Forest Response to Climate Change

Northern Institute of Applied Climate Science

Outline

- Climate change overview
  - Observations
  - Mechanisms
- Uncertainty
  - Scenarios and models
  - Perspective
  - Uncertainty in predictions
- Climate change and forests
  - Benefits to forests
  - Increases in forest stress
  - Potential impacts

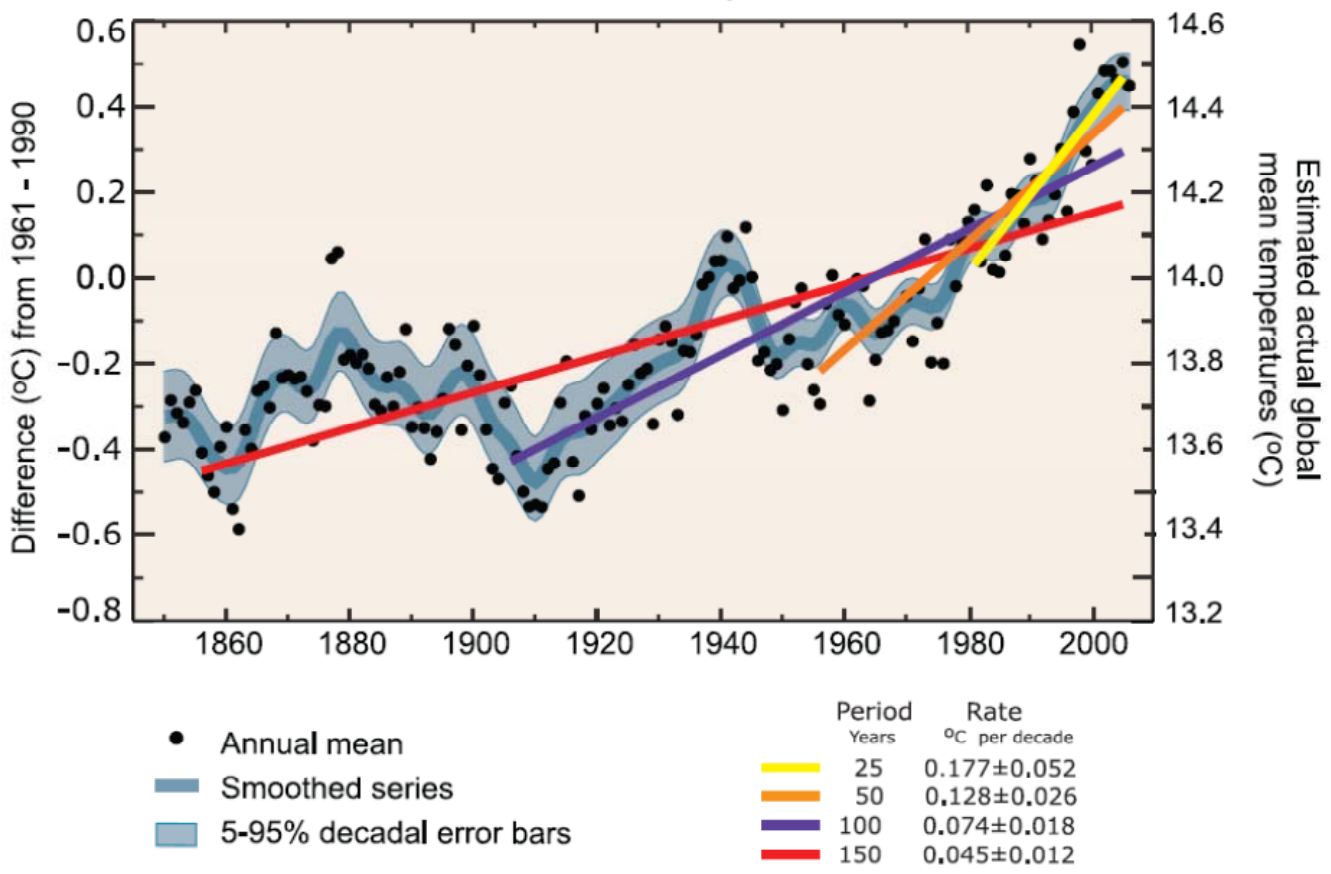
Climate Change …overview

Global climate is changing

- Intergovernmental Panel on Climate Change (2007)
  - Evidence for climate change is "unequivocal"
  - It is "extremely likely" that humans are major contributors
  - Future changes depend partly on human actions
- NASA Goddard Institute for Space Studies (2011)
  - 2001-2010 warmest decade on record
- World Meteorological Organization (2012)
  - 2002-2011 decade tied for warmest on record
- National Research Council, National Academy of Sciences (2011)
  - Risks of continuing "business as usual" are greater than the risks associated with strong efforts to limit and adapt to climate change.

Climate Change …warming trend

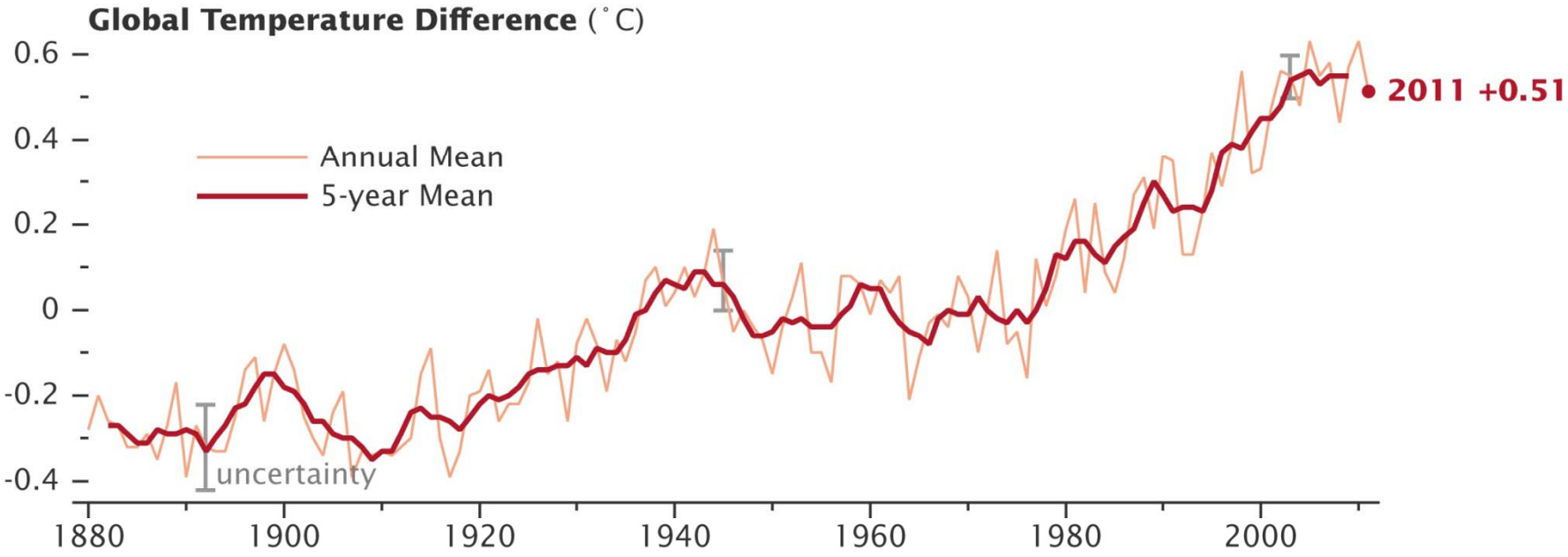
The average global surface temperature has risen 1.4 ºF over the past 100 years



IPCC 2007

Climate Change …warming trend

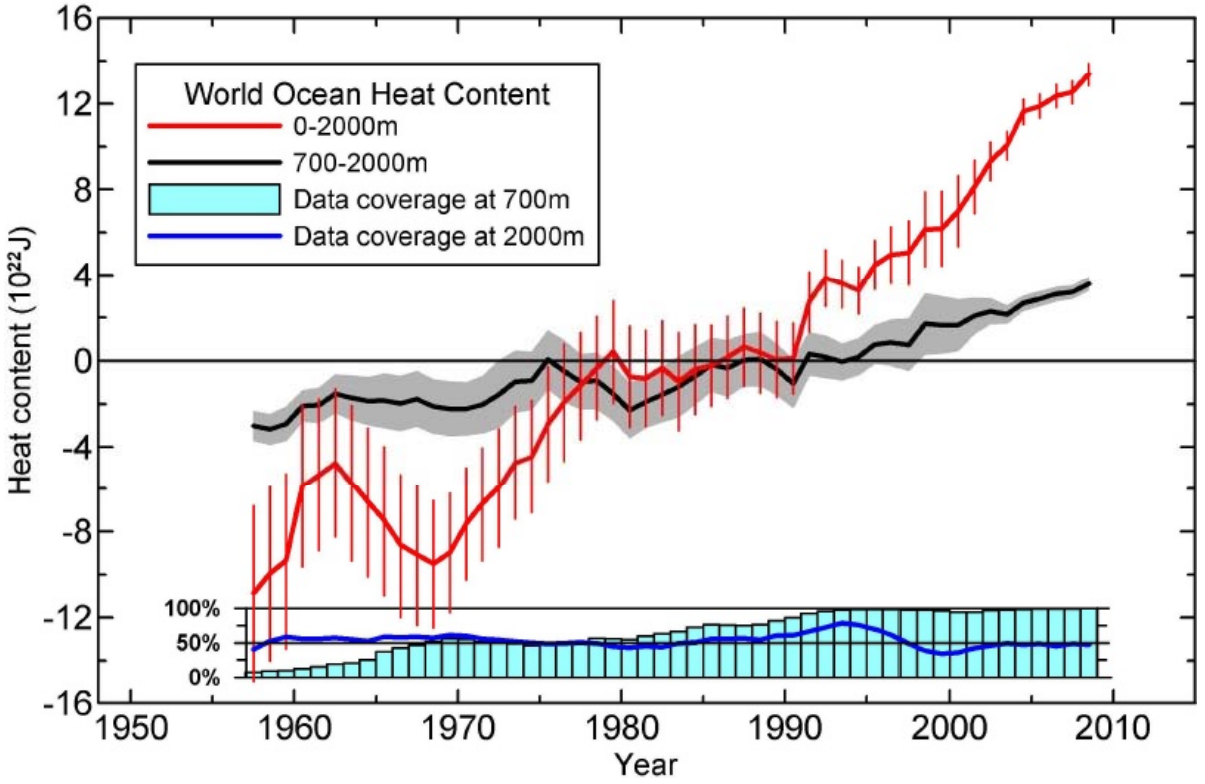
Recent years - La Niña, lower solar activity, and sulfate aerosols have reduced the rate of warming in surface air...



NASA GISS; NASA Earth Observatory, Robert Simmon

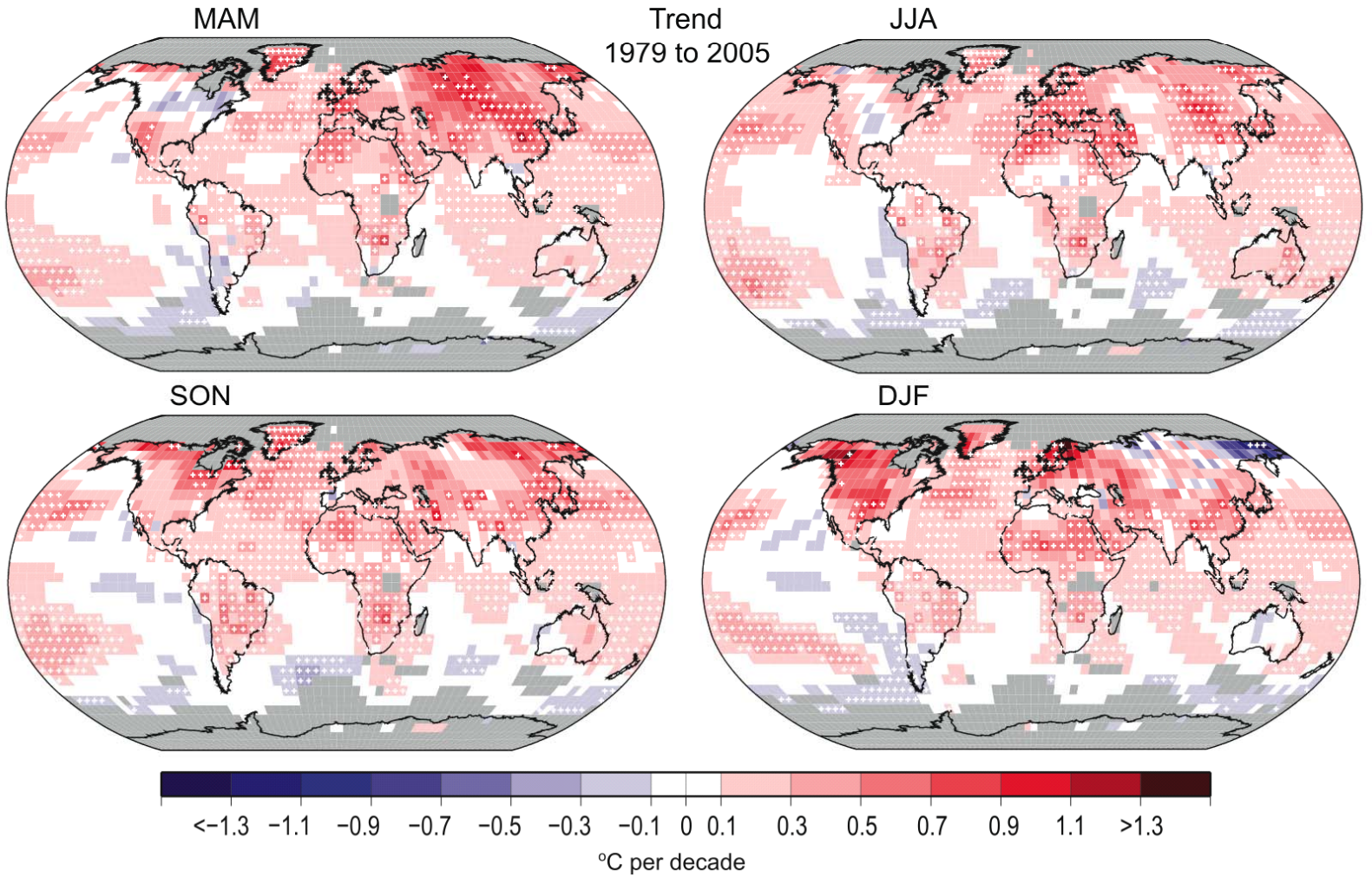
Climate Change …warming trend

...but not in oceans – which account for ~93% of earth system warming since 1955.



