Climates of the Future

EES 3310/5310

Global Climate Change

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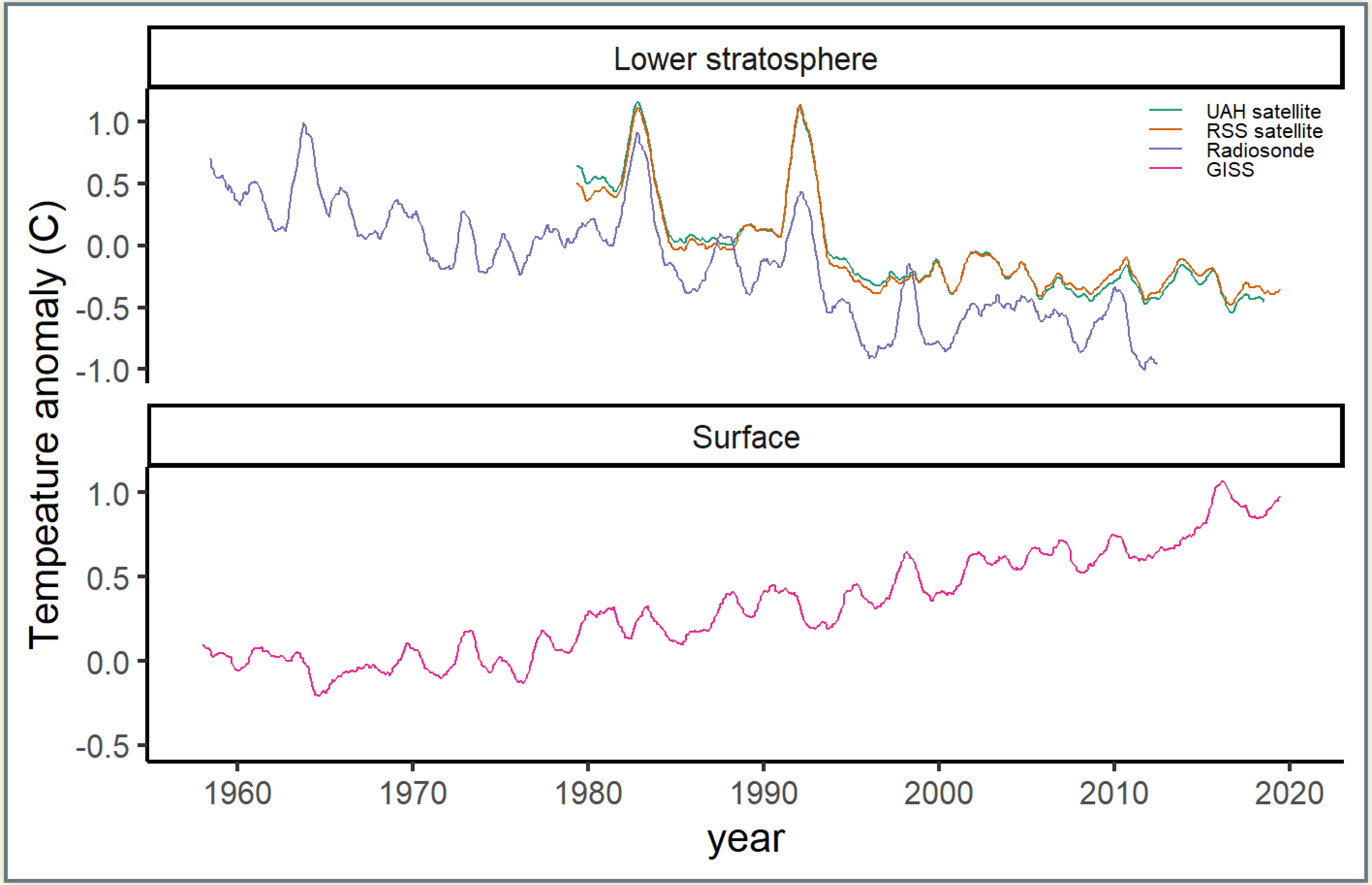
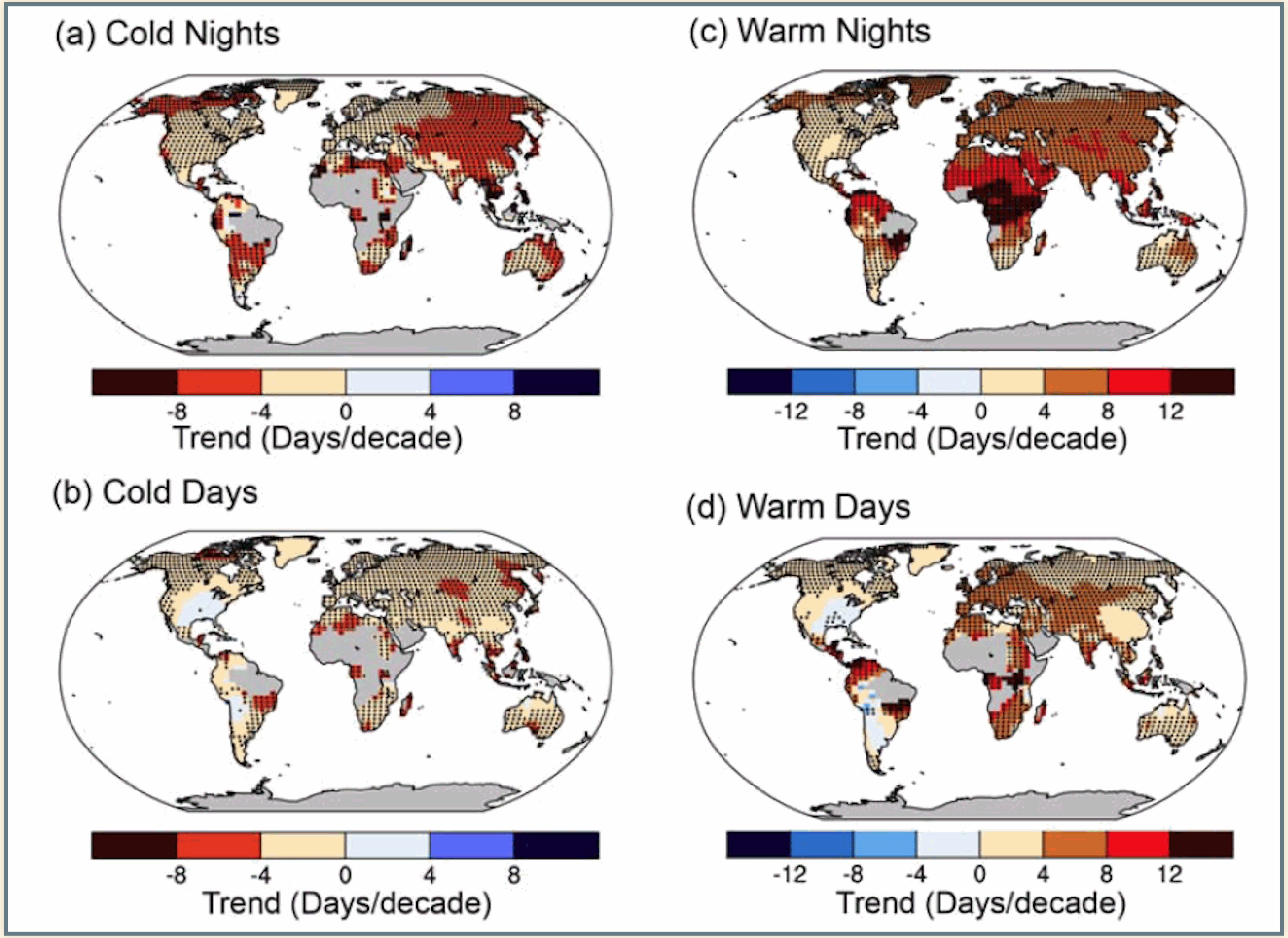
Class #17: Friday, February 14 2020

Using Models to Test Theories about the Cause of Global Warming

Stratosphere vs. Troposphere:



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)

Modeling for Science vs. Policy

Modeling for Science vs. Policy

Integrated Assessment Models (IAMS)

- Combine climate system and world economy
  - Emissions as a consequence of economic activity
    - Energy use for production (factories, etc.)
    - Energy use for consumption (households, etc.)
    - Farming: fertilizers, livestock, paddy fields, etc.
  - Climatic impacts on economy
    - Cost of severe weather
    - Sea level rise
    - Droughts & heat waves
    - ...
- **Optimize for greatest net economic output**

Predictions & Projections

- Predictions are hard:
- Biggest uncertainty in predicting future climates is GHG emissions
  - We can predict consequences of emissions
  - We can’t predict what emissions will be
- Projections:
  - Conditional predictions:
    - “**If** emissions do this, **then** climate will do that.”
  - Scenarios and Pathways of future emissions:
    - **Scenario**:
      - Start with a story of economic & political development
      - Calculate resulting emissions
    - **Pathway**:
      - Start with possible emissions trajectory
      - Develop a plausible story that could produce it

Projections for future emissions in US:

	2010	**2050**	**Growth rate**
g (\$/person)	42,300	83,495	1.7%
ef (tons/\$million)	432	228	-1.6%
P (millions)	309	393	0.6%
Total Emissions *F* (million tons CO_2)	**5,647**	**7,471**	1.7 - 1.6 + 0.6 = **0.7%**

Projections for future world emissions:

	2010	2050	Growth rate
g ($/person)	9,780	22,654	2.1%
ef (tons/$million)	522	275	-1.6%
P (millions)	6,410	9,188	0.9%
Total Emissions *F* (million tons CO_2)	**32,724**	**57,289**	2.1 - 1.6 + 0.9 = **1.4%**

Uncertainties in Projections

Projections for future world emissions:

	2010	**2050**	**2100**	**Growth rate**
g ($/person)	9,780	22,654	64,737	2.1%
ef (tons/$million)	522	275	124	-1.6%
P (millions)	6,410	9,188	14,409	0.9%
Total Emissions F (million tons CO_2)	**32,724**	**57,289**	**115,366**	**1.4%**

Uncertainties in Projections

Projections for future world emissions with slightly different growth rates:

	2010	**2050**	**2100**	**Growth rate**
g ($/person)	9,780	24,541	77,505	2.3%
ef (tons/$million)	522	298	148	-1.4%
P (millions)	6,410	9,563	15,766	1.0%
Total Emissions *F* (million tons CO_2)	**32,724**	**69,973**	**180,930**	**1.9%**
Difference		**12,684**	**65,564**	**0.5%**
Difference (%)		**22%**	**57%**	

Decisions Under Uncertainty

- **Global Climate change:**
  - Great Certainty:
    - People are warming the planet.
    - Warming will continue long after CO_2 stops rising.
    - Changes will persist for thousands of years.
  - Uncertain:
    - How much will planet warm (factor of ~2).
- **Impacts of Global Climate Change:**
  - Fairly Certain:
    - Severe heat waves will get worse.
    - Drought will get worse for much of the planet.
    - Intense rain & floods will get worse.
  - Very Uncertain:
    - Hurricanes & tornadoes.
- **Local/Regional Climate Change**
  - Fairly certain about some detailed local impacts.
  - Enormously uncertain about others.

Consequences of Climate Change

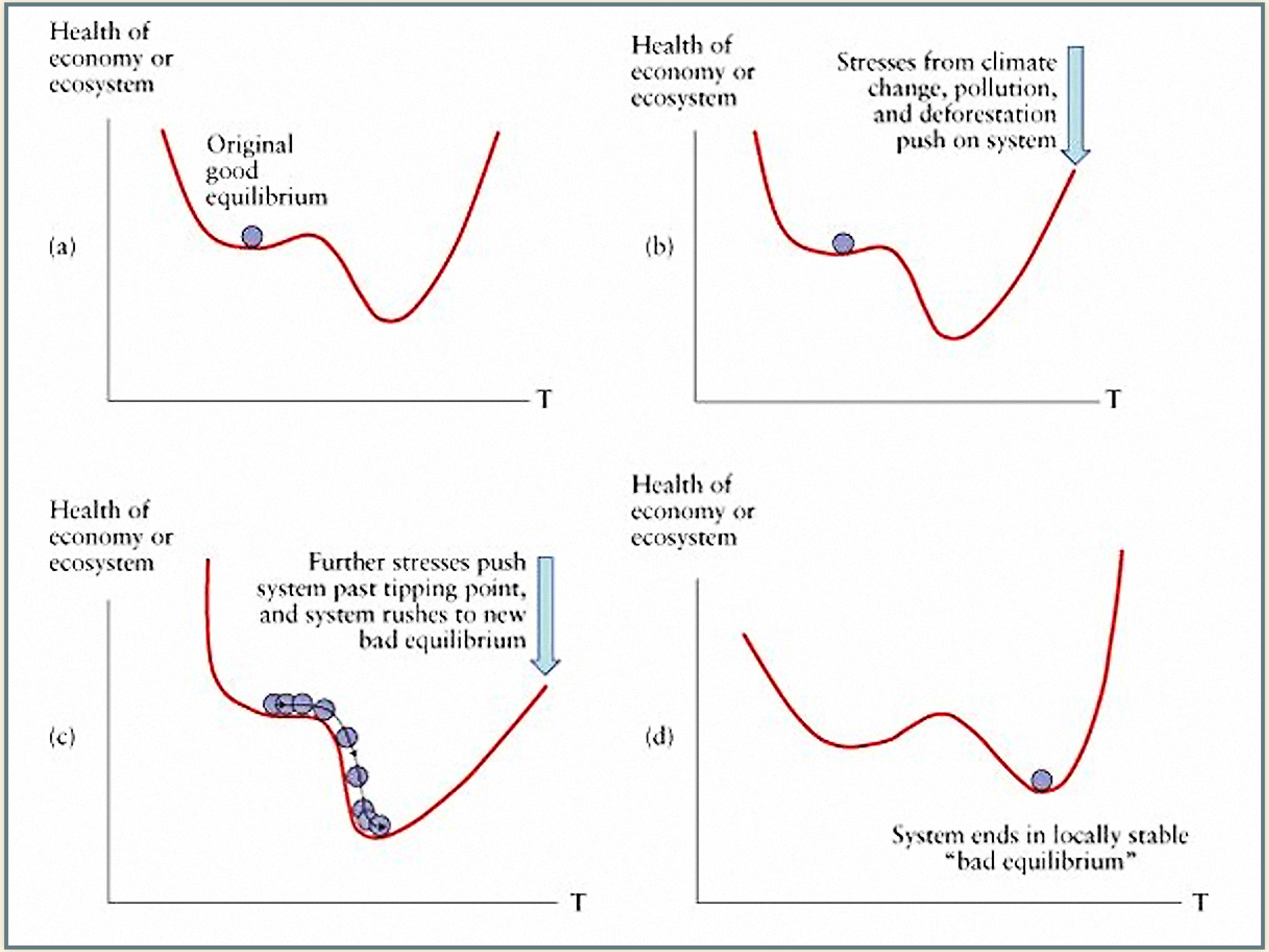
- **Economic effects:**
  - Costs of acting
  - Costs of inaction
  - Uncertainties
- **Policy issues:**
  - Markets vs. Regulation
    - Externalities
    - Kaya Identity: $F = P \times g \times e \times f$.

Tipping points

What we know about tipping points

- Very hard to predict them.
- *Climate Casino*: important tipping points:
  - Ice sheet melting
  - Coral reefs
  - Tropical rain Forests
  - Runaway greenhouse gas release
  - Slowdown of ocean conveyor belt circulation
  - ...

