Climate Change Impacts and Risk Analysis Project (CIRA):

An Overview

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Objectives and Drivers

- EPA routinely estimates the impacts and benefits of reducing air pollution in meaningful ways (e.g., avoided premature deaths, respiratory illness, economic loss).
- CIRA project aims to produce analogous estimates for GHG mitigation.
  - To date, EPA and the general climate community have had limited ability to show specific and full range of avoided impacts under GHG mitigation scenarios.
  - Climate change presents unique challenges compared to traditional EPA analyses (e.g., global nature, wide-reaching impacts, long time scales).
  - CIRA complements SCC, but differs in purpose and approach.
- CIRA will develop and communicate credible, robust, and meaningful climate impact and benefit estimates to inform policy.




Overview of CIRA

- CIRA is an EPA-led, collaborative modeling effort to analyze how climate change impacts and risks in the U.S. change under different global GHG mitigation scenarios.
  - CIRA describes the costs of inaction (and benefits of mitigation and adaptation) in terms of physical effects, economic damages, and changes in risk.
- CIRA uses *consistent* economic, emission and climate data to estimate impacts under scenarios with and without GHG mitigation.
  - The project also addresses key sources of uncertainty, including emissions pathway, climate sensitivity, climate projection, and impacts model.
  - The limited number of other comprehensive impact analysis efforts do not emphasize consistency and the exploration of uncertainty to the same extent as CIRA.
- CIRA examines *regional impacts* in the U.S. across sectors (e.g., water resources, human health, ecosystems, energy) where science is strong and modeling capacity can be leveraged.

Overview of the CIRA Process

Socioeconomics & Emissions → **Climate Data Generation** → **Impacts Estimation & Valuation**

CIRA emission scenarios

Reference (no mitigation) scenario:
- 2100 global emissions ~2.5 x 2005 levels
- 1750 ppm CO_2 eq (IPCC gases)

Global mitigation scenario:
- 2100 global emissions ~57% < 2005 levels
- 600 ppm CO_2 eq (IPCC gases)

Stronger global mitigation scenario:
- 2100 global emissions ~70% < 2005 levels
- 500 ppm CO_2 eq (IPCC gases)

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Project future climate data

- Temperature
- Precipitation
- Sea level rise
- Cloud cover
- Wind speed
- Relative humidity
- Solar radiation

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Run sectoral impacts models

- Coastal property damages
- Road infrastructure
- Bridge vulnerability
- Electricity supply/demand
- Extreme temp. health
- Ag & forestry yields
- Terrestrial carbon storage
- Forest fires
- Coral reefs
- Freshwater fish
- Inland flooding damages
- Water supply/demand
- Drought risk

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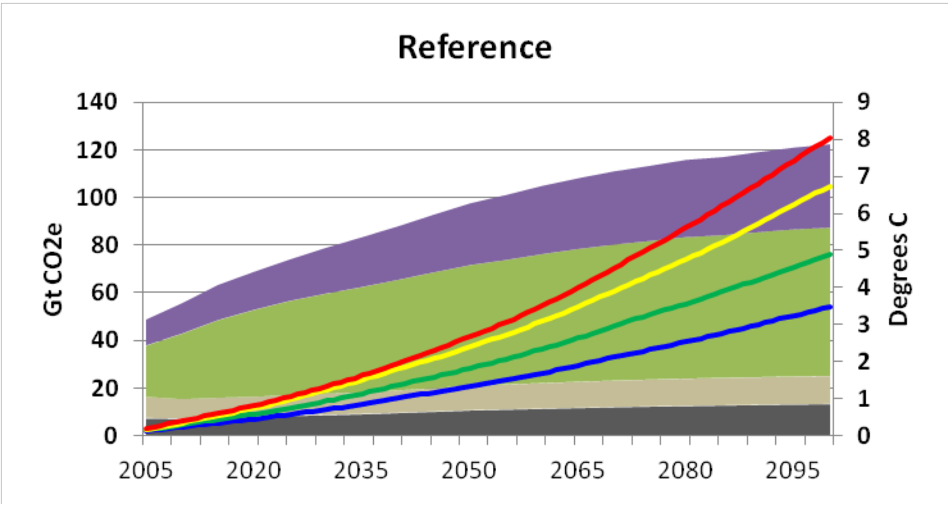
Impact/benefit estimates

- Physical impacts
- Economic damages
- Changes in risk

Analyzing Key Sources of Uncertainty

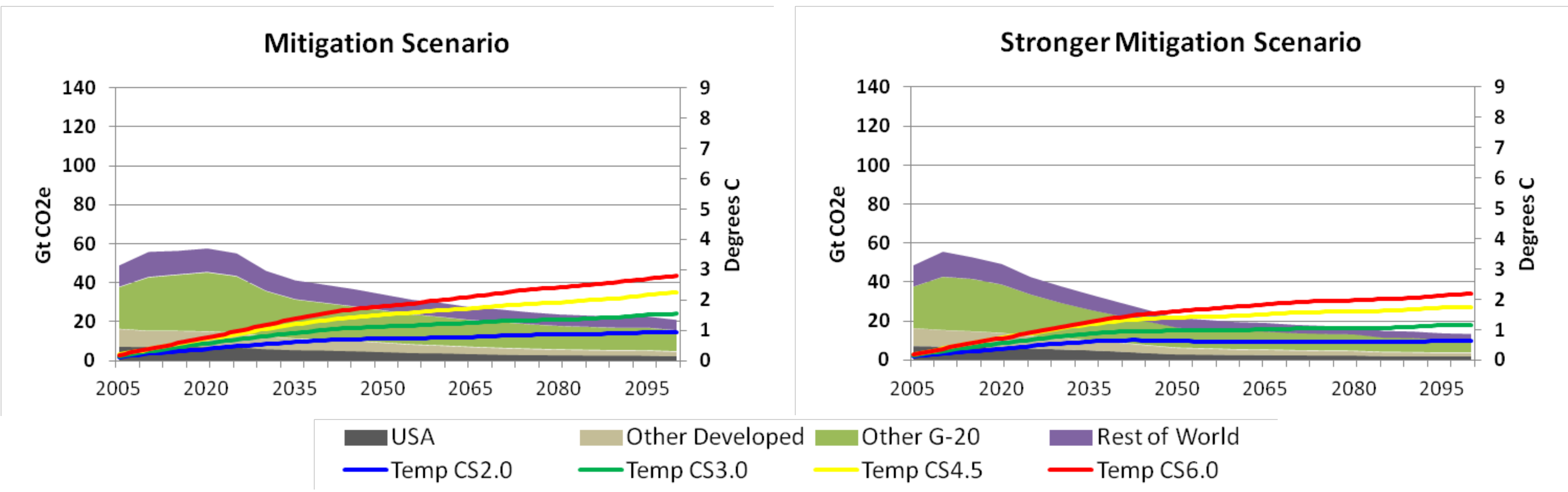
- GHG emissions
- Climate sensitivity
- Climate model selection
- Initial climate model condition
- Structural uncertainty in sectoral models

