



Climate Impact Lab

www.impactlab.org

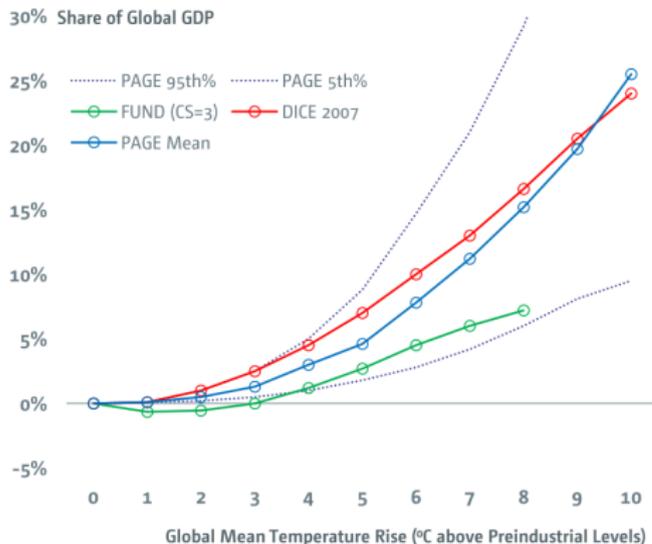
October 7th 2019

**Lives and Livelihoods: empirical estimations of climate damages,
adaptation, and inequality**

James Rising, Grantham Research Institute, LSE

PIs: Solomon Hsiang, Michael Greenstone, Robert Kopp, Trevor Houser

What problem are we solving?

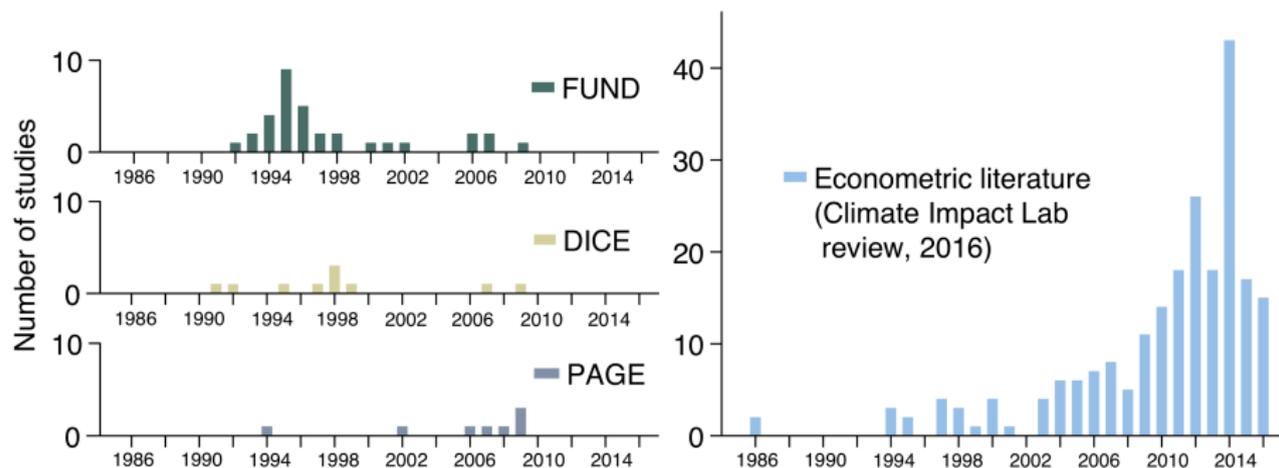


Source: *Intergency Working Group on SCC, 2010*

“[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)*

Climate Impact Lab methodology



“A newer and **substantial body of additional empirical and structural modelling literature** is now available.[providing] immediate opportunities to update the SC-IAMs.

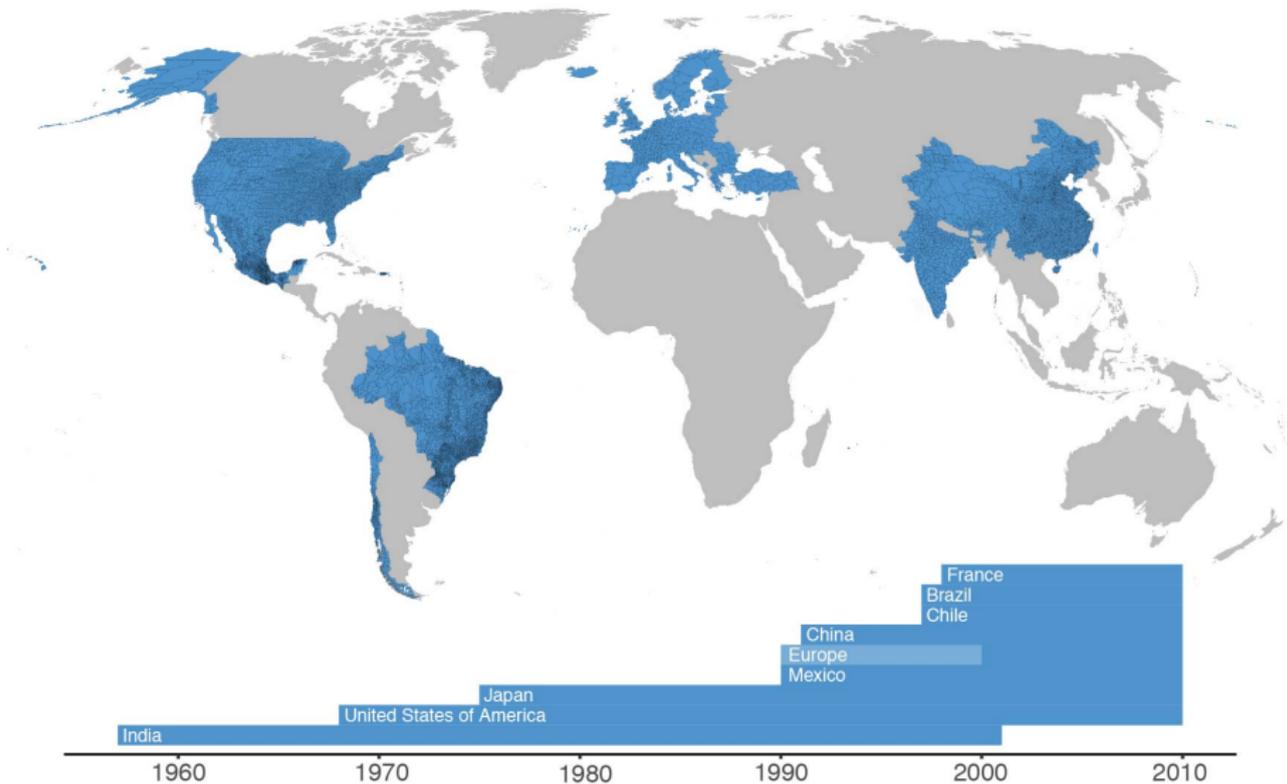
—National Academies of Sciences, Engineering, and Medicine (2017)

3 principles for developing estimates of climate damages

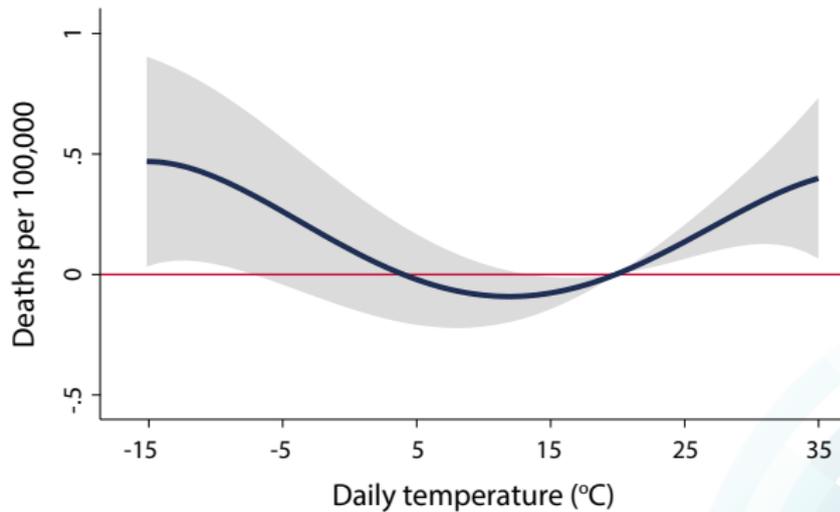
- ① **Best Available Evidence:** Damage functions should be informed by best available empirical estimates
- ② **Reflect Damage from Around the World:** Should use data representing the global population (not just rich pop.)
- ③ **Reflect Adaptation and its Costs:** Should reflect that agents adapt given income & climate, include these costs

