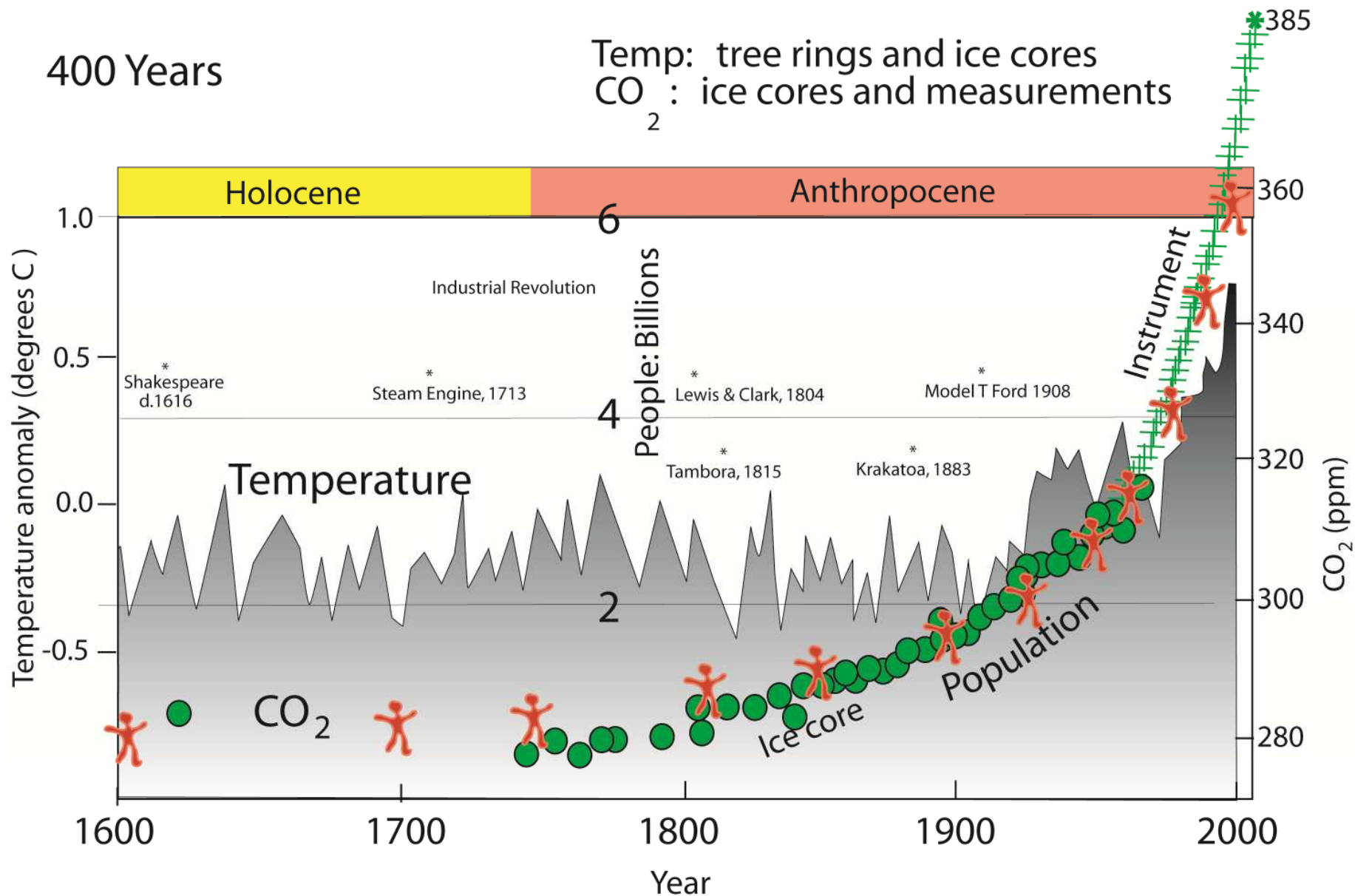


Temperature: Mann et al., 1999, Geophysical Research Letters

CO<sub>2</sub>: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

400 Years

Temp: tree rings and ice cores  
CO<sub>2</sub>: ice cores and measurements



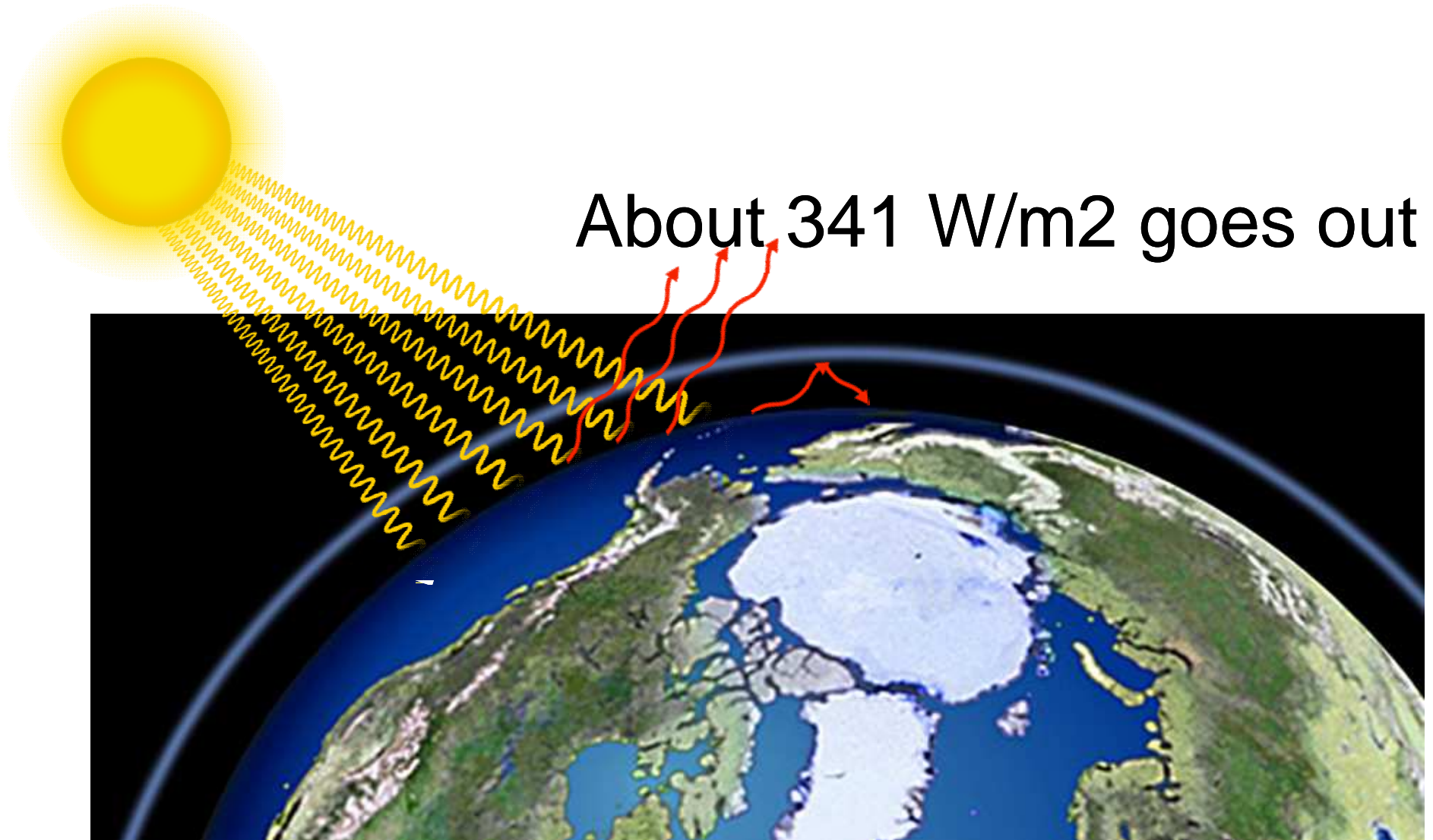
Temperature: Mann et al., 1999, Geophysical Research Letters

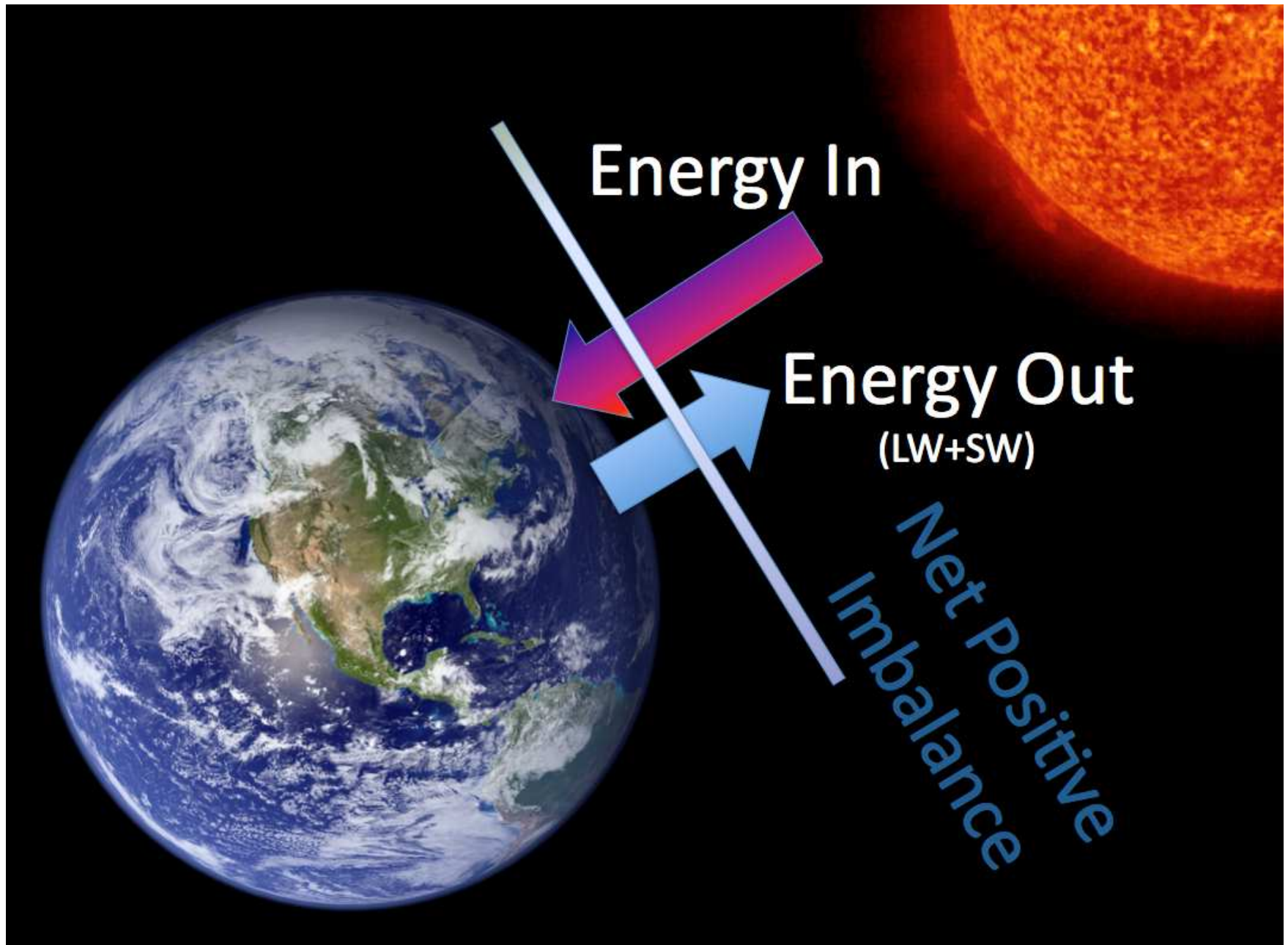
CO<sub>2</sub>: Friedli et al., 1986, Nature, in: Ruddiman fig. 17-12

