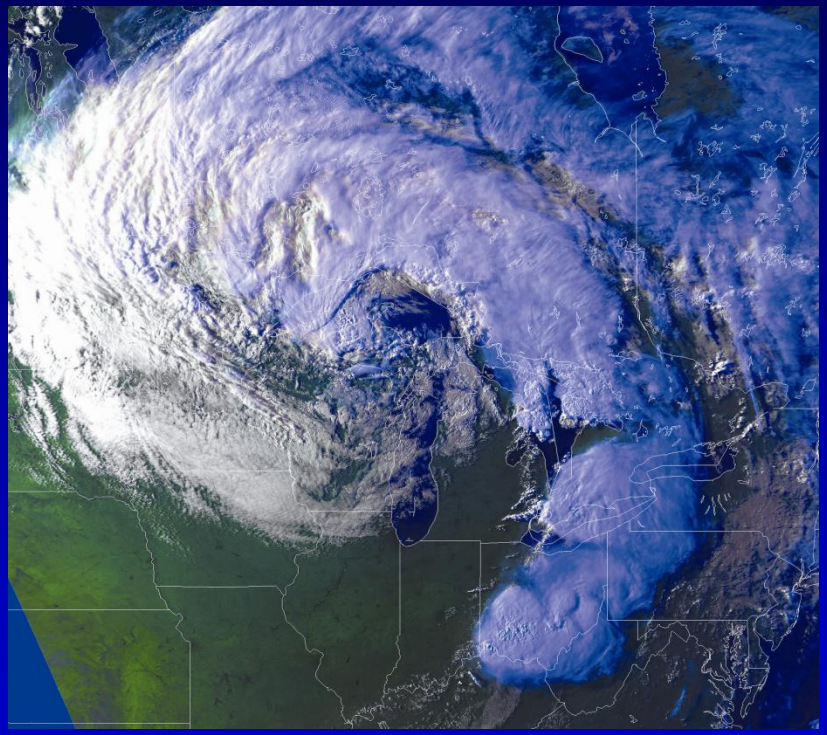
Michigan's Changing Climate:
Historical Trends and Future Projections



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July 2011 Heatwave Summary: USA

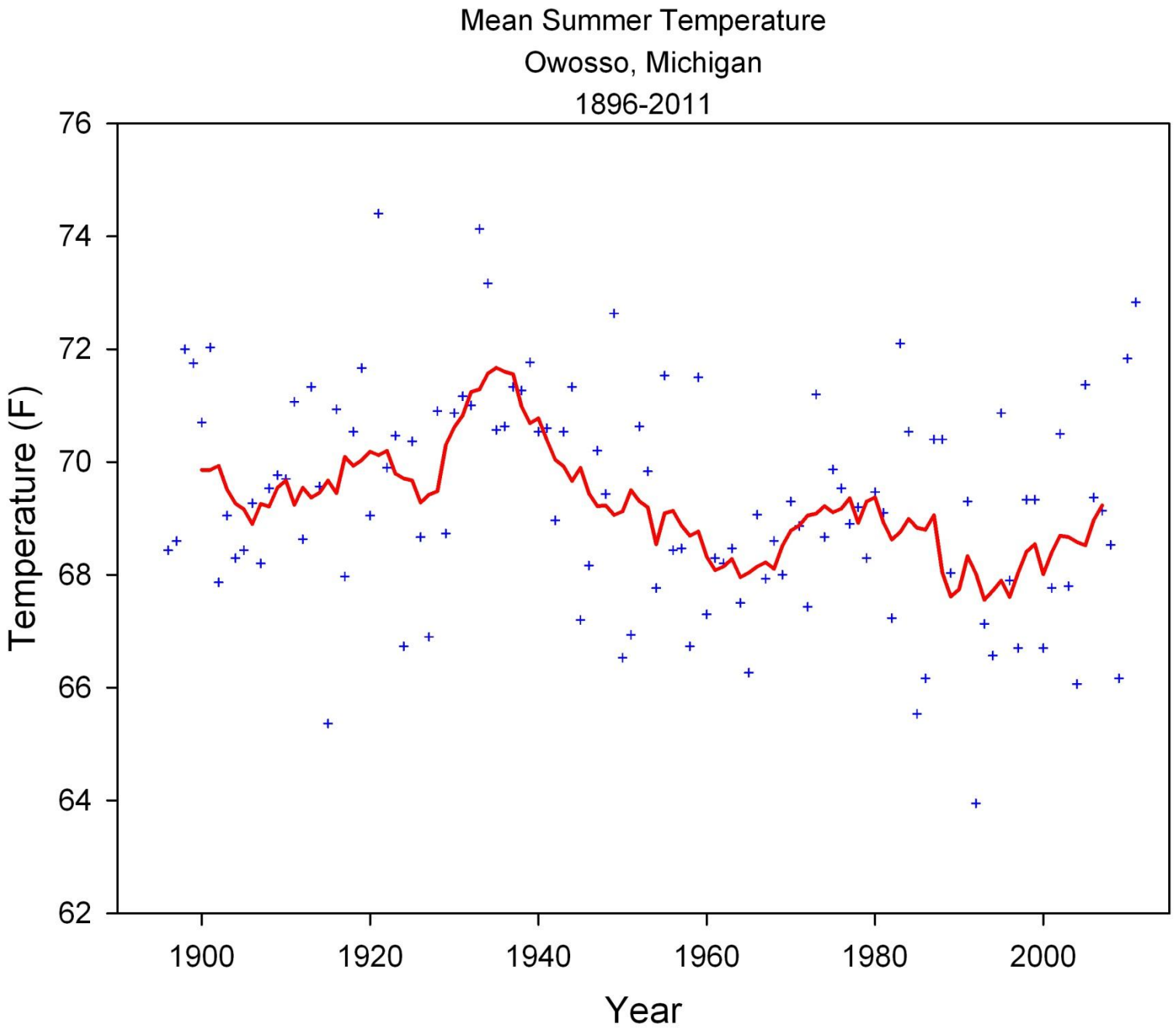
- At least 200 million people in the United States impacted
- 34 related fatalities in 10 states (as of 8 AUG)
- Heat linked with extreme drought conditions across much of southern Great Plains
- 2,712 high-temperature records were either tied or broken
- At least one weather station in all 50 states set or tied a daily high temperature record at some point during July
- Two weather stations tied for the hottest temperature ever recorded during July (120 F at Blythe, CA and Gila Bend, AZ)
- More than 70 days with max. temperature greater than 100 F, sections of TX and OK
- Highest heat index globally on July 19, Morehead, MN (134 F)

July 2011 Heatwave Summary: MI

- Mean temperatures averaged 3.7 F above normal
- Warmest July since 1955 and the 6th warmest statewide since 1895 (most of the warmest Julys on record occurred during the 1930's and 1920's)
- High temperatures during the month reached or exceeded 90 F on as many as 15 days in some southern areas of the state
- Total precipitation for the month varied greatly from north to south, with less than 0.50" (less than 25% of normal) across some areas of western Upper and northwestern Lower Michigan to more than 10.00" (more than 300% of normal) across portions of the south.

‘Weather’ versus ‘Climate’

- The American Meteorological Society’s Glossary of Meteorology defines **climate** as:“The slowly varying aspects of the atmosphere–hydrosphere–land surface system”
- **Weather** describes the same thing but on relatively short time scales (e.g. hours or days)
- *‘Climate is what we expect, weather is what we get…’*


Mean Summer Temperature
Owosso, Michigan
1896-2011
Temperature (F)
76
74
72
70
68
66
64
62
1900
1920
1940
1960
1980
2000
Year

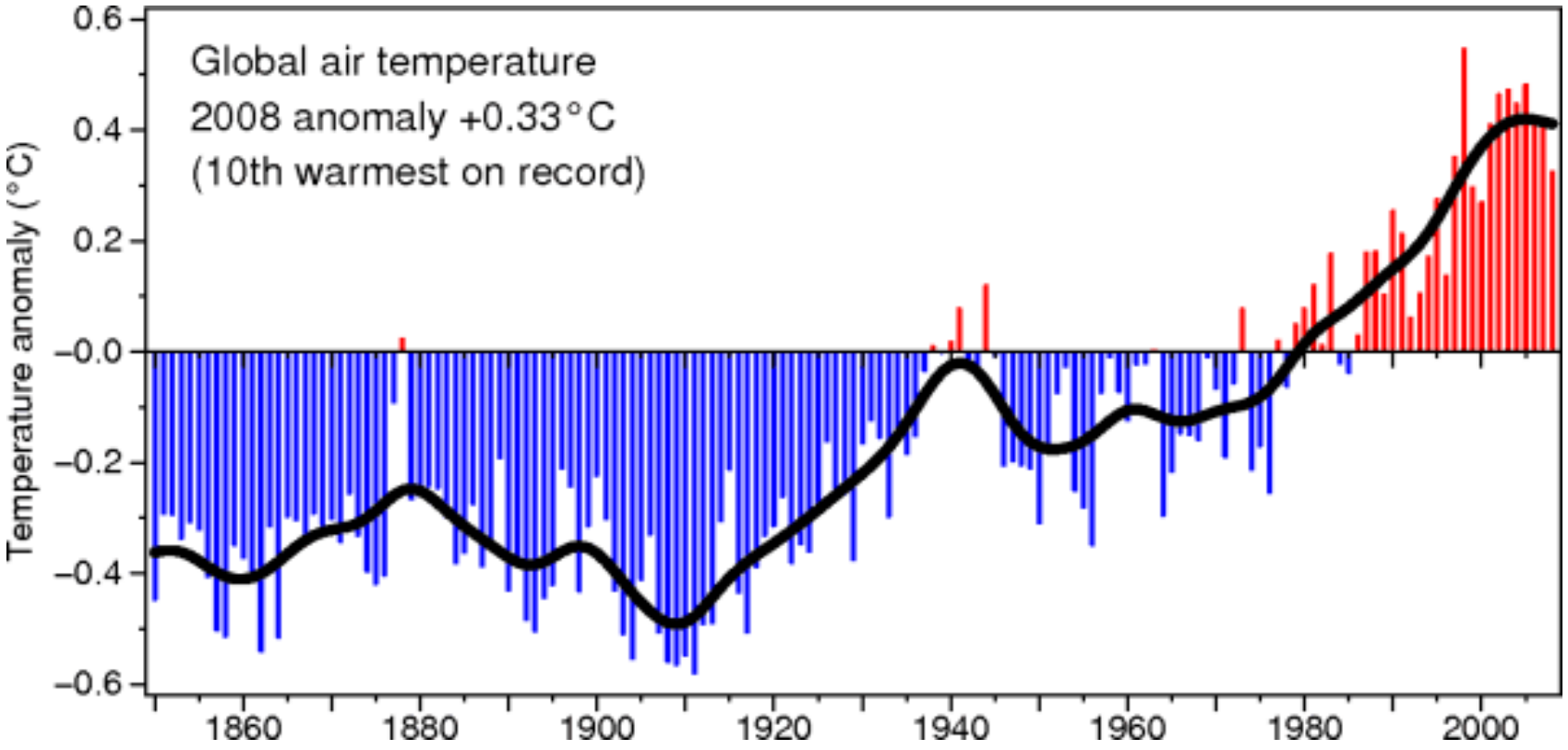
Reasons For Concern?

- "Warming of the climate system is ***unequivocal***, as is now evident from observations of increases in global air and ocean temperatures, widespread melting of snow and ice, and rising sea level".
- "Most of the observed increase in globally averaged temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic greenhouse concentrations".
- "Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global system during the 21st century that would ***very likely*** be larger than those observed during the 20th century".
- Current projections under a range of emission scenarios suggest a warming of 1-4ºC by the year 2100.