CIRA Global Emissions Scenarios



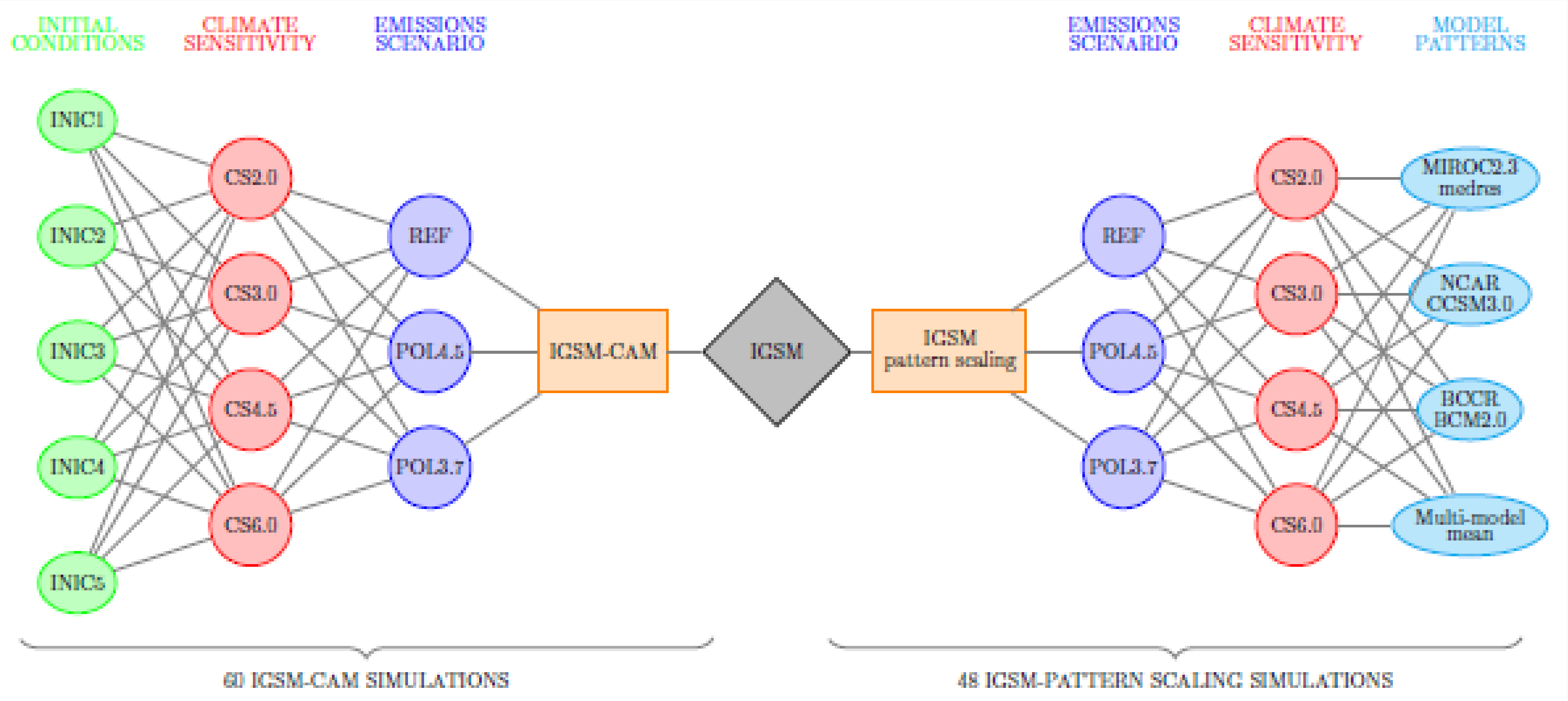
Three global emissions scenarios are used:

- **Reference (no mitigation) scenario**
  - 2100 global emissions ~ 2.5 x 2005 levels
  - 2100 U.S. emissions ~ 1.8x 2005 levels
  - 2100 radiative forcing ~ 10 *(8.8)* W/m^2
  - 2100 GHG concentrations (IPCC gases) ~1750 ppm
- **Global mitigation scenario**
  - 2100 global emissions ~ 57% below 2005 levels
  - 2100 U.S. emissions ~ 67% below (38% in 2050)
  - 2100 radiative forcing ~ 4.5 *(4.2)* W/m^2
  - 2100 GHG concentrations (IPCC gases) ~ 600 ppm
- **Stronger global mitigation scenario**
  - 2100 global emissions ~ 73% below 2005 levels
  - 2100 U.S. emissions ~ 73% below (60% in 2050)
  - 2100 radiative forcing ~ 3.7 *(3.6)* W/m^2
  - 2100 GHG concentrations (IPCC gases) ~ 500 ppm

