EPIC | ENERGY POLICY INSTITUTE AT THE UNIVERSITY OF CHICAGO

Incorporating Externalities into Climate Policy: The Social Cost of Carbon

AEA 2020 Continuing Education Program
San Diego, California

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Director
Energy Policy Institute at UChicago
Becker Friedman Institute



What is the social cost of carbon?

The most important number that you've never heard about.



The most important number you've never heard of

Definition

The social cost of carbon (SCC) is the the monetary value of the damages from emitting an incremental ton of CO2 into the atmosphere.

In principle, it should reflect the full cost to society of the impacts associated with a warming world, including through:

- Human health
- Agricultural and labor productivity
- Property damage from increased flood risk
- Ecosystem services

The SCC includes both direct damages and the costs of adaptation.

The most important number you've never heard of

To economists, the SCC is exactly the negative externality associated with emitting 1 ton of CO2 during production.

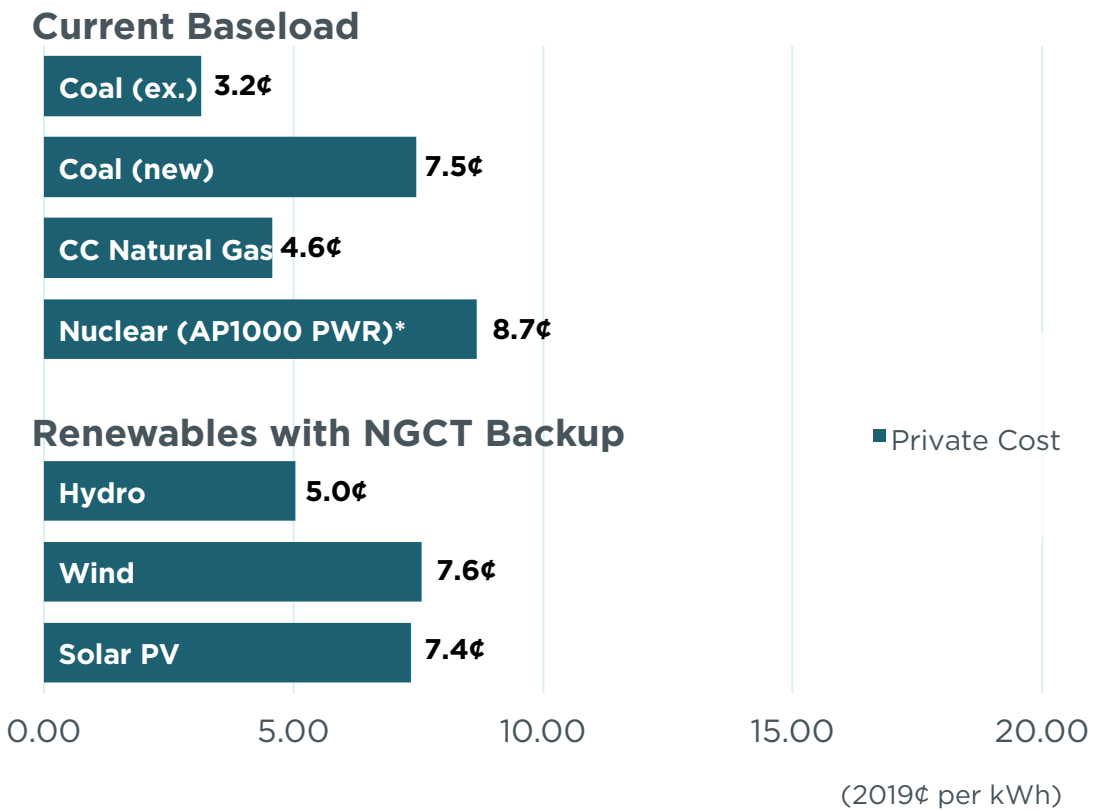
To policymakers, the SCC is a critical input for developing effective and efficient climate policies.

- It facilitates efficient carbon pricing, particularly a carbon tax.
- It can be fed directly into cost-benefit analysis of regulatory actions to limit GHG emissions.

In short, the SCC eliminates guesswork.

Leveling the energy playing field by incorporating the SCC and other externalities

Levelized Cost of Energy for New Plants in 2023

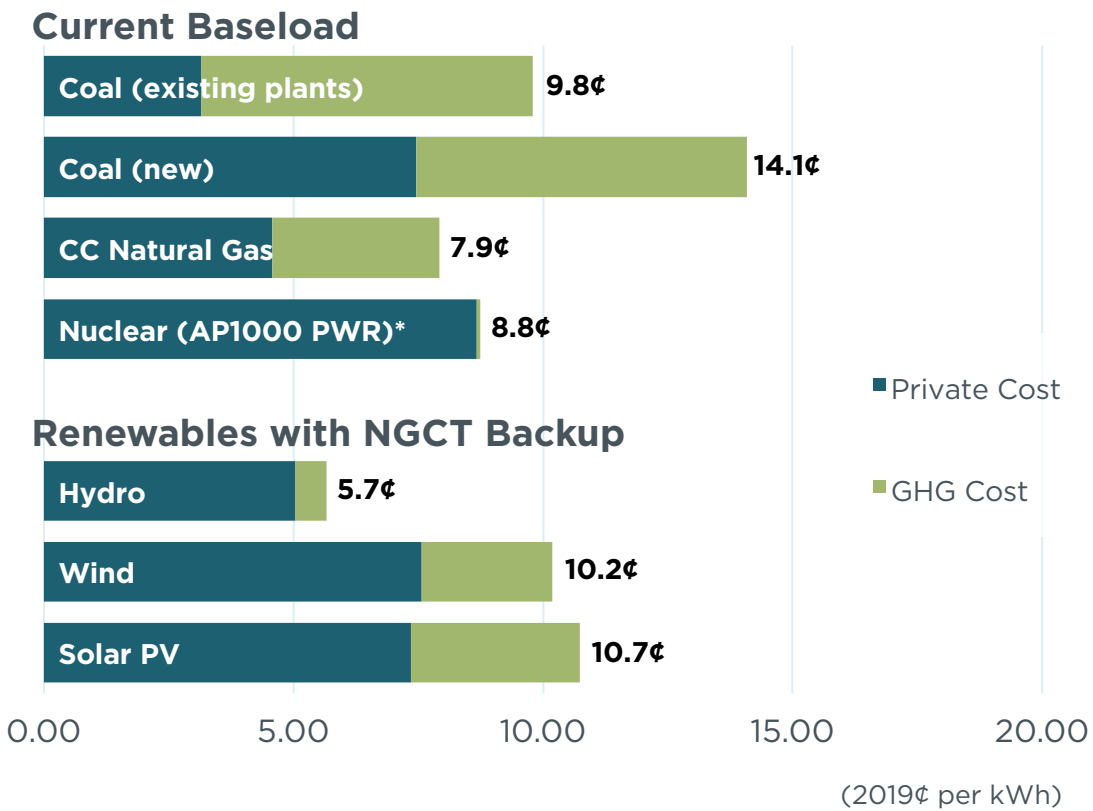


- Presenting energy costs in strictly private terms heavily favors conventional fossil generation.
- This is especially true if we limit our analysis to system configurations capable of providing baseload power.

Source: DOE, EIA, EPA, NREL, NAS, EPIC

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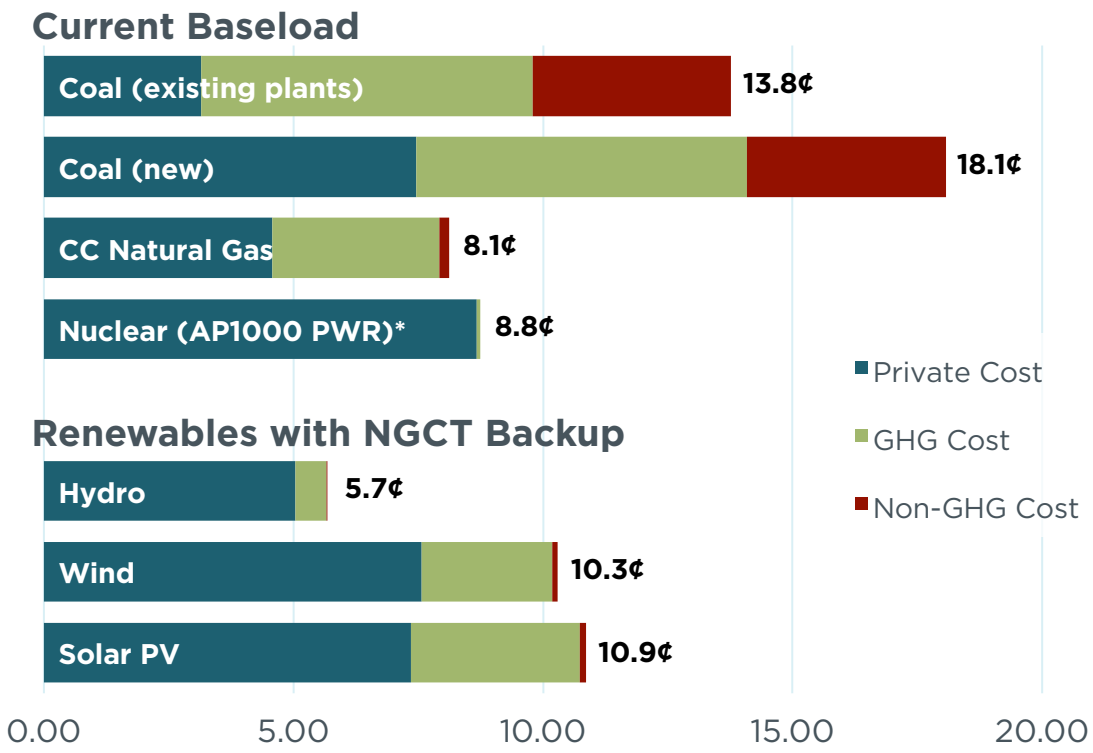


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- The story gets more interesting if we begin to include external costs, such as the climate impacts of fossil fuels.

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- This is especially true if we limit our analysis to system configurations capable of providing baseload power.
- The story gets more interesting if we begin to include external costs, such as the climate impacts of fossil fuels as well as the non-climate impacts of fuel combustion.

Source: DOE, EIA, EPA, NREL, NAS, EPIC
Note: *Unable to quantify non-GHG costs

Regulatory Policy: SCC in Action

Up-front Technology Costs and Social Benefits of EPA/DOT GHG Emissions Standards for Light-Duty Trucks 2010-2050

	2007 $s
Social Benefits	$277.5
Costs	-$345.9
Net Benefits, without SCC	-$68.4

(Note: NPV using 3% Discount Rate)

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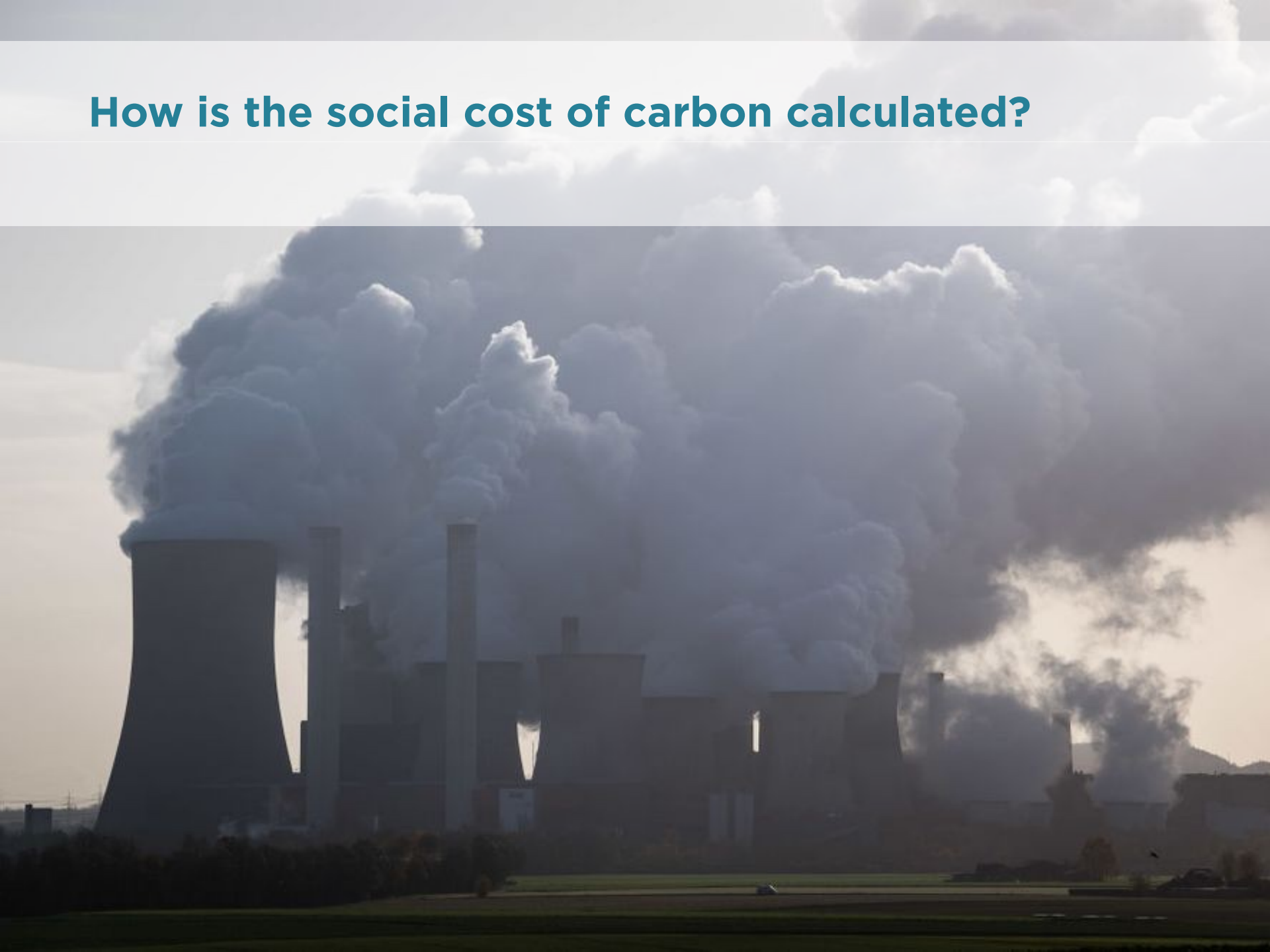
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Net Benefits, without SCC	-$68.4
Social Benefits of CO2 Reductions (Central Value)	$176.7
Total Net Benefits	**$108.3**

(Note: NPV using 3% Discount Rate)

The social cost of carbon in US policy

- The SCC has been used to account for carbon benefits in over eighty US regulations
  - (erstwhile) Clean Power Plan
  - CAFE fuel economy regulations
- These regulations have brought over a trillion dollars of benefits through lower CO_2 emissions

How is the social cost of carbon calculated?



A tale of two derivatives

A tale of two derivatives

$$\frac{\partial(\$ \text{ of damages})}{\partial(\text{tons of } CO_2)} =$$

A tale of two derivatives

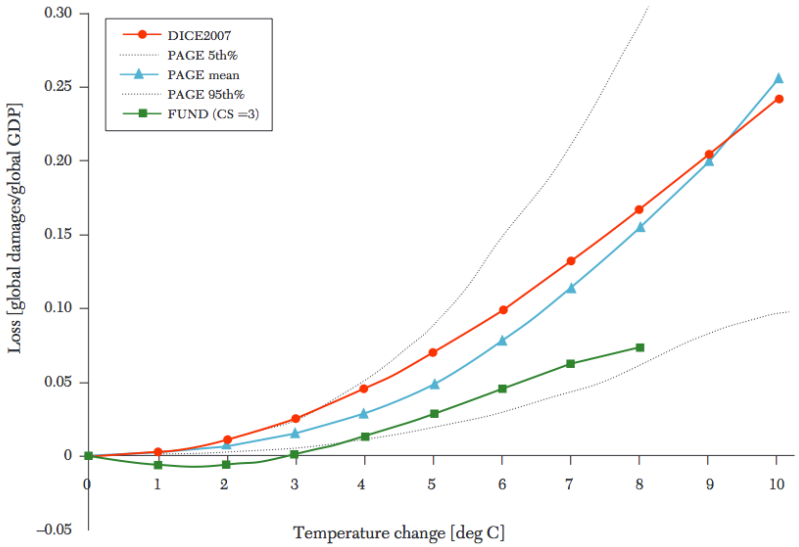
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A tale of two derivatives

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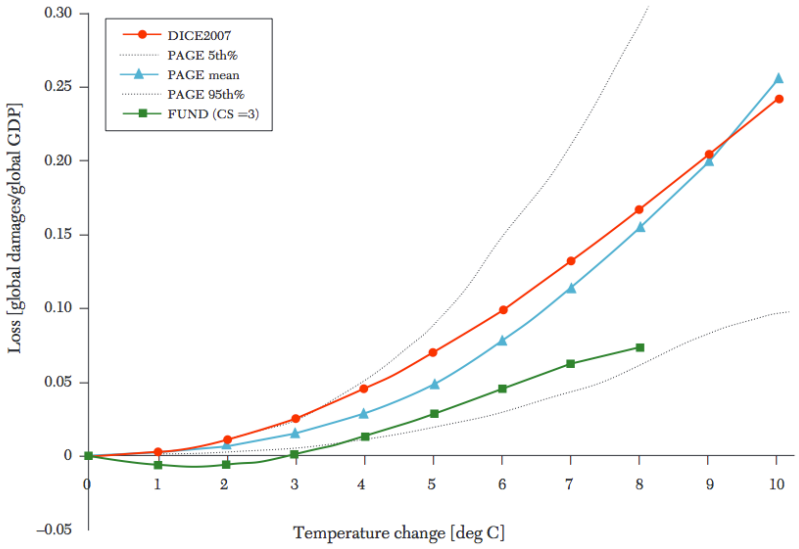
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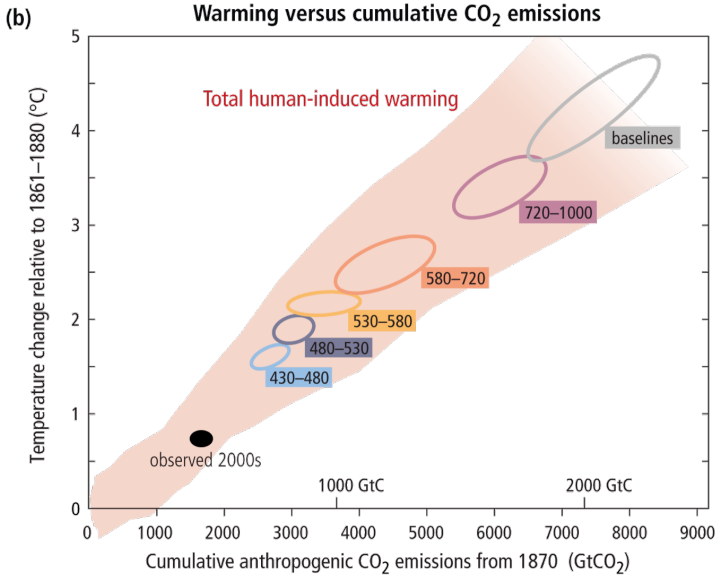
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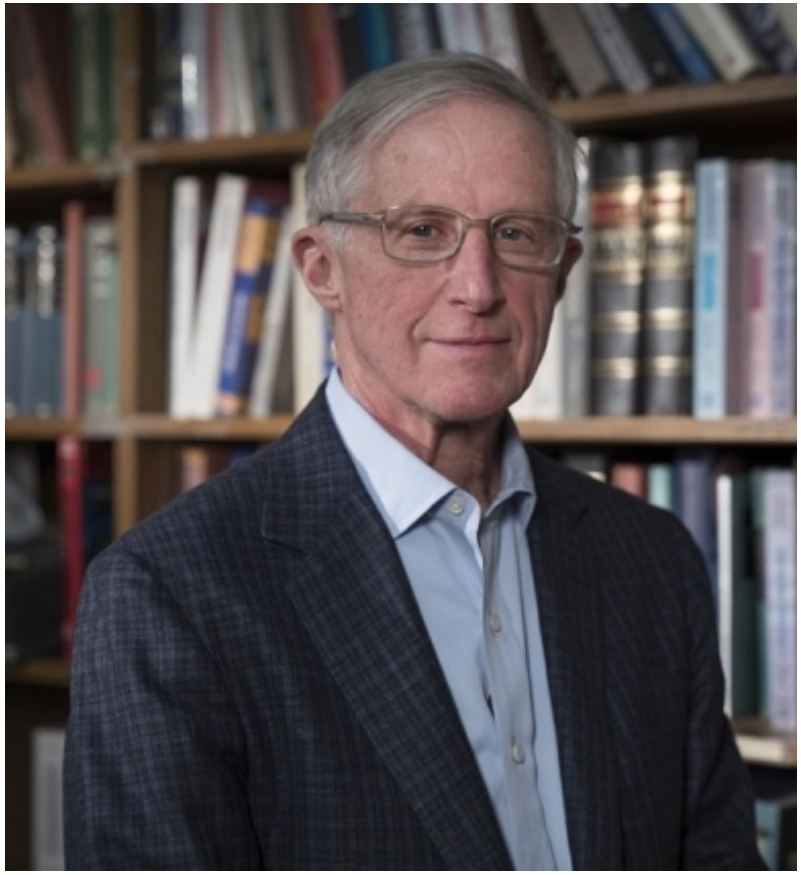
Source: IPCC Fifth Assessment Report

How is the social cost of carbon calculated?

US Government: Integrated Assessment Models



Integrated Assessment Models (IAMs)





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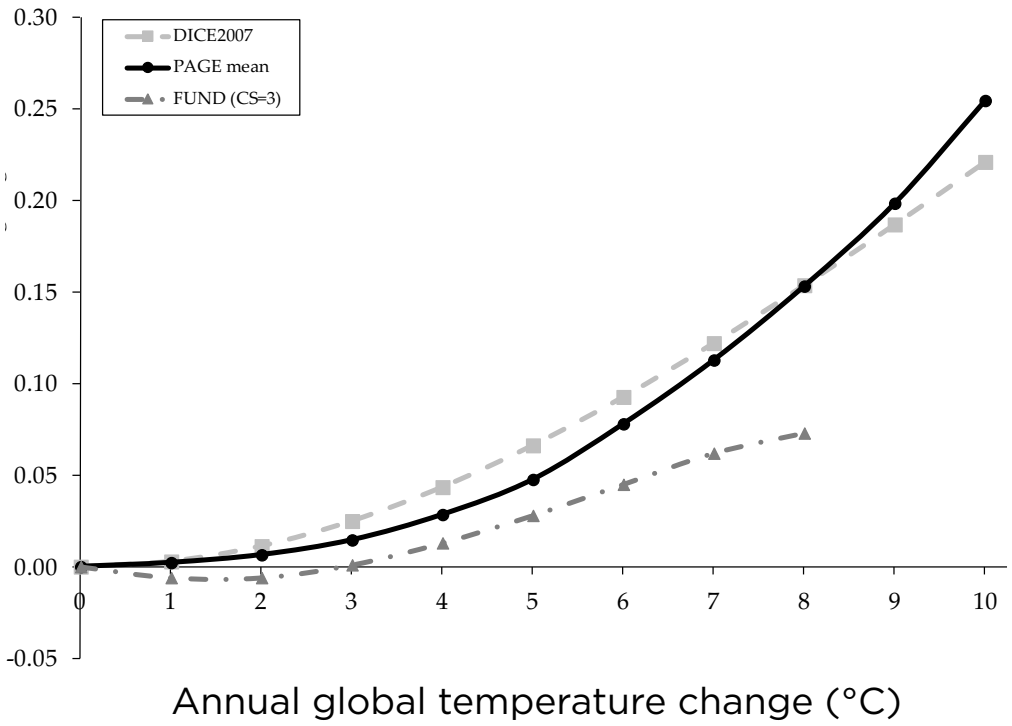
- **IAMs** combine climate processes, economic growth, and feedbacks between the two into a single model.
- Specifically, they translate changes in CO_2 emissions into economic damages.
- Benefits:
  - They answer everything.
- Costs:
  - They answer everything.
  - Highly dependent on validity of assumptions.

Integrated Assessment Models (IAMs)

- The Interagency Working Group on the Social Cost of Greenhouse Gases (IAWGSCGG) relied on three commonly used IAMs to estimate the SCC:
  - FUND (Richard Tol)
  - DICE (William Nordhaus)
  - PAGE (Chris Page)
- All are frequently cited, used in IPCC assessments, and given equal weight here.

Key Modeling Decision: Damage Function

Annual Consumption Loss as Fraction of Global GDP in 2100 due to Temperature Increases



- Each model suggests a different change in consumption for the same increase in temperature
- Model has single damage function for entire world, despite how in reality:
  - heterogeneous exposure to climate shocks
  - heterogeneous dollar (WTP) equivalents of human costs like mortality

Other IAM Modeling Decisions

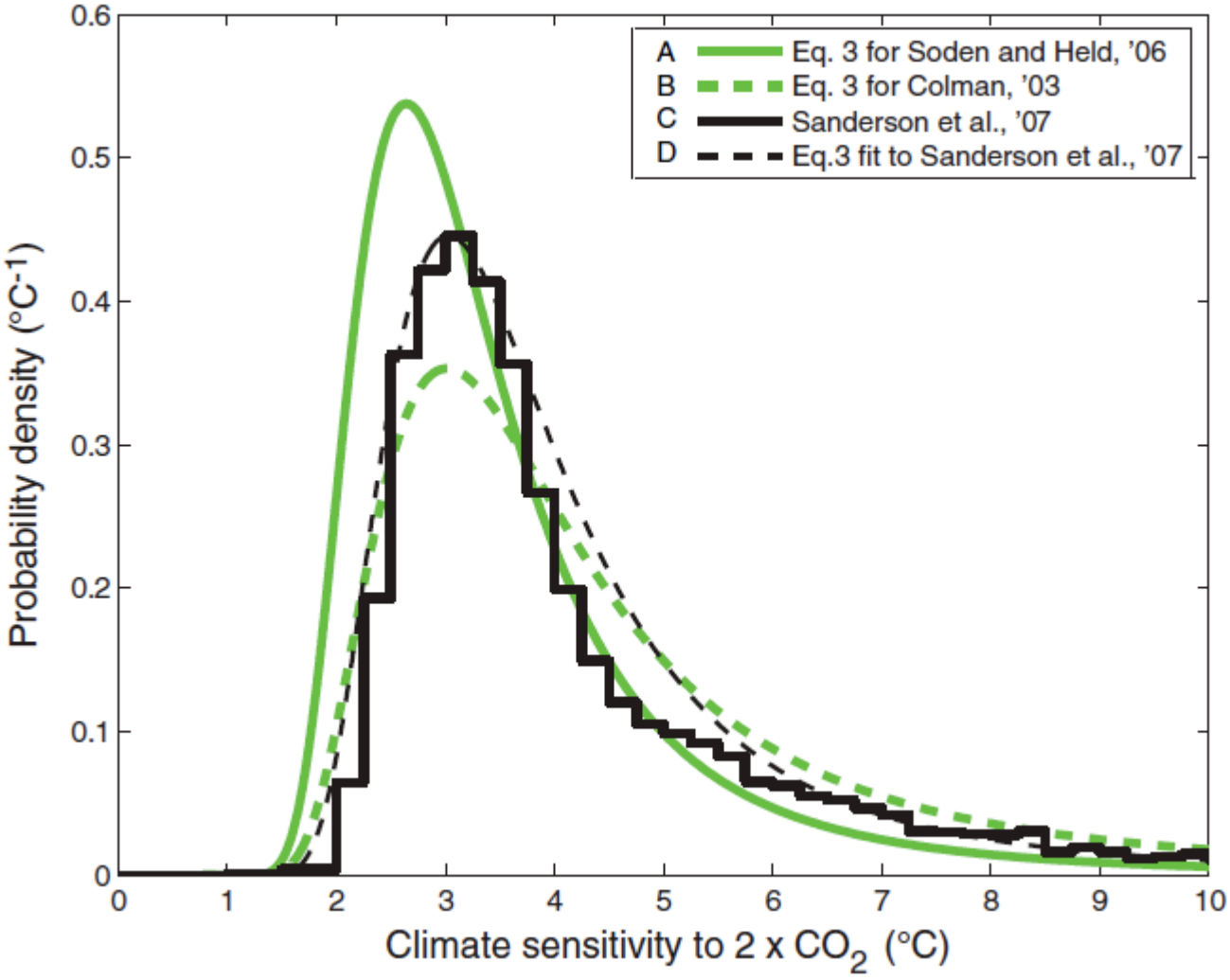
- **Socioeconomic and emissions trajectories**
  - *Importance:* Wealthier people emit more GHG and have higher willingness-to-pay to avoid climate disruption
  - *US government decision:* Input global GDP, population, and CO_2 emissions from present to 2100 from the Stanford Energy Modeling Forum exercise

Other IAM Modeling Decisions

- **Equilibrium climate sensitivity: long-term increase in annual global-average surface temperature due to a doubling of CO_2 concentrations relative to pre-industrial levels**
  - *Importance:* tells us "how much" climate change will happen
  - *US government decision:* use Roe and Baker distribution, which is theoretically founded and consistent with IPCC judgments

Recall from previous lecture: uncertainty about timing of damages increases their present value

Climate distribution from Roe and Baker (2007)



Source: Climate sensitivity distribution from Roe and Baker (2007)

Other IAM Modeling Decisions

- **Global or domestic damages**
  - *Importance:* Climate change is a global problem, but damages to US citizens are only 5-15% of global damages
  - *US government decision:* to best encourage responses from countries, estimate global damages
    - Do not weight monetary damages higher in poor countries, despite lower marginal utilities of income

Other IAM Modeling Decisions

- **Discount rates**
  - *Importance:* benefits of mitigation occur in future and must be discounted to present
  - *US government decision:* use three discount rates
    - 2.5%: low rate since climate investments might pay off in bad times
    - 3.0%: consistent with OMB guidelines for consumption rate of interest, close to after-tax riskless rate
    - 5.0%: if climate investment payoffs are positively correlated with growth

Recall from previous lecture: accounting for correlation between climate damages (or the return to mitigation) and the overall economy might lead to even lower discount rates.

This would increase the SCC.

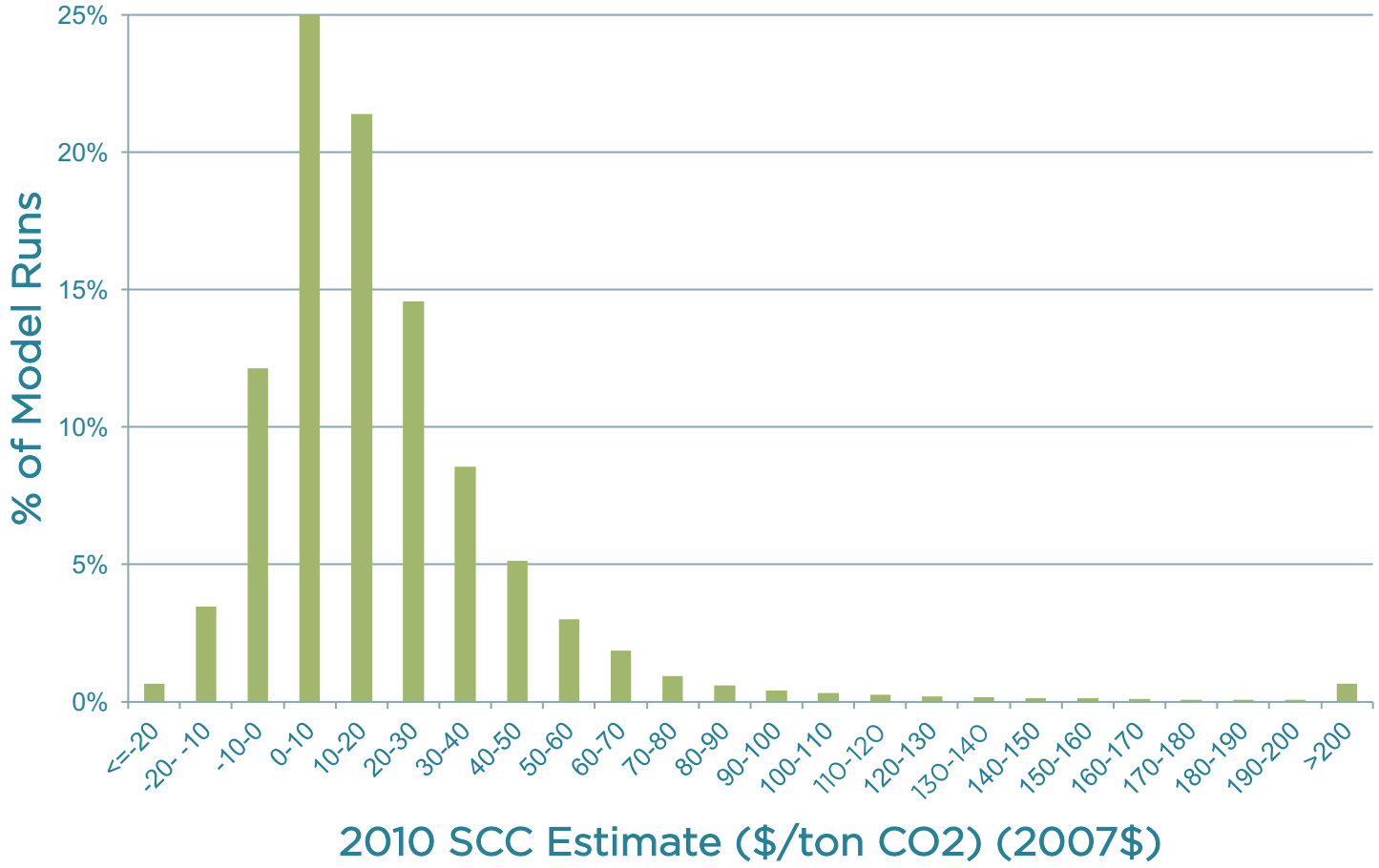
Putting it all together

For each IAM x socioeconomic scenario x discount rate (45 total):

1. Input future total emissions, GDP, and population; and calculate temperature-effects and consumption-equivalent damages for each year.
2. Add 1 unit of CO_2 in period t, recalculate total damages by year.
3. Subtract damages in step 1 from those in step 2 to obtain marginal damages
4. Sum marginal damages across years, discounting by agreed rate

Lastly, average across (IAM x socioeconomic scenario) to obtain one period-t SCC distribution per discount rate.

The original USG SCC: results with 3% discount rate



The original USG SCC: results

- Range of estimates (in 2007$) for the social cost of a ton of CO2 emitted in 2010:
  - $5 (r=5%)
  - **$21 (r=3%)**
  - $35 (r=2.5%)
  - $65 (r=3%, 95th percentile)

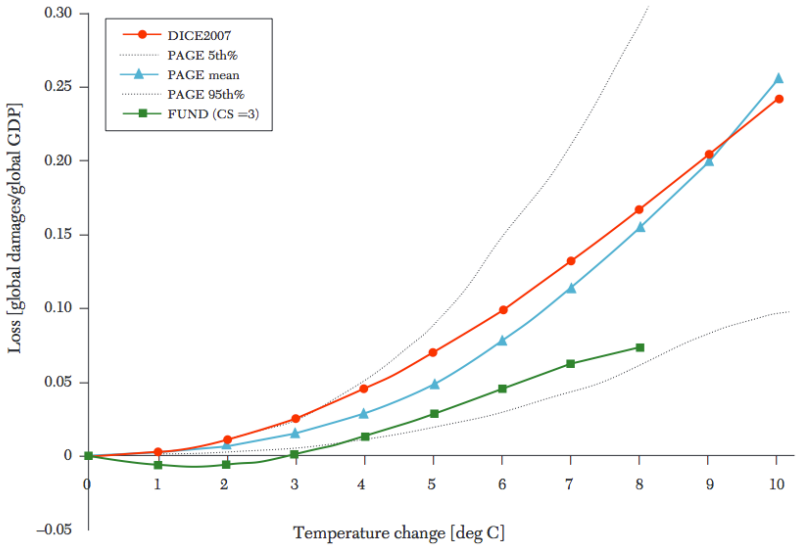
- 2016 IAWG report updated models and computed SCC for future years:
  - At 3% discount rate, SCC for 2020 is **$51 in 2019 dollars.**

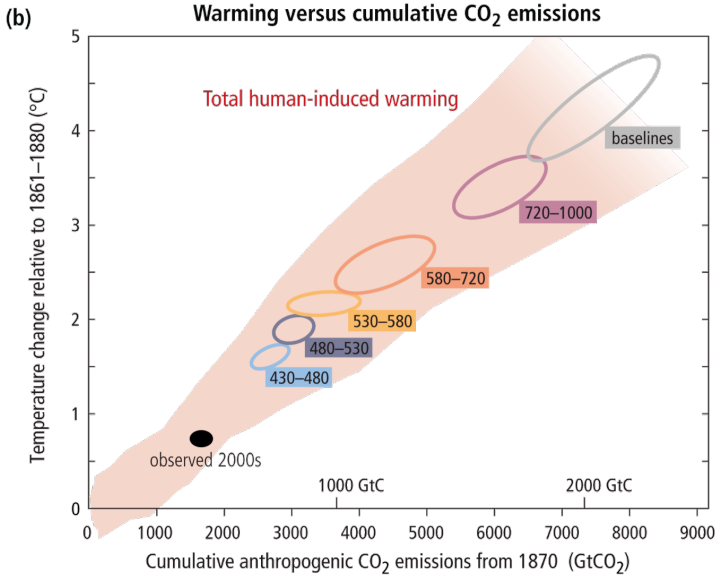
Economics and Science have Advanced Since the IAMs were Created



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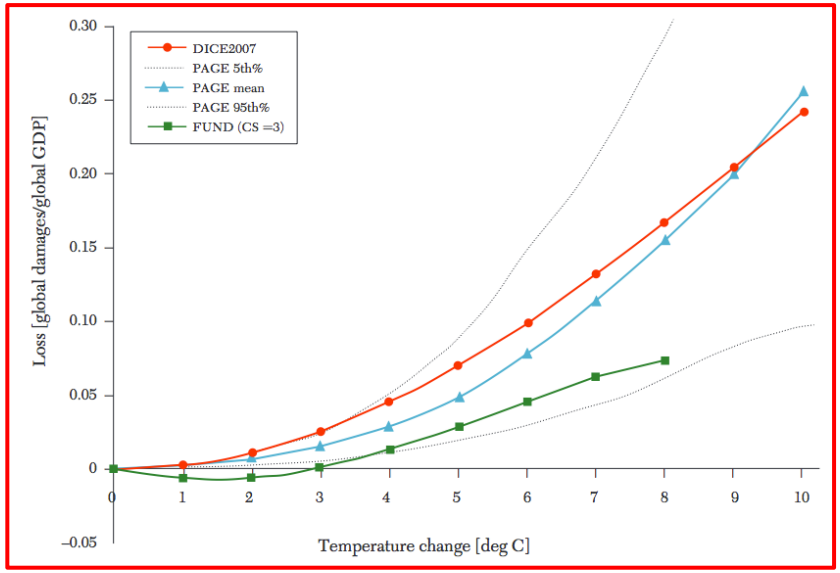


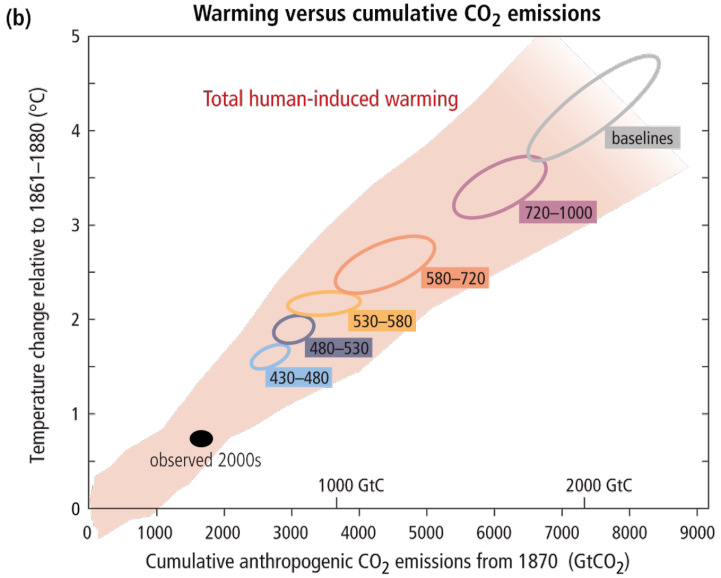


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Source: IPCC Fifth Assessment Report



"[M]uch of the research on which [the SC-IAMs] are based is dated…damage formulations do not in many cases reflect recent advances in the scientific literature."

