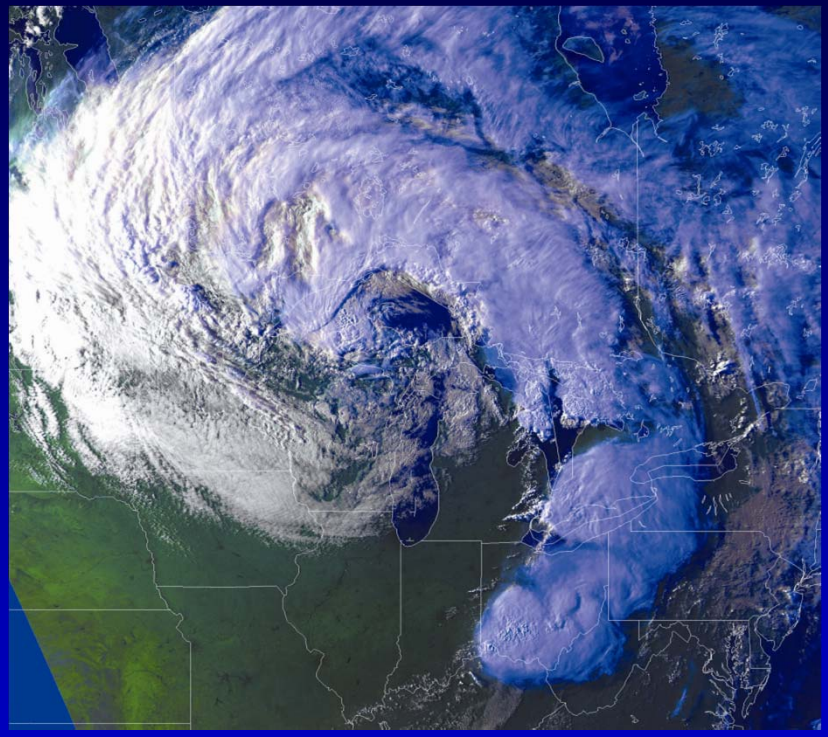
Climate Variability and Change: Basic Concepts



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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…'*

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.

The Earth's climate system is dynamic: It changes. It always has and it always will.

- So why are we concerned now?
  1. We might be responsible.
  2. We might not like the changes.

- The globe is projected to warm 1.0-4.0°C by 2100.
  - Is that a big deal?
  - Depths of the Ice Ages
    - 5-6°C colder than today.

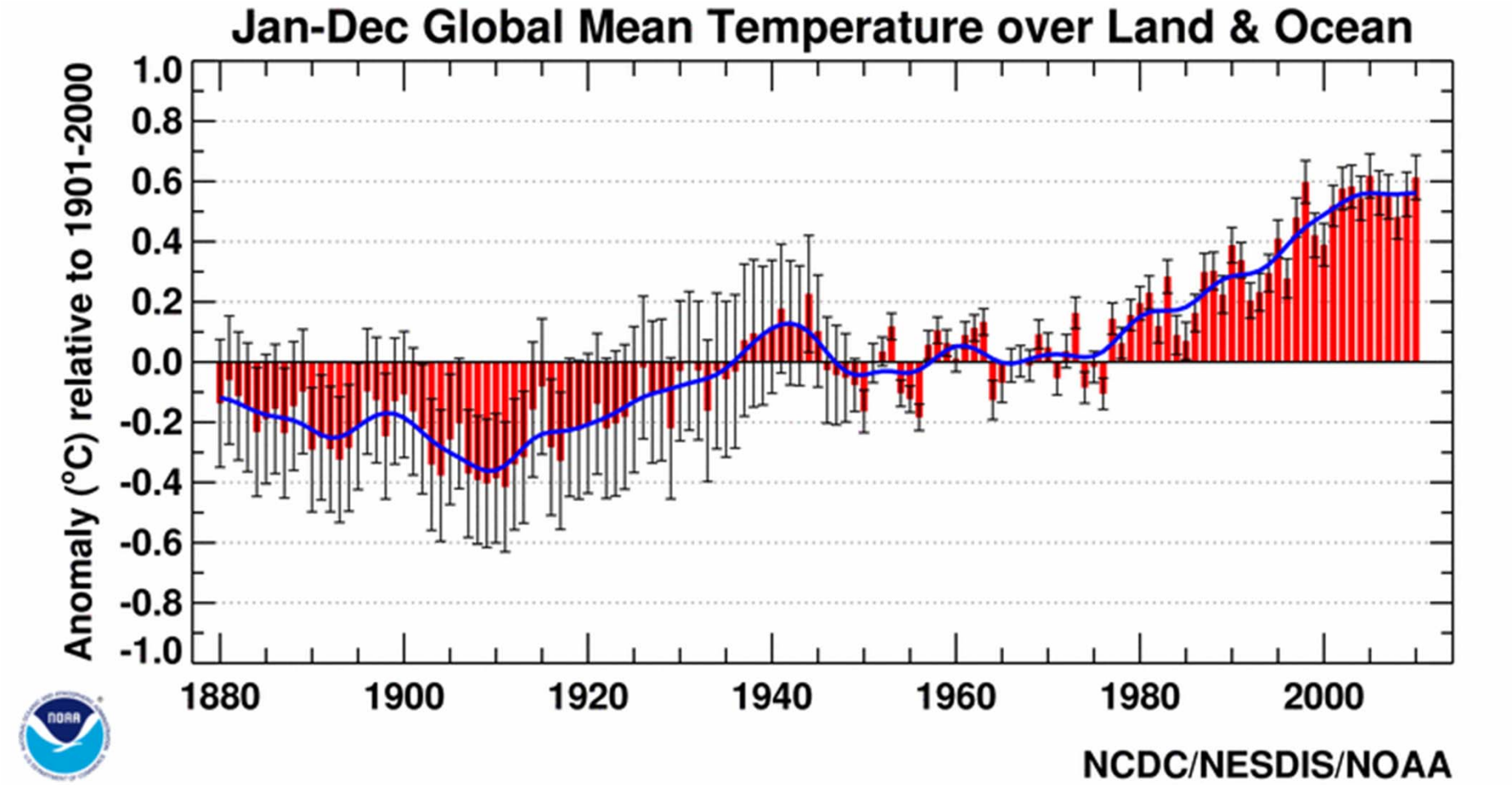
‘Natural’ Mechanisms and Processes Leading to Climate Change:

- Global Plate Tectonics
- Sunspots
- Variations in Earth orbit (Milankovitch Theory)
- Vulcanism (e.g. Mt. Pinatubo 1991)
- Meteor Impact (e.g. Chicxulub, K-T extinction 65M ybp)
- Periodic changes in the earth’s carbon, nitrogen cycles

Anthropogenic Mechanisms and Processes Leading to Climate Change:

- Changes in atmospheric greenhouse gas concentrations
- Changes in other atmospheric gas concentrations (e.g. ozone depletion)
- Land use changes

Mean global temperatures have increased approx. 0.9°C during the past century



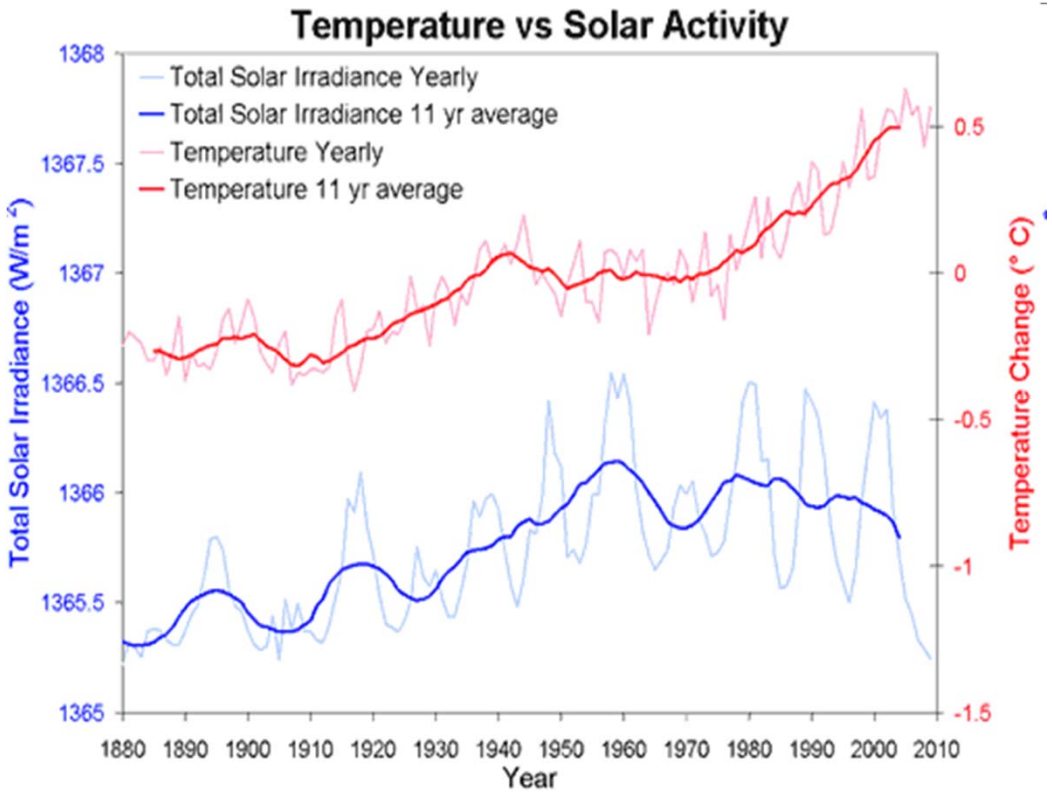
How can the Earth physically warm up over time?