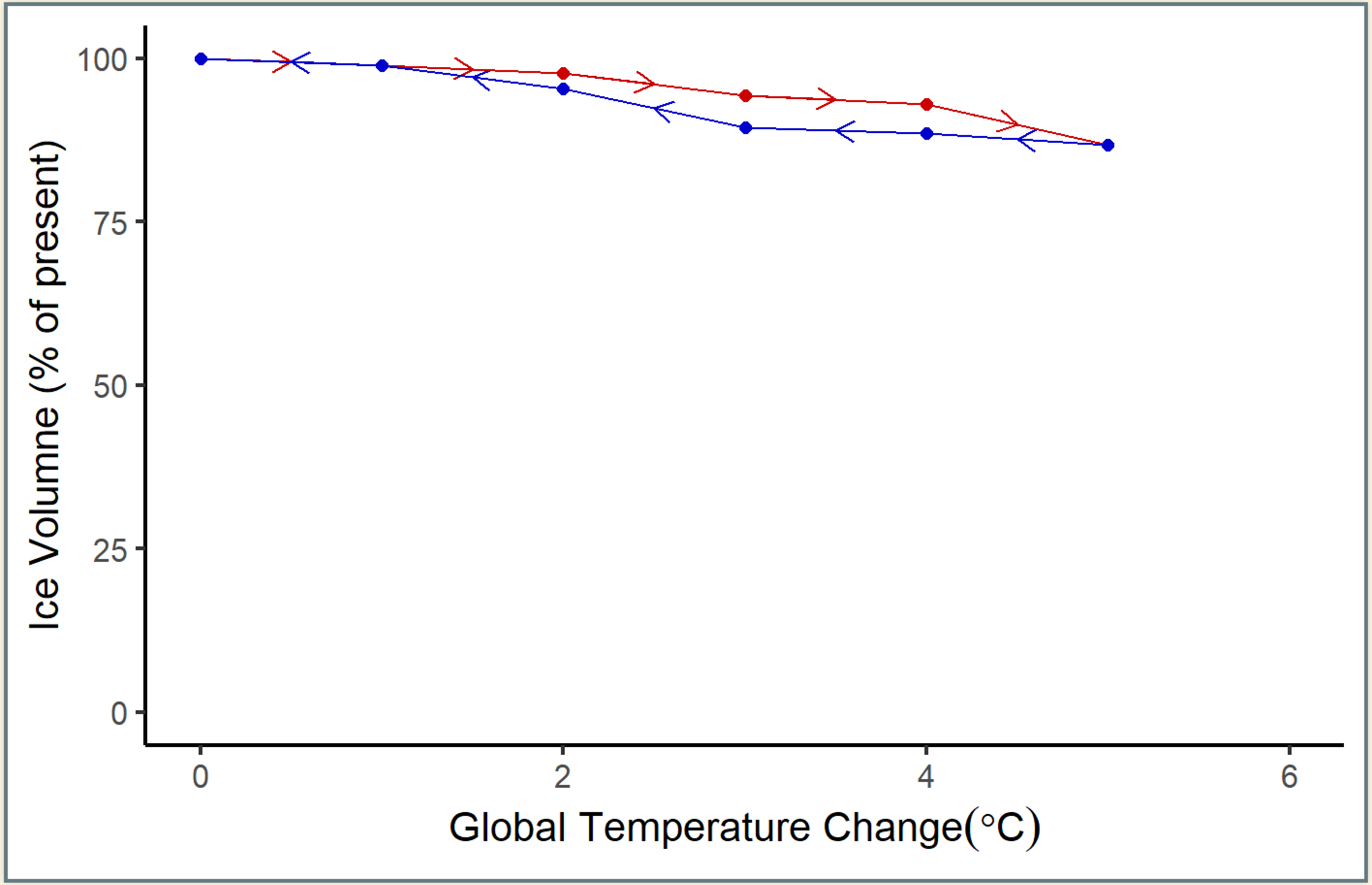
Bistability & Tipping Points



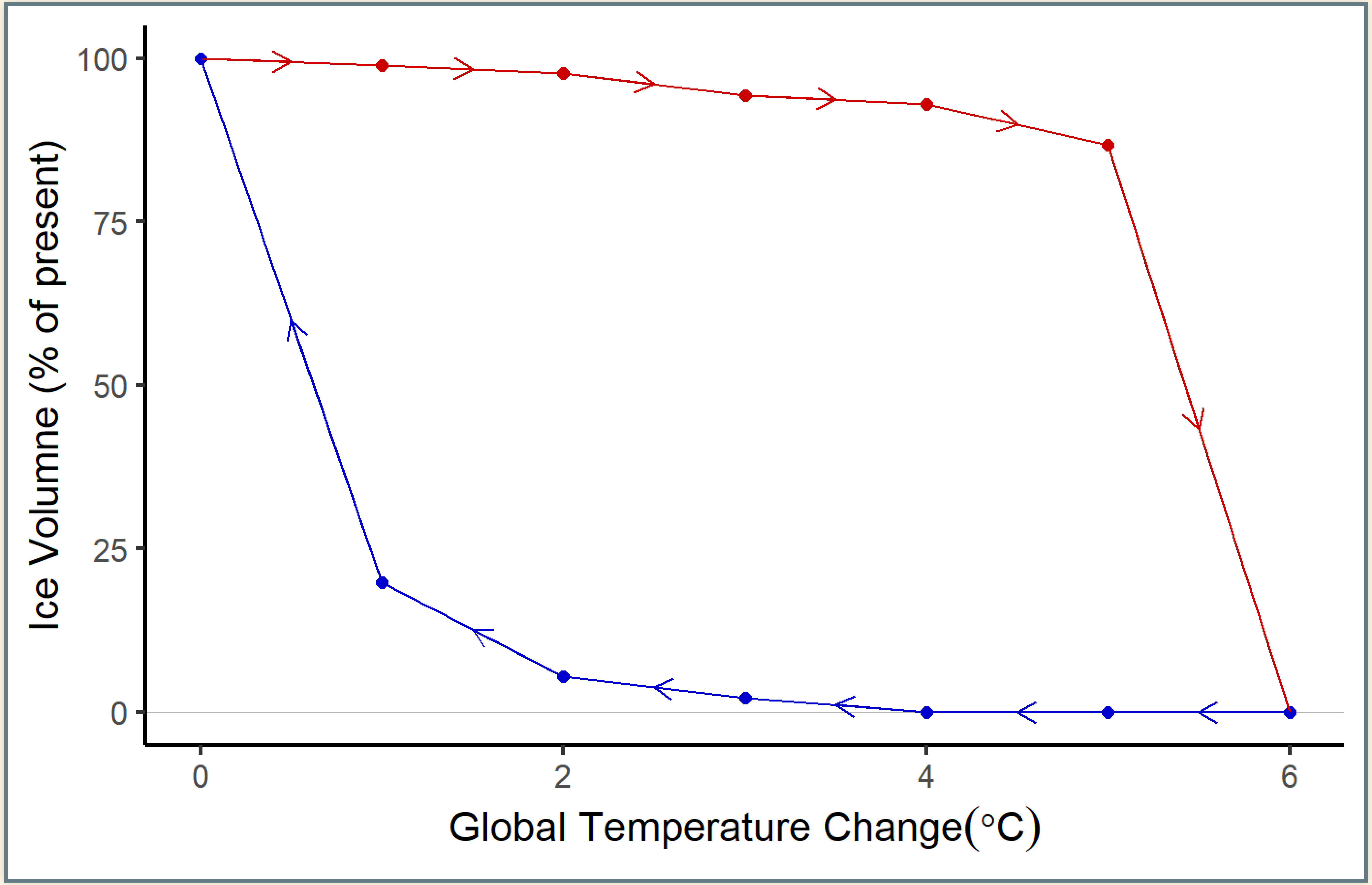
Hysteresis and Tipping Points

GRANTISM Model

Hysteresis:
Temperature and Ice Sheets


Ice Volumne (% of present)
100
75
50
25
0
0
2
4
6
Global Temperature Change(°C)

Hysteresis:
Crossing Tipping Point


Ice Volumne (% of present)
100
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Global Temperature Change(°C)

Principles of Tipping Points

- Ordinary positive feedbacks amplify changes
  (hot → hotter, cold → colder).
  - Small positive feedbacks amplify but the *system remains stable*.
- If positive feedbacks are too strong they become *self-perpetuating*.
  - Secondary forcing from feedback creates *unstoppable change*.
- If feedback *strengthens with warming*:
  - Tipping point: feedback becomes strong enough
    to continue warming independent of external forcing.
- **Not all positive feedbacks have tipping points.**
- **Hard to predict** when a positive feedback might go from *amplifying* to *runaway* (tipping point).

Where are they?

- *Climate Casino*: No big danger of fast tipping points if warming stays less than 3°C
- But, recent research finds that West Antarctic Ice Sheet has already crossed irreversible tipping point.

But Can We Trust the Experts?

