Impacts of Climate Change on Northern Ecosystems

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Ecological responses to climate change

11 of last 12 years are warmest in instrument record
Warming is especially pronounced at high latitudes

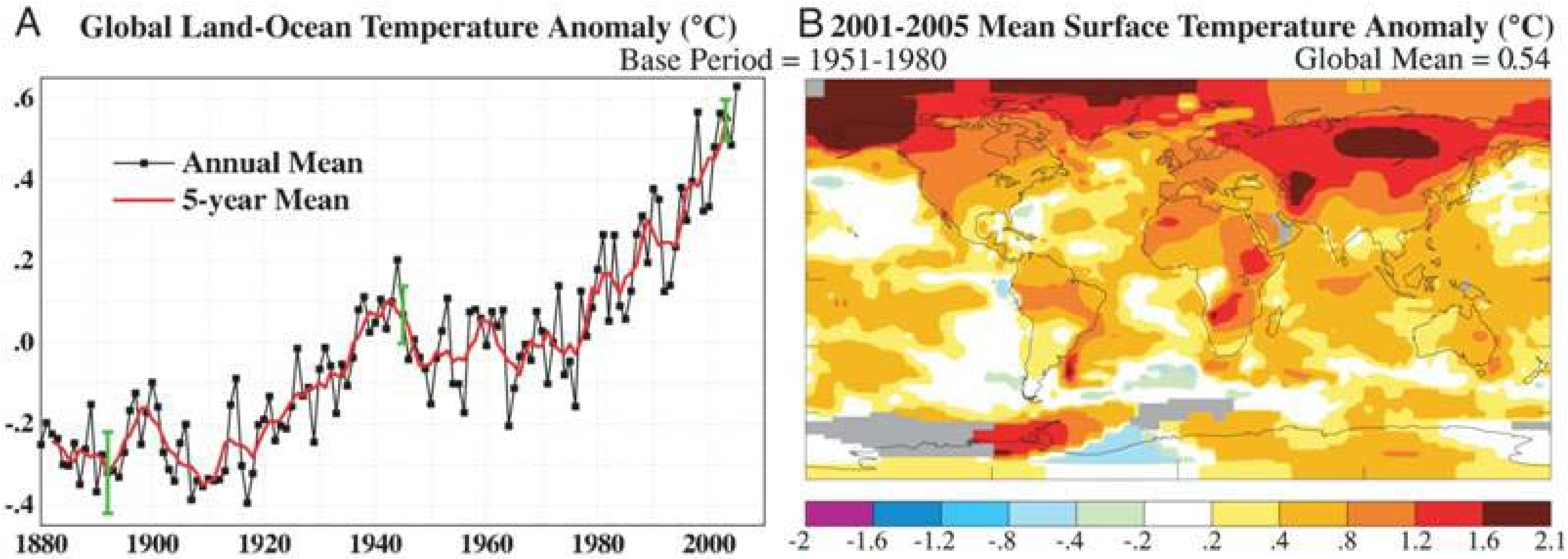
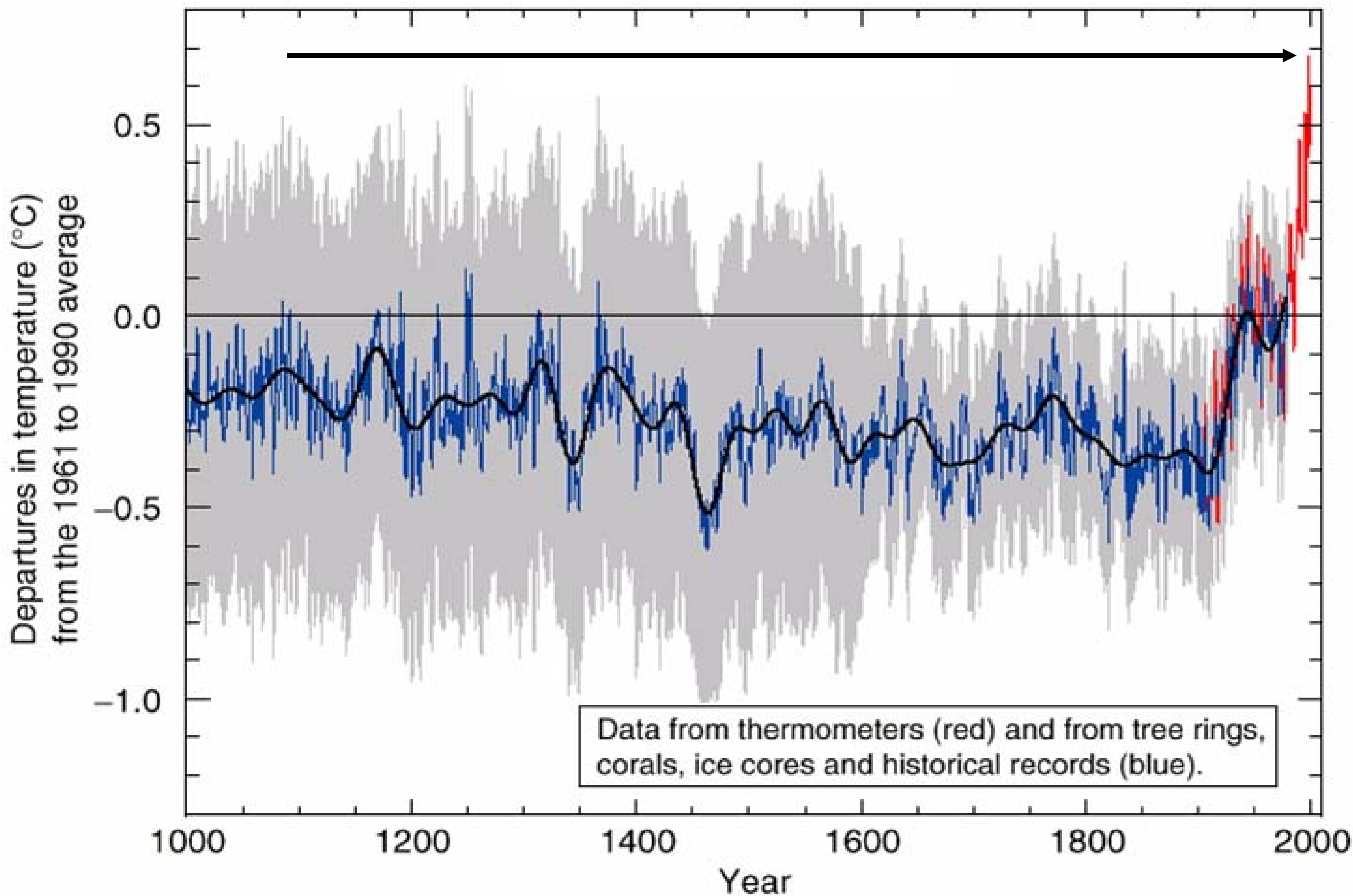


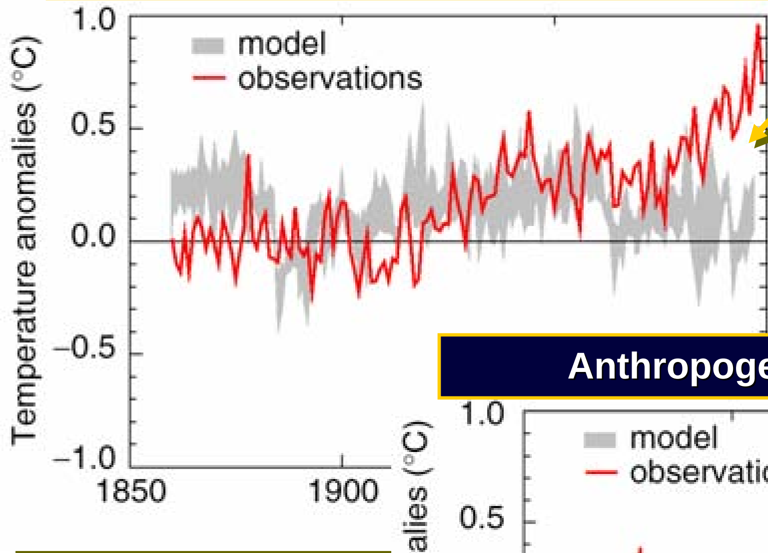
Fig. 1. Surface temperature anomalies relative to 1951–1980 from surface air measurements at meteorological stations and ship and satellite SST measurements. (*A*) Global annual mean anomalies. (*B*) Temperature anomaly for the first half decade of the 21st century.

Hansen et al. 2006

Northern Hemisphere Temperatures

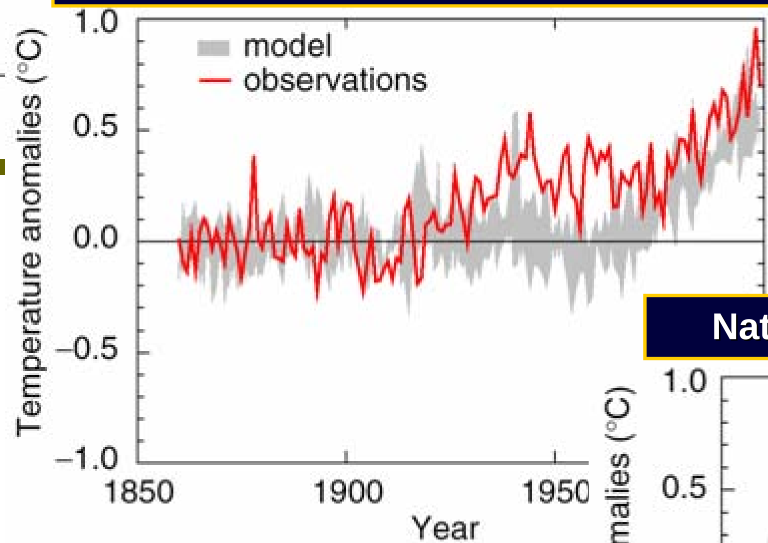


Natural Forcing



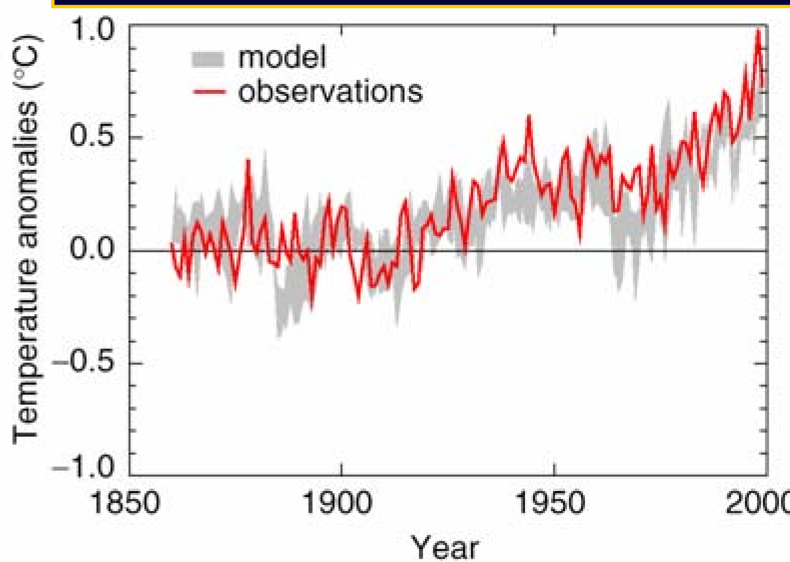
- Natural (solar + volcanic) forcing alone does not account for warming in the past 50 years.

