Climates of the Past

EES 3310/5310

Global Climate Change

Jonathan Gilligan

Class #13: Wednesday, February 16 2022

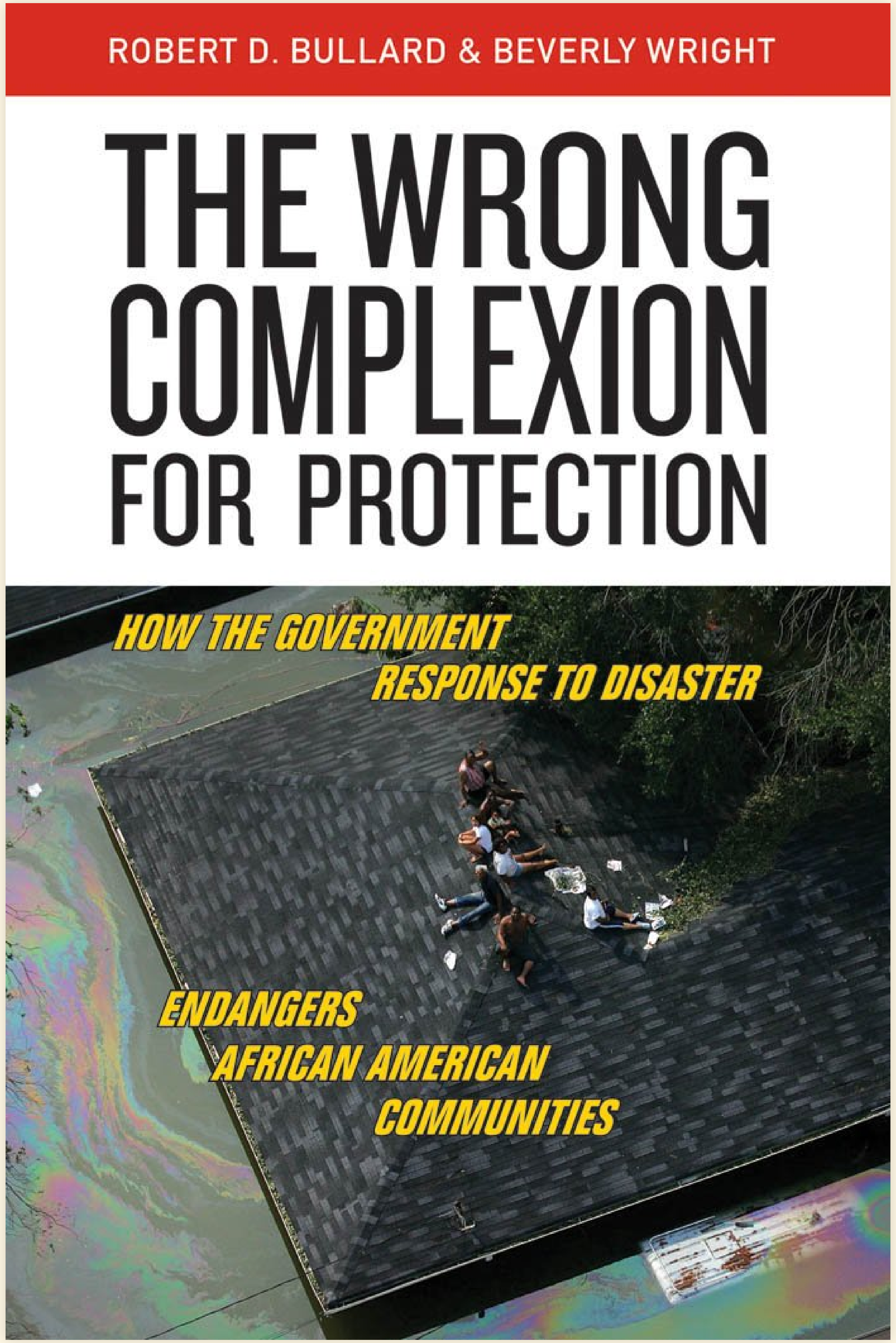
Black History Month
Black Leaders in Environmental Research

Dr. Robert D. Bullard

- Born in Elba, AL in 1946.
- Bachelor's degree, Alabama A&M University, 1968.
- Ph.D. in Sociology, Iowa State University, 1976.
- Distinguished Professor of Urban Planning and Environmental Policy, Texas Southern University
- Former Dean of the School of Public Affairs at Texas Southern.
- Director, Bullard Center for Environment and Climate Justice.
- Founding Director of Environmental Justice Resource Center, Clark Atlanta University
- Pioneered the concepts of environmental justice and environmental racism
- Author of 18 books, more than 50 articles

Dr. Robert D. Bullard

- Used civil rights laws to stop polluters from targeting Black communities.
- Organized First National People of Color Environmental Leadership Summit in 1991.
- Led the development of "Principles of Environmental Justice" which President Bill Clinton implemented in Executive Order 12898.
- Awards Include:
  - United Nations Champions of the Earth Lifetime Achievement Award (2020)
  - William Julius Wilson Award for the Advancement of Justice (2019)
  - Stephen Schneider Award for Outstanding Science Communication (2019).
  - One of Newsweek Magazine's 13 Environmental Leaders of the Century (2008).



Dr. Robert D. Bullard

"People who fight… People who do not let the garbage trucks and the landfills and the petrochemical plants roll over them. That has kept me in this movement for the last 25 years. And in the last 10 years, we've been winning: lawsuits are being won, reparations are being paid, apologies are being made. These companies have been put on notice that they can't do this anymore, anywhere."

Mineral Weathering

Carbonate vs. Silicate Weathering

- **Carbonate Weathering:**
  - Dissolves carbonate minerals on land
  - Increases ocean carbonate
    - Adds *twice as much carbonate* to oceans as silicate weathering
    - Relieves ocean acidification
    - Increases transfer of CO_2 from atmosphere to ocean
    - Creates carbonate rocks on sea floor with *carbon that originated on land*.
  - Does not transform atmospheric CO_2 to rocks
- **Silicate Weathering:**
  - Transforms carbon dioxide in atmosphere into carbonate in the ocean.
    - Ocean carbonate from *silicate weathering* turns into carbonate rocks on sea floor with *carbon that originated in atmosphere*.

Temperature of Earth

- Weathering acts as thermostat.
- Earth's temperature has been remarkably stable over time.
  - 4 billion years ago, sun was 30% dimmer…
  - With today's greenhouse effect the earth would have been frozen
  - But there has constantly been liquid water.
  - Early earth had more greenhouse gases (thermostat)
- Geologic change alters thermostat "setting":
  - Volcanic outgassing
  - Land surface (e.g., mountain ranges)
  - Vascular plants
- In the long run, silicate thermostat will fix global warming…
  - …but it will take tens to hundreds of thousands of years.

CO_2 vs. Methane

- \(\COO\):
  - After 1000 years, around 30% of excess \(\COO\) remains in atmosphere
  - After 10,000 years, 13% remains
  - After 100,000 years, 6% remains
- Methane (\(\methane\)):
  - 31 times more powerful (molecule-for-molecule) than \(\COO\)
  - Reacts with \(\OH\) (hydoxyl radicals) and oxydizes into \(\water\) and \(\COO\).
  - Atmospheric lifetime: 9.6 years:
    - After 25 years, 7% remains.
    - After 100 years, 0.003% remains.