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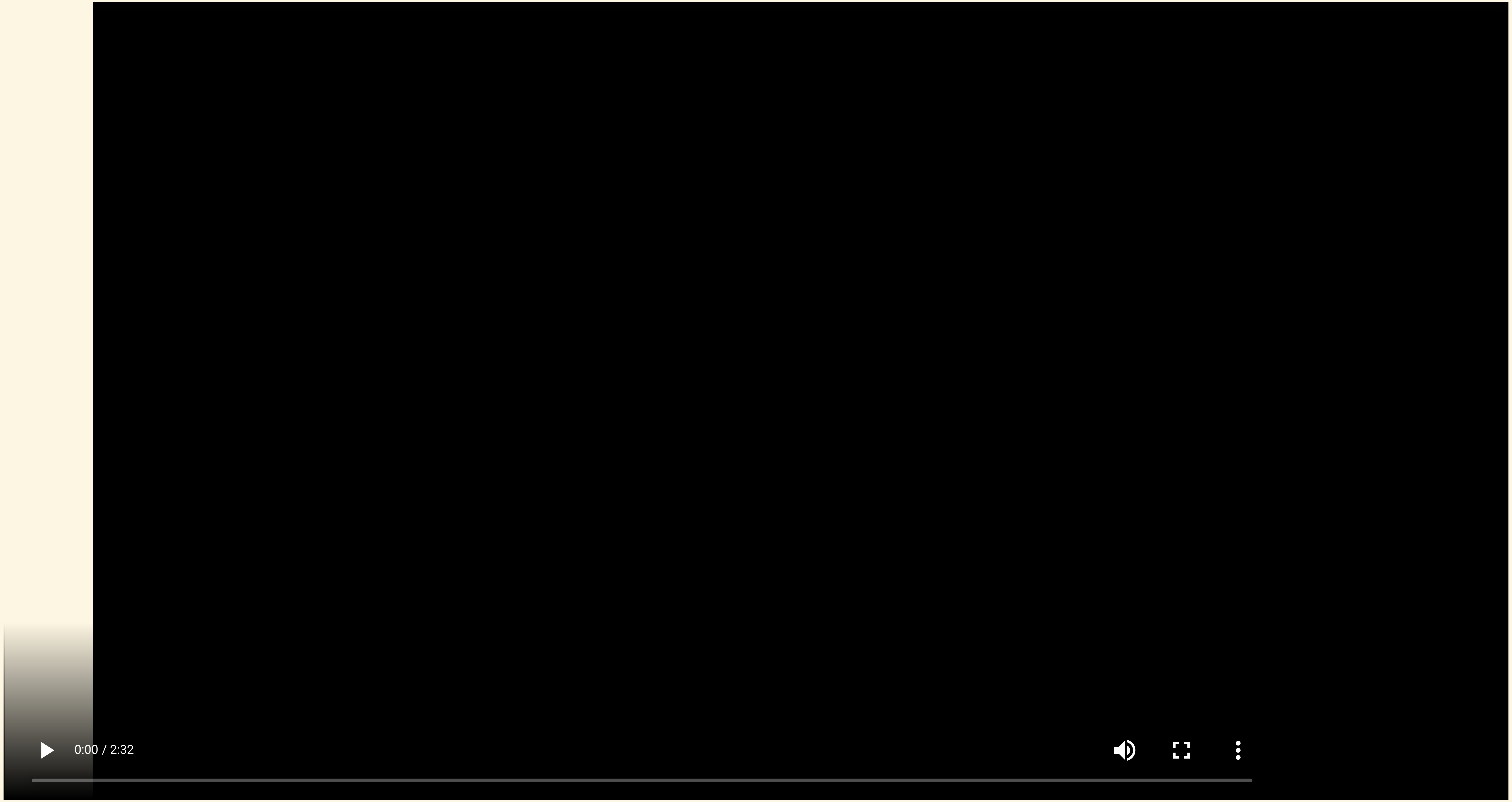
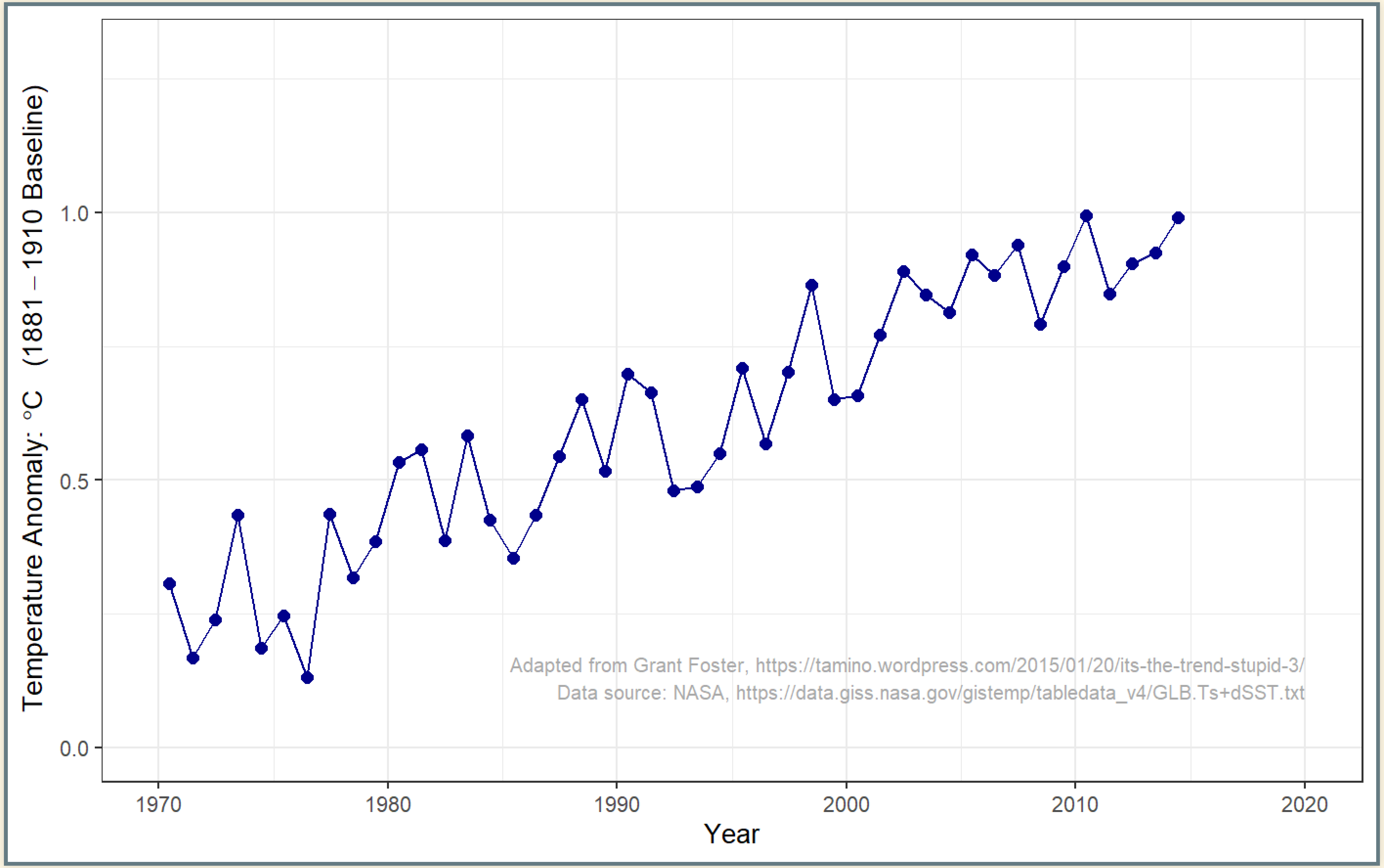
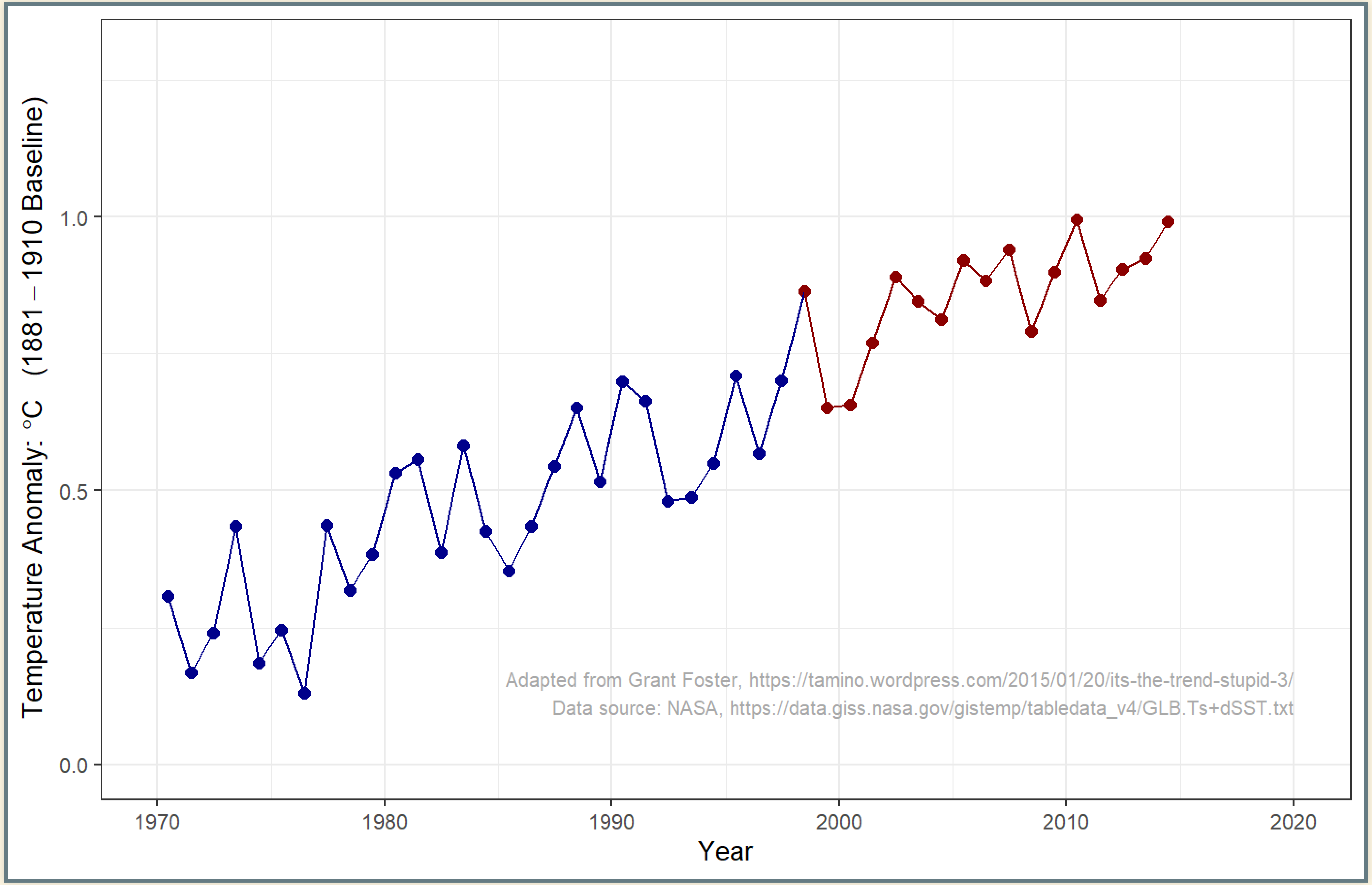


Did temperatures stop rising 18 years ago?

Look at 1970–2014



Did temperatures stop rising?