National Academies of Sciences, Engineering, and Medicine (2017)



"The bottom line here is that the damage functions used in most [climate models] are completely made up, with no theoretical or empirical foundation."

Robert Pindyck
Professor of Economics and Finance
Massachusetts Institute of Technology

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Enter: The Climate Impact Lab

An Effort to Advance Global Climate Research and Policy

Leadership



Michael Greenstone
University of Chicago
Milton Friedman Professor in Economics; Director, Energy Policy Institute at the University of Chicago



Trevor Houser
Rhodium Group
Partner



Solomon Hsiang
University of California, Berkeley
Chancellor's Associate Professor of Public Policy



Robert Kopp
Rutgers University
Associate Professor of Earth & Planetary Sciences, Associate Director of the Rutgers Energy Institute

20+

Economists, climate scientists, computer scientists, data experts, analysts, researchers, and students working together.

THE UNIVERSITY OF CHICAGO

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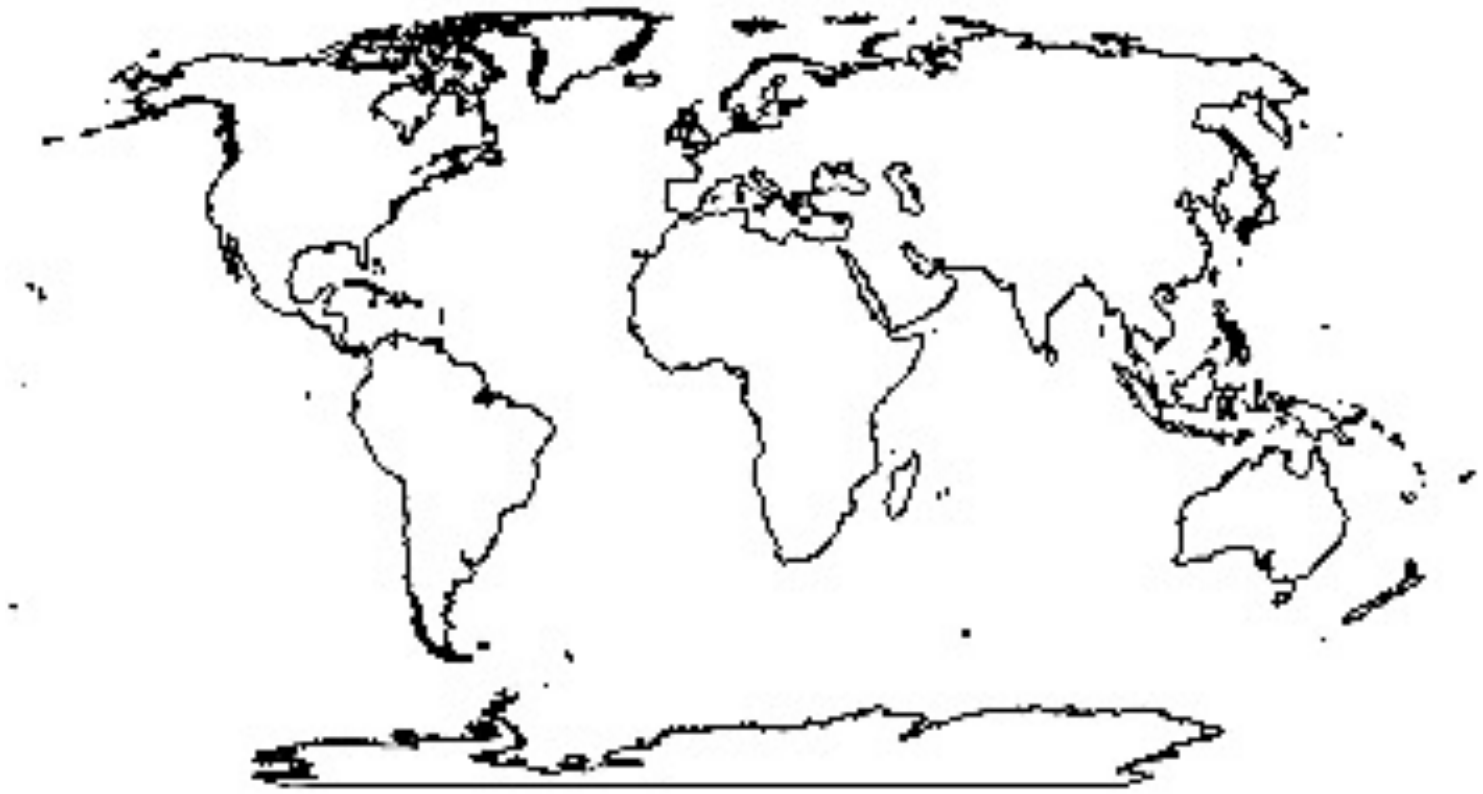
The Impact Lab Methodology: A Novel Approach

- Develop projections of temperature, precipitation, sea-level rise, and humidity using **the best available climate science**

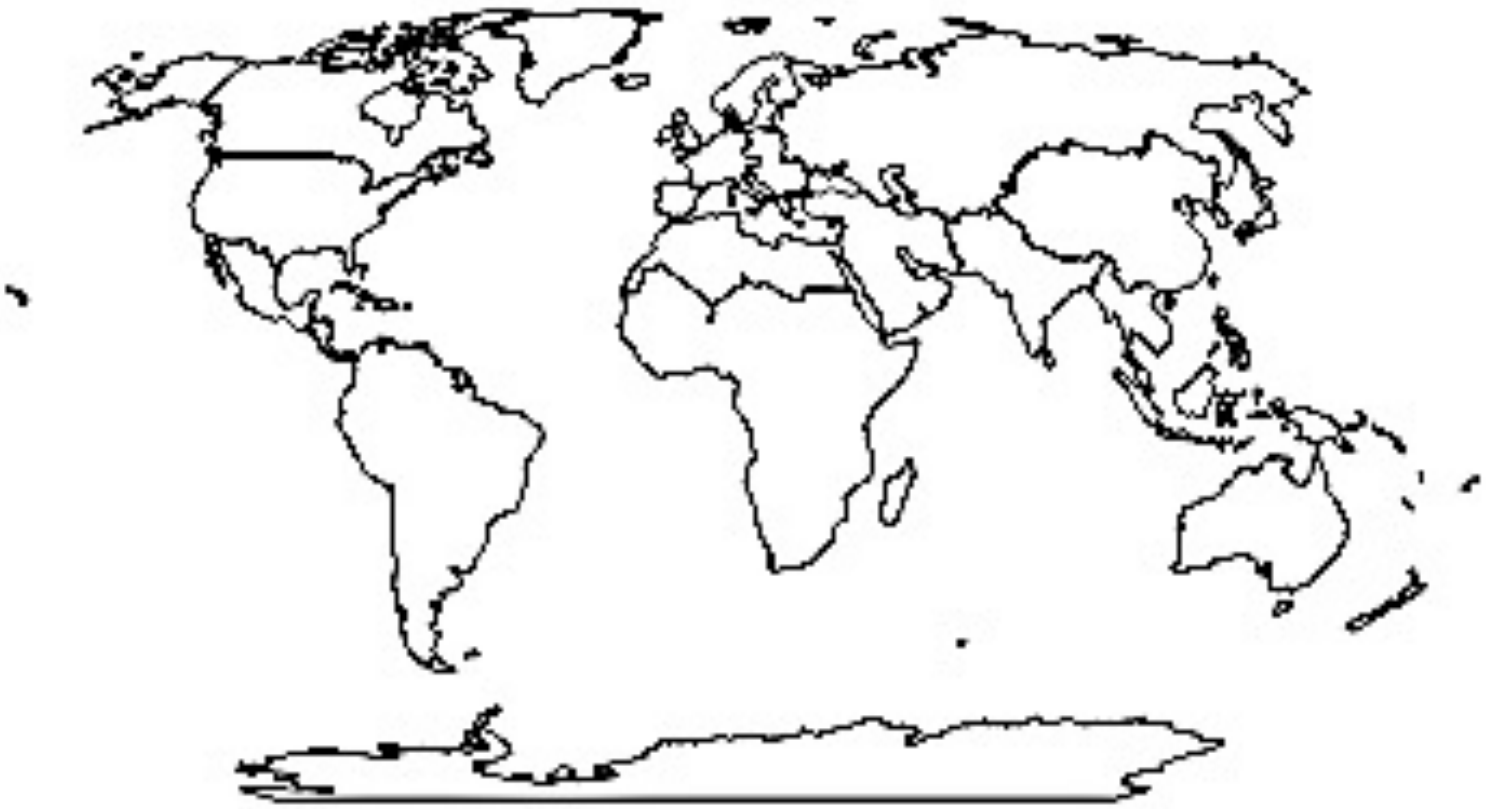
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    - Projections of damages for 25,000 impact regions (ex: US county)

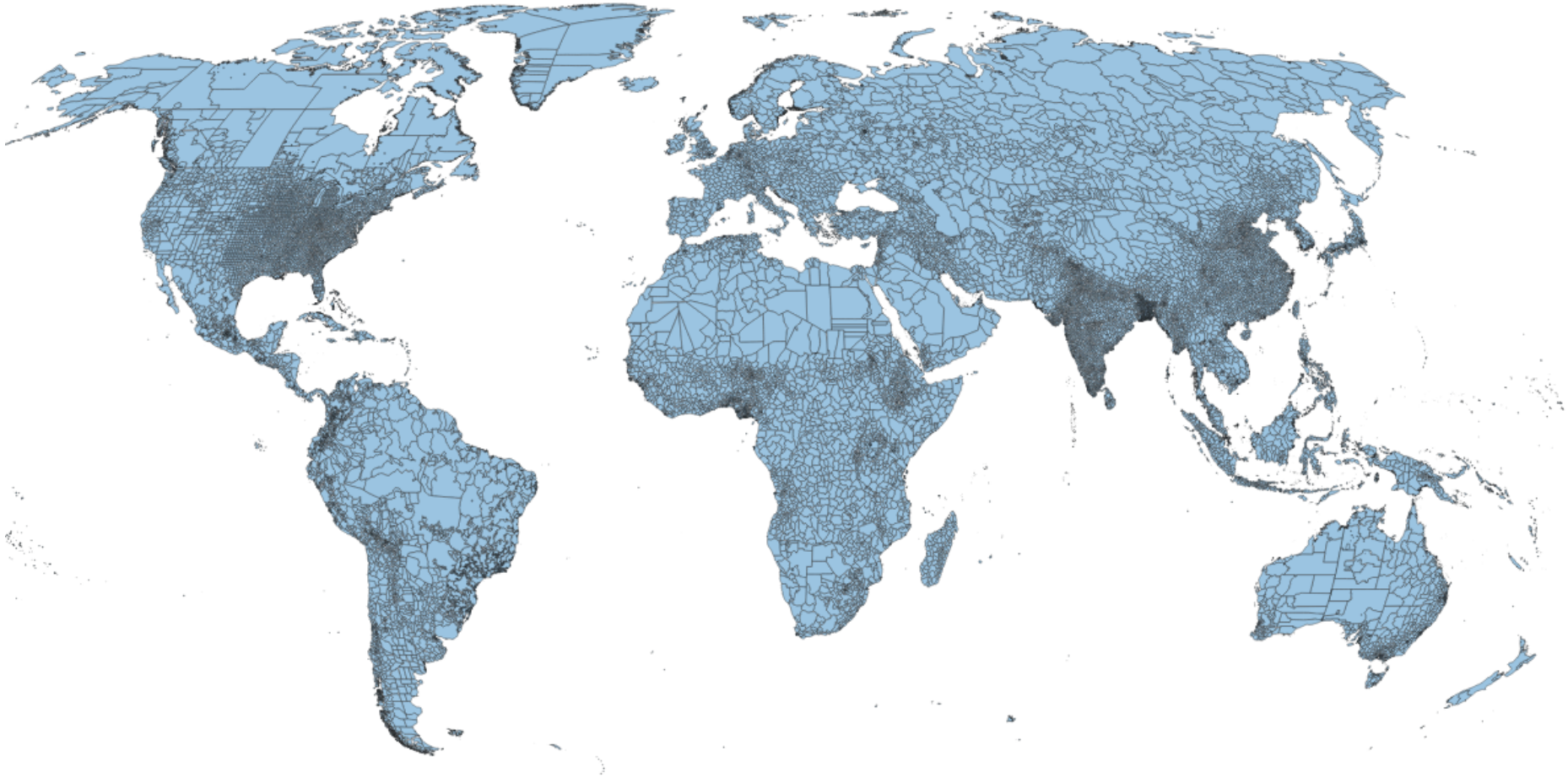
Early IAMs: 1 region in DICE (1992)



Early IAMs: 16 regions in FUND (1996)



Climate Impact Lab: 25,000 impact regions

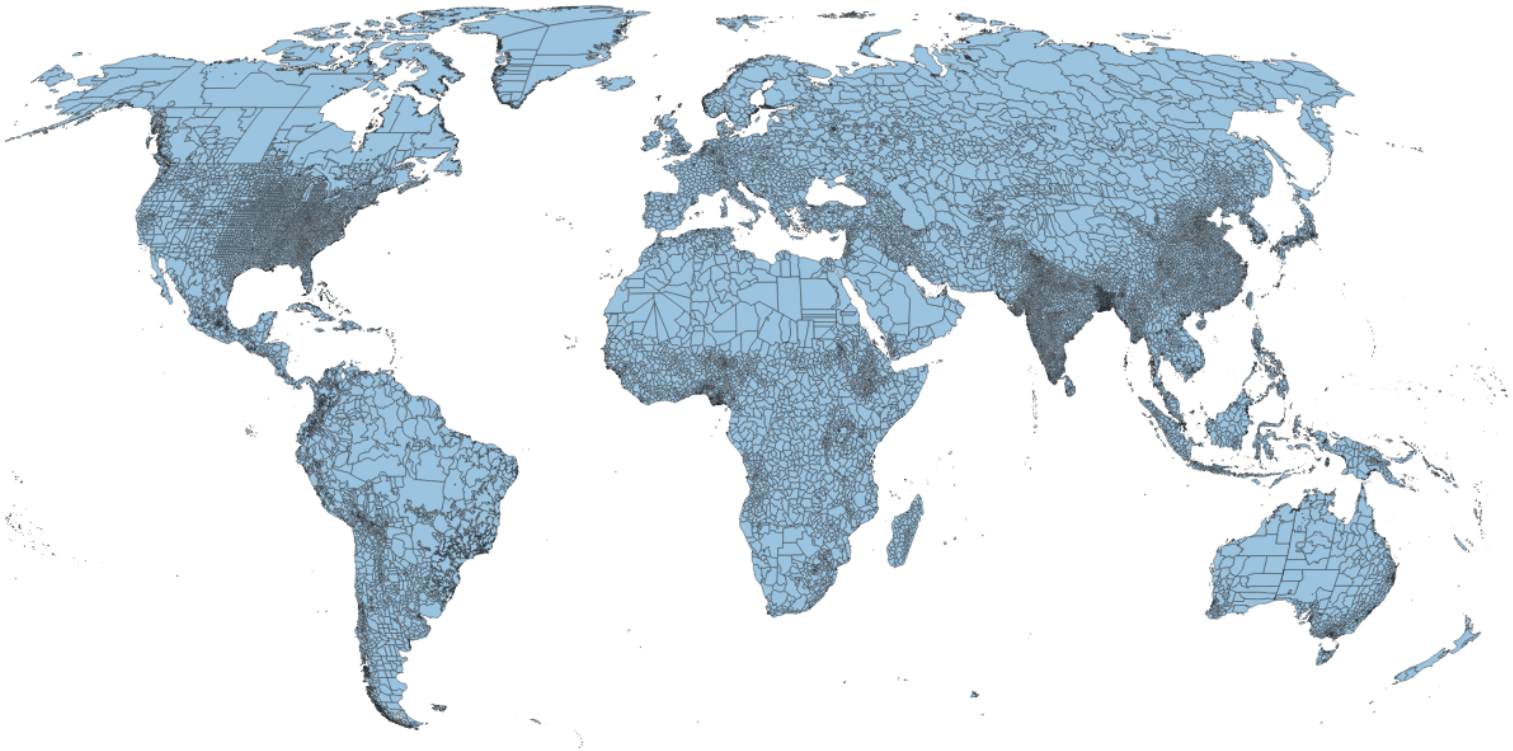


CIL can make local projections of climate impacts

DICE (1992): 1 region

FUND (1996): 16 regions

Climate Impact Lab: 25,000 regions



Damages from climate change are in many sectors

Mortality — heat and cold deaths

Agriculture — crop yields for seven major crops

Energy — energy and electricity demand

Labor — labor supply effects

Conflict — large-scale violent conflict

Crime — interpersonal violent crime

Migration — international and within-country

Coastal — sea level rise and storm damages

The Impact Lab Methodology: A Novel Approach

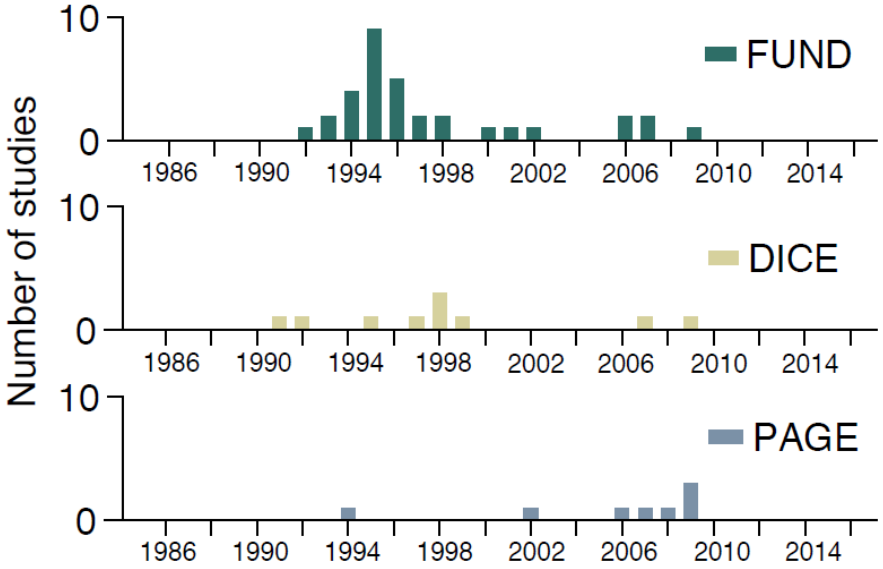
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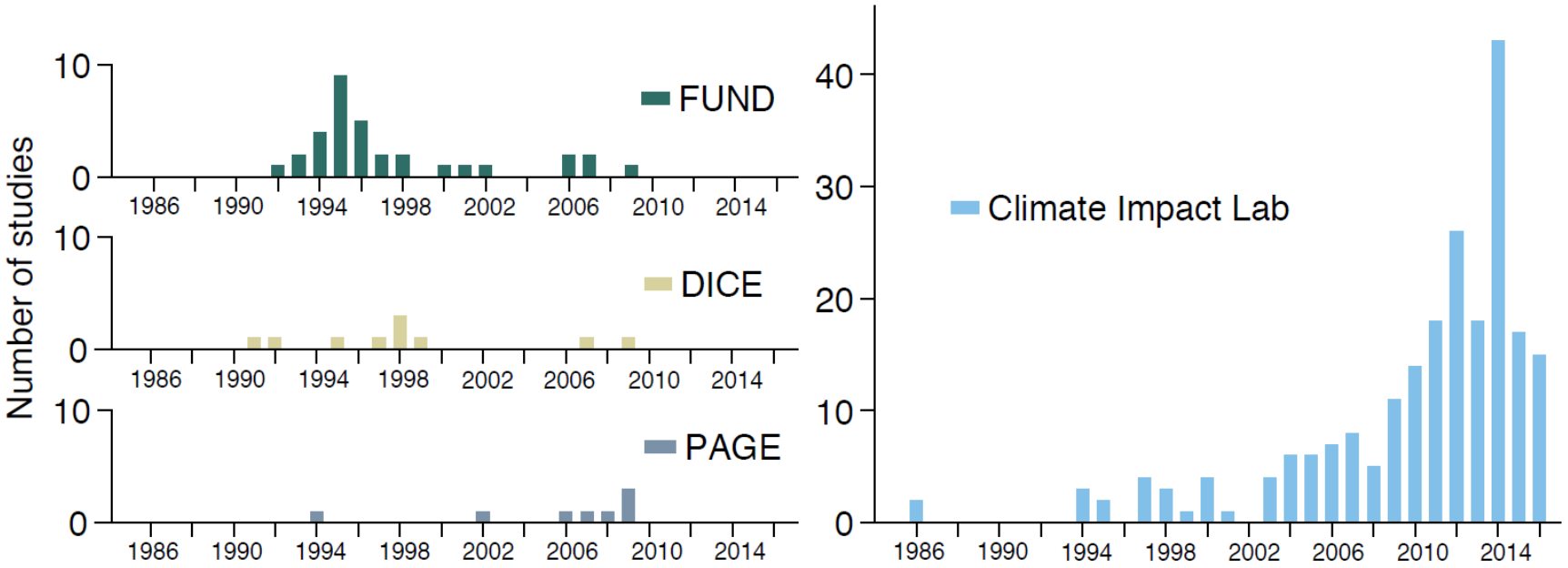
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Big picture: using data, get both the derivatives right

The latest science and economics have much to say



The latest science and economics have much to say



Carleton et al. “**Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits.**” (2019).

An output of the **Climate Impact Lab**

The path to a partial SCC due to mortality

1. Estimate causal effect of climate on mortality, allowing for differences in income and mean climate

2. Predict effect on mortality for every location and year, then sum worldwide

3. Add in adaptation costs

4. Fit global damage function using distribution of projected damages

5. Project global damages by year and compute PDV to obtain SCC

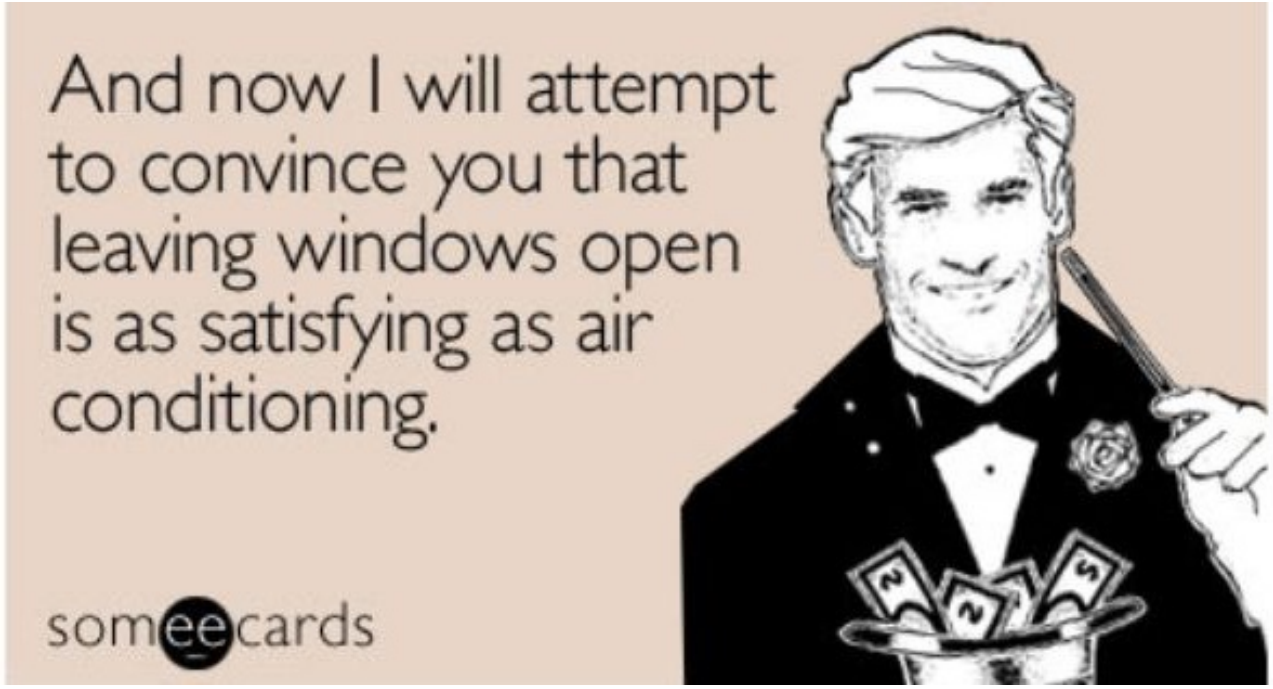
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Why Adaptation Matters



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Farmers in India must adapt to rising temperatures



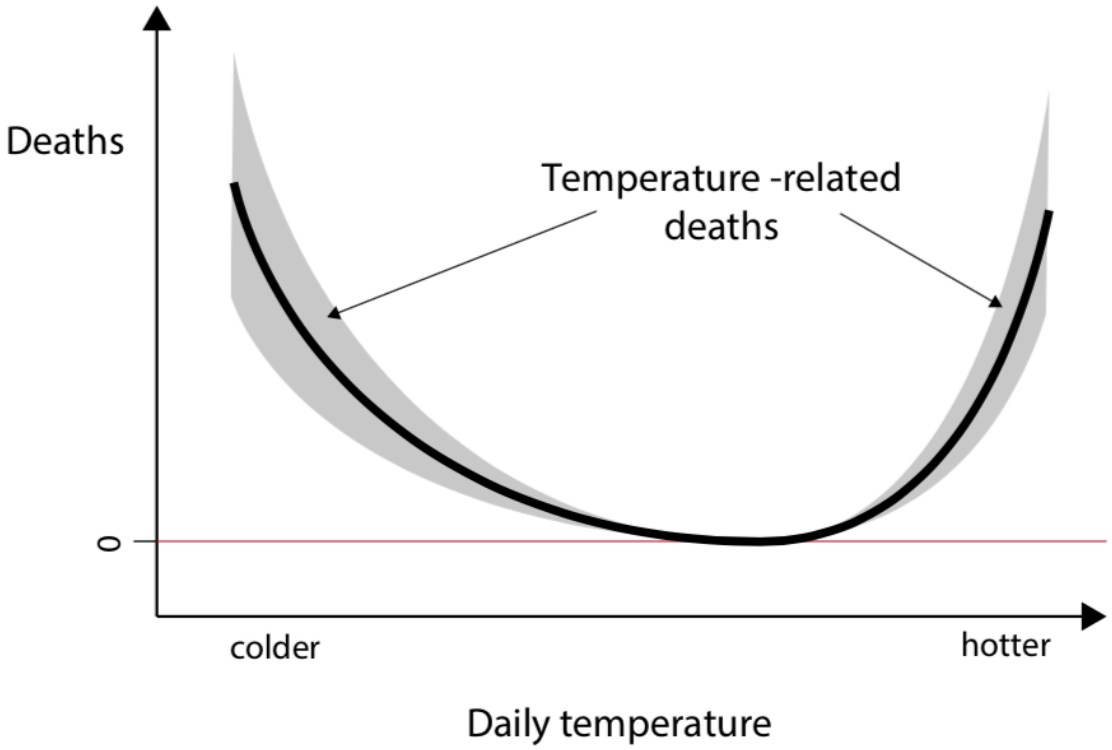
Houston benefits from investments in adaptation





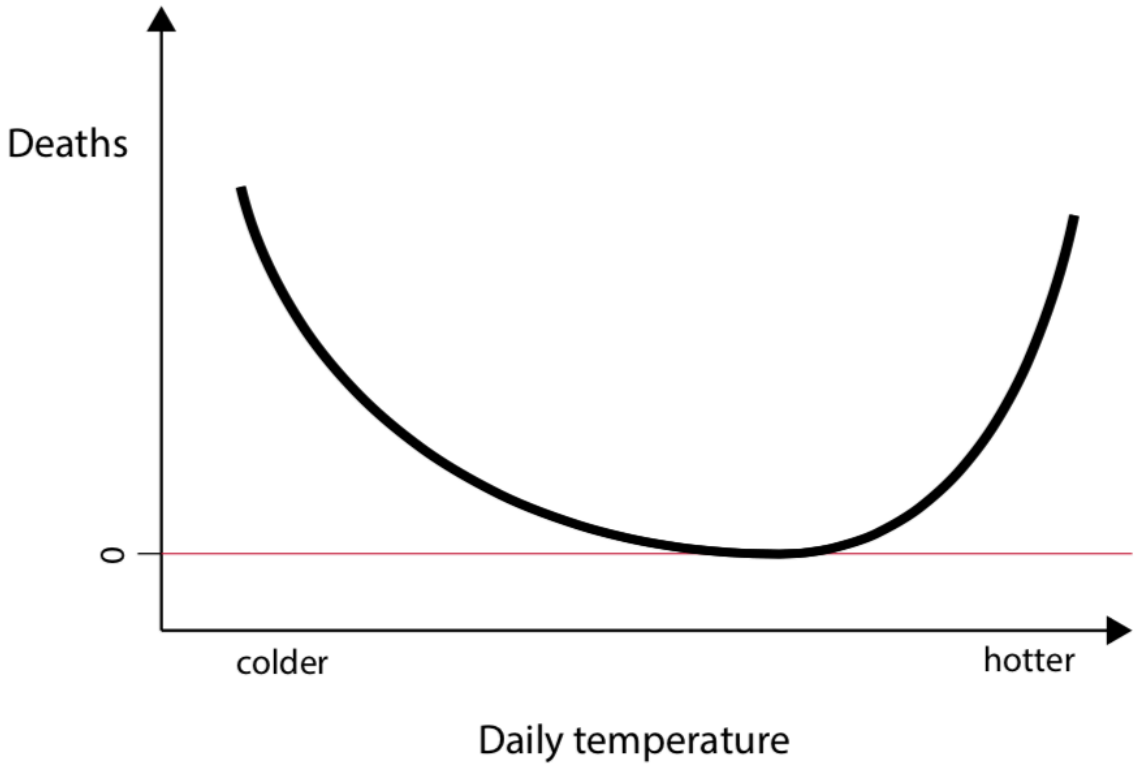
Why Adaptation Matters

Mortality typically responds to both cold and hot temperatures but may be less responsive as people become more adapted to their climate.



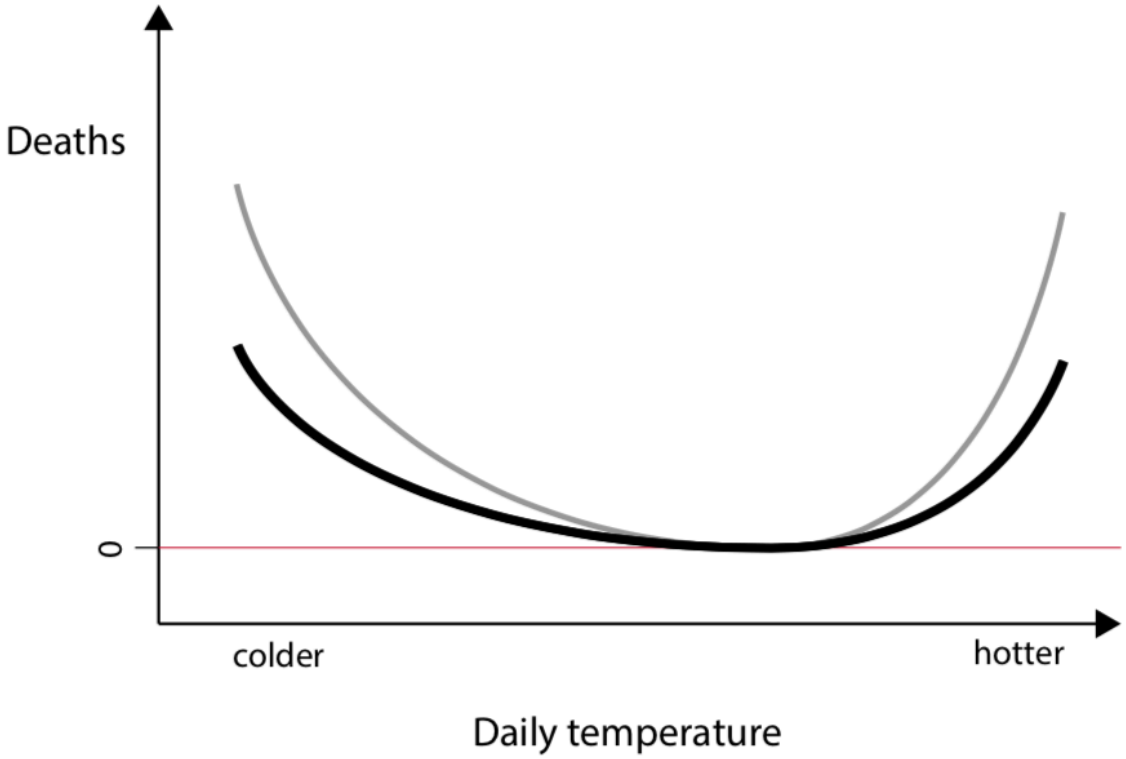
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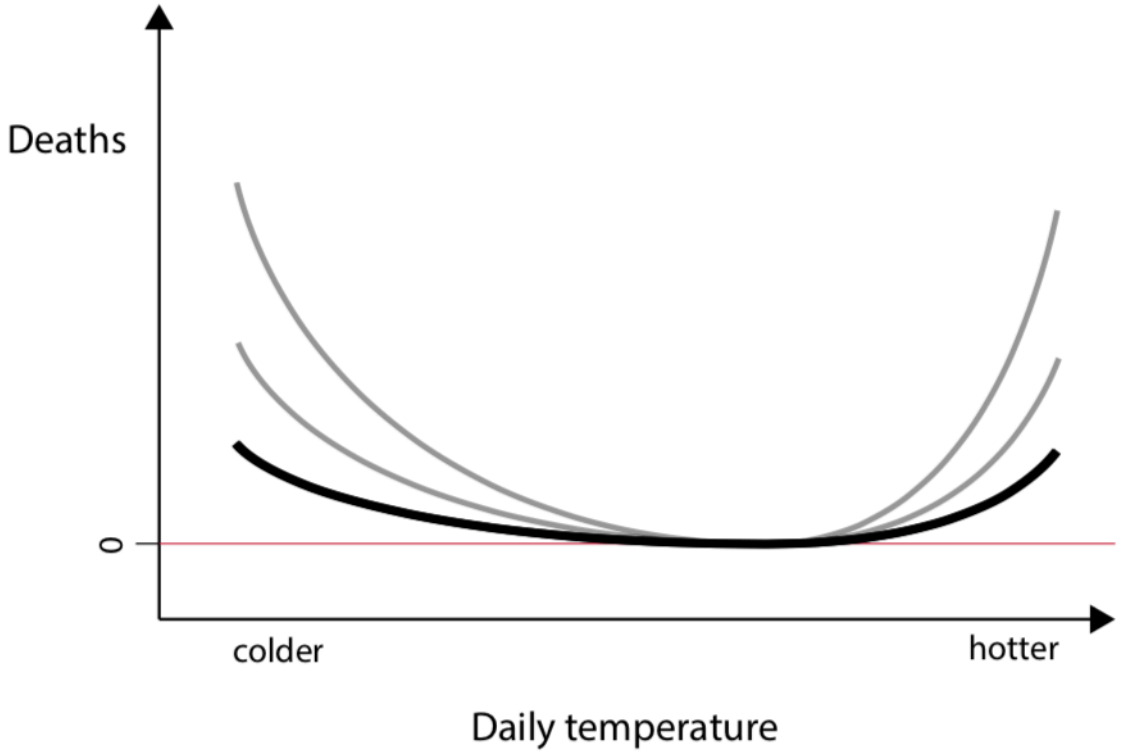
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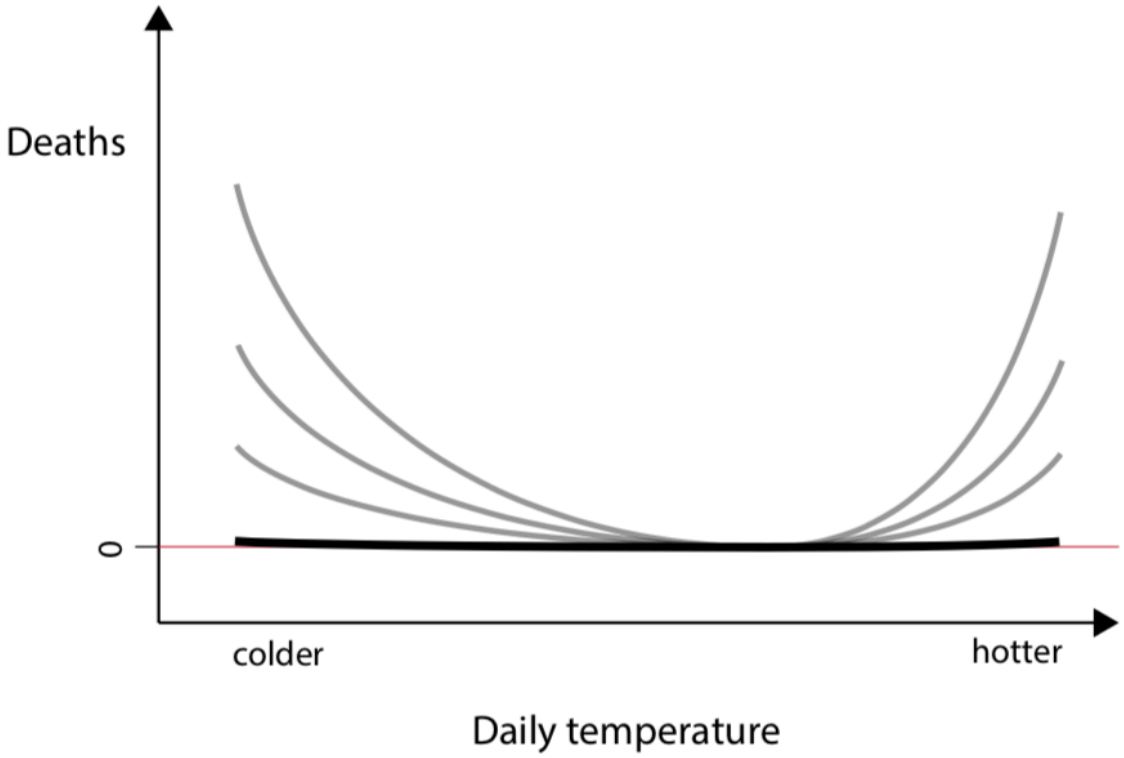
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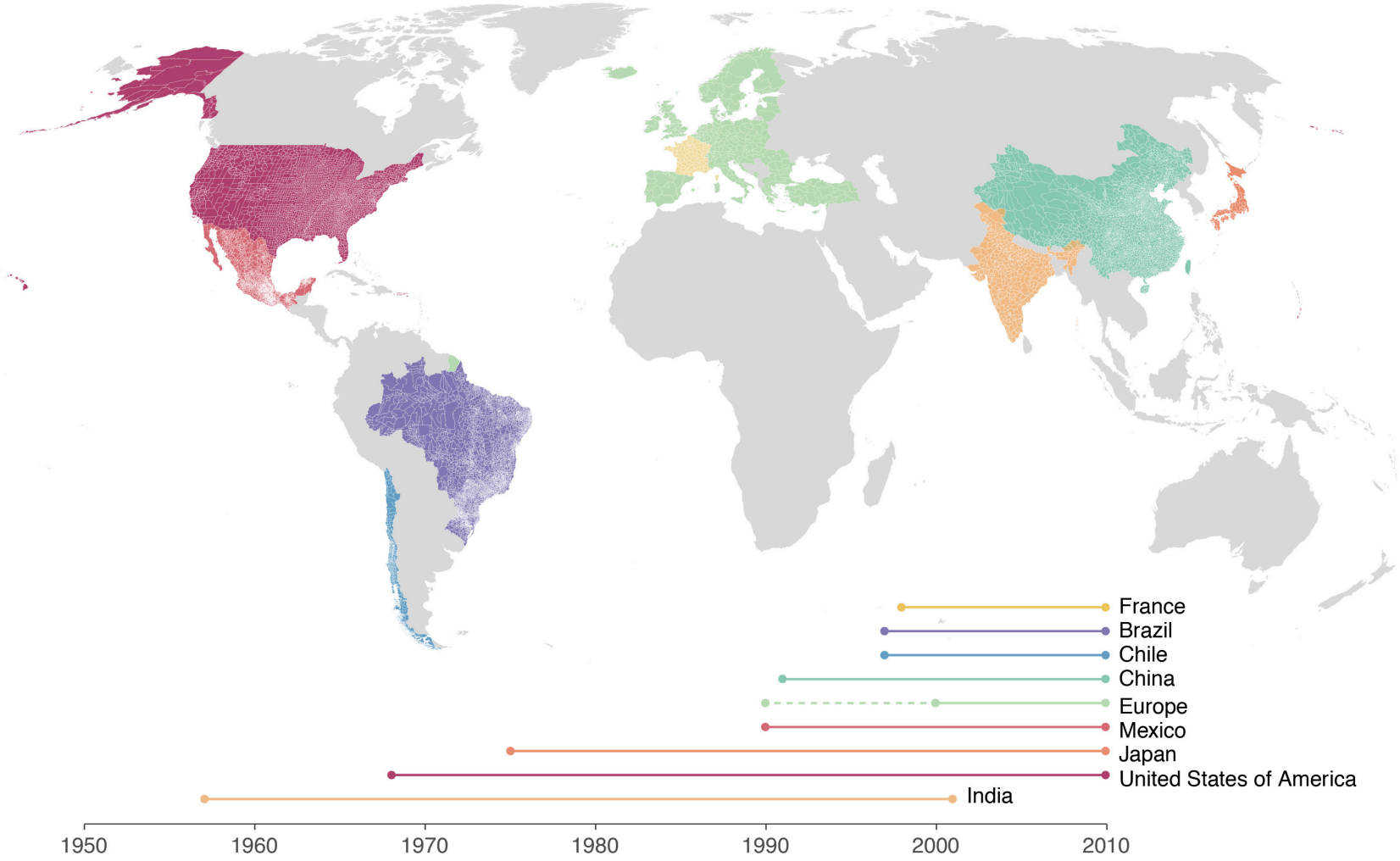


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Historical data on mortality



Estimating the mortality-temperature relationship that reflects adaptation

Allow the shape of the function to vary with income and long-run average temperature.

