Climates of the Past

EES 3310/5310

Global Climate Change

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Class #13: Monday, February 22 2021

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 rocks
    - Creates carbonate rocks on sea floor with carbon that originated in atmosphere

Weathering as Thermostat

CO_2 concentration is controlled by the balance of volcanic outgassing and chemical weathering

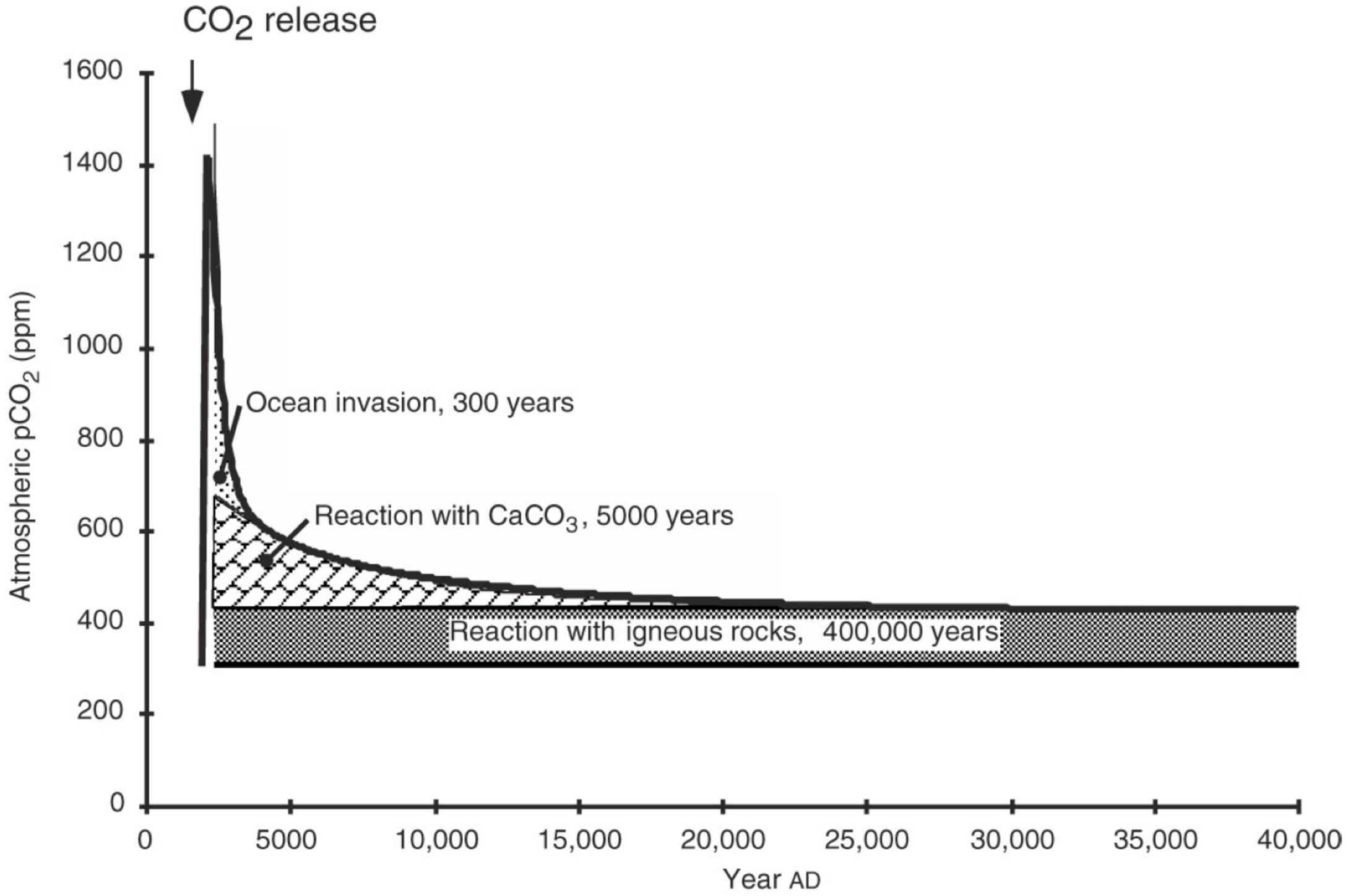
- **Higher temperatures:**
  - More rain, faster chemical reactions
  - Faster weathering
  - Atmospheric CO_2 falls
- **Lower temperatures**
  - Less rain, slower chemical reactions
  - Slower weathering
  - Atmospheric CO_2 rises

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.

Prospects for future:

- **Oceanic sinks:**
  - A few centuries:
    - Around 50% of excess CO_2 dissolves into oceans
    - Dissolution stops as oceans acidify
  - A few thousand years:
    - Reactions with limestone restore *p*H, CO_2 solubility
  - Hundreds of thousand of years
    - Silicate-mineral weathering removes and buries excess CO_2.
- **Bottom line:**
  - CO_2 stays in the atmosphere many thousands of years after we stop burning fossil fuels.


CO_2 release
1600
1400
1200
1000
800
600
400
200
0
Atmospheric pCO_2 (ppm)
Ocean invasion, 300 years
Reaction with $CaCO_3$, 5000 years
Reaction with igneous rocks, 400,000 years
0
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
Year AD

CO_2 vs. Methane

- CO_2:
  - After 1000 years, around 30% of excess CO_2 remains in atmosphere
  - After 10,000 years, 13% remains
  - After 100,000 years, 6% remains
- Methane (CH_4):
  - 31 times more powerful (molecule-for-molecule) than CO_2
  - Atmospheric lifetime: 12.4 years:
    - After 25 years, 13% remains.
    - After 100 years, 0.031% remains.