Source: IPCC(2007)

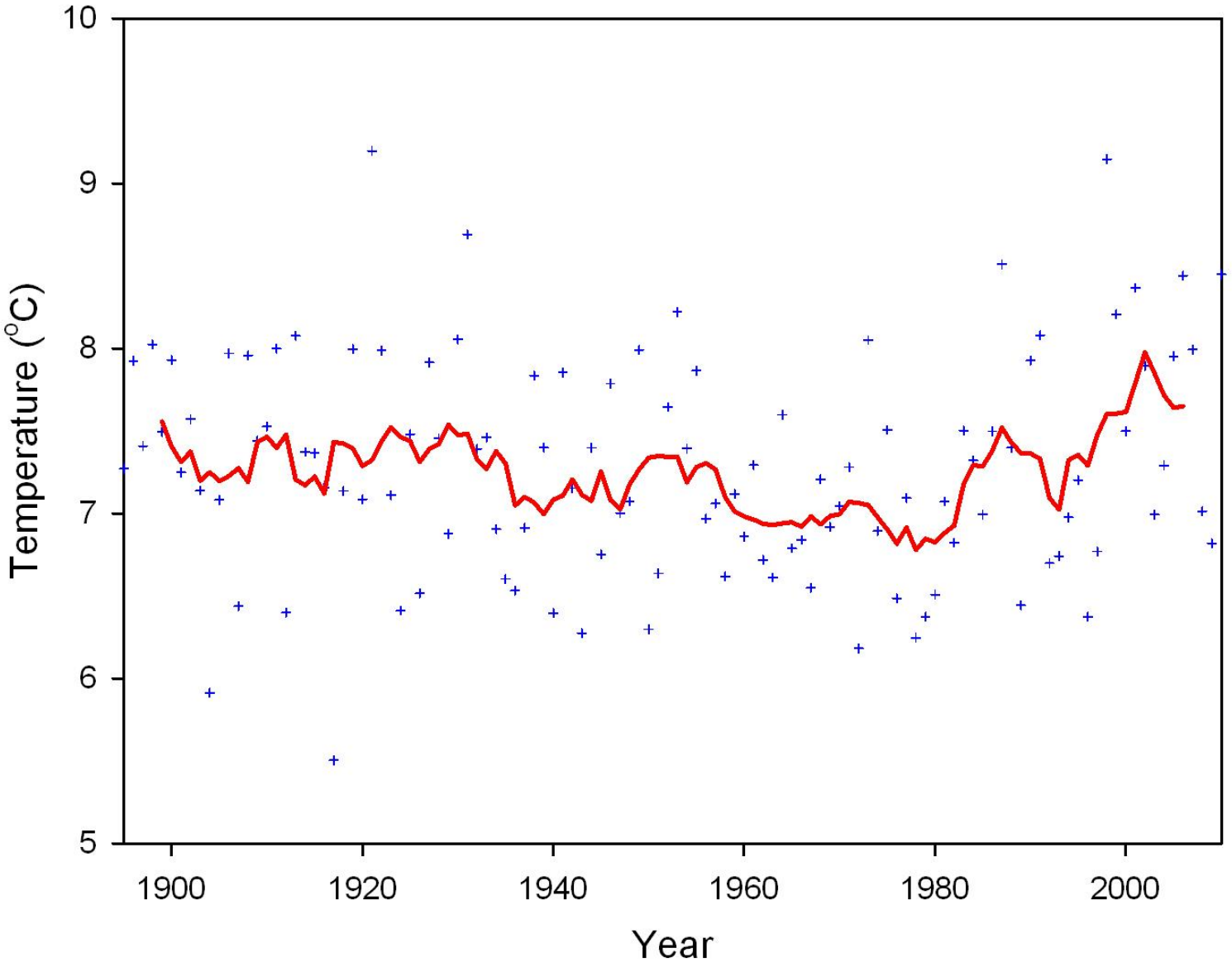
Some Notable Pre-Instrumental Trends in the Great Lakes Region

- Tropical humid conditions during the Carboniferous and Devonian eras. 
- Frigid, glacial/periglacial conditions as recently as 12,000 years ago during the end of the Pleistocene era.
- During early portions of the Holocene era, climate in the region warmed rapidly, resulting in a relatively mild and dry climate which lasted until about 5,000 YBP. Great Lakes levels fell until the lakes became terminal or confined about 7,900 YBP and vegetation in the region gradually transitioned from boreal to xeric species.
- Beginning about 5,000 YBP, climate cooled and precipitation totals increased, favoring the establishment of more mesic vegetation.
- During the late Holocene, the region experienced a period of relatively mild temperatures from approximately 800A.D. to 1300 A.D. followed by a period of relatively cool temperatures from about 1400A.D. until the late 19th Century.



Source: Jones et al., 2009

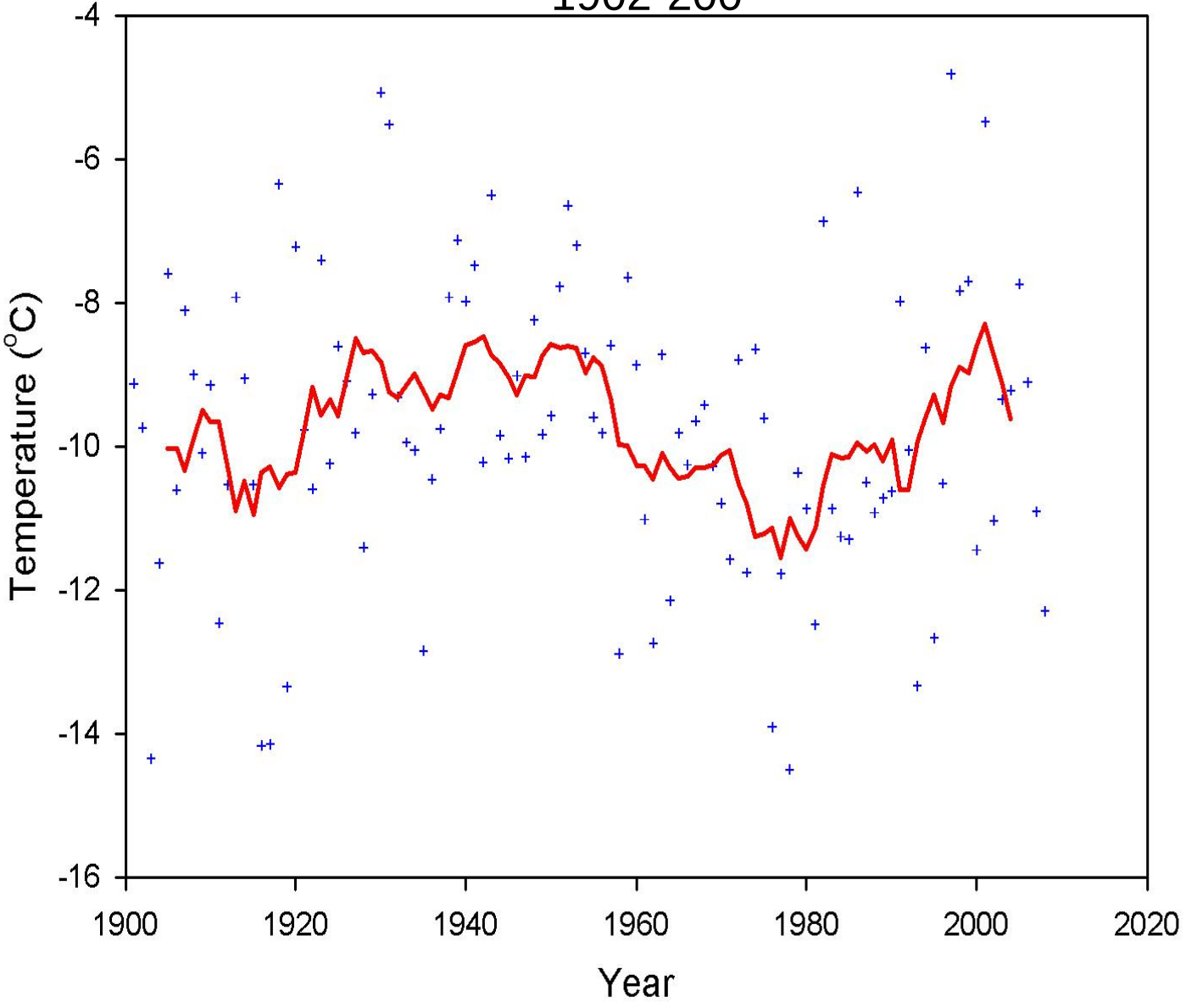
Mean Temperatures vs. Year, Michigan 1895-2010