Intuition: richer and hotter places are more likely to have air conditioning

Estimating the mortality-temperature relationship that reflects adaptation

Allow the shape of the function to vary with income and long-run average temperature.

Intuition: richer and hotter places are more likely to have air conditioning

$$Mortality\_rate_{ait} = \sum_p \beta_a^p \, \overline{Temp}_{it}^p + g_a(Precip_{it}) + \alpha_{ai} + \delta_{act} + \varepsilon_{ait}$$

$$\uparrow$$

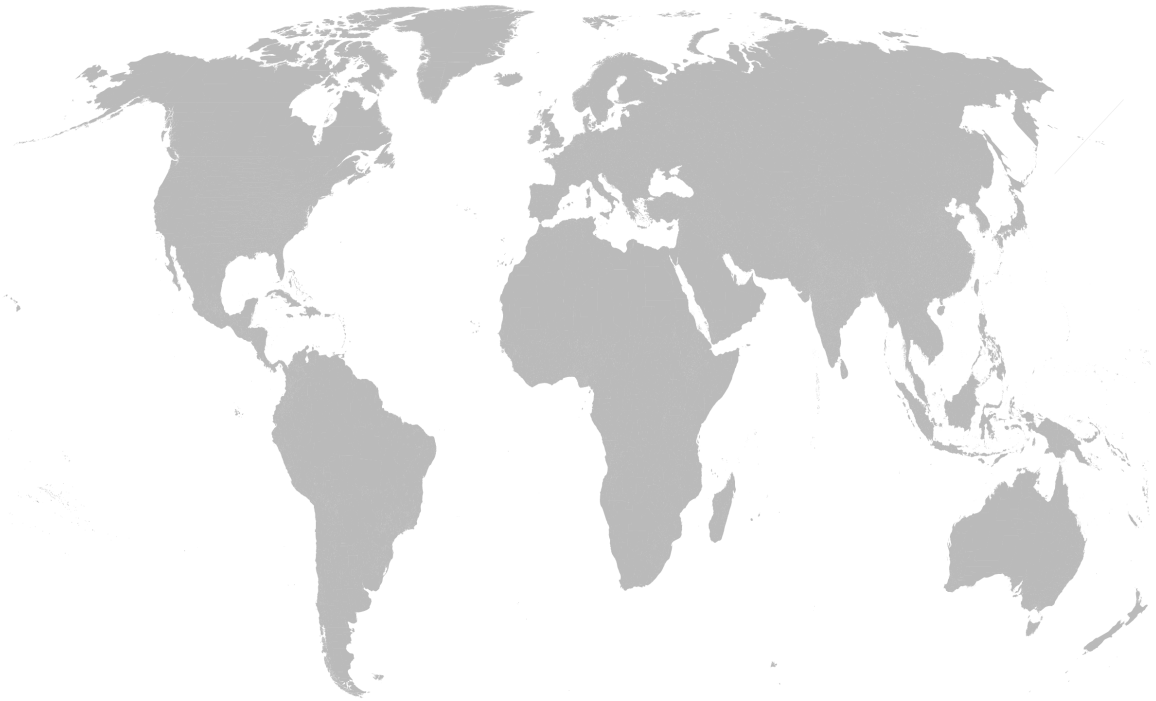
$$\beta^p(s) = \gamma_{a,0}^p + \gamma_{a,1}^p \, TMEAN_s + \gamma_{a,2}^p \, \log(GDPpc)_s$$

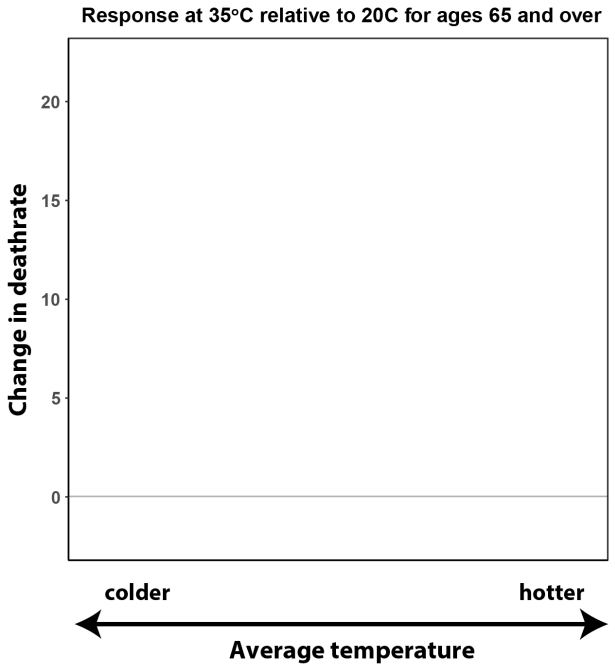
a = age group, i = county ("adm2"), s = state ("adm1"), c = country, t = year

Cross sectional covariates at "state" s (adm1)

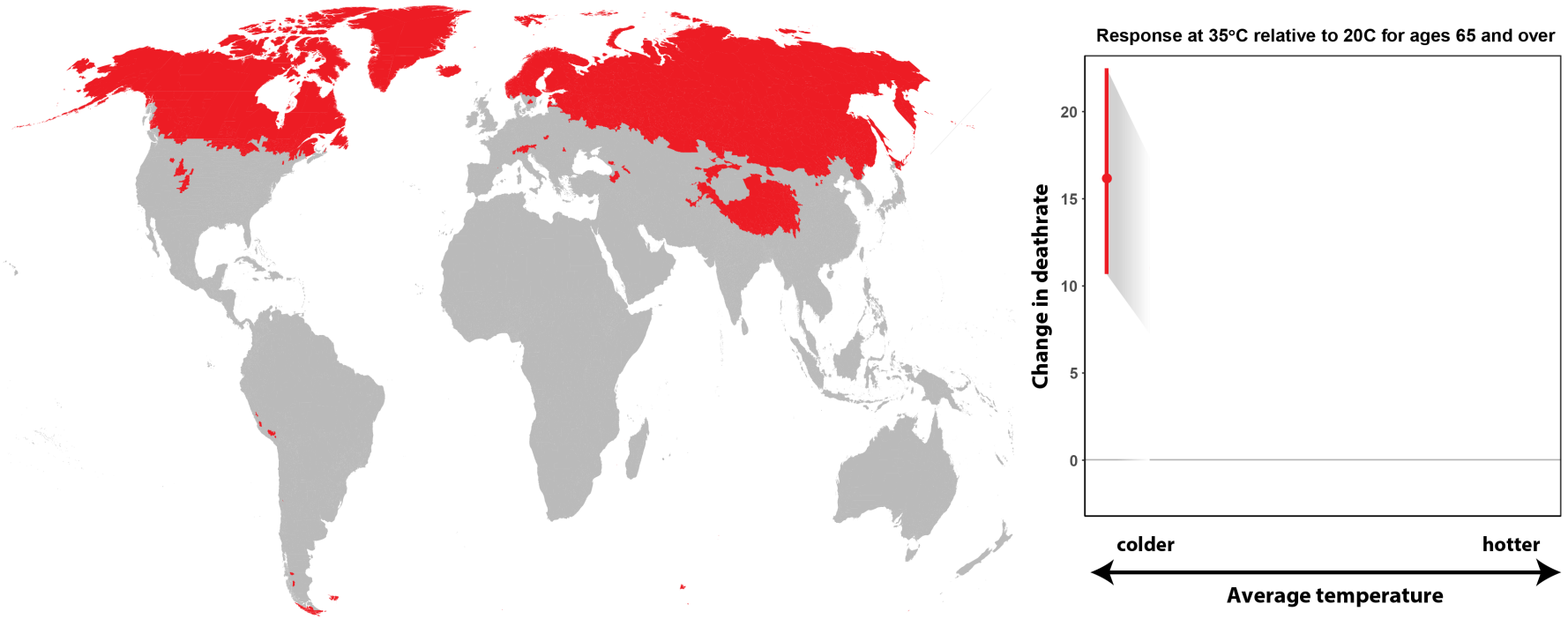
→ $TMEAN_s$ = long-run avg. temperature

→ $\log(GDPpc)_s$ = average log income per capita

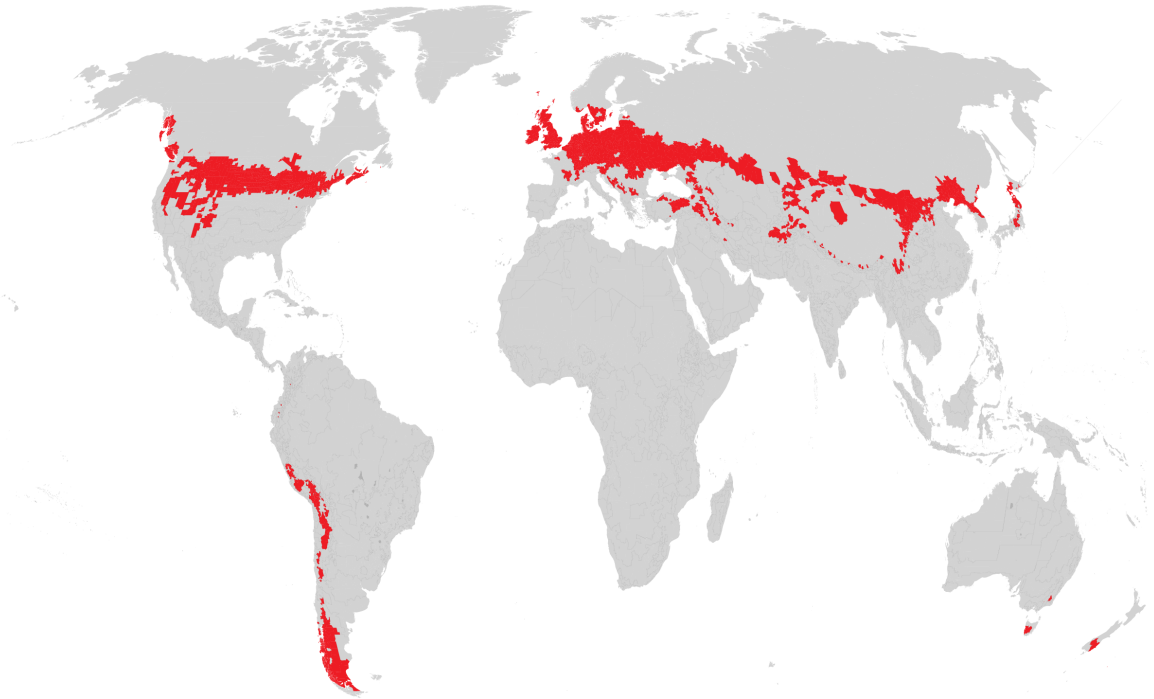


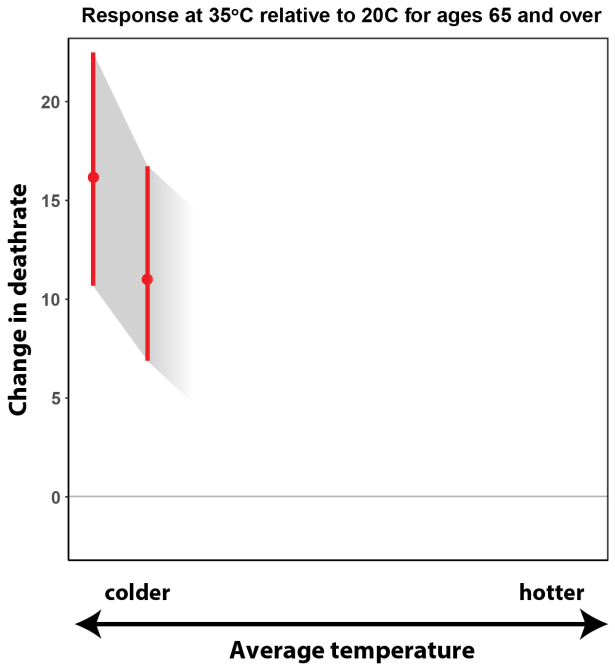


Effect day at 35°C relative to 20°C for ages 65 and over.
Coefficient calculated for deciles of *TMEAN* (red shaded area).

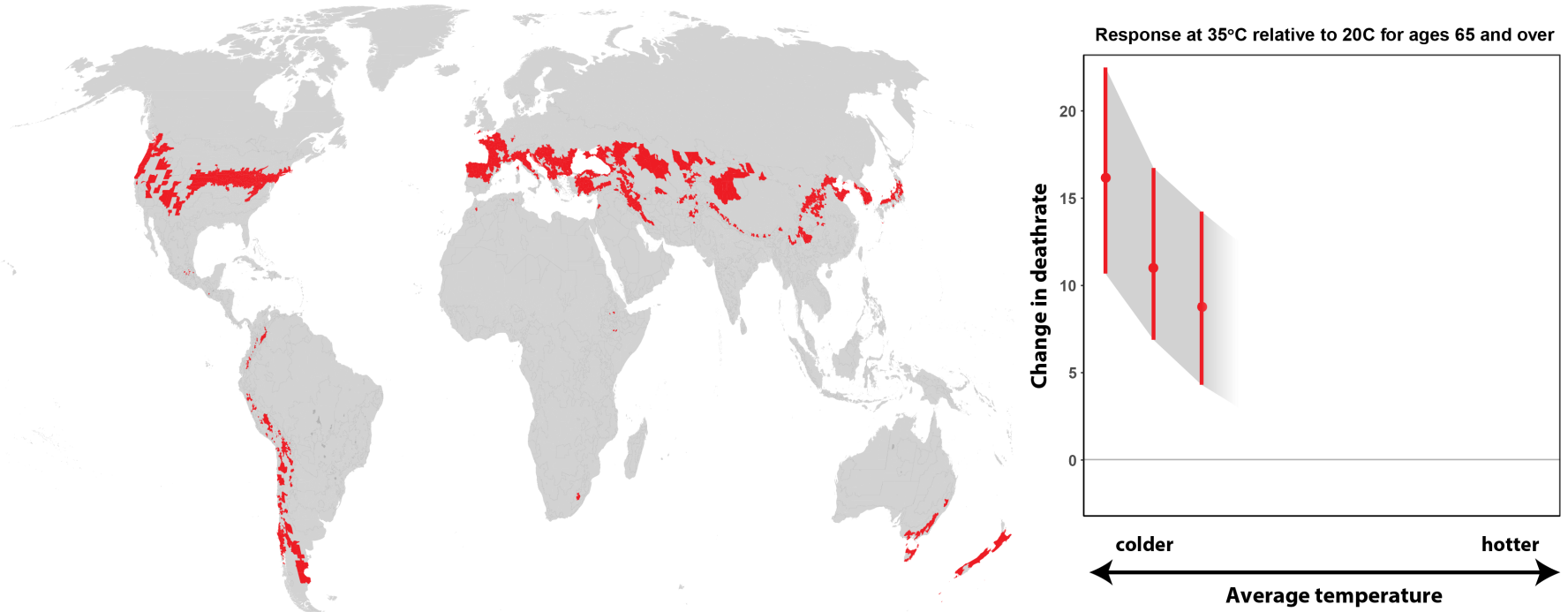


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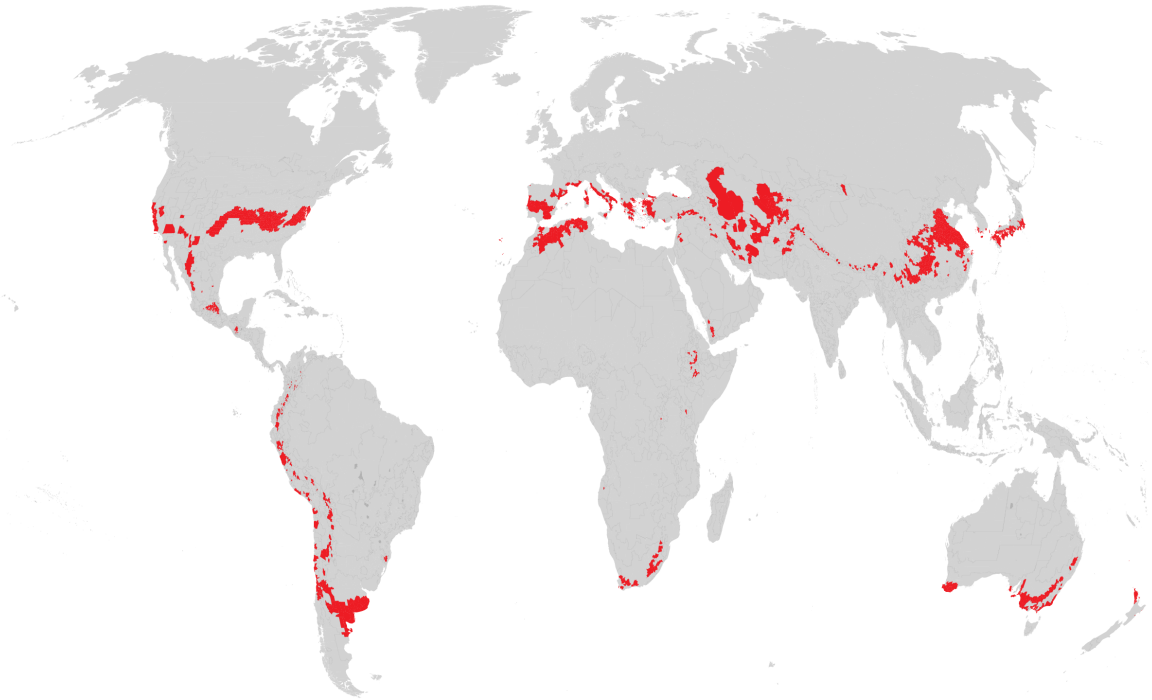


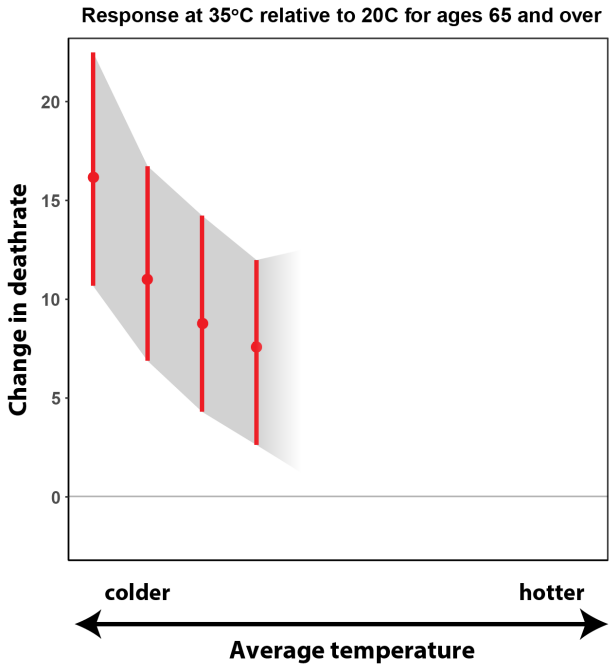


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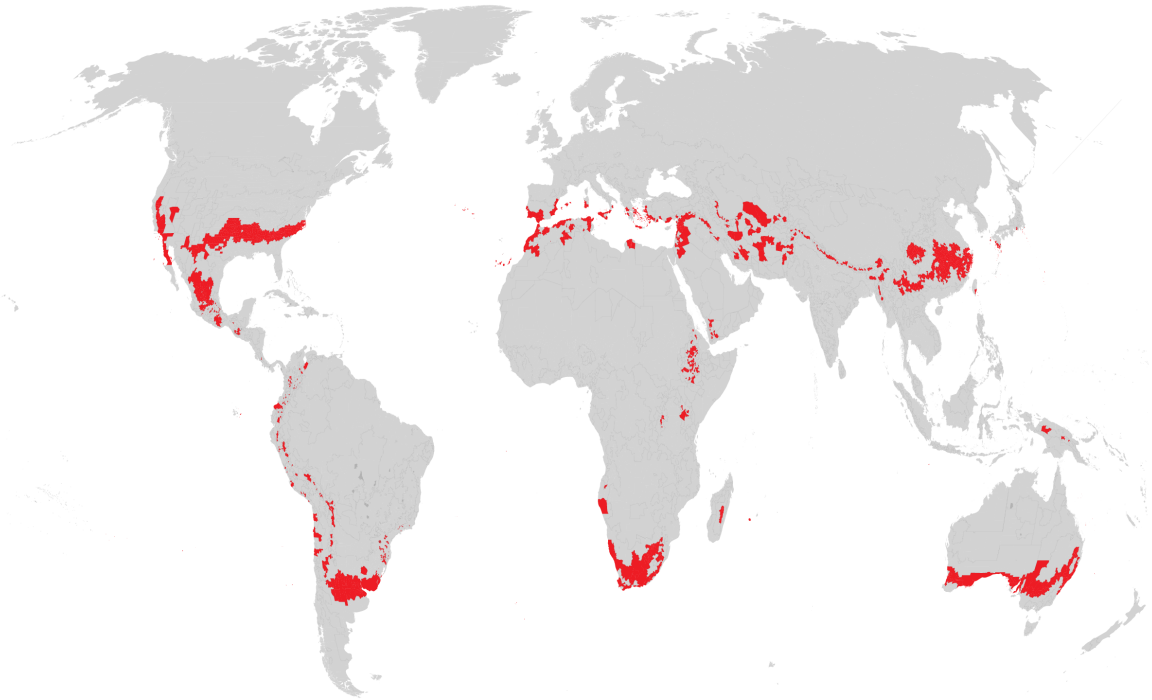


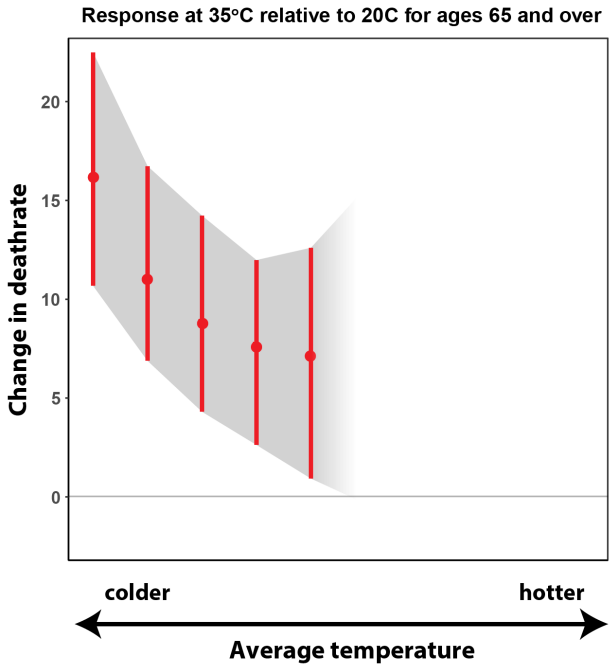
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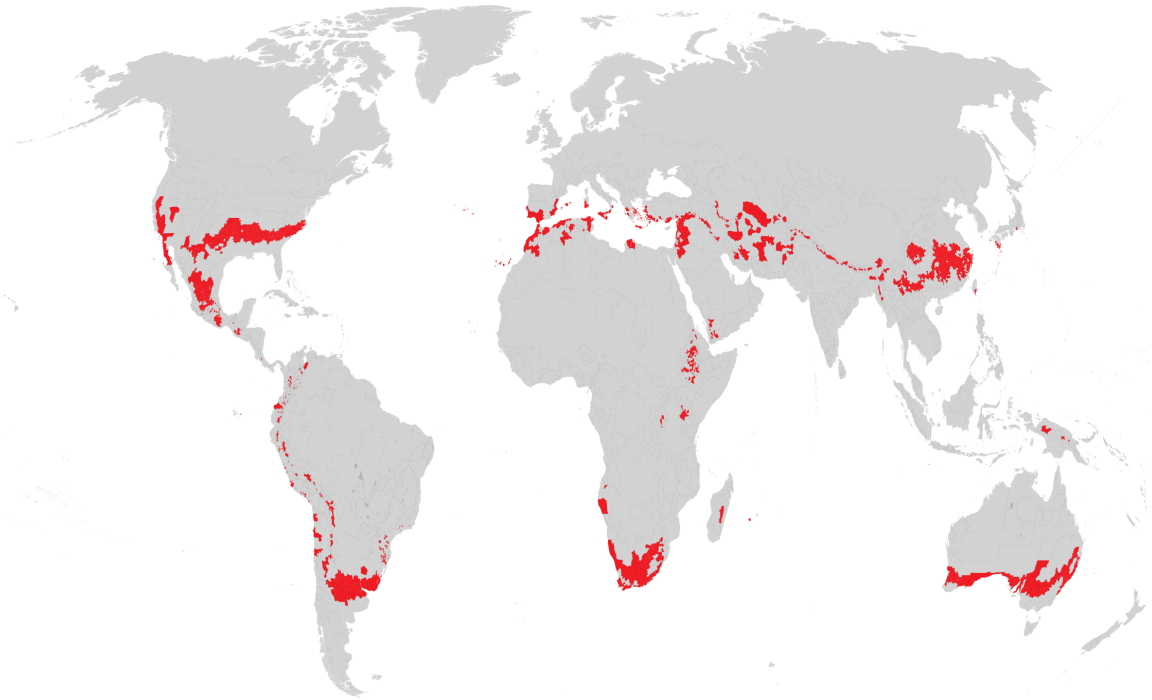


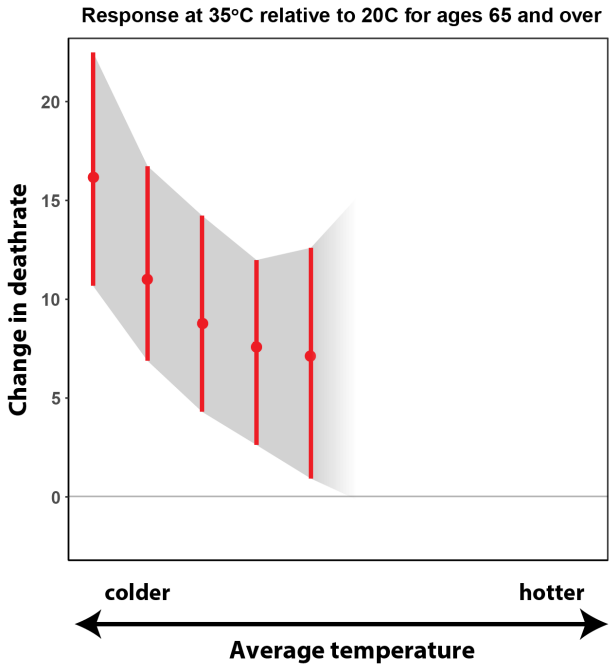
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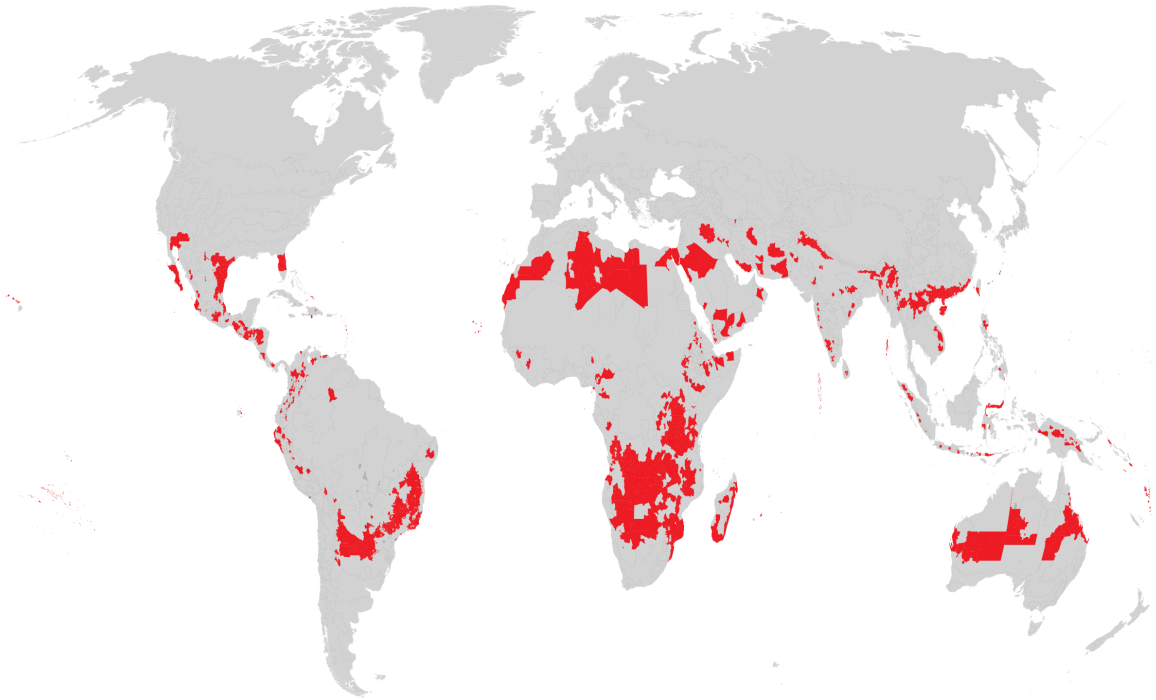


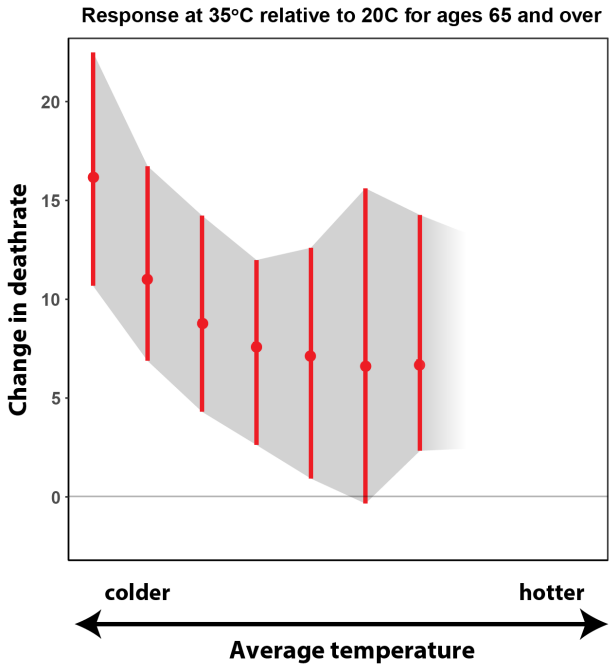
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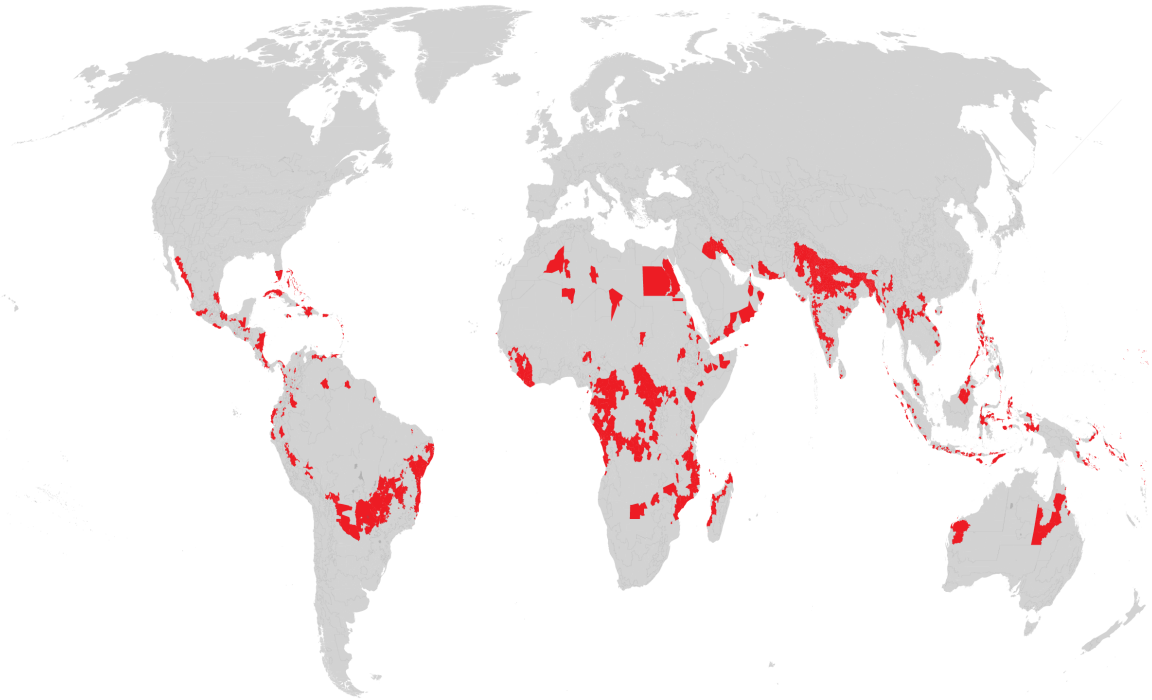


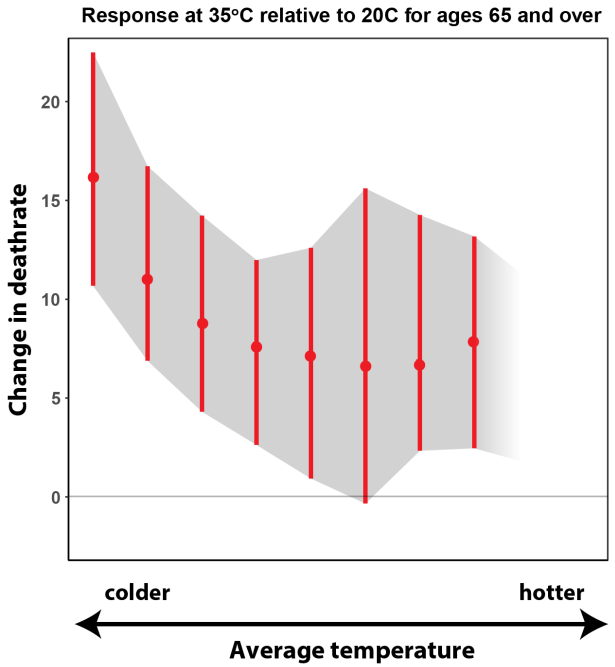
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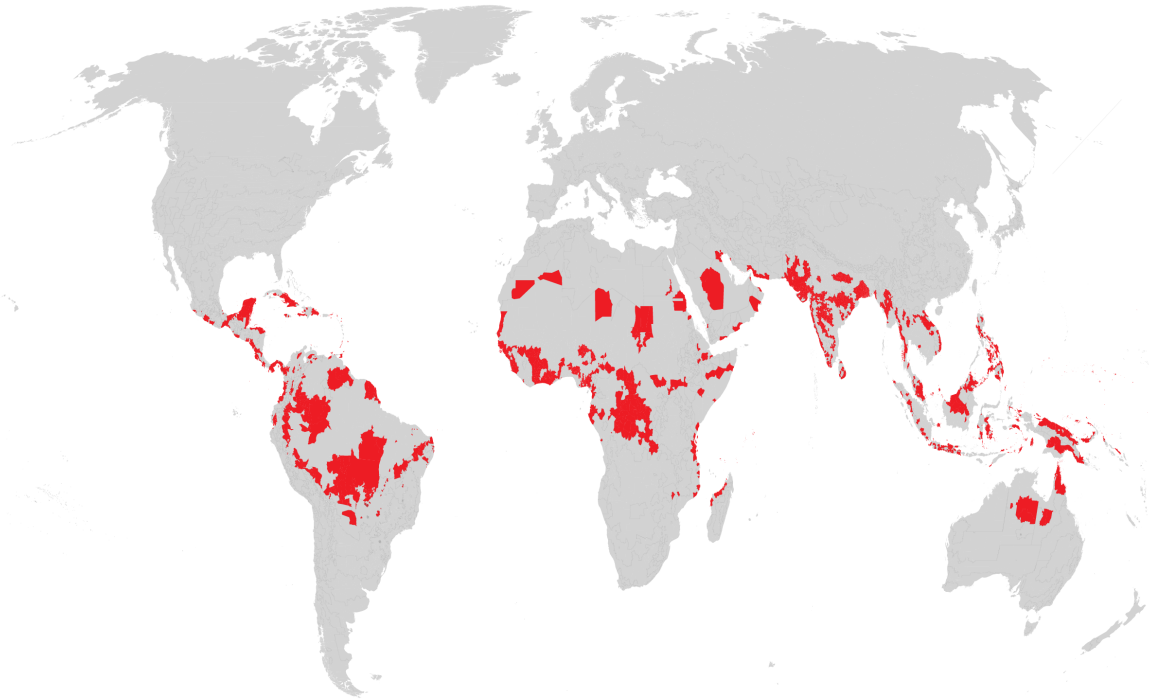


