# Climate Change (a.k.a. Challenge) 101 for Fruit Growers

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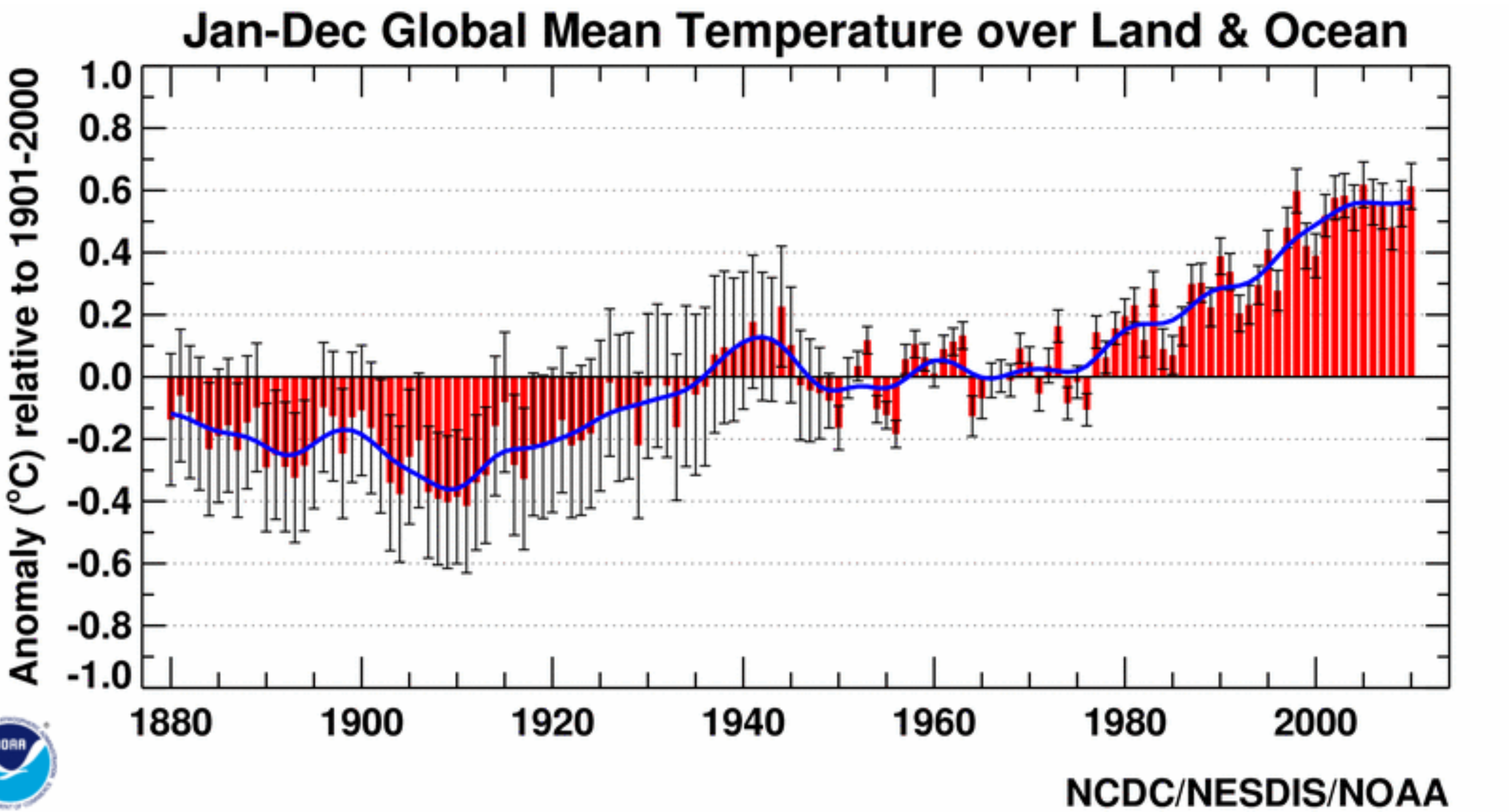
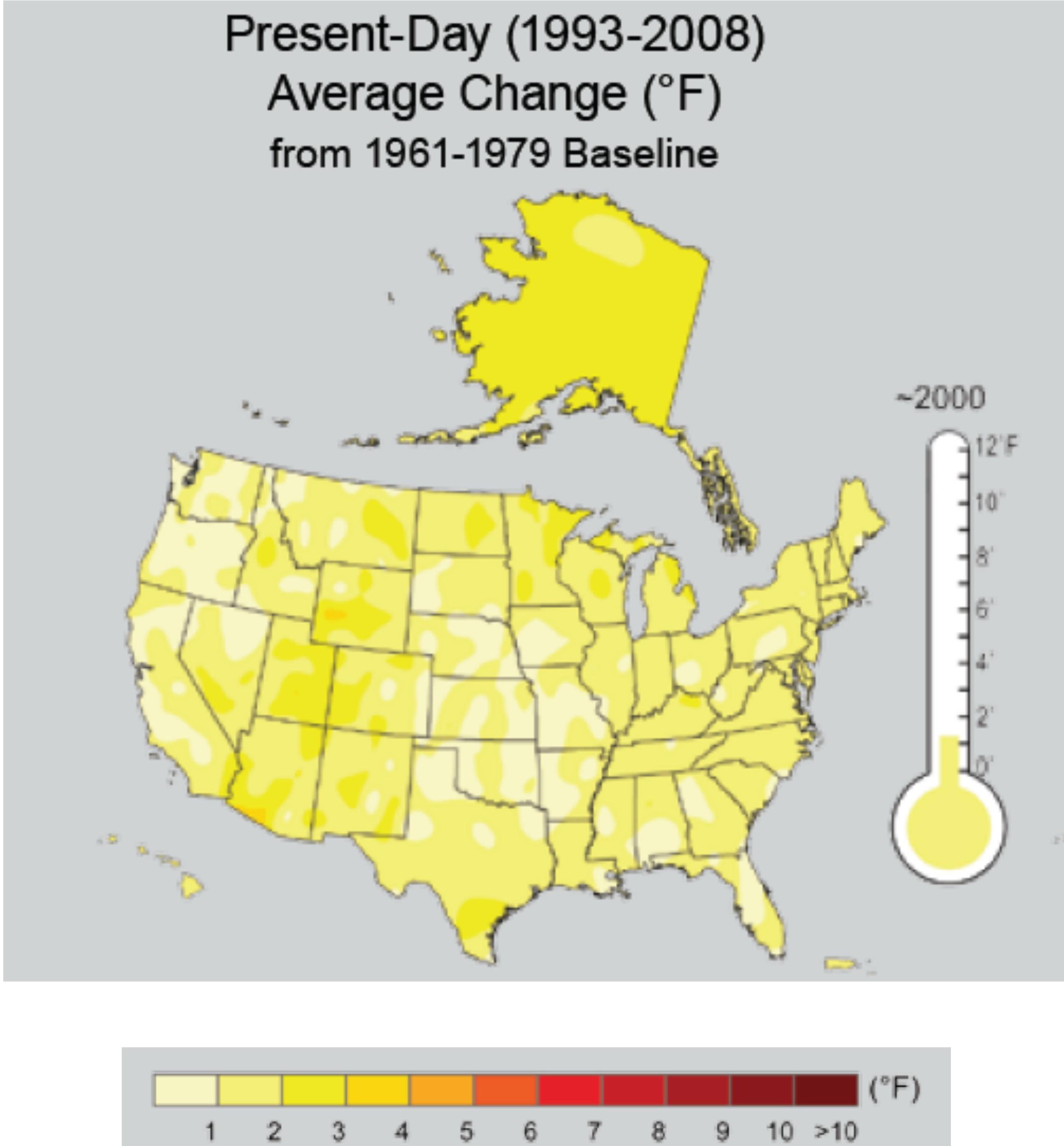
# Outline