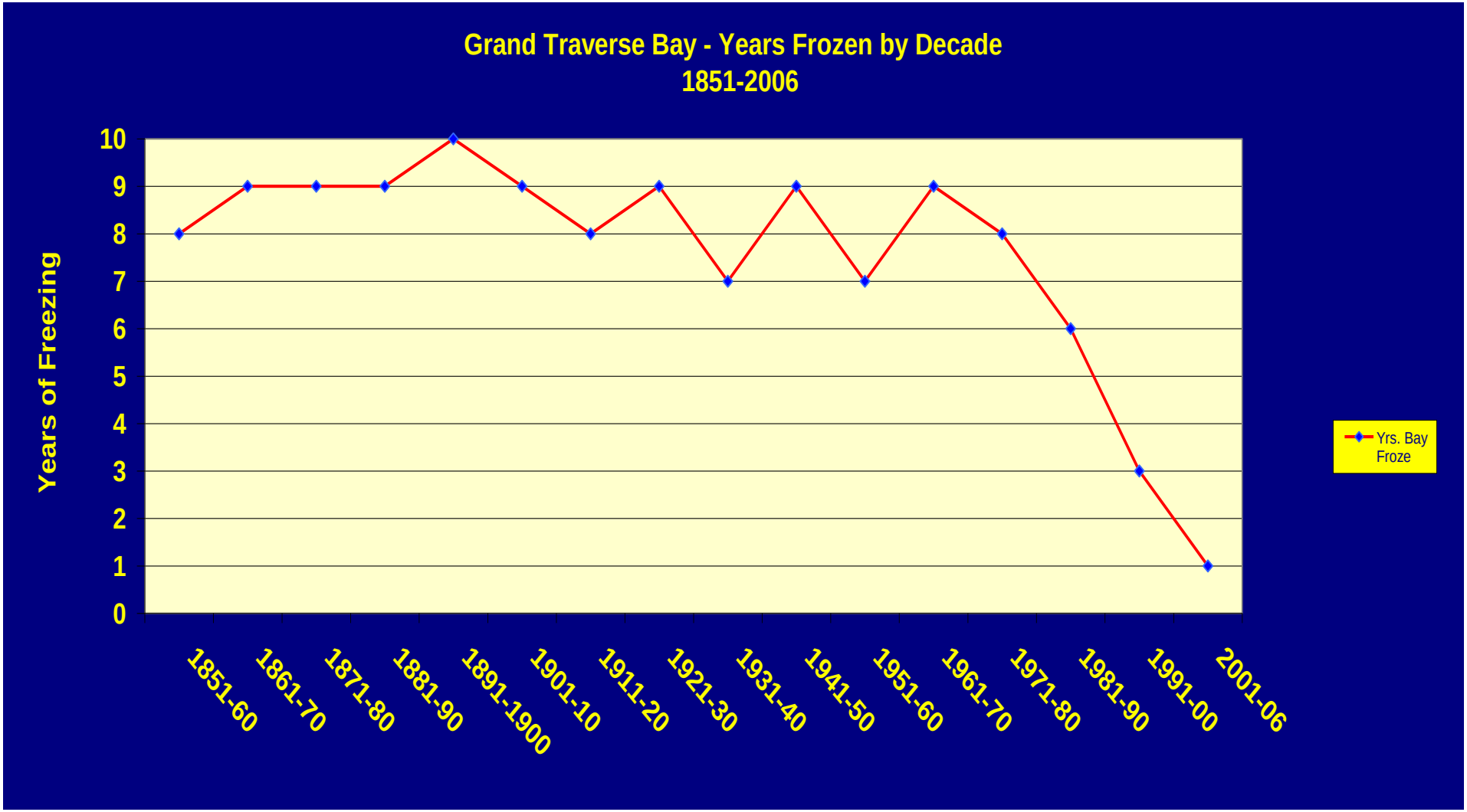


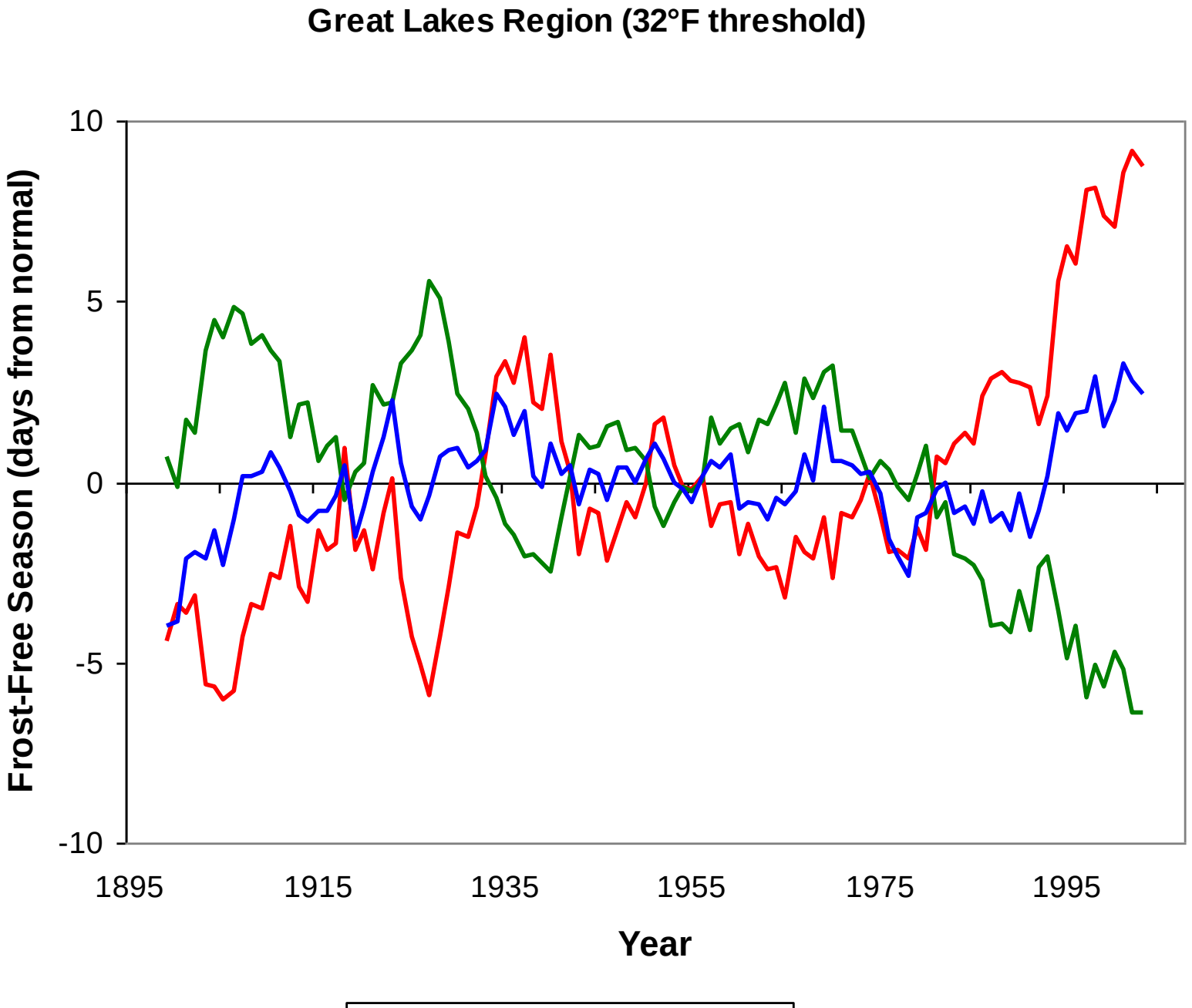
Mean Winter Temperatures vs. Year

Ironwood, MI

1902-200

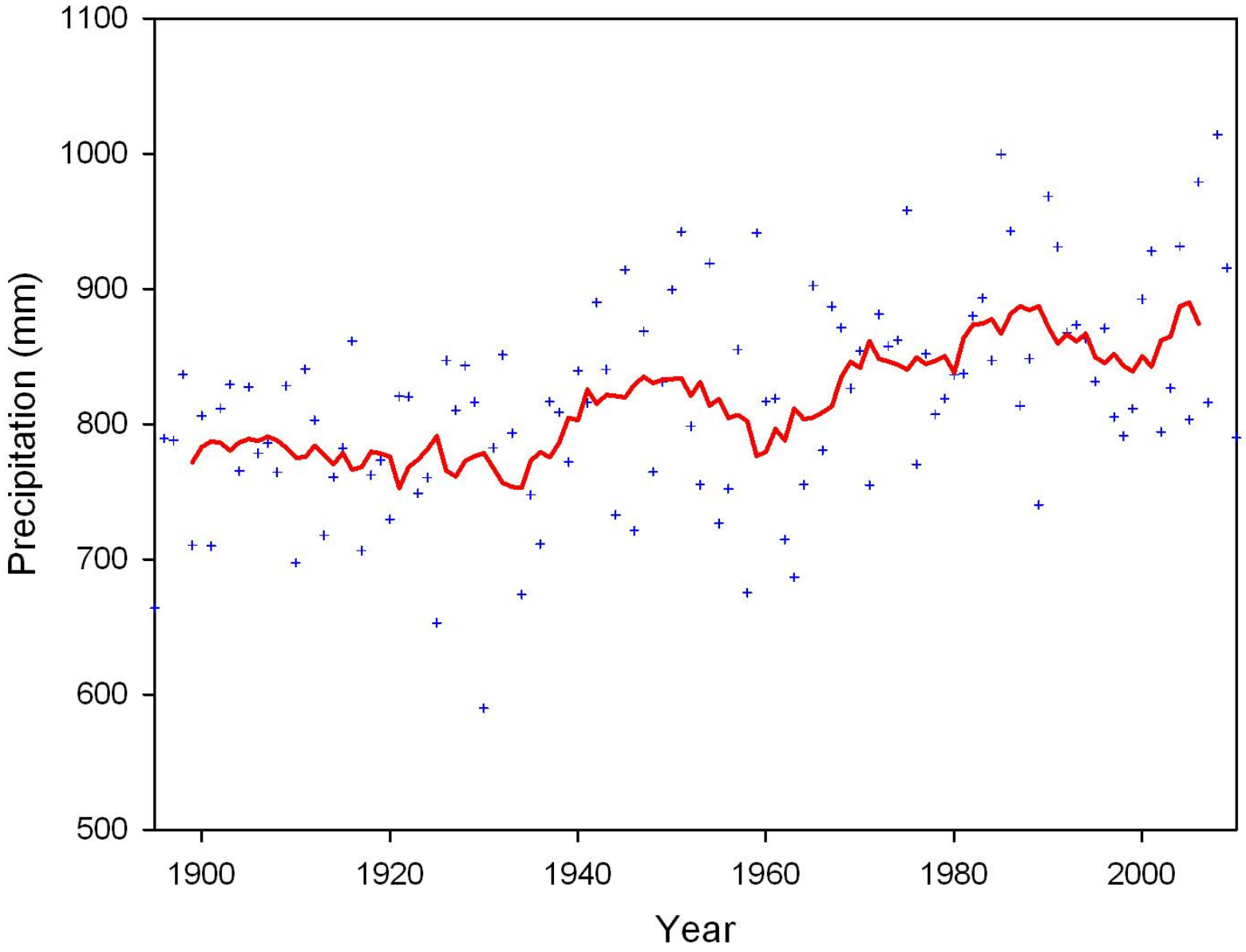



Grand Traverse Bay - Years Frozen by Decade
1851-2006
Years of Freezing
10
9
8
7
6
5
4
3
2
1
0
1851-60
1861-70
1871-80
1881-90
1891-1900
1901-10
1911-20
1921-30
1931-40
1941-50
1951-60
1961-70
1971-80
1981-90
1991-00
2001-06
Yrs. Bay Froze



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

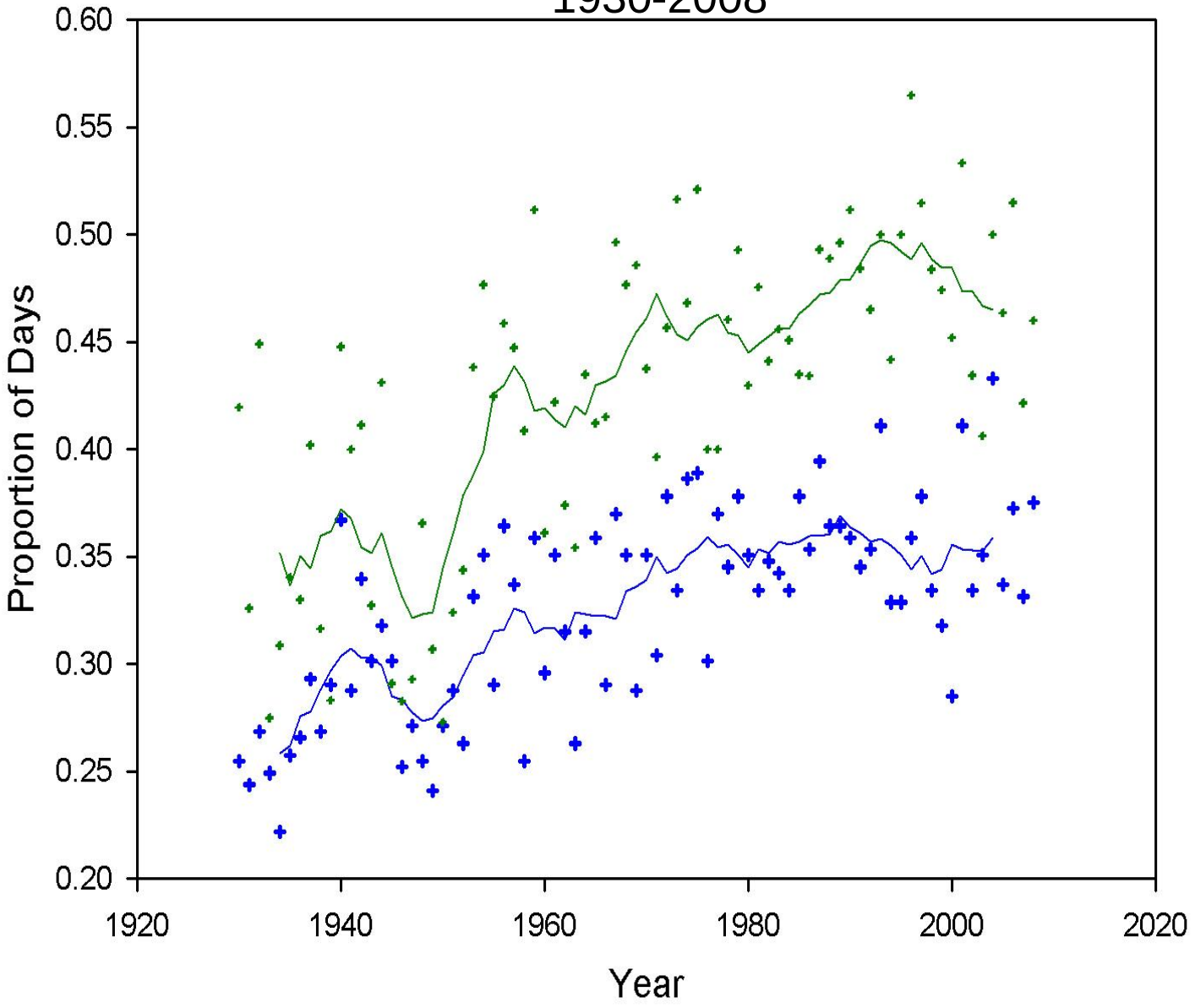
Annual Precipitation vs. Year, Michigan 1895-2010



