A Wild Solution for Climate Change

Blue Planet Prize Commemorative Lecture
Tokyo
November 1, 2012

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Environmental Science and Policy
George Mason University
Biodiversity Chair, The Heinz Center

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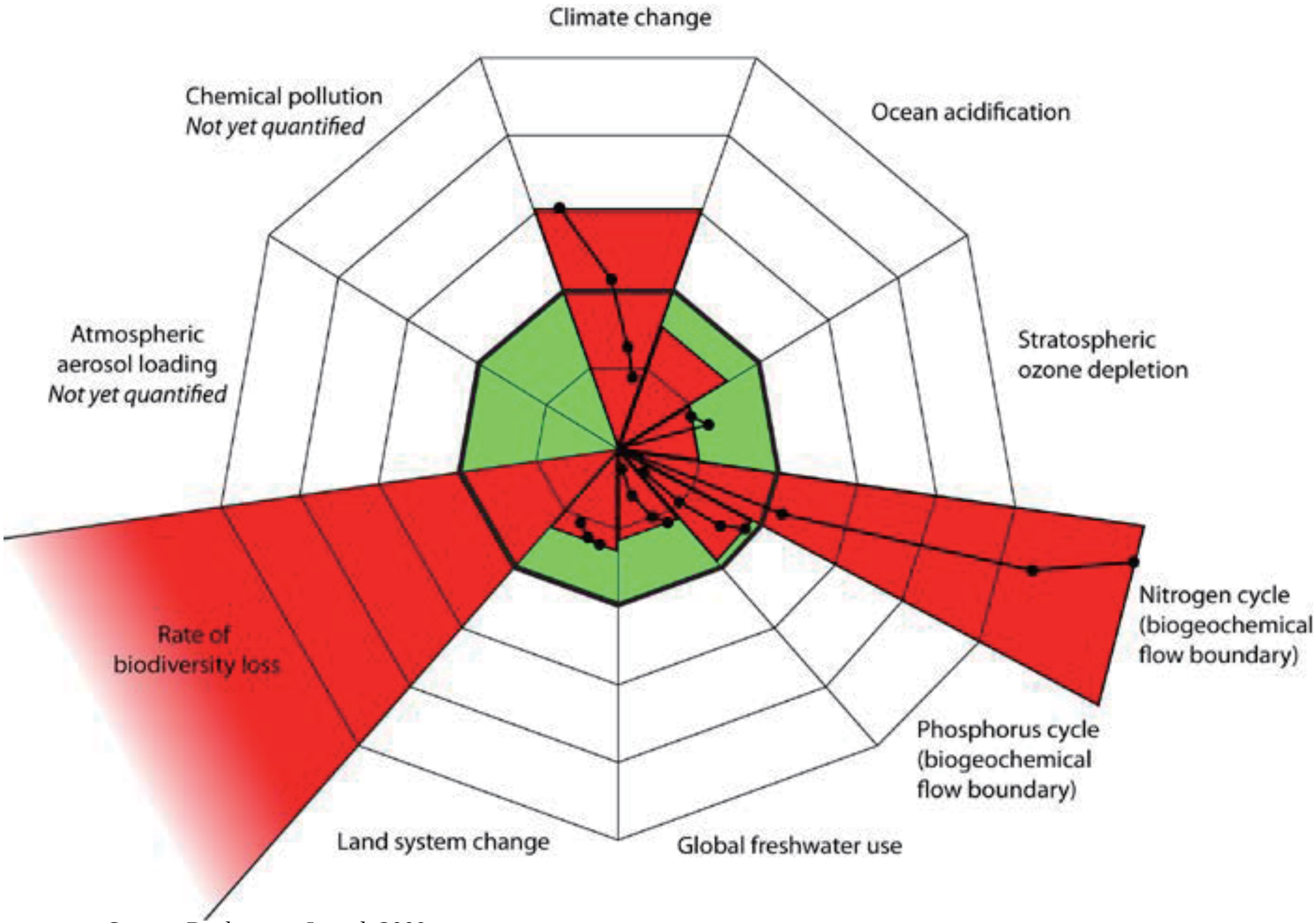
Planetary Boundaries

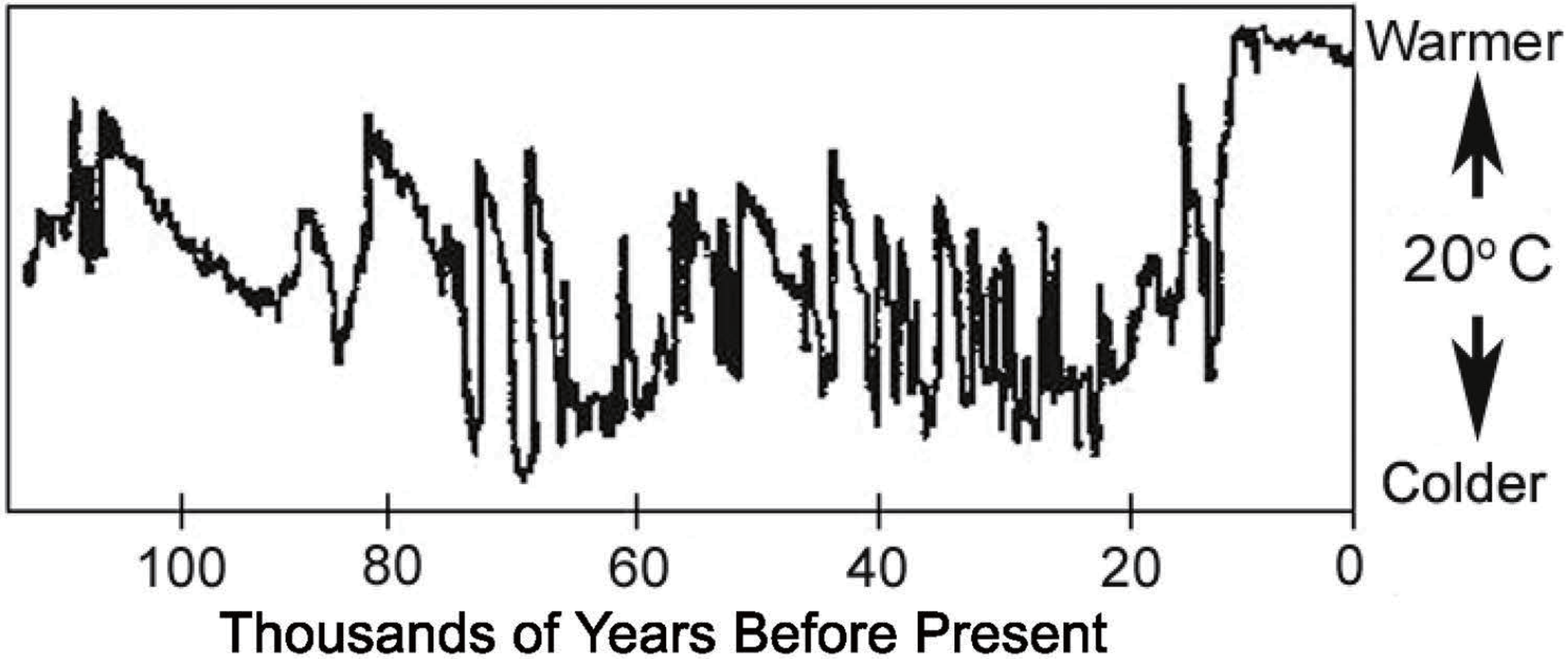


Source: Rockström, J. et al. 2009

Dr. Svante August Arrhenius

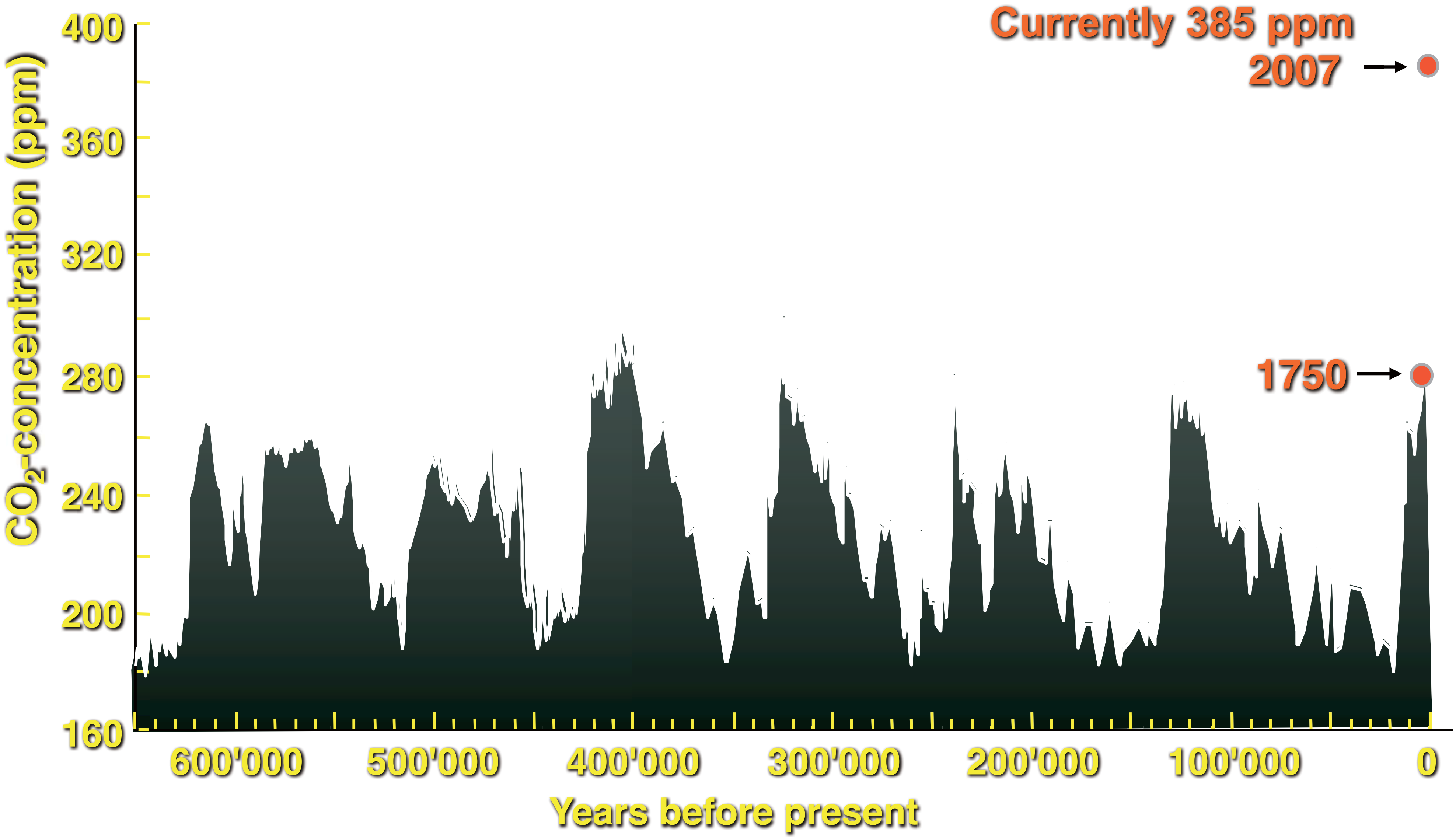
1859-1927

Analysis of a Greenland ice core oxygen isotope proxy



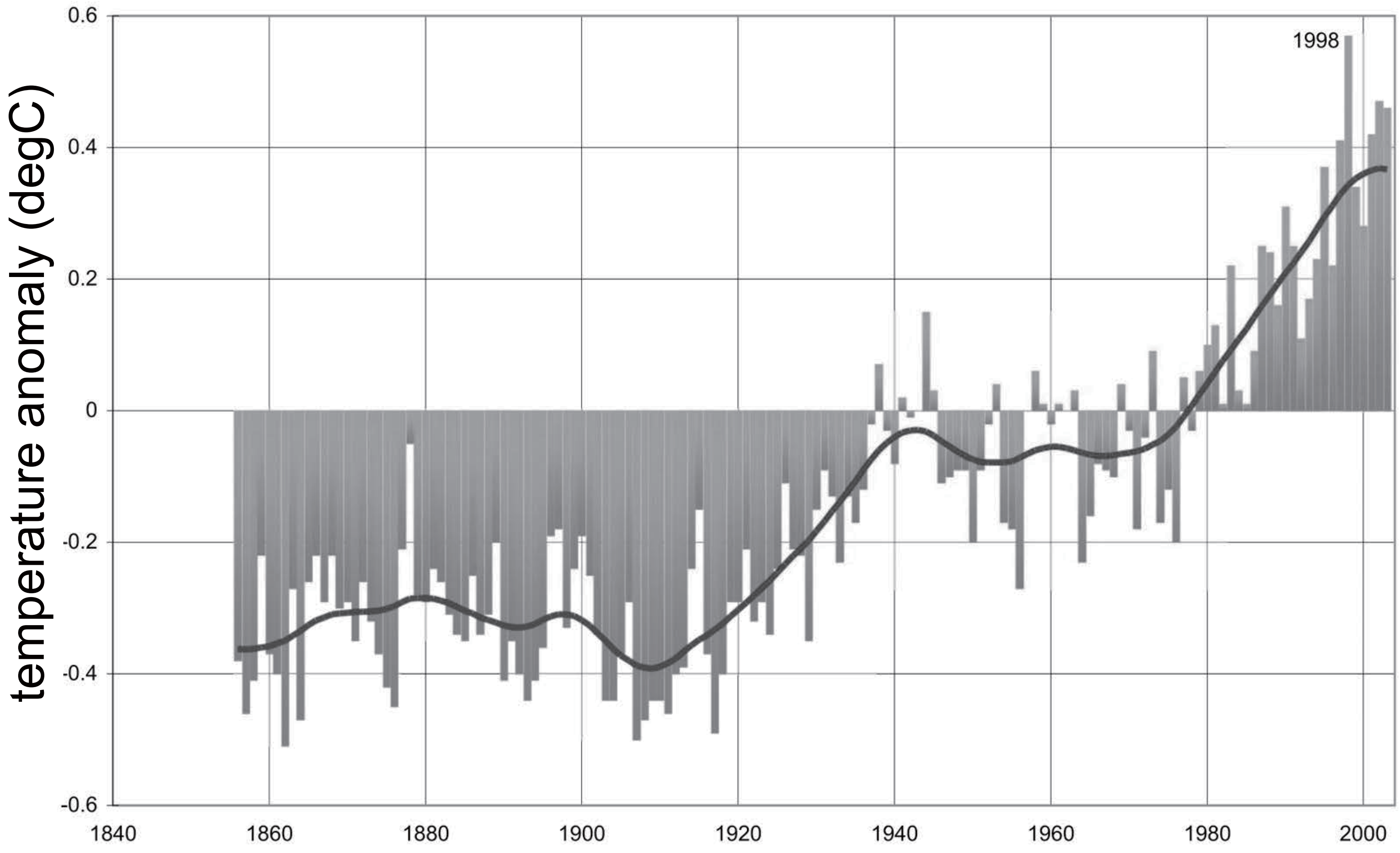
Source: Wallace Broecker

CO_2 for the Last 600,000 Years



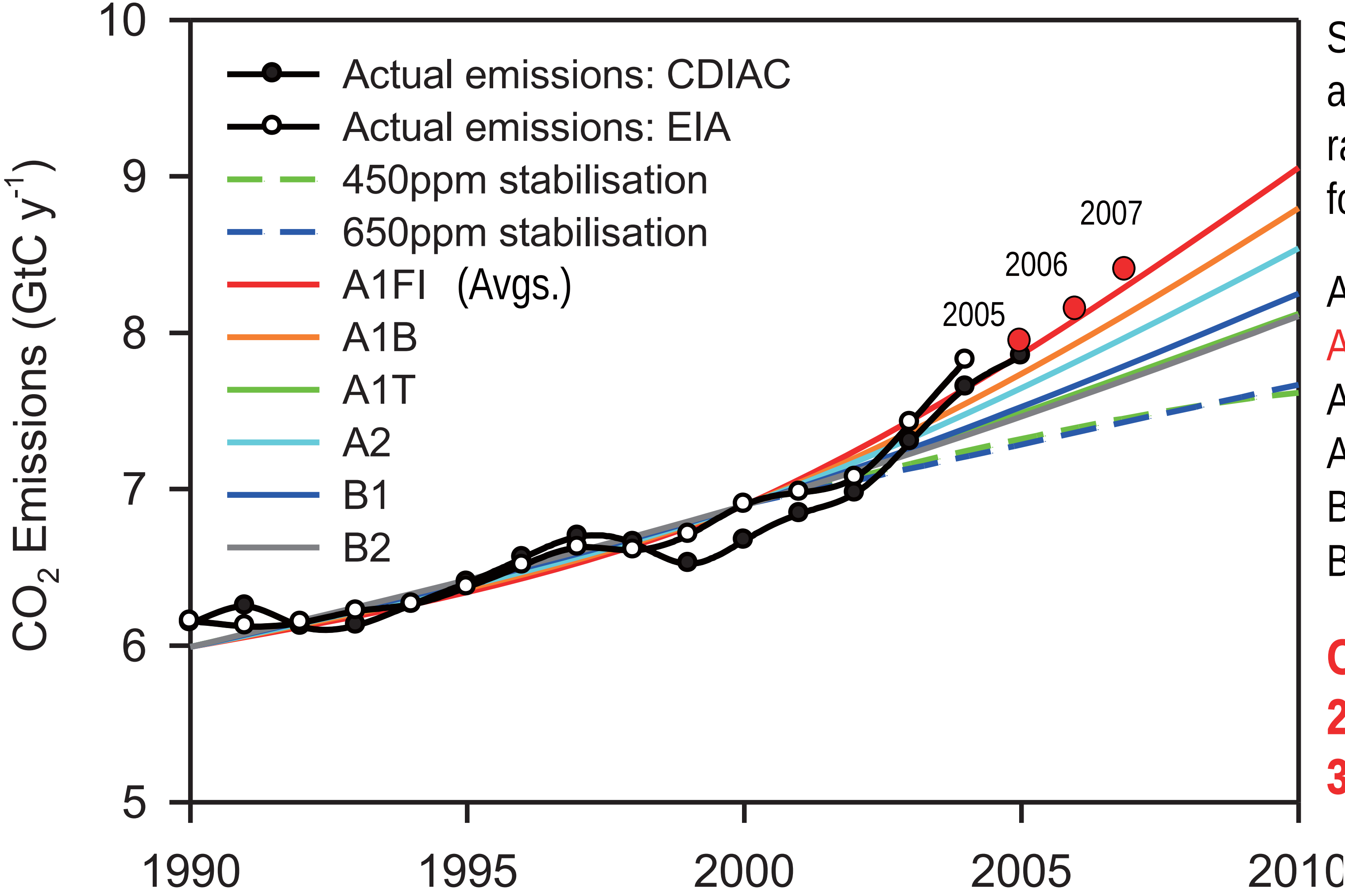
Siegenthaler U *et al.* (2005) Science 310:1313
Petit JR *et al.* (1999) Nature 399:429

Global temperature record



Source: Hadley Centre and Climatic Research Unit, School of Environmental Sciences, UEA

Fossil Fuel Emissions: Actual vs. IPCC Scenarios



SRES (2000) aver. growth rates in % y^{-1} for 2000-2010:

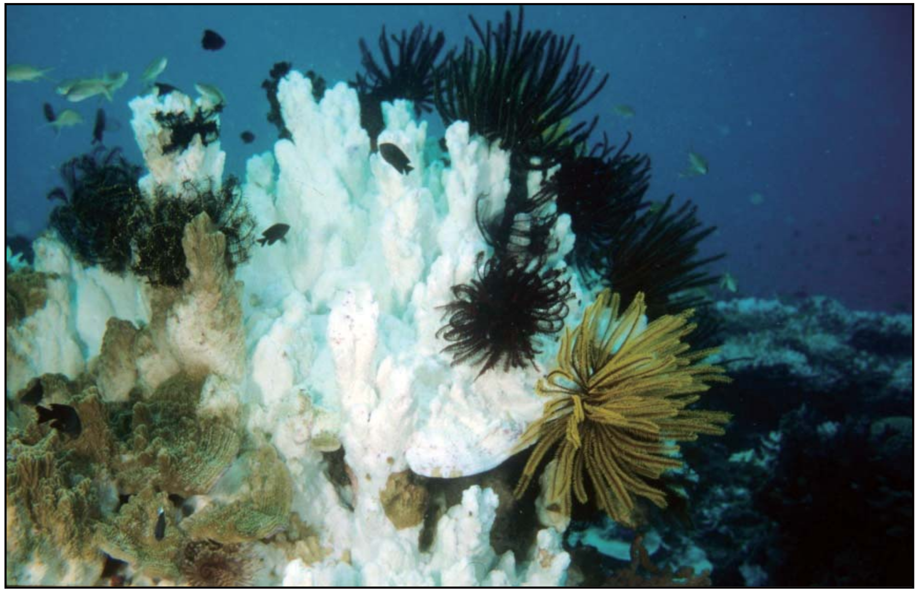
A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Observed 2000-2007 3.5%