2. Application to Real Data: Mortality

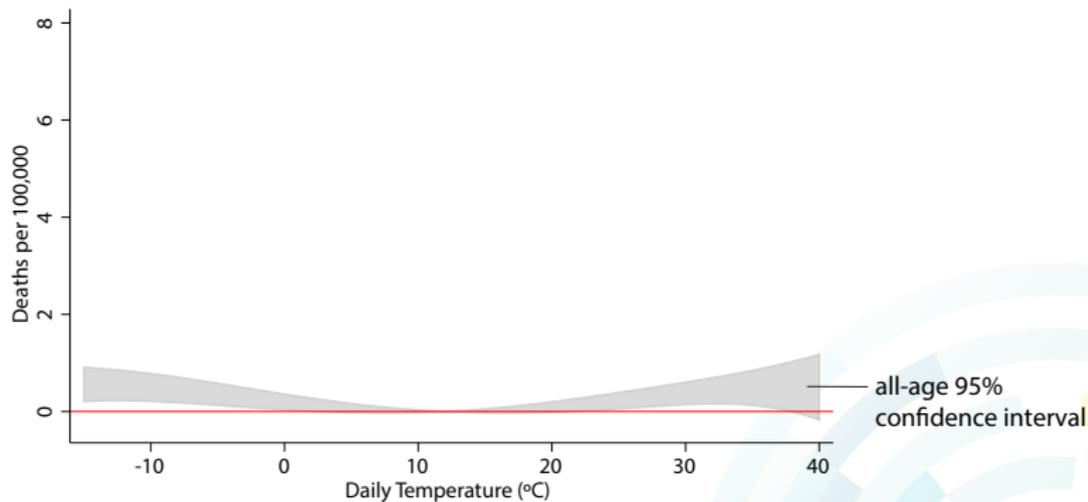
Historical mortality data



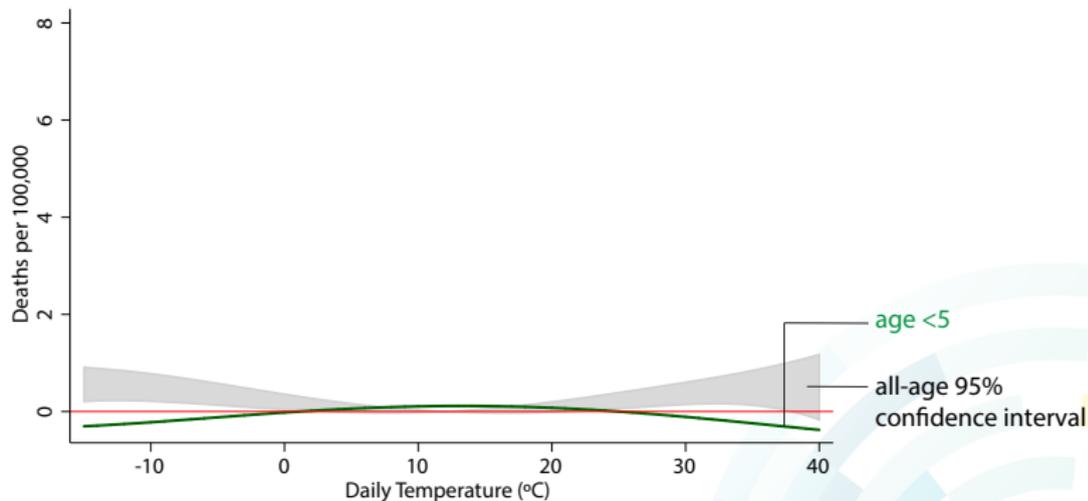
Global mortality-temperature response



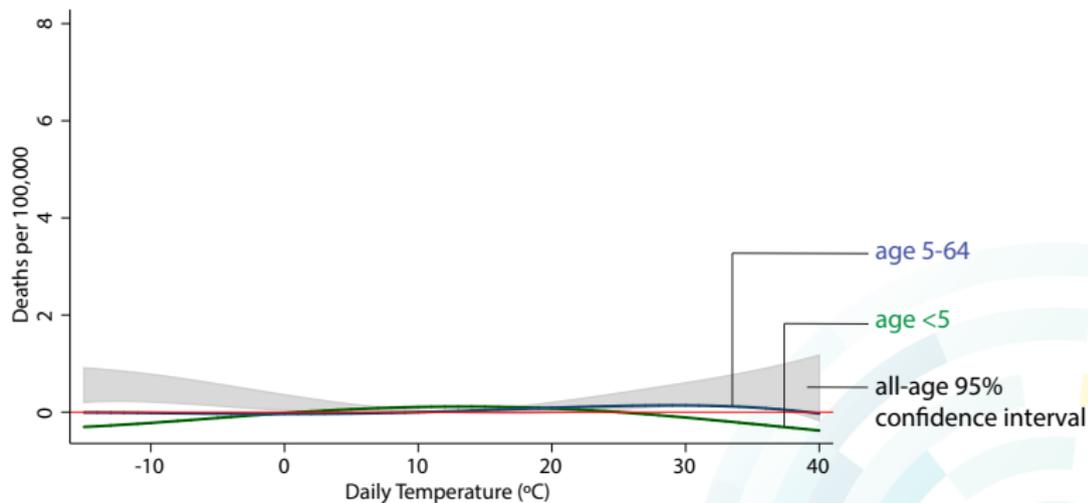
Accounting for demographics



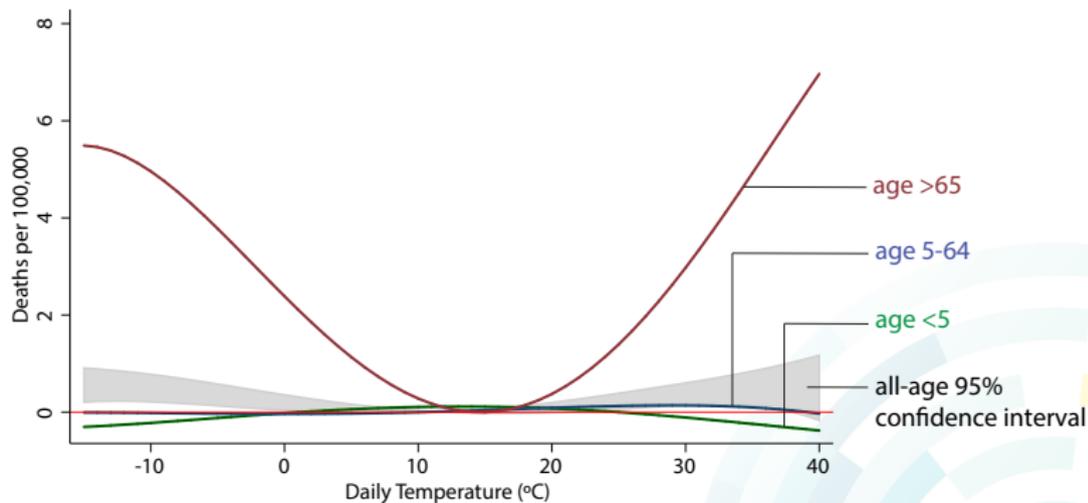
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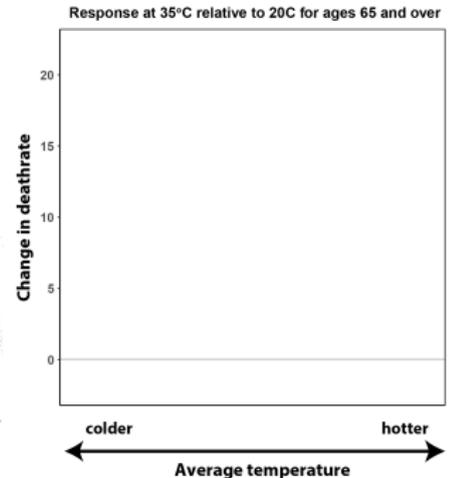
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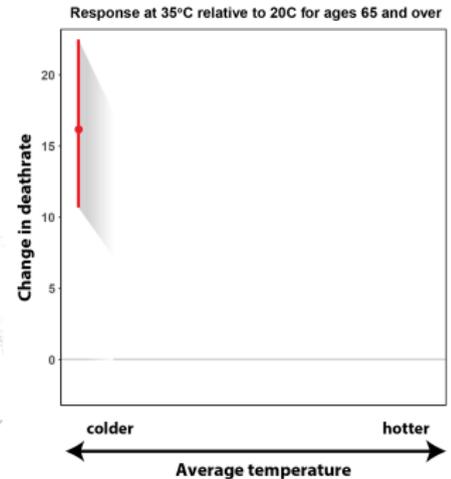
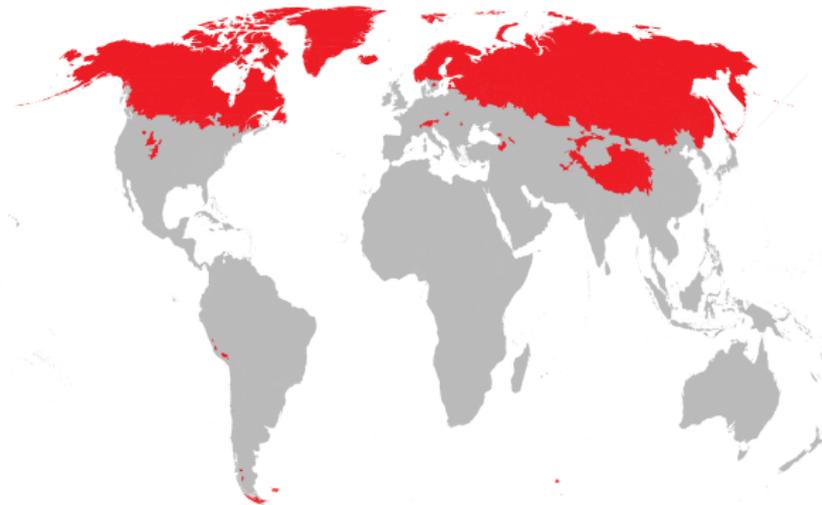


How do people adapt to long-run climate?



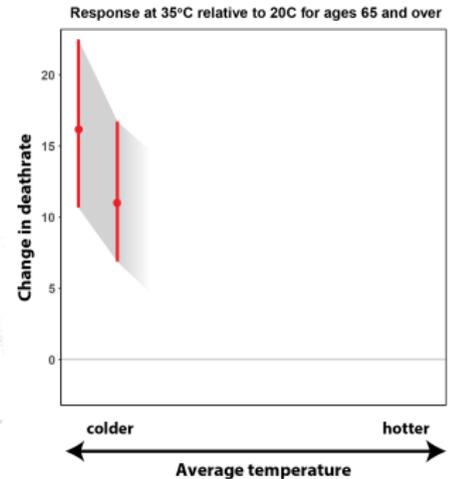
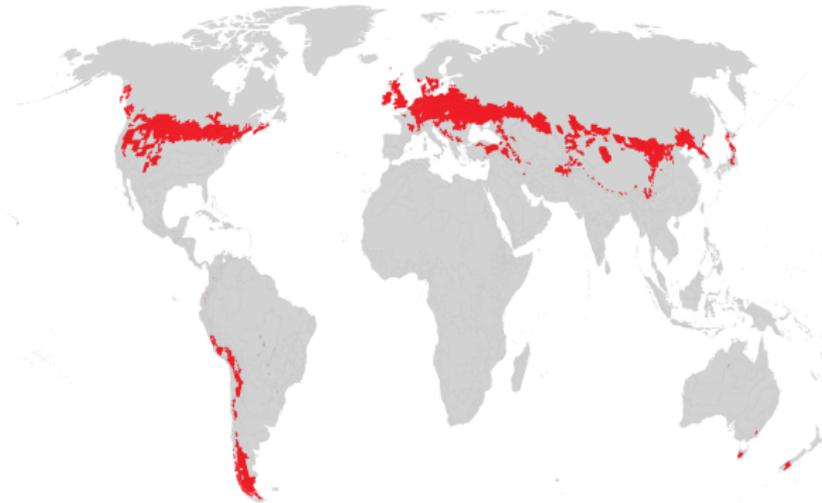
Effect day at 35°C relative to 20°C for ages 65 and over.
Coefficient calculated for deciles of *TMEAN* (red shaded area).

How do people adapt to long-run climate?