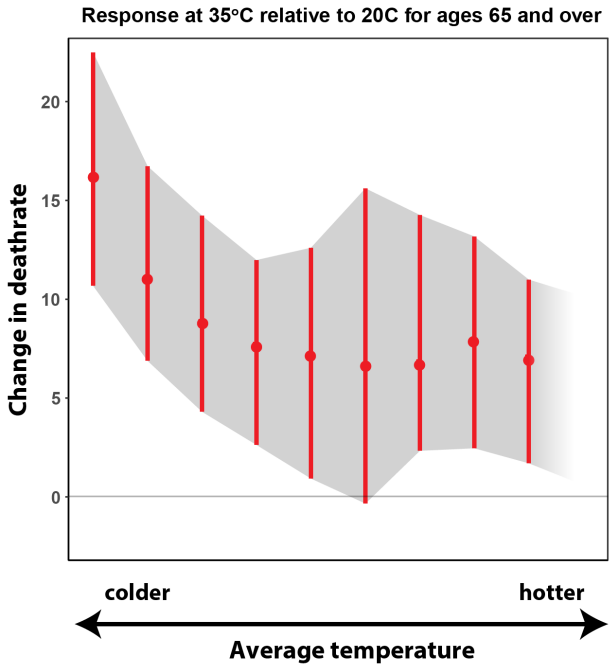
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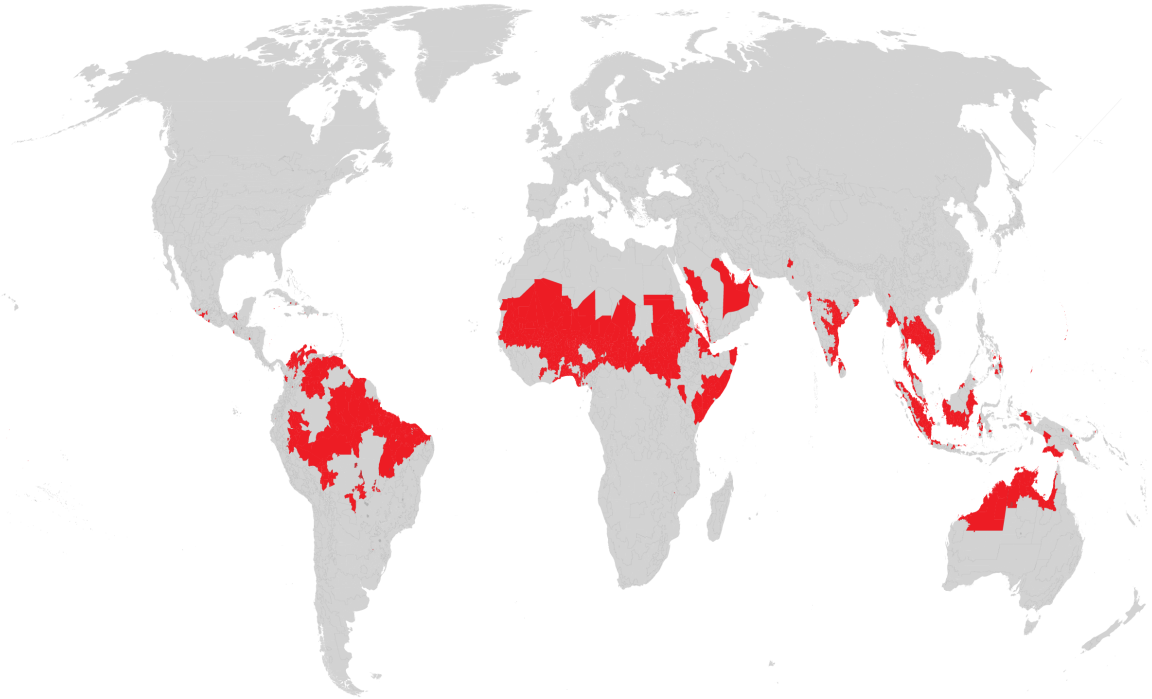


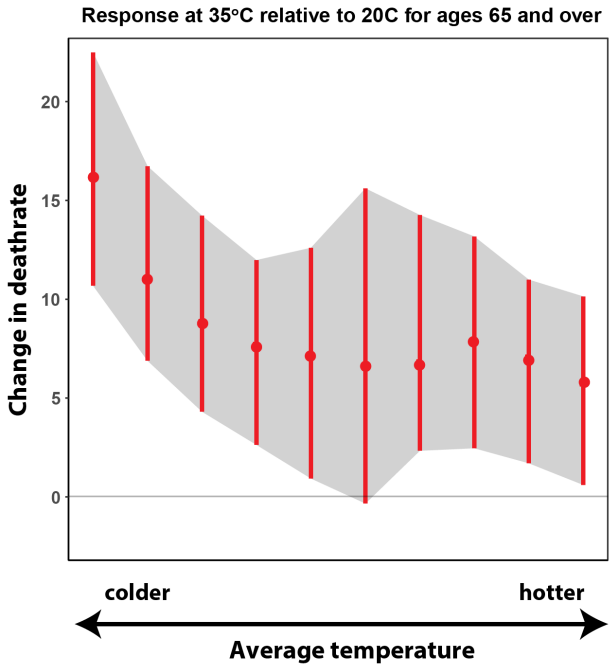
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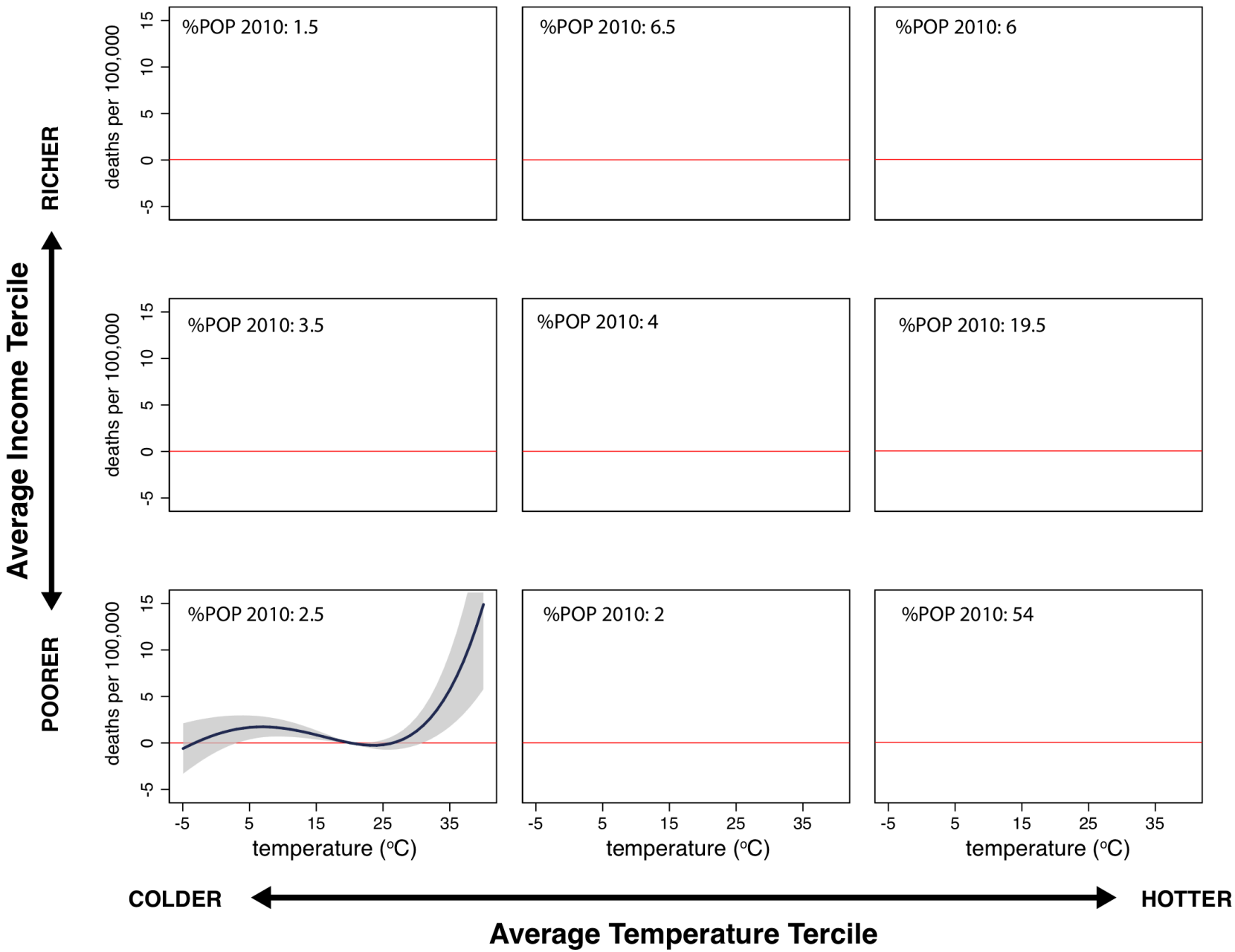


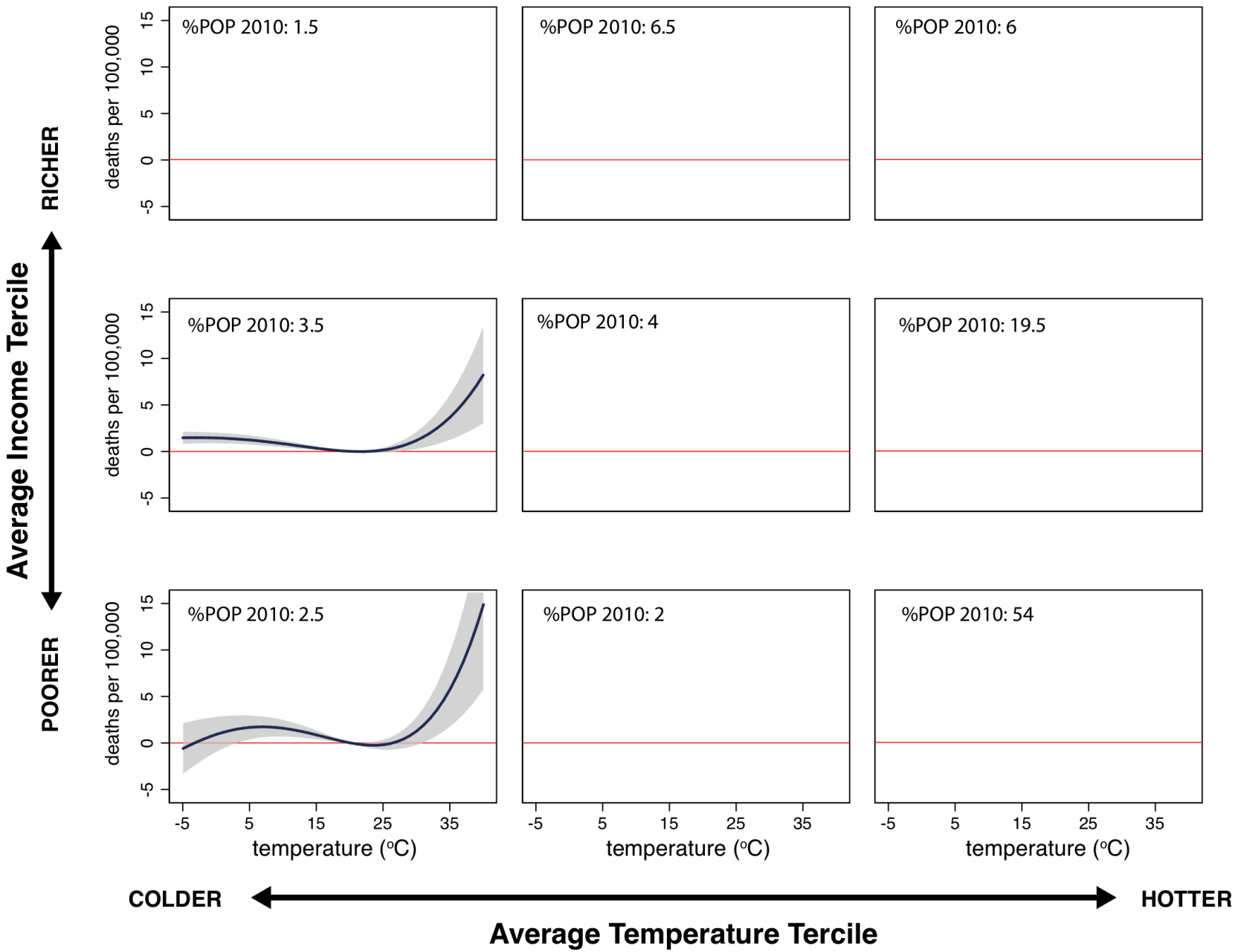
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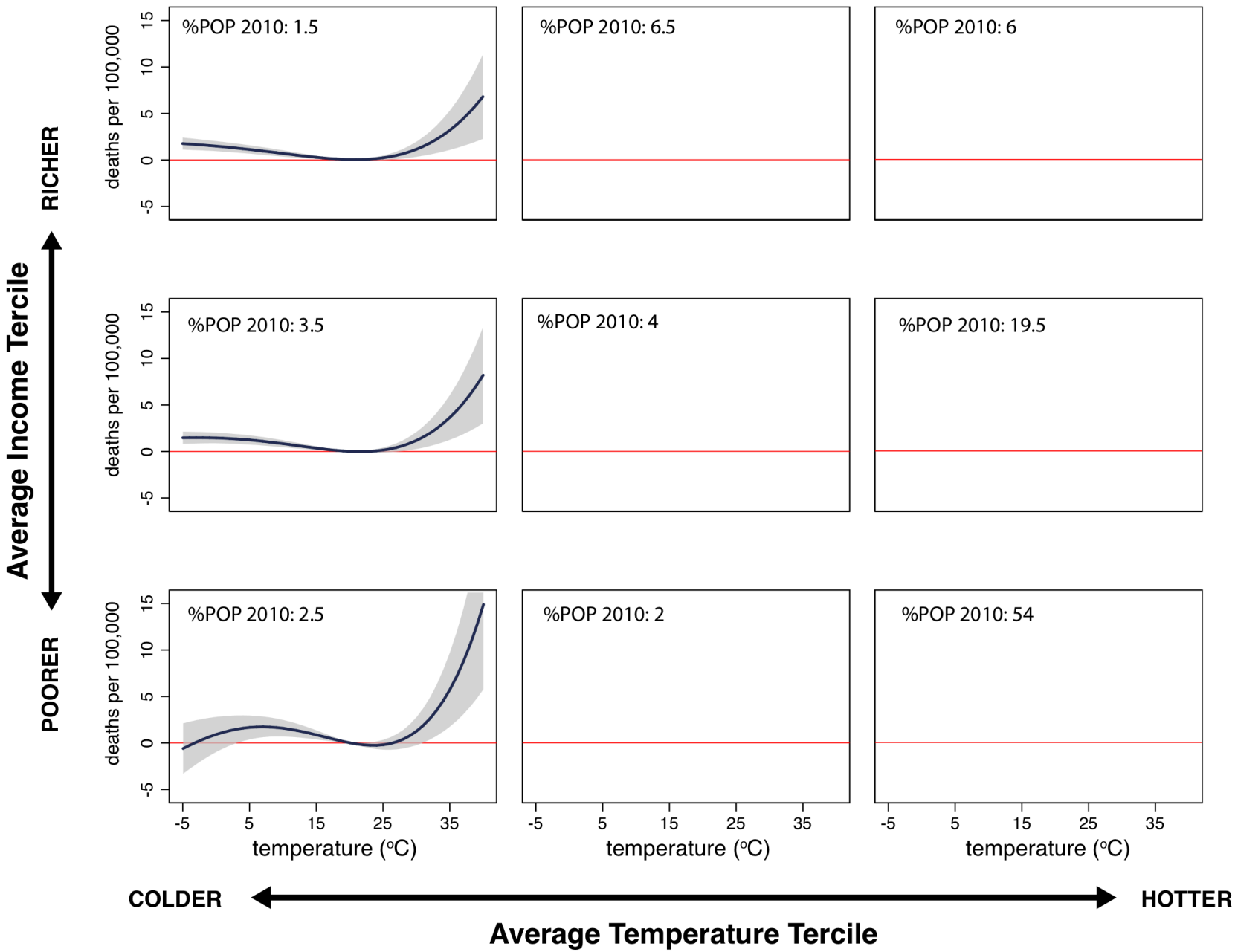


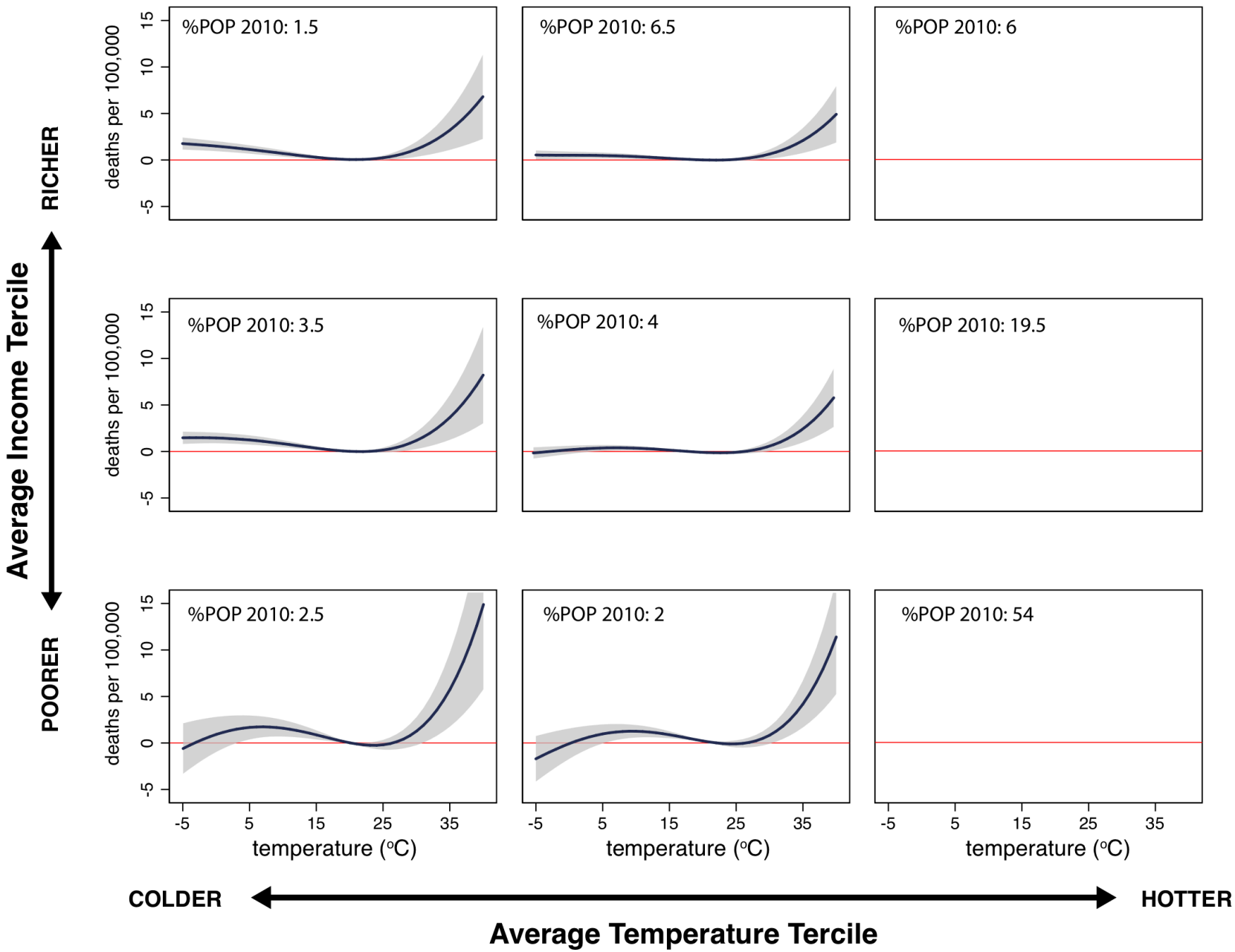


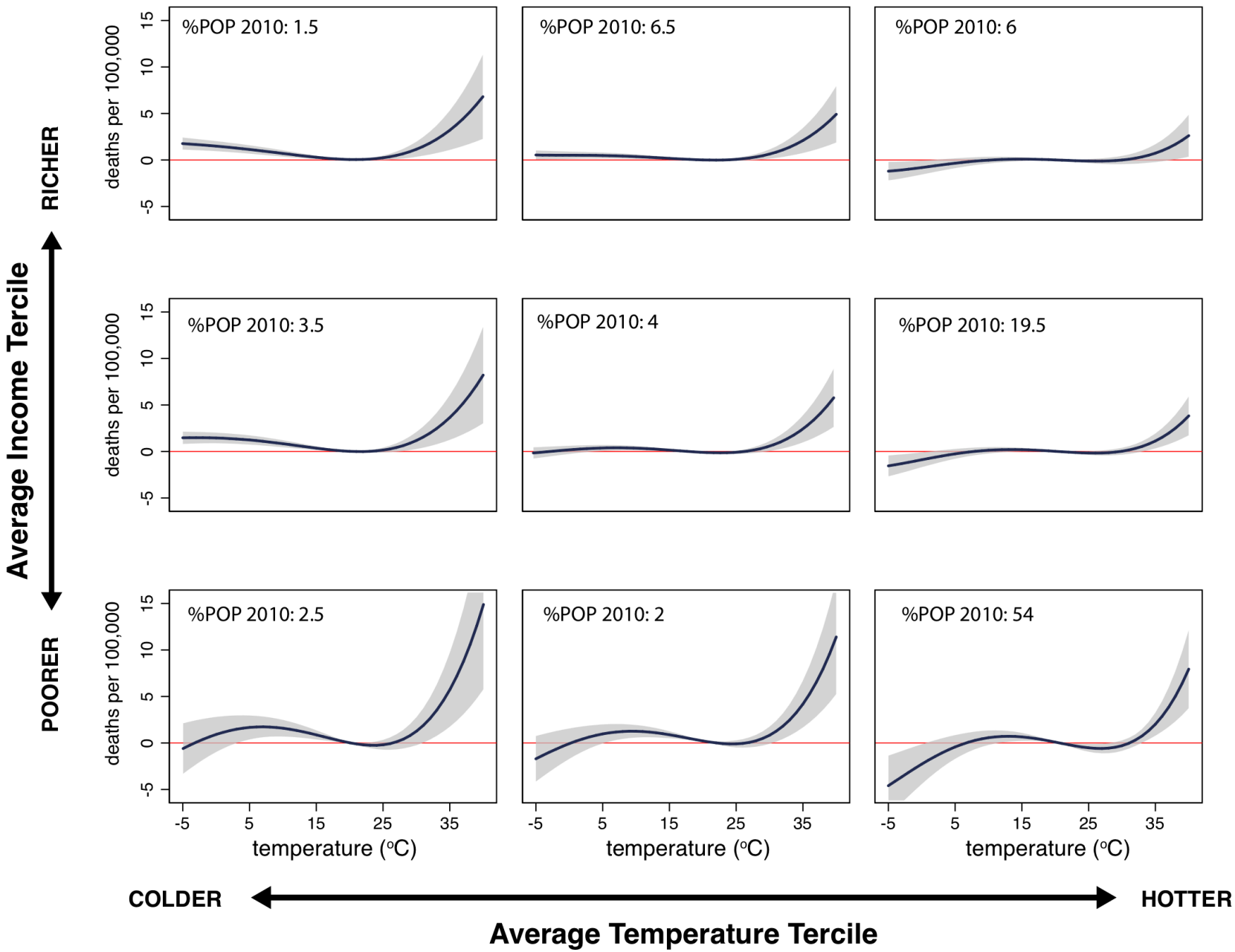
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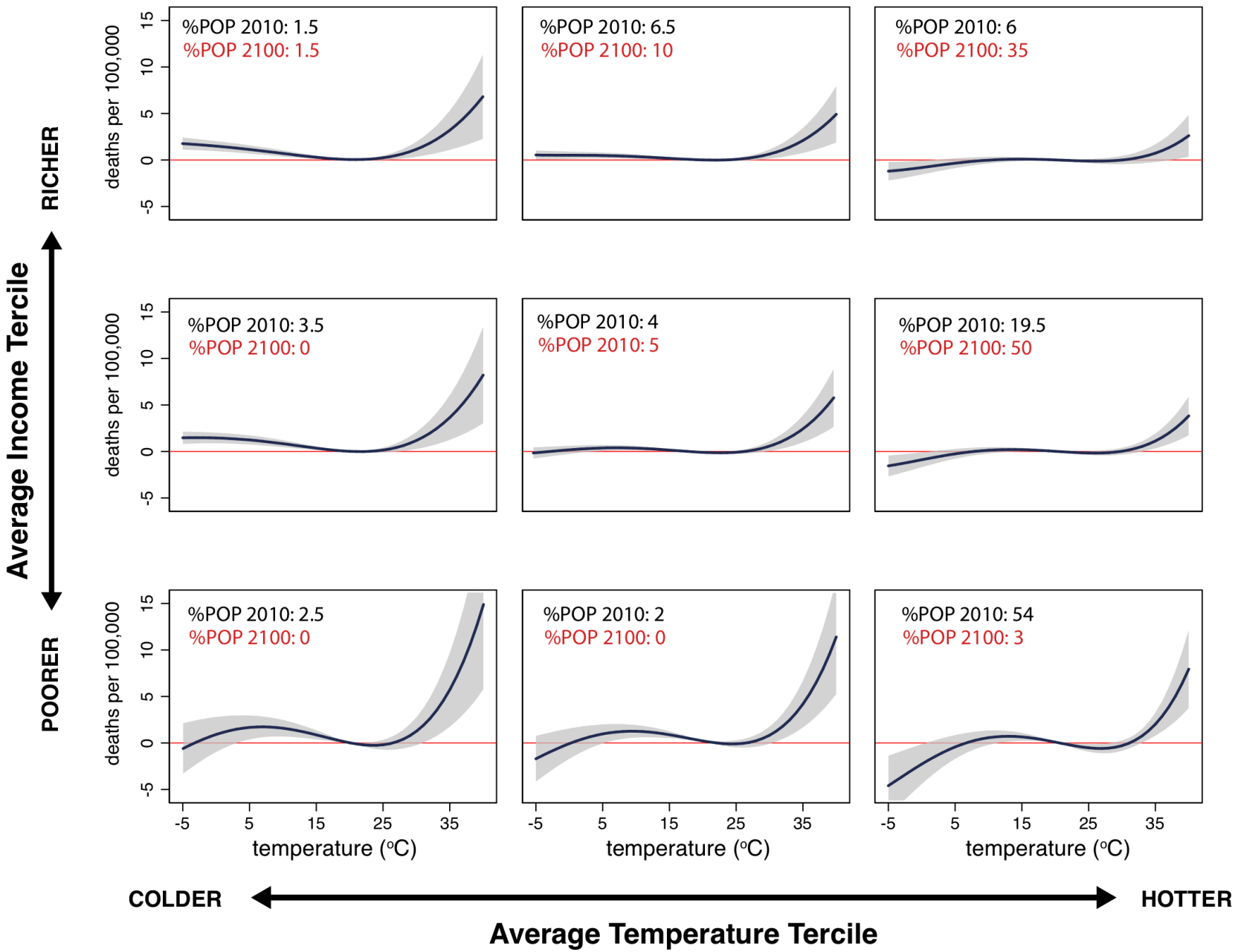

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%POP 2010: 6.5
%POP 2010: 6
%POP 2010: 3.5
%POP 2010: 4
%POP 2010: 19.5
%POP 2010: 2.5
%POP 2010: 2
%POP 2010: 54
deaths per 100,000
-5
0
5
10
15
-5
5
15
25
35
temperature (°C)
RICHER
POORER
Average Income Tercile
COLDER
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%POP 2010: 1.5
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%POP 2010: 2
%POP 2100: 0
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The path to a partial SCC due to mortality

1. Estimate causal effect of climate on mortality, allowing for differences in income and mean climate

2. **Predict effect on mortality for every location and year, then sum worldwide**

3. Add in adaptation costs

4. Fit global damage function using distribution of projected damages

5. Project global damages by year and compute PDV to obtain SCC

Project sensitivity to hot days around the world

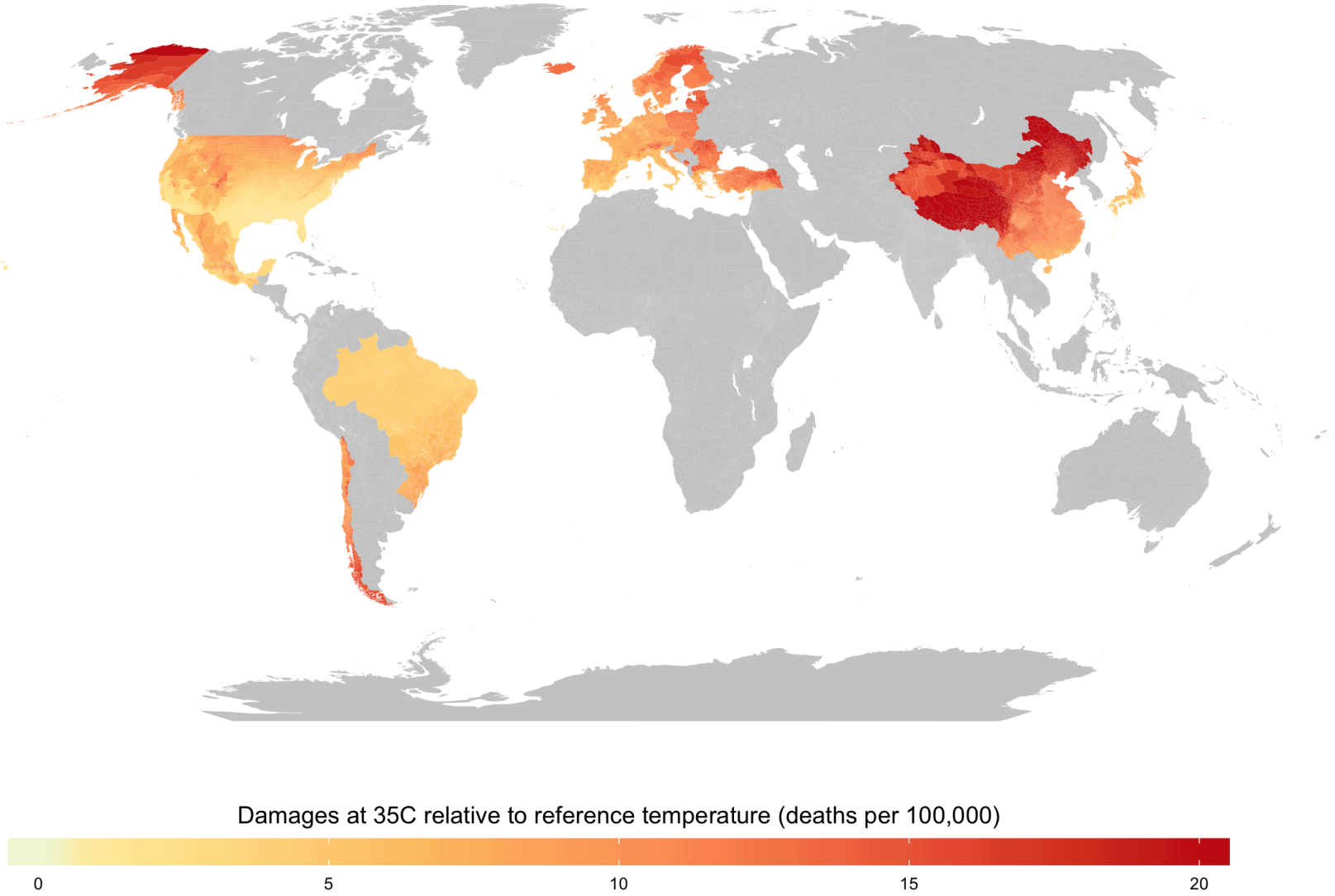
Give mean long-run temperature and GDP per capita, we can now project sensitivity to temperature **anywhere** and **anytime** as

$$\hat{\beta}^p(s) = \hat{\gamma}_0^p + \hat{\gamma}_1^p \underbrace{TMEAN_s}_{observable} + \hat{\gamma}_2^p \underbrace{\log(GDPpc)_s}_{observable}$$

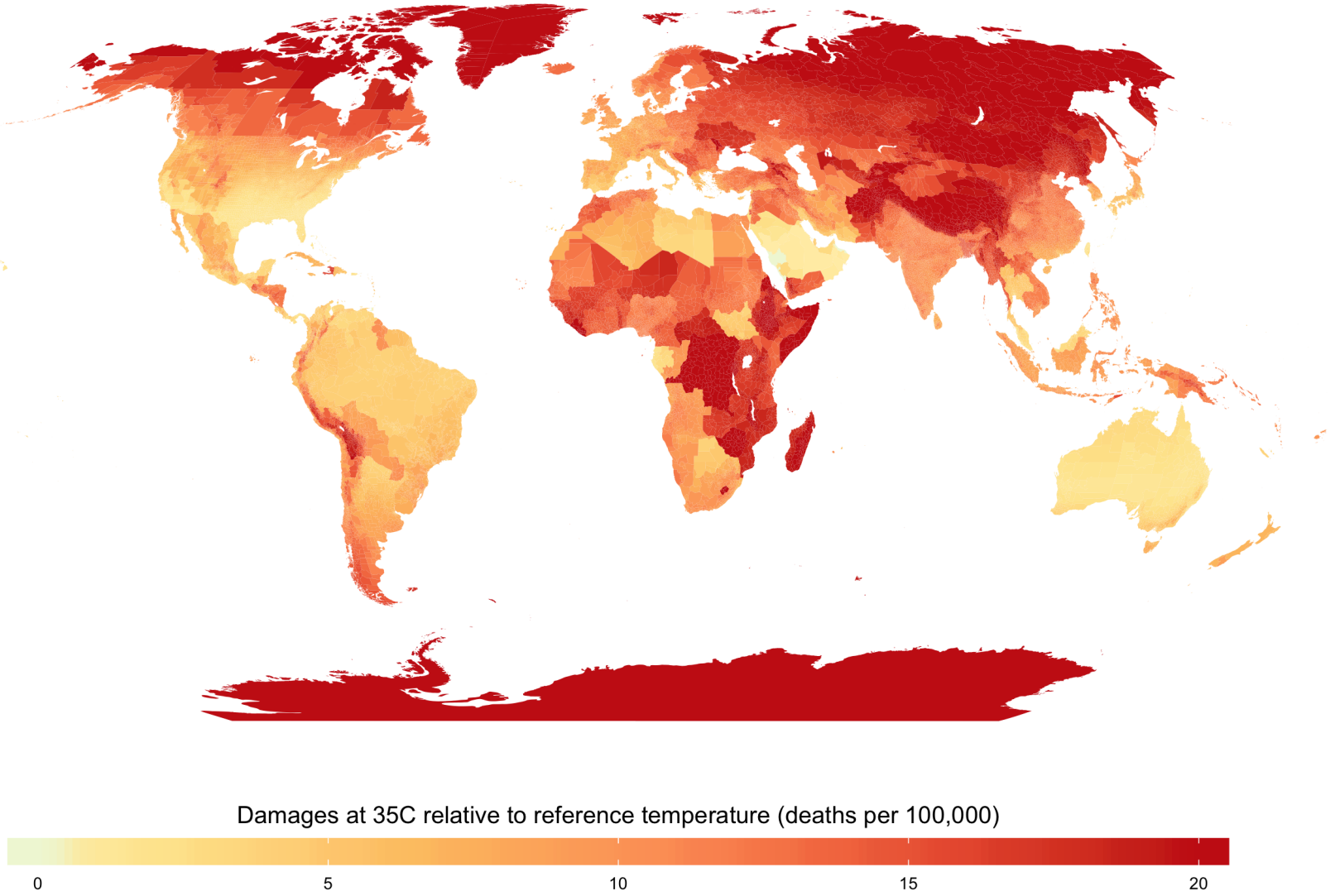
using data from:

- **GDP per capita (*GDP*):**
  - OECD x nightlights → downscale income to subnational level
  - IIASA Shared Socioeconomic Pathways (SSP) incomes to 2100
- **Long-run climate (*TMEAN*):**
  - 33 GCMs downscaled to impact region level
  - Average climate = 15-year average of temperature

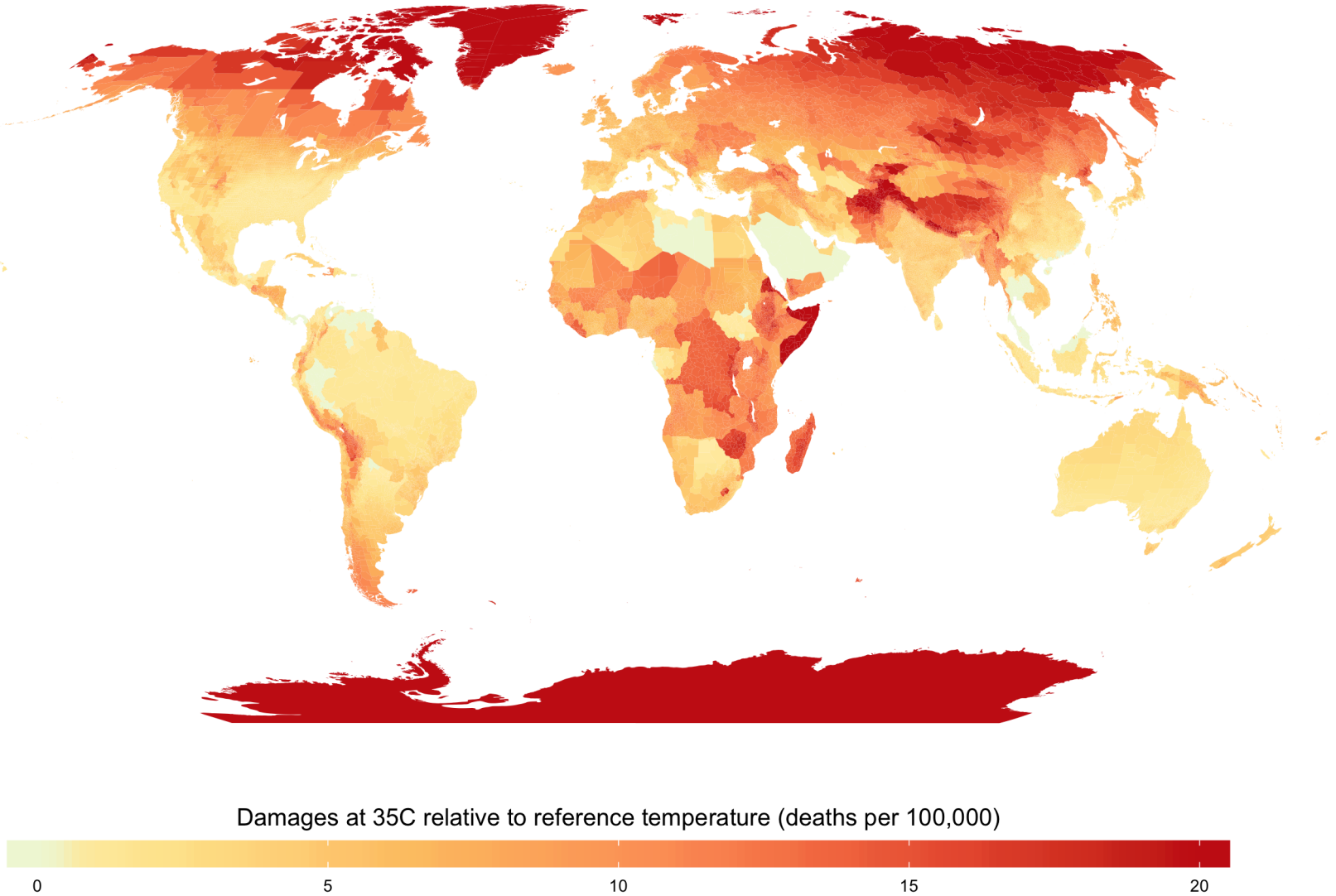
Sensitivity to hot days: our sample, 65+