Anthropogenic Forcing Only



- Human influences alone (greenhouse gases and sulfate aerosols) brings the models and observations into pretty good agreement.

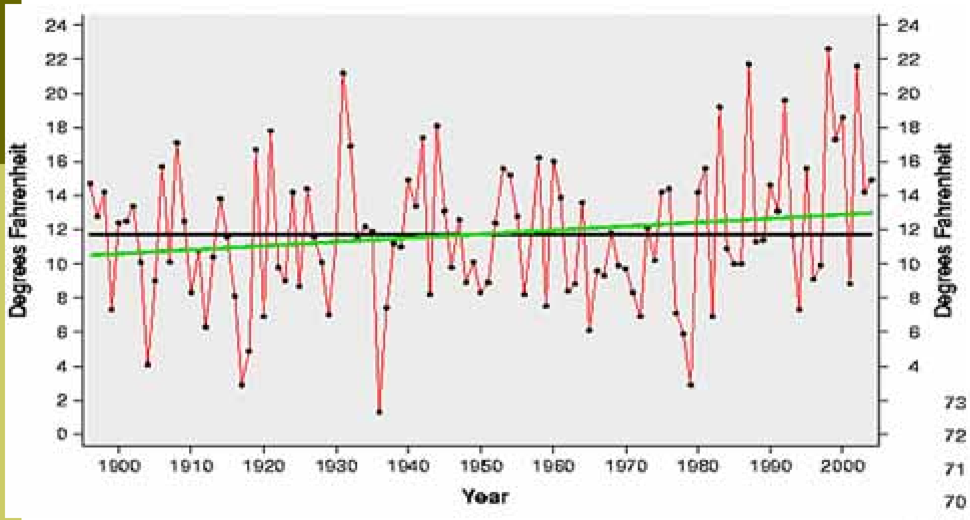
Natural and Anthropogenic Forcing



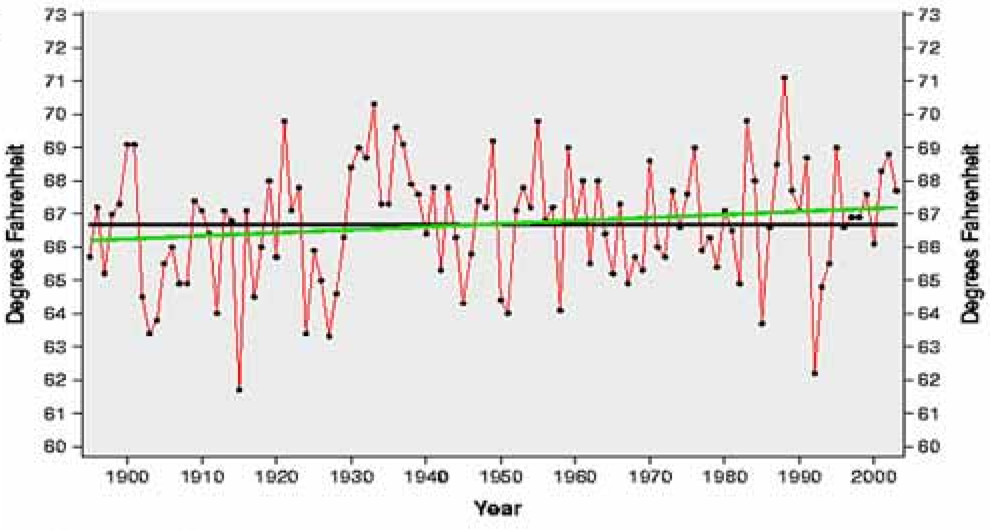
Global changes are much larger than can be explained by natural climate variability

Local Evidence for Global Warming
Minnesota Temperature Increases

MN Temperature Trends (1895-2004)



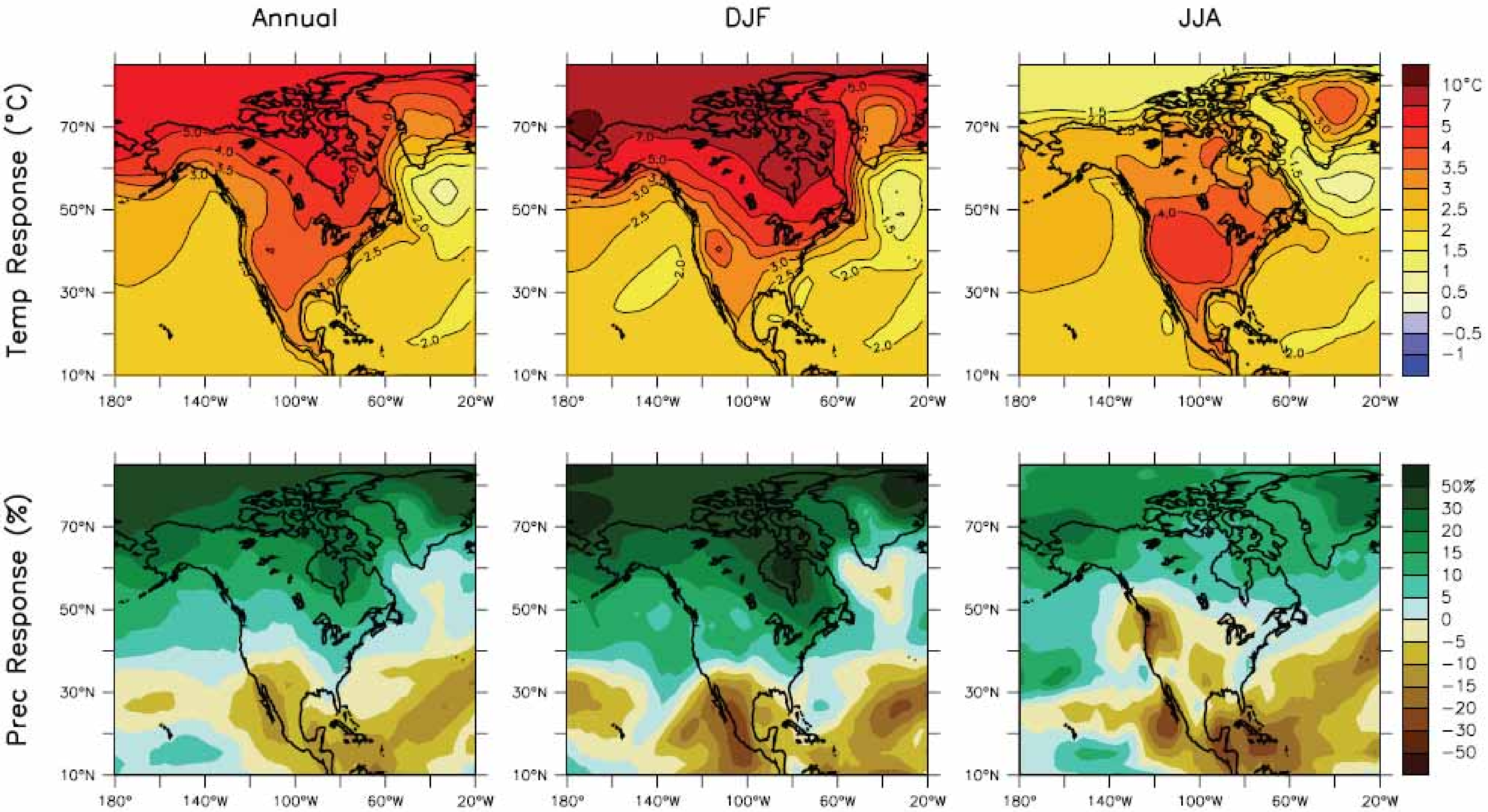
Winter +2.53^{o}F



Summer +1.0^{o}F

NCDC Climate at a Glance (http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html)