Climates of the Past

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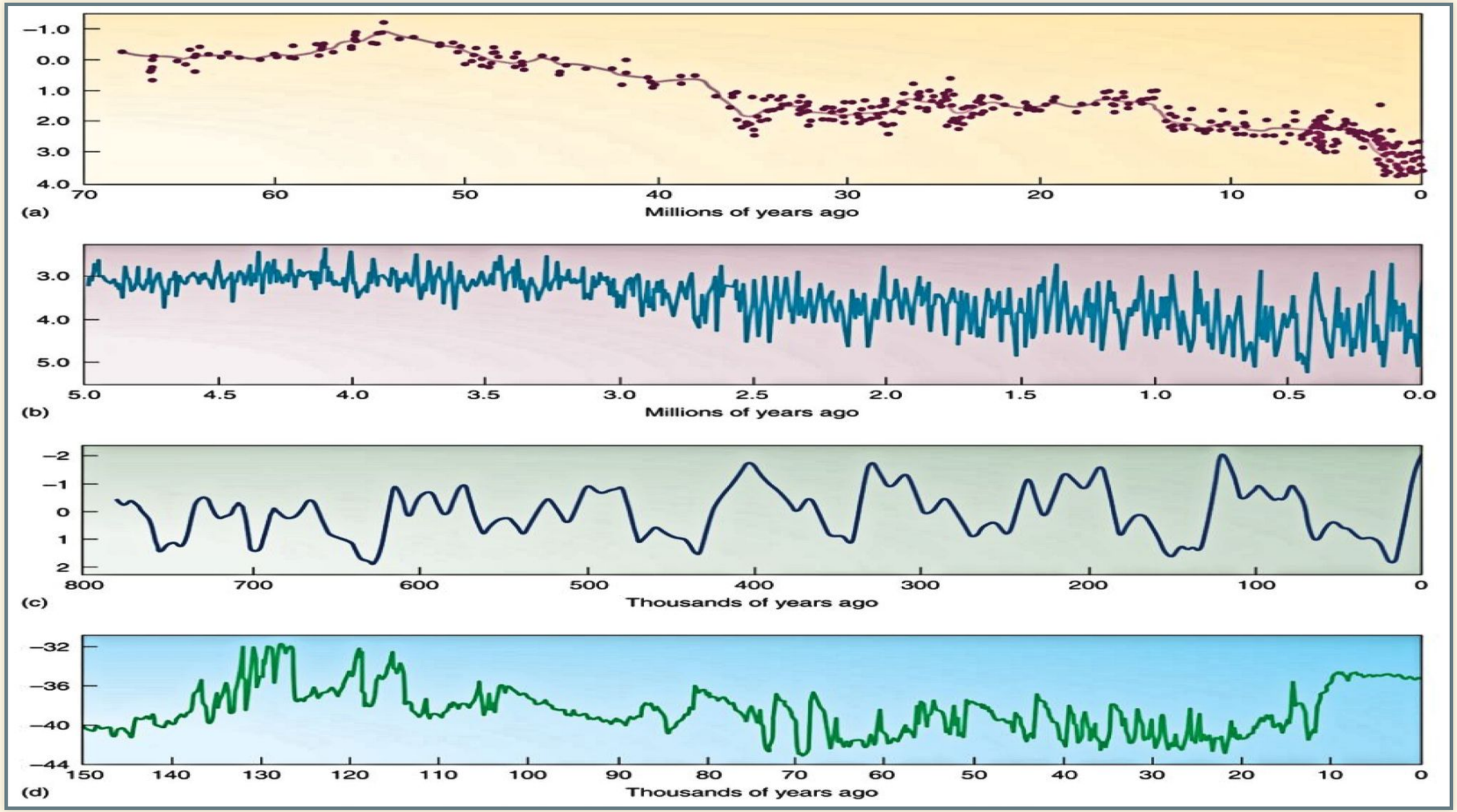
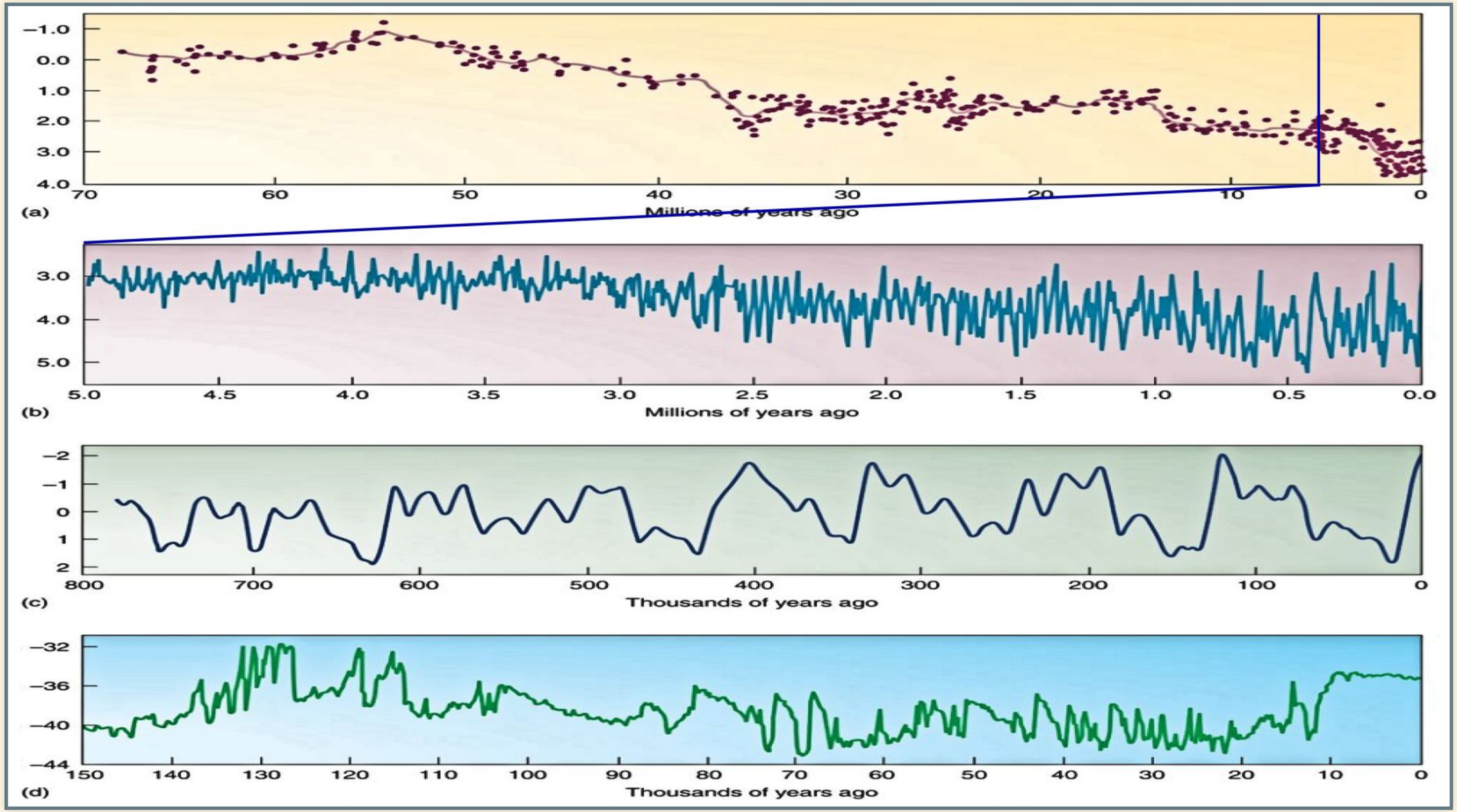
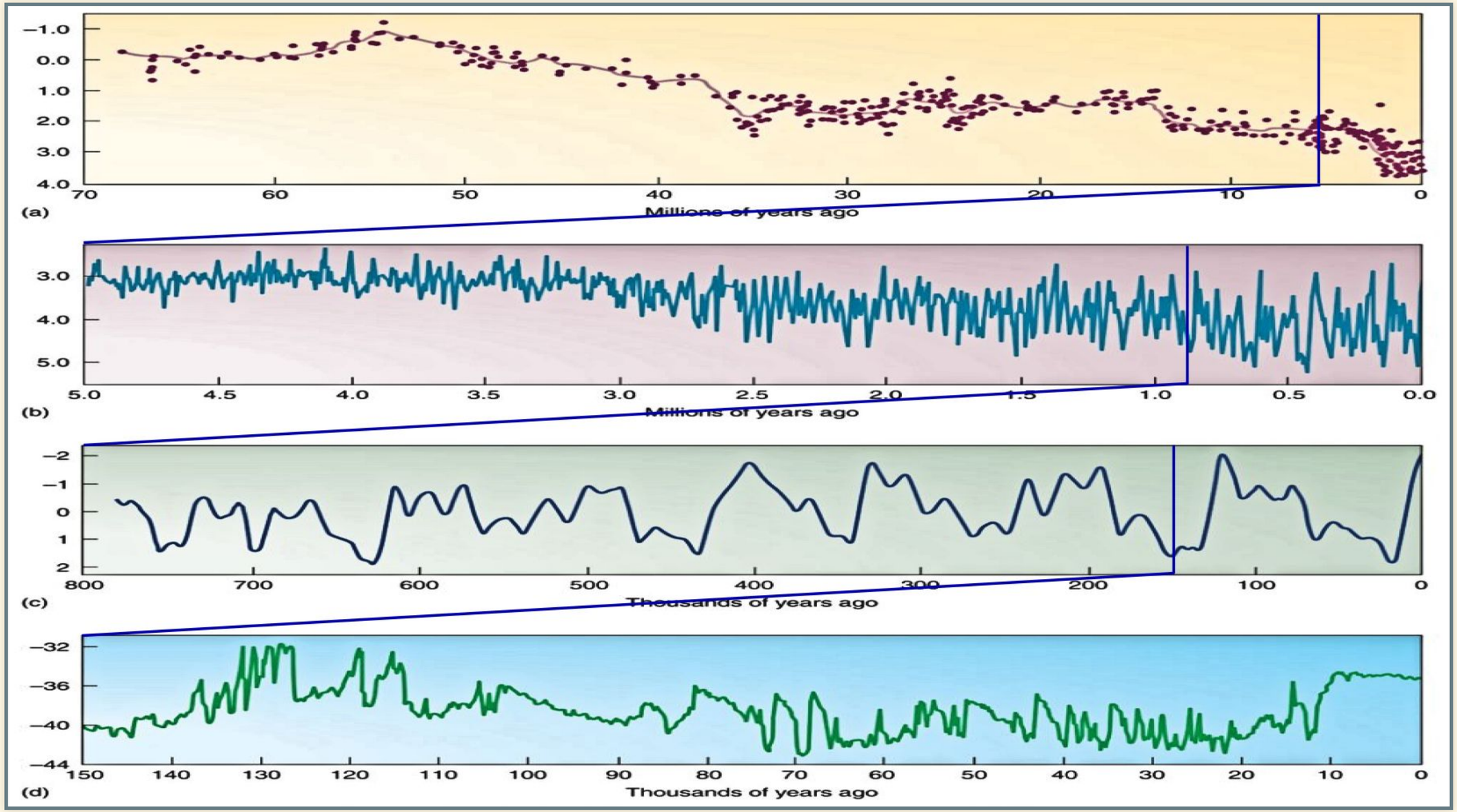