Population: UN

About 342 w/m<sup>2</sup> comes in

About 341 W/m<sup>2</sup> goes out

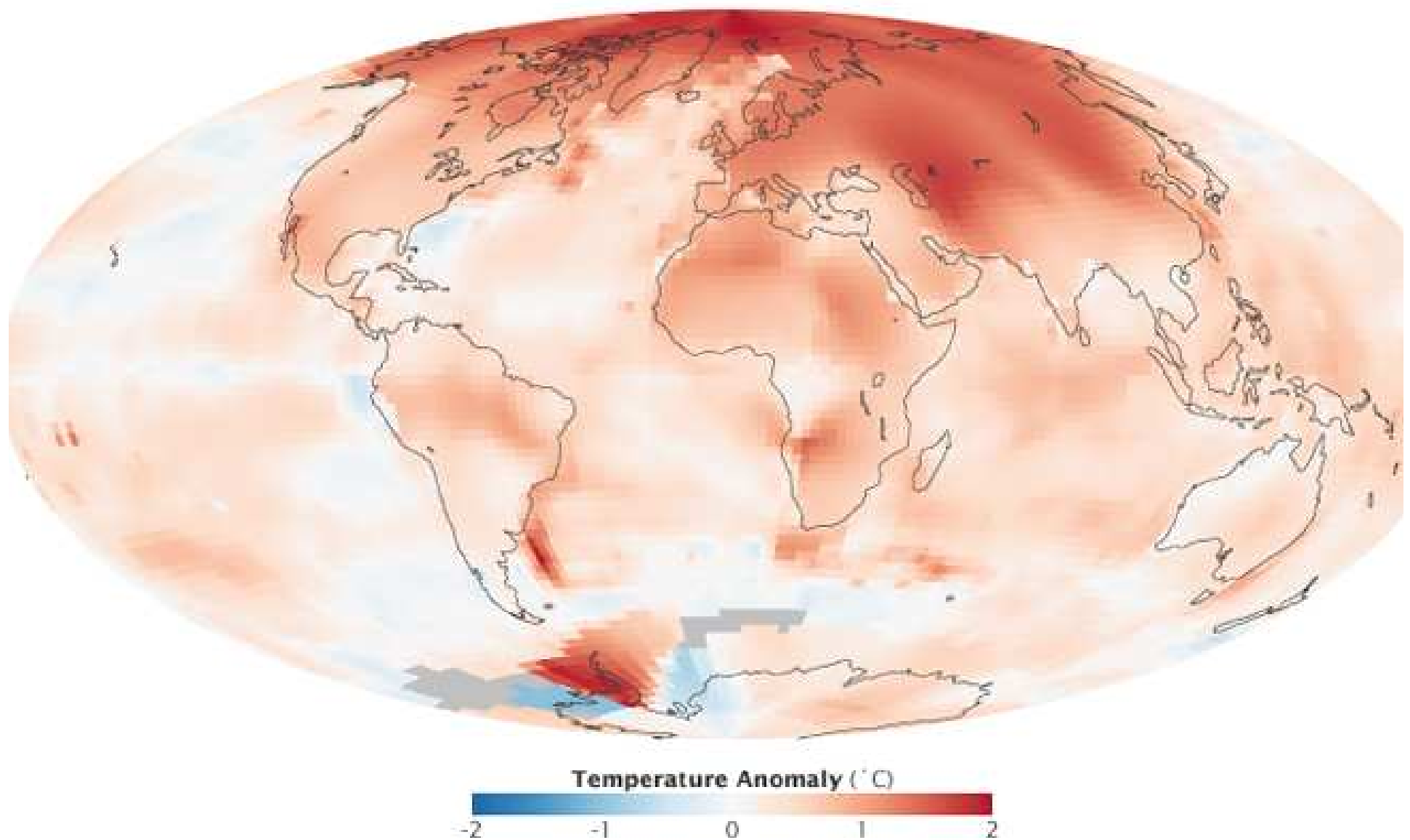




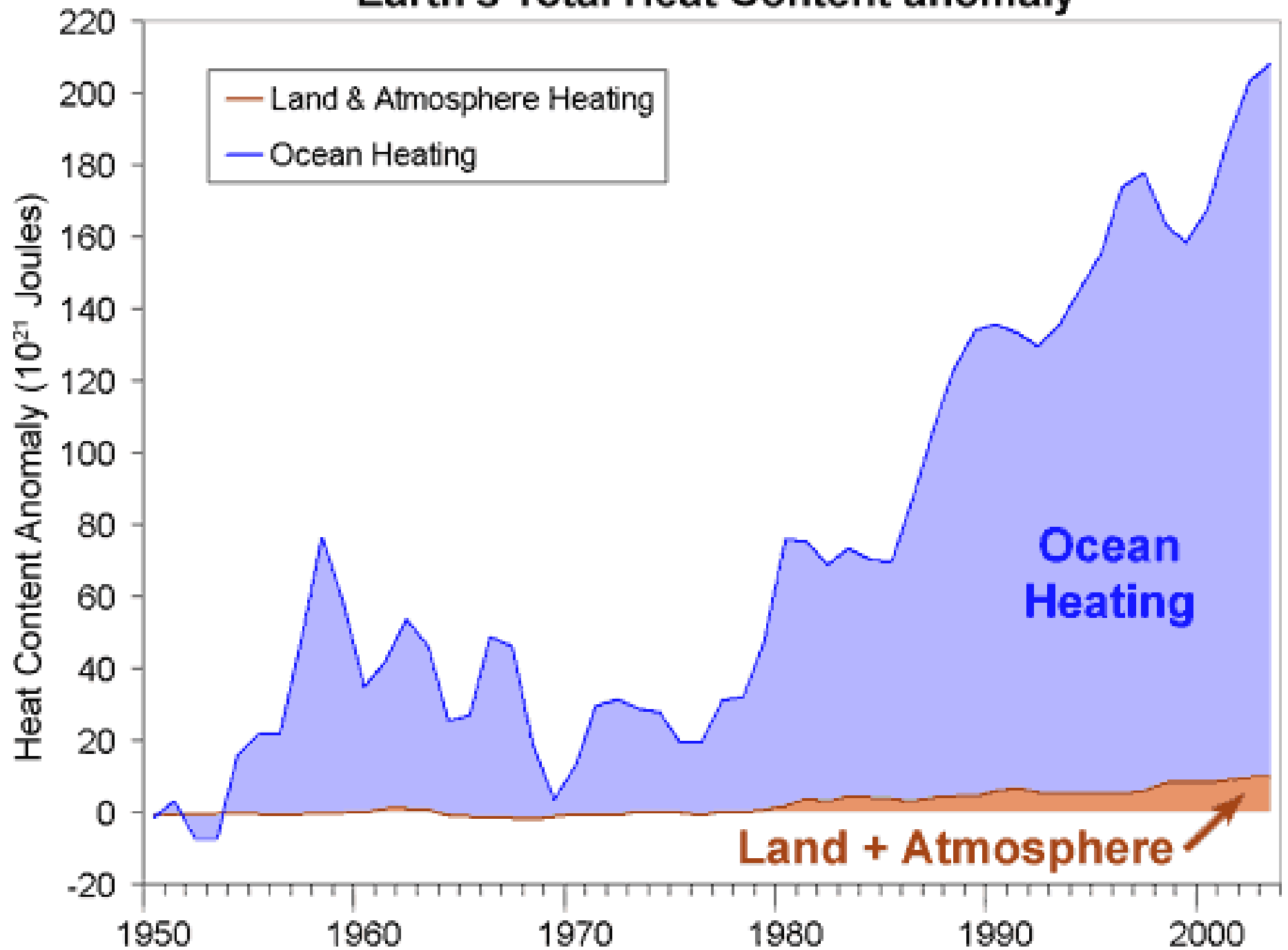


Change in temperature

2000-2009 vs. 1951-1980



## Earth's Total Heat Content anomaly



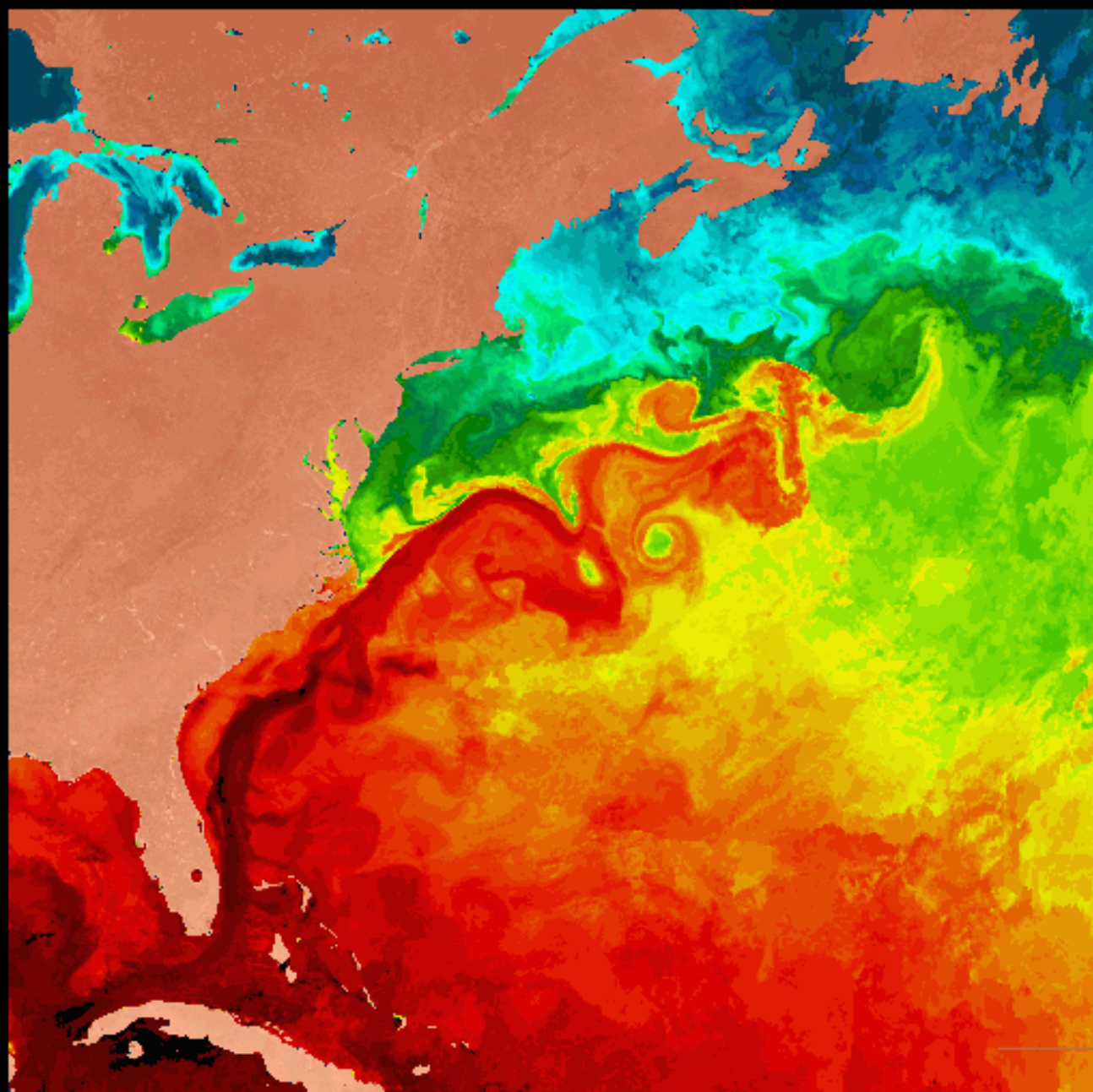
**Heat capacity of air: 1005 J/kg/K**

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



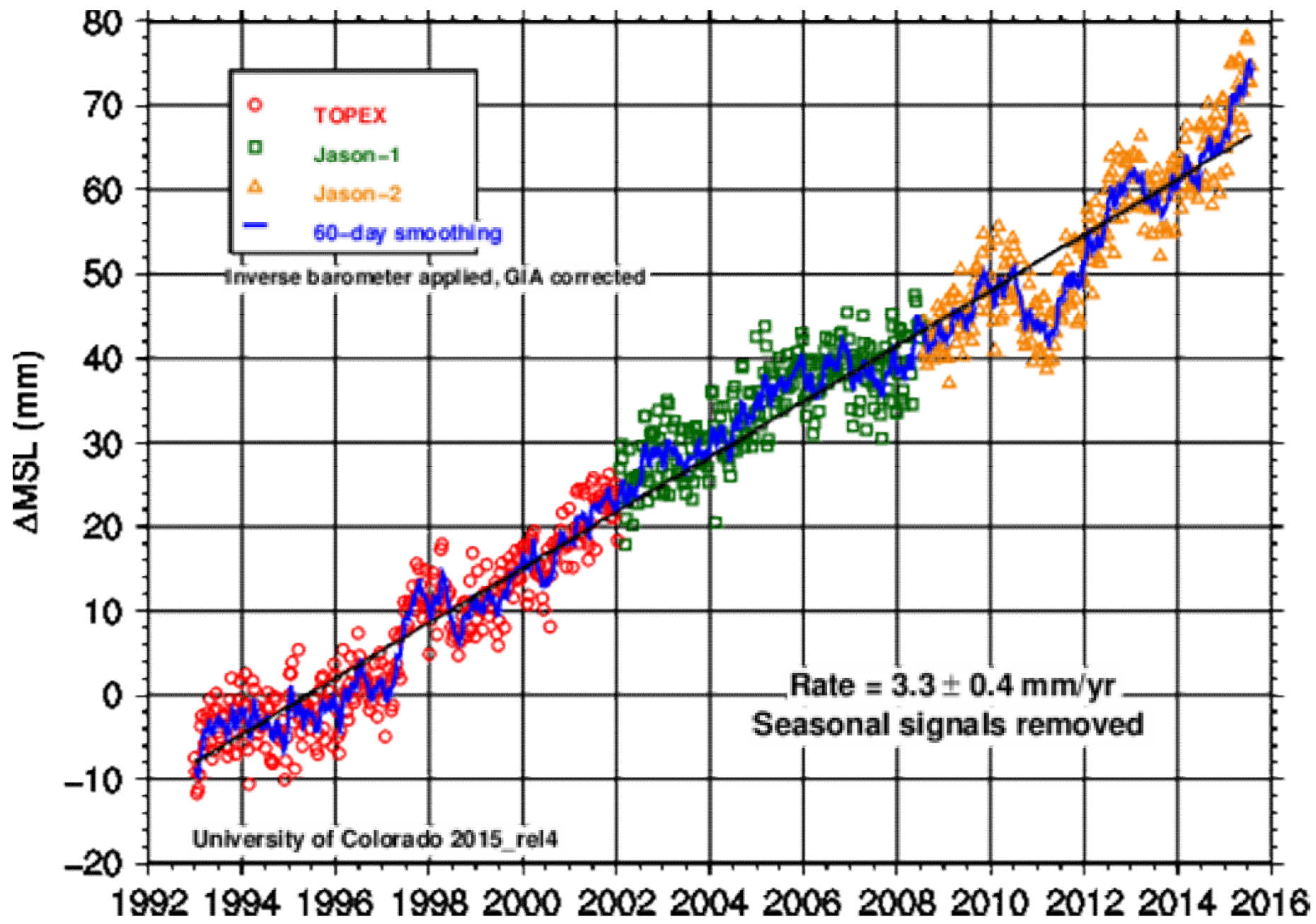
**Heat capacity of ocean water: 3993 J/kg/K**

Source: <http://noconsensus.wordpress.com/2011/04/05/234-5/>

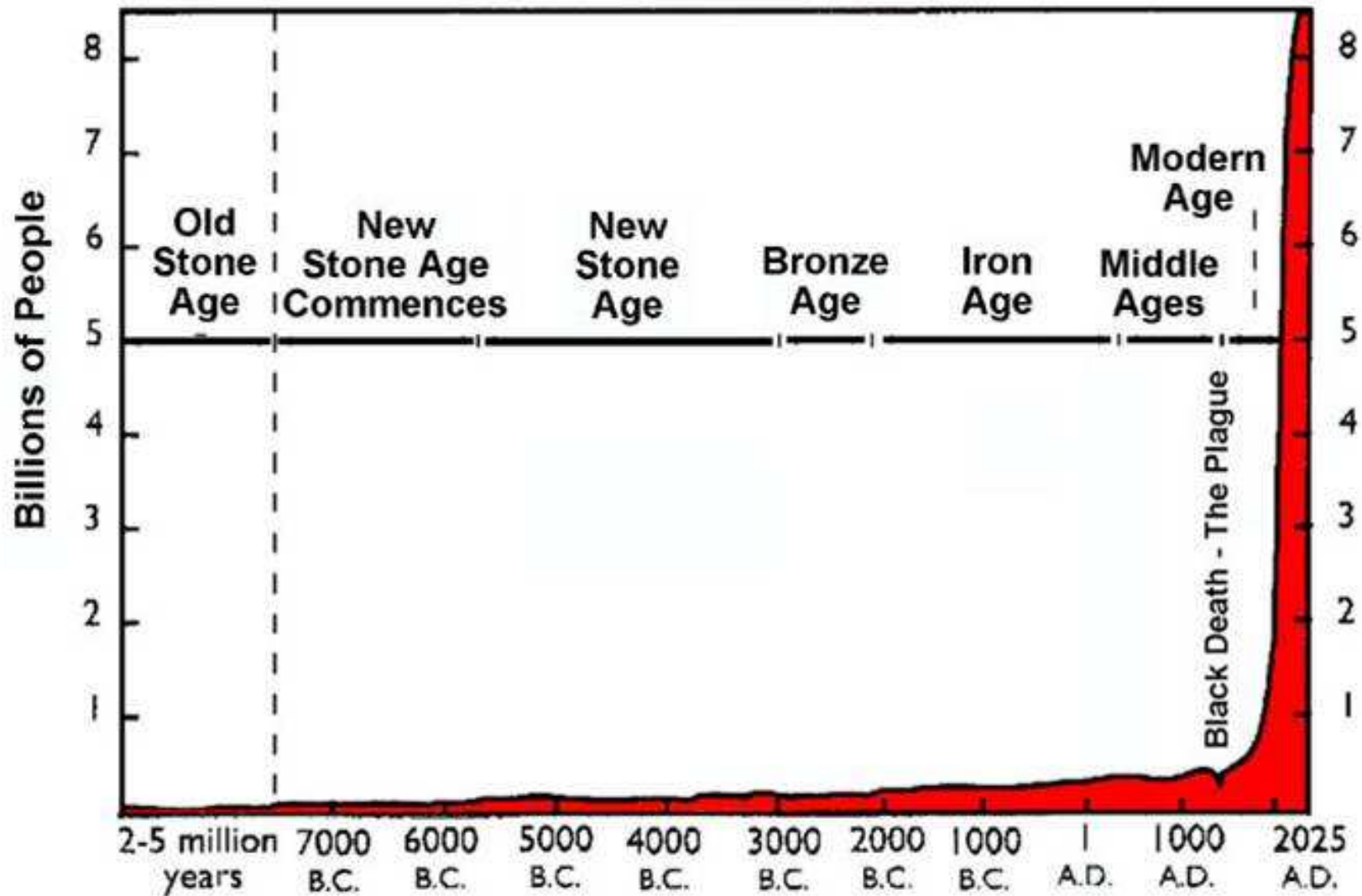


Gulf-Stream and mesoscale eddies pictured on a color-enhanced NOAA/AVHRR image (downloaded from <http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/eastcoast.gif>).



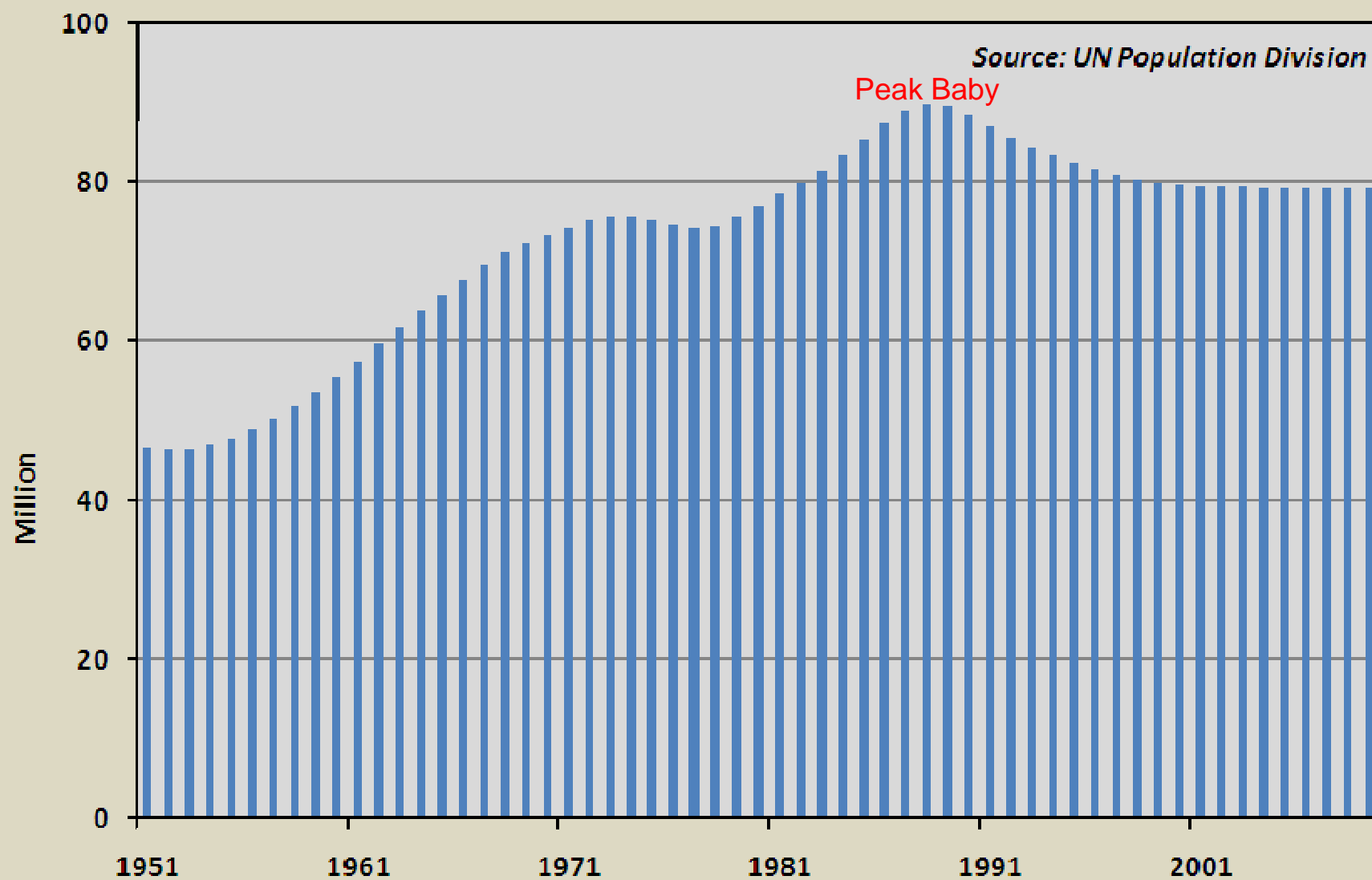


# World Population Growth Through History

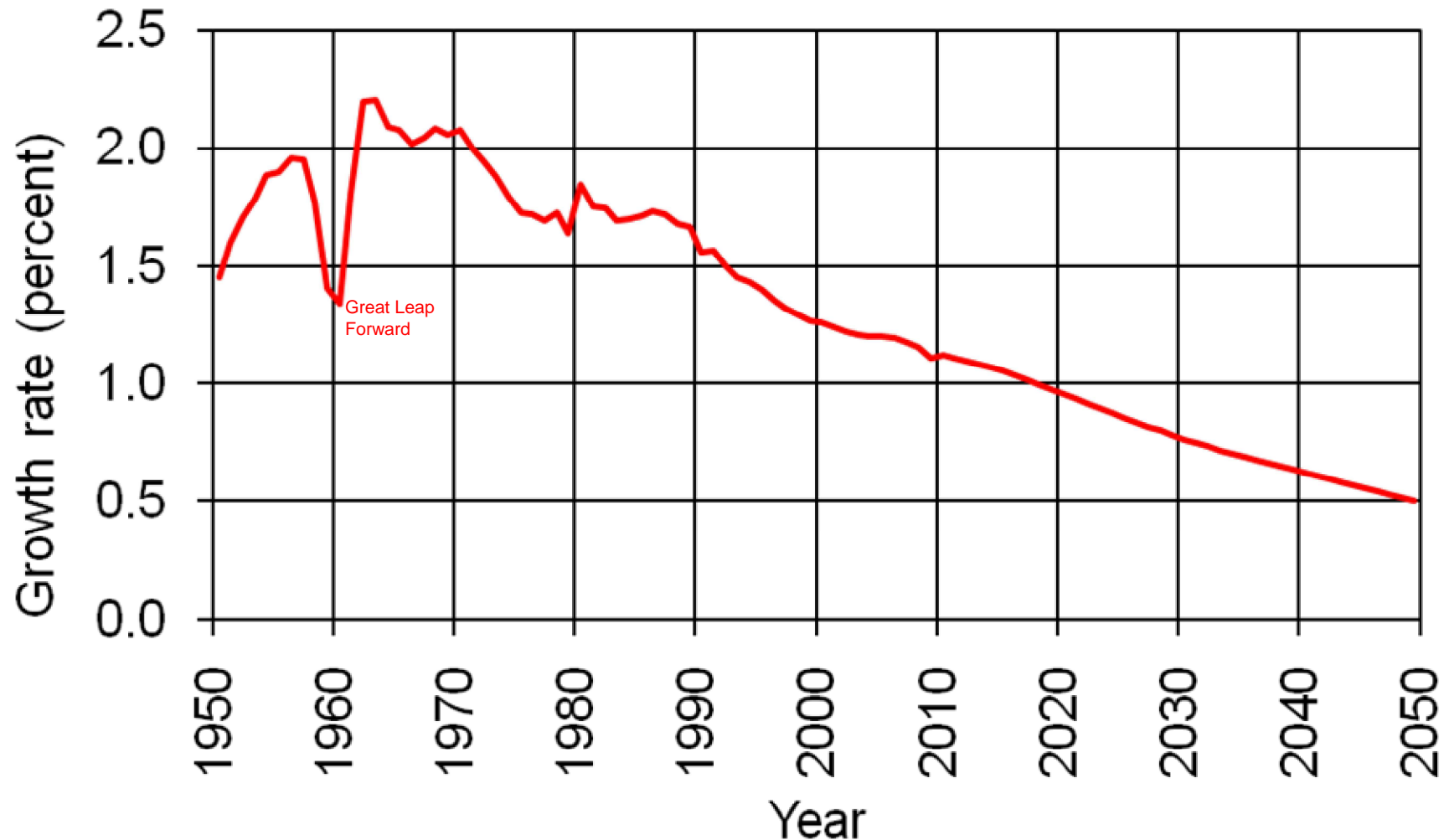


From "World Population: Toward the Next Century," copyright 1994  
by the Population Reference Bureau

