

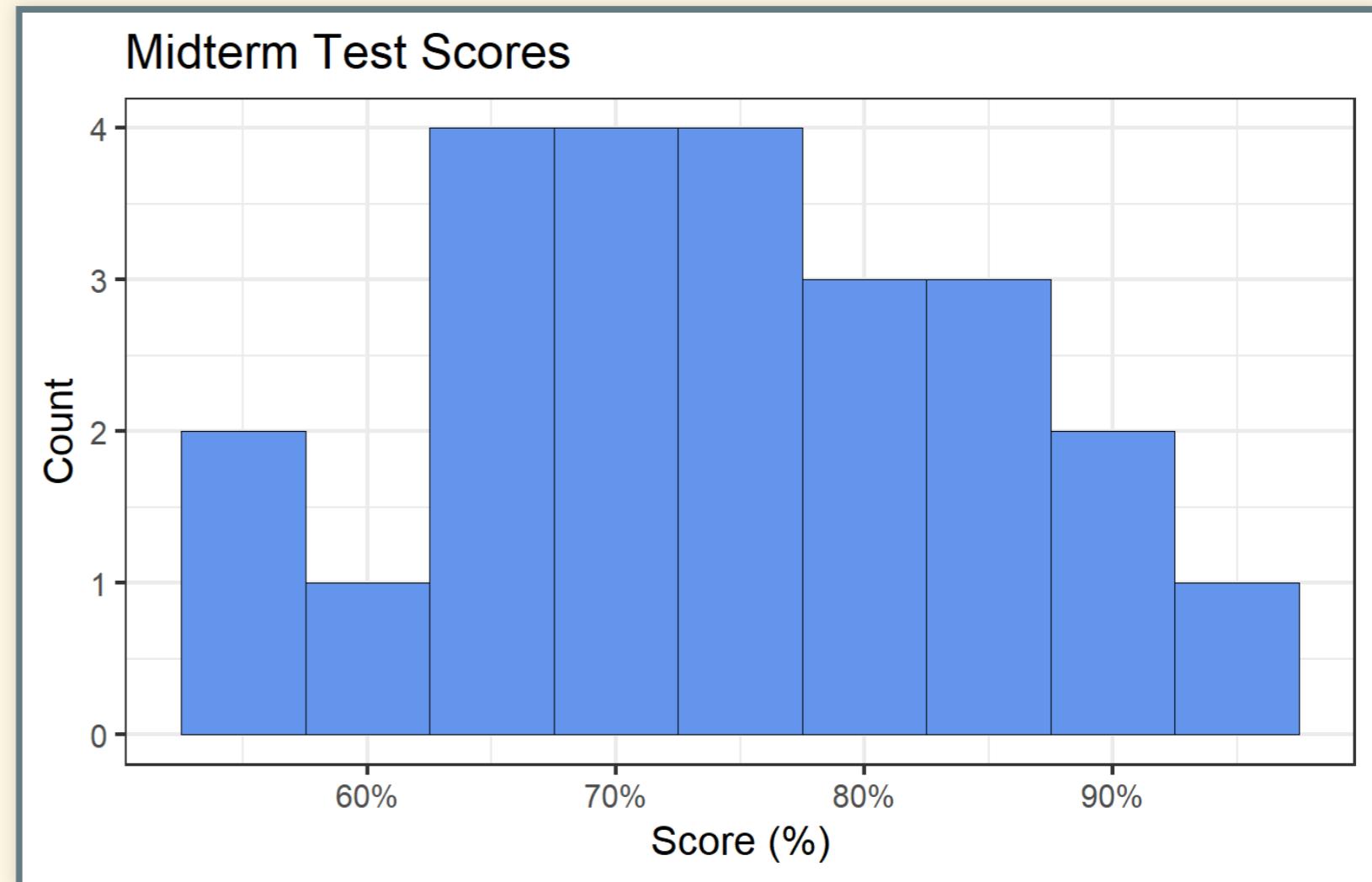
Impacts of Climate Change, Pt. 1

EES 3310/5310
Global Climate Change
Jonathan Gilligan
Class #21: Monday, March 14 2022

Midterm Test

Midterm Test

- I have graded the exam and will upload scores to Brightspace later today.
- You will be able to correct wrong answers, explain why you got them wrong, and what you learned.
 - This will earn 60% of missed points
 - This would bring a score of 75% up to 90%
 - Due Friday, March 25
 - Full instructions will be posted to Brightspace
- **Big picture:**
 - The midterm is 10% of the final grade.
 - Most of the grade is the lab work.
 - The final exam will be an open-book essay-format examining the big ideas from the semester.



- Average score: 74.2%
- Highest: 92.6%
- Lowest: 54.3%

Framework for Thinking about Climate Change

Sources of Vulnerability

Types of systems:

- Managed Systems
- Unmanaged Systems
- Unmanageable
- Examples?

Systems

Extensively Managed	Partially Managed	Unmanageable
<ul style="list-style-type: none">• Most economic sectors:<ul style="list-style-type: none">■ <i>Manufacturing</i>■ <i>Health care</i>• Most human activities:<ul style="list-style-type: none">■ <i>Sleeping</i>■ <i>Surfing the Internet</i>	<ul style="list-style-type: none">• Vulnerable economic sectors:<ul style="list-style-type: none">■ <i>Agriculture</i>■ <i>Forestry</i>• Nonmarket systems:<ul style="list-style-type: none">■ <i>Beaches and coastal ecosystems</i>■ <i>Wildfires</i>	<ul style="list-style-type: none">• <i>Hurricanes</i>• <i>Sea-level rise</i>• <i>Ocean acidification</i>

Managed, Unmanaged, & Unmanageable Systems

- Relevance?
 - Climate impacts?
- Transformations:
 - Unmanaged → managed
 - Unmanageable → manageable
- “Focal Policy”
 - What is it?
 - Examples?
 - Advantages and disadvantages?

Scientific Uncertainty

- Nordhaus:

"A sensible policy would pay an insurance premium to avoid playing the roulette wheel."

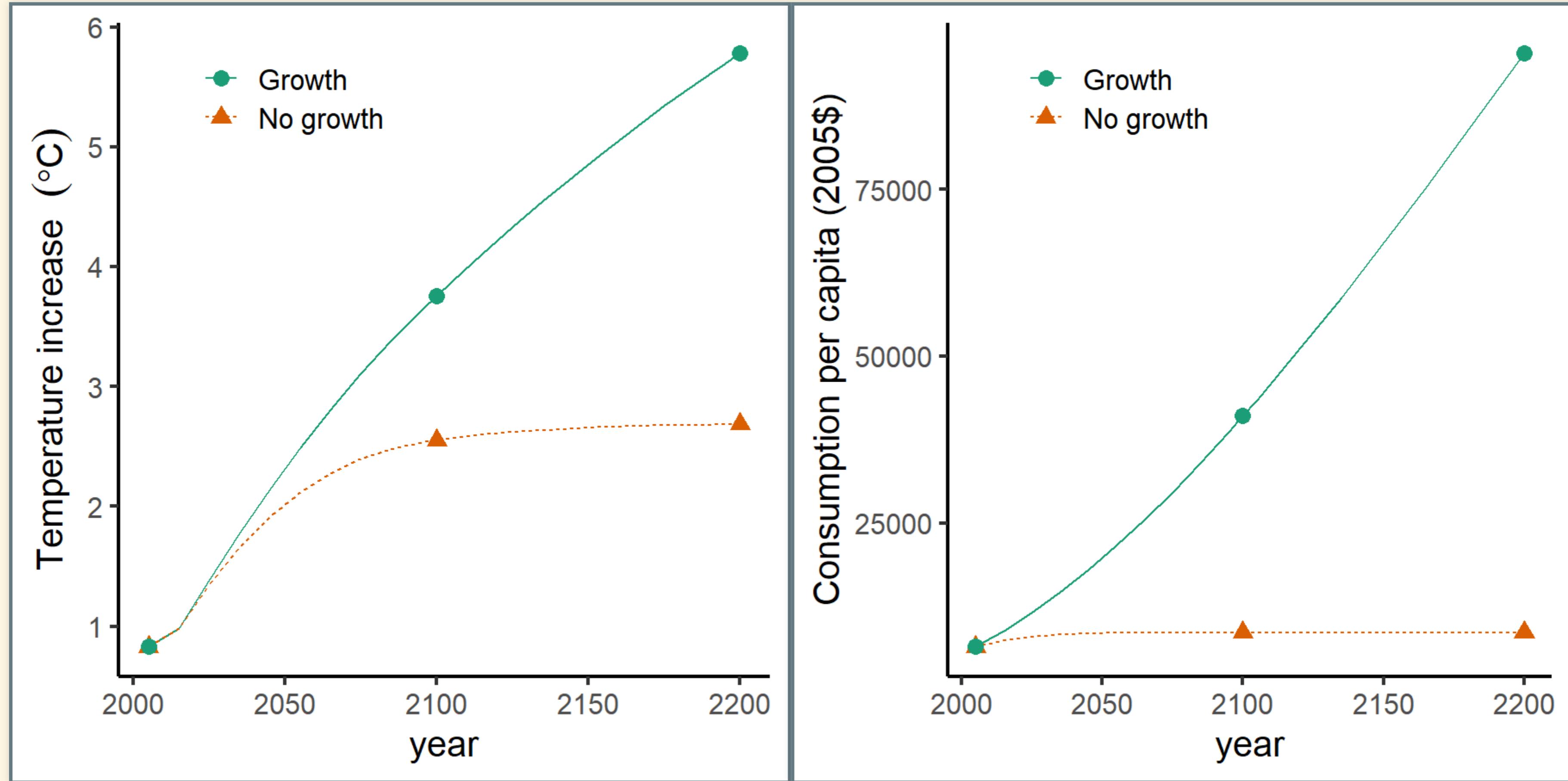
"The cost of delaying action for 50 years ... is [estimated] as \$6.5 trillion."

- Pielke:

"Policy makers routinely make decisions ... with a similar (or even less well-developed) state of understanding."

