The Unequal Burden of Climate Change in California

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Distributional Impacts of Climate Change in the Agricultural Sector
NBER, Chicago November 17, 2023

Climate Impact Lab

emLab

Climate change is a **global** challenge, but its impacts are felt **locally**

Source: Associated Press

Climate change is a **global** challenge, but its impacts are felt **locally**

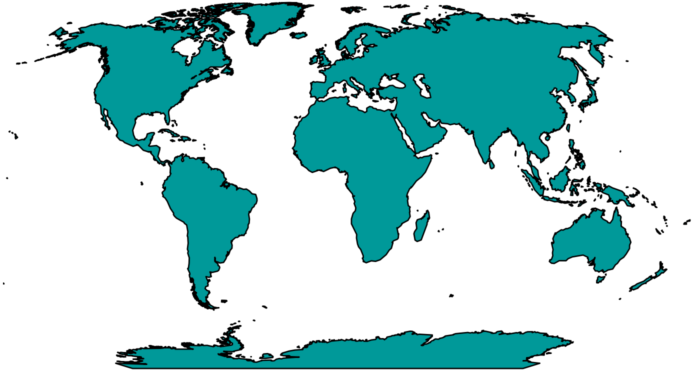
Accurate local damage estimates are critical to climate policy

- **Mitigation:** Aggregate climate damages are inaccurate if heterogeneity is ignored
- **Adaptation:** Planning for climate impacts requires accurate local projections


Early global climate damage assessments

"Estimating the damages from greenhouse warming has proved to be extremely difficult. The DICE model assumes that a 3°C warming would lower world output by **1.3 percent**."

–Nordhaus (AER, 1993)



Early California climate damage assessments

Emissions pathways, climate change, and impacts on California

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Contributed by Christopher B. Field, June 23, 2004

The magnitude of future climate change depends substantially on the greenhouse gas emission pathways we choose. Here we explore the implications of the highest and lowest Intergovernmental Panel on Climate Change emissions pathways for climate change and associated impacts in California. Based on climate projections from two state-of-the-art climate models with low and medium sensitivity (Parallel Climate Model and Hadley Centre Climate Model, version 3, respectively), we find that annual temperature increases nearly double from the lower B1 to the higher A1fi emissions scenario before 2100. Three of four simulations also show greater increases in summer temperatures as compared with winter. Extreme heat and the associated impacts on a range of temperature-sensitive sectors are substantially greater under the higher emissions scenario, with some interscenario differences apparent before midcentury. By the end of the century under the B1 scenario, heatwaves and extreme heat in Los Angeles quadruple in frequency while heat-related mortality increases two to three times; alpine/subalpine forests are reduced by 50–75%; and Sierra snowpack is reduced 30–70%. Under A1fi, heatwaves in Los Angeles are six to eight times more frequent, with heat-related

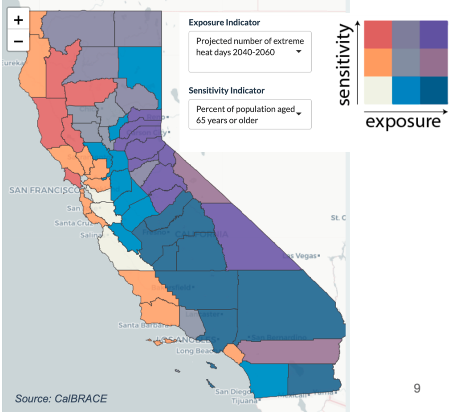
allel Climate Model (PCM) (3) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3), model (4, 5) are used to calculate climate change resulting from the SRES (Special Report on Emission Scenarios) B1 (lower) and A1fi (higher) emissions scenarios (1). These scenarios bracket a large part of the range of Intergovernmental Panel on Climate Change nonintervention emissions futures with atmospheric concentrations of CO_2 reaching ≈550 ppm (B1) and ≈970 ppm (A1fi) by 2100 (see *Emissions Scenarios* in *Supporting Text*, which is published as supporting information on the PNAS web site). Although the SRES scenarios do not explicitly assume any specific climate mitigation policies, they do serve as useful proxies for assessing the outcome of emissions pathways that could result from different emissions reduction policies. The scenarios at the lower end of the SRES family are comparable to emissions pathways that could be achieved by relatively aggressive emissions reduction policies, whereas those at the higher end are comparable to emissions pathways that would be more likely to occur in the absence of such policies.

- First large scale climate assessment for the 5th largest economy in the world
- Downscaled climate projections
- Mixture of process based and estimated damages functions
- Mortality, Ski Industry, SLR, Vegetation Distribution, Agriculture
- Spatial coverage limited
- Ad hoc selection of sectors

Recent California climate vulnerability assessments

Existing climate vulnerability tools:

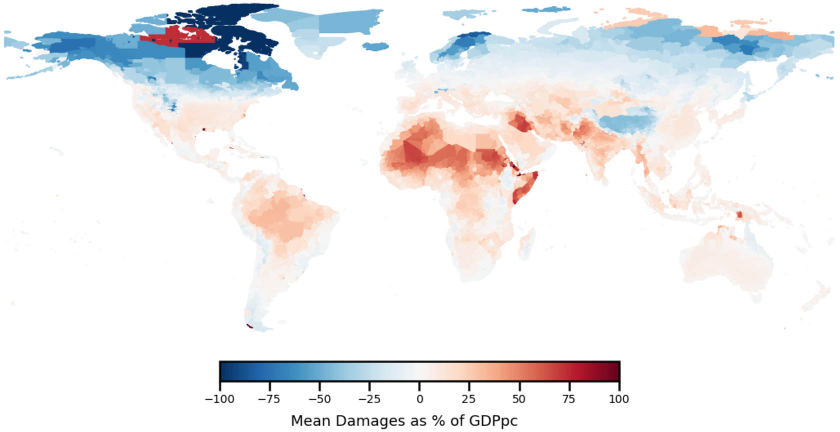
- Show physical hazards (e.g., extreme heat days) at local level
- Overlay hazards with social vulnerability indicators (e.g., % pop. over 65)
- **Do not** quantify climate impacts at local scale (e.g., 4^{th} Climate Assessment at regional level)
- **Do not** account for differential vulnerability (i.e., same exposure → same harm for all populations)



Note: Federal tools are the same! No local-level damage estimates account for differential vulnerability

A new era for climate damage estimation

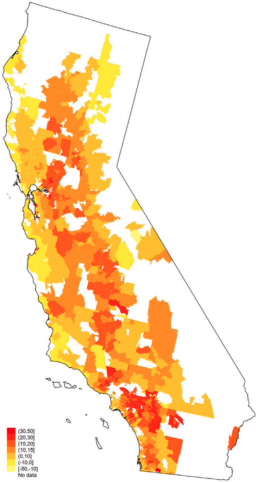
Climate Impact Lab: ∼25,000 regions capture subnational inequality of damages



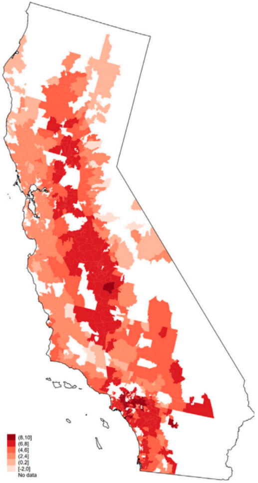
Nath et al (in prep)

A new era for climate damage estimation

Auffhammer (2022): 1,229 zip codes capture local inequality in California



(a) Intensive Margin



(b) Extensive Margin Delta

Auffhammer (2022)

This paper

1. **How unequal are climate damages in California?**
    - Generate distribution of damages across California at the community (i.e., census tract) level
    - Estimate hyperlocal damage functions and estimates for California for four sectors: mortality, energy, flooding, and labor)
    - Assess drivers of unequal impacts within each sector
    - Break down impacts for agricultural communities

This paper

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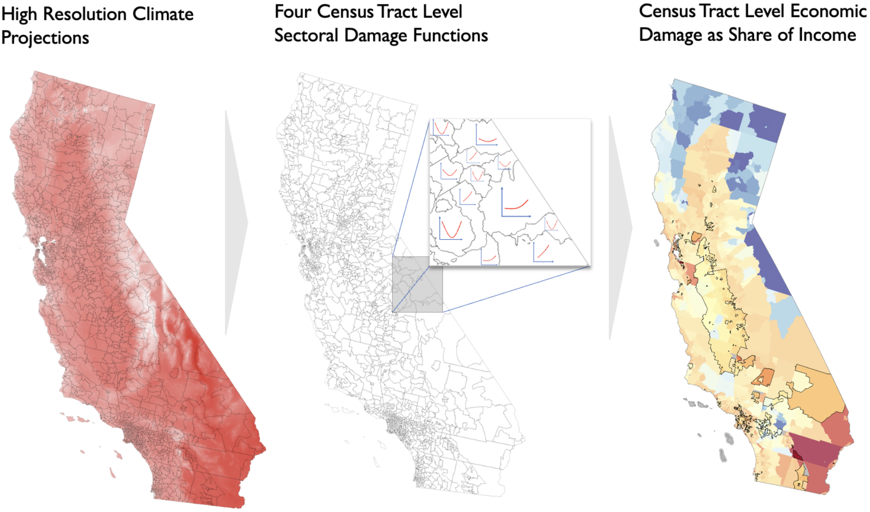
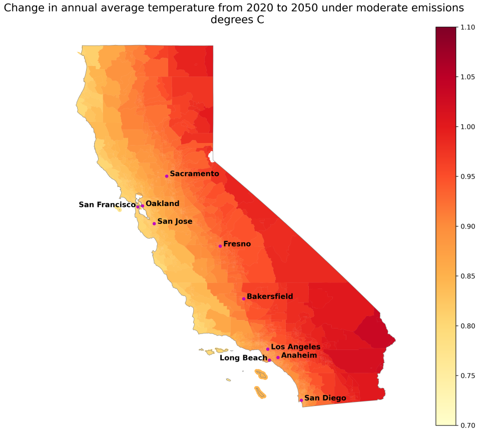
   - Assess drivers of unequal impacts within each sector
   - Break down impacts for agricultural communities

2. **How much does differential vulnerability matter?**
   - Differential exposure and differential vulnerability influence the equity implications of climate change
   - Assess how estimated damages and their spatial distribution change when vulnerability is assumed constant across Californian communities