Projected Mean Temperature and Precipitation for North America



Projections of Precipitation

IPCC 4th Assessment, 2007

Temperature Projections for Minnesota*

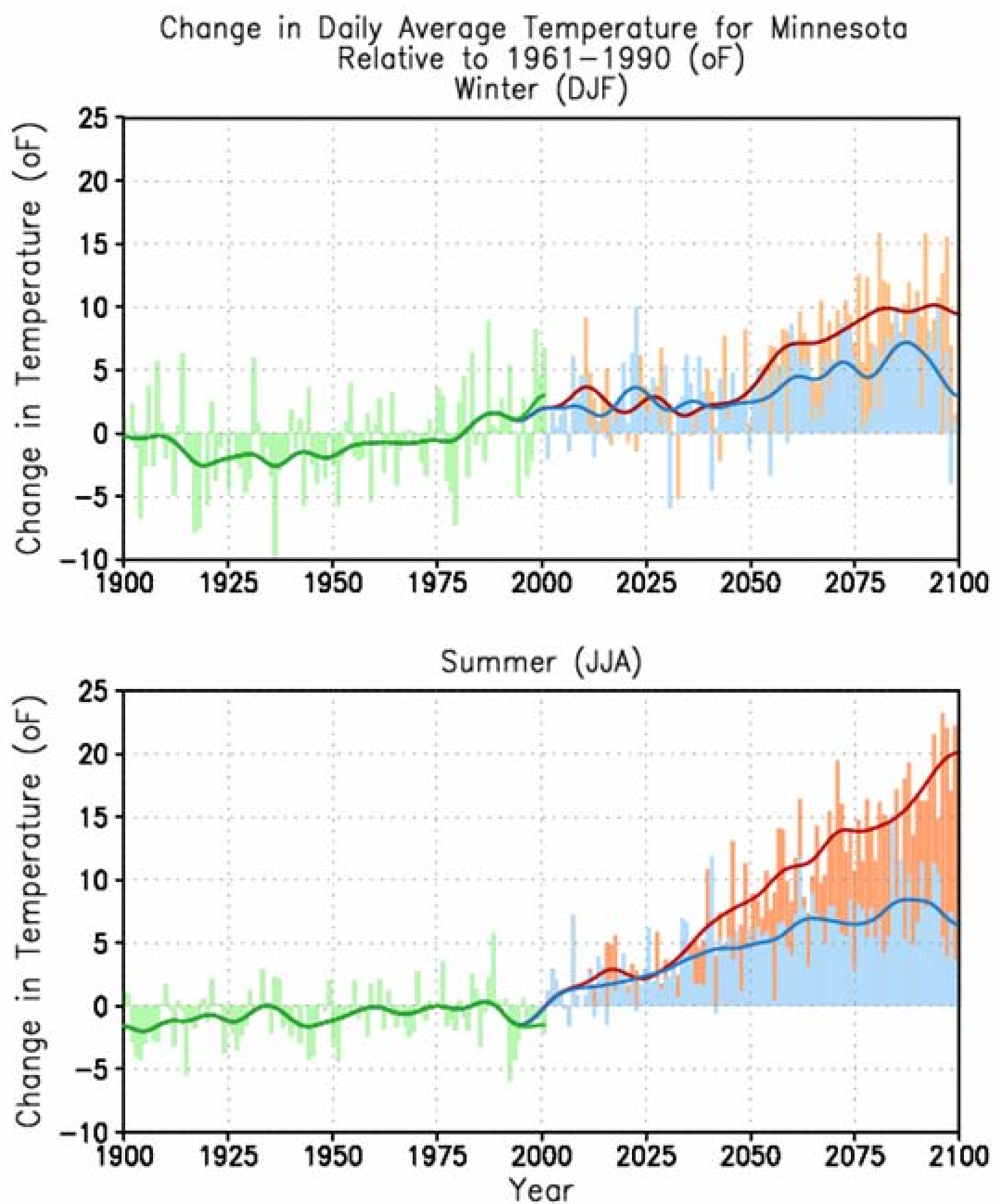
Historical Data

Lower Emissions

Higher Emissions

Steady increases
- 6-10ºF in winter
- 7-16ºF in summer

Growing season 3 – 6 weeks longer



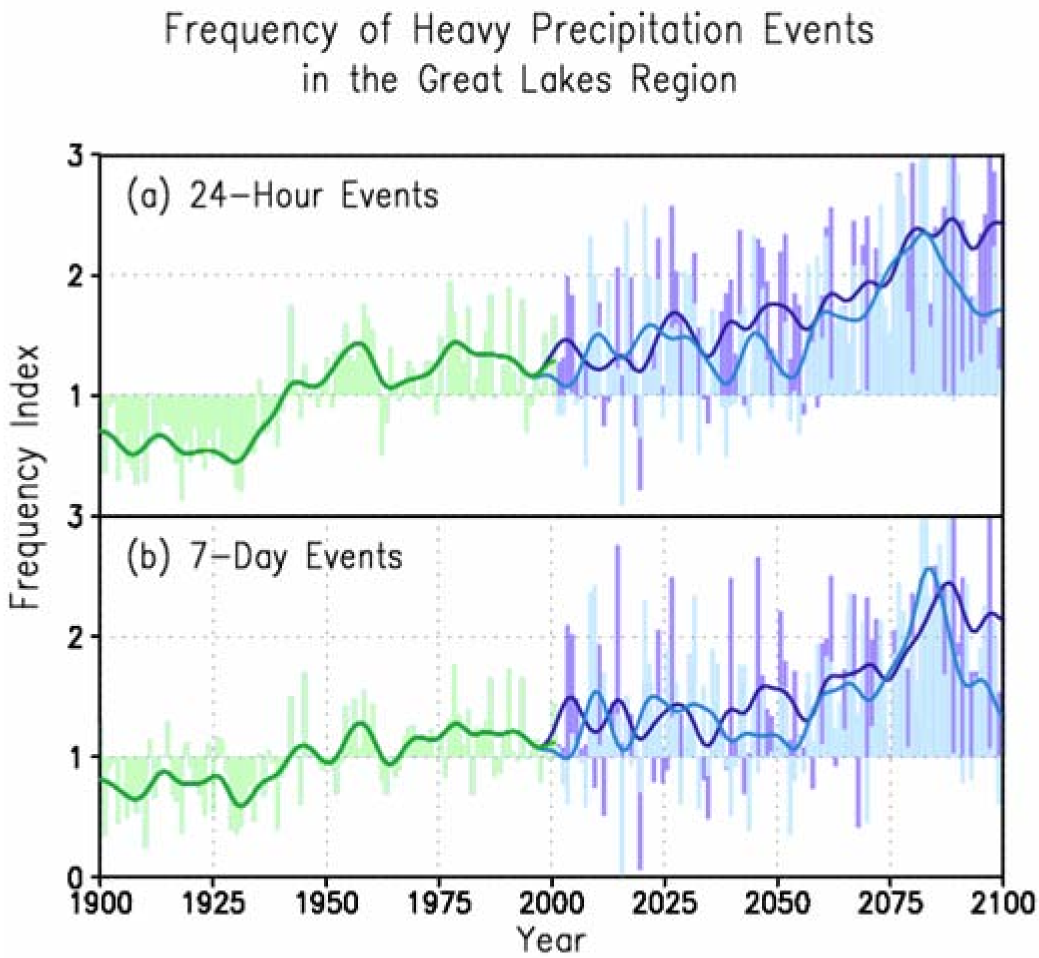
* Derived from HadCM3 & PCM (Wuebbles & Hayhoe 2004)