Global Carbon Project; Raupach et al 2007, PNAS (updated)

Signals from nature

Jeremy Little / University of Washington



Lara Hansen / WWF

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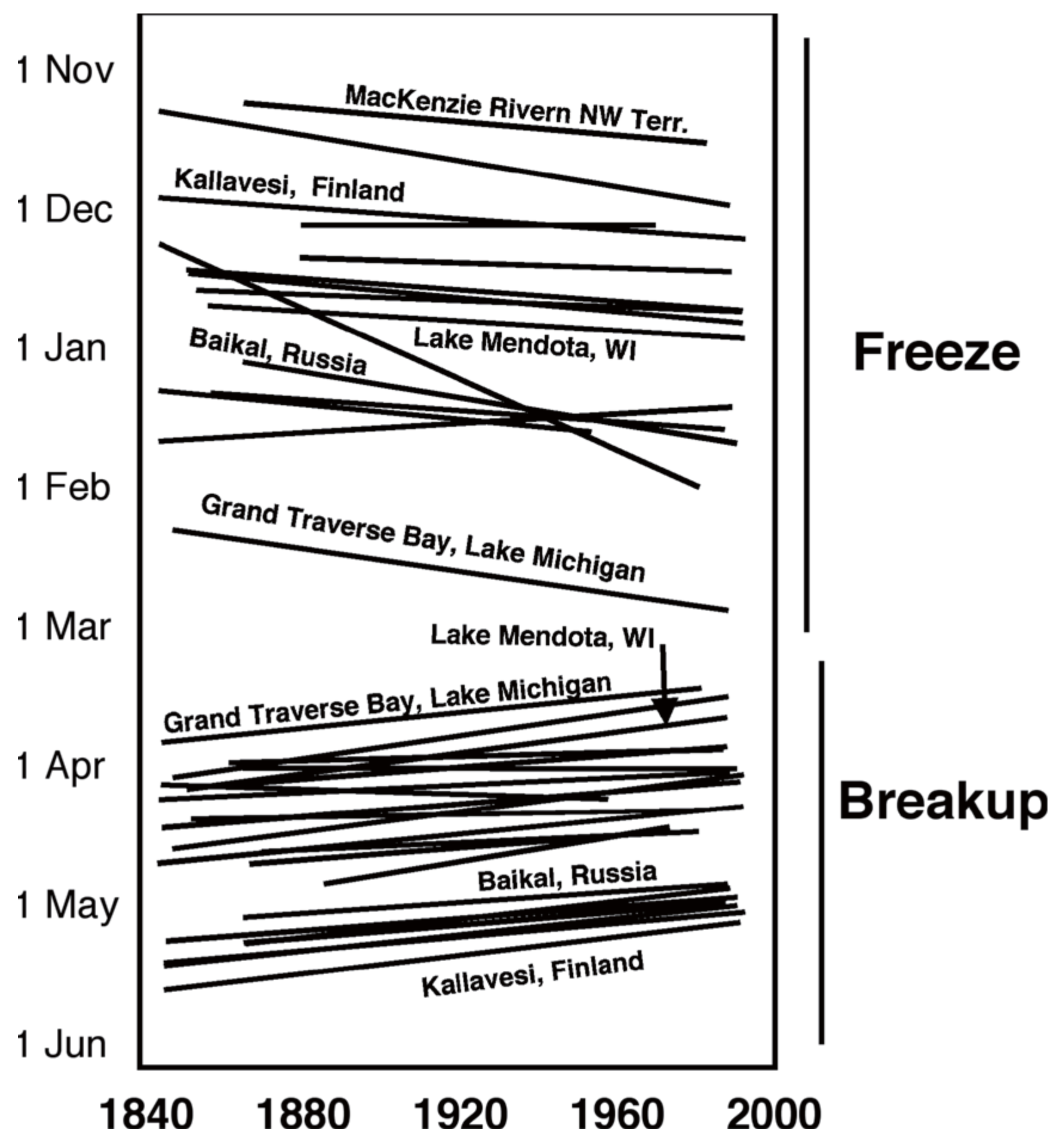
Warming trend in 37 of 39 Northern Hemisphere lakes and rivers



Source: IPCC 2001, modified from Magnuson et al. 2000

Grinnell Glacier, Glacier National Park

Late summer of 1938 (left) and 1981 (right)

Source: http://nrmsc.usgs.gov/research/glacier_retreat.htm

Rising sea level

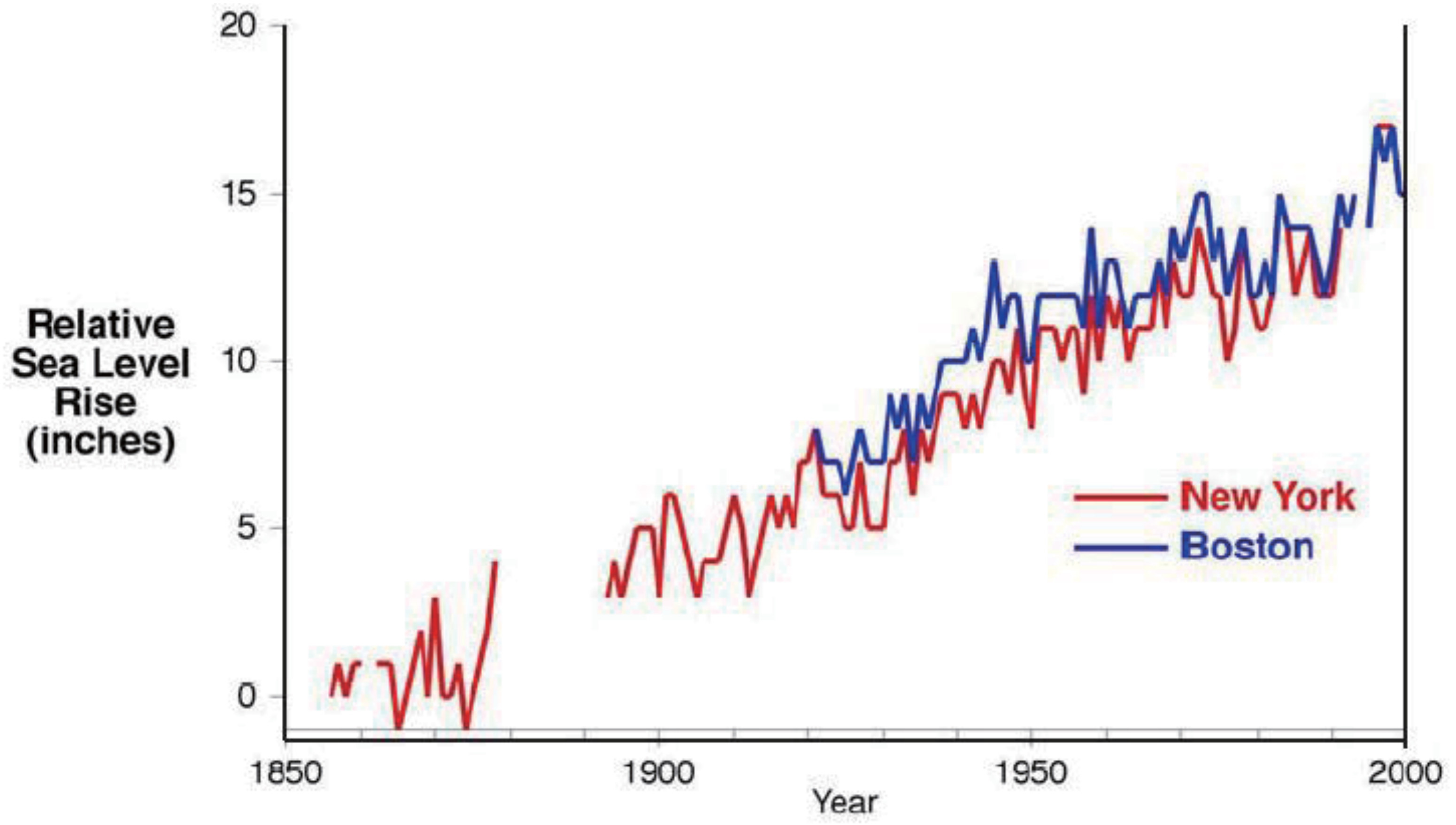
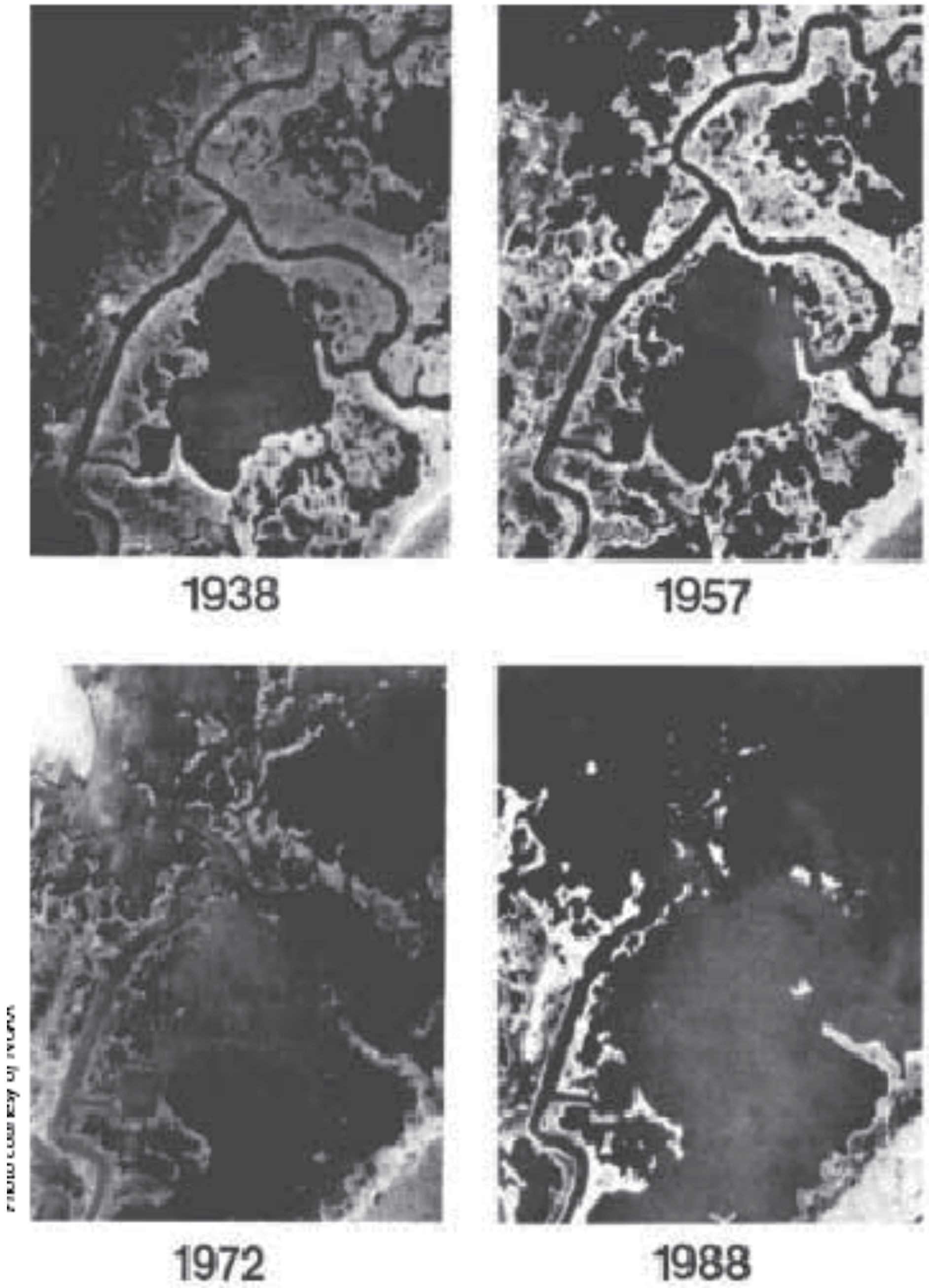


Figure 1: Sea level as measured at New York City, NY (from 1856, in red) and Boston, MA(from 1922, in blue) through 2000 in inches. The 1856 sea level was set to zero to illustrate the amount of increase over the past 150 years. Sea level has been increasing in the Northeast since it was recorded, due to natural phenomenon and perhaps human influence on climate. Human induced warming threatens to accelerate the rising sea level. Data from Permanent Service for Mean Sea Level, United Kingdom, http://www.pol.ac.uk/psmsl/

Sea Level Rise in the Chesapeake Bay

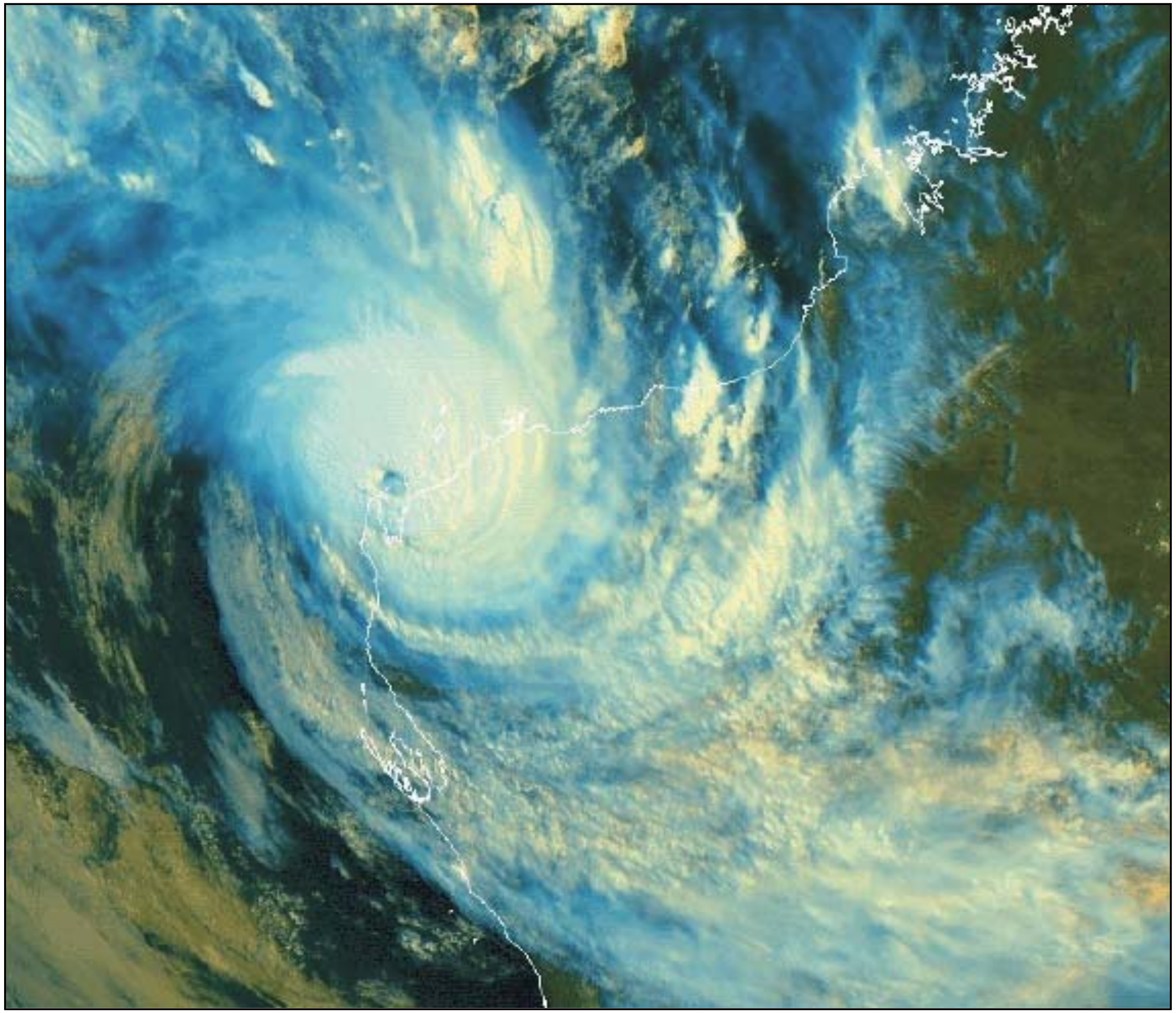


Blackwater National Refuge,

Maryland

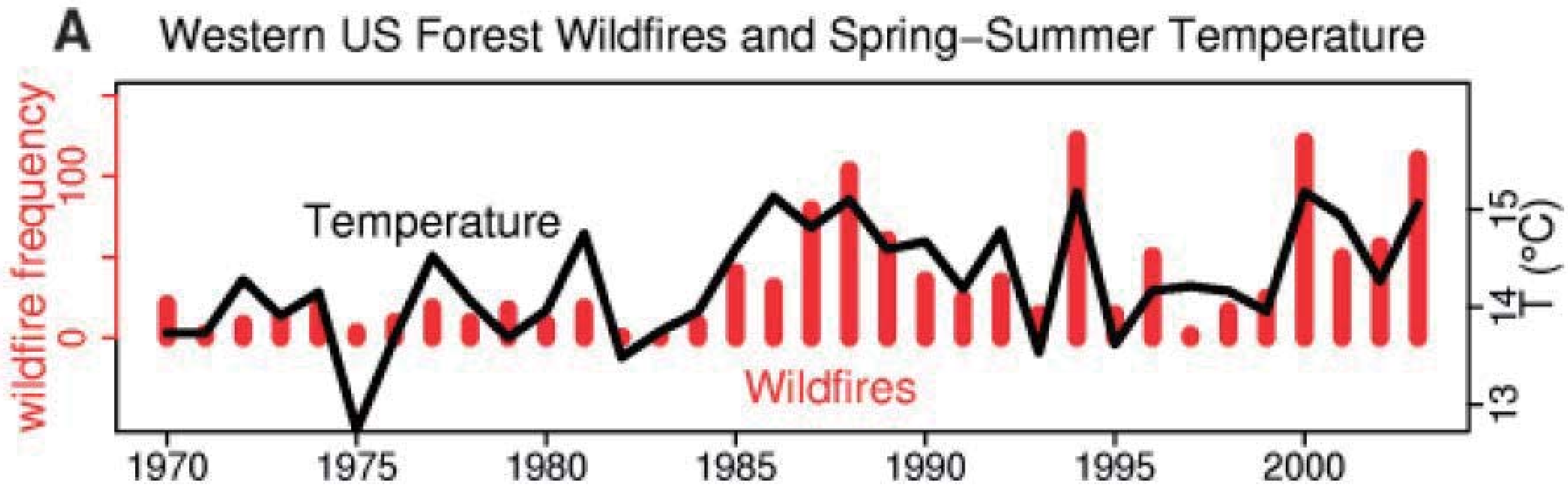
Photo Courtesy of NOAA

Probable Increased Frequency of More Intense Tropical Cyclones



Source: CSRIO 2001 (*www.dar.csiro.au/publications/projections2001.pdf*).

Wildfire increase in Western U.S.



Warmer summers and earlier snow melts increased opportunities for wildfire in the western U.S. beginning in the mid-1980s

Source: Westerling *et al*. 2006. *Science* 313: 940-943.