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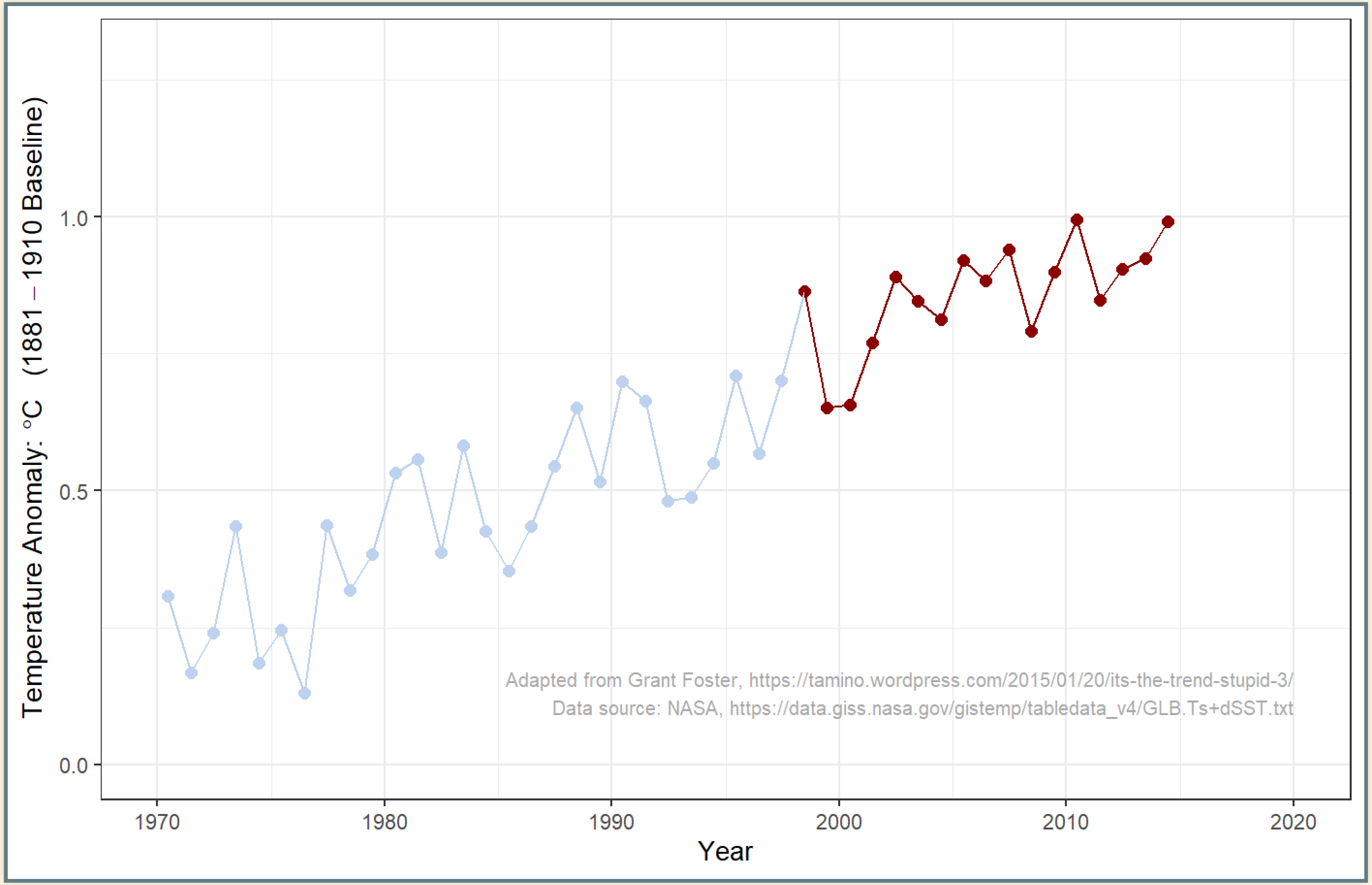
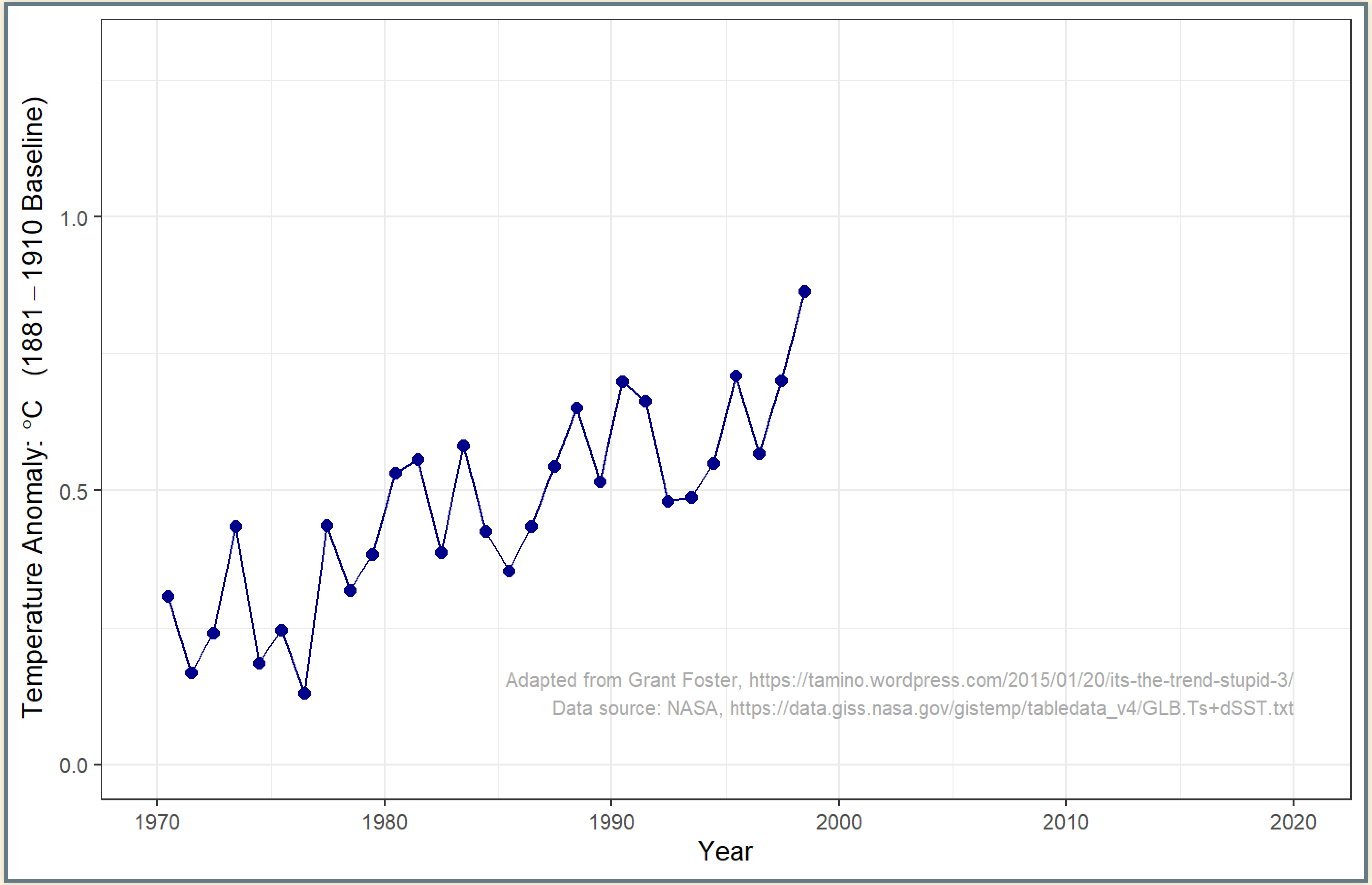
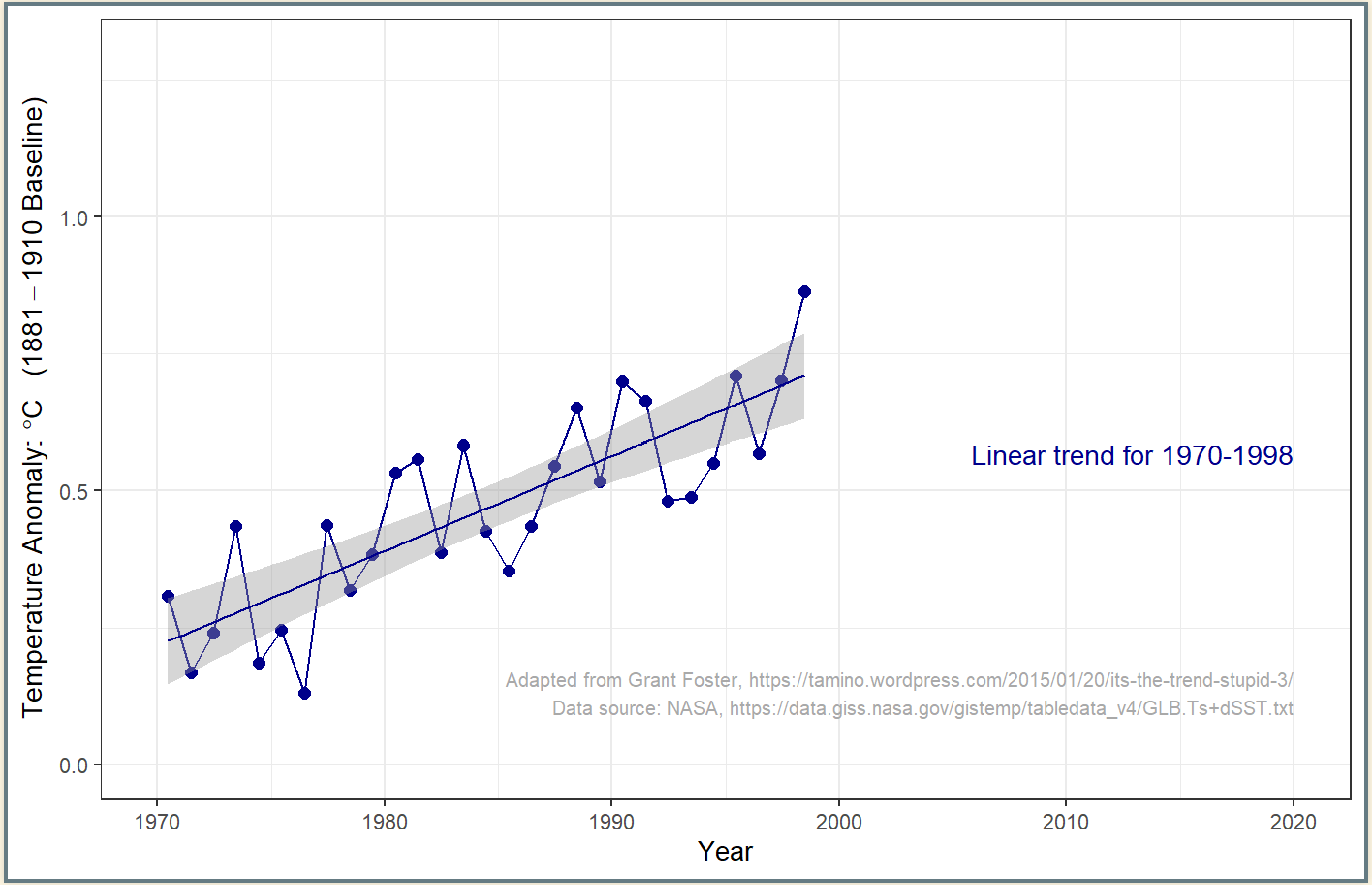