Economic Growth

Economic Growth



Mitigating Factors

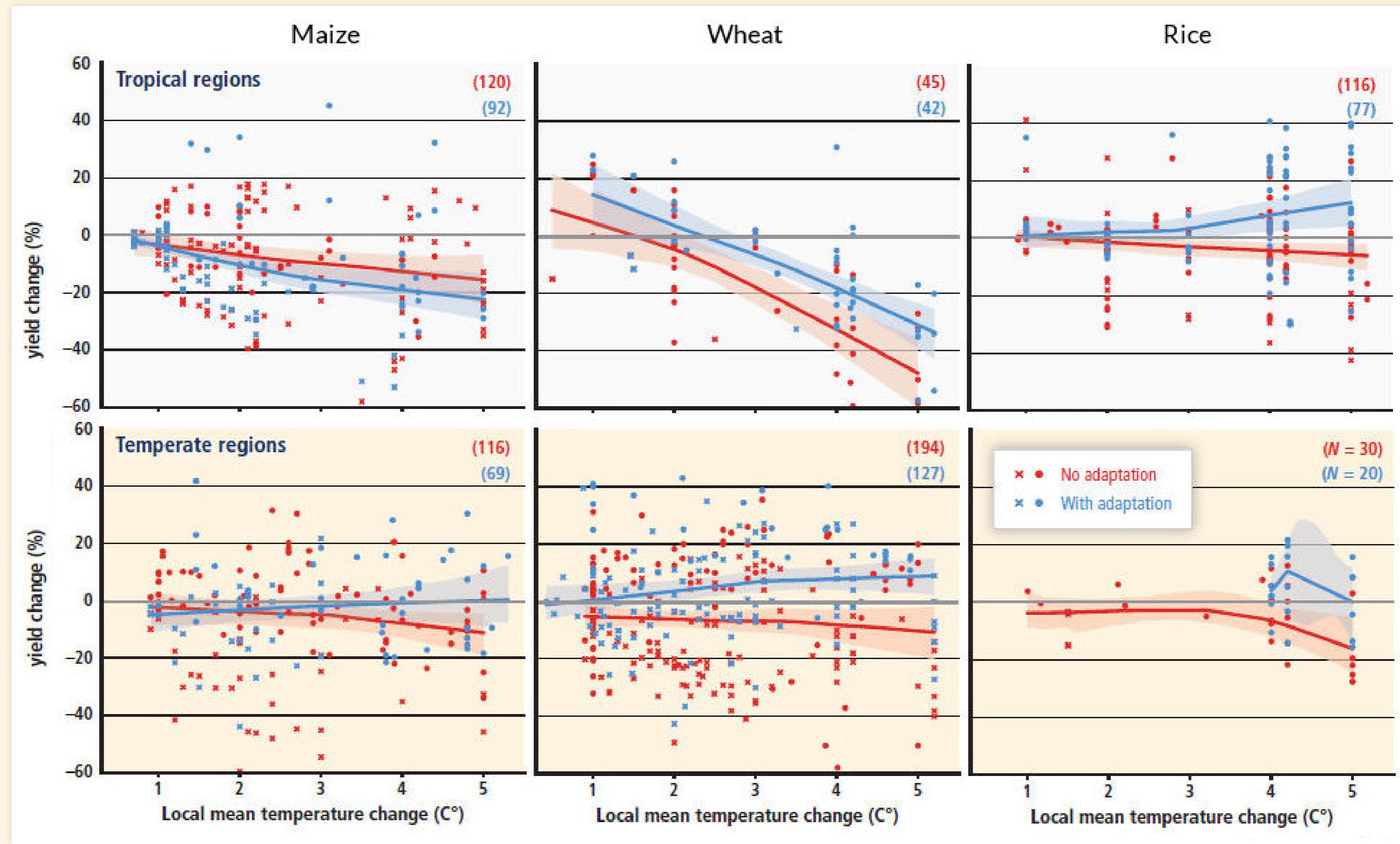
Mitigating Factors

- What are mitigating factors?
- Note:
 - Most policy analysis defines mitigation = reducing the **amount** of climate change (e.g. by cutting GHG emissions).
 - Nordhaus also uses the term to mean reducing the **impacts** of climate change
- Examples?
 - Carbon fertilization
 - Longer growing seasons at high latitudes
 - Higher temperature \(\downarrow\) more snow falling on Antarctica
- Artificial Mitigation
 - Geoengineering

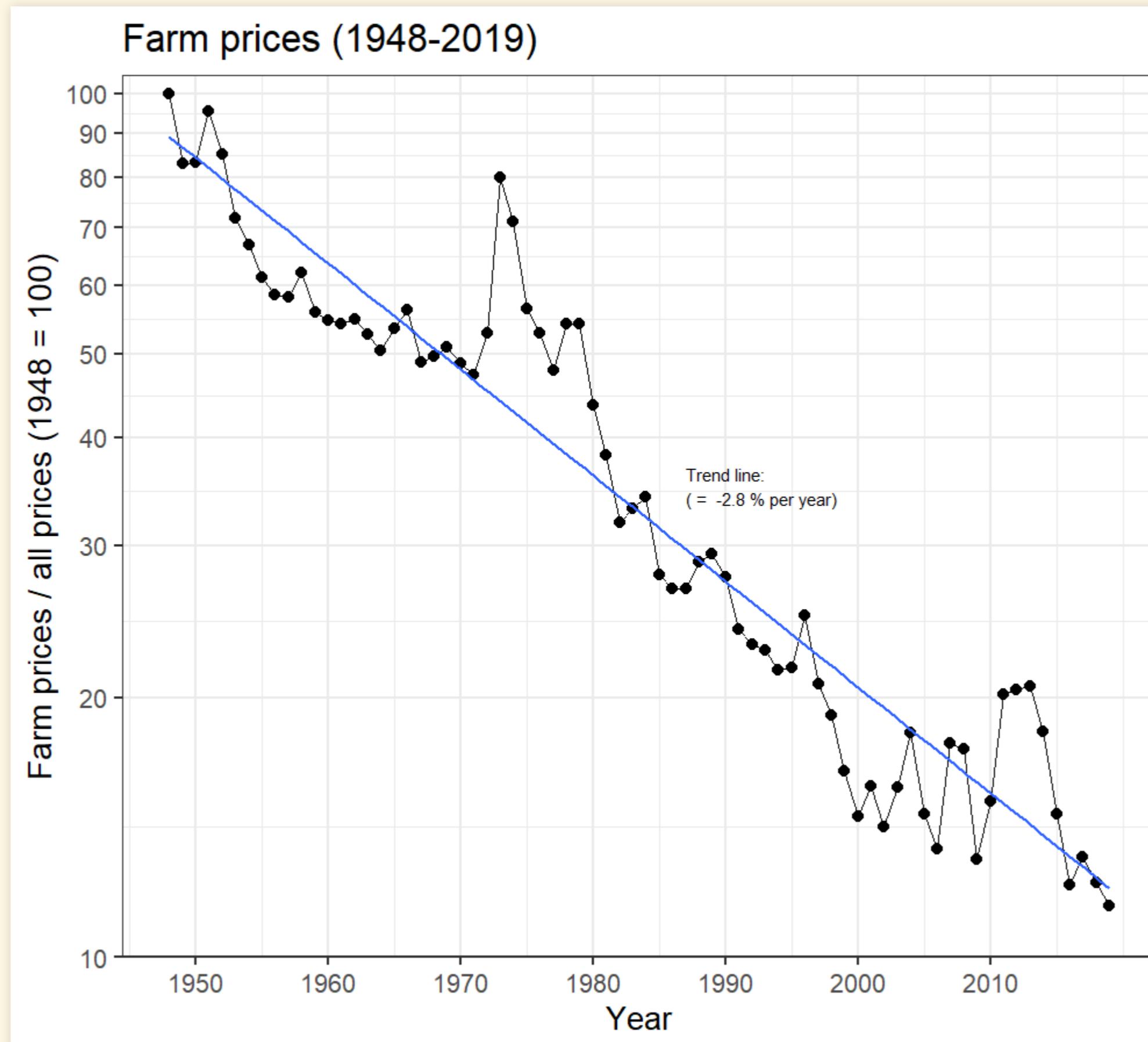
Adaptation

What kinds of things can people do
to adapt to climate change?

Crop Yields



Prices of Farm Products



Impact of Declining Food Prices

Category	% of income	Expense	25% price rise	as % of income
Income	100%	\$60,000		
Housing	20%	\$12,000	\$3,000	5%
Food	5%	\$3,000	\$750	1%

Agricultural Price Shocks



Winter Temperatures

- Cold winters are important
 - Freezing temperatures kill pests
 - Many trees need cold winters to tell them to reset for growing in the spring
 - Peach trees need more than 800 hours below 40°F to make good fruit
 - The winter of 2016–2017 had less than 500 “cold-soaking” hours in Georgia
 - 85% of the Georgia peach crop was lost.



Health Impacts

Deaths due to Climate Change

Years of life lost per 1,000 persons

Region	Total	Diarrheal disease	Malaria	Malnutrition
Africa	14.91	6.99	7.13	0.80
Wealthy countries	0.02	0.02	0.00	0.00

As % of all deaths

Region	Total	Diarrheal disease	Malaria	Malnutrition
Africa	2.92	1.37	1.40	0.16
Wealthy countries	0.01	0.01	0.00	0.00

Heat Waves

- Extreme summer heat that was **practically non-existent** before 1989 now affects about **10% of the earth's land surface** in a typical summer.
 - Six of the ten deadliest heat waves in history happened since 2000.
 - 2003 European heat wave:
 - 70,000 deaths
 - 2010 Russian heat wave:
 - 50,000 deaths
 - 2021 Pacific Northwest heat wave killed around 1,200 people.

Pacific Northwest, June 27–29 2021

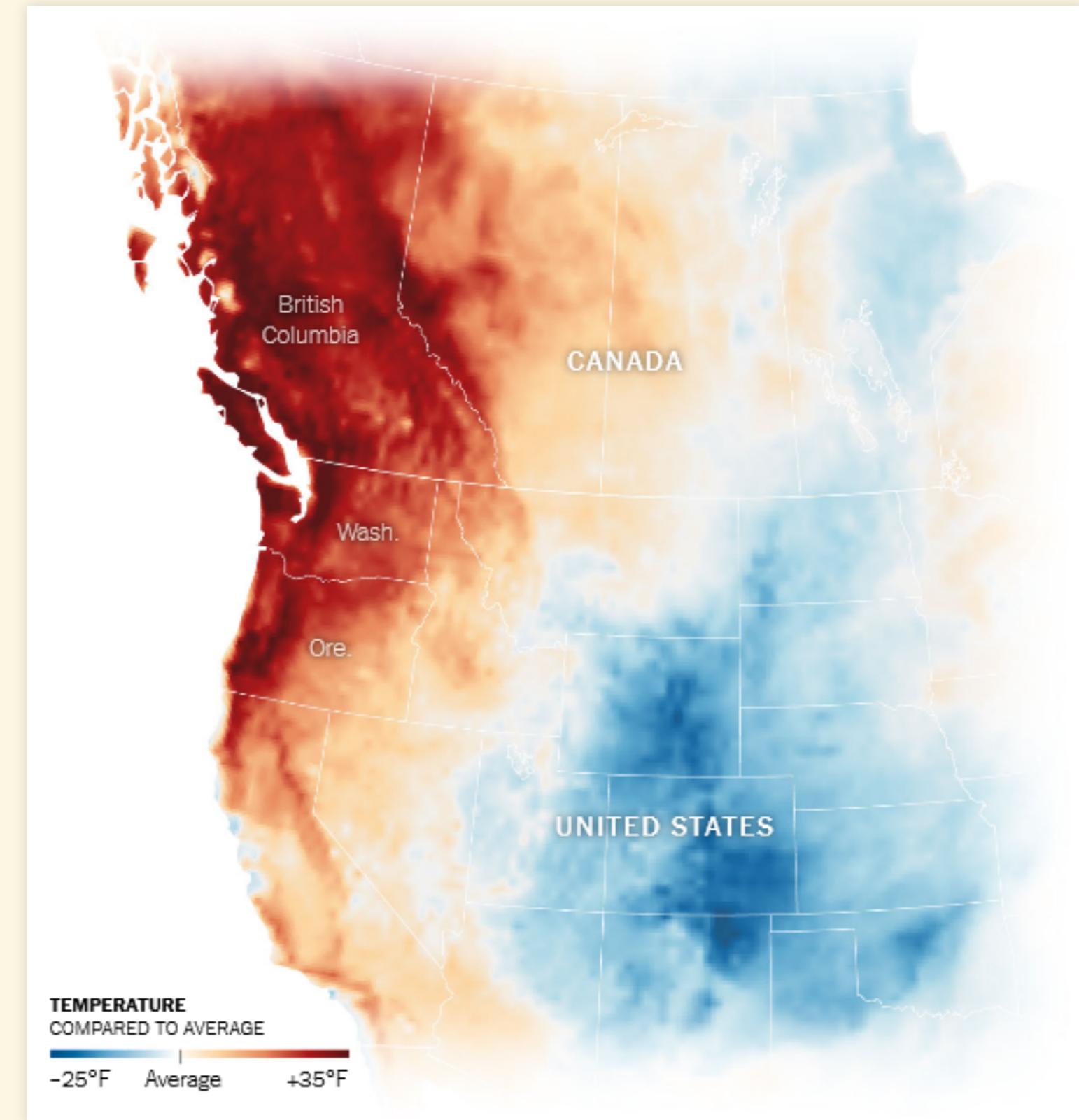


Image credit: N. Popovich & W. Choi-Schagrin, New York Times, Aug. 11, 2021

2021 Extreme Heat: Pacific Northwest

- June 27-29 the Pacific Northwest (US and Canada) experienced record-breaking heat
- Temperatures reached 16–20°C (29–36°F) higher than maximum temperatures in a normal year
- Temperatures broke all-time records by about 5°C (9°F).
- Death toll:
 - 450 in Washington
 - 160 in Oregon
 - 600 in Canada