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



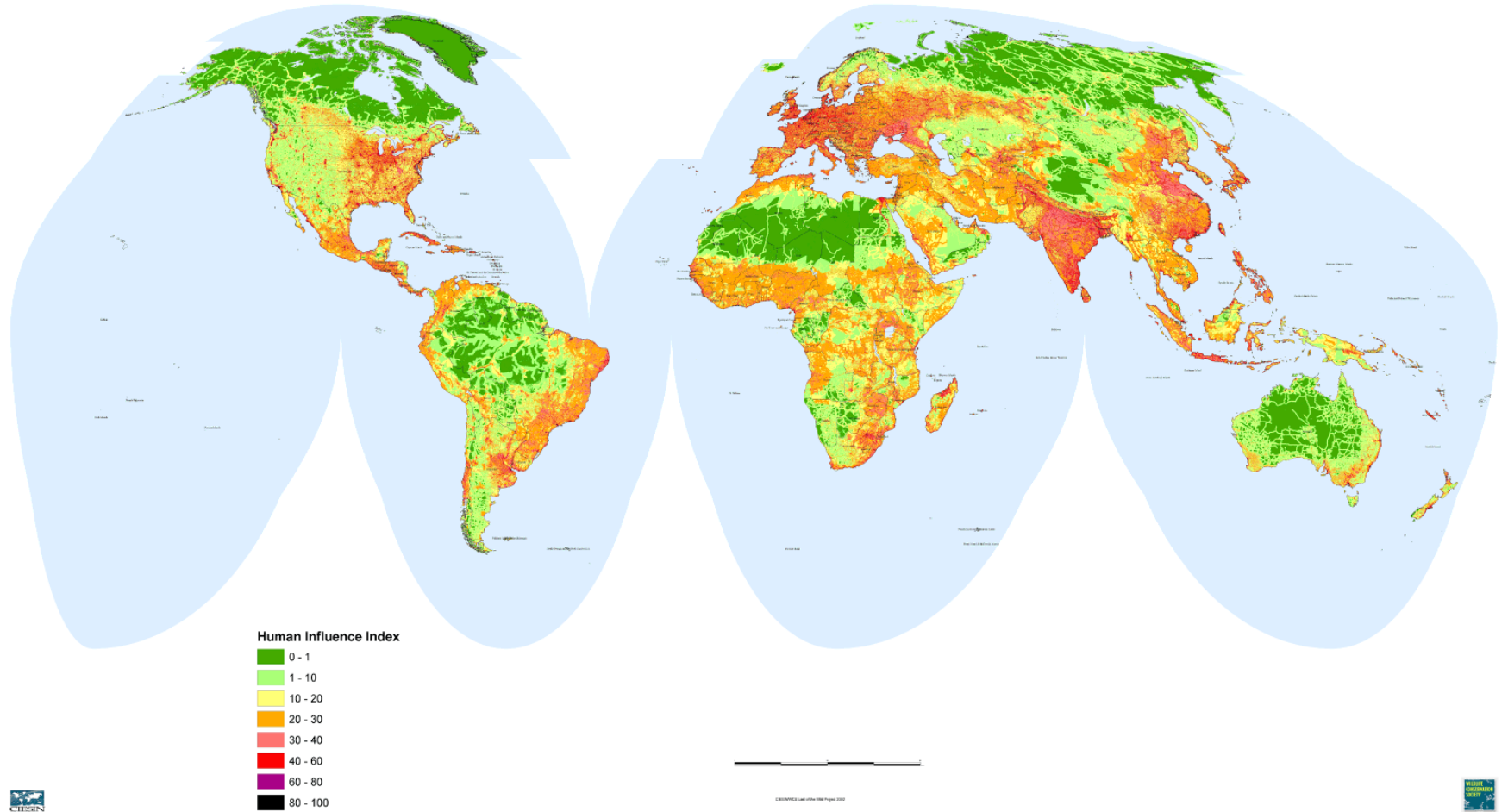
# World Population Growth Rates: 1950-2050