Climates of the Past



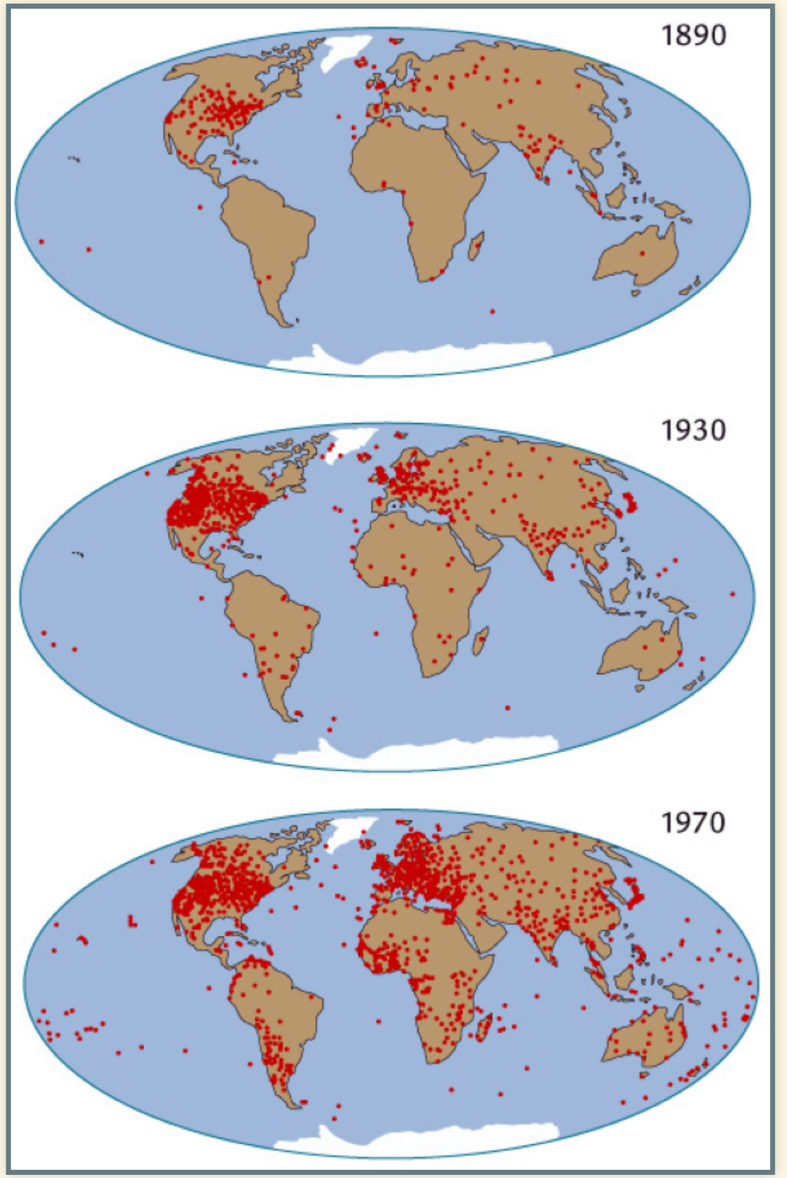
Climates of the Past



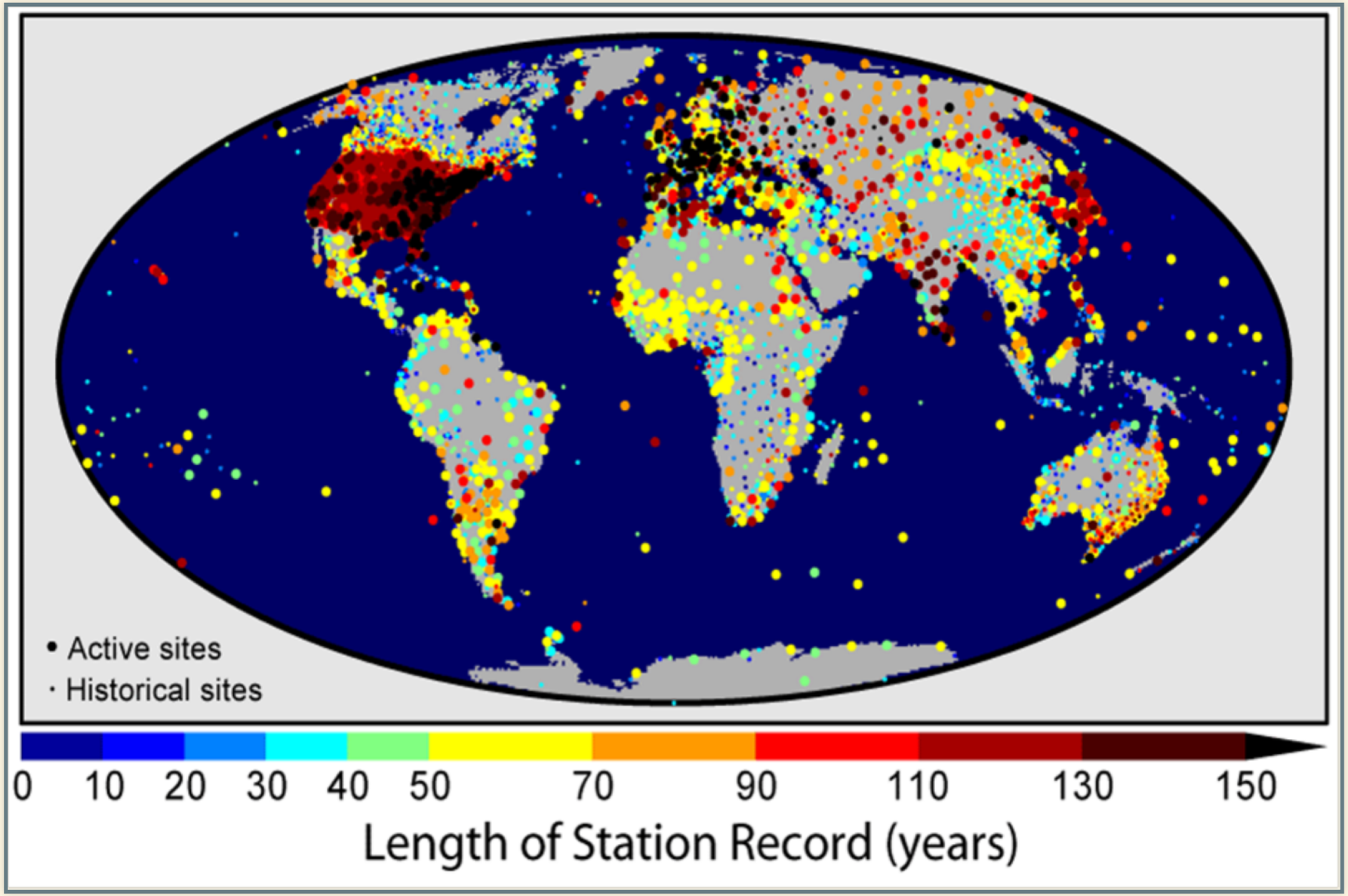
Digging into the past

Digging into the past:

Temperature measuring stations over the last 130 years.