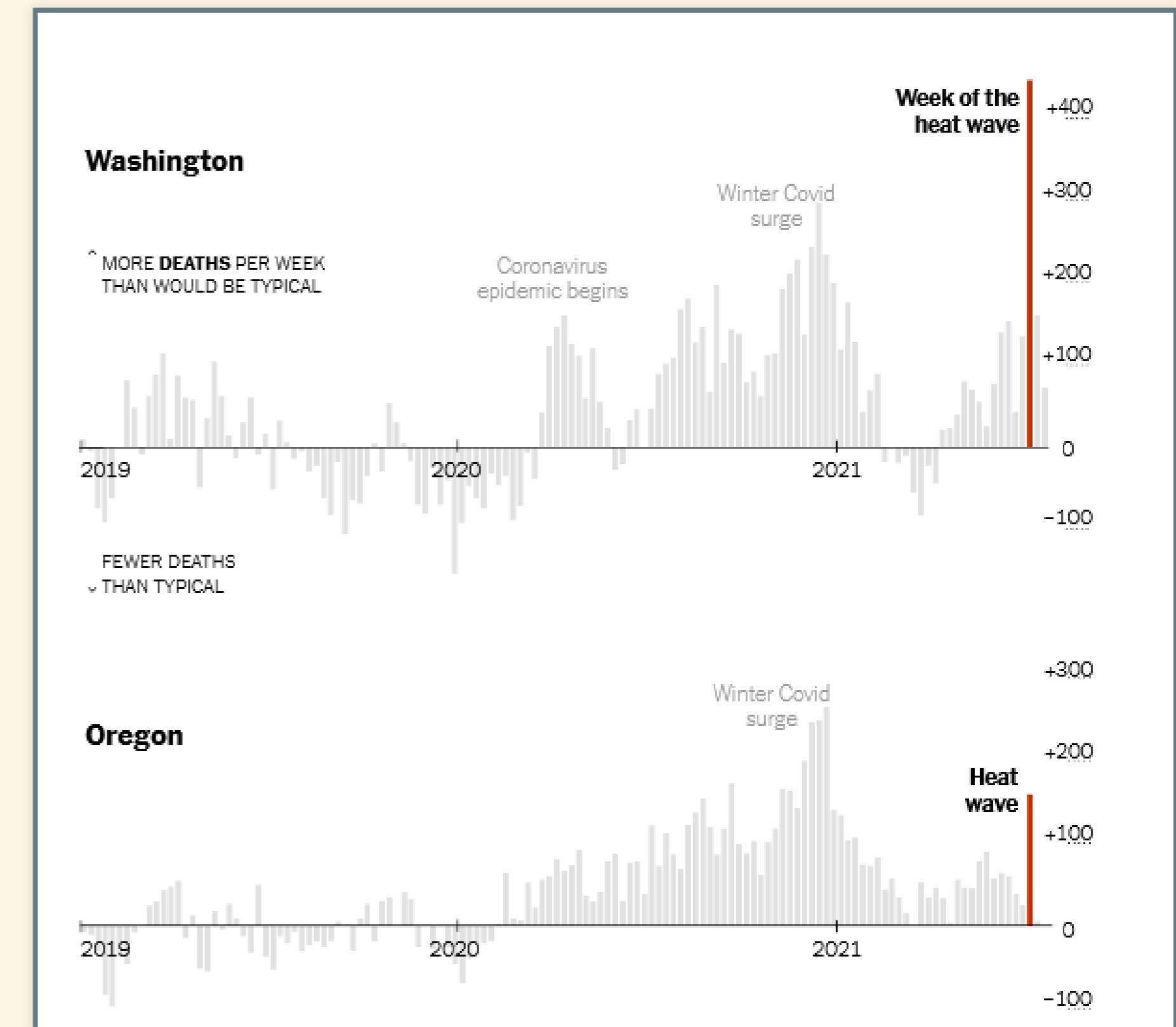
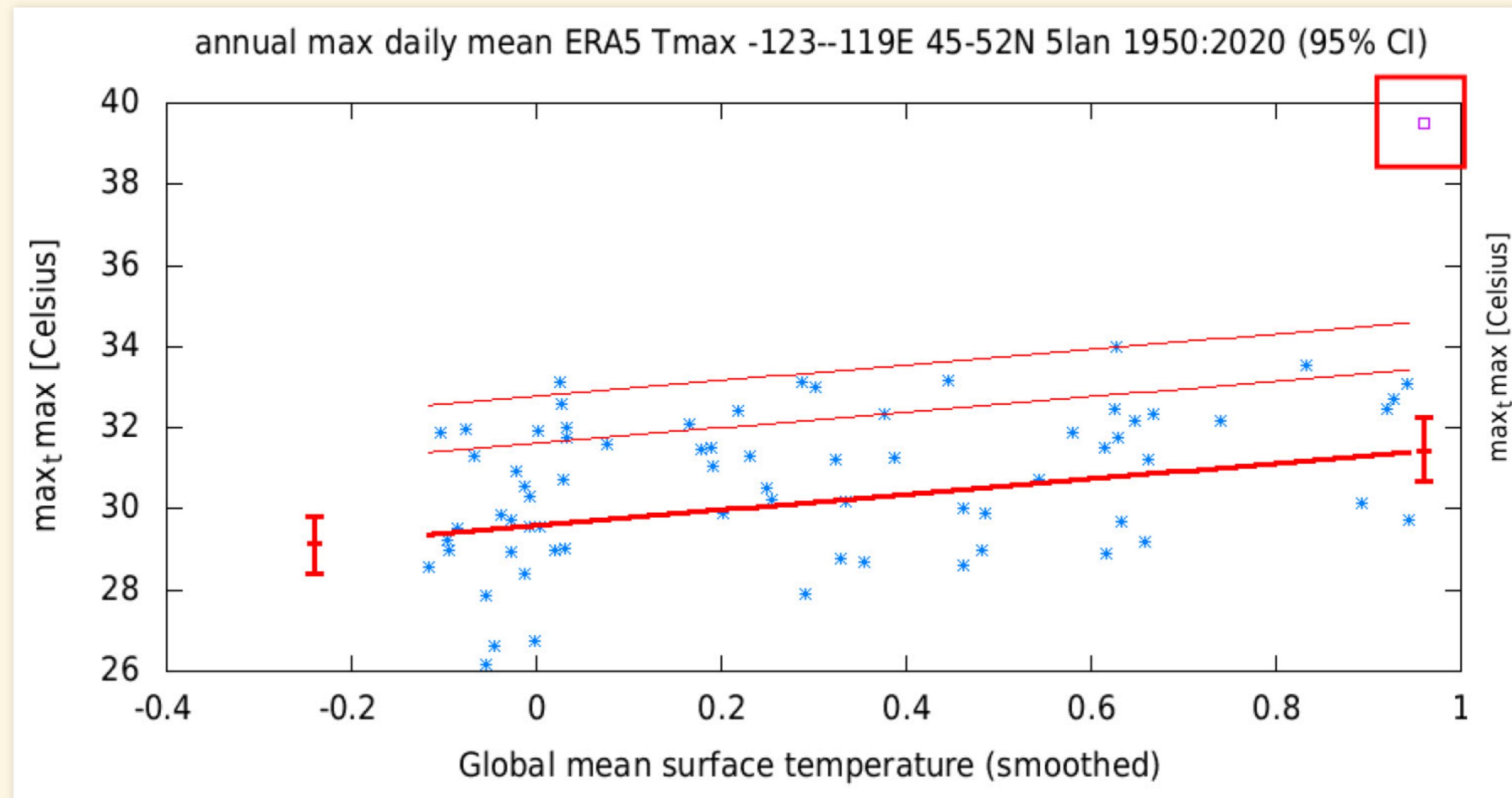


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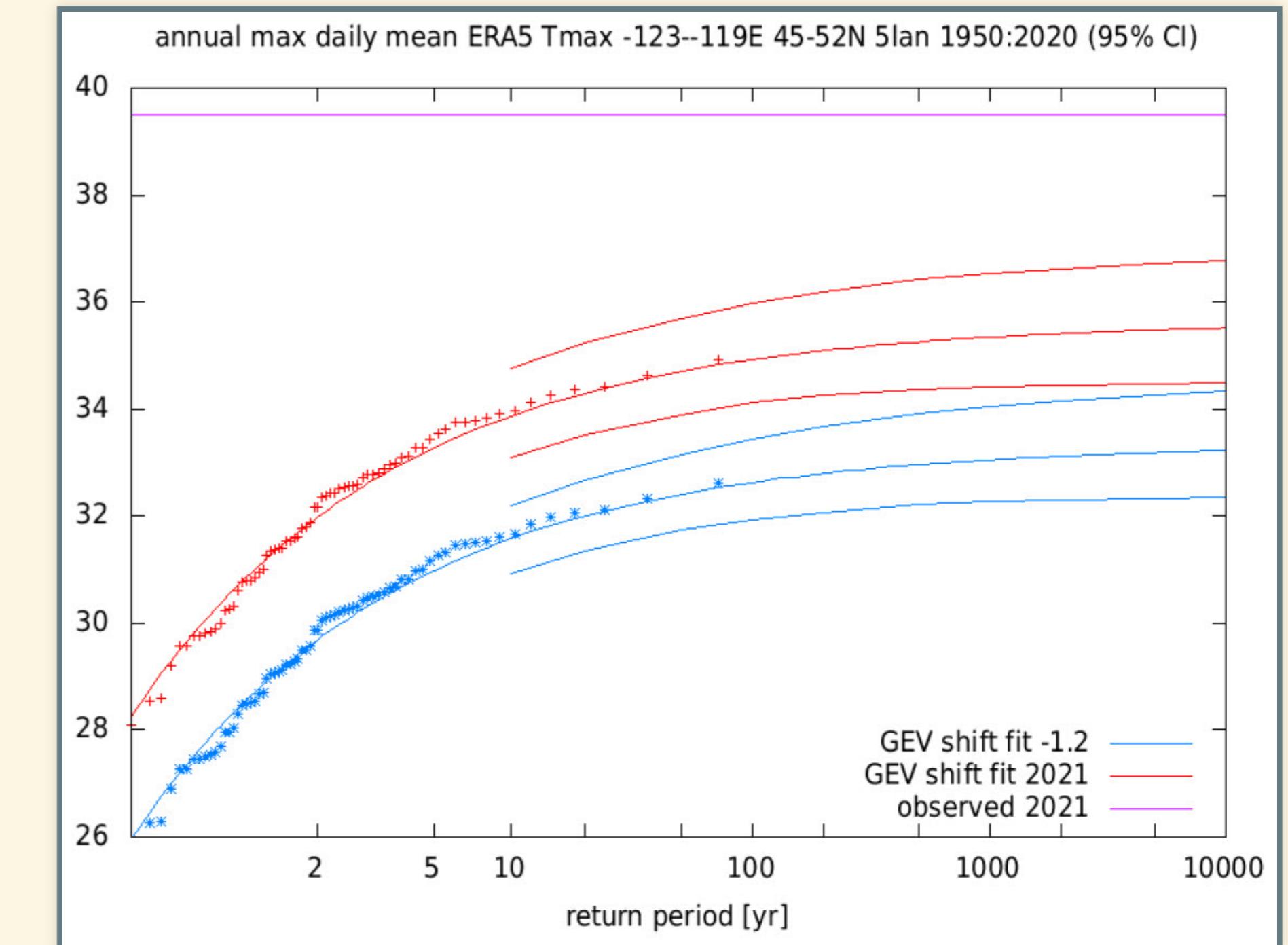
Unprecedented Heat



- S.Y. Philip *et al.*, "Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021," World Weather Attribution, July 2021.
- World Weather Attribution, "Western North American extreme heat virtually impossible without human-caused climate change," July 7, 2021.