- Historical Trends
- Future Projections
- Potential Impacts

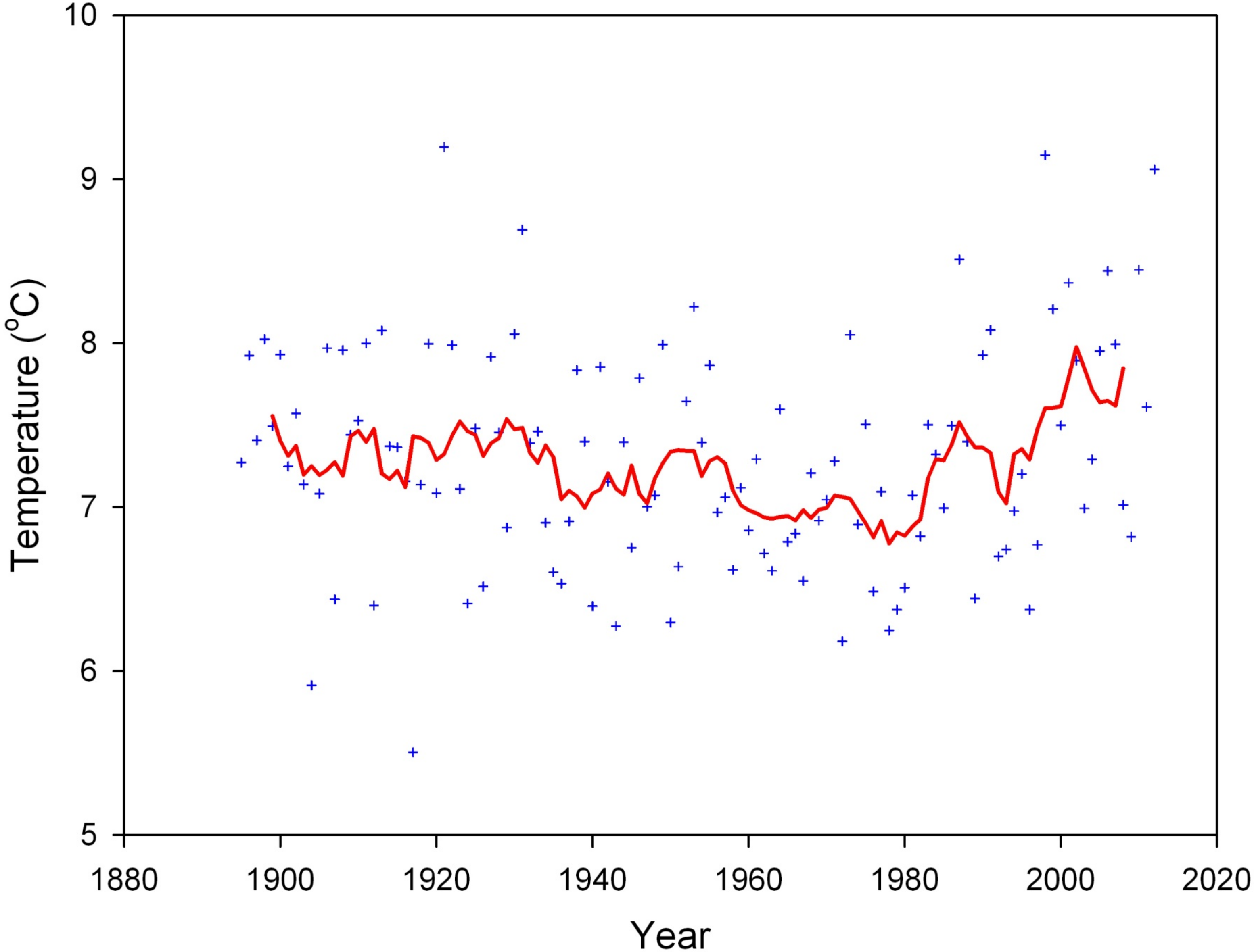
# Historical Trends


300,000 Years Ago
200,000 Years Ago
100,000 Years Ago
Today
-60°
-64°
-68°
-72°
-76°
-80°
-84°
300
280
260
240
220
200
180
TEMPERATURE
CO2 CONCENTRATION
This graph is based on on ice cores drilled in Vostok, Antarctica. It shows temperature changes near the South Pole, which were more extreme than in the middle latitudes.
YOUNGER DRYAS
(Primarily a Northern Hemisphere Phenomenon, Not Visible In The Vostok Ice Core Data)
EL NIÑO
(Not Known When El Niño Events First Began)
ICE AGE/ INTERGLACIAL CYCLES
TEMPERATURE IN ANTARCTICA IN °F
CARBON DIOXIDE CONCENTRATION IN PPM


Jan-Dec Global Mean Temperature over Land & Ocean
Anomaly (°C) relative to 1901-2000
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1880
1900
1920
1940
1960
1980
2000
NCDC/NESDIS/NOAA


Present-Day (1993-2008)
Average Change (°F)
from 1961-1979 Baseline
~2000
12°F
10°
8°
6°
4°
2°
0°
(°F)
1 2 3 4 5 6 7 8 9 10 >10

Mean Temperatures vs. Year, Michigan
1895-2012

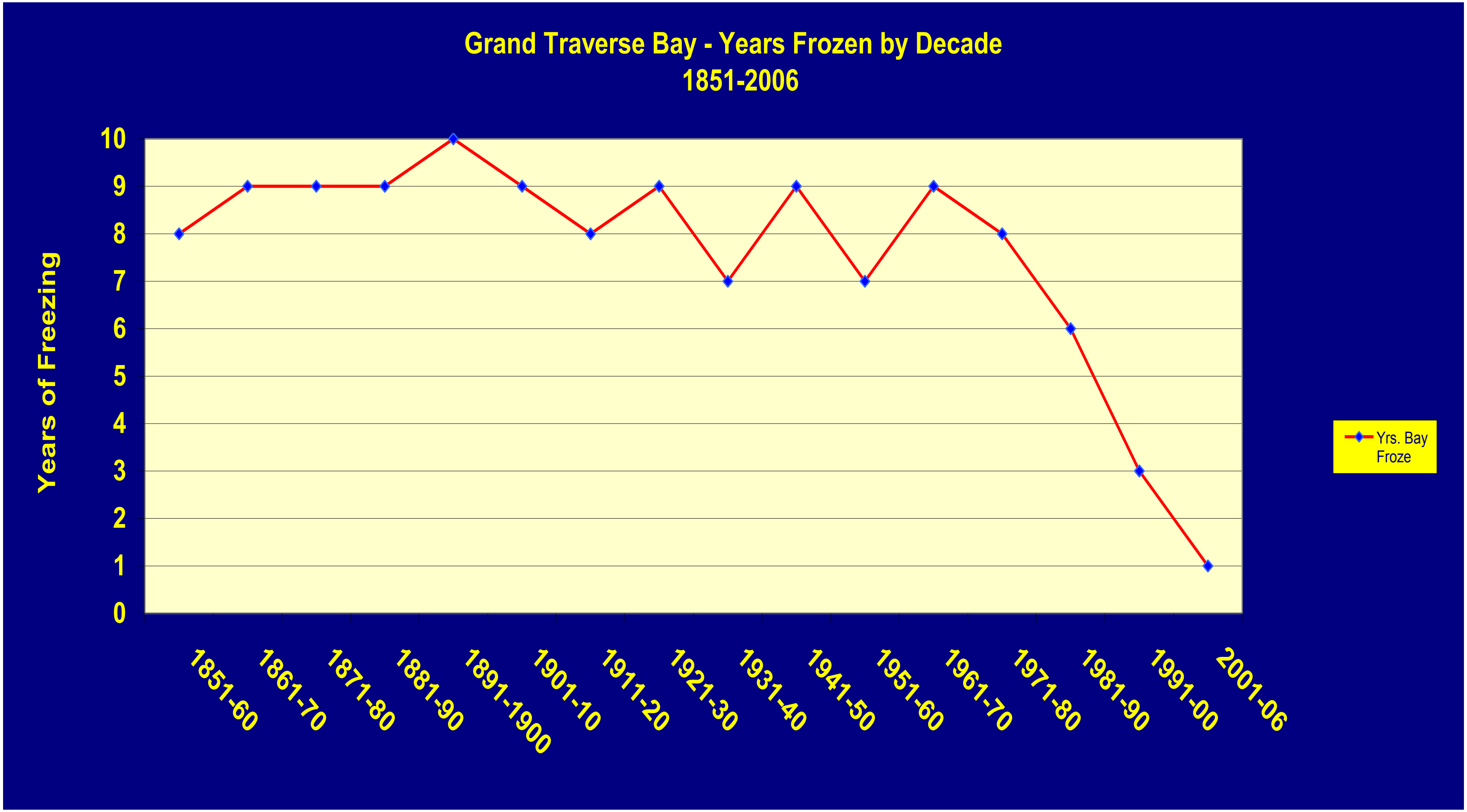


# Seasonal Changes in Mean Temperature

1895-2010 (ºF/year)

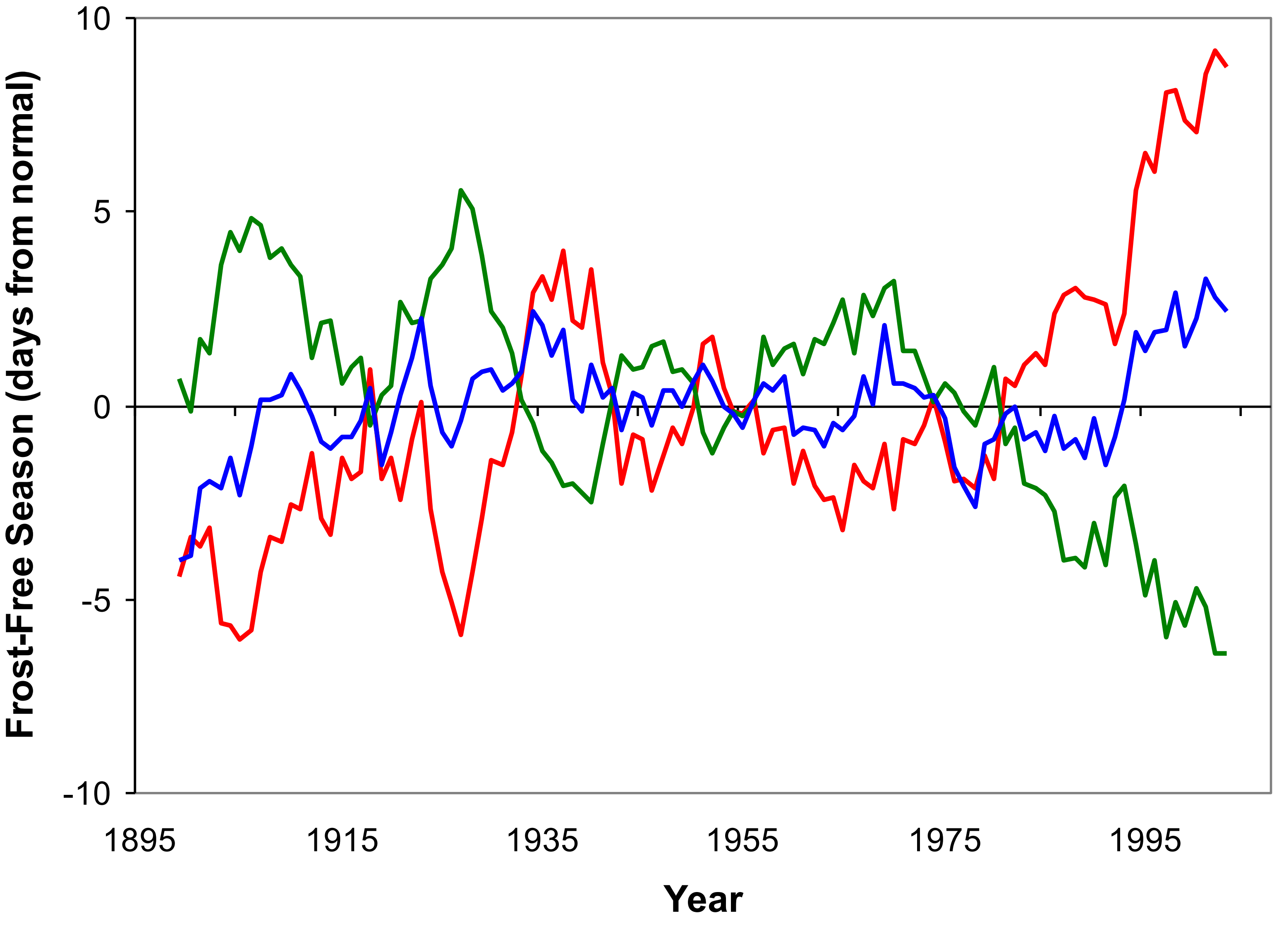
| State | Season | | | | |
|---|---|---|---|---|---|
| | Annual | Winter | Spring | Summer | Fall |
| IA | 0.009** | 0.014 | 0.014** | 0.004 | 0.001 |
| IL | 0.004 | 0.005 | 0.011* | -0.001 | -0.001 |
| IN | 0.003 | 0.006 | 0.010* | -0.005 | -0.001 |
| MI | 0.001 | 0.008 | 0.007 | -0.006 | -0.008 |
| MN | 0.014*** | 0.022* | 0.015** | 0.008* | 0.006 |
| MO | 0.005 | 0.008 | 0.010* | 0.002 | -0.004 |
| OH | 0.008*** | 0.011 | 0.014*** | 0.002 | 0.003 |
| WI | 0.009*** | 0.019* | 0.013* | 0.002 | 0.002 |
| Reg. Avg. | 0.007 | 0.012 | 0.012 | 0.001 | 0.000 |