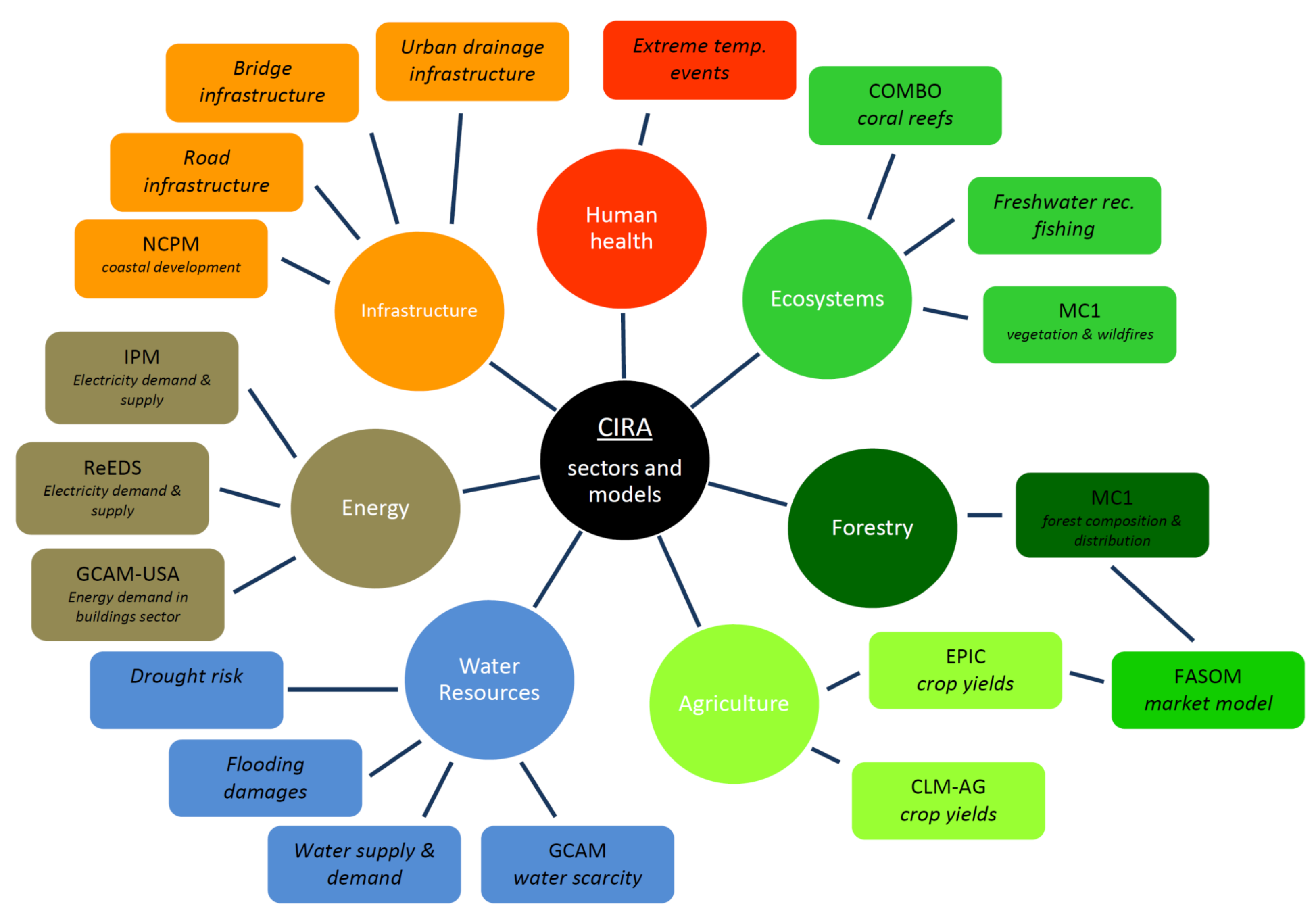


Anthropogenic emissions: CO_2 (fossil and industrial), CH_4, N_2O, HFCs, SF_6, and PFCs Emissions (CO_2-equivalent). Temp anomaly vs. 1991-2010 avg.

Climate Scenario Design



Current CIRA Sectoral Models
(others in development)



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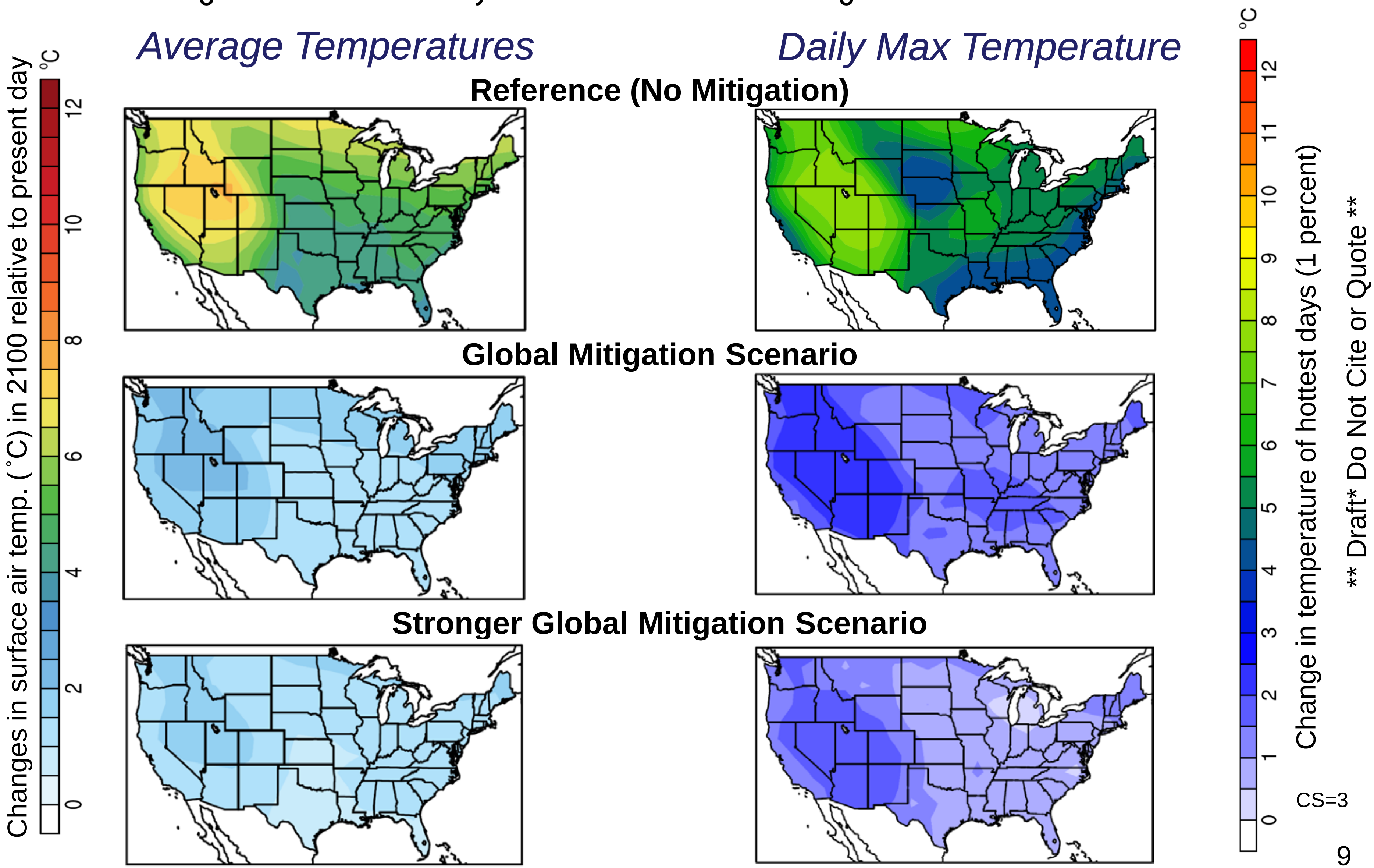
CIRA Impact Sector Coverage

- **Human health**
  - Thermal stress (mortality)
  - Air quality
  - Environmental justice / vulnerable populations
  - Vector-borne disease
  - Extreme event morbidity, mortality
  - Thermal stress (labor productivity)
- **Agriculture**
  - Crop yield (U.S.)
  - Crop yield (global)
  - Livestock production
  - Carbon storage
- **Forests**
  - Change in production (U.S., global)
  - Change in CO_2 storage (U.S., global)
  - Wildfire (U.S., global)
- **Freshwater Resources**
  - Drought
  - Flooding damages
  - Water supply and demand
  - Water quality
- **Ecosystems**
  - Species (coral, freshwater fish, others)
  - Biodiversity
  - Other acidification effects
- **Energy**
  - Temperature effects on energy (electricity) supply and demand
  - Precipitation and system effects on hydro power
  - Change in cooling capacity
  - Climate and system effects on wind and solar generation
- **Infrastructure**
  - Roads and bridges
  - Coastal property and infrastructure
  - Urban drainage
  - Inland property damages from floods
  - Waterways
  - Telecommunication infrastructure
- **Tourism**
  - Coral reef recreation
  - Recreational fishing
  - Other recreation (e.g., winter, boating, birding)
- **Other extreme events**
  - Residual damages post extreme events (e.g., hurricanes)
  - Catastrophic climate change (e.g., ocean circulation shutdown)
  - National security risks (e.g., mass migration)