Frequency of Wet Days and Wet/Wet Days

Caro, MI

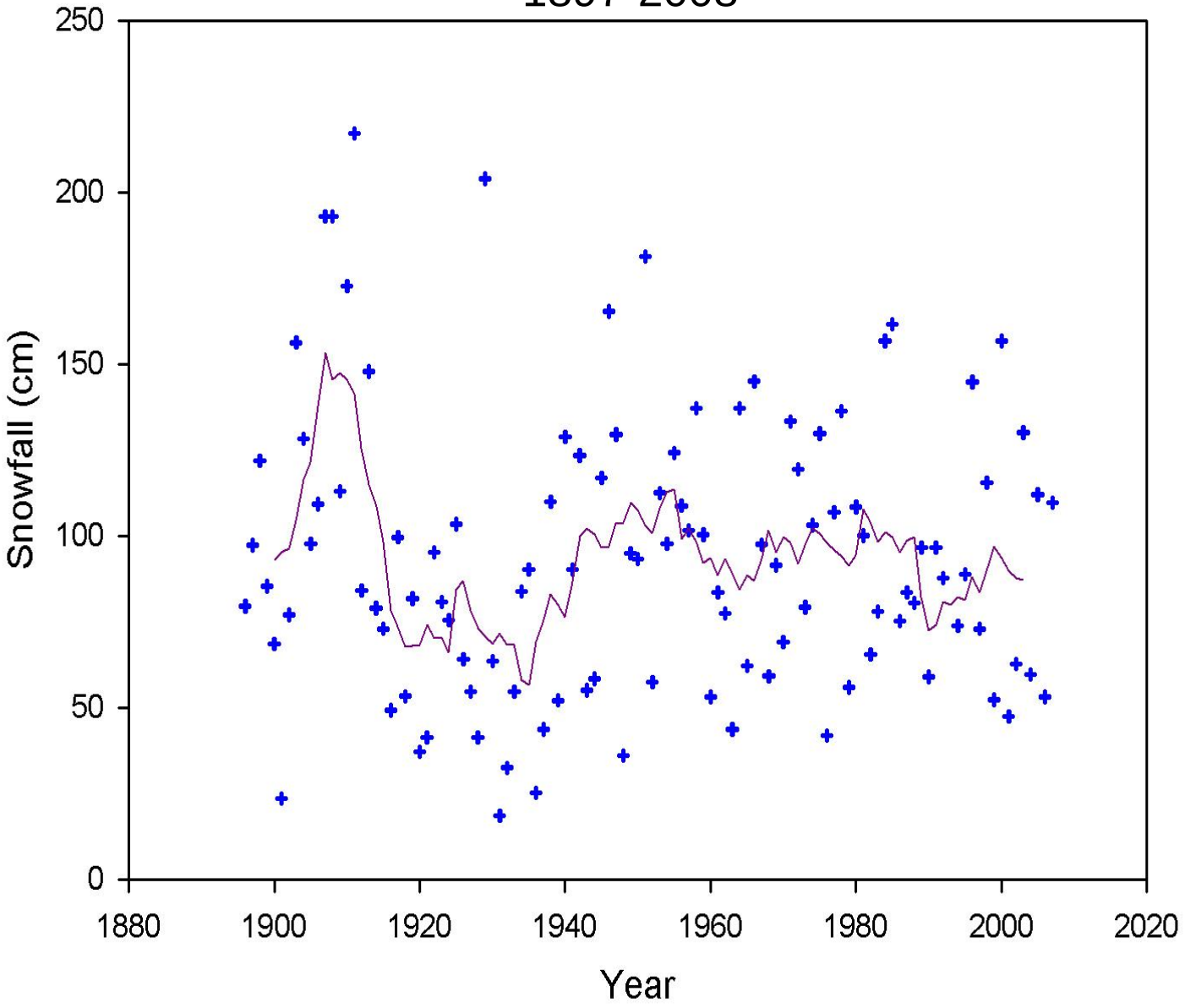
1930-2008



Total Seasonal Snowfall vs. Year

Bay City, MI

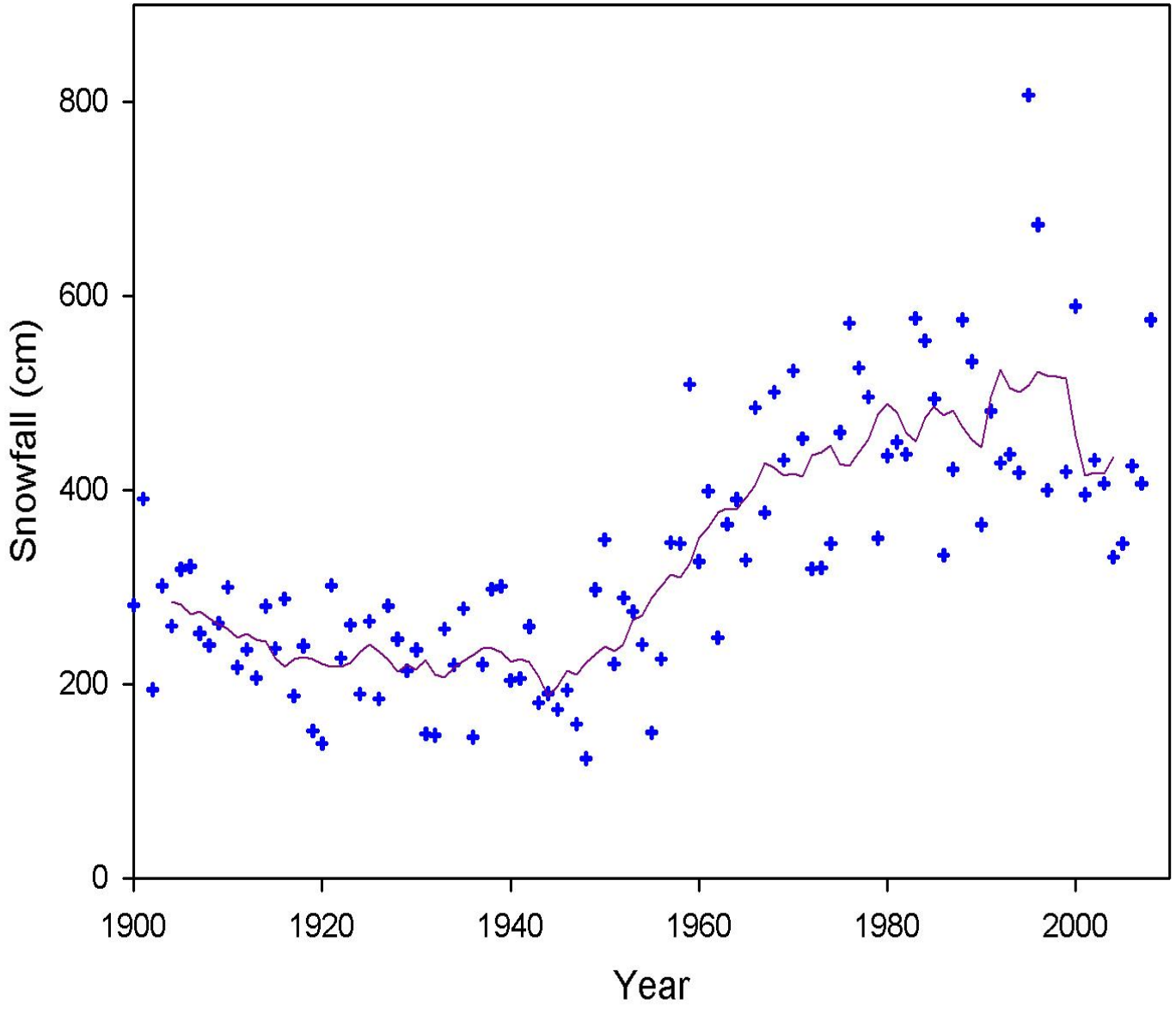
1897-2008



Total Seasonal Snowfall vs. Year

Chatham, MI

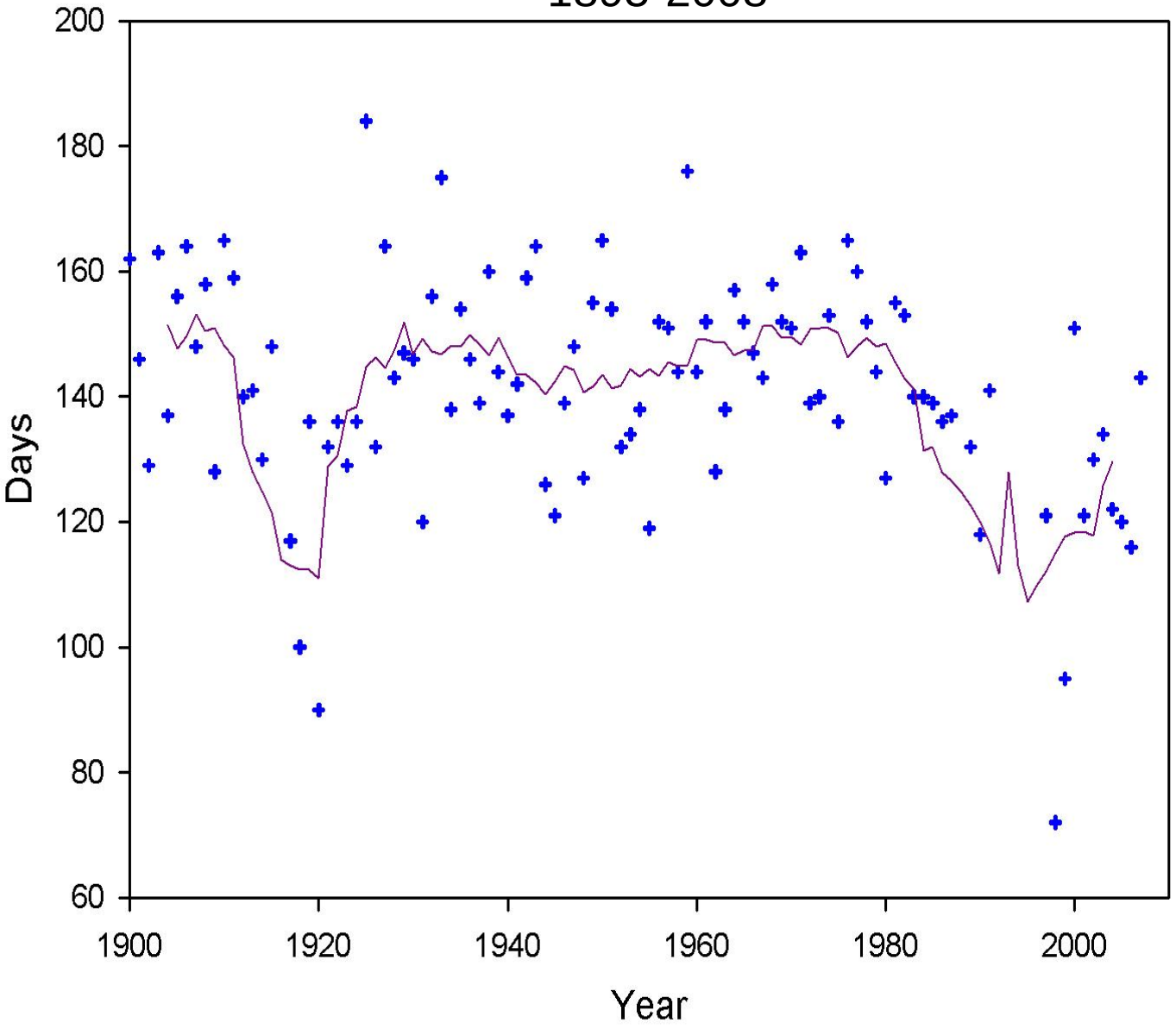
1901-2008



Annual Number of Days with Snowcover >= 1” vs. Year,

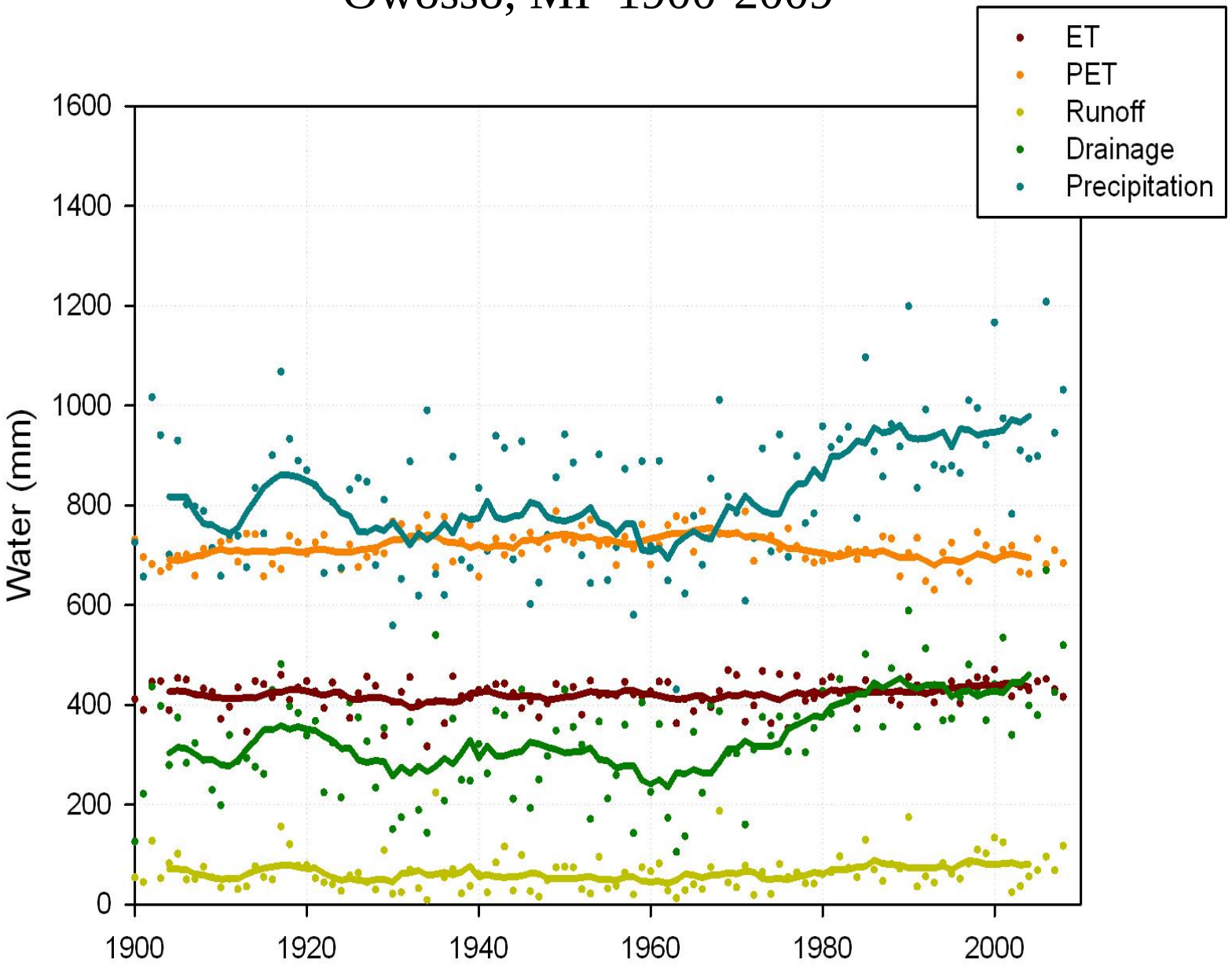
Chatham, MI