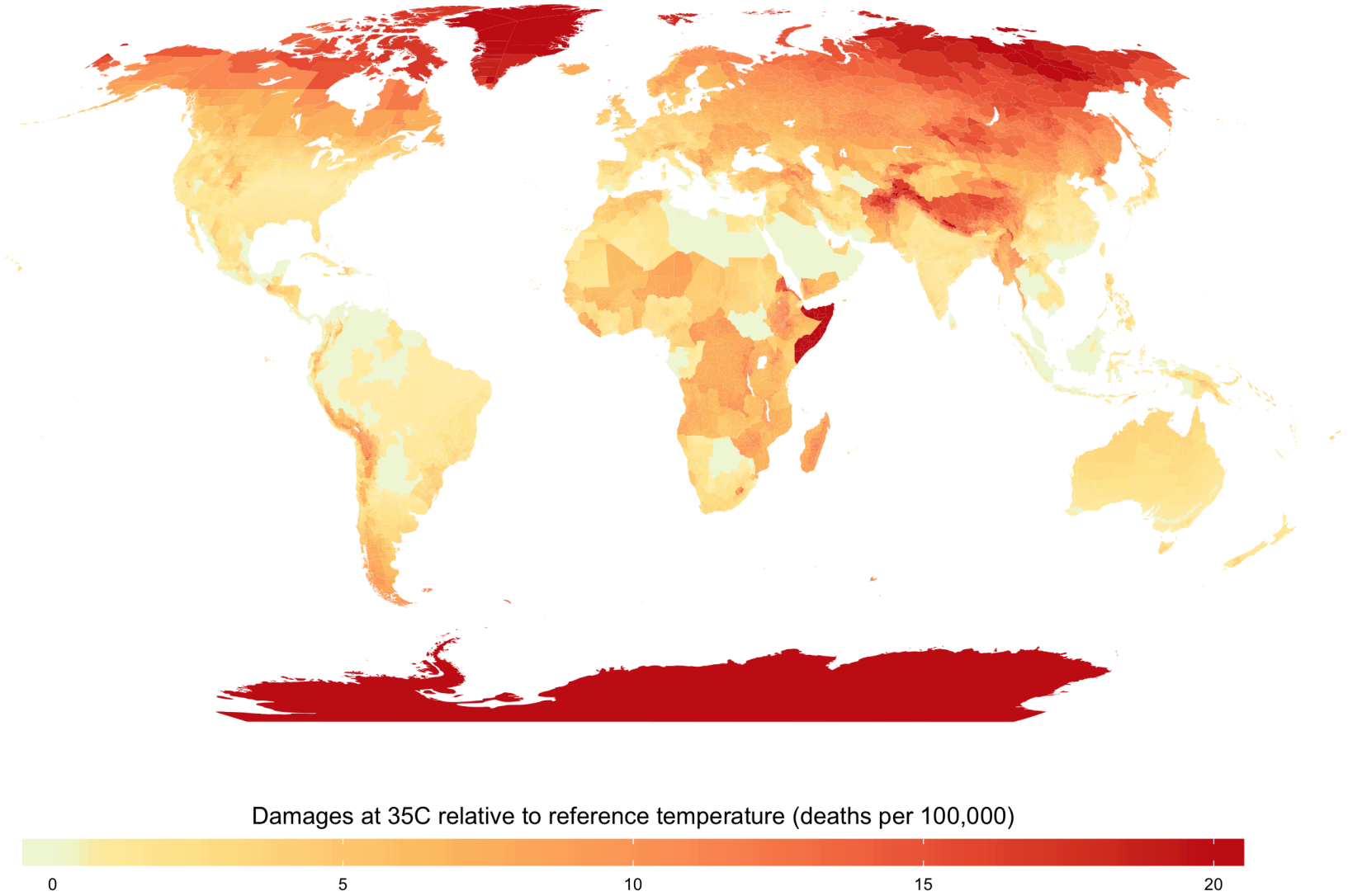
Sensitivity to hot days: global, 65+



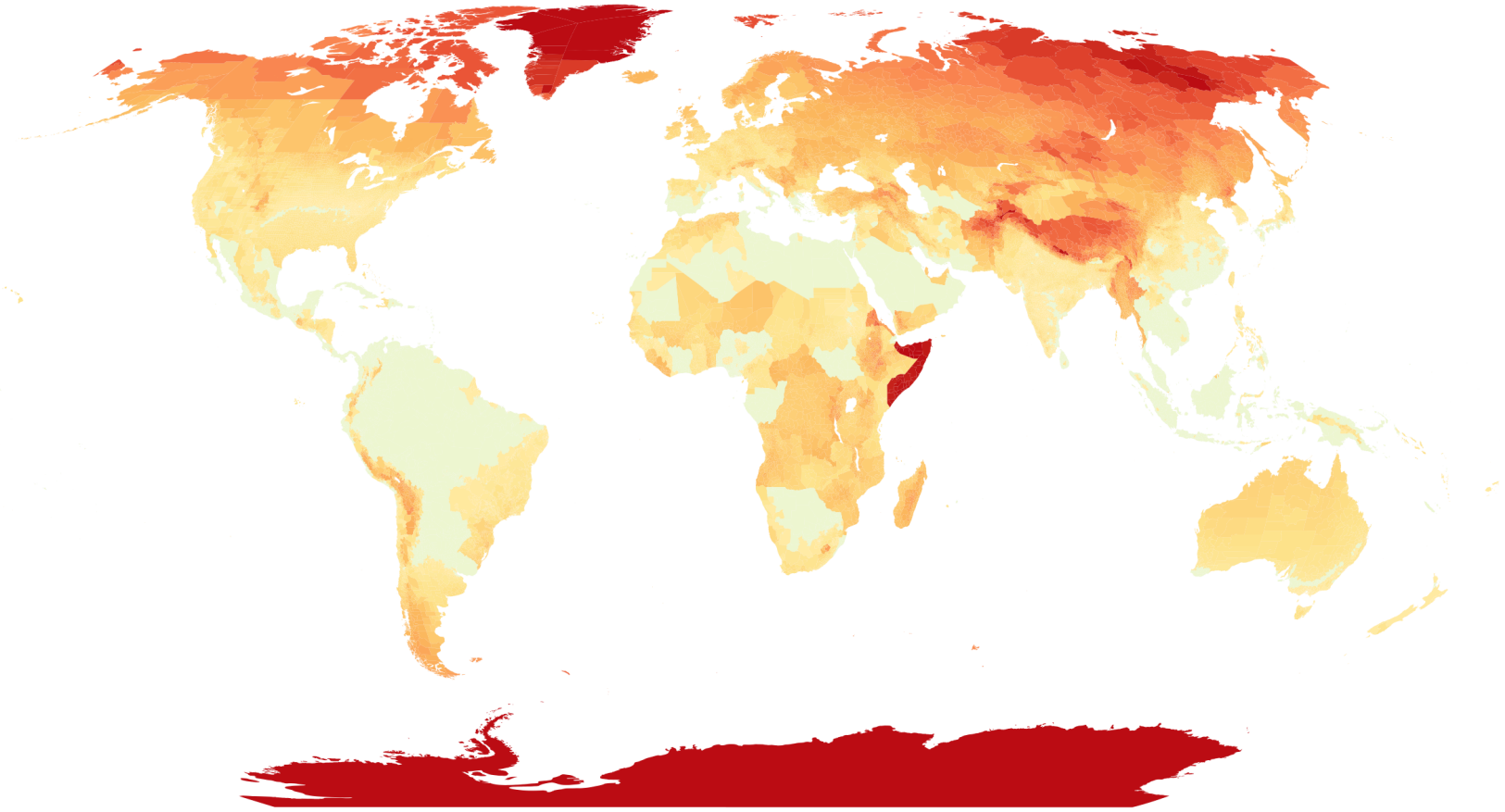
Sensitivity to hot days: 2050



Sensitivity to hot days: 2080



Sensitivity to hot days: 2100



Damages at 35C relative to reference temperature (deaths per 100,000)

0 5 10 15 20

Next: use projected sensitivities to obtain distribution of deaths by year

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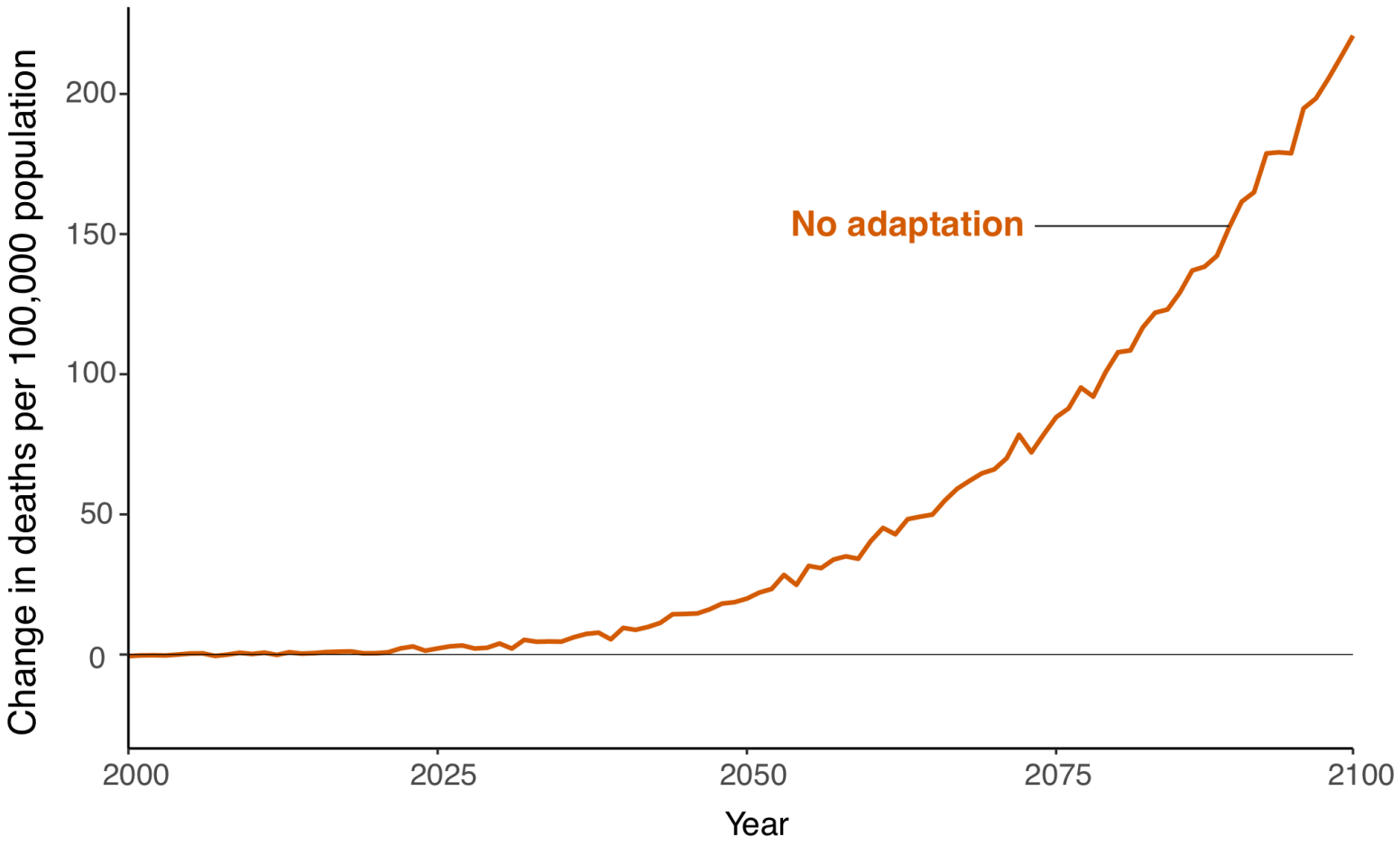
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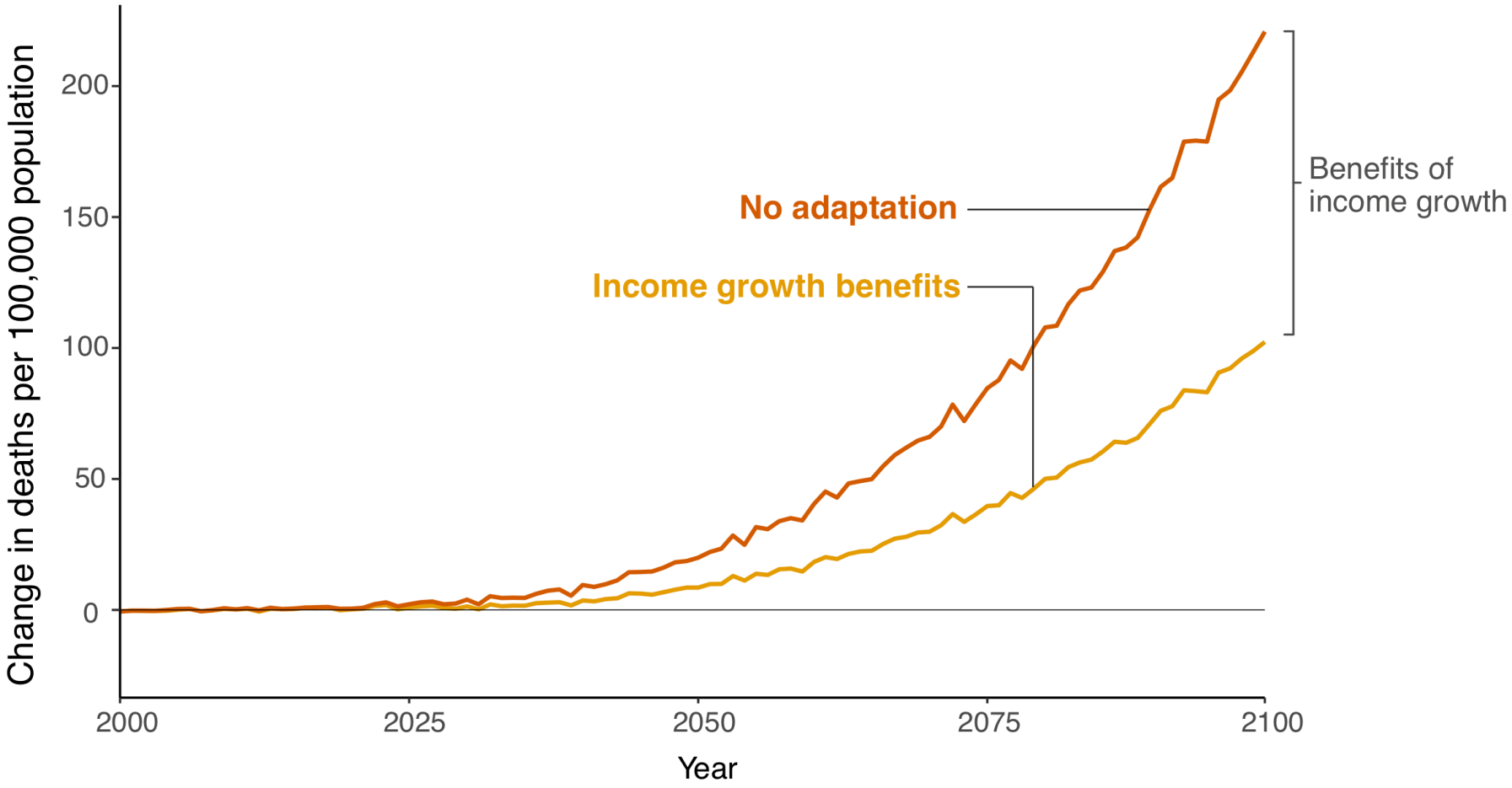
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- $\hat{\beta}$ is the change in mortality from an additional day at an extreme temperature.
- By combining $\hat{\beta}$ with a climate model, we can obtain a joint distribution of $(\Delta\, temperature, \Delta\, mortality\ rate)$ consisting of 1 observation for each of:
  - 33 climate models
  - 25,000 impact regions
  - 365 days
  - 100 years
  - X samples through resampling of response surface parameters

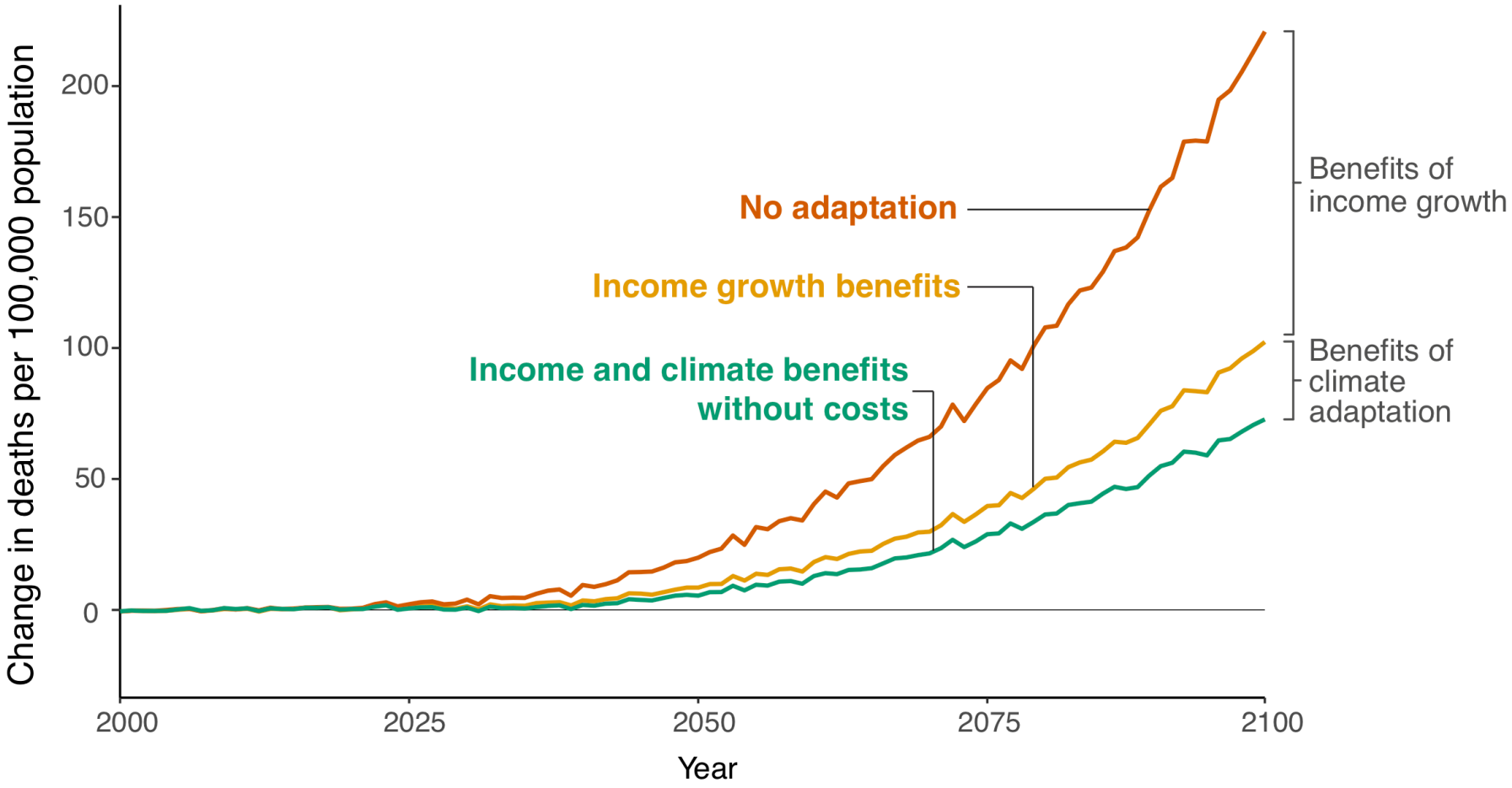
Projected Mean Mortality Risk from Climate Change



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Adaptation benefits are obtained at a cost

Adaptation to higher long-term temperature can take many forms:

- Air conditioning
- Moving to cities
- Growing heat-resistant crops

Each response may reduce mortality but will cost money in the process.

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Empirical challenge:

We do not observe money spent on ACs, heat-resistant crops, etc.

Solution: use benefits to approximate costs

People will only buy an AC if the benefit (lower chance of death) exceeds the cost in $.

- It follows that for the **marginal** AC purchased, the benefit must roughly **equal** the cost.
- More generally, for all adaptation we know MB = MC.

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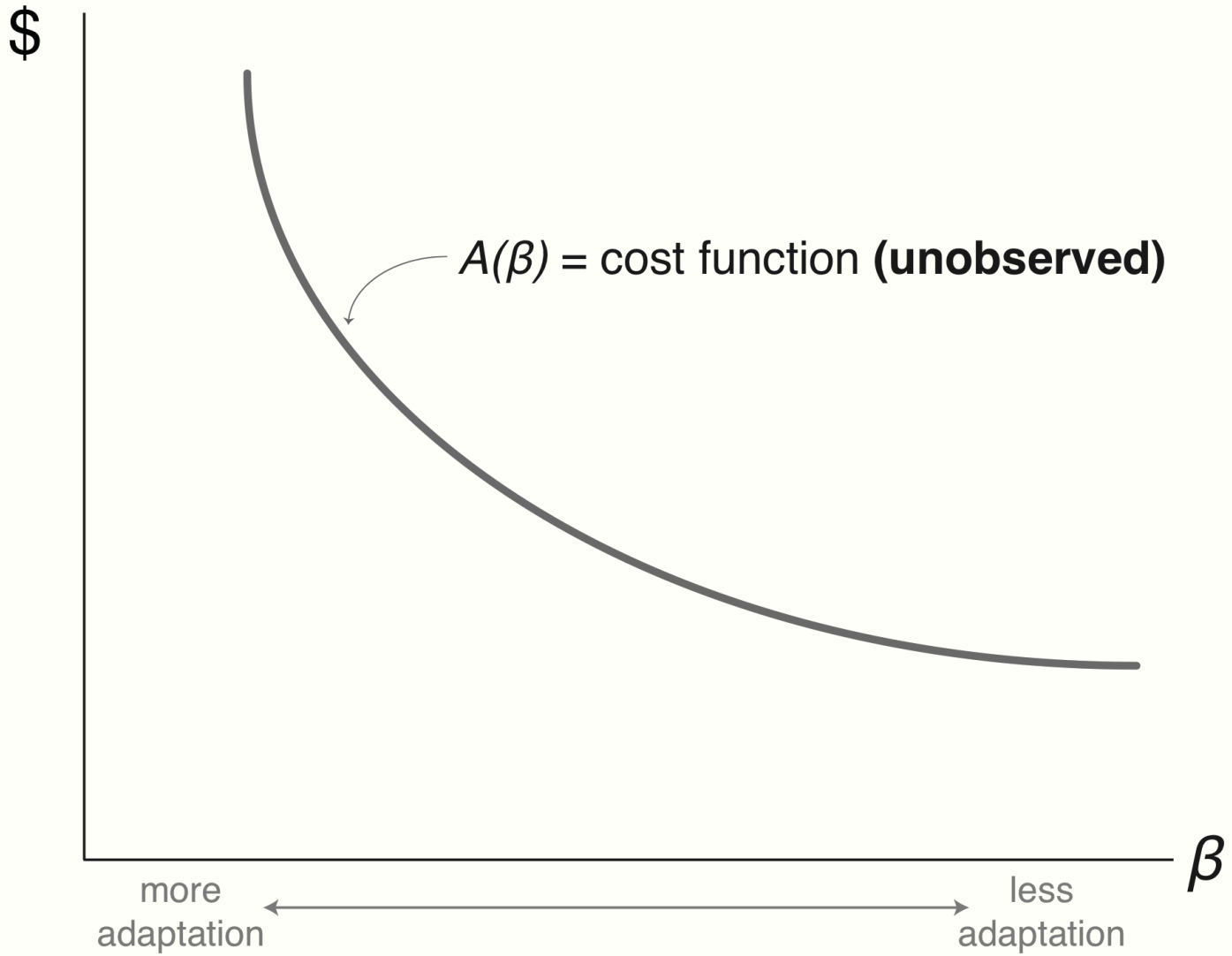
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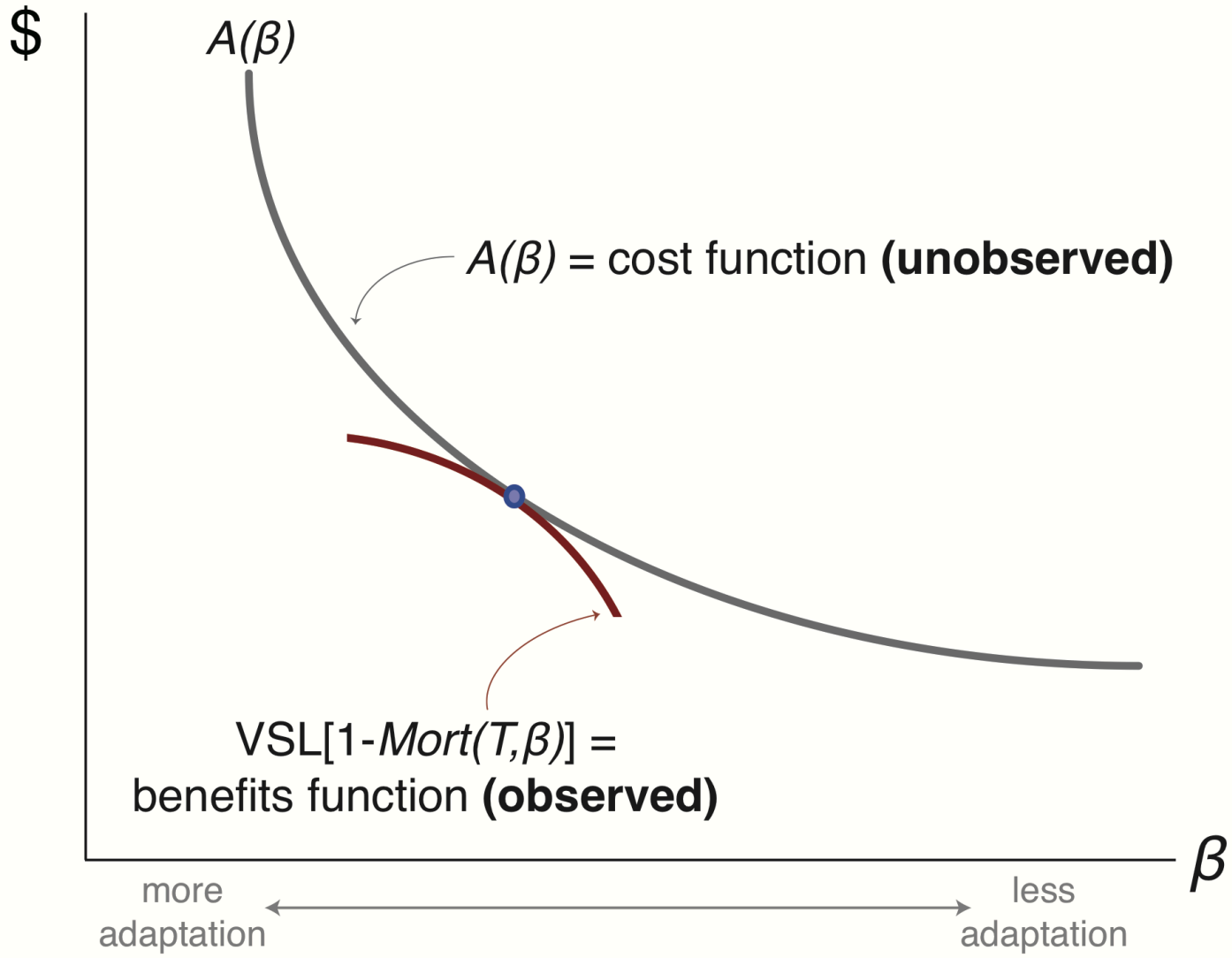
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- On the margin, we know this marginal adaptation benefit (roughly) equals marginal adaptation cost

Lastly, to obtain total adaptation cost, we sum the marginal cost over the full temperature change we expect to observe.

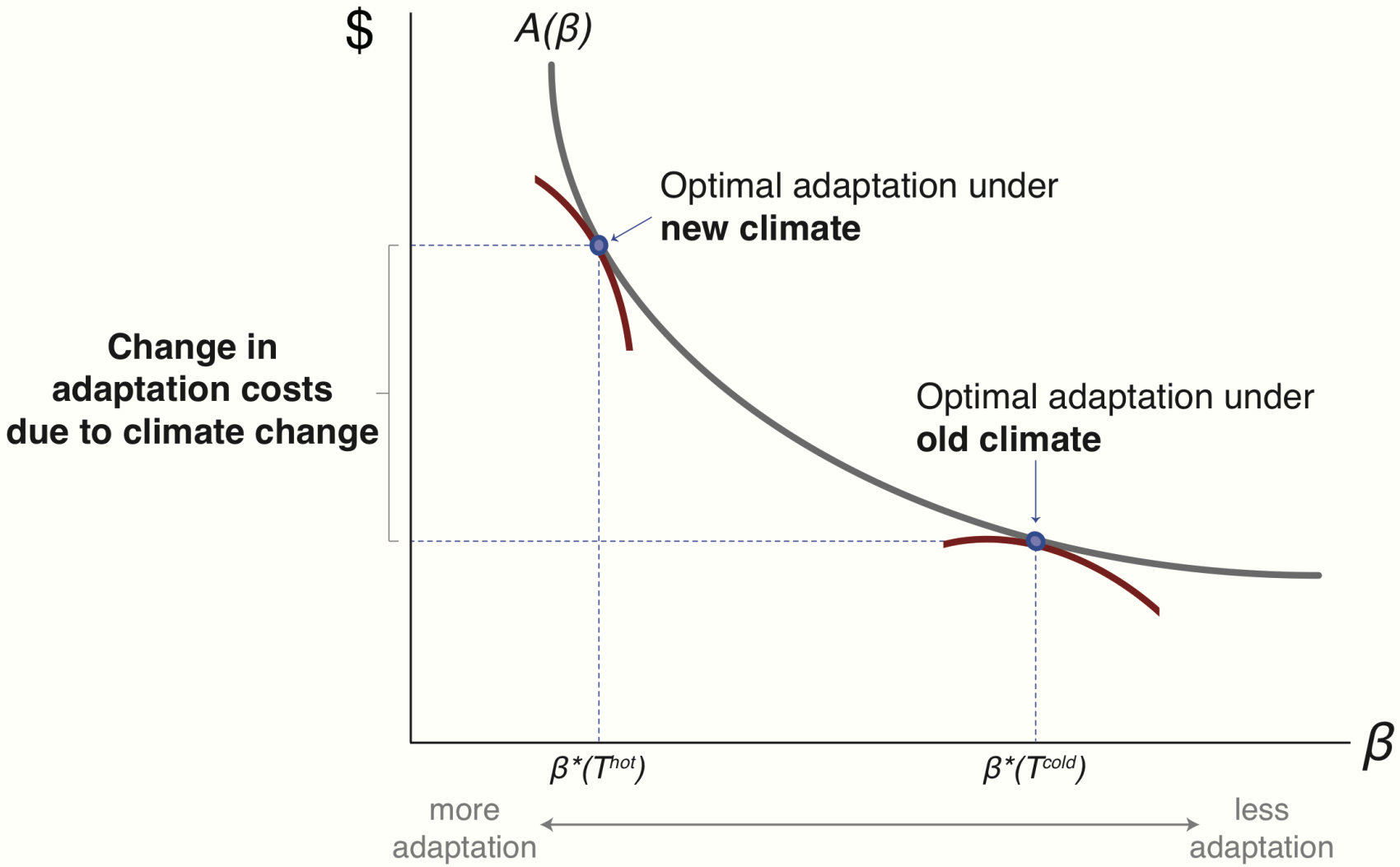
Using adaptation benefits to approximate the costs