2021 PNW Heat Wave In Perspective

- Red = return periods for extreme heat with 2021 climate
- Blue = return periods for extreme heat without global warming
- Even with recent trends of global warming, this summer's heat wave was a far more extreme than a one-in-10,000 year event.

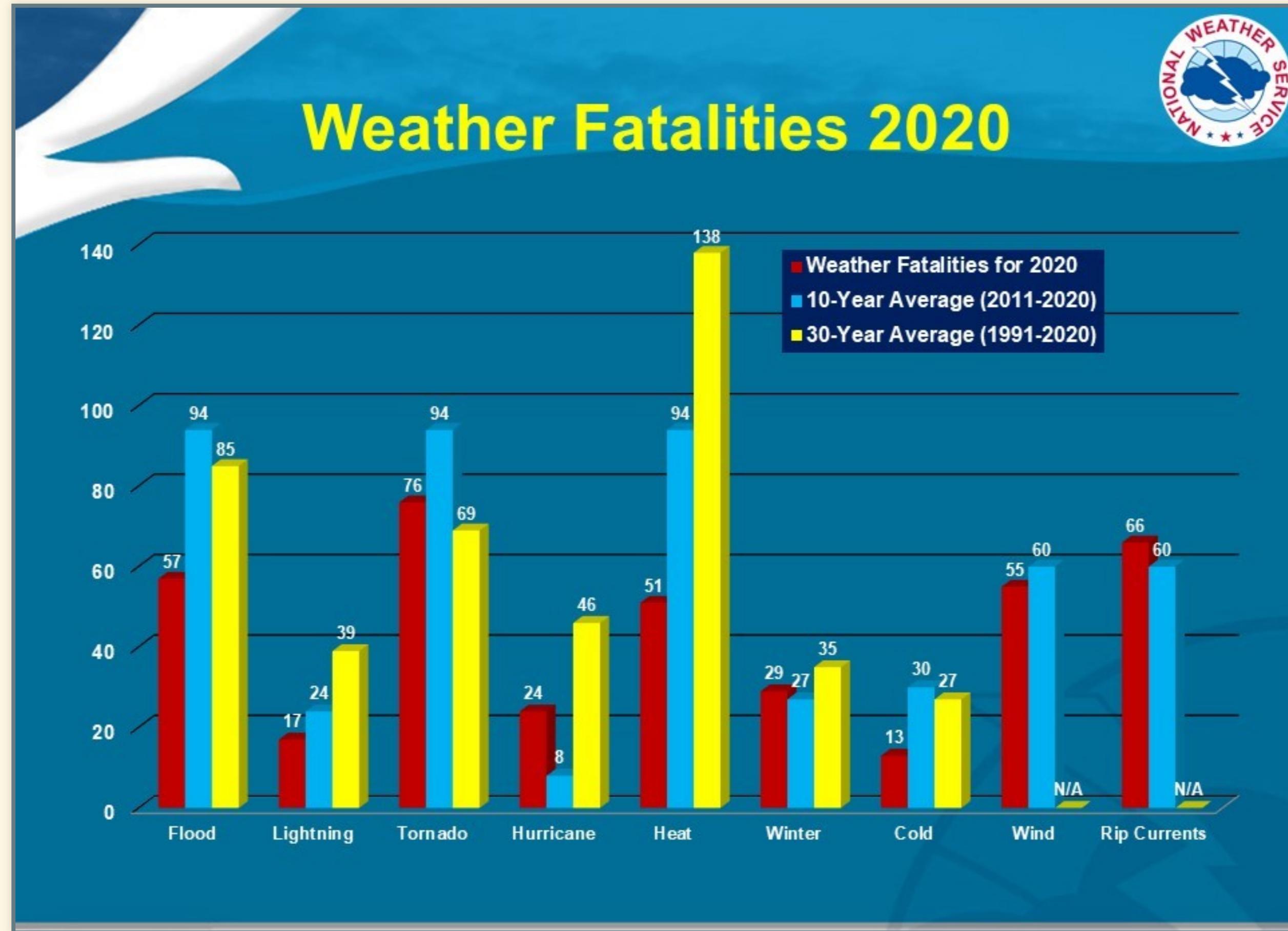


- S.Y. Philip *et al.*, "Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021," World Weather Attribution, July 2021.
- World Weather Attribution, "Western North American extreme heat virtually impossible without human-caused climate change," July 7, 2021.

Temperature, Humidity, and Health

- How does your body regulate temperature?
- What limits how well you can thermo-regulate when ambient temperatures are hot?
- **Wet-Bulb Temperature:**
 - Limit of evaporative cooling
 - Depends on both temperature and humidity
 - For a given T , higher humidity \rightarrow higher T_w
- $T_w > 35^\circ\text{C} \rightarrow$ death within hours

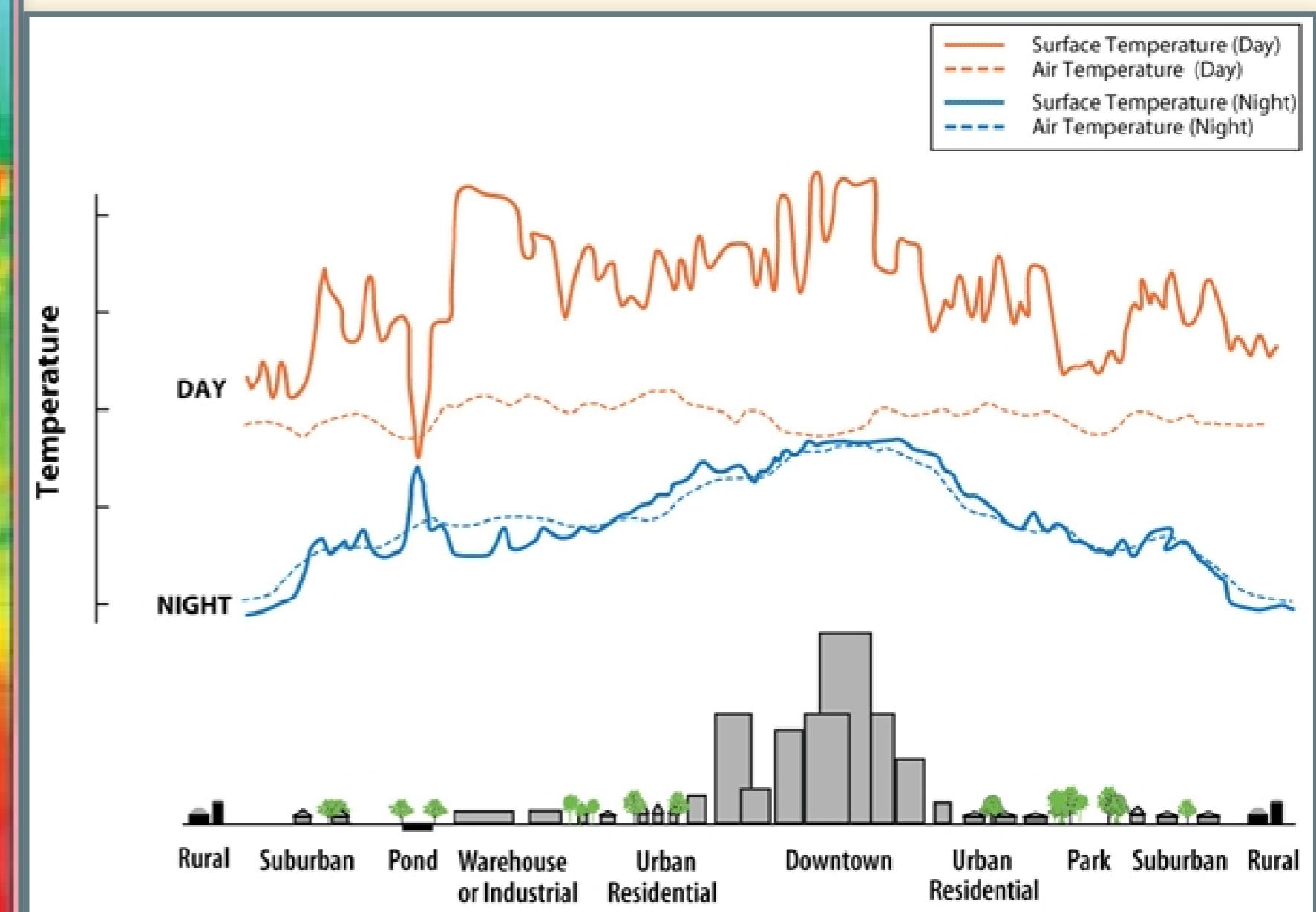
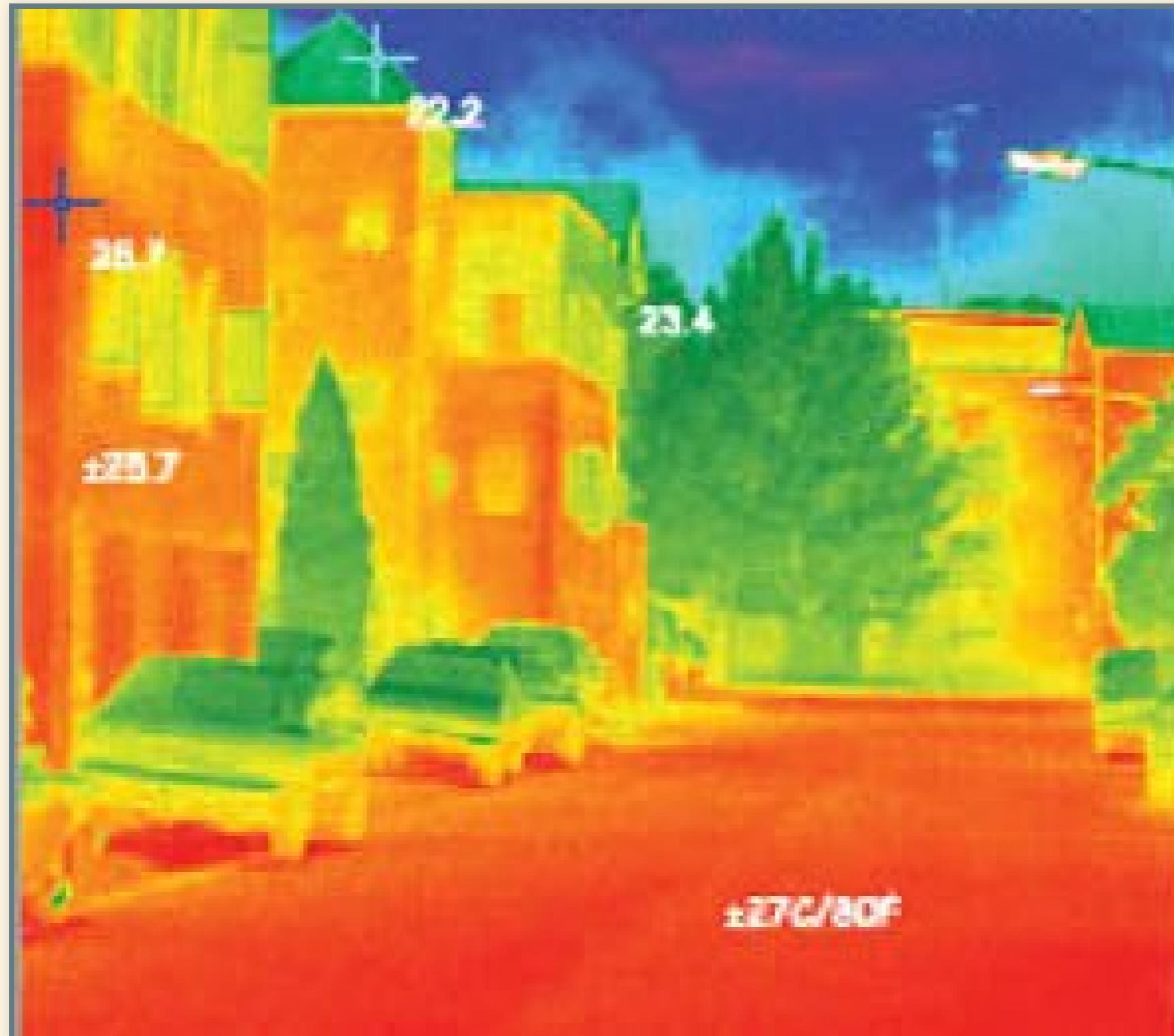
Heat versus Cold