1895-2008



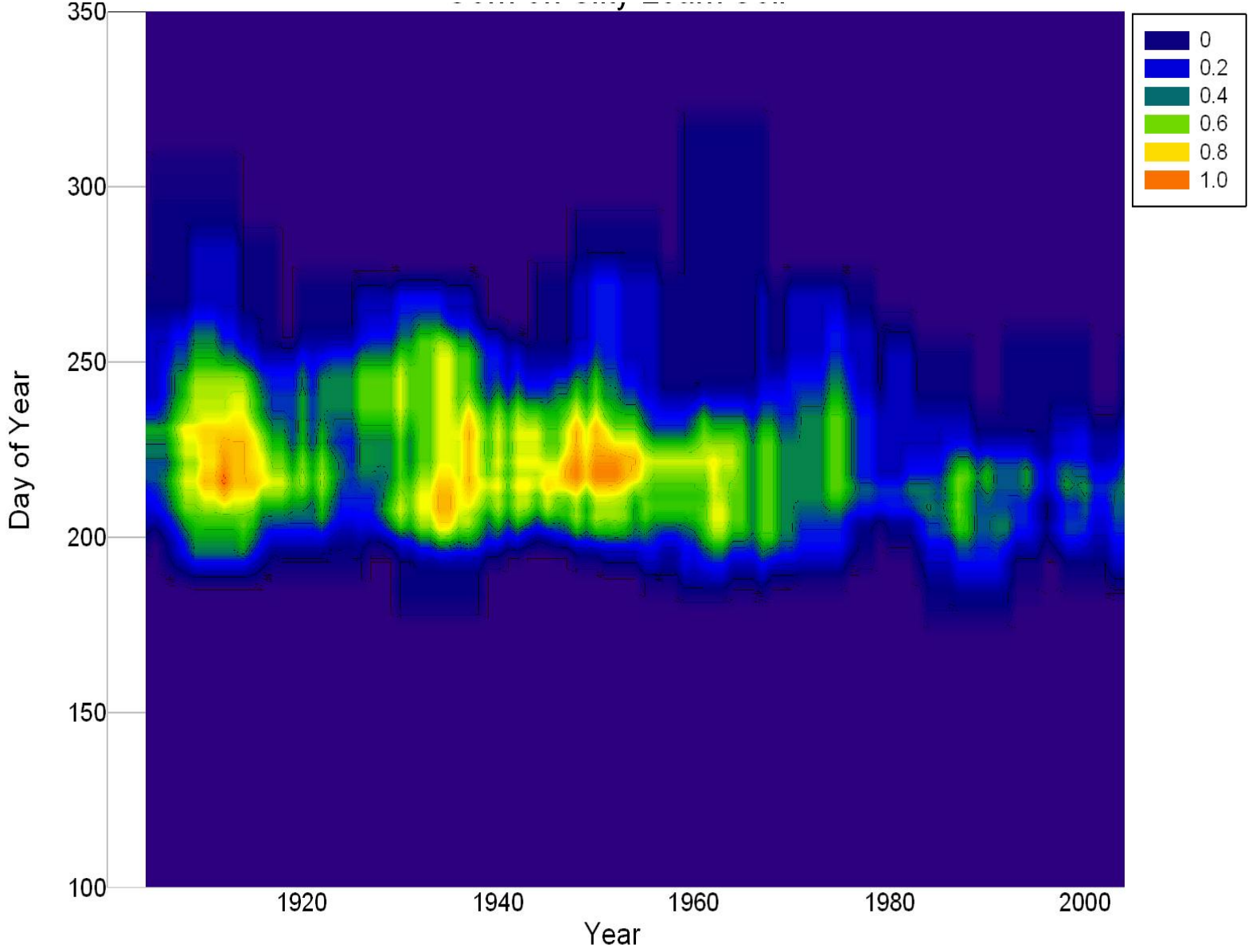
Hydrologic Variables vs. Year

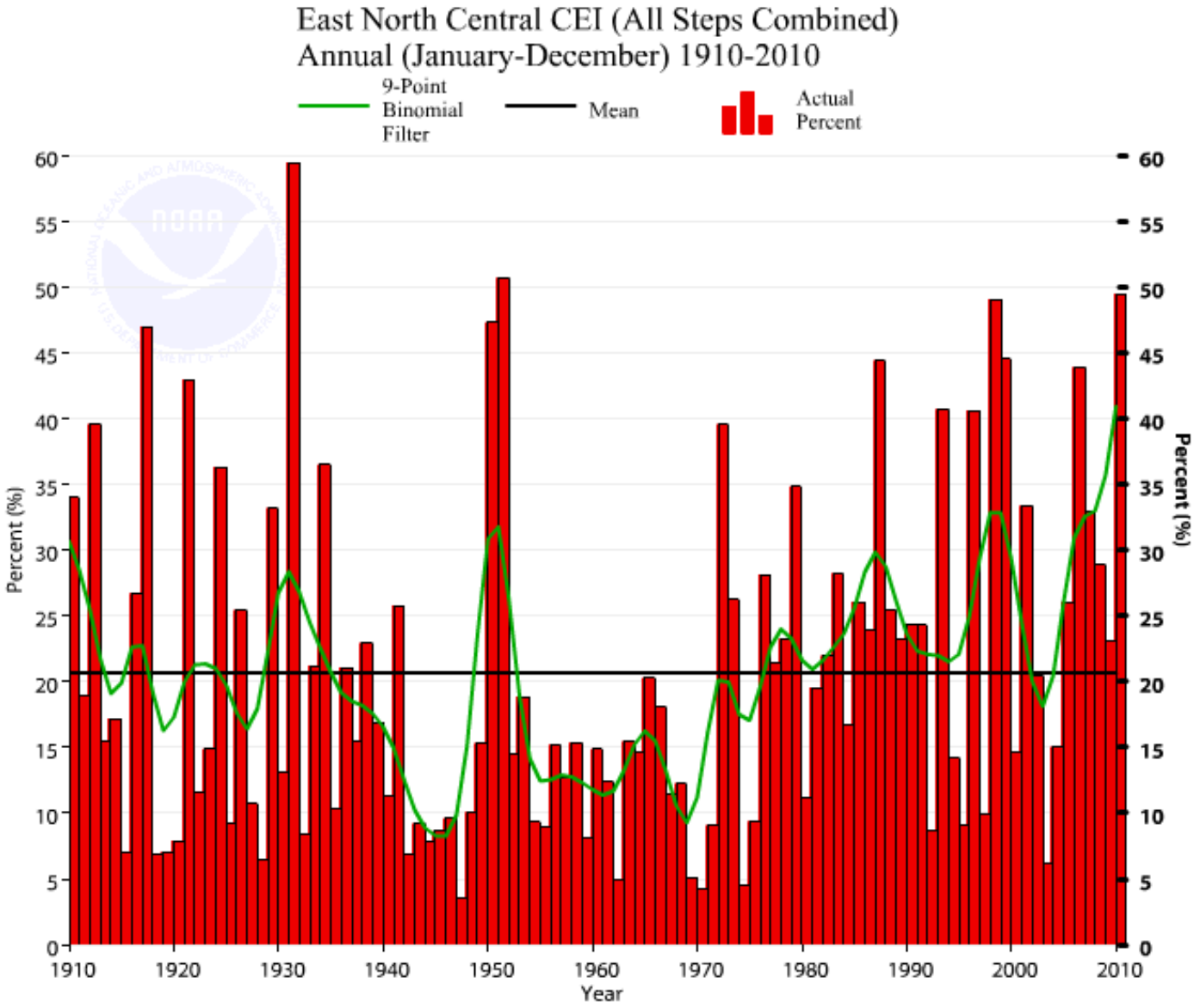
Owosso, MI 1900-2009



Frequency of Days PAW_{150} < 0.50 Potential PAW_{150}

Ann Arbor, MI, Silt Loam, 1900-2009

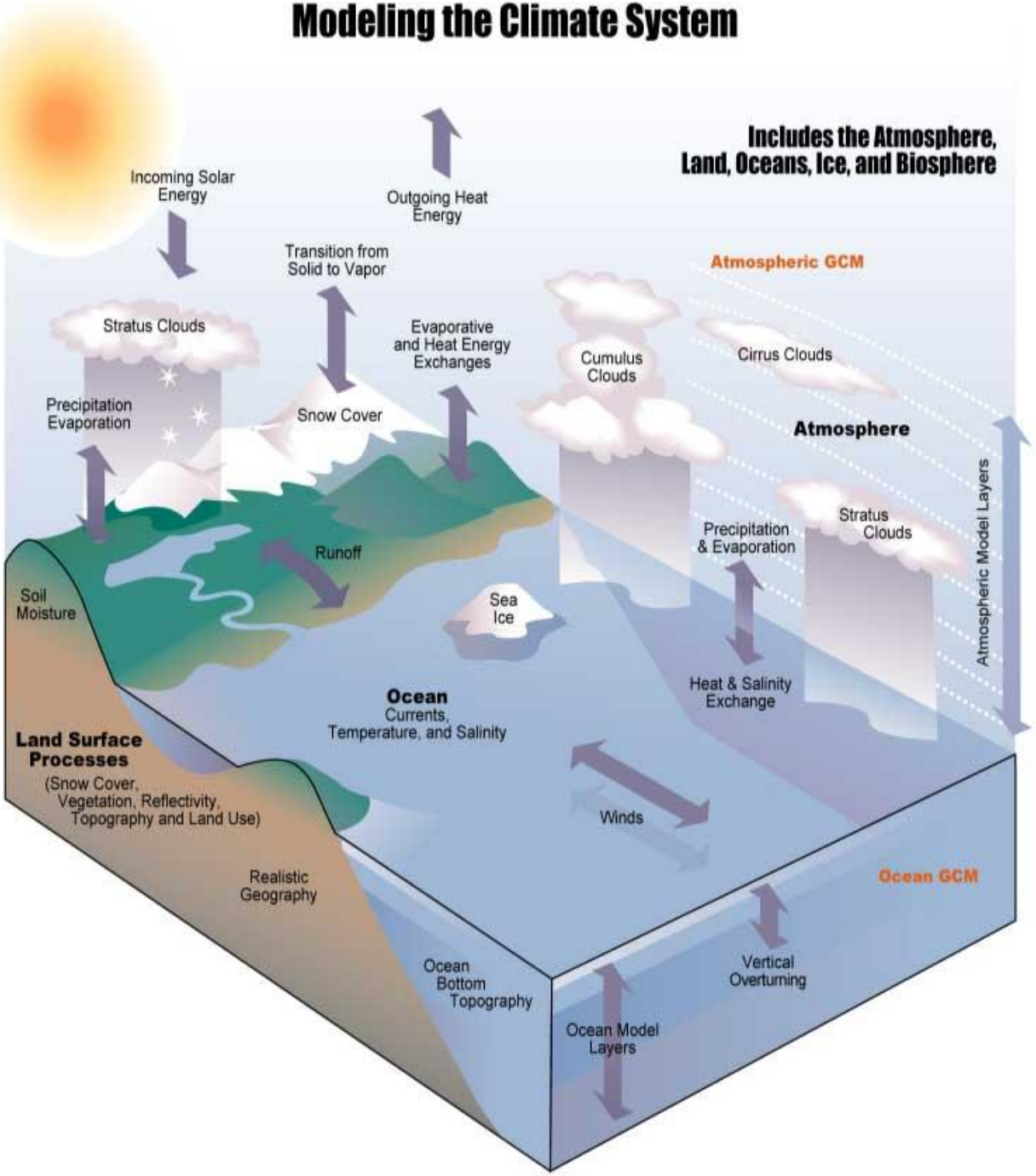




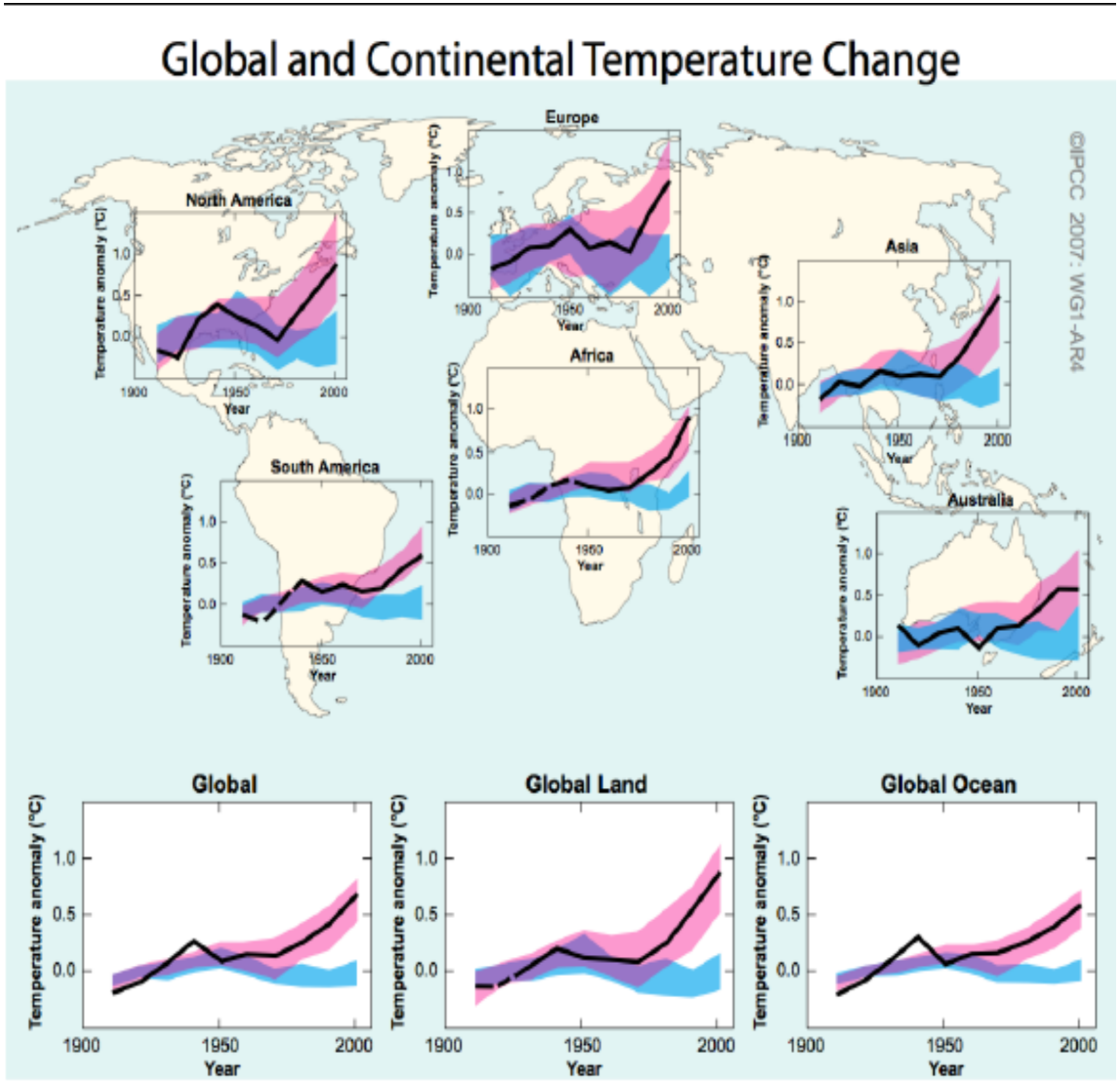
(Source: NCDC, 2011)

Projecting the Future:
Global Climate Models (GCMs)