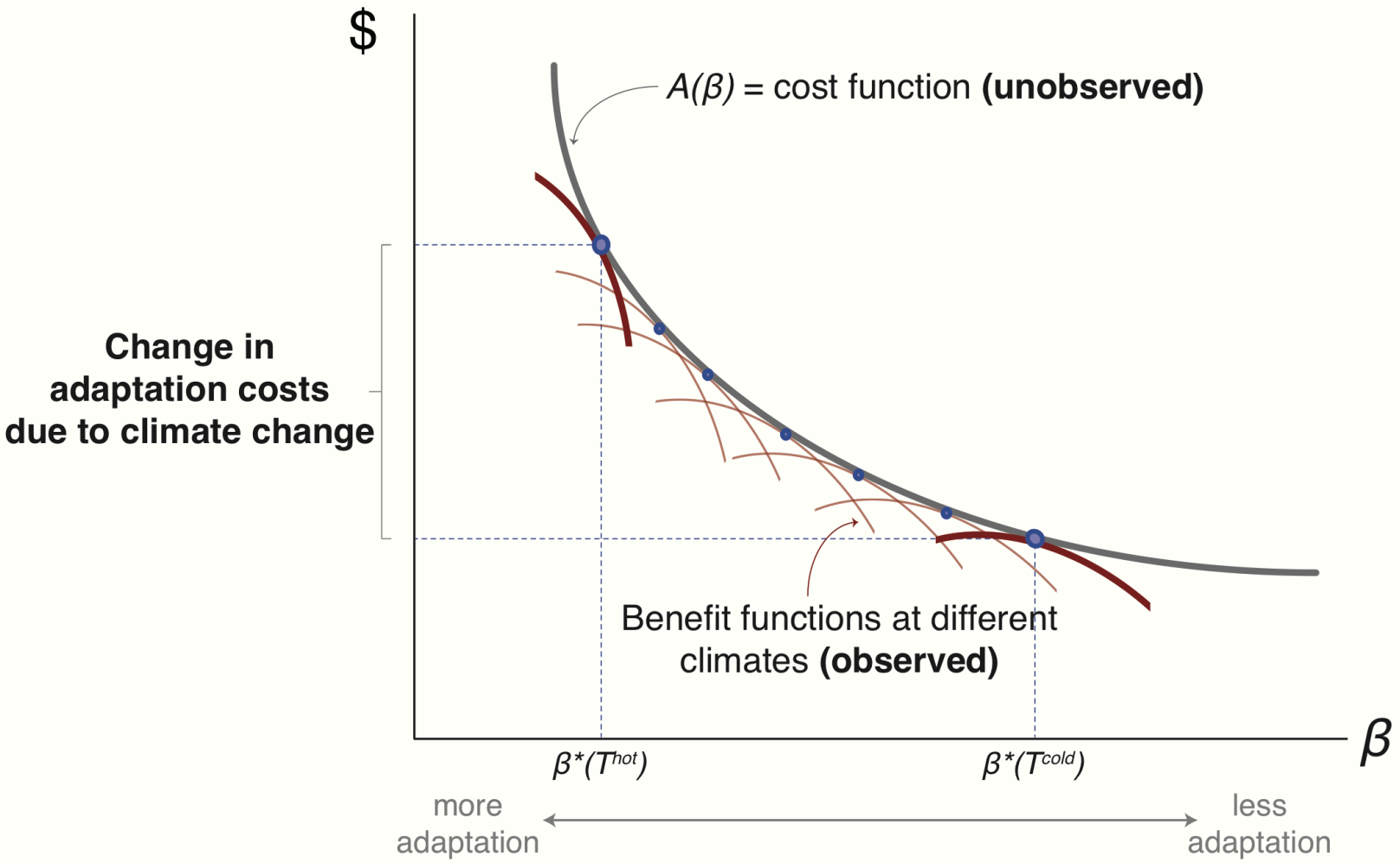
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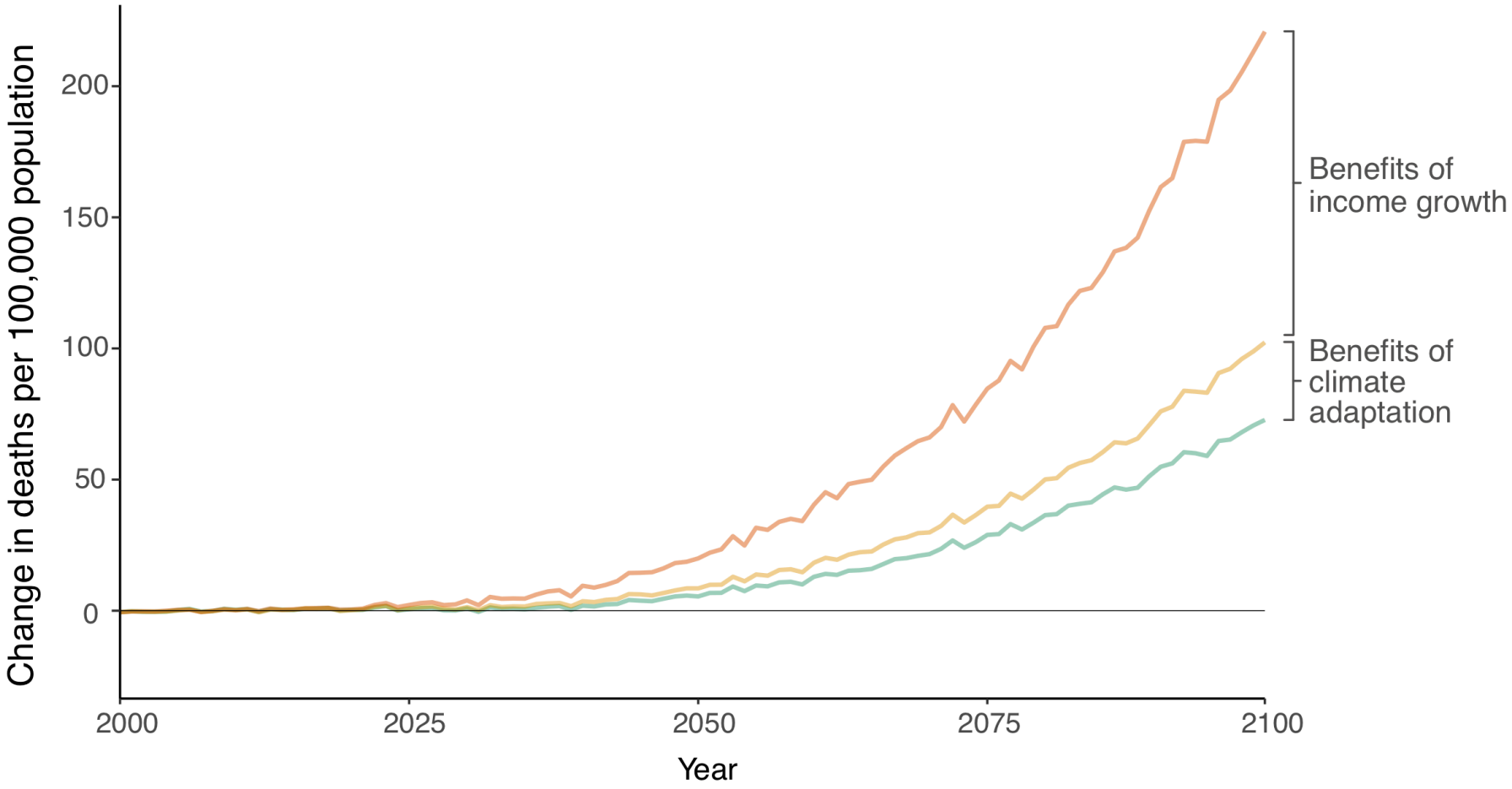
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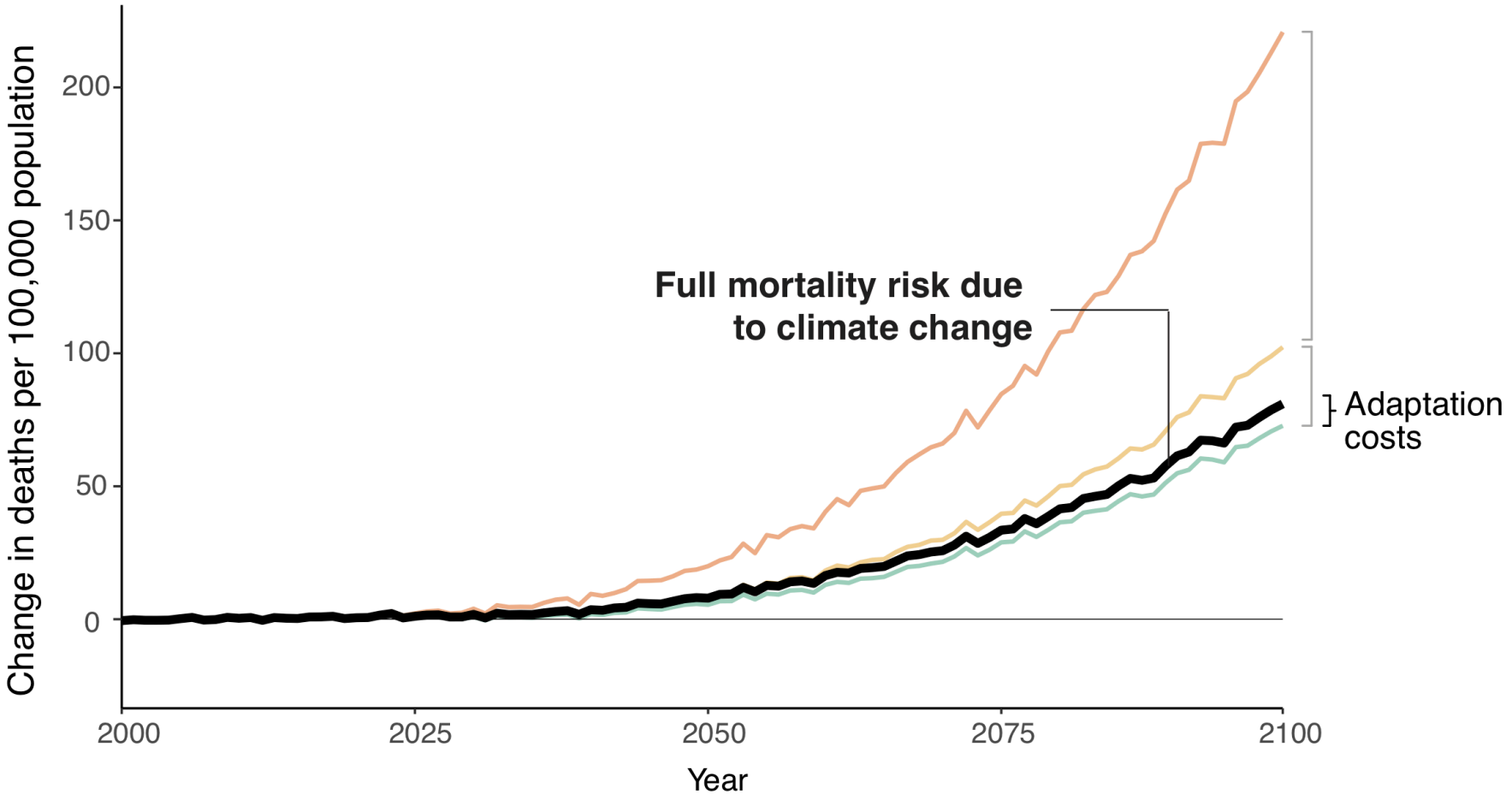
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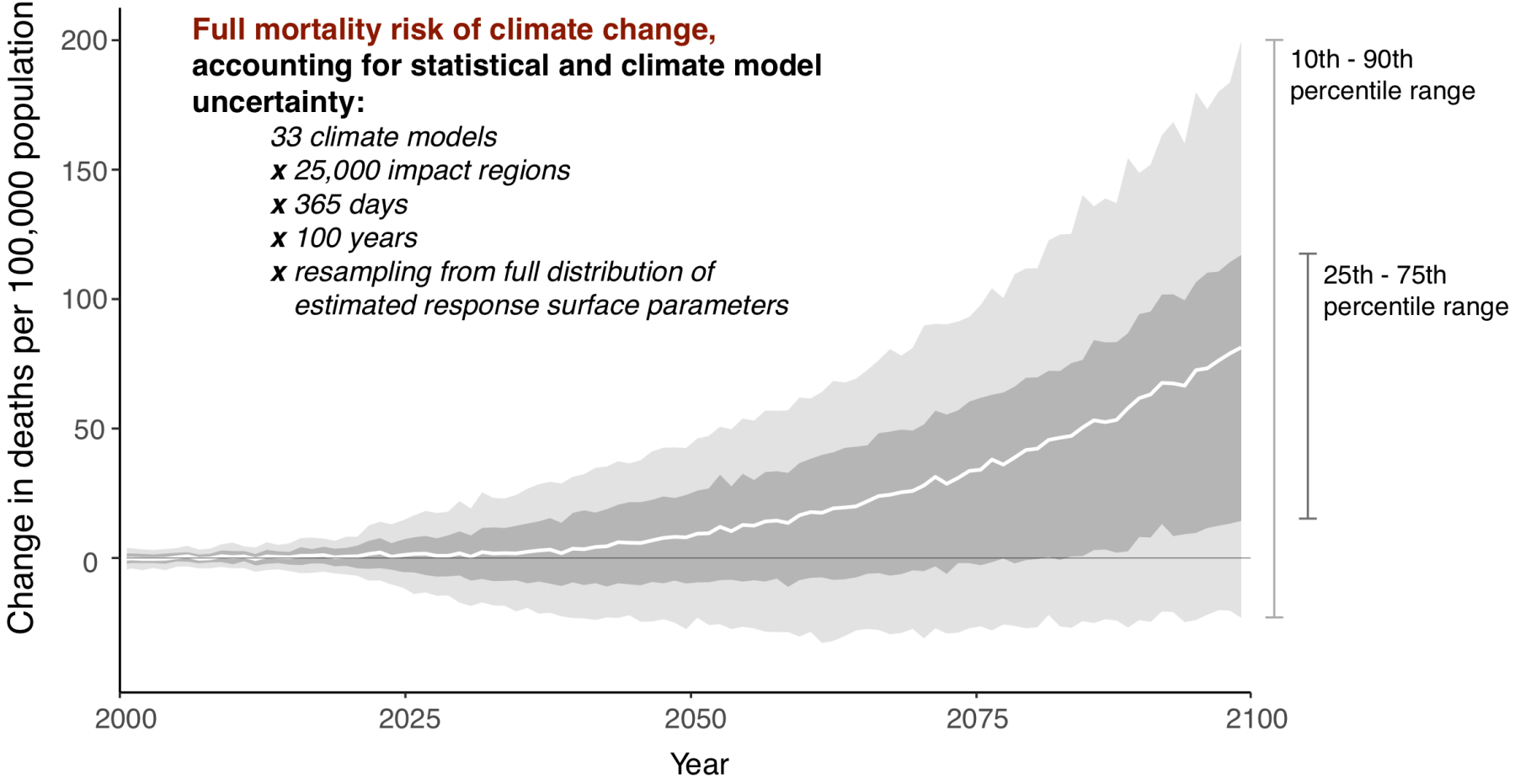
Distribution of yearly mortality impacts



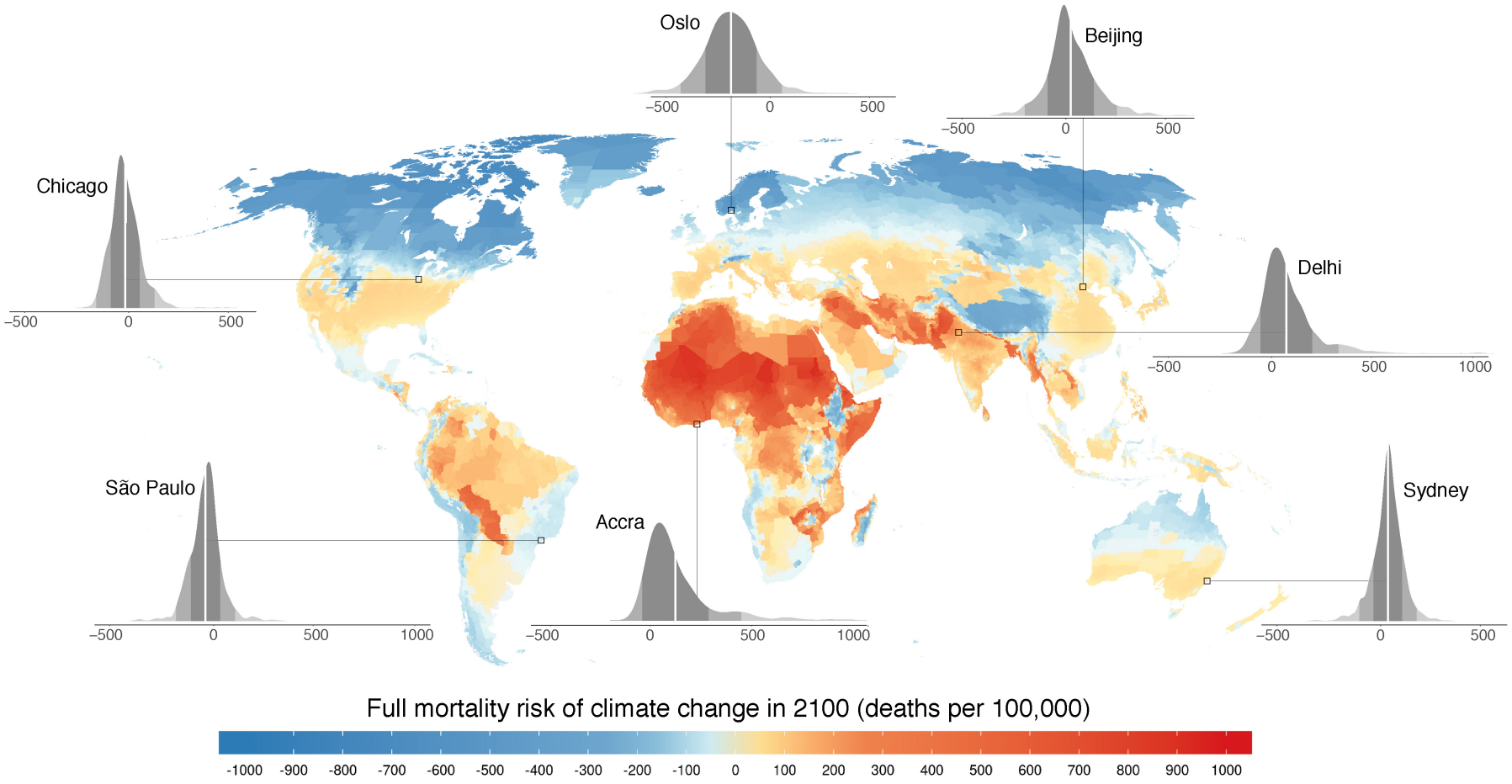
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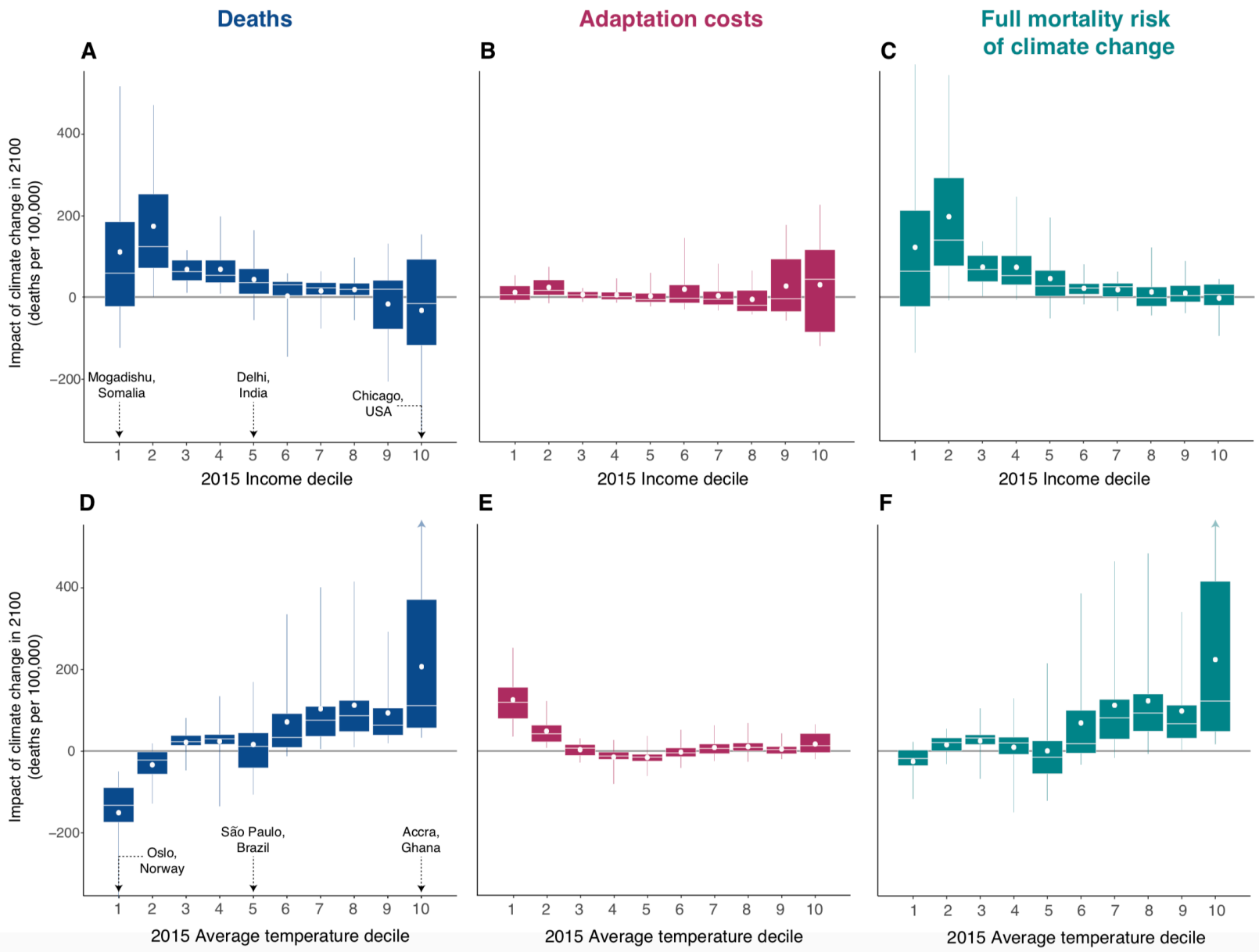
Distribution of yearly mortality impacts – RCP8.5



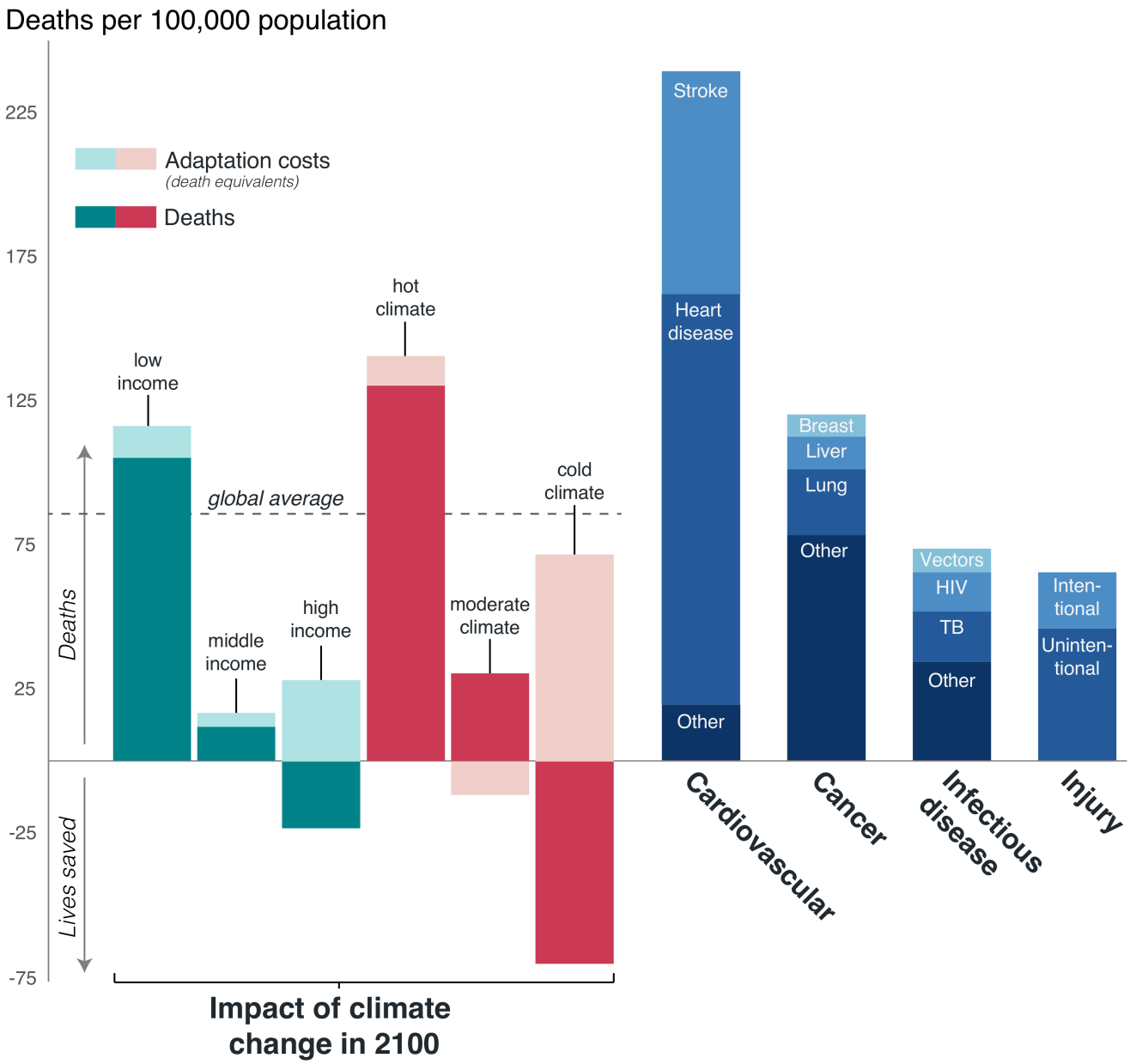
Poor countries face higher mortality risk than rich ones
where mortality risk includes deaths *and* adaptation costs



Cold and low-income countries face higher mortality risk



Climate impacts on mortality rival leading causes of death



The path to a partial SCC due to mortality

1. Estimate causal effect of climate on mortality, allowing for differences in income and mean climate
2. Predict effect on mortality for every location and year, then sum worldwide
3. Add in adaptation costs
4. **Fit global damage function using distribution of projected damages**
5. Project global damages by year and compute PDV to obtain SCC

Turning mortality impacts into an empirical damage function

Next, we aggregate to **yearly impacts** (across days) at the **global level** (across regions). We are left with a joint $(°C\ of\ warming, \Delta\ mortality\ rate)$ projection for each of:

- 100 years
- 2 emissions scenarios (RCP4.5 and RCP8.5)
- 33 climate models
- X simulations through resampling of response surface parameters

This distribution accounts for uncertainty in both **how emissions affect climate** (bullets 2 and 3) and **how climate affects mortality** (bullet 4).

Turning mortality impacts into an empirical damage function

To turn mortality rates into dollars, we use a **value of a statistical life**.

- Recall from Becker et al. (2011) that the VSL is the consumption equivalent of being alive.
- We use the US EPA VSL of $10.4 million and adjust for other countries assuming the income elasticity of the VSL is 1.
  - The same number of deaths will have a lower USD consumption equivalent if in a poor country.

Turning mortality impacts into an empirical damage function

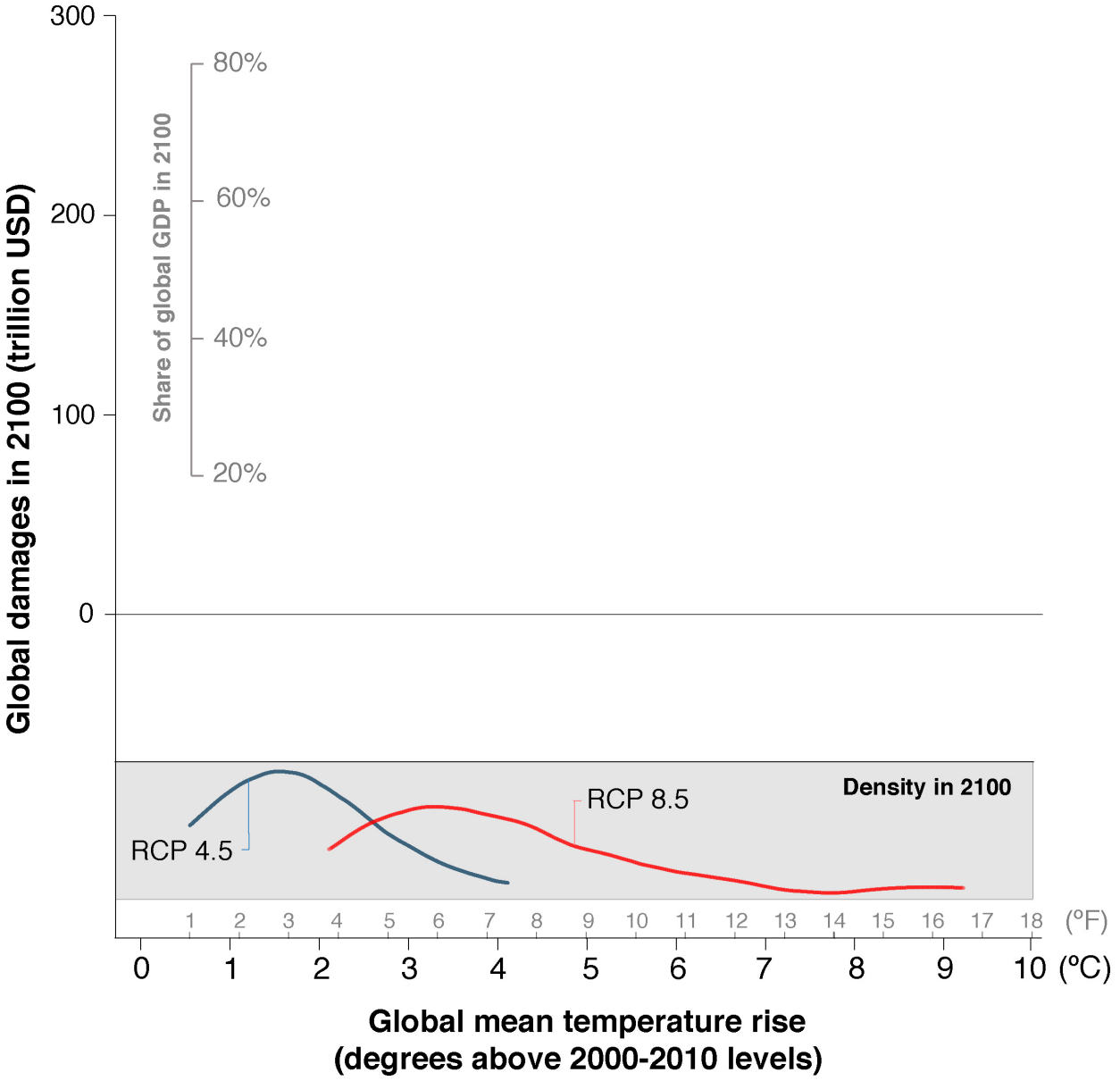
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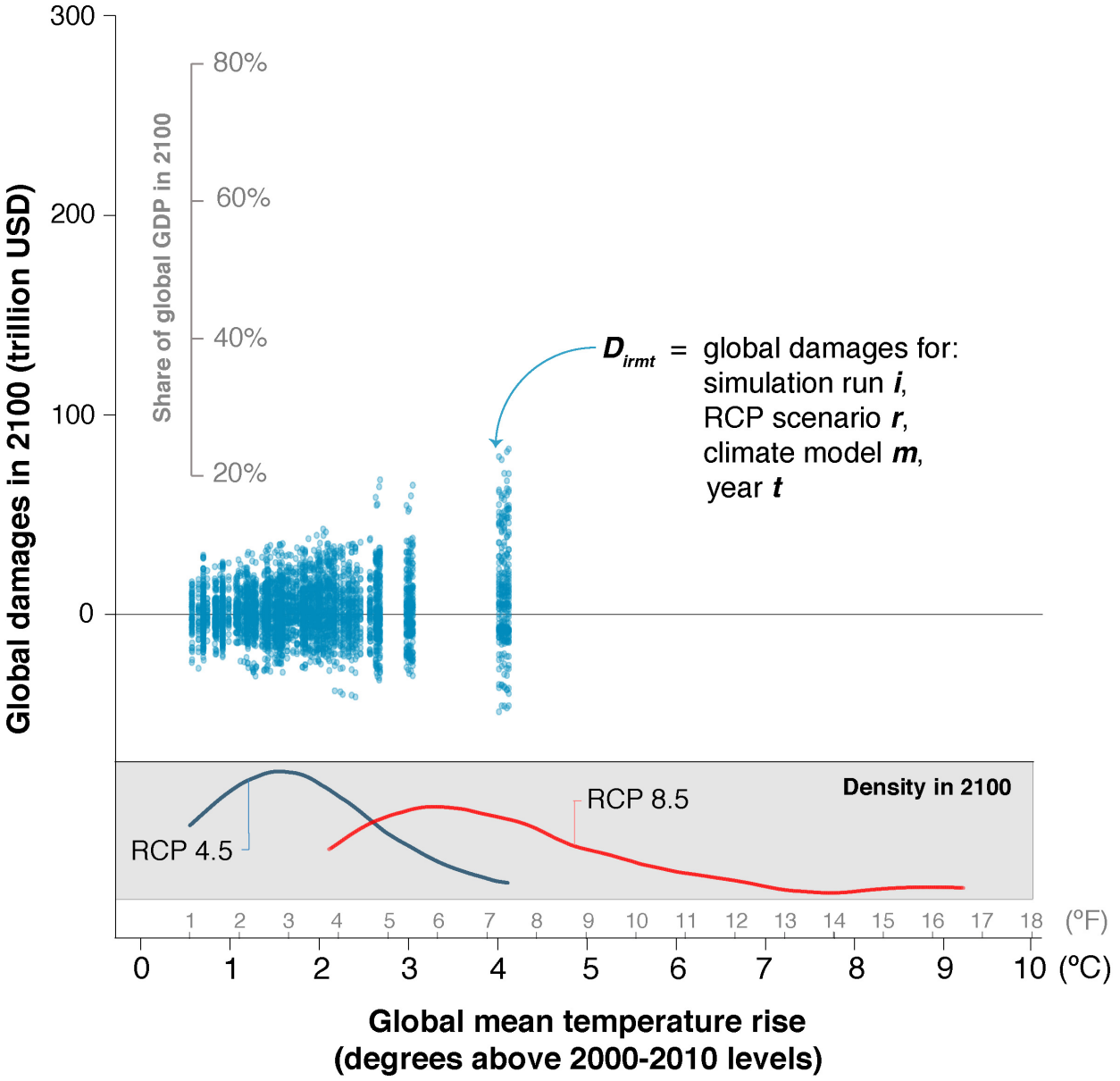
At last, we have a distribution of $(°C\ of\ warming, \$\ of\ damages)$ and can estimate a damage function:

$$\$\ of\ damages = f(°C\ of\ warming)$$

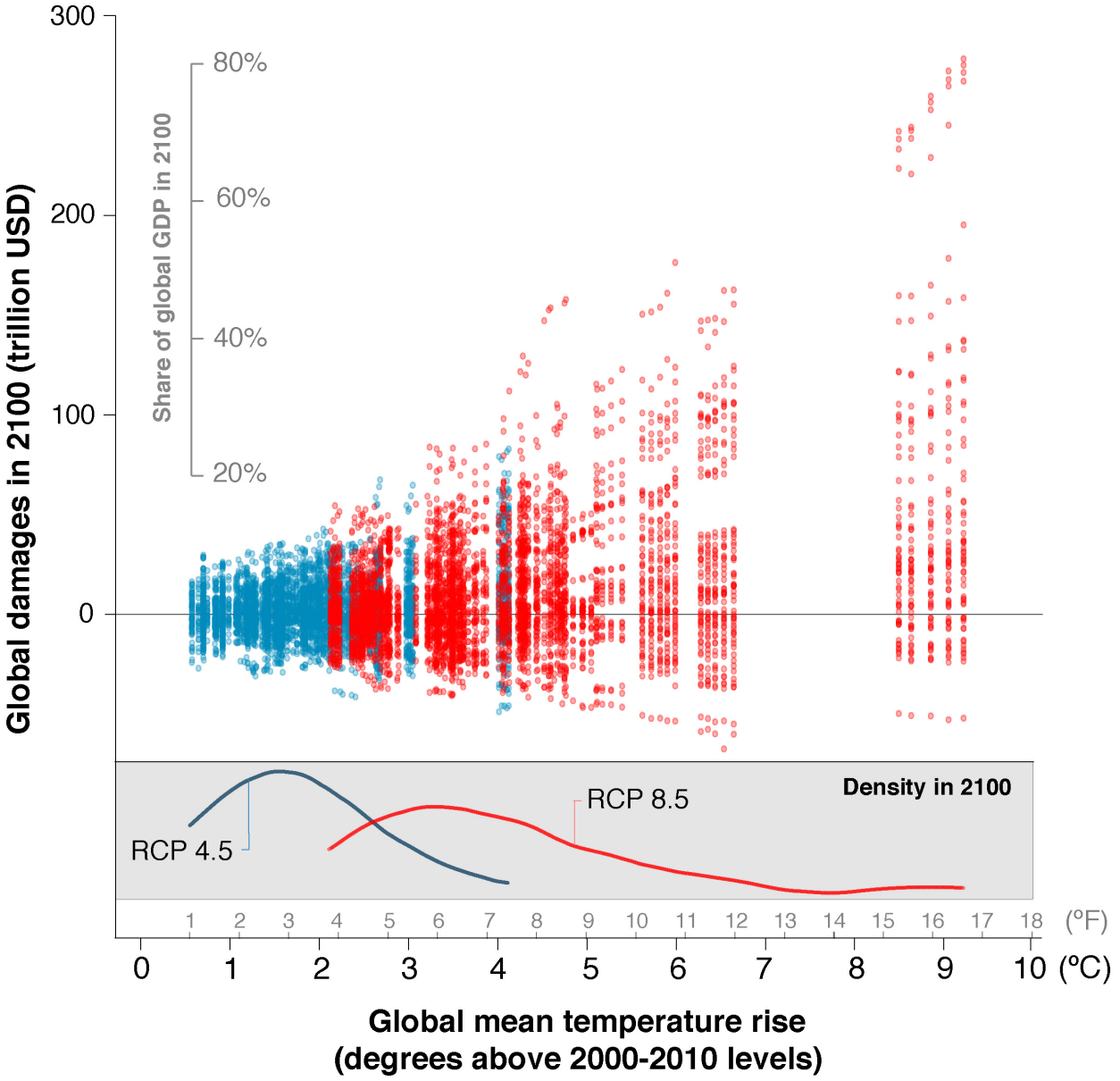
Estimating the empirical damage function



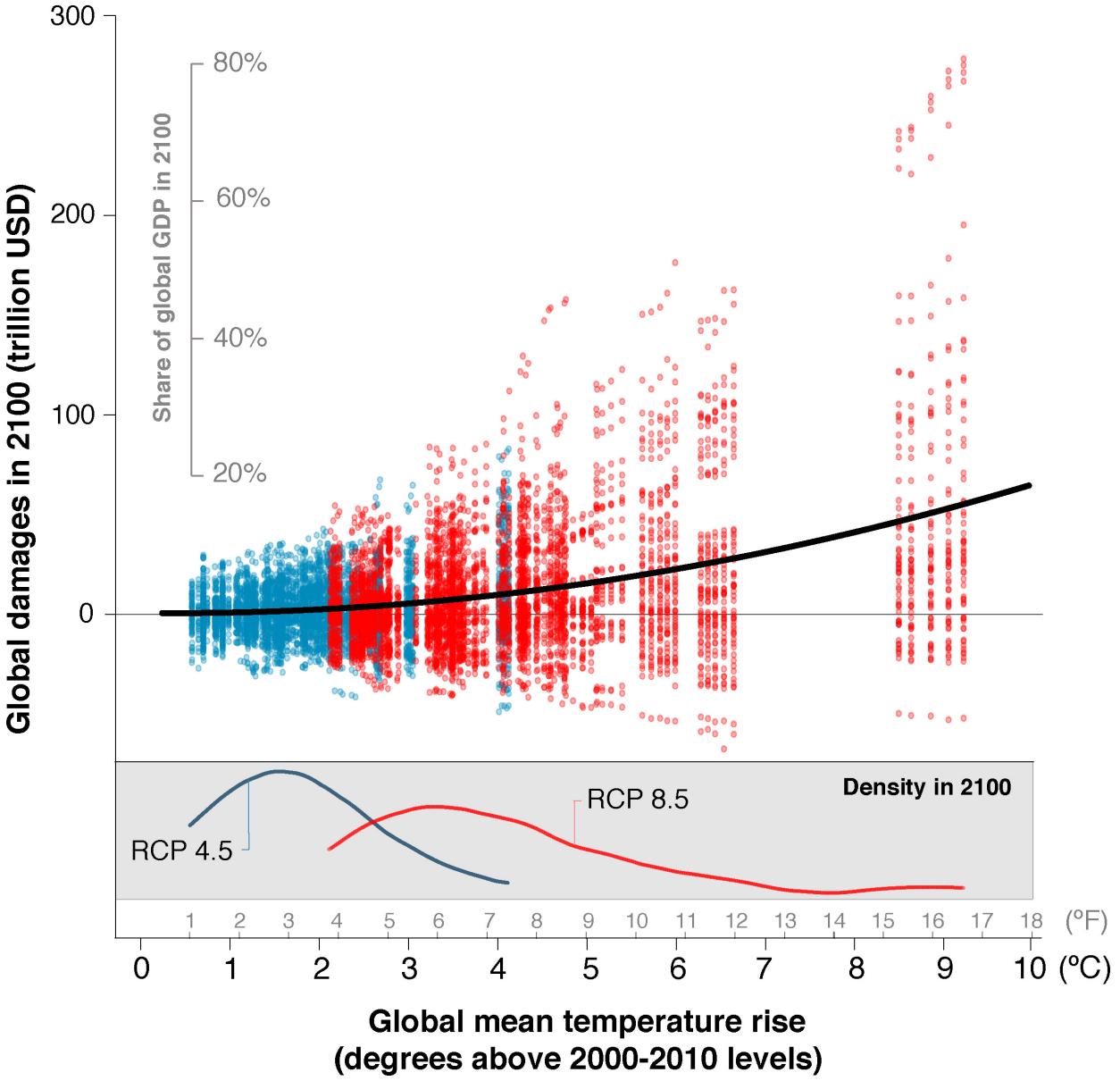
Estimating the empirical damage function



Estimating the empirical damage function

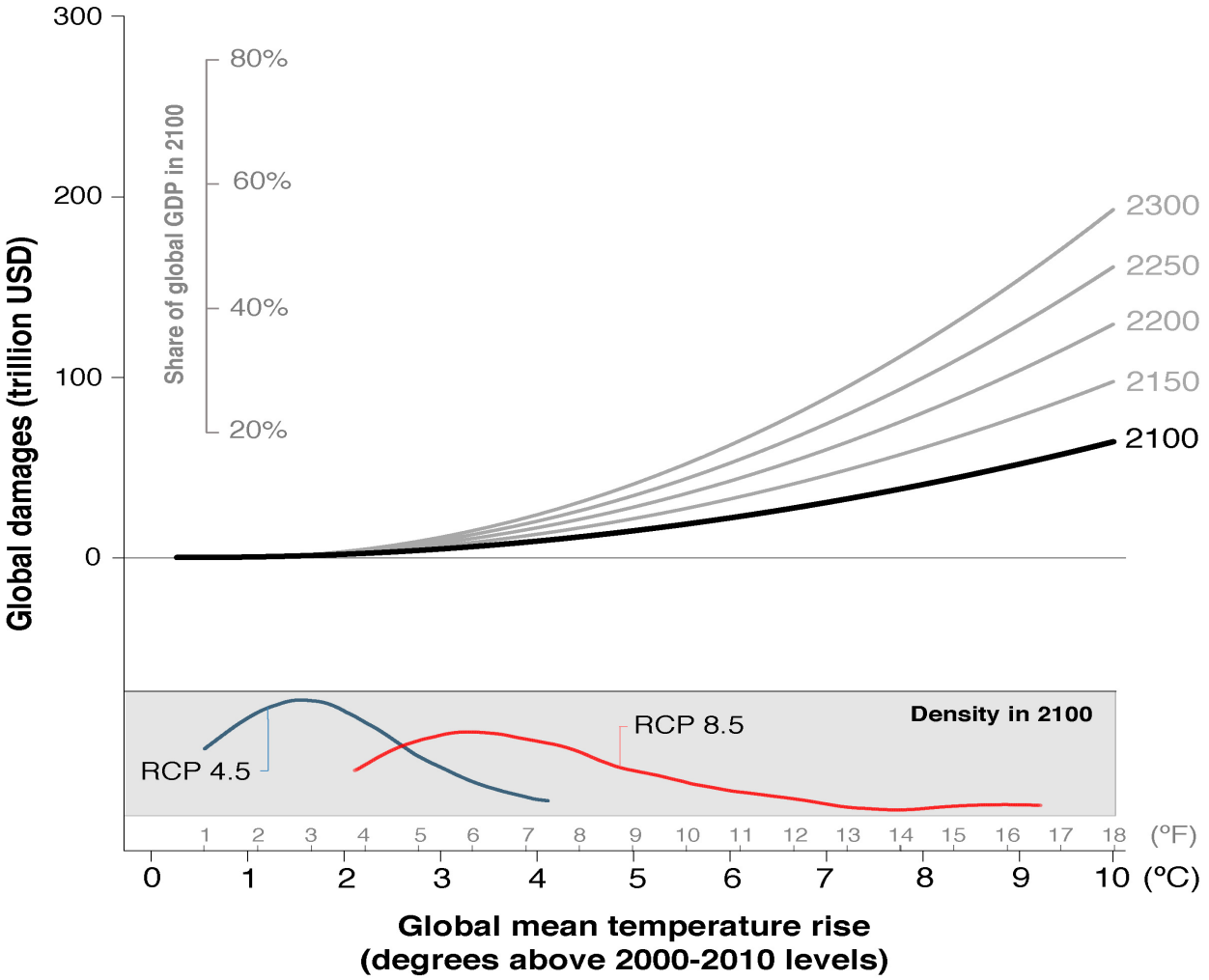


Estimating the empirical damage function



Estimating the empirical damage function

Countervailing forces: 1) In later years, populations are larger, older, and richer (increase damage functions for a given temperature changes); 2) Populations are better adapted in later years



The path to a partial SCC due to mortality

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Finally, compute a partial SCC for mortality

Definition: The partial social cost of carbon for mortality is the present discounted value (PDV) of all damages associated with a marginal ton of CO_2 emissions.