Levitus et al. 2012

Climate Change …global temp



IPCC 2007

Climate Change …global precip

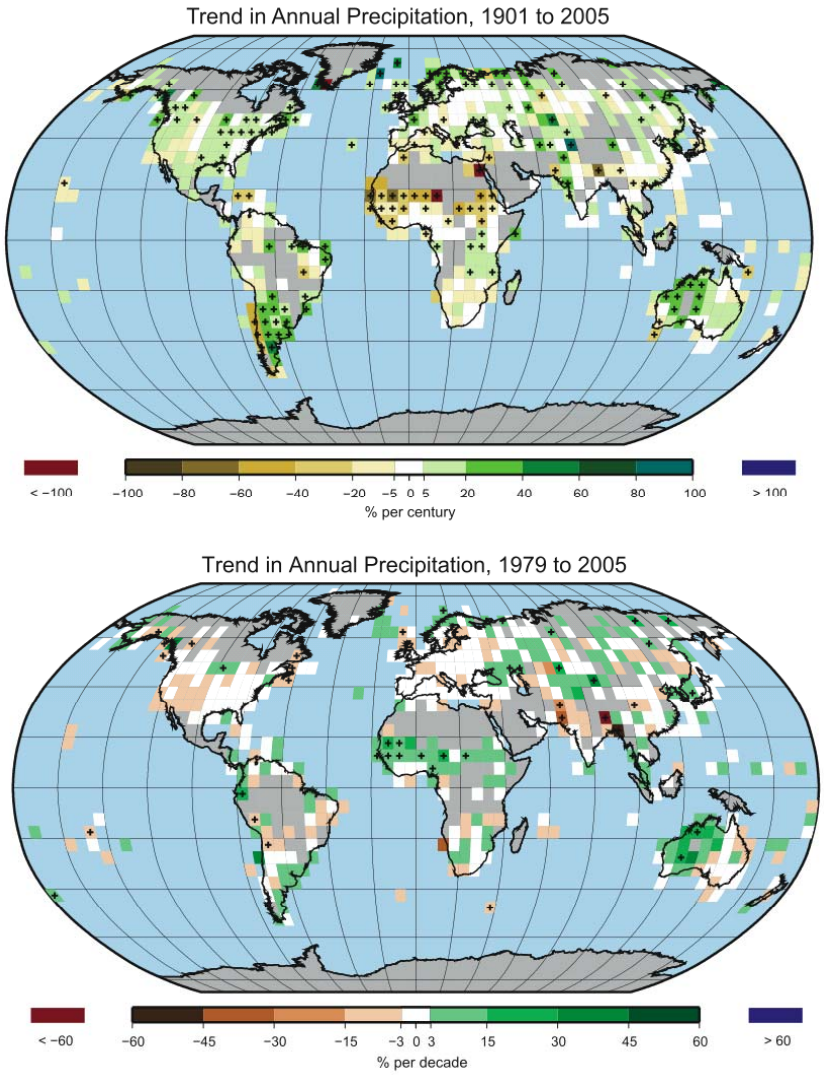
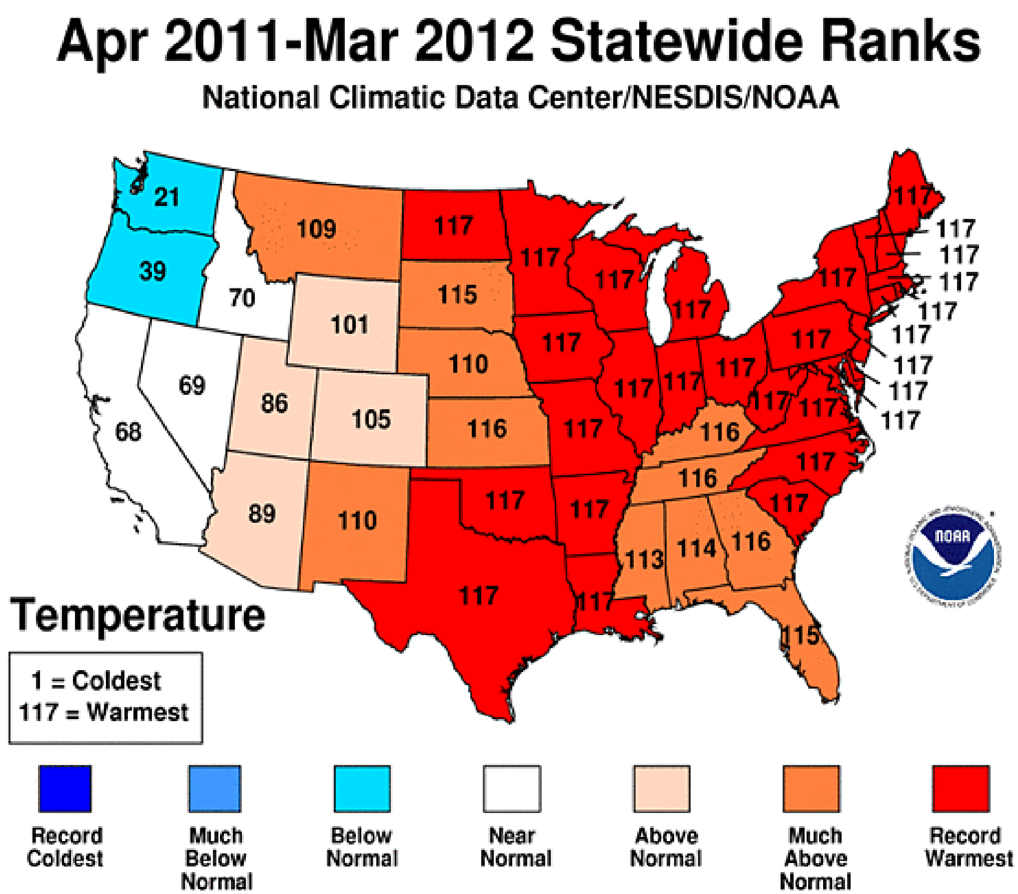


Figure 3.13

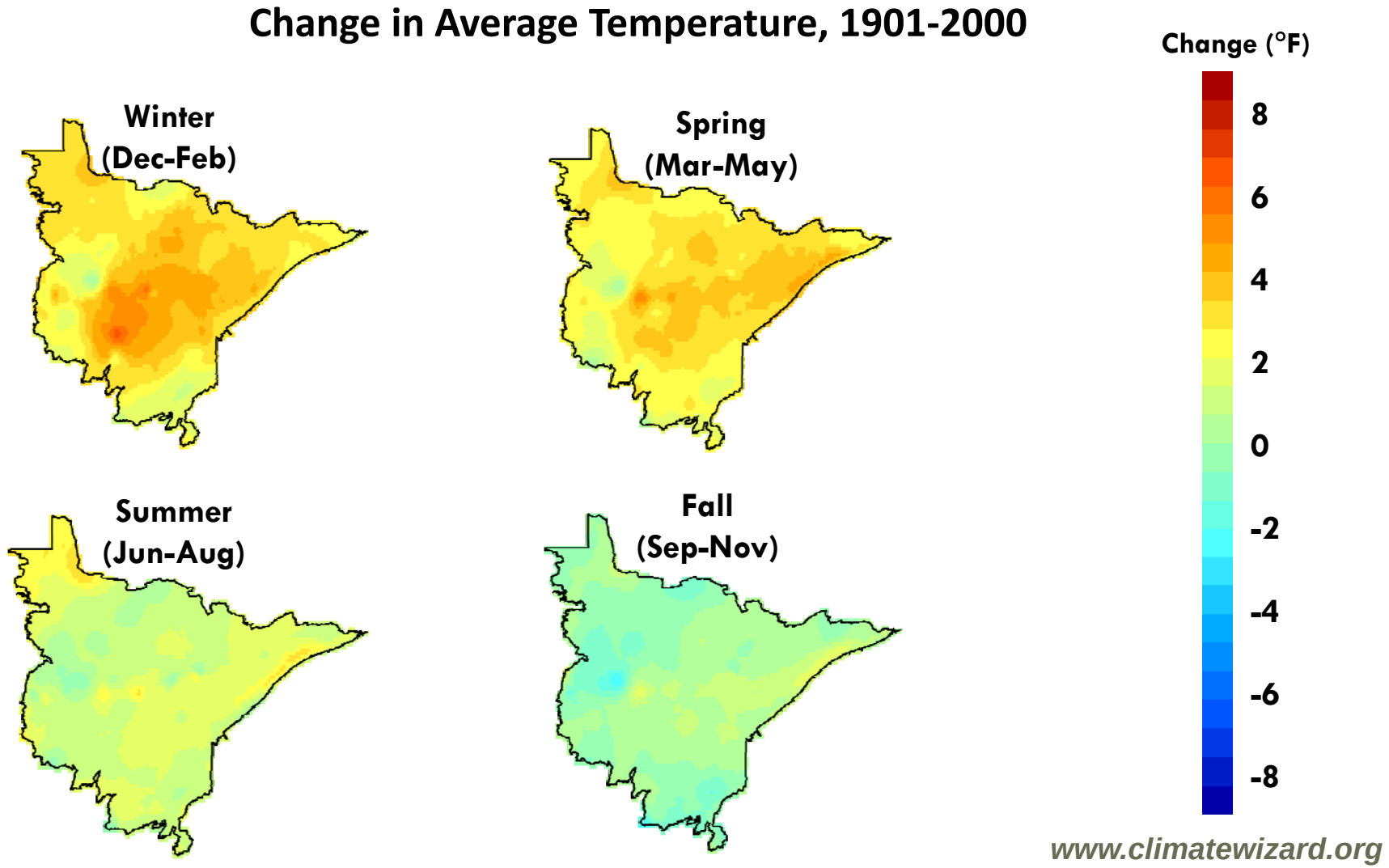
IPCC 2007

Climate Change ...warming trend

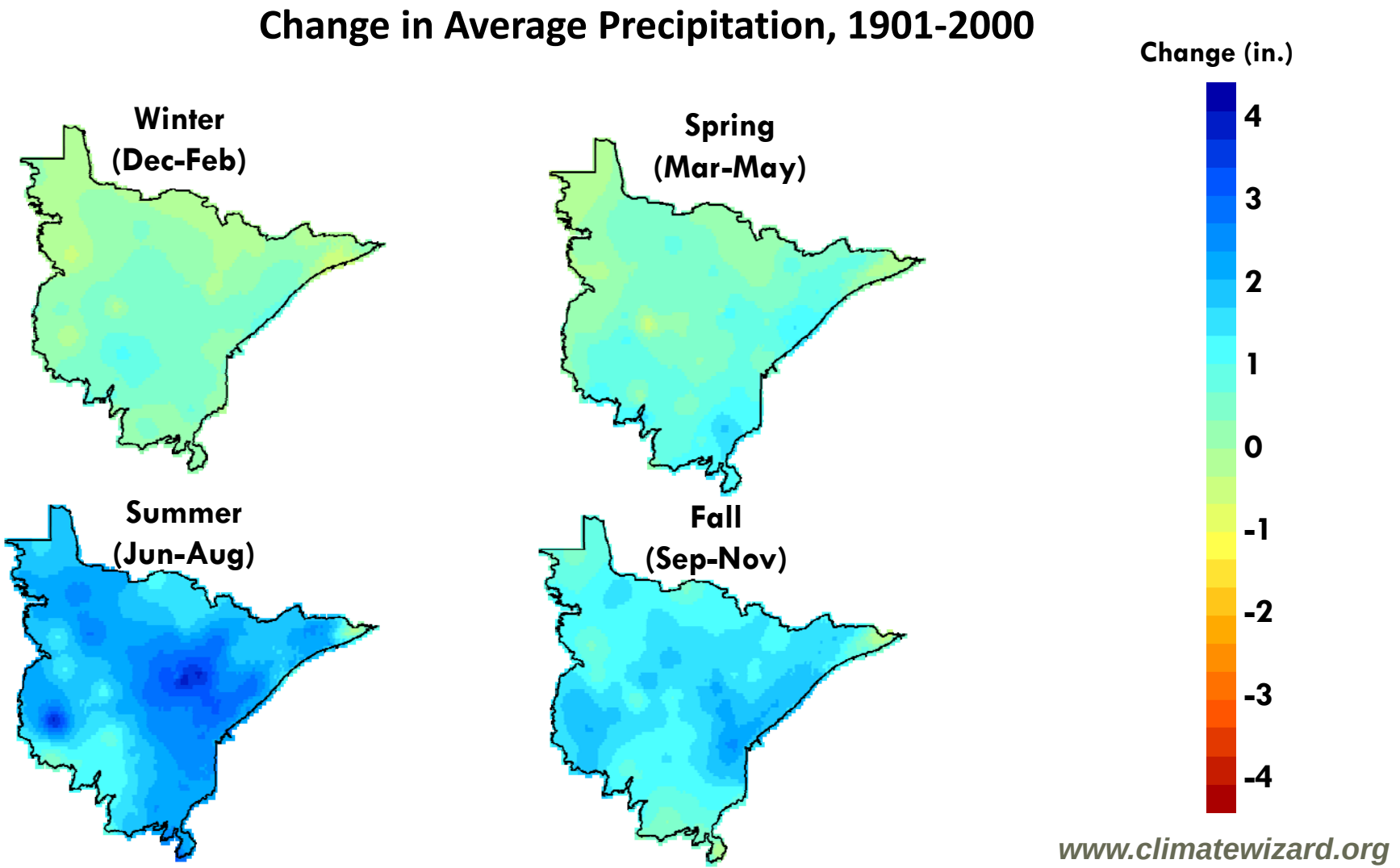
The most recent 12-month period in the USA was the warmest in the past 117 years.