Projections of Intense Storm Events

Historical Data

Lower Emissions

Higher Emissions

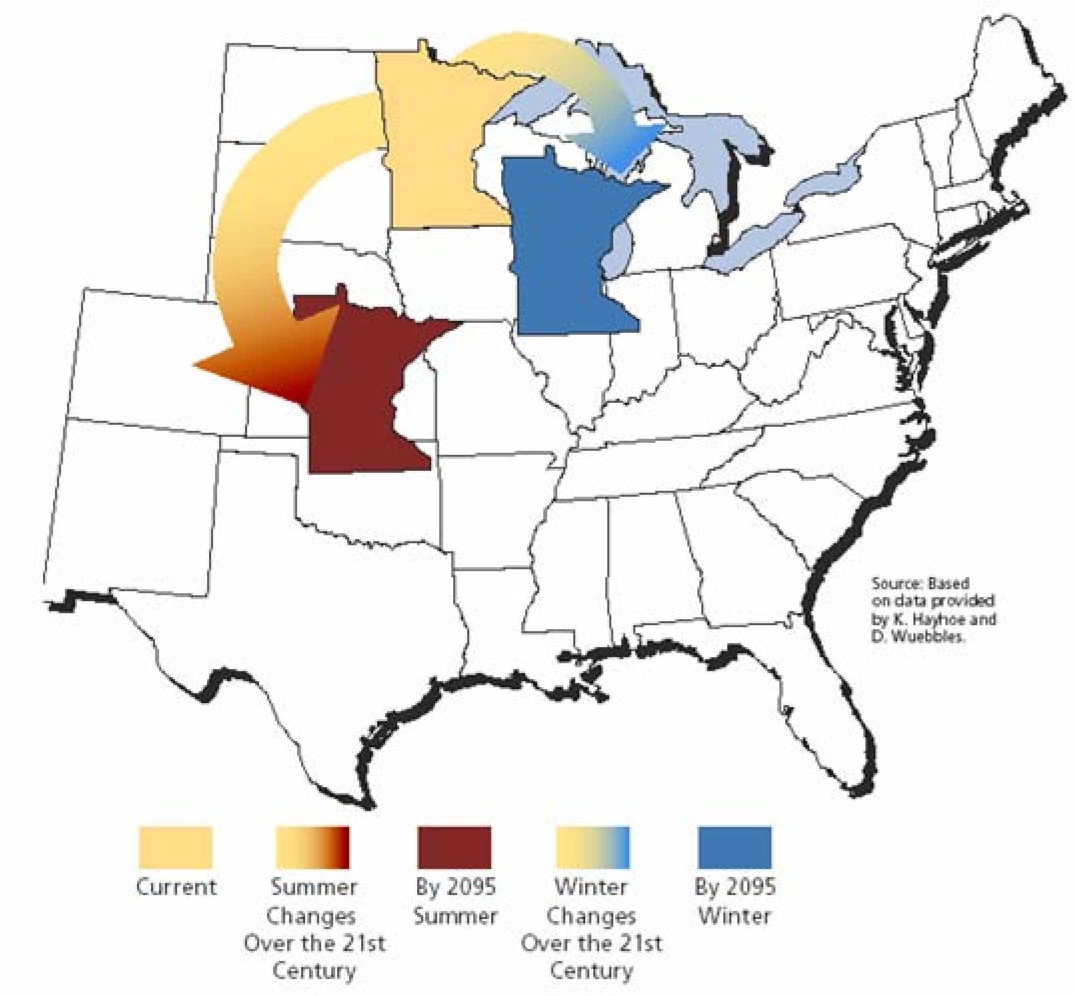


Changes in rainfall distribution

- Doubling of heavy rain events since 1900's
- Doubling again by 2100

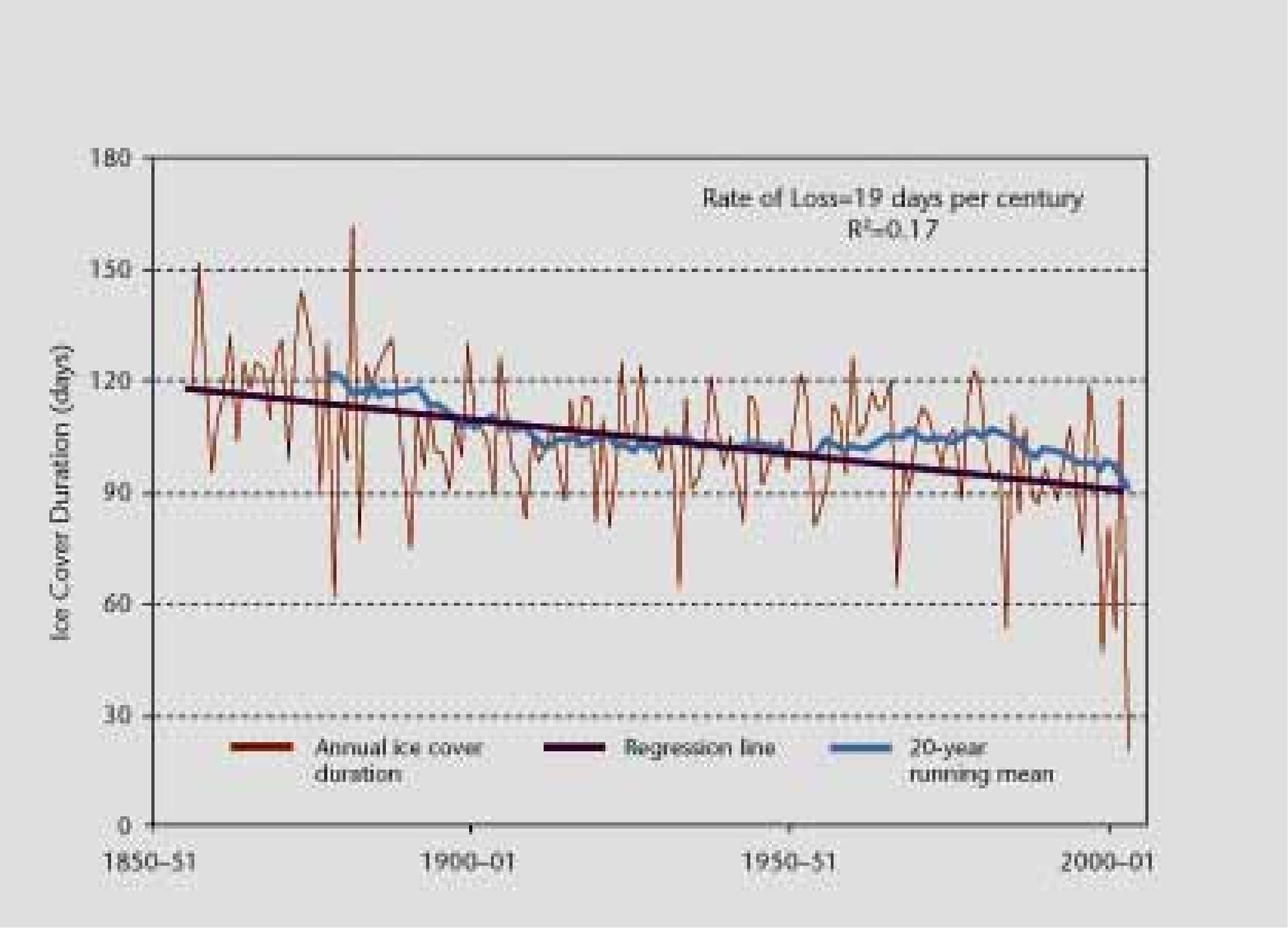
* Derived from HadCM3 & PCM (Wuebbles & Hayhoe 2004)

Where could Minnesota ‘move’ to?



Declining Ice Cover (Days)

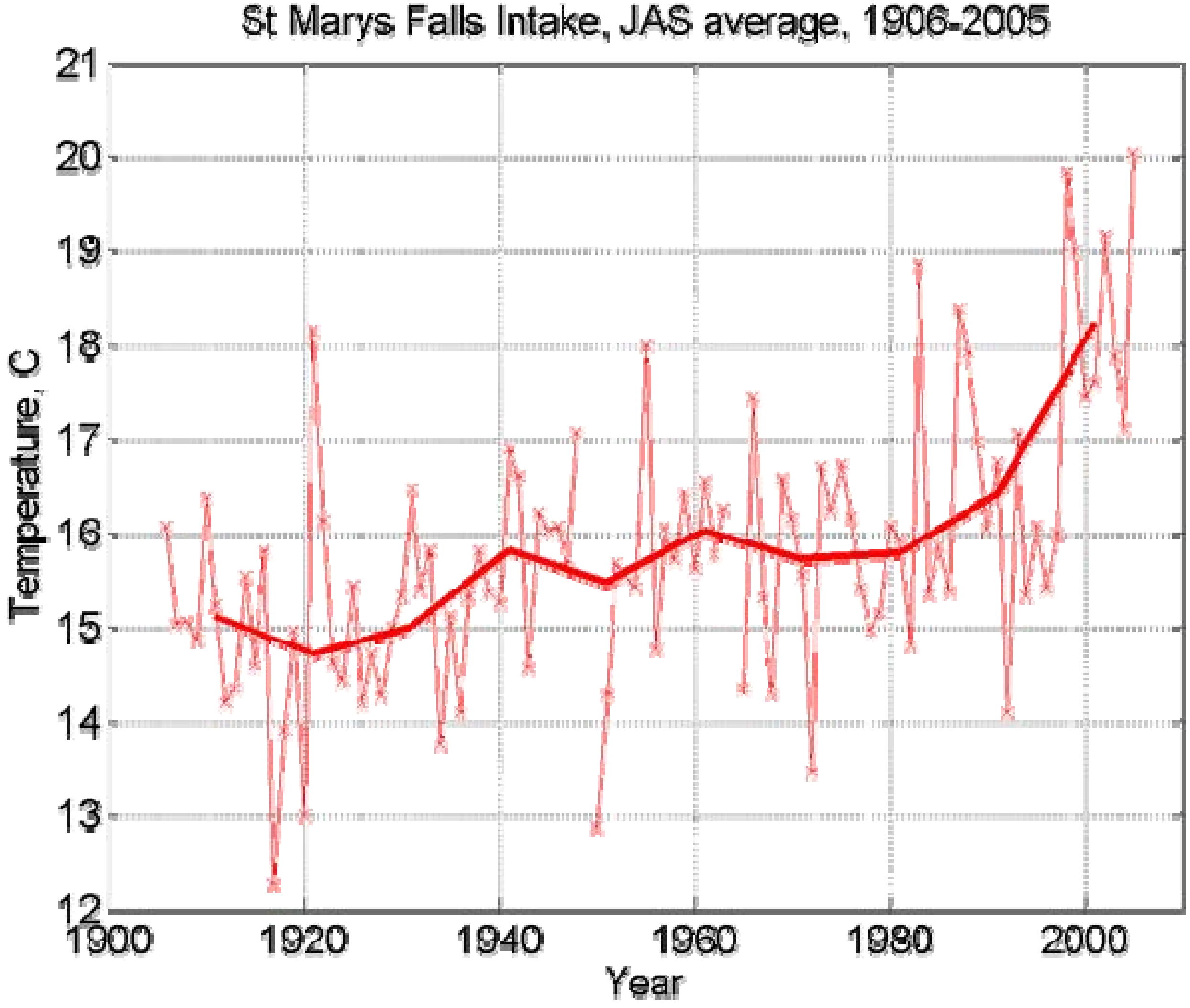
Lake Mendota, WI



Corresponds to ca. 1°C in Air Temperature per 100 Years

Summer Temperatures: Lake Superior

From: Jay Austin, in press.



Impacts of Changing Climate


pollution


flooding


fire


biodiversity

- **Ecosystems**
- **Agriculture**
- **Infrastructure**
- **Health**


mosquito


recreation

CLIMATE CHANGE WILL NOT OCCUR IN A VACUUM!

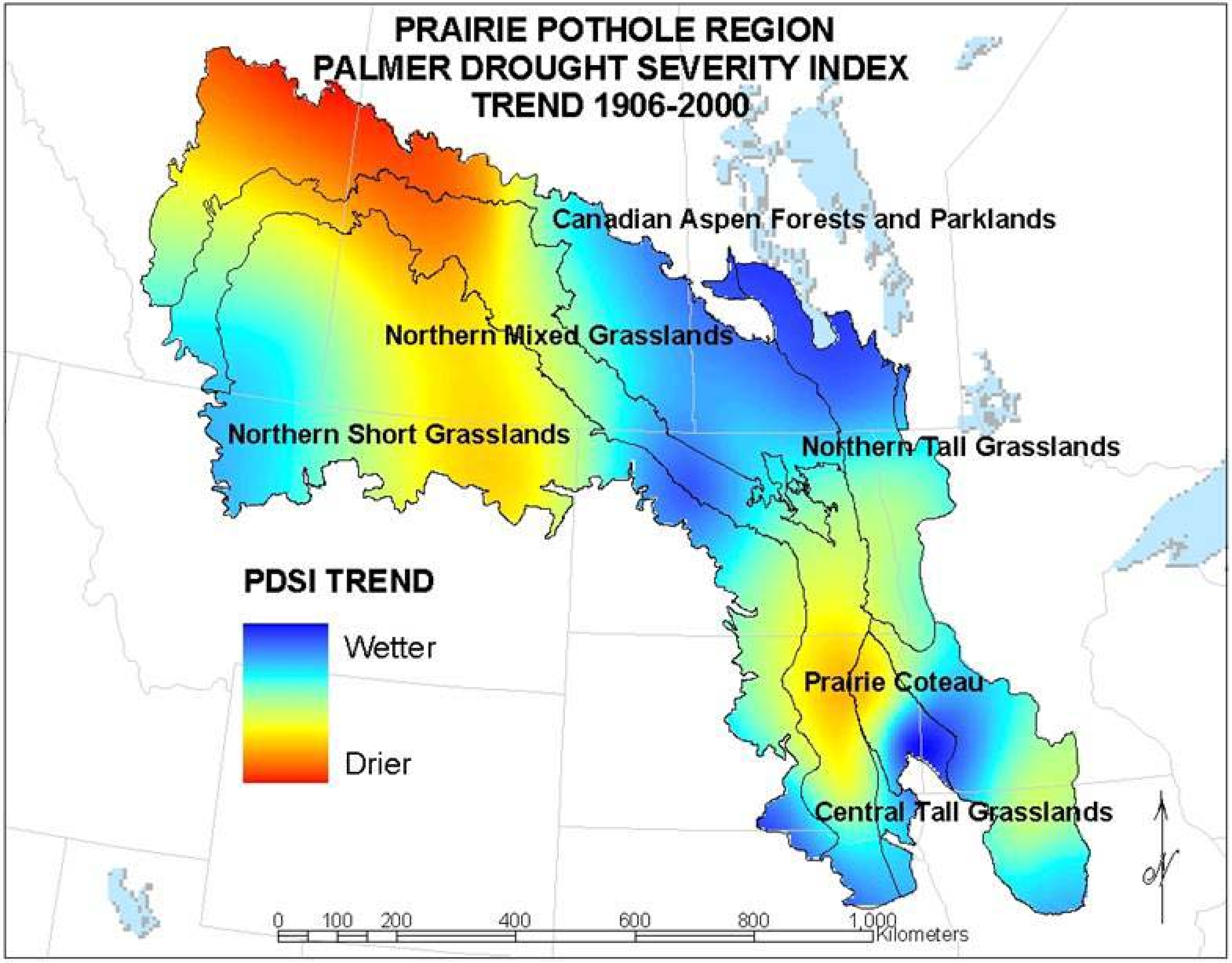
What we already know: Observed responses to recent climate change

- 50% of species studied worldwide show measurable response
- Every major group studied has been affected, and impacts have occurred on every major continent and in every major ocean
- Northward range shifts from 30 - 600 miles, and upward shifts of 300 - 2,000 feet (snow line) have occurred
- Almost everywhere, spring earlier & fall later, all taxa
- Parasites and their vectors have also shifted northward, some of these affect human health as well as wildlife