Climates of the Past

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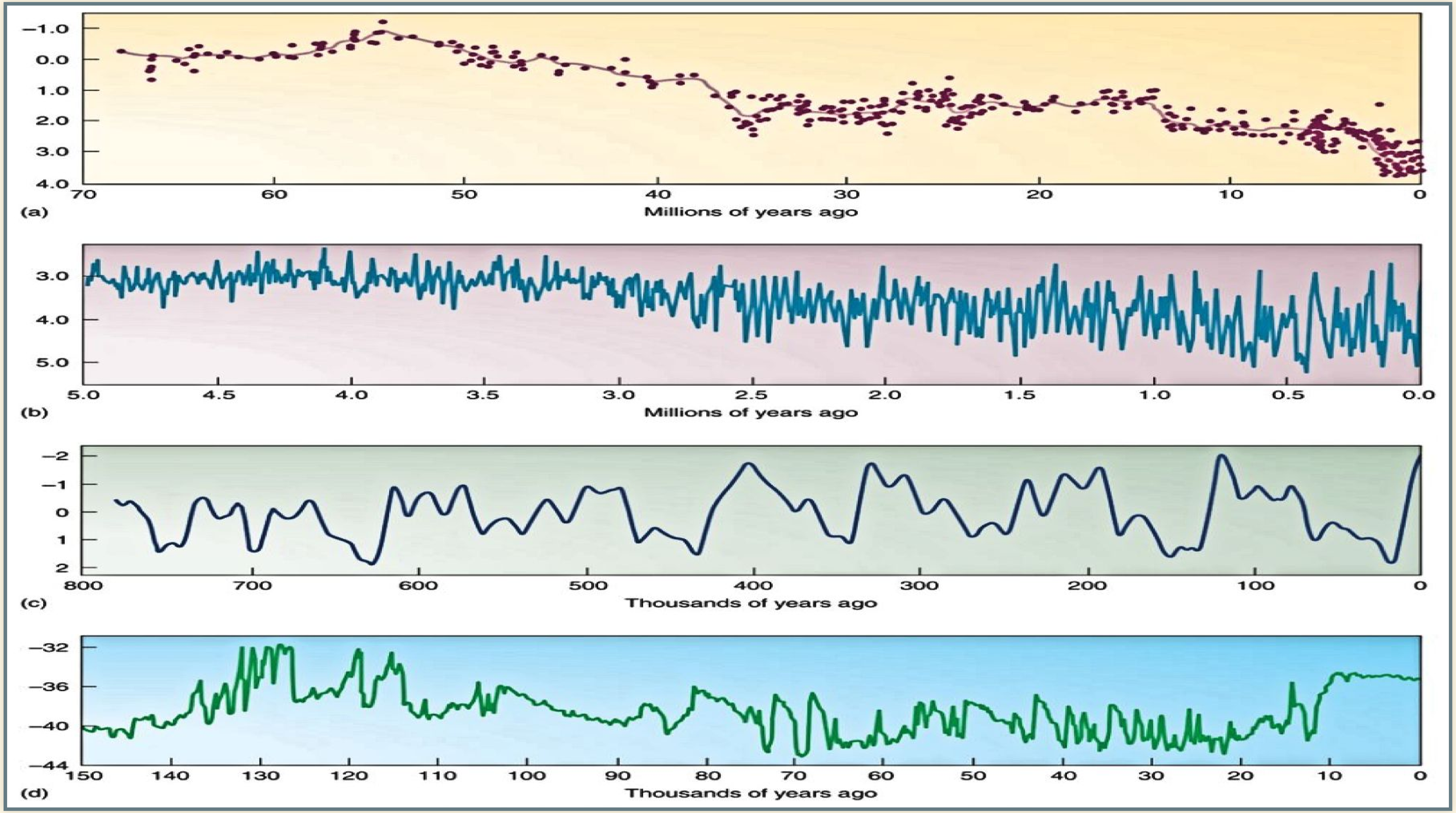
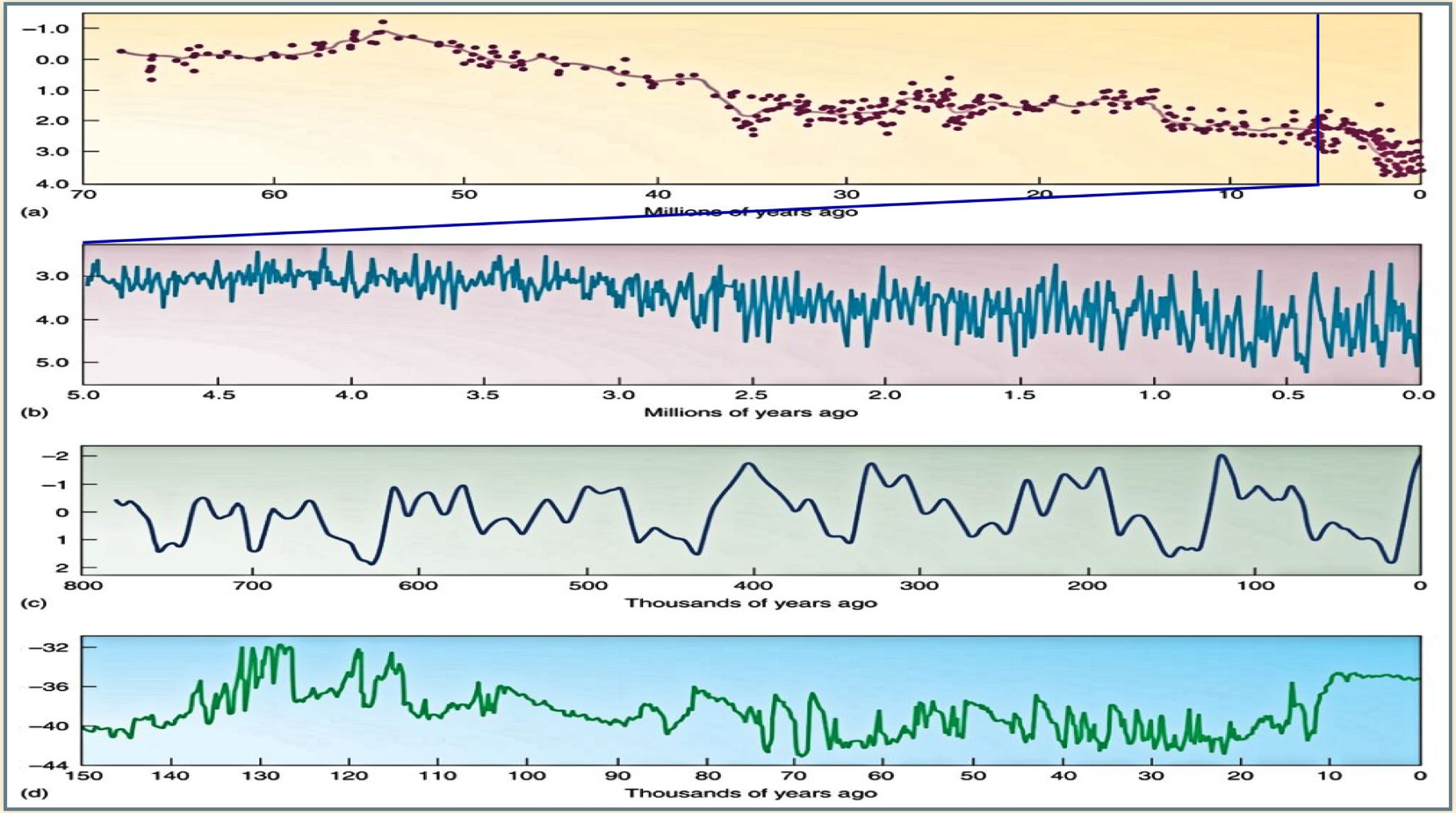
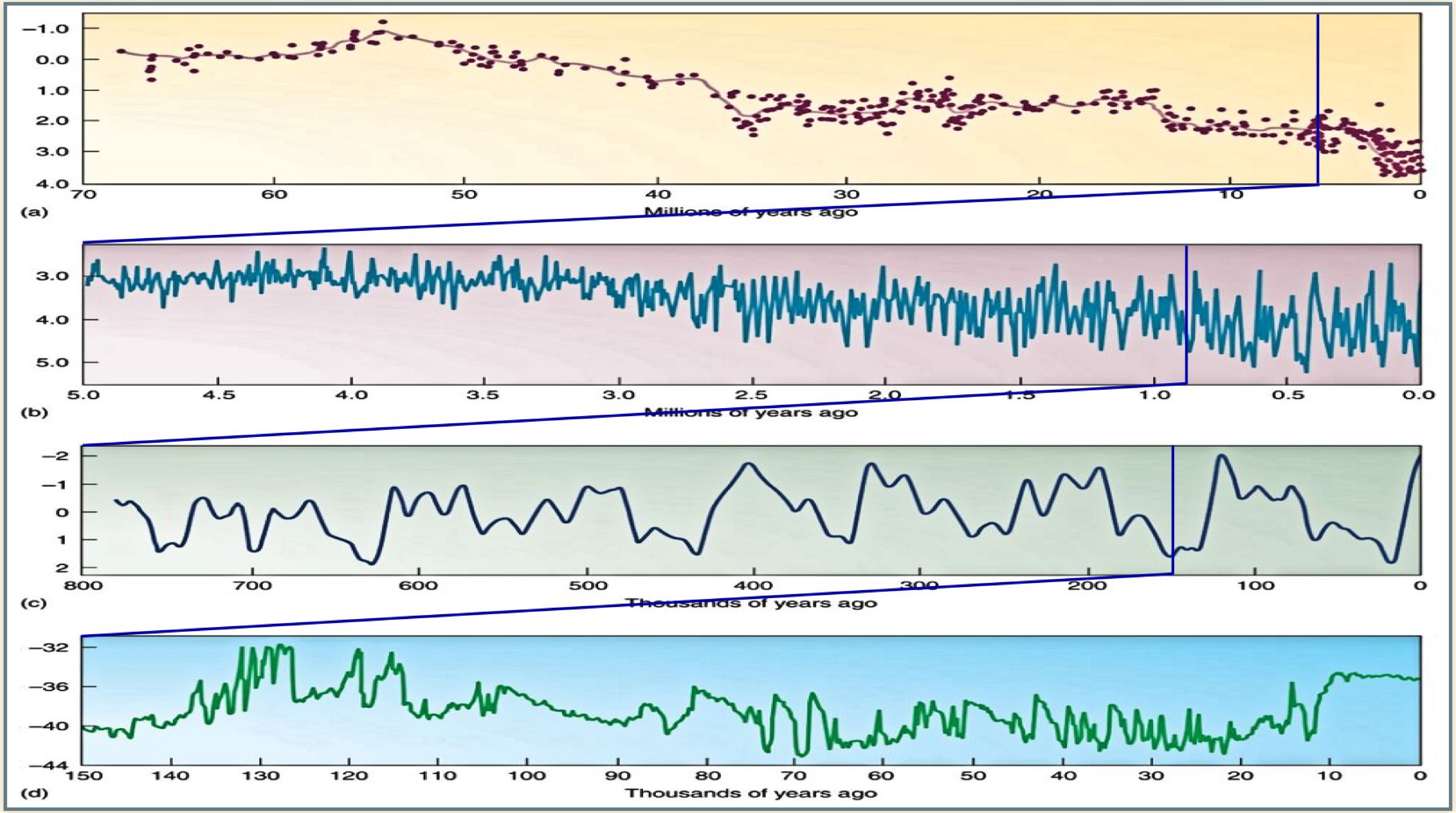


