Climate Change and Arboriculture: As Earth Warms, Trees Feel the Heat

Dan Herms,

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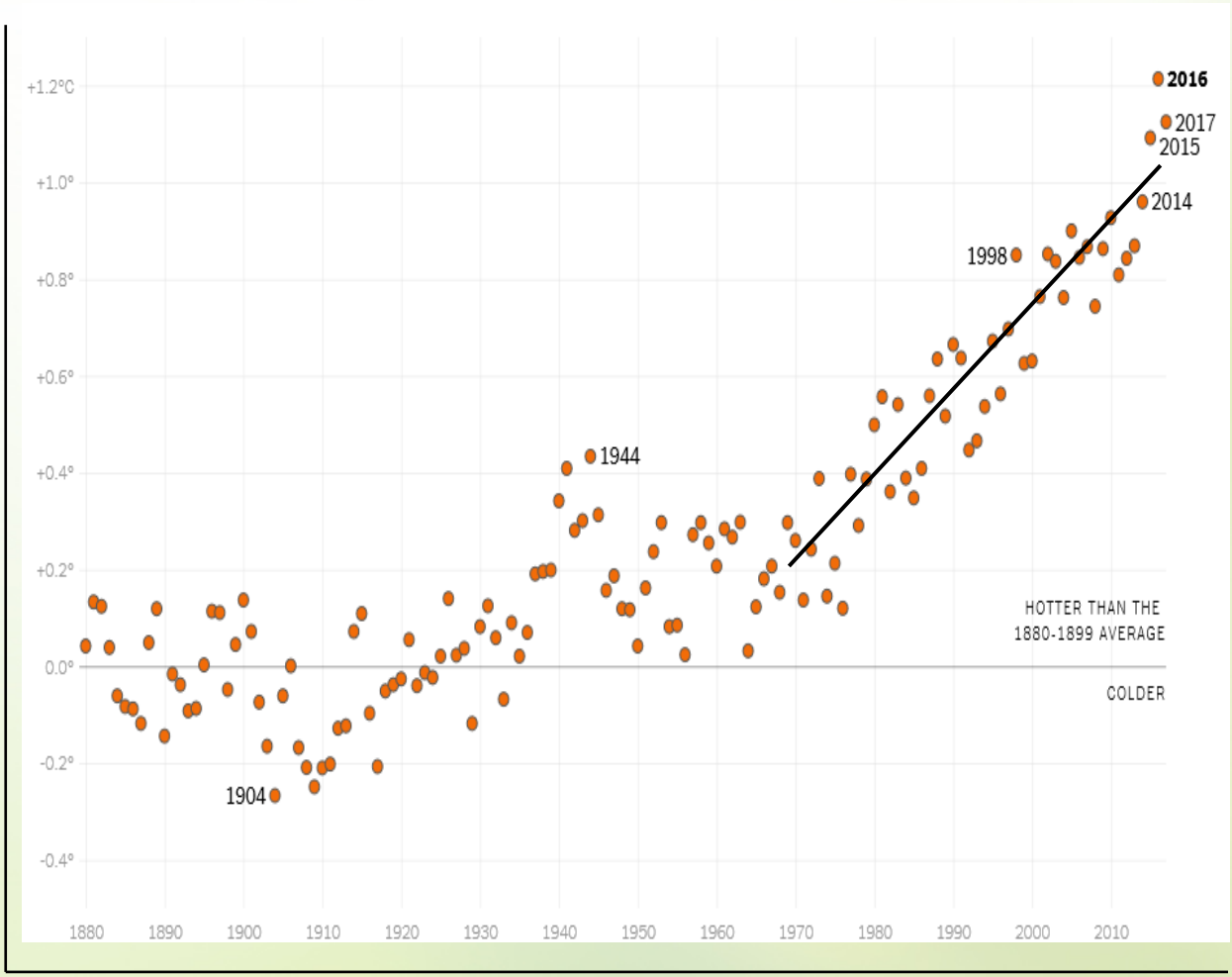
Presentation Outline

1. Evidence that Earth is warming
2. Evidence that warming is caused by greenhouse gas emissions
3. Climate change projections
4. Arboriculture impacts

10 warmest years in the instrument record (18 of 19 have occurred since 2000)

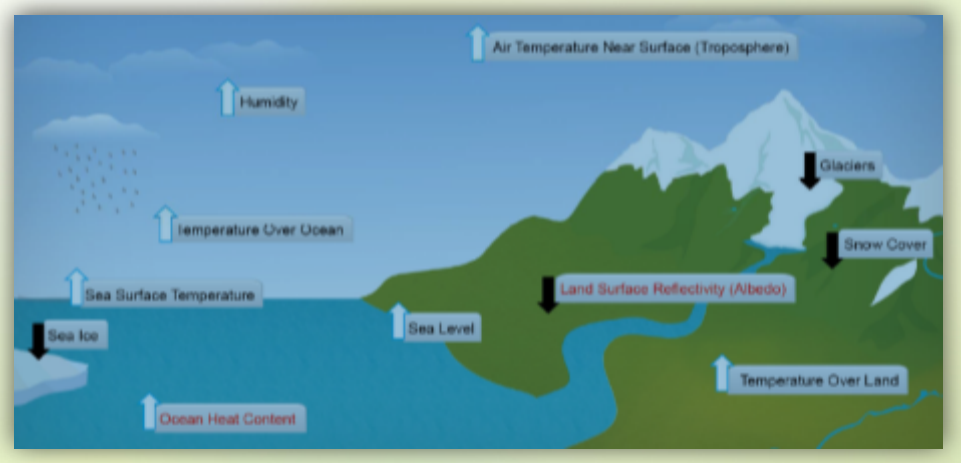
1. 2016
2. 2017
3. 2015
4. 2018
5. 2014
6. 2010
7. 2005
8. 2013
9. 2007
10. 2009



Source: NASA

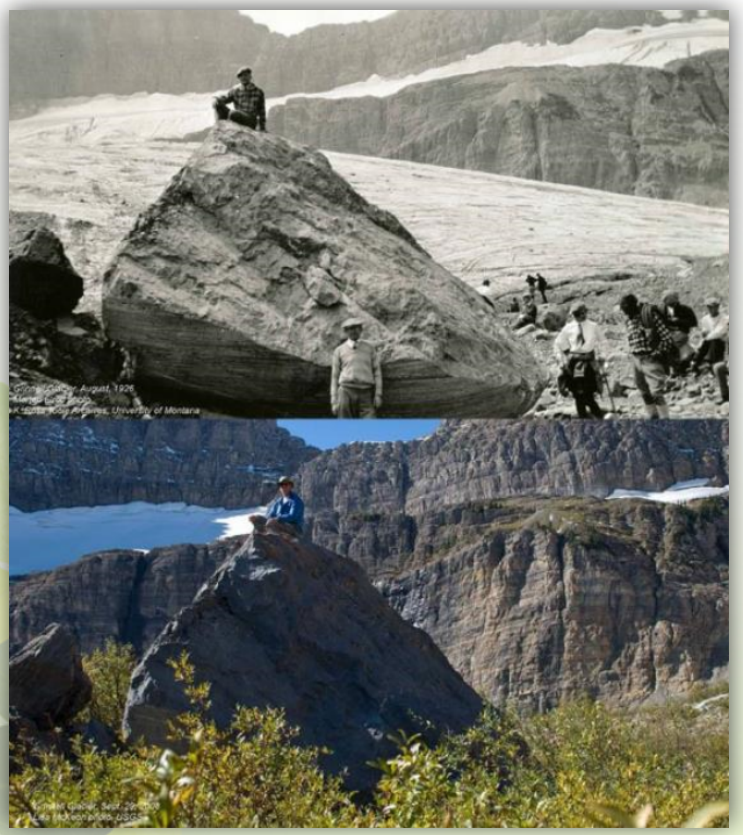
Earth is Warming: 30-year Trends

1. Increasing air temperature in lower atmosphere
2. Increasing temperature over land
3. Increasing temperature over oceans
4. Increasing sea-surface temperature
5. Increasing ocean heat content
6. Increasing humidity
7. Increasing sea level
8. Decreasing glacier cover
9. Decreasing sea ice cover
10. Decreasing snow cover



NOAA National Climatic Data Center

Glacier National Park

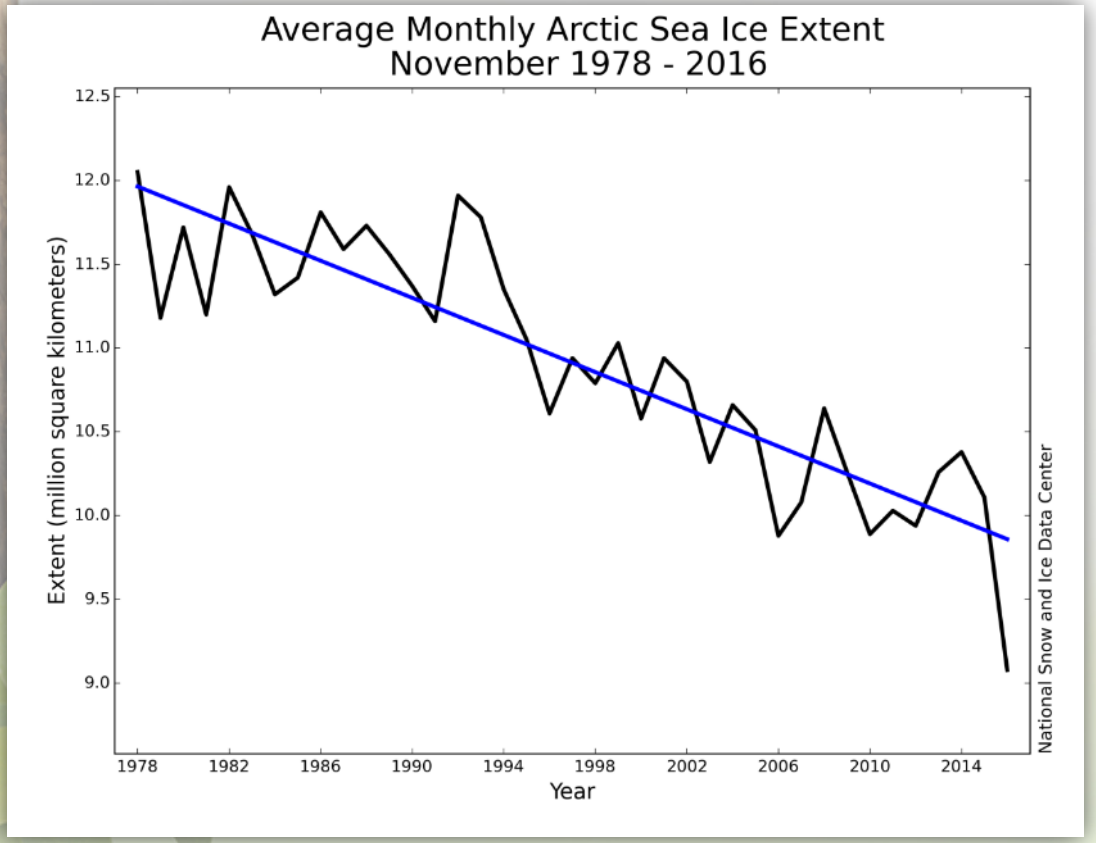


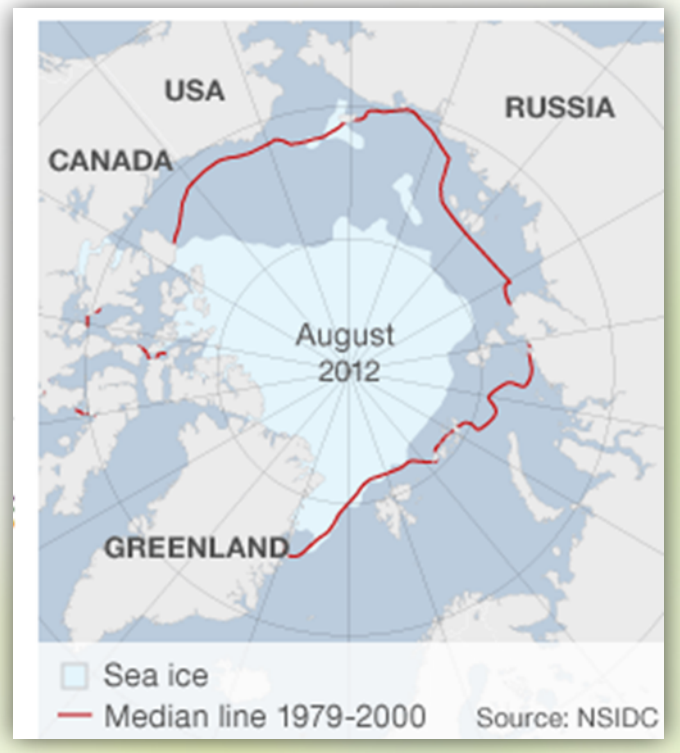
http://www.signoeditoresfotografia.es/wp-content/uploads/2015/10/GrnRock2_1926_Elrod_UM486-XII_114-037_c_L.jpg

Number of glaciers in 1910: 150

Today: 25

Grinnel Glacier, 1926 and 2008





Accelerated decline in the Arctic sea ice cover

Josefino C. Comiso,[1] Claire L. Parkinson,[1] Robert Gersten,[1,2,3] and Larry Stock[1,4]

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L01703, doi:10.1029/2007GL031972, 2008

Northwest Passage Opened for First Time in 2007; and Northeast Passage in 2011

The luxury ship Crystal Serenity, anchored off Nome, Alaska, in August 2016, on its inaugural Northwest Passage voyage. "We had to look for ice rather that try to avoid it," a passenger said.

