

Internal variability in projections of climate change impacts on air quality and health

NCAR Large Ensembles Workshop
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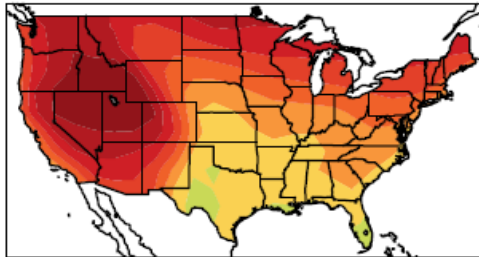
Erwan Monier - University of California, Davis

Climate change impacts on air quality

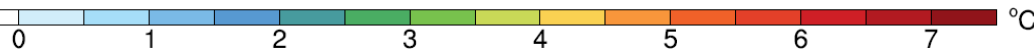
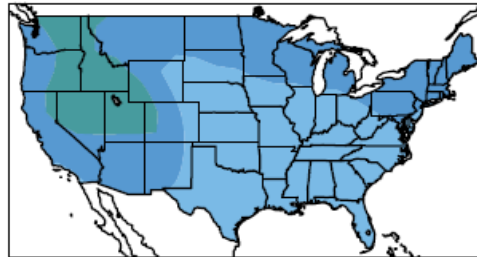
Projected changes in 2100

Air Surface Temperature:

REF

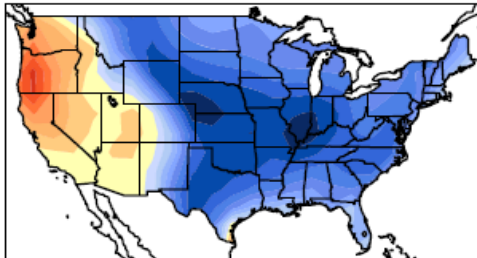


POL4.5

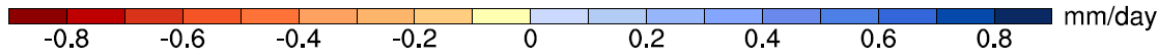
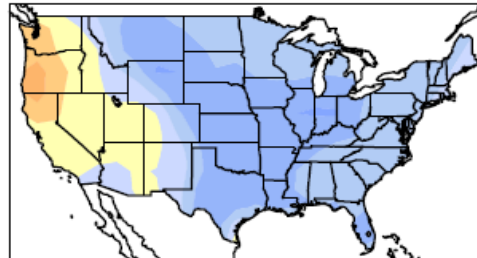


Precipitation:

REF



POL4.5



Climate change impacts air quality through many coupled mechanisms:

- Atmospheric chemistry
- Atmospheric ventilation
- Natural emissions
- Deposition rates



“Climate penalty” on air quality

Climate change impacts on air quality

Fourth National Climate Assessment

Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II

13

Air Quality



Carr Fire, Shasta County, California, August 2018

Key Message 1

Increasing Risks from Air Pollution

More than 100 million people in the United States live in communities where air pollution exceeds health-based air quality standards. Unless counteracting efforts to improve air quality are implemented, climate change will worsen existing air pollution levels. This worsened air pollution would increase the incidence of adverse respiratory and cardiovascular health effects, including premature death. Increased air pollution would also have other environmental consequences, including reduced visibility and damage to agricultural crops and forests.

Climate change impacts air quality through many coupled mechanisms:

- Atmospheric chemistry
- Atmospheric ventilation
- Natural emissions
- Deposition rates



“Climate penalty” on air quality

Projecting climate penalty on air quality

Focus on climate-induced impact:

Δ Climate + Δ Emissions \rightarrow Δ Air Quality

Modeling framework:

U.S. EPA **CIRA** projections^[1]

MIT IGSM: Policy and climate projections^[2]

CAM-Chem: Global atmospheric chemistry

BenMAP: Health and economic impacts

Emissions held at start-of-century levels

Simulated periods: start (**2000**), middle (**2050**), and end (**2100**) of 21st century

Ensemble simulations:

1. Emissions-scenario uncertainty:

- Reference: No policy
2100 RF = 9.7 W/m²
- Policy 4.5: Stabilization
2100 RF = 4.5 W/m²
- Policy 3.7: Stringent stabilization
2100 RF = 3.7 W/m²

2. Natural variability

- 30-year simulations
- 5 different initializations

3. Climate model response

- Climate sensitivity = 2.0°C, 3.0°C or 4.5°C

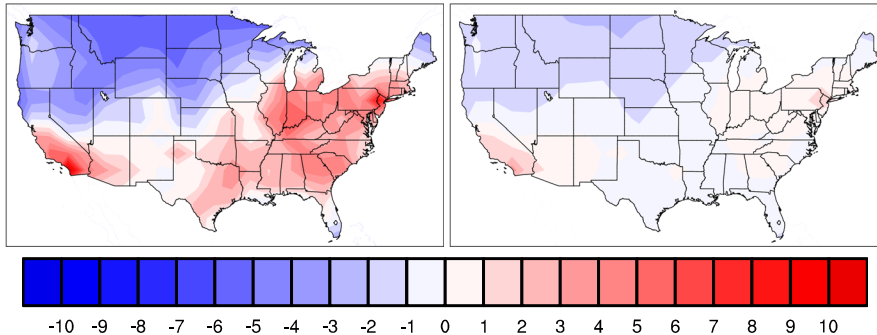
Ensemble-mean projections

2100 Climate Penalty

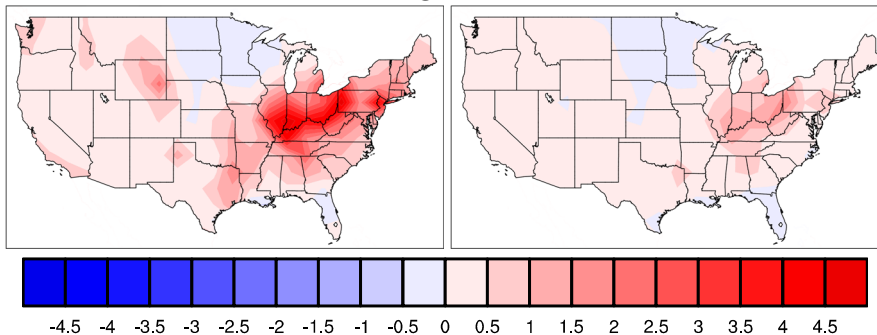
No Policy

Climate Policy

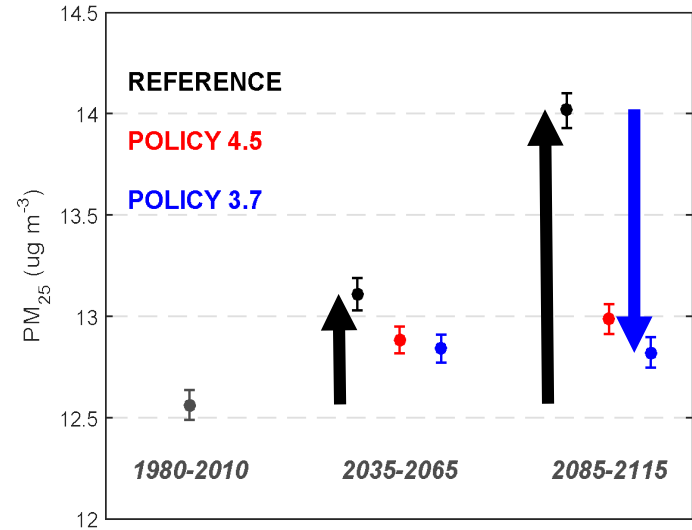
ΔO_3 (ppb)