Surface Temperature Monitoring



- 7280 stations
- 2277 active
- 1656 > 100 years

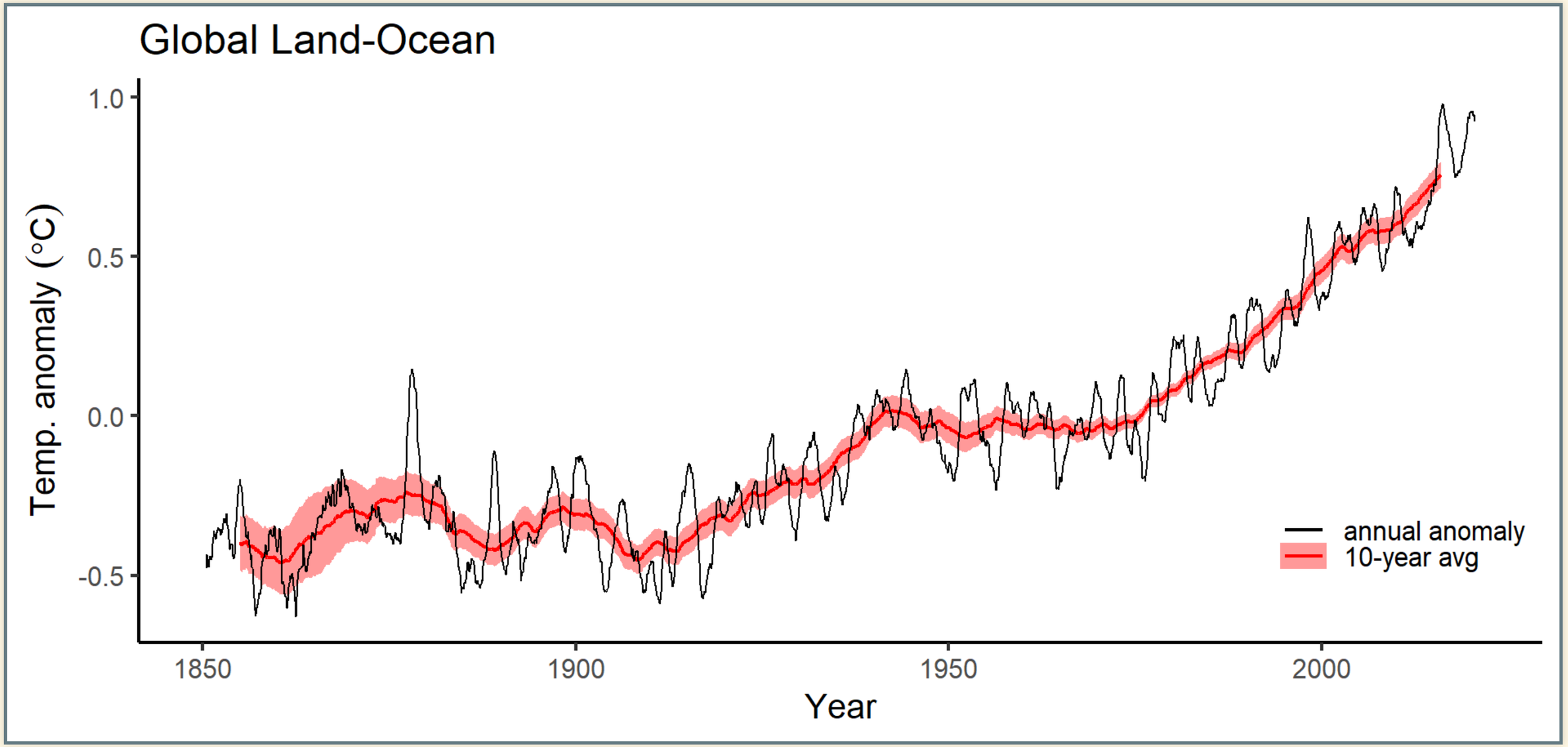
Temperature Anomaly

- **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

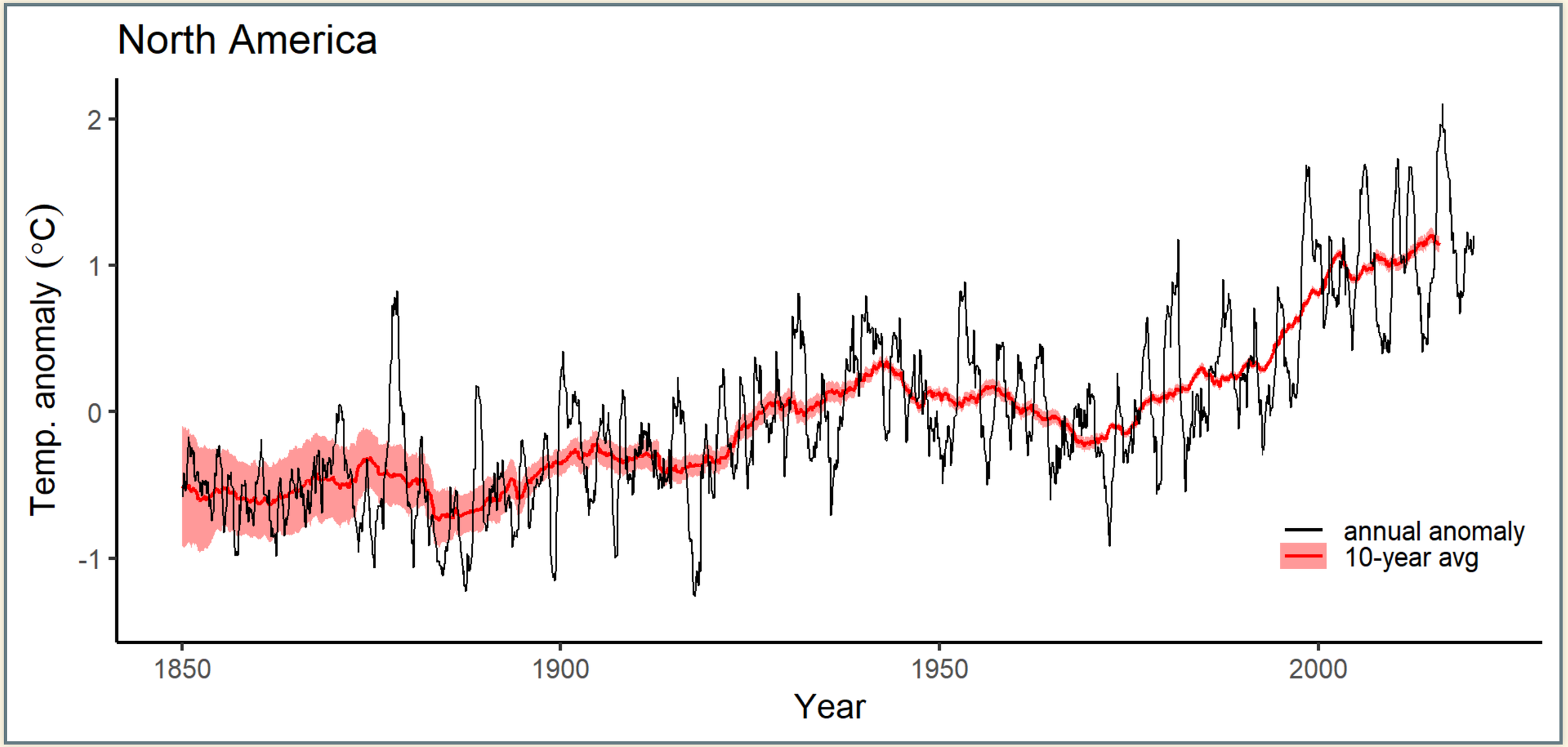
Temperature Anomaly

- 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 = 7.2°C
  - Average January temp 1950–1979 = 3.0°C
  - Anomaly = $7.2^\circ\text{C} - 3.0^\circ\text{C} = 4.3^\circ\text{C}$