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

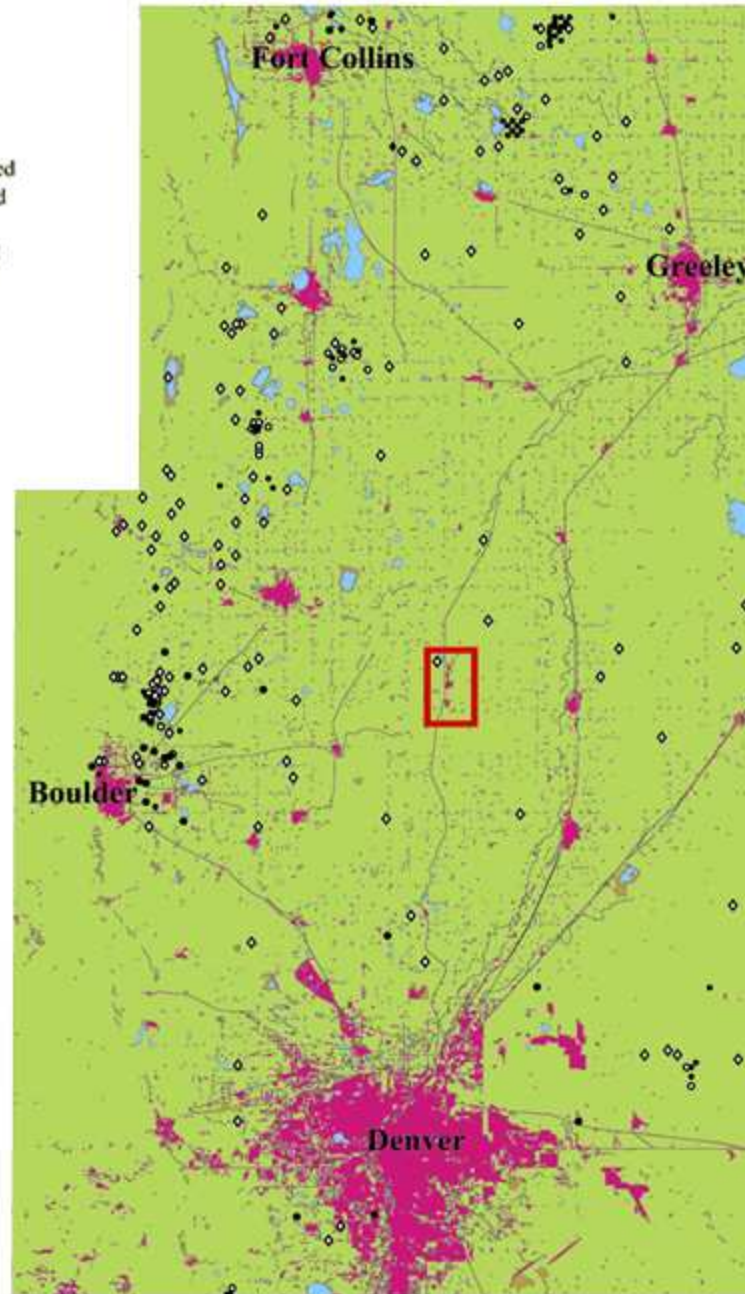


Map of Human Footprint



# 1960

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

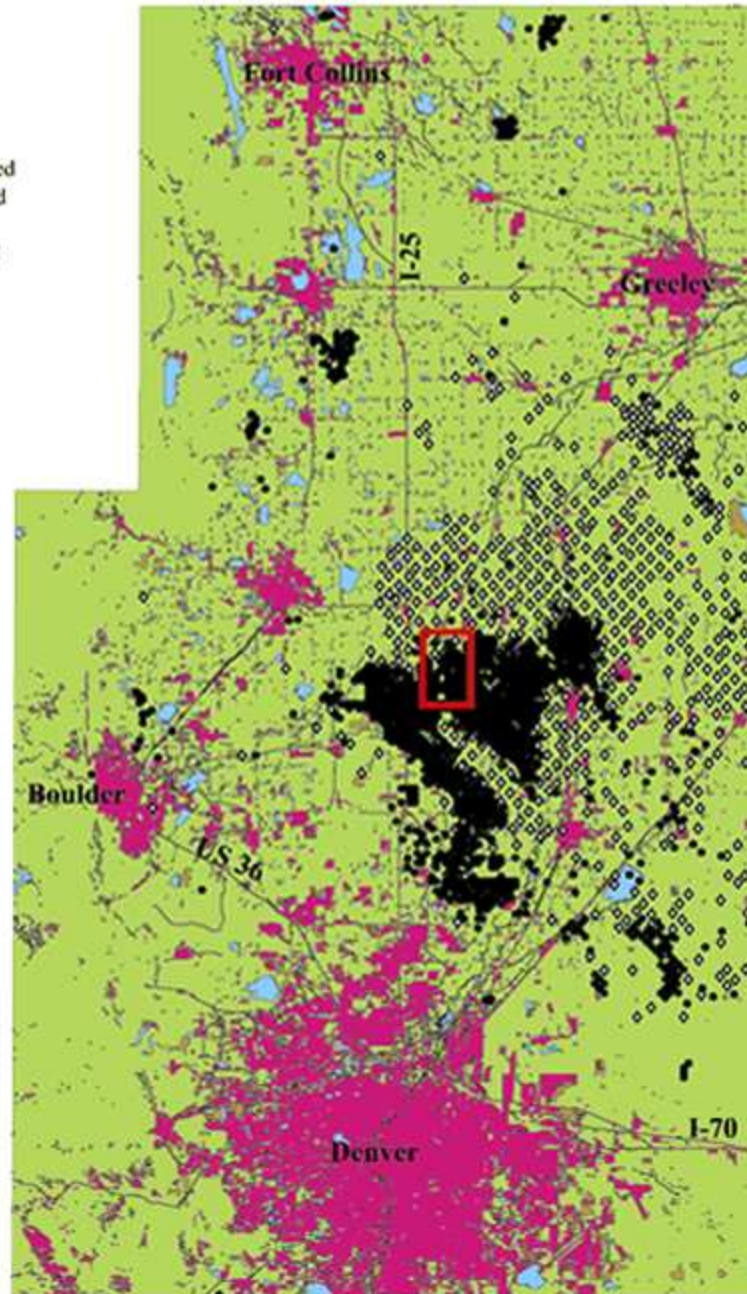


U

USGS

# 1980

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



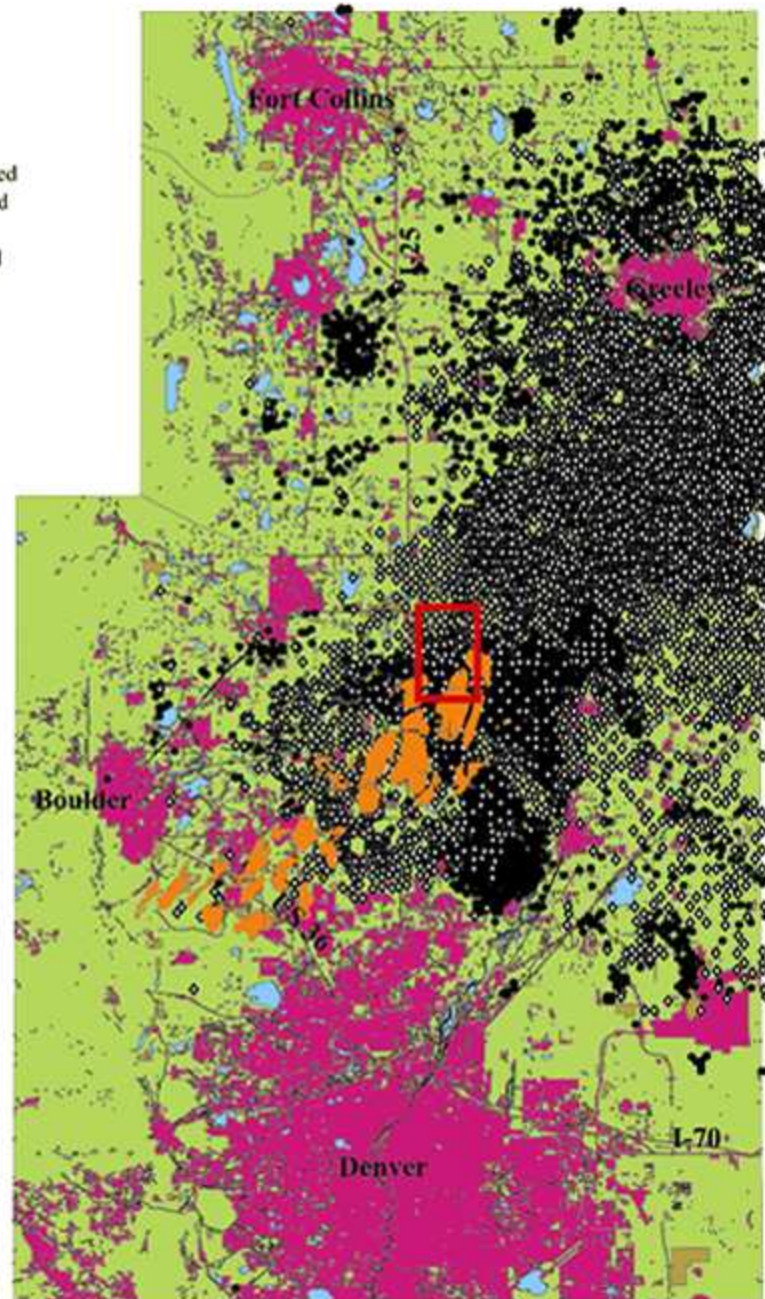
U

USGS



2000

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



U

USGS



# Jonah Field, Wyoming August 1994





# Jonah Field, Wyoming August 2006





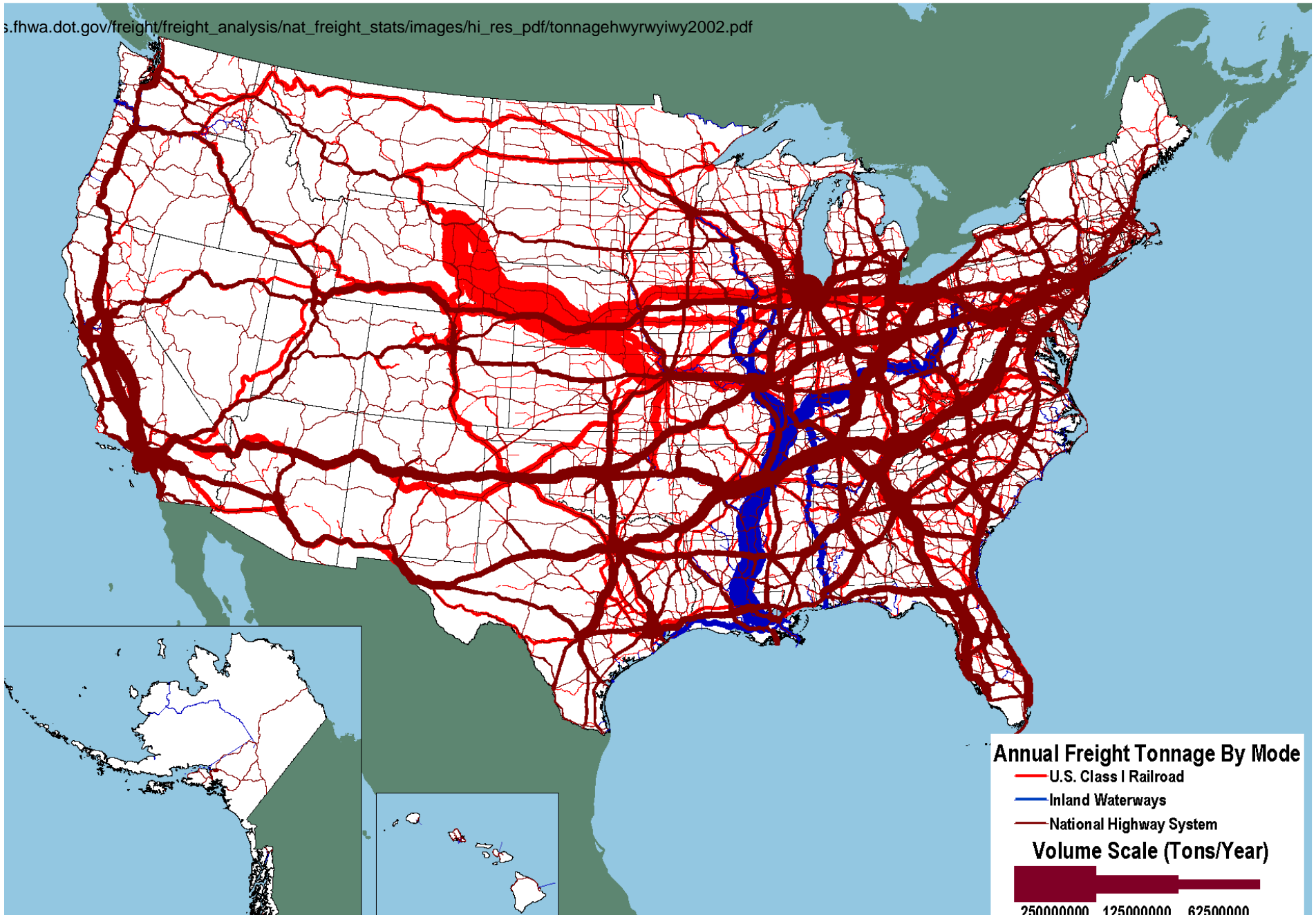


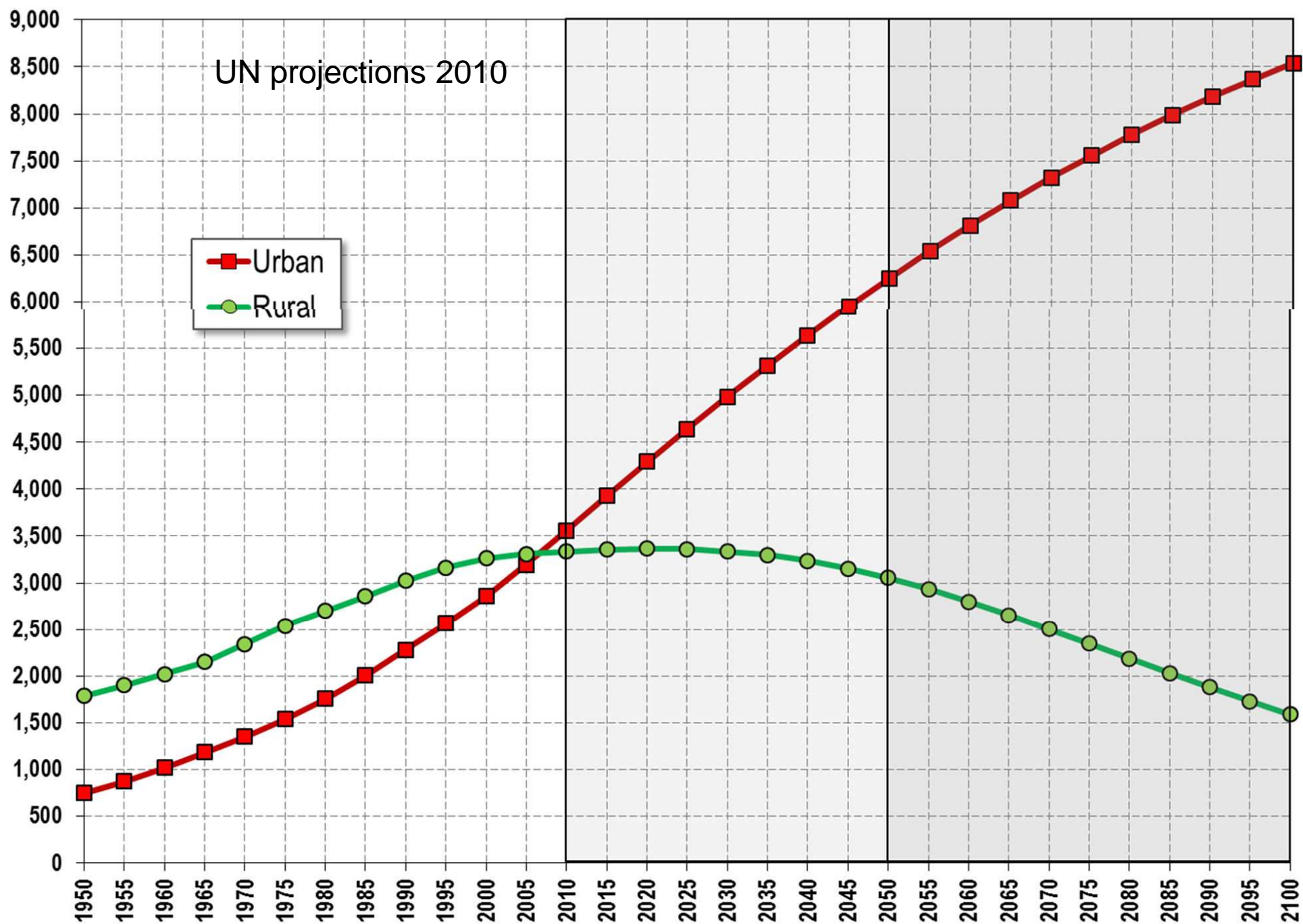
Neft Dashlari, oily rock

Off Baku, Caspian Sea

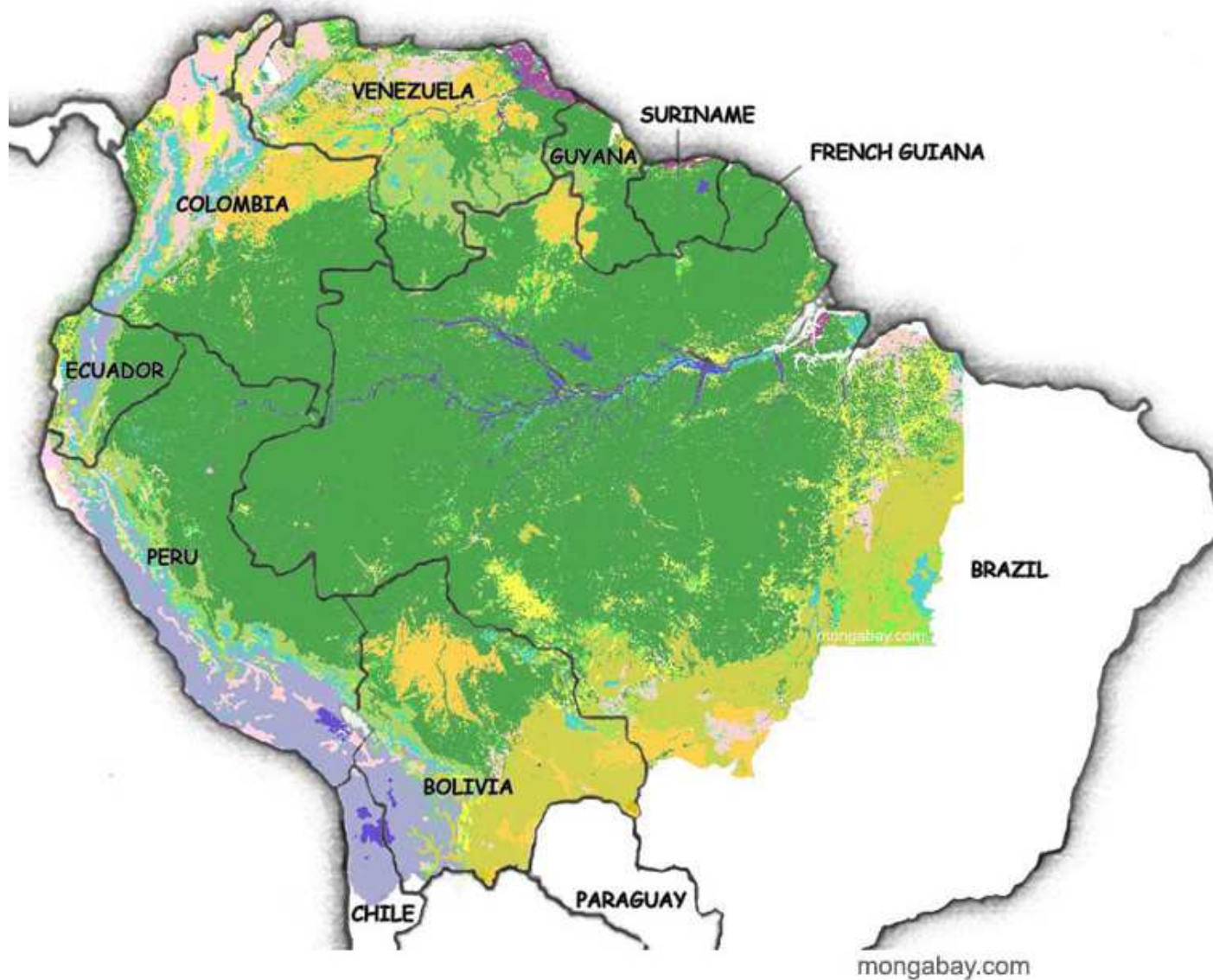
## Tonnage on Highways, Railroads and Inland Waterways: 2002

s.fhwa.dot.gov/freight/freight\_analysis/nat\_freight\_stats/images/hi\_res\_pdf/tonnagehwyrywy2002.pdf









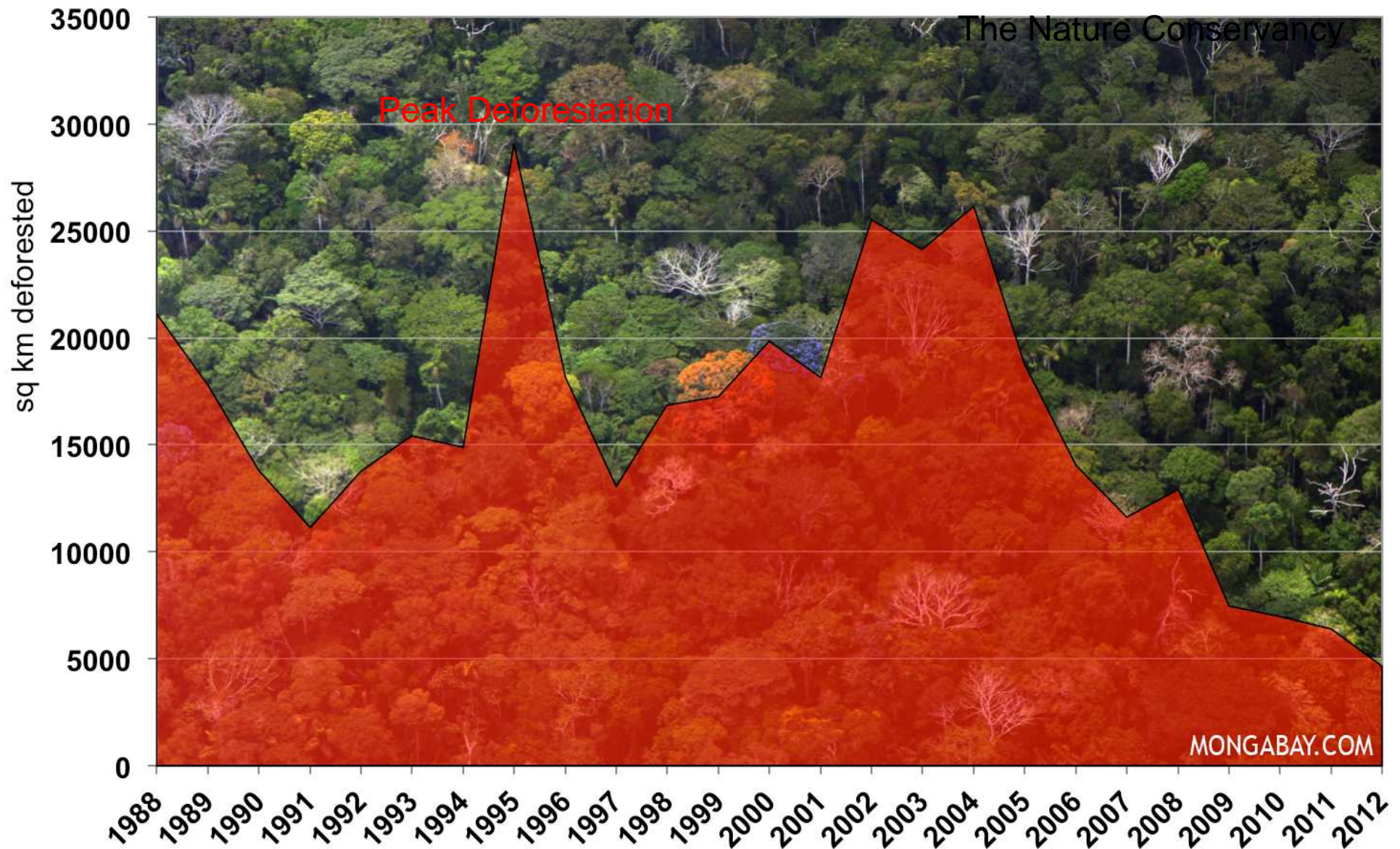
- Lowland moist forest
- Mangrove and coastal swamp forest
- Sub-montane forest
- Montane forest
- Fragmented forest
- Converted forest
- Inland water

