Quantifying Co-benefits of CO_2 Emission Reductions for the US: An Adjoint Sensitivity Analysis

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Outline

- Introduction
- Methodology
- Results
  - Co-benefit through NO_x reduction
  - Sectoral co-benefits
- Discussion
- Future steps

Introduction

- Co-benefits due to reduced emissions of criteria pollutants (or their precursors)

- What are the impacts of emission reductions on:
  - Climate change (GHGs): Not considering the climate feedback on air quality
  - Air quality and human health (criteria pollutants): The effects that are related to human health

- Co-benefit components:
  - Sectoral
  - Spatial
- Initial focus on co-benefits due to reduced No_x, CO and VOC emissions (through O_3 health impacts).

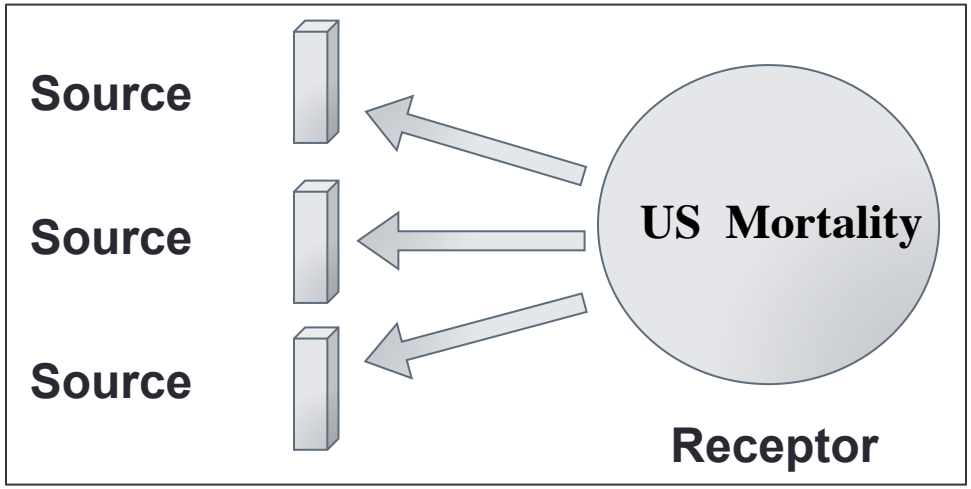
Methodology

$$\frac{\$}{E_{CO_2(x,y)}} = \frac{\$}{E_{NO_x(x,y)}} \times \frac{E_{NO_x(x,y)}}{E_{CO_2(x,y)}}$$

Co-benefit | **Marginal Benefit*** | **Emission Ratio**

*(*Pappin and Hakami. EHP, 2013*)

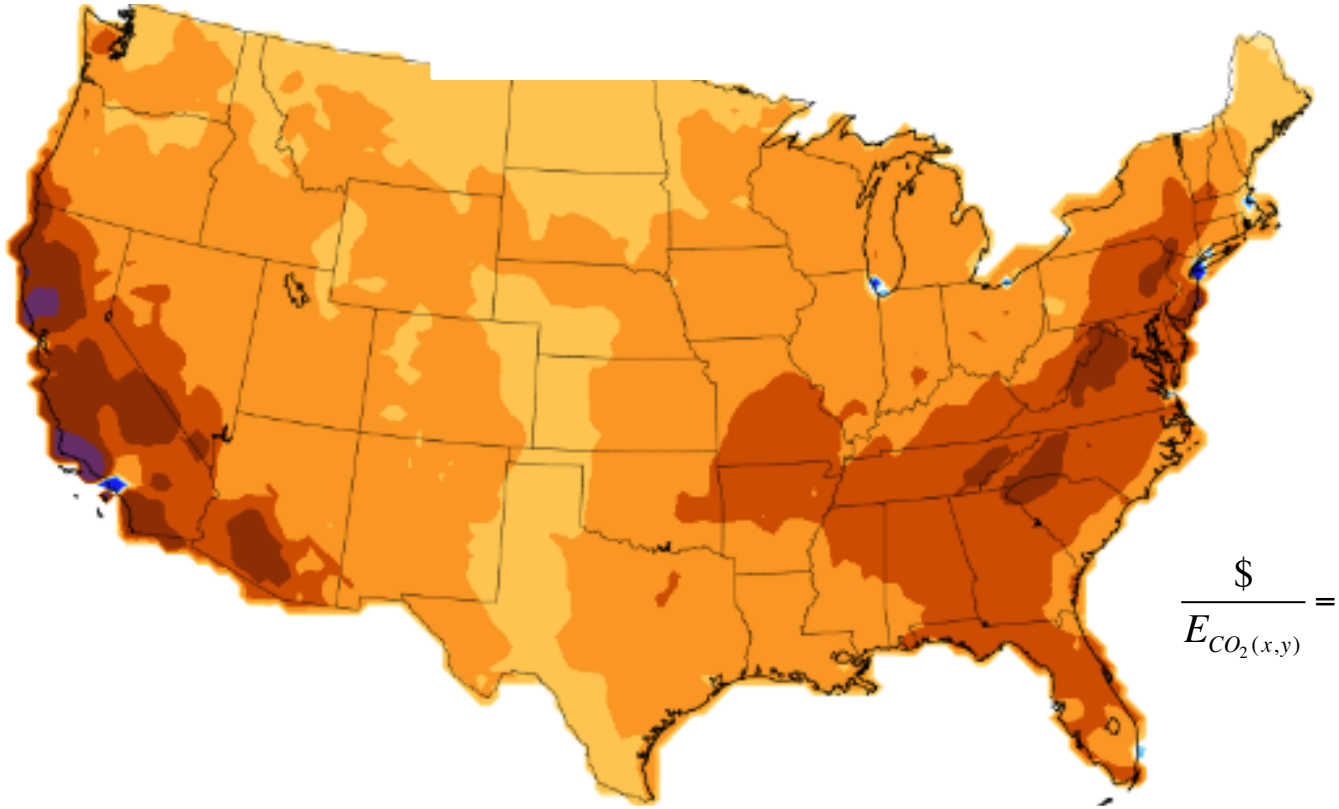
Marginal Benefit Estimation: Adjoint model