Constructing local climate damages for California



Ingredient 1: Climate data & projections



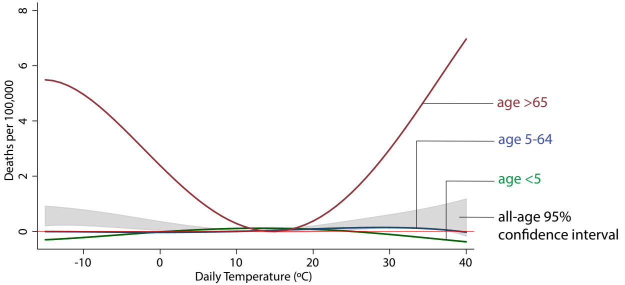
- Downscaled and Bias Corrected
- Daily 0.25°grid resolution
- Future: NASA Earth Exchange Global Daily Downscaled Projections (NASA NEXGDDP)
- Representative concentration pathway 4.5 (RCP4.5)
- Impacts relative to “historical” scenario simulations.

Ingredient 2: Estimating an impact relationship

Use <u>random variation</u> in short-run weather to causally identify the effect of weather realizations on sector-specific outcomes.

For example:

$$Mortality\_rate_{ait} = f_a(Temp_{it}, Precip_{it}) + \underbrace{\alpha_{ai} + \delta_{act}}_{\text{nonparametric location \& time controls}} + \varepsilon_{iat}$$



Reviews of related literature: Auffhammer (2018), Carleton & Hsiang (2016), Dell et al. (2014)

Heterogeneity in response to weather

Allow the shape of the function describing the impact relationship at a location be a function of conditions at that location.

$$Outcome_{it} = \sum_p \beta^p \, Weather_{it}^p \, ... \, controls$$

$$\uparrow$$

$$\beta^p(i) = \gamma_0^p + \gamma_1^p \, Climate_i + \gamma_2^p \, \log(GDPpc)_i + ...$$

Covariates determining heterogeneity depend on sector

$\rightarrow$ $Climate_i$ = long-run avg. climate (e.g. temperature, degree days, precipitation)

$\rightarrow$ $\log(GDPpc)_i$ = average log income per capita

$\rightarrow$ $area\_irrigated_i$ = share of area equipped for irrigation

Similar approaches: Auffhammer (2022); Heutel et al. (2021); Garg et al. (2020); Butler & Huybers (2013); Roberts & Schlenker (2009)

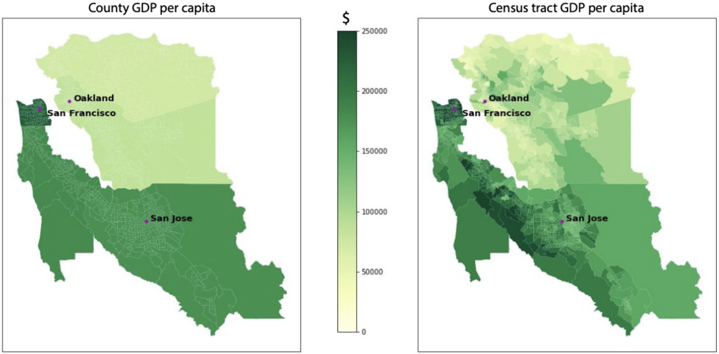
Ingredient 3: Local measures of vulnerability

Use <u>census tract level income</u> to downscale county GDP

→ per-capita income from American Community Survey

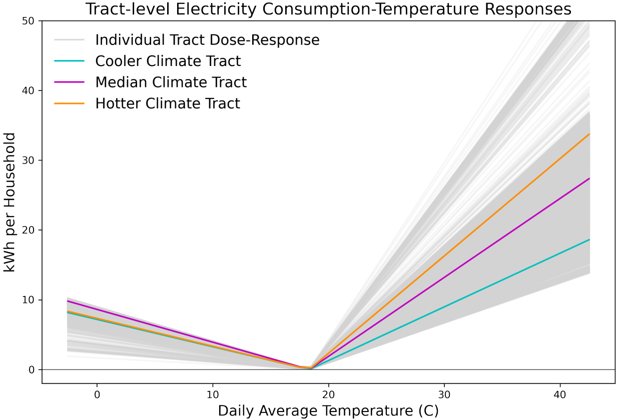
→ county-level GDP from the Bureau of Economic Analysis

→ downscaling method allows some, but not all, variation in vulnerability to occur at the tract level



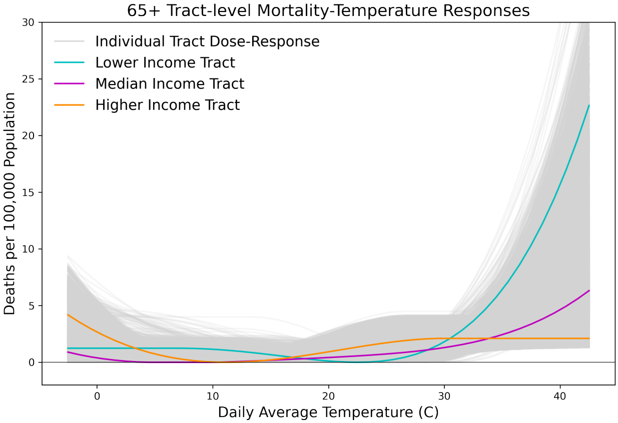
Electricity dose-response function

- **Data:** Zip-code level electricity and natural gas billing data (Auffhammer, 2022)
- **Estimation:** Income, average CDDs, and average HDDs shape electricity and natural gas response functions individually