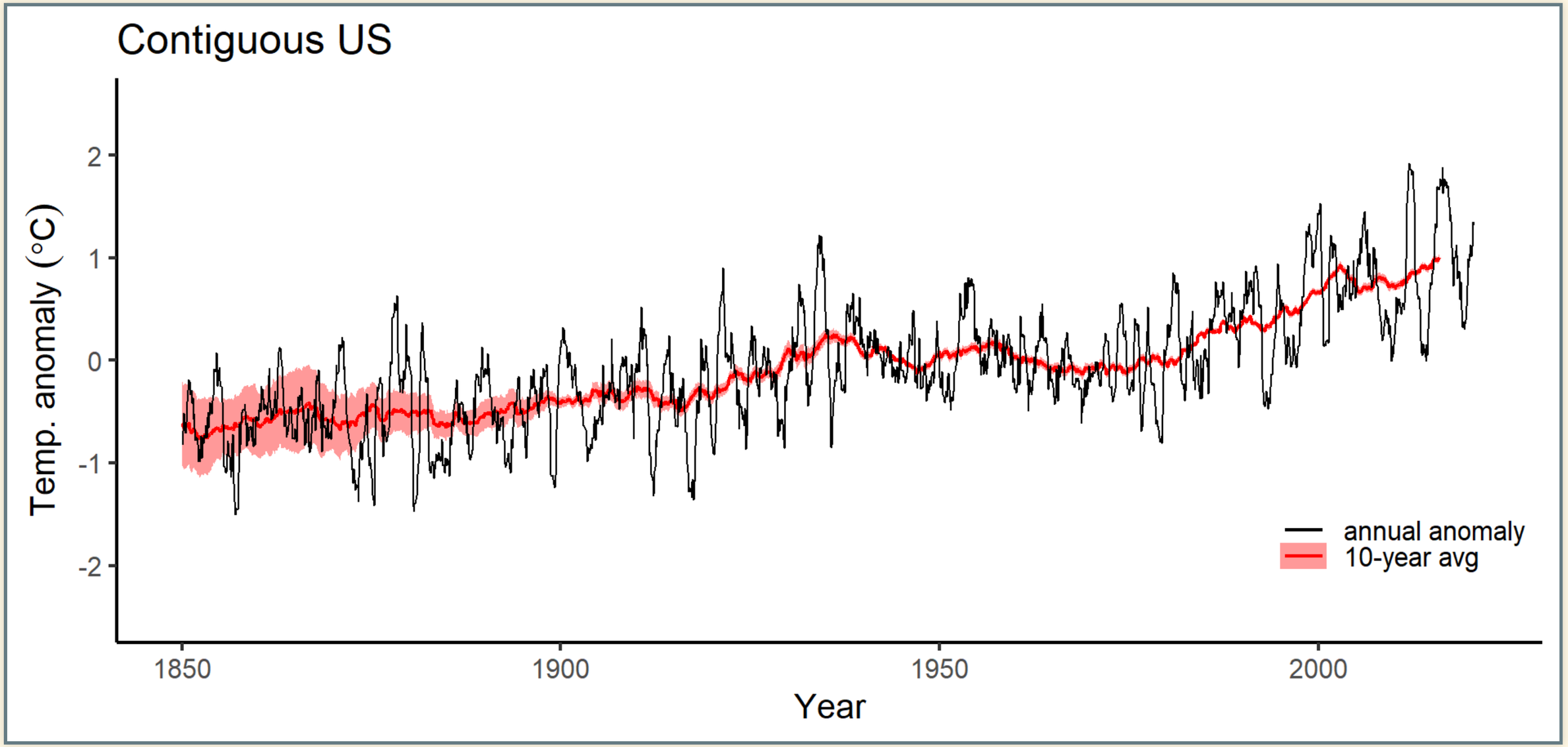
Global Anomaly
1850–2020



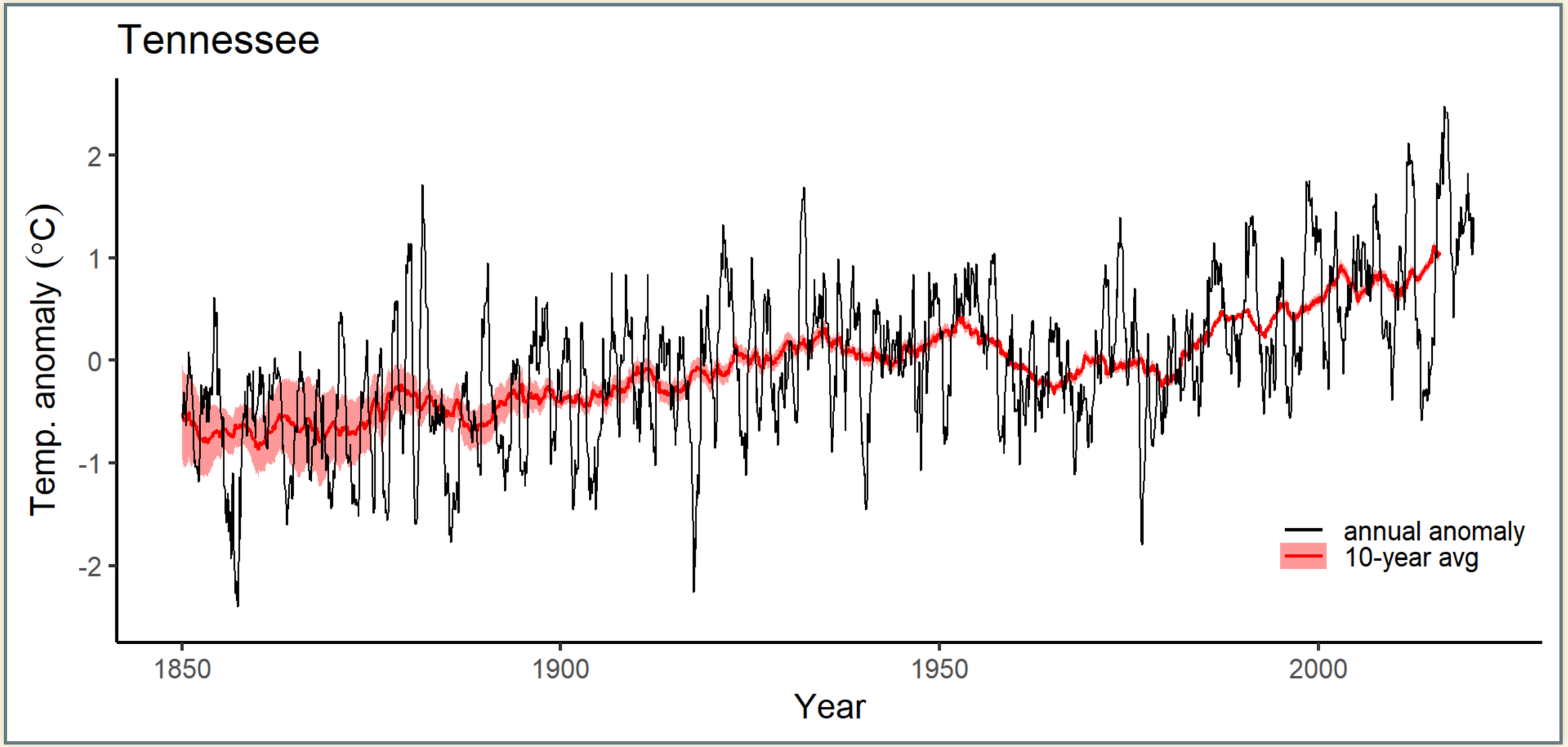
North America
1850–2020



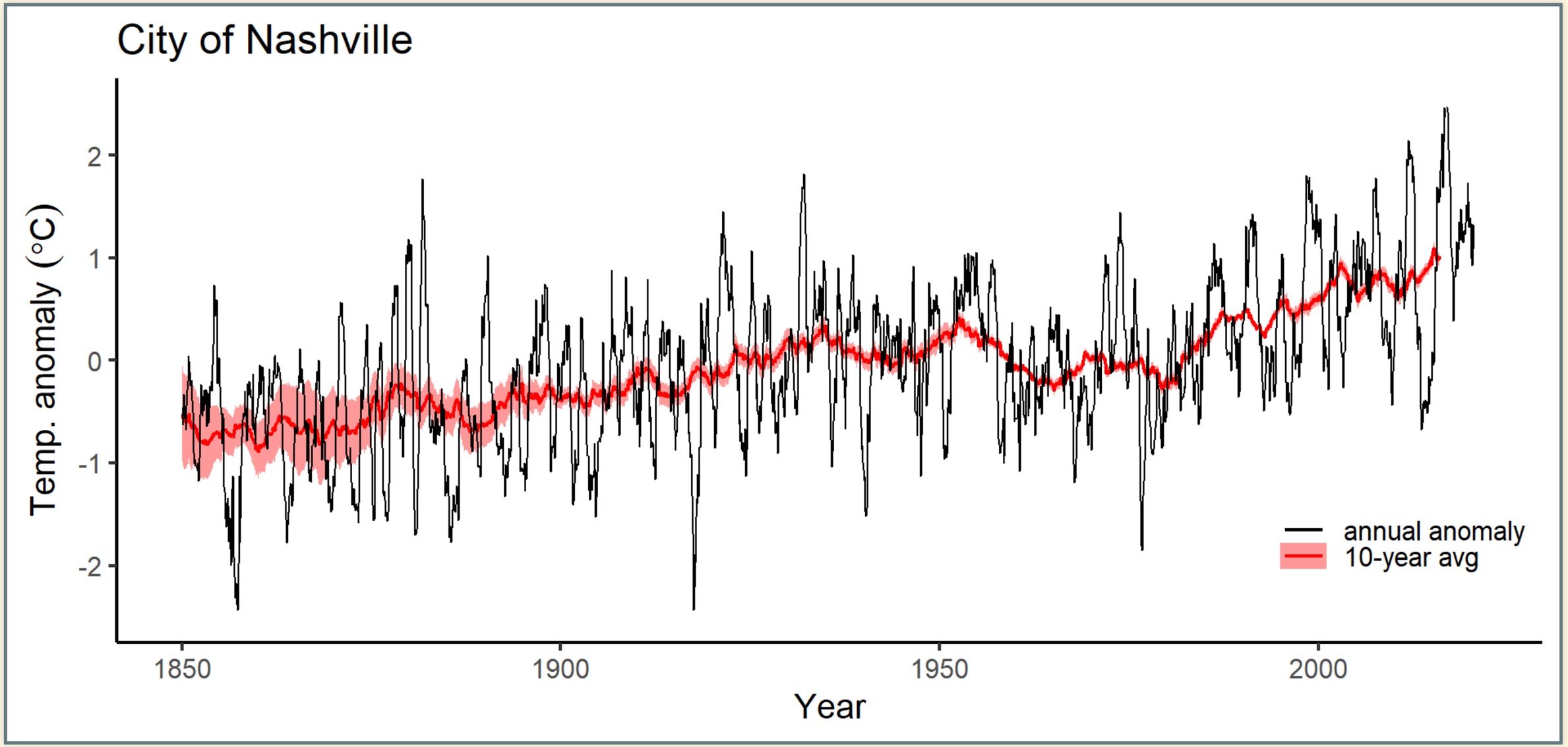
Continental US Anomaly 1850–2020