- Benefits of reducing mortality due to long-term ozone exposure in the U.S. (based on *Pappin and Hakami. EHP, 2013)*
- Gas-phase CMAQ-Adjoint
- 36 km CONUS domain
- Modeled over ozone season of May-September 2007 (153 days)
- 34 vertical layers

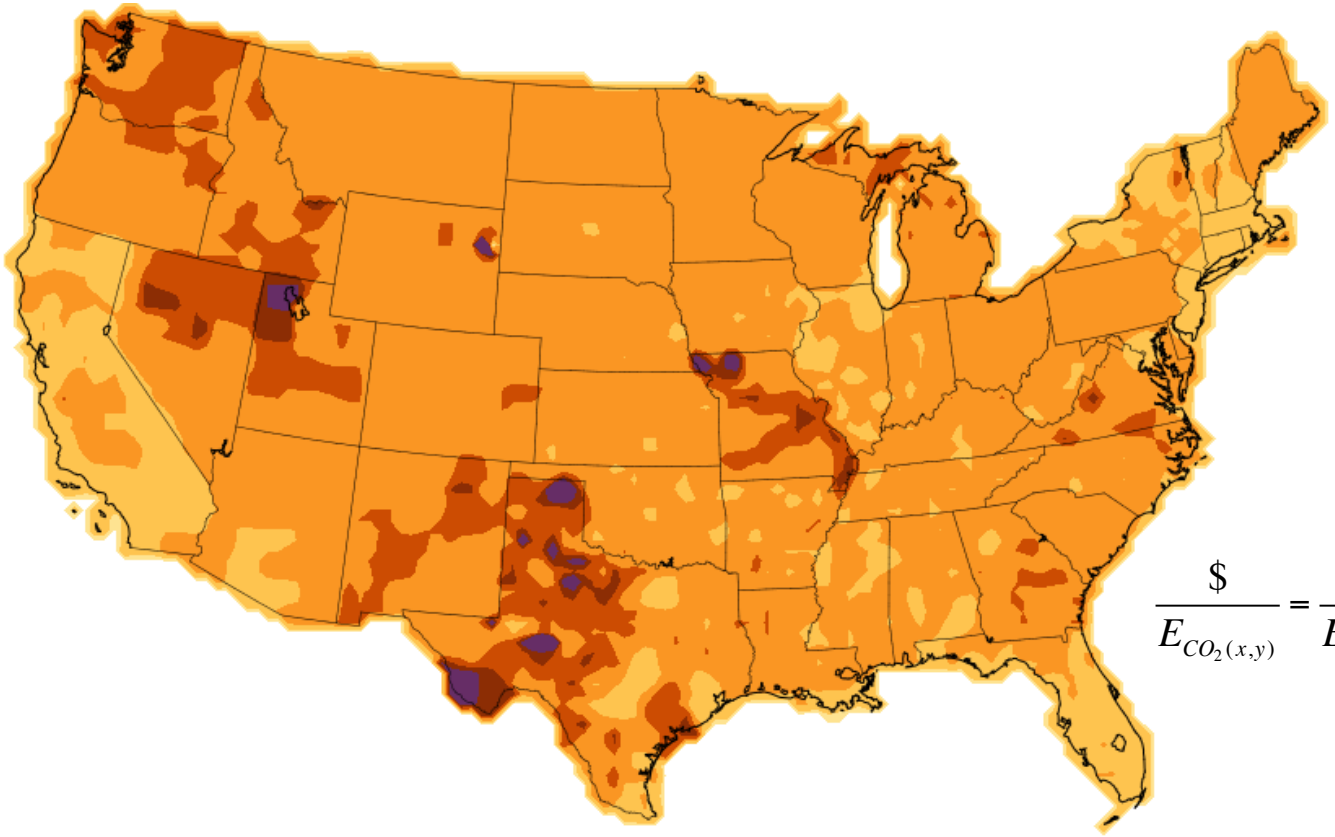
NO_x Marginal Benefit: Mobile Sources

Long-term health effect estimations based on Jerrett et al. (2009)



$$\frac{\$}{E_{CO_2(x,y)}} = \frac{\$}{E_{NO_x(x,y)}} \times \frac{E_{NO_x(x,y)}}{E_{CO_2(x,y)}}$$