Earlier flowering date

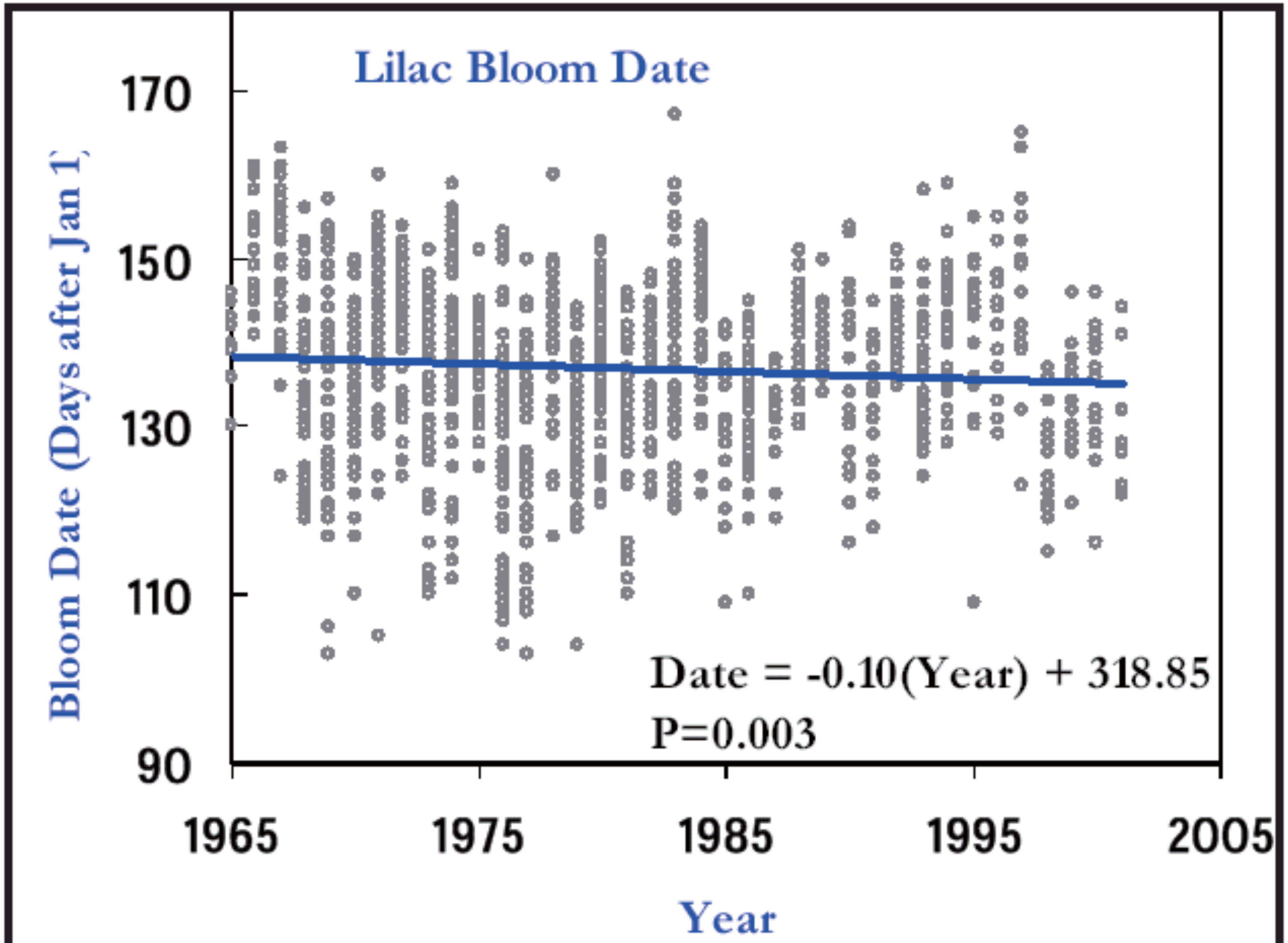


Figure 2. Trend of lilac bloom dates is indicated by the blue line.

Climate Change at the Royal Botanic Gardens, Kew

Advances in flower opening since the 1980s

	1980s – AVERAGE OPENING DATE	2000s – AVERAGE OPENING DATE	NUMBER OF DAYS ADVANCED
Anemone nemorosa	1 April	13 March	19 days
Buxus sempervirens	1 April	13 March	19 days
Eranthis hyemalis	29 January	11 January	18 days
Narcissus pseudonarcissus	12 February	27 January	16 days
Crocus chrysanthus	15 February	4 February	11 days
Galanthus nivalis	10 February	30 January	11 days
Syringa vulgaris	29 April	18 April	11 days
Cercis siliquastrum	3 May	24 April	9 days
Aesculus indica 'Sydney Pearce'	1 June	23 May	9 days
Laburnum anagyroides	30 April	22 April	8 days


Eranthis hyemalis

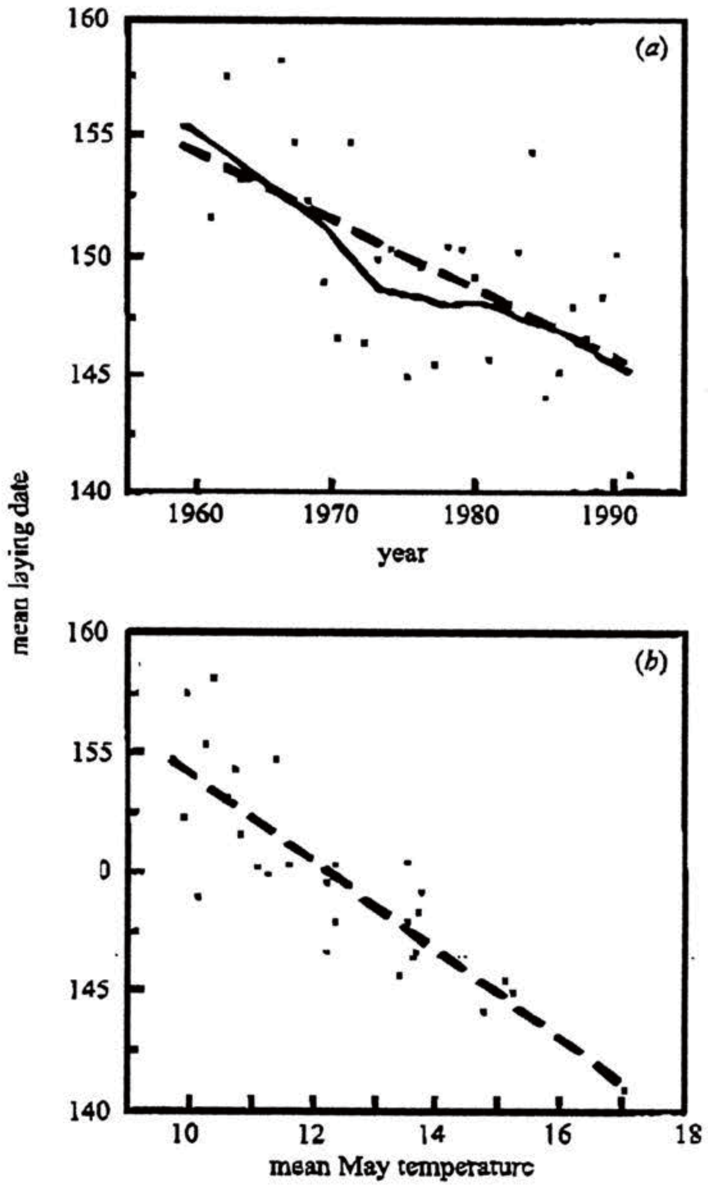

Crocus chrysanthus


Galanthus nivalis


Anemone nemorosa

Kew Magazine, Summer 2007

Spring comes about 2 weeks earlier

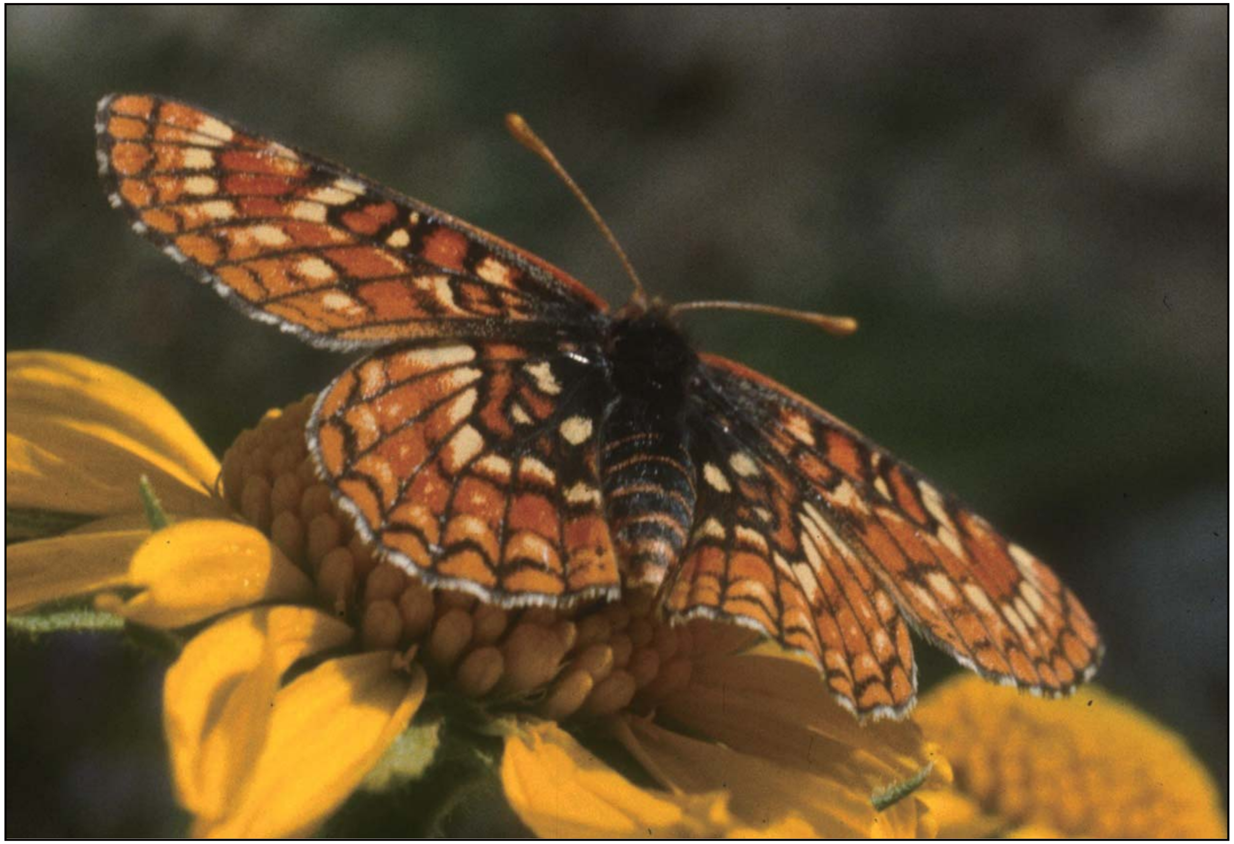


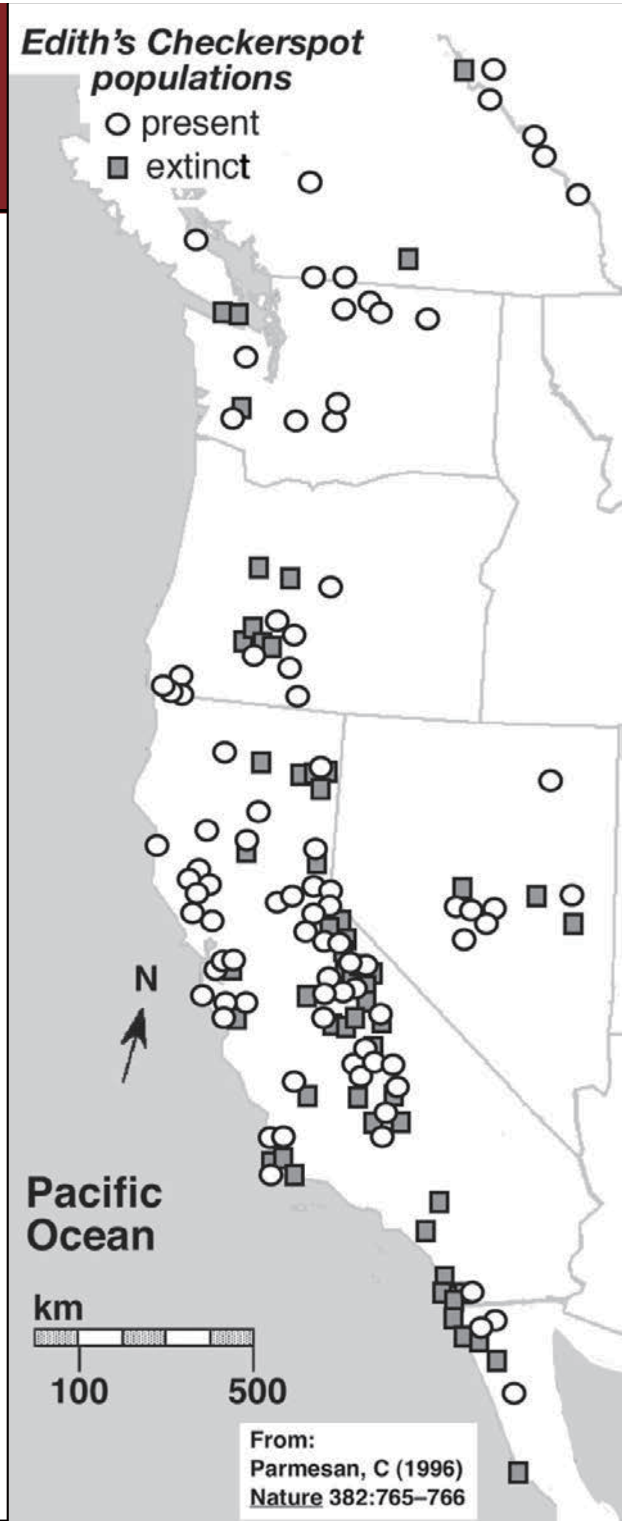
- Across the USA, tree swallows are nesting 9 days earlier than 40 years ago
- Laying date is highly correlated with May temperature

Source: Camille Parmesan

Edith's Checkerspot

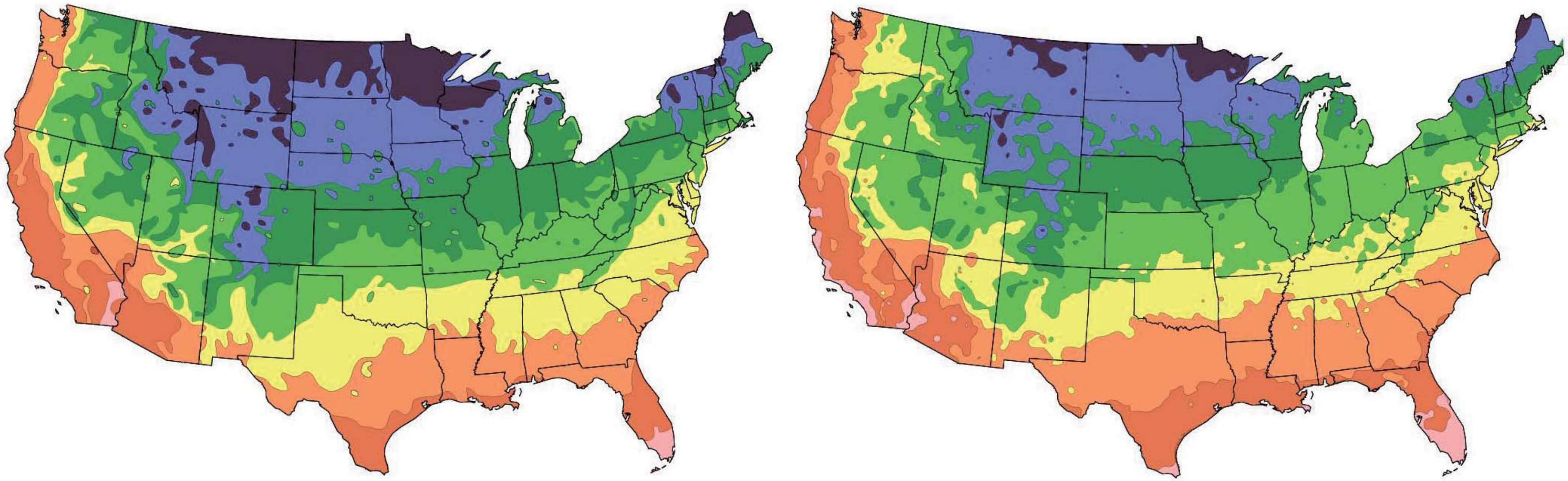
- Range shift northward and upward during the 20th century
- Most extinctions in south and low elevations





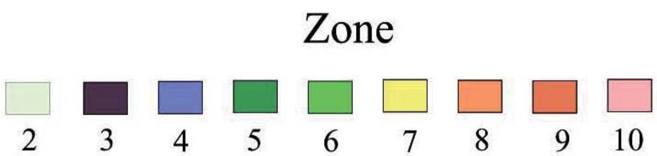
Hardiness zones adjusted to warmer climate

1990 Map | 2006 Map



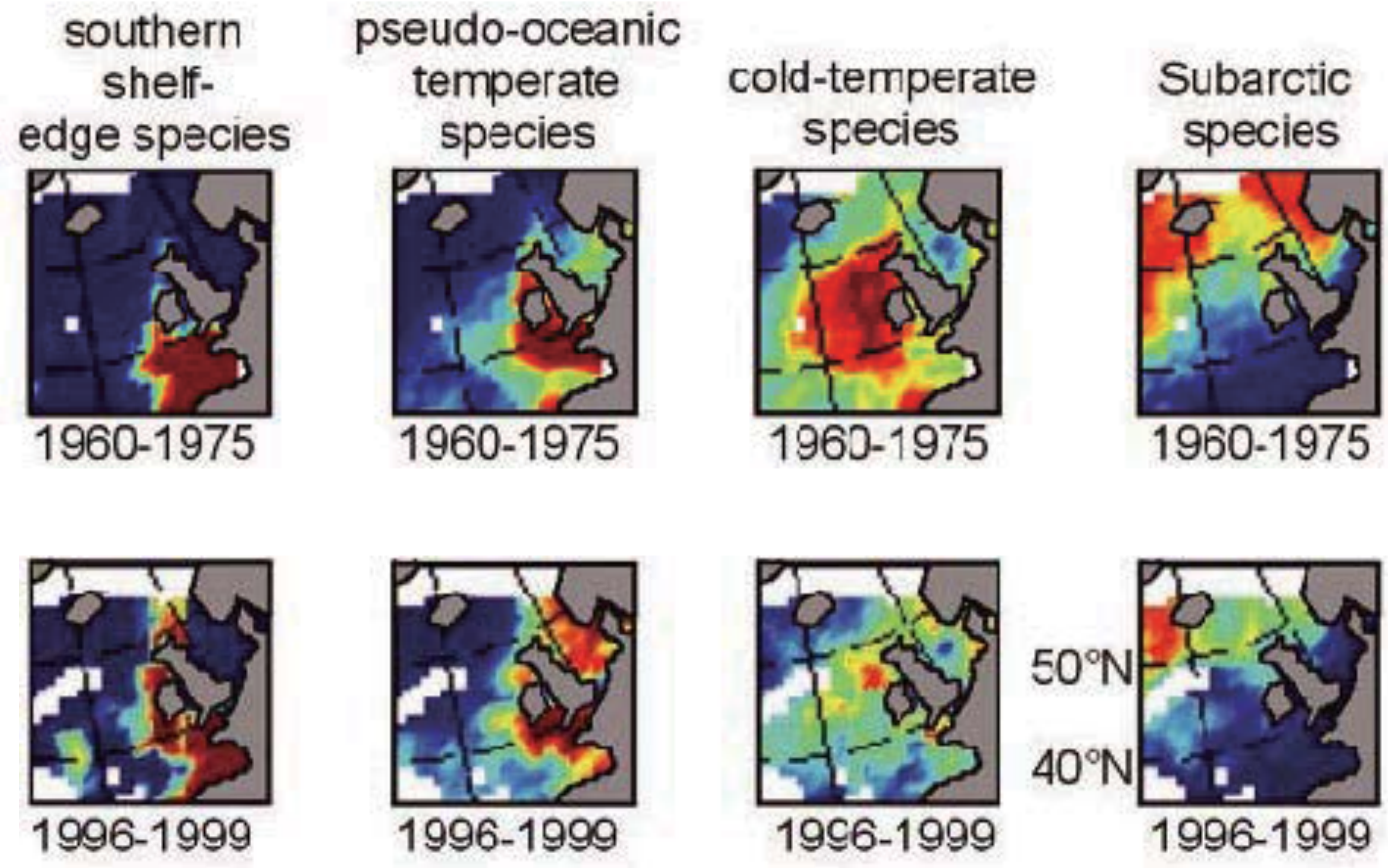
After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990.