Tennessee Anomaly 1850–2020



Nashville Anomaly
1850–2020



Ocean Temperatures

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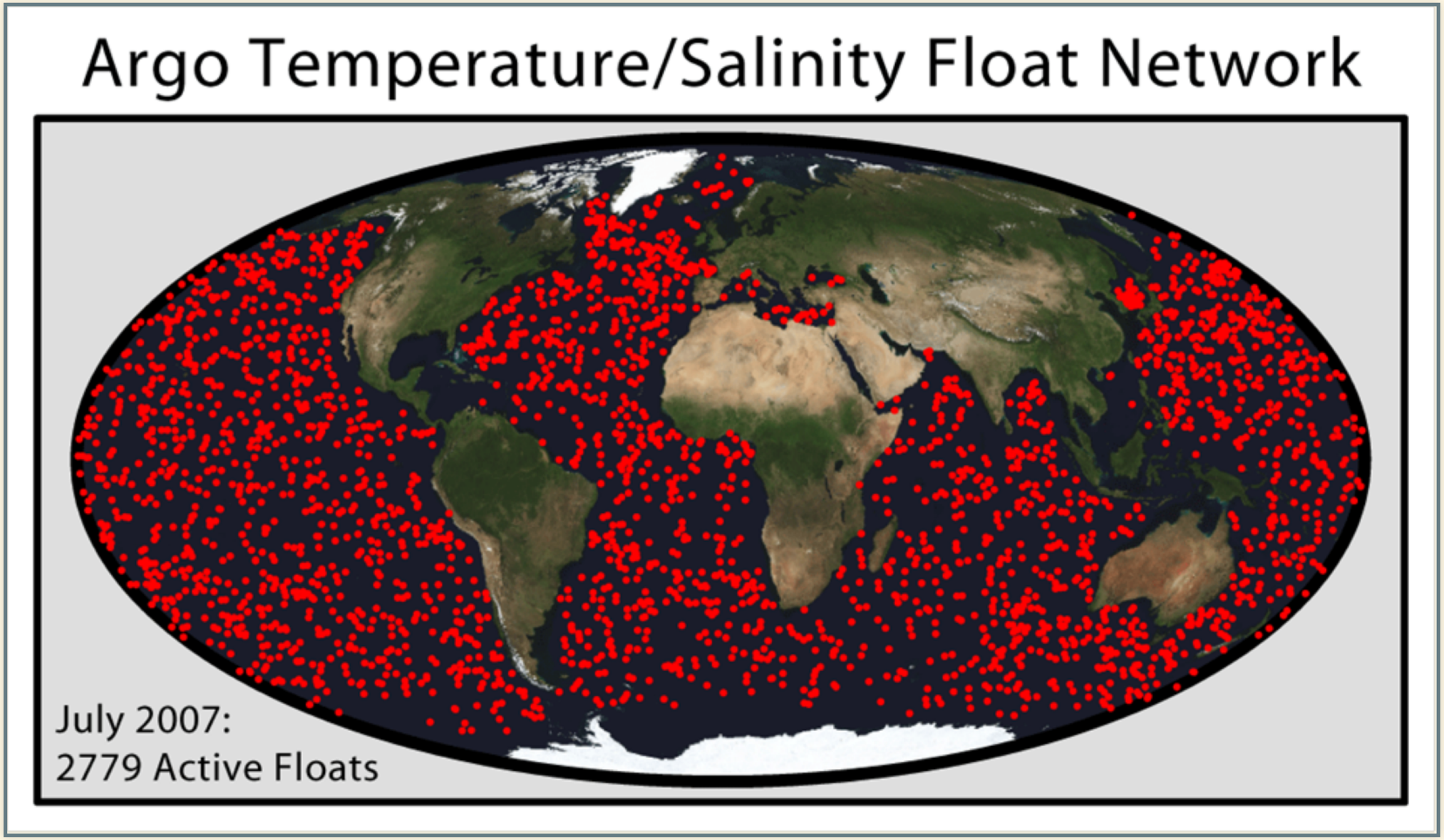
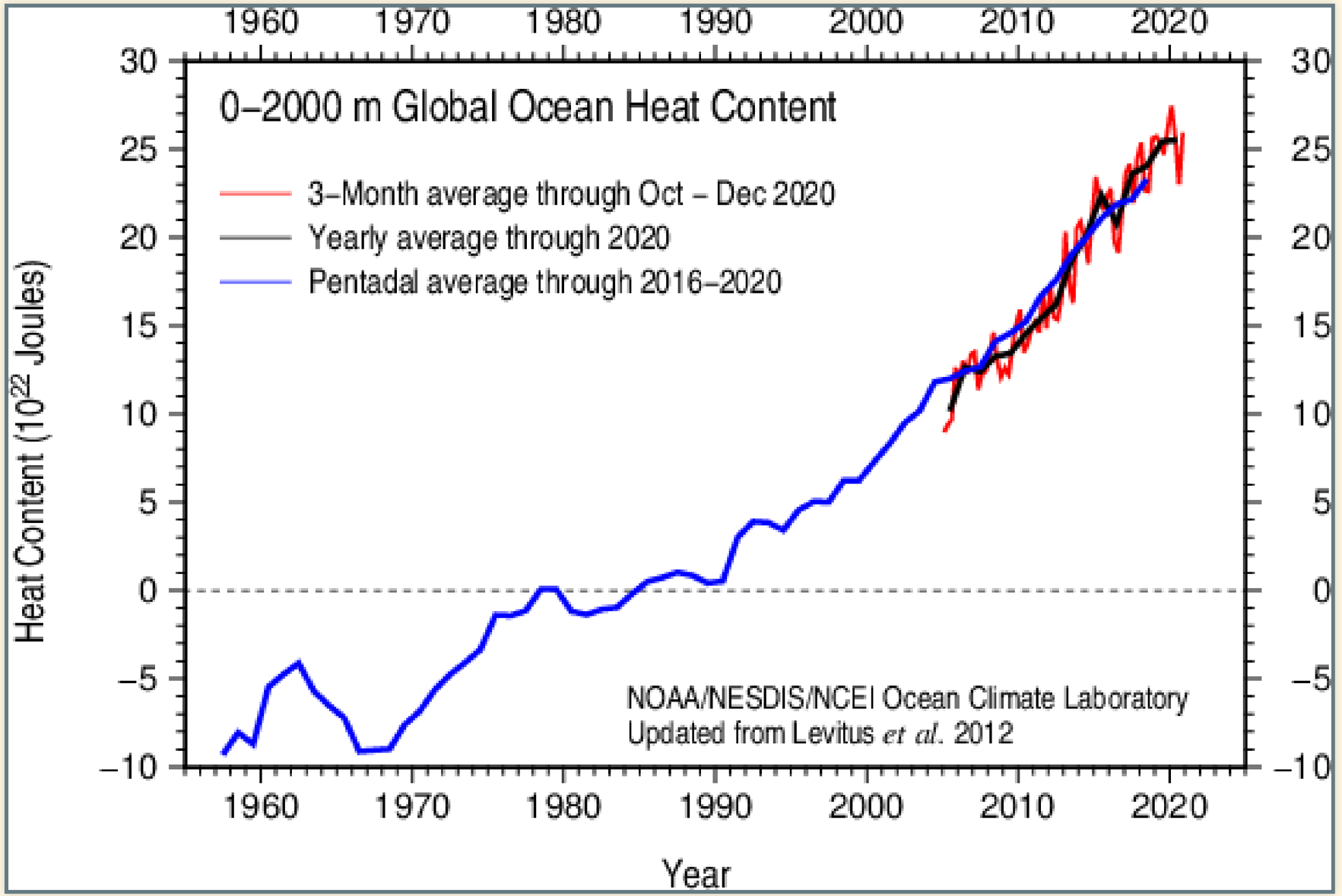