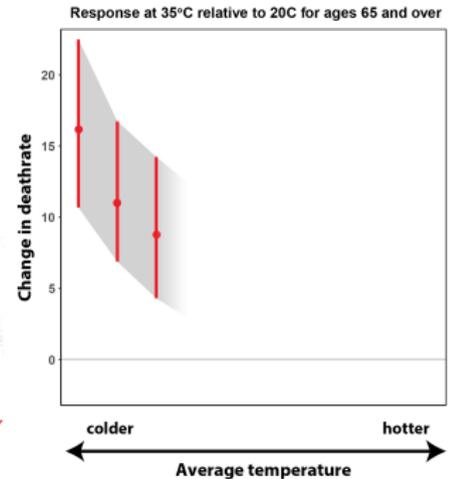
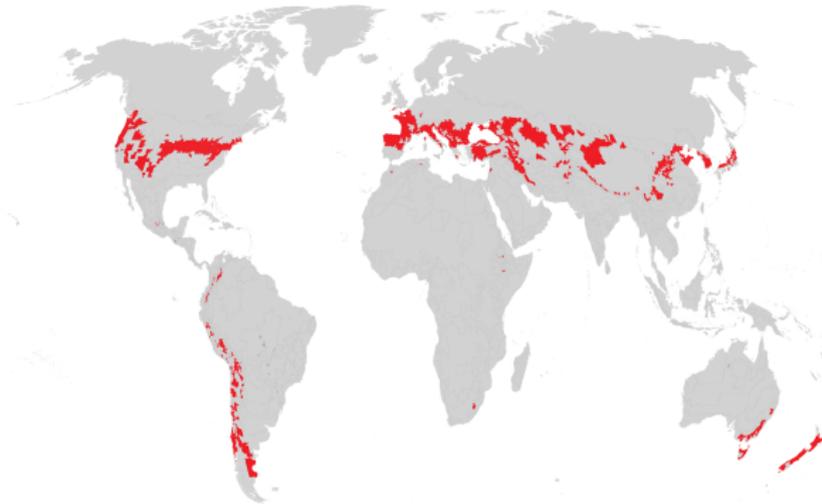
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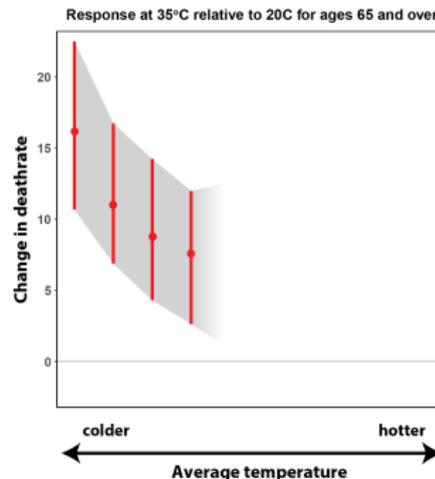
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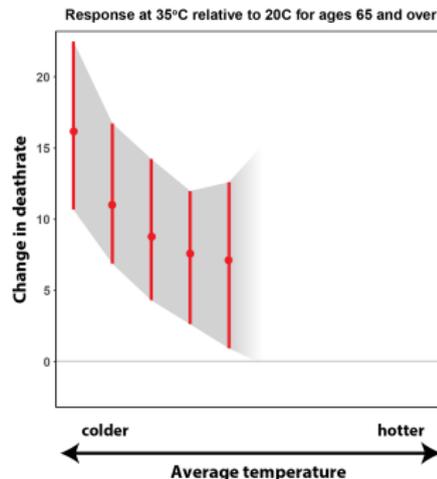
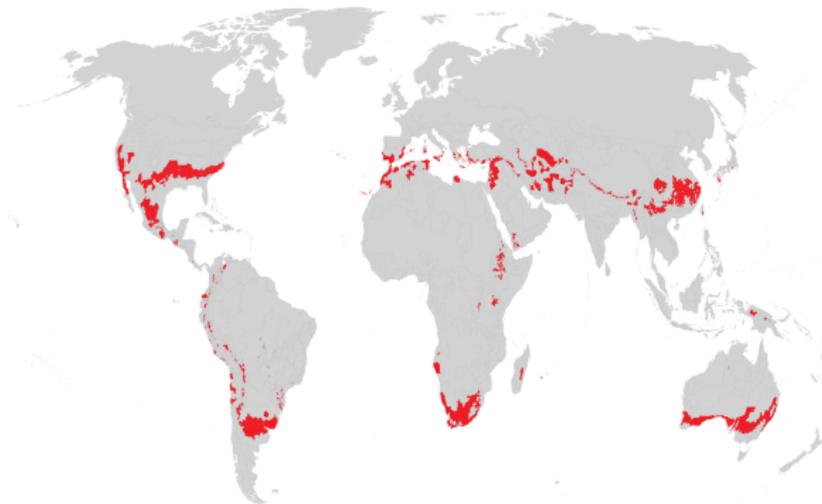
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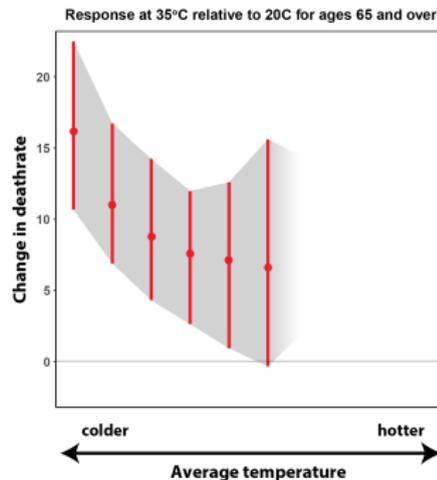
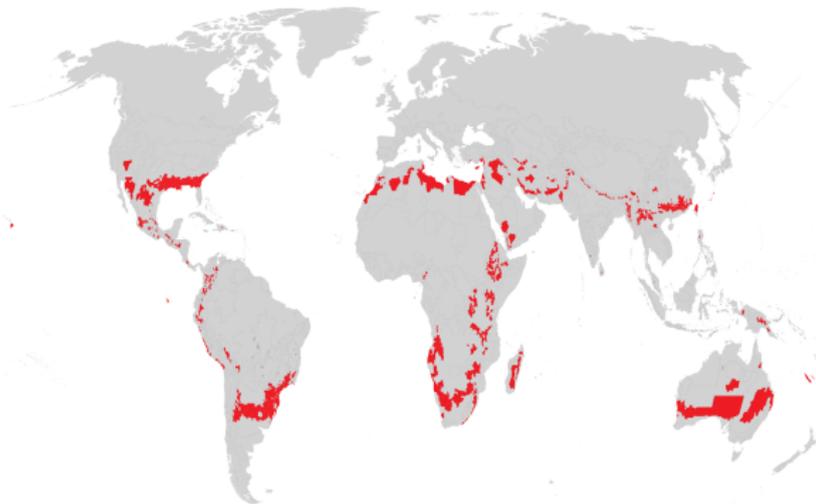
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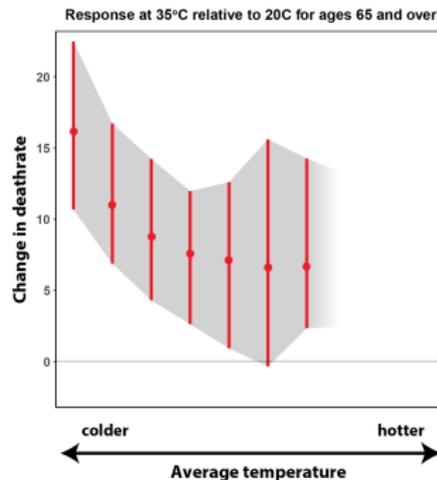
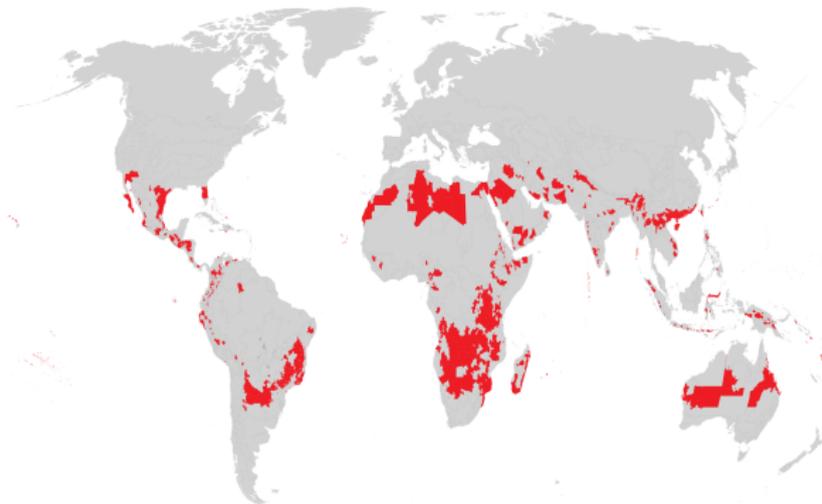
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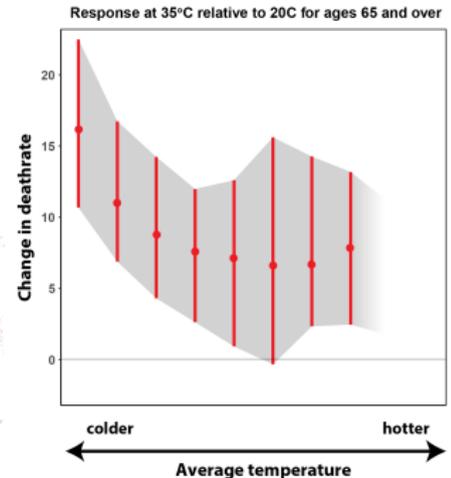
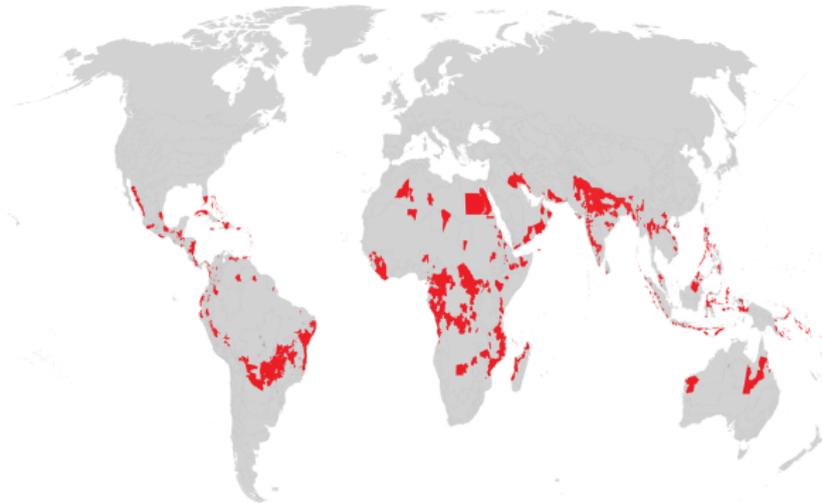
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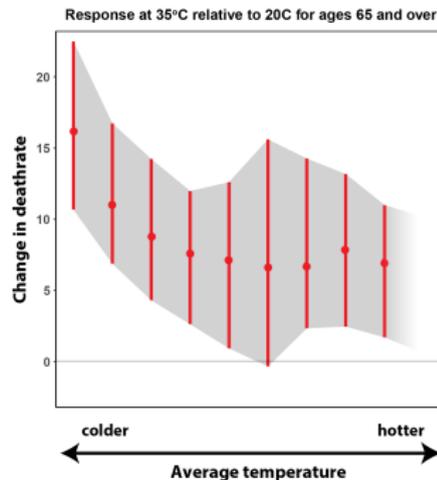
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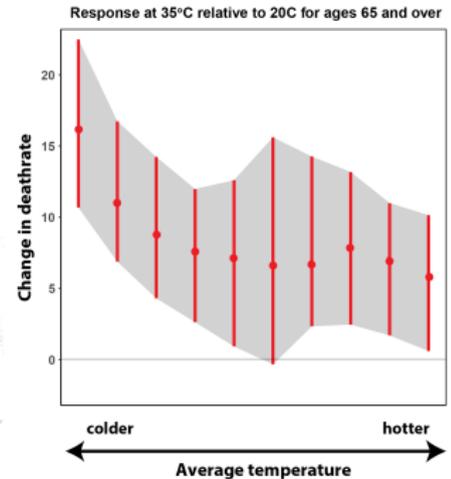
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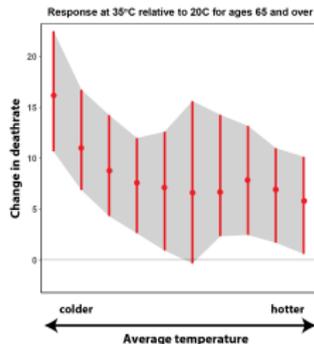
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Applying adaptation estimates across time