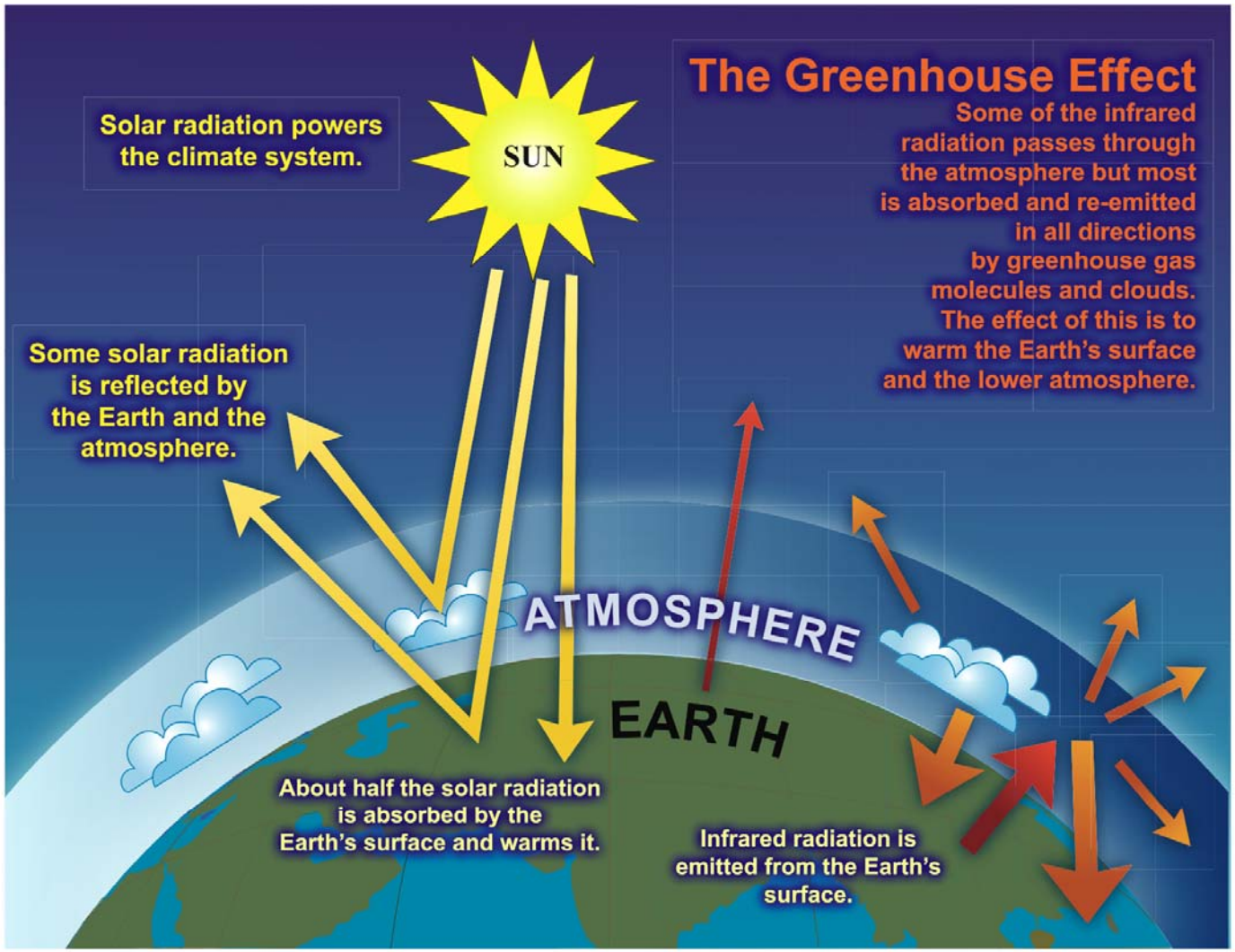
Climate Change …NE MN temp



Climate Change …NE MN precip



Climate Change …greenhouse effect



IPCC 2007

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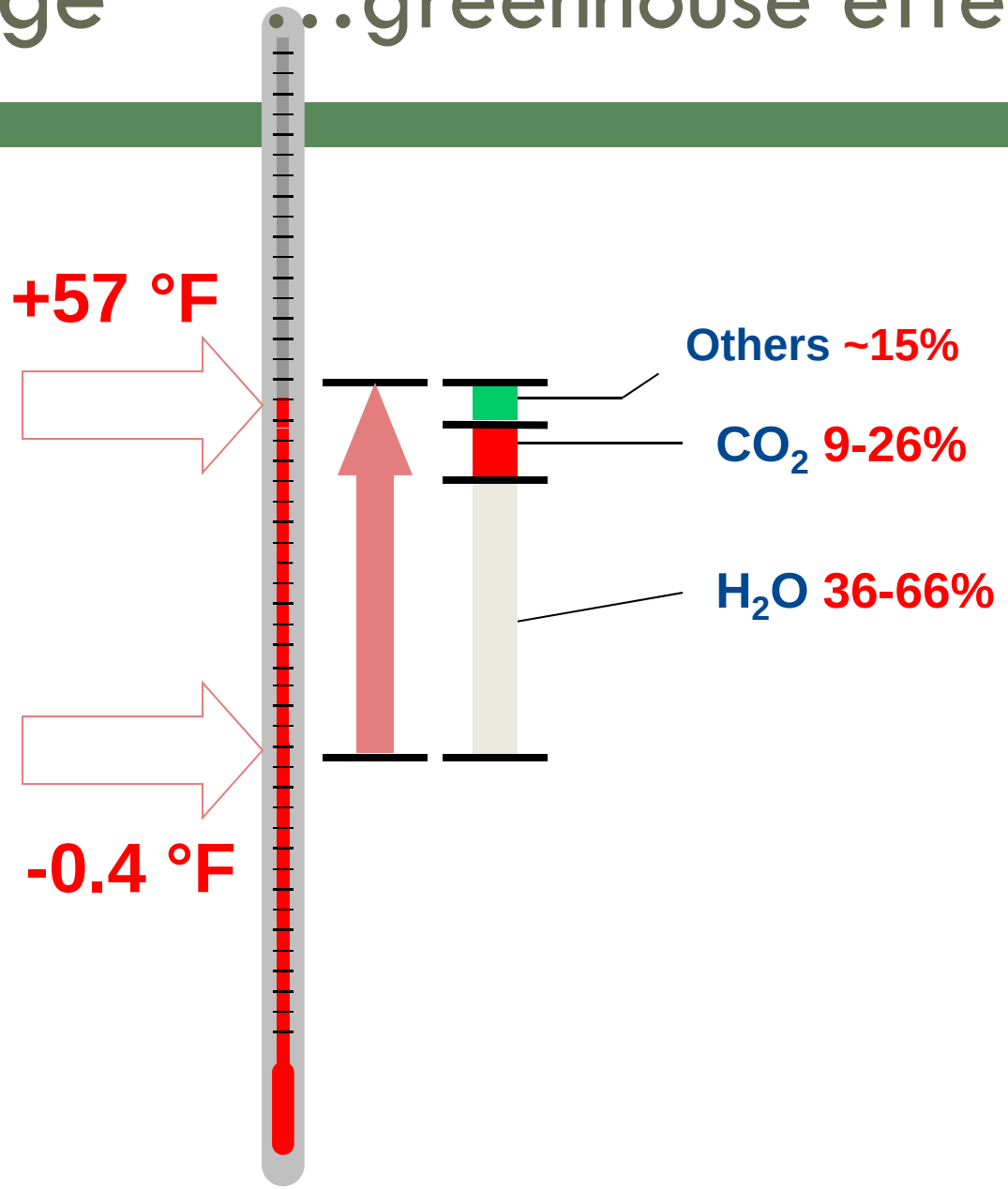

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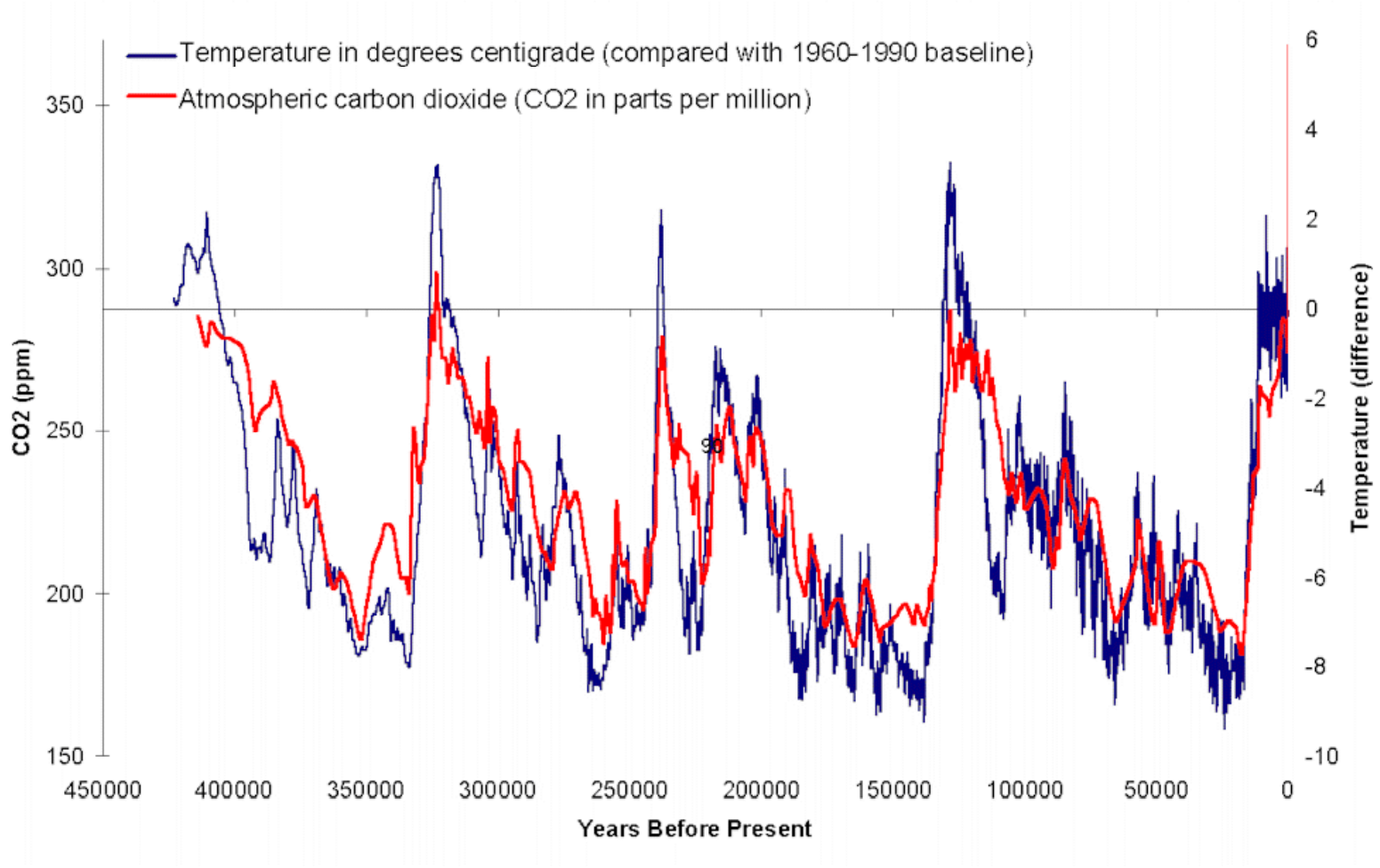

http://www.brighton73.freeserve.co.uk/gw/paleo/400000yrfig.htm; see also: Hansen et al. 1990, Petit et al. 1999, Shackleton 2000, Ruddiman 2006, Shakun et al. 2012

Uncertainty

Public uncertainty

- “Not sure if I believe in climate change.”
- “Scientists are a bunch of pinheads, anyway.”

Scientific uncertainty

- “The mean of all the 8 year trends is close to the long term trend (0.19ºC/decade), but the standard deviation is almost as large (0.17ºC/decade), implying that a trend would have to be either >0.5ºC/decade or much more negative (< -0.2ºC/decade) for it to obviously fall outside the distribution. Thus comparing short trends has very little power to distinguish between alternate expectations.”

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Public uncertainty

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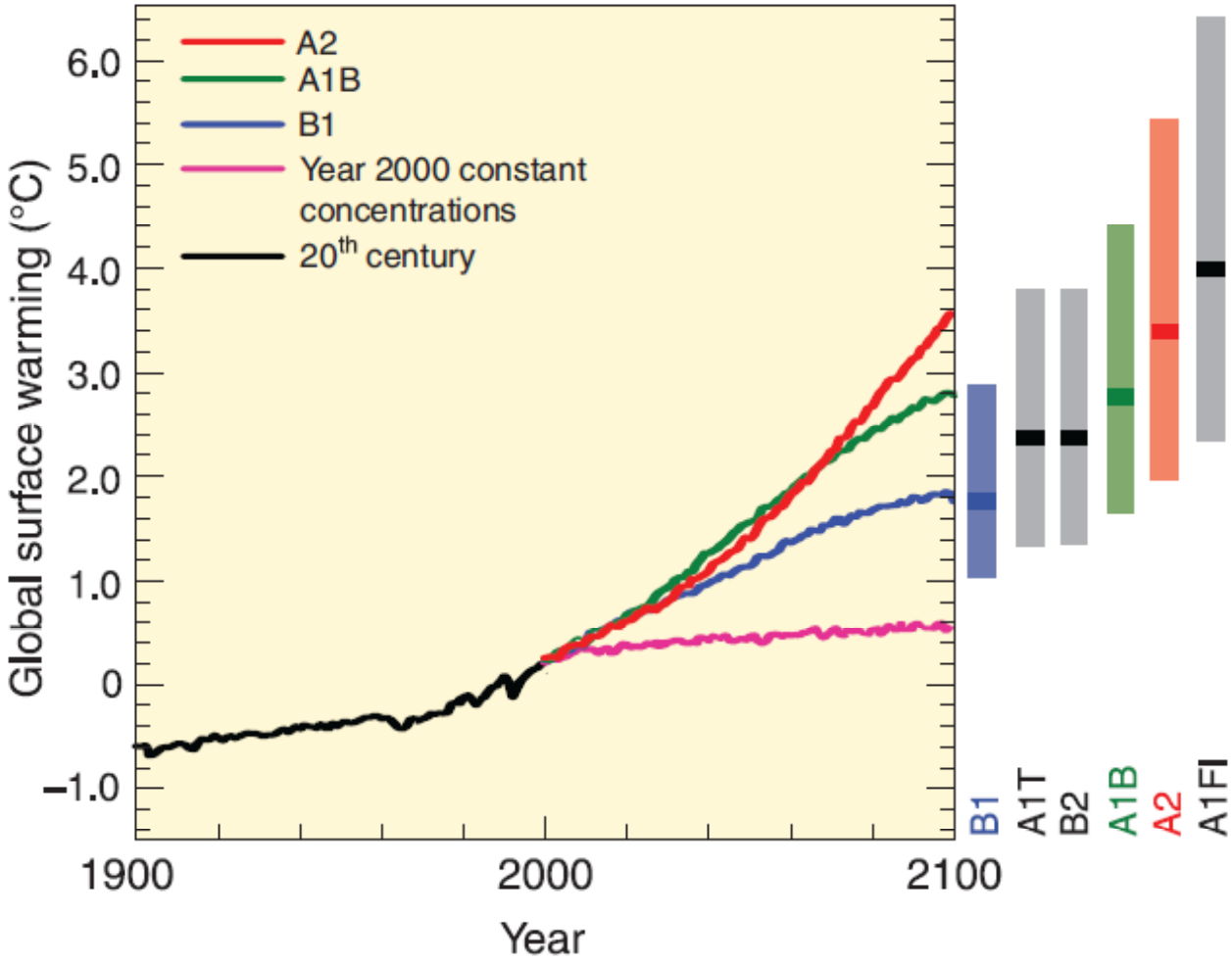
Scientific uncertainty