Parmesan & Yohe *Nature* 2003; Parmesan *AREES* 2006; IPCC 2007; Parmesan & Martens in press

Responding to climate change: Amphibians

- Biphasic life cycle
  - Aquatic and terrestrial
- Limited home range and dispersal capabilities
- Permeable skin
  - Sensitive to moisture gradients

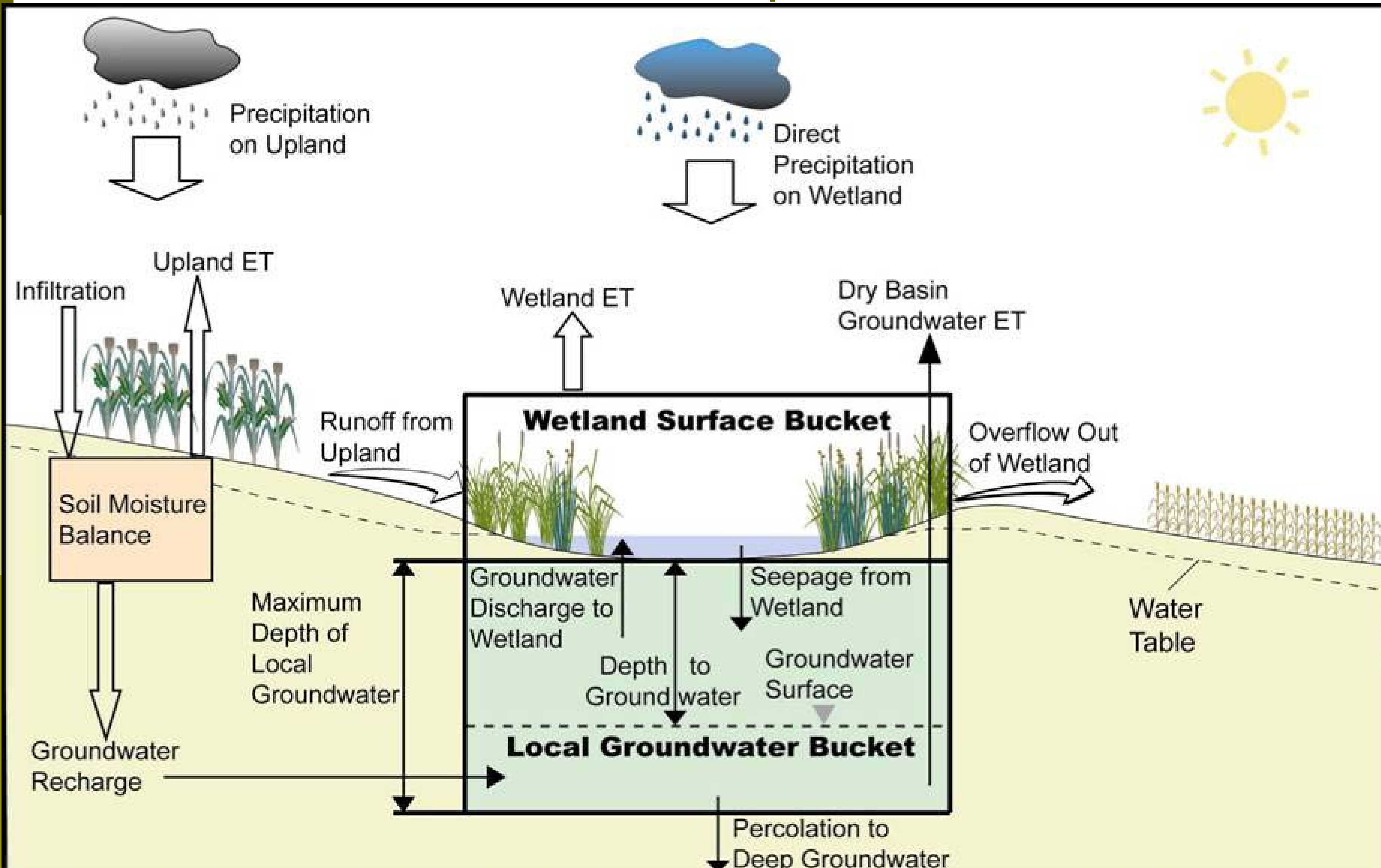


PRAIRIE POTHOLE REGION
PALMER DROUGHT SEVERITY INDEX
TREND 1906-2000
Canadian Aspen Forests and Parklands
Northern Mixed Grasslands
Northern Short Grasslands
Northern Tall Grasslands
Prairie Coteau
Central Tall Grasslands
PDSI TREND
Wetter
Drier
0
100
200
400
600
800
1,000
Kilometers
N

Case Study: N. Leopard Frog

- Quantify potential impacts of climate change on amphibian populations in the Prairie Pothole Region of the United States.
  - Case study: northern leopard frog
  - Scenarios:
    - 2 and 4 °C temperature increases
    - - 5%, +5. +10% precipitation

WETLANDSCAPE:
A Multi-basin wetland complex model



Johnson, C., et al. 2005. Bioscience.