Heat versus Cold

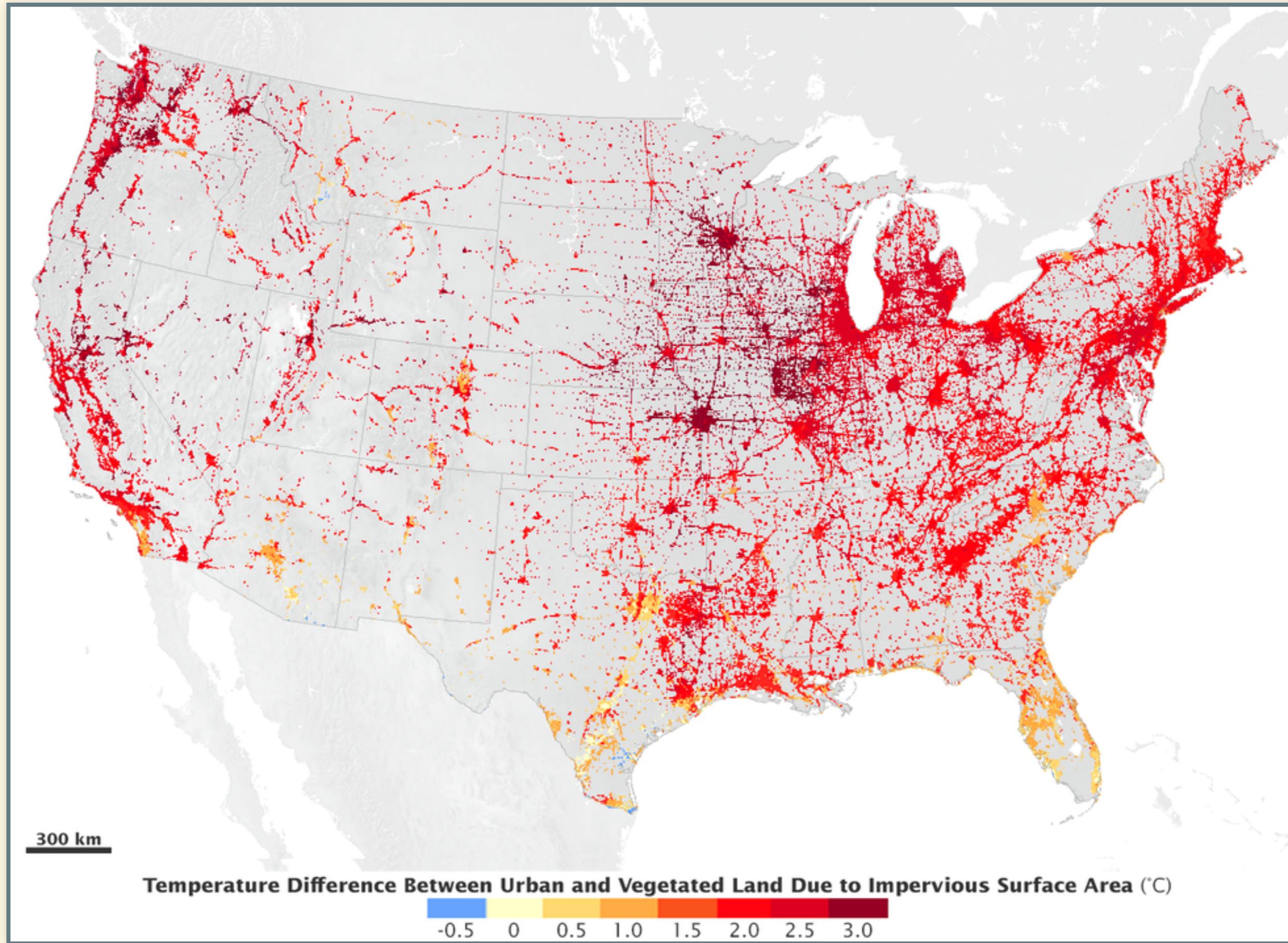
- More people die during cold months than hot months each year
 - Confounding factor: Seasonality of diseases (flu, etc.)
 - Deaths from cold are relative: it's about acclimation
 - Deaths from heat are absolute: threshold temperatures
- Adding extremely hot days raises mortality much more than adding extremely cold days

Urban Heat Islands



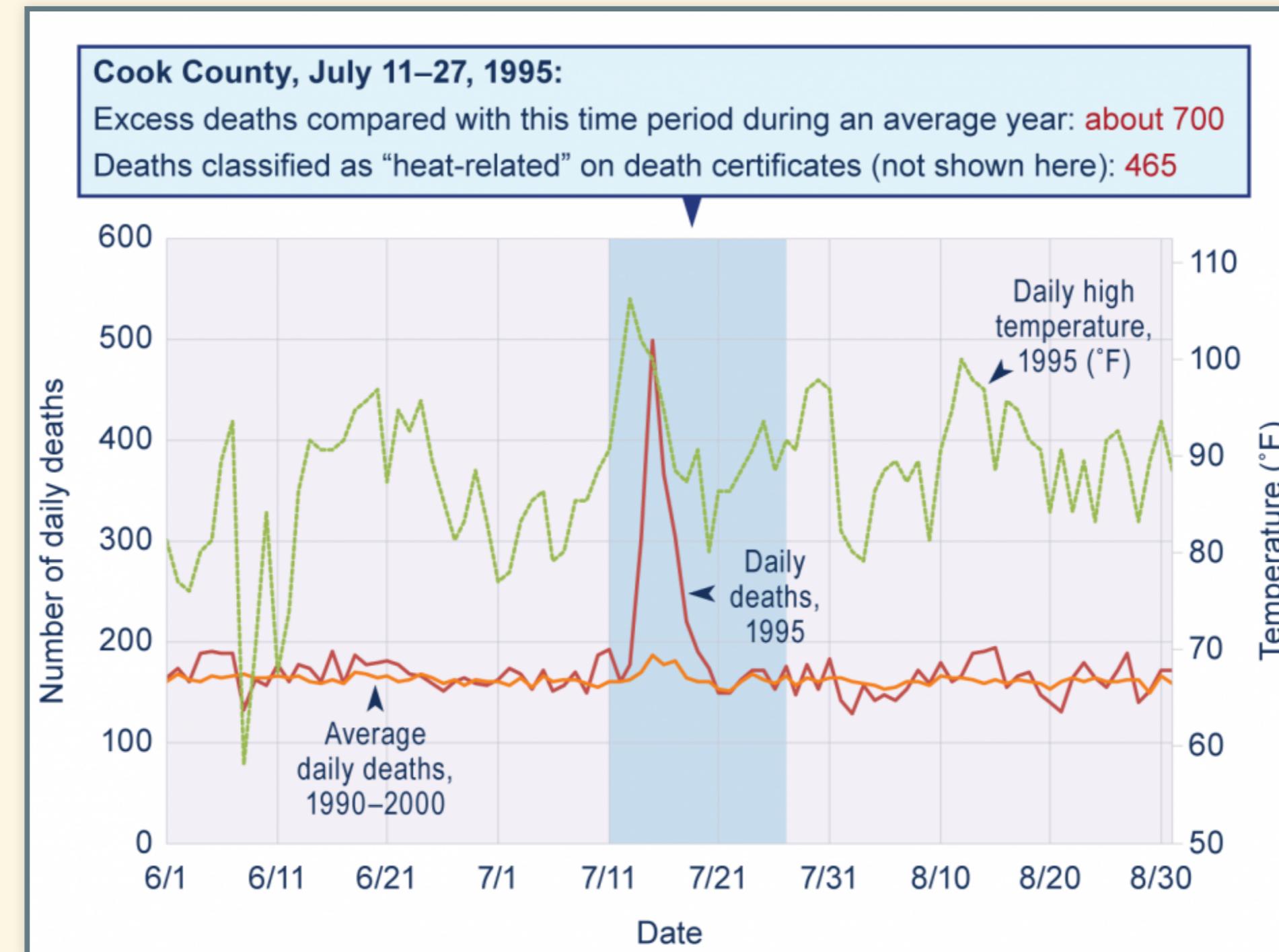
Source: Environmental Protection Agency

Urban Heat Islands in the United States



Urban Heat Mortality

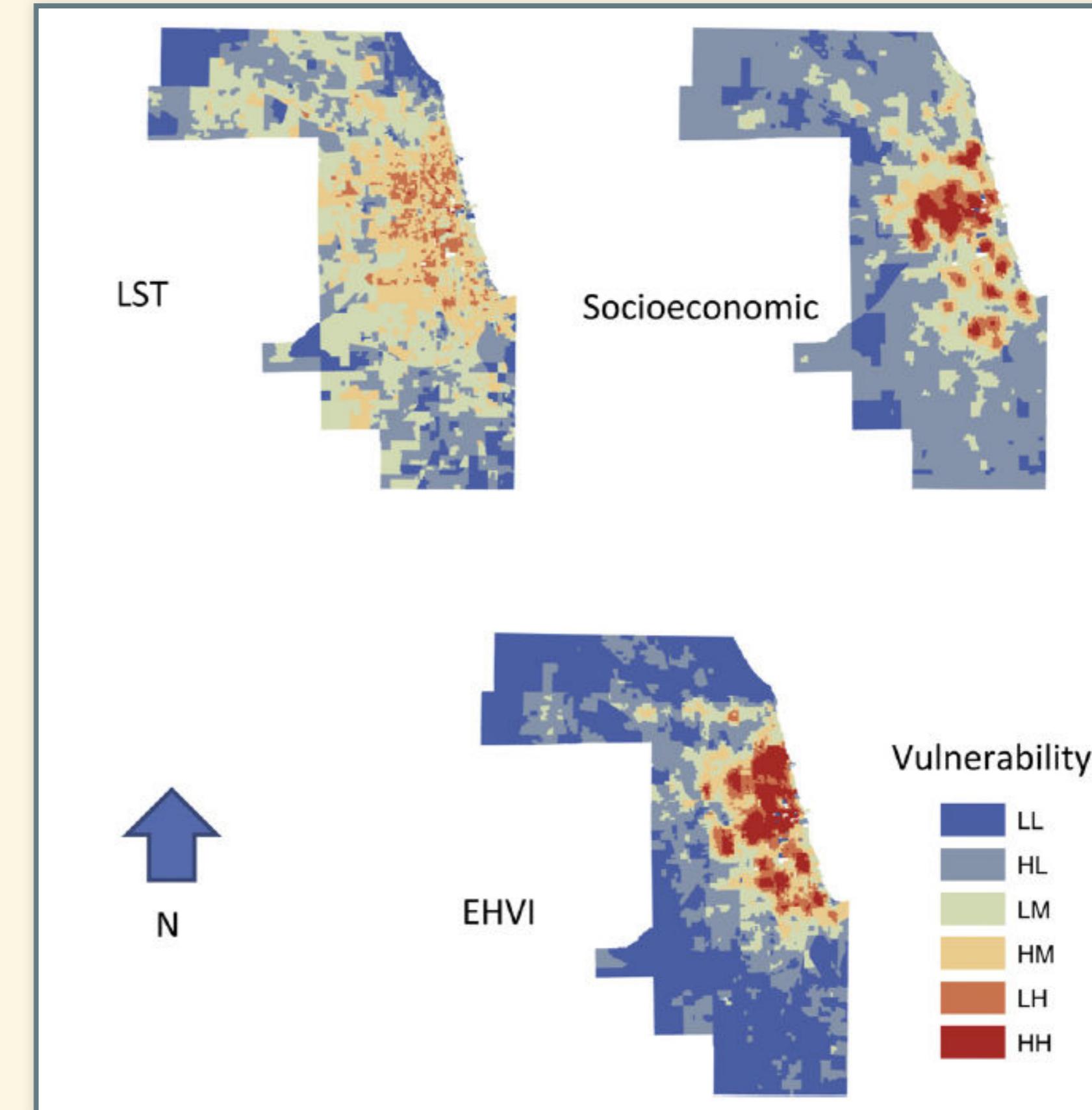
Chicago, 1995



Source: USGCRP, *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (2016).