- At its simplest, long term warming of the earth's surface boils down to three possibilities.

- The Earth will warm if:
  - The Sun gets brighter
  - The Earth gets darker (less reflective)
  - The Earth cannot reradiate heat fast enough

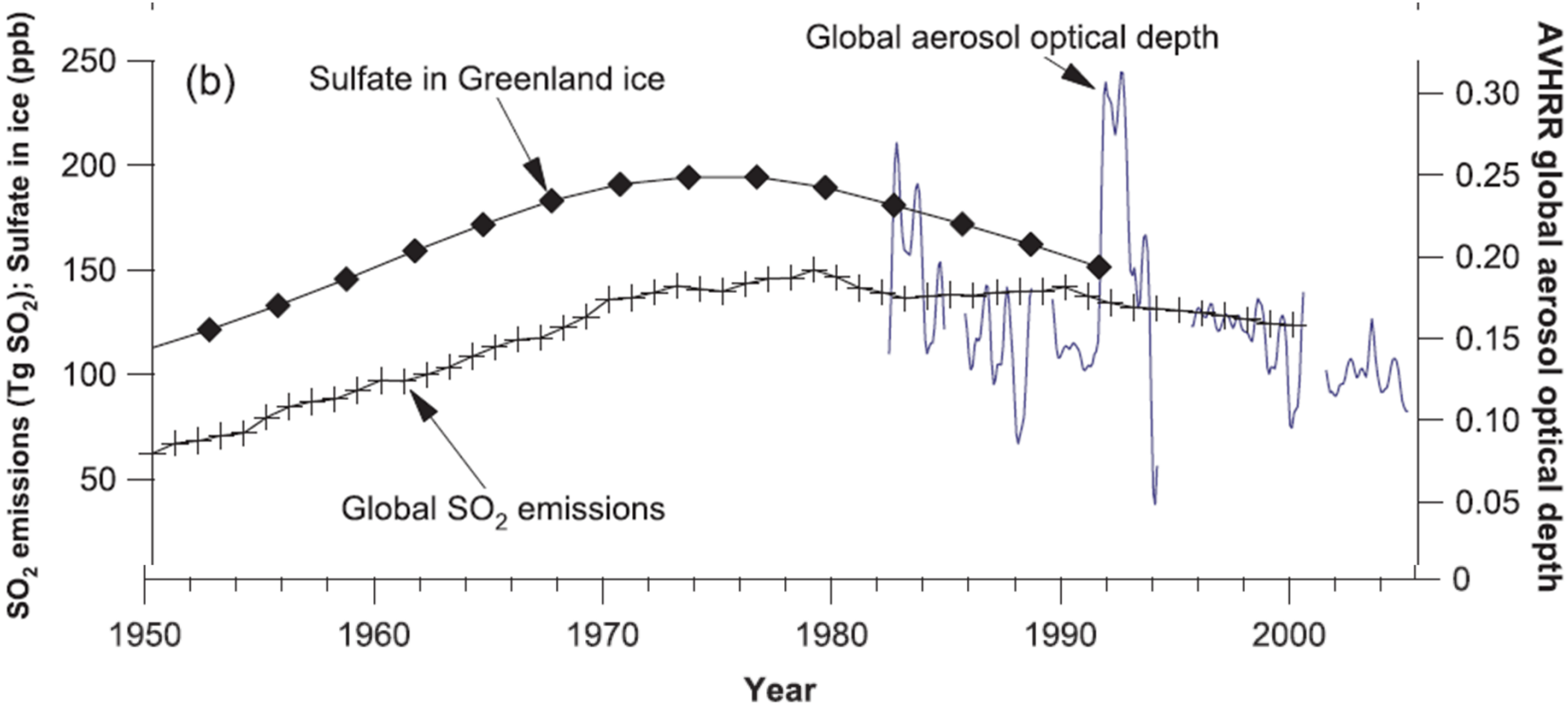
Has the Sun been getting brighter?

- In short, no.
- During the last 35 years the solar ‘constant’ has decreased.
- Solar cycle 24 is now beginning so we should experience roughly 0.24 W/m^2 heating by 2013



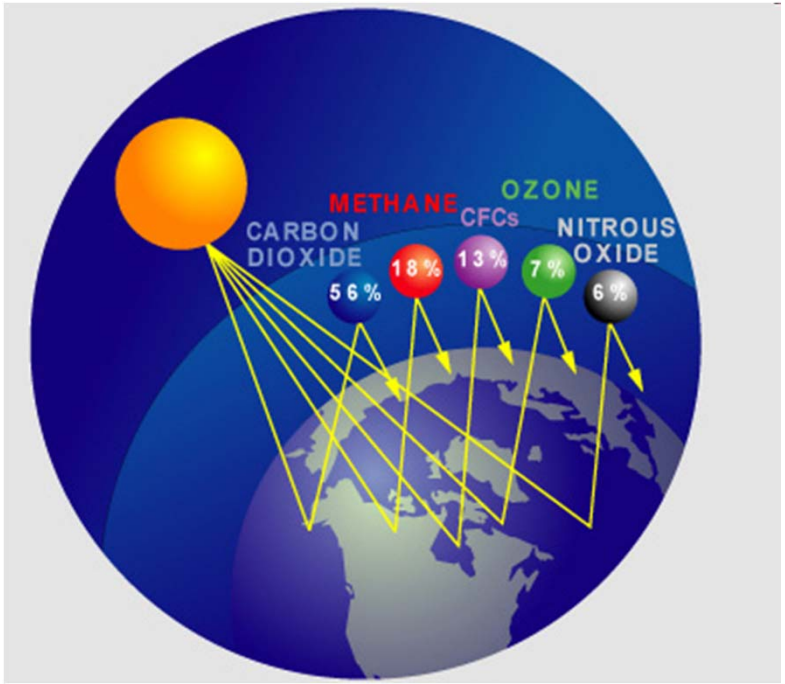
Has the Earth been getting darker?

- No. If anything, it has been brighter/more reflective.

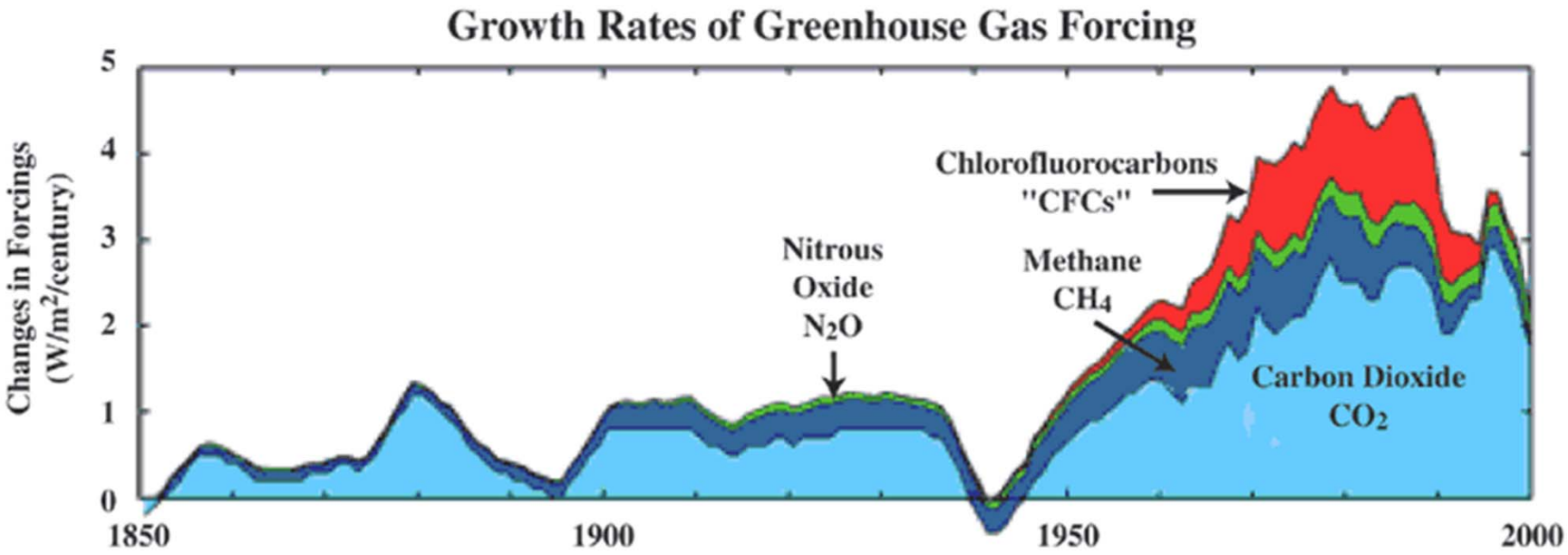


Process of elimination means…

- Something must be keeping energy (heat) from escaping like it previously did.
- That ‘something’ is the set of greenhouse gases, which include:
  - **Carbon dioxide**
  - **Methane**
  - **Halocarbons**
  - **Ozone**
  - **Nitrous oxide**