Ocean Heat Content

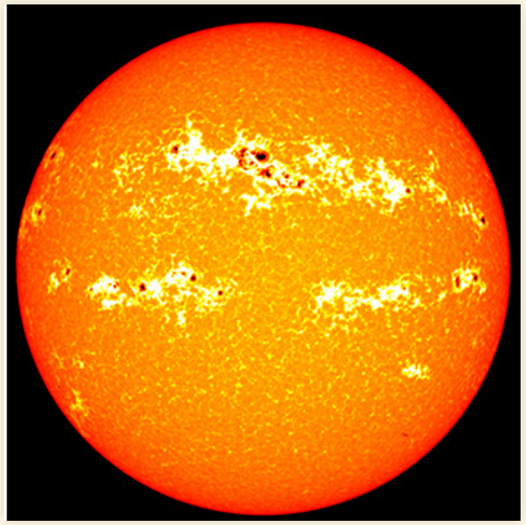


Searching for a Smoking Gun:

What caused the warming?

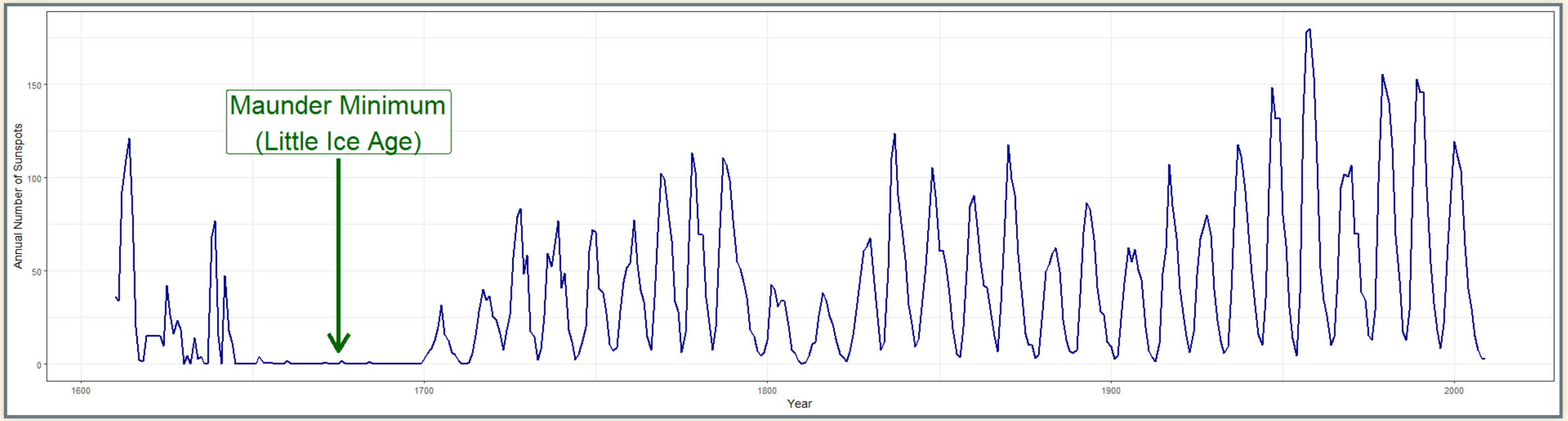
Sunspots?

Sunspots?

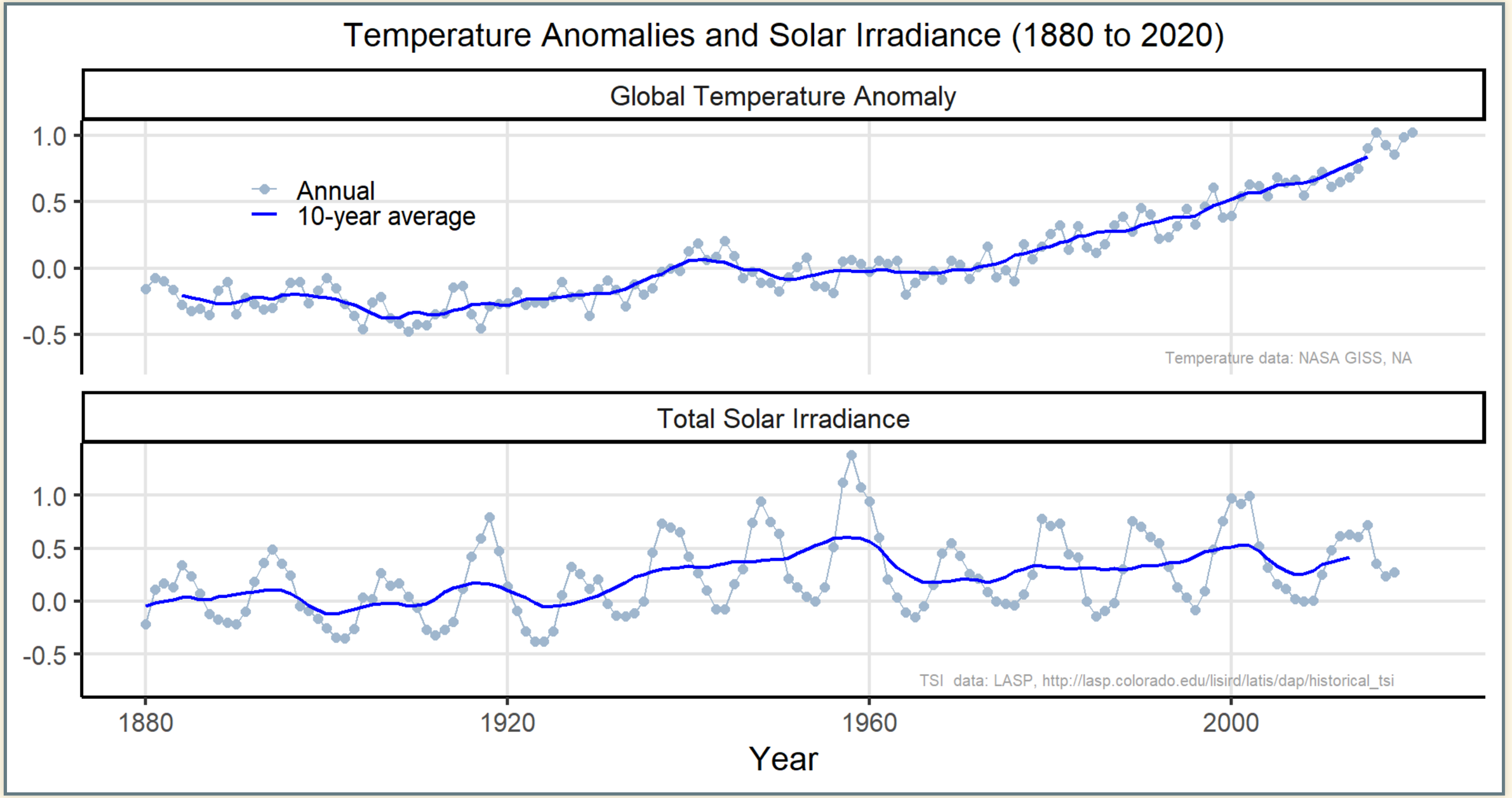


Sunspots

- 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

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(Manuscript received 2 November 1966)