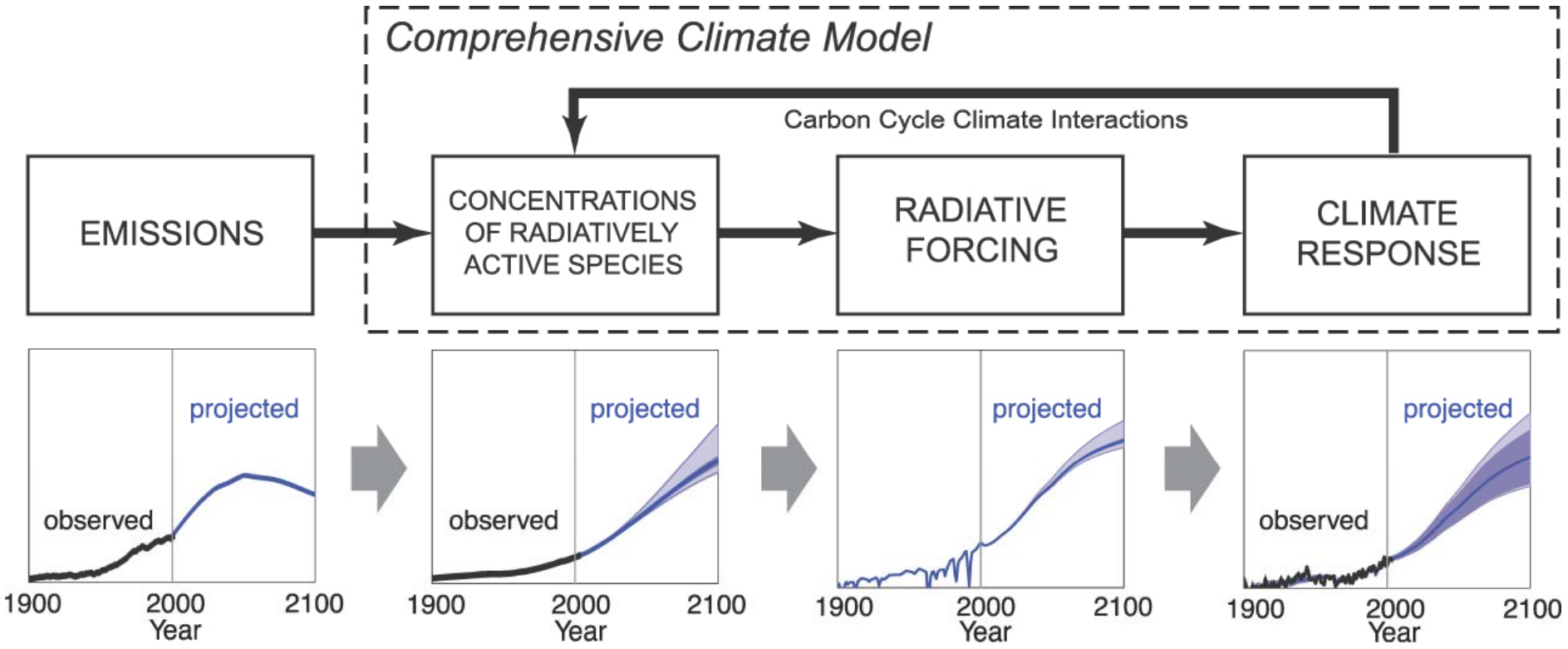
- Current change: “unequivocal”
- Future change:
  - Earthwide simulations include physics, chemistry, biology, randomness, feedbacks.
  - Unknown system inputs (scenarios).

Uncertainty …emissions



IPCC 2007

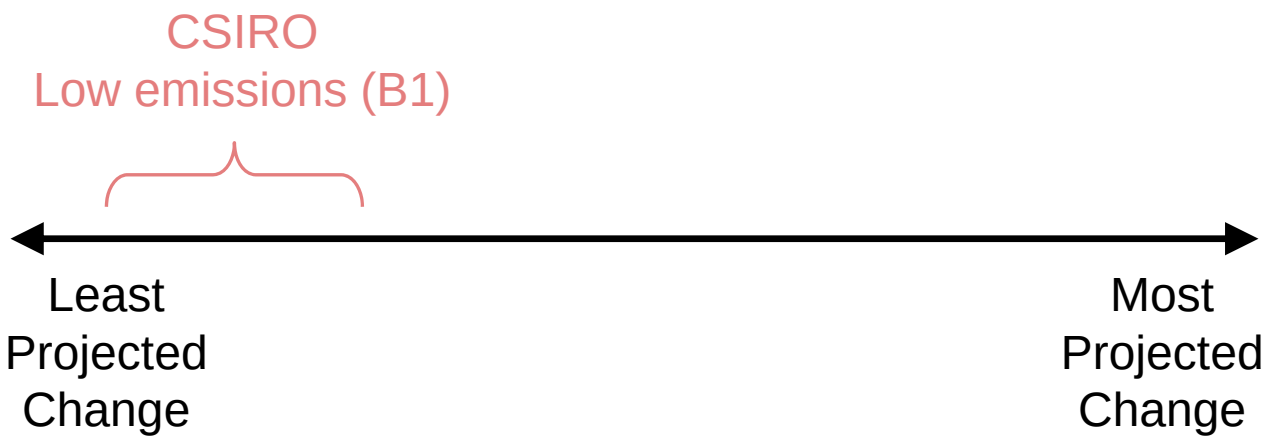
Uncertainty …feedbacks



IPCC 2007

Uncertainty …simulations

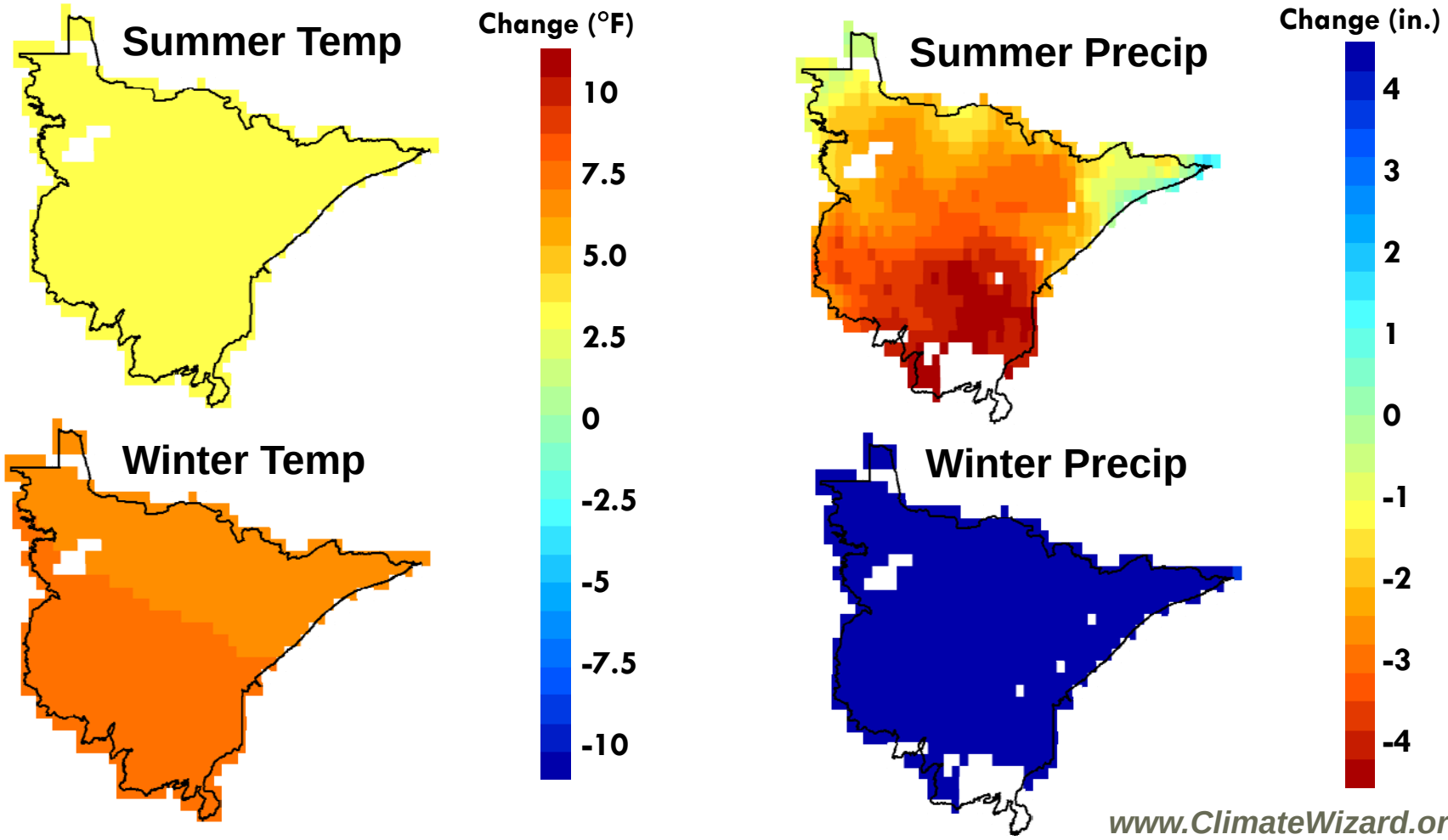
Uncertainty in simulations of future climate:



Model with less warming sensitivity to greenhouse gases
Fewer emissions

Uncertainty …simulations

CSIRO Low Emissions (B1), 2070-2099 compared to 1961-1990 base



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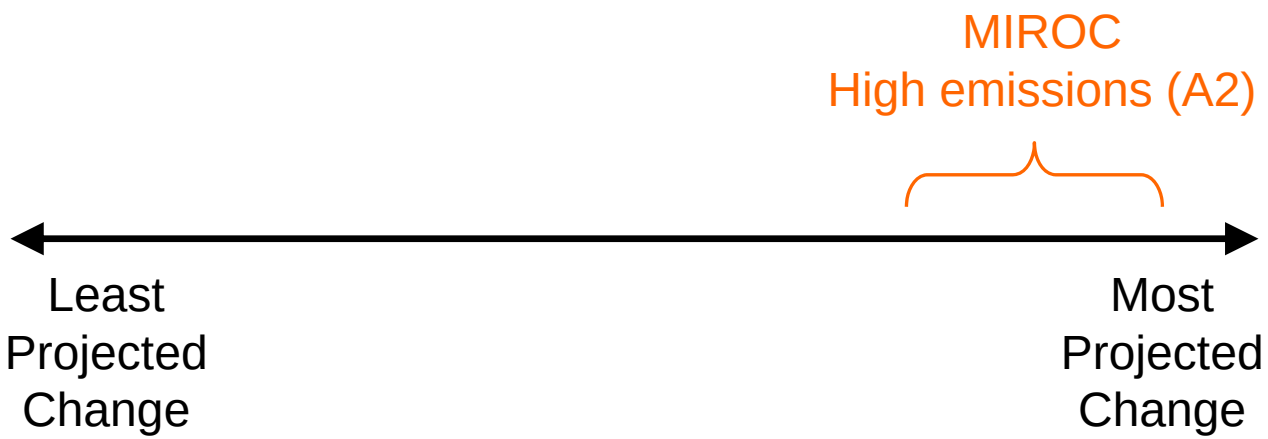
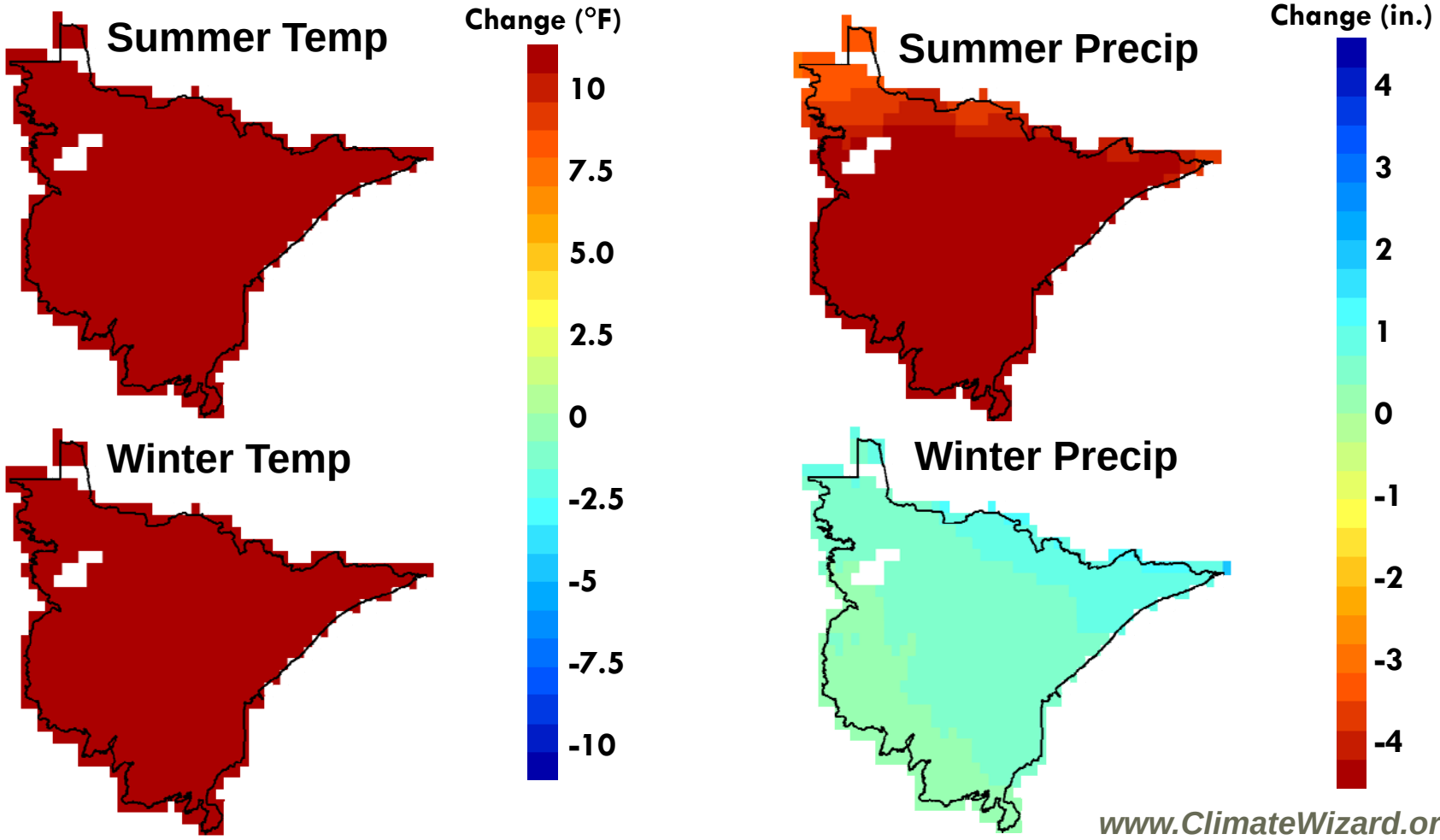