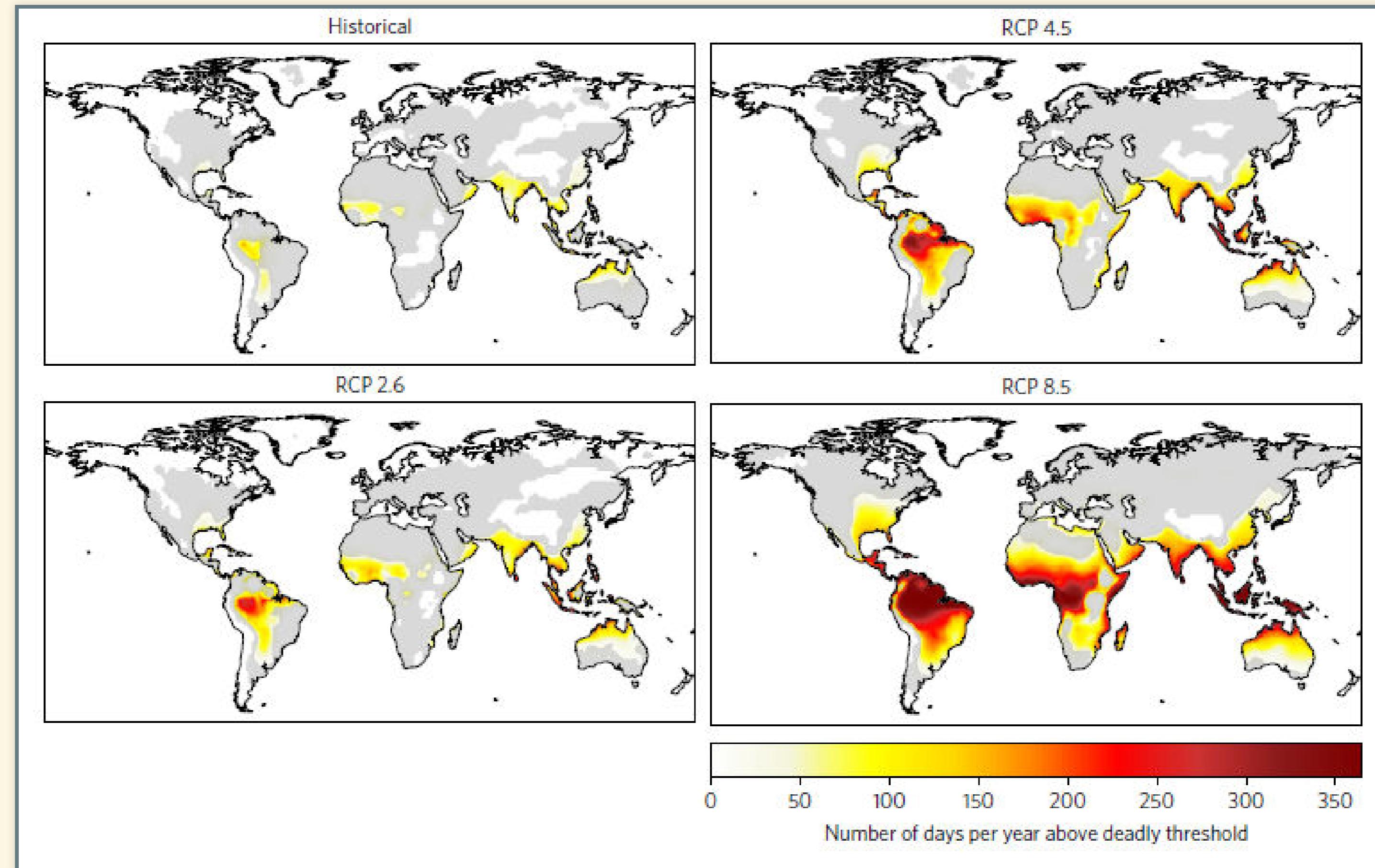
Socioeconomic Status and Vulnerability to Heat

- LST = Urban heat island effect
- EHVI = extreme heat vulnerability index
- EHVI correlates very strongly with socioeconomic variables



Source: D.P. Johnson *et al.*, Appl. Geography 35, 23 (2012).

Climate Change and Deadly Heat



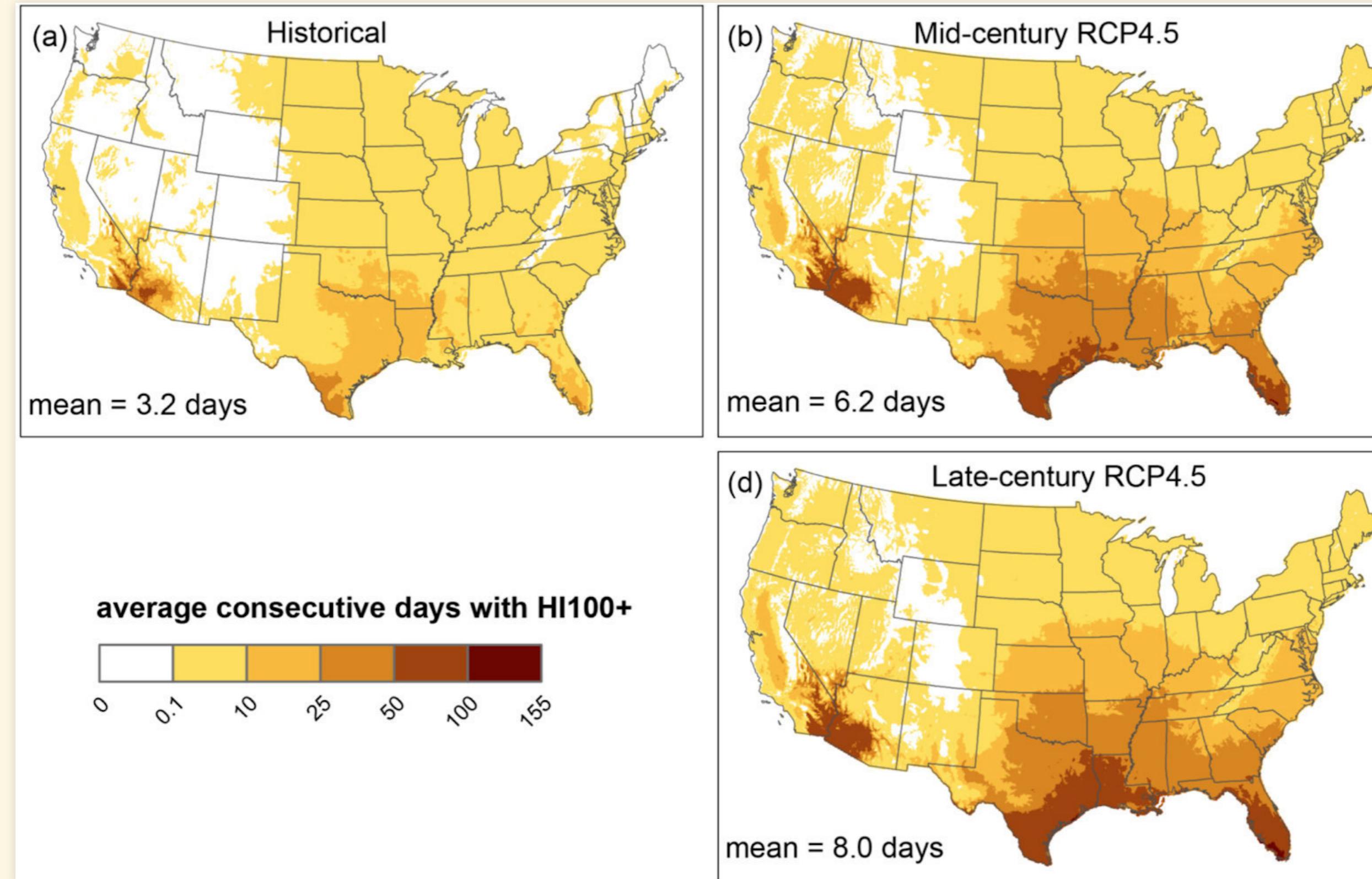
More than Deaths

- In the South, many people work outside
 - Construction, farming, logging, etc.
 - Summer heat waves could make it dangerous to be physically active outdoors
 - Loss of working hours, lower economic productivity, less money



Severe Heat Waves

- Severe heat waves even with serious emission reductions.



Football Practice in Heat

Football practice health/safety rules:

- Heat index of 104 or more is considered **dangerous**
 - Constant observation and supervision for overheating
 - No pads or equipment
 - 5 minutes mandatory rest and water break every 15 minutes
- After 2070:
 - Average of 3 weeks per year in Southeast & Midwest
 - 2 months per year in Texas, Louisiana, Southern Florida