Finally, compute a partial SCC for mortality

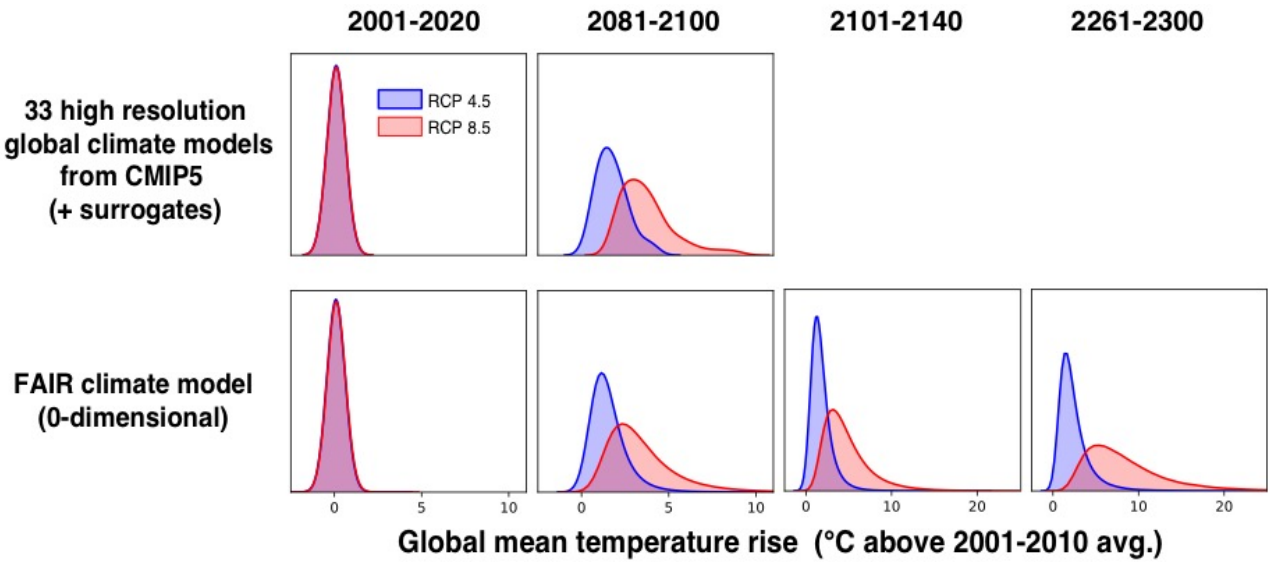
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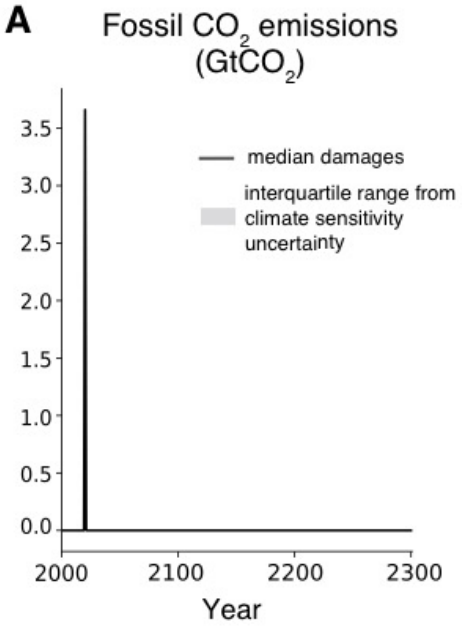
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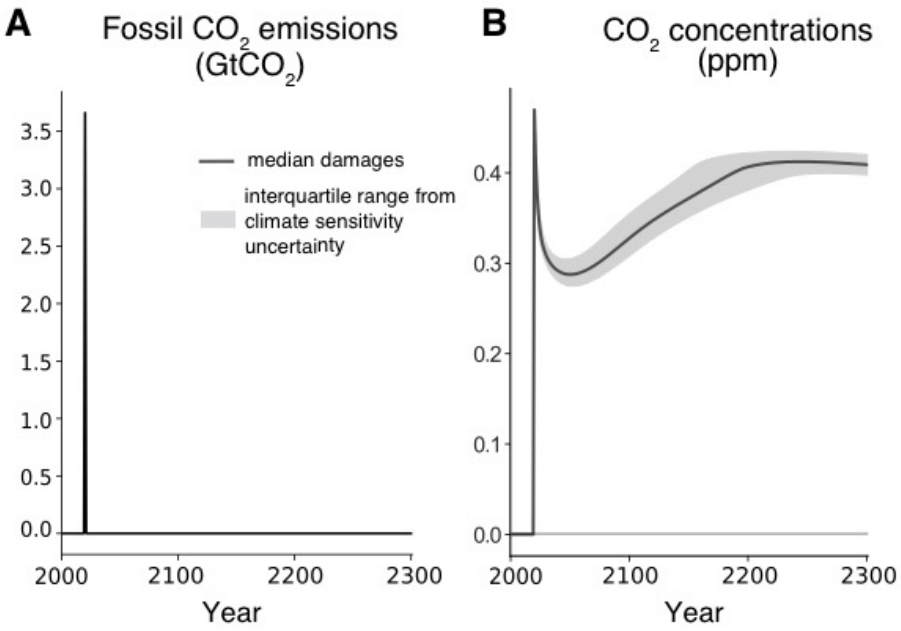
- For our purposes, all damages means **damages to 2300.**
- Most climate models do not go beyond 2100. To input temperature changes to 2300 into the damage function, we use the simple FAIR climate model.



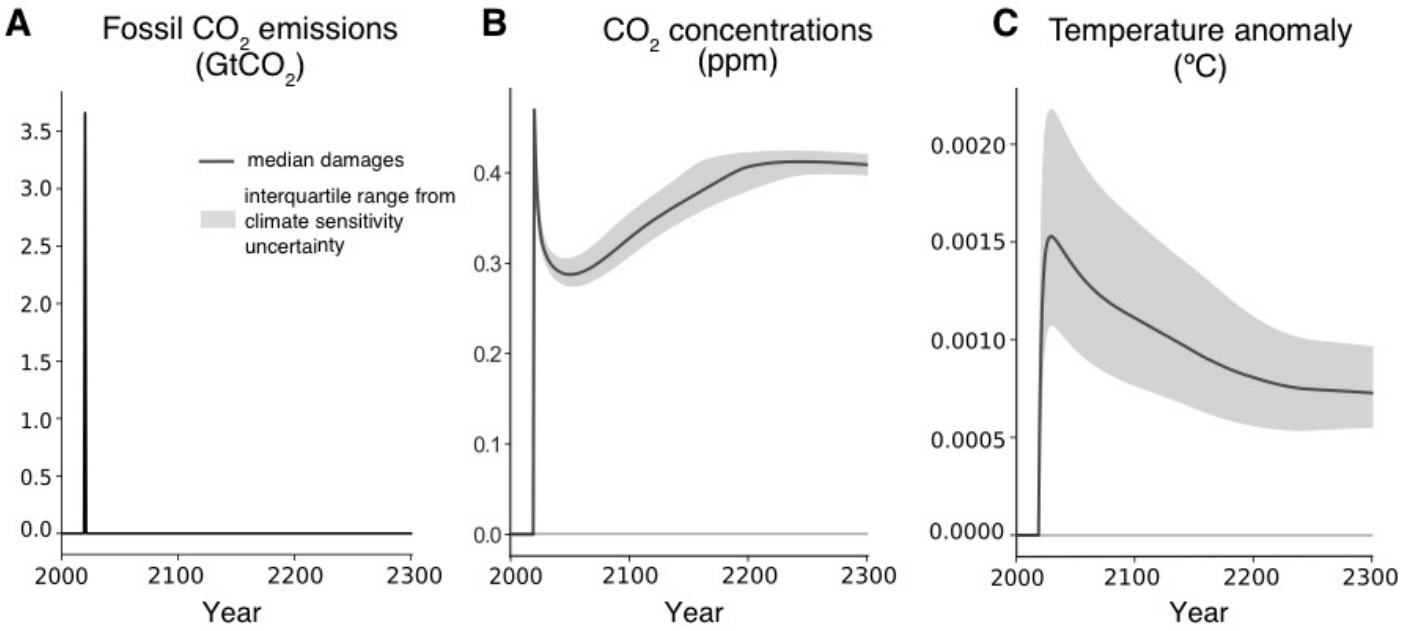
Damages from a single ton of CO_2



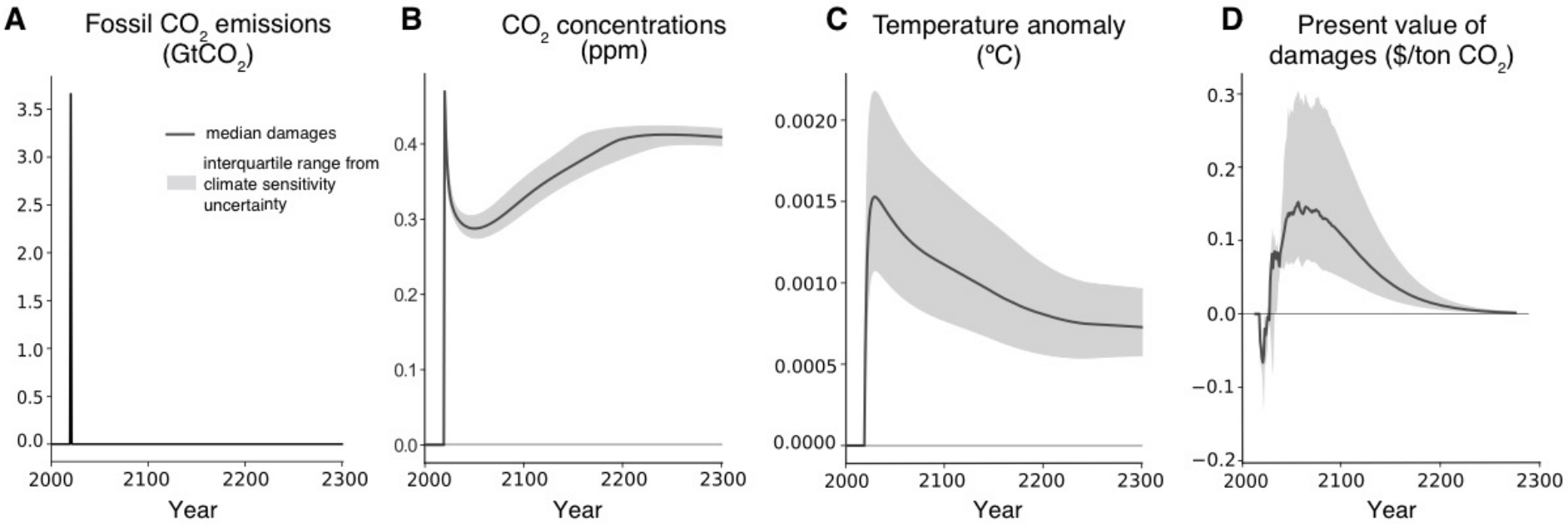
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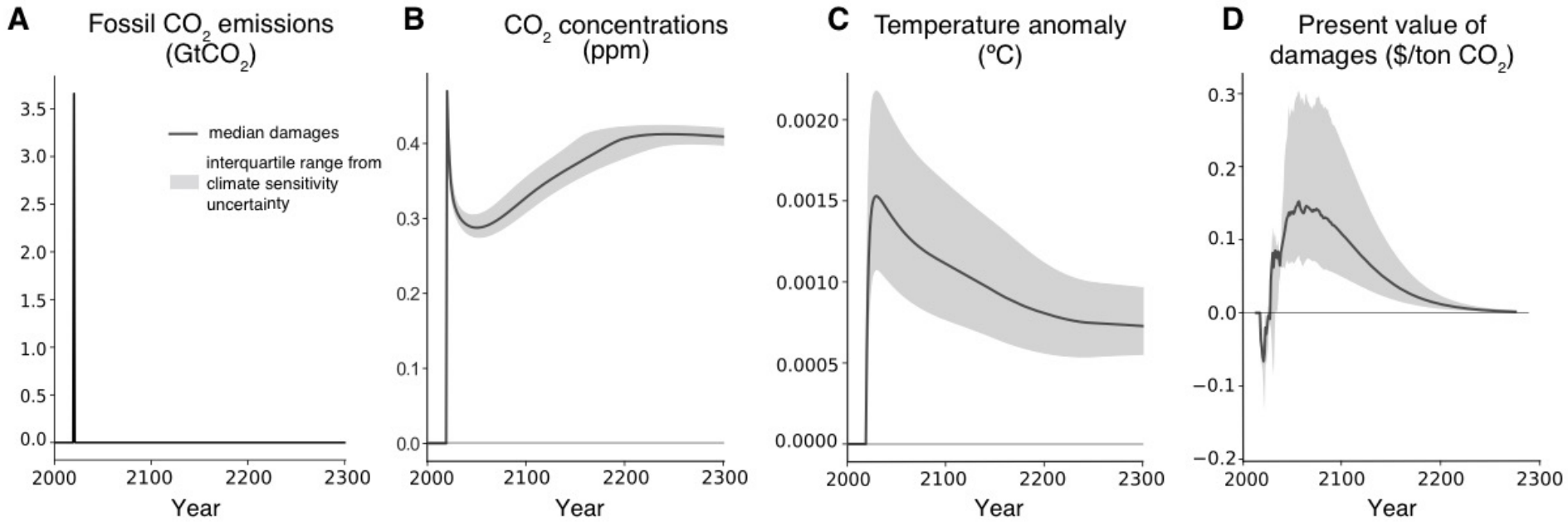
Damages from a single ton of CO_2



Damages from a single ton of CO_2



Damages from a single ton of CO_2



$$\text{Partial SCC} = \frac{\partial(\$ \text{ of damages})}{\partial(°\text{C of warming})} \times \frac{\partial(°\text{C of warming})}{\partial(\text{tons of } CO_2)}$$

A Partial Social Cost of Carbon for Mortality

Table 1: Estimates of a partial Social Cost of Carbon for excess mortality risk incorporating the costs and benefits of adaptation

	Annual discount rate		
	$\delta = 2.5\%$	$\delta = 3\%$	$\delta = 5\%$
Panel A: Globally varying life-year adjusted valuation of mortality risk			
RCP 4.5	11.4	8.1	3.0
Full uncertainty	[-20.2, 35.1]	[-15.7, 25.2]	[-7.8, 10.6]
RCP 8.5	22.4	14.5	4.0
Full uncertainty	[-10.7, 50.2]	[-10.9, 34.7]	[-7.7, 12.8]
Panel B: Globally varying statistical life valuation of mortality risk			
RCP 4.5	11.4	8.4	3.0
Full uncertainty	[-13.7, 39.3]	[-12.6, 29.6]	[-9.2, 14.9]
RCP 8.5	38.6	23.6	4.6
Full uncertainty	[-4.4, 79.3]	[-7.1, 51.0]	[-8.9, 16.5]

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Damages from climate change are in many sectors

Mortality — heat and cold deaths

Damages from climate change are in many sectors

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Damages from climate change are in many sectors

Mortality — heat and cold deaths ✓

Agriculture — crop yields for seven major crops

Energy — energy and electricity demand

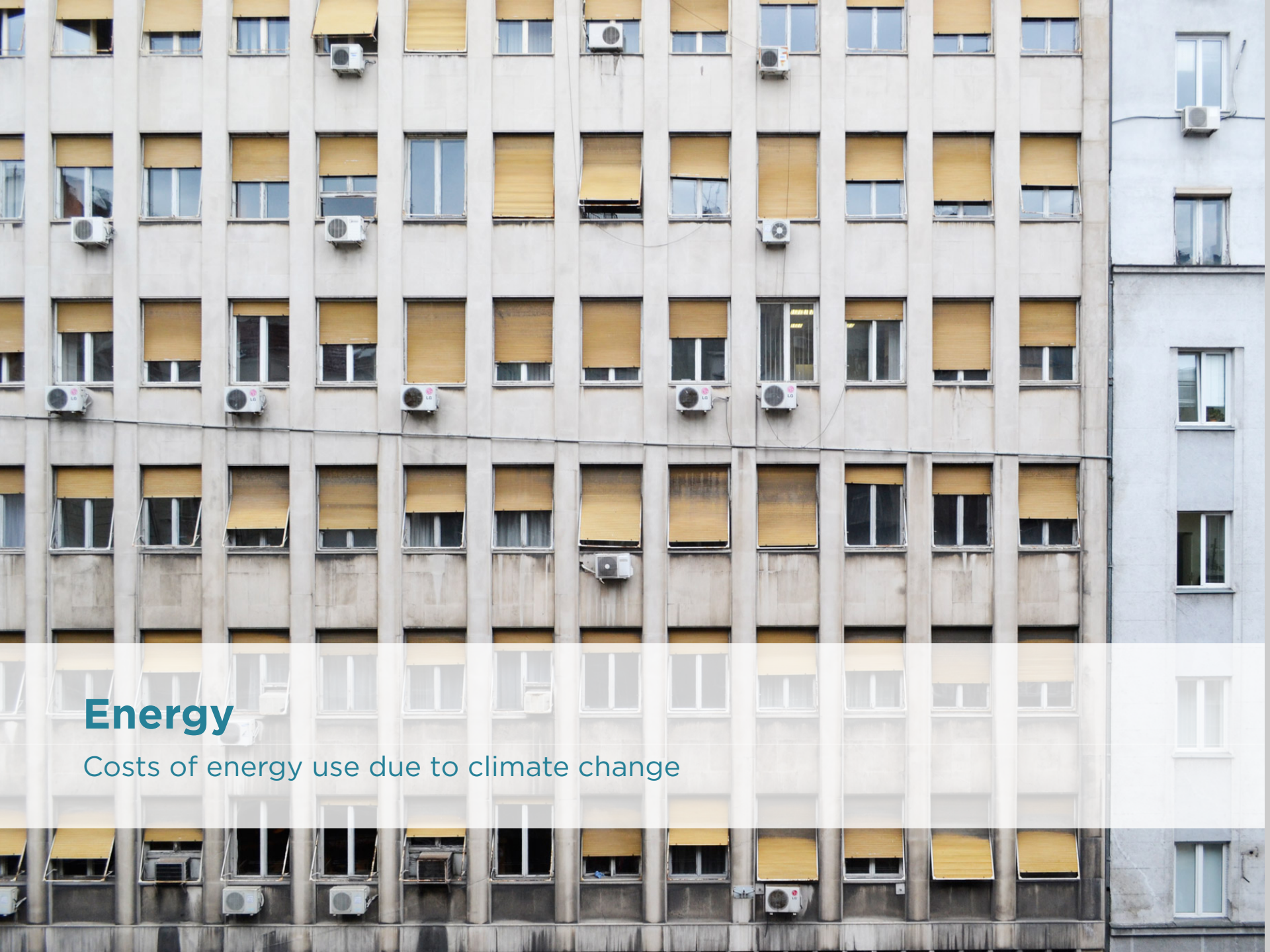
Labor — labor supply effects

Conflict — large-scale violent conflict

Crime — interpersonal violent crime

Migration — international and within-country

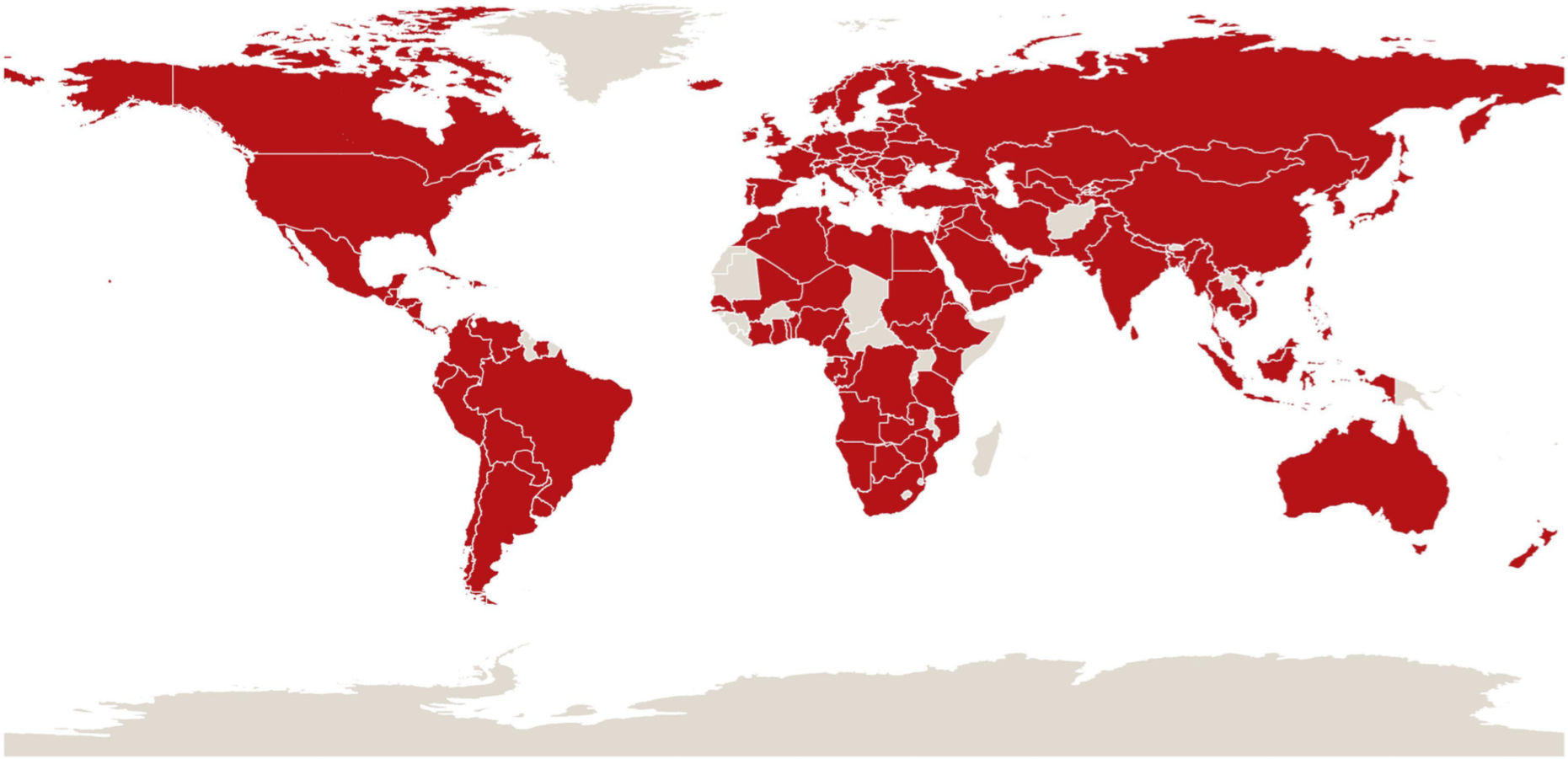
Coastal — sea level rise and storm damages



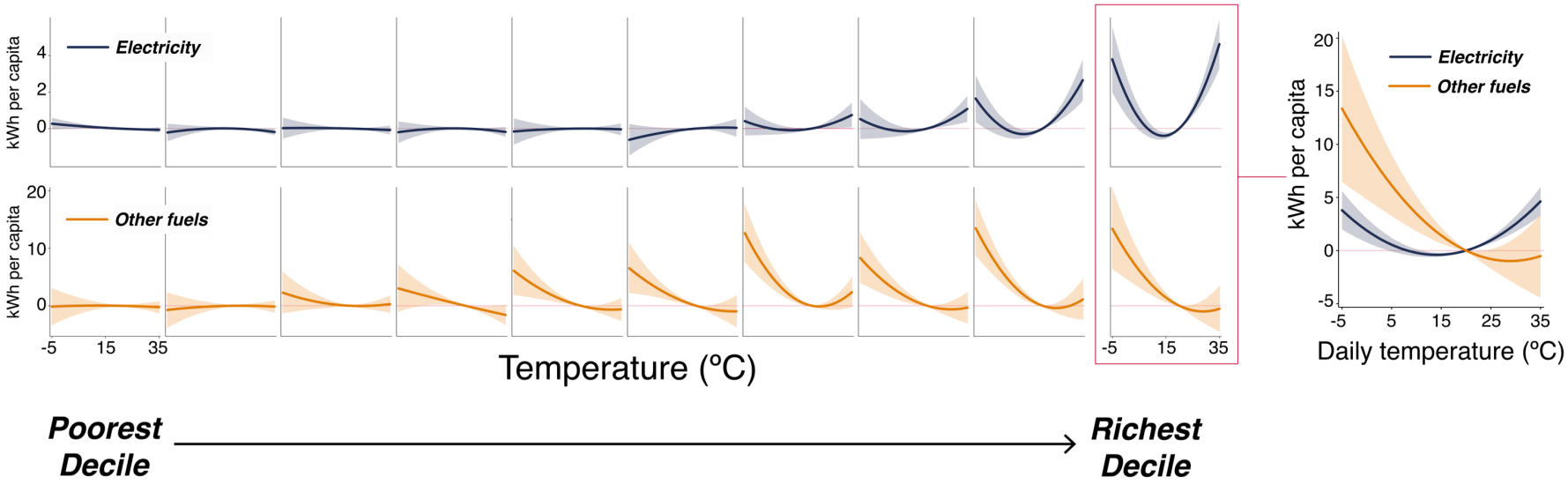
Energy

Costs of energy use due to climate change

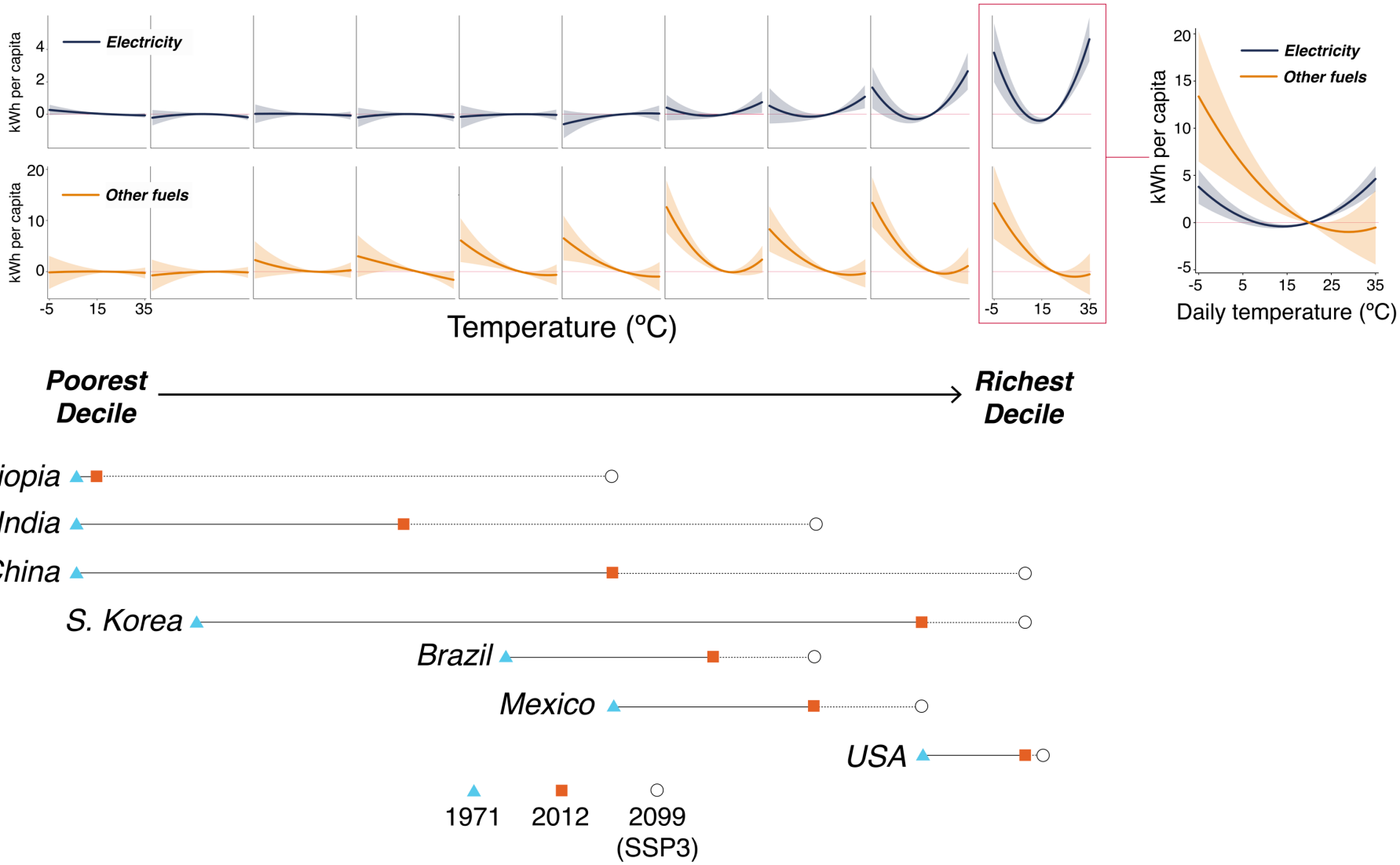
Historical energy consumption: data coverage



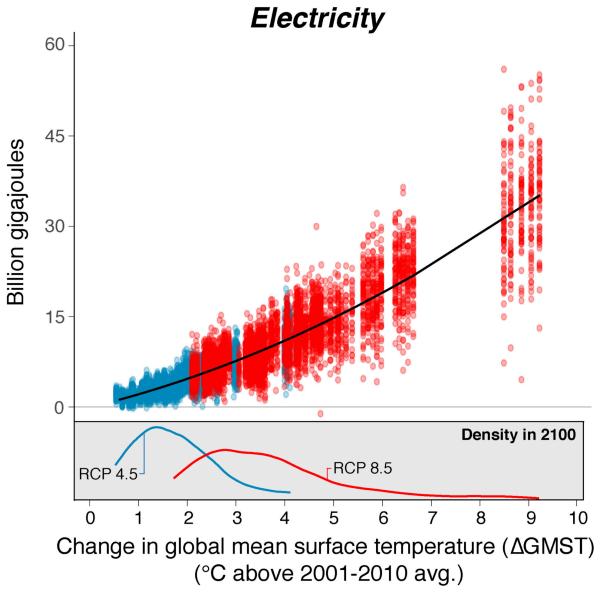
Energy use responds to temperature in rich countries



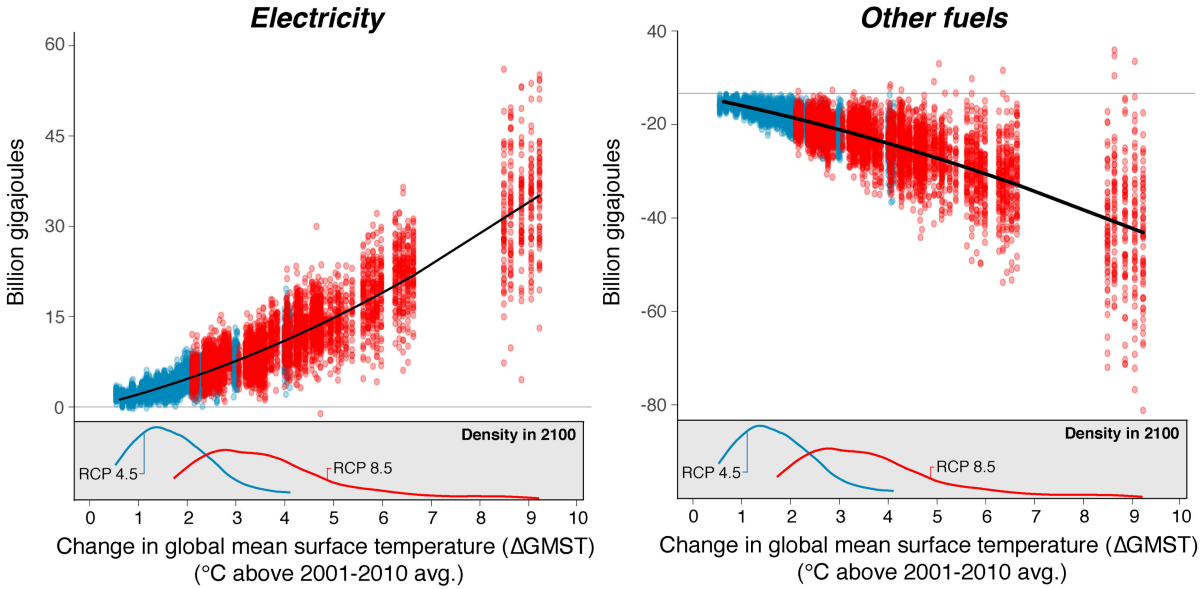
Energy use responds to temperature in rich countries, but places facing most warming are not (yet) wealthy



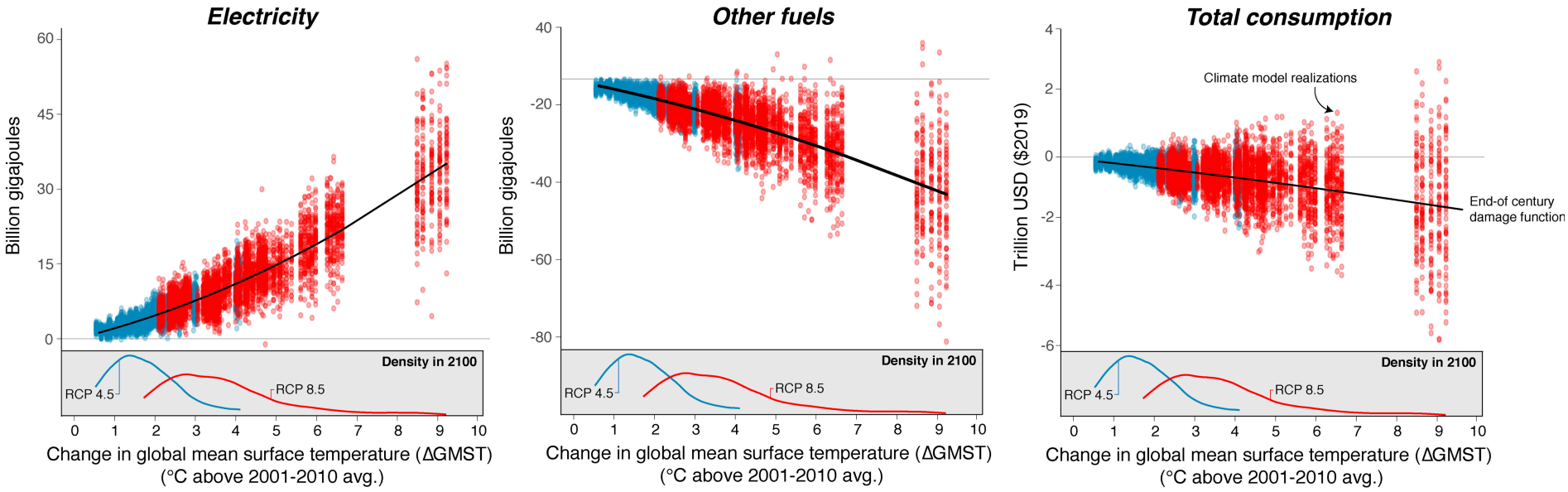
Declining use of heating fuels cancels out higher electricity consumption