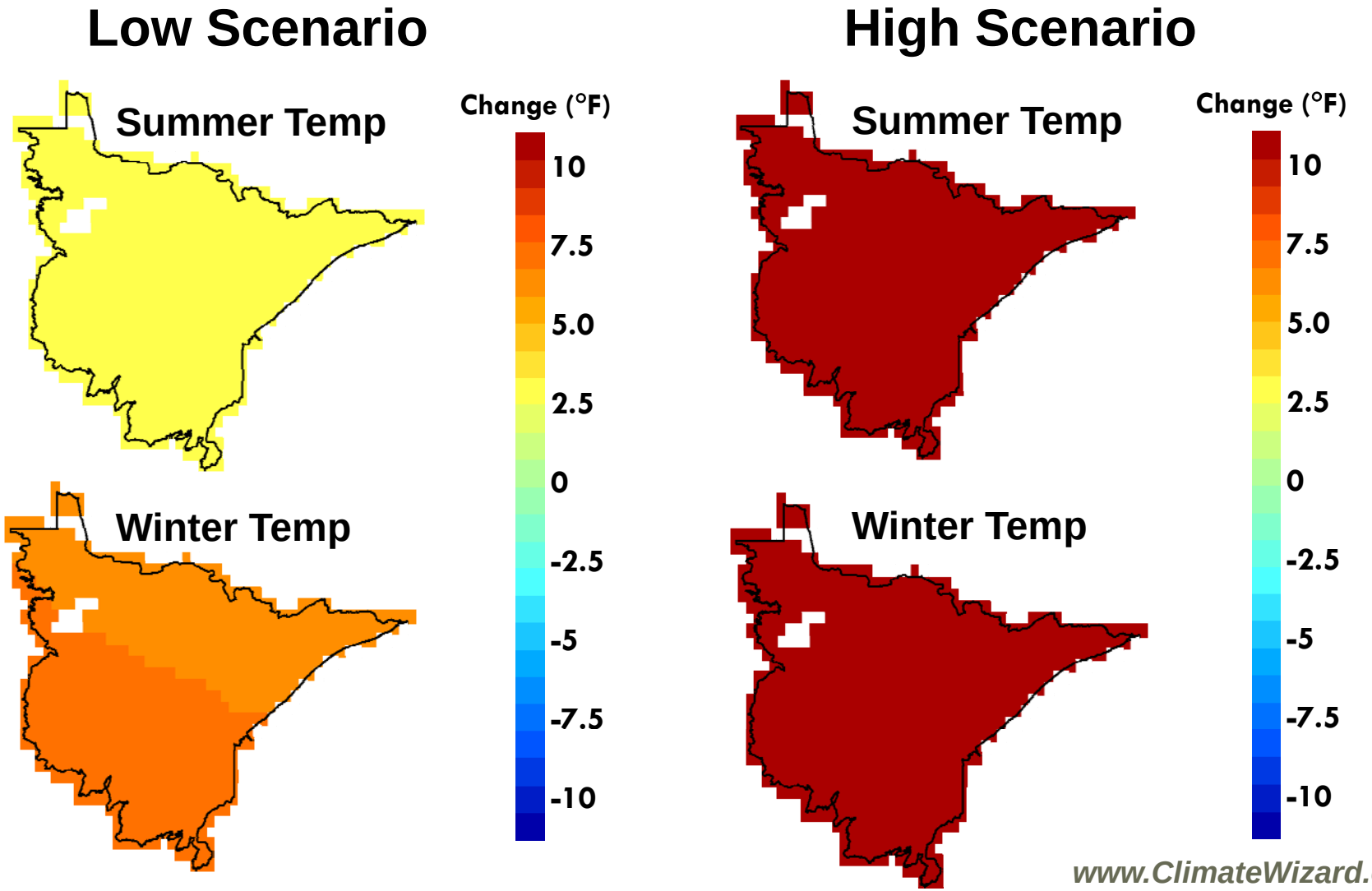
Model with more warming sensitivity to greenhouse gases
Higher emissions

Uncertainty …simulations

MIROC High Emissions (A2), 2070-2099 compared to 1961-1990 base



Uncertainty …simulations



www.ClimateWizard.org

Benefits

It’s not all bad….

Benefits

- Longer growing seasons

McCarty 2001

Benefits

- Longer growing seasons
  - Evidence of phenological shifts
    - Meta-analysis
    - 677 species (>400 plant spp.)
    - 87% shifted in direction expected by climate change

Parmesan and Yohe 2003

Benefits

- Longer growing seasons
- Increased precipitation in some regions

IPCC 2007

Benefits

- Longer growing seasons
- Increased precipitation in some regions
  - Precipitation has increased in the 20th century
    - Not a uniform increase!
    - Wet areas have gotten wetter, and dry areas drier
    - NE MN: summer in particular is wetter
  - Variability in future projections is very high

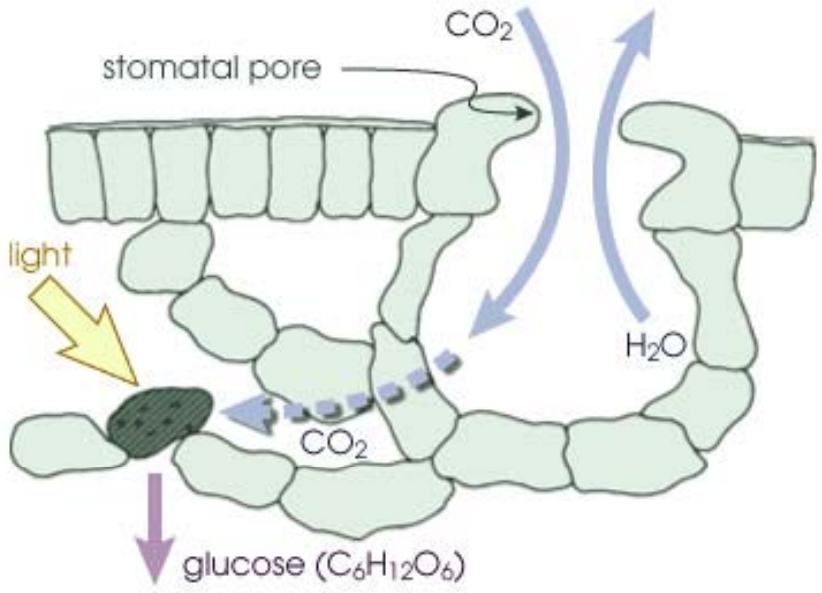
Dore 2005, IPCC 2007, www.climatewizard.org

Benefits

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization

Benefits

CO_2 fertilization:



- Increased photosynthesis
  - More CO_2 in stomatal cavity
  - Greater RuBisCO activity
- Reduced stomatal conductance
  - Increase in water use efficiency
- Potential increases in NPP
- Greater biomass (trees: 28%)
- Potential increases in soil inputs

Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

Benefits

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization
- Increased foraging and voltinism

Benefits

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization
- Increased foraging and voltinism
  - Minimum temperatures increasing 2x rate of maximum
  - Affecting broad suite of organisms
    - Positive affects on species such as Karner Blue Butterfly

Haack 1993, Swengel and Swengel 1998, Walther et al. 2002, Altermatt 2010

Benefits

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization
- Increased foraging and voltinism

Increased stresses

…but not all good.

Increased stresses

- Acclimation to CO_2 fertilization

Increased stresses

Acclimation of CO_2 fertilization:

- Varies by species and site
- Nutrient deficiencies (especially N)
- Limited sink strength
- Sensitive to ozone pollution (+/-)
- Evidence increased NPP and biomass, but limited evidence of long-term sequestration
  - Old trees
  - Wood growth and soil carbon - varies

Oren et al. 2001, Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

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→ The fertilization effect may be transitory – photosynthesis may not stay elevated, ecosystem carbon may not increase.

Oren et al. 2001, Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
  - Wind storms and hurricanes
  - Ice storms
  - Heat waves and droughts
  - Heavy precipitation
  - "Events" are not well modeled

Ciais 2005, Mills 2005, WMO 2007, IPCC 2007, Coumou and Rahmstorf 2012

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons

IPCC 2007

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
  - Altered timing of aquifer recharge
  - Potential declines in summer seasonal stream flow
  - Potential increases in flashiness and episodic high flows
  - Increased water stress in late summer
  - Phenological shifts and asynchrony

Dale et al. 2001, Huntington 2004, Parmesan 2006, Cherkauer and Sinha 2010

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
  - Pests migrating northward
  - Accelerated lifecycles
  - Decreased probability of lower lethal temperatures

Ayres and Lombardero 2000, Woods et al. 2005, Parmesan 2006, Soja et al., 2006

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
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- Decreased snow pack and early thaw

Increased stresses

- Acclimation to CO_2 fertilization
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- Decreased snow pack and early thaw
  - Early bud break and loss of cold hardening
  - Frost damage during spring freezing
  - Less insulation to cold snaps

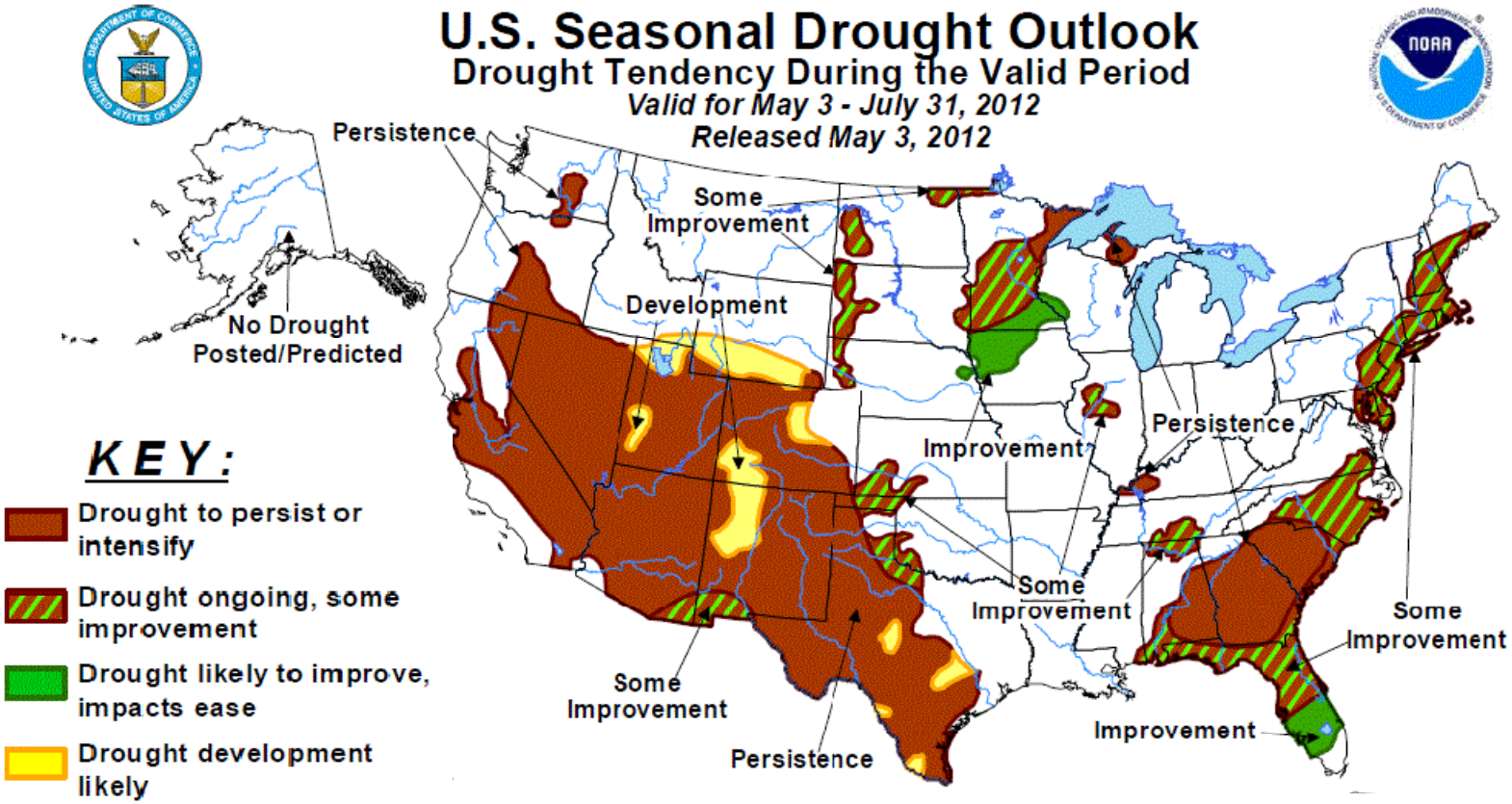
Ayres and Lombardero 2000, Hennon et al. 2006