- 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

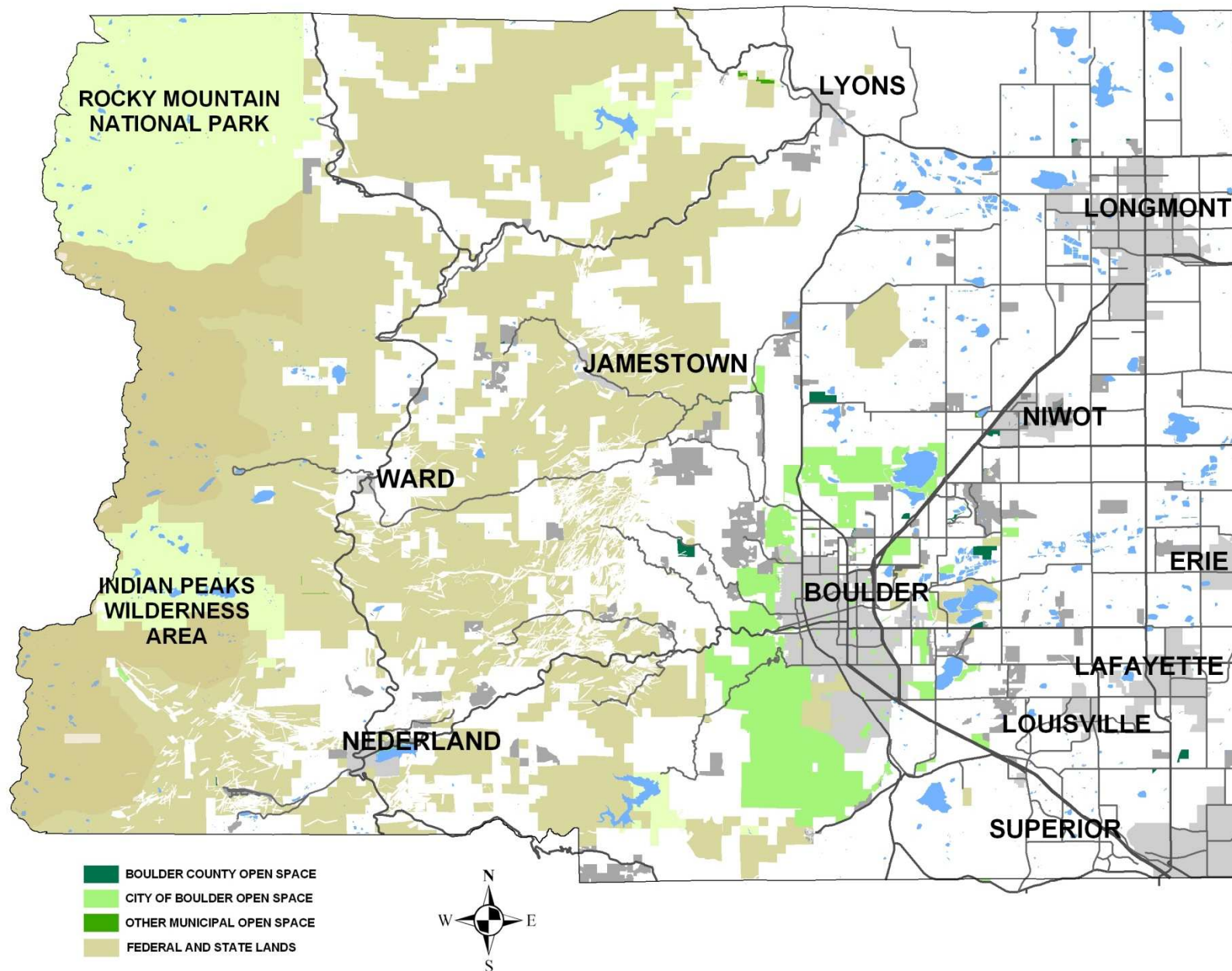


## Deforestation in the Brazilian Amazon, 1988-2012

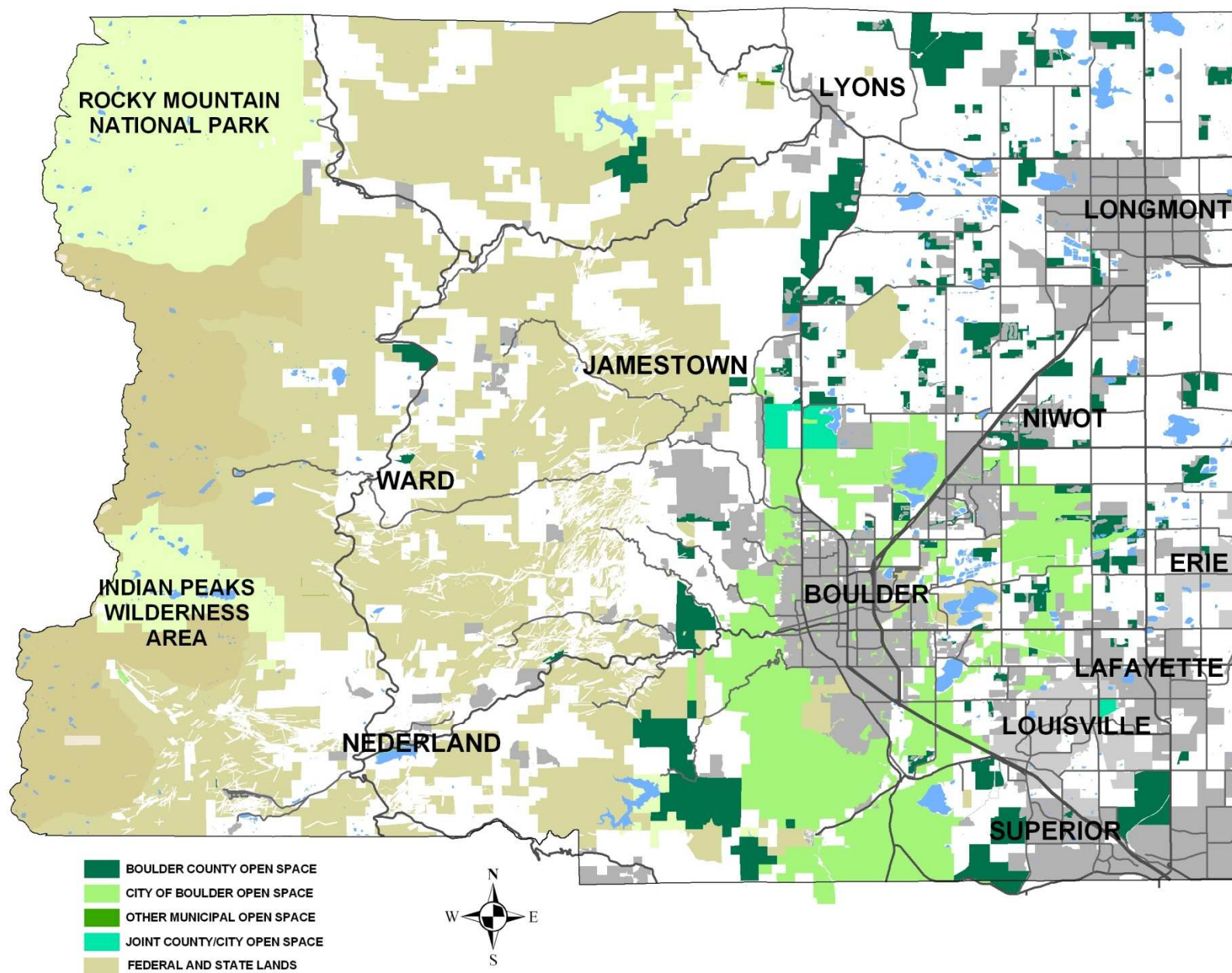




# Open Space 1975

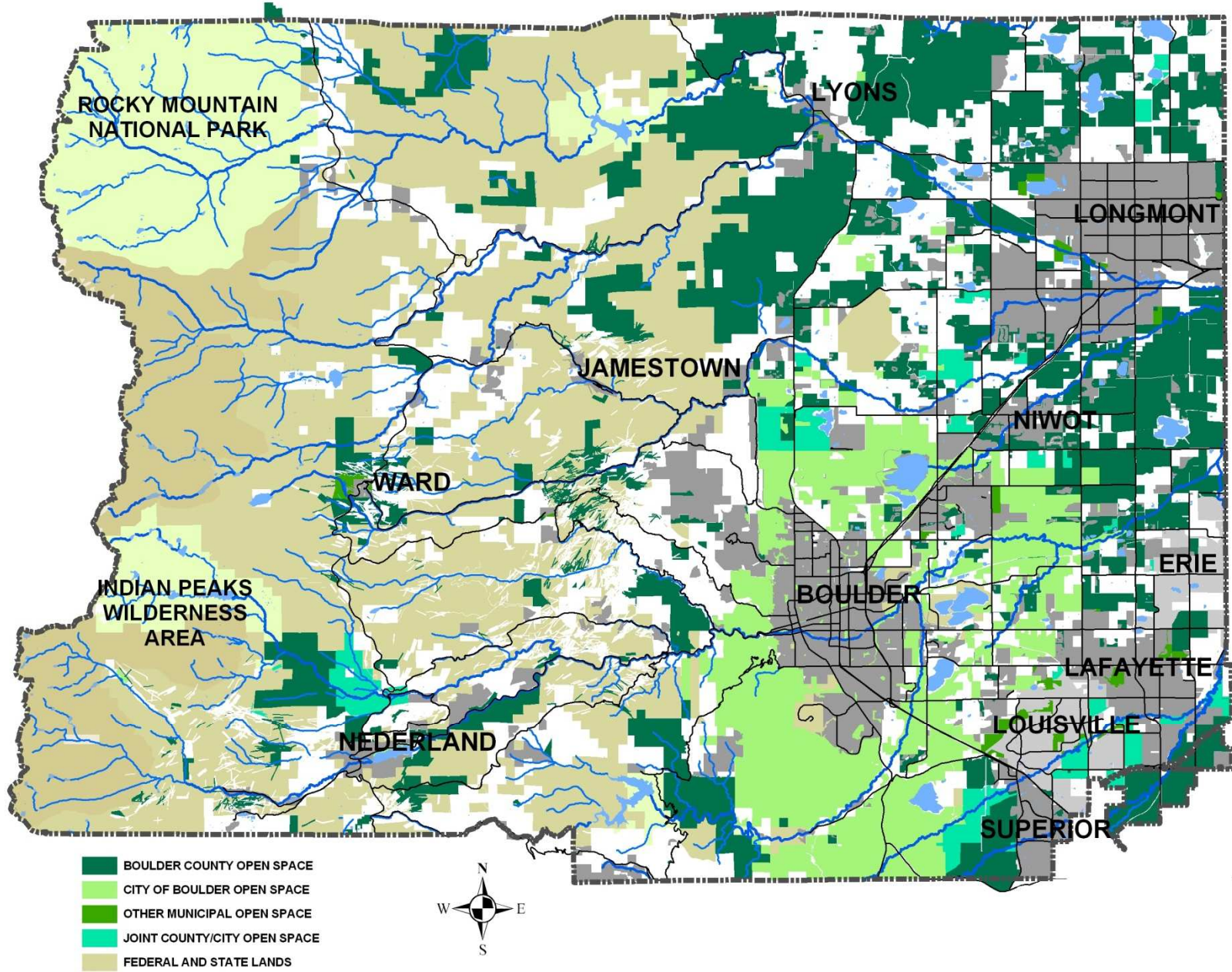


# Open Space 1994





# Open Space 2007



# Fate of the penultimate tree, Ethiopia



# Fate of the penultimate tree, Ethiopia





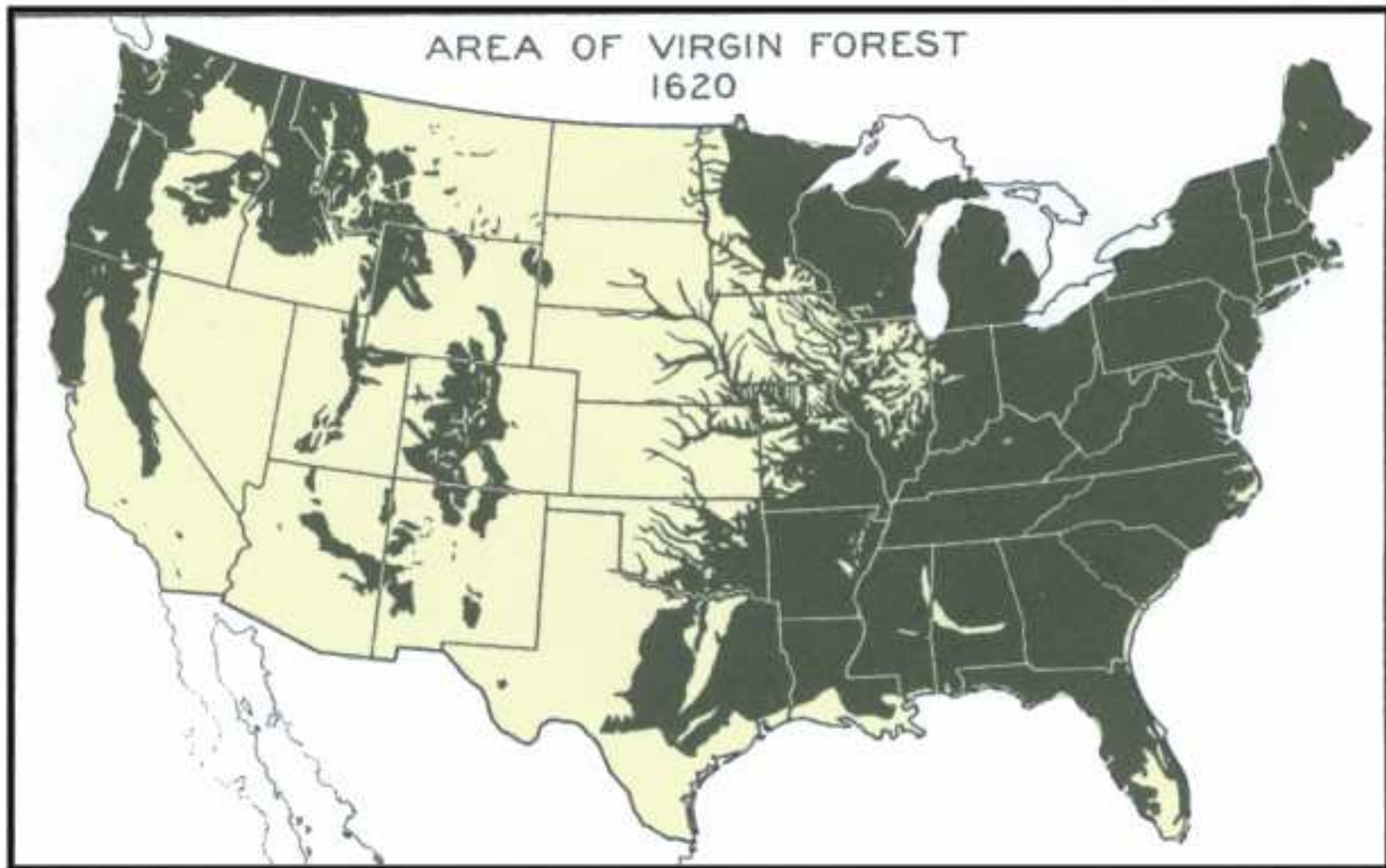


Figure 12.2 "Area of virgin forest," United States, 1620. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)



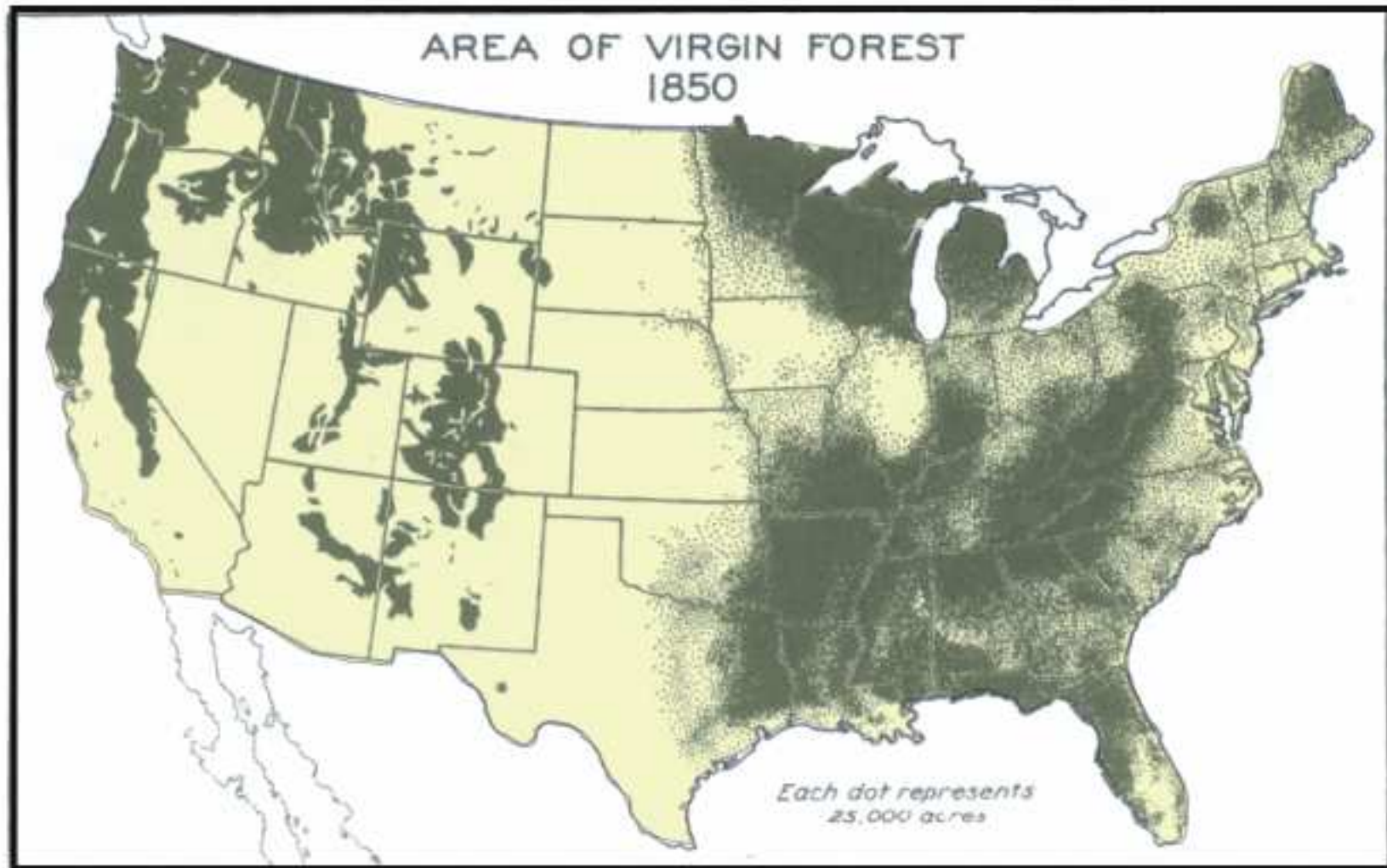


Figure 12.3 "Area of virgin forest," United States, 1850. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)

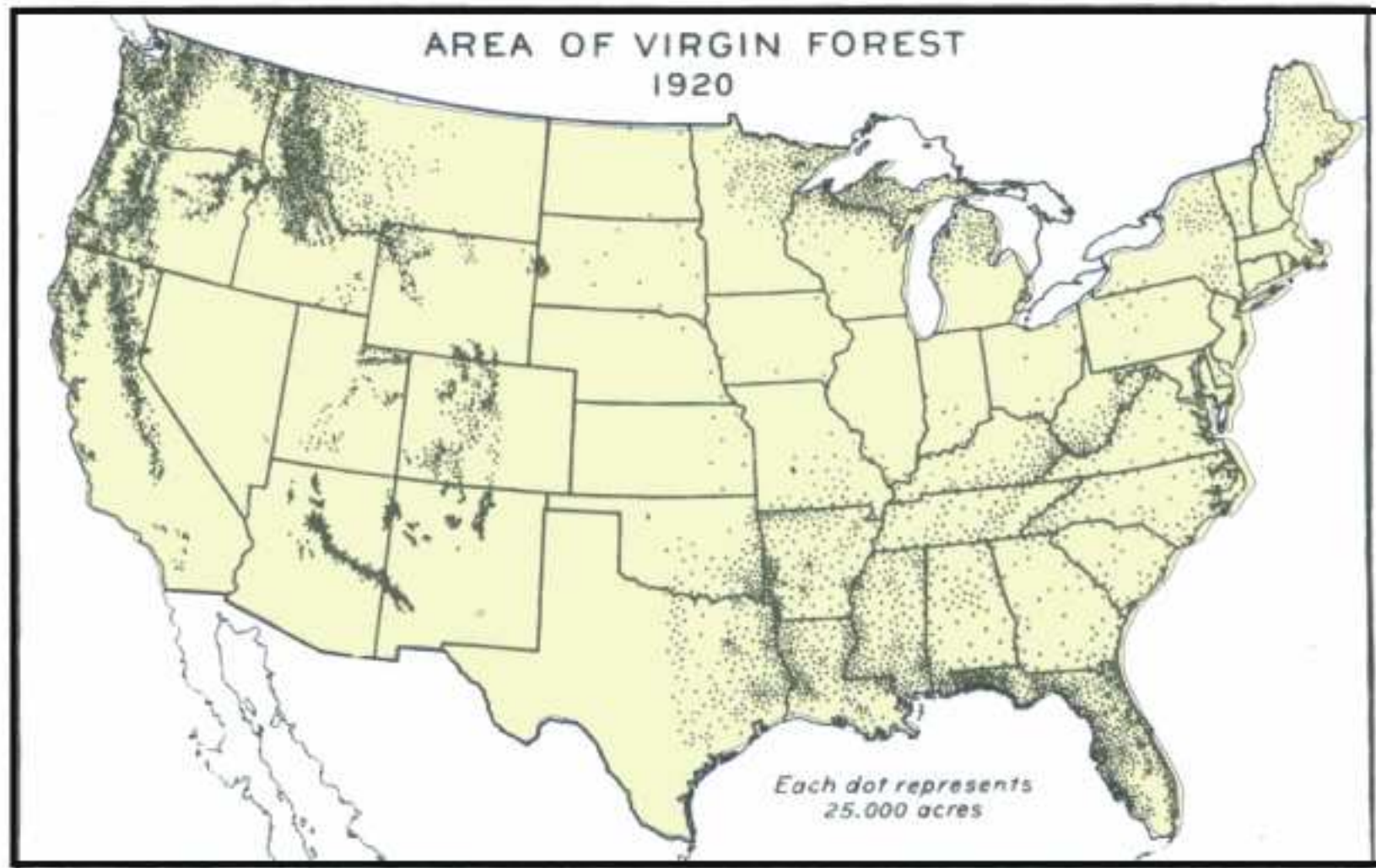


Figure 12.4 "Area of virgin forest," United States, 1920. (Source: W. B. Greeley, "The Relations of Geography to Timber Supply," *Economic Geography* 1 [1925]: 4-5.)



Doug Wheelock, ISS NASA Nov 2, 2010





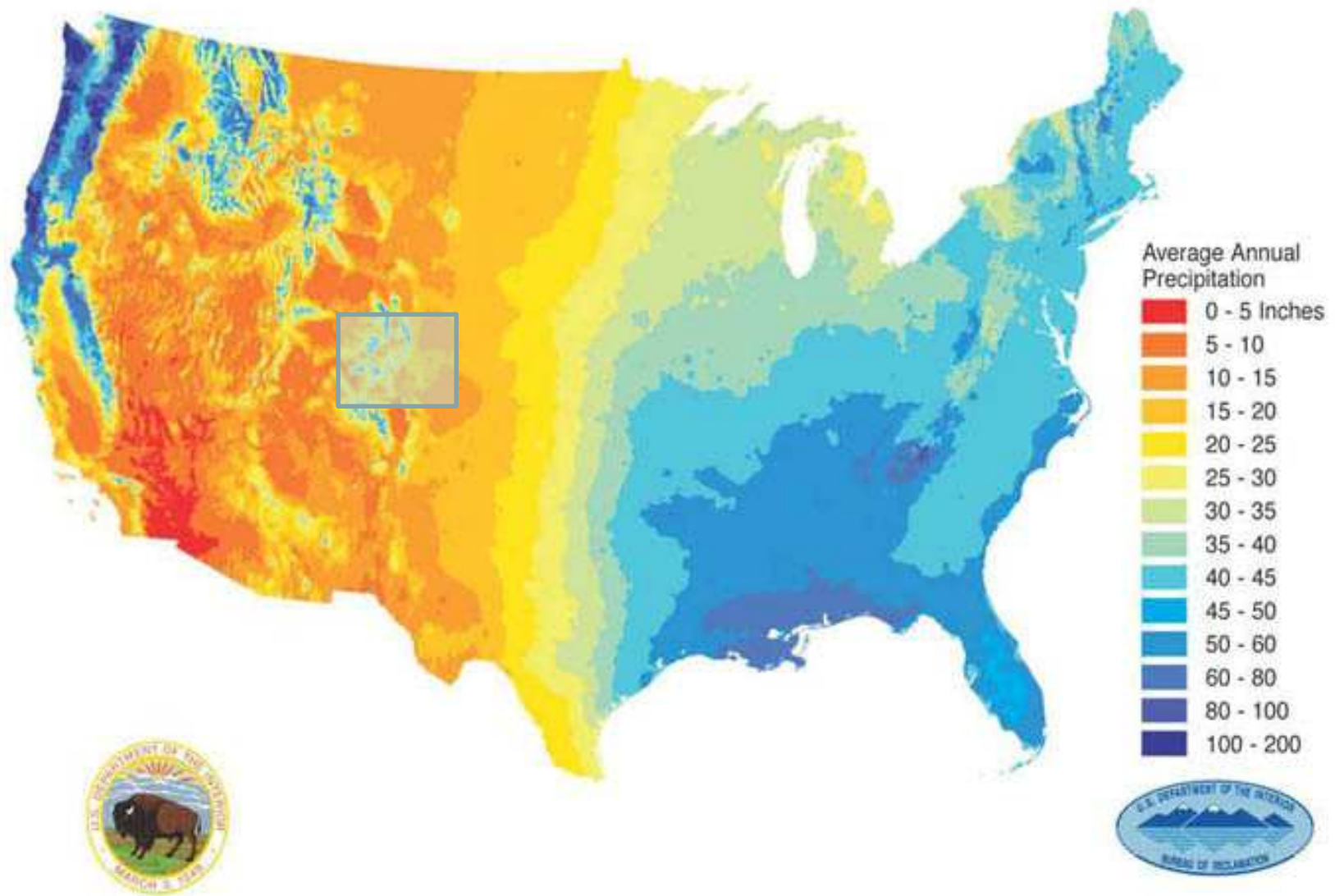
Doug Wheelock, ISS NASA Jan 31, 2010





Doug Wheelock, ISS NASA Aug 22, 2010

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

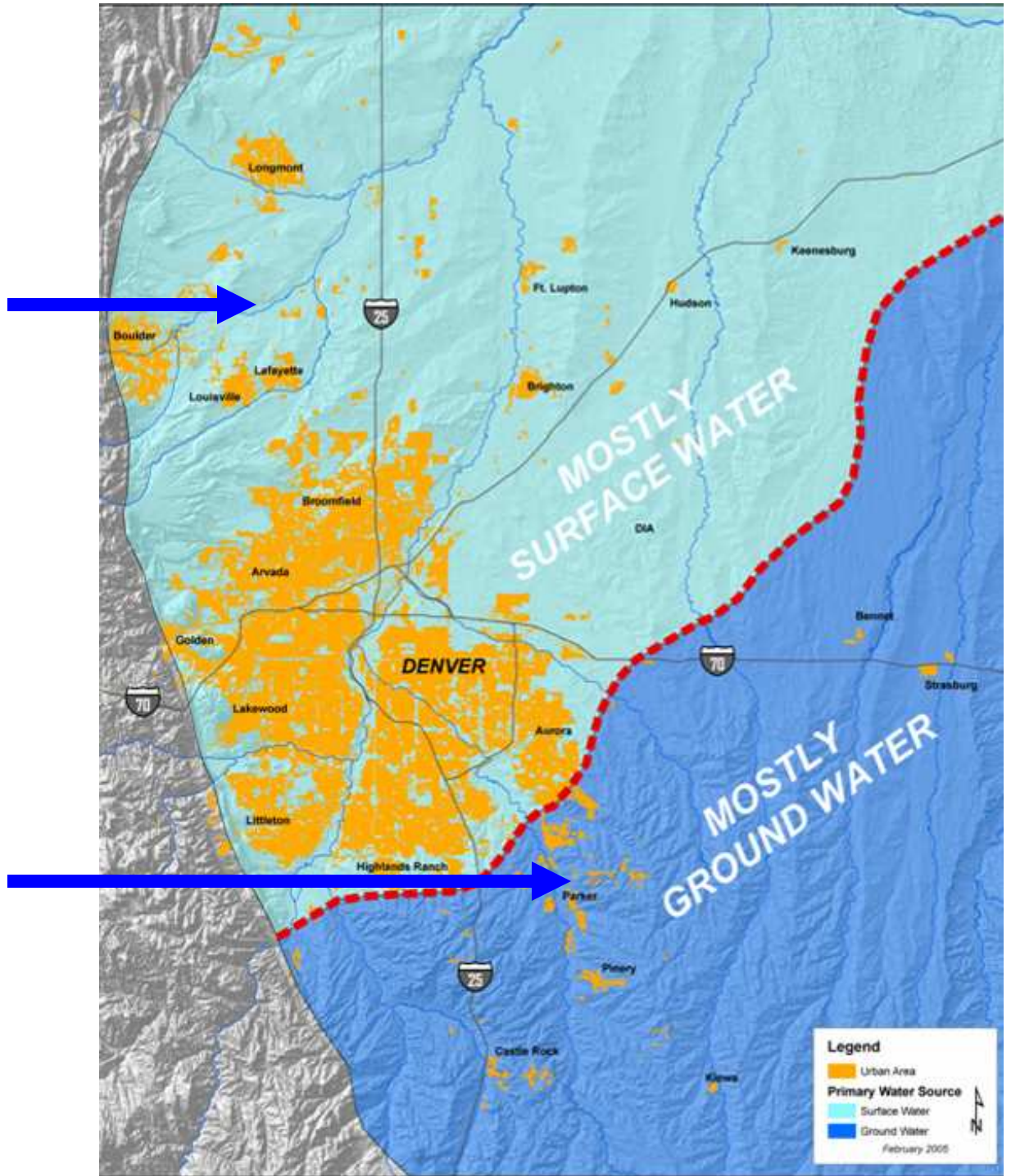


Source: USDA-NRCS: <http://www.fhw.nrcs.usda.gov/prism.html>



Climate  
dependent  
(drought)

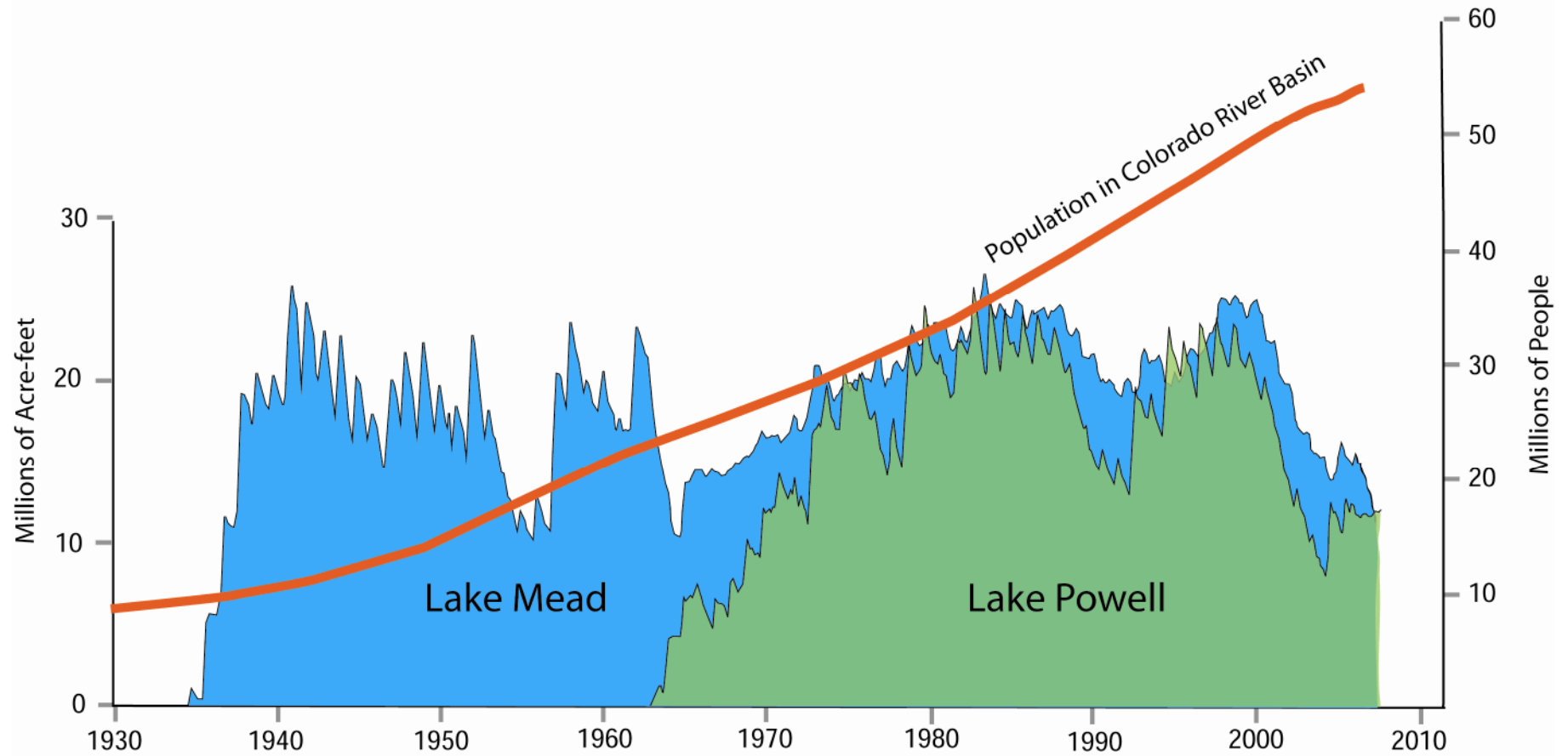
Aquifer  
dependent  
(finite resource)







## Water Storage and Population in the Colorado River System



Modified after Western Water Assessment 2008

















קולחי אילת  
11  
מי קולחין  
השתיה אסורה !

