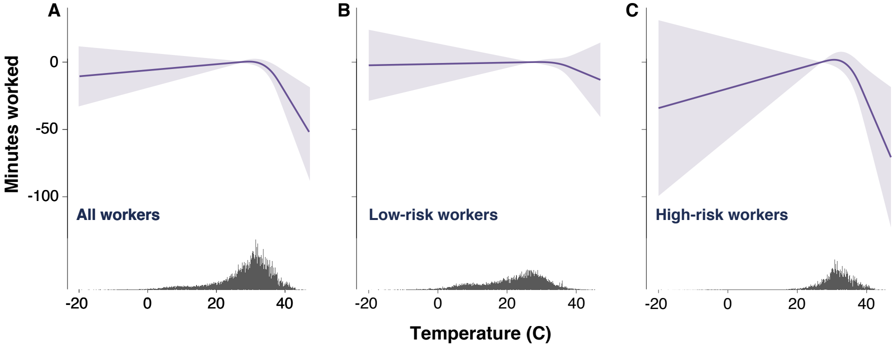
Mortality dose-response function

- **Data:** ∼county-level age-specific mortality for 35% of global pop. (Carleton et al., 2022)
- **Estimation:** Income and average temperature shape age-specific response functions individually



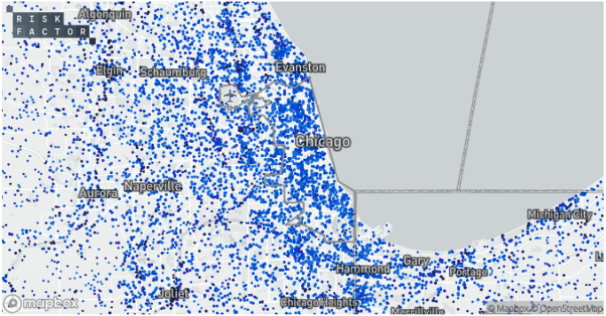
Labor dose-response function

- **Data & estimation:** ∼county-level time use and labor force surveys. Sector of employment shapes vulnerability of labor supply to temperature (Rode et al., 2023)



Flooding damages

- **Data & estimation:** First Street Foundation estimates of average annual property loss



Chicago Flood Risk

Residential **Moderate Risk**
200,747 out of **463,011** homes

Road **Minor Risk**
3,920 out of **7,536** miles of roads

Commercial **Moderate Risk**
18,030 out of **47,208** commercial properties

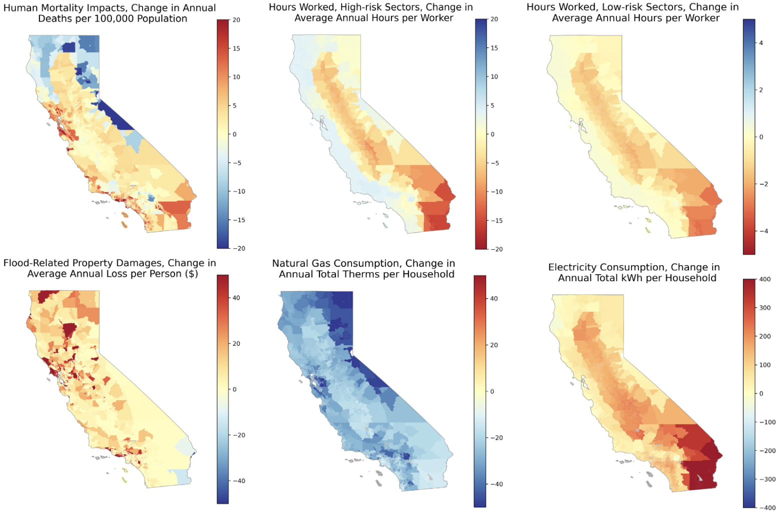
Critical Infrastructure **Moderate Risk**
118 out of **1,021** infrastructure facilities

Social Facilities **Minor Risk**
1,438 out of **3,304** social facilities

Minor Moderate Major Severe Extreme

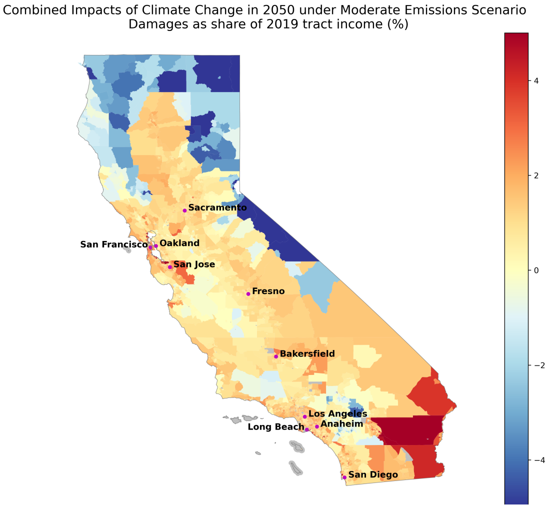
Sector-specific damages

Category specific impacts of climate are estimated, then monetized using category specific valuation techniques so that they can be summed.