Adaptation measured across space



Socioeconomic & climate projections

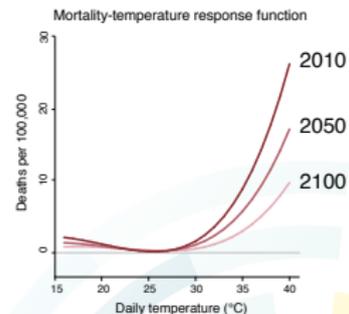
Shared socio-economic pathways



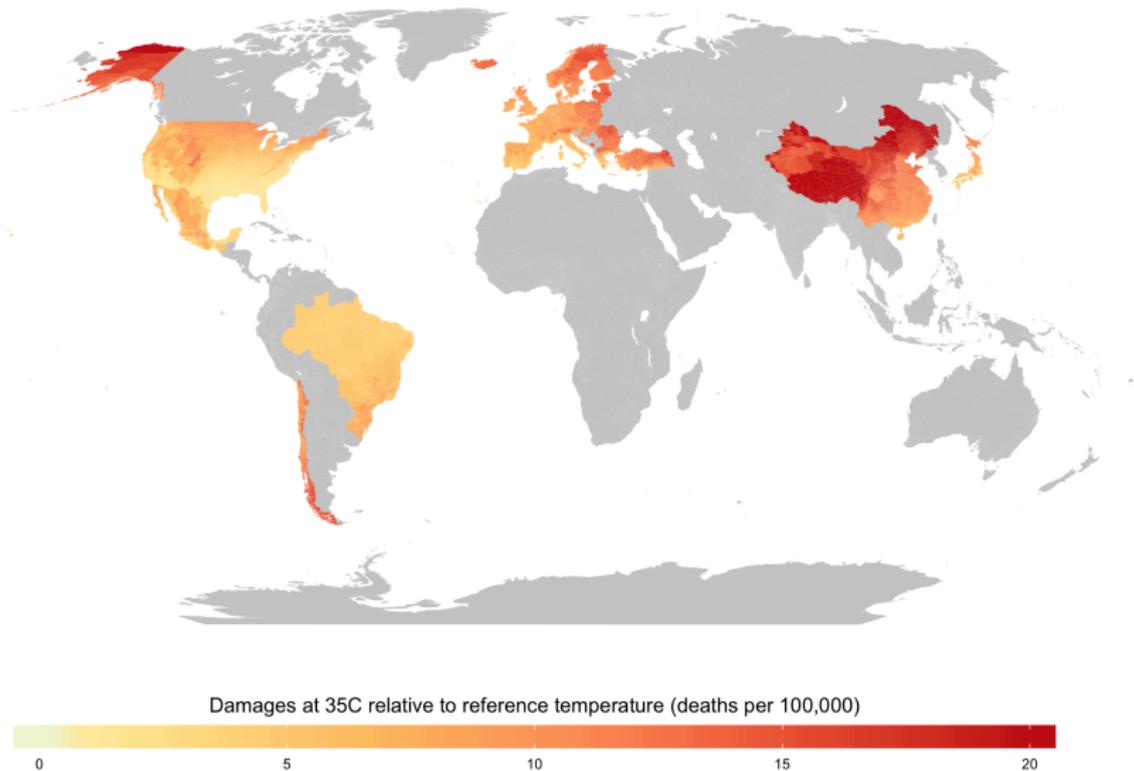
Probabilistic climate projections



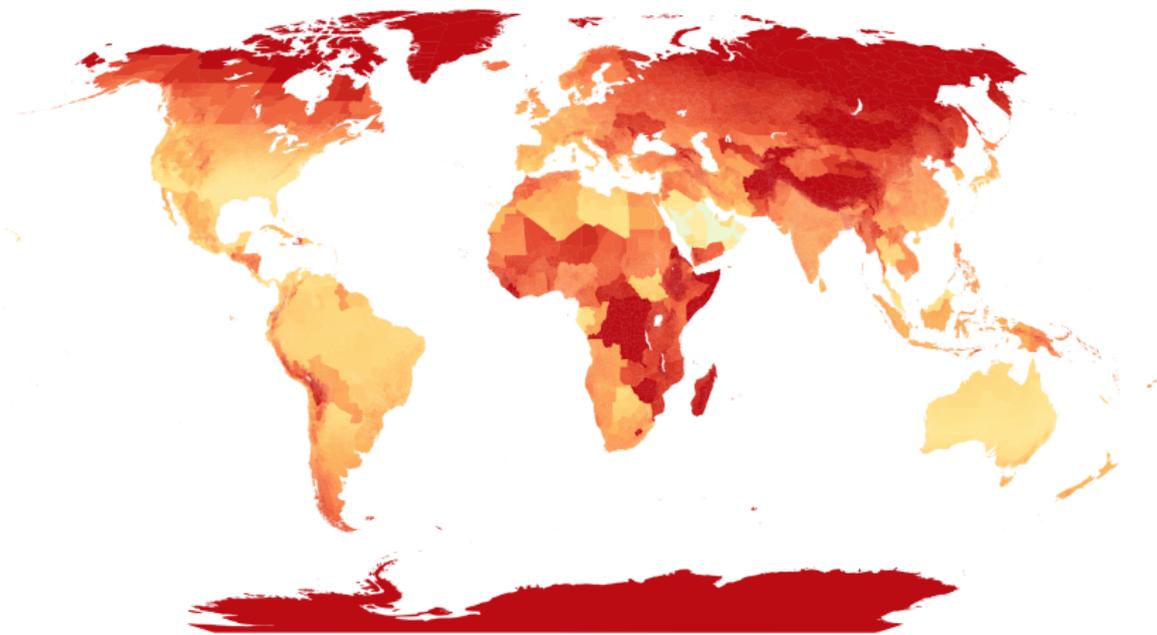
Adaptation predicted across time



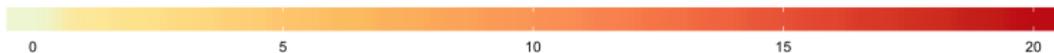
Sensitivity to hot days: Our sample, 65+



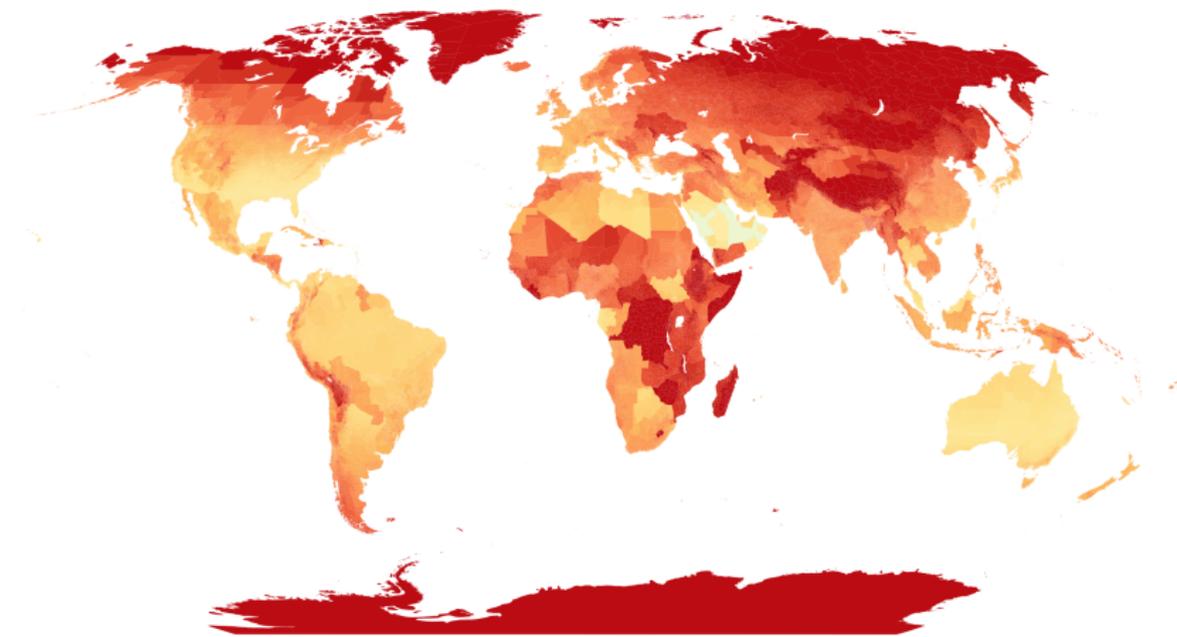
Sensitivity to hot days: Global, 65+



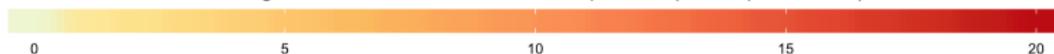
Damages at 35C relative to reference temperature (deaths per 100,000)



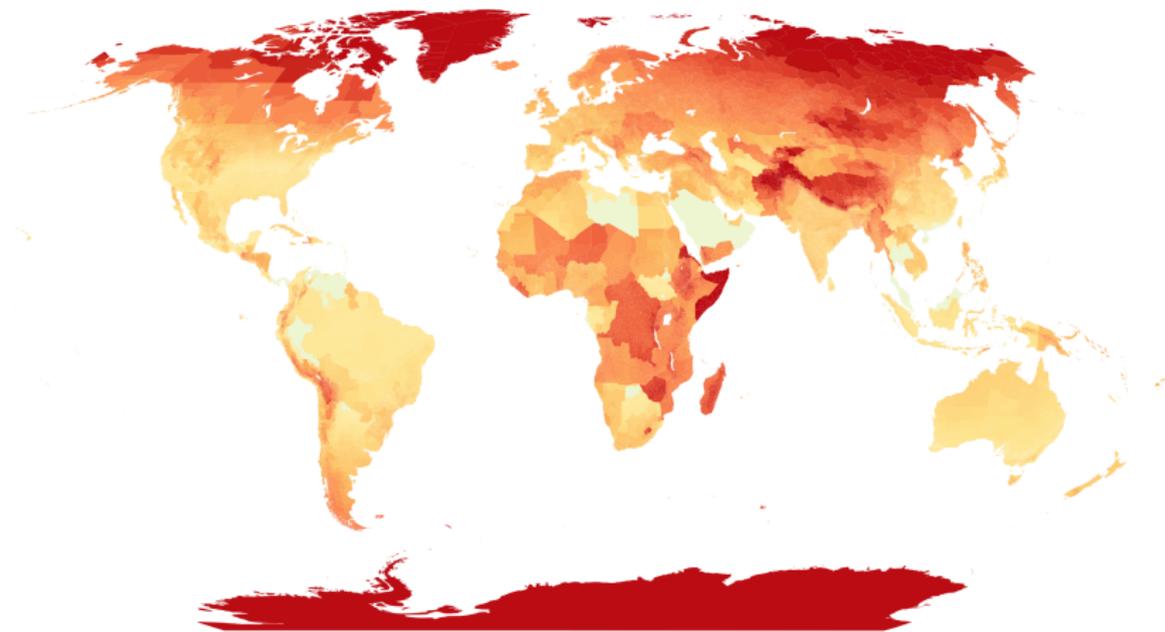
Projecting sensitivity to temperature - 2020