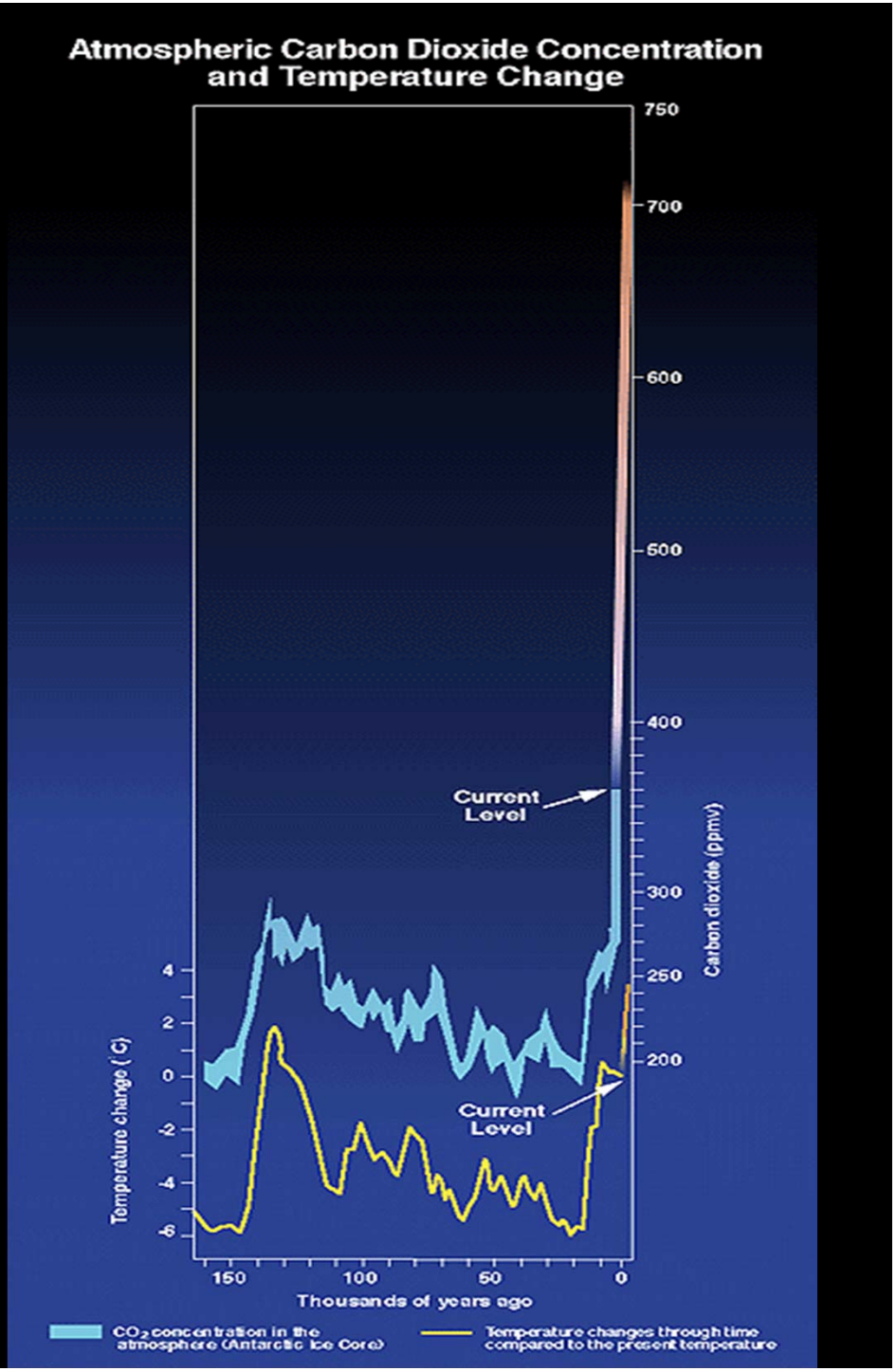


Concentrations of GHGs in the atmosphere are increasing…



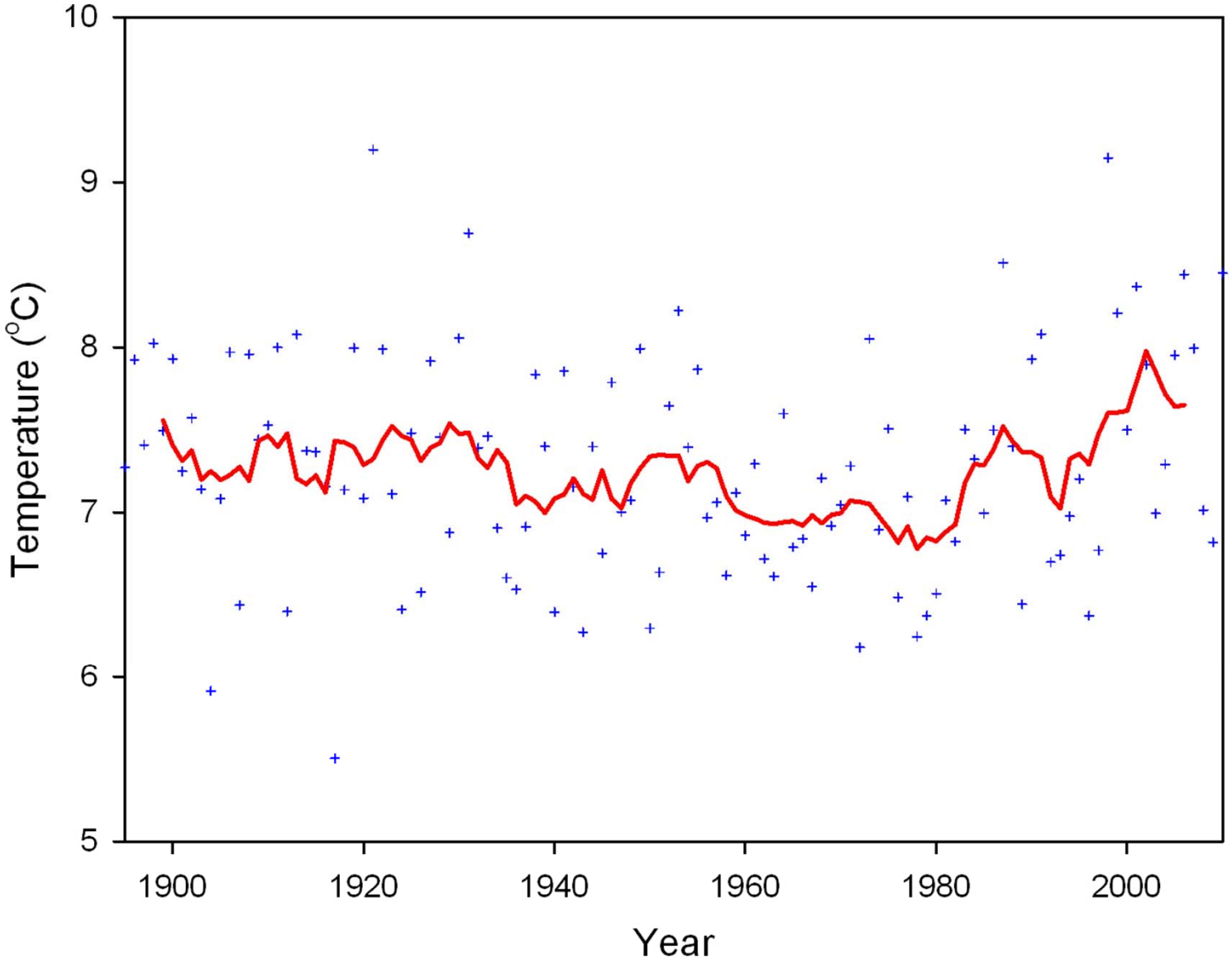
*** For reference, the amount of solar energy absorbed at the top of the atmosphere averaged globally is 240 W/m$^{2.}$

…and have been strongly correlated with temperature changes in the past.



Historical Climatic Trends: Instrumental Record

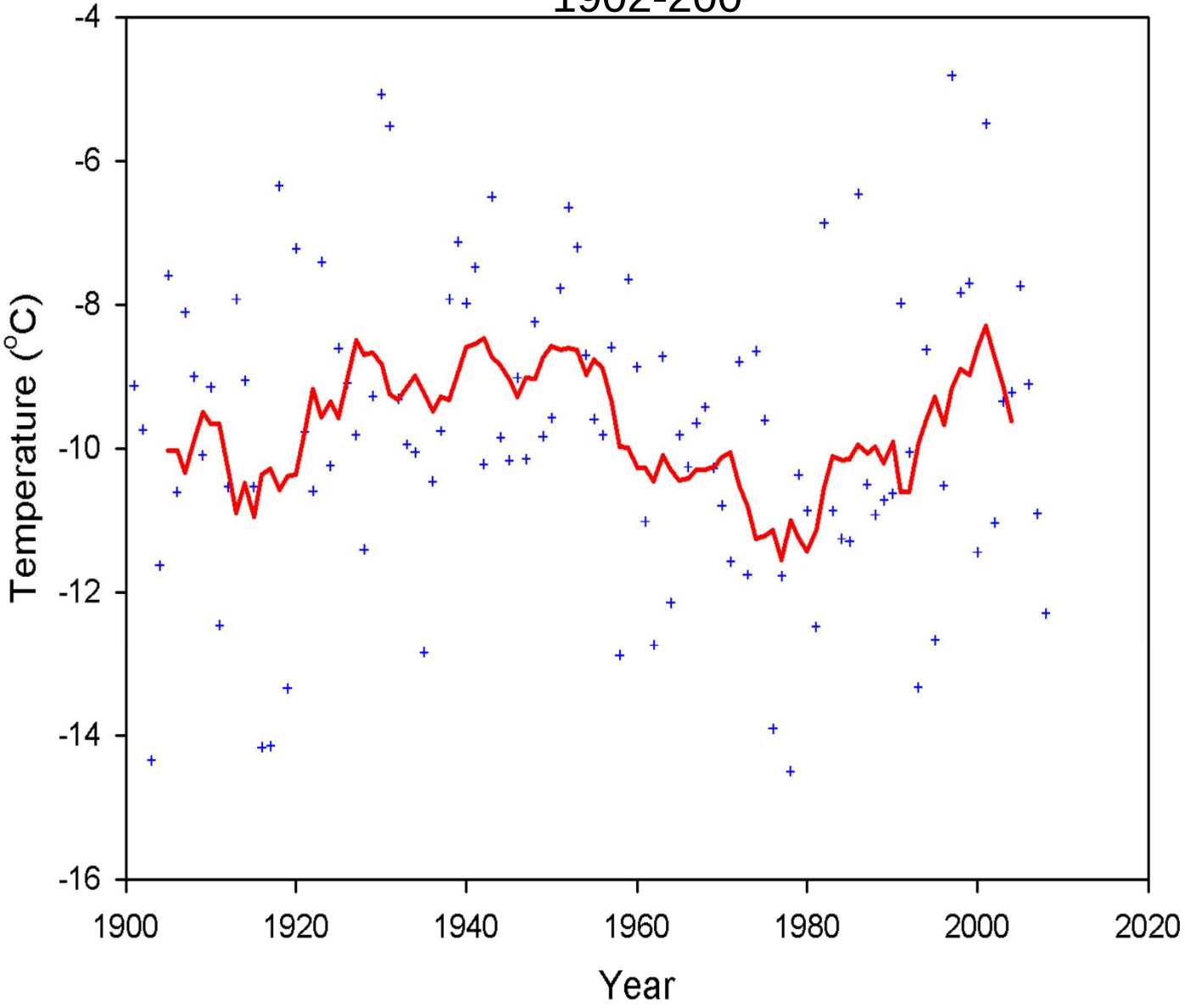
Mean Temperatures vs. Year, Michigan
1895-2010