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



Source: National Arbor Day Foundation

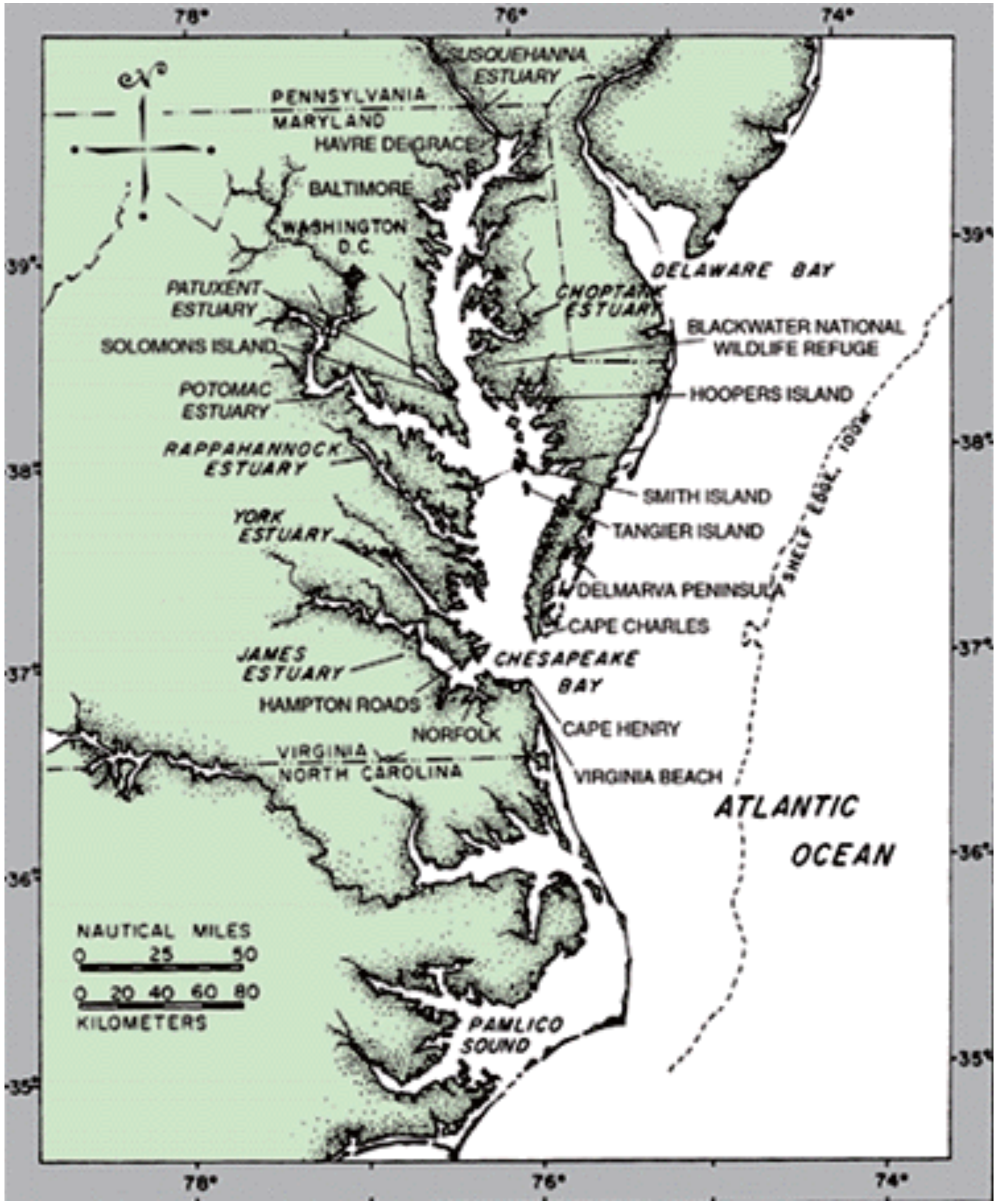
Replacement of marine copepod plankton communities in NE Atlantic



Source: Beaugrand et al. Science 2002

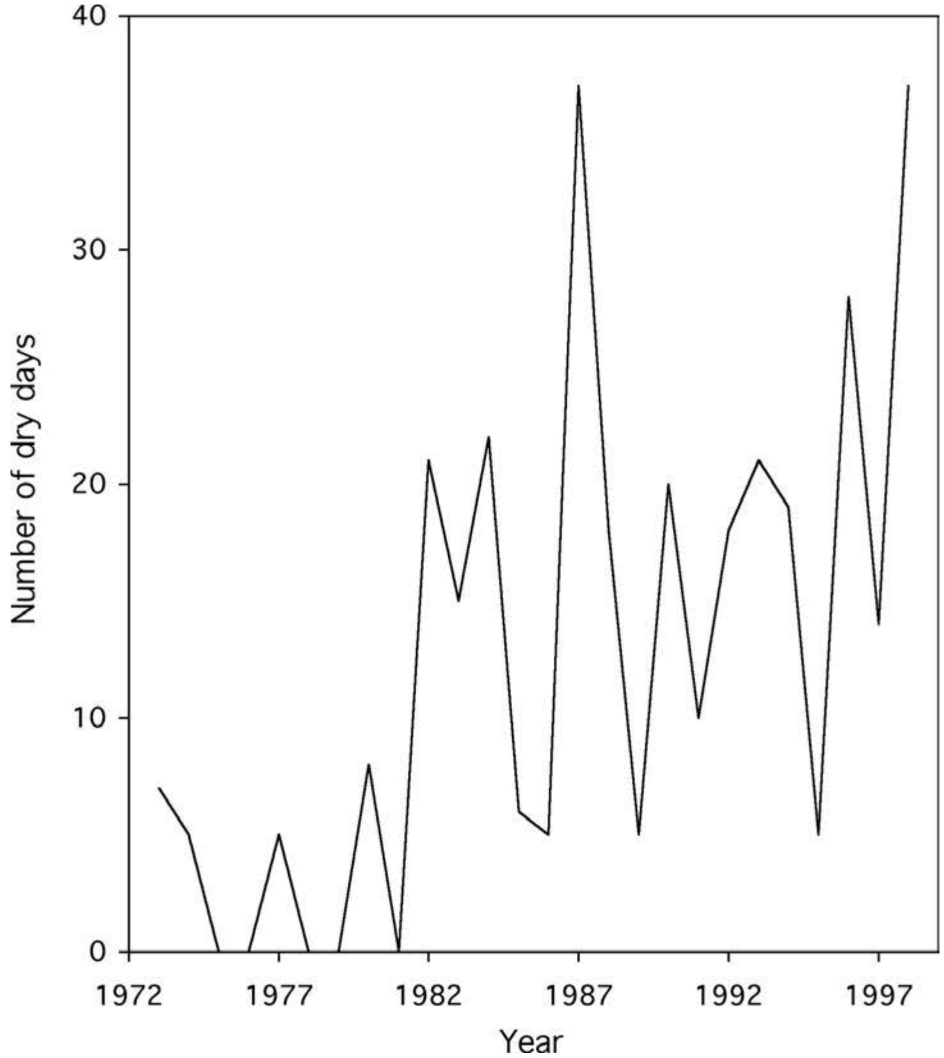
Eelgrass

Chesapeake Bay



- Largest estuary in the United States
- In 2006 Underwater grasses decreased by 25% Baywide
- Decrease from 78,263 acres in 2005 to 59,090 acres in 2006

Increasing number of dry days



Source: J.A. Pounds et al 2005

Decoupling

Snowshoe Hare (*Lepus Americanus*)

Photos: University of Michigan

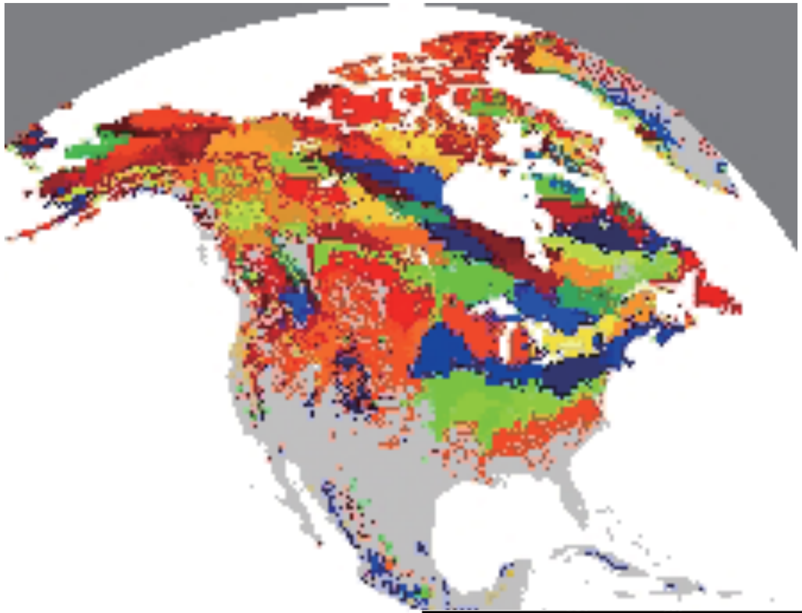
Decoupling: Arctic cod and black guillemot

Source: www.sfos.uaf.edu/research/seaicebiota

National Ecological Observatory Network (NEON)

Biological Response

Phenological changes attributed to recent climate change

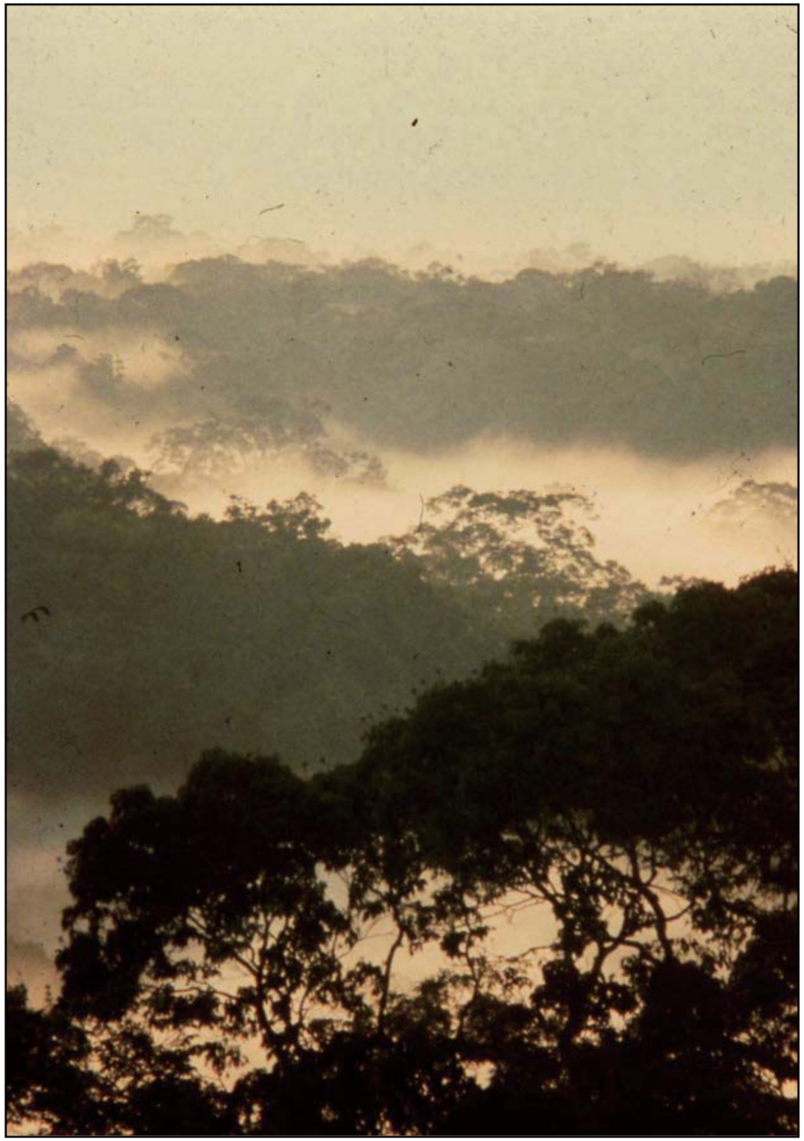


White et al. (2004)

McCarty (2001)

Variable observed	Species observed	Change	Time span[b] (years)	Reference
Geographic range	59 bird species	18.9 km	20	C. D. Thomas & Lennon
Geographic range	Edith's checkerspot butterfly	92 km	100	Parmesan 1996
Geographic range	speckled wood butterfly	88–149 km	55	Hill et al. 1999
Geographic range	22 butterfly species	35–240 km	30–100	Parmesan et al. 1999
Elevational range	9 plant species	70–360 m	70–90	Grabherr et al. 1994
Breeding range	Adelie Penguin	3 km	10	Taylor & Wilson 1990
Flowering date	6 wildflower species	19.8 days	50	Oglesby & Smith 1995
Flowering date	36 species	8.2 days	61	Bradley et al. 1999
Flight period	5 aphid species	3–6 days	25	Fleming & Tatchell 199
Spawning date	2 frog species	14–21 days	17	Beebee 1995
Breeding migration	3 newt species	35–49 days	17	Beebee 1995
Breeding date	20 bird species	8.8 days	25	Crick et al. 1997
Breeding date	3 bird species	3–9 days	25	Winkel & Hudde 1997
Breeding date	Pied Flycatcher	13 days	24	Slater 1999
Breeding date	Tree Swallow	5–9 days	33	Dunn & Winkler 1999
Breeding date	Great Tit	11.9 days	27	McCleery & Perrins 199
Breeding date	2 bird species	30 days	35	MacInnes et al. 1990
Breeding date	Mexican Jay	10.1 days	27	Brown et al. 1999
Migration date	4 bird species	11.9 days	50	Mason 1995
Migration date	39 bird species	5.5 days	50	Oglesby & Smith 1995
Migration date	American Robin	14 days	19	Inouye et al. 2000
Migration date/first song	19 bird species	4.4 days	61	Bradley et al. 1999
End of hibernation	yellow-bellied marmot	23 days	23	Inouye et al. 2000
Growing season	Europe	10.8 days	34	Menzel & Fabian 1999
Growing season	northern hemisphere	12 ± 4 days	9	Myneni et al. 1997
Growing season	northern hemisphere	7 days	20	Keeling et al. 1996

Looking ahead

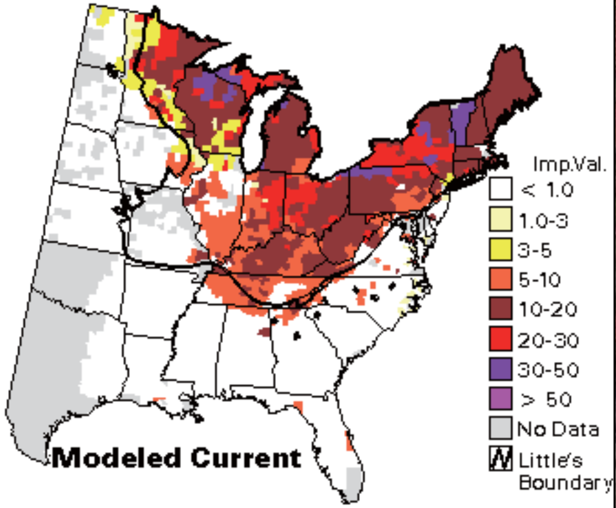


Jaan Lepson

The H. John Heinz III Center for Science, Economics and the Environment

The Heinz Center

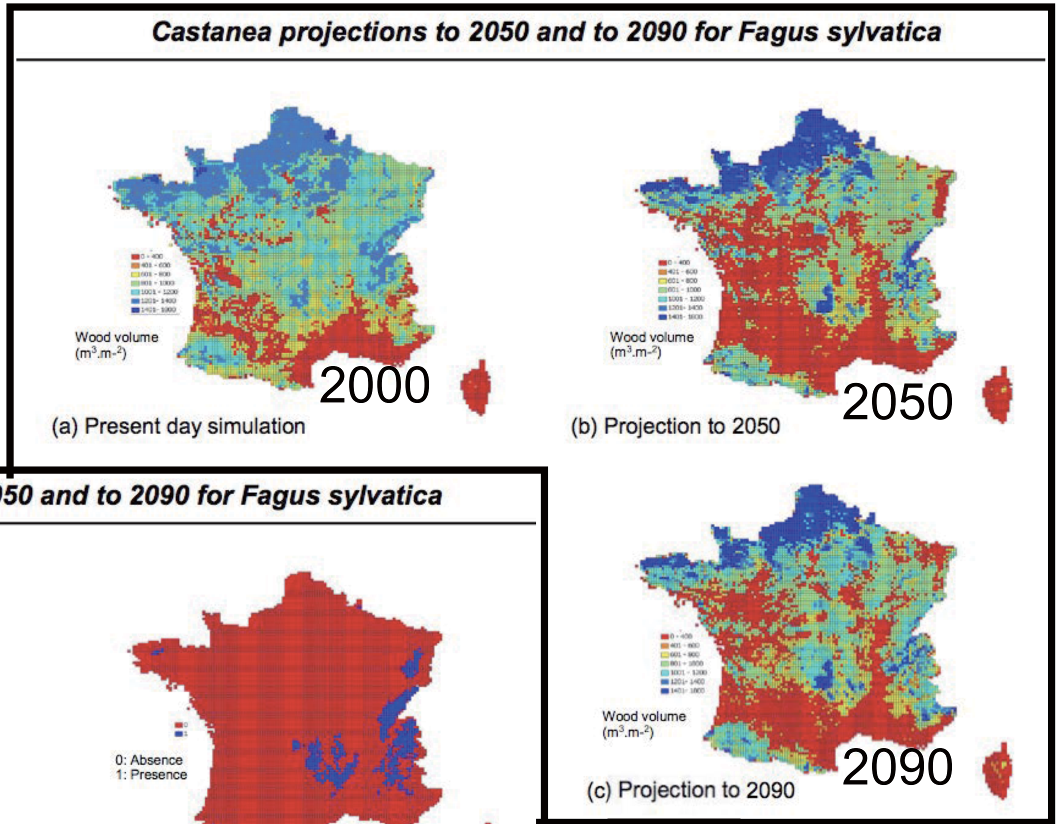
Sugar Maple range projections by 5 GCMs with 2 x CO_2