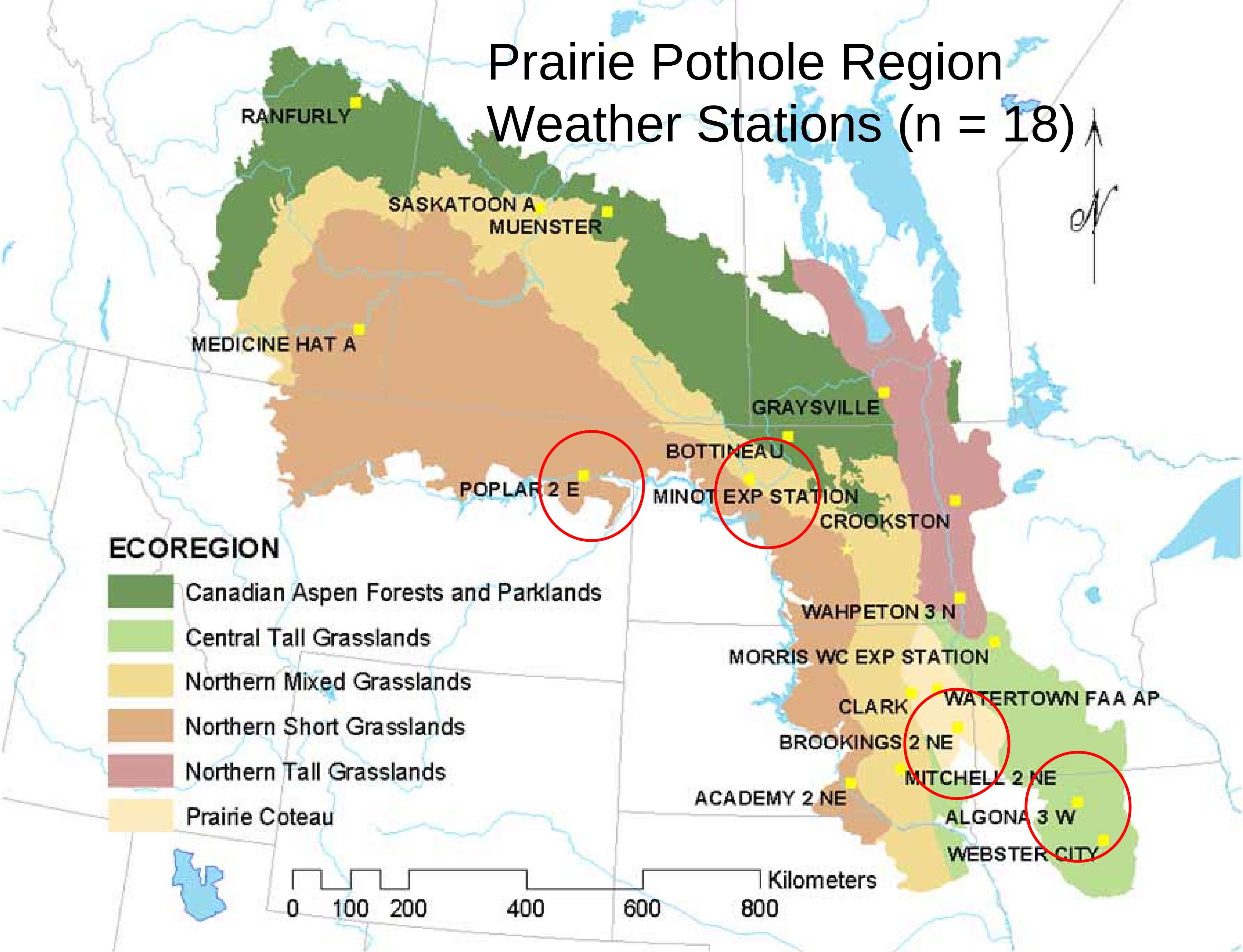
N. Leopard Frog species traits

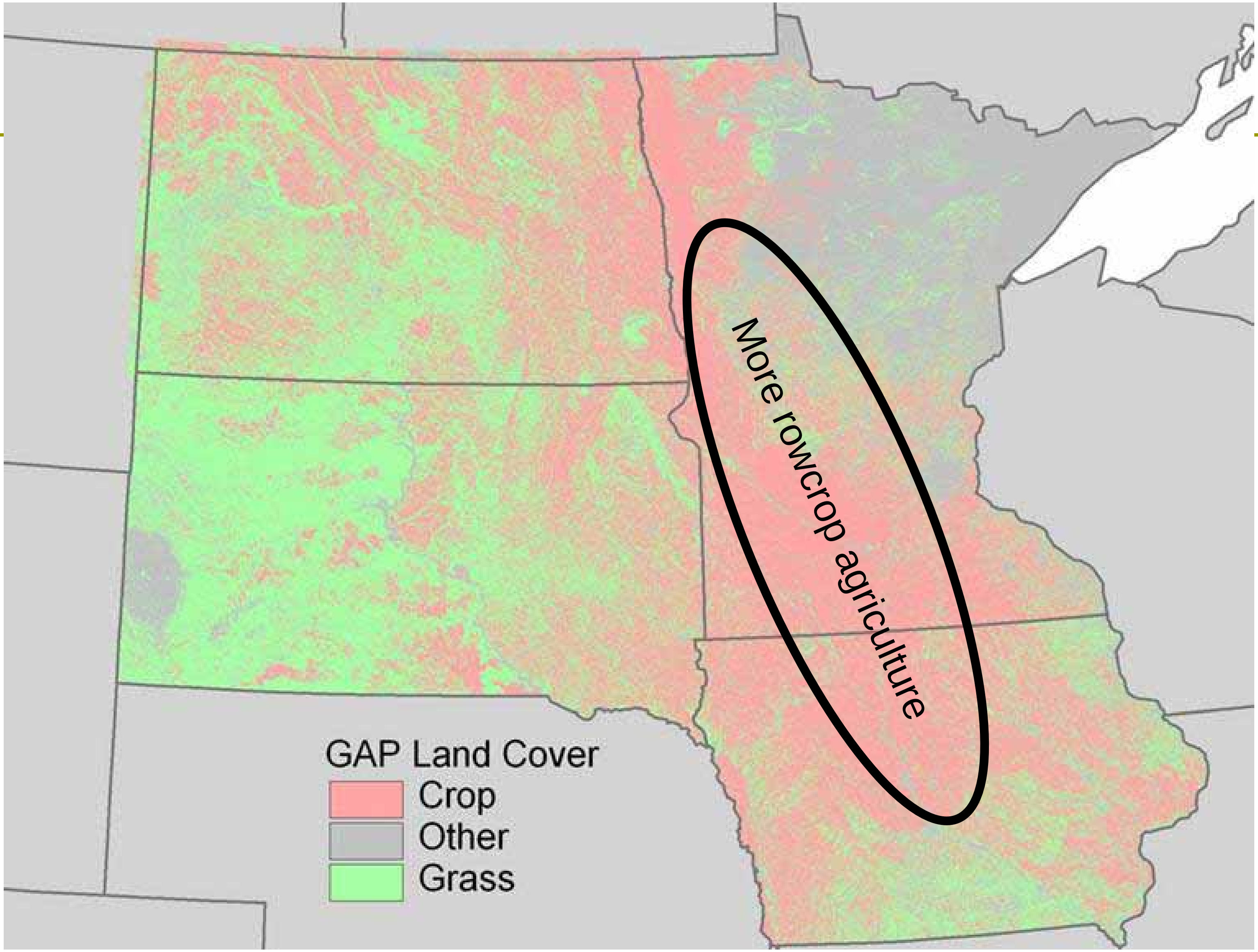
- Preferred habitat type for breeding
  - Seasonal wetlands
- Timing breeding (days post-snowmelt)
  - 1st week of April current average initiation date
- Development time (egg to metamorphosis)
  - 90 – 120 days

Modeling

- Preliminary findings based on four weather stations
  - increased temperature of 2 and 4 °C;
  - - 5%, + 5%, + 10% precipitation
- Initiation of breeding: March 1
- Development time: 90 - 120 days
- Output:
  - Number of days of inundation following March 1 (date set for onset of breeding)
  - Number of years (out of 100) with minimum water for 90, 120 days following March 1.

Prairie Pothole Region Weather Stations (n = 18)

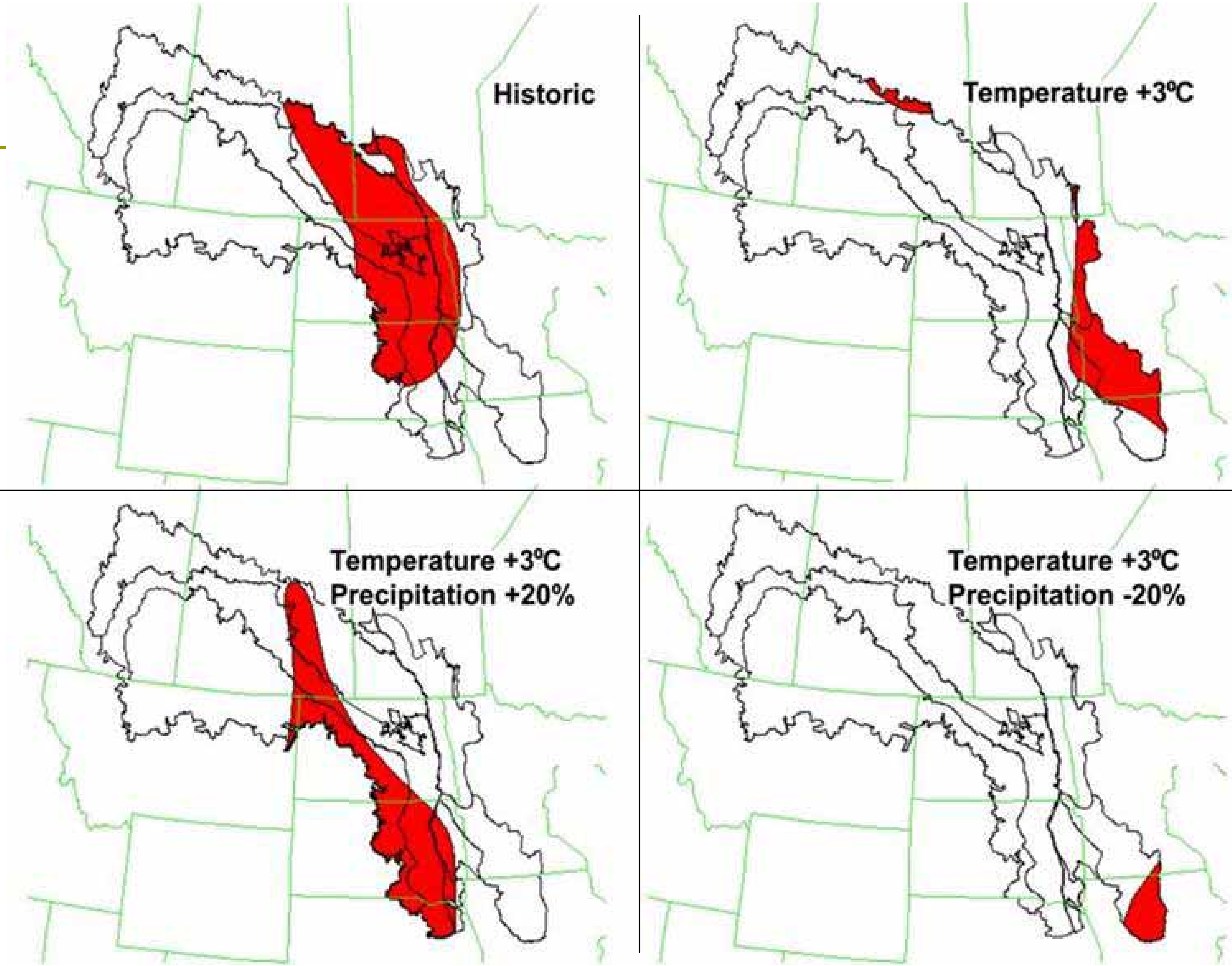



More rowcrop agriculture
GAP Land Cover
Crop
Other
Grass

Conclusions-Science continued

- **Suitable hydrologic regimes to sustain amphibian populations could shift to the south and east**
- **These areas have a lower density of wetlands and higher agricultural pressure, landscape conditions not optimal for leopard frogs**

Model simulations that locate the most favorable wetland conditions for breeding waterfowl under historic and alternative future climates.



Carter Johnson, et al. 2005. Vulnerability of Northern Prairie wetlands to climate change. BioScience 55:863-872.

Warming Climate & Forests

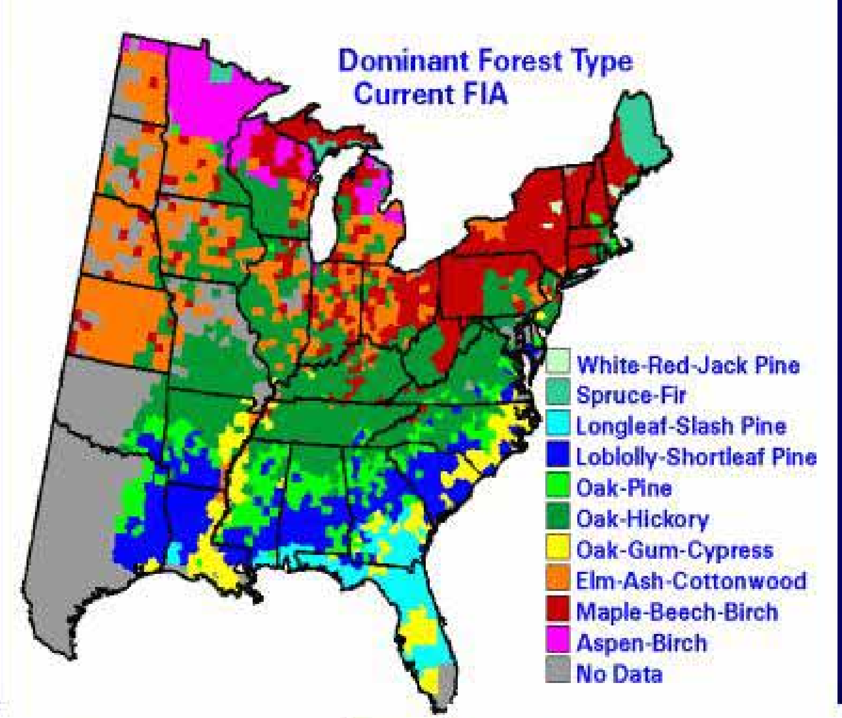
- Grasslands expand north & east;
- Maple & oak will expand their ranges northward;
- Boreal forests will disappear;