Increased stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire

Increased stresses

Less moisture – more fires (not a new idea or observation)



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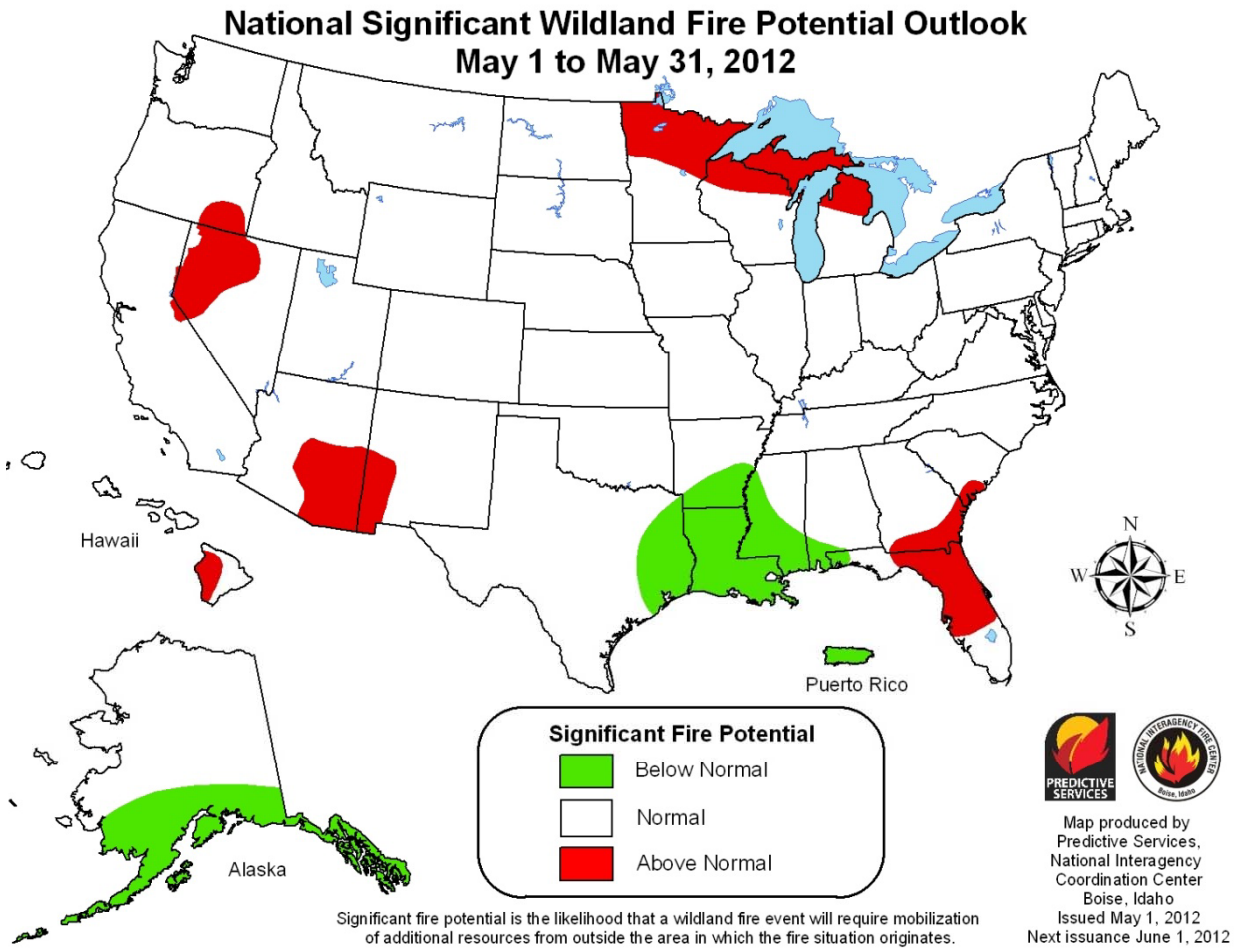
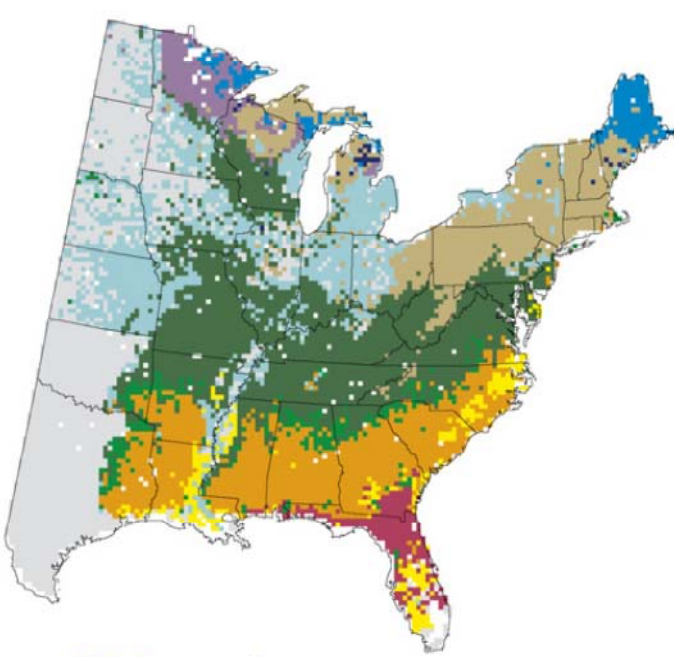


Increased stresses

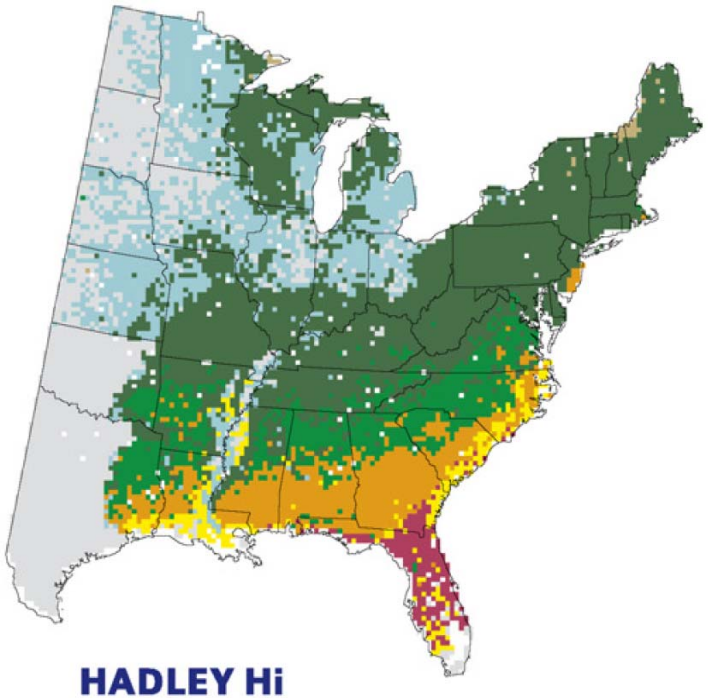
- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire
- Species range shifts

Increased stresses

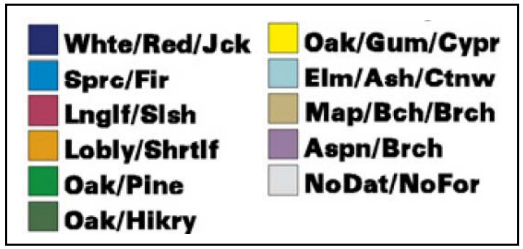
Species range shifts:



RF-Current



HADLEY Hi



Iverson et al. 2008

Increased stresses

Species range shifts:

- Range shifts ≠ instant catastrophic dieback
- Mature trees should fare better
  - Developed root systems
  - Greater carbohydrate reserves
- Stress factors will increase in severity
  - Temperature
  - Moisture
  - Competition
- Increased susceptibility to disturbance

Dale et al. 2001, Iverson et al. 2008

Increased stresses

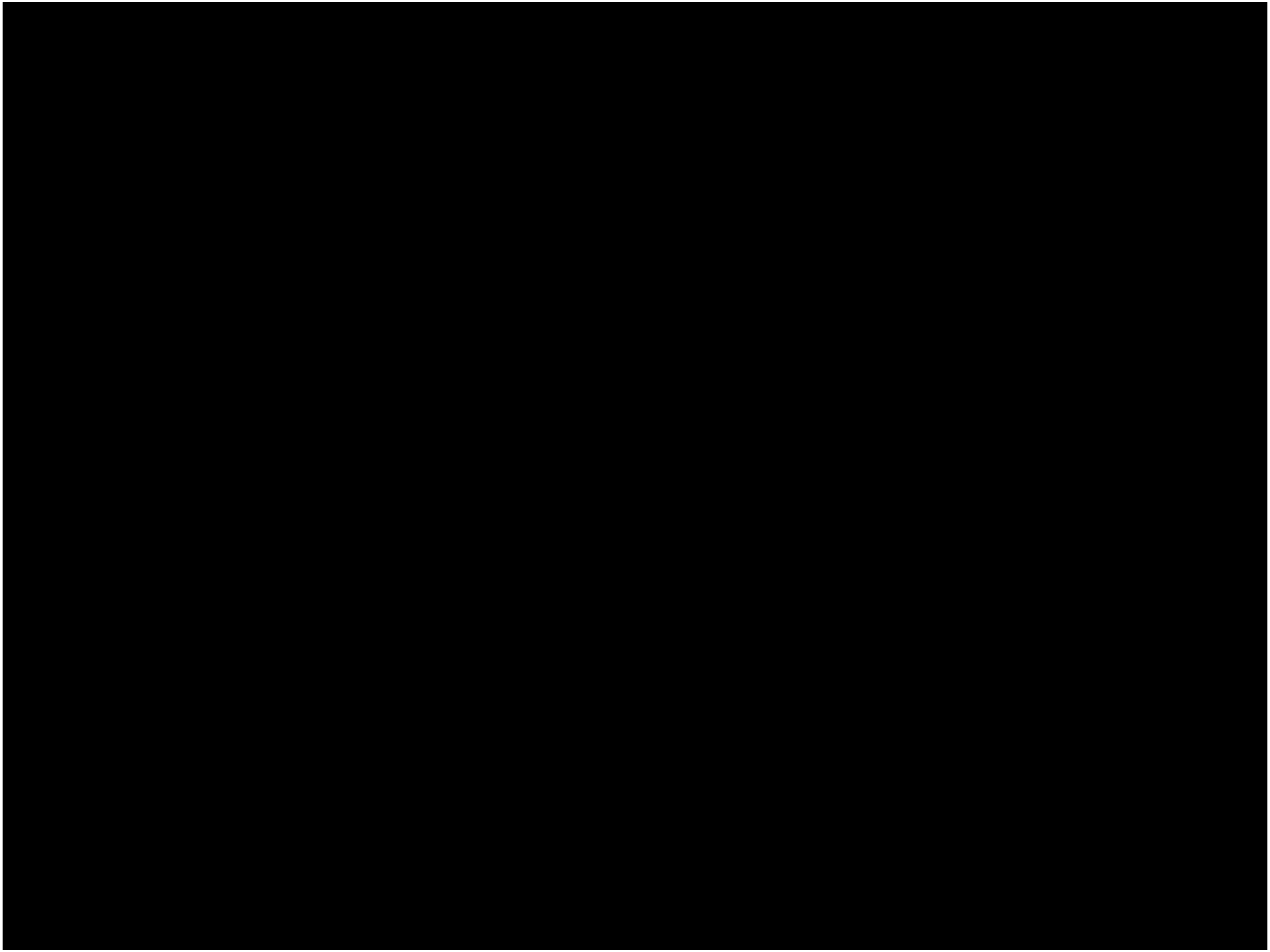
- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire
- Species range shifts

→ *Interactions between these limits are highly likely.*

Summary

- Climate change: overwhelming evidence, multiple sources, old news. *Embrace uncertainty!*
- Climate change and forests: the same old stresses, but new patterns and agents. *Same job – new challenges!*
- No shiny new tool. *Your skills and experience are the best tools!*

Thank you!