Relatively greater changes in winter, spring

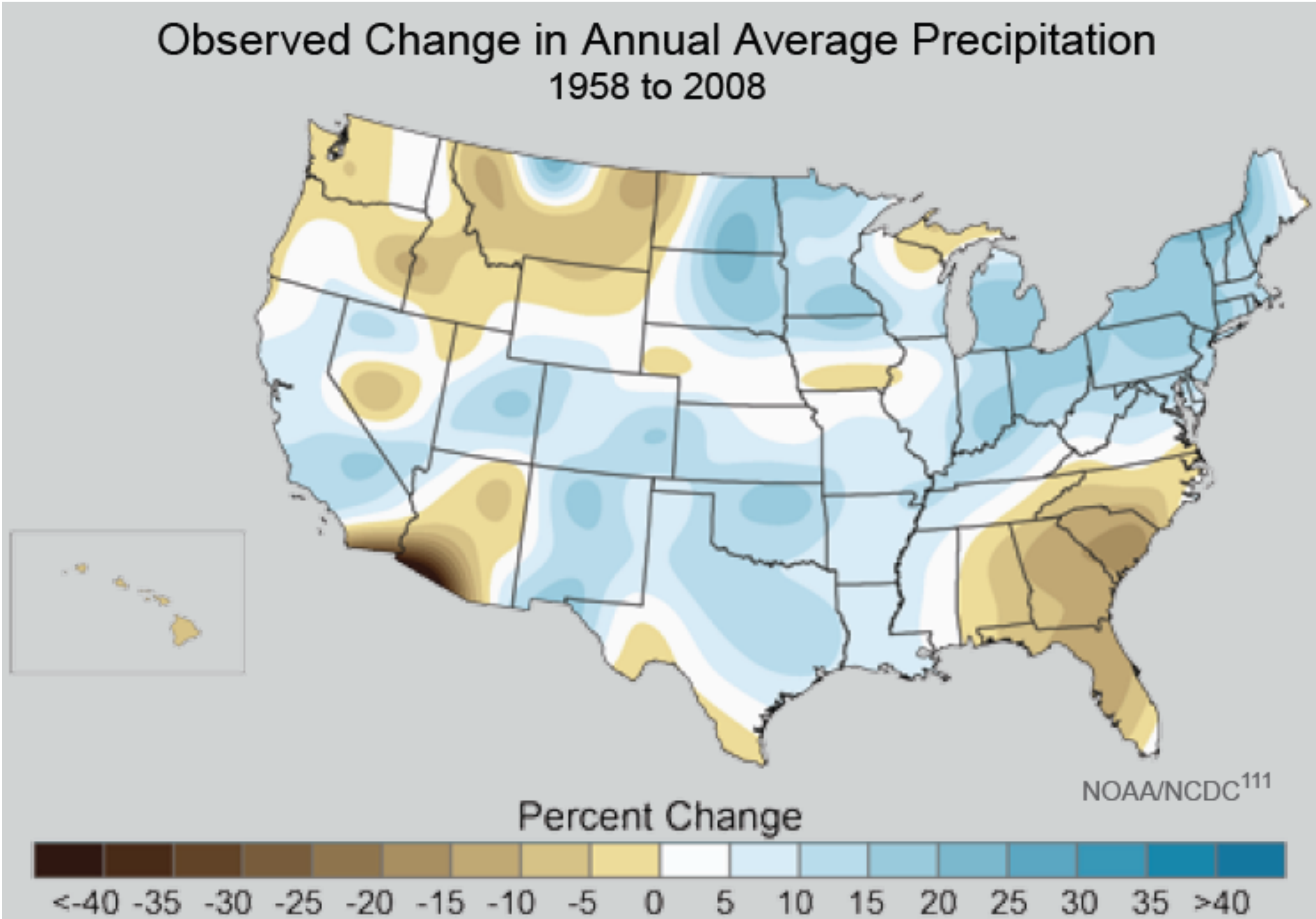


Grand Traverse Bay - Years Frozen by Decade
1851-2006
Years of Freezing
10
9
8
7
6
5
4
3
2
1
0
1851-60
1861-70
1871-80
1881-90
1891-1900
1901-10
1911-20
1921-30
1931-40
1941-50
1951-60
1961-70
1971-80
1981-90
1991-00
2001-06
Yrs. Bay Froze

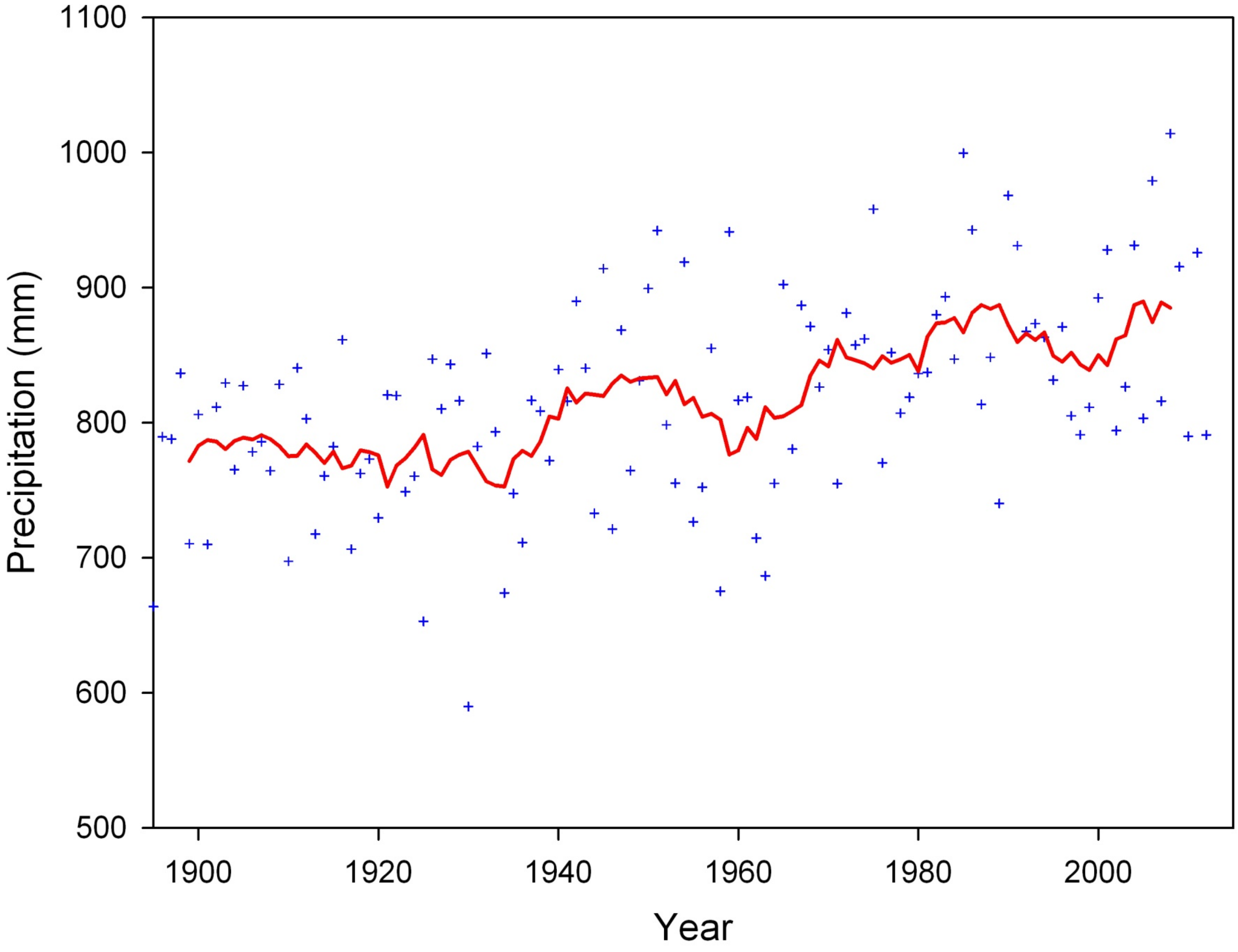
## Great Lakes Region (32°F threshold)