Mark Thiessen / Associated Press

Land Ice

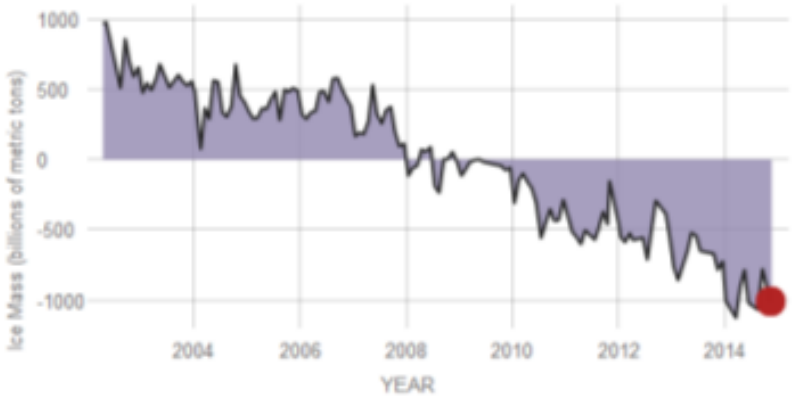
ANTARCTICA MASS VARIATION SINCE 2002

Data source: Ice mass measurement by NASA's Grace satellites.
Credit: NASA

RATE OF CHANGE

↓ 134.0

billion metric tons per year



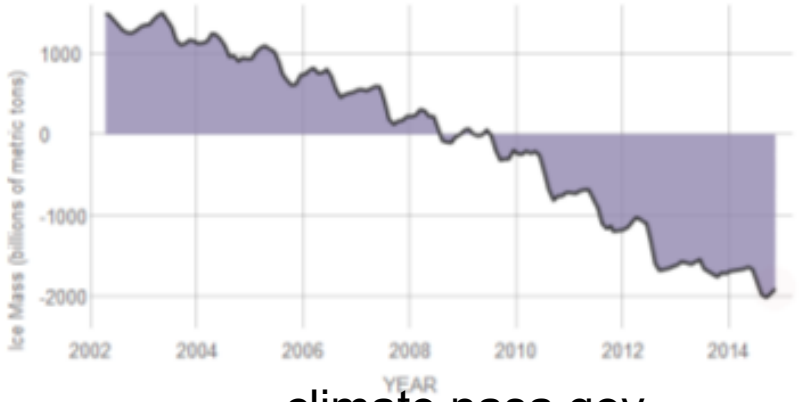
GREENLAND MASS VARIATION SINCE 2002

Data source: Ice mass measurement by NASA's Grace satellites.
Credit: NASA

RATE OF CHANGE

↓ 287.0

billion metric tons per year

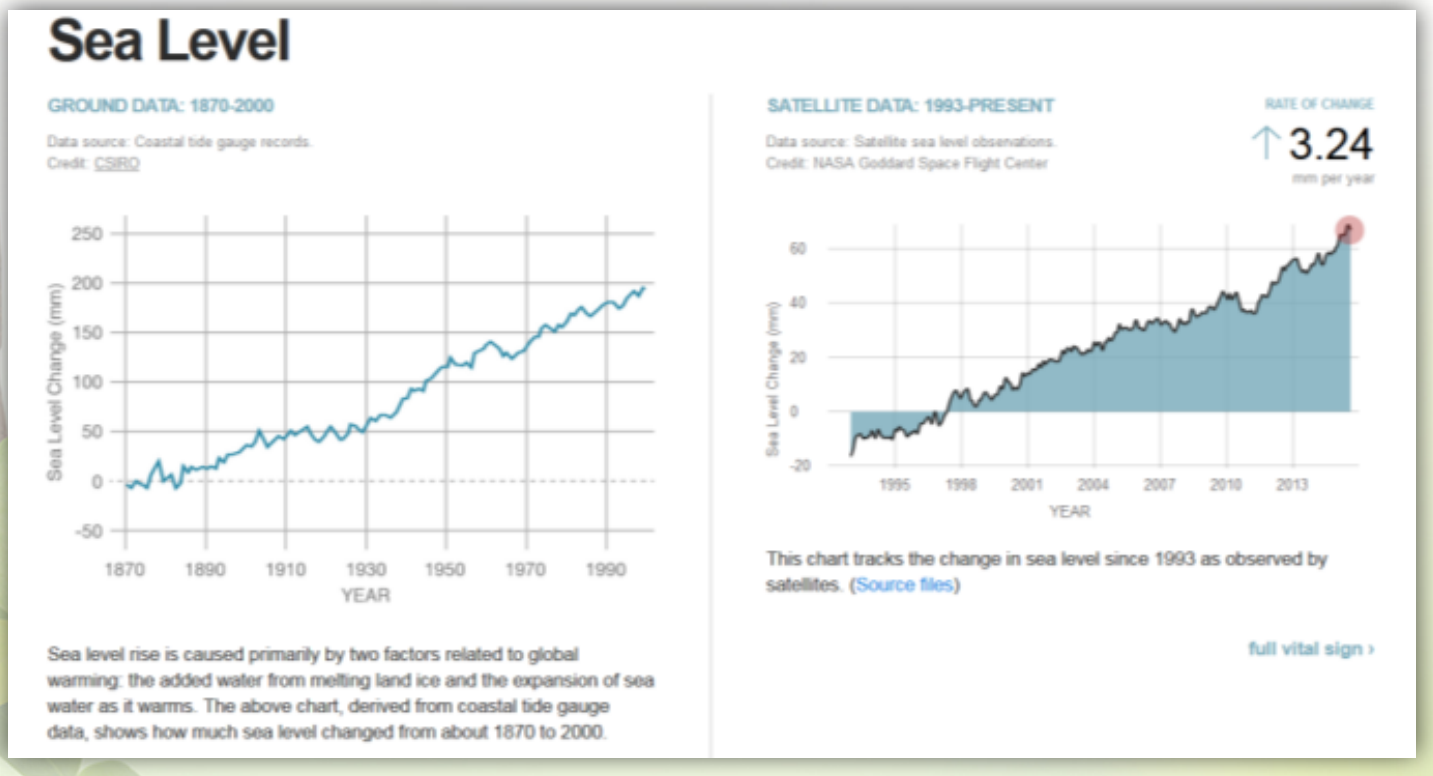


Data from NASA's Grace satellites show that the land ice sheets in both Antarctica and Greenland are losing mass. The continent of Antarctica (left chart) has been losing about 134 billion metric tons of ice per year since 2002, while the Greenland ice sheet (right) has been losing an estimated 287 billion metric tons per year. (Source: Grace satellite data)

climate.nasa.gov

full vital sign ›

Rate of sea level rise is increasing (currently 3.24 mm / yr)



climate.nasa.gov

Extreme Weather Events are More Frequent:

- **Increased frequency of heavy precipitation and heat waves.**
- **Frequency of strong (class 4-5) hurricanes has doubled.**

Hurricane Patricia: strongest ever recorded in Western Hemisphere

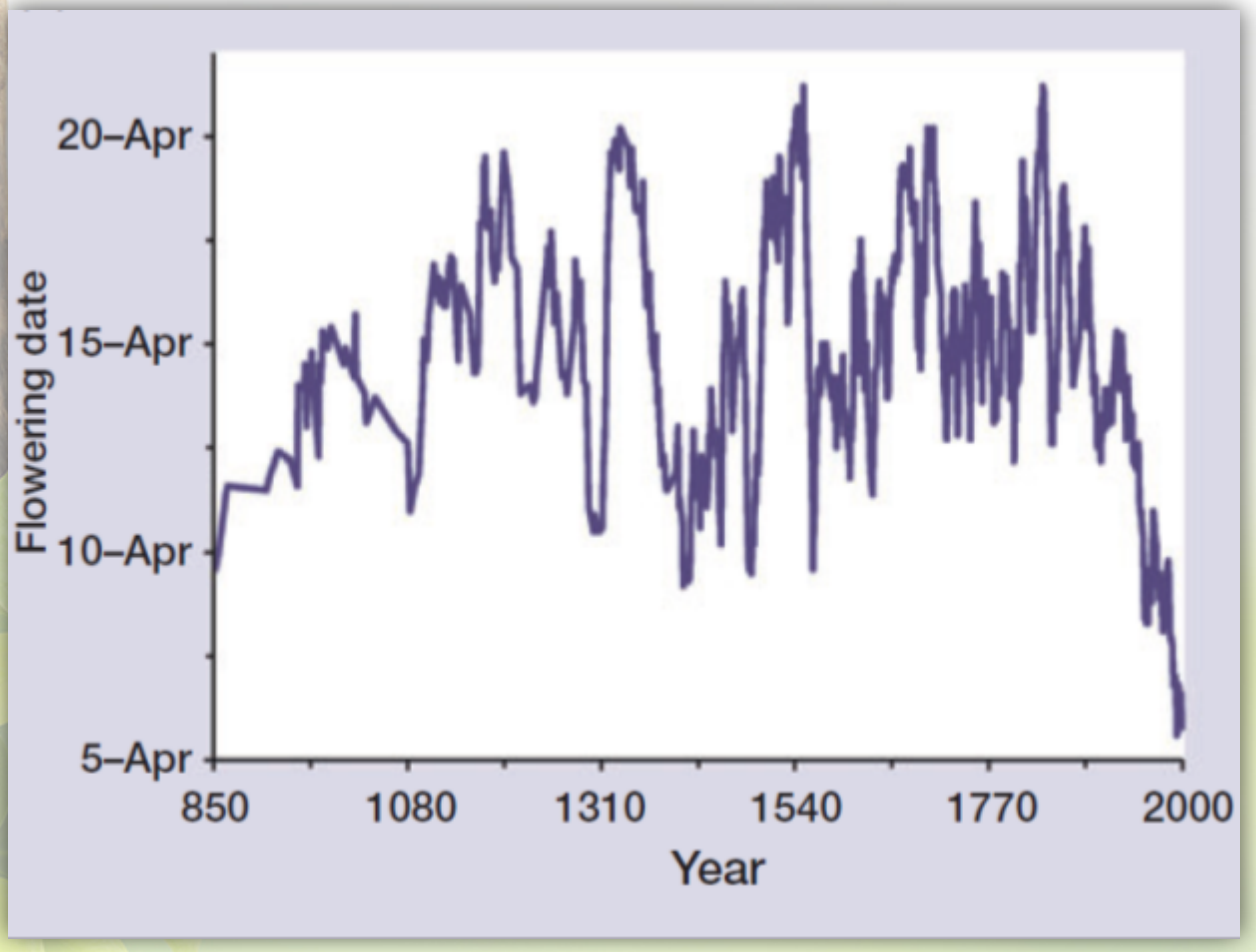
Webster, et al. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309:1844-1846.

Climate Change at Thoreau's Walden Pond

"We determined that plants bloomed seven days earlier on average than they did in Thoreau's times."

Miller-Rushing & Primack. 2008. Global warming and flowering times in Thoreau's Concord: a community perspective. *Ecology* 89:332-341.

1150 Year Record of Cherry Blossom Phenology in Kyoto, Japan

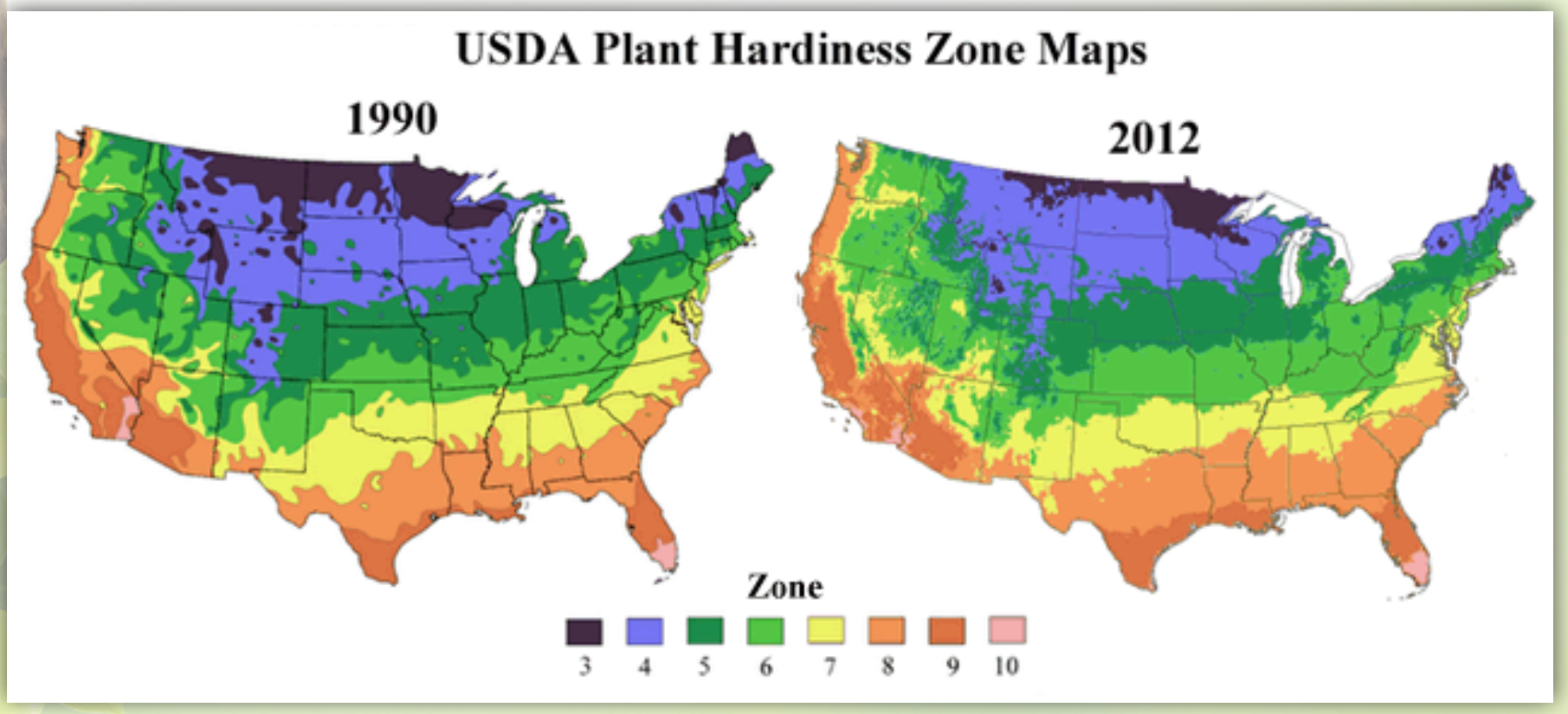


http://www.citypictures.org/data/media/231/Cherry_Blossoms_Ninnaji_Temple_Kyoto_Japan.jpg

http://columbusmmug.com/wp-content/uploads/2012/07/under-the-Japanese-Cherry-B.jpg