Key
Existing CIRA capacity
In development
Not currently in CIRA

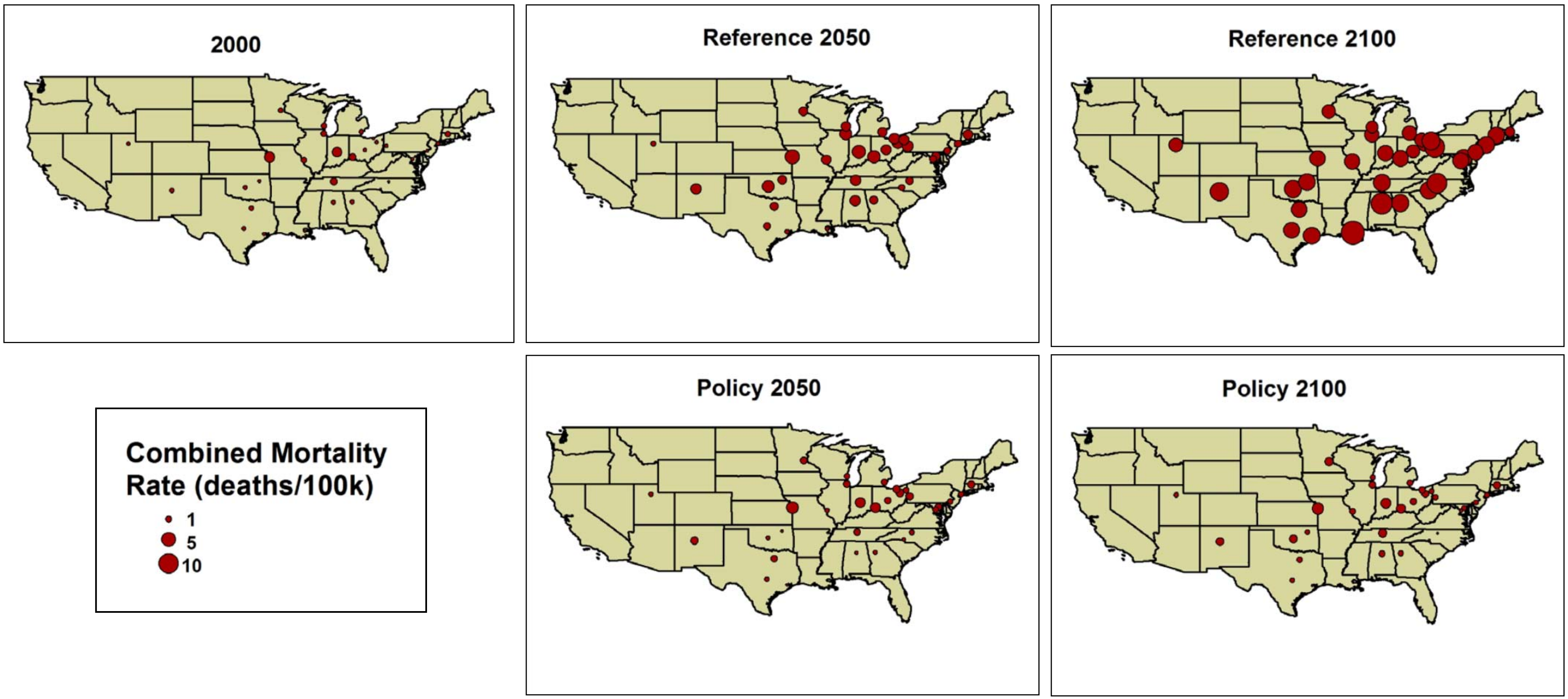
Changes in Temperature in 2100

- With no mitigation, avg. and extreme temps increase substantially.
- These changes are substantially reduced under both mitigation scenarios.



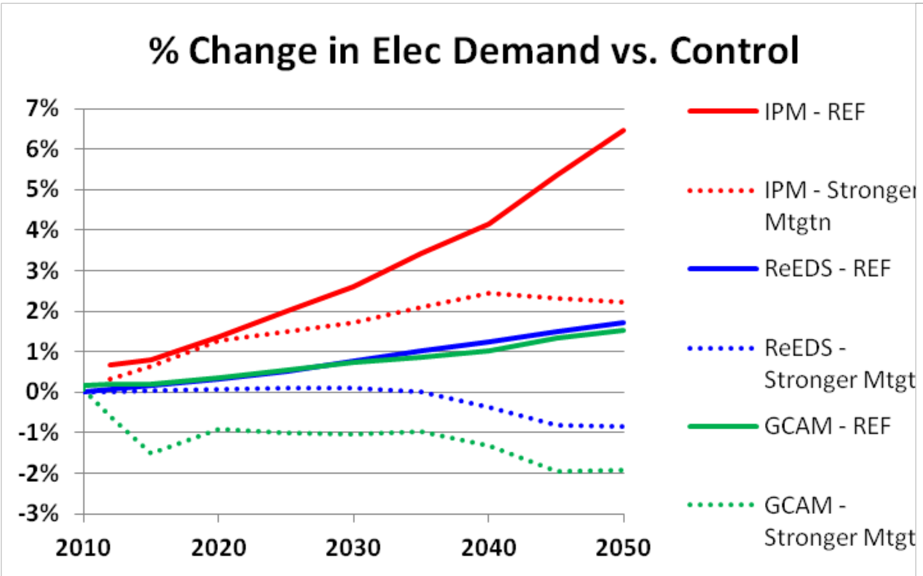
Extreme Temperature Mortality

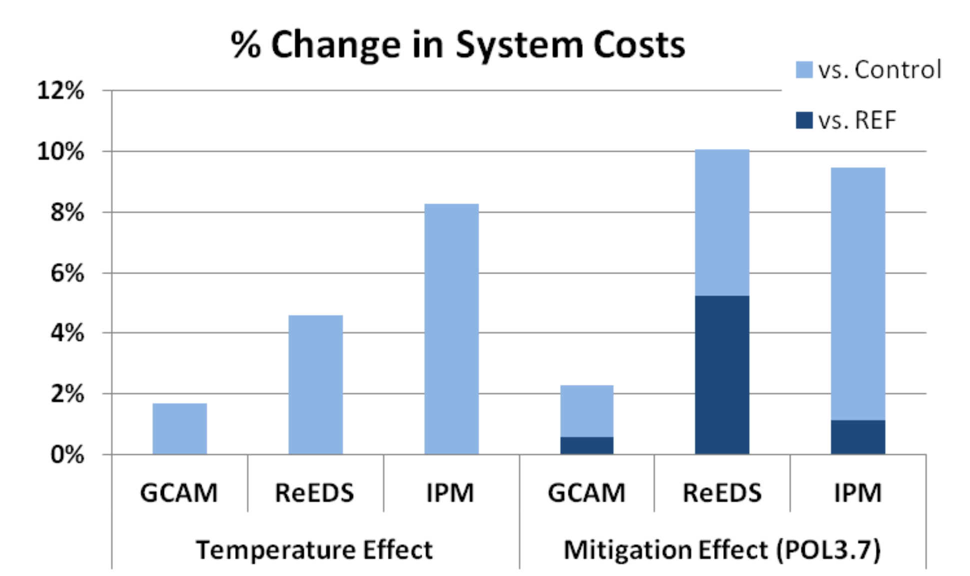
- Dramatic increase in national projected heat mortality over time; cold mortality continues to diminish.
- Results suggest a considerable annual risk reduction for ETM that grows over time with GHG policy implementation (4,000 to 12,000 deaths/year by 2100).
- Does not fully consider the effect that adaptation would have in reducing mortality.