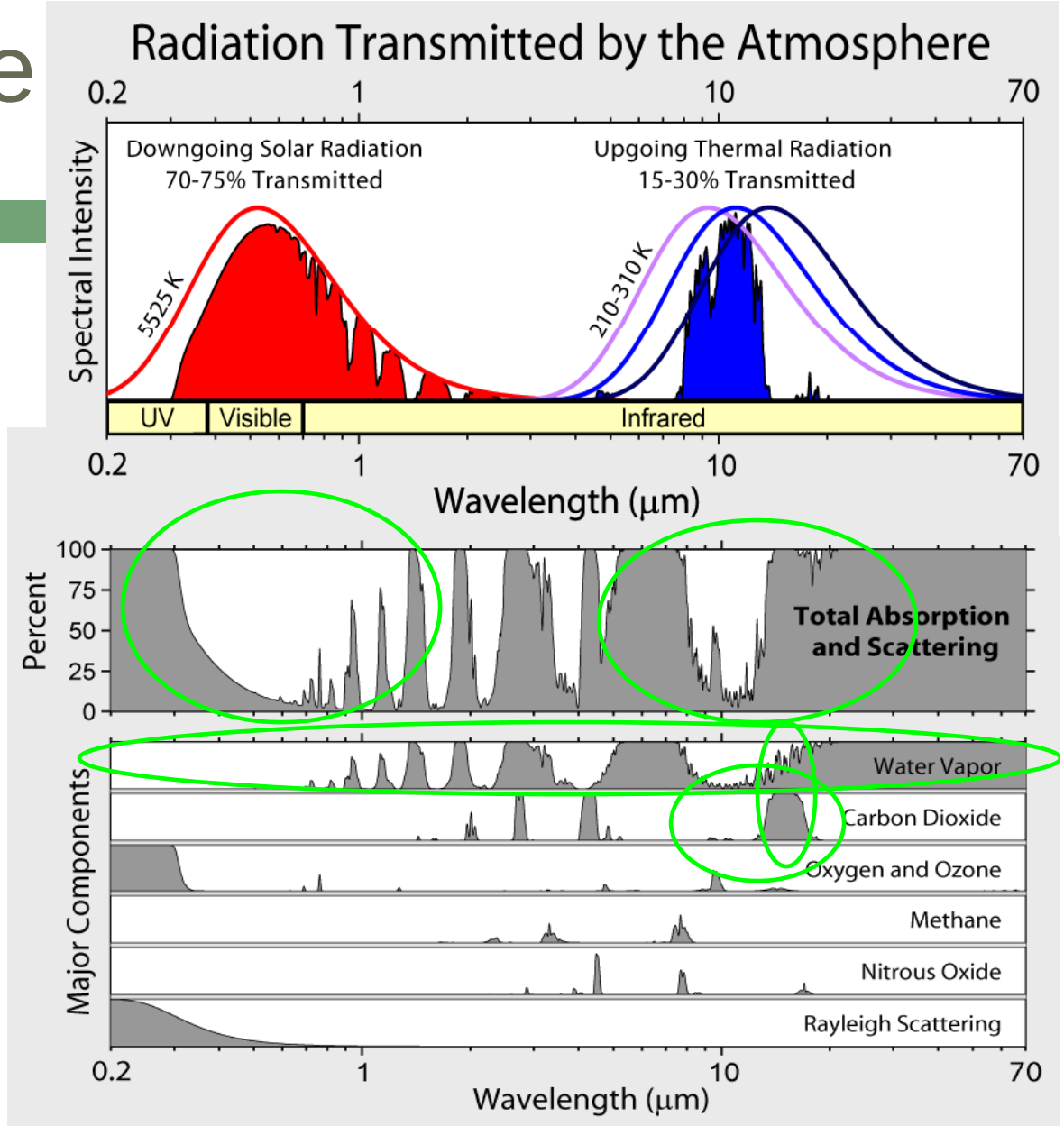
Discussion Question

What considerations does climate change add or alter for the forest sector in northeastern MN?

Climate Change

…greenhouse effect

- More absorption and scattering for outgoing energy
- Water vapor is important
- CO_2 absorbs only outgoing energy
- Impact of CO_2 greatest in situations with less water vapor (dry, cold)



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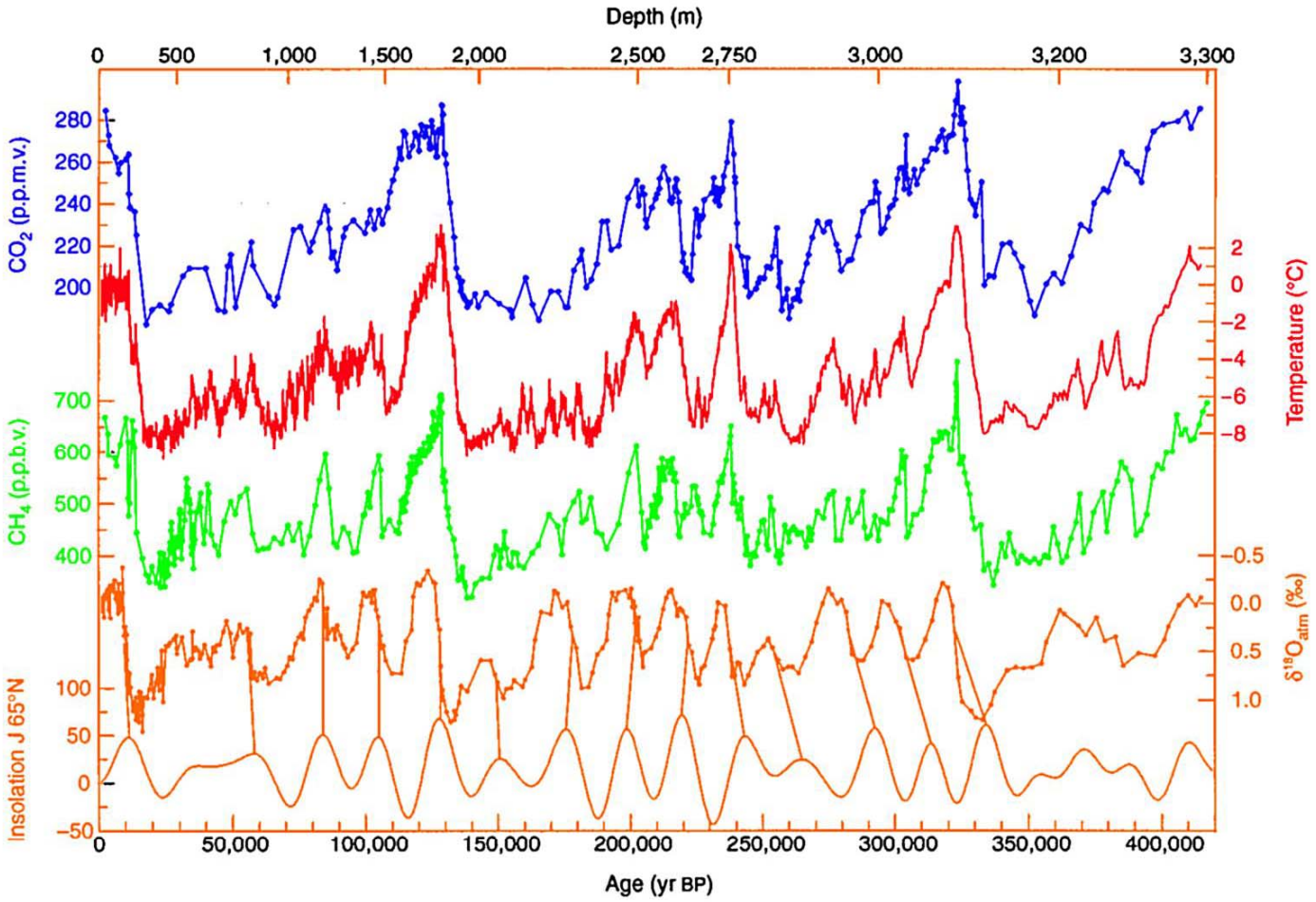
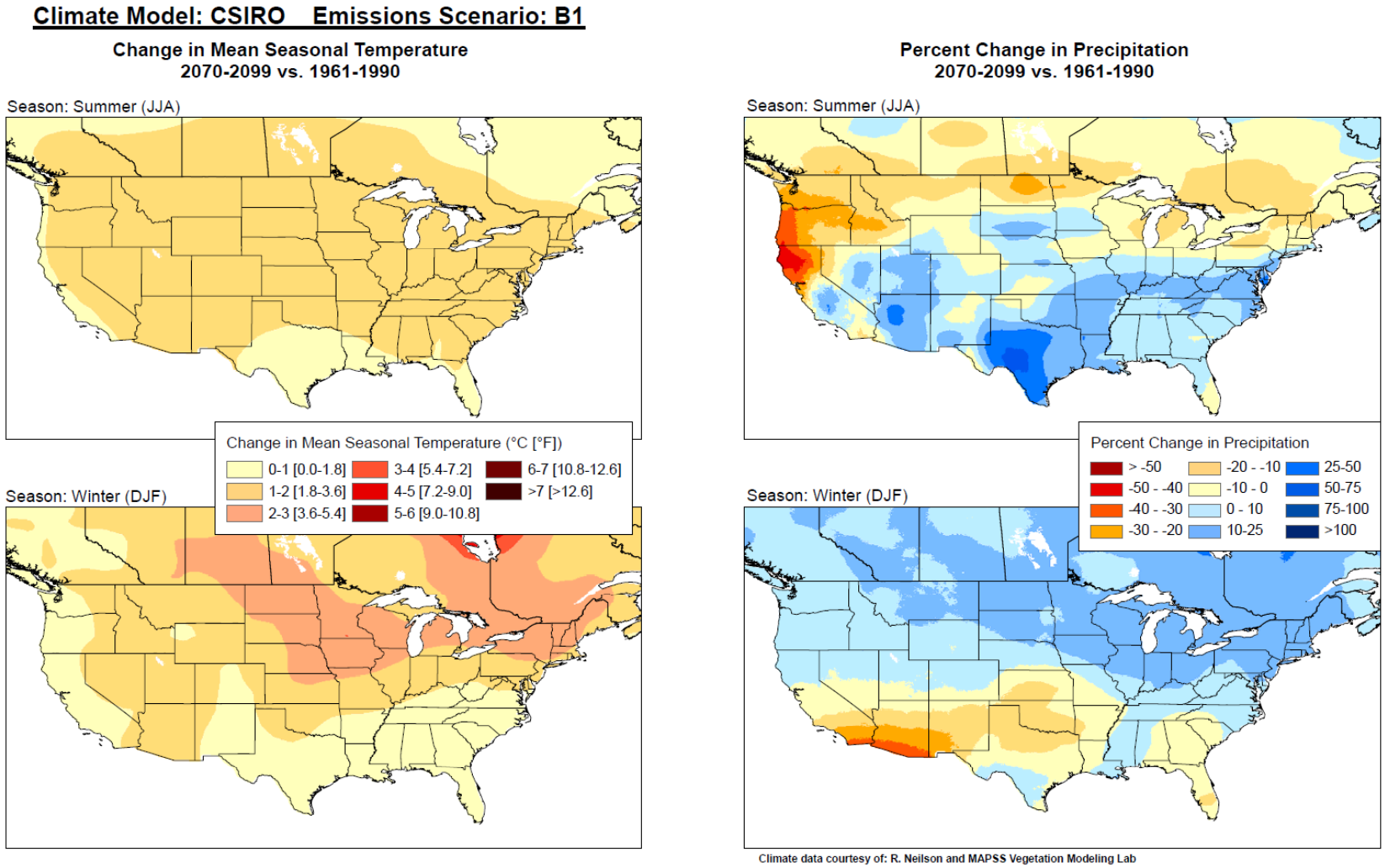


Source: Wikimedia Commons and Petit et al., 1999

Uncertainty …simulations



Climate data courtesy of R. Neilson and MAPSS Vegetation Modeling Lab

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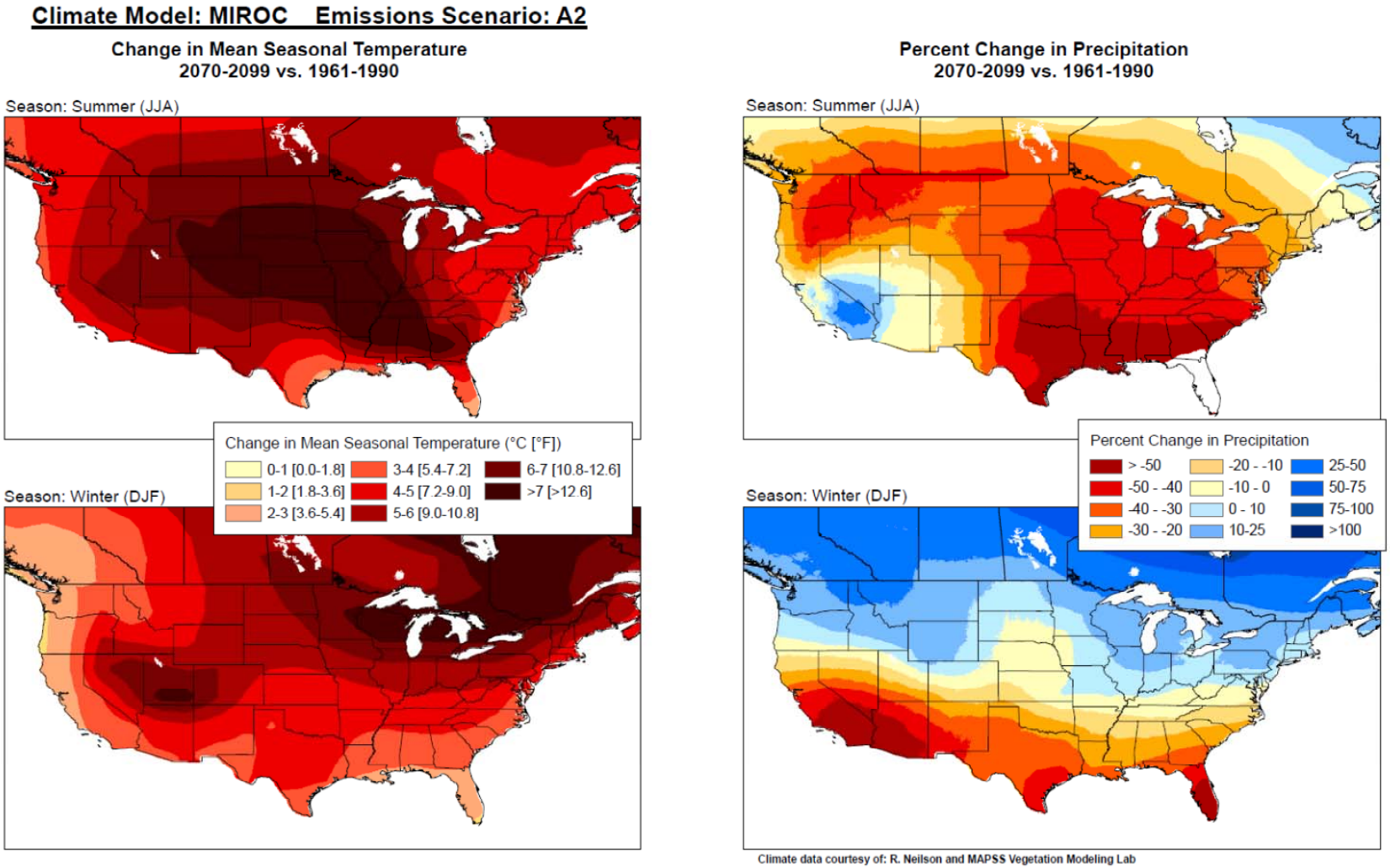