Mean Winter Temperatures vs. Year

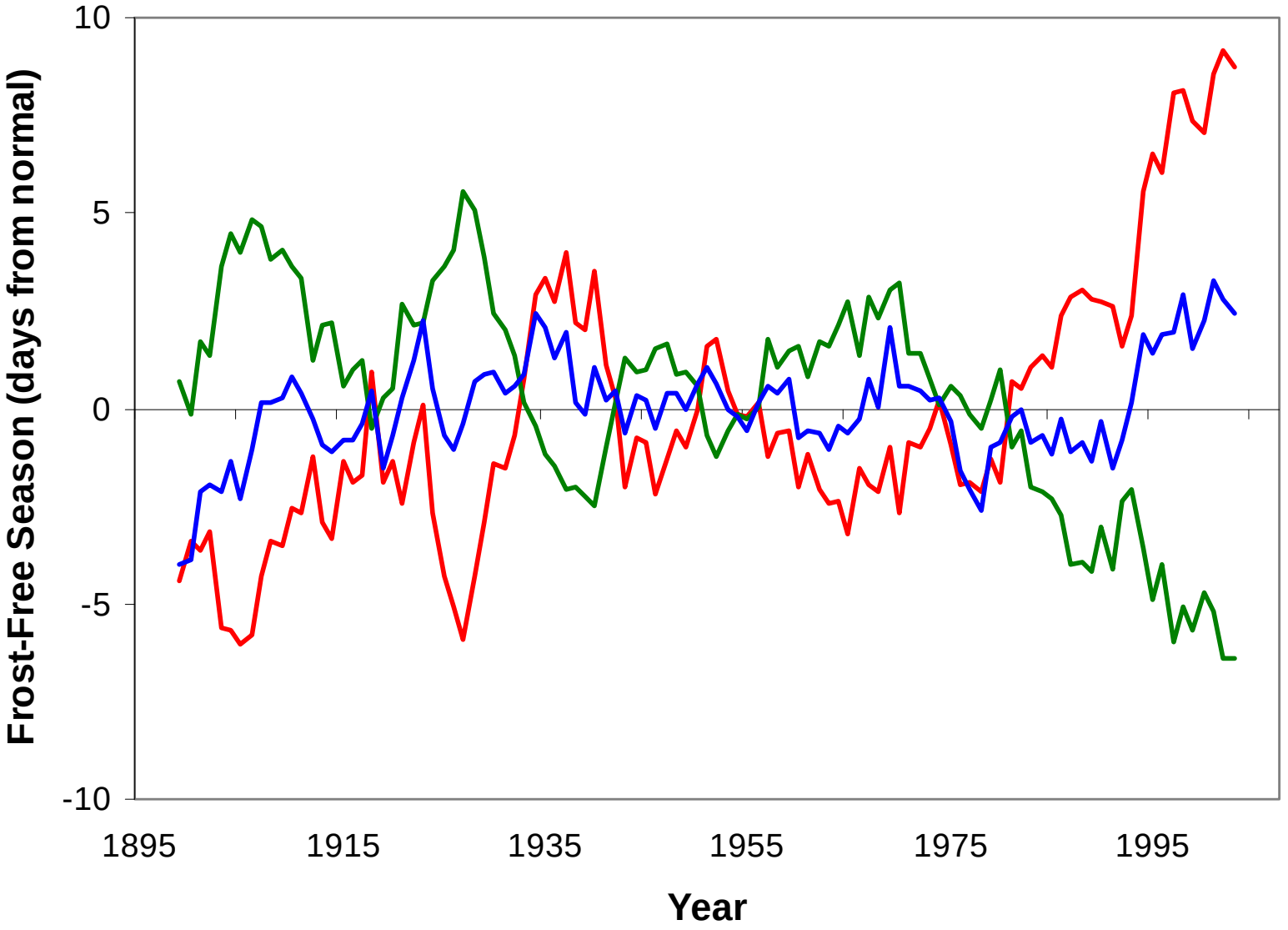
Ironwood, MI

1902-200



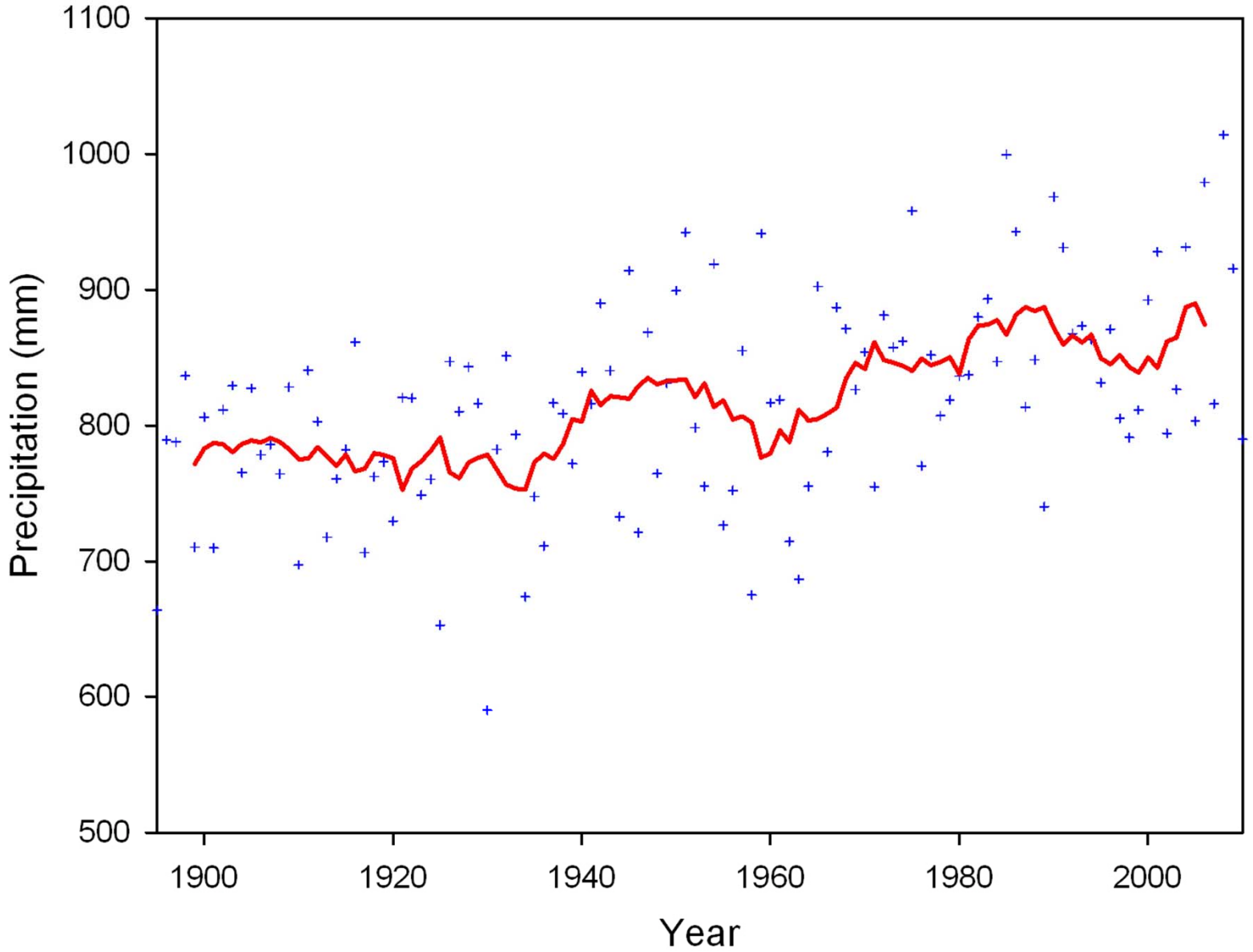
Changes in the Length of the Frost Free Season