Did temperatures stop rising?



Did temperatures stop rising?



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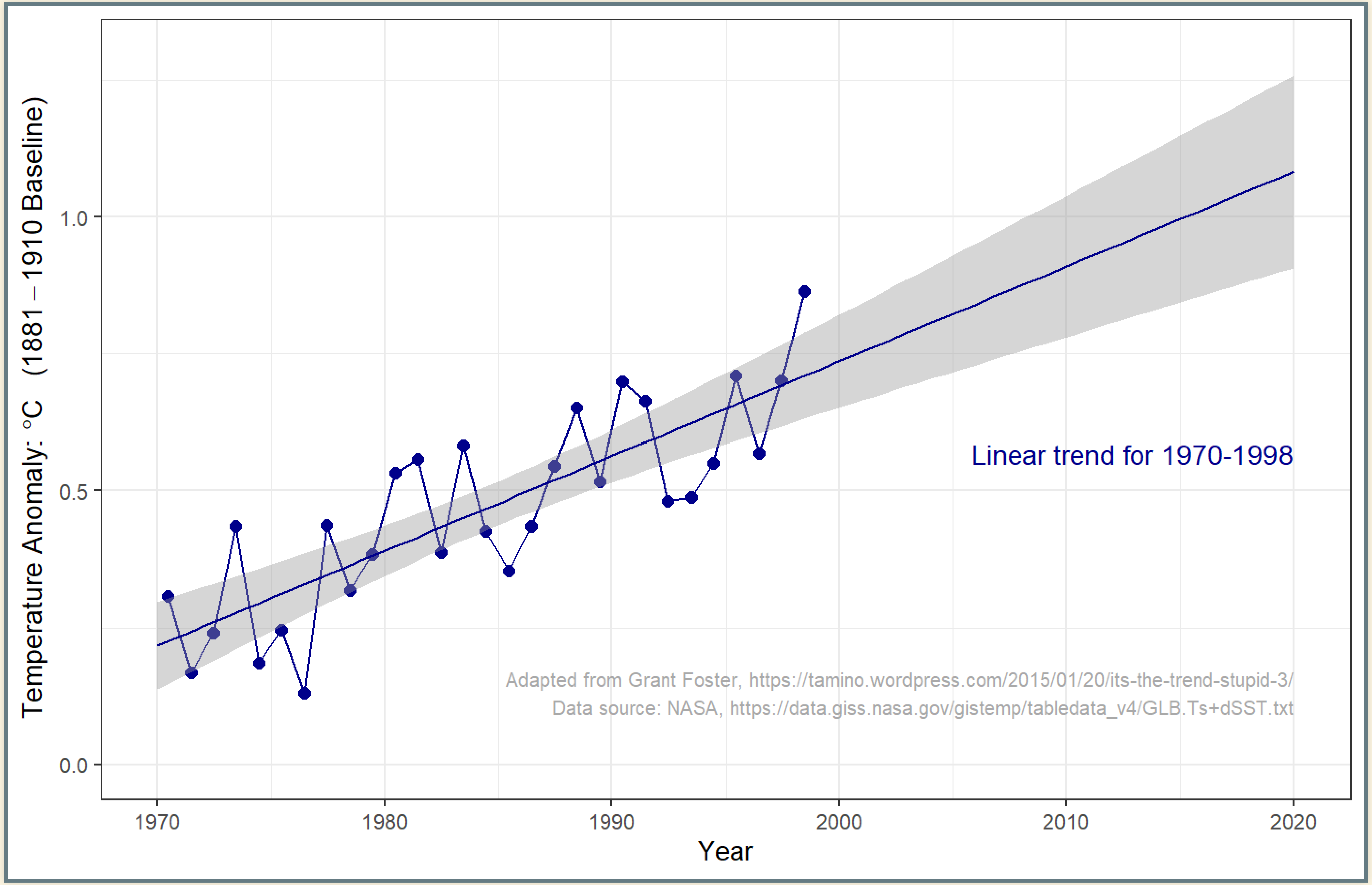

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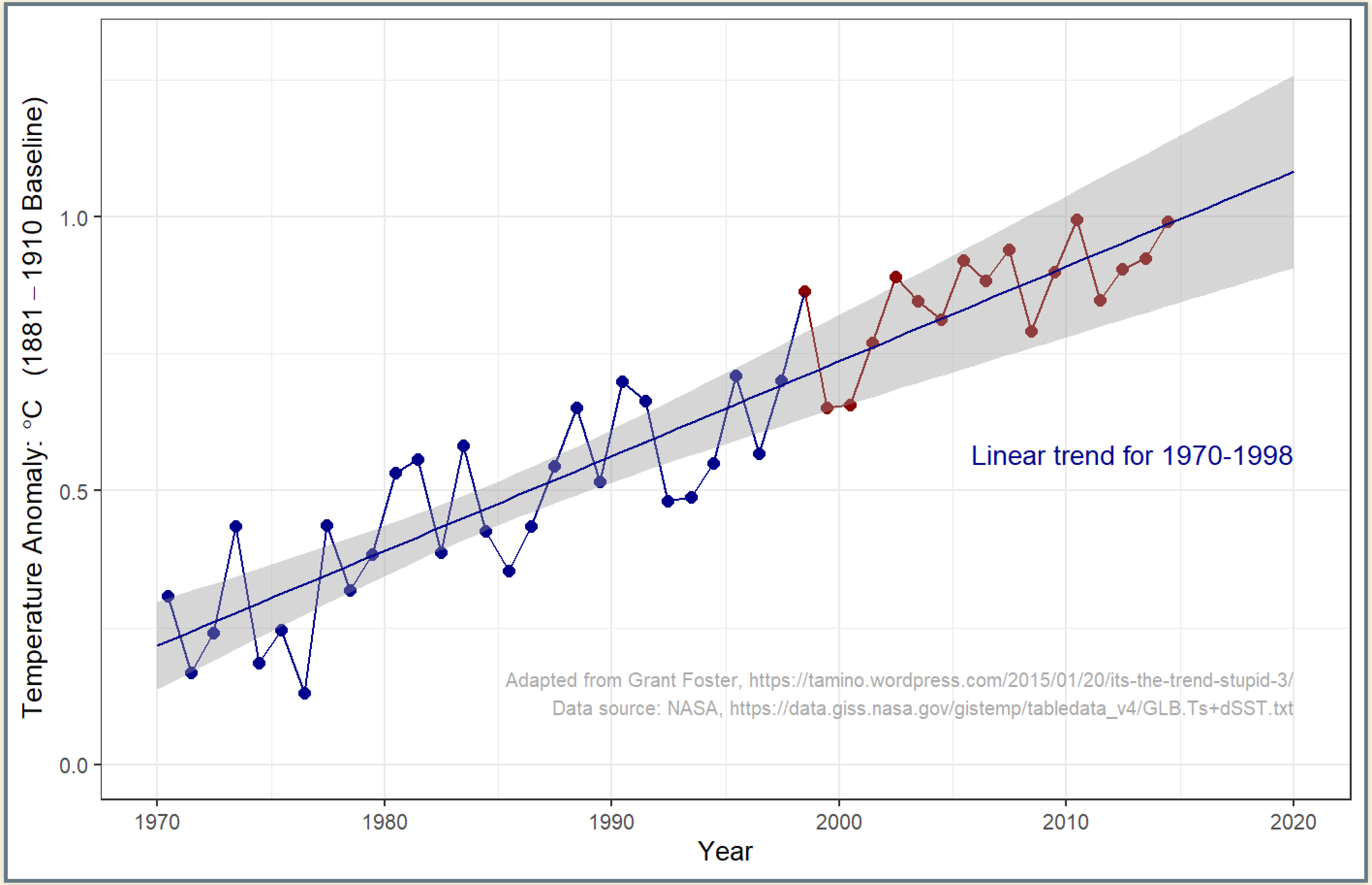