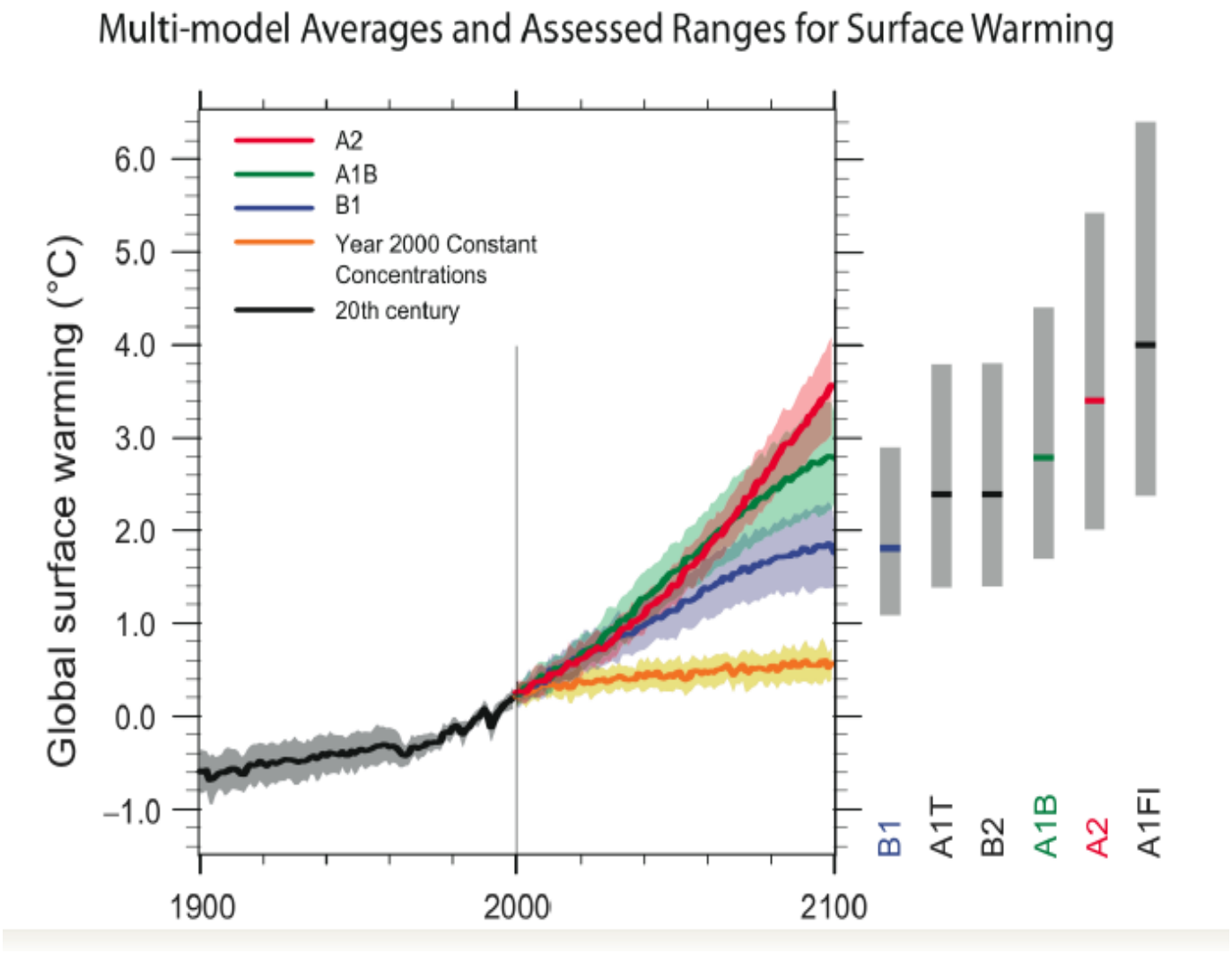
Modeling the Climate System



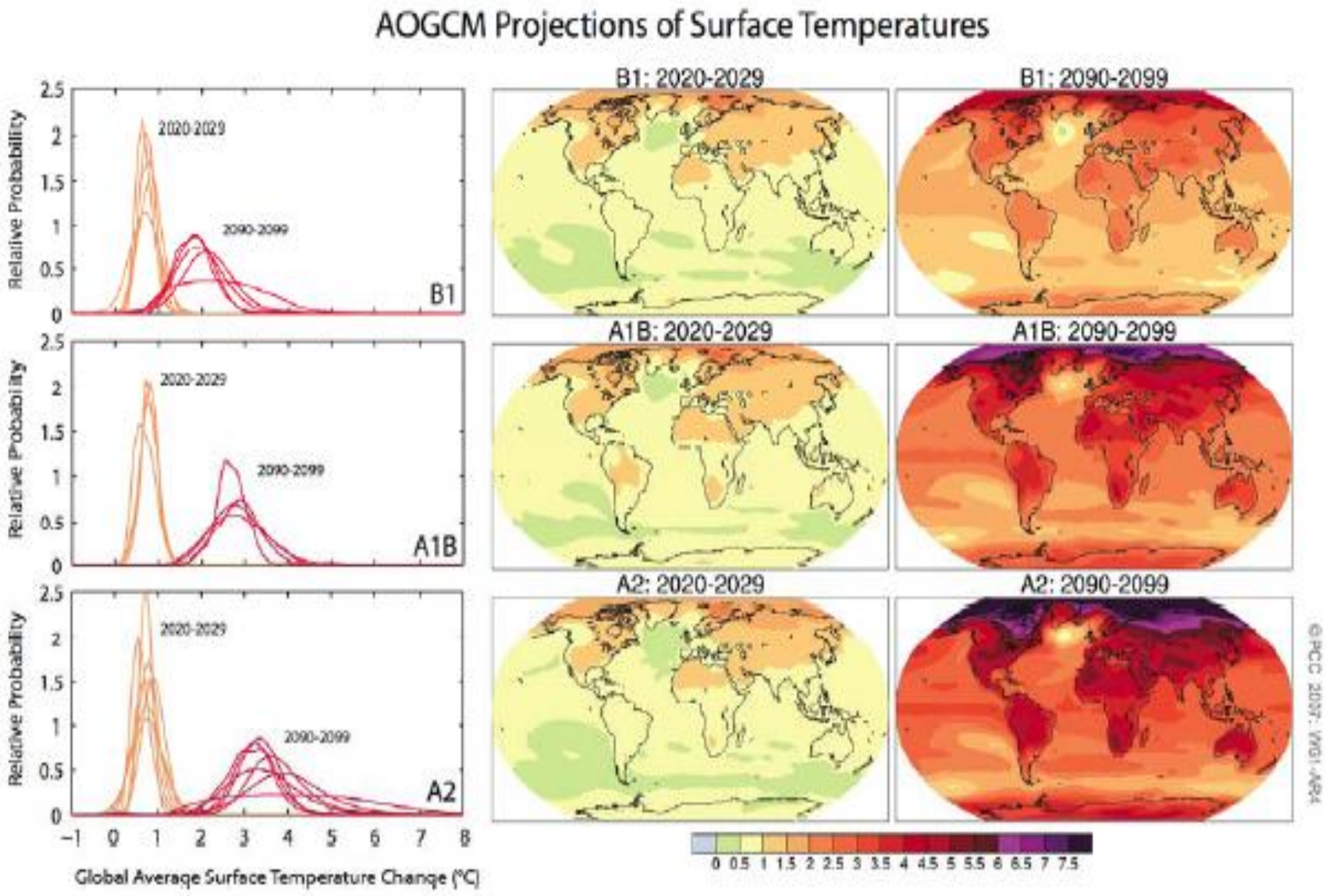
Natural Variability or Anthropogenic Signal?



(Source: IPCC, 2007)



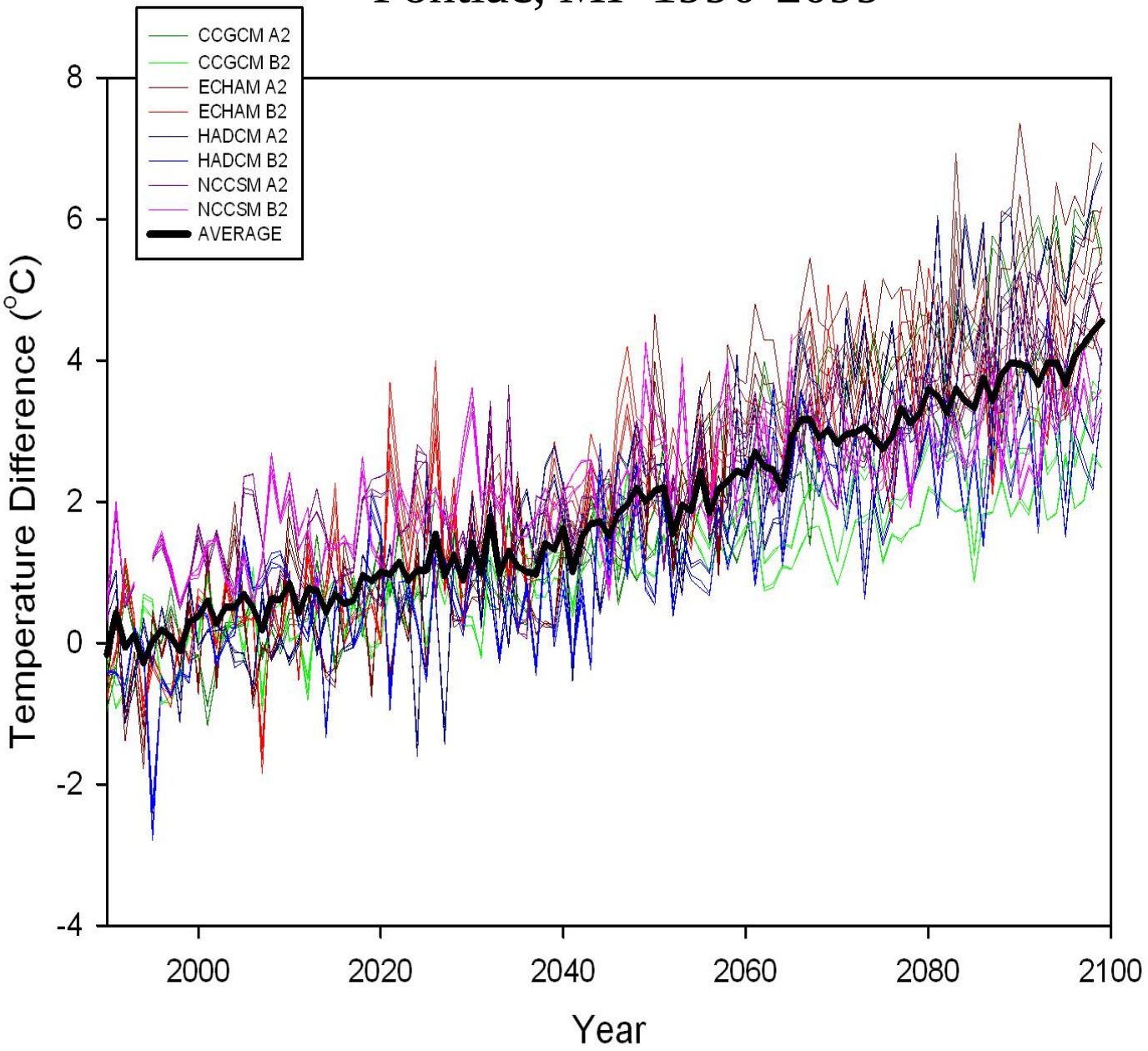
Source: (IPCC, 2007)



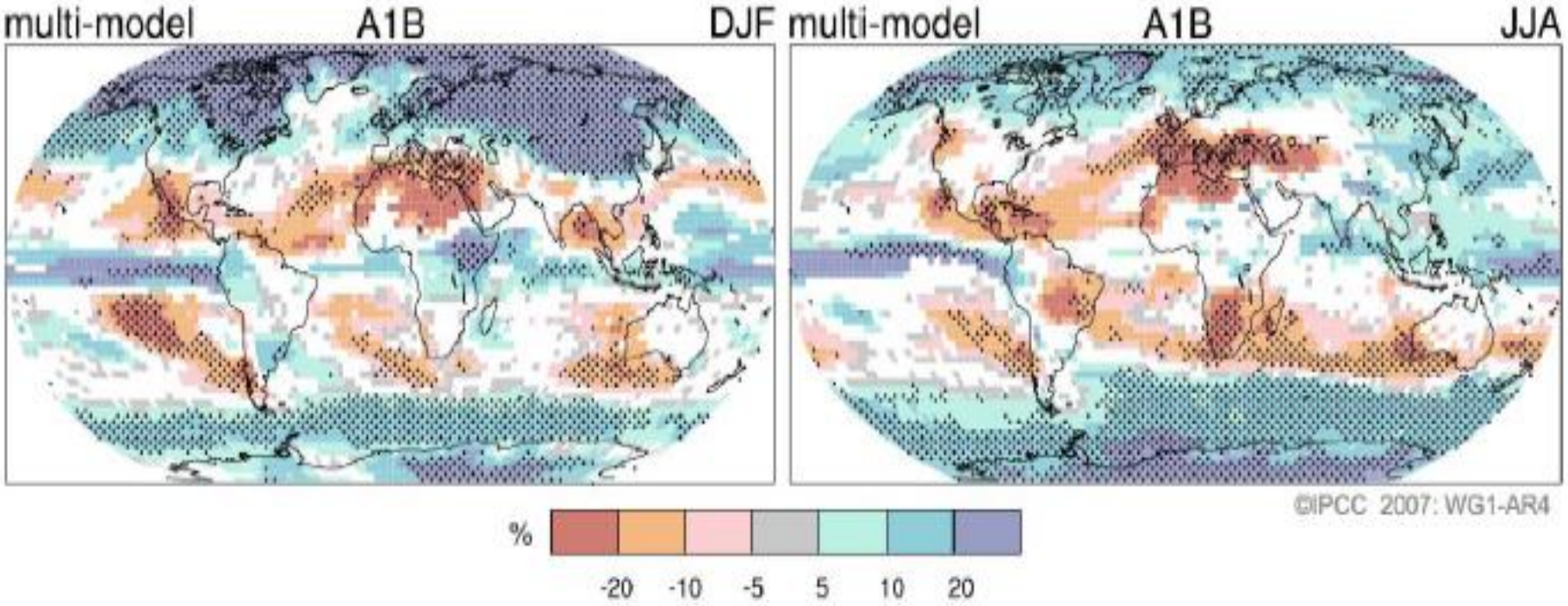
Source: (IPCC, 2007)