Photo credit: Nathaniel Rutherford/RTI

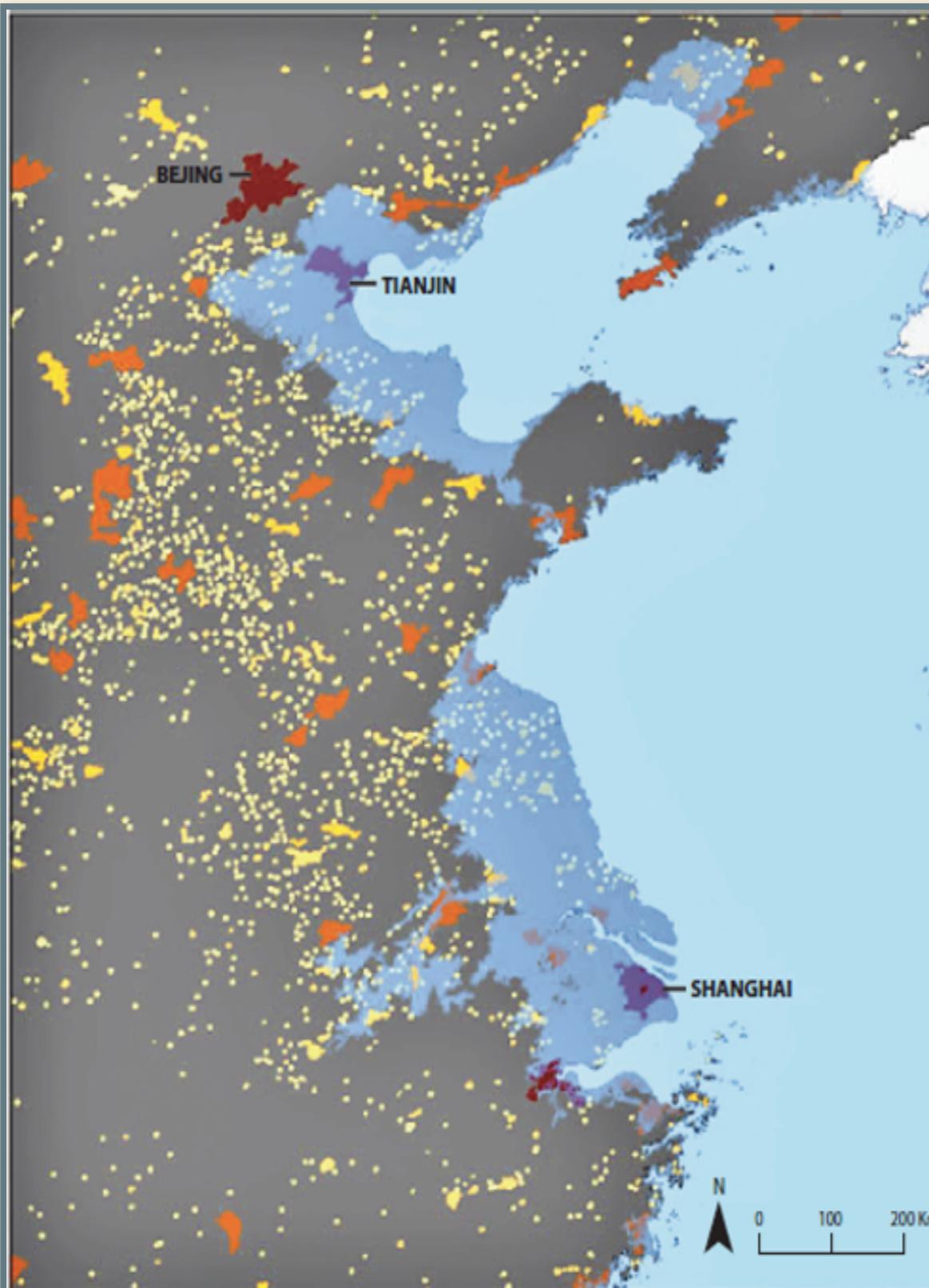
Sea-Level Rise

Sea-Level Rise

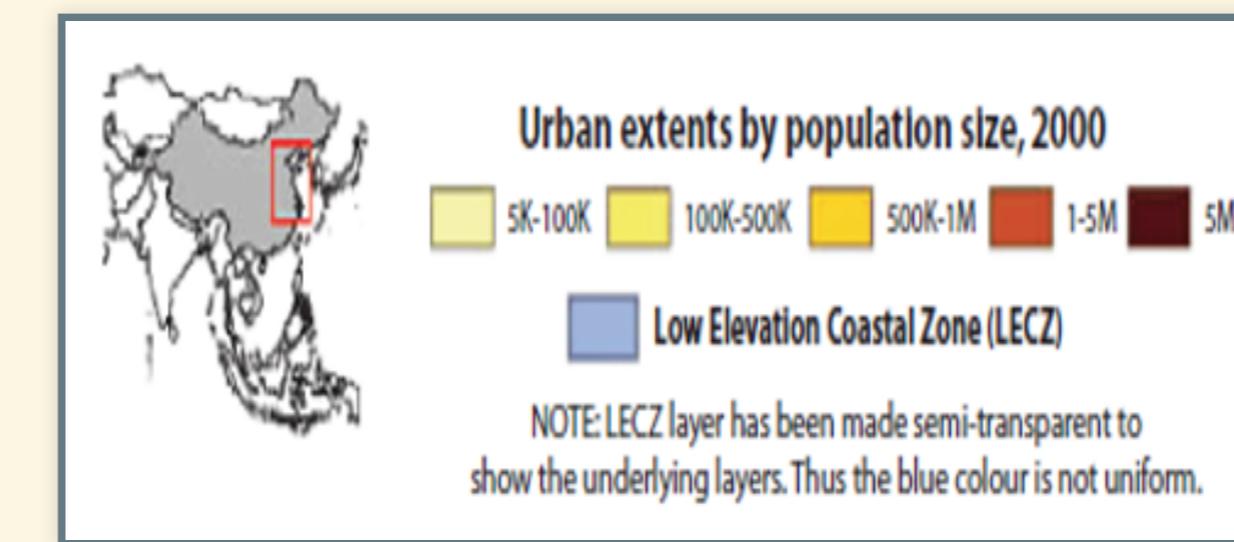
- Sea level rise is causing increasing flooding in coastal cities
 - “King tides” in Miami are flooding the city even in good weather.
 - When hurricanes come, storm surges are higher and more destructive



Low-Elevation Coastal Zone



- Within 10 meters of sea level
- 2/3 of cities with >5 million people
- 10% of world population



Greenland

- Melt descending into Moulin
 - Meltwater lubricates base of glacier
 - Accelerates ice-flow
 - Speeds up melting



Peterman Glacier 2009



Peterman Glacier 2011



Ice Loss from Greenland

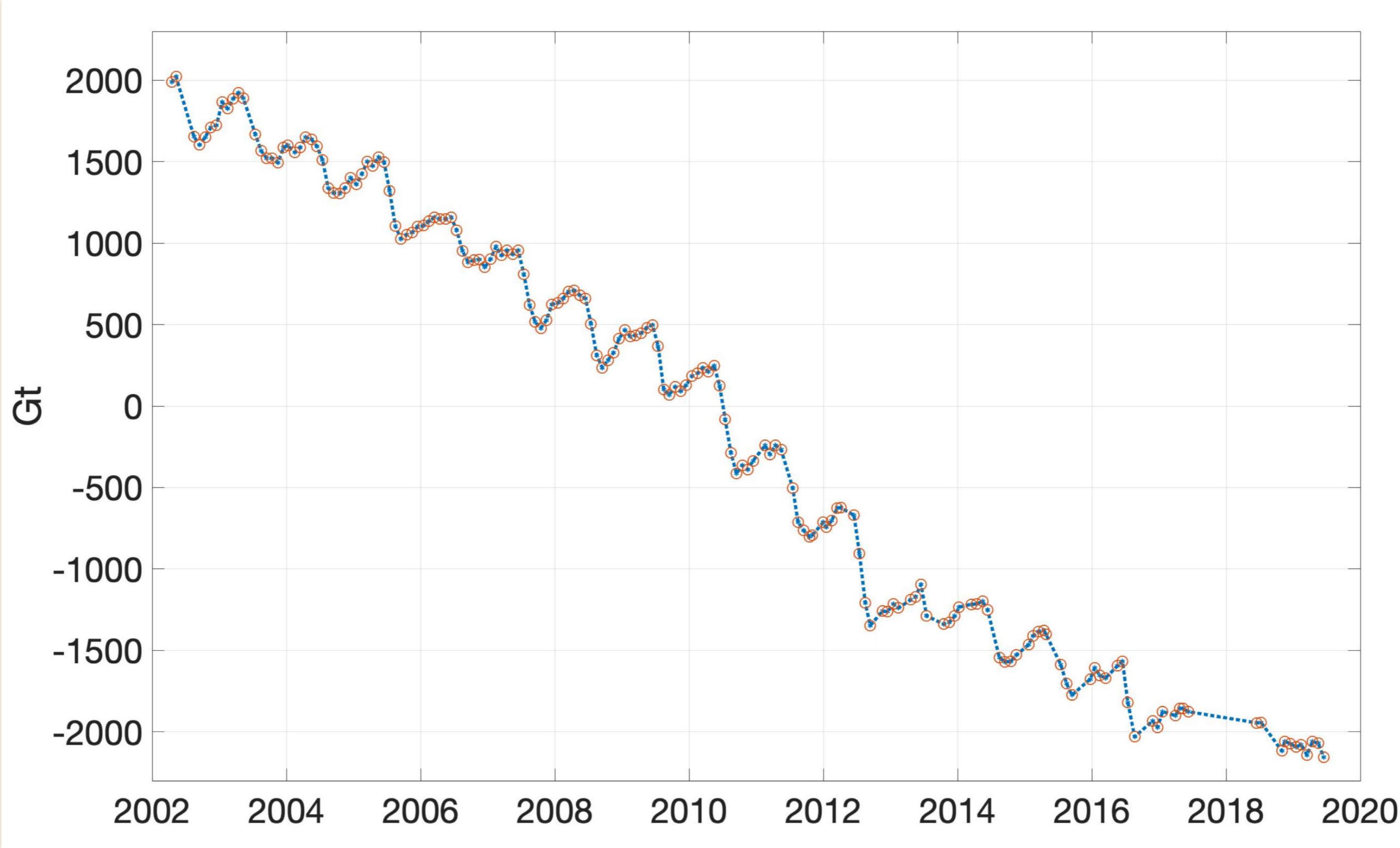
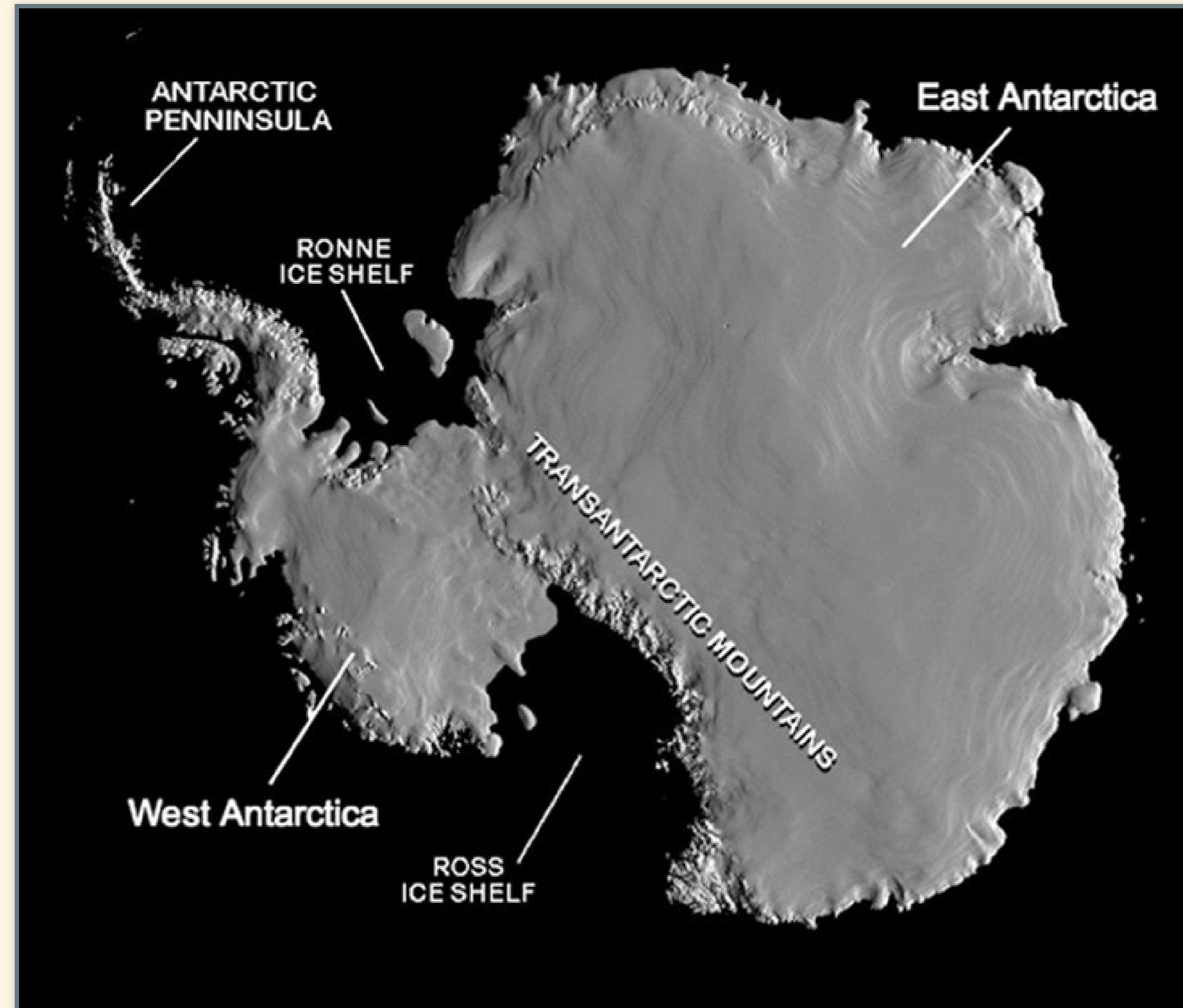