Climates of the Past



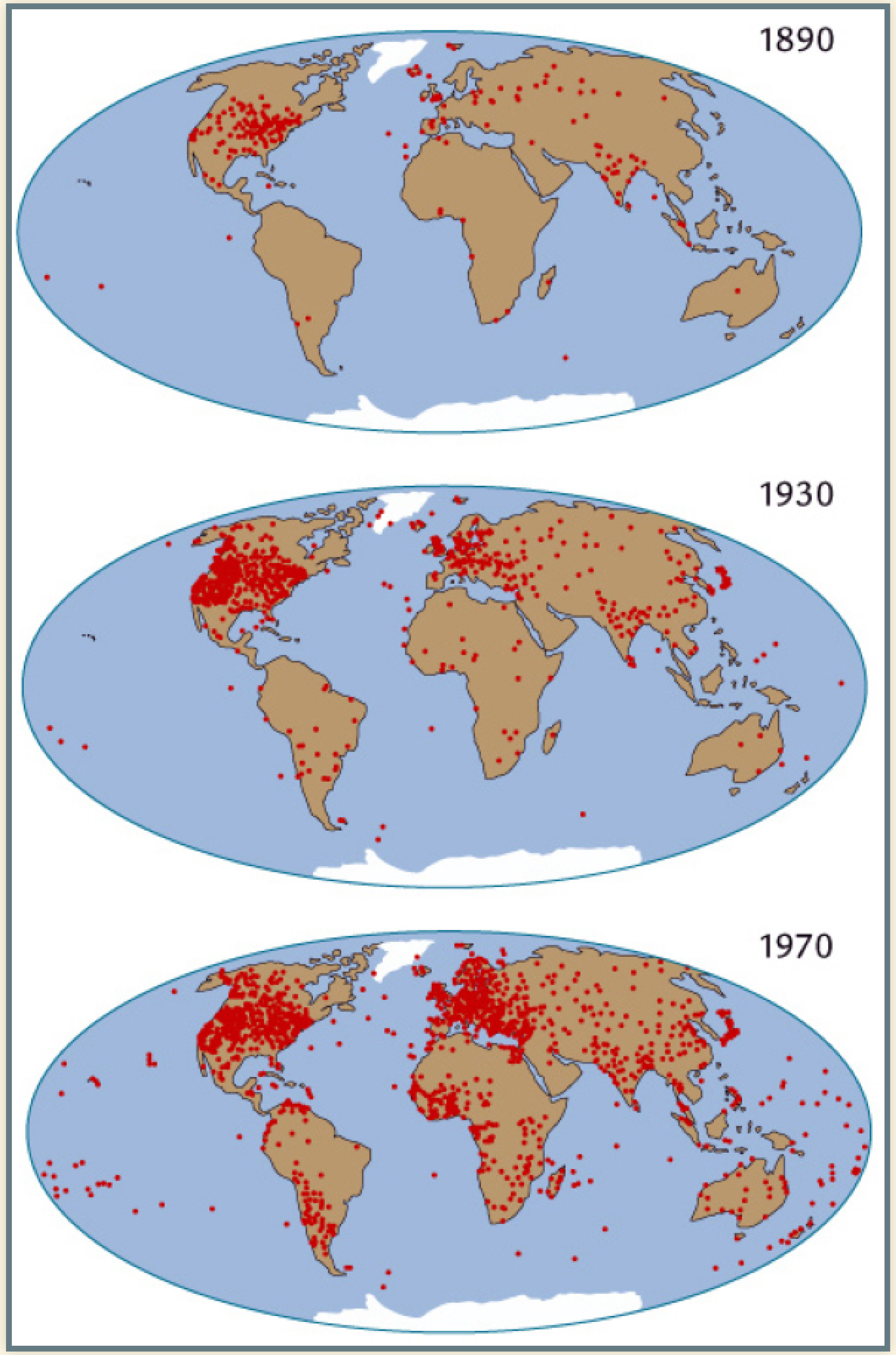
Climates of the Past



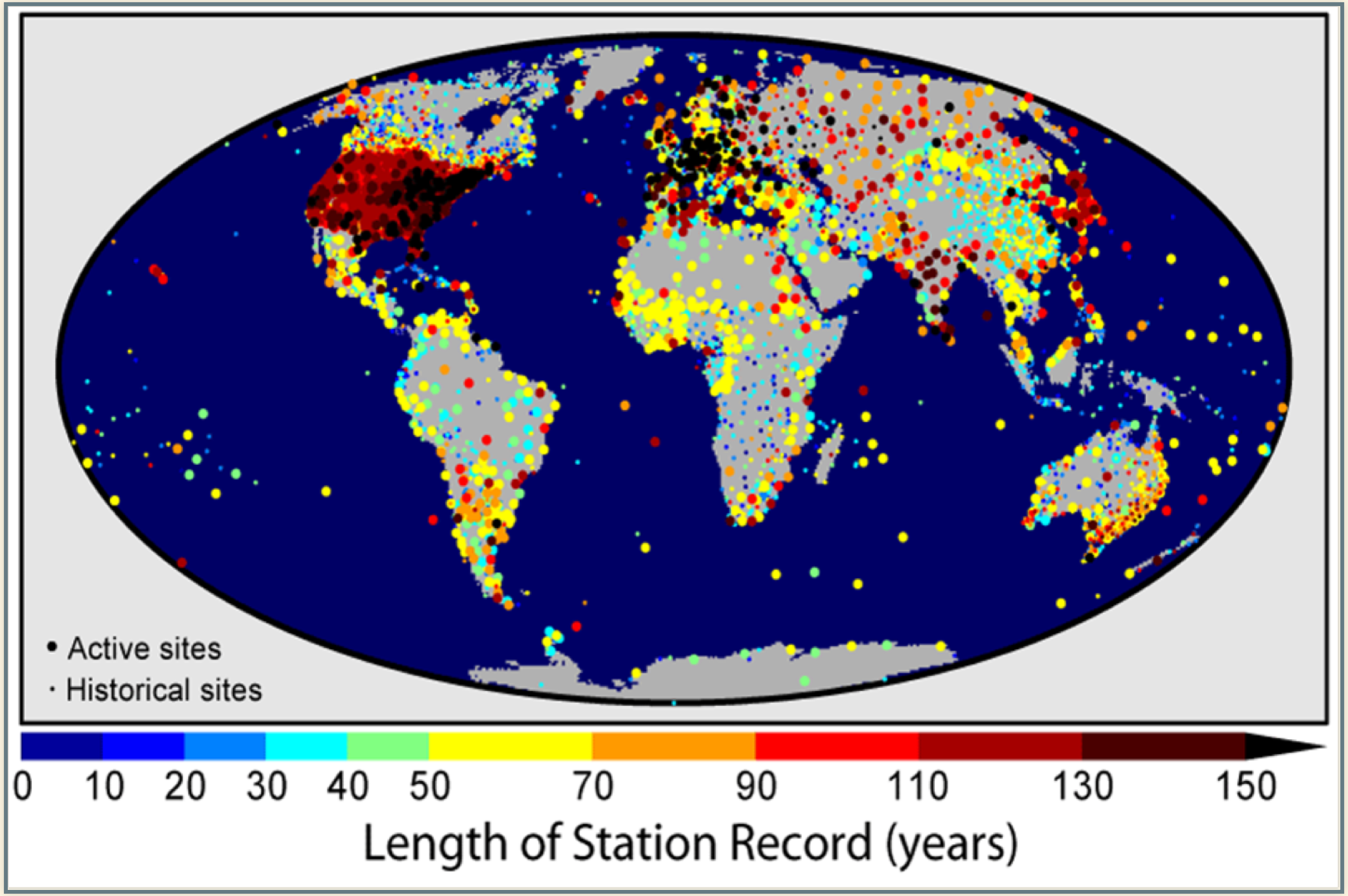
Digging into the past

Digging into the past:

Temperature measuring stations over the last 130 years.