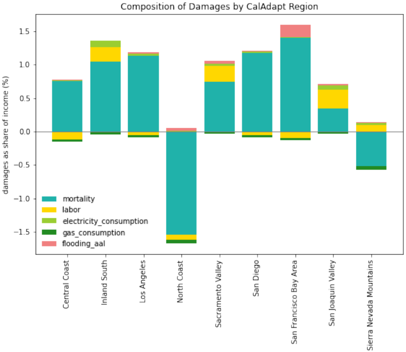
A possible Climate Vulnerability Metric: Accounting for baseline income inequality

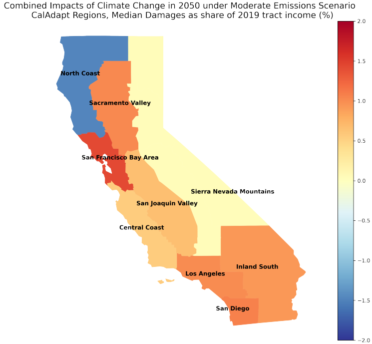
Climate Vulnerability Metric (CVM) is normalized and reported as a share of tract income



CVM decomposition by sector and region

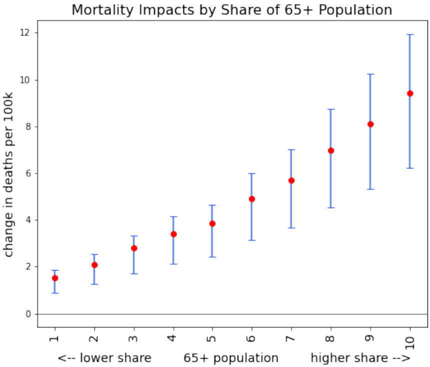
Unequal climate damages operate through diverse channels

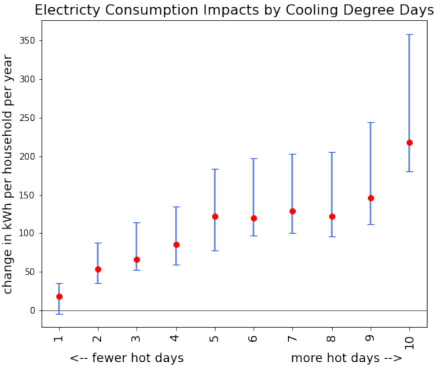




Determinants of vulnerability differ by sector

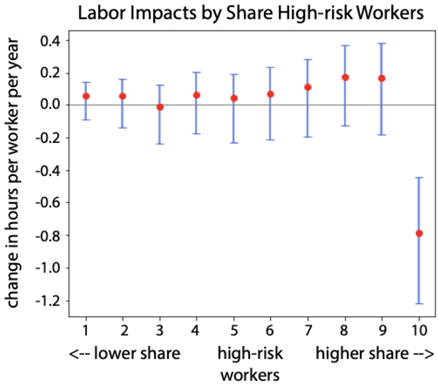
- Mortality damages driven (mostly) by demographics
- Electricity & natural gas damages driven (mostly) by climatology

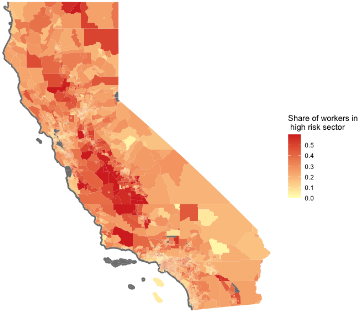




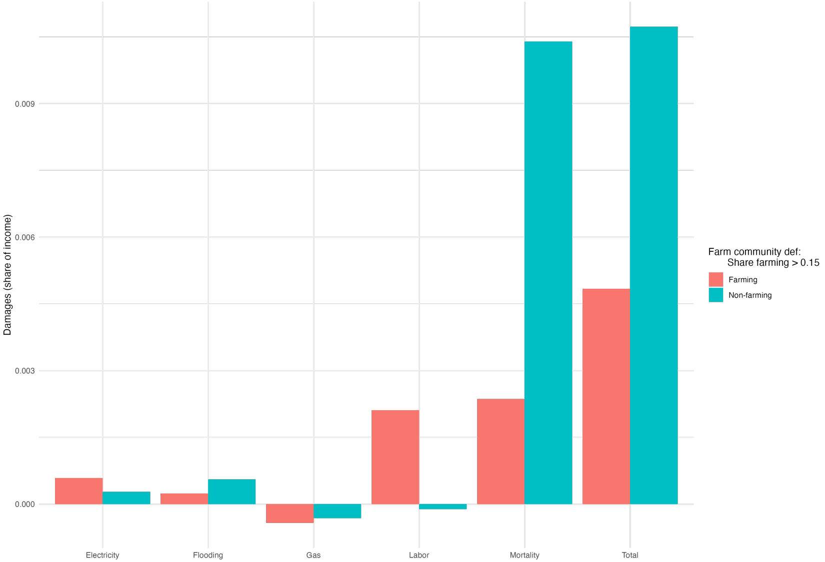
Determinants of vulnerability differ by sector