Image credit: M. Tedesco et al., NOAA Arctic Program

Antarctica

Antarctica



GRACE Satellite

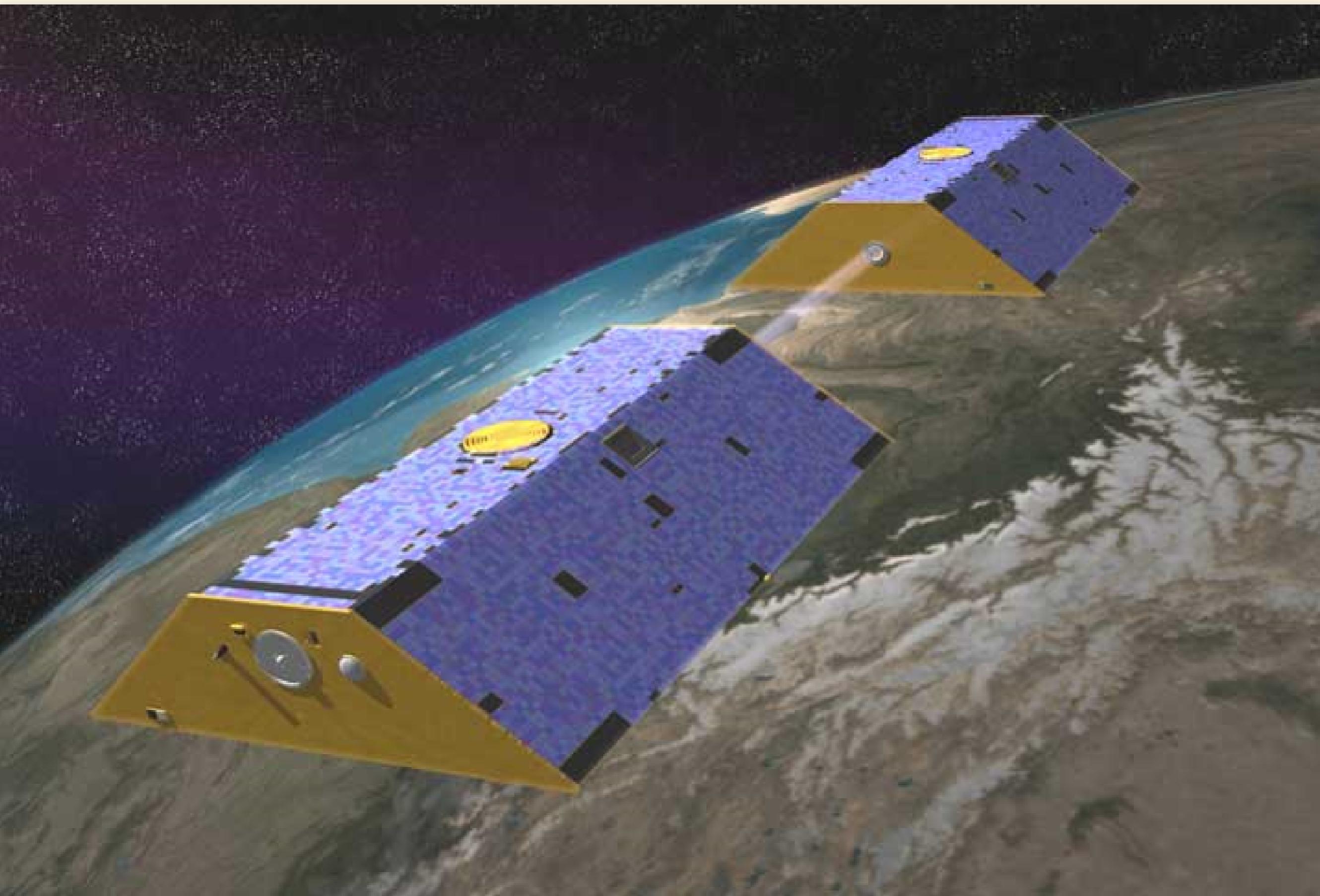


Image credit: NASA

Observations

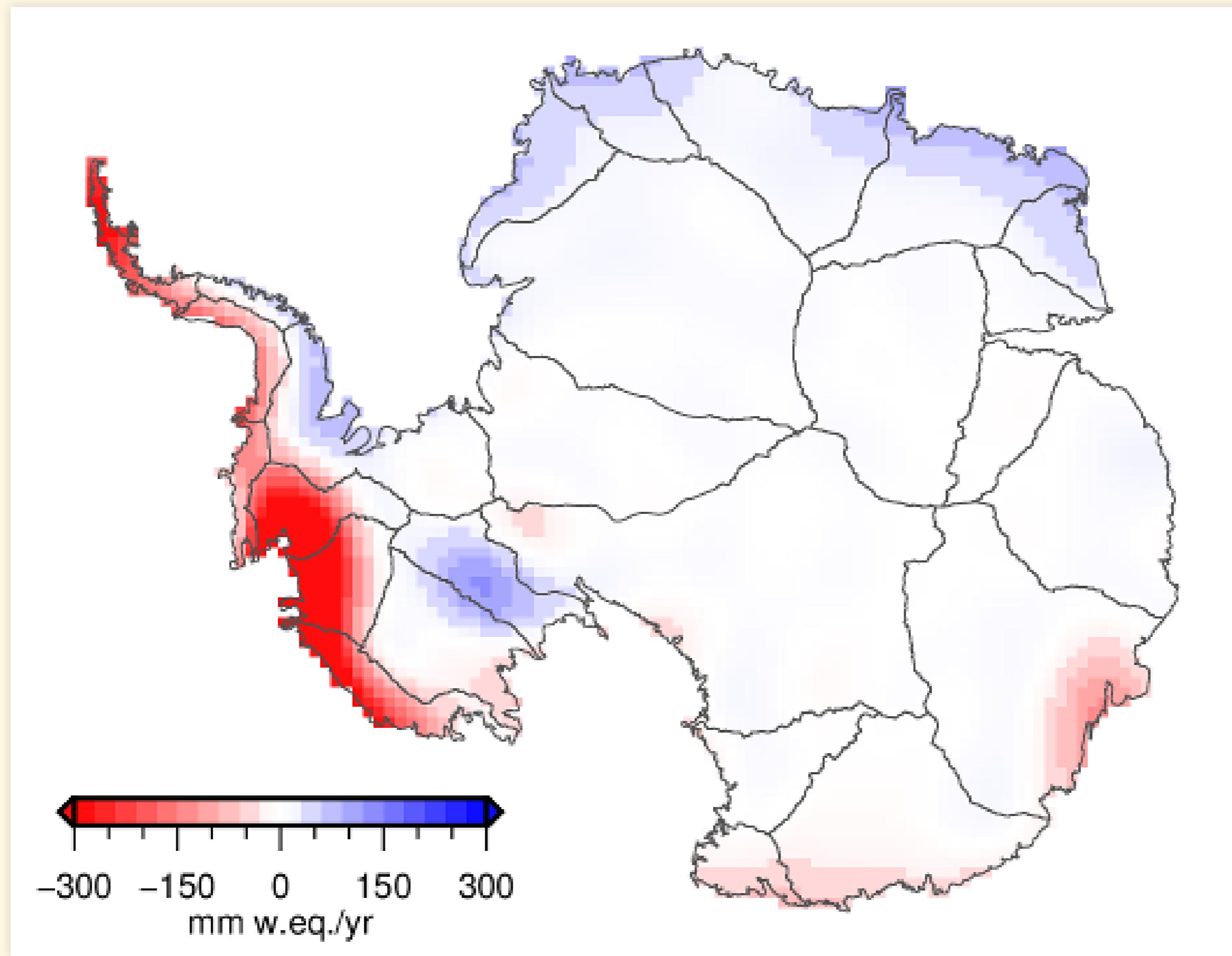
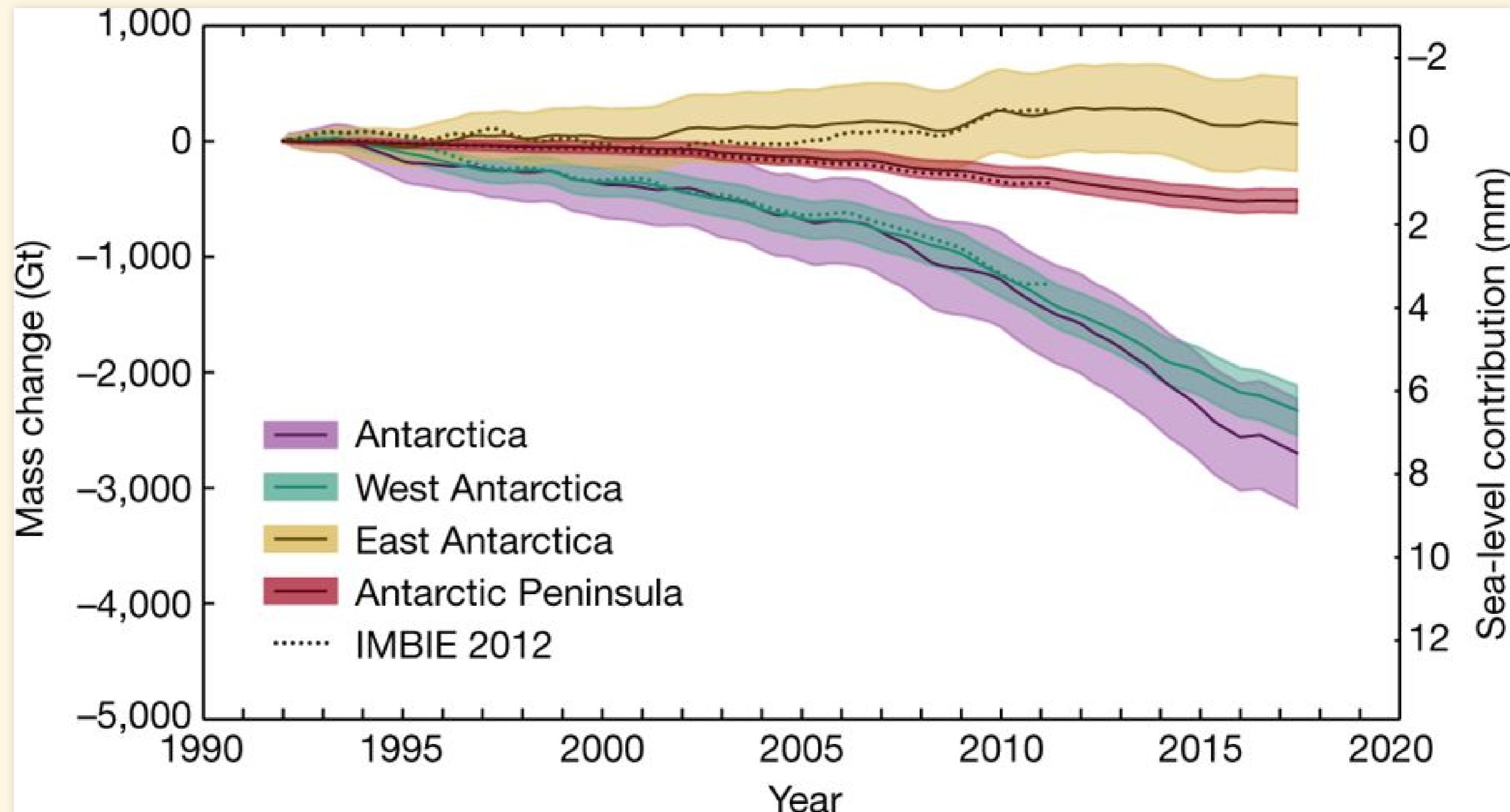


Image credit: Arnoud Jochemsen, Technical University of Dresden

Ice loss



GRACE Results

- Greenland melting faster than previously thought
 - Almost 150 cubic miles per year
 - Loss is accelerating
 - Melting more than 7 times faster than in 1990s.
- Antarctica is losing ice instead of gaining
 - 150 cubic miles per year

Bottom Line:

- Sea level is rising
- Hard to estimate future rise:
 - Glacier dynamics is very uncertain
- Rate matters!
 - Rapid sea-level rise makes it hard to adapt

Impacts

- Population displacement, migration
- Amplified impacts of coastal storms
- Coastal ecosystems
- World Heritage Sites



Photo credit: Soumyajit Nandy

Adaptation

- Abandon vulnerable land
- Protect valuable land
- Raise buildings
- Move inland



Photo credit: Wikipedia

Summing Up

Perspective

- Cost of cutting emissions vs. cost of adapting or living with climate change
- Extreme positions versus balanced mixture
- What about uncertainties, tipping points, and irreversibility?

End