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



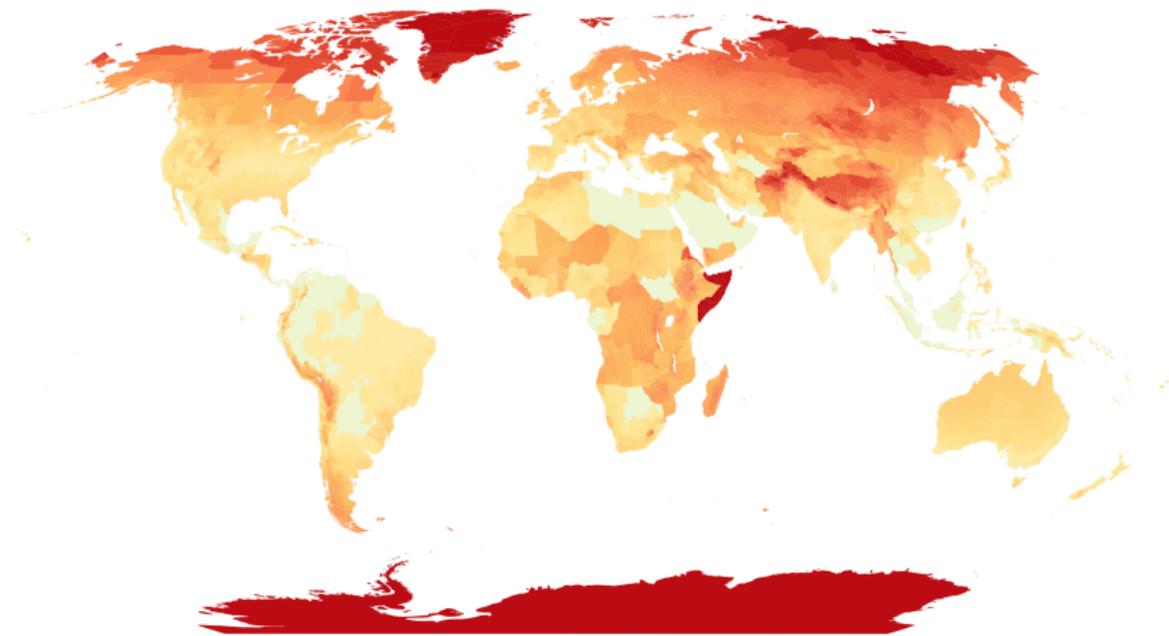
Projecting sensitivity to temperature - 2050



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



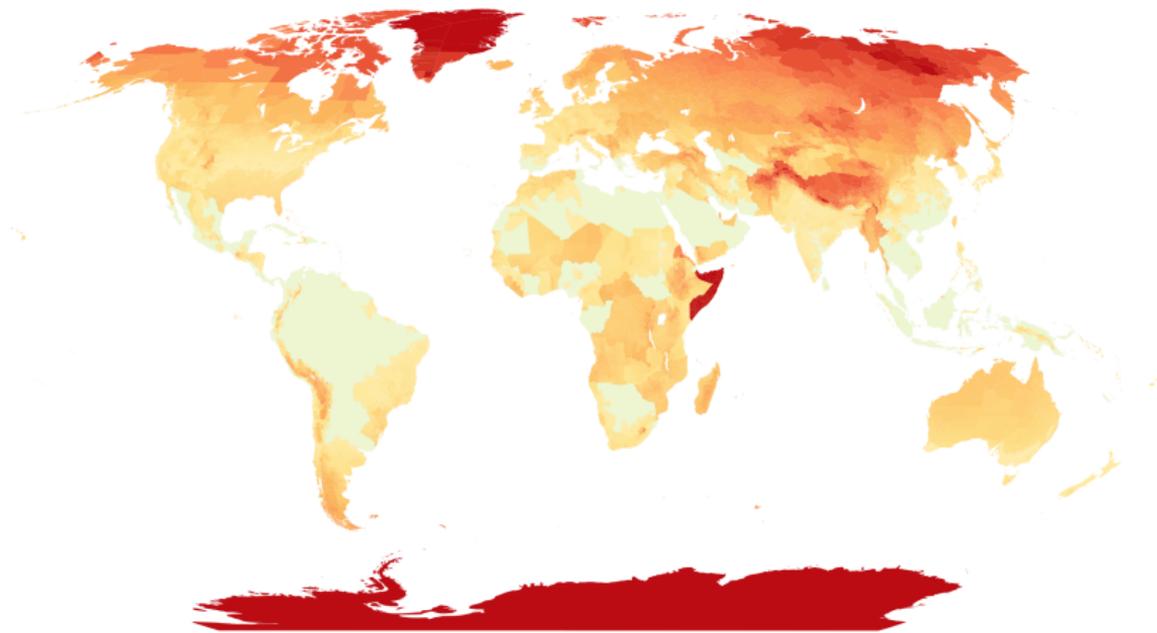
Projecting sensitivity to temperature - 2080



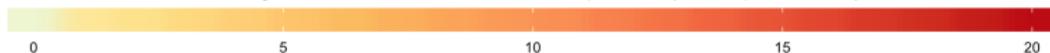
Damages at 35C relative to reference temperature (deaths per 100,000)



Projecting sensitivity to temperature - 2100



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



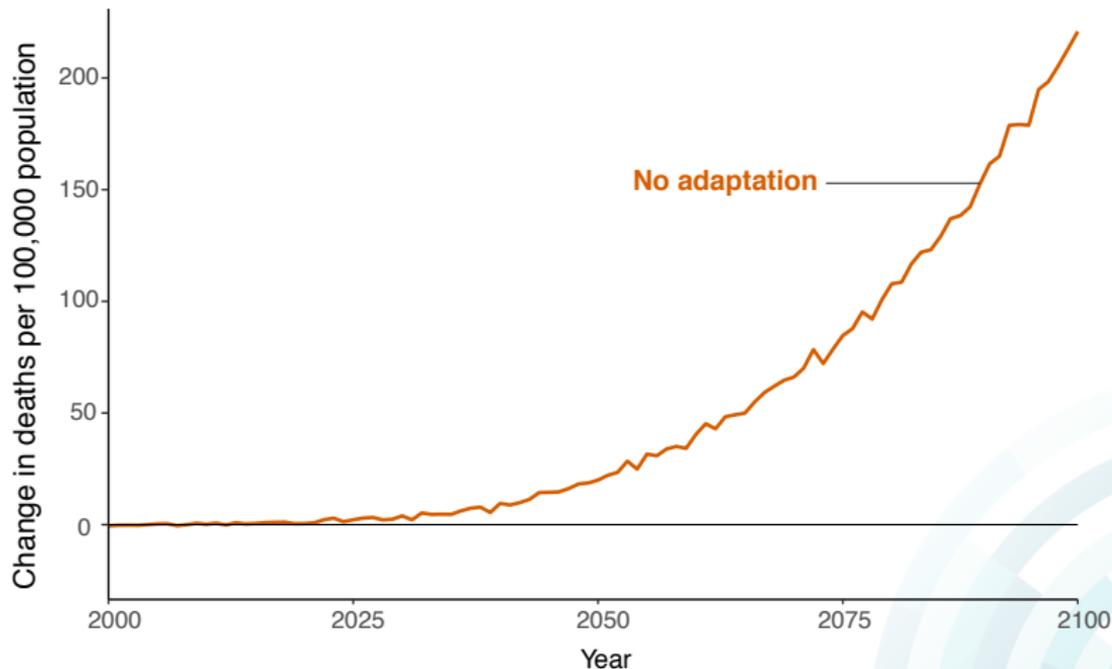
Projecting future impacts of climate change

We develop a new method to estimate the costs incurred by populations as they adapt to warming

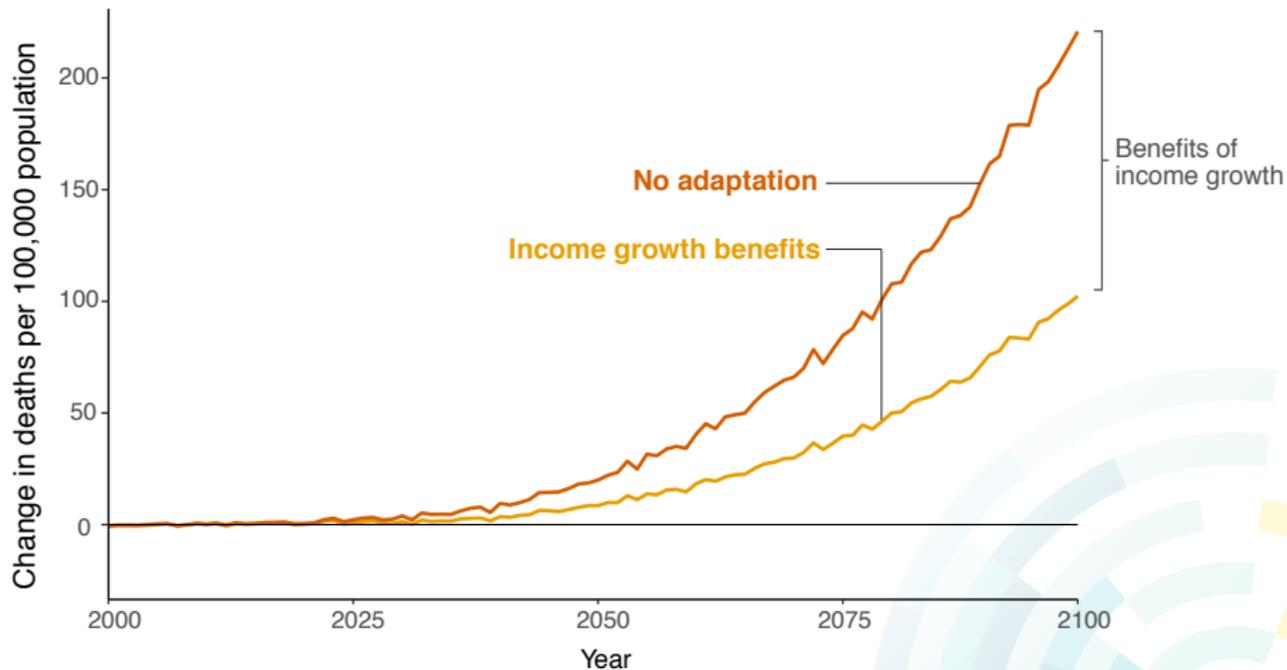
Intuition:

- People invest in adaptive behaviors and technologies **until the costs of doing so just equal the protective benefits**
- **We observe the protective benefits** — changes in sensitivity of mortality to temperature as the climate gradually warms
- We use empirical estimates of these benefits to **back out the costs**

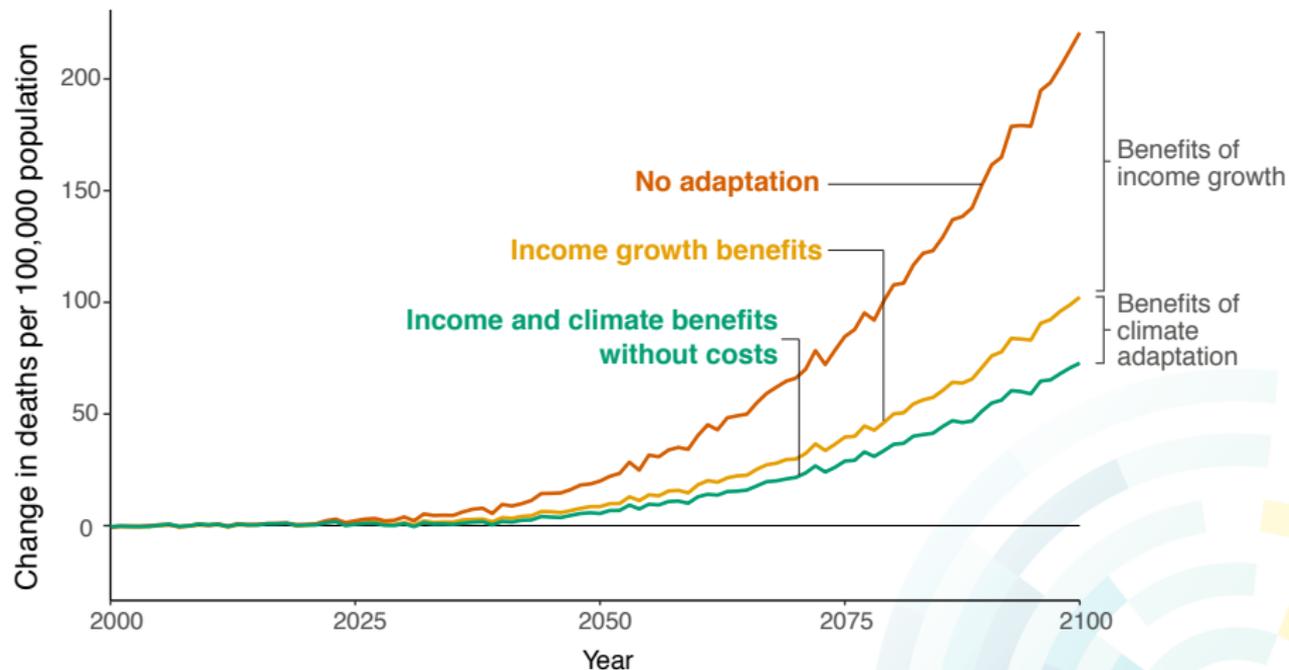
Projected impacts for the globe under RCP8.5



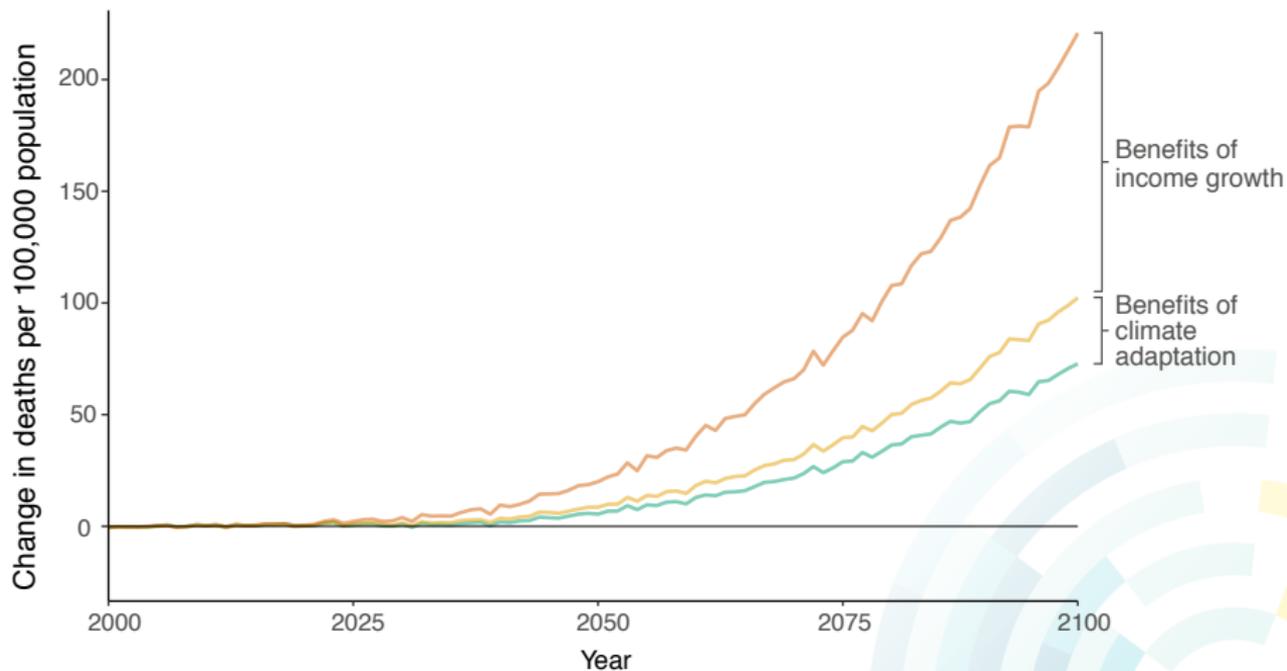
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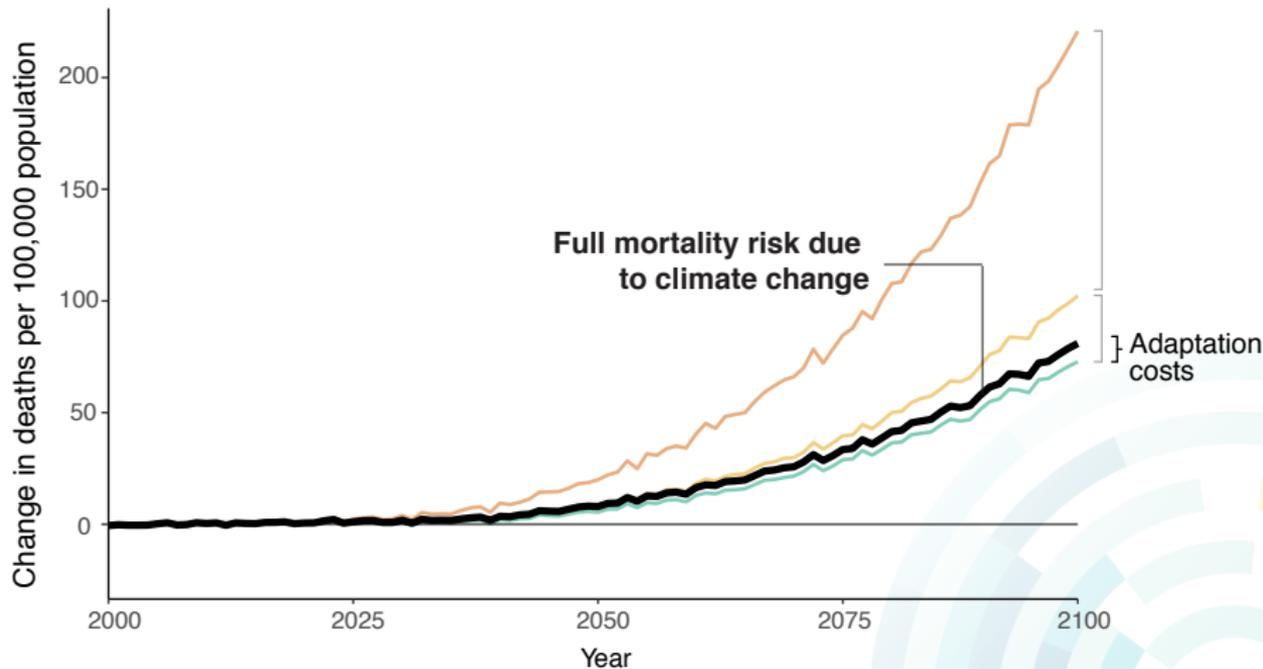
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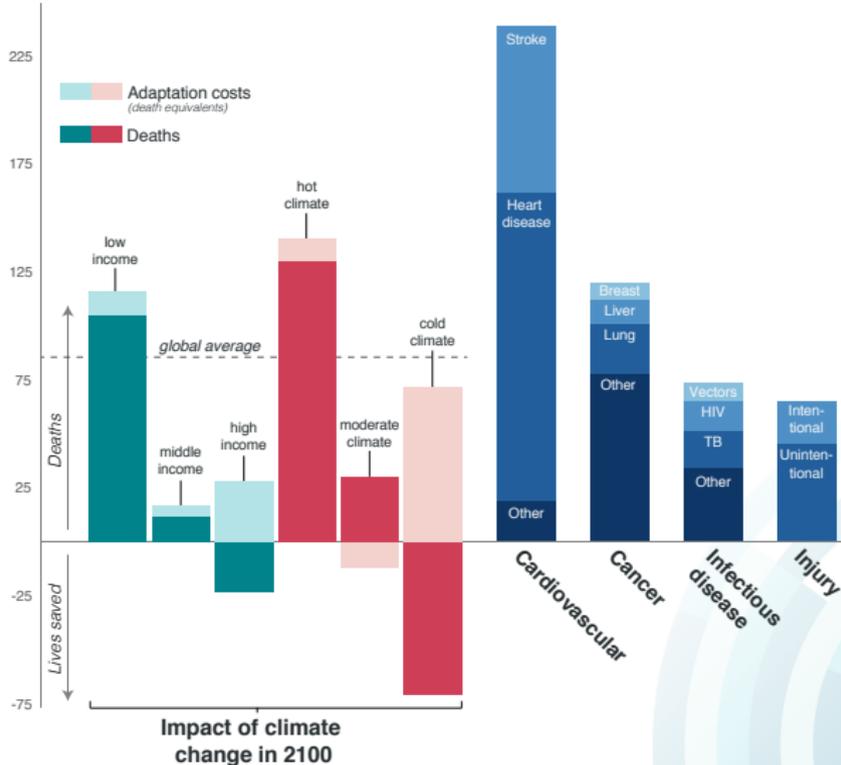