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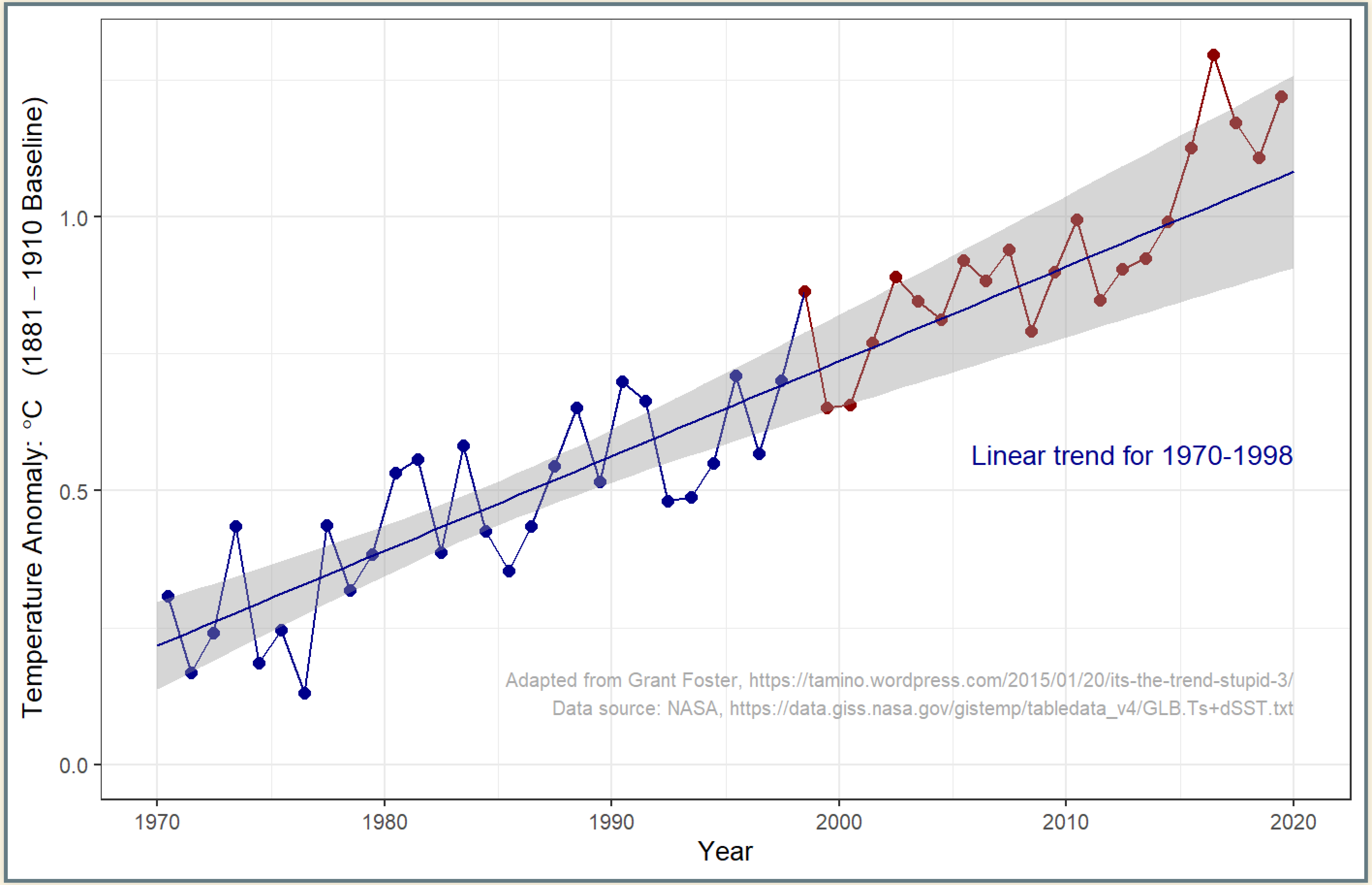


What is the Scientific Consensus?

What is the Scientific Consensus?

- Is there a consensus?
- If there is, should we trust it?

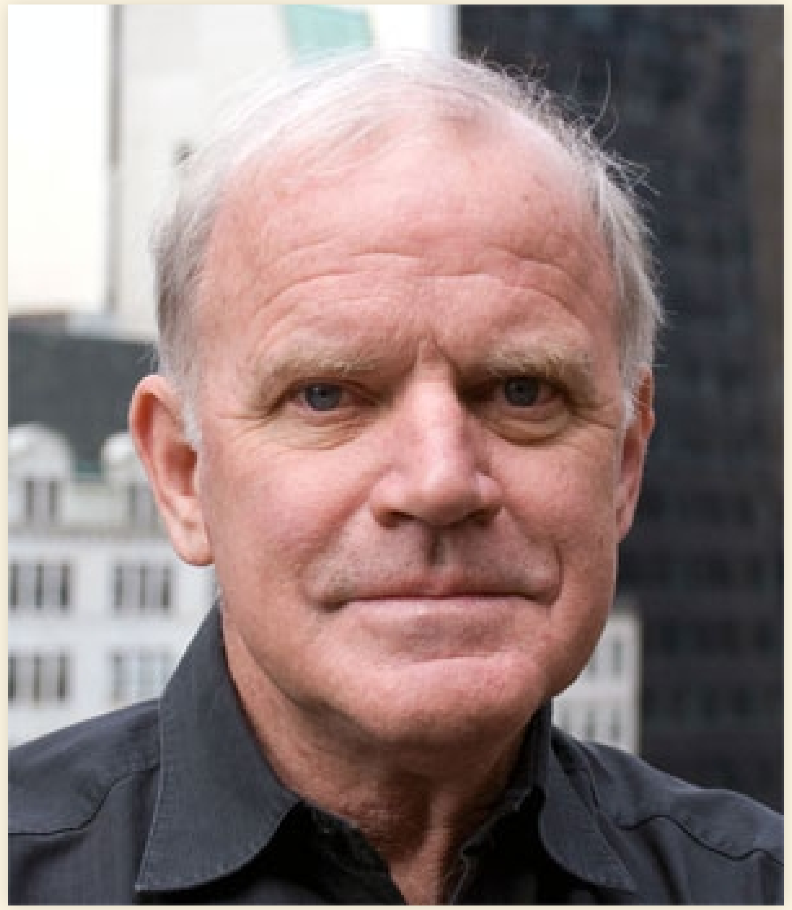
What is the Scientific Consensus?

- Is it important whether most scientists agree or not?
- What if some scientists disagree?
- Do most scientists agree?
  - Careful reviews of scientific literature find 95% of scientists publishing about climate change believe planet is warming because of human activity.

Dissident Scientists

Peter Duesberg

- Famous biology professor
- Member National Academy of Science
- Major discovery of cancer-causing virus
- Claims that HIV virus does not cause AIDS



Kary Mullis

- Nobel Prize in medicine/biology
- Invented PCR for analyzing DNA
- Endorses Duesberg’s theory of AIDS

Meaning of Consensus

- Does scientific consensus mean we can be 100% certain that people are warming the planet?
- What about the future impacts of climate change?

What Gets in the Way of Policy?

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- Politicians don’t understand science?
- Public doesn’t understand science?
- Scientists don’t understand politics?

Issues for Policy

- What do scientists agree on?
- Should policy focus on limits to CO_2 or ΔT?
- Should policy wait for better scientific certainty?
- Uncertainty:
  - How much warming is "dangerous"?
  - How much CO_2 would produce dangerous warming?
  - Are there tipping points?
  - If so, where are they?
- Addressing uncertainty:
  - Precautionary principle
    - *Better safe than sorry*
  - No regrets policy
    - *Worth doing even if global warming turns out to be not so bad.*

1979 Report

Carbon Dioxide and Climate:
A Scientific Assessment

The conclusions of this brief but intense investigation may be comforting to scientists but disturbing to policymakers. If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible. … A wait-and-see policy may mean waiting until it is too late.