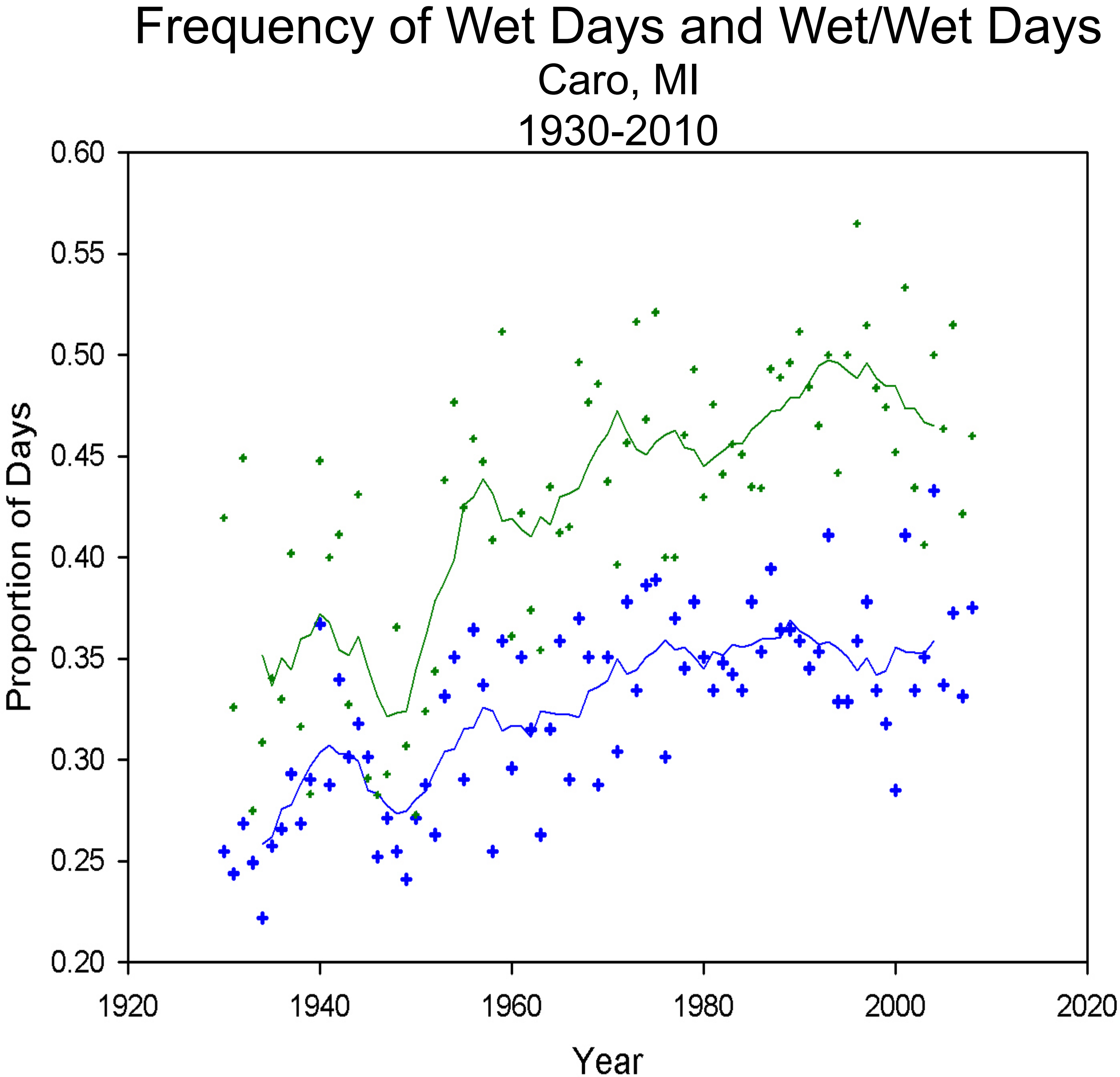



Source: K. Kunkel, Midwest. Reg. Clim. Center


Observed Change in Annual Average Precipitation
1958 to 2008
NOAA/NCDC111
Percent Change
<-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 >40

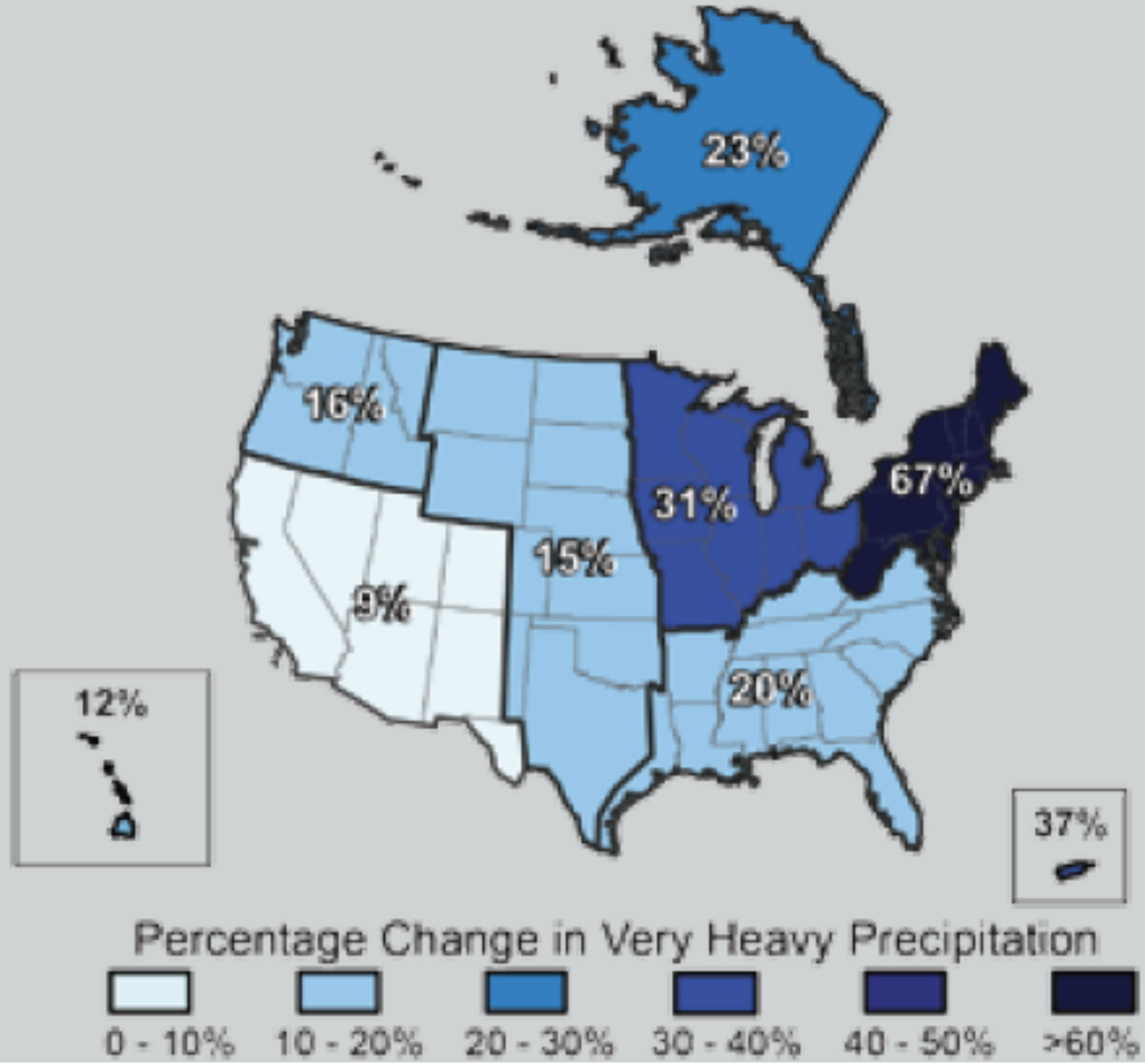
# Annual Precipitation vs. Year, Michigan 1895-2012



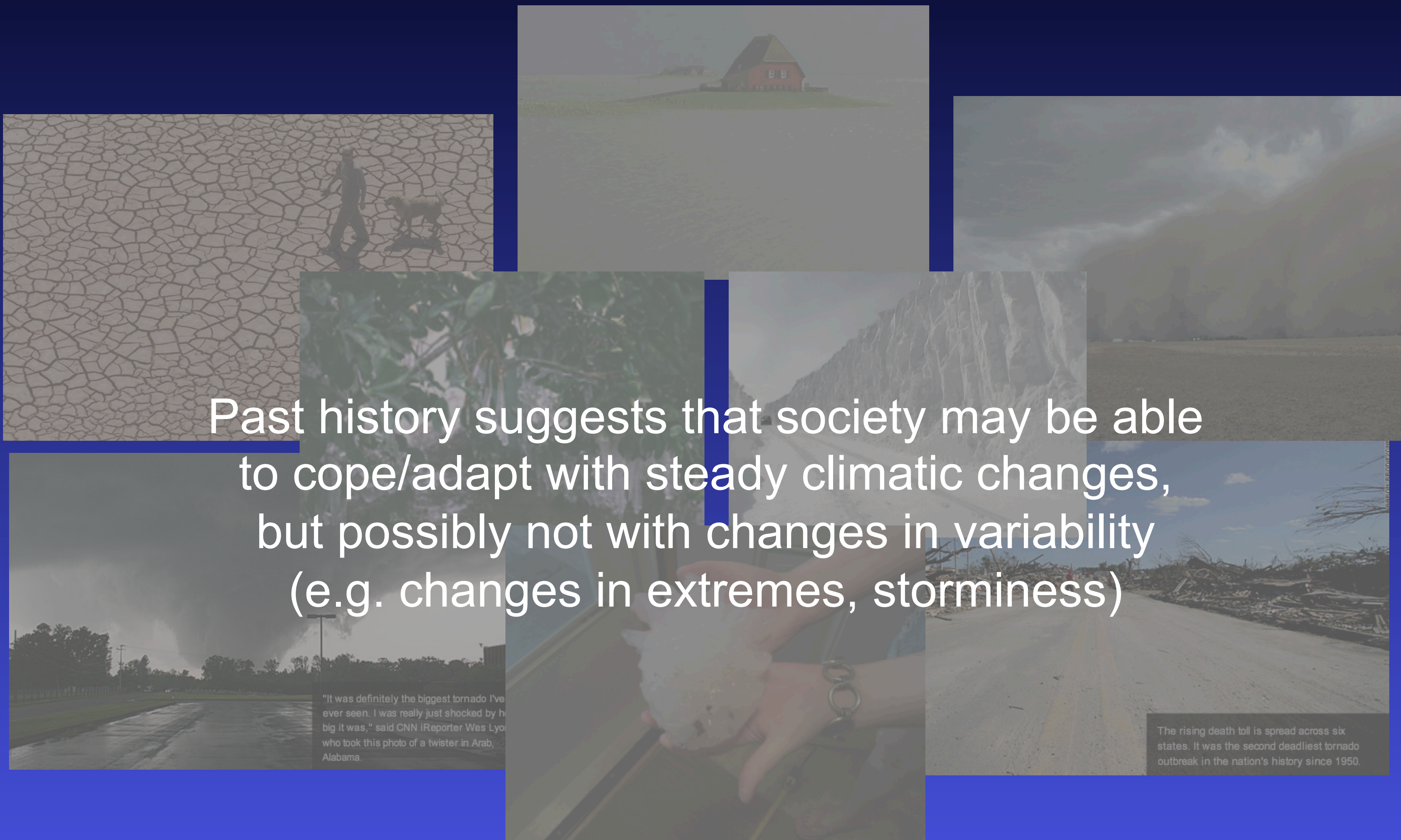


Frequency of Wet Days and Wet/Wet Days
Caro, MI
1930-2010
Proportion of Days
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
1920
1940
1960
1980
2000
2020
Year