$\Delta PM_{2.5}$ ($\mu g/m^3$)



U.S. population-weighted annual $PM_{2.5}$



Avoided U.S. deaths under climate policy:

2050: > 10,000 (4,000 - 22,000)

2100: > 50,000 (19,000 - 95,000)

Ensemble-mean projections

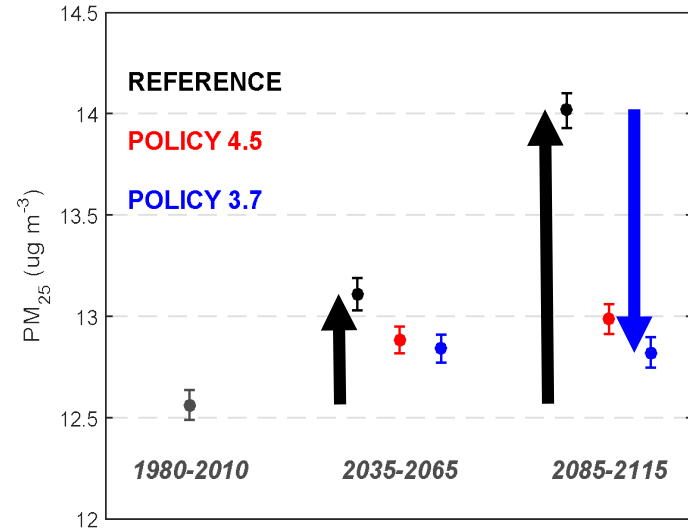
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EPA boss: Climate change could kill thousands

“Climate change is the greatest threat of our time ... We're projecting that, if you take action, you could avoid approximately 13,000 deaths in 2050, and 57,000 from poor air quality that's associated with climate change.”

EPA Administrator

U.S. population-weighted annual PM_{2.5}



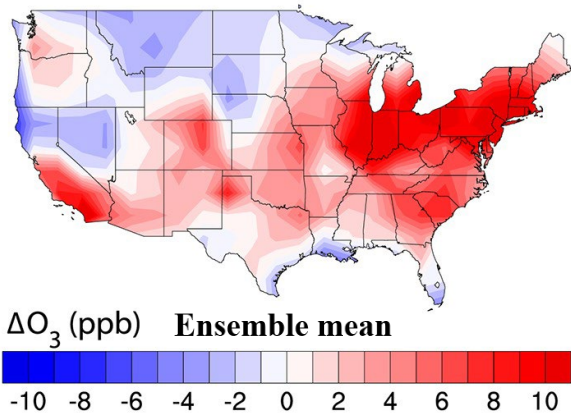
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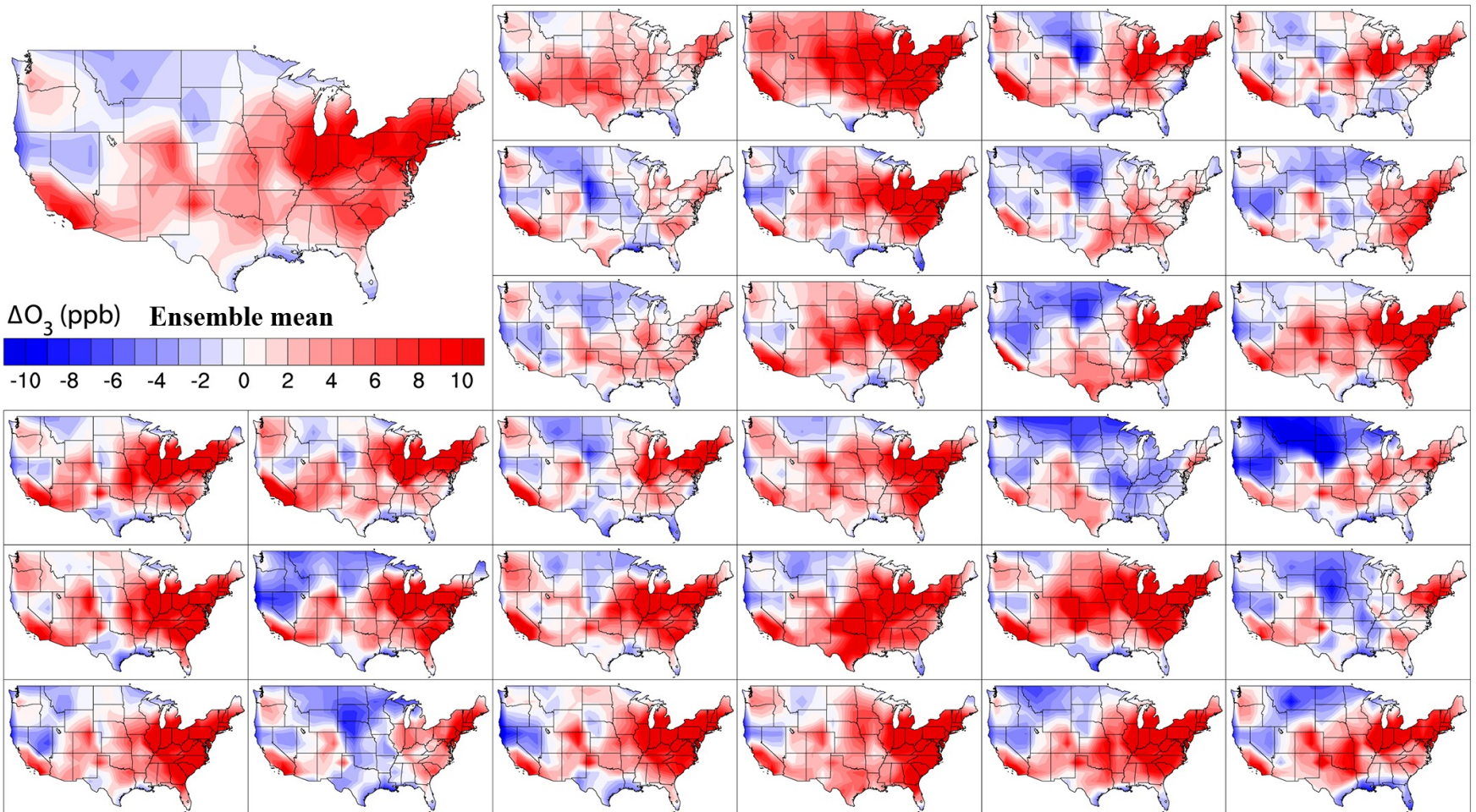
Natural variability