NO_X/CO_2 Emission Ratio: Mobile On-road



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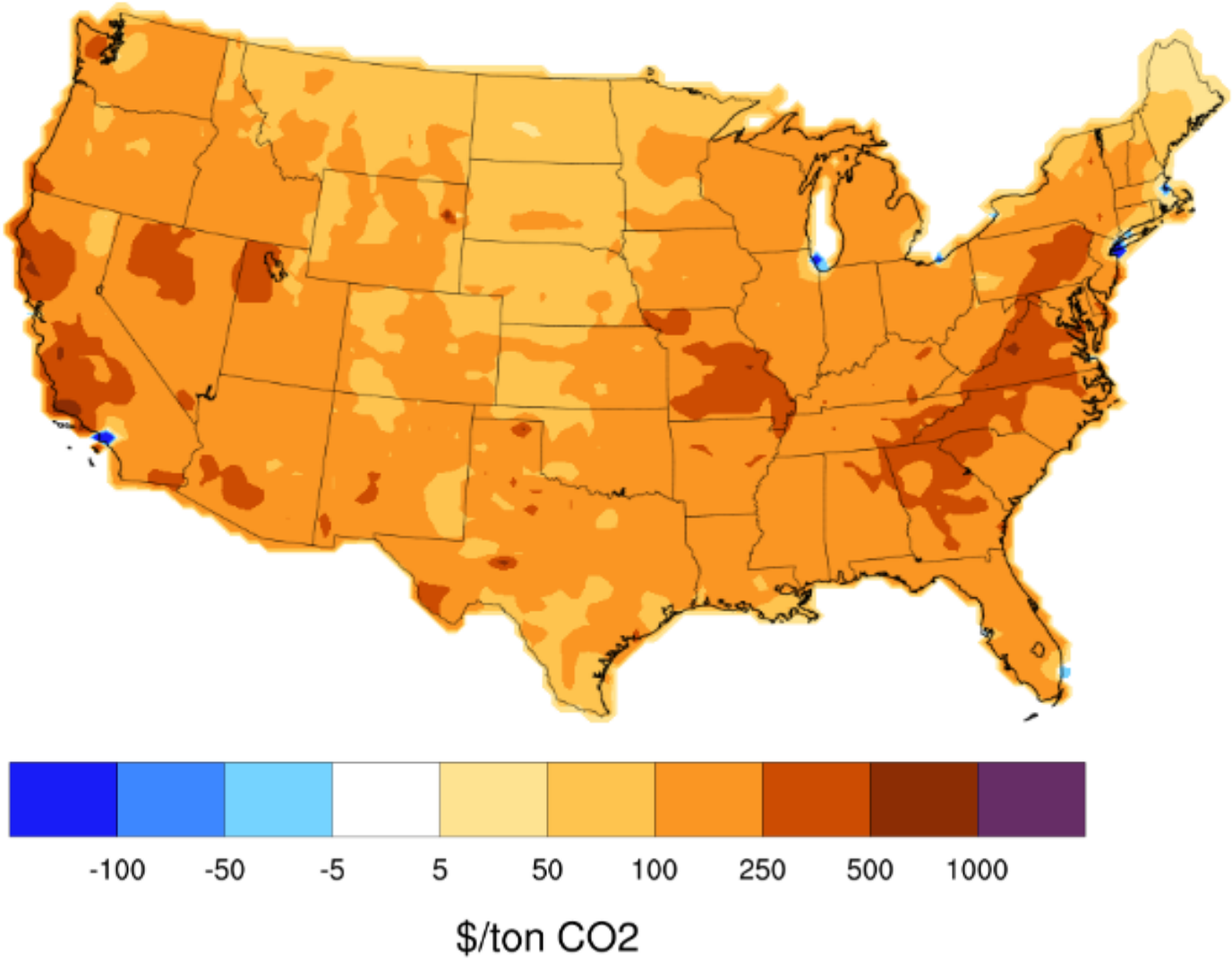
Mobile On-road, Non-road

Emissions Data Sources

- NO_X, CO, and CO_2 data from the 2011 NEI
  - On-road: cars, motorcycles, heavy and light duty truck
    - Diesel/non-diesel and heavy/light duty vehicles
  - Non-road: construction, agriculture and recreational engines

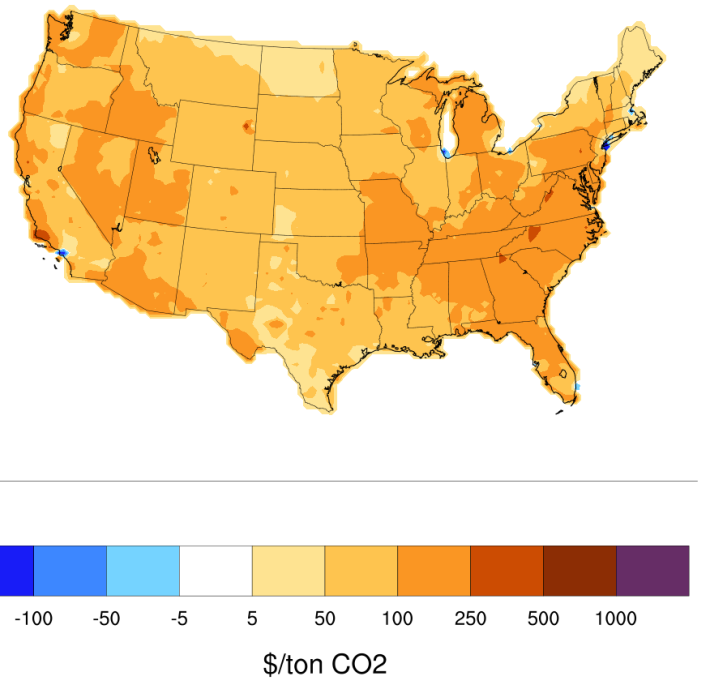
- County-level data gridded to 36-km resolution