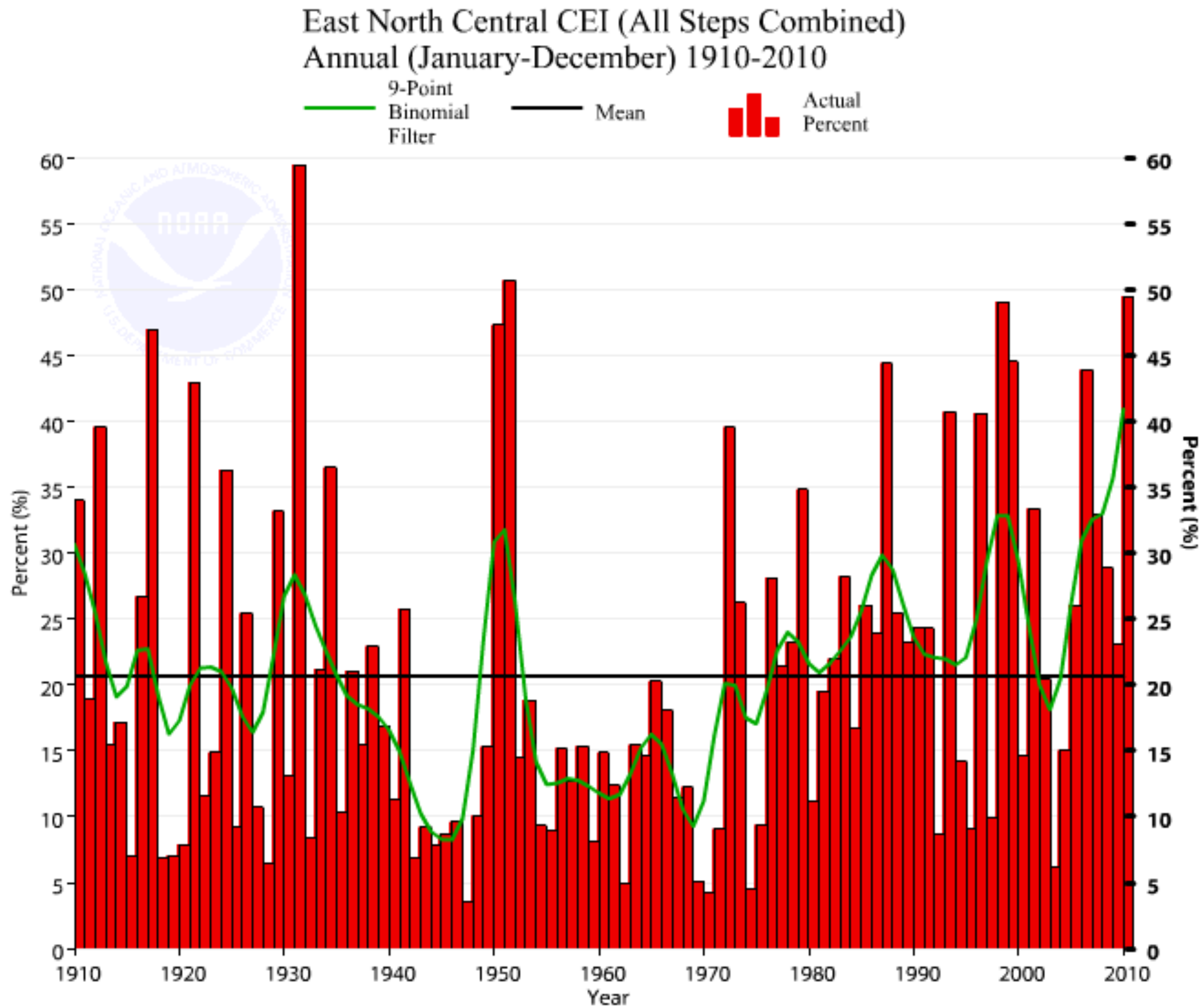
# Increases in Amounts of Very Heavy Precipitation (1958 to 2007)



# Impacts of Climatic Variability



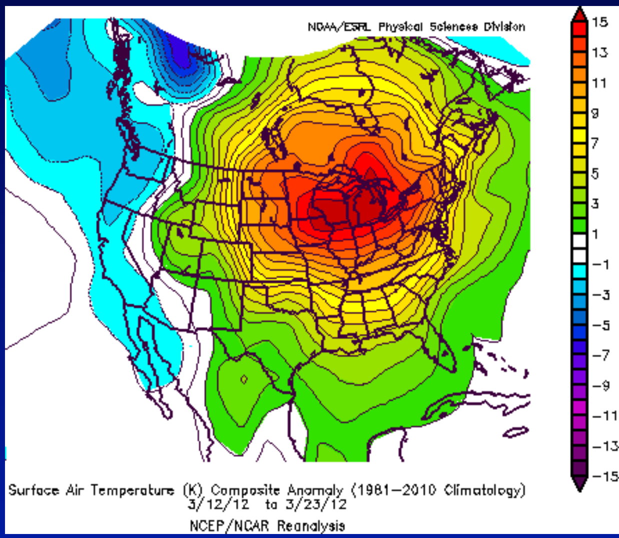

Past history suggests that society may be able to cope/adapt with steady climatic changes, but possibly not with changes in variability (e.g. changes in extremes, storminess)




(Source: NCDC, 2011)

# March 2012 Summary

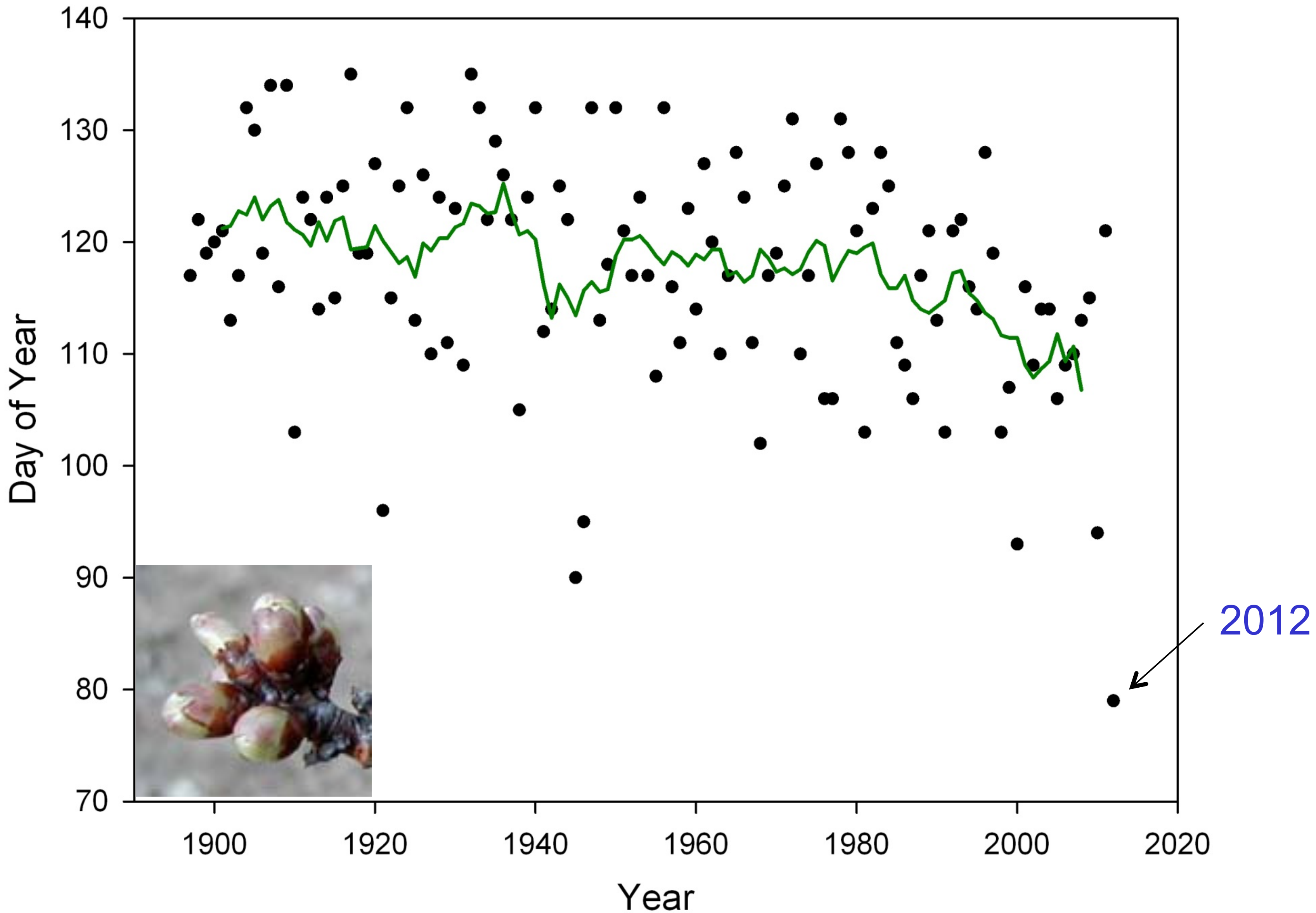
- Nationally, mean March temperature was 10.6˚C, 4.8˚C above normal.
  - Departure was 0.3˚C warmer than previous all time warmest March (1910)
  - Only one month (JAN 2006) with a greater departure from normal
  - 15,292 warm temperature records broken (7,775 daytime, 7,517 nighttime)
  - Warmest March ever for 25 states