2100 Reference scenario O₃ season climate penalty (Δ 8h-max ppb)



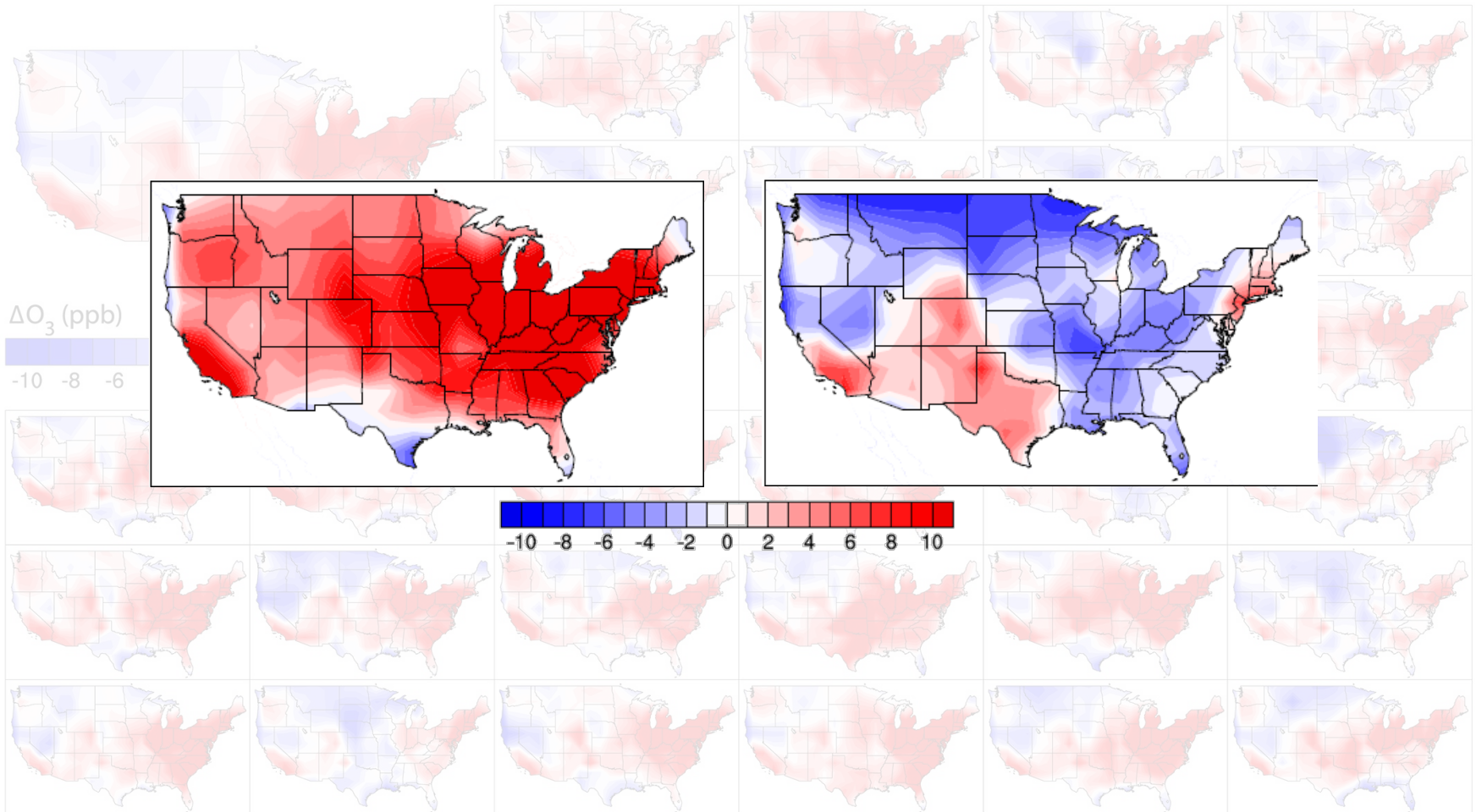
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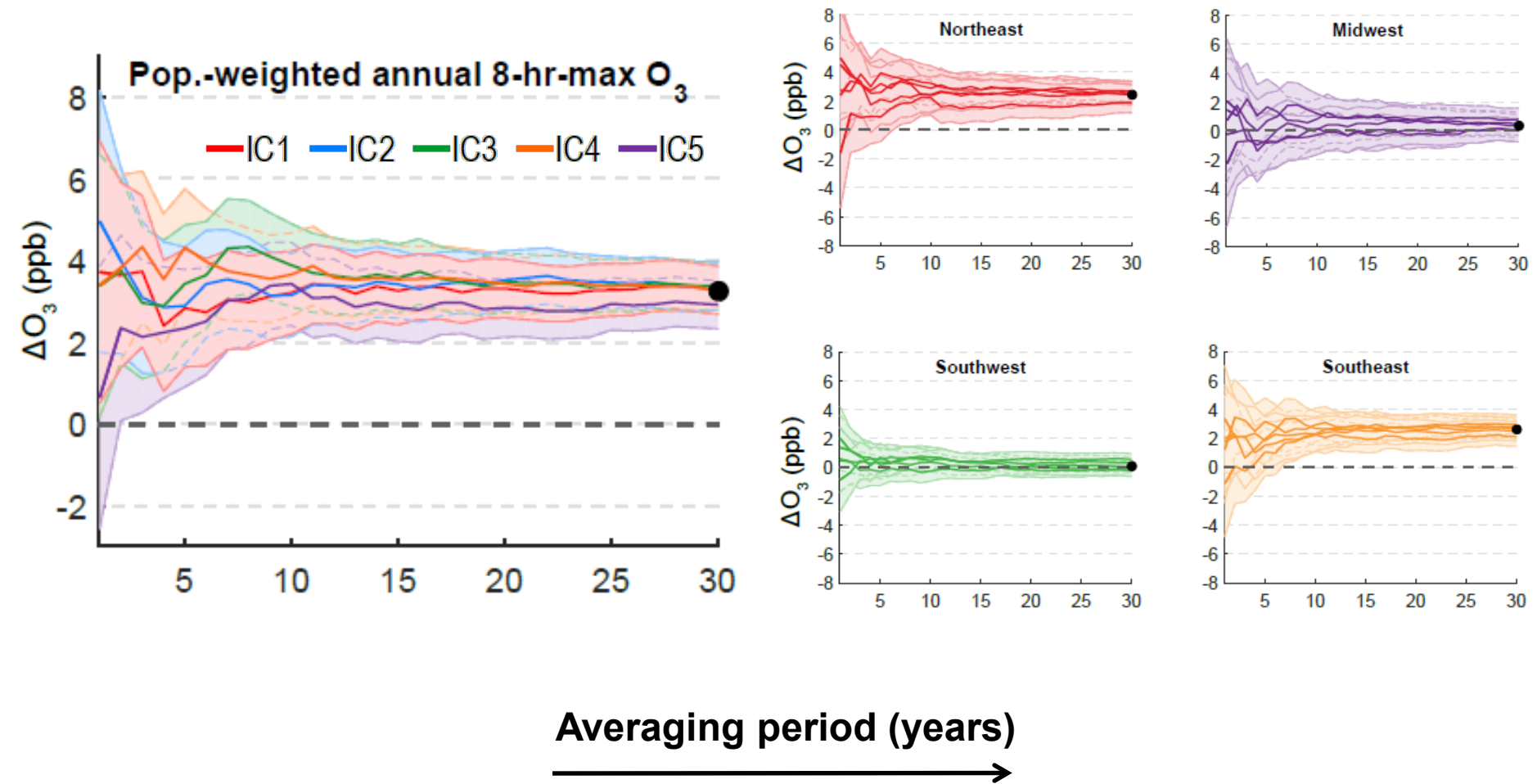
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Natural variability in O₃ penalty projections