Miller-Rushing et al. 2012. *Front. Ecol. Environ.* 10: 285–290

New USDA Plant Hardiness Zone Map: Much of Northern US Updated to Warmer Zone



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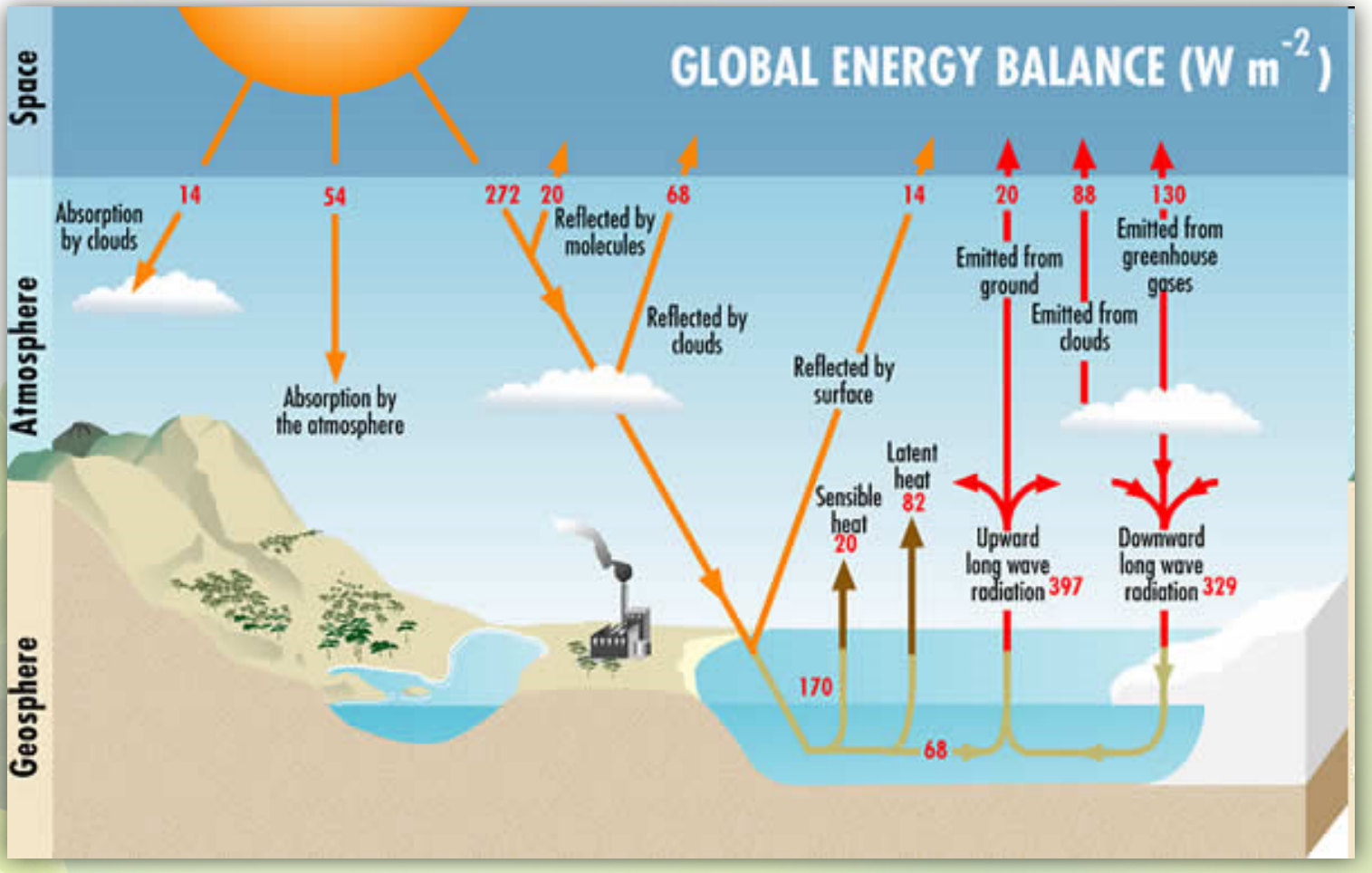
For Earth to warm or cool, some force must change the global energy balance



Kiehl, J. T. and Trenberth, K. E. 1997. Earth's annual global mean energy budget. ***Bull. Am. Meteorol. Assoc.*** **78: 197-208.**

CO_2 is at Highest Level in 650,000 Years (407 ppm)

www.climate.nasa.gov

CO_2 as a greenhouse gas

1. The amount of heat trapped increases with CO_2 concentration.

2. After remaining stable for thousands of years, CO_2 has risen rapidly to record levels, and is now rising even faster.

3. Earth is absorbing more heat than it dissipates.

Earth's Energy Imbalance

Earth's Energy Imbalance: Confirmation and Implications

James Hansen,[1,2]* Larissa Nazarenko,[1,2] Reto Ruedy,[3] Makiko Sato,[1,2] Josh Willis,[4] Anthony Del Genio,[1,5] Dorothy Koch,[1,2] Andrew Lacis,[1,5] Ken Lo,[3] Surabi Menon,[6] Tica Novakov,[6] Judith Perlwitz,[1,2] Gary Russell,[1] Gavin A. Schmidt,[1,2] Nicholas Tausnev[3]

Hansen et al. 2005. *Science* 308:1431-1435

Earth is absorbing 0.85 W / m^2 more than it is dissipating

Globally:

excess heat = 250 trillion Watts / day

= 400,000 Hiroshima-scale atomic bomb detonations / day

The climate has always changed: Ice ages occur predictably every 100,000 years

http://members.aol.com/scipioiv/globice.jpg

articles

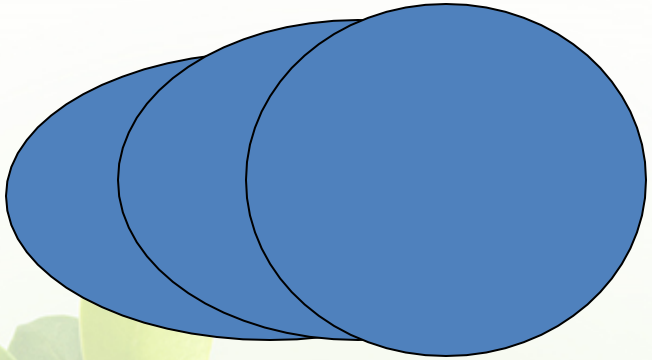
Eight glacial cycles from an Antarctic ice core

EPICA community members*

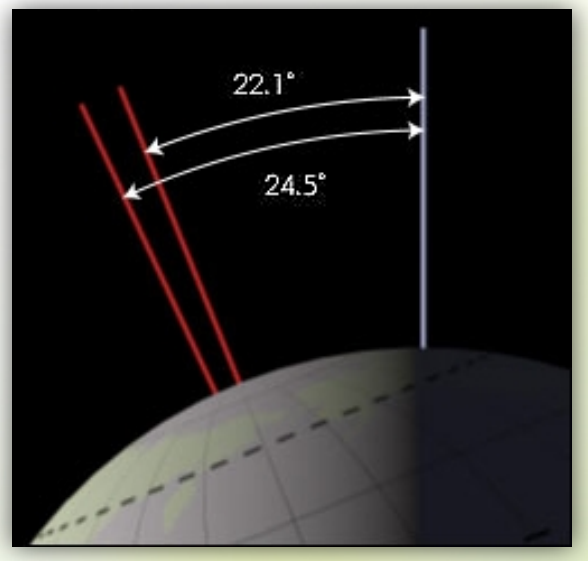
***Nature* (2004) 429:623-628**

http://www.emporia.edu/earthsci/student/tinsley1/drilling.jpg

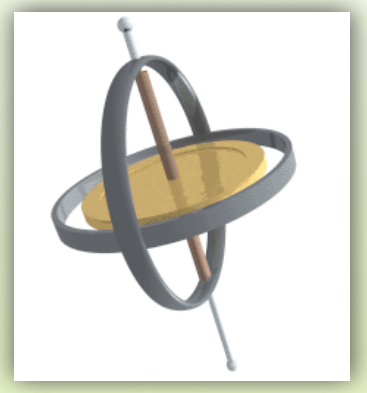
Predictable Variation in Earth's Orbit, Wobble and Tilt (Milanković Cycles) Change the Amount of Solar Radiation Intercepted by Earth (Solar Forcing)



Eccentricity: 100K yrs



Obliquity: 41K years

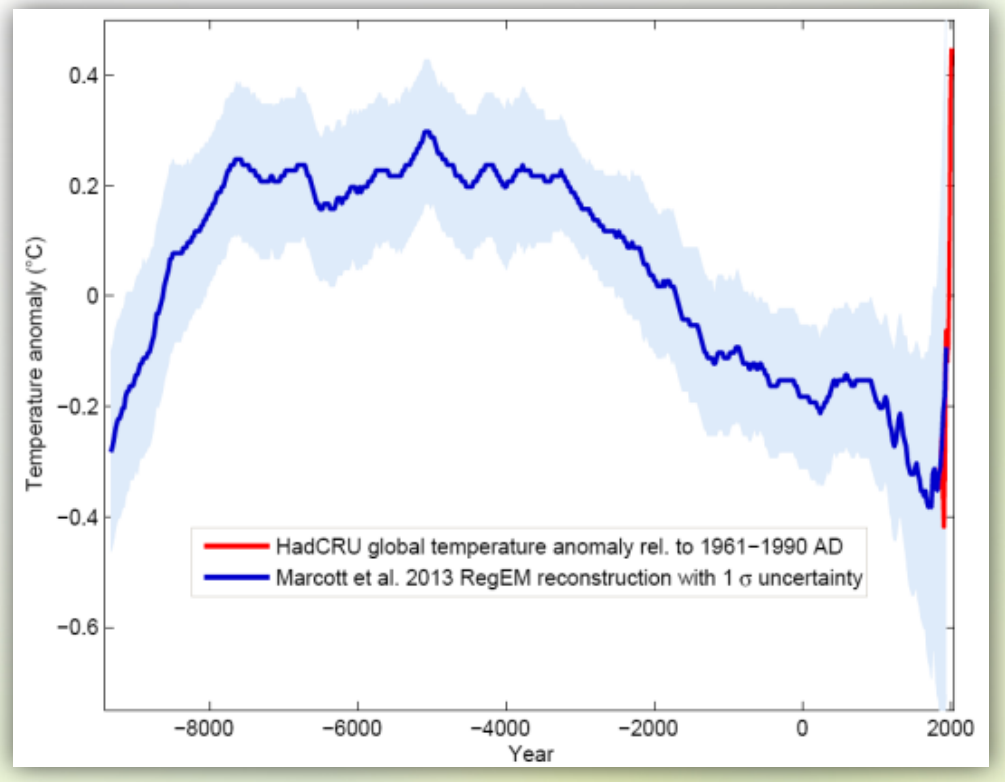


Precession: 20K years

Earth should now be cooling gradually…

http://images.allposters.com/images/102/039_ice_age_2sided.jpg

…and it was for more than 5,000 years until very recently.

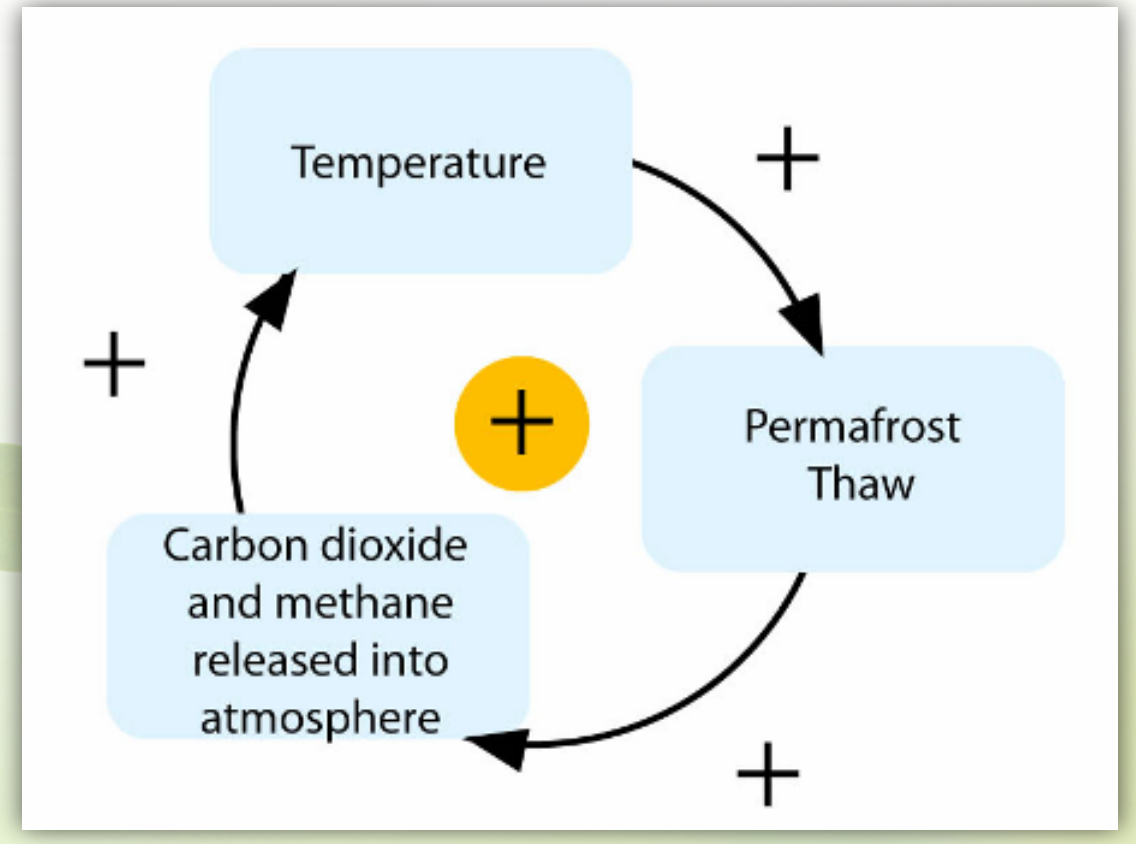


A Reconstruction of Regional and Global Temperature for the Past 11,300 Years

Shaun A. Marcott,[1] Jeremy D. Shakun,[2] Peter U. Clark,[1] Alan C. Mix[1]

8 MARCH 2013 VOL 339 SCIENCE

CO_2 Amplifies Global Warming Caused by Solar Forcing



http://sitemaker.umich.edu/section2_group1/files/secondfeedback.jpg

Vicious Cycle as Earth Warms:

Decomposition releases greenhouse gasses: melting permafrost releases huge amounts of CO_2 and methane.

Humidity increases: water vapor is the most powerful greenhouse gas.