- In Michigan, mean March temperature was 6.9°C, which was 7.6˚C warmer than normal and 1.8˚C warmer than the previous record (1945)
  - A new all-time record for warmest temp ever in March, 32.2˚C at Lapeer on the 21st.
  - Individual days where mean temp was more than 20˚C above normal

# Date of Side Green vs. Year

1901-2012, Traverse City, MI

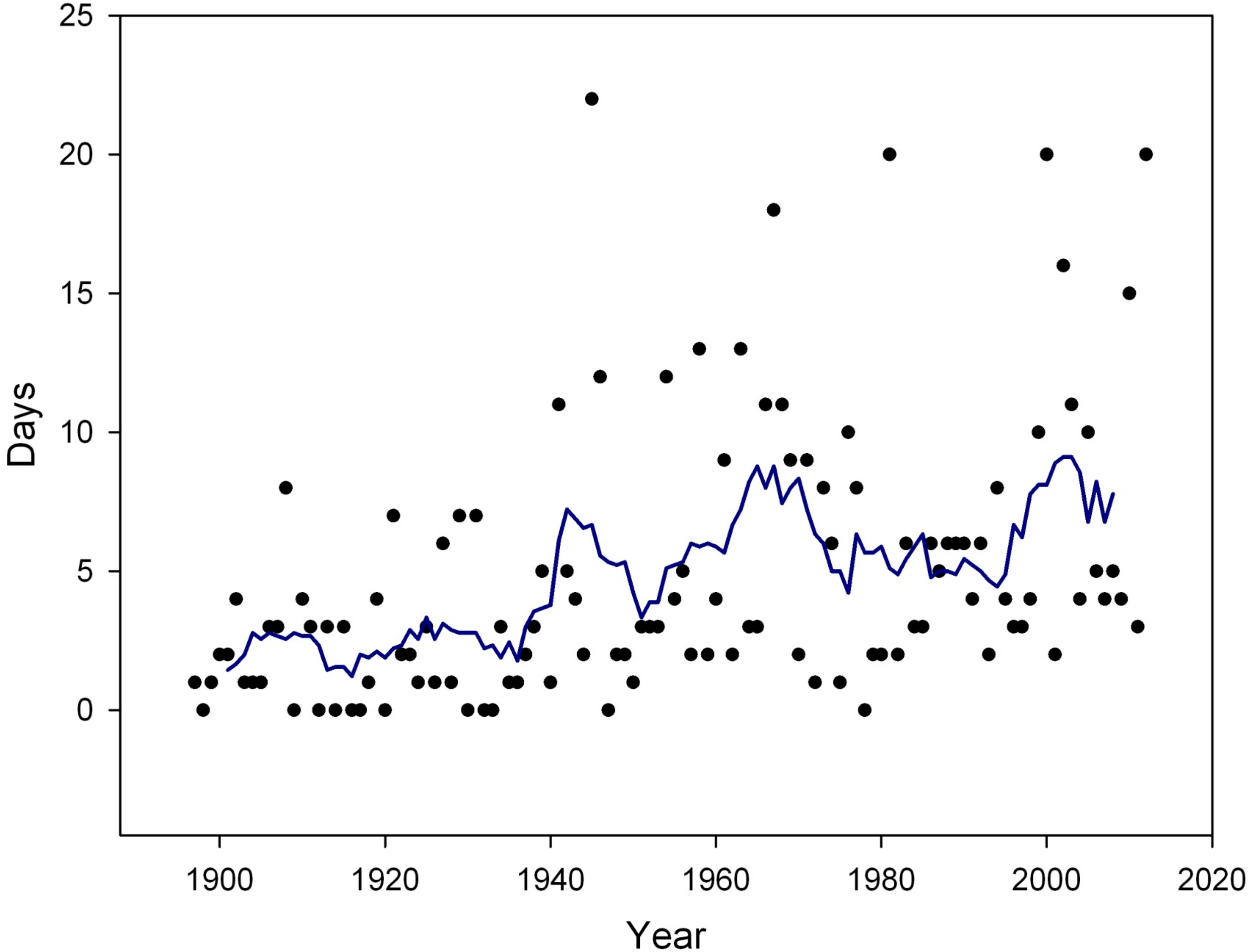


# Epilogue

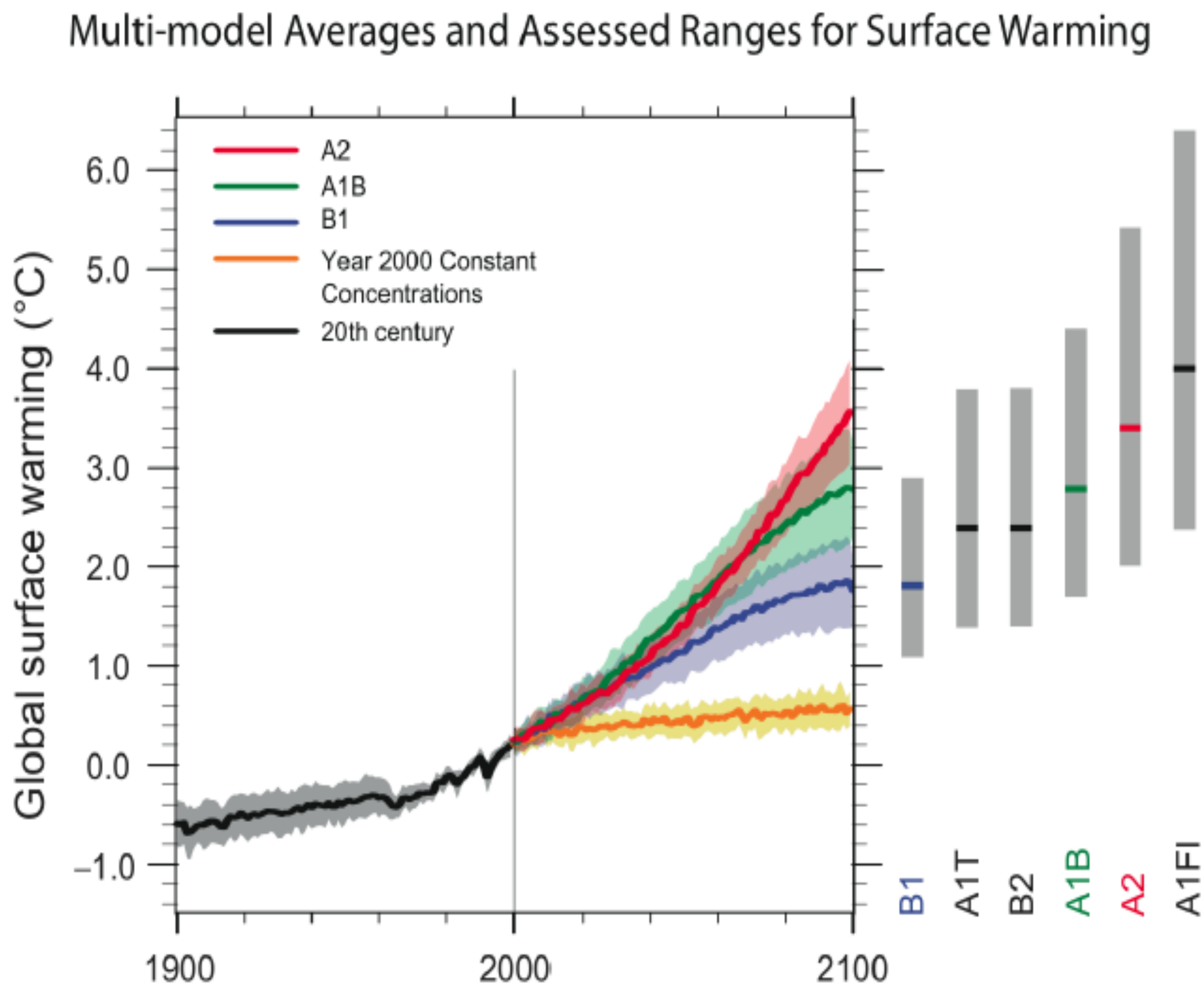
- More than 15 freeze events (more than 5 with $T_{min}$ < -2˚C) during late March through early May damaged a number of agricultural crops. Some of the freezes were of the advective variety.
- Fruit crops were especially impacted, with less than 10% of normal sour cherry production in Michigan.
- A survey of fruit crops across the state estimated direct production losses of more than $220M. Costs including indirect losses exceed $0.5B.
- Damage is highly location and crop variety-dependent.
- Costs associated with frost protection were much greater than normal.