Labor sector damages concentrated in the Central Valley, where workers are employed in high-risk sectors





Sectoral impacts for agricultural communities



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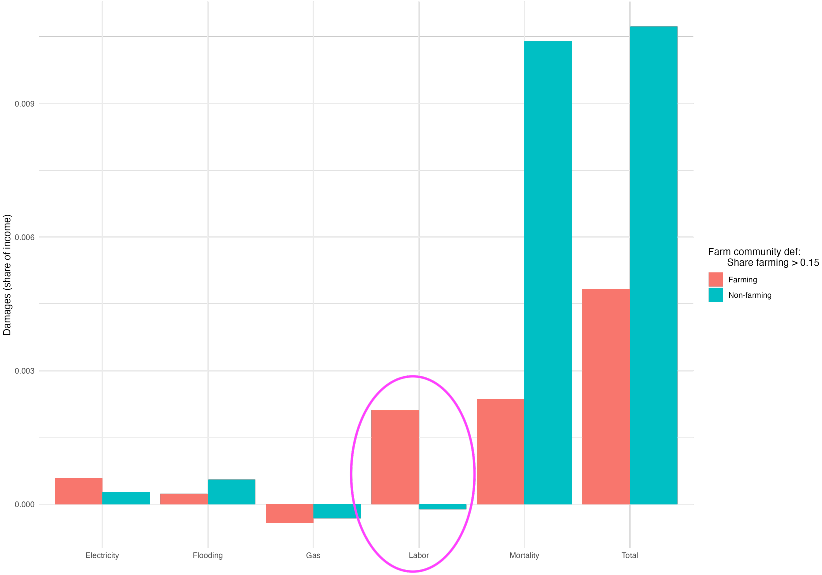
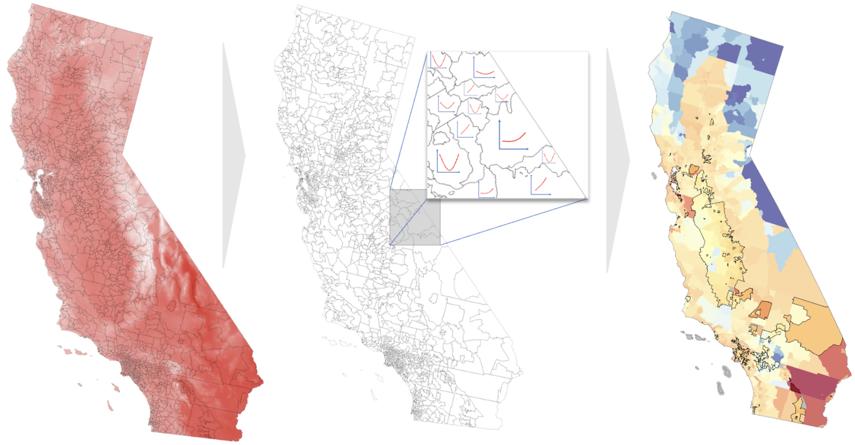


What if we go from local damage functions....

High Resolution Climate Projections

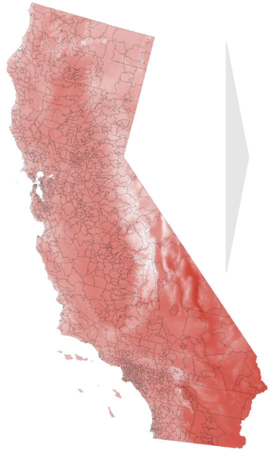
Four Census Tract Level Sectoral Damage Functions

Census Tract Level Economic Damage as Share of Income

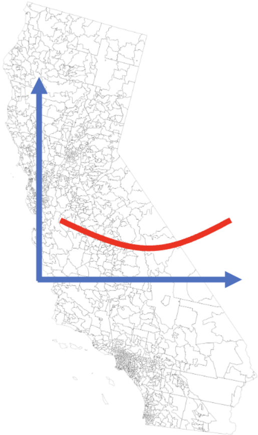


... statewide damage functions?

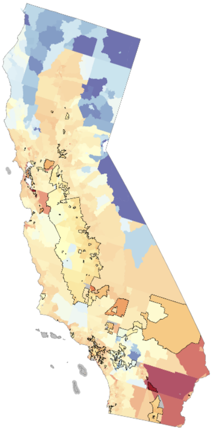
High Resolution Climate Projections



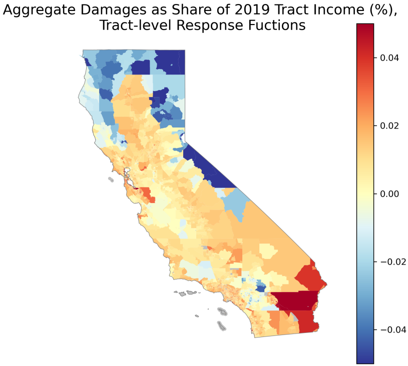
Four State Level Sectoral Damage Functions