- Higher CO_2 and N could increase short-term forest productivity, but …

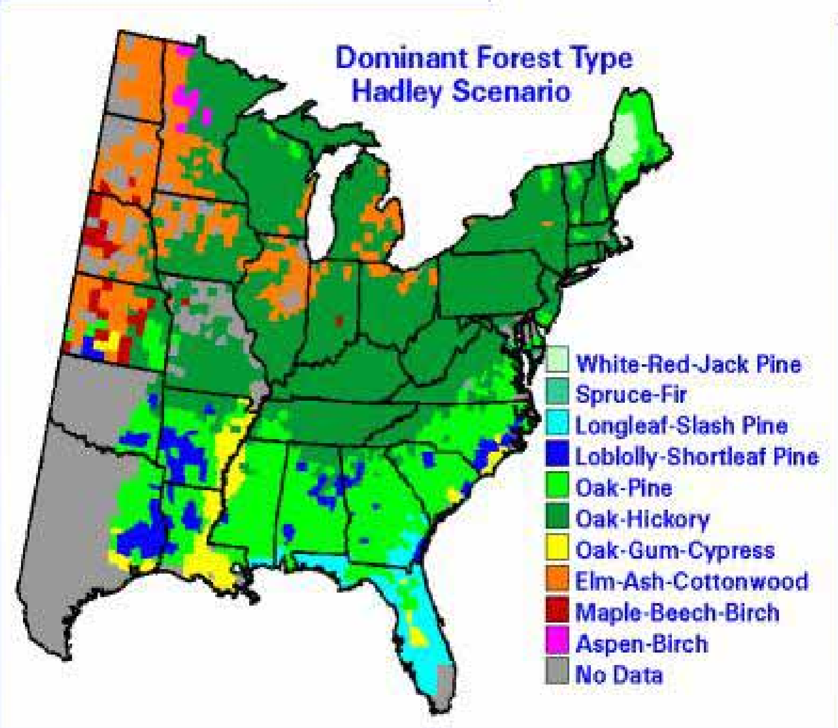
Forestry

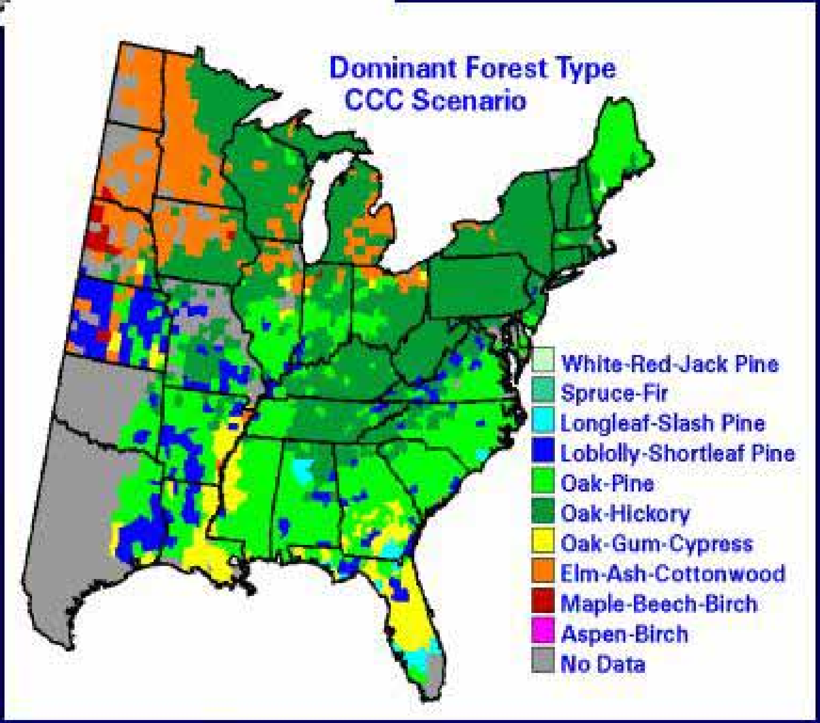
- Higher ozone, more frequent droughts, forest fires, lower soil moisture will stress forest species
- Greater risk from insect pests could damage long-term forest health
- Forest species composition will change, impacting paper and saw timber industries

Photo: USDA Forest Service



From: Louis Iverson



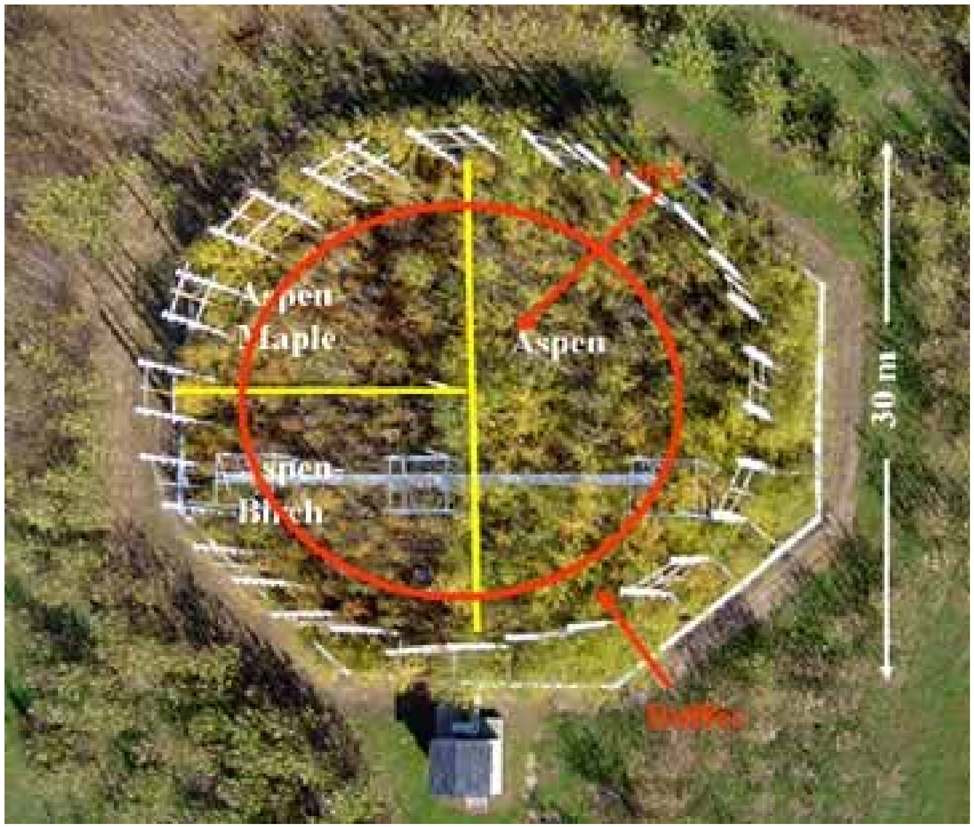


Effects on forests and food webs

herbivory

ozone damage

leaf quality



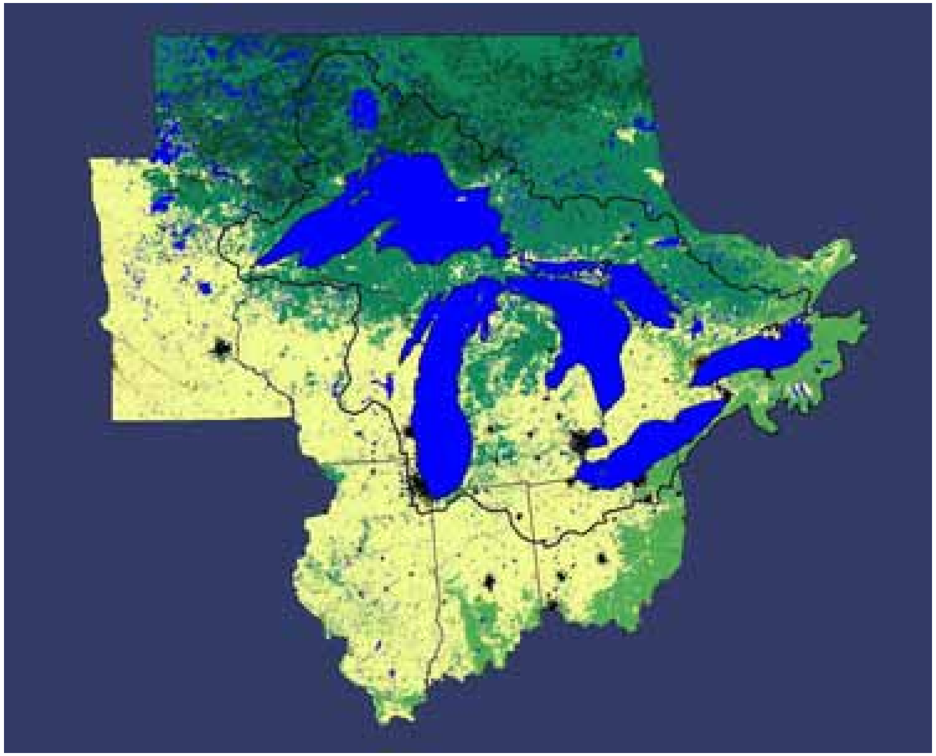
litter quality

invasive species

phenology

range expansions and contractions

Surface Geology & Land Use

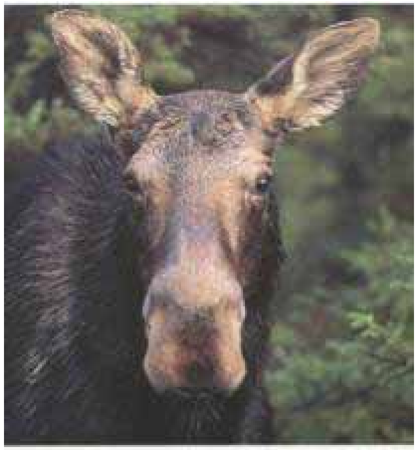


- Impervious and thin soils limit agriculture, other land use activities
  - Although climate may warm, corn and soybeans will not grow on bedrock and in thin soils
- Alter hydrologic responses to floods and drought

Wildlife Health

- Cold-related health problems will decline while heat-related morbidity and mortality will increase
- Extreme heat more likely:
  - 40+ days exceeding 90°F
  - 10-25 days exceeding 97°F
- Higher ground-level ozone concentrations
- Waterborne and other vector-borne infectious diseases may become more frequent and widespread (Lyme; West Nile virus)
- Parasites (e.g., chichrid fungus, ticks)
- Extreme weather (migratory birds, nesting survival)