Great Lakes Region



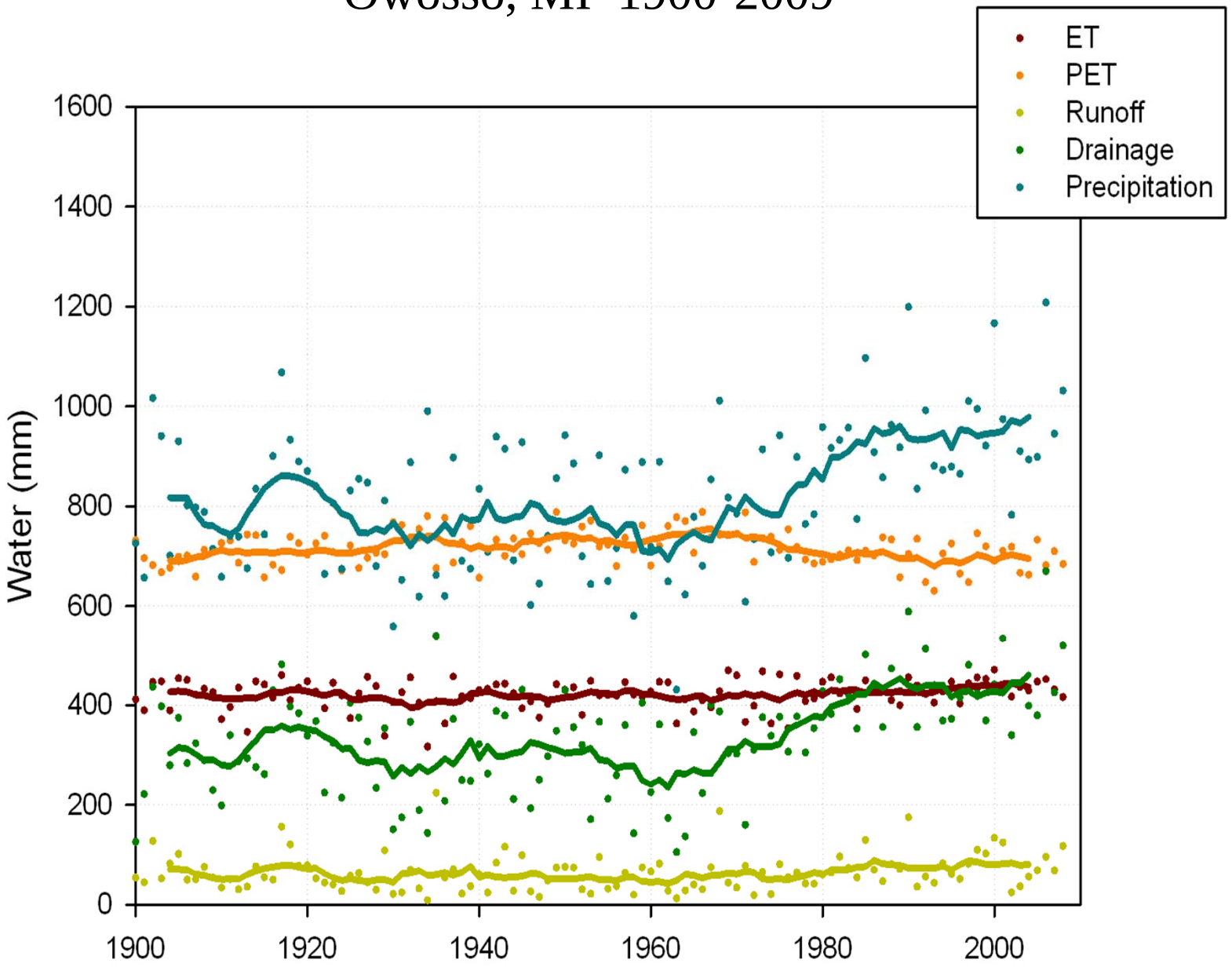
Source: K. Kunkel, Midwest. Reg. Clim. Center