2100 Reference scenario O₃ season climate penalty (Δ 8h-max ppb)



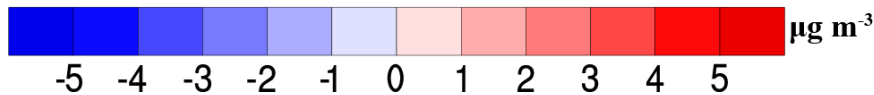
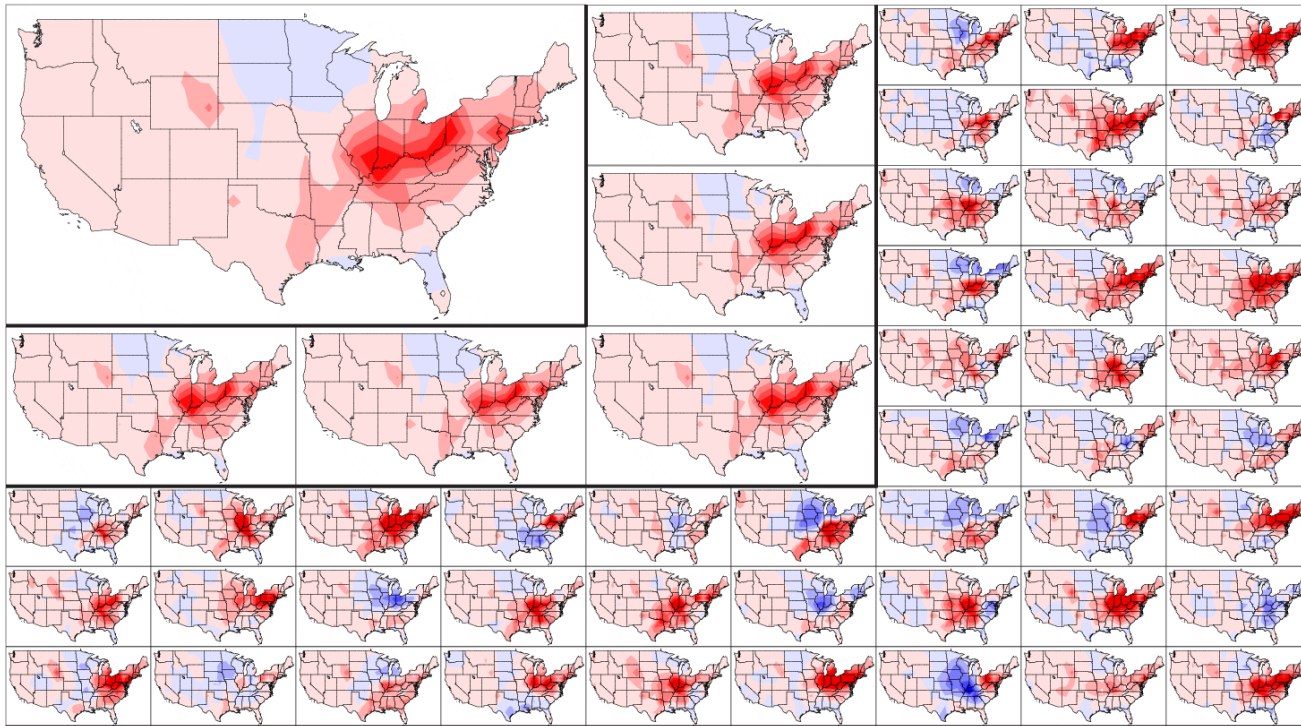
Natural variability in PM_{2.5} penalty projections