Source: USDA



snowe.senate.gov/images

Climate Change and the Spread of Infectious Diseases

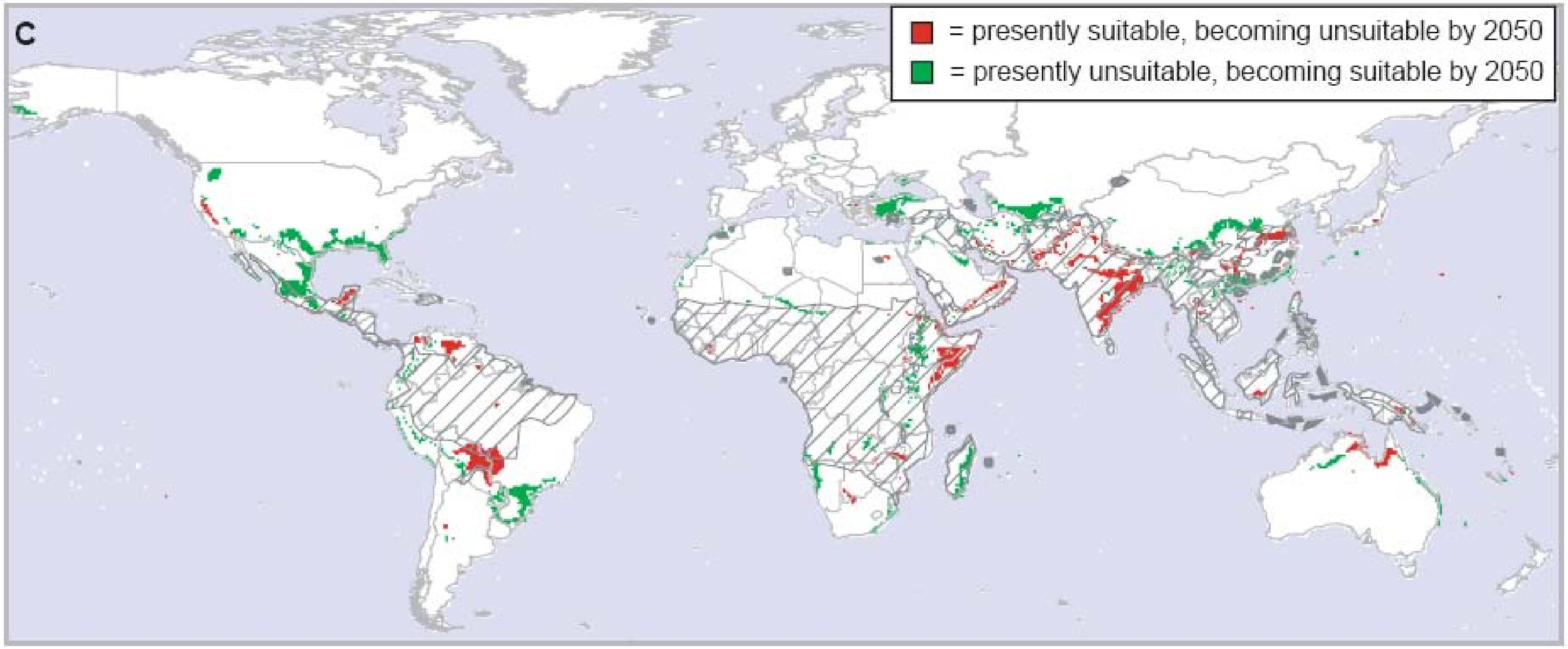
- Infectious diseases are often spread by animal hosts (mosquitoes, ticks, mammals)
- As the climate warms, the habitats of these hosts will shift
- This will cause infectious diseases to spread to new areas where they are not now found
- Example: Two degree Centigrade warming in New York City gets you Anopheles mosquitoes (host for malaria)

REPORTS

The Global Spread of Malaria in a Future, Warmer World

David J. Rogers[1*] and Sarah E. Randolph[2]

SCIENCE VOL 289 8 SEPTEMBER 2000



SCIENCE VOL 289 8 SEPTEMBER 2000

The Ecology of Lyme-Disease Risk

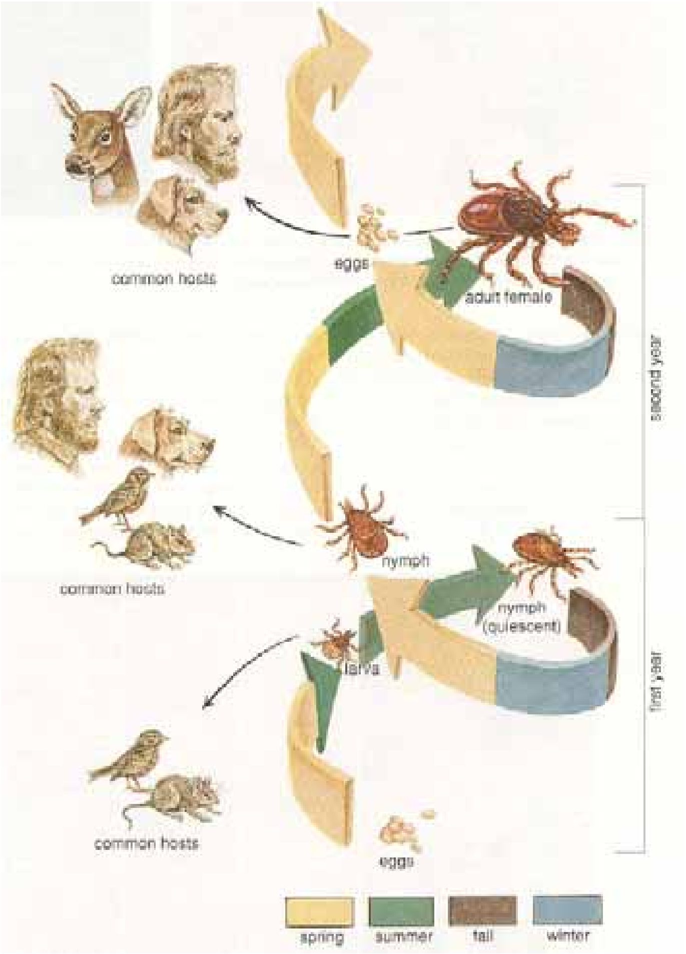
Complex interactions between seemingly unconnected phenomena determine risk of exposure to this expanding disease

Richard S. Ostfeld

American Scientist, Volume 85 1997 July–August

Spread of Lyme Disease northward

- Lyme disease is spread by deer tick
- The tick requires deer only in its adult phase
- In larval phases, the tick requires white-footed mice as a host
- White footed mice live in oak forests and are currently uncommon in northern Minnesota
- With global warming, oak forests move northward, bring white footed mice, deer ticks, and Lyme disease



Indicators of Ecosystems in Jeopardy

population reductions

Human epidemiology
- cancers
- asthma
- heart disease

Emerging diseases of wildlife

- CWD
- BSE / vJCD
- AIDS
- SARS
- Ebola
- Avian Influenza
- West Nile Virus

local extinctions

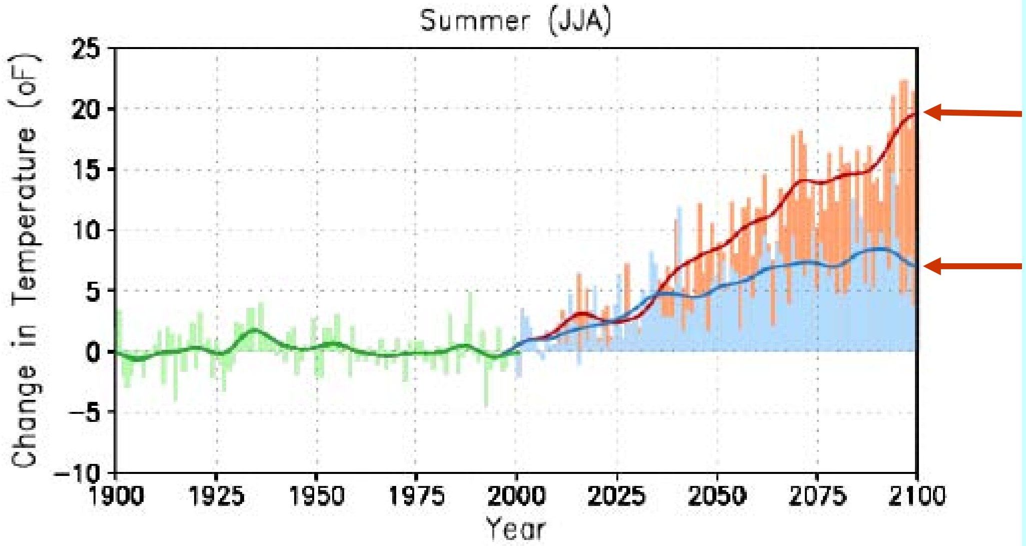
Emerging diseases in humans

Wildlife epidemiology
- intersex
- parasites
- cancers
- malformation

species extinction

exotic / invasive species

Predicted Temperature Changes



Model predictions using "business as usual" versus "conservation" scenarios result in very different degrees of warming by 2100.

We can dampen the rate of increase by reducing carbon emissions.

Management Issues

- Monitoring and assessment
  - Water quality and quantity
  - Biodiversity / non-indigenous species
  - Disease
  - Toxic chemicals
  - Fire
- Harvest Practices
  - Riparian zone management
- Conservation, Restoration, Mitigation
- Risk assessment
  - Refugia: at-risk species and ecosystems
  - Heat Stress
  - Infrastructure damage

Management
Issues & Recommendations

- Alleviate effects of other stressors.
- Implement conservation options at every opportunity.
- Practice dynamic rather than static planning;
- Revise infrastructure planning standards
- Reassess landform classifications to evaluate relative vulnerabilities to climate change;
- Implement conservation, restoration and land management that account for the shifts in the distribution of target species and ecosystem;
- Promote planting of native vegetation, especially in riparian zones;

Easy Things You Can Do To Help Our Climate

- **TIP: Travel light**. Walk or bike instead of driving a car. Cars and trucks run on fossil fuels, which release carbon dioxide into the atmosphere. In the United States, automobiles produce over 20 percent of total carbon emissions. Walk or bike and you'll save one pound of carbon for every mile you travel.
- **TIP: Teleconference instead of flying**. For office meetings, if you can telephone or videoconference, you will save time, money, and carbon emissions. Airplanes pump carbon emissions high into the atmosphere, producing 12 percent of transportation sector emissions.
- **TIP: See the light**. Use compact fluorescent light bulbs. These energy-efficient bulbs help fight climate change because they reduce the amount of fossil fuels that utilities burn. You will save 100 pounds of carbon for each incandescent bulb that you replace with a compact fluorescent, over the life of the bulb.
- **TIP: Recycle and use recycled products**. Products made from recycled paper, glass, metal and plastic reduce carbon emissions because they use less energy to manufacture than products made from completely new materials. For instance, you'll save two pounds of carbon for every 20 glass bottles that you recycle. Recycling paper also saves trees and lets them continue to reduce climate change naturally as they remain in the forest, where they remove carbon from the atmosphere.
- **TIP: Inflate your tires**. If you own a car, it will get better gas mileage when the tires are fully inflated, so it will burn less gas and emit less carbon. Check your automobile monthly to ensure that the tires are fully inflated. Follow this tip and save 300 pounds of carbon dioxide for every 10,000 miles you drive.
- **TIP: Plant native trees**. Trees absorb carbon dioxide from the air and use it as their energy source, producing oxygen for us to breathe. A tree in the temperate zone — found between the tropics and the polar circles—can remove and store 700 to 7,000 pounds of carbon over its lifetime. A tree that shades a house can reduce the energy required to run the air conditioner and save an additional 200 to 2,000 pounds of carbon over its lifetime.
- **TIP: Turn down the heat**. Heating and air conditioning draw more than half of the energy that a home uses in the United States. Turn down the heat or air conditioning when you leave the house or go to bed. You can easily install a programmable thermostat that can save up money and carbon.
- **TIP: Buy renewable energy**. Electricity generation produces 40 percent of carbon emissions from the United States. A growing number of utilities generate electricity from renewable energy sources with solar panels, windmills and other technologies. If your utility offers renewable energy, buy it. If not, send them a message asking for clean energy.
- **TIP: Act globally, eat locally**. If you shop at a supermarket, the food you buy may travel in a plane from the other side of the world, burning fossil fuels the entire trip. Shop at a local farmers' markets and you will find fresh and healthy food, and help save our climate.

http://www.nature.org/initiatives/climatechange/activities/art19630.html

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