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

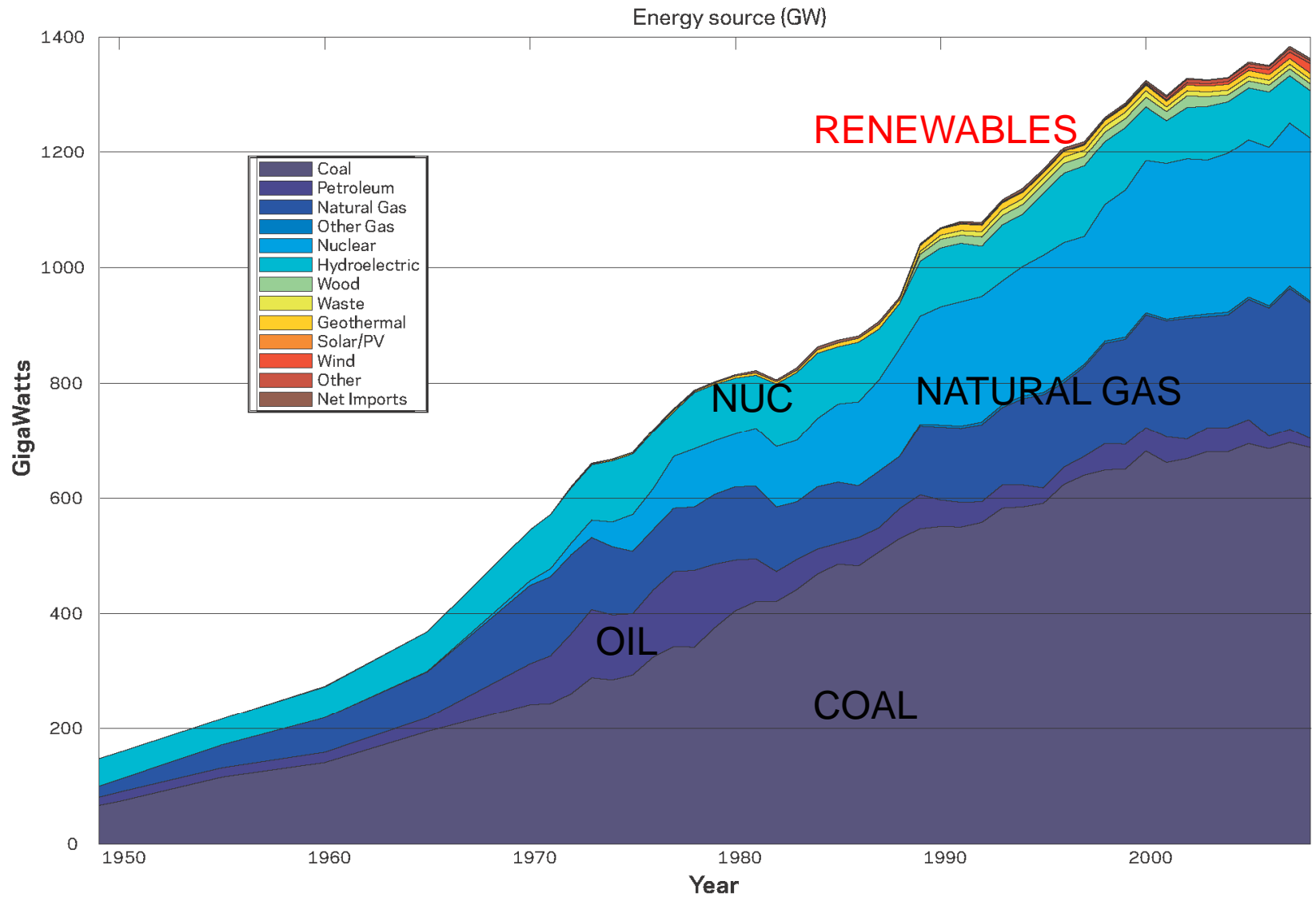




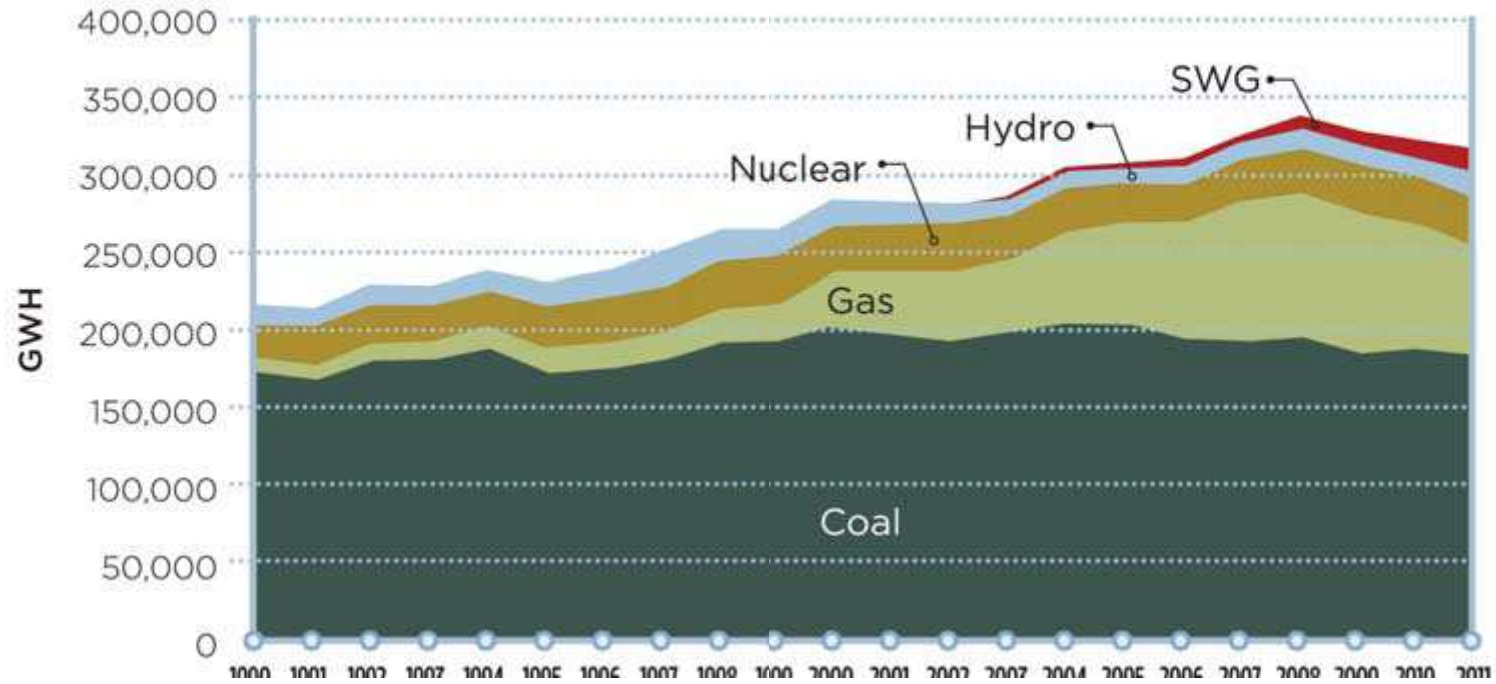
Courtesy of <http://www.peabodyenergy.com/>



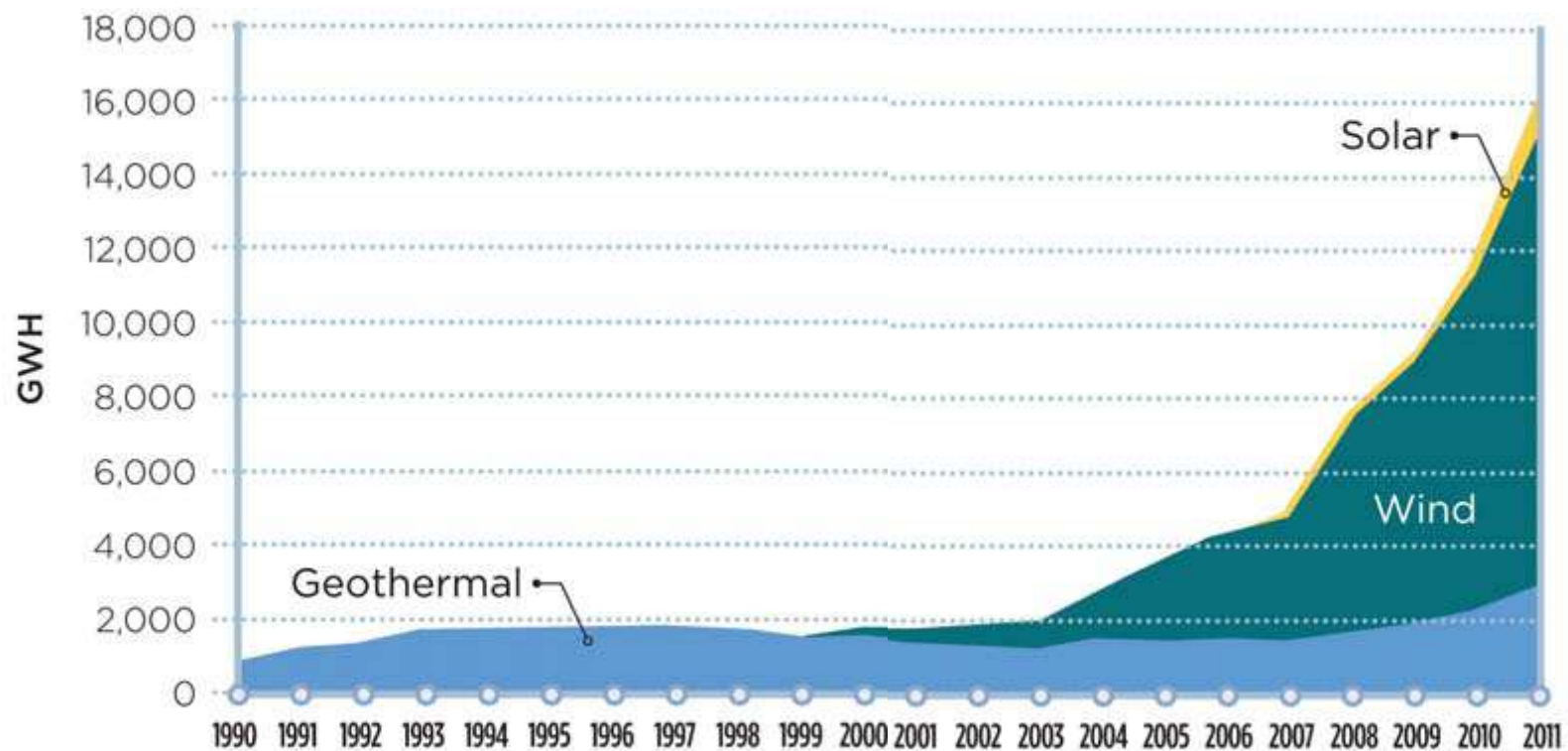
Historical US electricity production, by generation source.



# ROCKY MT REGION



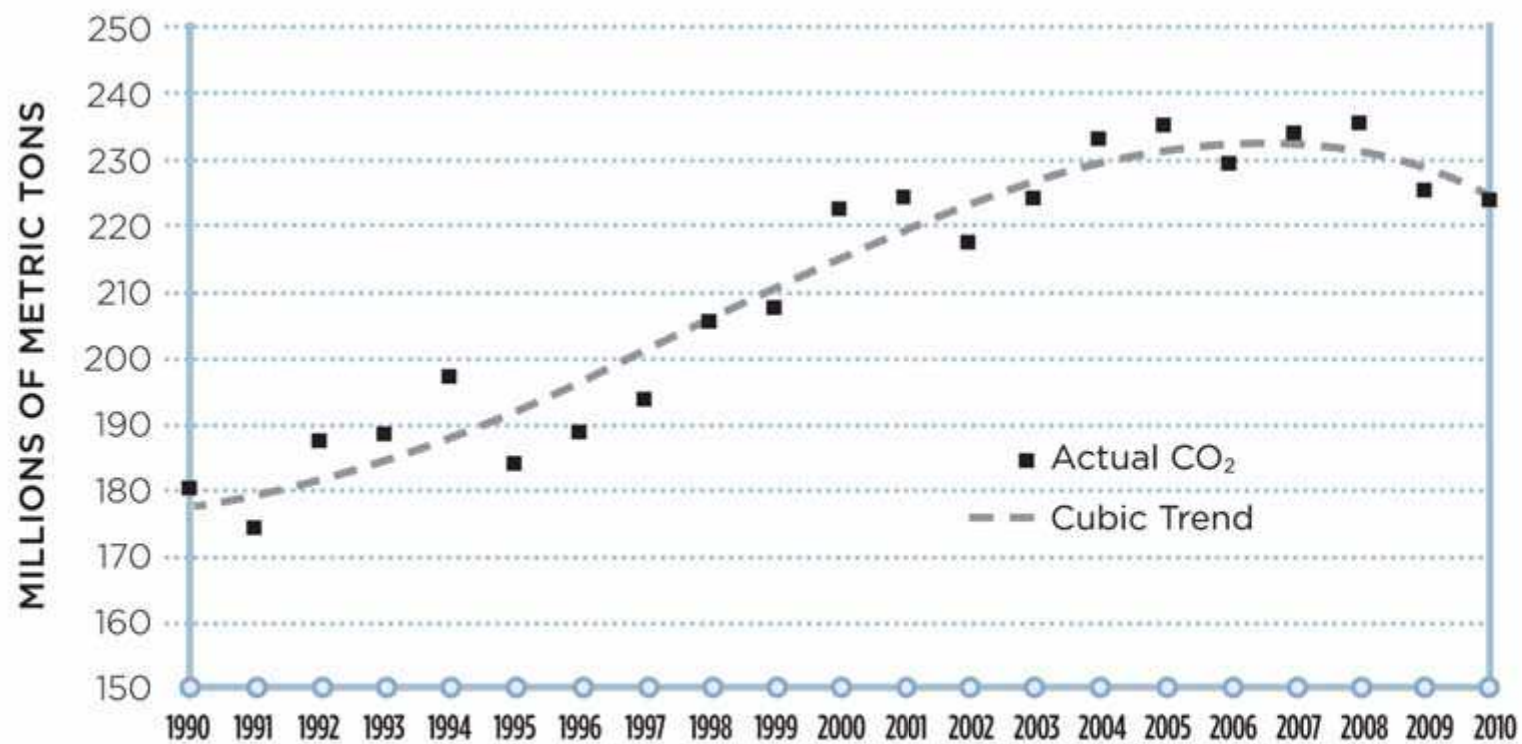
Mountain West power generation by fuel type