Climate Impacts on Electricity Demand and Supply using multiple models–GCAM, ReEDS, & IPM

- Projected temperature changes increase electricity demand for air conditioning and lower the demand for heating. This effect is frequently omitted from demand projections.
- Electricity demand increases 1.5%–6.5% nationally in 2050 when the air temperature projections from the Reference scenario are included in power sector models (left figure).
- Meeting this additional demand raises power system costs by 1.7%–8.3% across the models (cumulative costs discounted at 3% from 2015–2050, right figure).
- Including temperature effects in baseline scenarios is important. Under the Stronger Mitigation scenario, the change in power system costs from the Reference (0.6%–5.2%) is lower than the change in costs from a Control (2.3%–10.1%) that does not account for temperature effects.





•Temp Effect compares Reference with Control case
•Mitigation Effect compares Stronger Mitigation vs. REF and Control
•System costs include capital, operations, maintenance, and fuel

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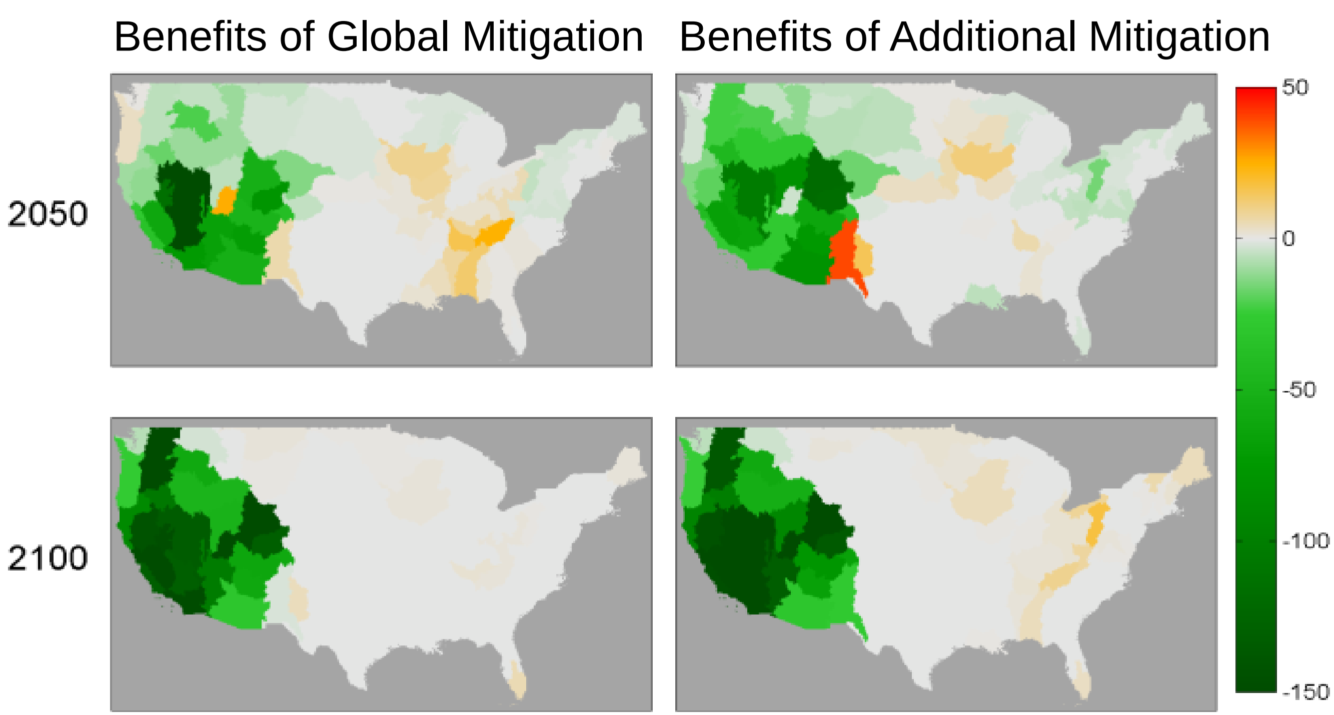
Changes in Drought Risk Through 2100

- Drought risk is estimated using the Palmer Drought Severity Index (PDSI, measured by changes in both precipitation and temperature).
- In the figures below, green represents reductions in drought risk associated with the GHG mitigation policies compared to the reference scenario.
- Largest increases in drought frequency under the reference case are in the southwestern U.S., which is also where the largest benefits of mitigation occur.
- Given the ‘wetness’ of the climate model used, these are likely to be underestimates of impacts/benefits.



Change in the # of PDSI drought months in a 30-yr period due to mitigation (policy-reference)