Model-Projected Mean Temperature Differences

Pontiac, MI 1990-2099



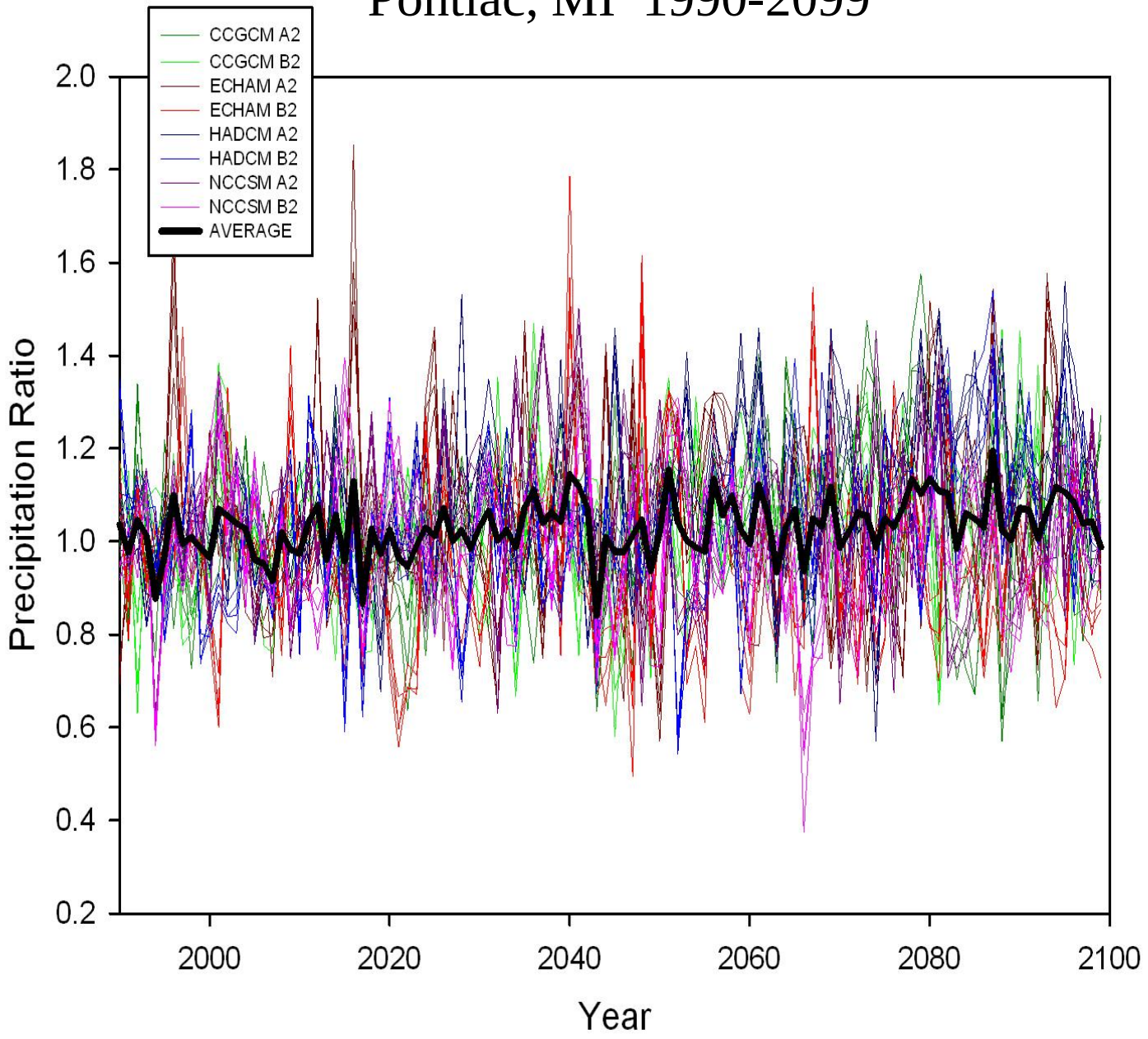
Projected Patterns of Precipitation Changes



Source: (IPCC, 2007)

Model-Projected Precipitation Ratios

Pontiac, MI 1990-2099



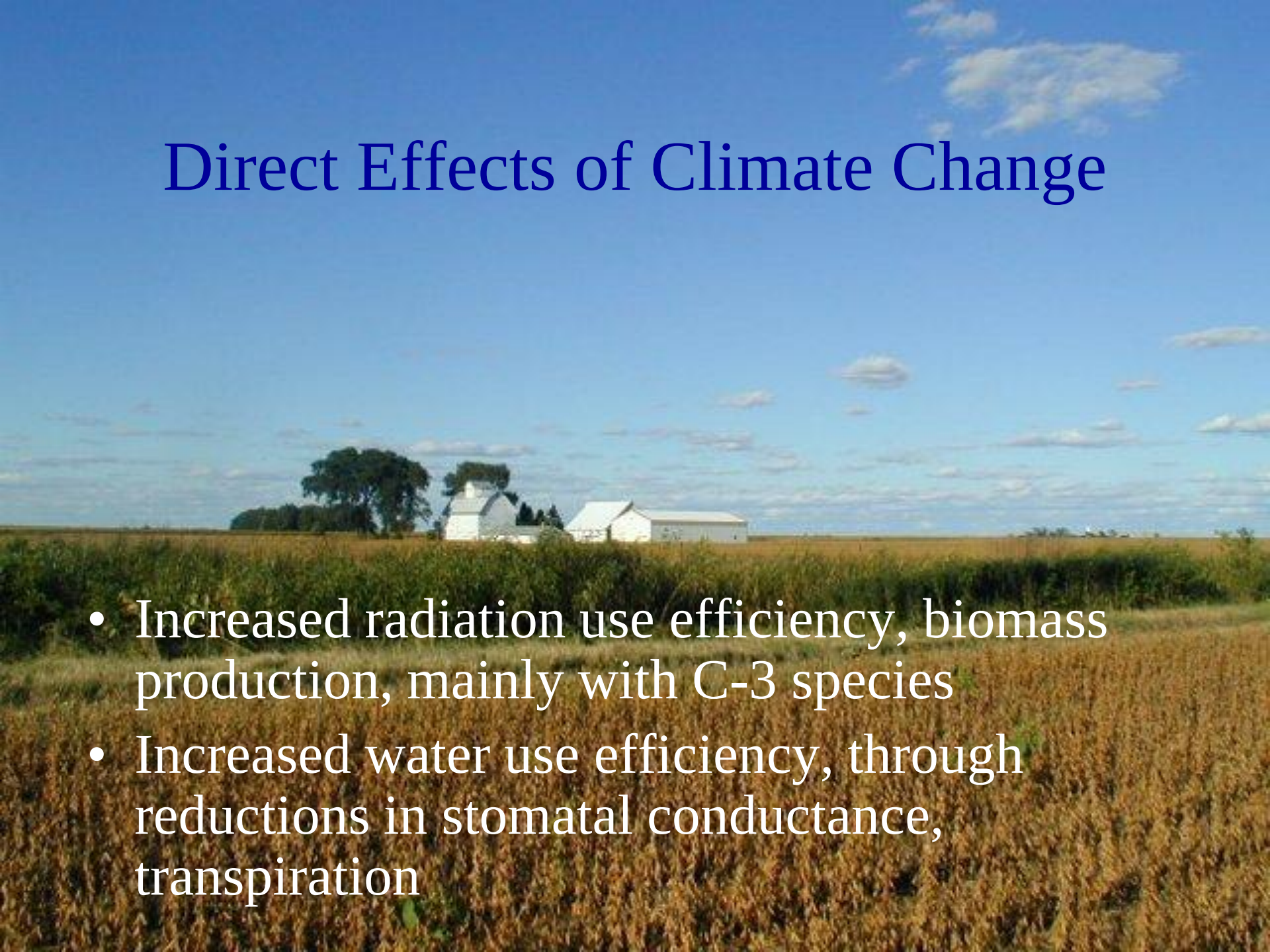
Potential Impacts

- Climate change threatens the basic elements of life for people around the world — access to water, food production, health, and use of land and the environment.
- The impacts of climate change are not evenly distributed: the poorest countries and people will suffer earliest and most.
- Eventual economic costs estimated at 5-20% of global GDP each year $4-15T: largest fraction was associated with sea level rise, greatest unknown with social instability/mass migration.
- ***The benefits of strong, early action on climate change outweigh the potential costs.***

Response Strategies

- Adaptation (learn to cope, adapt)
  - Migration, Abandonment (‘habitat tracking’)
- Mitigation (e.g. technology to reduce or solve problem)
  - Emission reductions
  - Energy conservation
  - Carbon sequestration
  - Geoengineering

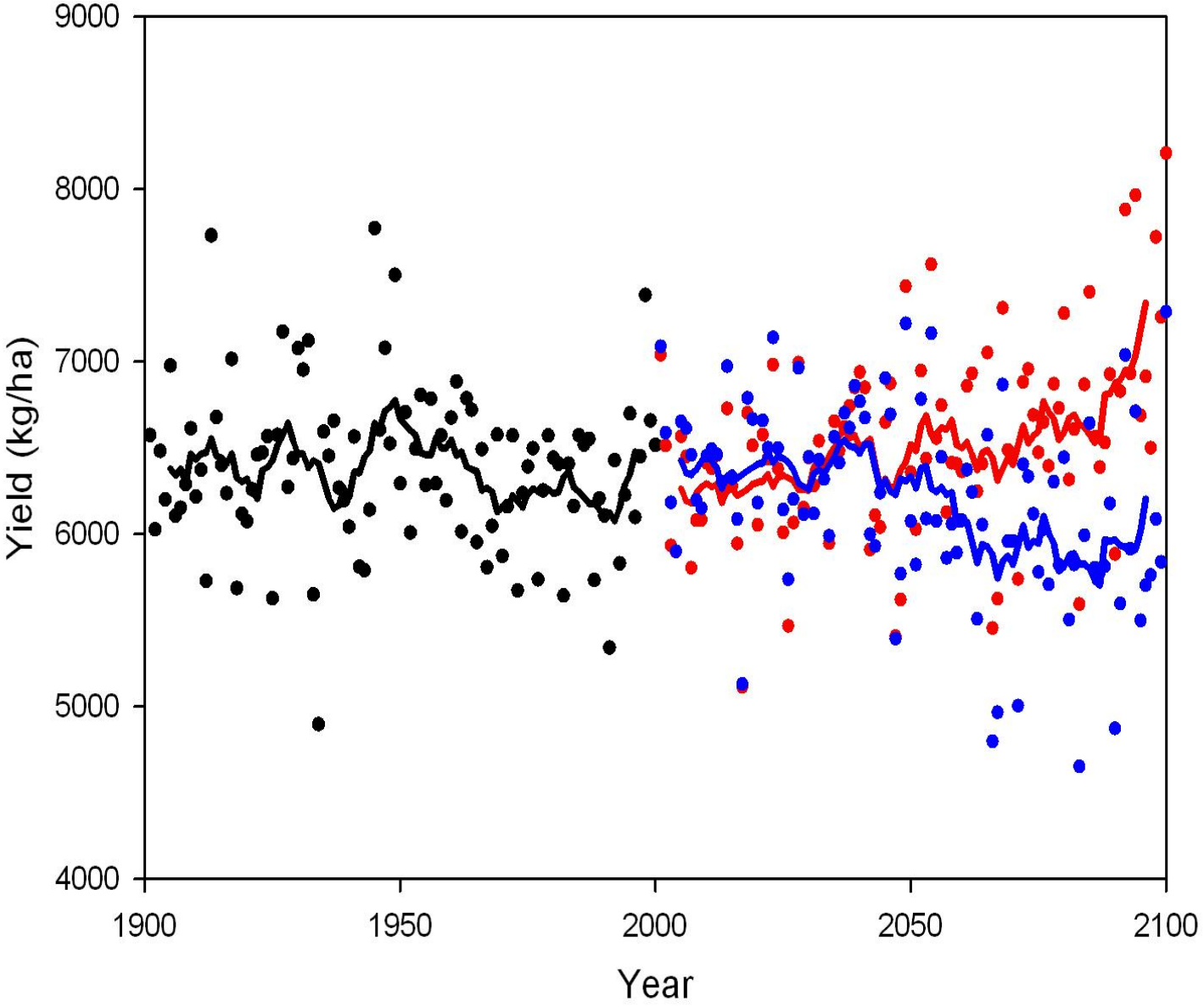
Direct Effects of Climate Change



- Increased radiation use efficiency, biomass production, mainly with C-3 species
- Increased water use efficiency, through reductions in stomatal conductance, transpiration