Annual Precipitation vs. Year, Michigan
1895-2010

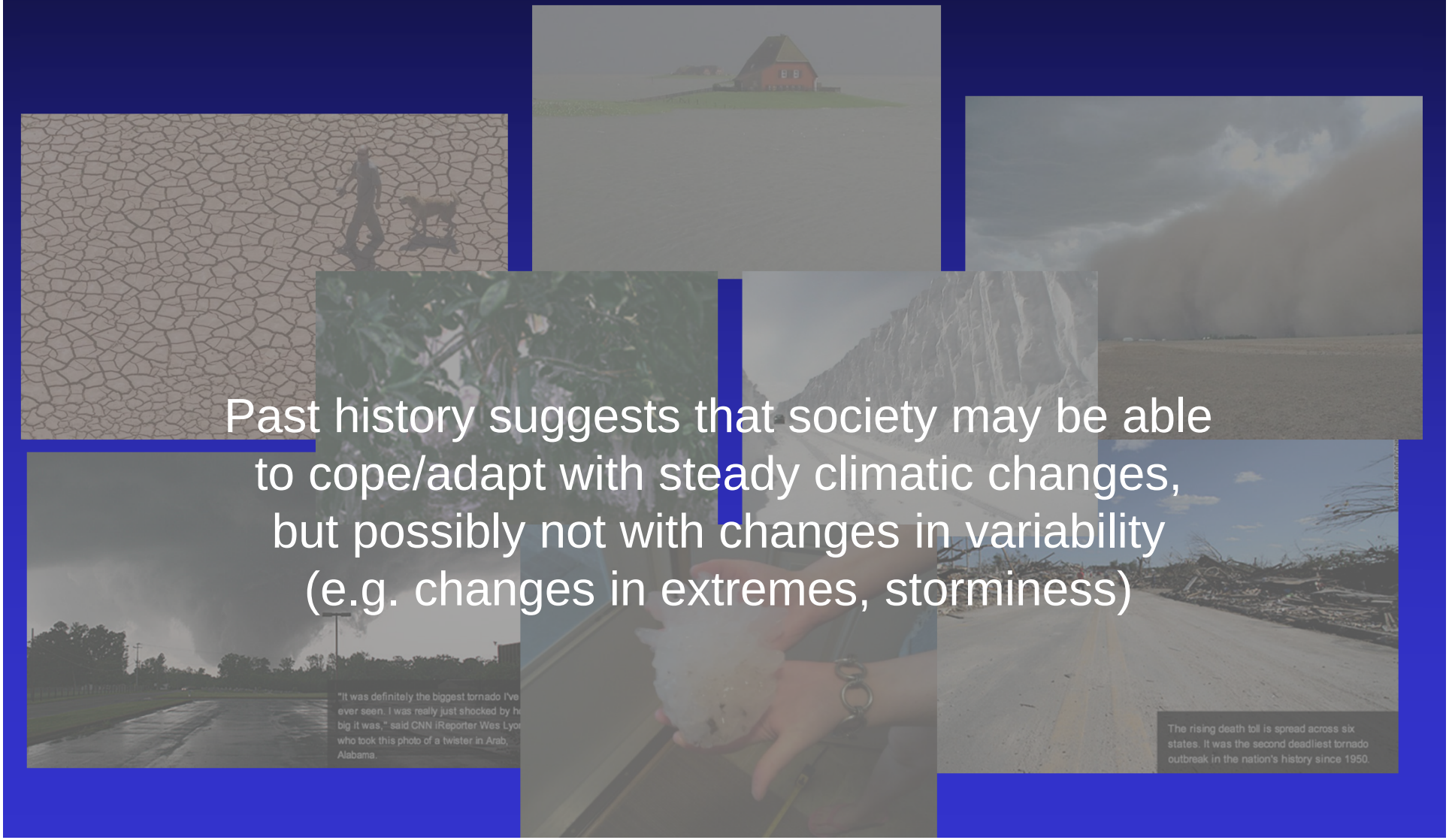


Hydrologic Variables vs. Year

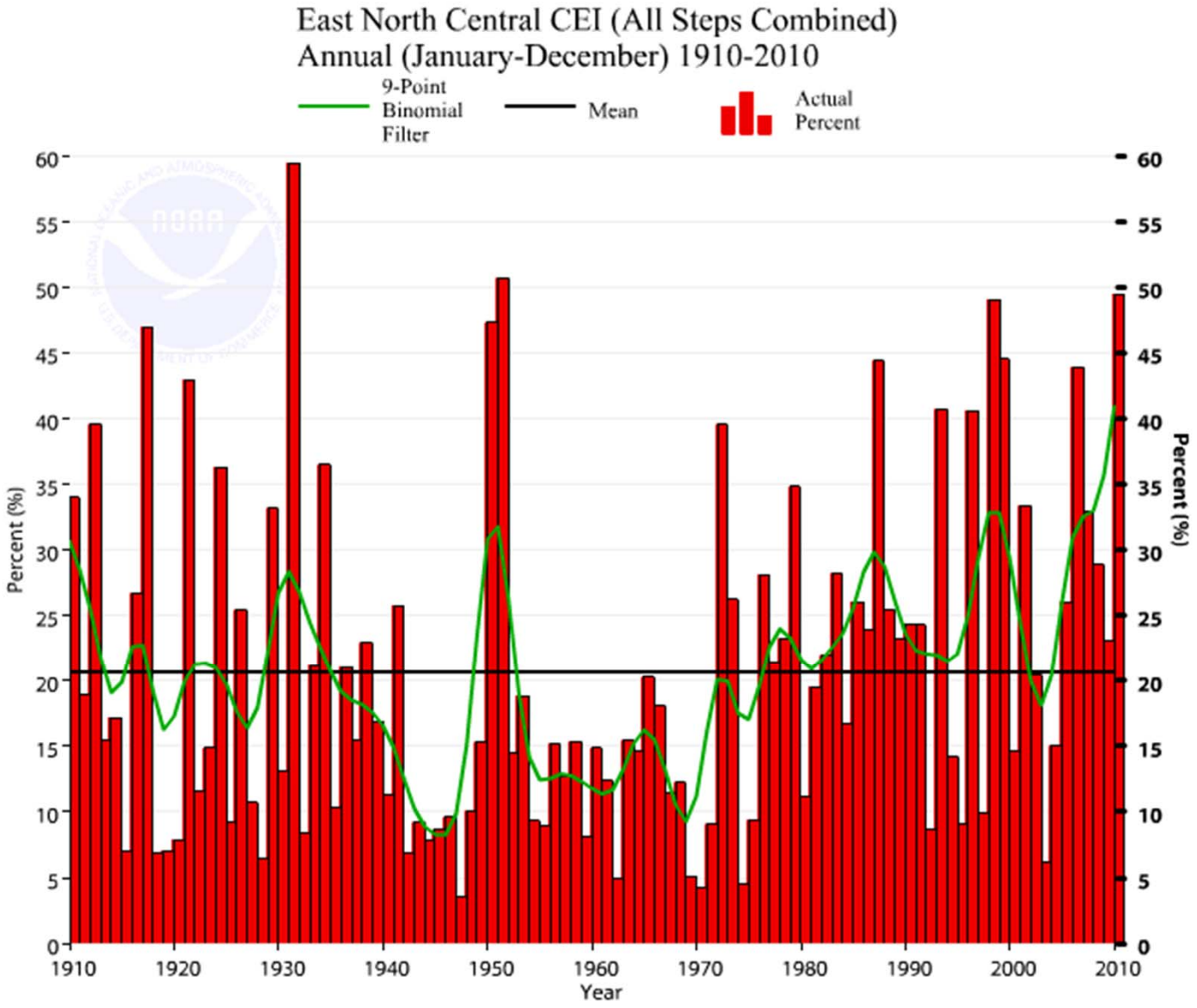
Owosso, MI 1900-2009



Impacts of Climatic Variability



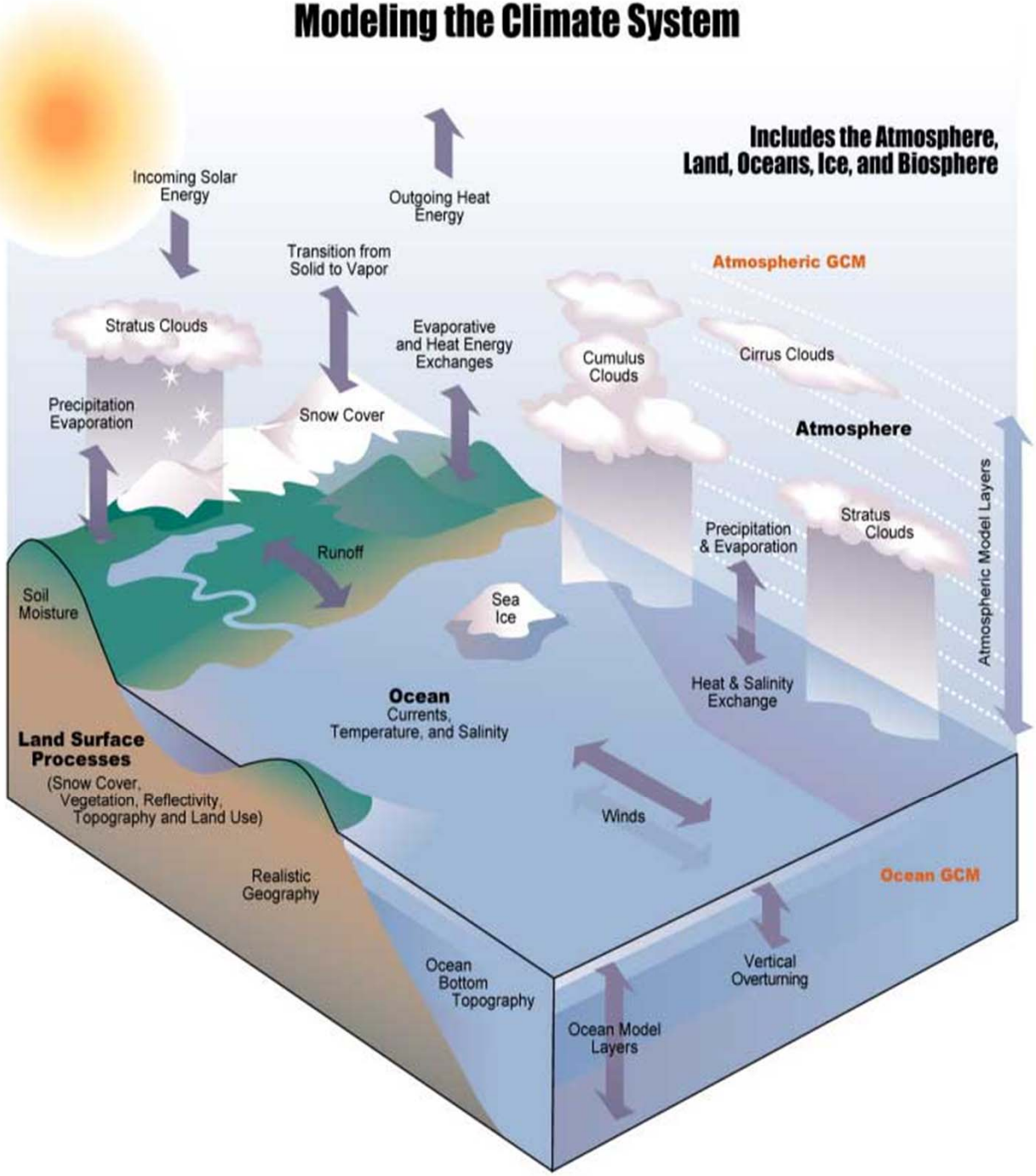
Past history suggests that society may be able to cope/adapt with steady climatic changes, but possibly not with changes in variability (e.g. changes in extremes, storminess)



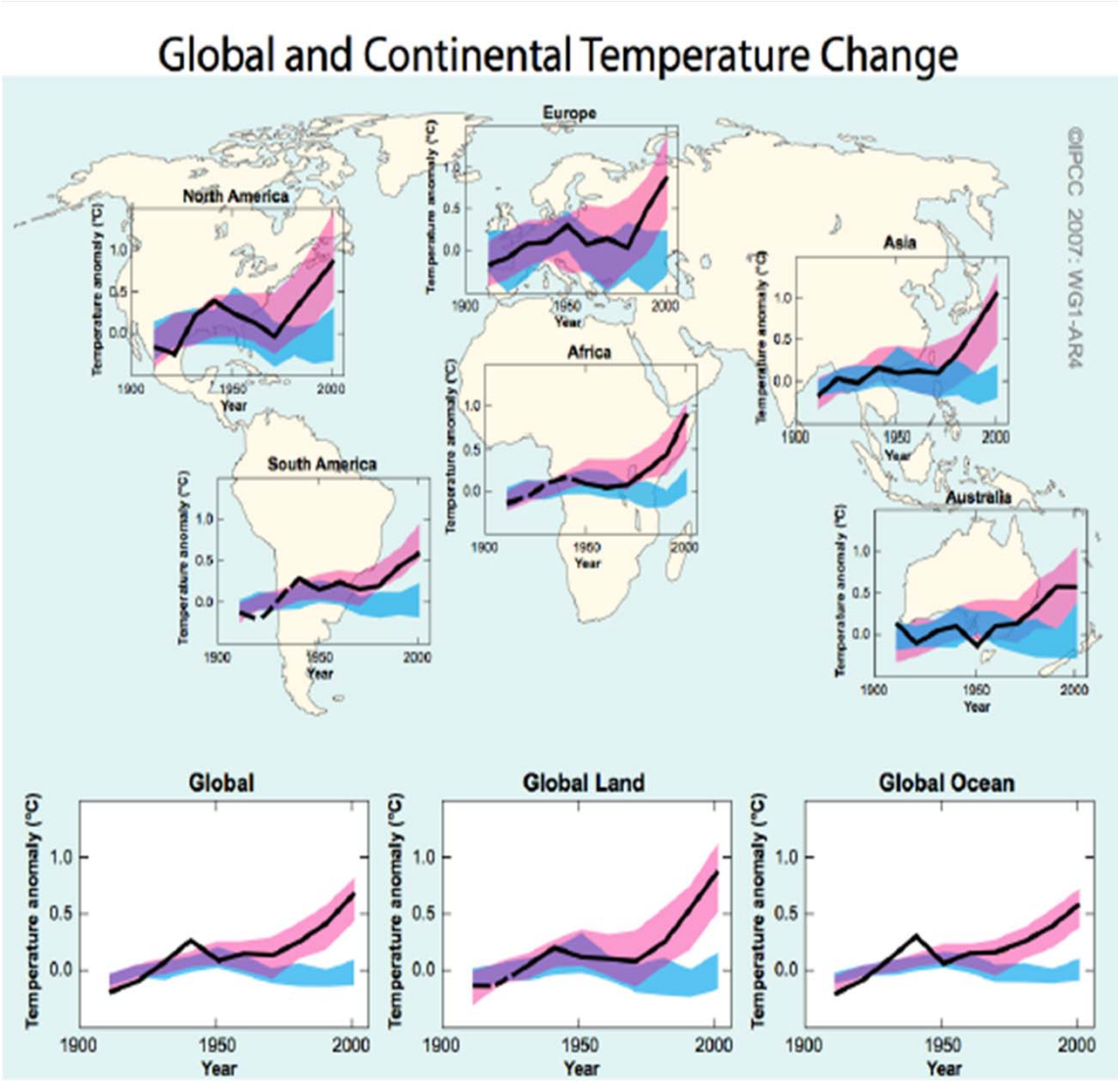
(Source: NCDC, 2011)

Projecting the Future:
Global Climate Models (GCMs)