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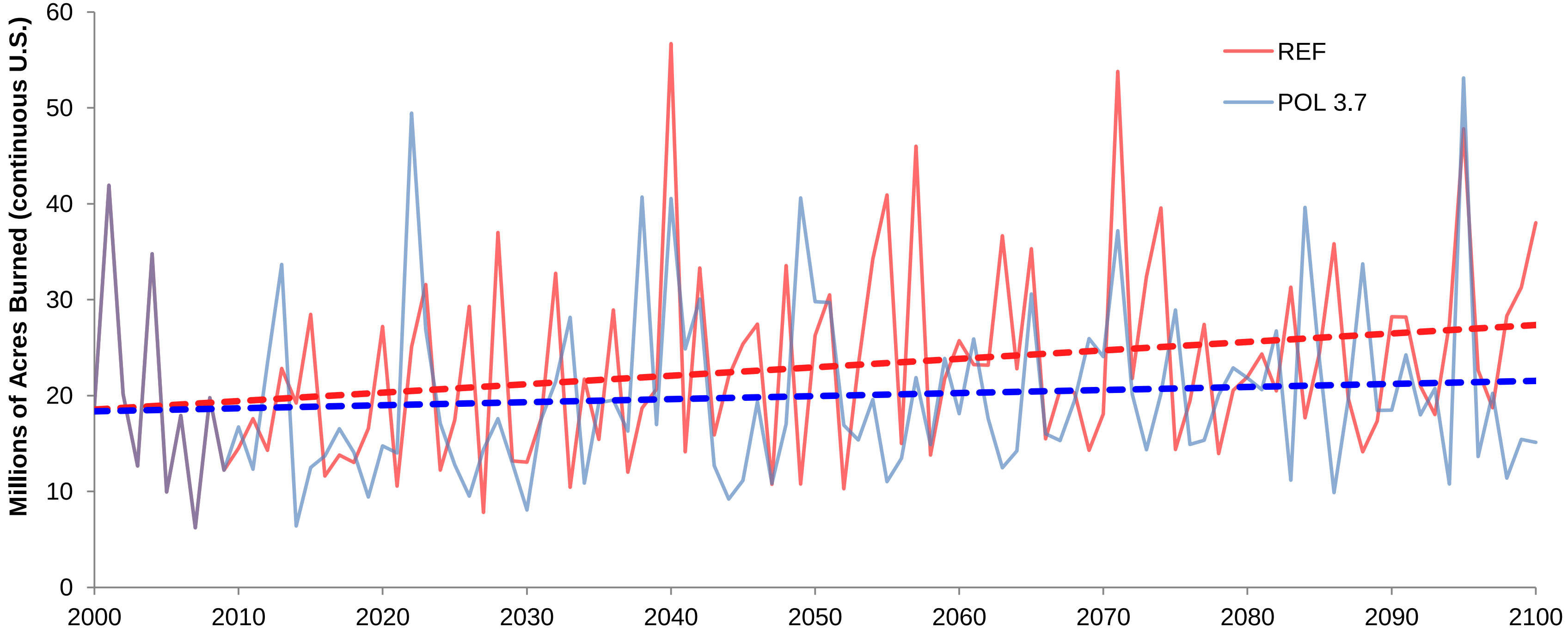
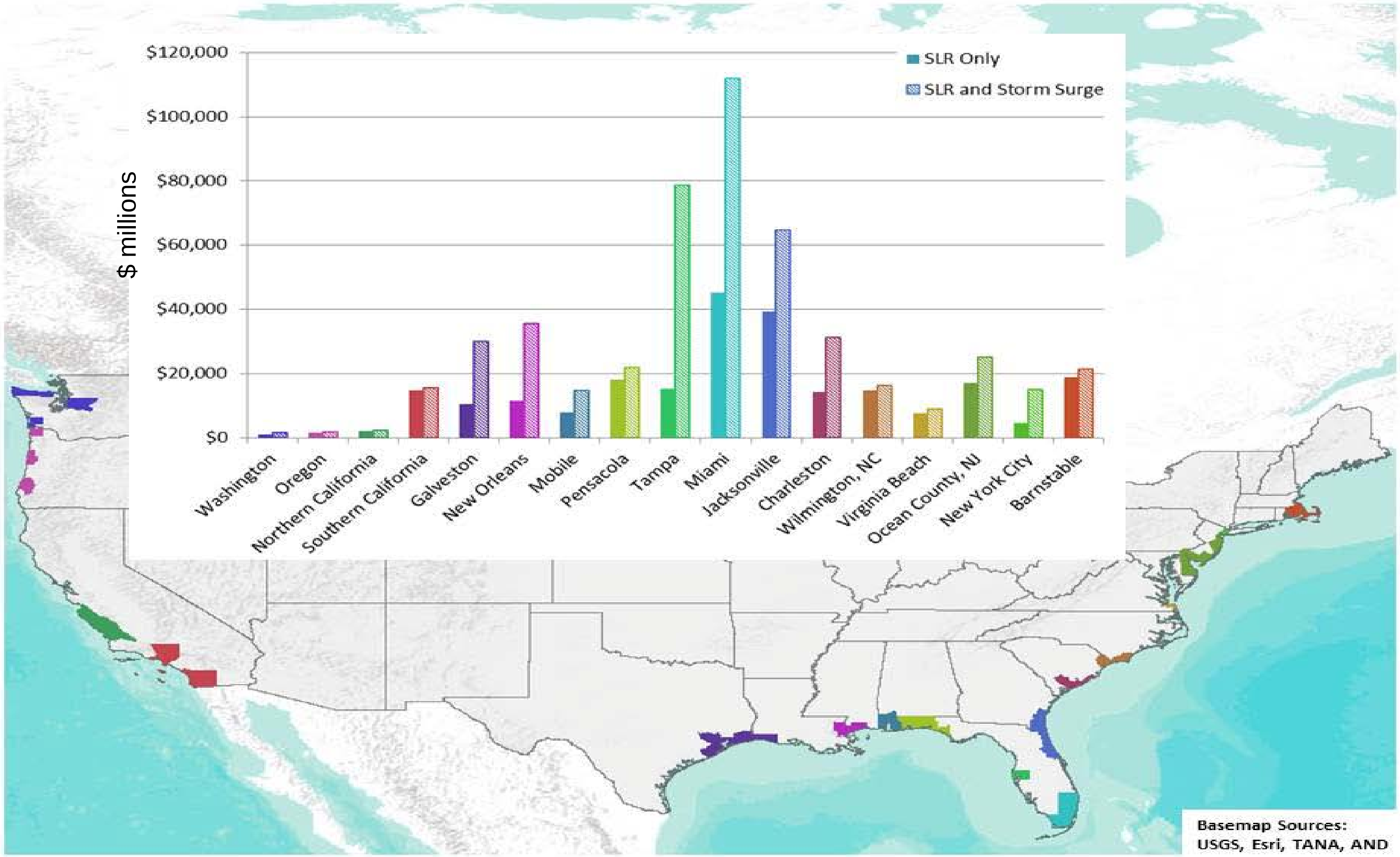
Changes in Wildfire Incidence and Response Costs



- Implementing the POL3.7 scenario would reduce cumulative acreage burned by wildfires in the continental U.S. between 2011 and 2100 by roughly 303 million acres, relative to the REF scenario.
- The corresponding discounted (3%) monetized estimate of reduced wildfire response costs (i.e., labor, equipment) over this period is $9.24 billion (2005$).
- Aggregated results at the national level appear driven by wildfire incidence from a limited number of regions (e.g., Rocky Mountains).

Coastal Property Damages and Adaptation Response Costs

- The cumulative, discounted economic impacts through 2100 for the REF (140cm) are $85B (for SLR only). Mitigation (POL3.7) avoids $7.5B (SLR only) of these costs. Including the effects of both SLR and storm surge increases these numbers considerably in many locations.
- Areas projected to be abandoned have a higher percentage of socially vulnerable populations than areas likely to be protected.