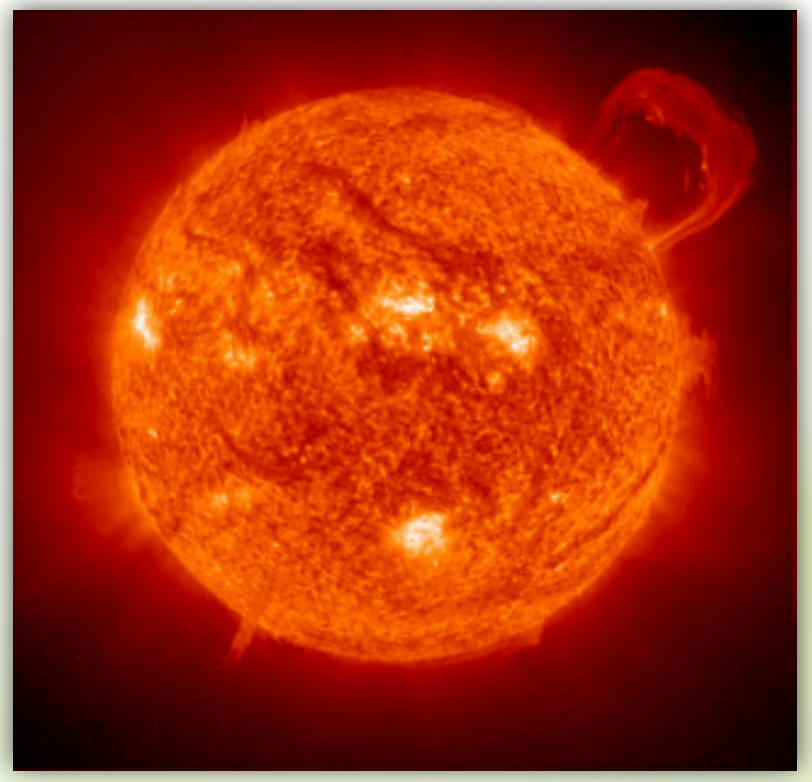
Oceans absorb less CO_2: oceans saturate and more CO_2 remains in the atmosphere.

Ice melts and white becomes dark: radiation that was reflected to space is now absorbed as heat.

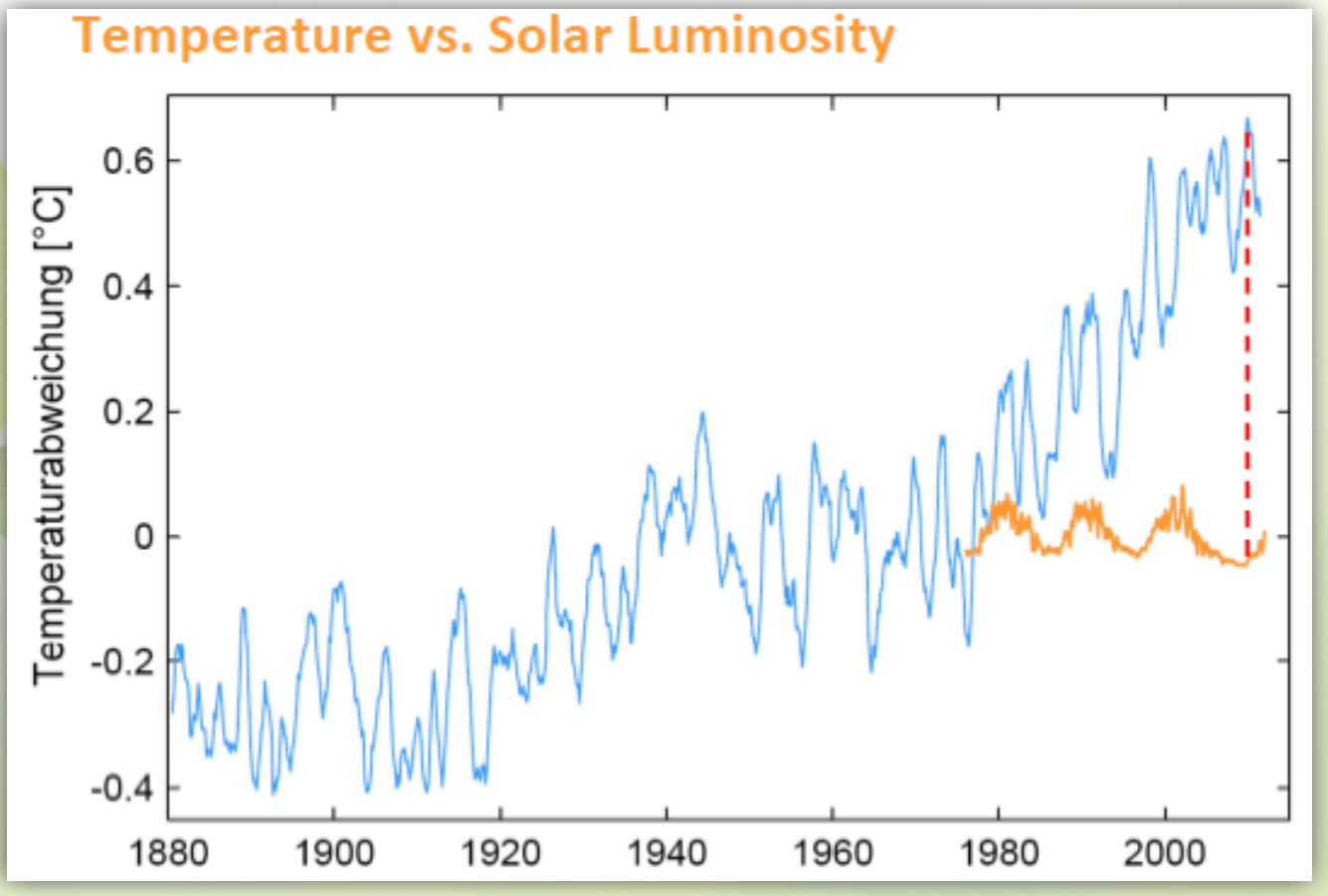
Is there a “tipping point” beyond which feedbacks generate unstoppable warming even if CO_2 emissions stabilize?

www.motherjones.com/

Is the sun responsible for recent warming?

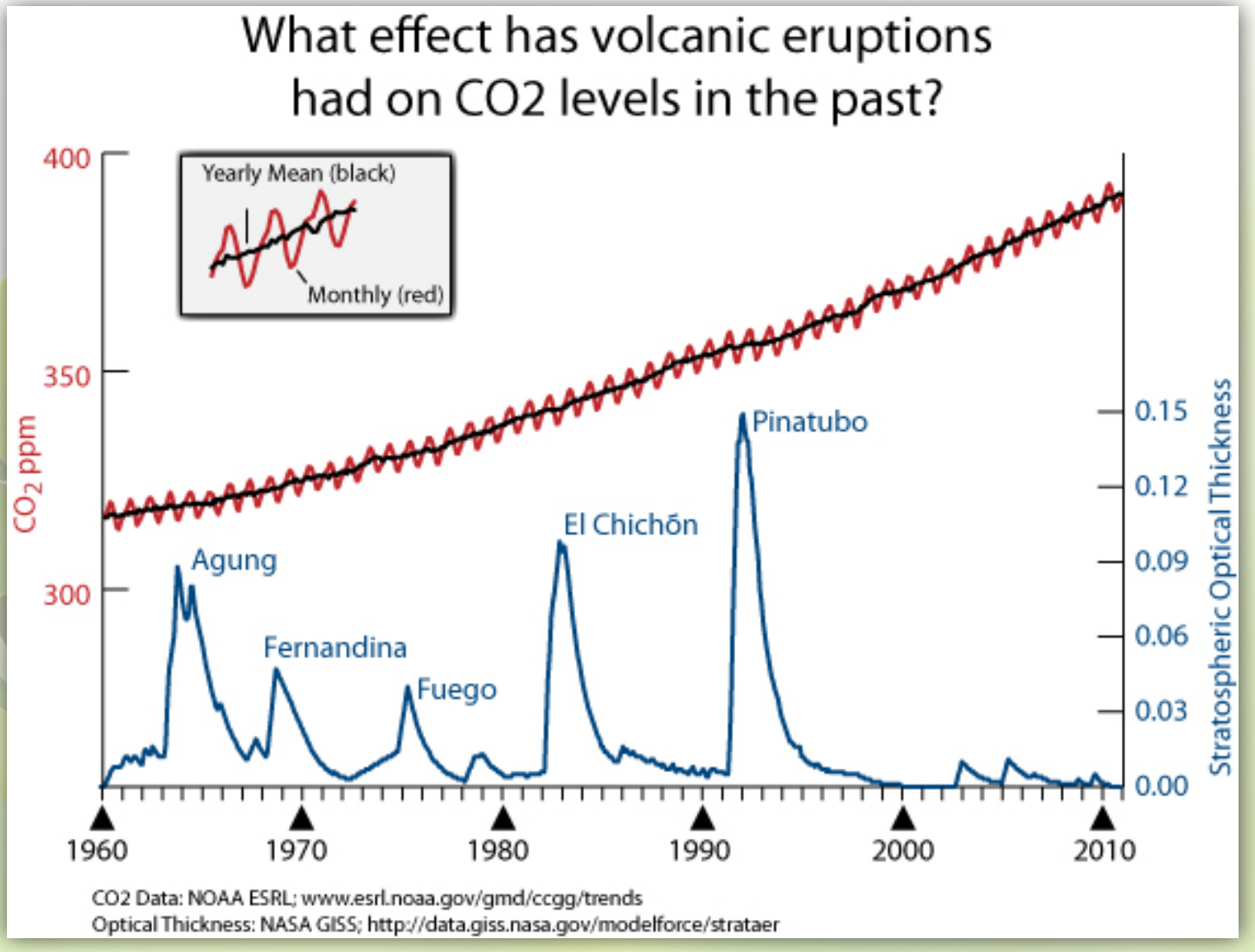


Since Satellite Measurements Began, No Relationship Between Solar Irradiance and Warming



http://www.realclimate.org/images//T_vs_solar.png

No Volcanic Signature on Atmospheric CO_2 Concentration



Alternative Hypotheses Considered and Rejected by US National Academy of Sciences

- **Earth's orbit**: slight cooling effect.
- **Solar activity**: sun is not warming; atmosphere is warming from bottom up, not top down.
- **Ocean vents**: ocean is warming from surface down, not bottom up.
- **Volcanic activity**: major eruptions have short-term cooling effect; minor eruptions have no effect.
- **Air pollution**: global dimming caused by sulfate aerosols has cooling effect (but is relaxing).

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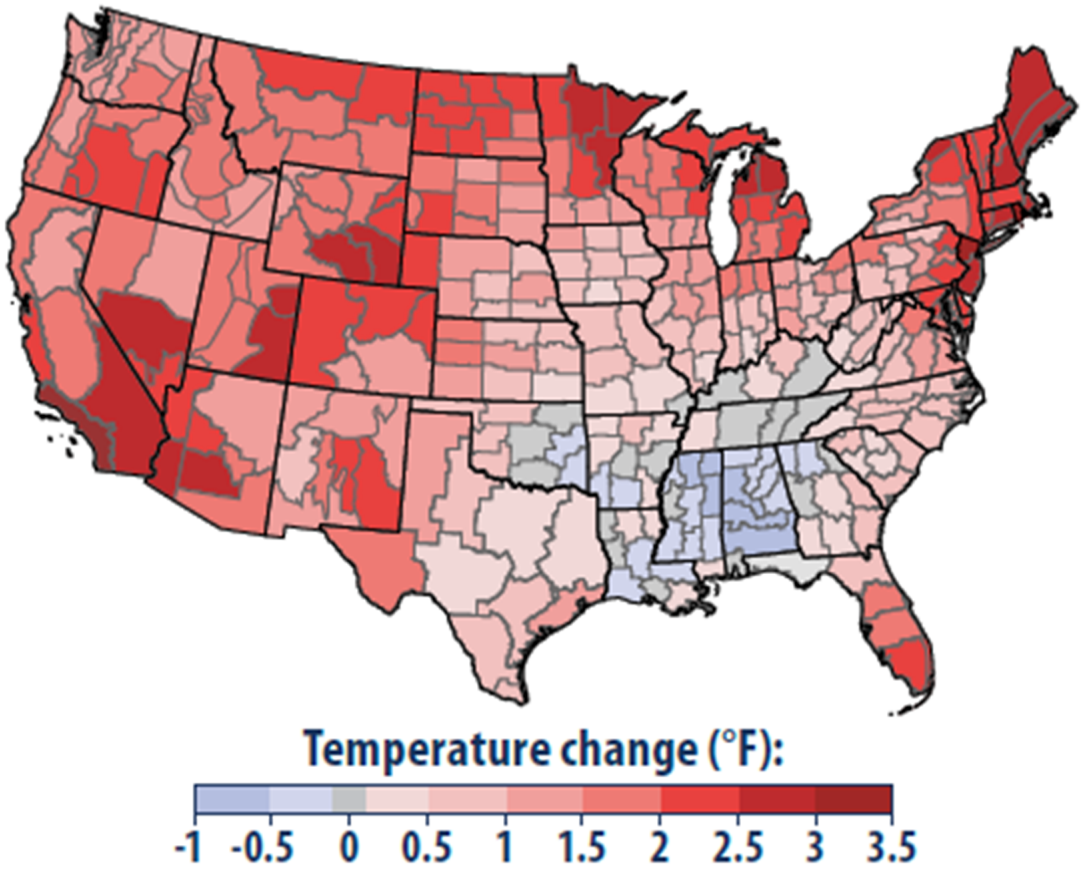
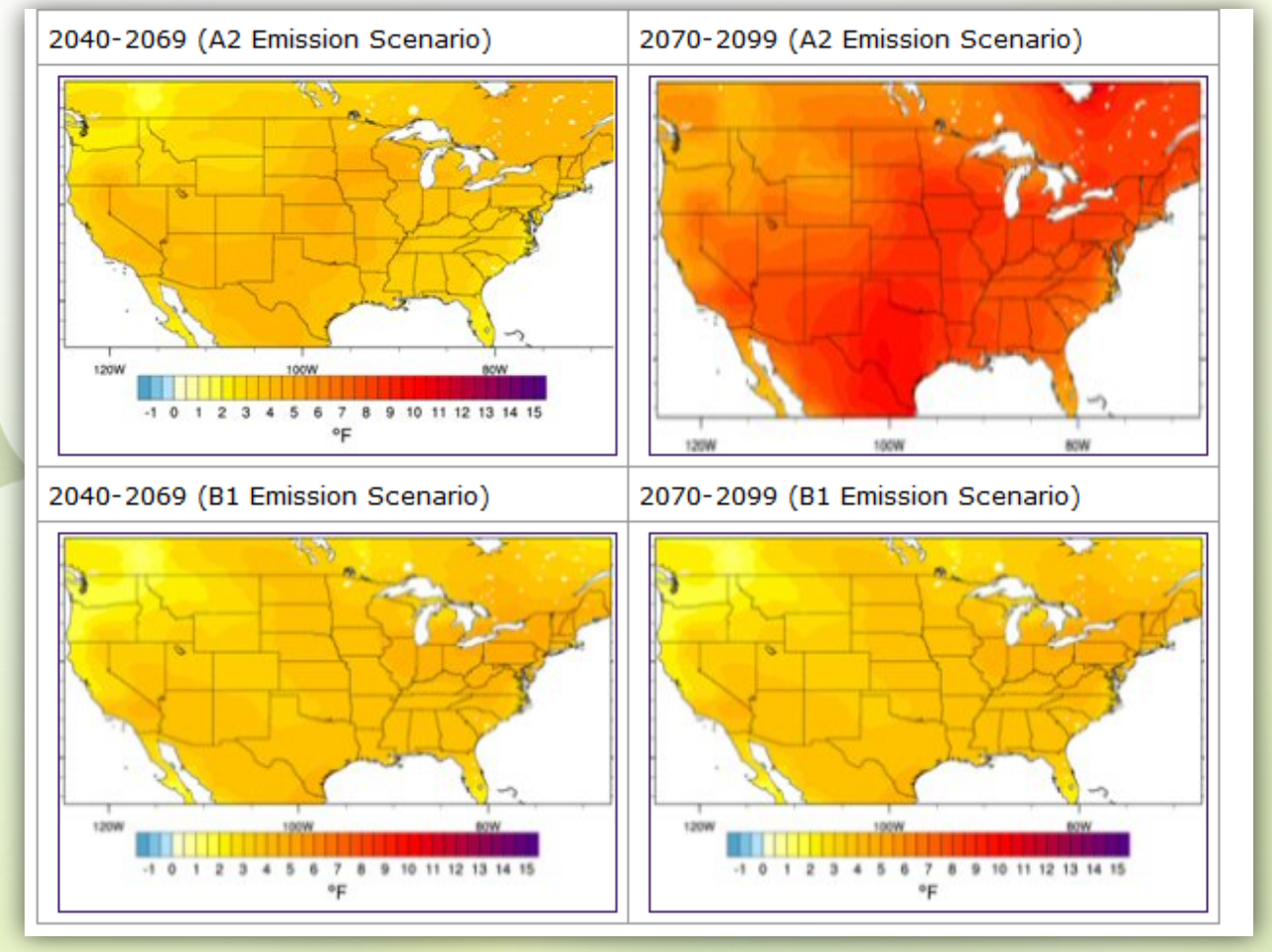