Census Tract Level Economic Damage as Share of Income



Differential vulnerability is critical for accurate climate equity analysis



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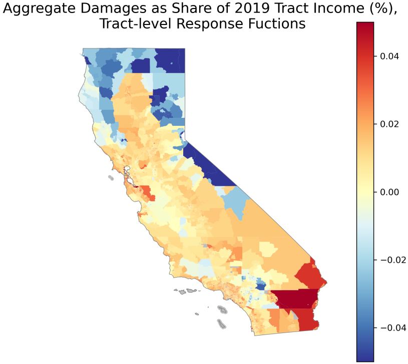
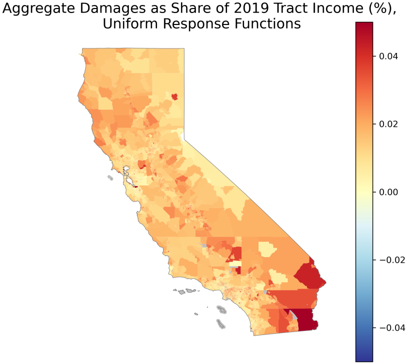
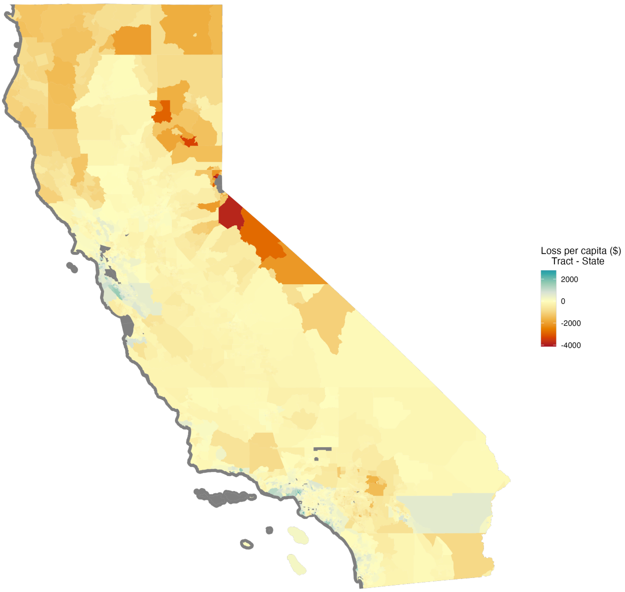




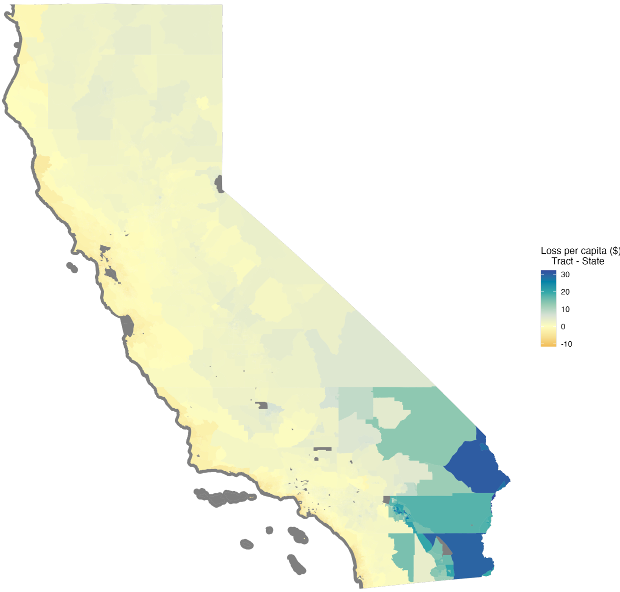
$\rightarrow$ 30% reduction in across-tract variance in damages