Co-benefit through NO_X Mobile On-road: All Fuel Types

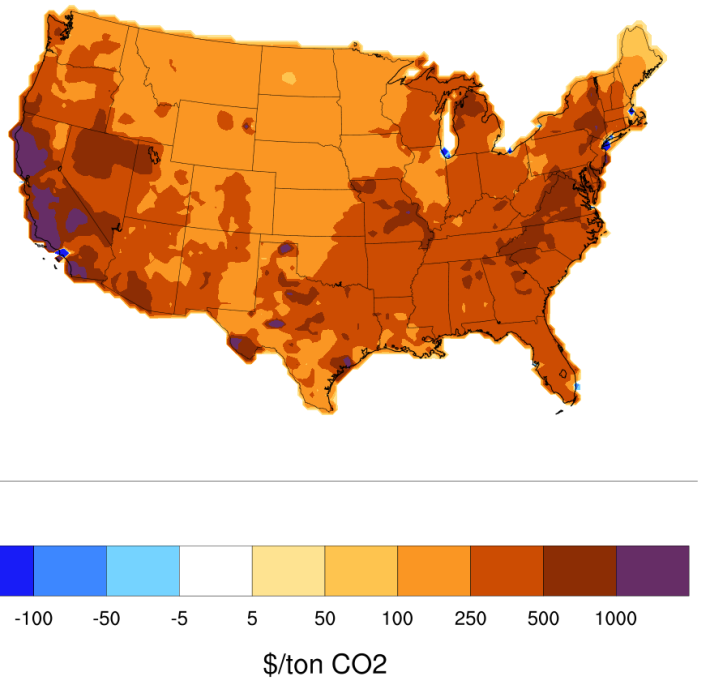


Co-benefit through NO_X: Mobile On-road

Non-Diesel Light Duty



Diesel Heavy Duty



Co-benefit through NO_X: Mobile On-road

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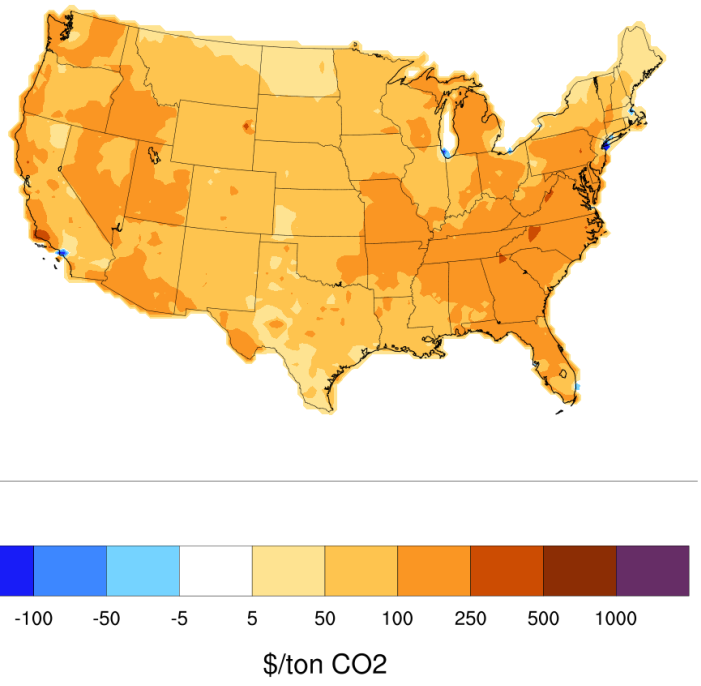
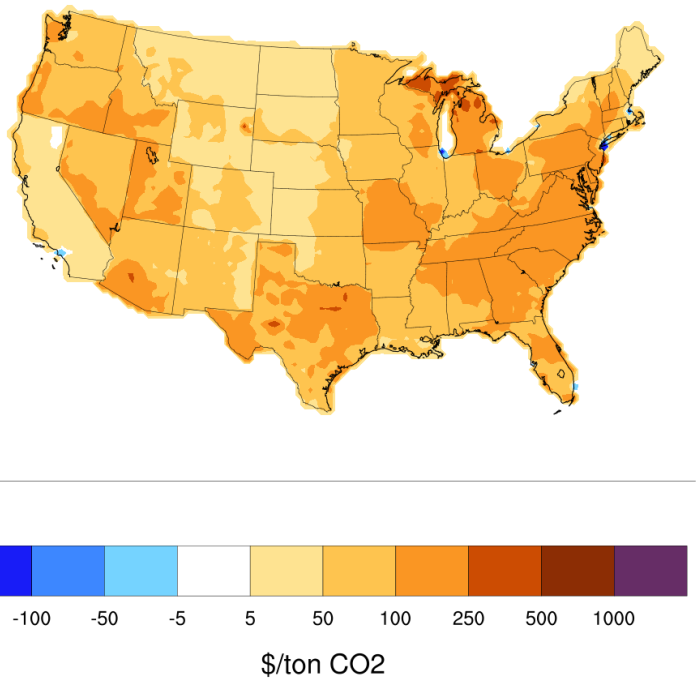
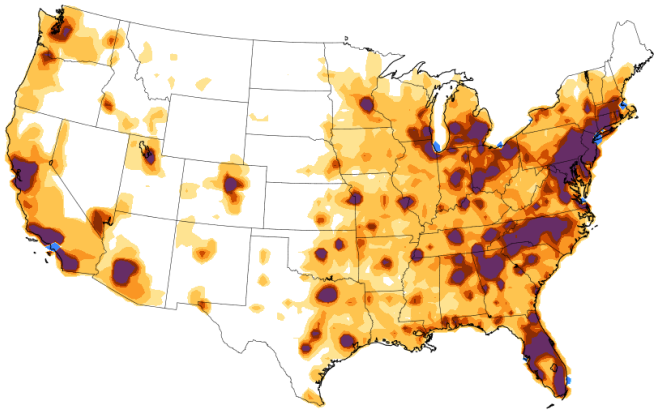