Surface Temperature Monitoring



- 7280 stations
- 2277 active
- 1656 > 100 years

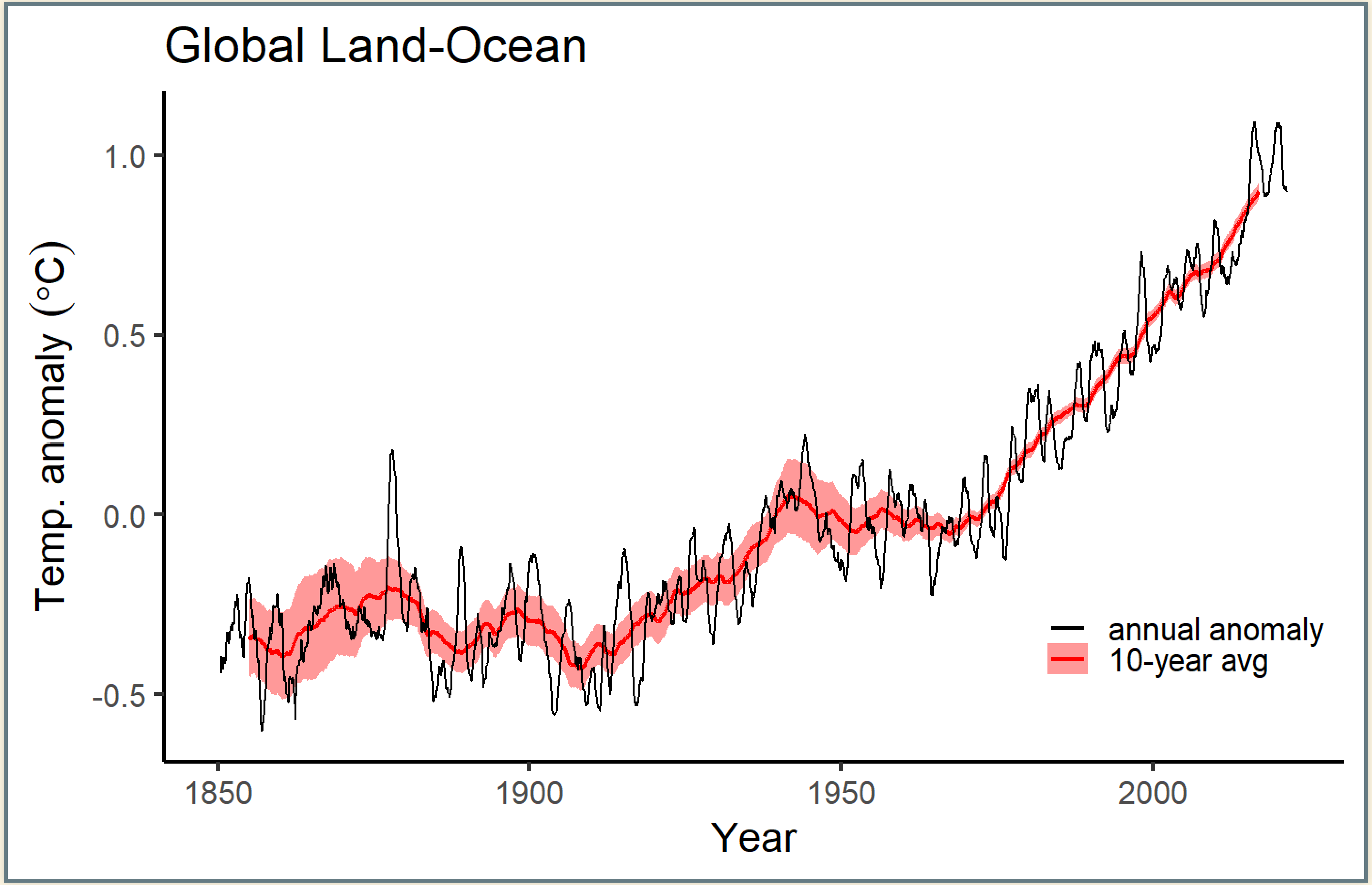
Temperature Anomaly

- **Global temperature change:**
  - Average temperatures are different at different places.
  - Temperatures change with the seasons
  - How to compare temperature change between places with different climates?
- **Temperature anomaly:**
  - Define a reference time period (several decades)
  - Anomaly = **actual temperature** at a place and time *minus* **average temperature** at that place during reference period

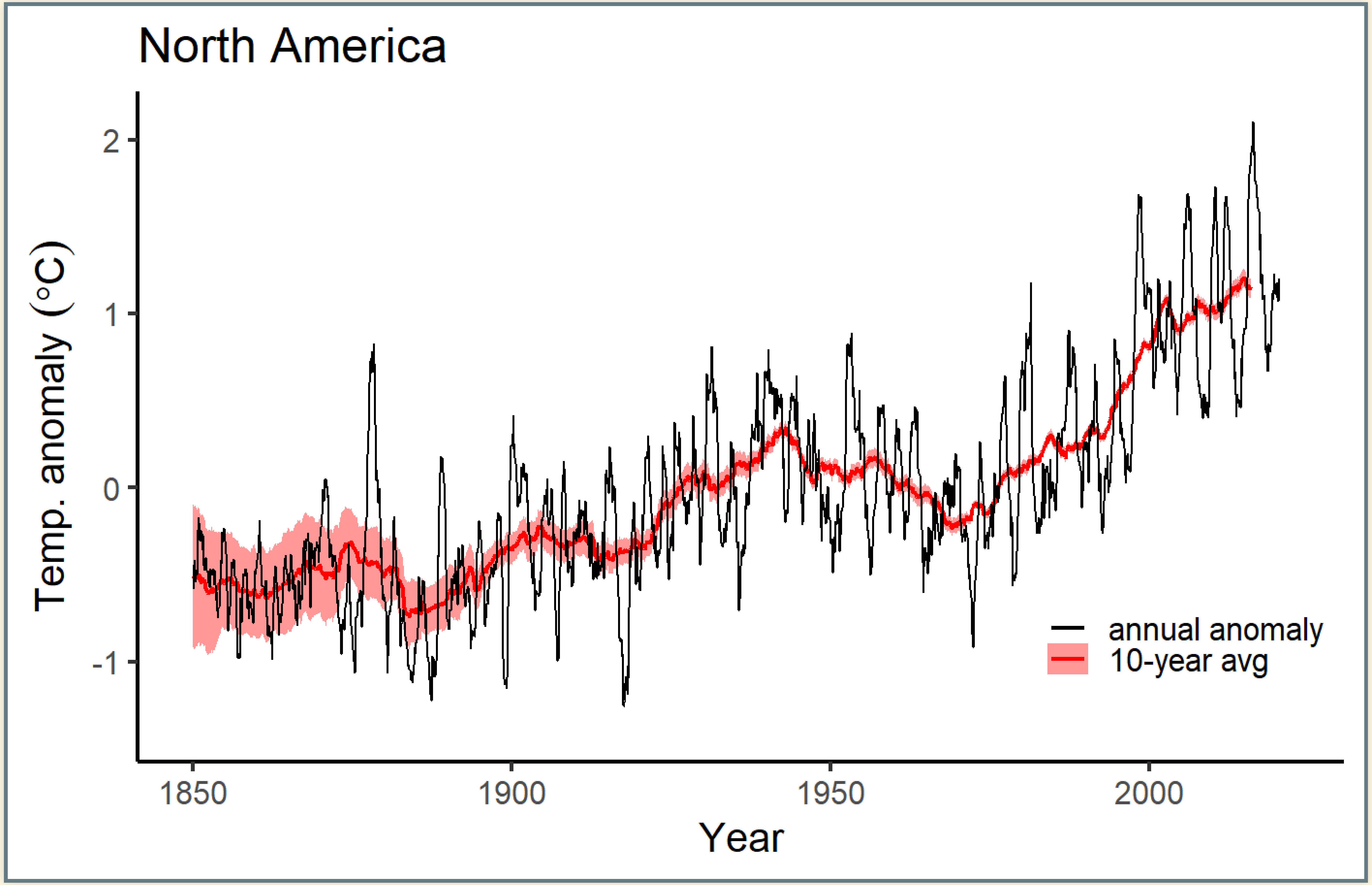
Temperature Anomaly

- Anomaly = **actual temperature** at a place and time *minus* **average temperature** at that place during reference period
- **Example: Anomaly for Nashville, January, 2020**
    - Monthly avg. temp. for January, 2020 = $7.3^\circ\mathrm{C}$
    - Average January temp 1950–1979 = $3.0^\circ\mathrm{C}$
    - Anomaly = ${\color{darkblue}7.3^\circ\mathrm{C}} - {\color{darkgreen}3.0^\circ\mathrm{C}} = 4.3^\circ\mathrm{C}$