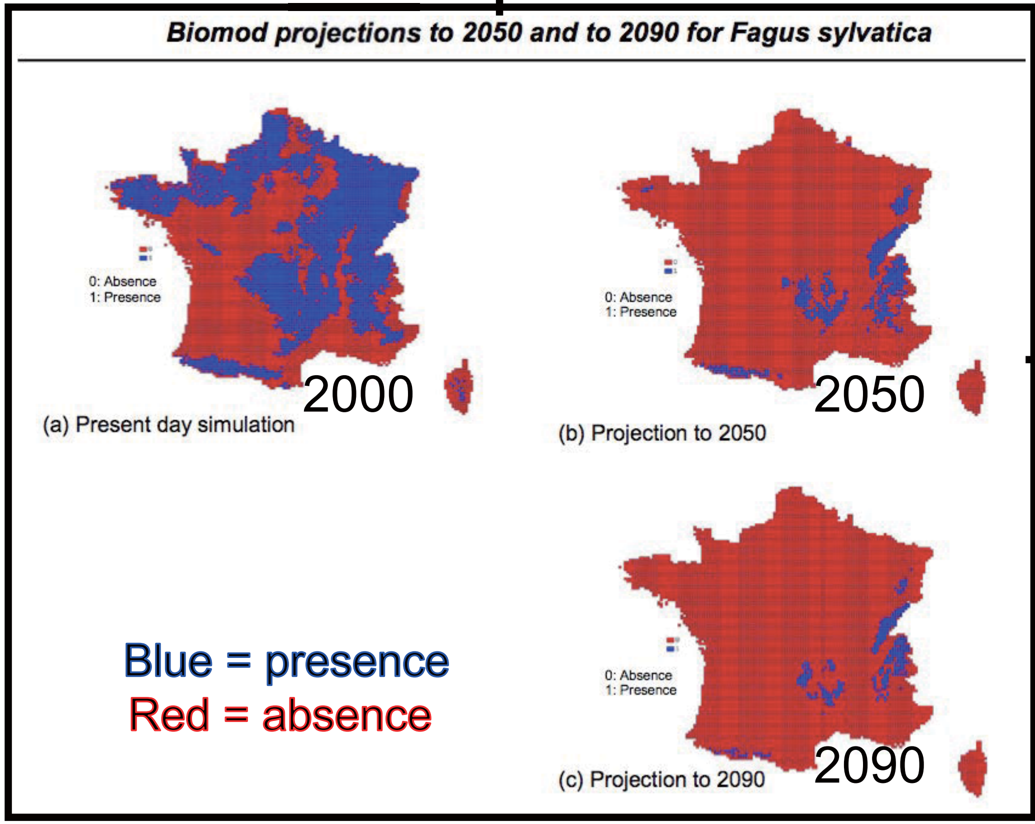


Source: A.M. Prasad and Iverson, L.R: www.fs.fed.us/ne/delaware/atlas/index.html

Climate change impacts on European beech

Niche-based model
BIOMOD
W. Thuiller

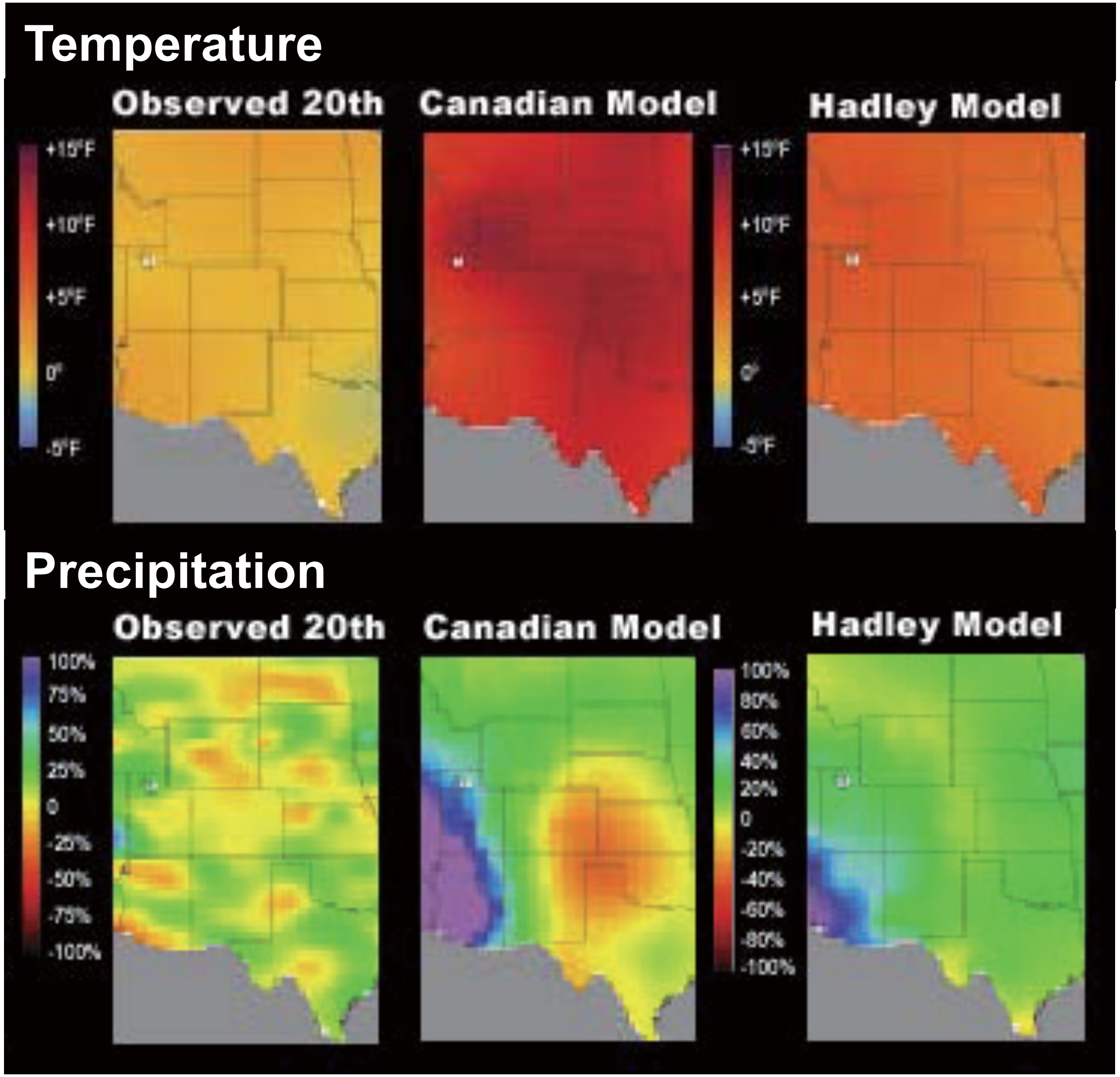




Mechanistic tree growth model
CASTANEA
A Cheaib,
C François,
E Dufrêne

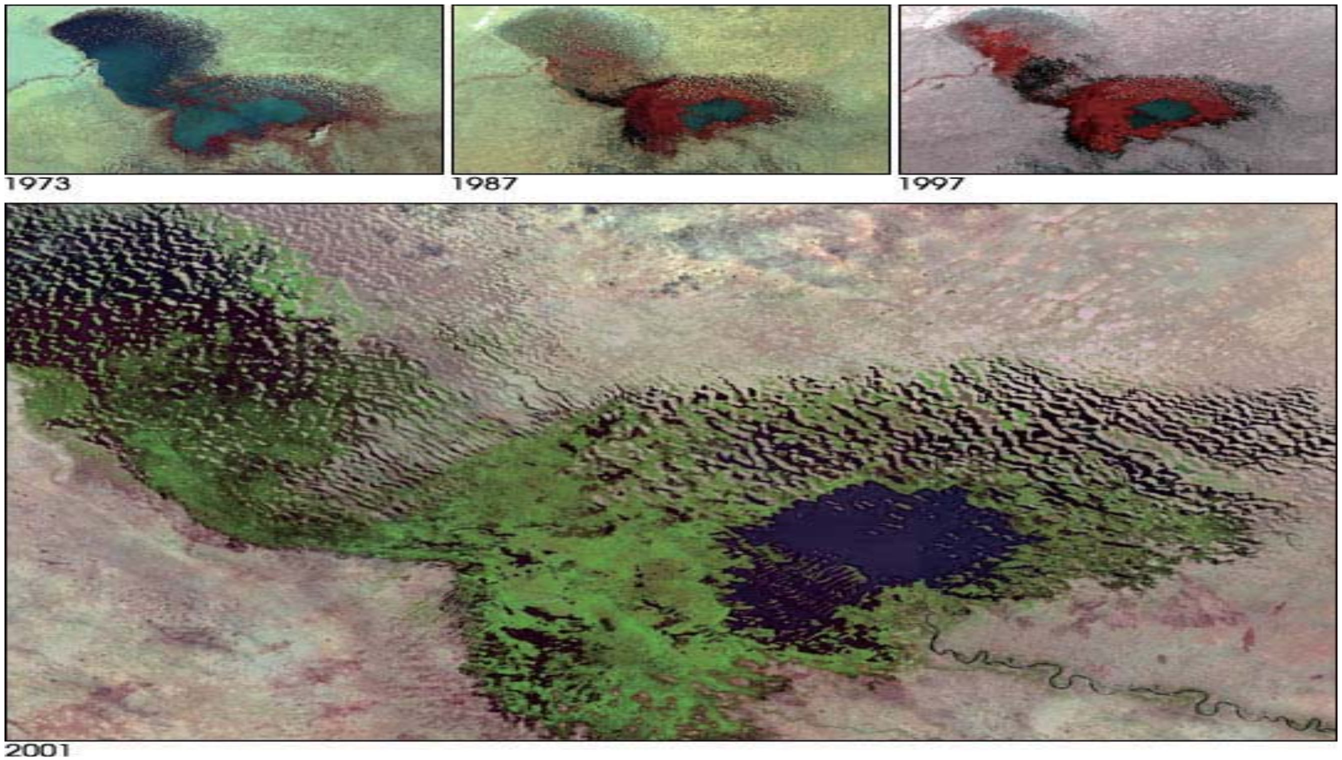
Climate Change includes precipitation change

Projected changes for 2090

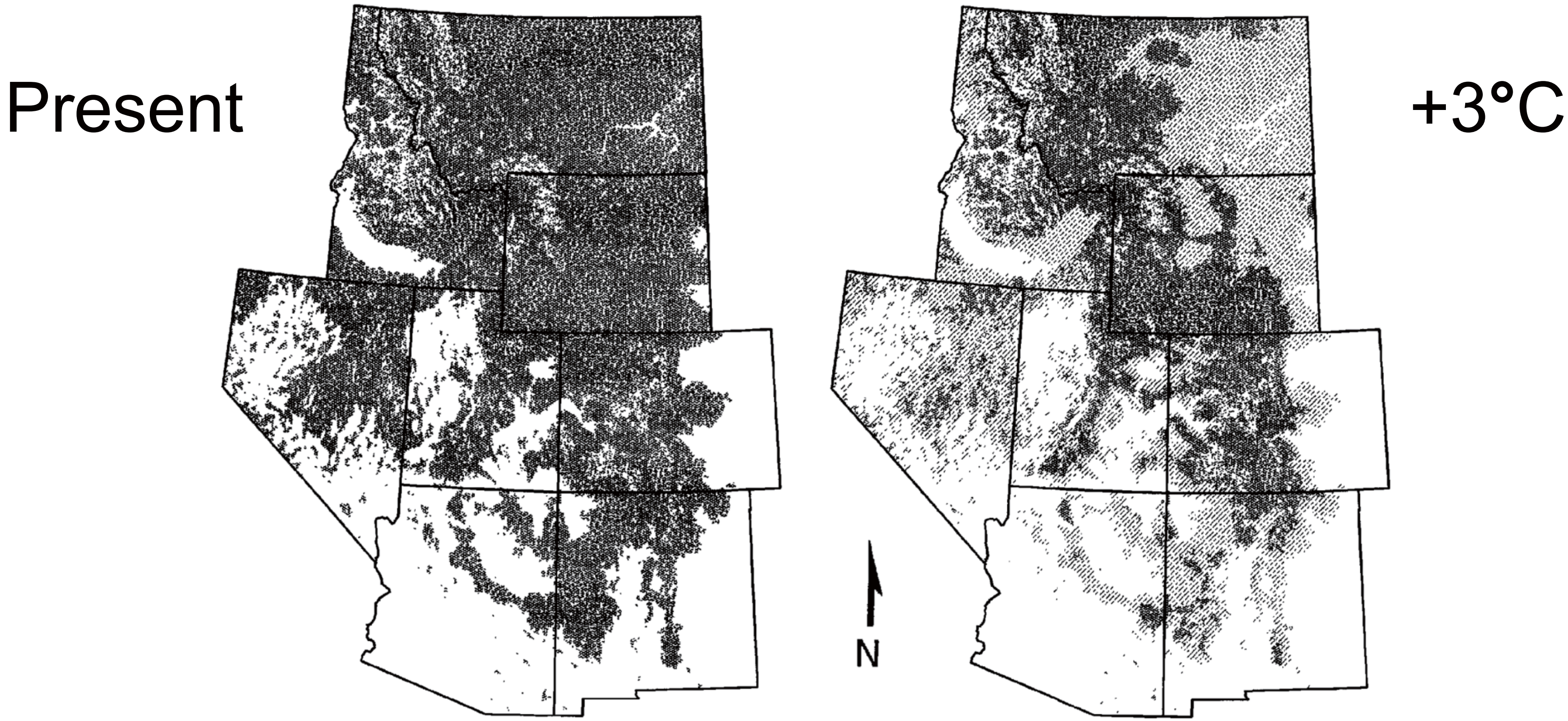


Lake Chad Basin

Lake Chad is 1/20th the size it was 35 years ago



Loss of stream segments able to support cold-water trout



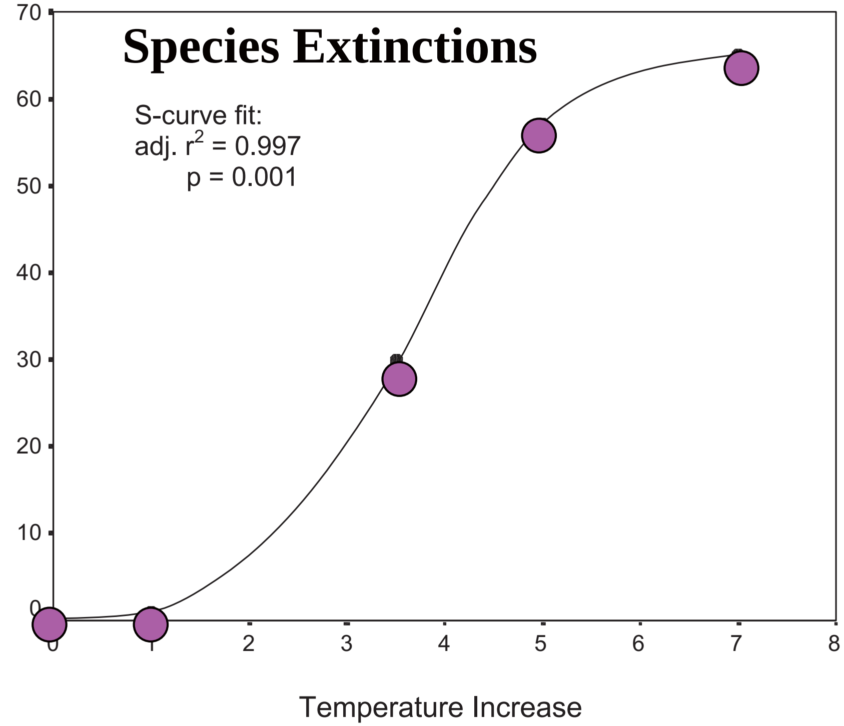
Source: Poff et al. 2002, based on Keheler and Rahel 1996

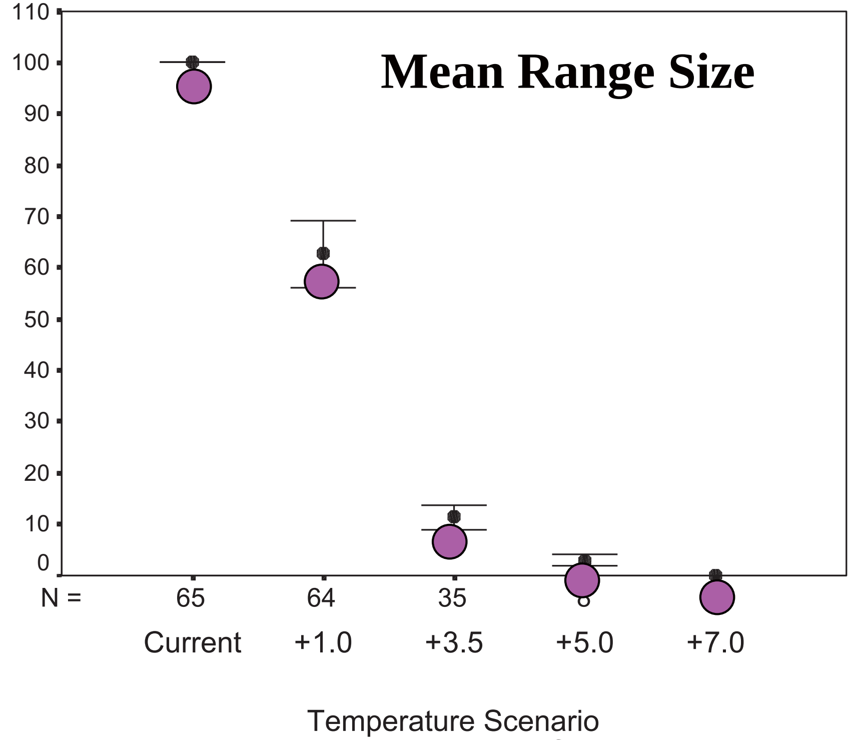
American pika (*Ochotona princeps*)

Spatial Pattern of Species Richness

Dark red = high species richness

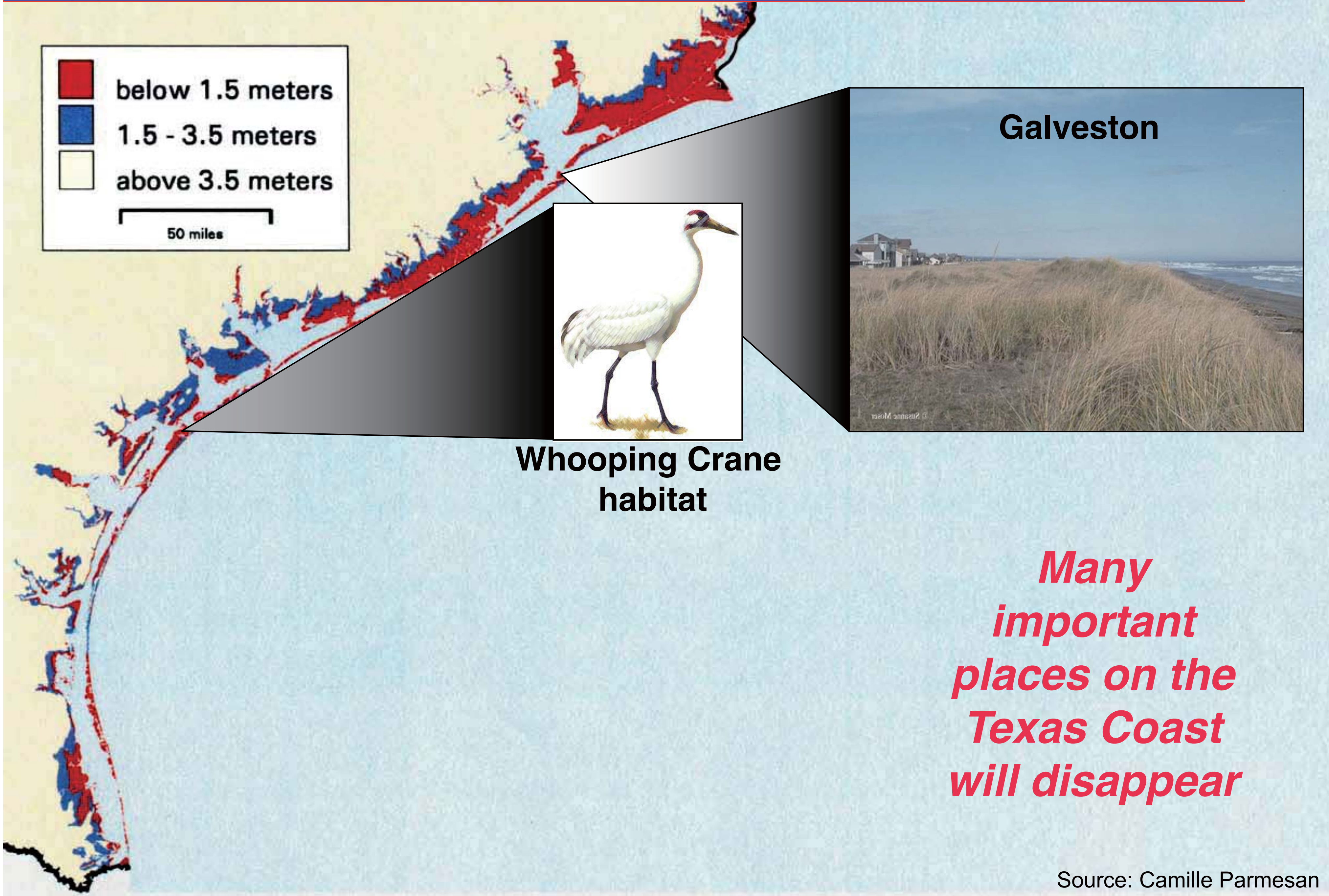
Williams et al. 2003. Proc Roy Soc Lond. B: 270:1887-1892





Slide courtesy of Stephen Williams

Sea Level Rise in the Next 100 Years



Many important places on the Texas Coast will disappear

Source: Camille Parmesan

Key Deer

<u>National Key Deer Refuge</u>

Big Pine Key, Florida

•84,000 acres, Established 1957

Population Low:

27 in 1957

Population today:

Between 700 and 800

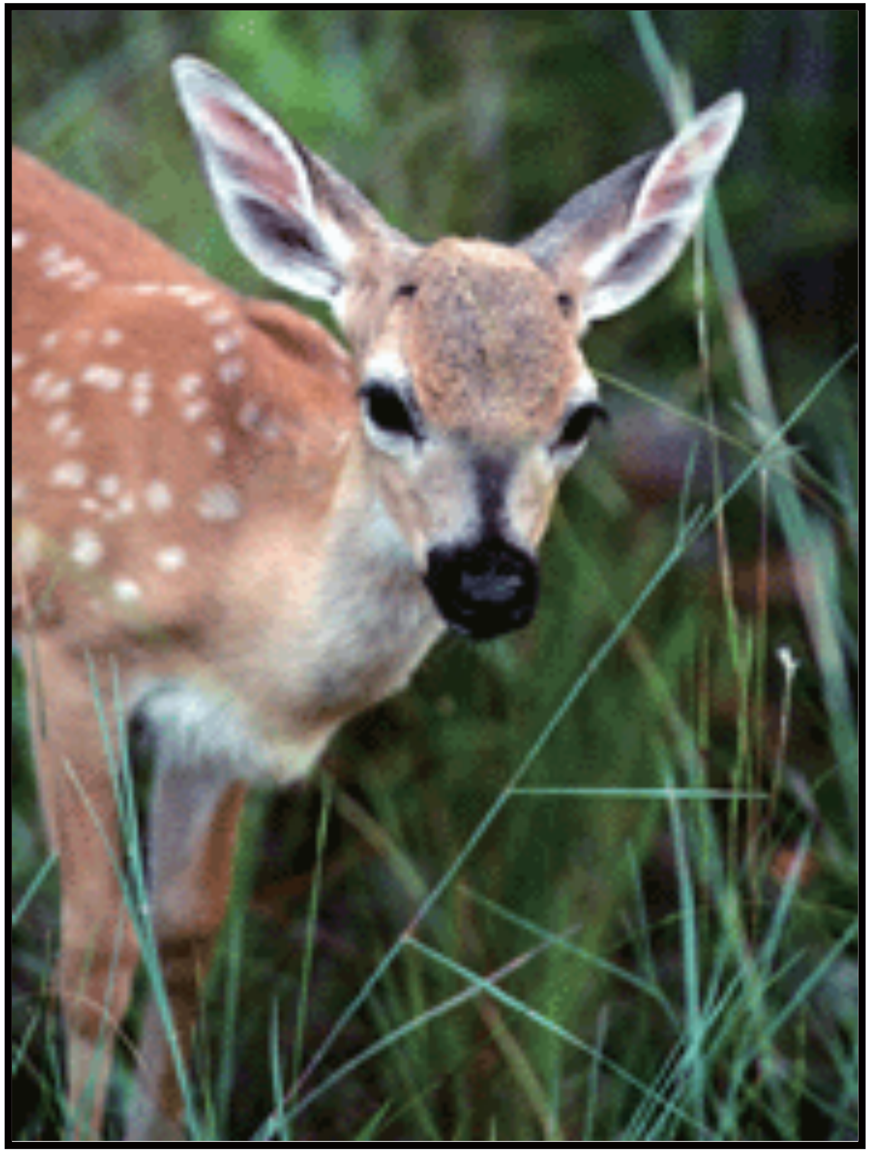
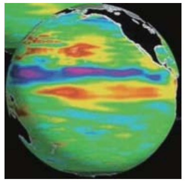


Photo courtesy of National Key Deer Refuge

Source: World Wildlife Fund

Complications

1. Landscape is human dominated & habitat is fragmented
2. Species don't move together
3. Change will not be linear or gradual
4. System change



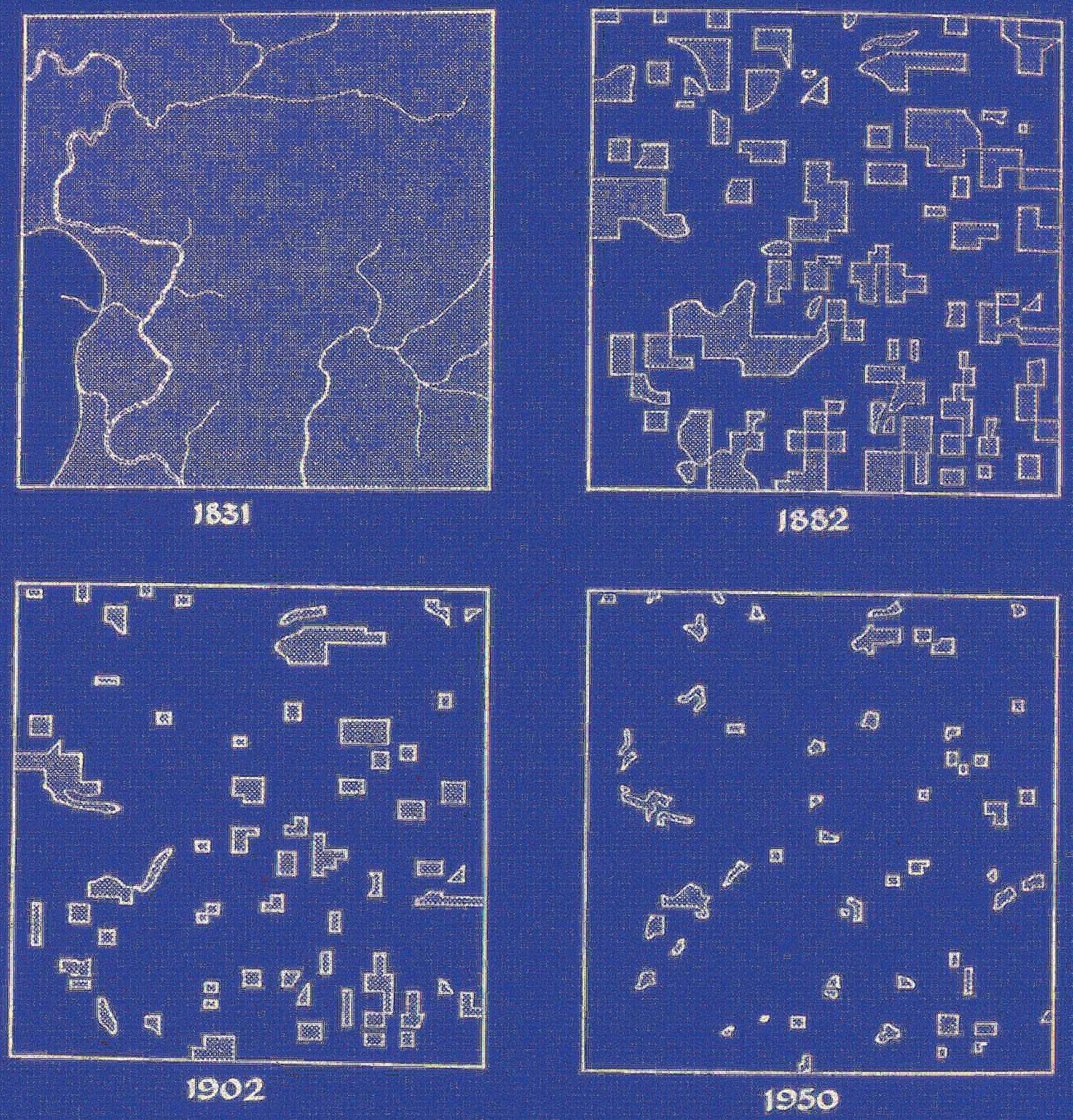


FIGURE 1. Reduction and fragmentation of the woodland in Cadiz Township, Wisconsin, 1831–1950. (After Curtis, 1956.)

Complications

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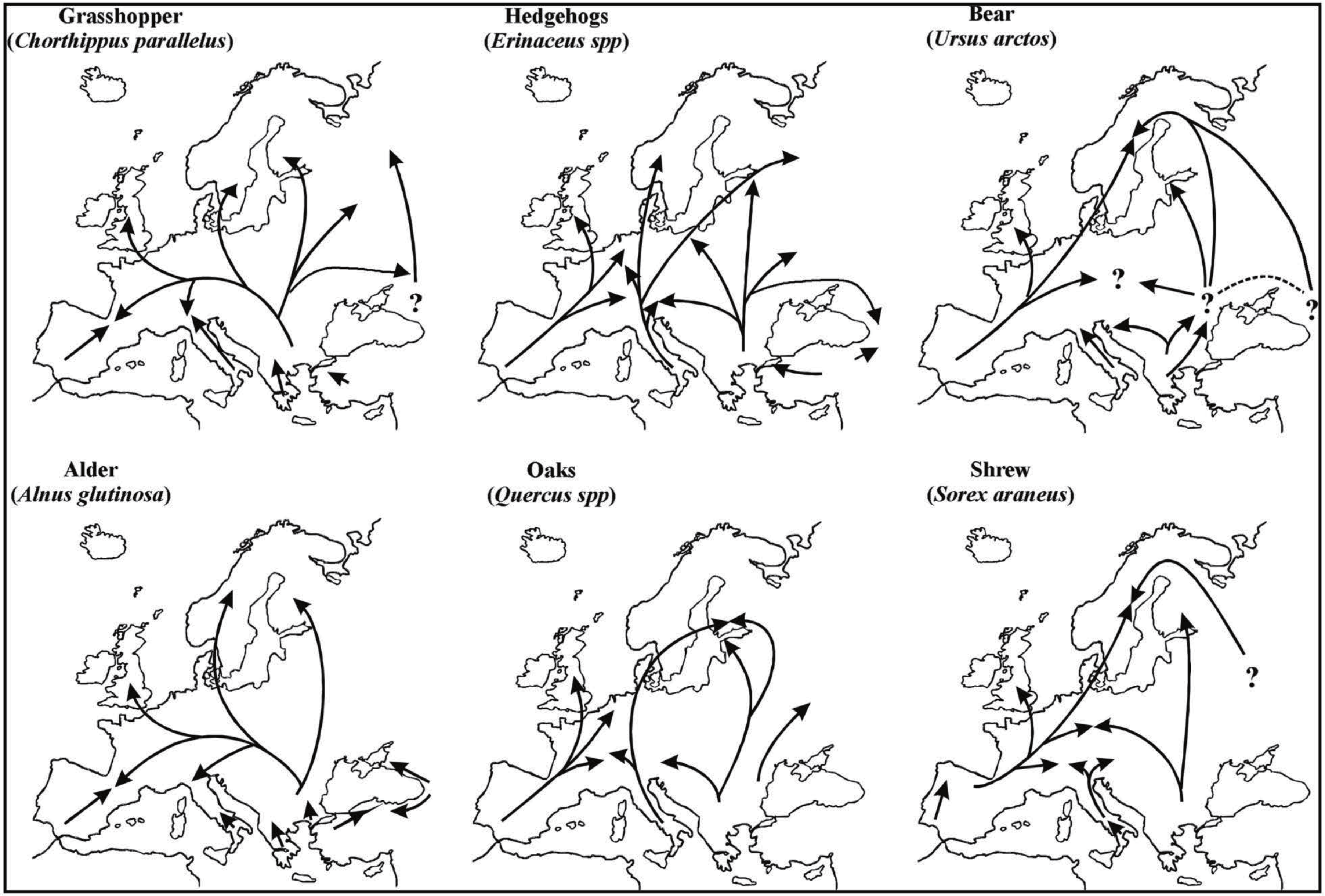
Ecosystems disassemble and species reassemble into new ecosystems



Source: G.M. Hewitt and Nichols, R.A. 2005

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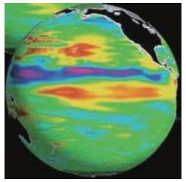
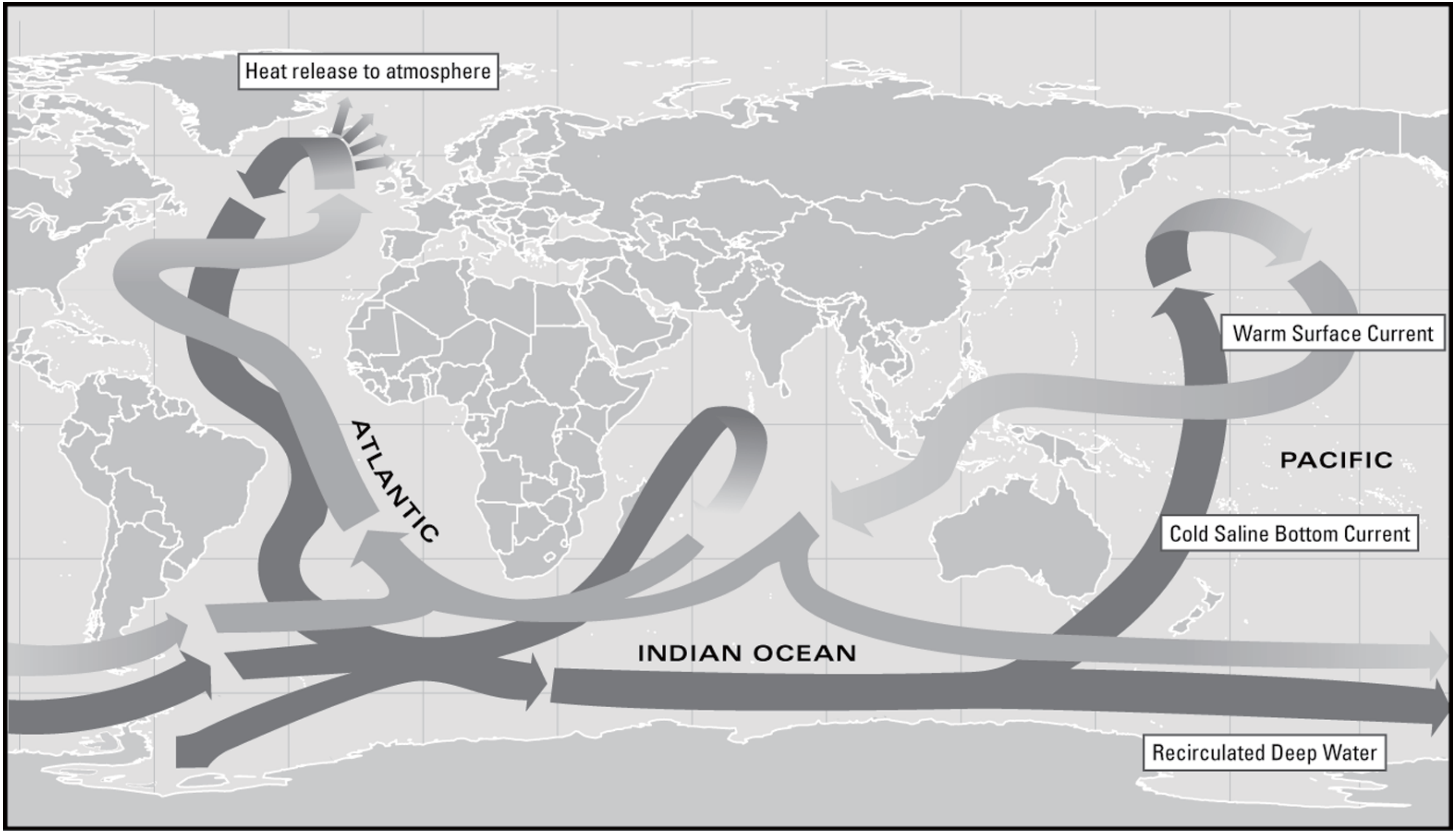




Source: E. Maier-Reimer

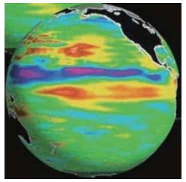
Elevated night time temperatures magnify bark beetle impact

The Washington Post
Wednesday, March 1, 2006

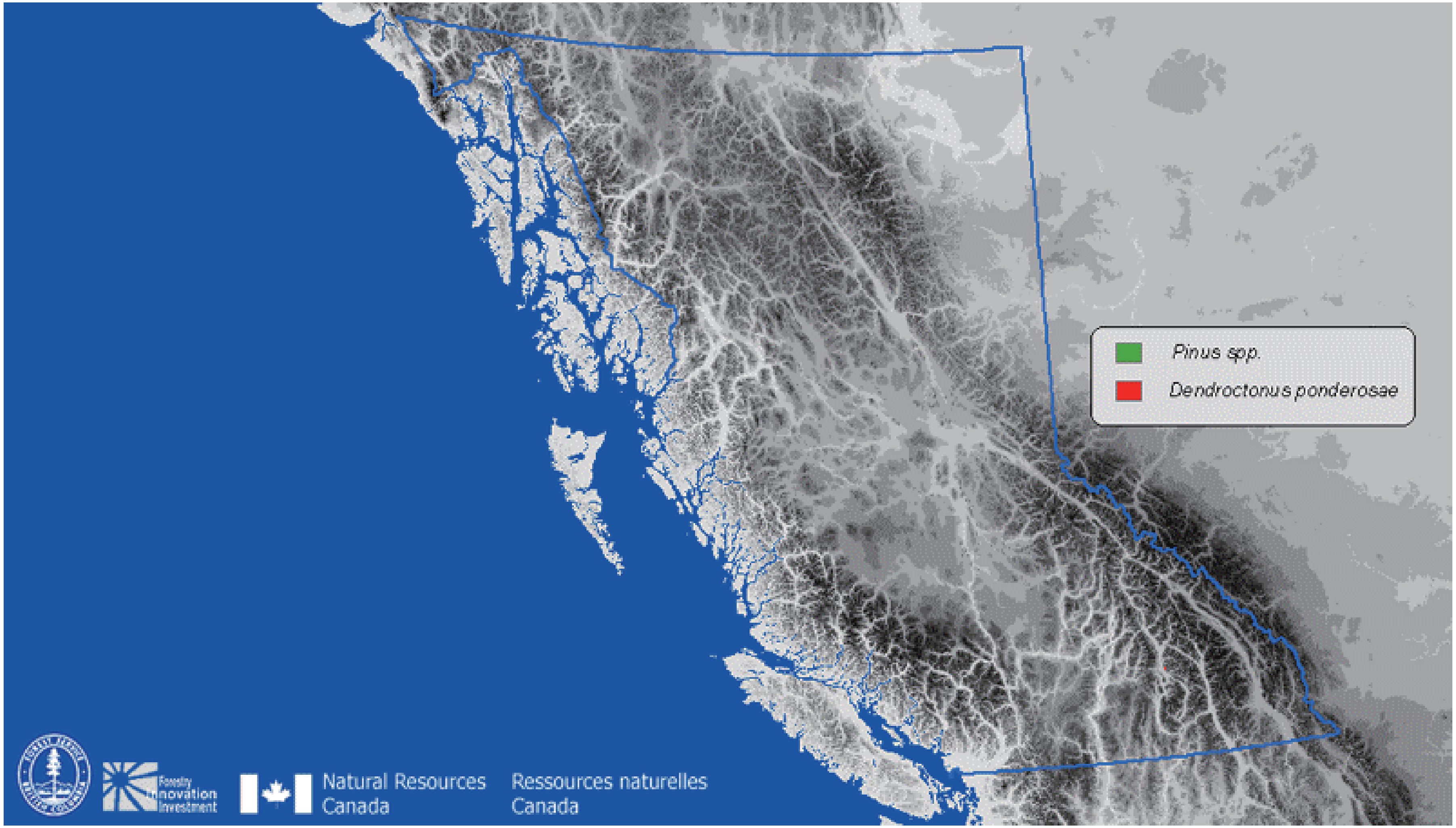
'Rapid Warming' Spreads Havoc in Canada's Forests

QUESNEL, B.C. -- Millions of acres of Canada's lush green forests are turning red in spasms of death. A voracious beetle, whose population has exploded with the warming climate, is killing more trees than wildfires or logging.