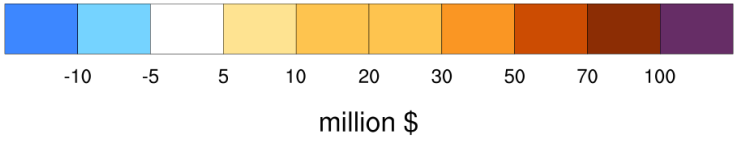
Diesel Light Duty



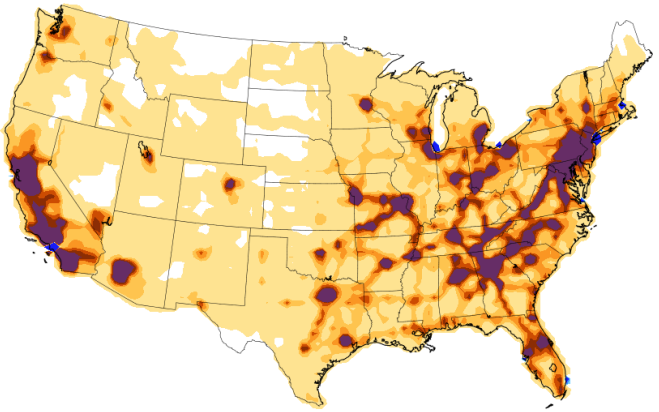
Total Co-benefit: Mobile On-road

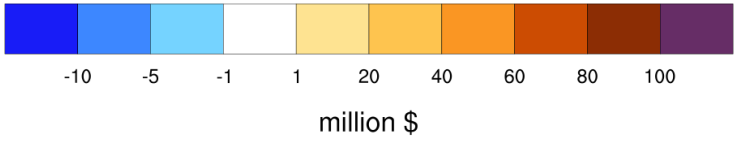
Non-Diesel Light Duty





Diesel Heavy Duty





Total Co-benefit: Mobile On-road

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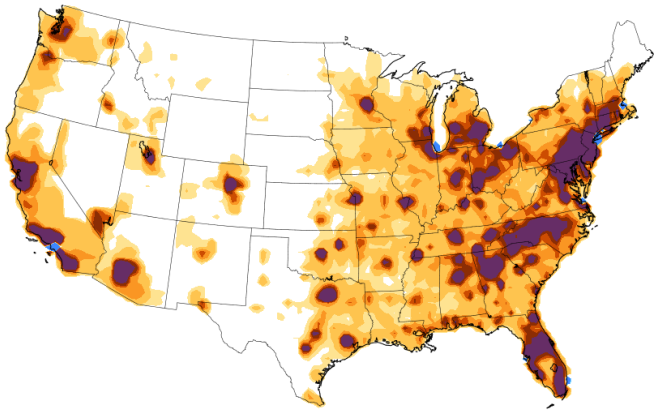
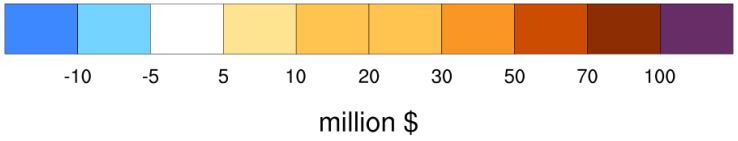
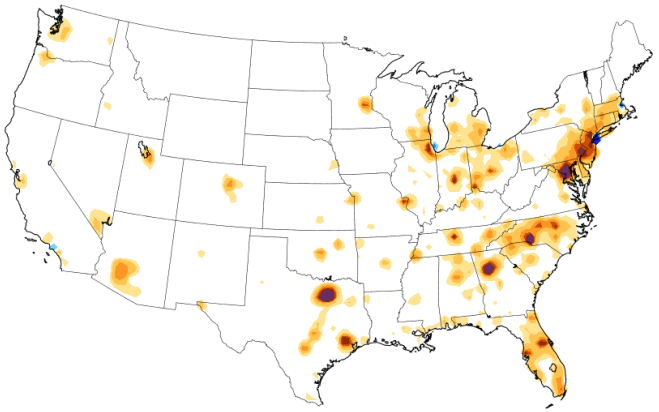
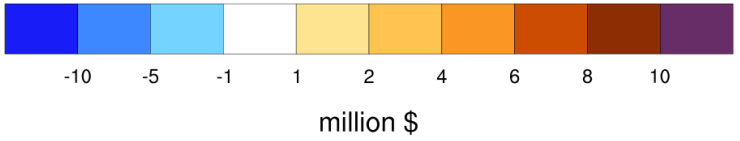