Projected impacts for the globe under RCP8.5

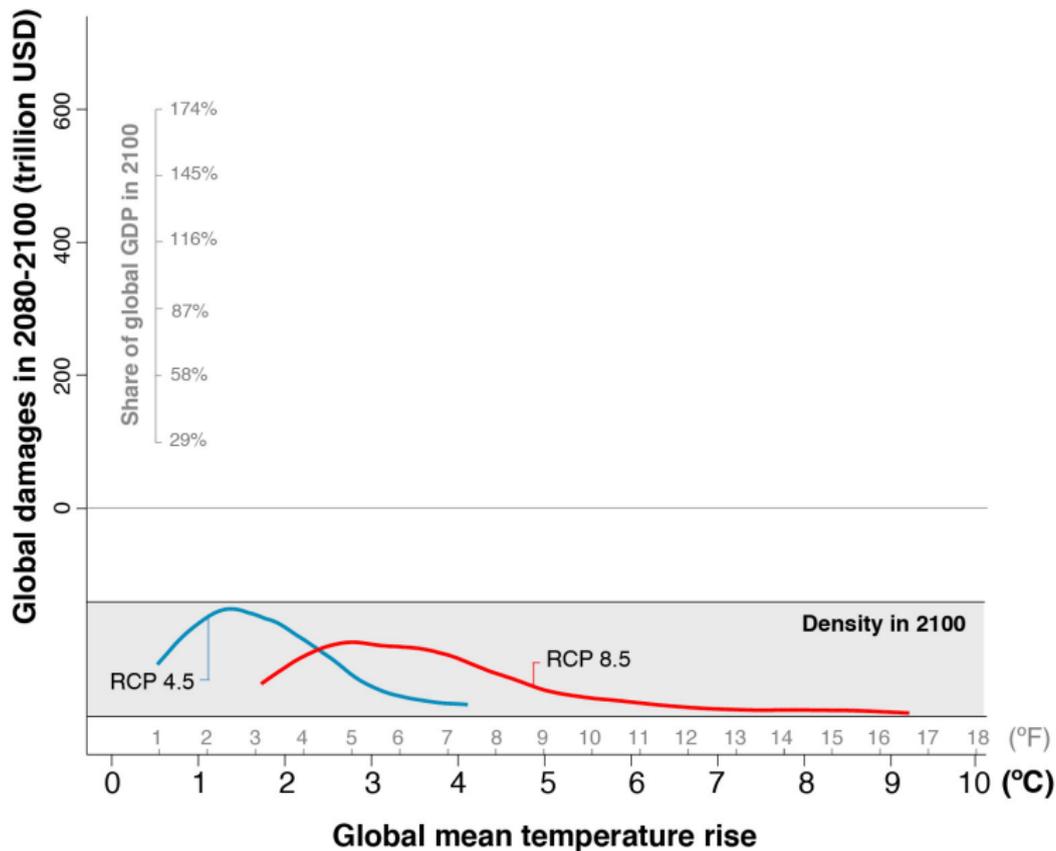


Unequal distribution of impacts - RCP 8.5 in 2100

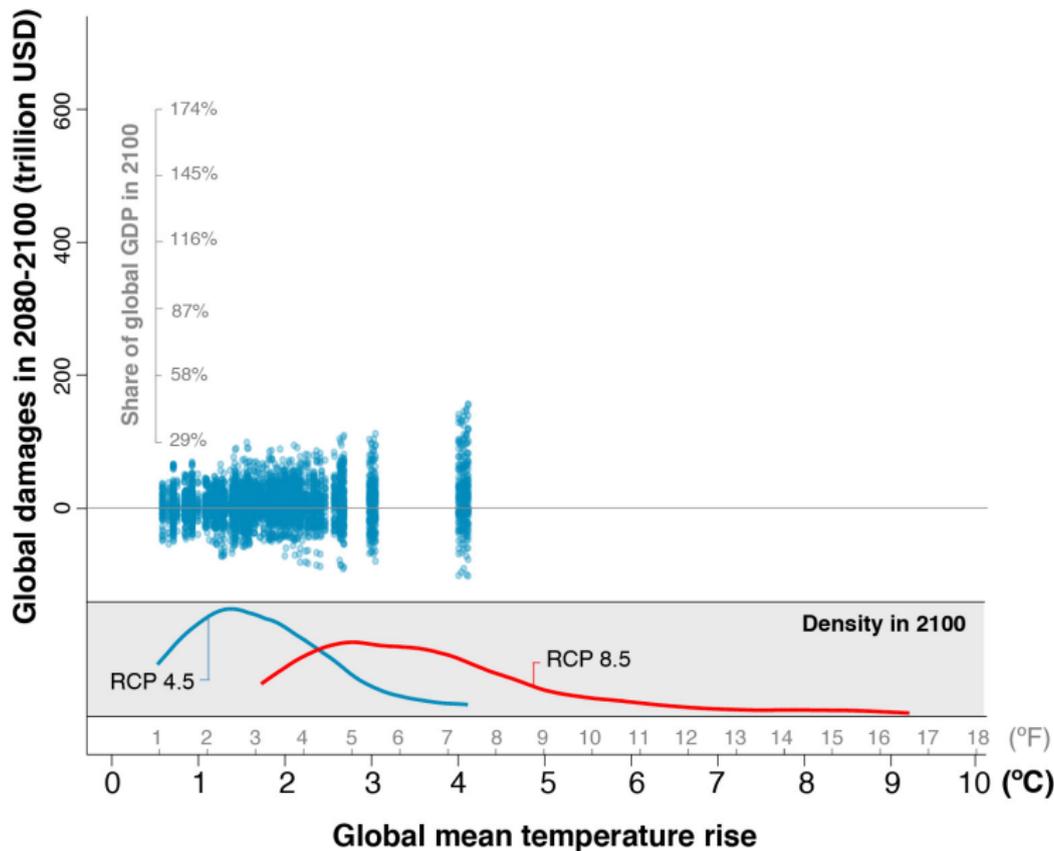
Deaths per 100,000 population



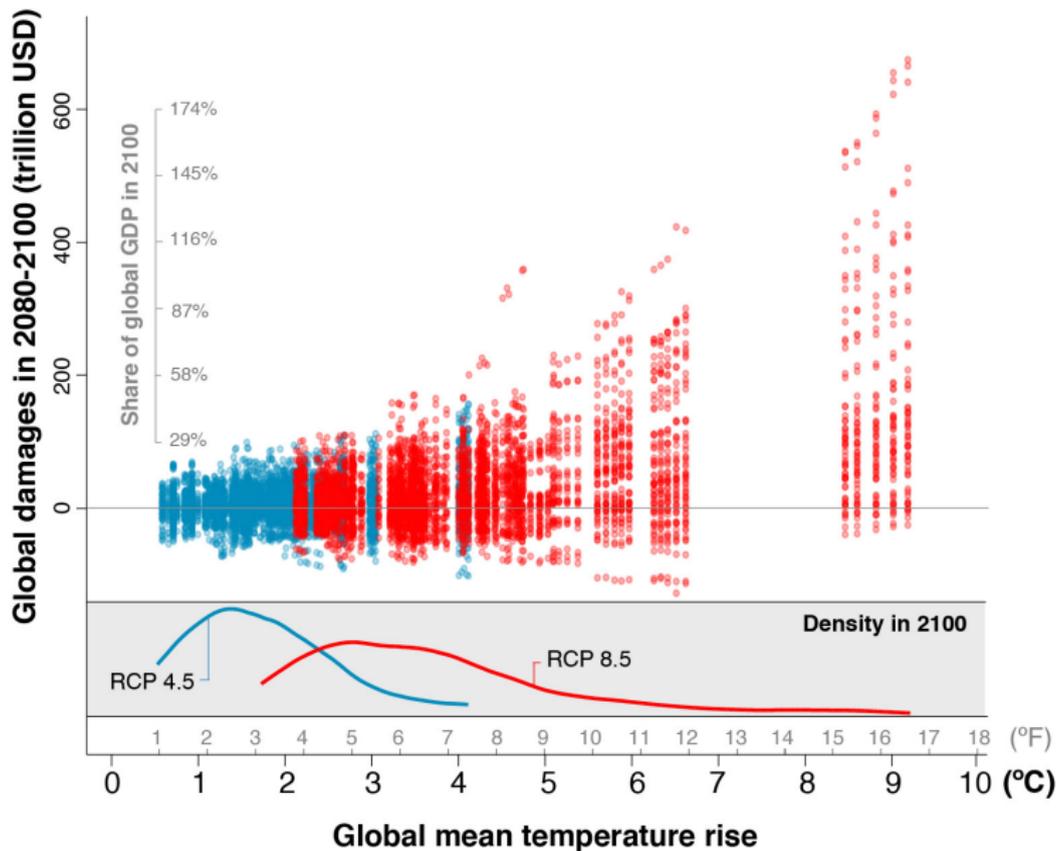
Empirical mortality damage function



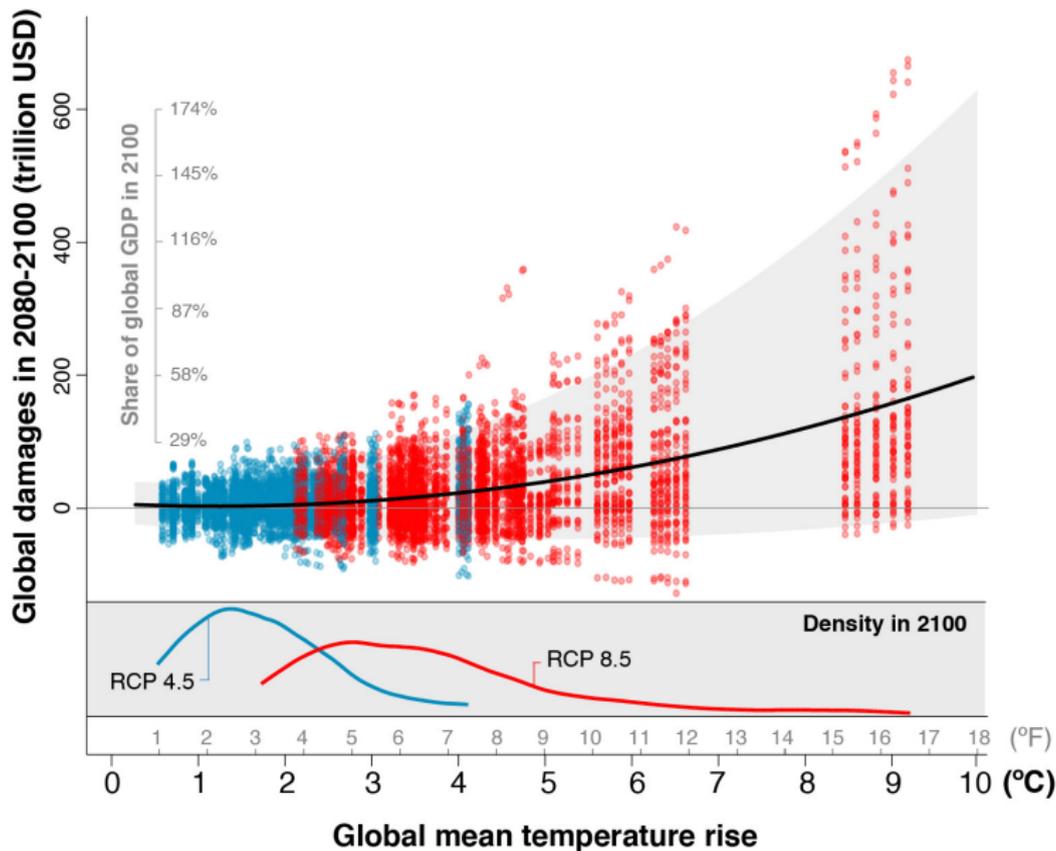
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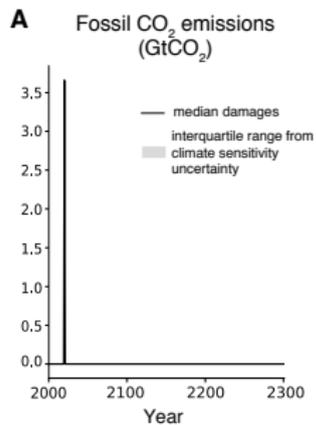
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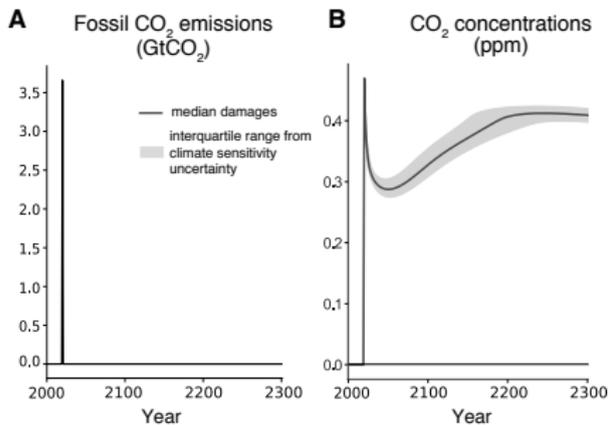
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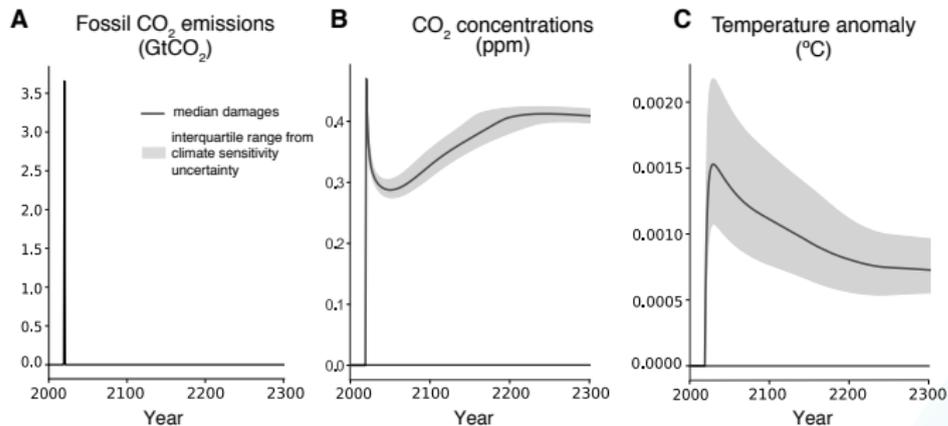
Damages from a single ton of CO₂



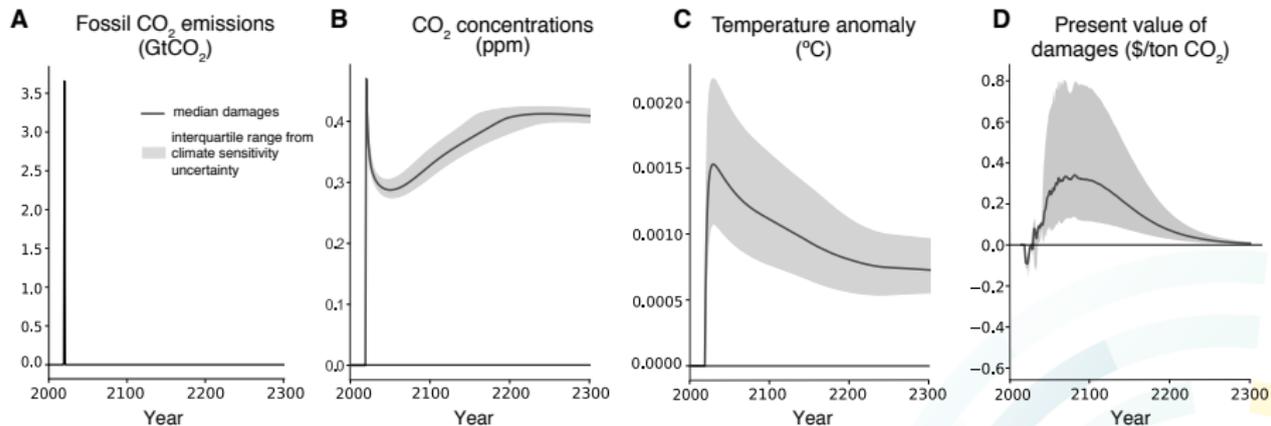
Damages from a single ton of CO₂



Damages from a single ton of CO₂



Damages from a single ton of CO₂



Partial Social Cost of Carbon for Mortality

Annual discount rate

$\delta = 2.5\%$

$\delta = 3\%$

$\delta = 5\%$

**Global net damages from marginal emission
(2015 US Dollars per ton CO₂ emitted in 2015)**

RCP 4.5

	6.3	4.6	1.4
<i>Climate uncertainty</i>	[-3.3, 38.8]	[-1.4, 24.6]	[0.0, 5.8]
<i>Statistical uncertainty</i>	[-29.1, 45.2]	[-22.0, 32.7]	[-10.6, 13.4]
<i>Climate + statistical uncertainty</i>	[-28.2, 49.6]	[-22.0, 33.8]	[-10.3, 11.4]

RCP 8.5

	50.0	29.6	5.8
<i>Climate uncertainty</i>	[20.7, 121.5]	[12.2, 72.4]	[2.3, 14.5]
<i>Statistical uncertainty</i>	[-10.5, 85.5]	[-12.6, 58.6]	[-10.9, 20.4]
<i>Climate + statistical uncertainty</i>	[-9.4, 104.4]	[-11.6, 66.6]	[-10.4, 18.6]

Values shown adjust for life expectancy and apply an income elasticity of one for the VSL, pinned down by EPA VSL for USA (\$7.9 million).

Roughly comparable value for FUND (including diarrhea and vector-borne disease): ~\$1.50 —Diaz (2014)

3. Ongoing work on other sectors