Rising temperatures in the last century. The last decade was the warmest on record throughout the West. Source: EPA, Climate Change Indicators in the United States.

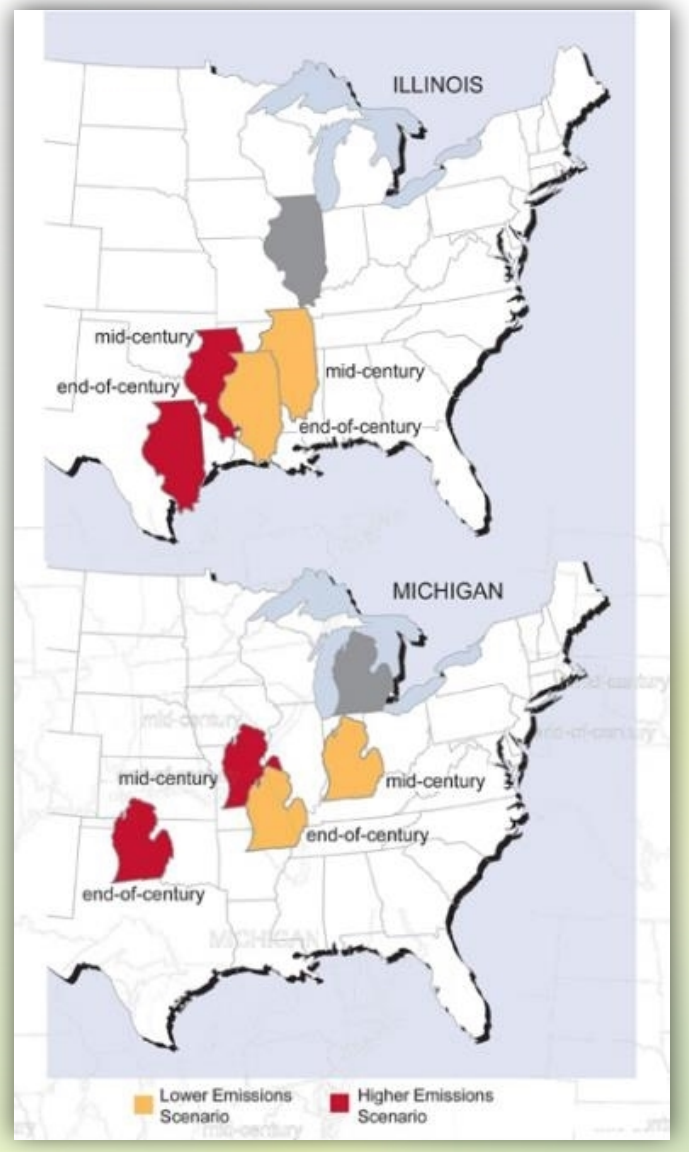
Warming Projected for US in 21st Century

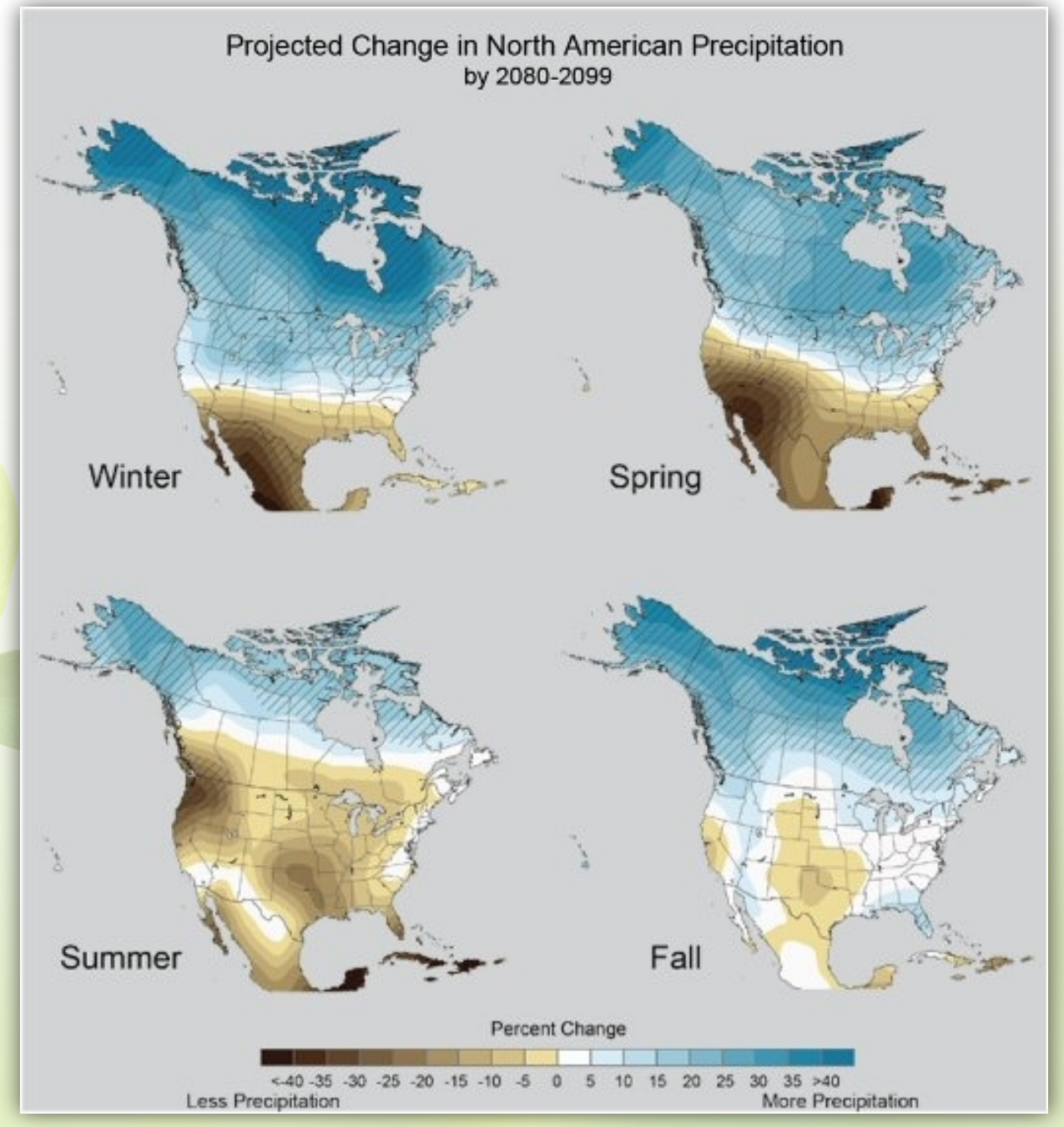
- 7 – 11˚F under high emission scenario
- 4 – 6.5˚F under low emission scenario

(USGCRP 2009)



Climate Change Projections (US EPA)




Projected Change in North American Precipitation
by 2080-2099
Winter
Spring
Summer
Fall
Percent Change
<-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 >40
Less Precipitation
More Precipitation

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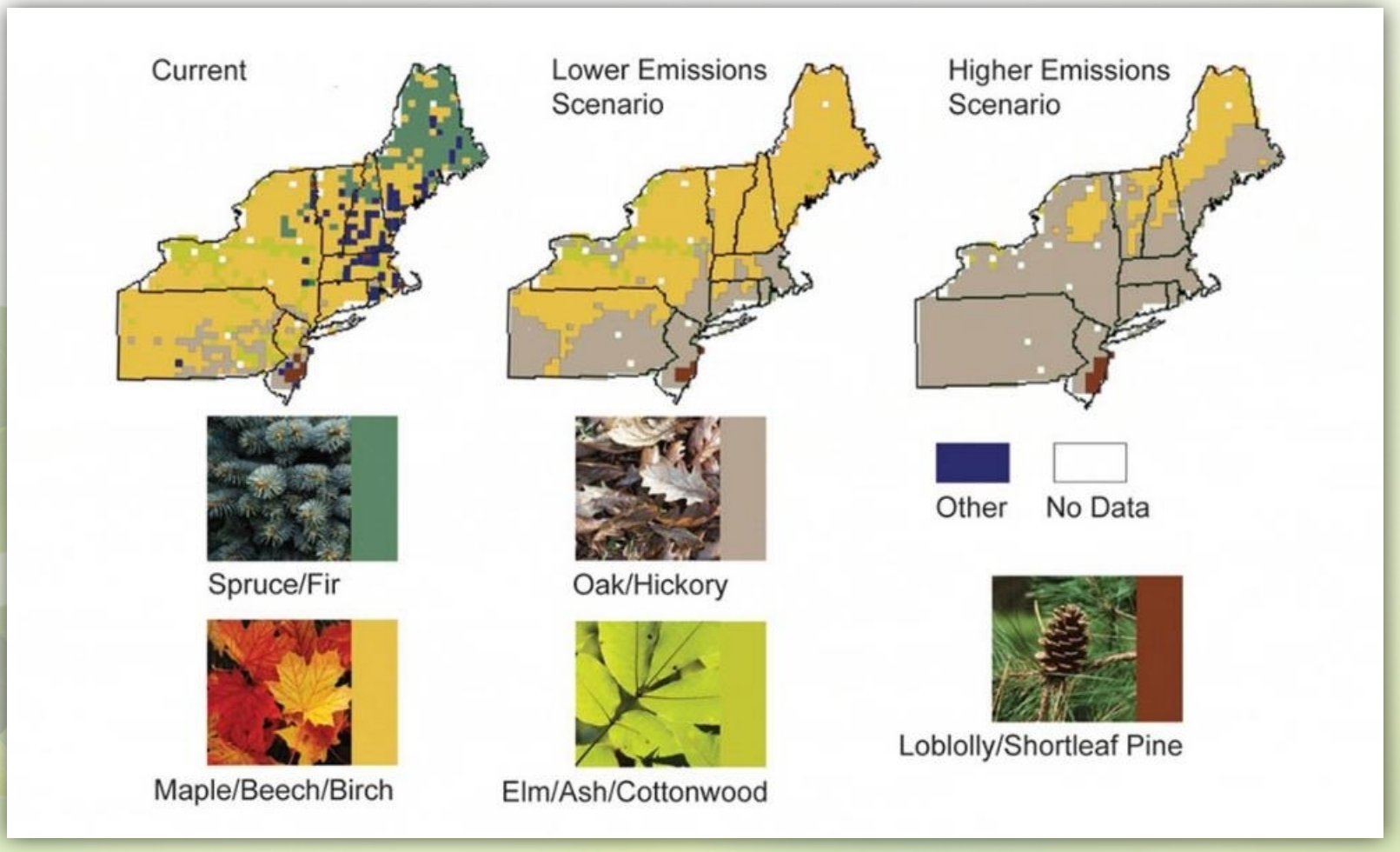
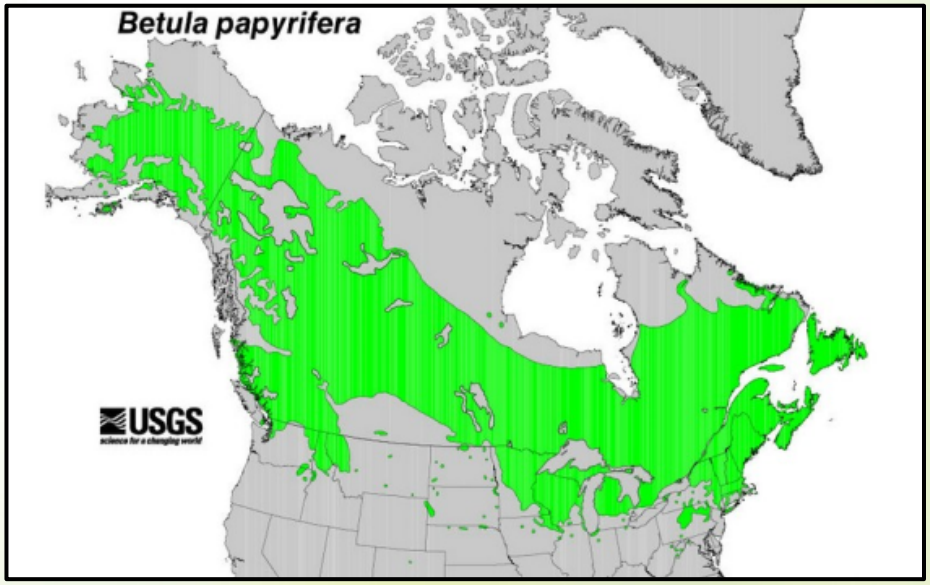
Trees stressed on south edge of distribution; benefit on north