Source: D. Struck 3/1/2006, *Washington Post*, pA1



Mountain Pine Beetle outbreaks (1959-2002)



Courtesy of Mike Bradley, Canfor Corporation

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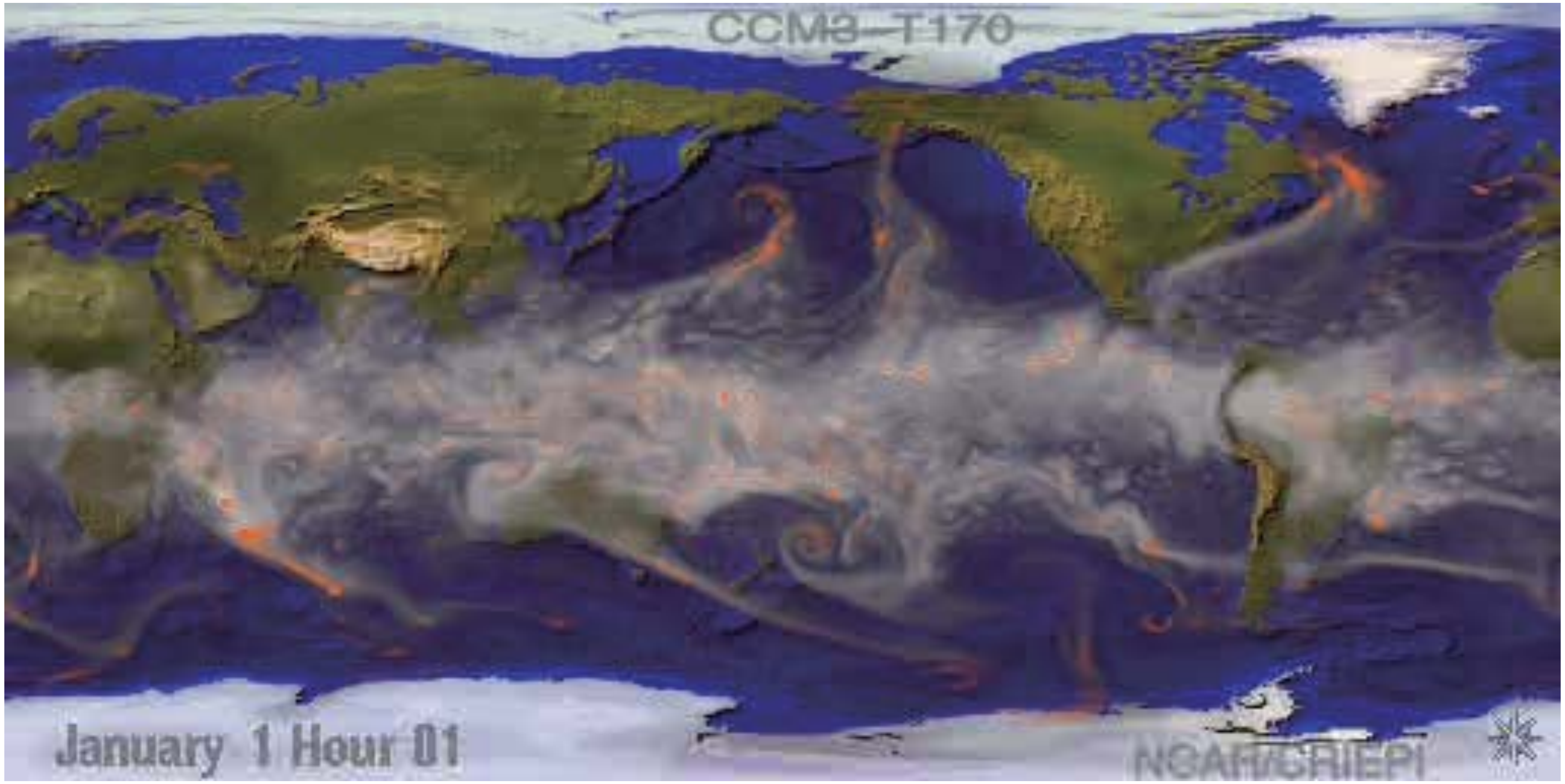
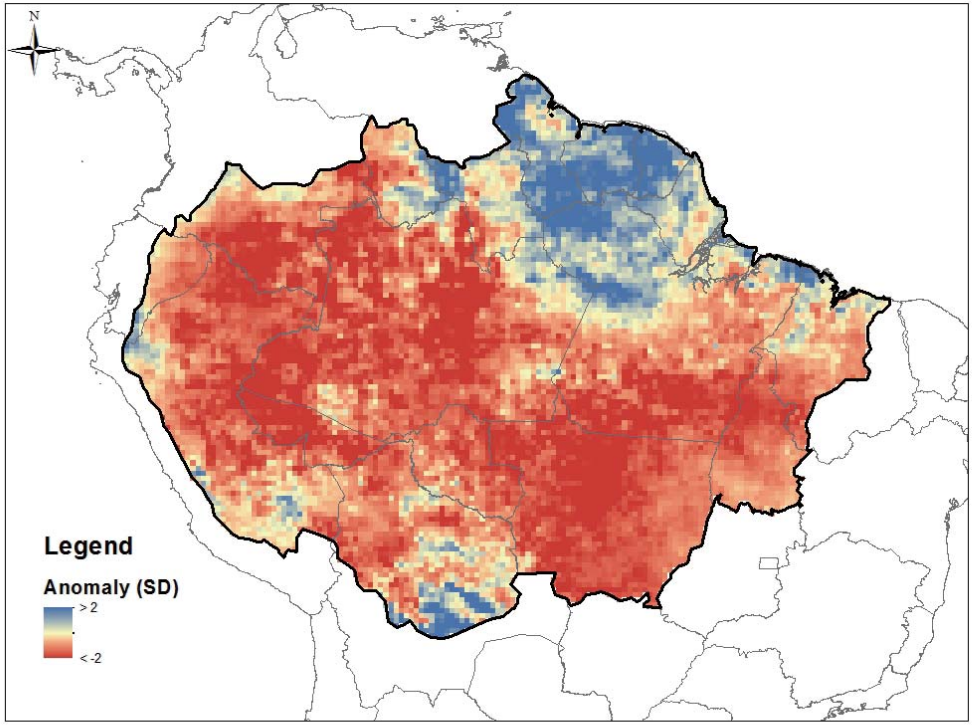


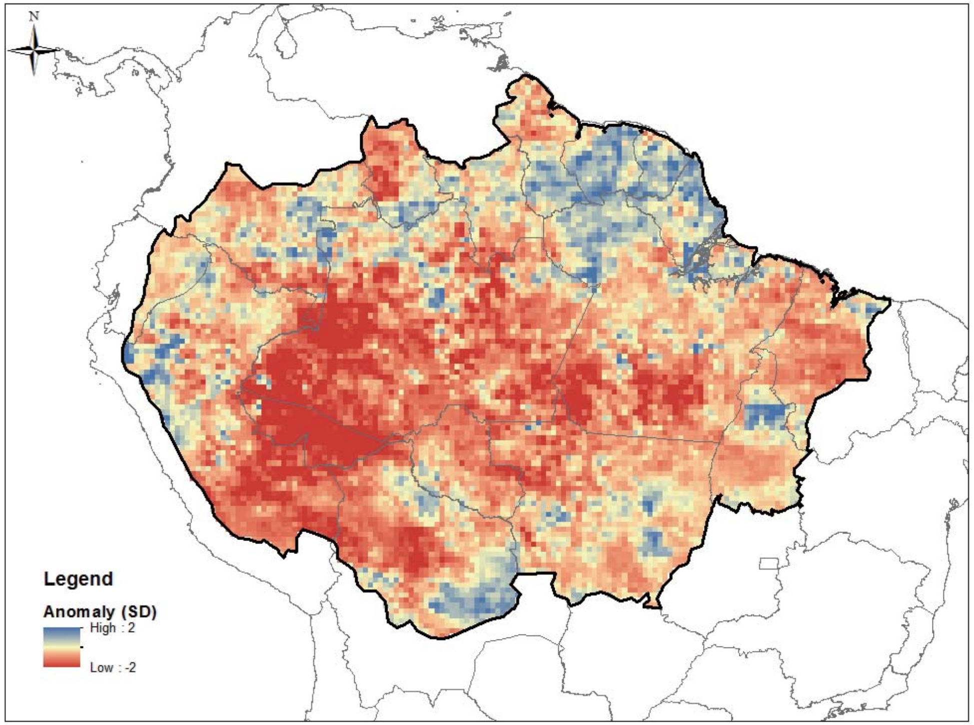
Courtesy of NOAA/NCAR

Amazon Rainfall in 2010 and 2005
(deviation from 10-year mean)

2010

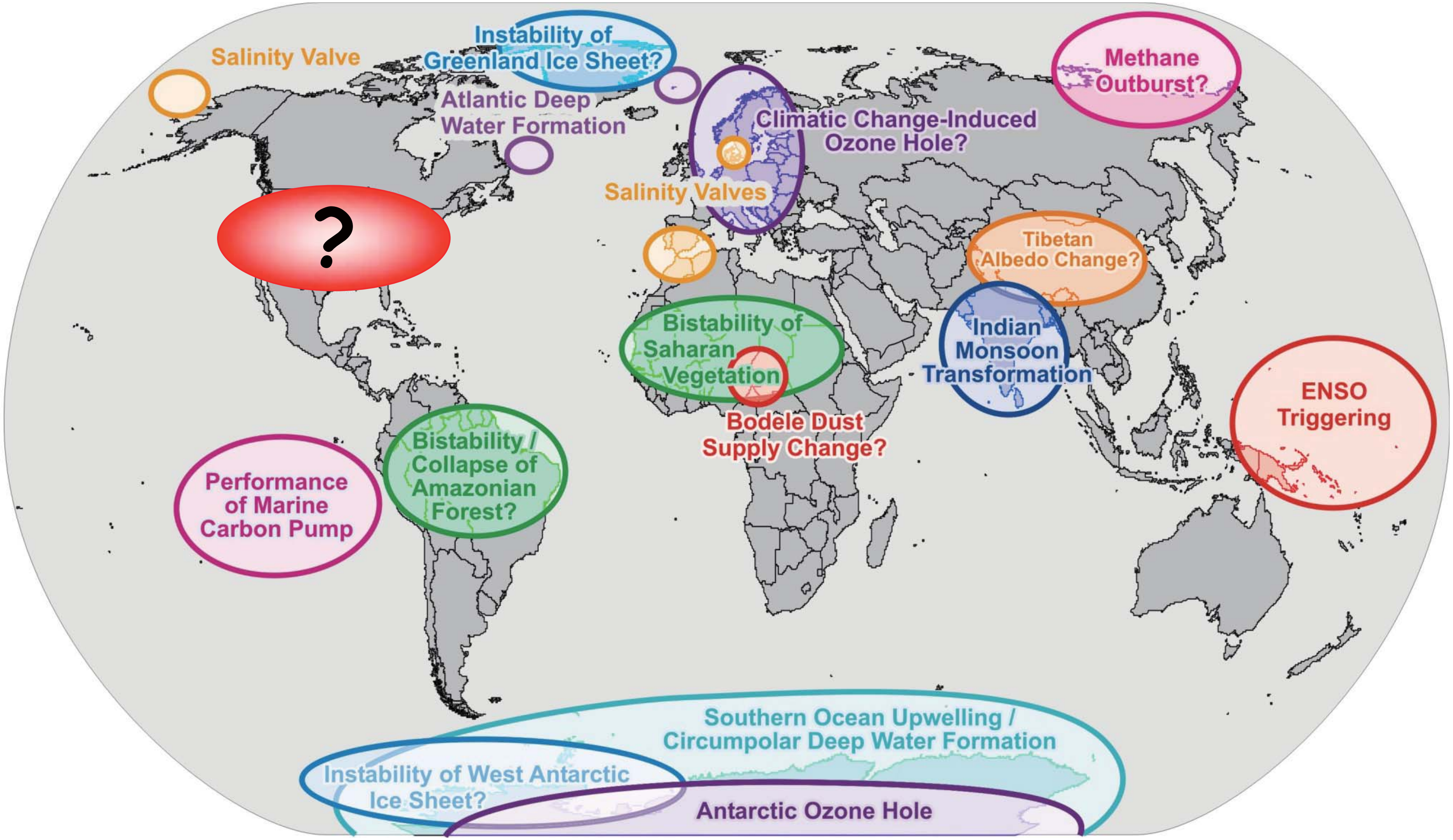


2005



S. Lewis, P. Brando, D. Nepstad, submitted

Critical thresholds in the Earth system



Where local or regional changes may have strong effects on earth system interactions, feedbacks, or teleconnections

INTERNATIONAL
Herald Tribune
PUBLISHED BY THE NEW YORK TIMES

Wednesday, June 7, 2006

Oceans II ▪ By Thomas E. Lovejoy

Rising acidity threatens marine life

WASHINGTON

The problems of acid rain and acid lakes, which came to public attention in the 1980s, have been addressed to a considerable degree. Today we face a far more profound challenge: increasingly acid oceans.

It is little known outside of scientific circles that a fundamental change has already taken place in the chemistry of the two thirds of the earth's surface occupied by oceans. The change, of 0.1 of a pH unit, sounds trivial when expressed in the logarithmic scale that science uses, but it translates to the upper layers of the oceans already being 30 percent more acid than in preindustrial times.

The change is being causes by increased atmospheric levels of greenhouse gases, in particular carbon dioxide. In addition to forcing climate change, more carbon dioxide combines with water and produces carbonic acid.

The consequences for marine ecosystems are only beginning to be understood but are bound to be far-reaching.

Tom Ondway/Jean-Michel Cousteau Productions via AP

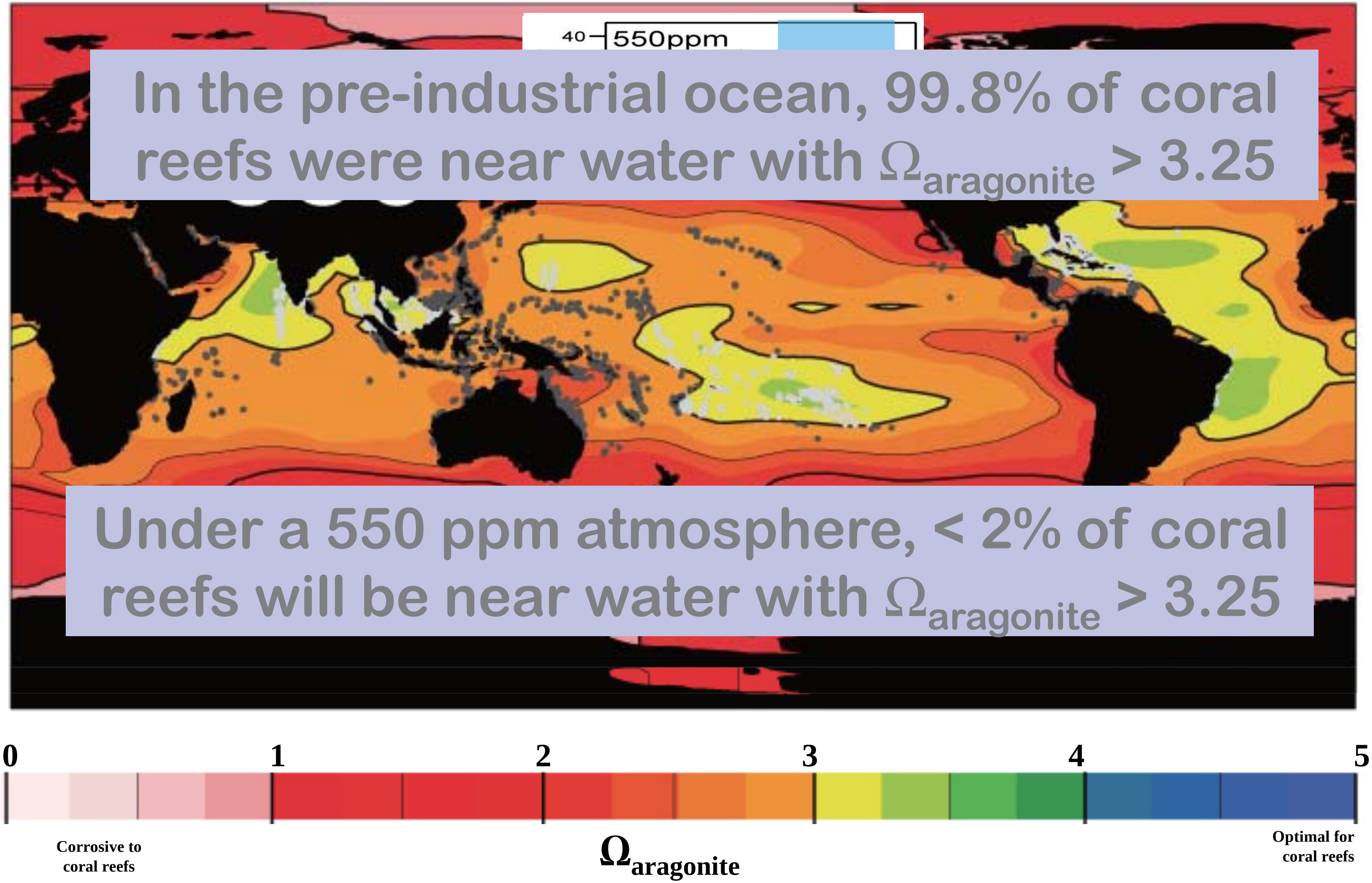
Acidifying oceans are a challenge for species using calcium carbonate

Acidifying oceans are a challenge for species at the base of the marine food chain

[Source: www.ipsl.jussieu.fr/~jomce/acidification]

a <u>pteropod</u>, or sea butterfly, is a type of planktonic mollusk

Deteriorating chemical condition for coral reefs



In the pre-industrial ocean, 99.8% of coral reefs were near water with $\Omega_{aragonite}$ > 3.25

Under a 550 ppm atmosphere, < 2% of coral reefs will be near water with $\Omega_{aragonite}$ > 3.25

Why is a CO_2 target of 450ppm too high ?

Two degrees is too much

(1) Arctic sea-ice

(2) Greenland ice-sheet stability

(3) Antarctic ice-sheet stability

(4) Major ecosystem disruption

Ice-sheet collapse and sea-level rise

Last time Earth was 2°C warmer, sea-level was 4-6m higher

Data: Rohling *et al.* (2008) *Nature Geoscience*, **1,** 38-42.

- At today’s level of 387ppm CO_2, reefs are seriously declining and time-lagged effects will result in their continued demise with parallel impacts on other marine and coastal ecosystems.

- Proposals to limit CO_2 levels to 450ppm will not prevent the catastrophic loss of coral reefs from the combined effects of climate change and ocean acidification.

- To ensure the long-term viability of coral reefs atmospheric carbon dioxide level must be reduced significantly below 350ppm.

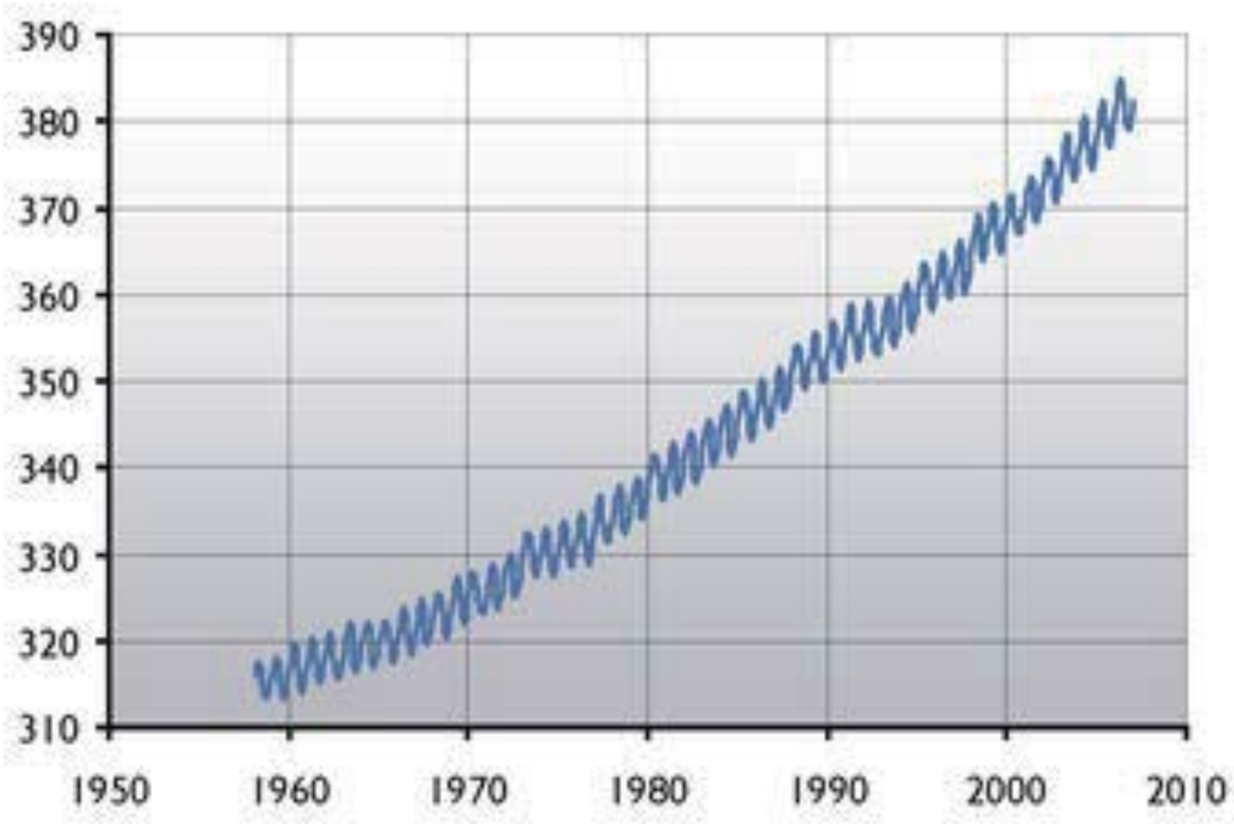
Royal Society Meeting,
July 6th 2009

What is a “safe” level?