$\rightarrow$ 43% reduction in 90^{th} percentile of damages

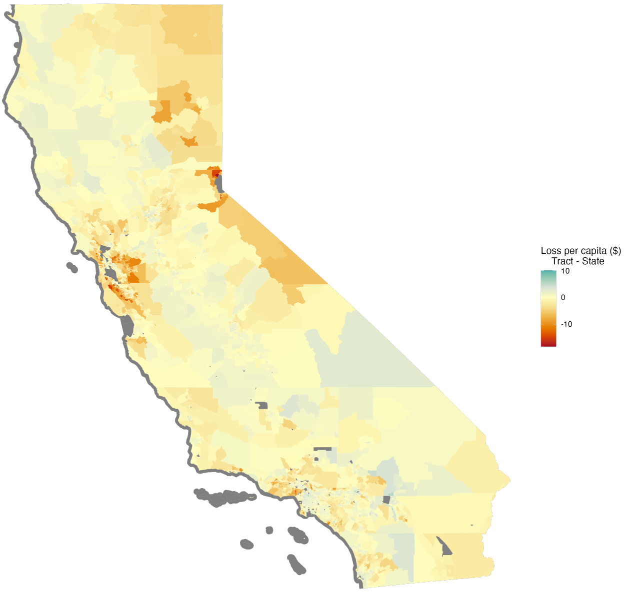
Difference in projected mortality



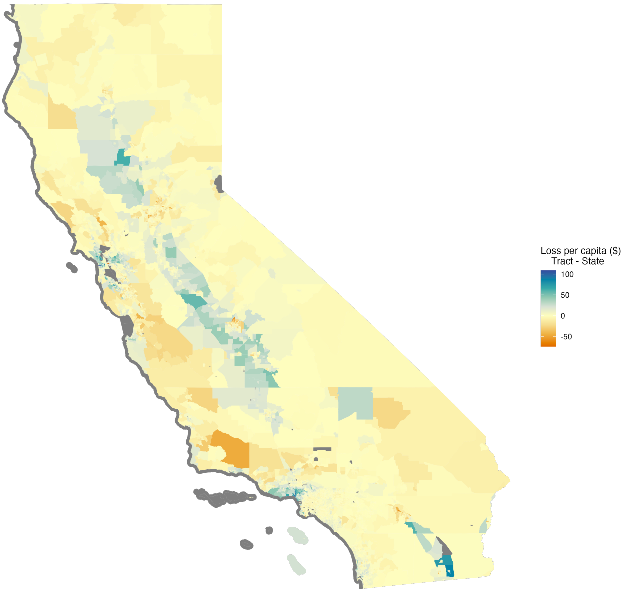
Difference in projected electricity consumption



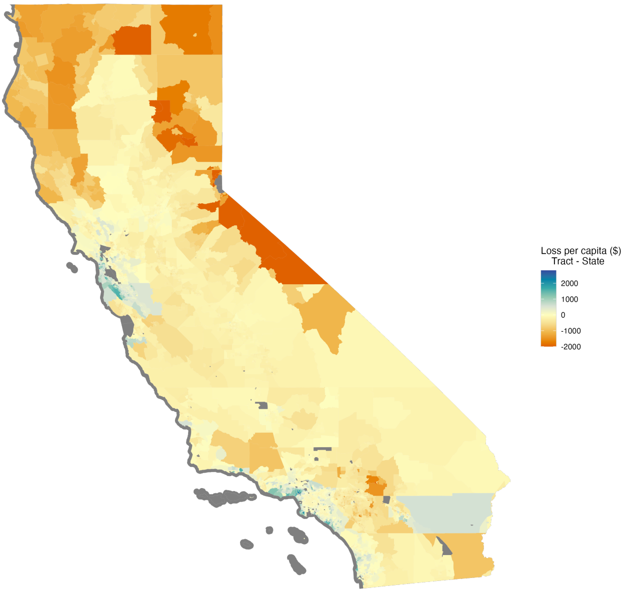
Difference in projected gas consumption



Difference in projected hours worked



Total Difference



Building equity-focused adaptation policy

Policy makers are faced with the following questions when considering how to best deploy adaptation and resiliency investments:

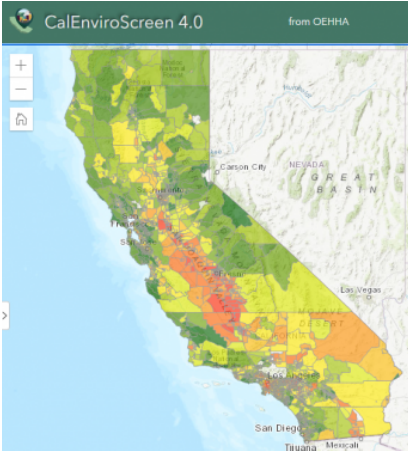
- How well prepared are today's populations for tomorrow's climate?
- Which communities will experience the greatest impacts from climate change?
- Through which channels will they be the most prevalent?

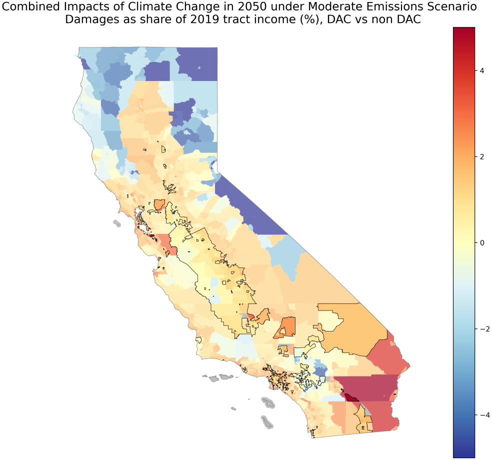
The California Climate Vulnerability Metric

- California uses CalEnviroScreen to assess community-level vulnerability to pollutant exposure and other local environmental harms
- But there is no existing quantitative framework for measuring vulnerability to climate change

The **Climate Vulnerability Metric (CVM)** is part of the 2022 Climate Change Scoping Plan – you can download details and data from the project here

A CVM complements other environmental justice screening tools





Many opportunities for further research

1. Climate damage estimates **omit key categories of impacts**
    - Specialty agricultural crops
    - Wildfire
    - Ecosystem services
    - Vector borne disease
    - ...

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2. Many **dimensions of inequality** are insufficiently studied
   - Individual-level data could enable investigation of race, class, gender, education, access to healthcare, etc.

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    - Specialty agricultural crops
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    - Ecosystem services
    - Vector borne disease
    - ...
2. Many **dimensions of inequality** are insufficiently studied
    - Individual-level data could enable investigation of race, class, gender, education, access to healthcare, etc.
3. **Mechanisms behind adaptation** are poorly understood
    - Experimental work can help with causality and precision (e.g., Masuda et al. (2021))
    - When is adaptation optimal or suboptimal? When is adaptation intervention necessary? (e.g., Baylis & Boomhower (2022))

Thank you!

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