Climate change, bronze birch borer, and the distribution of paper birch



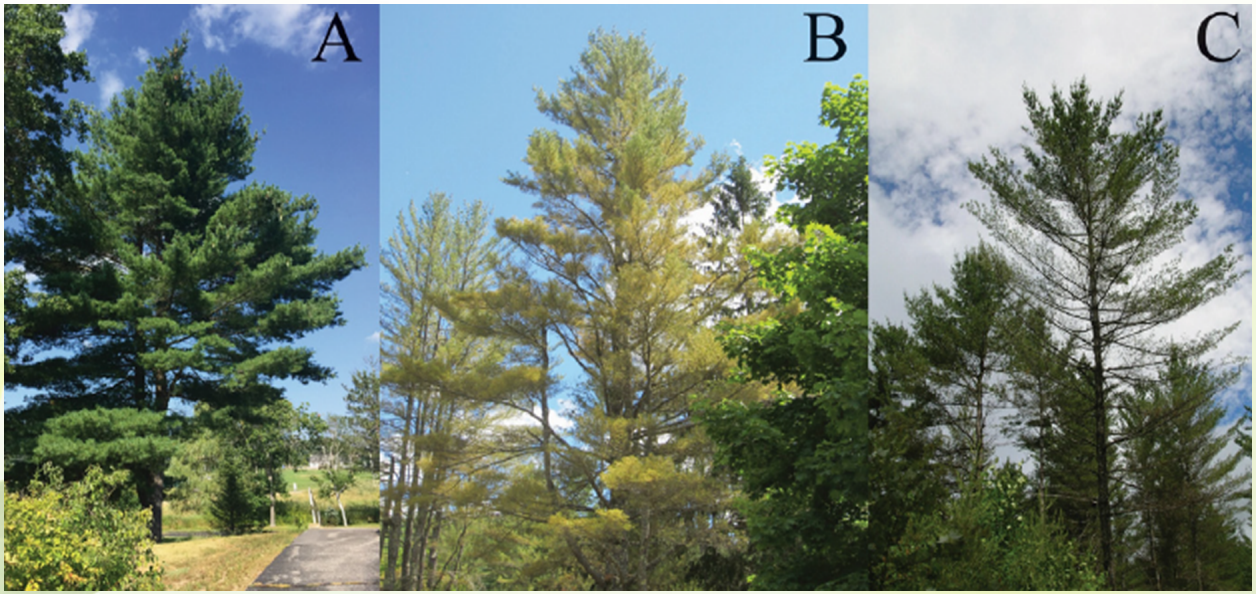
COMMUNITY AND ECOSYSTEM ECOLOGY

A Review of Bronze Birch Borer (Coleoptera: Buprestidae) Life History, Ecology, and Management

VANESSA L. MUILENBURG[1] AND DANIEL A. HERMS

Environ. Entomol. (2012) 41:1372-1385

Warmer, wetter weather has increased disease pressure from foliar pathogens on eastern white pine in the NE



ELSEVIER

Forest Ecology and Management

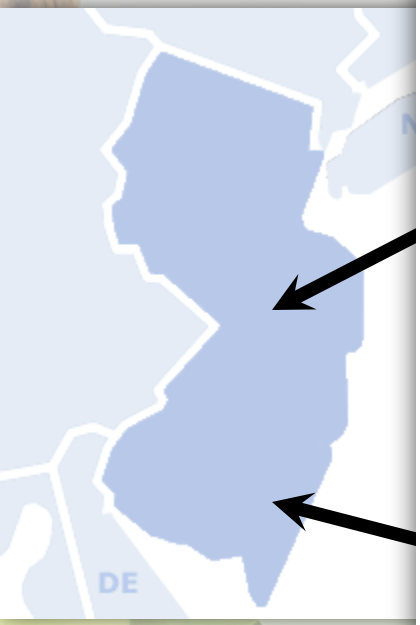
journal homepage: www.elsevier.com/locate/foreco

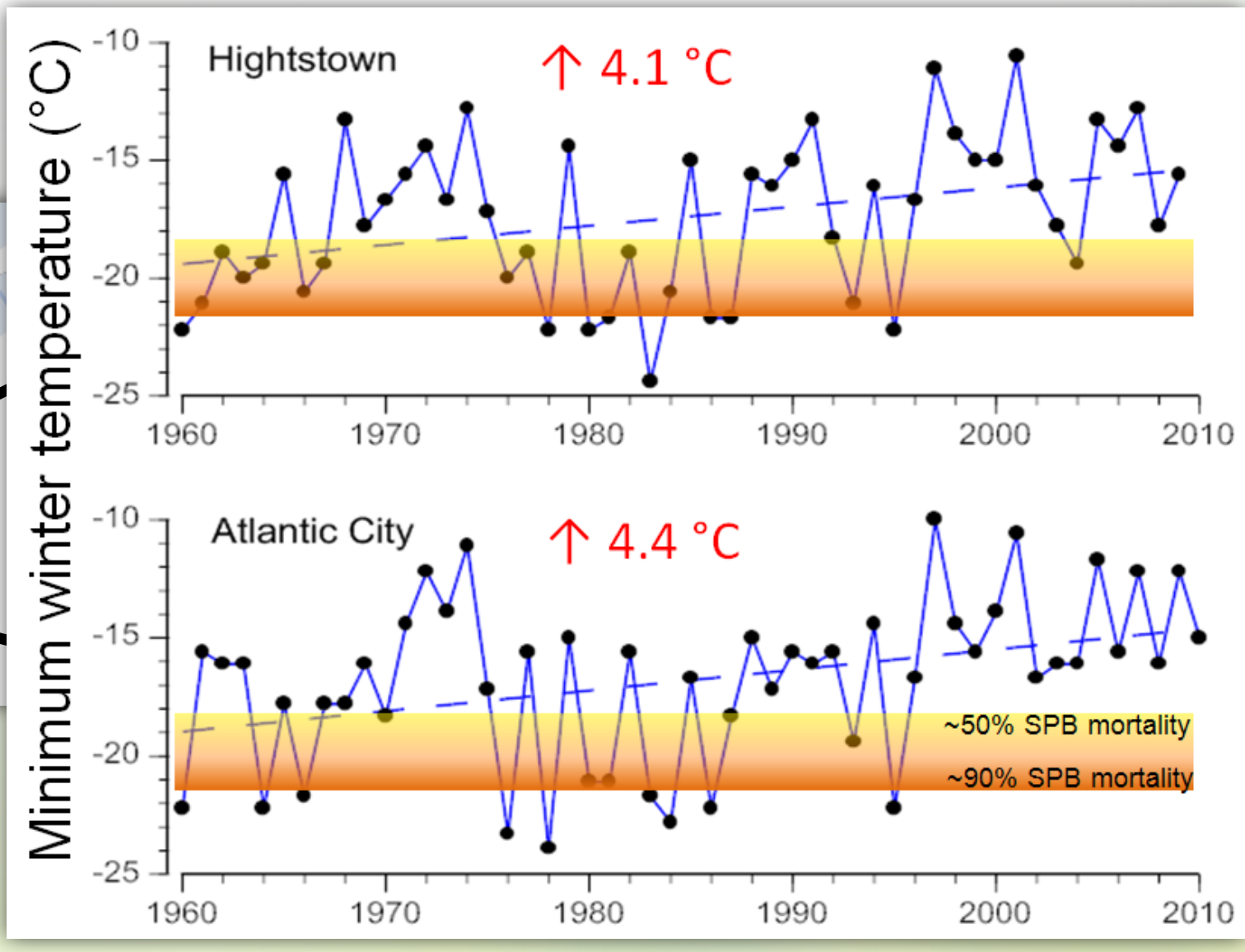
Response of eastern white pine and associated foliar, blister rust, canker and root rot pathogens to climate change☆

Stephen A. Wyka[a,*], Isabel A. Munck[b], Nicholas J. Brazee[c], Kirk D. Broders[a]

Range Expansion of Southern Pine Beetle New Jersey Pinelands

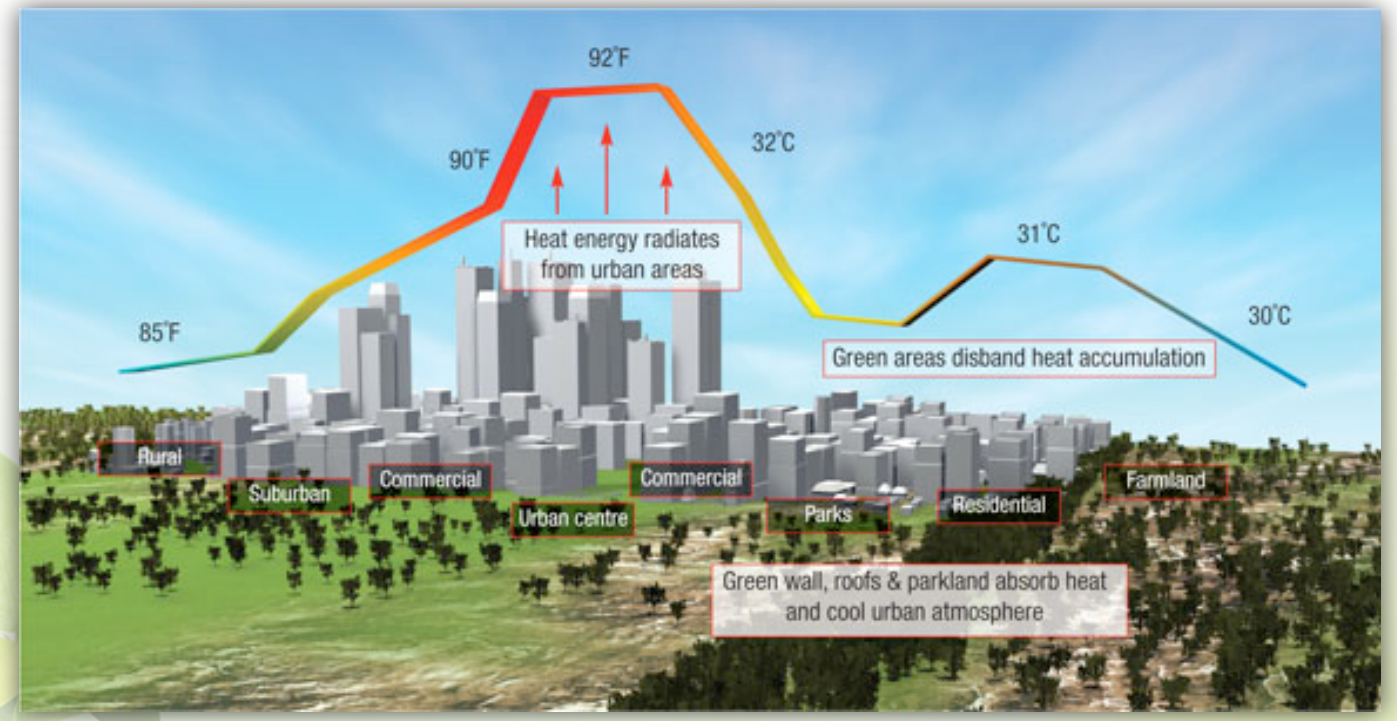
Photo by Bob Williams, Land Dimensions





Matt Ayres, Dartmouth College

Urban Heat Islands and Pests



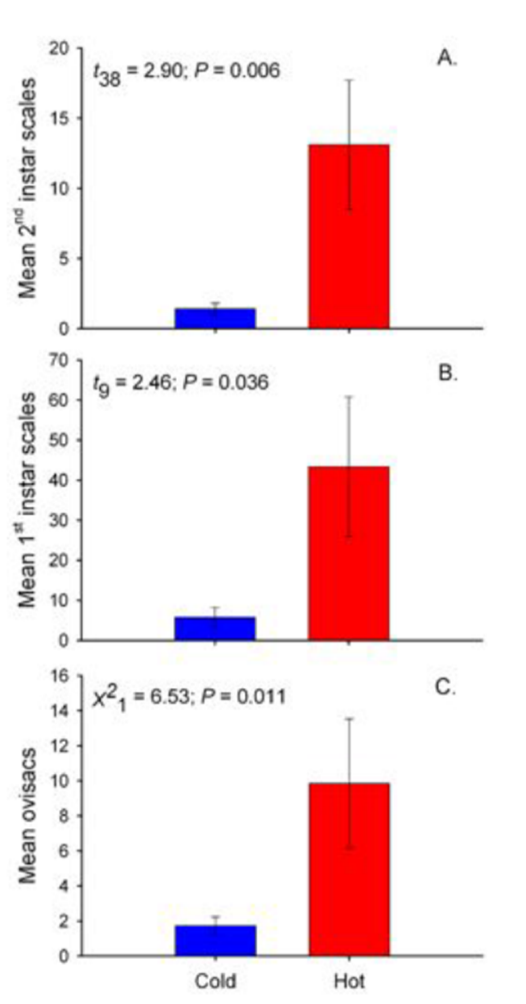
- Cities up to 10° warmer than surrounding areas.
- Decreased cooling from evapo-transpiration.
- Increased radiant heat.

OPEN ACCESS Freely available online

PLOS | ONE

Urban Warming Drives Insect Pest Abundance on Street Trees

Emily K. Meineke[1]*, Robert R. Dunn[2], Joseph O. Sexton[3], Steven D. Frank[1]



James Solomon

Oak lecanium 13x more abundant on willow oaks in hot vs cooler urban areas.