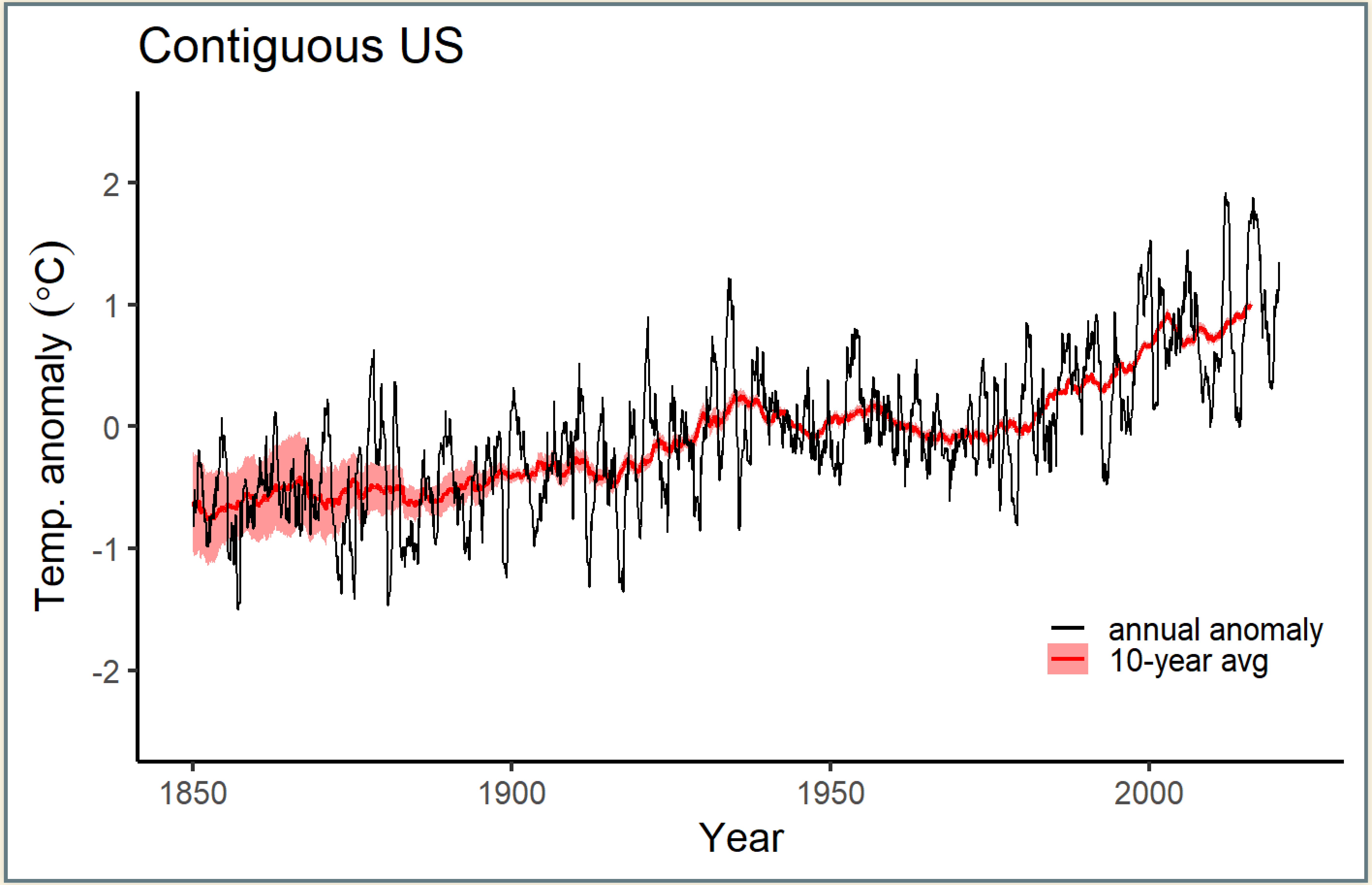
Global Anomaly
1850–2021


Global Land-Ocean
Temp. anomaly (°C)
1.0
0.5
0.0
-0.5
1850
1900
1950
2000
Year
annual anomaly
10-year avg

North America
1850–2021

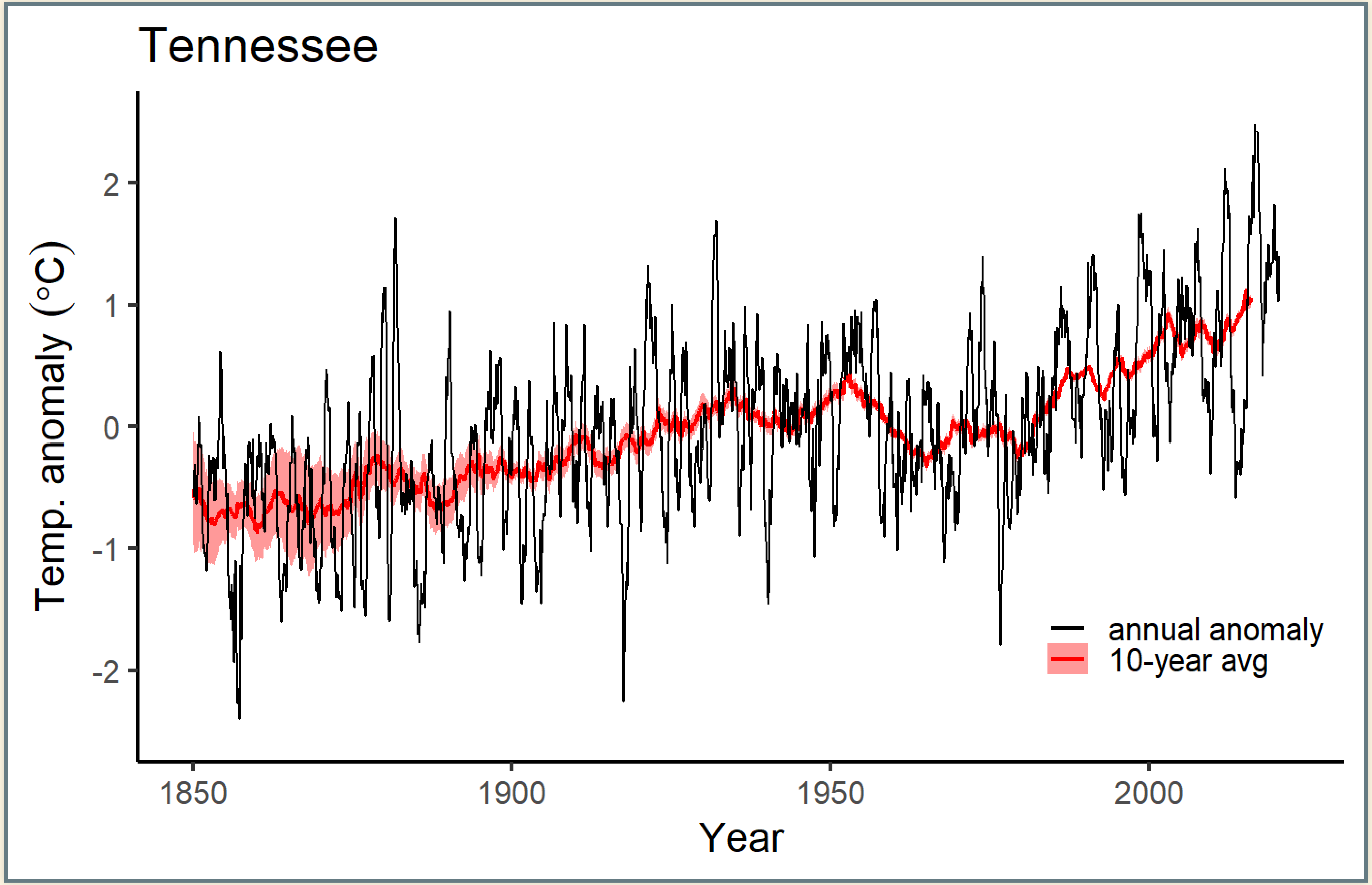

North America
Temp. anomaly (°C)
2
1
0
-1
1850
1900
1950
2000
Year
annual anomaly
10-year avg

Continental US Anomaly
1850–2021



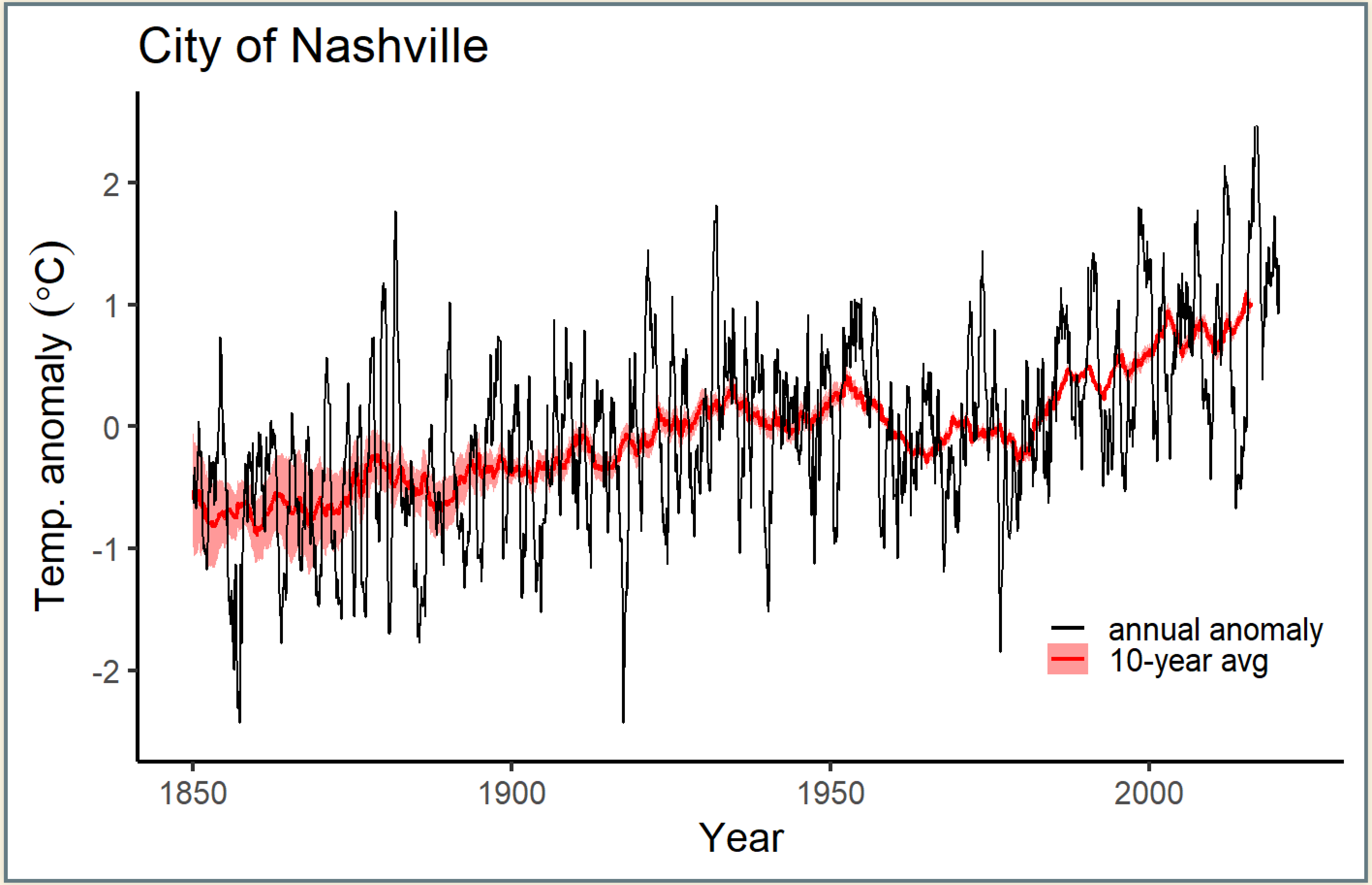
Contiguous US
Temp. anomaly (°C)
2
1
0
-1
-2
1850
1900
1950
2000
Year
annual anomaly
10-year avg