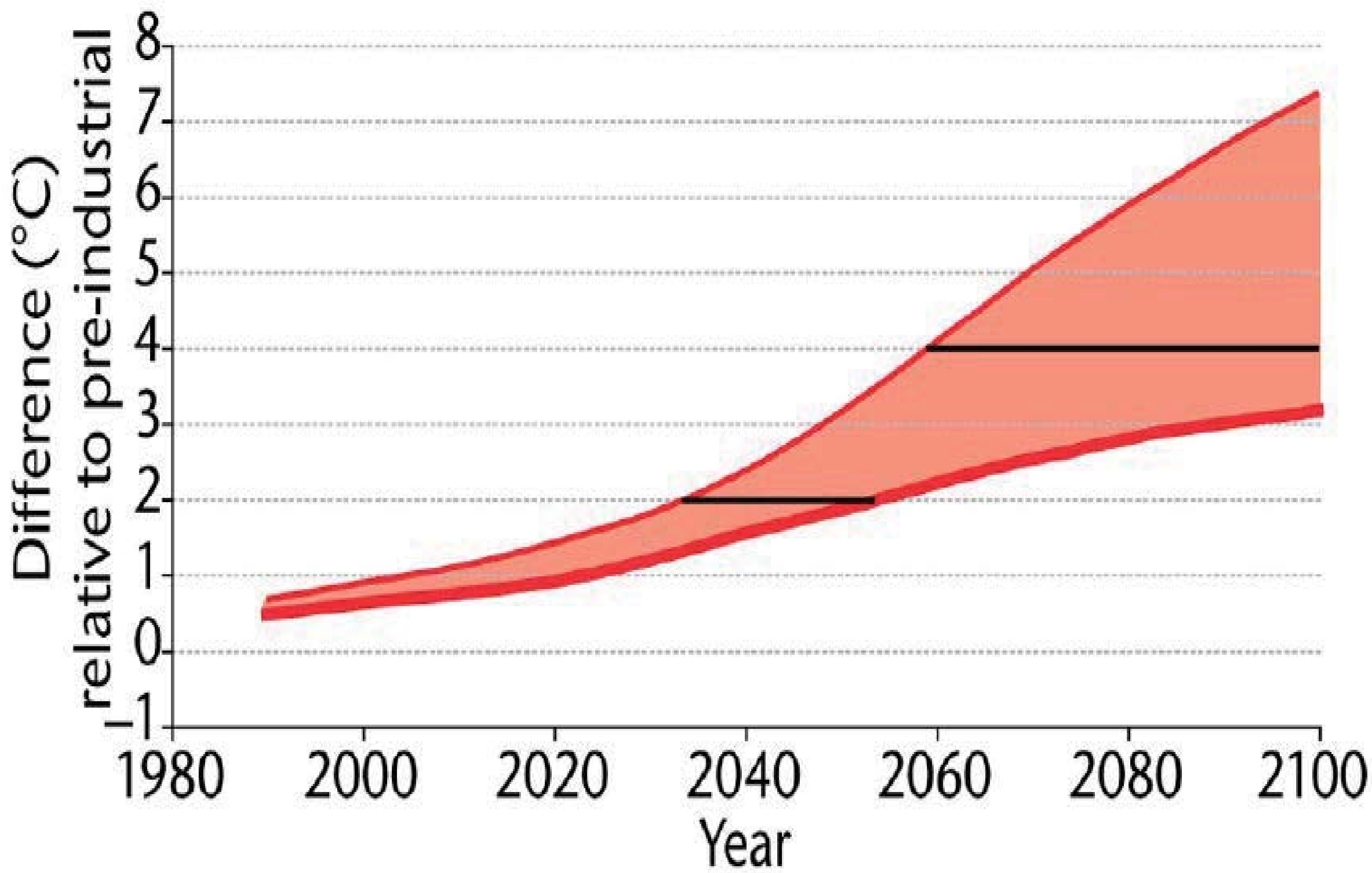
James Hansen,

et al., 2008

350 ppm

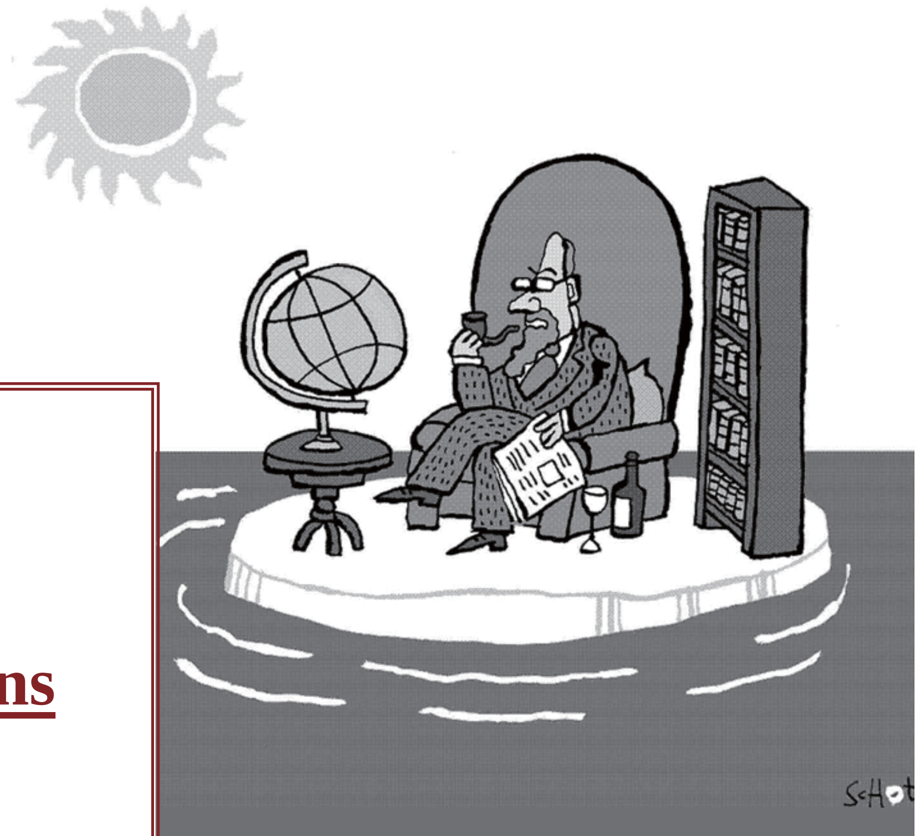


Projected temperature rise for A1B & A1F1 scenarios (Hadley, 2009)



What can be done

SCHOT
NRC HANDELSBLAD
Rotterdam
NETHERLANDS



Adaptation

-Revise Conservation Strategies

Limit Greenhouse Gas Concentrations

-Reduce and eliminate emissions

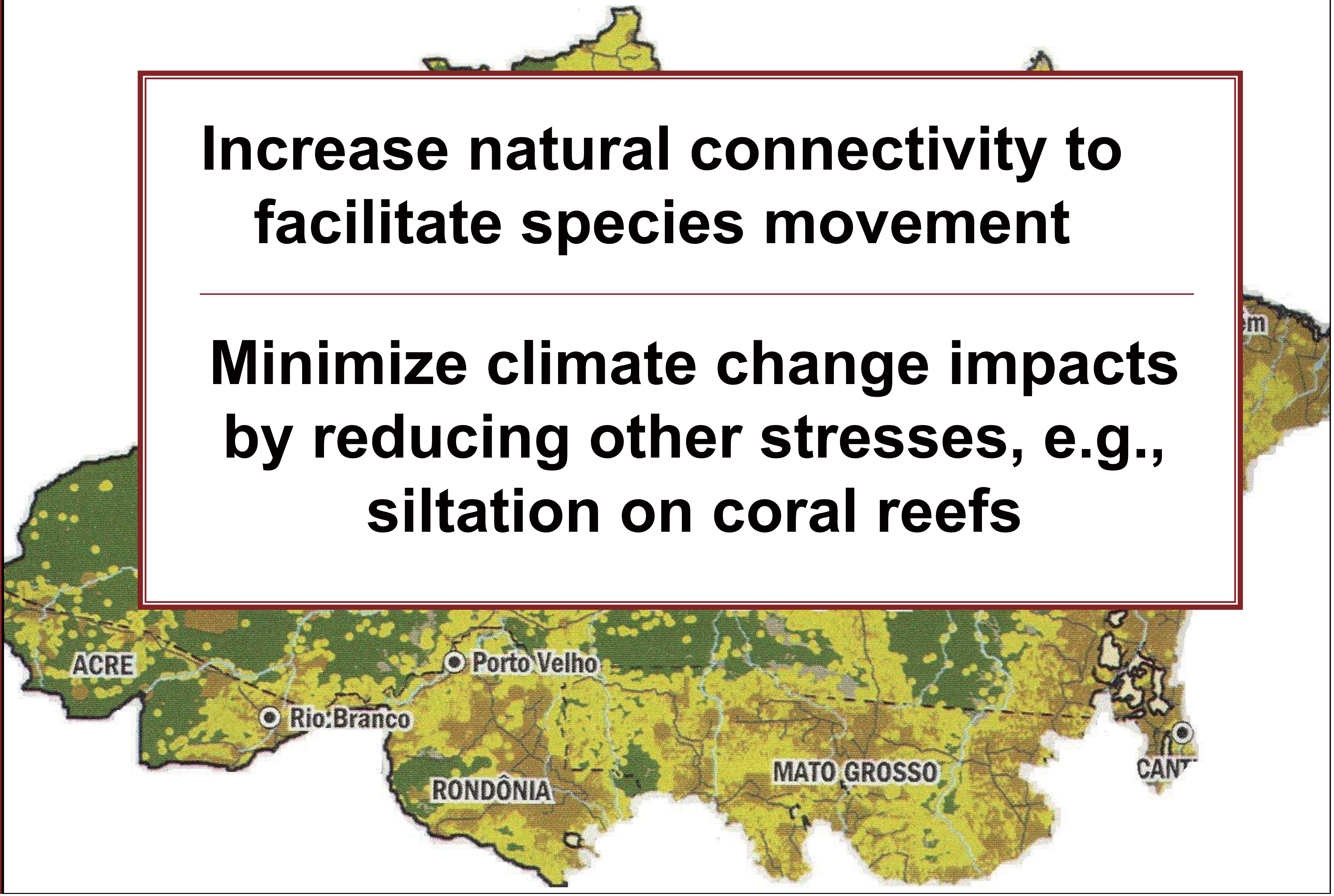
--revise energy base for society

--reduce/eliminate deforestation

Adaptation: Revise conservation strategies

Increase natural connectivity to facilitate species movement

Minimize climate change impacts by reducing other stresses, e.g., siltation on coral reefs



Limit Greenhouse Gas Concentrations

Revise Energy Base for Society

Limit Greenhouse Gas Concentrations

20% of Annual Emissions come from deforestation

1.5 Pg C y^{-1}

+

7.5 Pg C y^{-1}

4.2 Pg y^{-1}

Atmosphere

46%

2.6 Pg y^{-1}

Land

29%

2.3 Pg y^{-1}

Oceans

26%

Canadell et al. 2007, PNAS (updated)

Long atmospheric residence times for greenhouse gases

What can be done

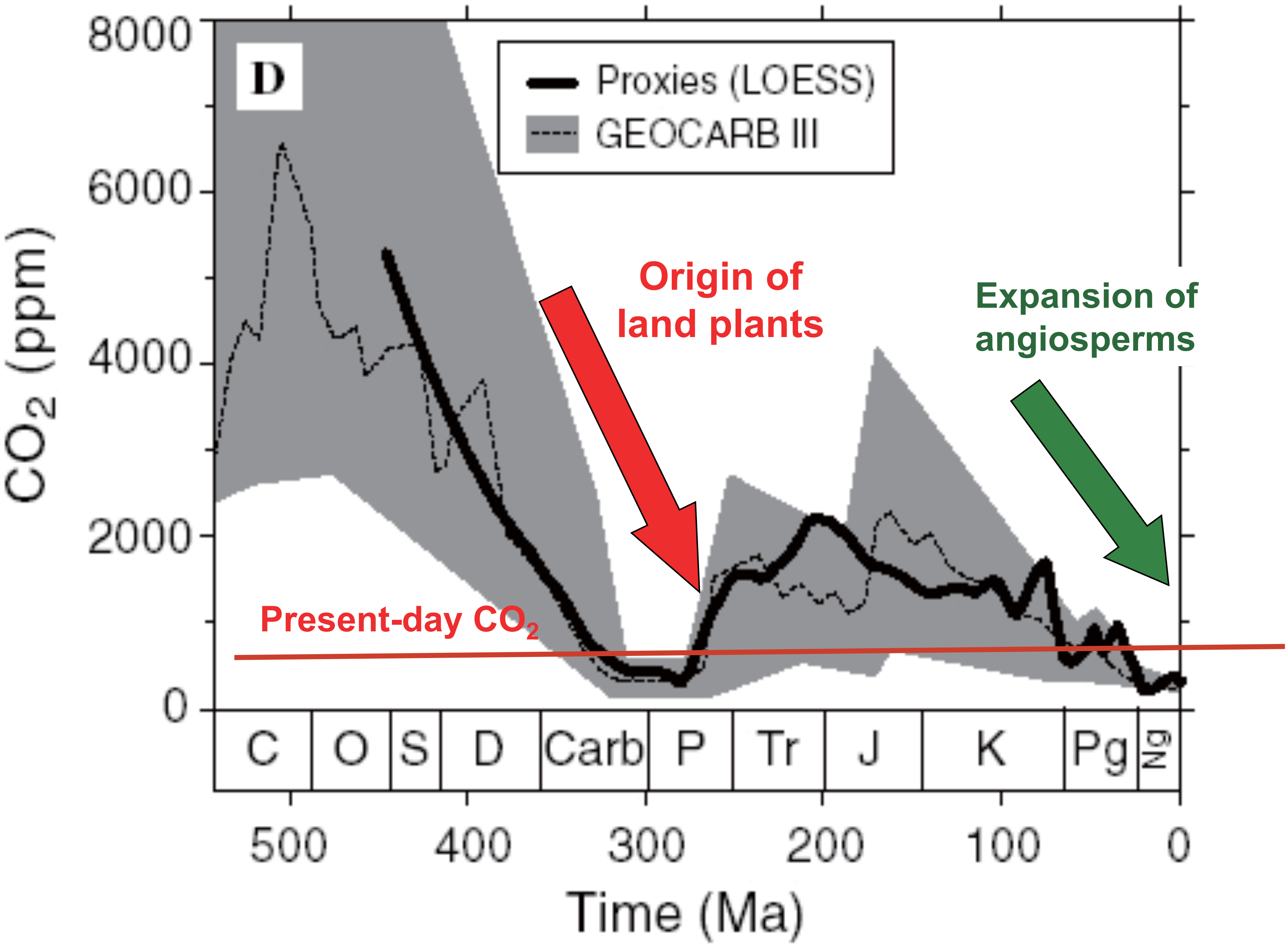
Lower Atmospheric CO_2

- **Restore ecosystems**

  (*biodiversity and carbon*)

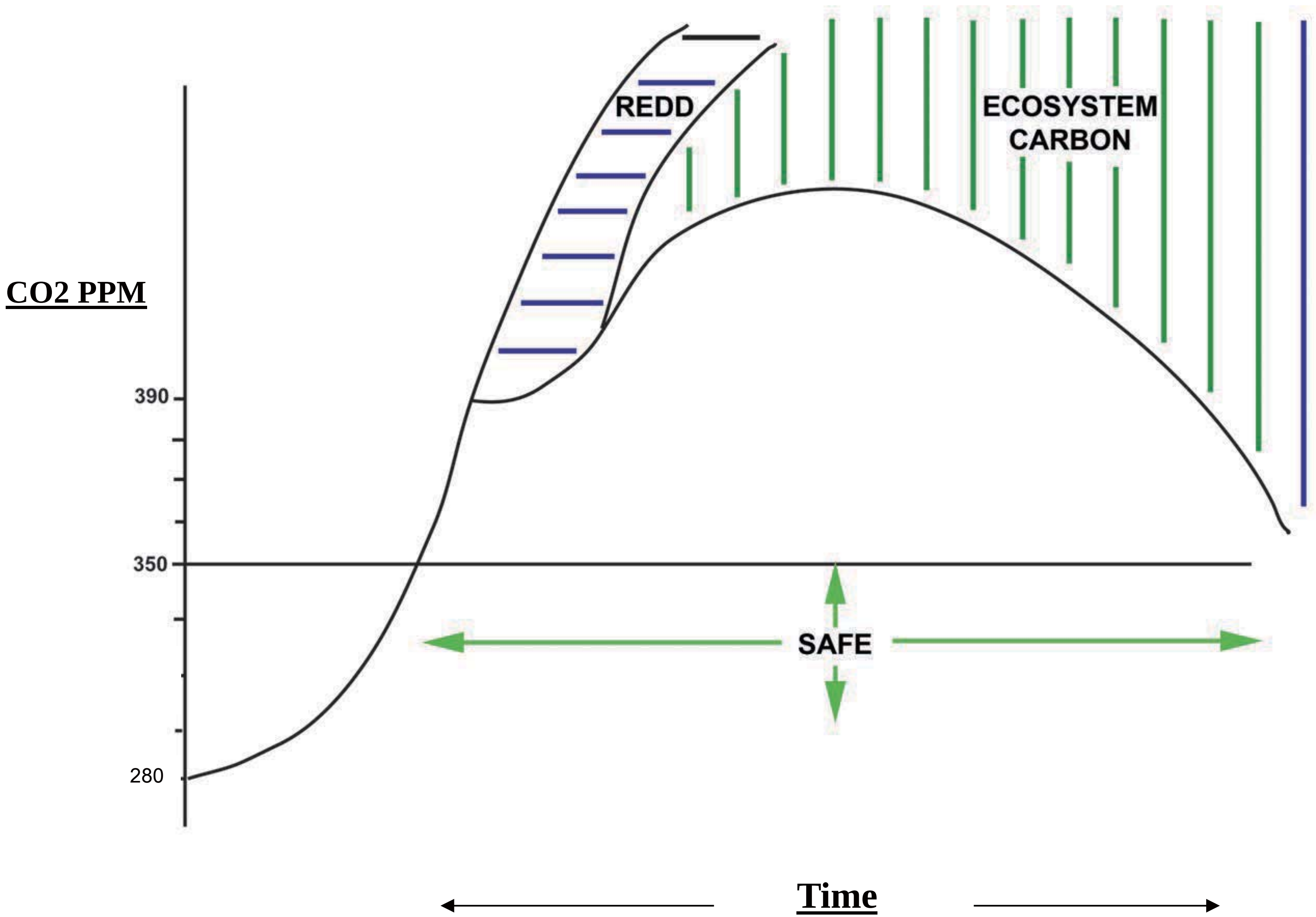
- **Non-biological CO_2 removal**

The Role of Life Processes



Over the past three centuries, ecosystems have lost 200-250 billion tons of carbon

Planetary Engineering Using Ecosystems



The Role of Forests

Restoring Grazing Land

Photo courtesy USDA NRCS

Modify Agriculture to Build up Soil Carbon

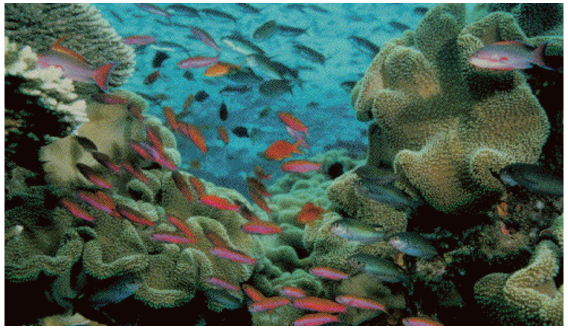
Photos: United States Department of Agriculture—Natural Resources Conservation Service.

Re-Greening the Emerald Planet







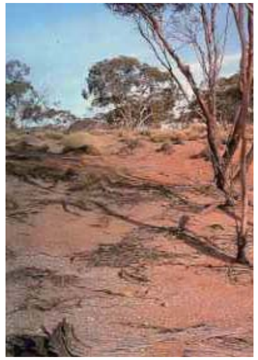










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