2100 REF-scenario annual PM_{2.5} climate penalty ($\Delta \mu\text{g m}^{-3}$)

Ensemble mean

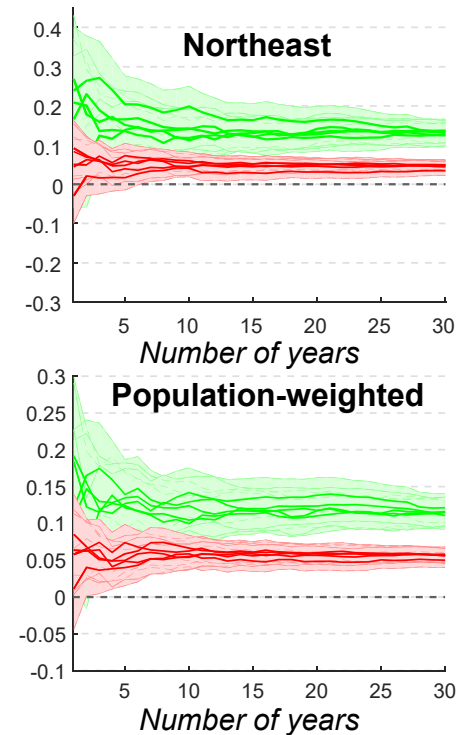
IC means

Individual years



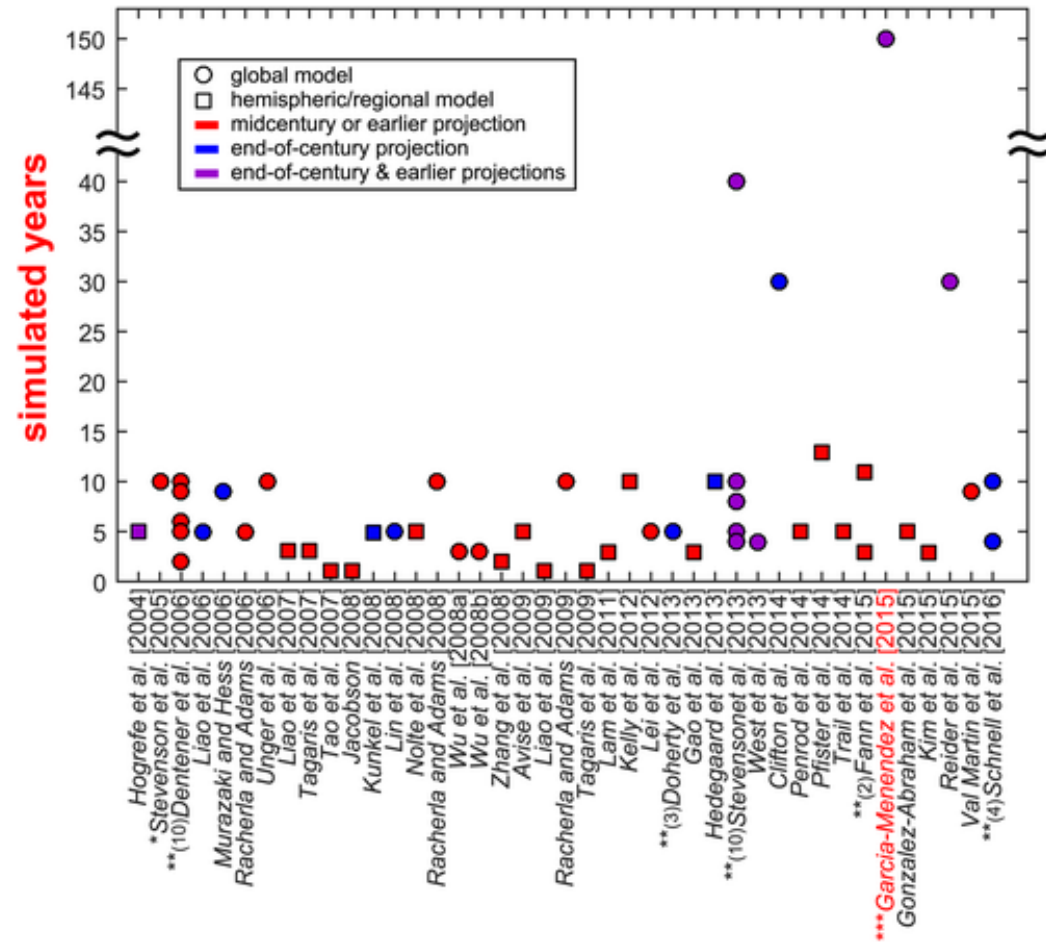
— ΔO_3

— $\Delta \text{PM}_{2.5}$



Relative change with respect to start-of-century mean

Projections of climate penalty on air quality



2100 REF-scenario climate penalty on population-weighted concentrations in this ensemble:

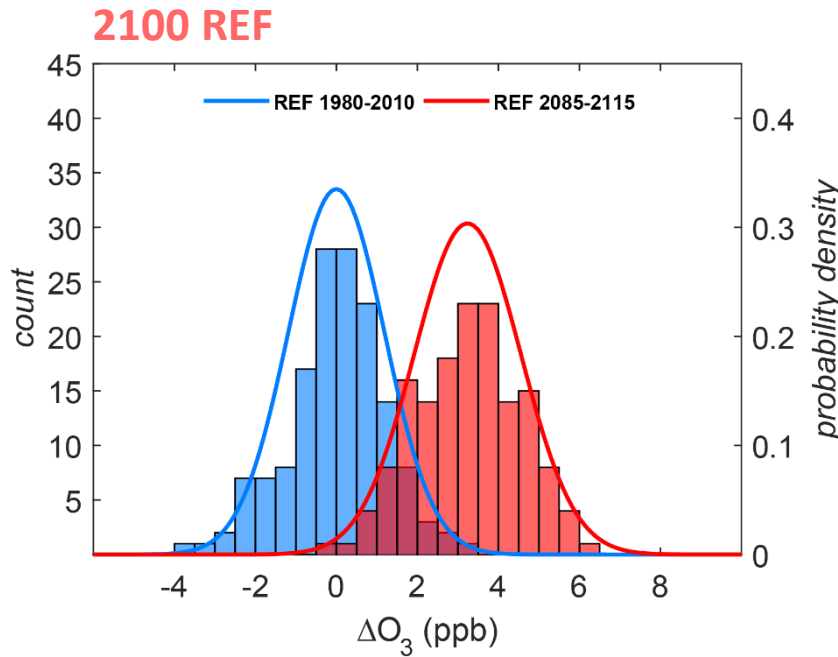
O₃:

- + 3.2 ppb
- 15 years for ± 1.0 ppb margin of error (95% confidence)

PM_{2.5}:

- + 1.5 µg/m³
- 10 years for ± 0.5 µg/m³ margin of error (95% confidence)

Projections of climate penalty on air quality



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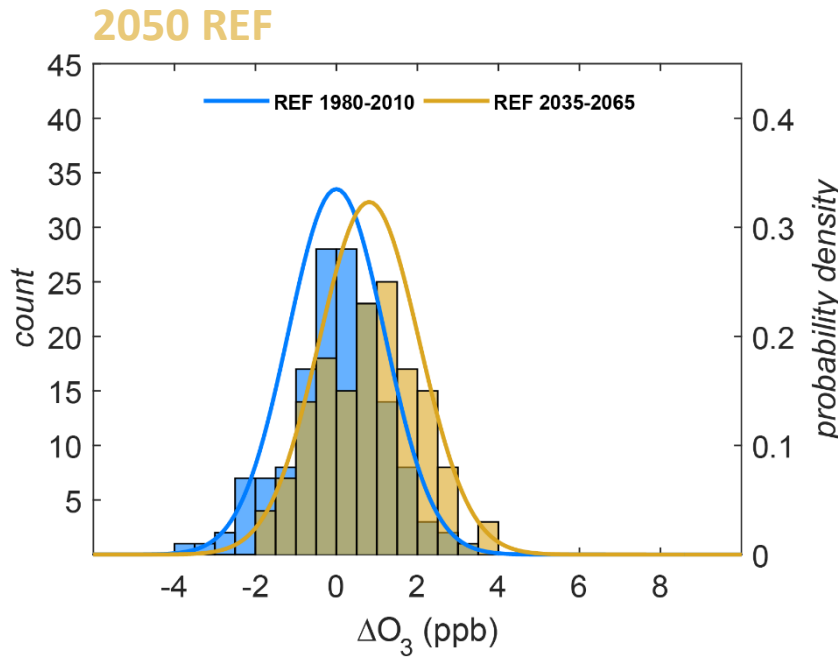
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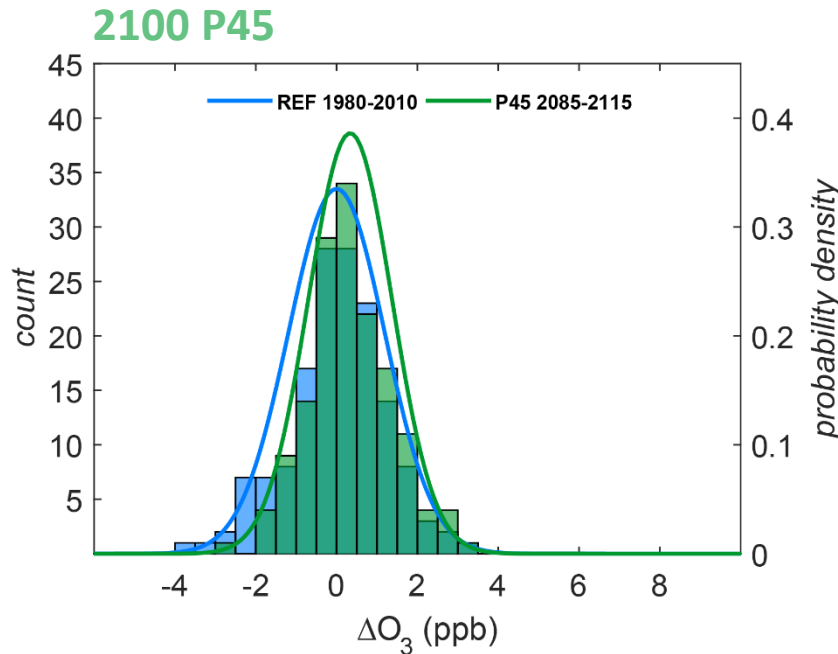
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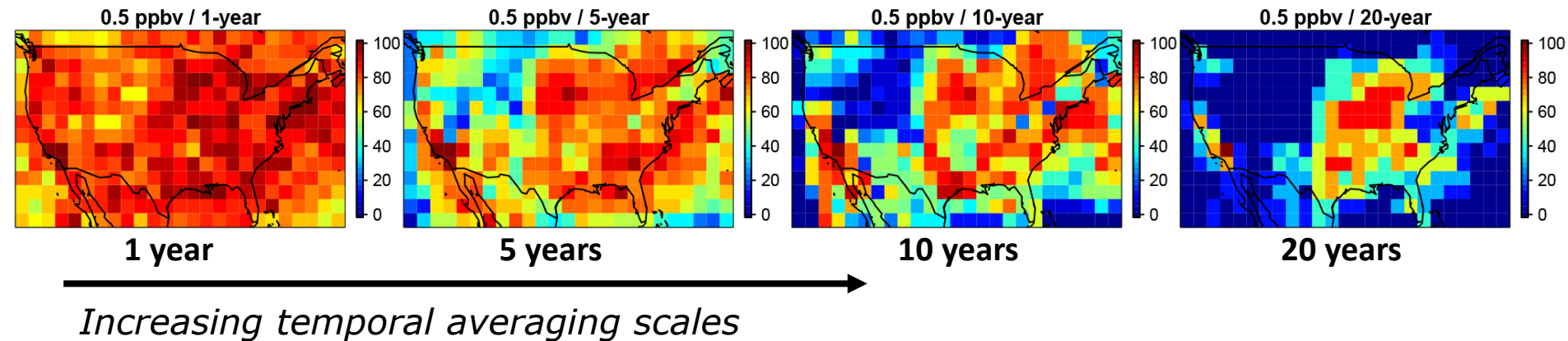
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Ensemble-mean projections