Diesel Light Duty



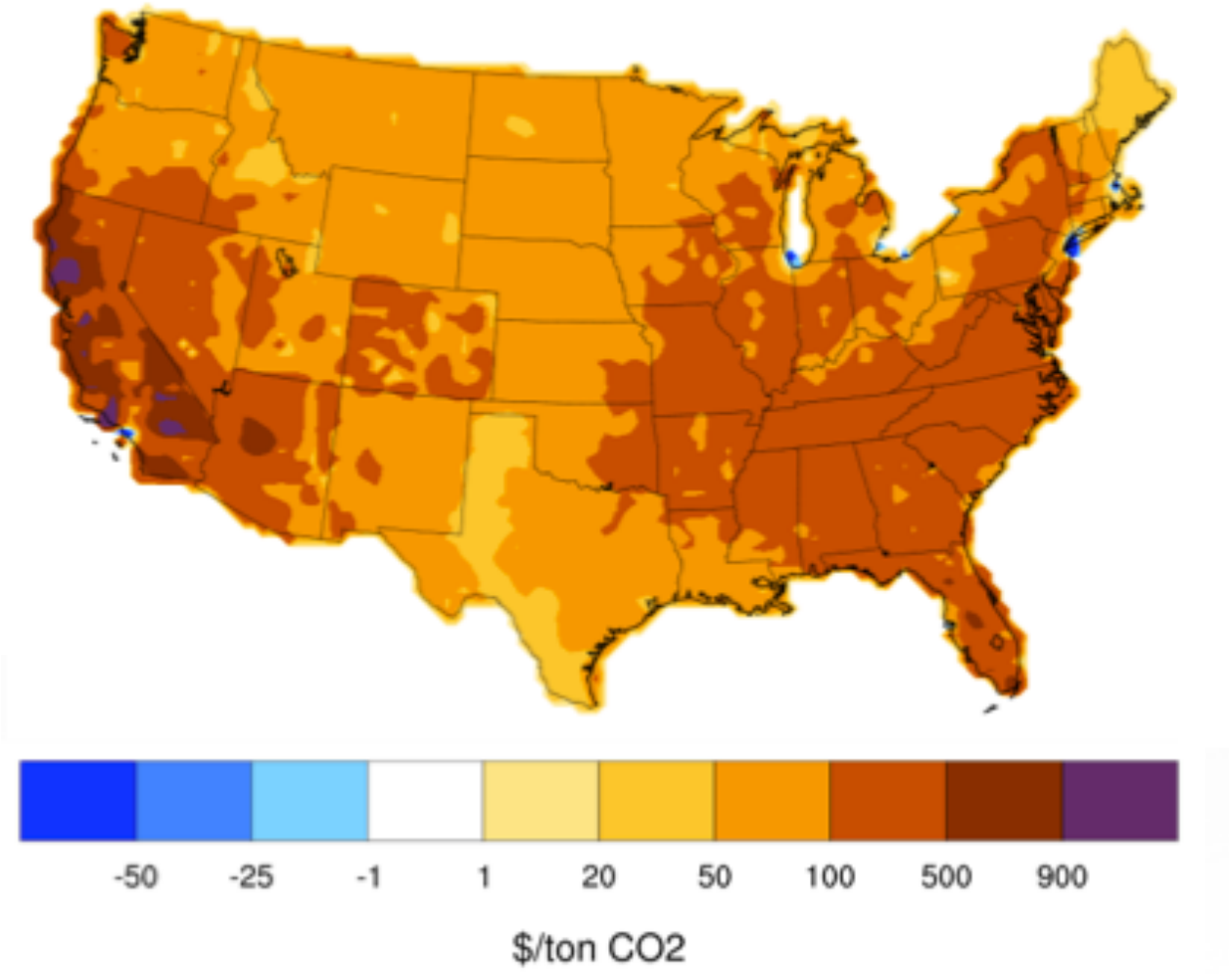


Average Mobile On-road Co-benefit

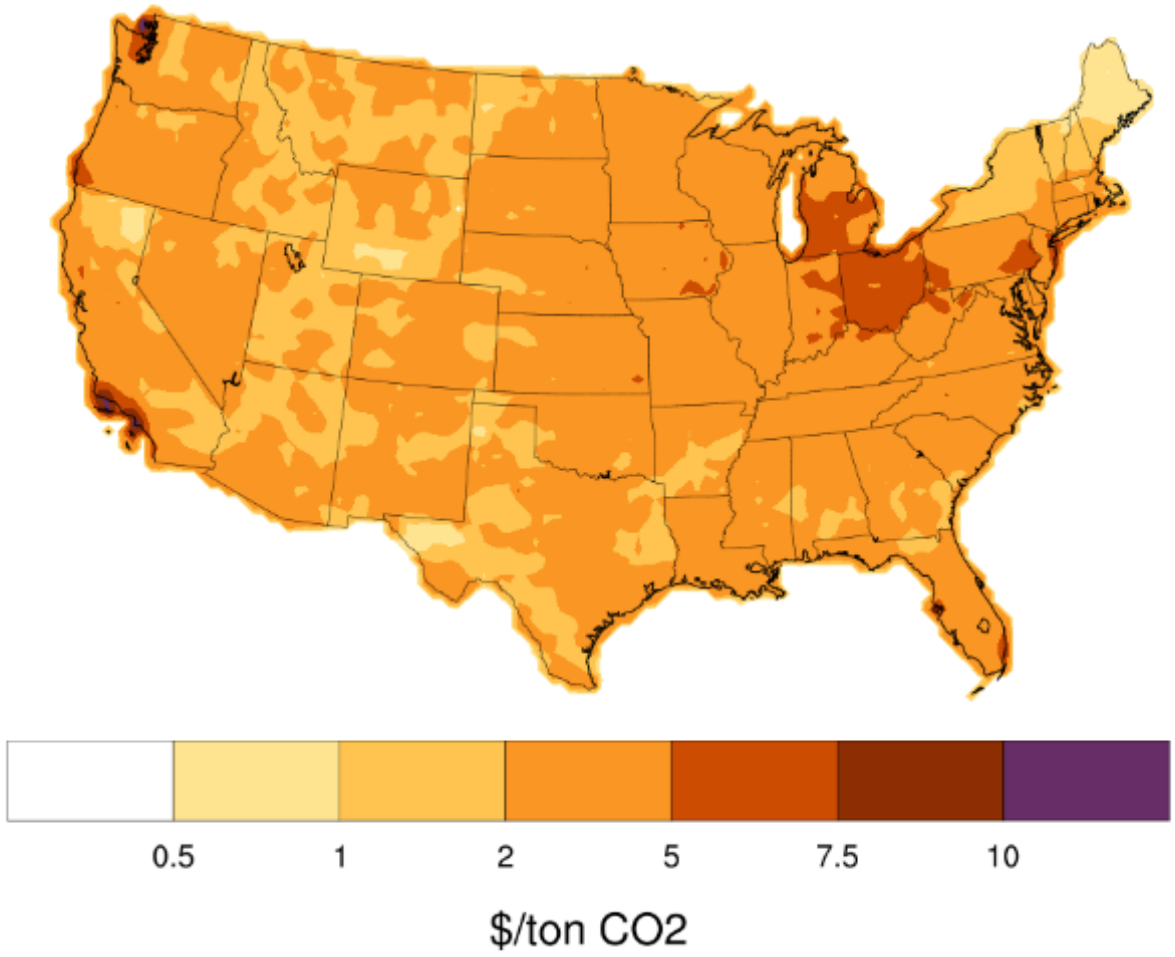
Sector	Average Mobile on-Road co-benefit
Diesel heavy duty	$352
Diesel on-road light duty	$86
Non-diesel on-road heavy duty	$414
Non-diesel on-road light duty	$90