National Research Council, *Carbon Dioxide and Climate: A Scientific Assessment* (Nat'l. Academy Press, 1979)

Review of MODTRAN

MODTRAN:

- MODTRAN calculates *emissions* and *absorption* of longwave light in the atmosphere.
- Things that don't change during a run:
  - Heat from the sun
    - Set by "locality" of the atmosphere
  - Temperature of the ground and every layer of the atmosphere.
    - Set by "locality" of the atmosphere and "temperature offset"

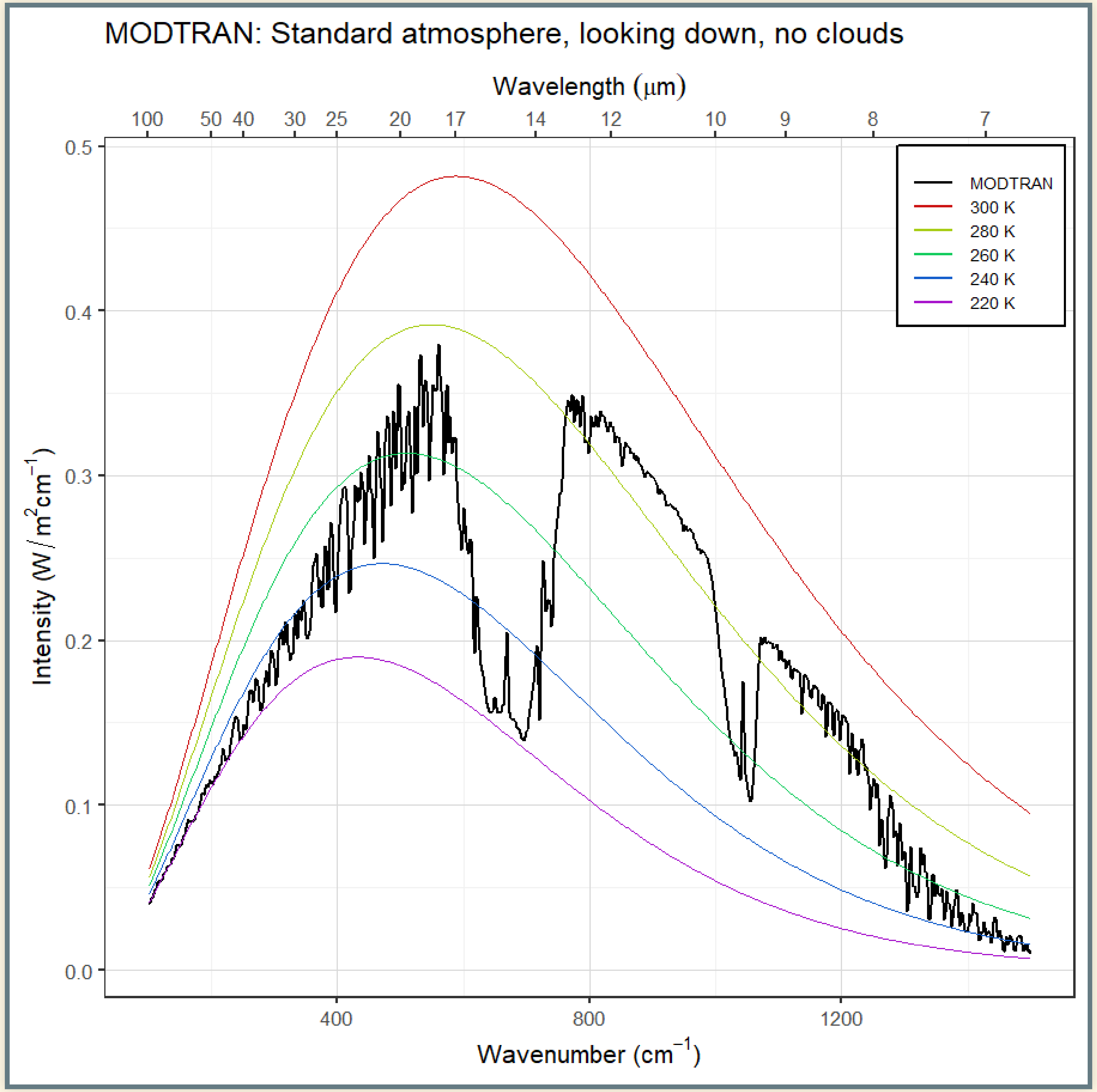
Locale	**I_{out} (W/m^2)**	**T_{ground} (K)**
U.S. Standard Atmosphere	267.98	288.2
Tropical	298.67	299.7
Midlatitude winter	235.34	272.2

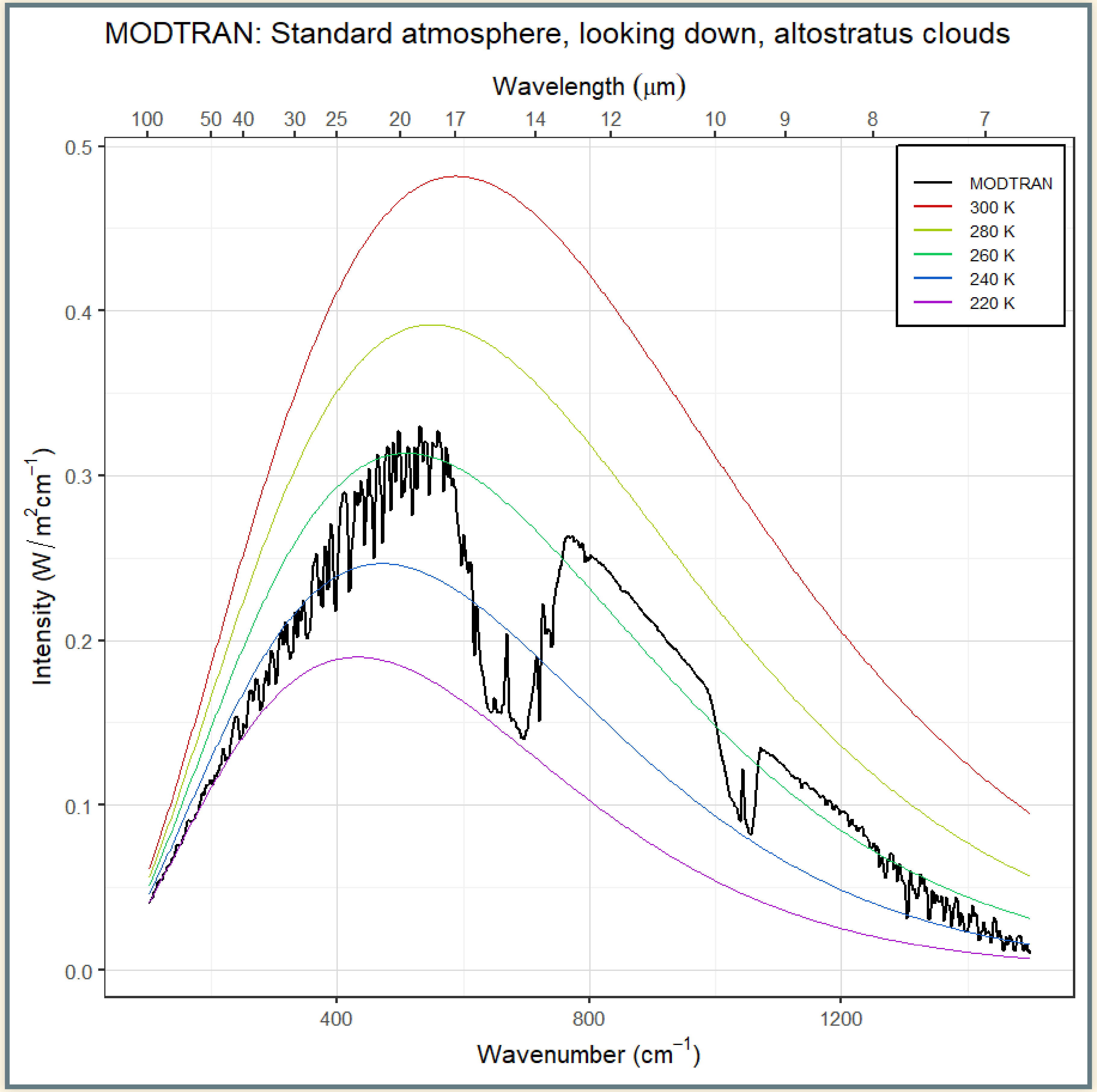
- For every wavenumber, MODTRAN calculates heat emission and absorption up and down at each layer.

MODTRAN:

- Emissivity (ε) = absorption
  - Fraction absorbed by layer $= \varepsilon$
  - Radiation emitted by layer $= \varepsilon\sigma T^4$
- ε small (near zero):
  - Little absorption or emission.
- ε large (near one):
  - Almost all incoming radiation is absorbed
  - Emission close to black body at temperature *T*.
- ε is large for wavenumbers where greenhouse gases absorb strongly.
  - Greater concentration $\rightarrow$ larger ε
- ε is small where there is little absorption
  - Atmospheric window
- Sensor sees emission at the temperature of the ***nearest layer*** with large ε:
- **Looking down from space:**
  - ***highest layer* with large ε.**
  - In atmospheric window, that layer is near the ground
  - With clouds, it's often the top of the highest cloud
- **Looking up from ground:**
  - ***lowest layer* with large ε.**
  - In atmospheric window, there's no such layer, so you see very little emission
  - With clouds, it's often the bottom of the lowest cloud

Example: Looking Down





Example: Looking Up