ABSTRACT

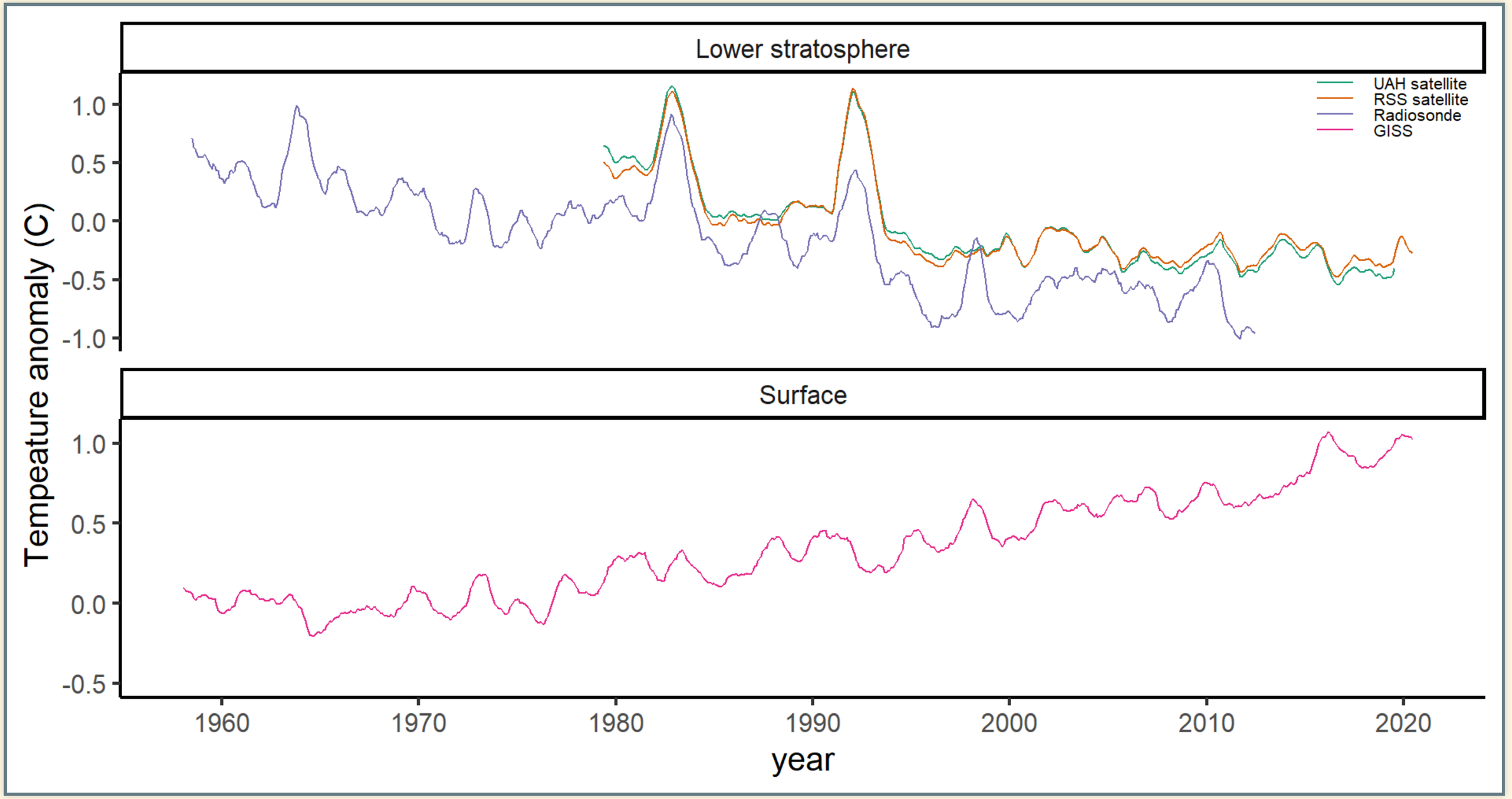
Radiative convective equilibrium of the atmosphere with a given distribution of relative humidity is computed as the asymptotic state of an initial value problem.

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.

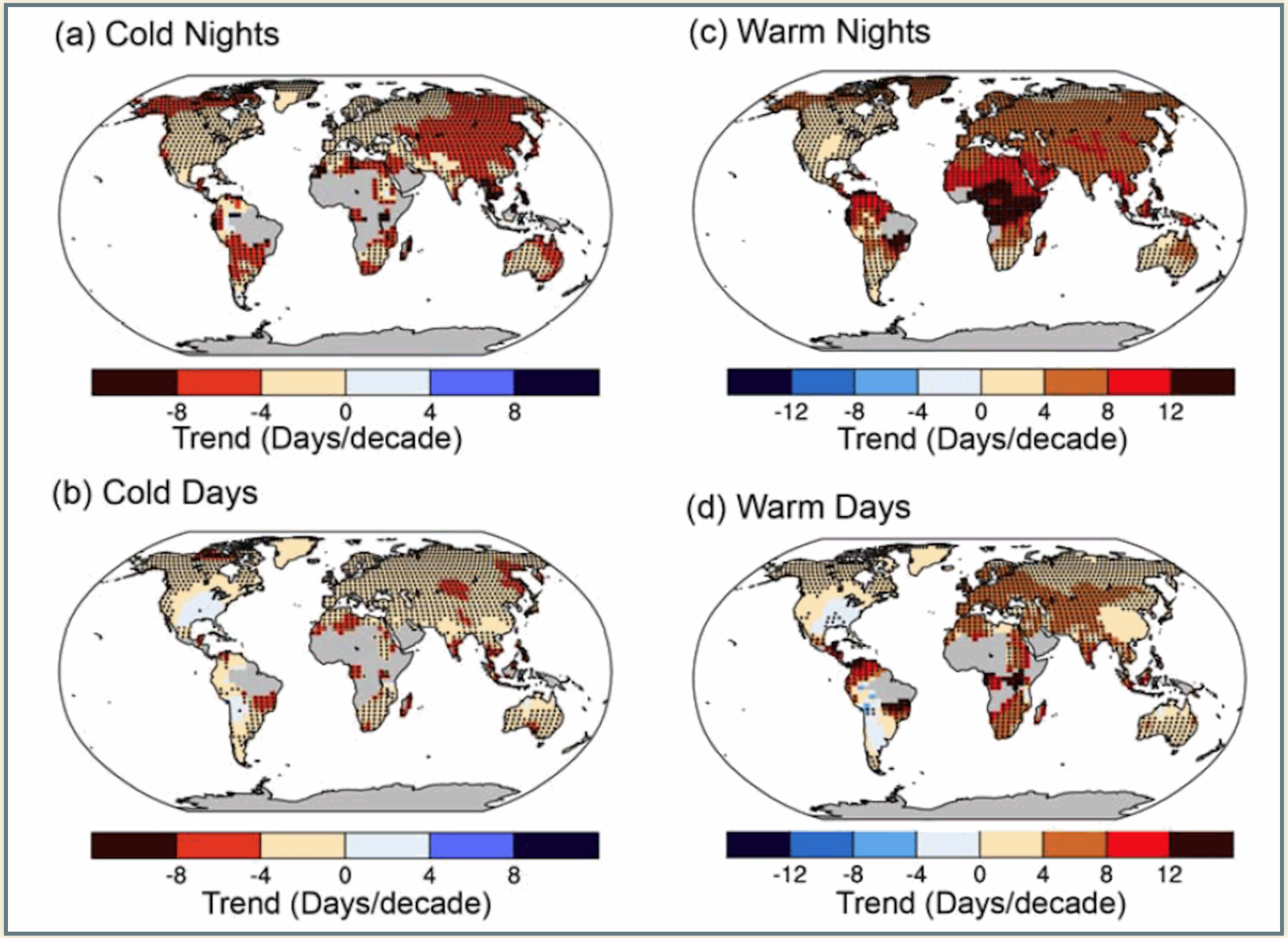
Also, the surface equilibrium temperature of the former is almost twice as sensitive to change of various factors such as solar constant, CO_2 content, O_3 content, and cloudiness, than that of the latter, due to the adjustment of water vapor content to the temperature variation of the atmosphere.

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:


Lower stratosphere
Surface
UAH satellite
RSS satellite
Radiosonde
GISS
Tempeature anomaly (C)
1.0
0.5
0.0
-0.5
-1.0
1960
1970
1980
1990
2000
2010
2020
year

Day vs. Night


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