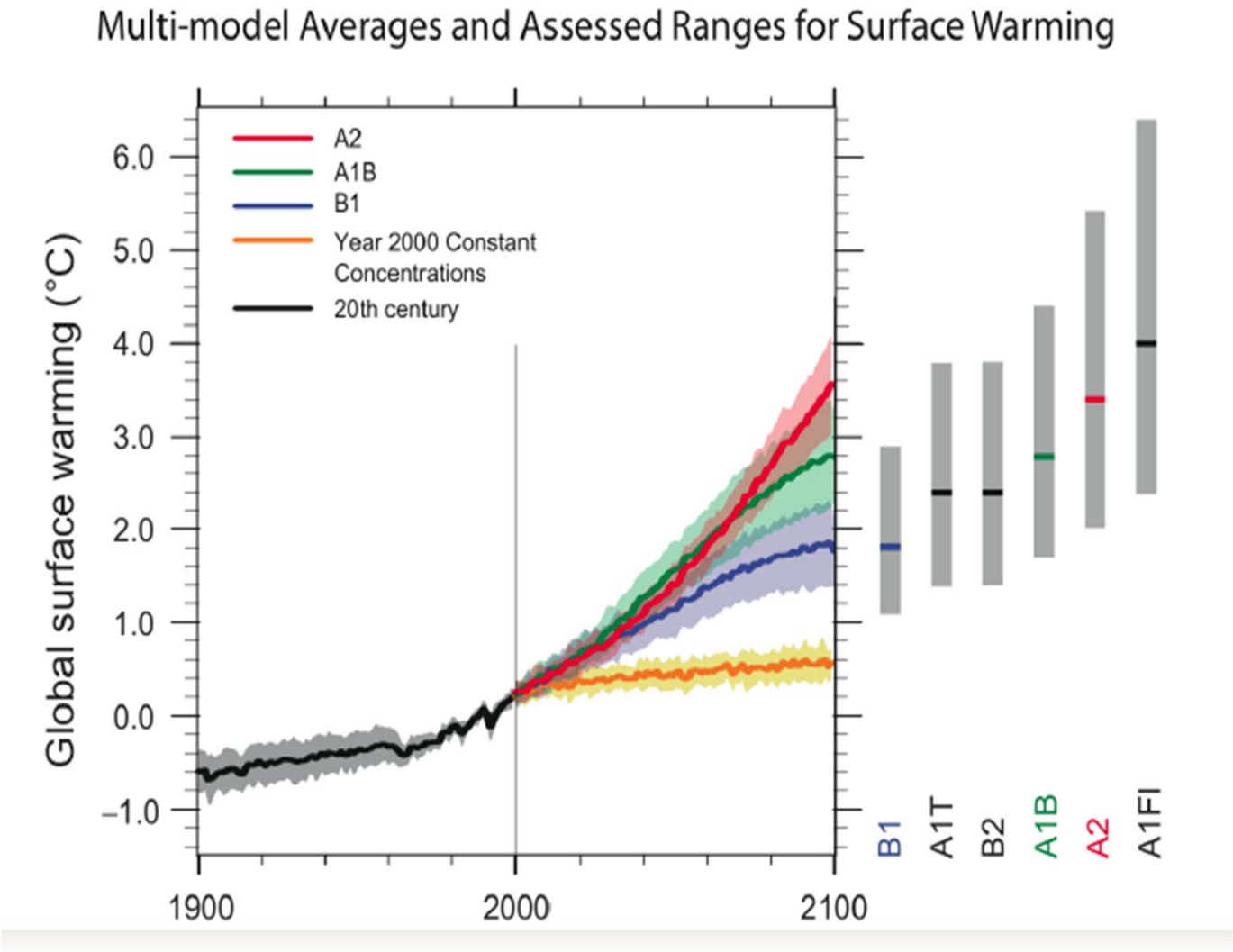
Modeling the Climate System



Natural Variability or Anthropogenic Signal?



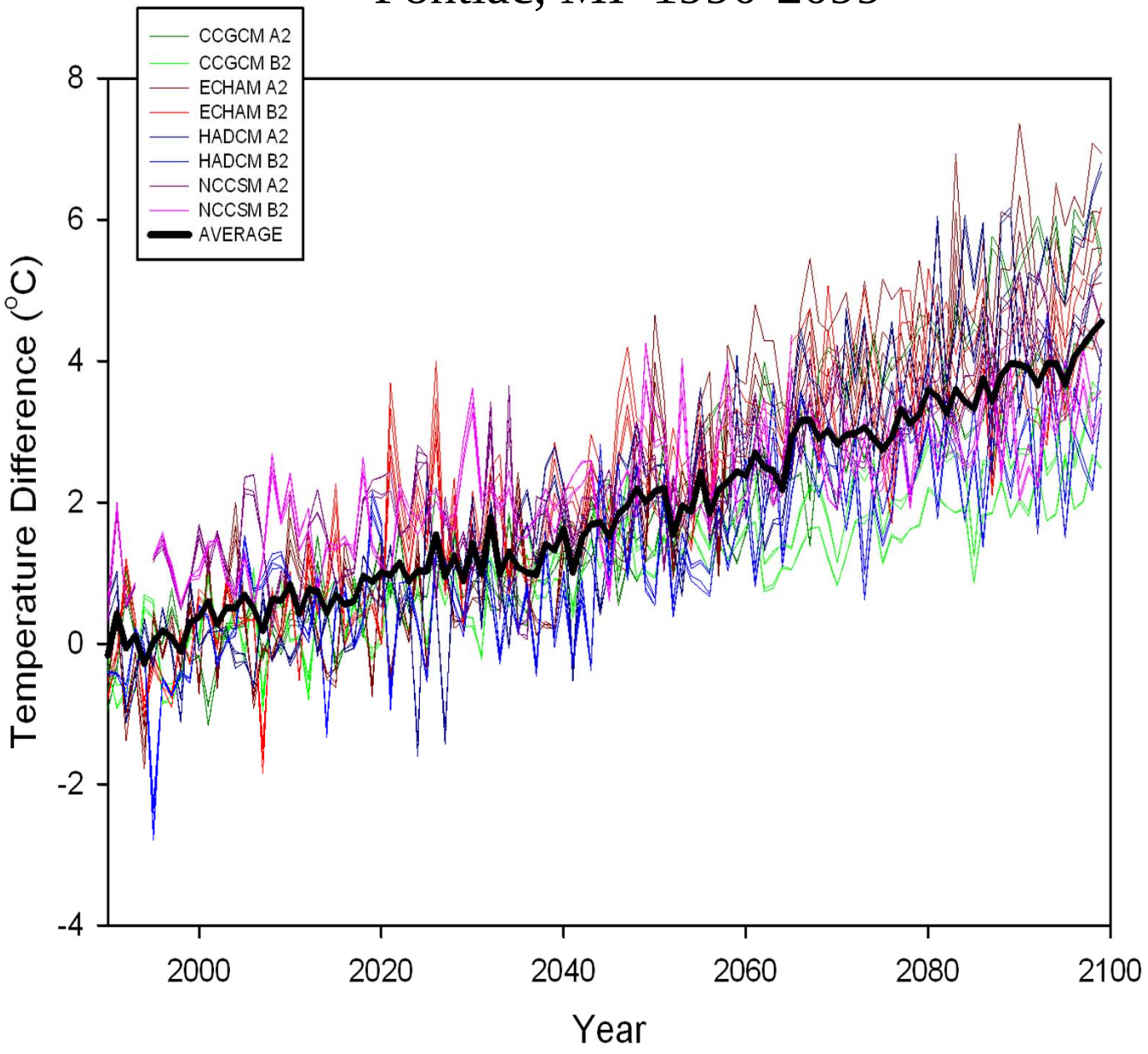
(Source: IPCC, 2007)



Source: (IPCC, 2007)

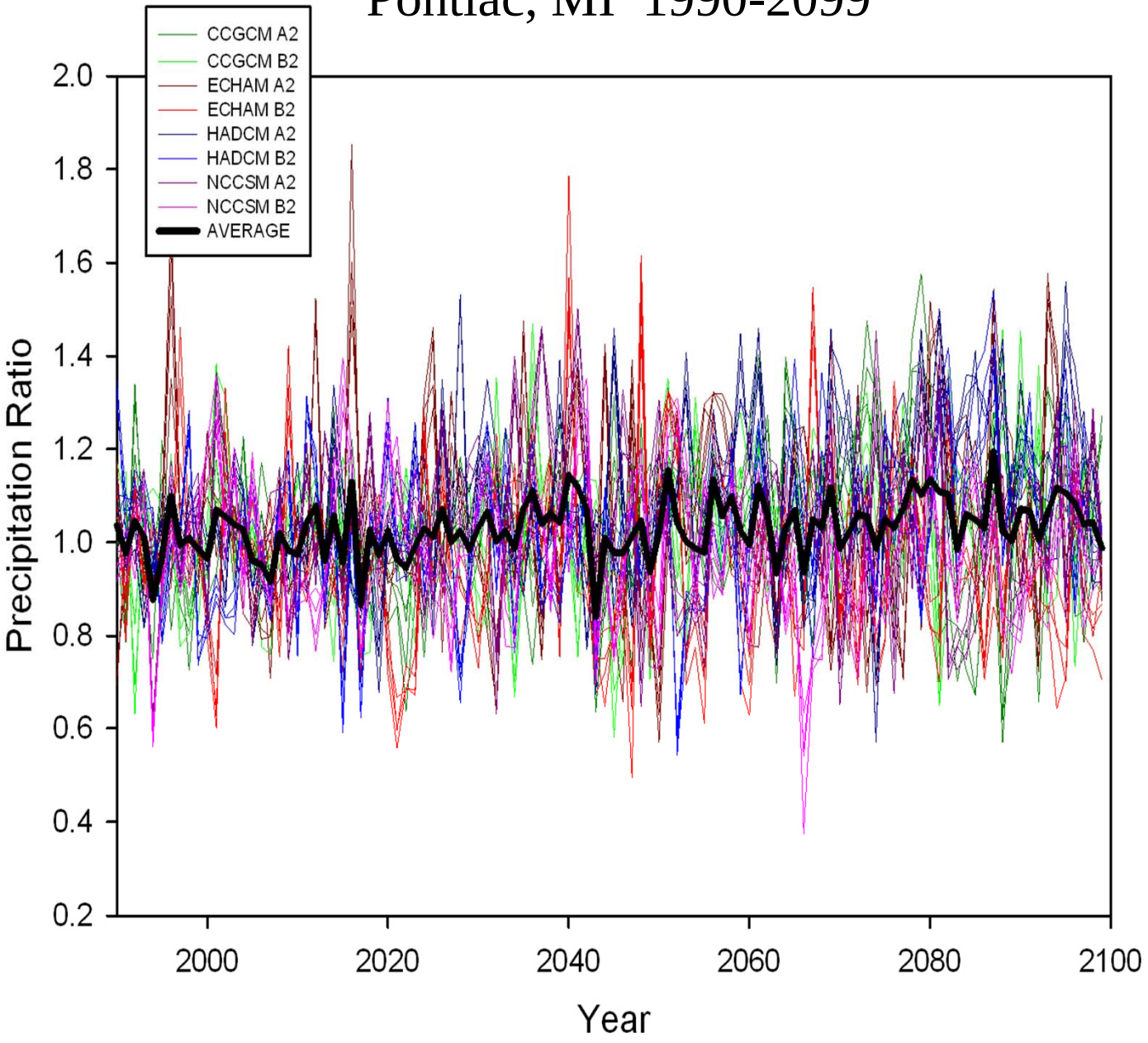
Model-Projected Mean Temperature Differences