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

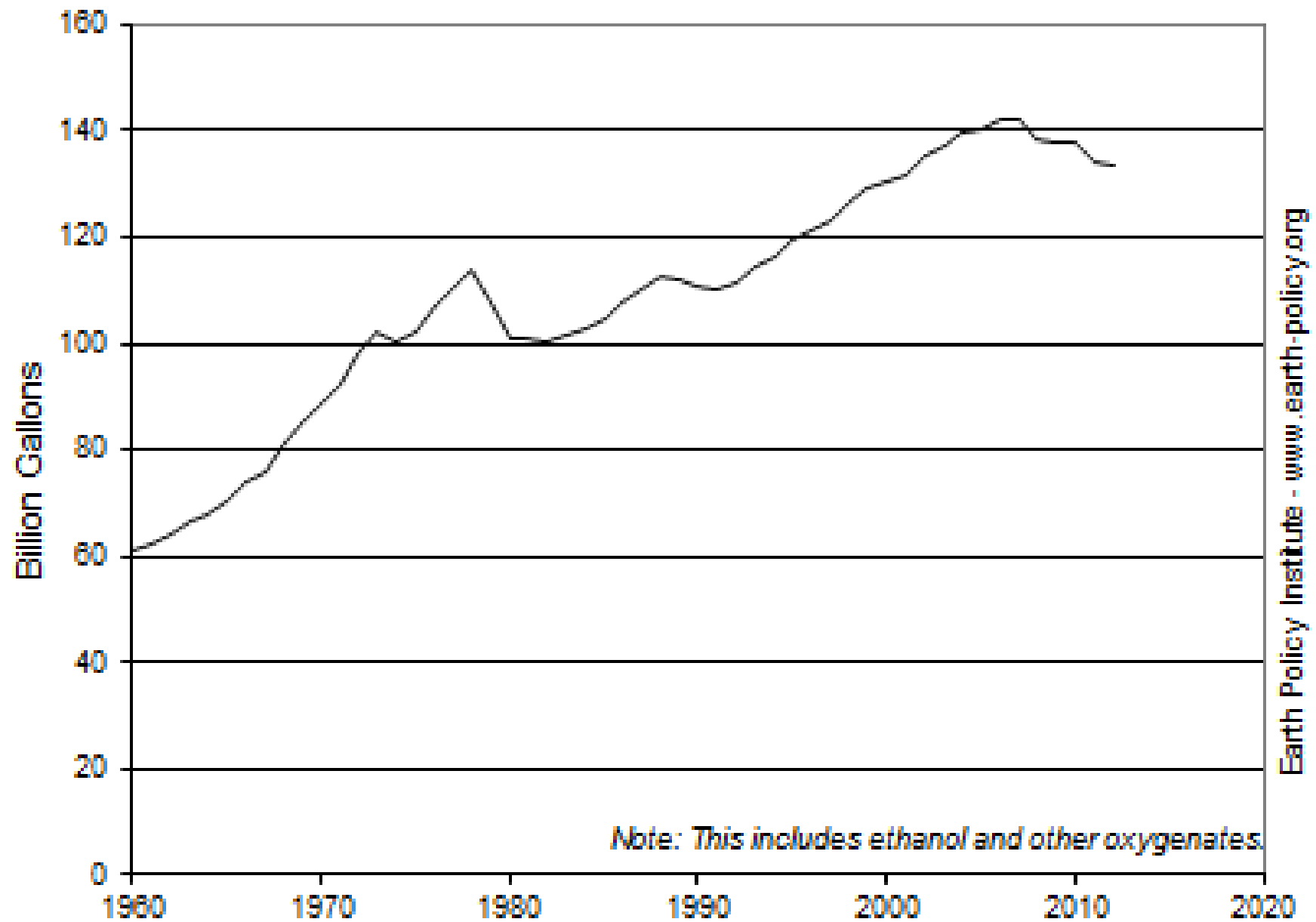
WESTERN RESOURCE ADVOCATES





**Figure 1.** *CO<sub>2</sub> Emissions from the Electric Power Sector in the Mountain West*

## U.S. Motor Gasoline Consumption, 1960-2012



Source: EIA

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

17

Rd N 108

Aug 2003

Google earth

Image © 2013 DigitalGlobe  
Image U.S. Geological Survey

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

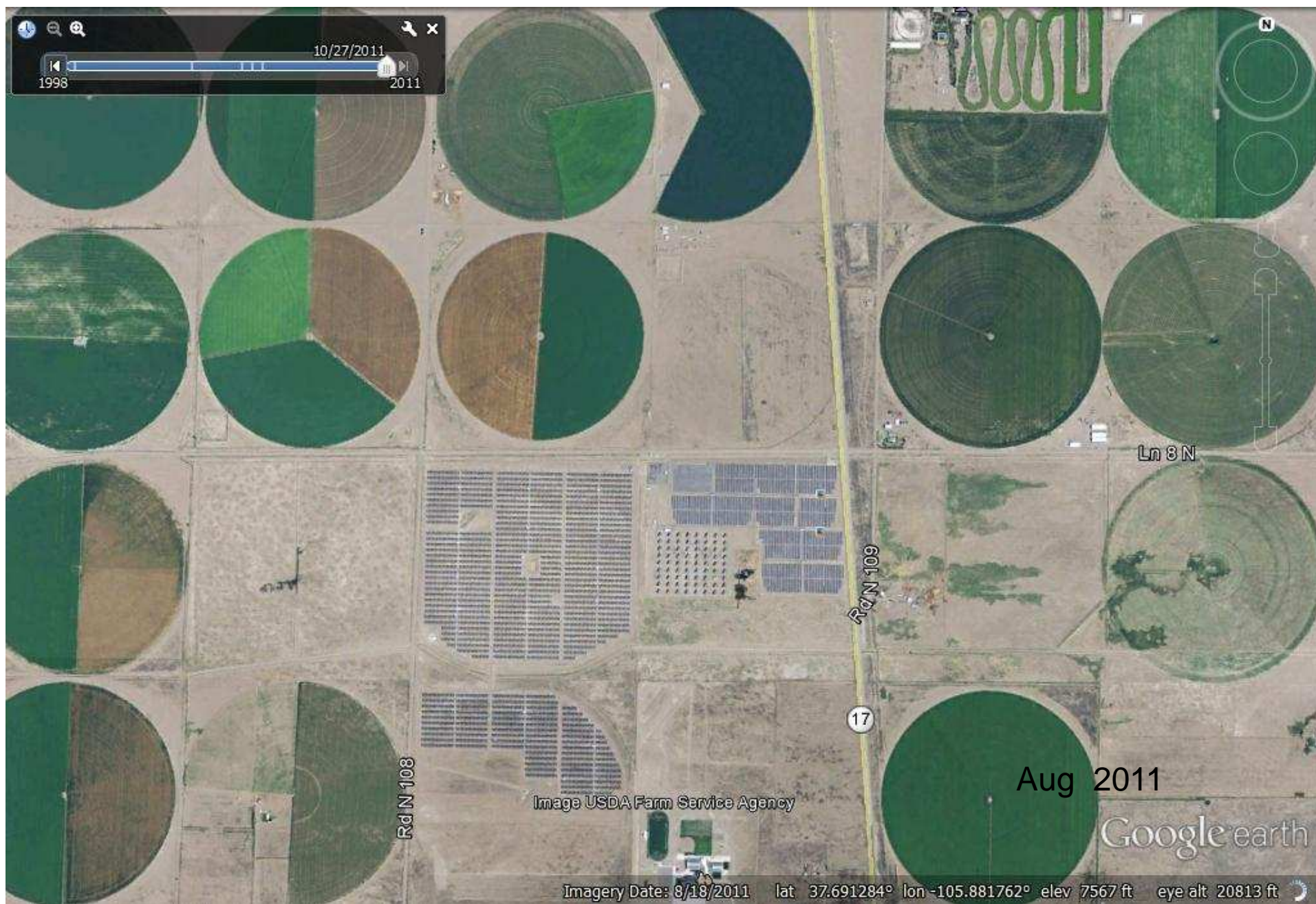
Image USDA Farm Service Agency

June 2005

Google earth

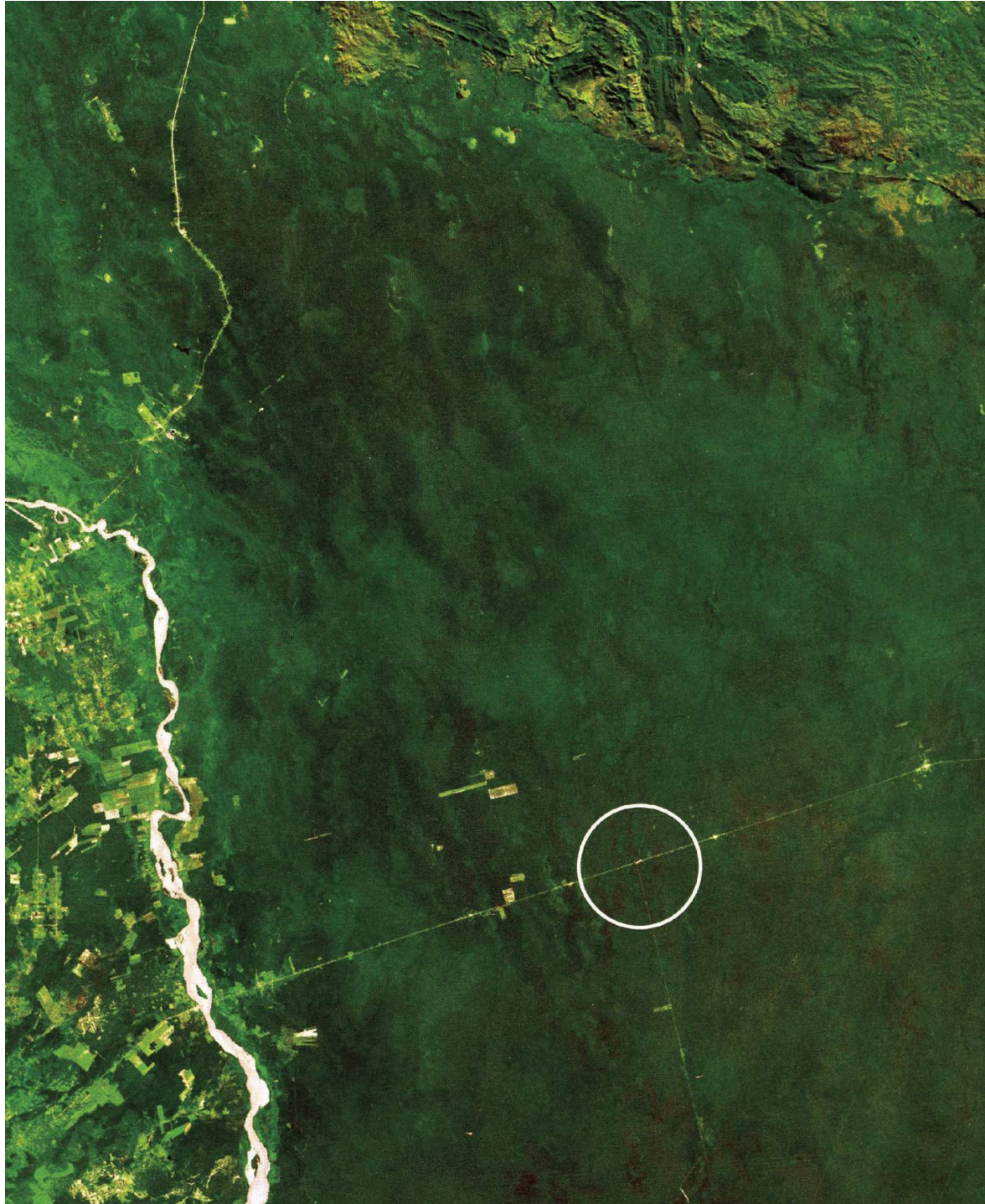
Imagery Date: 6/16/2005 lat 37.691284° lon -105.881762° elev 7567 ft eye alt 20813 ft







Bolivia



**1975**



Bolivia



**2003**





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





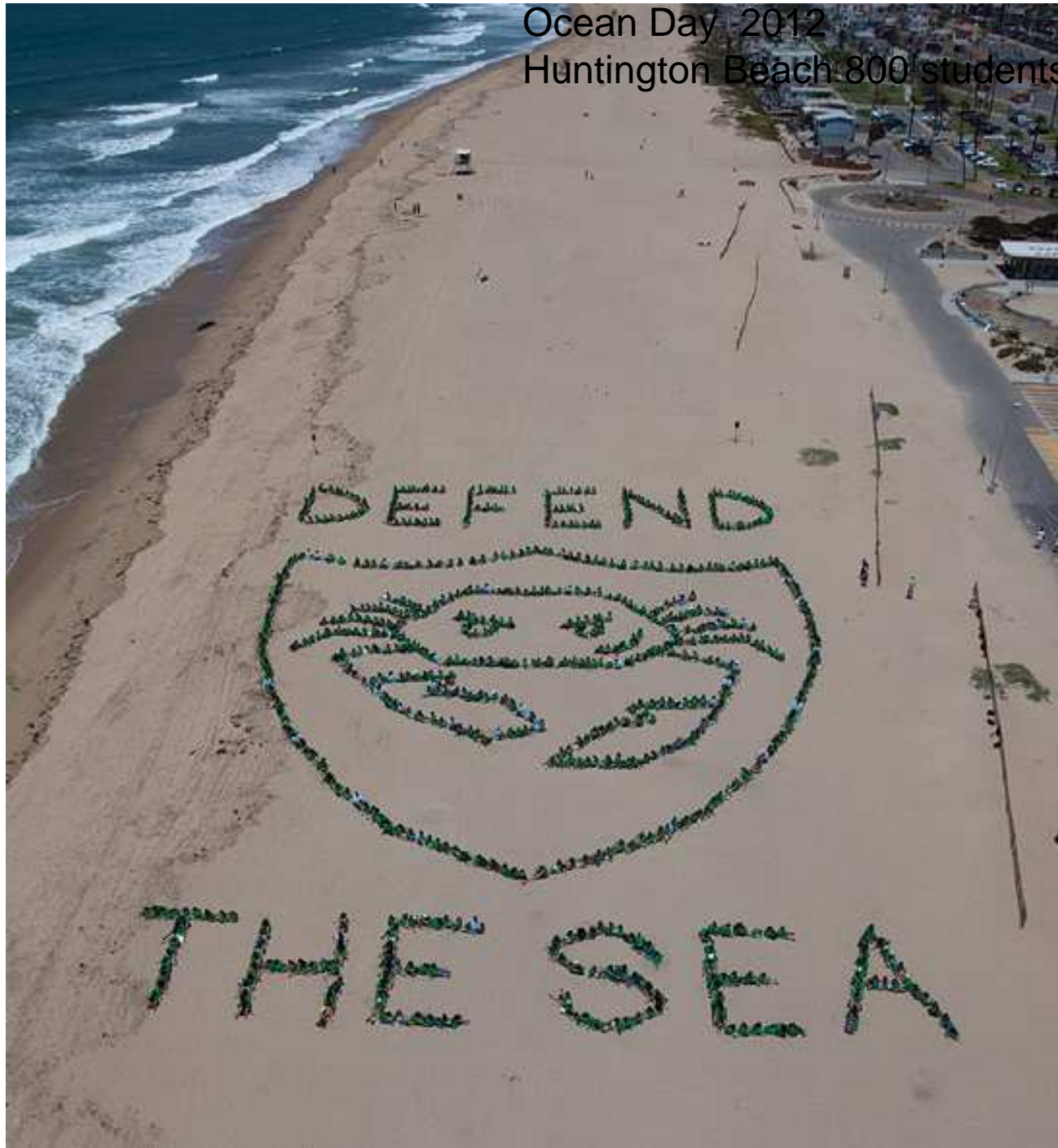


Tijuana River





Ocean Day 2012  
Huntington Beach 800 students

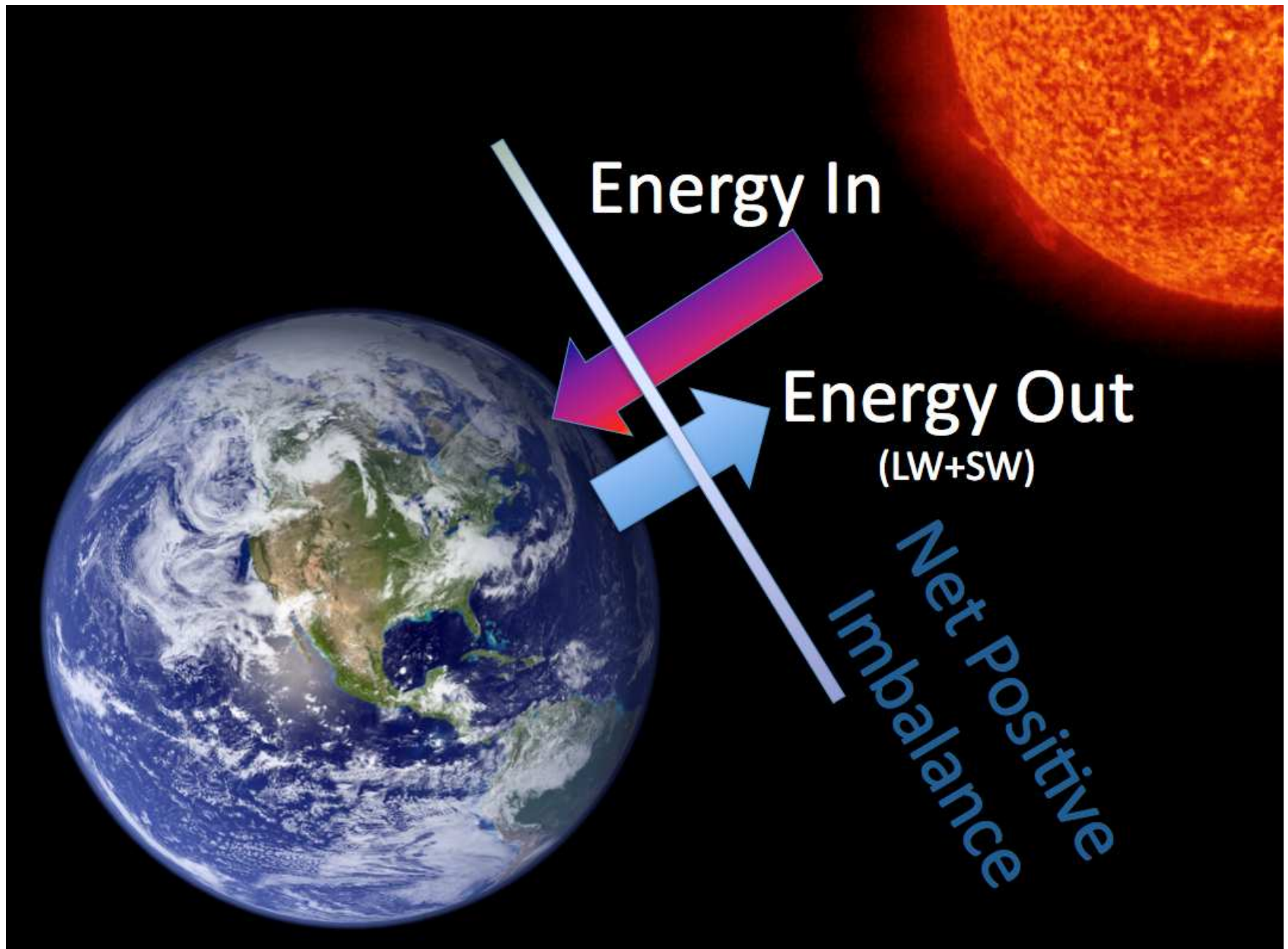






Ocean Day  
Dockweiler Beach, LA  
5000 students

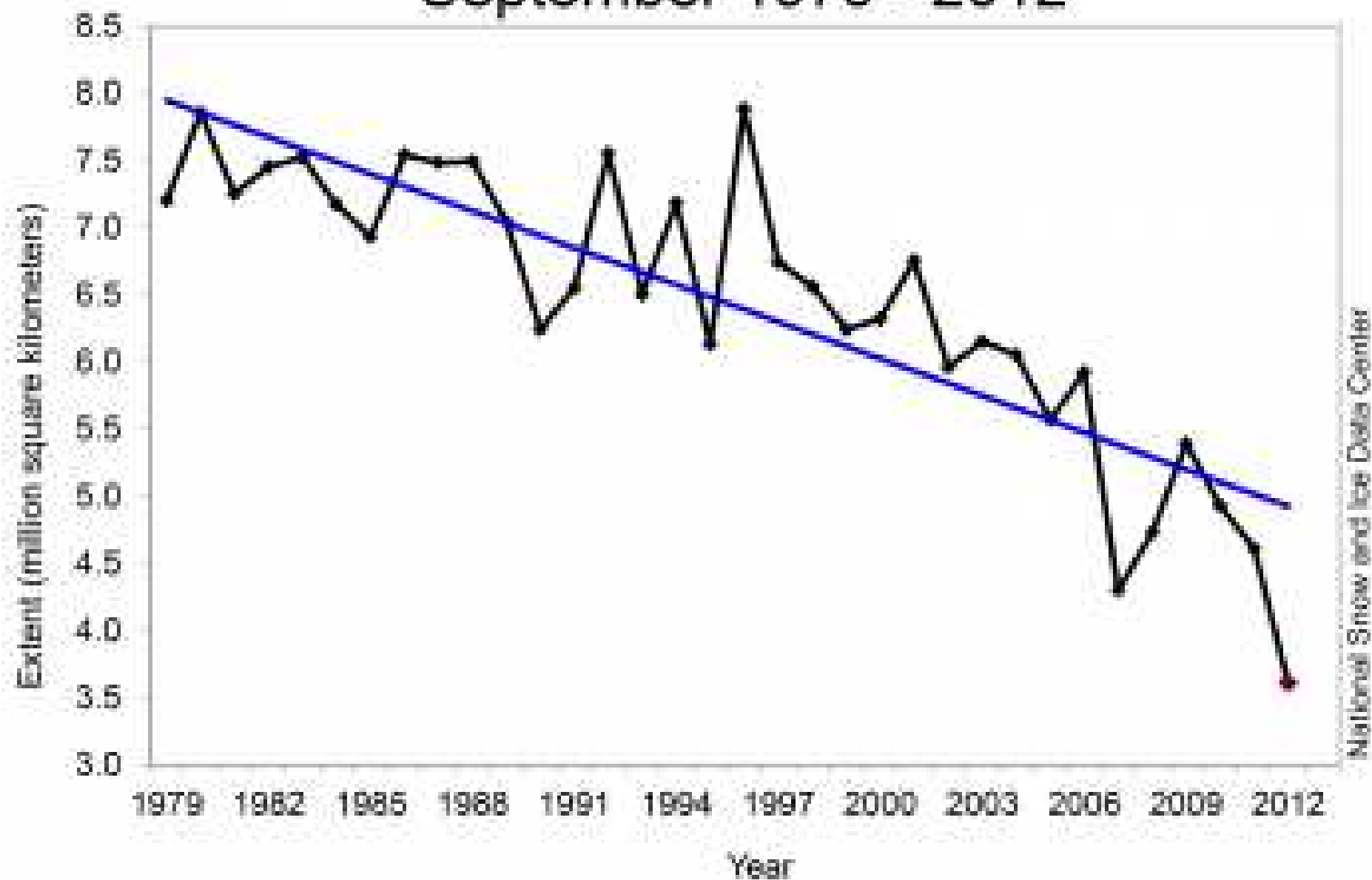
# THE PAST IS YOUR FUTURE







# Average Monthly Arctic Sea Ice Extent September 1979 - 2012



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

Number 234 in a series of DIESEL "New York"