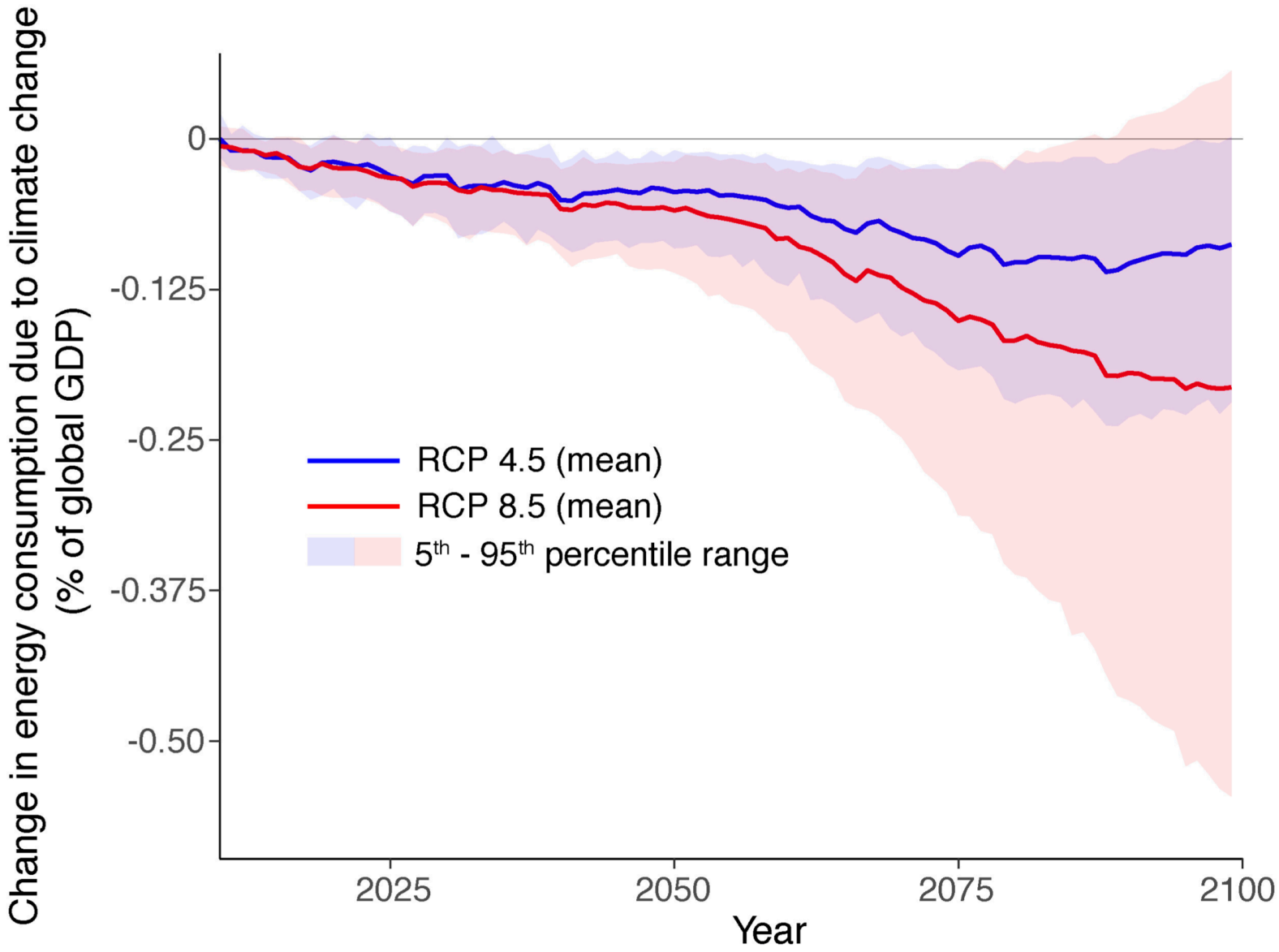
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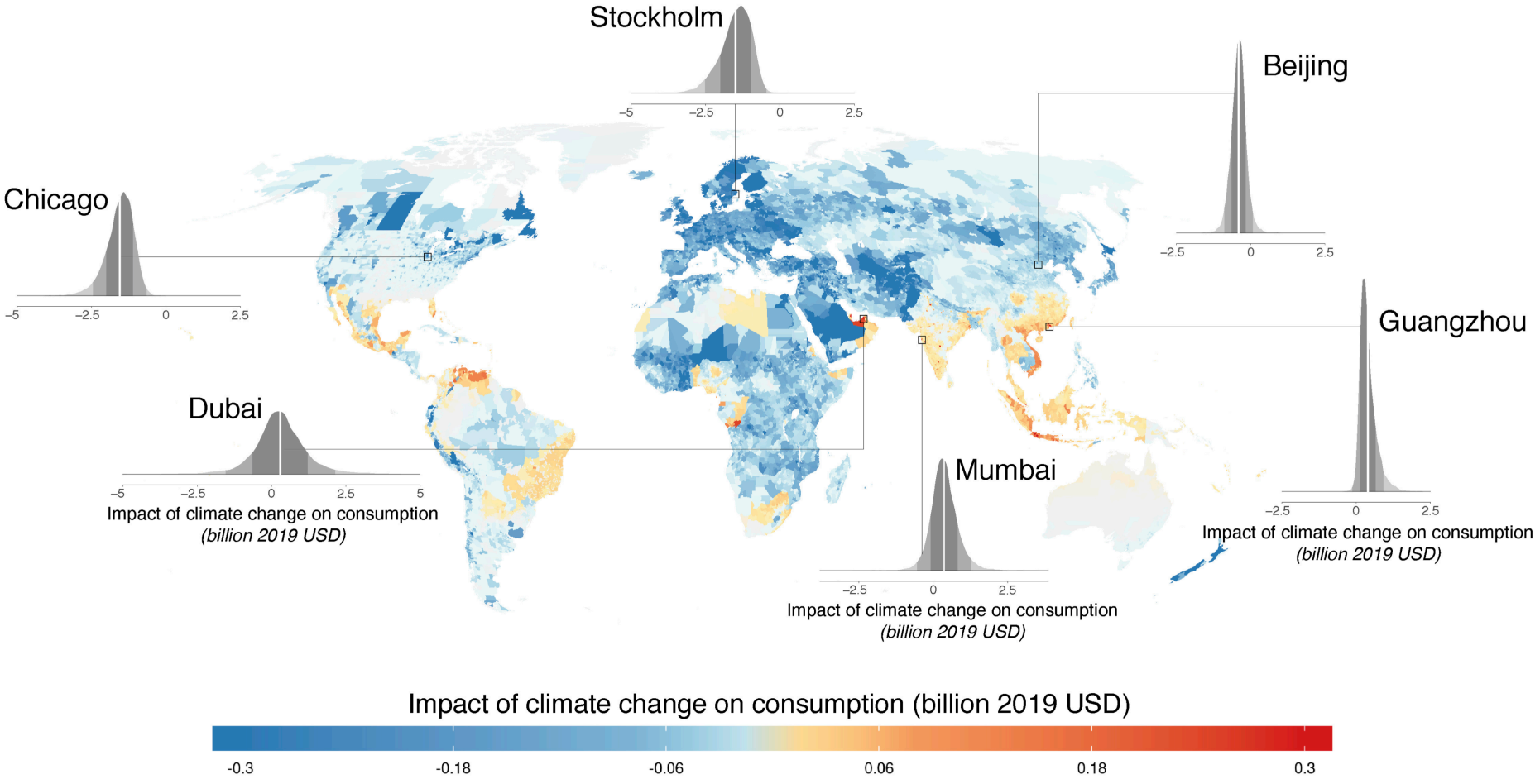
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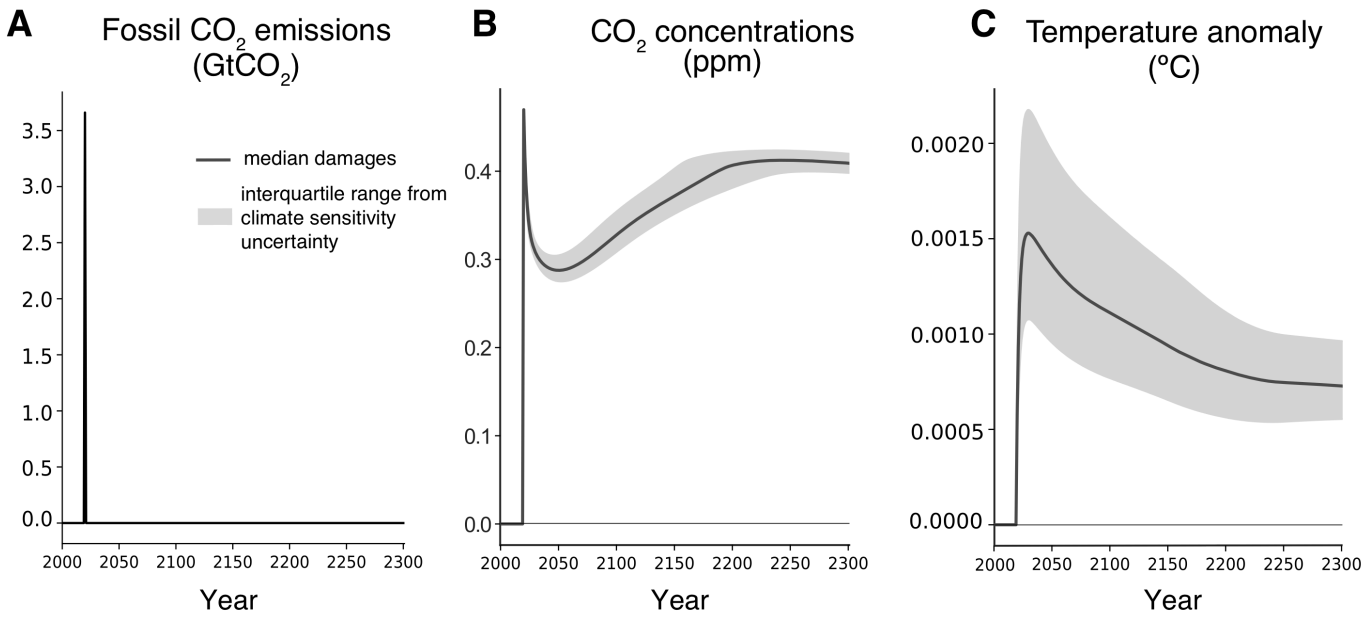
Projected global energy use decreases under climate change



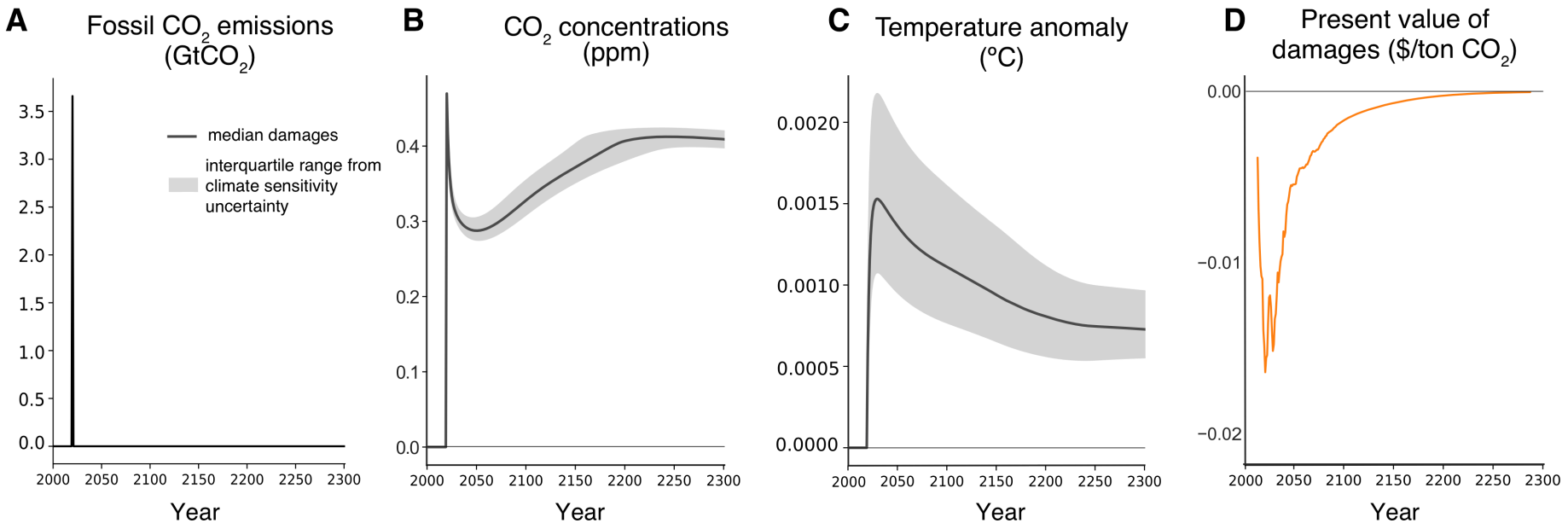
In many regions, total energy consumption may *decrease*



A marginal ton of CO_2 thus results in *negative* damages



A marginal ton of CO_2 thus results in *negative* damages



Partial social cost of carbon due to energy consumption

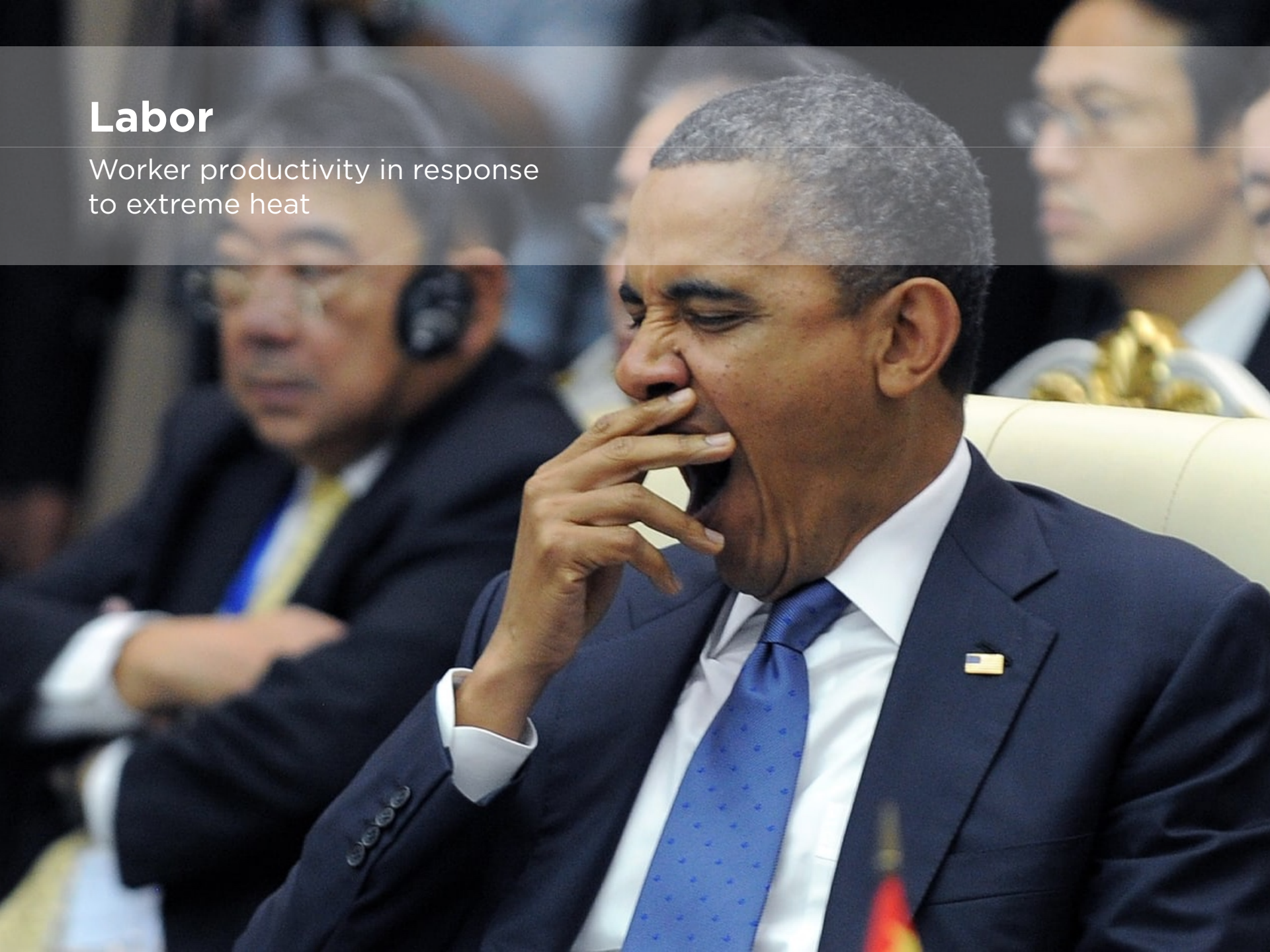
Discount rate:	$\delta = 2.5\%$	$\delta = 3\%$	$\delta = 5\%$
	1.4% price growth		
RCP 8.5	-1.41 [-0.19]	-1.08 [-0.10]	-0.55 [-0.01]
RCP 4.5	-1.27 [-0.08]	-1.00 [-0.05]	-0.51 [-0.01]
	0% price growth		
RCP 8.5	-0.71 [-0.04]	-0.60 [-0.02]	-0.37 [-0.002]
RCP 4.5	-0.64 [-0.0007]	-0.55 [-0.003]	-0.35 [-0.001]
	MERGE-ETL 6.0 prices		
RCP 8.5	-1.03 [-1.16]	-0.75 [-0.61]	-0.35 [-0.06]
RCP 4.5	-1.05 [-1.01]	-0.75 [-0.54]	-0.33 [-0.06]

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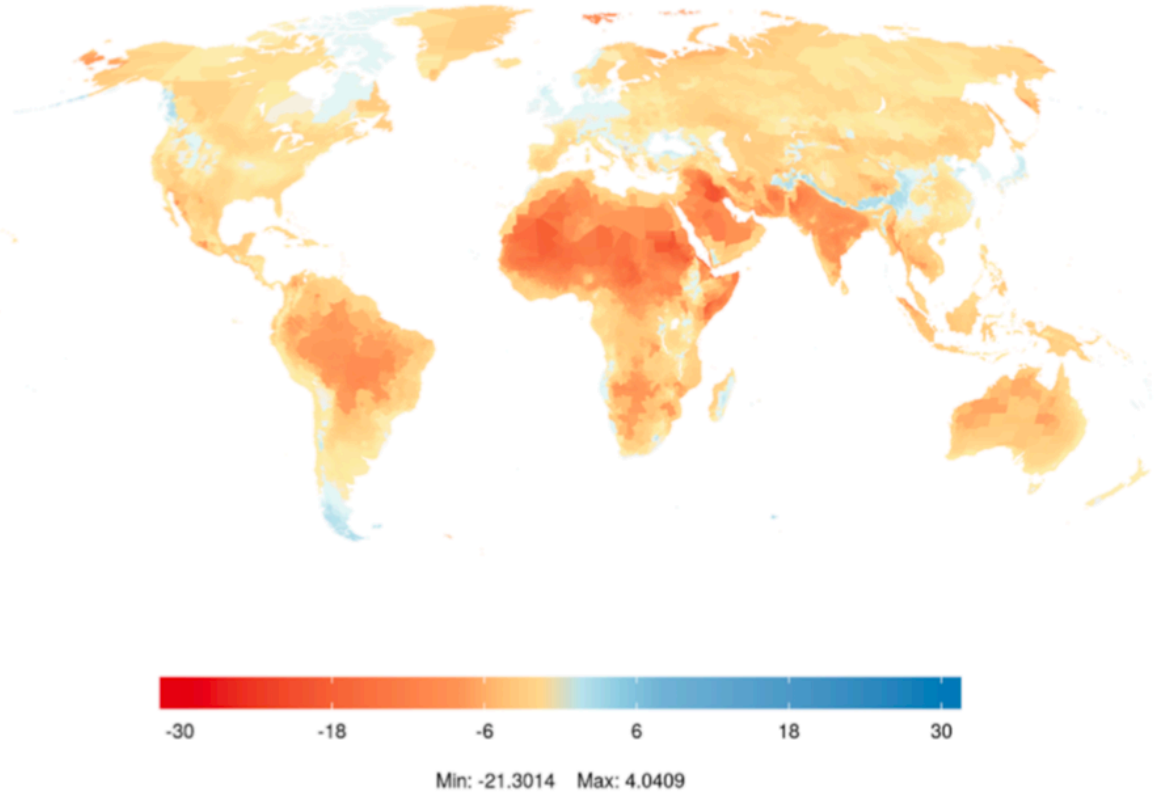
Labor

Worker productivity in response to extreme heat



Worker productivity projected to decline

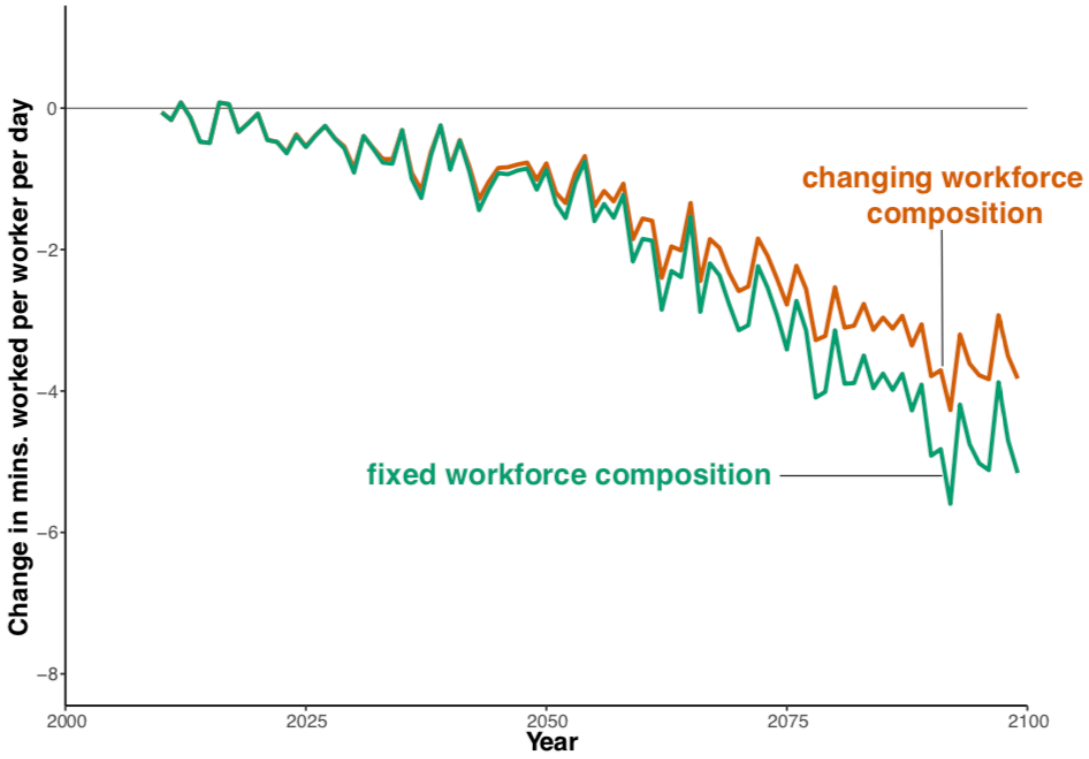
Projected impacts (min/worker/day) in 2100 under RCP8.5



- We estimate the share of high-risk workers as a function of income and climate in the cross section
- We then project yearly changes in productivity weighted by high risk share

Worker productivity projected to decline

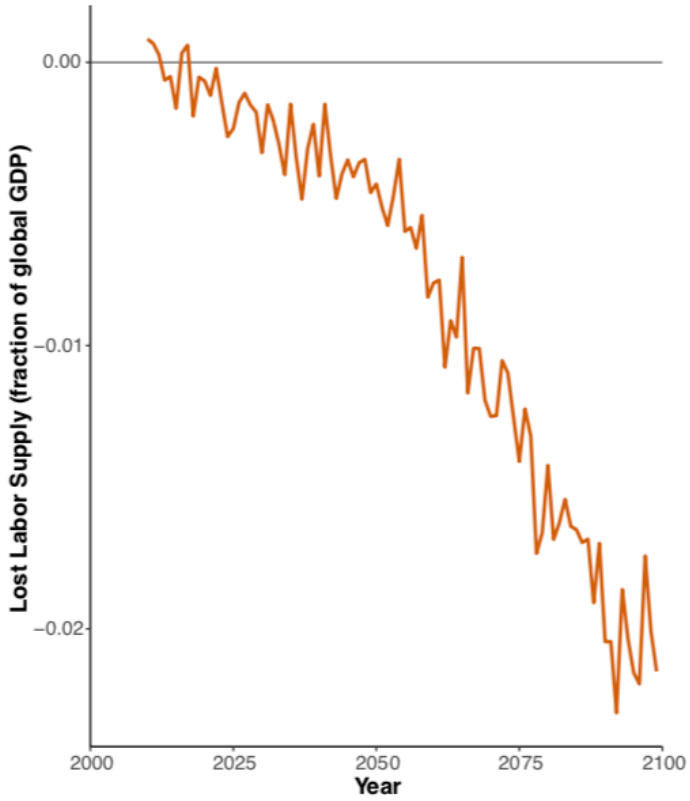
Projected impacts (min/worker/day)
under RCP8.5 (CCSM4 climate model)



- We estimate the share of high-risk workers as a function of income and climate in the cross section
- We then project yearly changes in productivity weighted by high risk share

Worker productivity projected to decline

Monetized impacts under RCP8.5 assuming a labor supply elasticity of 0.5



- We estimate the share of high-risk workers as a function of income and climate in the cross section
- We then project yearly changes in productivity weighted by high risk share
- Lastly, we use the estimated labor supply elasticity from Chetty et al. (2011) to monetize impacts on productivity

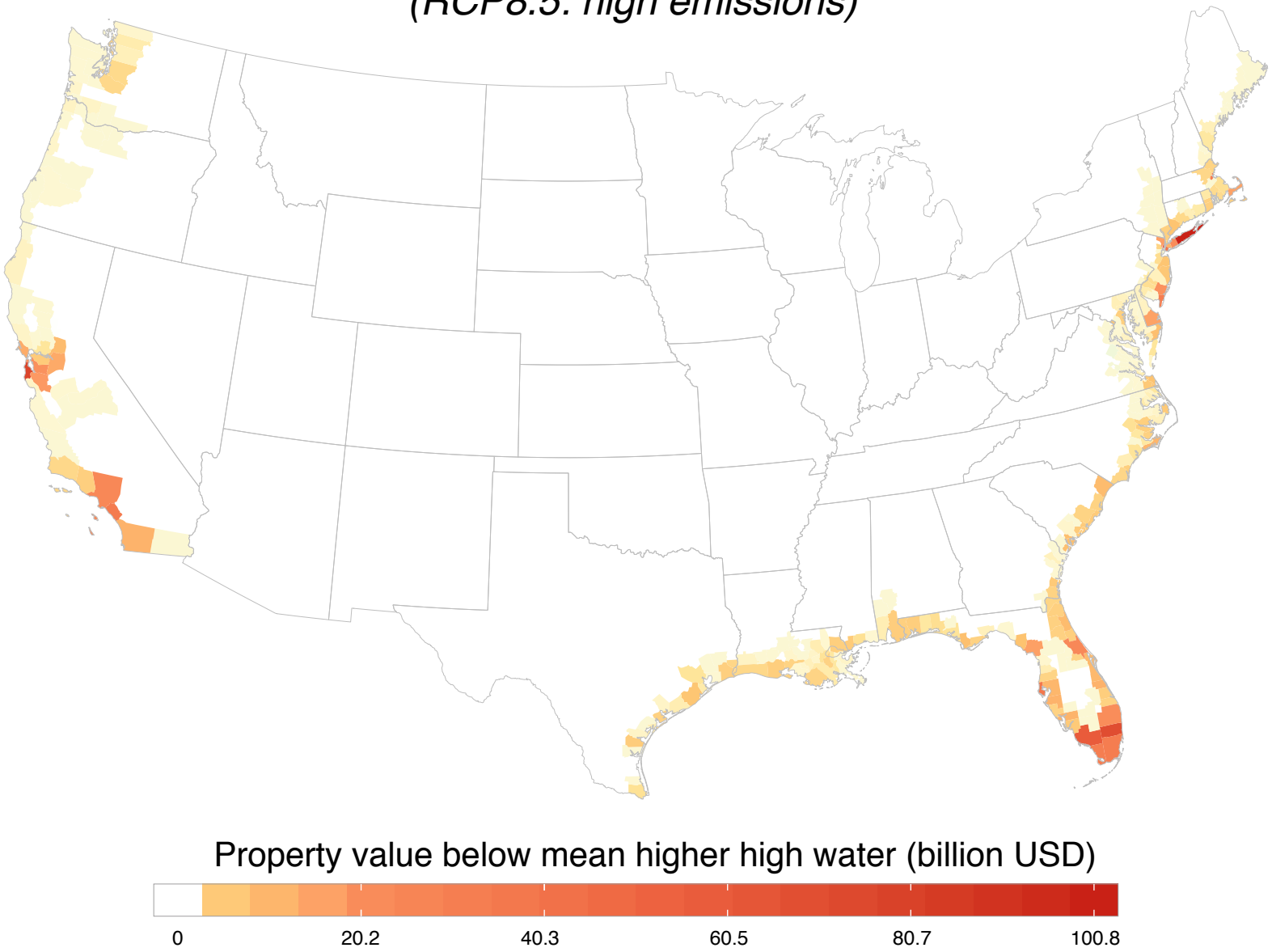


Coastal

Damages from sea level rise

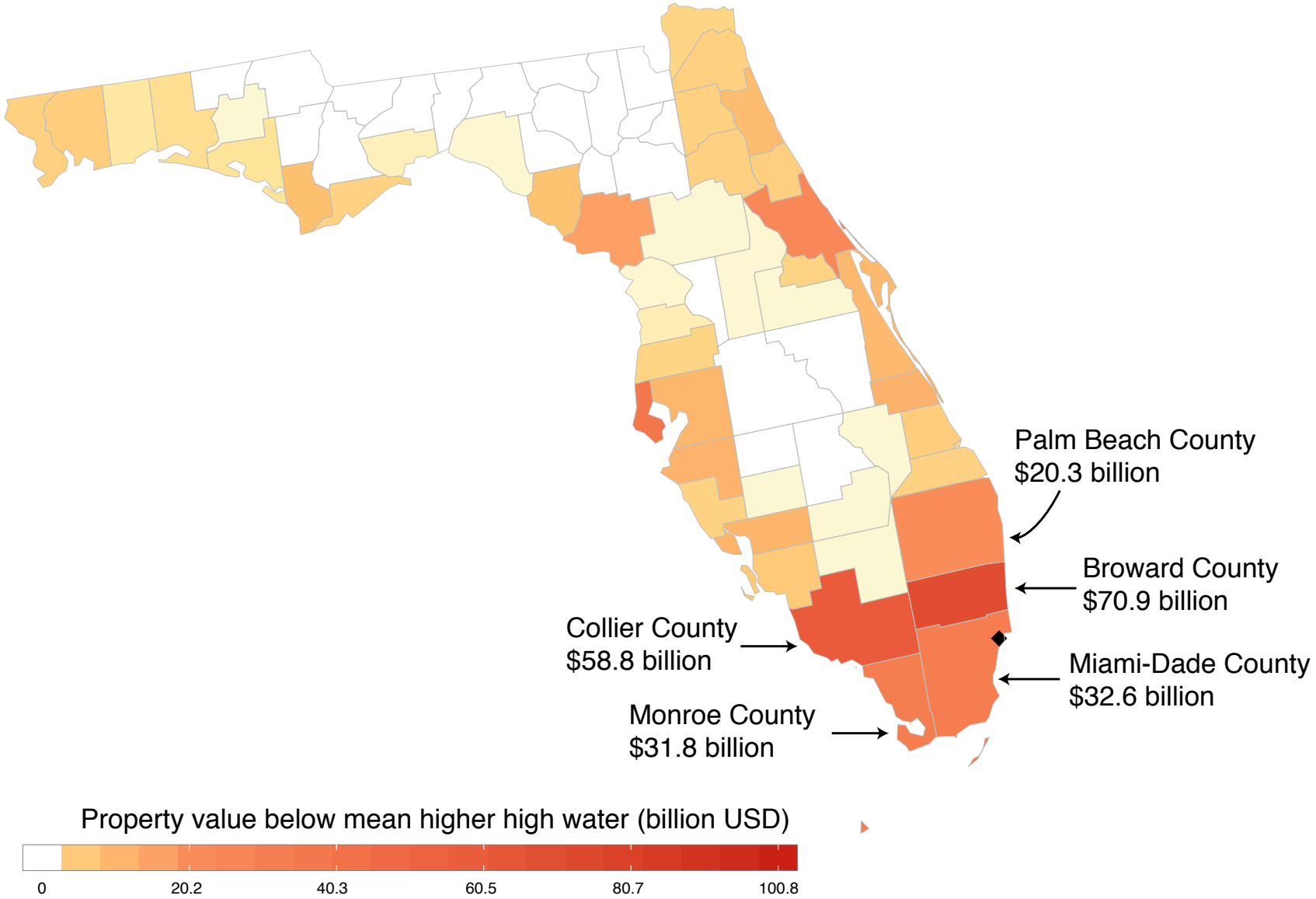
Coastal inundation damages in 2100

(RCP8.5: high emissions)



Coastal inundation damages in 2100

(RCP8.5: high emissions)



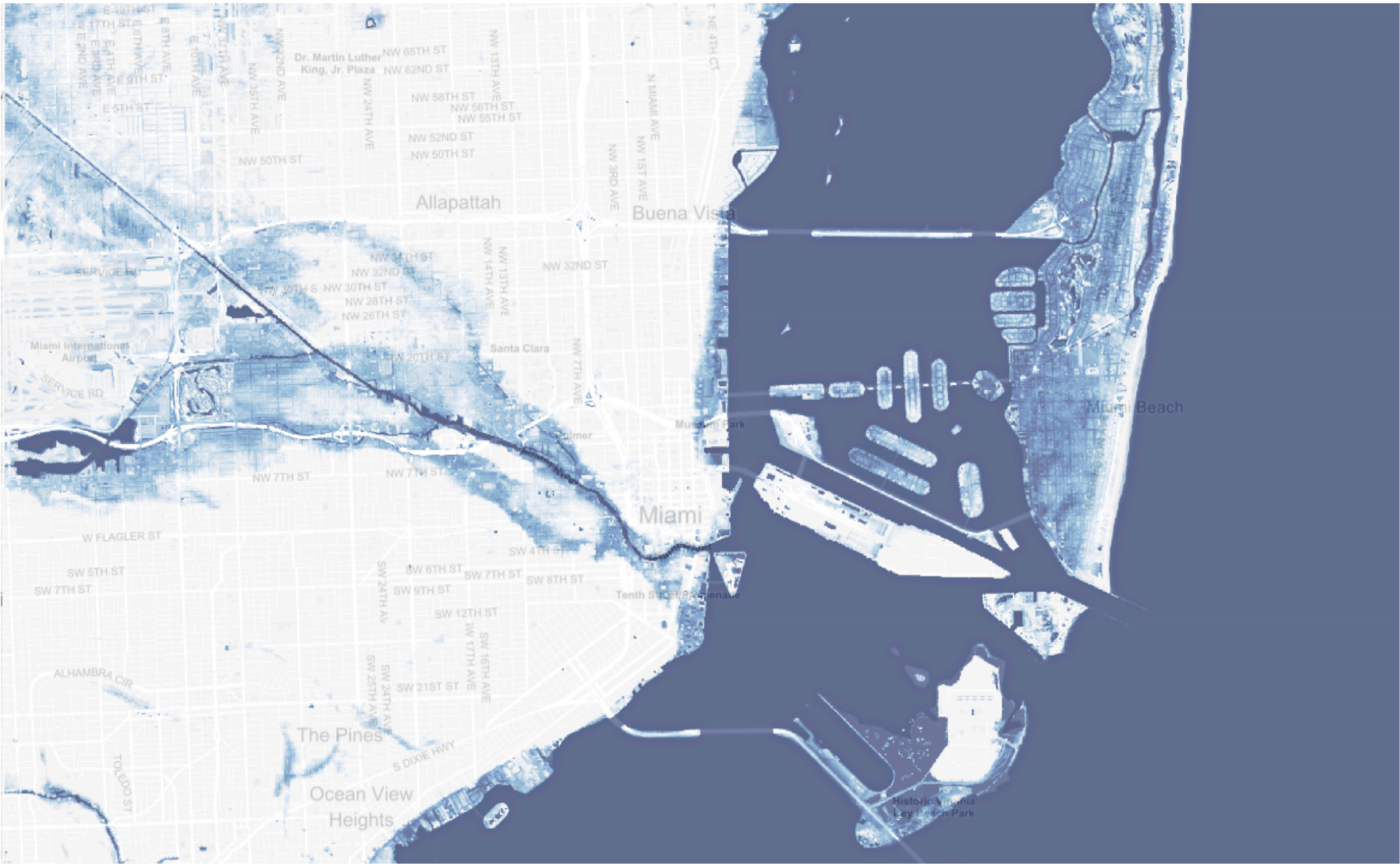
2020


Allapattah
Buena Vista
Miami
Miami Beach
Santa Clara
Culmer
Museum Park
The Pines
Ocean View Heights
Miami International Airport
Tenth Street/Precinct
Historic Virginia Key Beach Park
Dr. Martin Luther King, Jr. Plaza
NW 65TH ST
NW 62ND ST
NW 58TH ST
NW 56TH ST
NW 55TH ST
NW 52ND ST
NW 50TH ST
NW 34TH ST
NW 32ND ST
NW 30TH ST
NW 28TH ST
NW 26TH ST
NW 20TH ST
NW 7TH ST
W FLAGLER ST
SW 4TH ST
SW 6TH ST
SW 7TH ST
SW 8TH ST
SW 9TH ST
SW 12TH ST
SW 21ST ST
SW 24TH AVE
S DIXIE HWY
NW 24TH AVE
NW 32ND AVE
NW 37TH AVE
NW 13TH AVE
NW 14TH AVE
NW 7TH AVE
NW 3RD AVE
NW 1ST AVE
N MIAMI AVE
NE 4TH CT
WASHINGTON AVE
PRAIRIE AVE
ROYAL PALM AVE
SERVICE RD
ALHAMBRA CIR
TOLEDO ST

2050

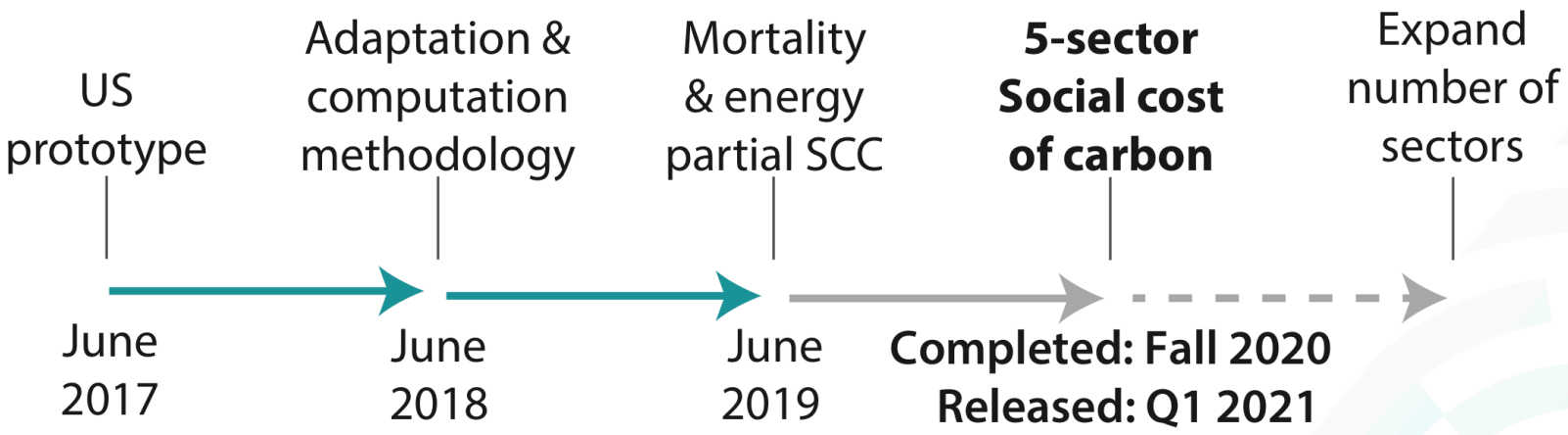

Allapattah
Buena Vista
Miami International Airport
Santa Clara
Culmer
Museum Park
Miami
Miami Beach
The Pines
Ocean View Heights
Tenth Street/Pro
Dr. Martin Luther King, Jr. Plaza
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E 3RD AVE
E 2ND AVE
E 9TH ST
E 5TH ST
NW 35TH AVE
SW 24TH AV
SW 25TH AVE
SW 17TH AVE
SW 16TH AVE
PRAIRIE AVE
ROYAL PALM AVE
WASHINGTON AVE

2100


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E 2ND AVE
E 9TH ST
E 5TH ST
NW 2ND AVE
NE 4TH CT

Social cost of carbon timeline

Climate Impact Lab



5-sector SCC: Agriculture, Coastal, Energy, Labor, Mortality
(plus Migration complete but not fully integrated)

EPIC | ENERGY POLICY INSTITUTE AT THE UNIVERSITY OF CHICAGO

Incorporating Externalities into Climate Policy: The Social Cost of Carbon

AEA 2020 Continuing Education Program
San Diego, California

Michael Greenstone
Milton Friedman Distinguished Service Professor in Economics, the College, and the Harris School

Director
Energy Policy Institute at UChicago
Becker Friedman Institute