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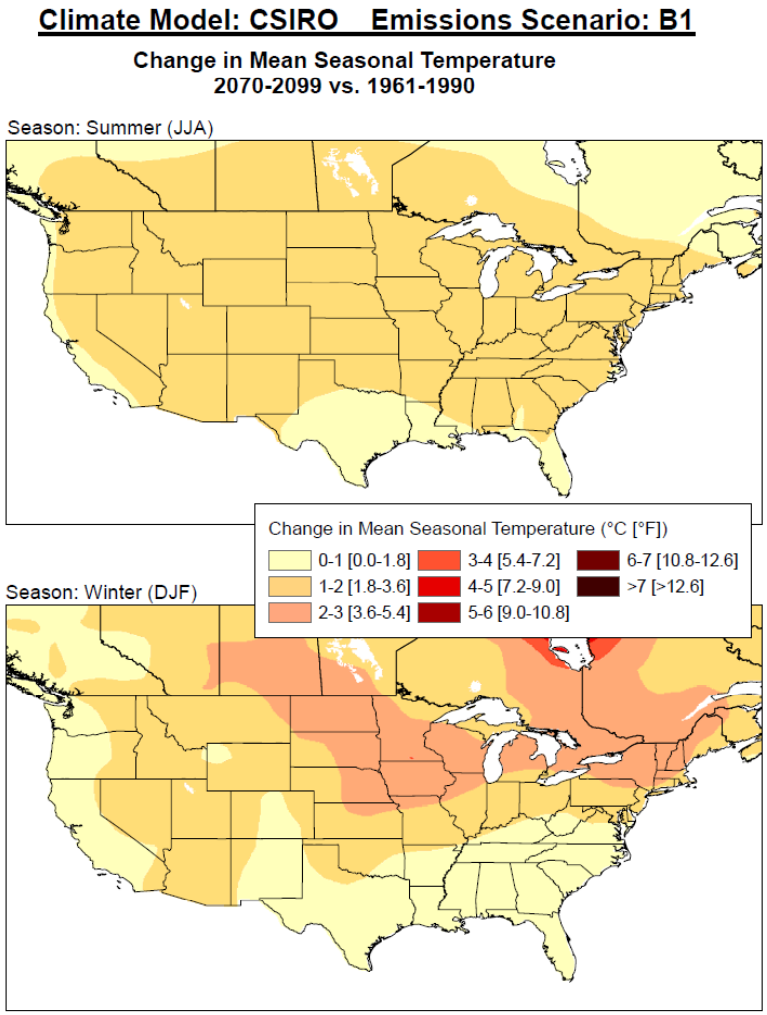

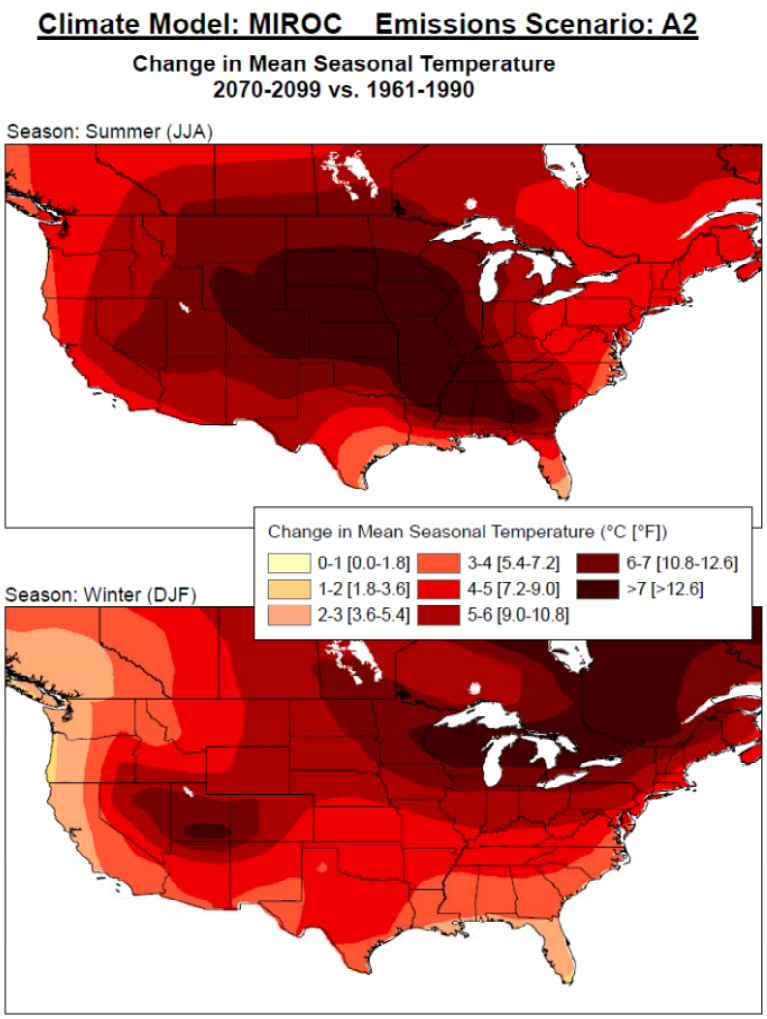

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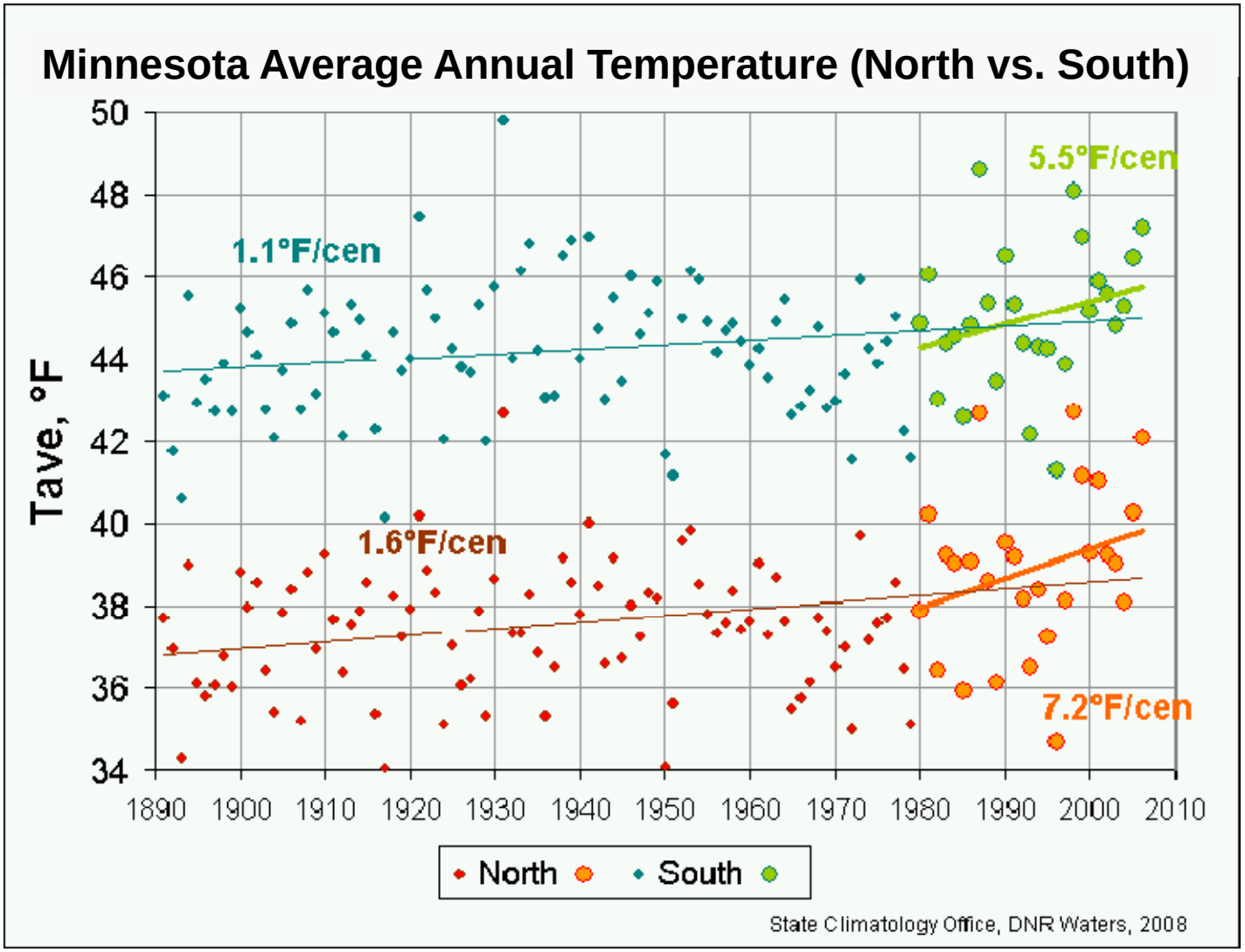
Climate Change …MN temp



Increased stresses

Increased frequency and intensity of wildfire:

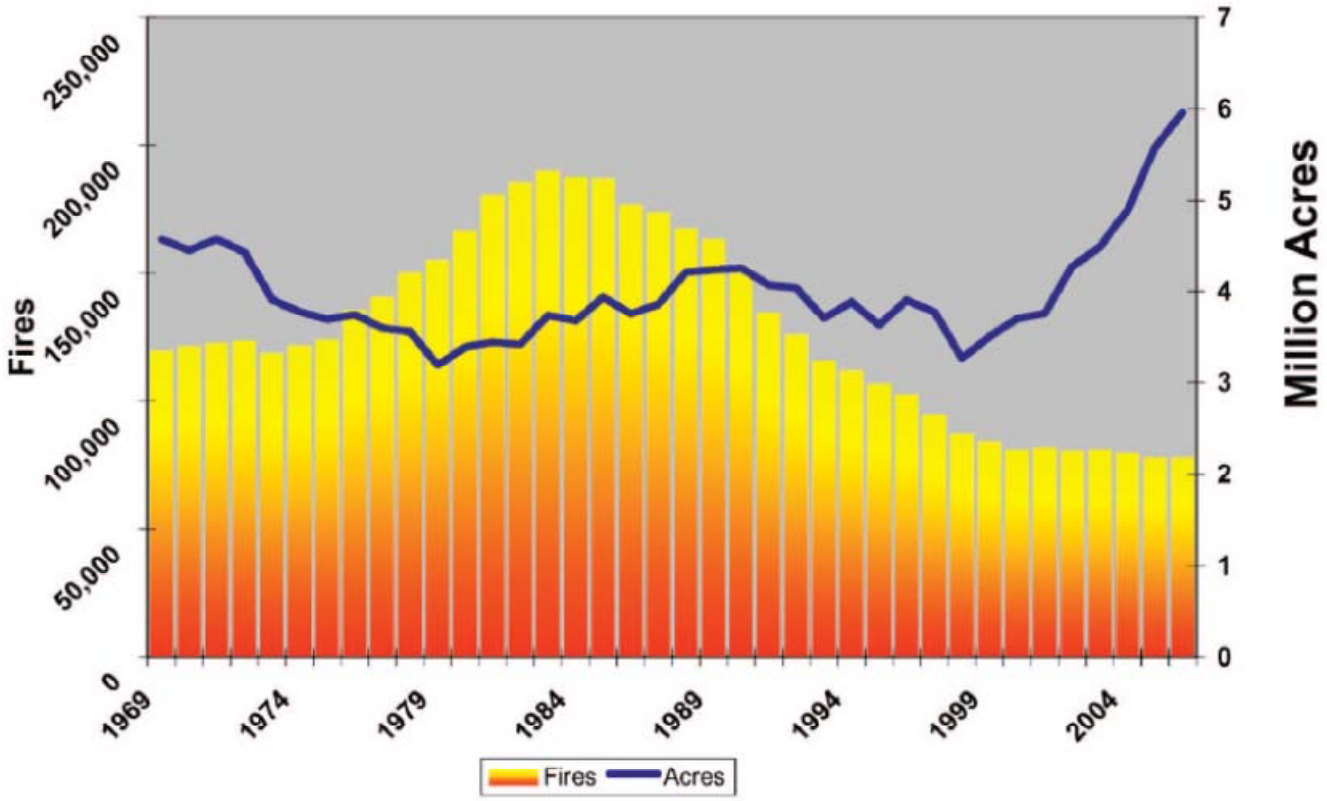


Figure 5-1. Ten-year averages of acres burned and number of fires (Source: Compiled from National Interagency Fire Center 2007).

Suitable habitat projections

(Losers 15)

Extirpated

MountainMaple

Large Decrease.

Black spruce
Balsam fir
Northern white-cedar
Balsam poplar
Quaking aspen
Paper birch
White spruce

Small Decrease

Pin cherry
Tamarack
Black ash
Jack pine
Bigtooth aspen
Yellow birch
Butternut

(Same 3)

No Change

Chokecherry
Rock elm
Striped maple

Large Increase

American hornbeam
American elm
Northern pinoak
Boxelder
Black cherry
Black willow
White oak
Silver maple
Eastern hemlock
Bitternut hickory
White ash
Black oak
Eastern cottonwood
Slippery elm
Hackberry
Eastern redcedar
Black walnut
Wild plum
Swamp white oak
Peachleaf willow

(Gainers 29)

Small Increase

Red pine
Eastern white pine
Red maple
Sugar maple
Green ash
Eastern hophornbeam
Bur oak
Northern red oak
American basswood

(New Migrants 31)

New (Low & High)

American beech
Osage-orange
Shagbark hickory
Red mulberry
Flowering dogwood
Honeylocust
Chinkapin oak
Black locust
Sassafras

New (High Only)

Ohio buckeye
Gray birch
Pignut hickory
Pin oak
Post oak
Sweet birch
Pecan
Black hickory
Mockernut hickory
Northern catalpa
Sugarberry
Eastern redbud
Common persimmon
Kentucky coffeetree
Sweetgum
Yellow-poplar
Blackgum
Sycamore
Scarlet oak
Shingle oak
Blackjack oak
Chestnut oak

Iverson et al. - draft results