Divergent temperature effects on survival of hemlock and hemlock woolly adelgid (HWA)

Drs. Angela Mech and Kamal Gandhi

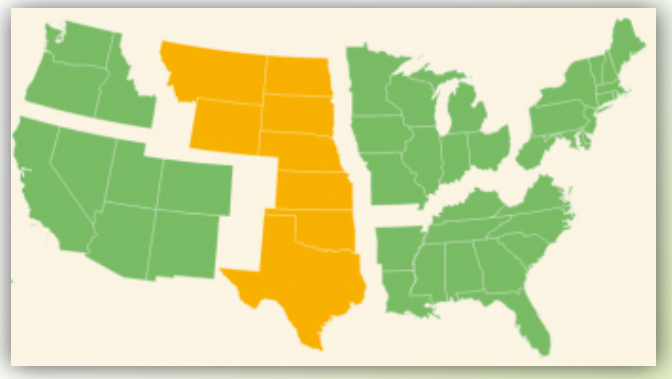
Low altitude: healthy stands

High altitude: severe decline

As temperature increased, so did HWA mortality

Mech and Gandhi, Univ of GA

Climate Change Projections (US EPA)



- Continued warming
- Reduced snowpack
- More drought
- More heat waves
- Southern states: 4x increase in days over 100˚F
- Decreased ground water supply
- More intense storms
- More wildfire

Fire: More Frequent and More Intense

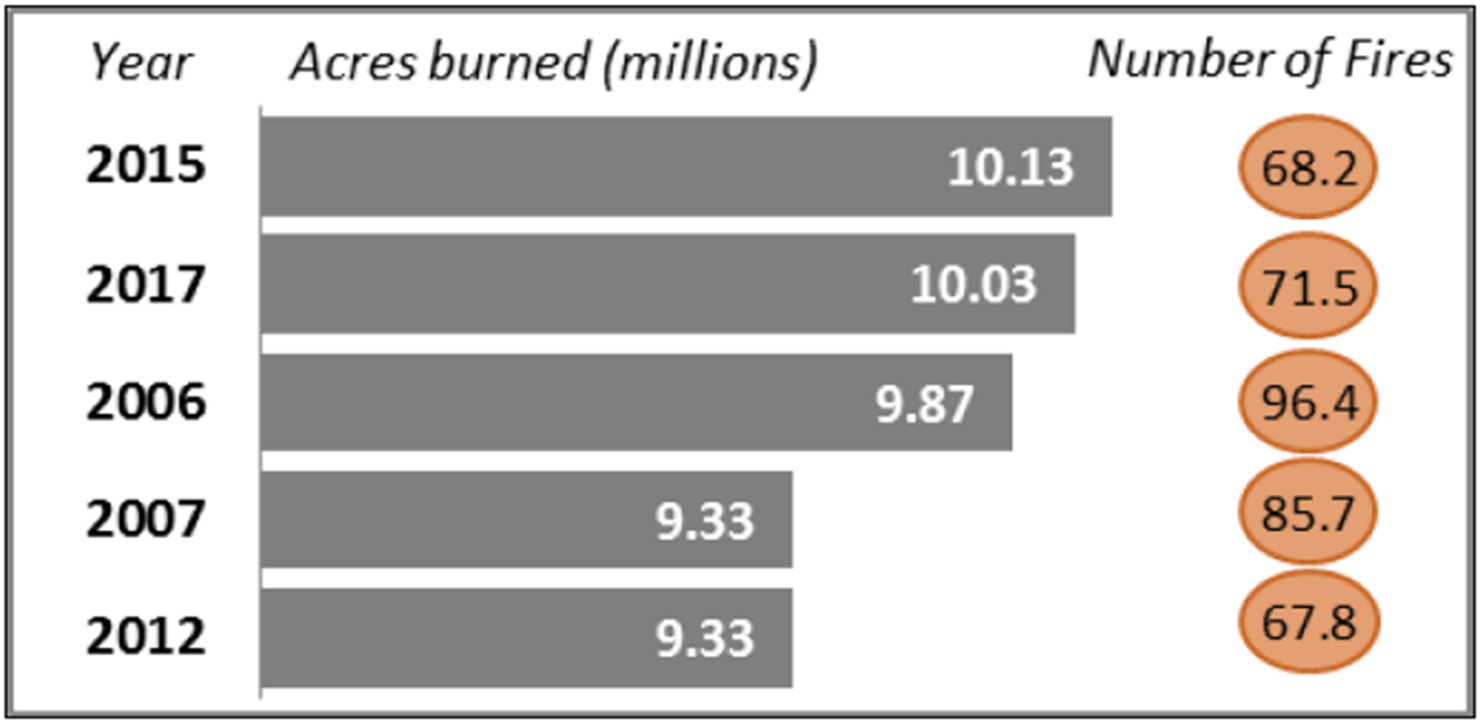
Since 2000: 10 worst wildfire years on record.

Since 2002: Acreage burned is 211% higher than 48 year average.

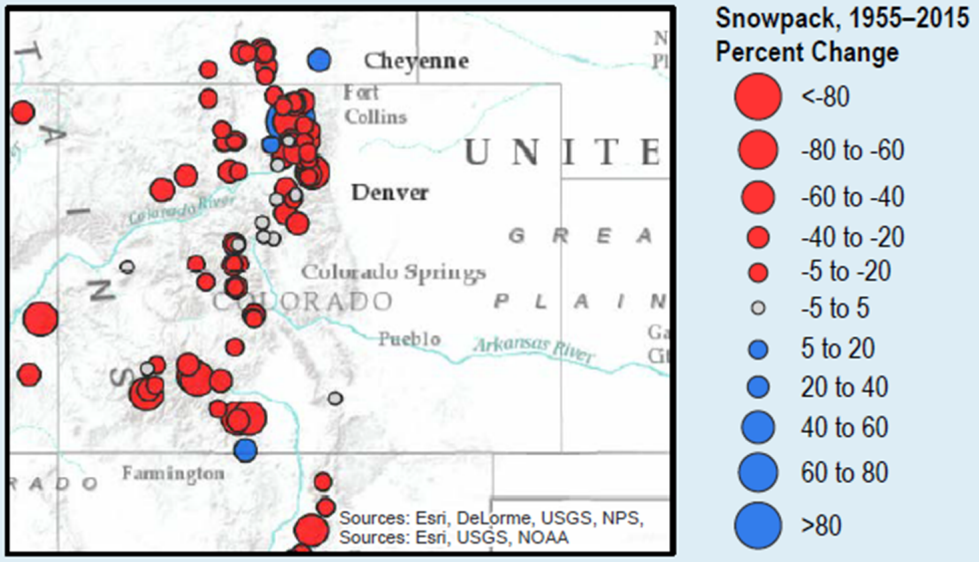
John McColgan, BLM Alaska Fire Service

Westerling et al. 2006. Warming and earlier spring increase western US forest wildfire activity. *Science* 313:940-943

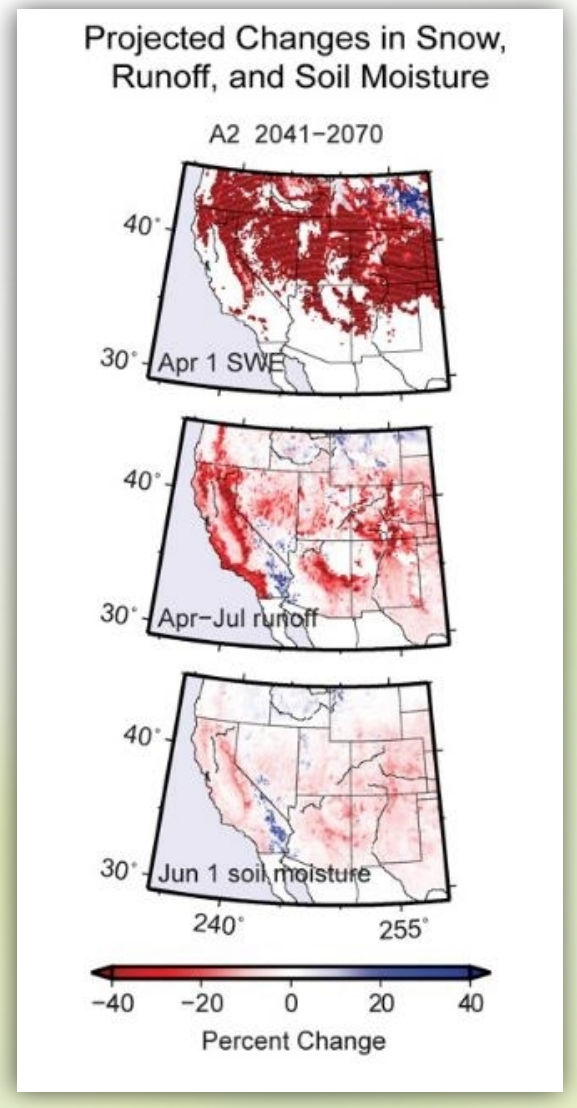
Figure 2. Top Five Years with Largest Wildfire Acreage Burned Since 1960



Sources: National Interagency Fire Center; Congressional Research Service



Trends in April snowpack in Colorado, 1955–2013. The snowpack has declined at most monitoring sites in Colorado. Source: EPA.



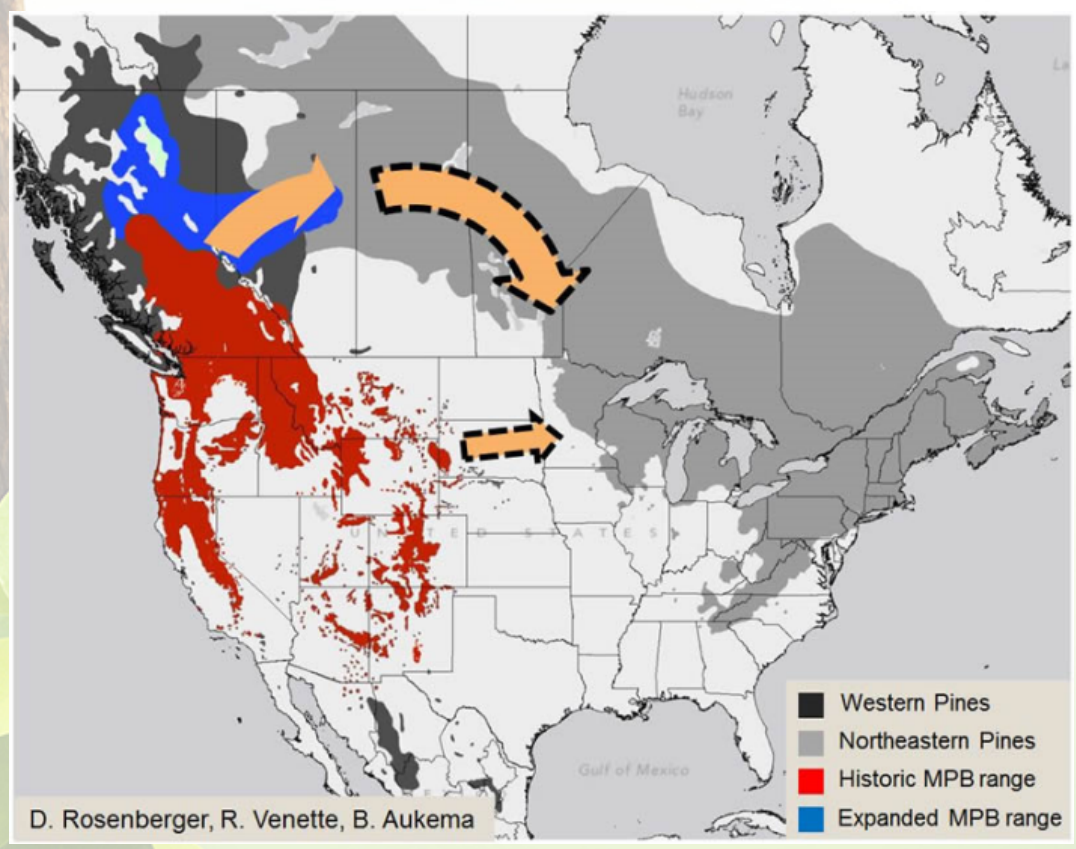
Massive mountain pine beetle outbreaks where winters used to be too cold for the beetles

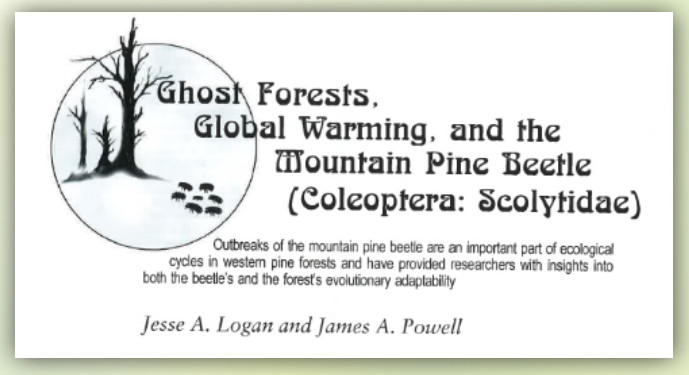
http://www.for.gov.bc.ca/hfp

http://www.garna.org/

Kurz et al. 2008. Mountain pine beetle and carbon feedback to climate change. *Nature* 452:987-990.