Tennessee Anomaly
1850–2021



Tennessee
Temp. anomaly (°C)
2
1
0
-1
-2
1850
1900
1950
2000
Year
annual anomaly
10-year avg

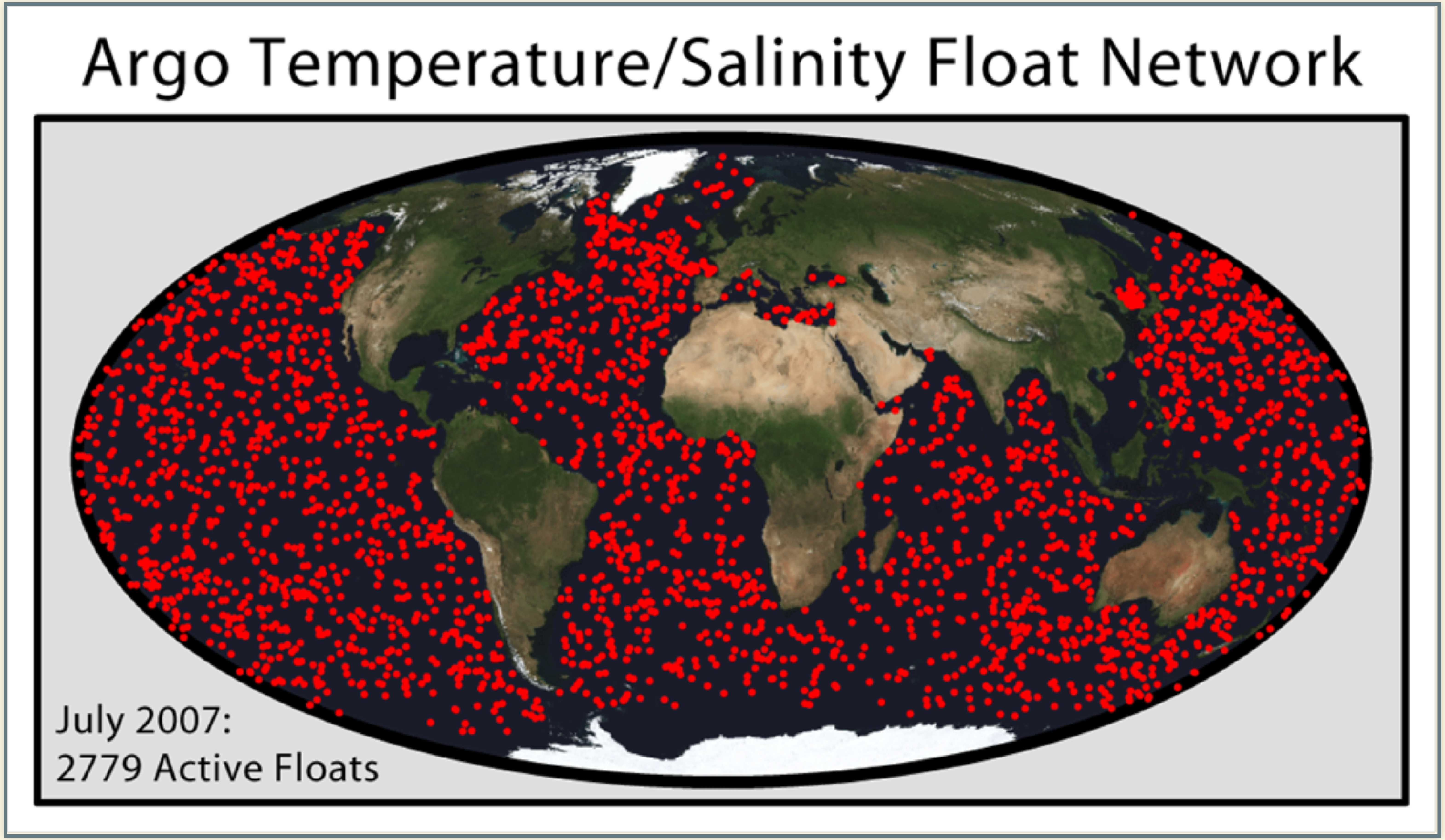
Nashville Anomaly
1850–2021


City of Nashville
Temp. anomaly (°C)
2
1
0
-1
-2
1850
1900
1950
2000
Year
annual anomaly
10-year avg