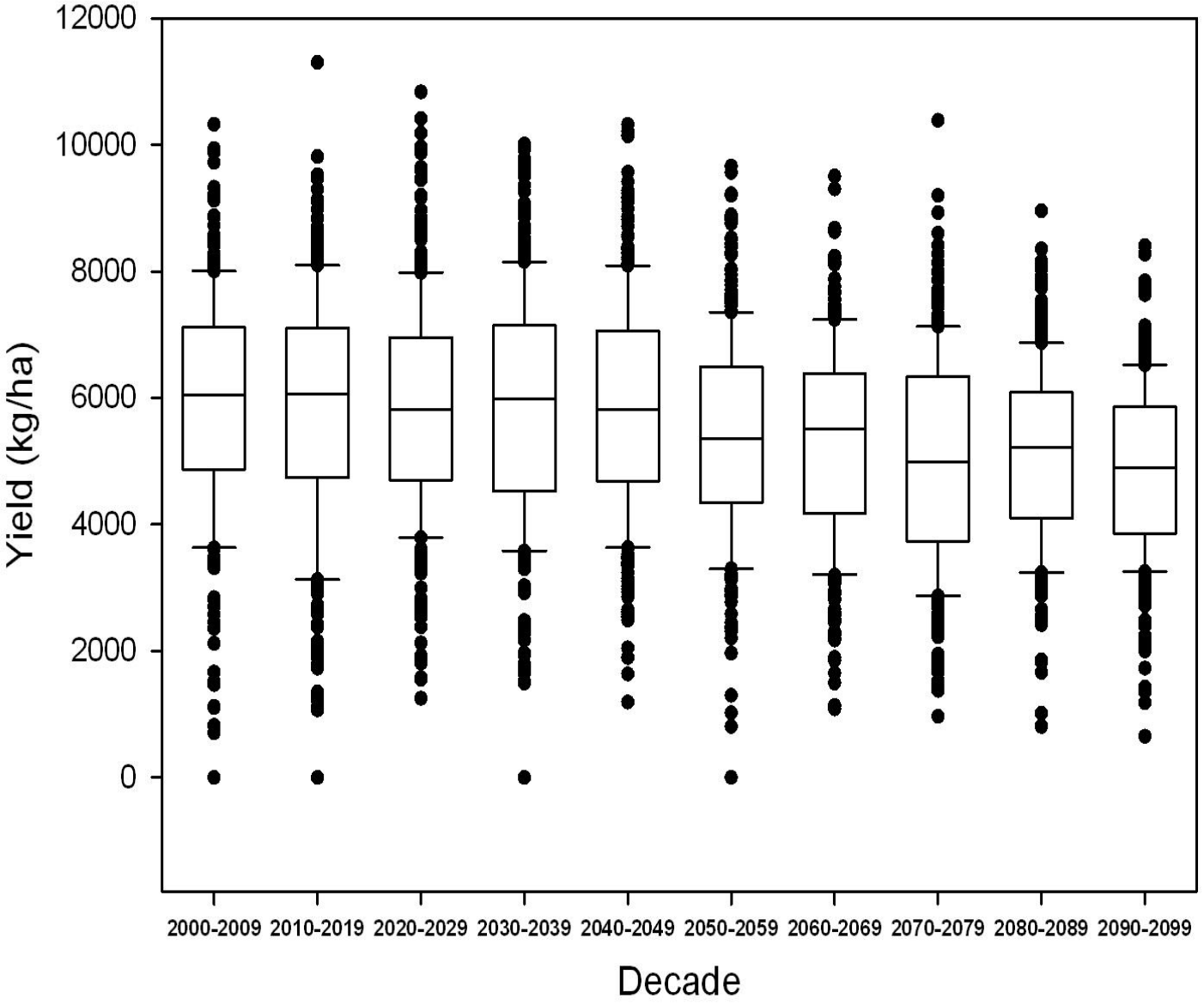
Historical and Projected Wheat Yields by Year With and Without CO_2 Enrichment

Pontiac, MI



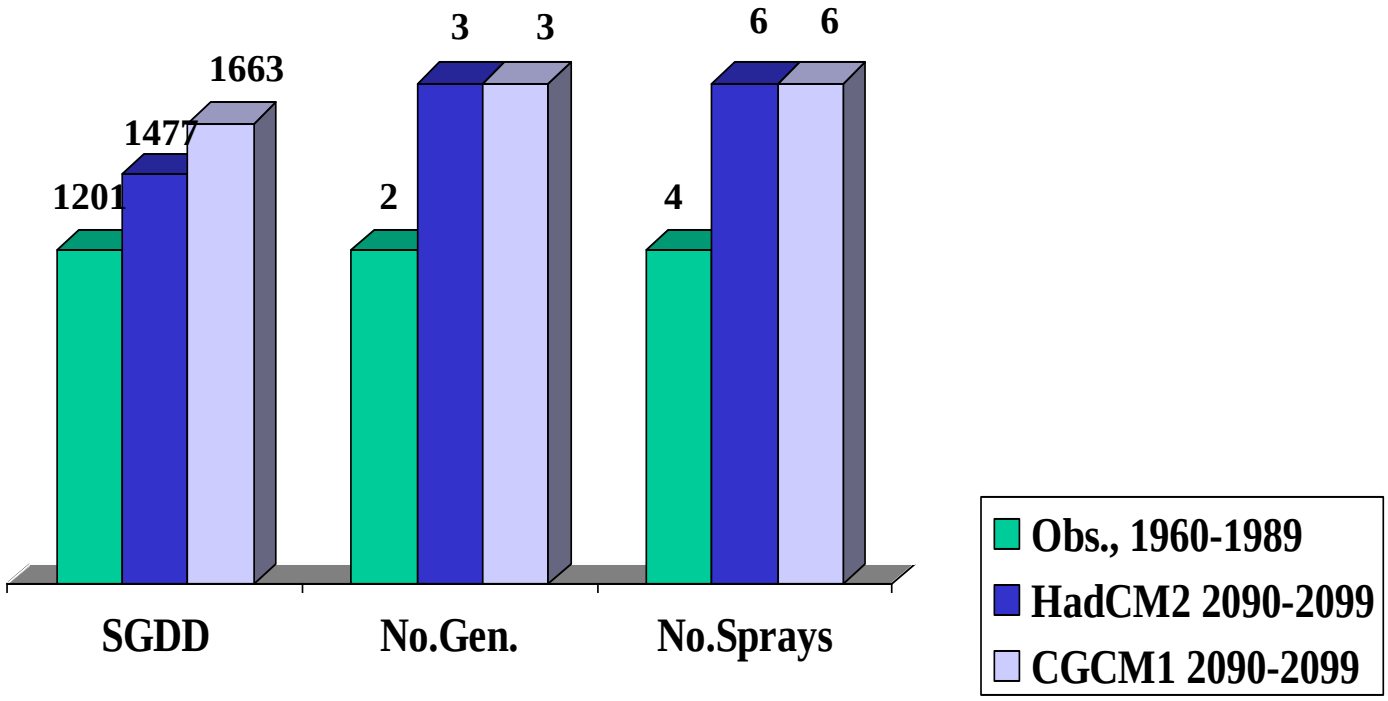
Projected Maize Yields by Decade, all Scenarios w/o CO_2 Enrichment

Fredonia, NY



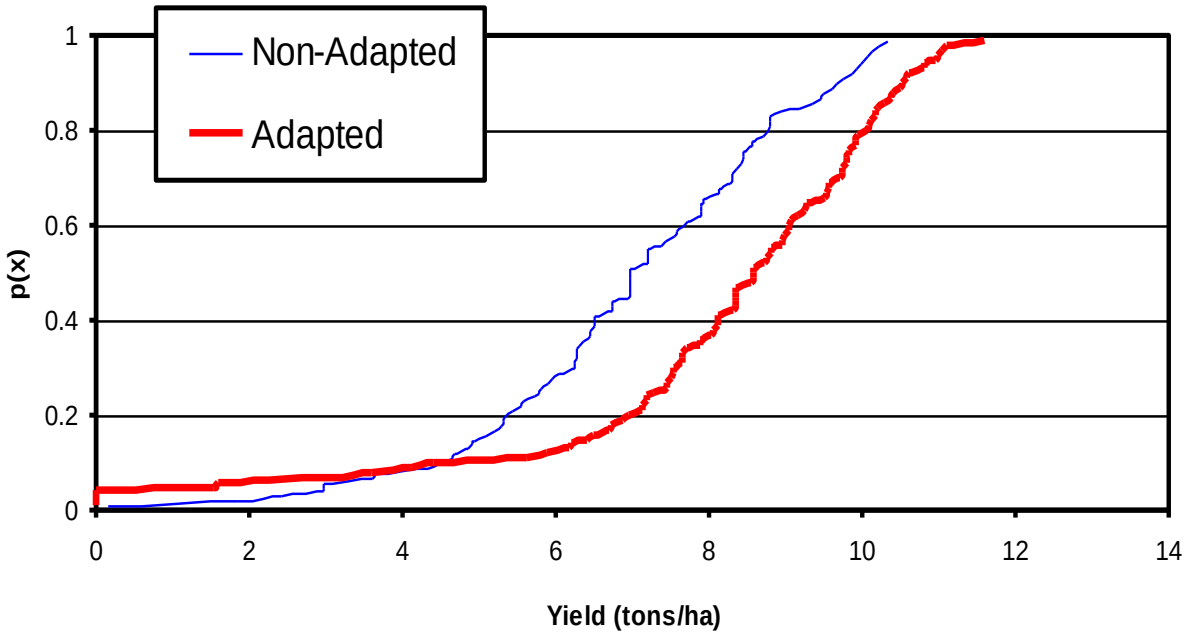
Simulated Pest Management Parameters, Apple Codling Moth

East Jordan, MI

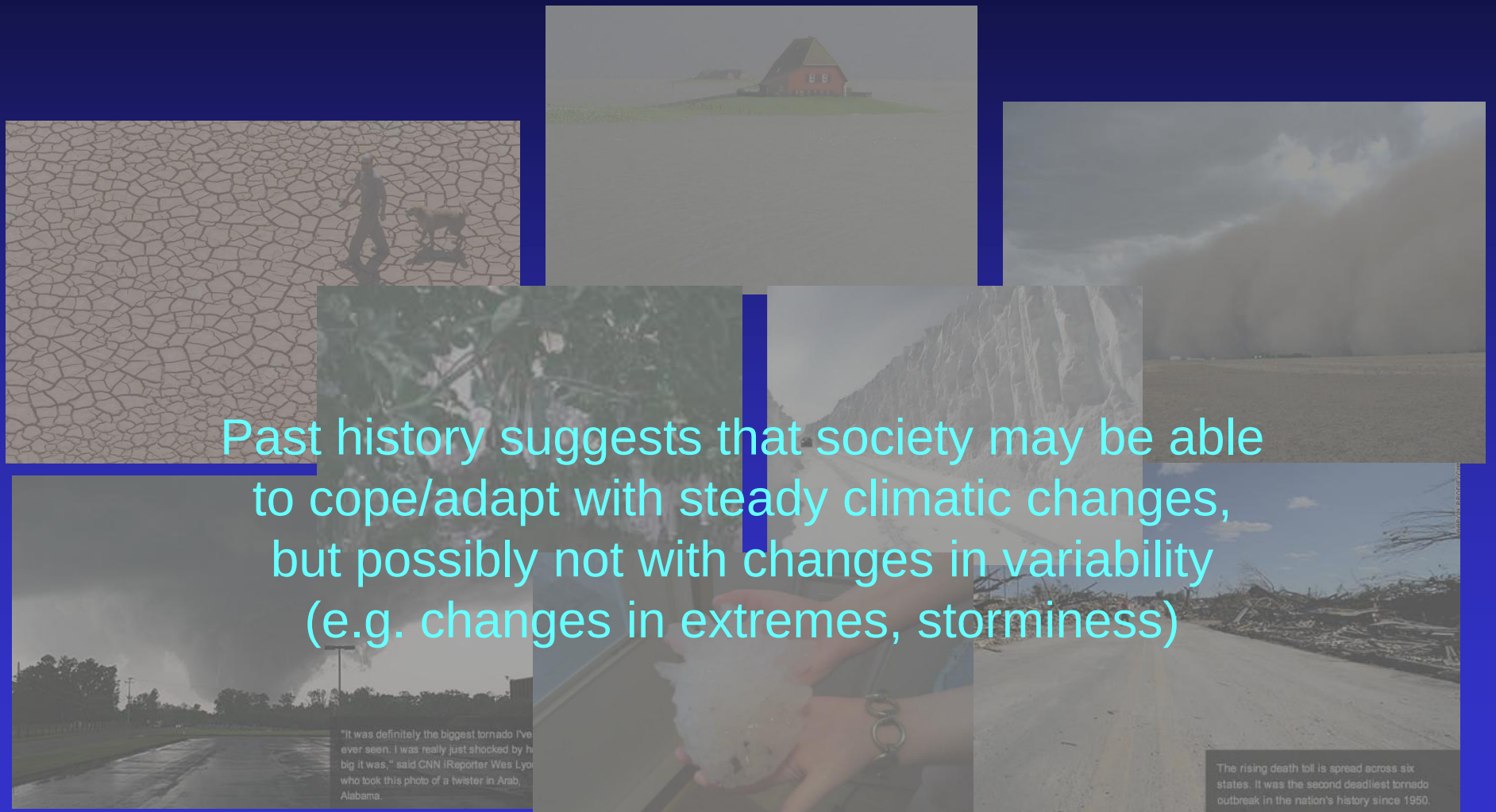


Maize Yields for Adapted vs. Non-adapted Cultivar

2010-2099, Owosso, MI



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)

Summary

- Overall, mean average temperatures in Michigan rose approximately 1.0ºF during the past century. Warming of about 2.0ºF has occurred between 1980 and the present, much of it concentrated during the winter season and at night.
- Milder winter temperatures have led to less ice cover on the Great Lakes and the seasonal spring warm-up is occurring earlier than in the past.
- Annual precipitation rates increased from the 1930's through the 1990's but have leveled off recently.
- Most recent GCM simulations of the Great Lakes region suggest a warmer and wetter climate in the distant future, with much of the additional precipitation coming during the cold season months.
- Projections of future climate change in Michigan suggest a mix of beneficial and adverse impacts.
- A changing climate leads to many potential challenges for dependent human and natural systems, especially with respect to climate variability.