As predicted in 2001, mountain pine beetle has breached the Rocky Mountains



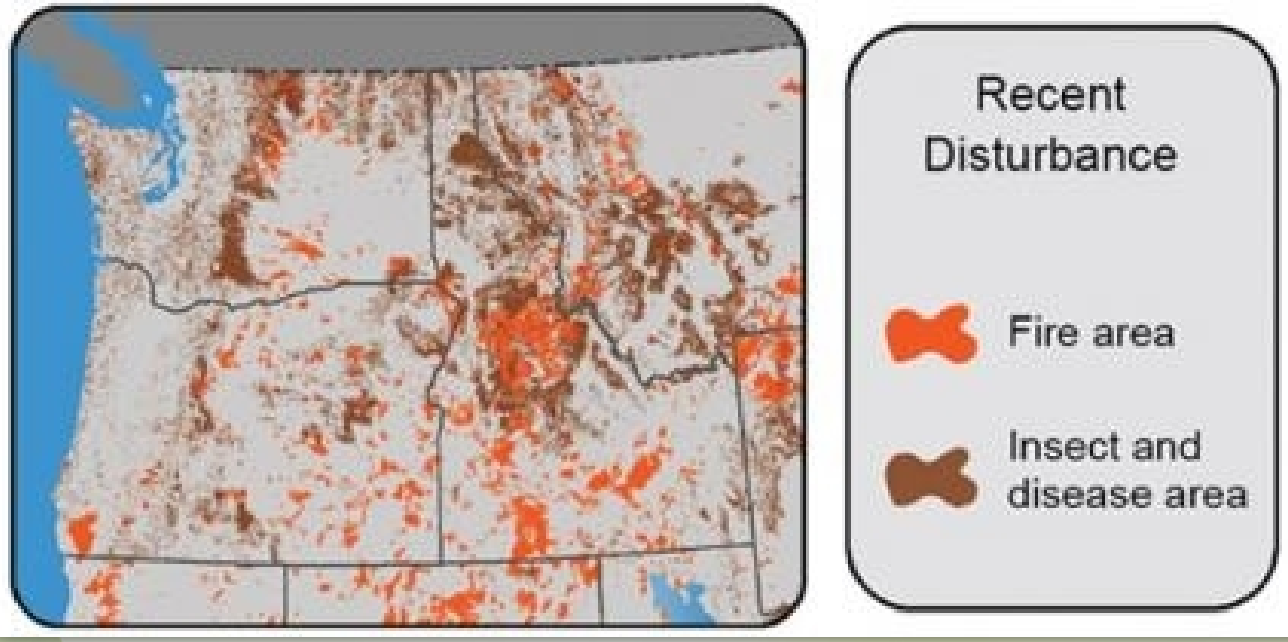

Ghost Forests, Global Warming, and the Mountain Pine Beetle (Coleoptera: Scolytidae)

Outbreaks of the mountain pine beetle are an important part of ecological cycles in western pine forests and have provided researchers with insights into both the beetle's and the forest's evolutionary adaptability

Jesse A. Logan and James A. Powell

Logan and Powell (2001) *Amer. Entomol.* 47:160-173

Insects and Fire in Northwest Forests



Widespread Increase of Tree Mortality Rates in the Western United States

Phillip J. van Mantgem,[1]*†‡ Nathan L. Stephenson,[1]*† John C. Byrne,[2] Lori D. Daniels,[3] Jerry F. Franklin,[4] Peter Z. Fulé,[5] Mark E. Harmon,[6] Andrew J. Larson,[4] Jeremy M. Smith,[7] Alan H. Taylor,[8] Thomas T. Veblen[7]

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Climate change accelerates growth of urban trees in metropolises worldwide

Hans Pretzsch[1], Peter Biber[1], Enno Uhl[1], Jens Dahlhausen[1], Gerhard Schütze[1], Diana Perkins[1], Thomas Rötzer[1], Juan Caldentey[2], Takayoshi Koike[3], Tran van Con[4], Aurélia Chavanne[5], Ben du Toit[6], Keith Foster[7] & Barry Lefer[8]

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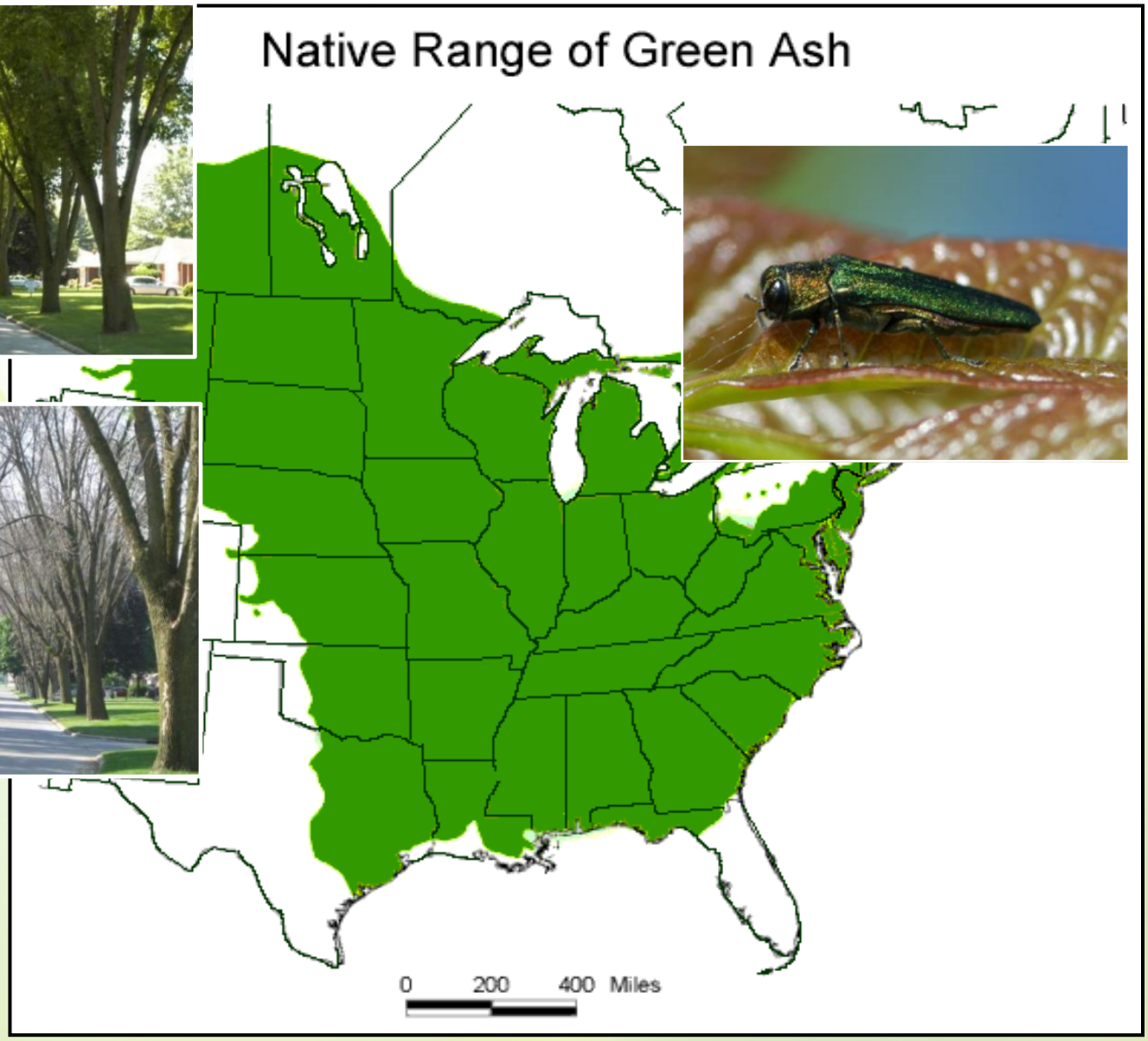
Since 1960:

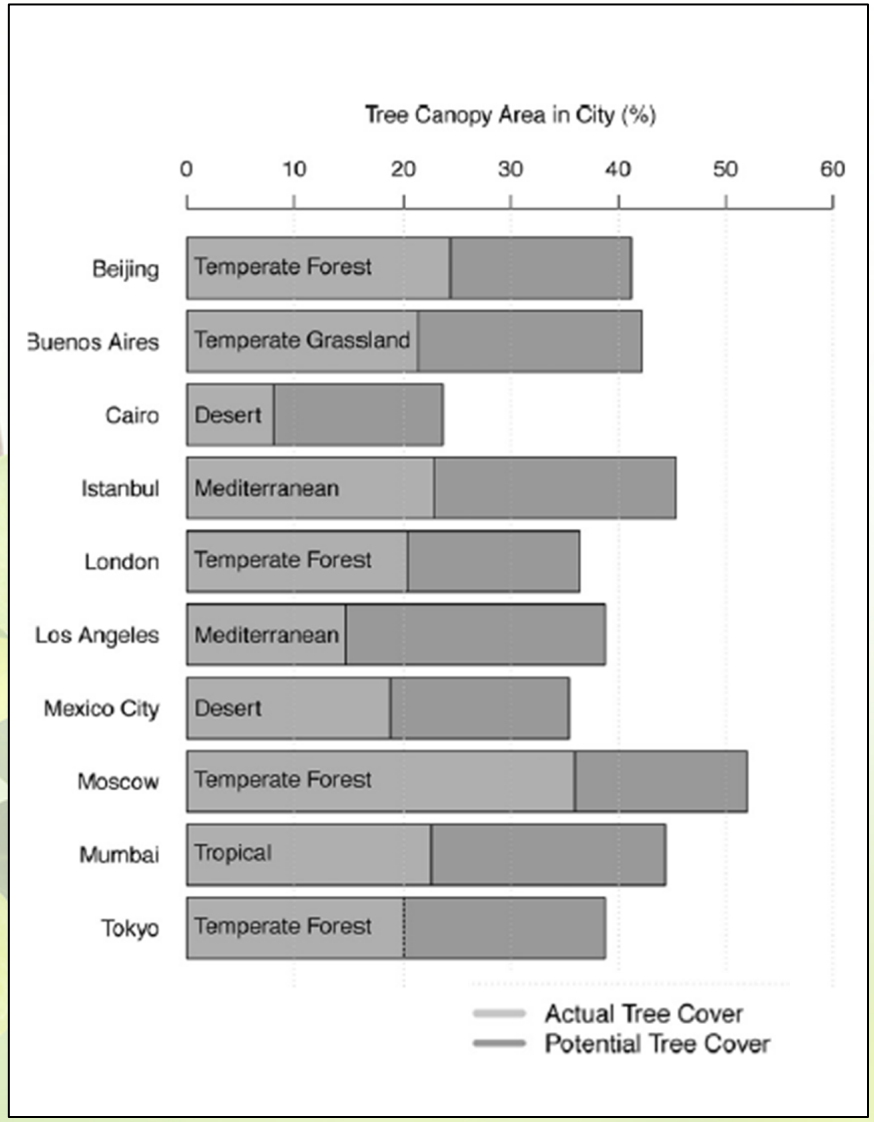
- Longer growing season
- Increased CO_2
- Increased N deposition
- More favorable precipitation patterns

Generality?

- One species / city
- Growing in the optimum zone of their distribution
- Well-adapted to urban environments


Native Range of Green Ash
0
200
400 Miles

i-Tree Eco analysis: planting more trees in 10 megacities could double environmental benefits



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Implementing and managing urban forests: A much needed conservation strategy to increase ecosystem services and urban wellbeing

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Benefits of the Urban Forest: Ecosystem Services

Stormwater runoff reduction
(Dwyer et al. 1992, Tyrvainen et al. 2005)

Habitat and biodiversity
(Dreistadt et al. 1990, Koh and Sodhi 2004)

CO_2 storage and sequestration
(Nowak and Crane 2002)

Property value increase
(Nowak et al. 2002)

Energy savings
(Akbari et al. 2001, Donovan and Butry 2009)

Air quality improvement
(Nowak et al. 2006)

Slide courtesy of Chris Riley

Mary Gardiner

Chris Riley, OSU

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Chris Riley

Urban Forestry & Urban Greening

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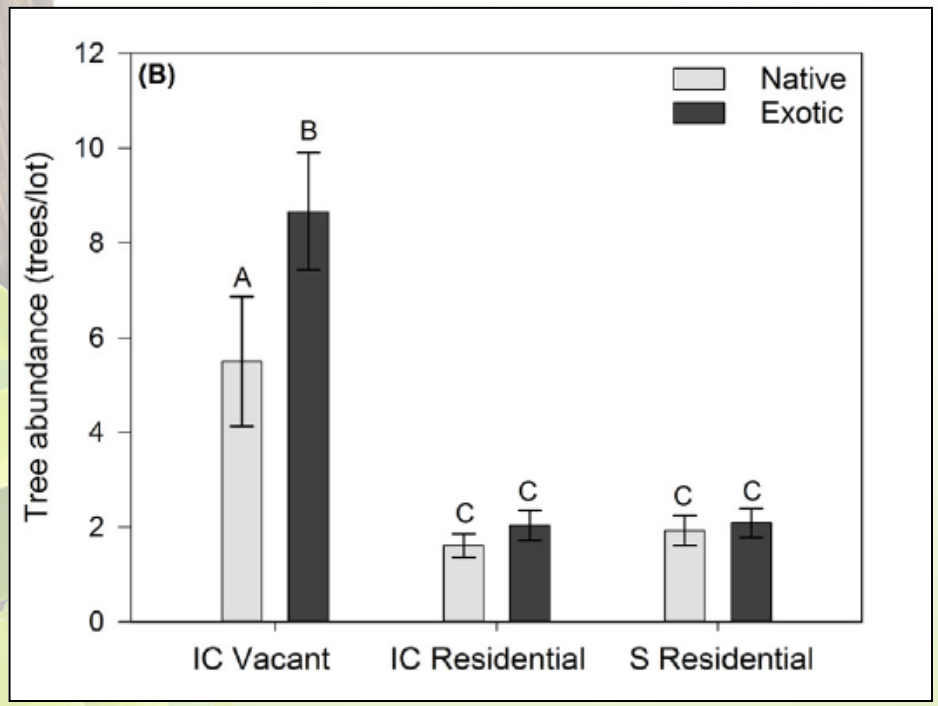
Original article

Exotic trees contribute to urban forest diversity and ecosystem services in inner-city Cleveland, OH

Christopher B. Riley[a,*], Daniel A. Herms[b], Mary M. Gardiner[a]

Chris Riley, OSU



Carbon Storage (kg):

Inner-City Vacant Lots	57,448
Suburban Residential Lots	17,997

C sequestration by trees in vacated lots: 1,483 kg / ha / yr

1,457 ha vacant land in CLE = 2,161,120 kg C / yr

Avg car emits 6 tons of $C0_2$ / yr (= 1.63 tons C)

Spontaneous trees on vacated land in CLE offset
C emissions of 12,850 cars / yr

Global C emissions: 10 billion tons / yr
US C emissions: 1.5 billion tons / yr

C sequestered in US urban forests: 25.6 million tons / yr
(Nowak et al. 2013. *Environ. Pollut*. 178:229-236)

Arboriculture implications next 30 years:

- Increasing temperature nationwide
- Increasing storm intensity NE, SE, MW
- Decreasing precipitation SE, West
- Increasing insect pest pressure
- Increased stress for some trees; increased growth for others
- Increasing wildfire
- Increased worker stress, especially in southern US
- Trees can help mitigate effects of climate change