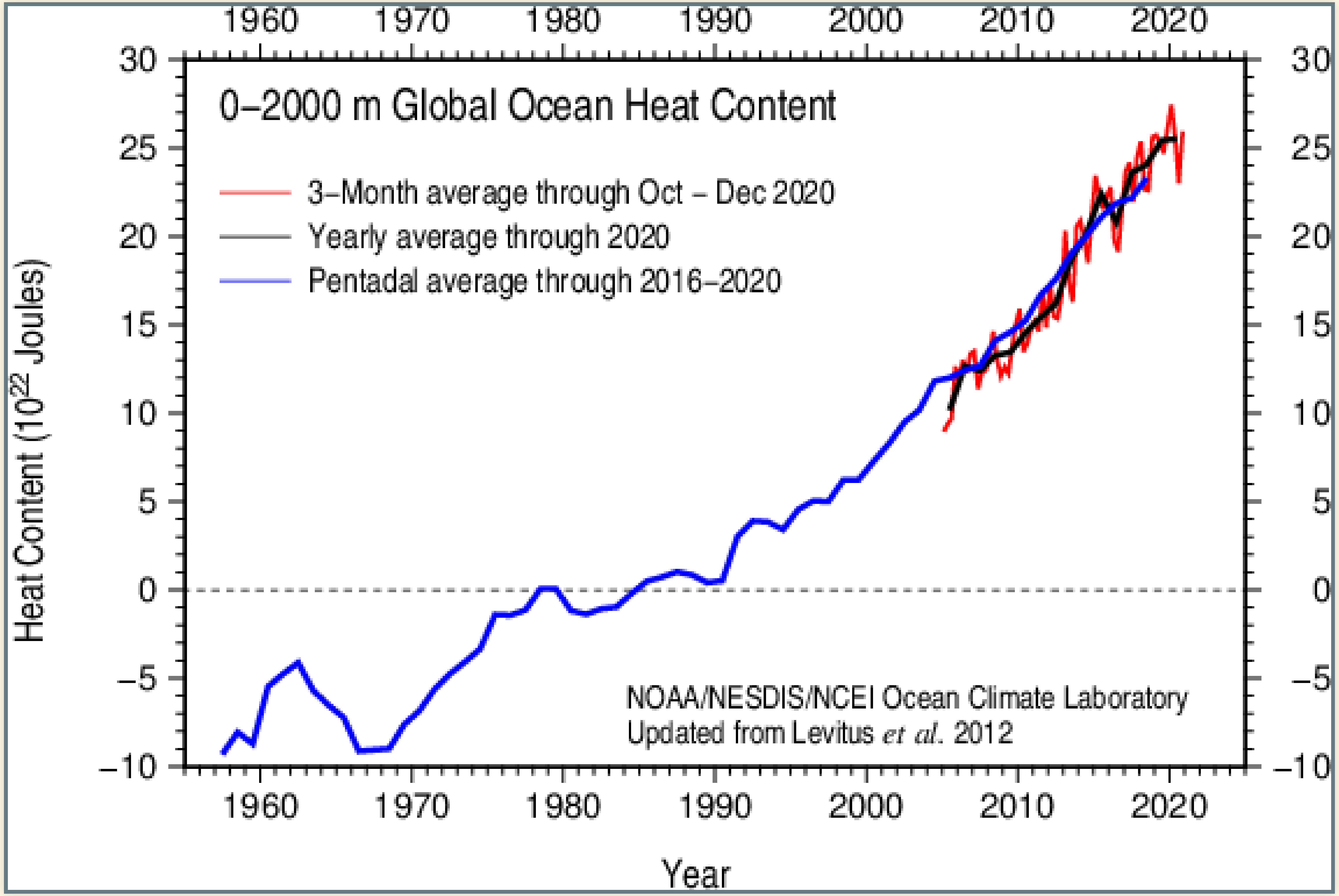
Ocean Temperatures

Ocean Temperatures

Ocean Temperatures



Ocean Heat Content

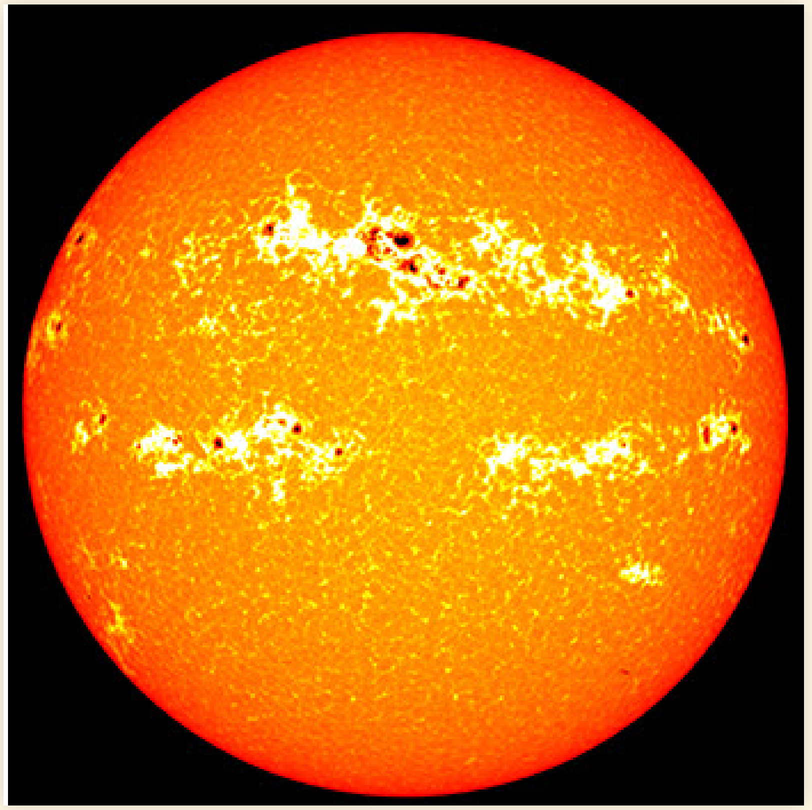


Searching for a Smoking Gun:

What caused the warming?

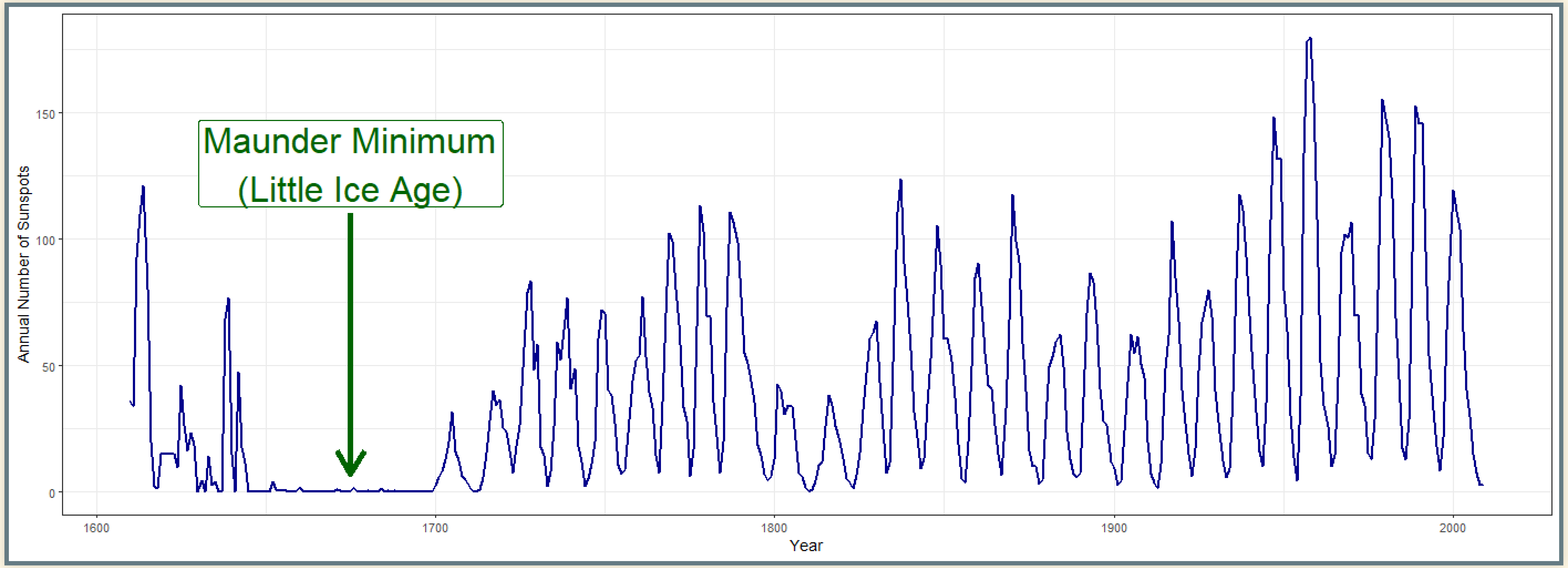
Sunspots?

Sunspots?

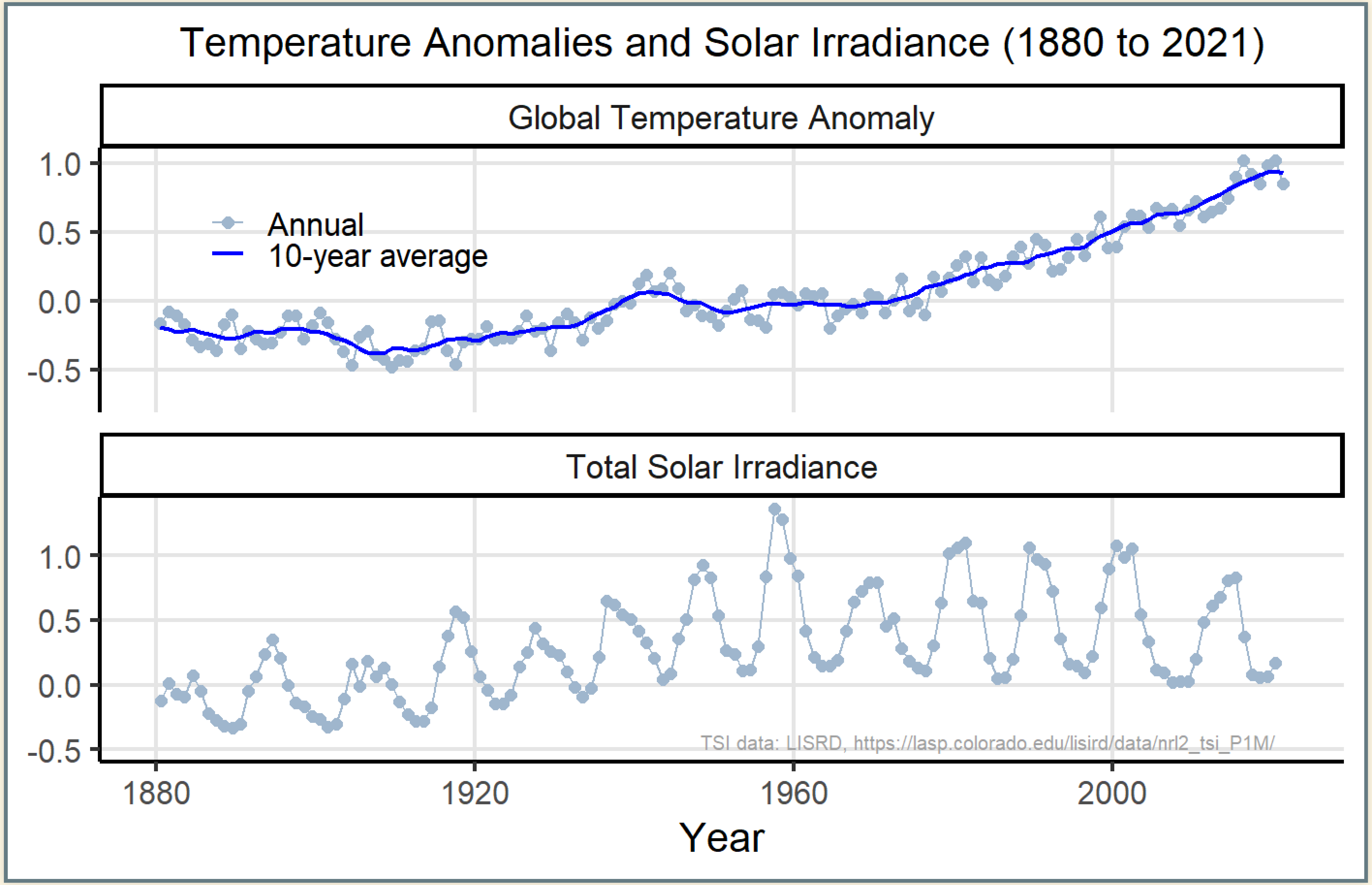


Sunspots

- Discovered 1611 by Galileo and J. Fabricius
- More sunspots \(\rightarrow\) brighter
- 11 year cycle
- Intensity changes:
  - <1% for 11-year cycle
  - <0.1% change in decadal average from little ice age to present



Sunspots didn't cause recent warming



Fingerprints:
Predictions and Patterns

Predictions: 1967

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Thermal Equilibrium of the Atmosphere with a Given Distribution of Relative Humidity

SYUKURO MANABE AND RICHARD T. WETHERALD

Geophysical Fluid Dynamics Laboratory, ESSA, Washington, D. C.