- PM health impact not included; just a fraction of co-benefits
- Significant compared to the price of carbon (~$40)

Co-benefit through NO_x: Mobile Non-road



Co-benefit through CO: Mobile On-road



Point Sources

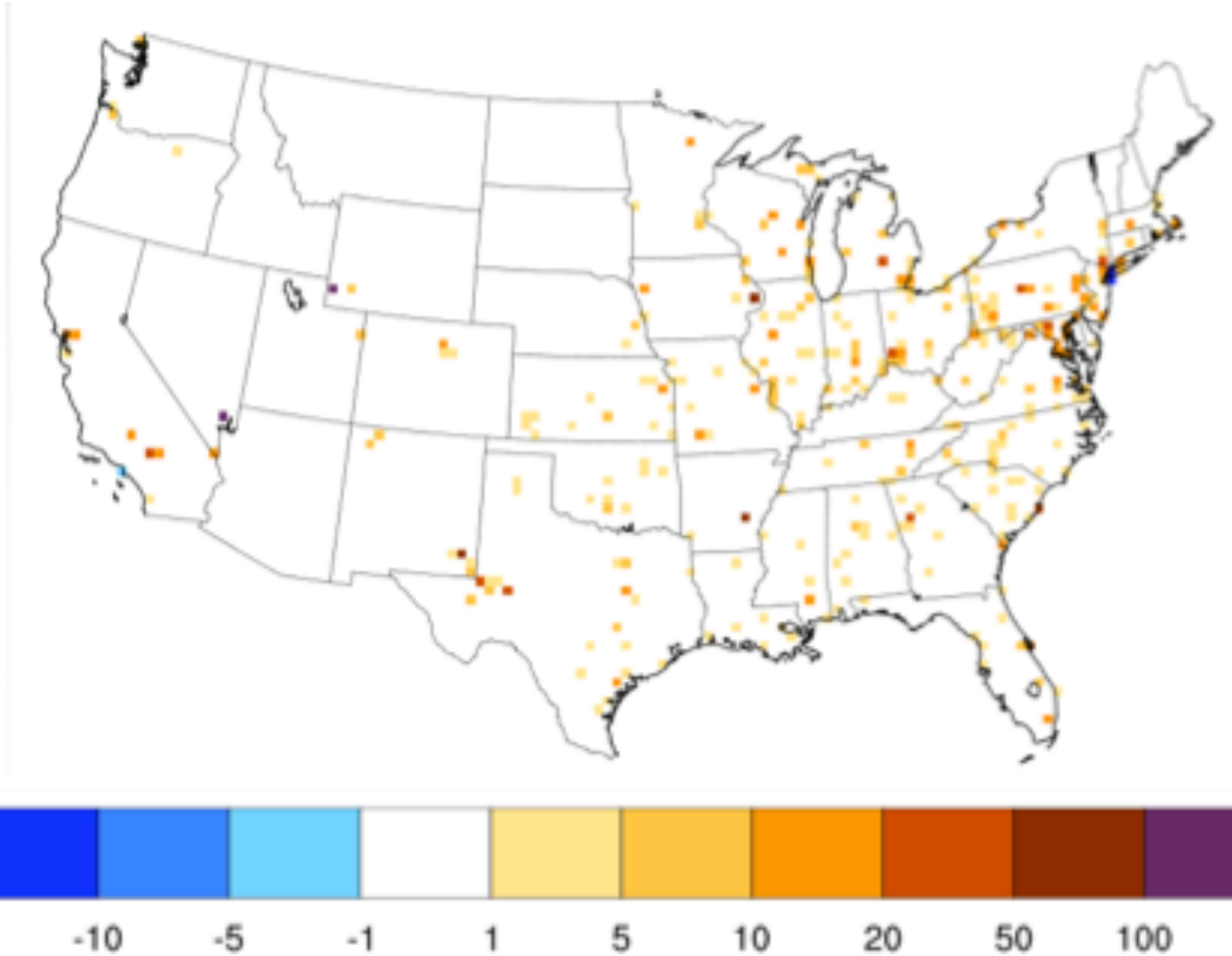
Emissions Data Sources

- ✓ Electrical Generation Units (EGU)