GLOBAL  
WARMING  
READY



# Tianjin Eco City, China [Kepcorp.com](http://Kepcorp.com)





# Geologists study the Earth



I HEAR HOOFBEATS







Thomas Cole The Course of the Empire 1836











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

# Museums, Zoos and Your Children will save the World

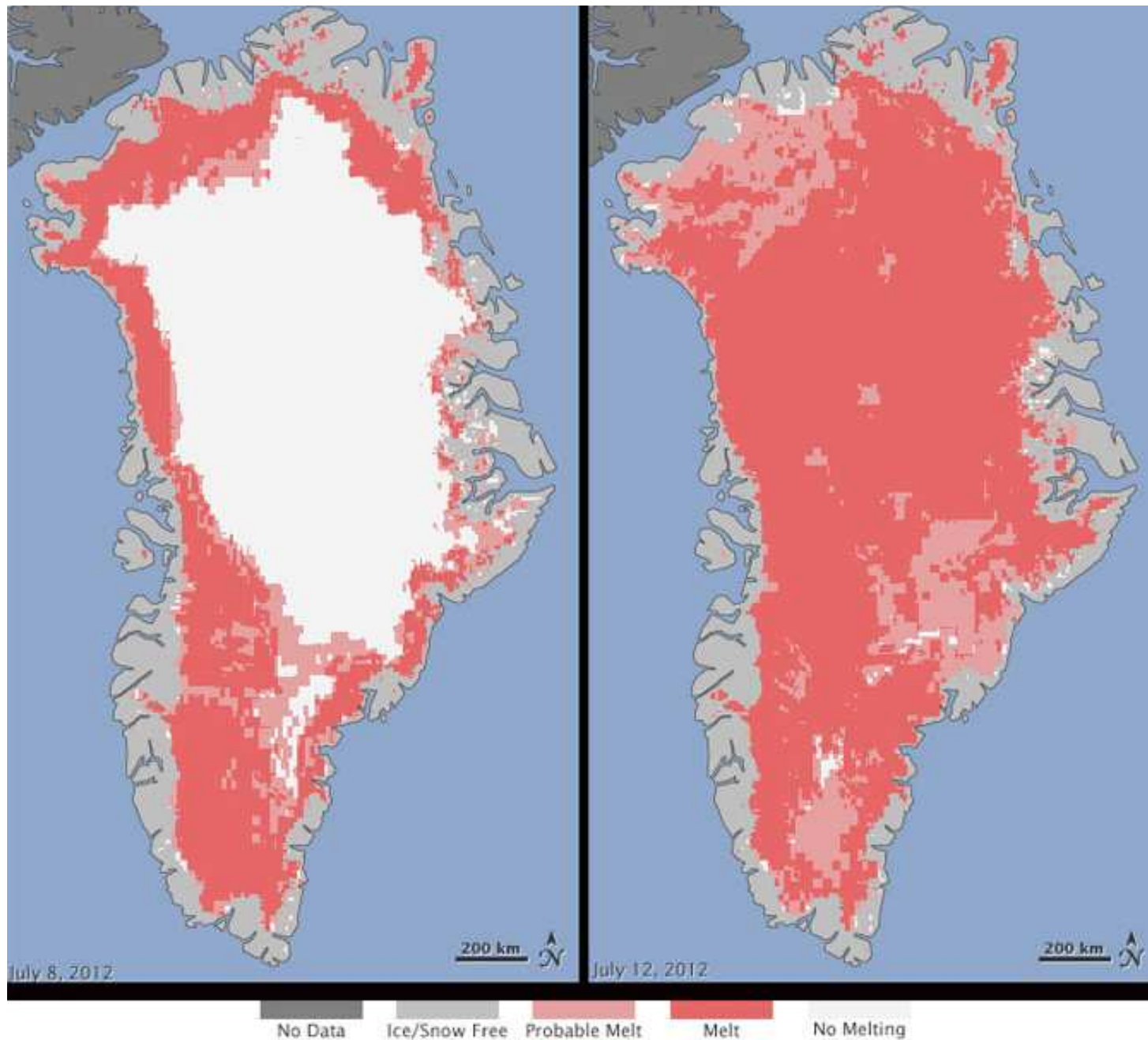






[Azsolarhotwater.com](http://Azsolarhotwater.com)





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

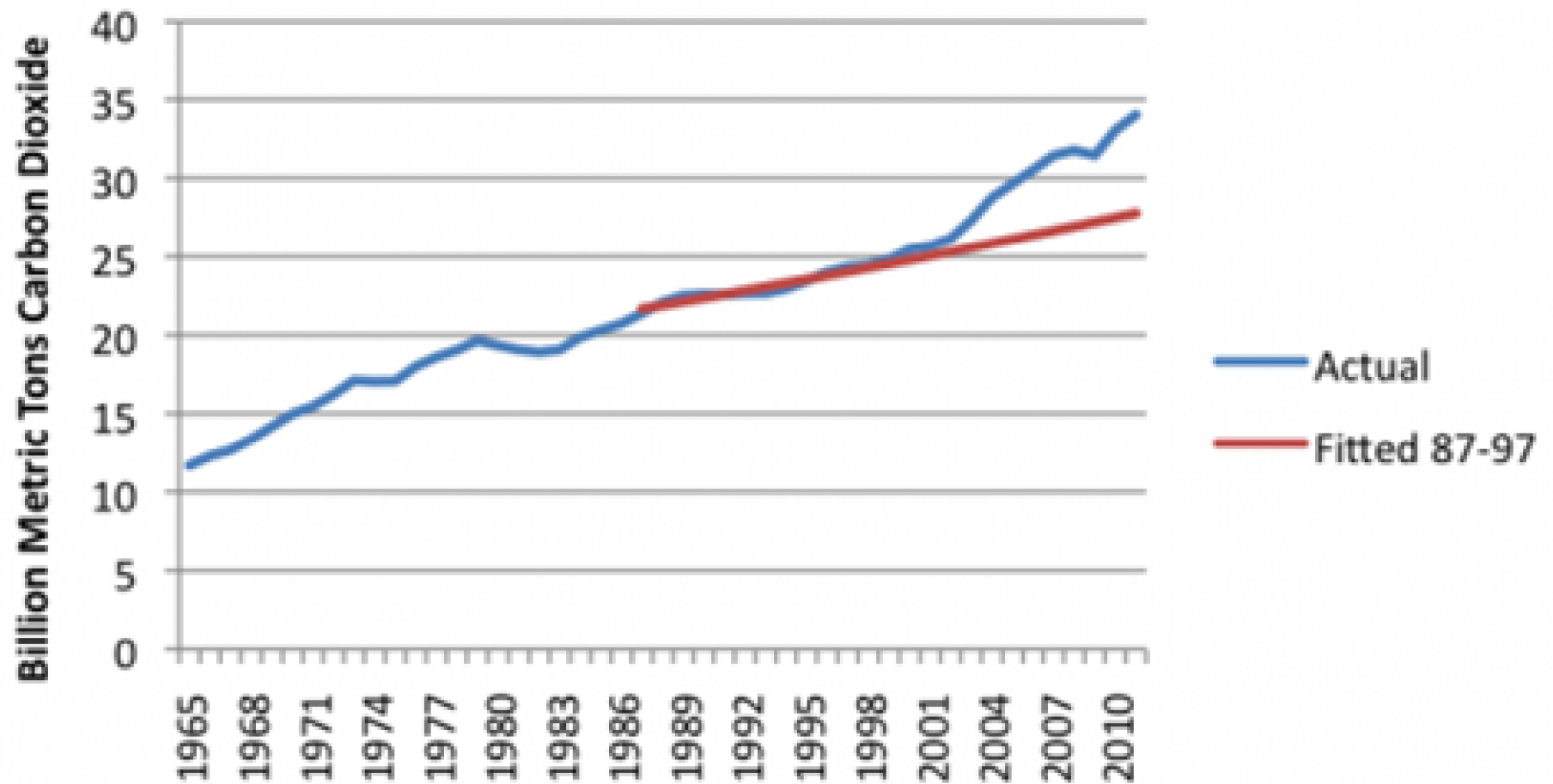
Imagery Date: 7/3/2012 lat 25.840290° lon 50.603416° elev 0 ft eye alt 17313 ft





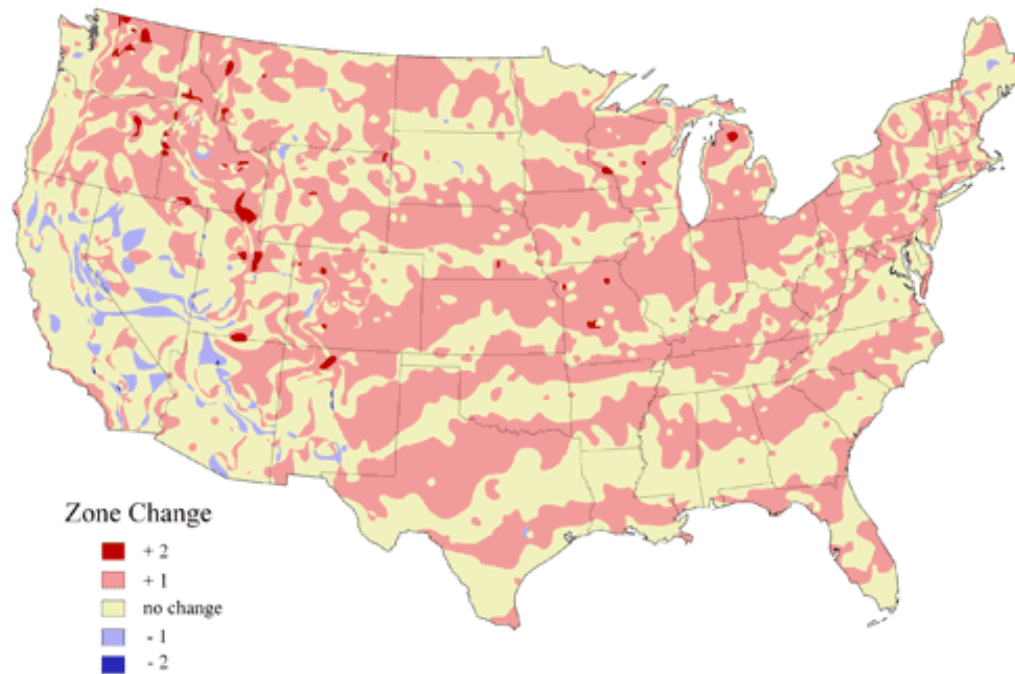


## World Fossil Fuel Carbon Dioxide Emissions

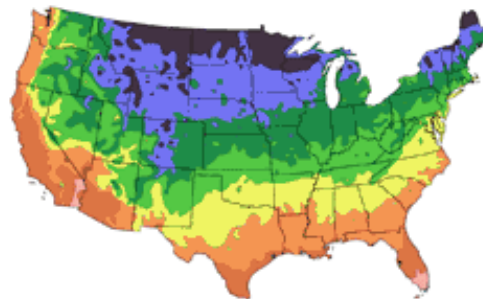


BP, 2012;

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

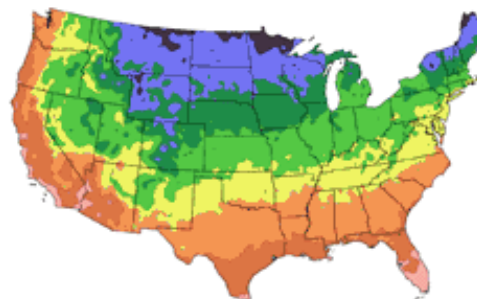


1990 Map



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

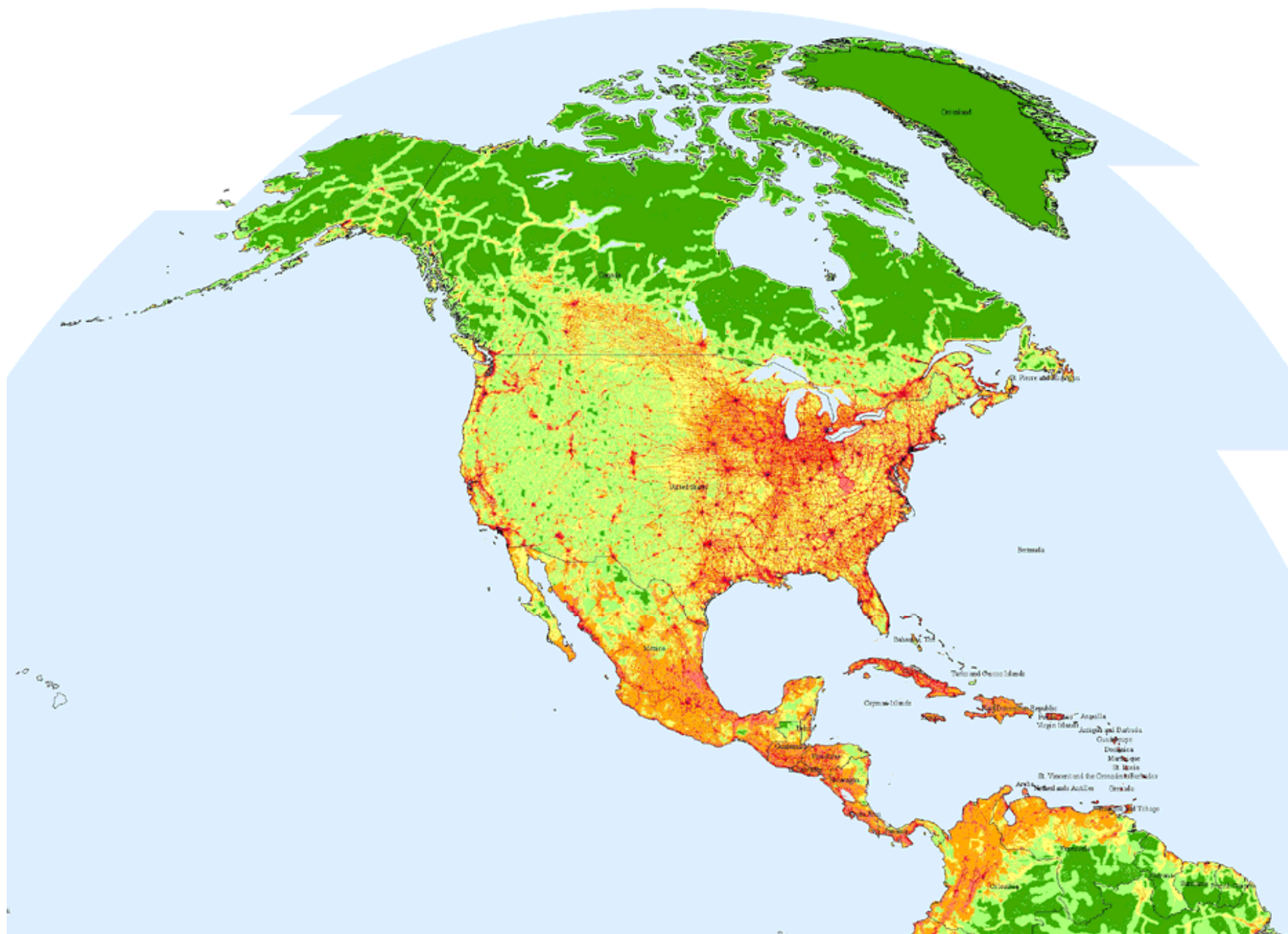
2006 Map



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



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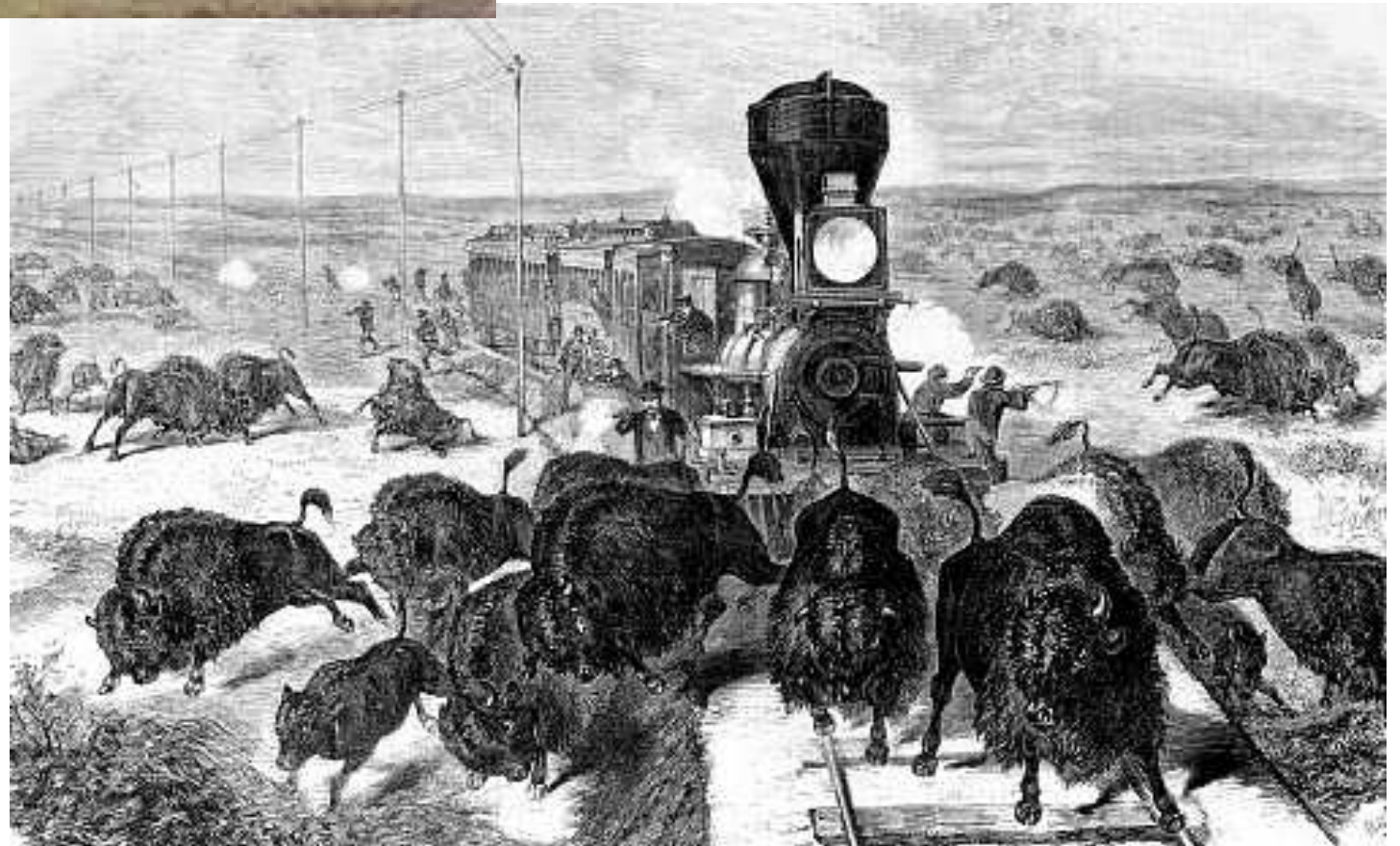






Among the Redwoods

A.E. Ericson, ca. 1890







1870