Implementation for eight sectors underway

- **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



A multi-sector approach



Energy:

International Energy Agency (IEA) provides data from 146 Countries (1971-2012).

Residential, Commercial, and Industrial Consumption of Electricity and Other Fuels.

A multi-sector approach



Agriculture:

Largest sub-national dataset ever assembled. Shares of global production: 80% (maize), 78% (soy), 76% (rice), 62% (wheat), 32% (sorghum), 29% (cassava), 14.5% (cotton)

A multi-sector approach



Labor supply:

Sub-daily time use data, daily and weekly labor force surveys representing 2.1 billion people

A multi-sector approach



Intergroup conflict:

Civil conflict data for the entire globe

A multi-sector approach



Violent crime:

Violent crime records for 3.3 billion people

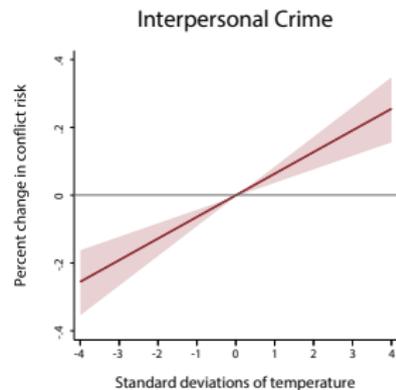
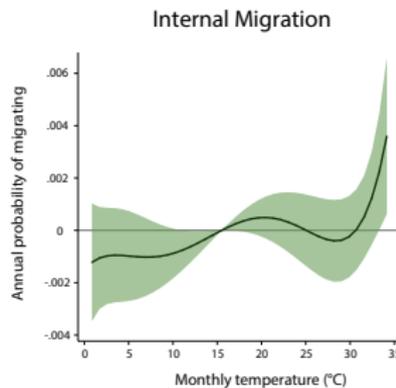
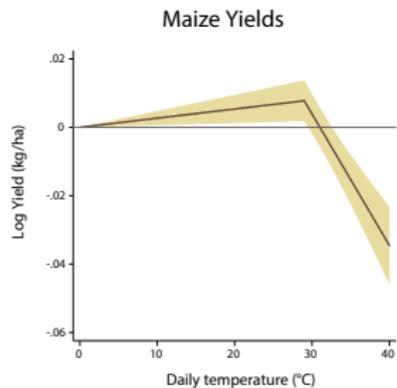
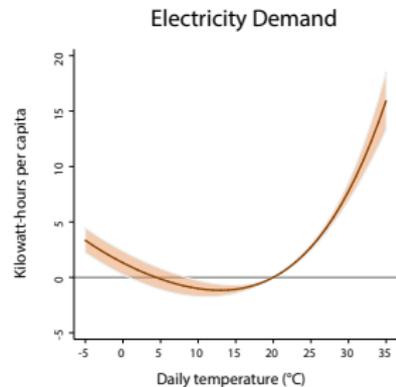
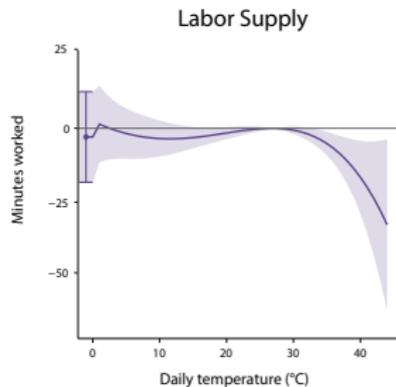
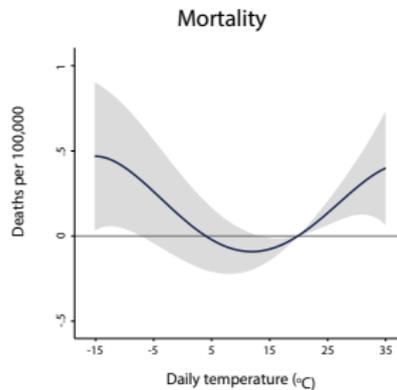
A multi-sector approach



Migration:

Internal migration data for 3.1 billion people; annual bilateral international migration from 163 origin countries to 42 OECD destination countries

A multi-sector approach



Principles for future climate damages

- Transparently estimate and update partial equilibrium damage functions based on **best scientific evidence**
- Adopt **modular approach** to incorporate latest climate and socioeconomic projections
- Make all systems **open-source**
- Hyper-local, sector specific, probabilistic **climate impact estimates** to inform **adaptation**
- **Engage with stakeholders** in governments, business, and civil society, tailoring outputs to policy needs