Pontiac, MI 1990-2099

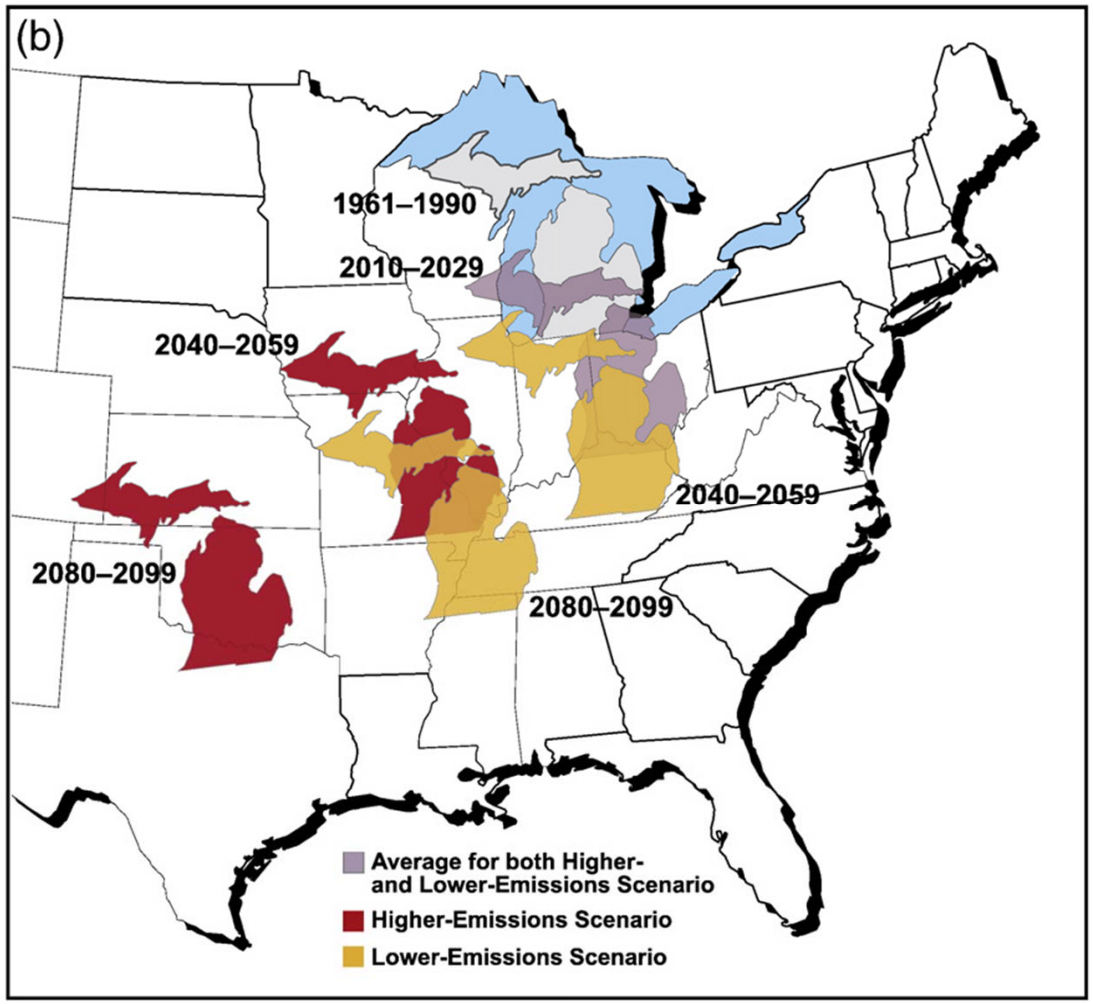


Model-Projected Precipitation Ratios

Pontiac, MI 1990-2099



Projected Temperature Changes



Hayhoe et al (2010)

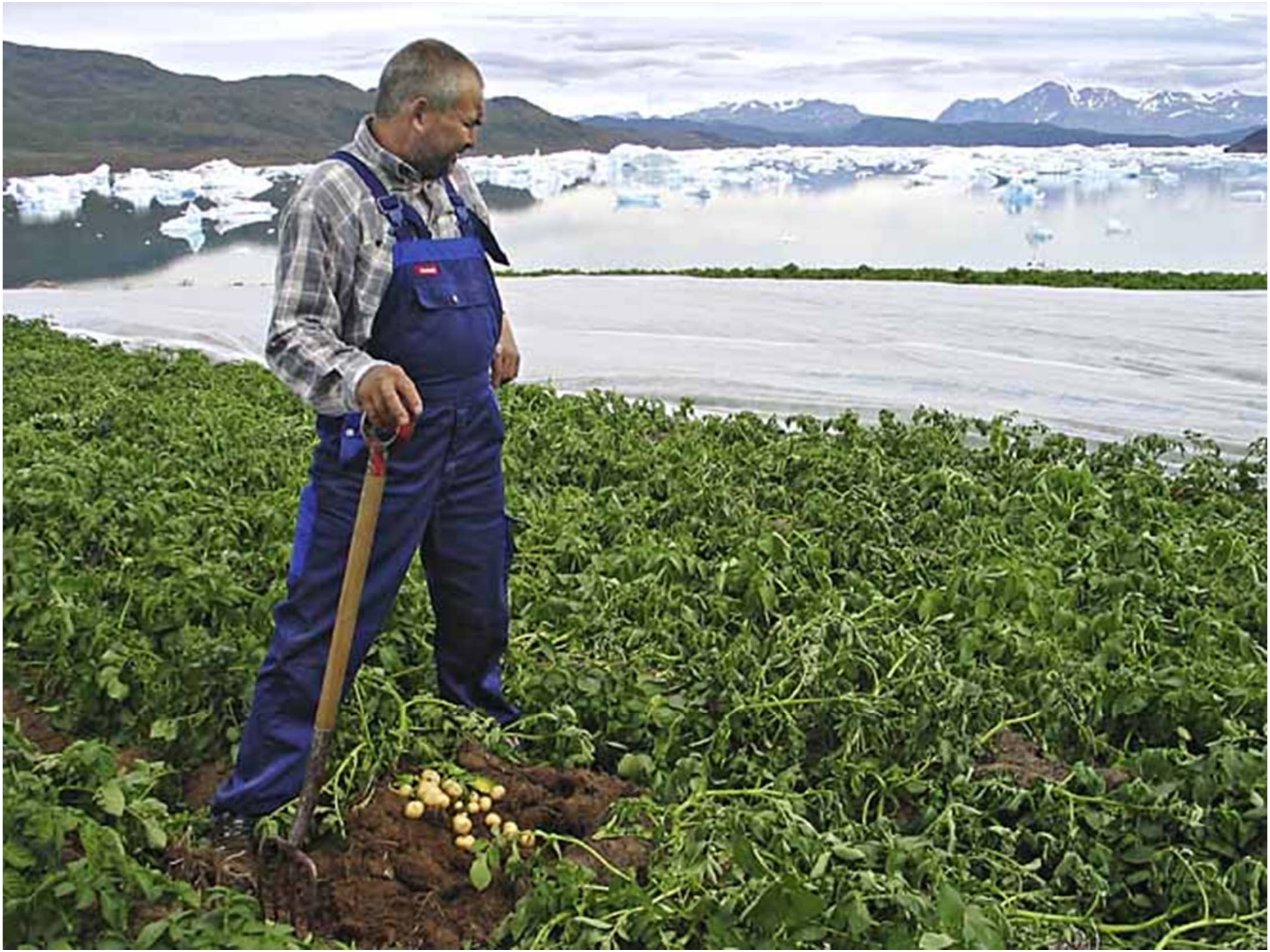
GLISA

Strategies

- Adaptation (learn to cope, adapt)
  - New technology
  - Migration, Abandonment (‘habitat tracking’)
- Mitigation (reduce or solve problem)
  - Collection/Storage of carbon
    - Anthropogenic
    - Biological
  - Geoengineering

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.




Questions?