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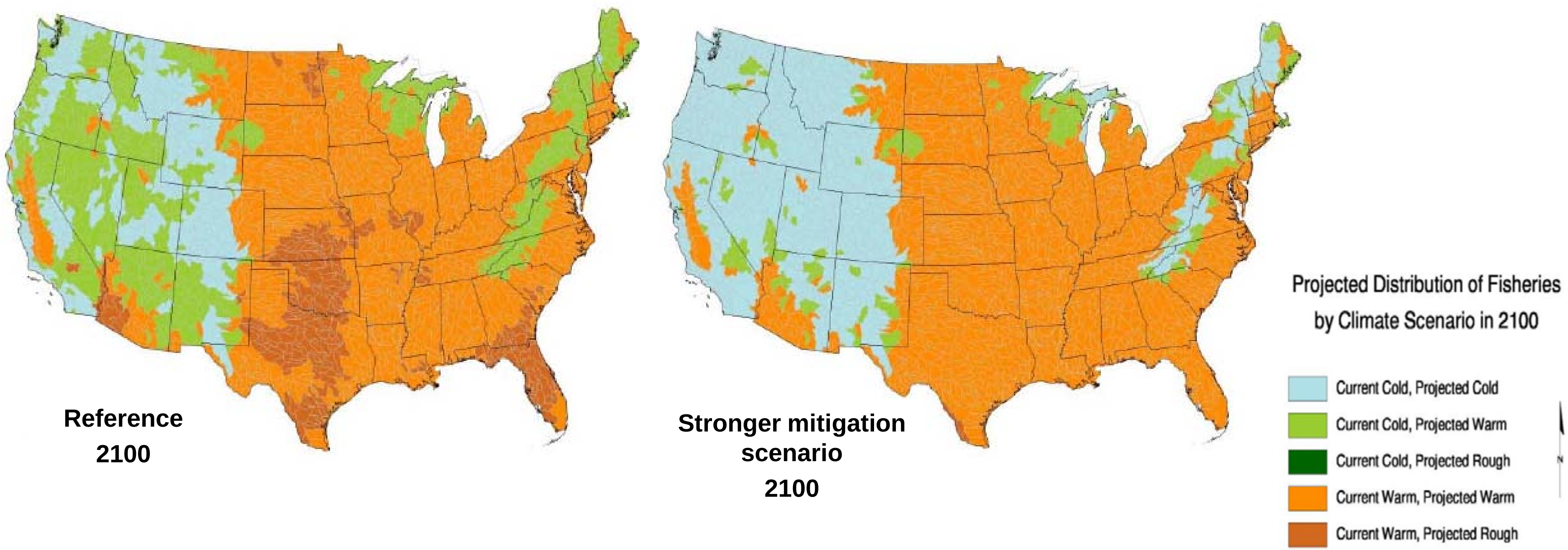
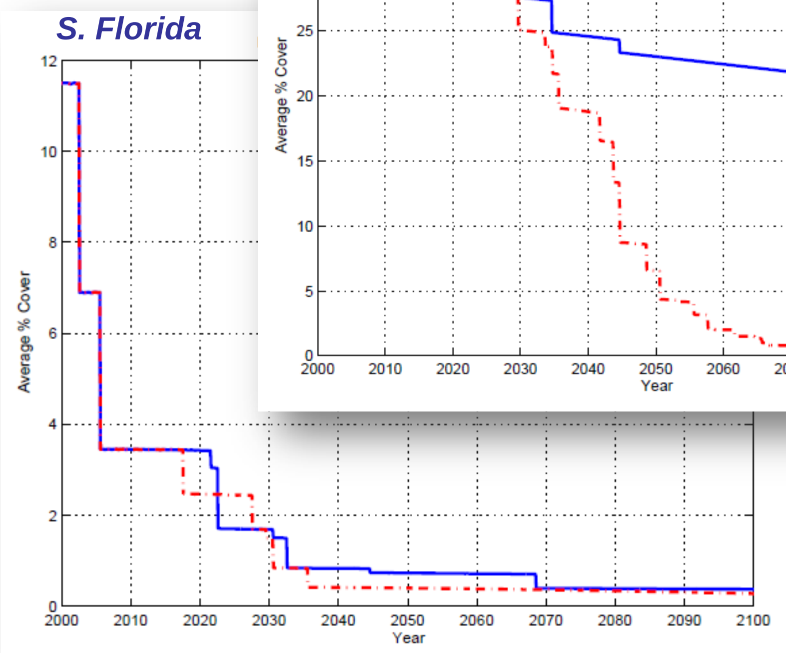
Freshwater Recreational Fishing

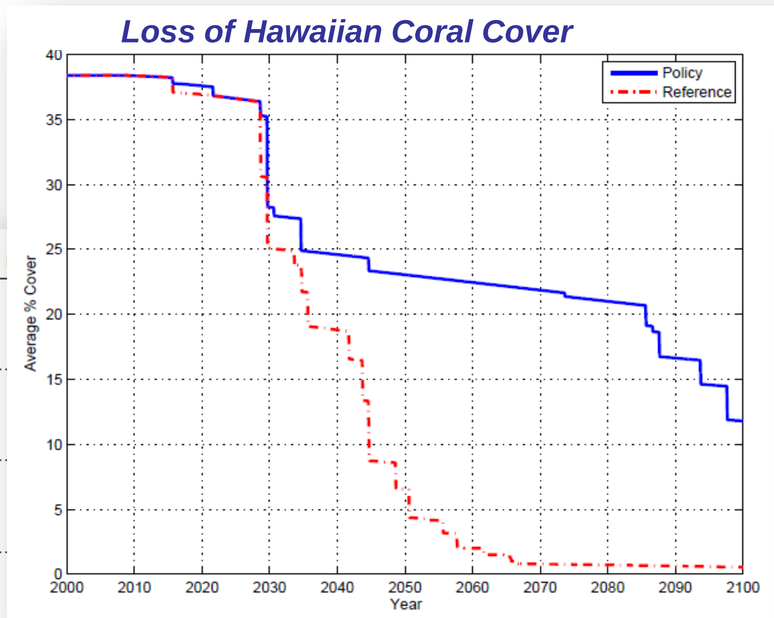
- Significant changes to the spatial distribution of where fish are today.
- Coldwater fish habitat declines by ~62% by 2100 under the reference, but only by12% and 11% under the GHG mitigation scenarios.
  - Mitigation preserves coldwater habitat in most of Appalachia & the Mountain West.
- The stronger mitigation scenario (POL3.7) avoids $324M (disc. at 3%) in total recreational fishing damages by 2100 compared to the reference.

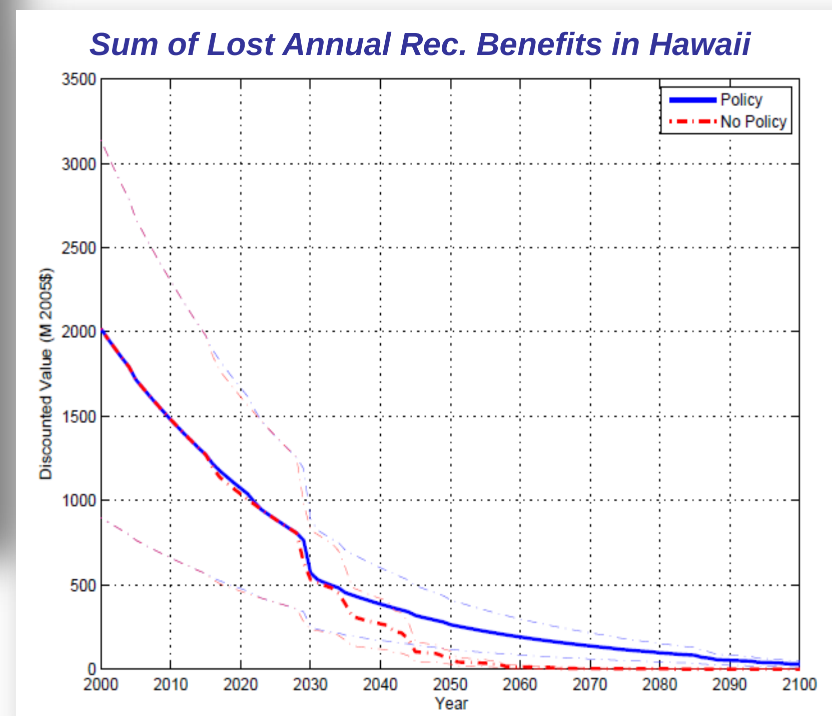


Estimated Decline in U.S. Coral Reefs

- GHG mitigation delays Hawaiian coral reef loss compared to the reference.
- The stronger mitigation scenario (POL3.7) avoids ~$18B (disc. at 3%) by 2100 in lost recreational value for all 3 regions, compared to the reference.
- GHG mitigation provides only minor benefit to coral cover in South Florida and Puerto Rico *(not shown)*, as these reefs are already being affected by climate change, acidification, and other stressors.