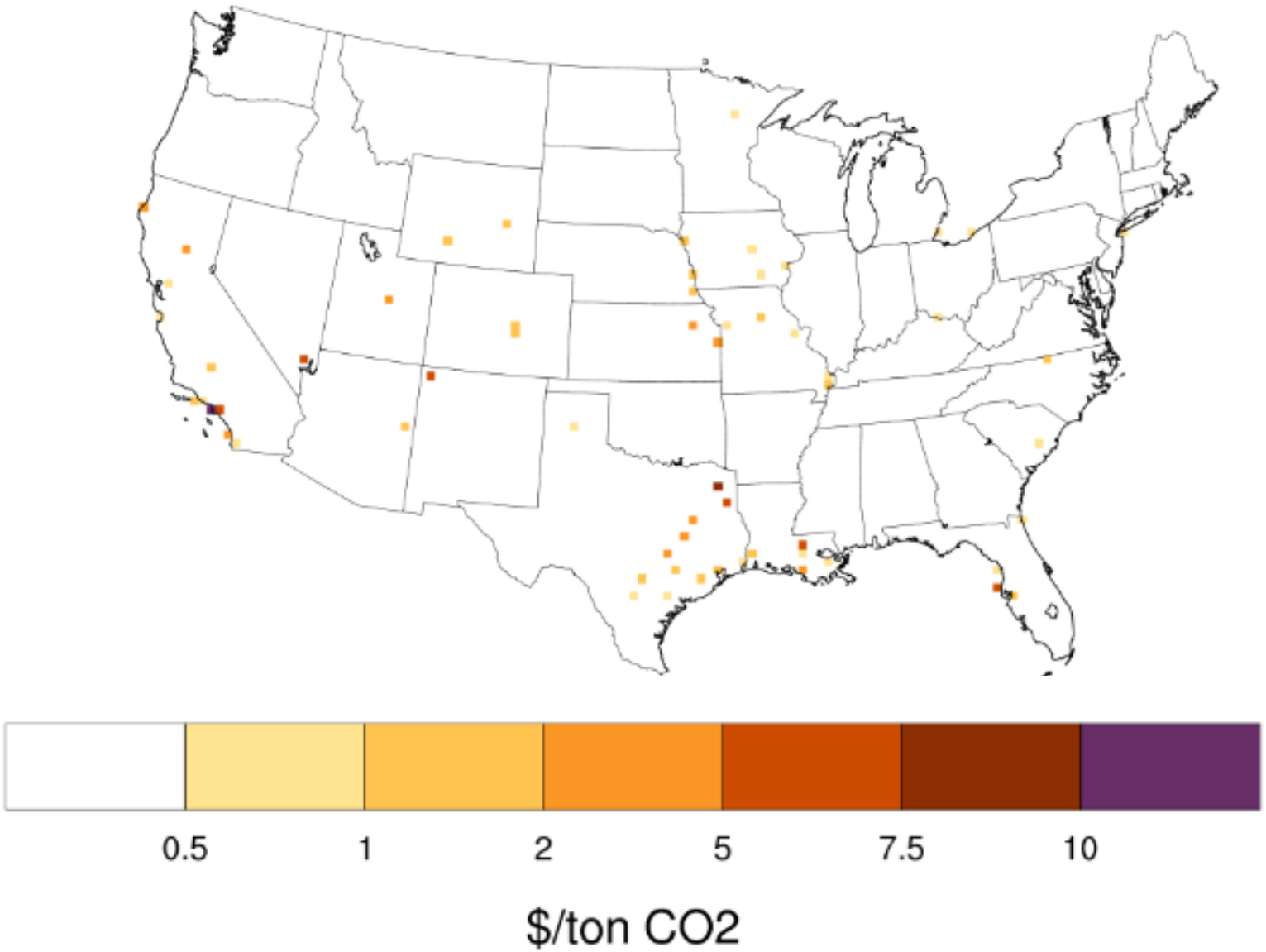
- Criteria pollutant from SMOKE

- Aggregated CO_2 data (regional) from MARKAL

Co-benefit through NO_x: Point EGU



Co-benefit through CO: Point EGU



Discussion

- Our preliminary results show that the monetized health impacts (O_3-related long-term mortality) associated with reductions in 1 ton of CO_2 emissions range from:

Sector	**\$/ton of CO_2 through NO_X**
Mobile on-road sector	-650 – 1000
Mobile non-road sector	-200 – 900
EGU	-10 – 100

Discussion

- Our co-benefit values are comparable to those found previously in scenario-based studies (Nemet et al., 2010).
  - Co-benefits show a great deal of spatial variability across different emission locations
- Estimated co-benefits significantly larger than the price of carbon
- PM-related health impact not considered
  - These results are likely to be underestimations without PM health effects

Discussion (cont'd)

- Large co-benefit values provide strong justification for integrated climate and air quality policies
  - The Clean Power Plan
- Availability of consistent emission data for GHG and criteria pollutant emissions is a limitation
  - Can SMOKE also process GHG emissions (at least CO_2) by default?

Future Steps

- Including PM when the full adjoint is ready

- Distinguishing between the impact from sub-sectors (gas vs. coal power plants)

Acknowledgment

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  - NSERC, Health Canada

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THANK YOU