(Manuscript received 2 November 1966)

ABSTRACT

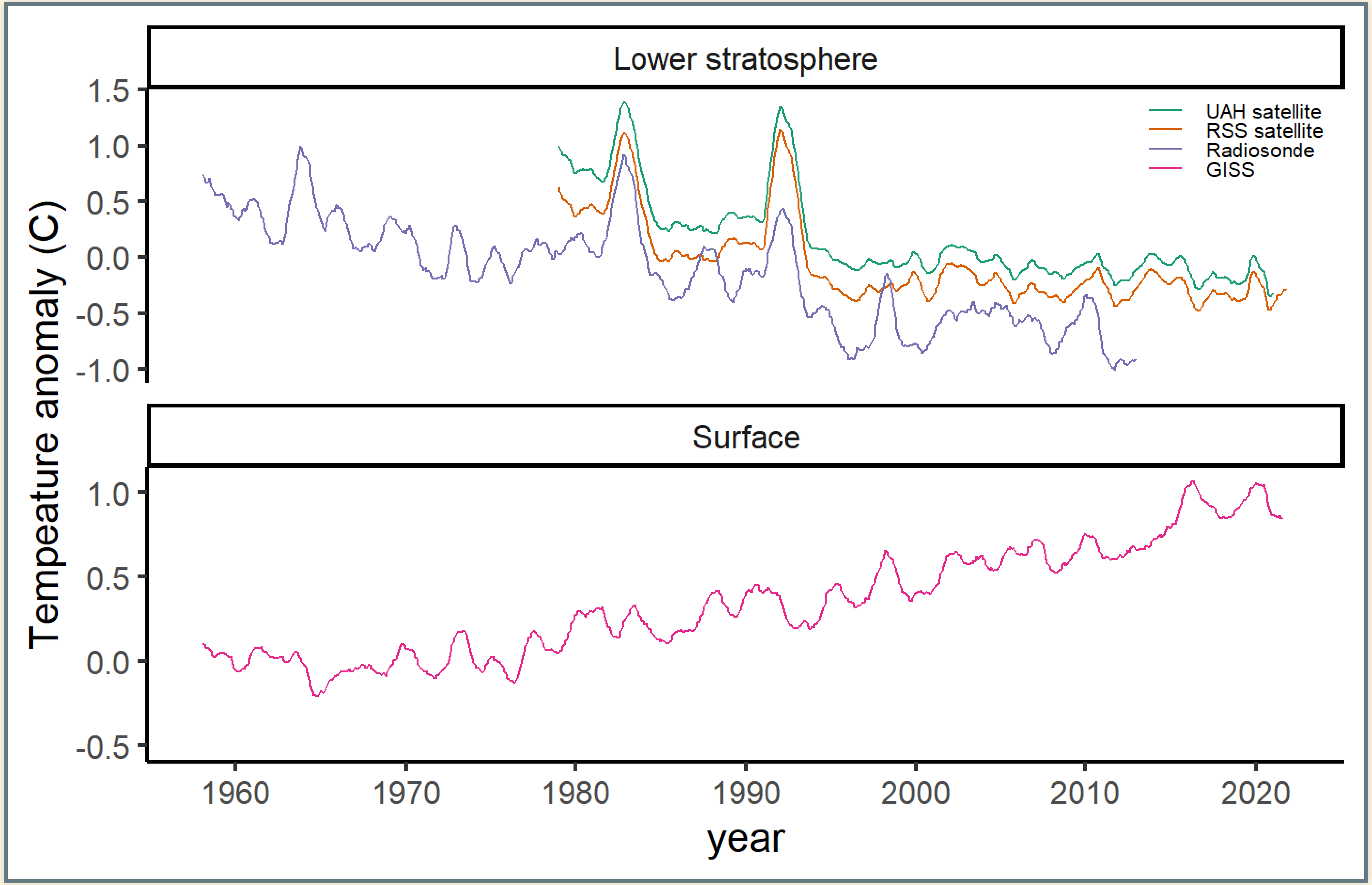
Radiative convective equilibrium of the atmosphere with a given distribution of relative humidity is computed as the asymptotic state of an initial value problem.

The results show that it takes almost twice as long to reach the state of radiative convective equilibrinm for the atmosphere with a given distribution of relative humidity than for the atmosphere with a given distribution of absolute humidity.

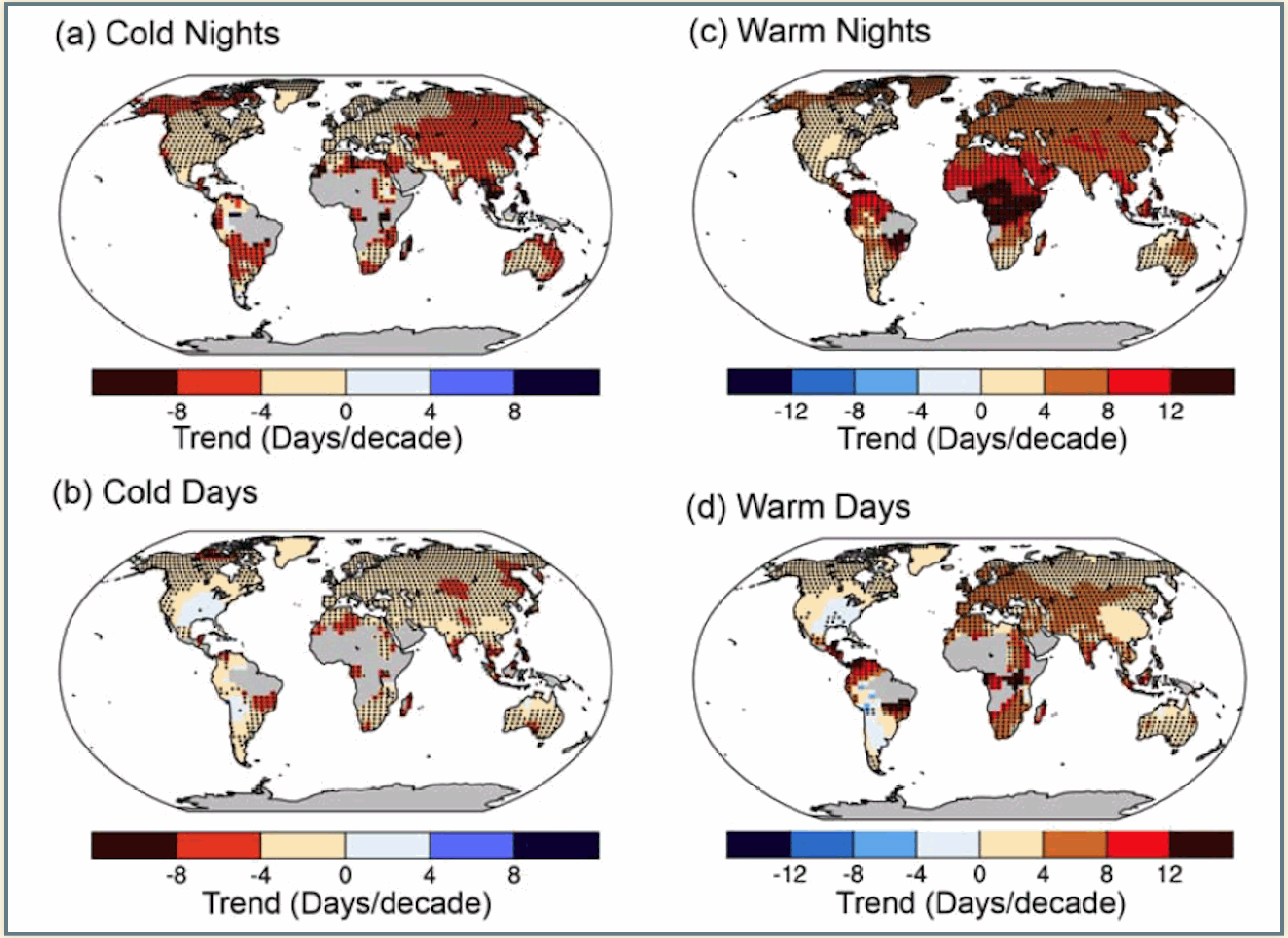
Also, the surface equilibrium temperature of the former is almost twice as sensitive to change of various factors such as solar constant, CO_2 content, O_3 content, and cloudiness, than that of the latter, due to the adjustment of water vapor content to the temperature variation of the atmosphere.

According to our estimate, a doubling of the CO_2 content in the atmosphere has the effect of raising the temperature of the atmosphere (whose relative humidity is fixed) by about 2C. Our model does not have the extreme sensitivity of atmospheric temperature to changes of CO_2 content which was adduced by Möller.

Stratosphere vs. Surface:



Day vs. Night



(a) Cold Nights
-8 -4 0 4 8
Trend (Days/decade)
(b) Cold Days
-8 -4 0 4 8
Trend (Days/decade)
(c) Warm Nights
-12 -8 -4 0 4 8 12
Trend (Days/decade)
(d) Warm Days
-12 -8 -4 0 4 8 12
Trend (Days/decade)