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Important Limitations and Caveats

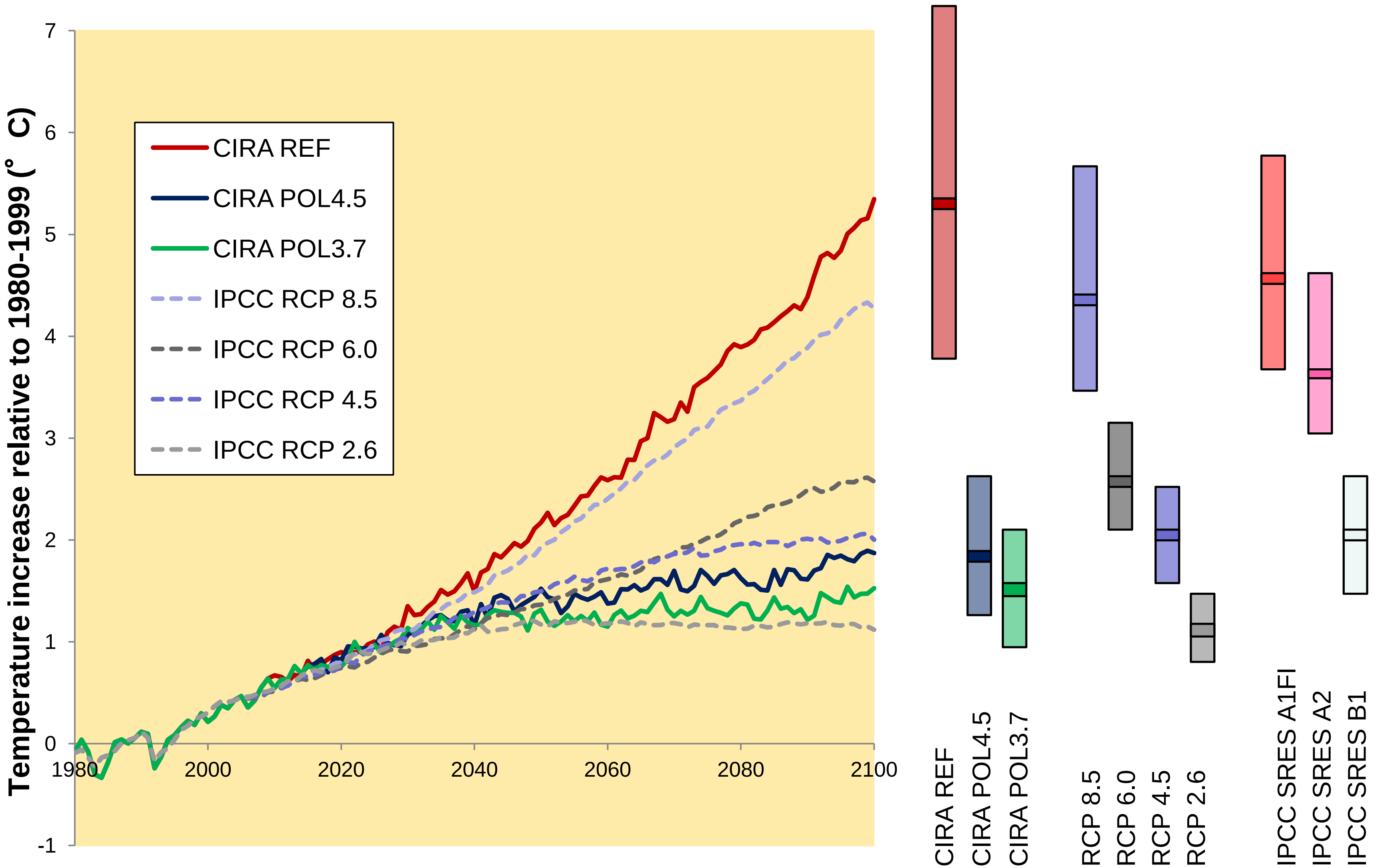
- CIRA is a policy analysis tool and different from the comprehensive climate science assessments conducted by IPCC and USGCRP.
- Although some of the sectoral models used can estimate impacts at regional (multi-state) to sub-regional (state to county) scales, none of the CIRA results should be used for local scale vulnerability assessment. The CIRA analyses are specifically designed to answer national-scale impacts and benefits questions.
- CIRA does not currently have the capacity to analyze marginal levels of mitigation (e.g., for use with EPA regulatory actions).
- CIRA results likely underestimate the benefits of avoided climate change; there are known impacts that are not currently included.
- The CIRA climate projections employ a limited number of climate models.
- While adaptation is not extensively addressed in the CIRA project, some of the impact estimates produced by the sectoral models do include adaptation costs.

Next Steps

- Completing peer-review and publication of 11 papers in a special issue of *Climatic Change* describing CIRA.
  - Papers cover: emissions, carbon cycle, climate projections, climate extremes, water resources, electric power, infrastructure, human health (extr temp.), ecosystems, and forests.
  - Most of the underlying components of CIRA (integrated assessment and sectoral models) have already been published in the scientific literature (~30 papers).
- Complete ‘in-progress’ sectoral analyses: agriculture, forestry, water quality, air quality.
- Run additional mitigation scenarios to develop reduced-form models that analyze ‘smaller’ (non-global) mitigation levels.
- Identify next steps to address highest priority sectoral gaps.
- Incorporate climate impacts into economy-wide models.

Appendix

Emission Scenario Comparison



*Likely ranges for CIRA scenarios represent year 2100 values for climate sensitivity 2 and 4.5˚C

Likely range

[RCP & SRES ranges adapted from Rogelj et al. 2012]

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CIRA in Context:
Complement to SCC

- Both efforts use model-based approaches to estimate mitigation benefits and address climate and model uncertainty, however the approaches differ in important ways:

	CIRA	SCC
Geographic scope	U.S. regional + global	Global
Applicability and usage	• Significant global action. • Informs analysis and helps tell story of benefits of mitigation.	• Assess marginal changes in GHG trajectories. • Meant to provide a comprehensive metric for benefit-cost analysis. • Limited communication tool.
Characterization of impacts	• Highly specific for U.S. • Meaningful physical impacts (e.g., heat mortality, drought, habitat loss). • Physical + monetized estimates.	• Too aggregated for U.S. specific impacts. • Only monetized estimates. • Often difficult to see underlying physical impacts.
Coverage of impacted sectors	Detailed U.S.- and sector-specific coverage. A number of known impacts not included (e.g., vector-borne disease, catastrophic events).	Aims to measure economic damages from all impact sectors; in practice models do not capture all important damages.
Approach to impact estimates	Bottom-up modeling: directly modeled at sector level using consistent data, assumptions, and scenarios.	Aggregated damage functions developed from available literature (with inconsistent inputs, data, etc.).

- In the future, results from CIRA's impact analyses may help inform aggregate damage functions used in the SCC models' estimates.