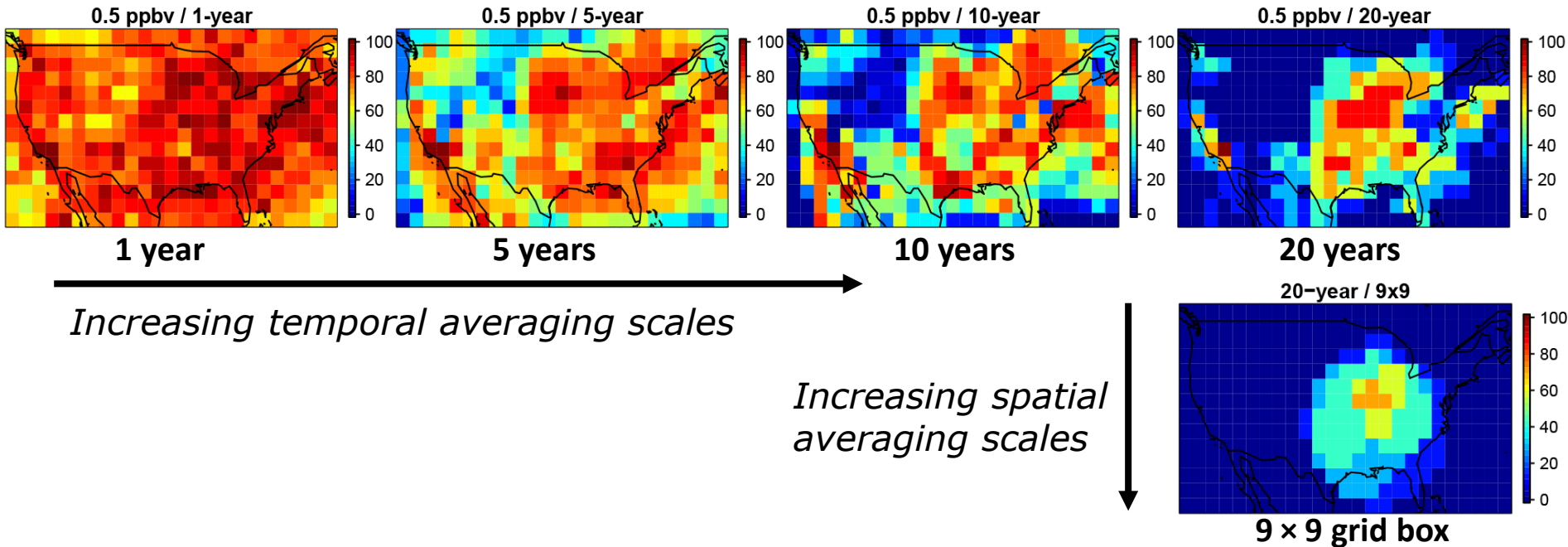


Likelihood (%) that ozone estimate exceeds 0.5 ppb threshold due to meteorological variability in the present-day simulation:



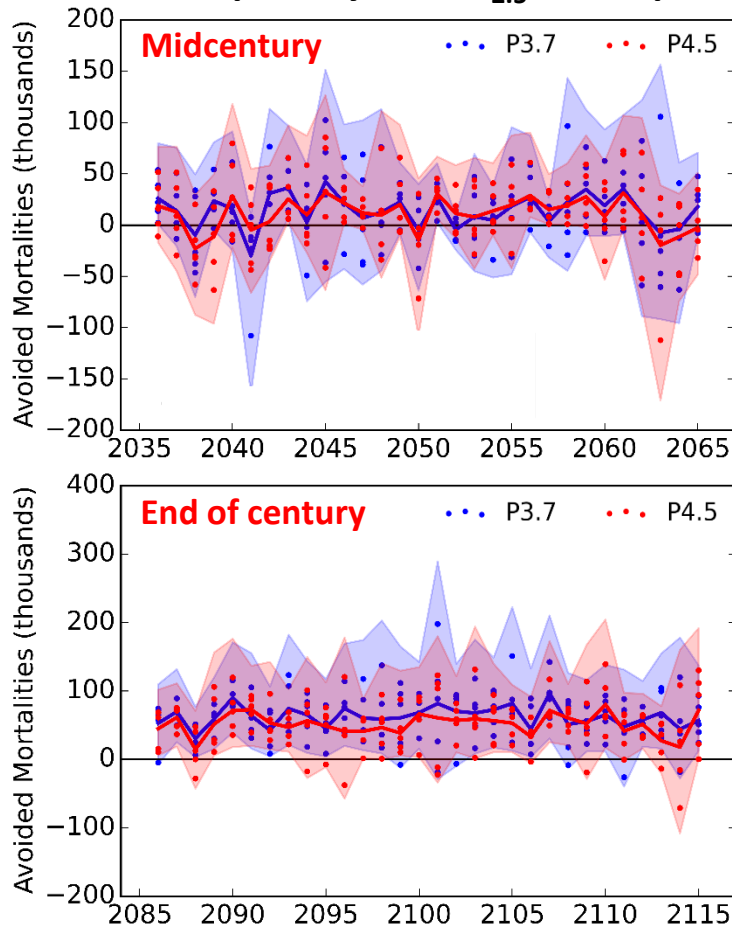
Ensemble-mean projections

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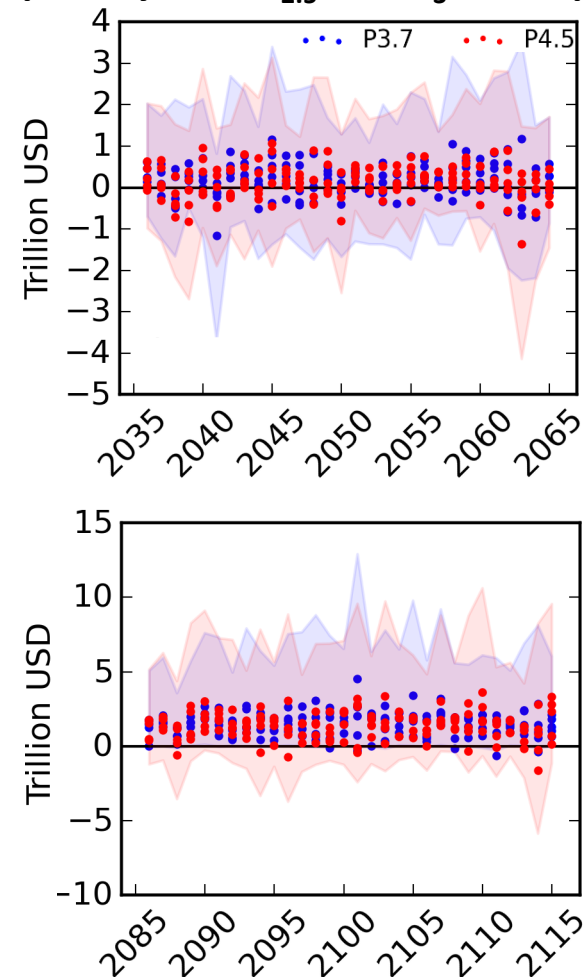
Projections of health and economic impacts

Annual mortalities avoided by reducing climate penalty on PM_{2.5} under policy



Health impacts

Annual benefits from reducing climate penalty on PM_{2.5} and O₃ under policy



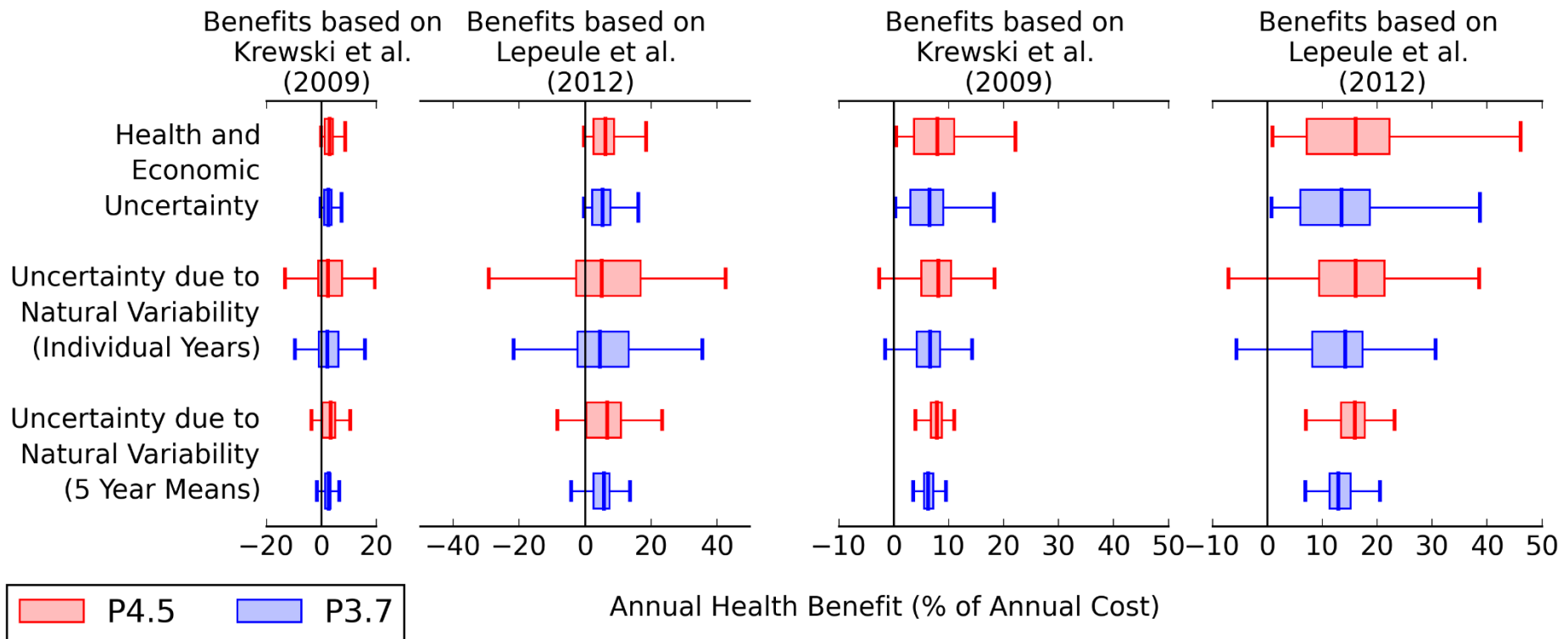
Economic impacts

Projections of co-benefits of climate policy

Effect of uncertainties on percent of policy costs offset by reducing health risks from climate penalty