# Number of Freeze Events (<= 0°C) Following Side Green vs. Year

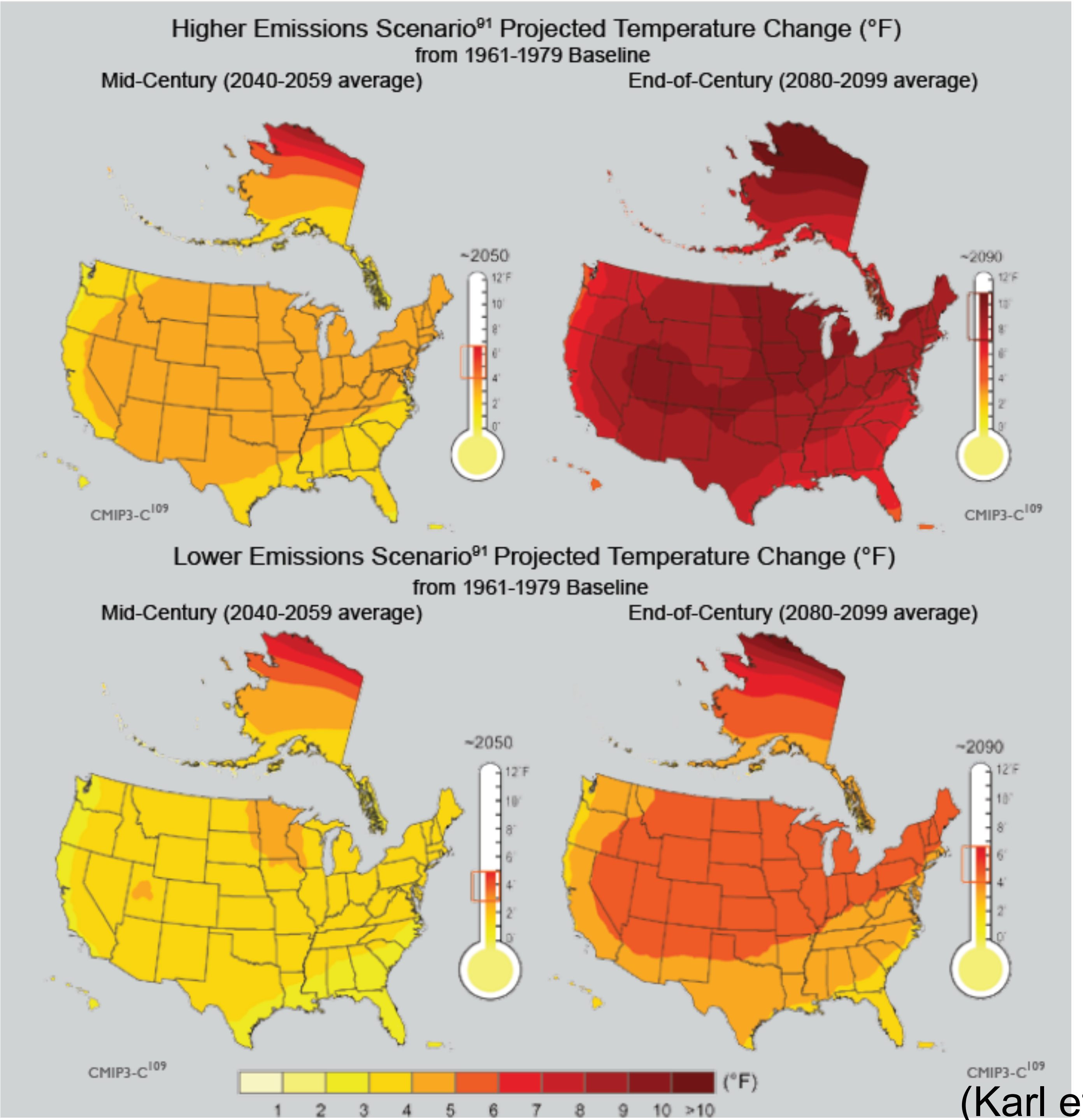
1901-2012, Traverse City, MI



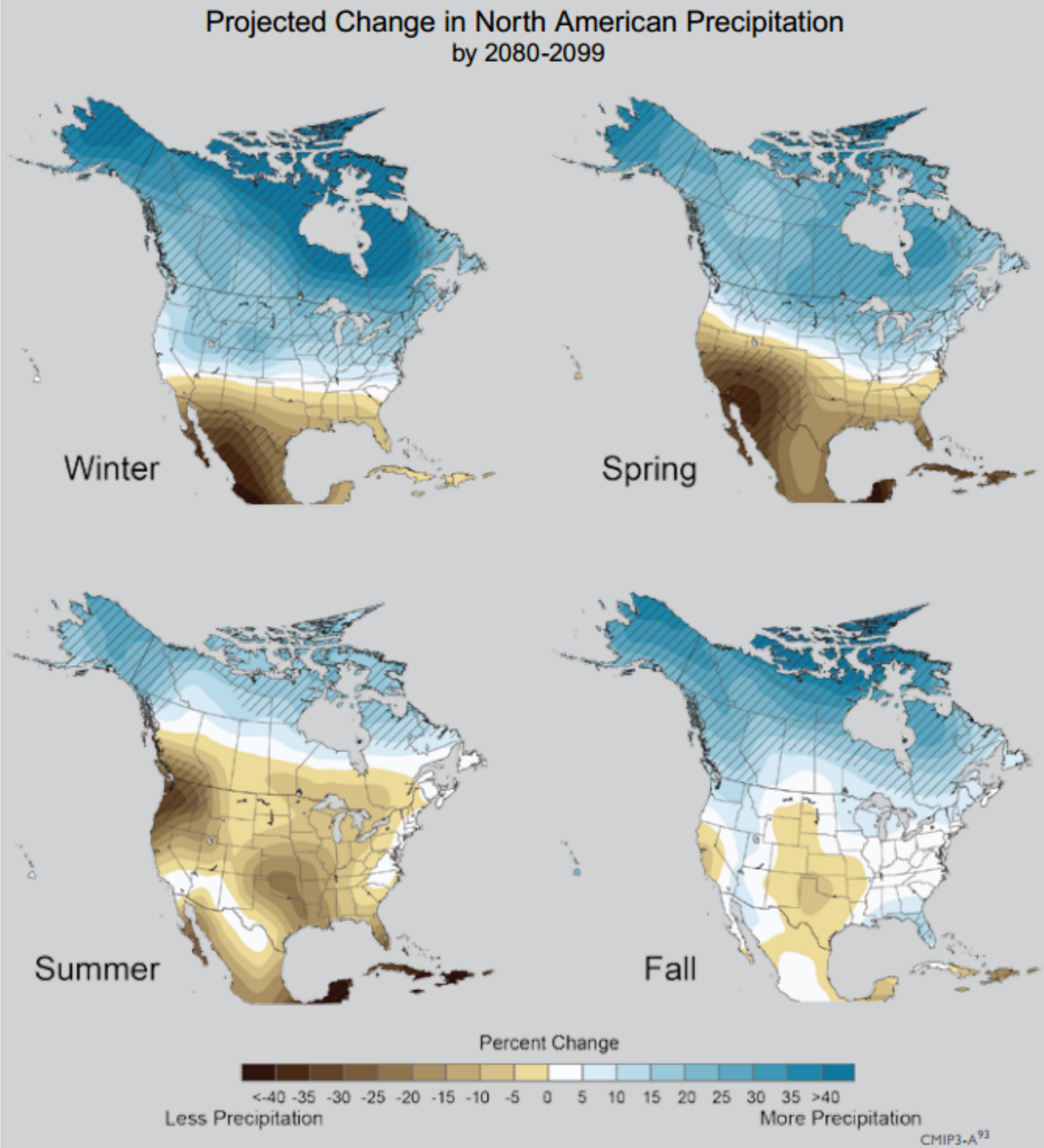
# Future Projections




Source: (IPCC, 2007)




(Karl et al., 2009)


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
CMIP3-A93

# Projected Future Weather Extremes-Related Impacts (IPCC, 2012)

- ***Virtual Certainty:*** increases in the frequency and magnitude of warm daily temp. extremes and decreases in cold extremes.
- ***Very Likely:*** Increase in the length, frequency, and/or intensity of warm spells or heat waves. Mean sea level rise will contribute to upward trends in extreme coastal high water levels.
- ***Likely:*** Increase in the frequency of heavy precipitation and the proportion of total rainfall from heavy events, and in avg. tropical cyclone maximum wind speed.
- ***Medium Confidence:*** Intensification of droughts, and decreases in the global frequency of tropical cyclones and the number of extratropical cyclones.

# Weather Anomaly or Climate Change?

- It is very difficult to distinguish anthropogenic signal from natural variability
- Ultimately, the physical processes and mechanisms responsible for weather and climate are the same
- Changes in the frequency of some extremes are consistent with long term trends
- Recent extremes are also generally consistent with future climate projections
- The recent weather extremes and climate change are likely not mutually exclusive: "…Although global warming is likely playing a role in this event, it probably did not play a major one. Meteorology, not climate change, is the main ingredient in the March 2012 U.S. extreme warmth". Of climate change, he said, ". . . its contribution to the magnitude of current conditions is quite small (but not zero) indeed." *Marty Hoerling (NOAA ESRL)*