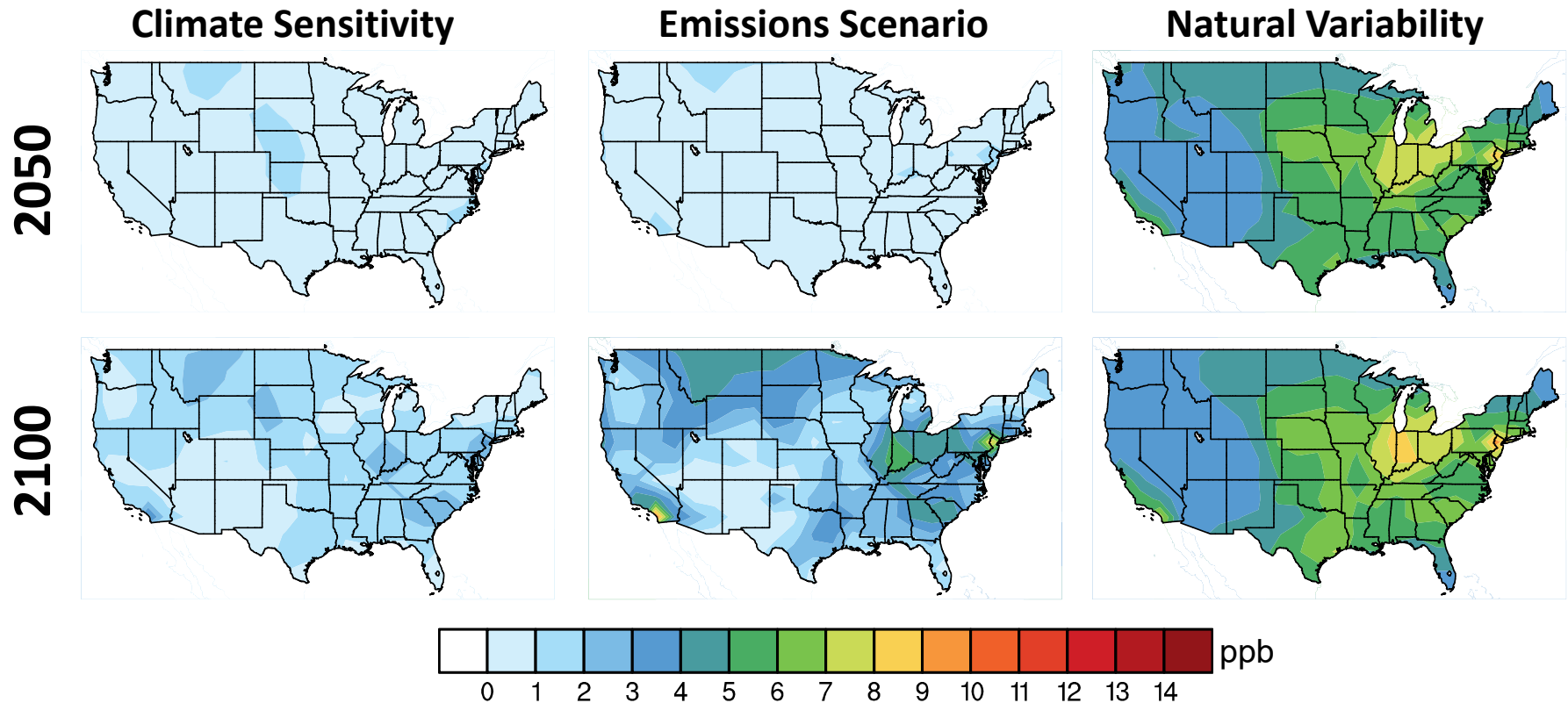
2050

2100



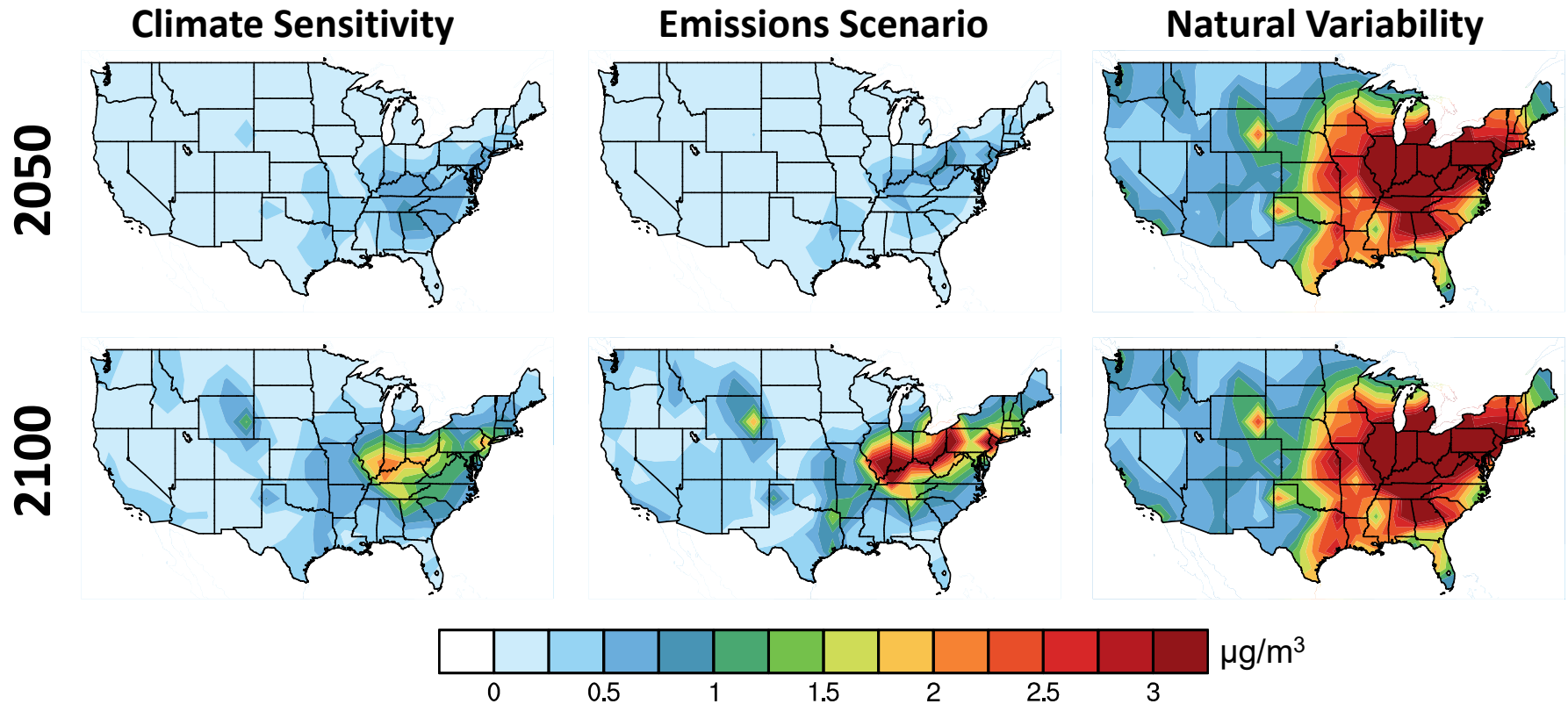
Range of climate penalty projections

Mean range of climate-induced O₃ change for each source of uncertainty



Range of climate penalty projections

Mean range of climate-induced PM_{2.5} change for each source of uncertainty

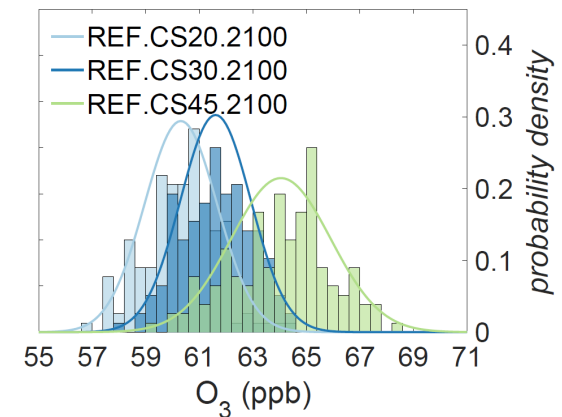


Projections of climate change impacts on air quality

Examining natural variability can inform projections of air quality under climate change, related health impacts, and climate policy assessments

Air quality considerations:

- Location and period of interest
- High concentrations and extreme air pollution
- Varying emissions and chemical composition
- Structural uncertainty in climate and chemistry models
- Simulations with interactive chemistry
- PM_{2.5} composition
- Complex treatment of SOA chemistry
- Natural emission sources (wildfires and dust)
- Increased resolution



Thank you

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