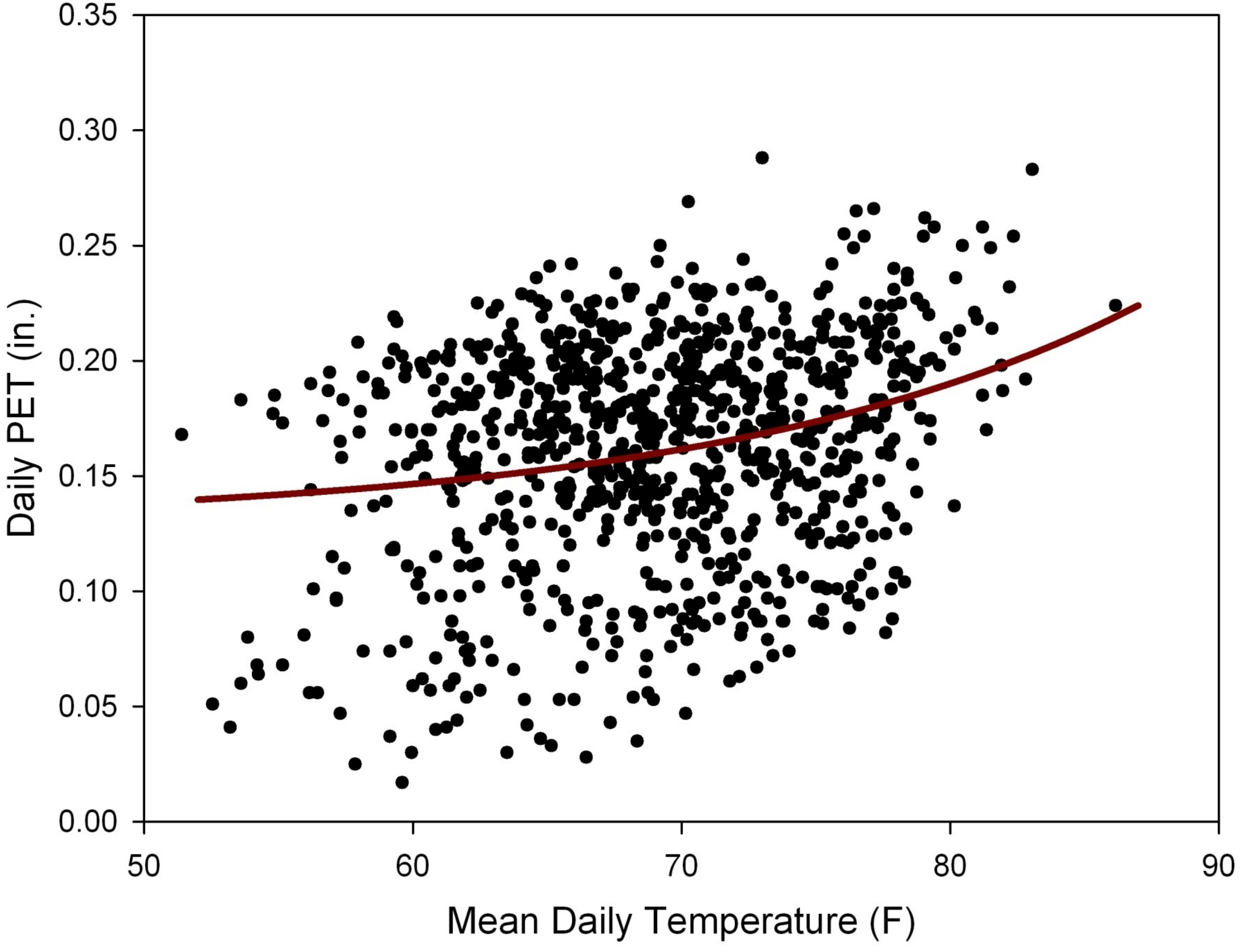
# Potential Impacts

# Direct Impacts of Climate Change

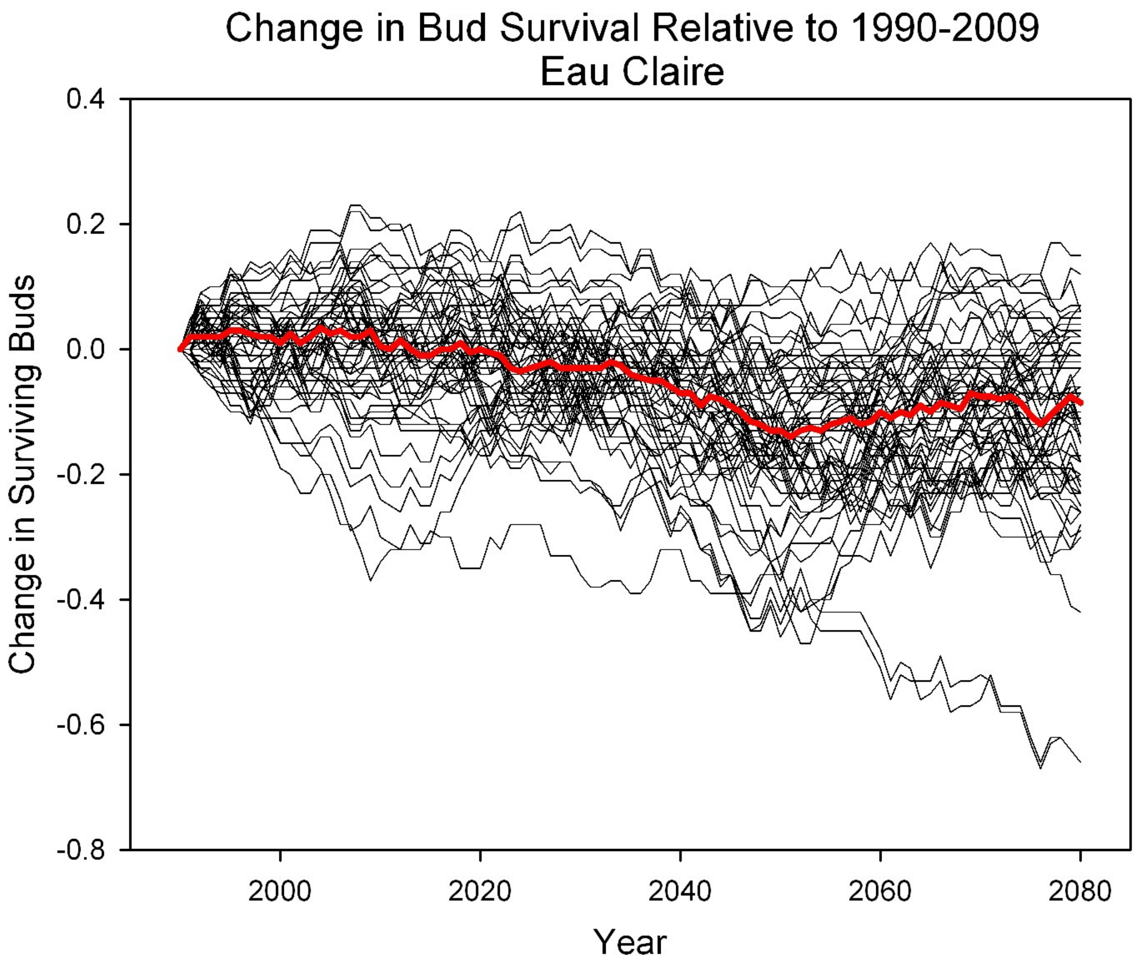
- Direct influence of changing environment, seasonality
- $CO_2$ enrichment
- Occurrence of extremes

# Mean Air Temperature vs. PET

East Lansing, MI  June-August, 2002-2011



# Projected Change in Bud Survival



# Other $CO_2$-related impacts

Herbicide Loses Effectiveness at Higher $CO_2$

Current $CO_2$ (380 ppm) Potential Future $CO_2$ (680 ppm)

The left photo shows weeds in a plot grown at a carbon dioxide ($CO_2$) concentration of about 380 parts per million (ppm), which approximates the current level. The right photo shows a plot in which the $CO_2$ level has been raised to about 680 ppm. Both plots were equally treated with herbicide.[233]

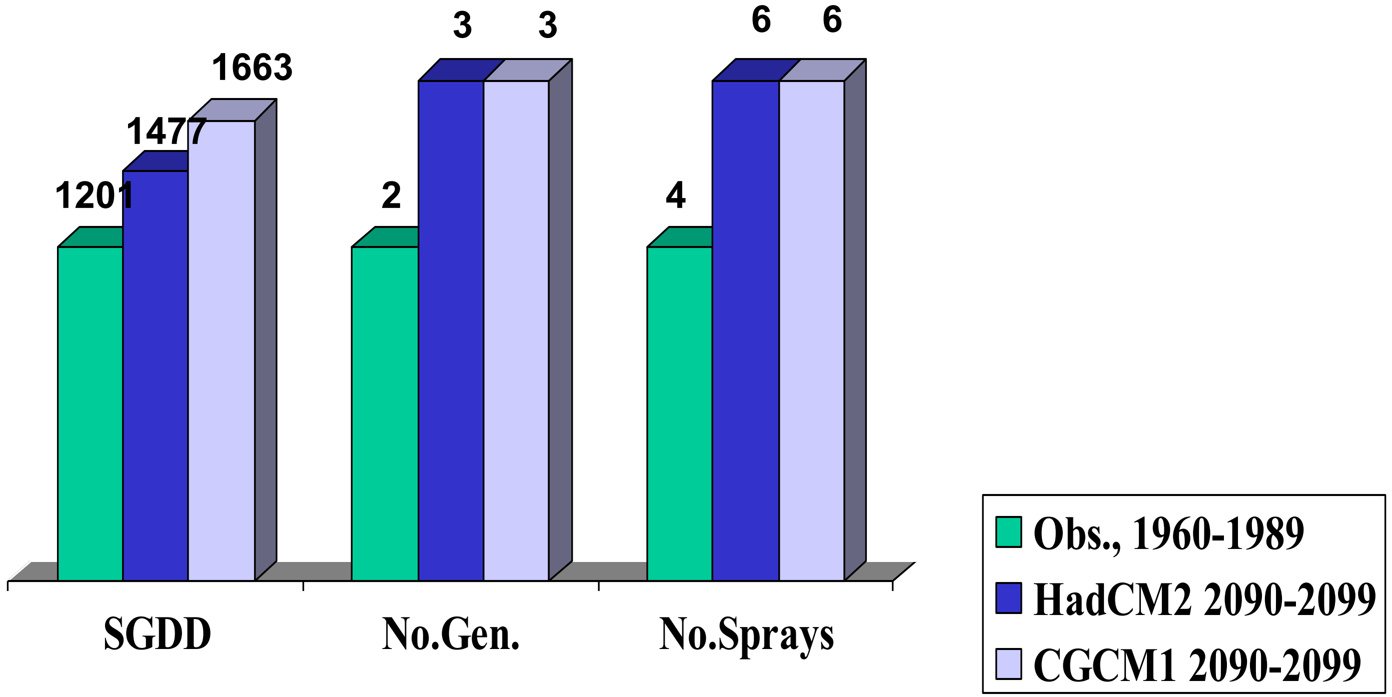
(Wolfe et al., 2007)

# Indirect Impacts of Climate Change

- Changing incidence of pests and pathogens
- Increased rates of soil erosion and degradation
- Increased pressure on environmental and natural resources, loss of biodiversity
  - Surface and ground water availability
  - Loss of species
- Possible imbalance between production areas in cool/temperate zones and those in tropical areas

# Simulated Pest Management Parameters, Apple Codling Moth

East Jordan, MI



# Potential Tree Fruit-Related Impacts

- Lack of chilling hours
- Heat stress
- Increasing water needs (irrigation)
- Extreme weather events
- Changes in the distribution of pests (inc. exotics)
- Changing international production, trade patterns

# Summary

- Overall, almost all U.S. production areas have become warmer during the past half century (+1-2°F nationally). More of the warming has occurred during the cold season and the past couple decades.
- Seasonality has changed in many areas, especially in the spring.
- Some areas of the country have become wetter while others have become drier (+5% on avg). Most of the increase has been associated with extreme events.
- Most recent projections suggest continued warming in all U.S. production areas (4-11°F by 2100). Annual precipitation is projected to increase in northern areas and decrease in the south. Summers may be drier.
- Projected future climate trends suggest a mix of beneficial and adverse impacts.
- Climate variability is a critical factor in determining impacts.
- Adaptive strategies are especially important given the relatively long planning horizons.


Questions?