Environmental Health, Racial/Ethnic Health Disparity, and Climate Impacts of Inter Regional Freight Transport in the United States

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International Aerosol Modeling Algorithms Conference 2023
December 6, 2023

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Acknowledgments

- Published in Environmental Science & Technology (Thind et al., 2023)

Environmental Science & Technology

pubs.acs.org/est Article

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Cite This: *Environ. Sci. Technol.* 2023, 57, 884–895 Read Online

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Link to Paper

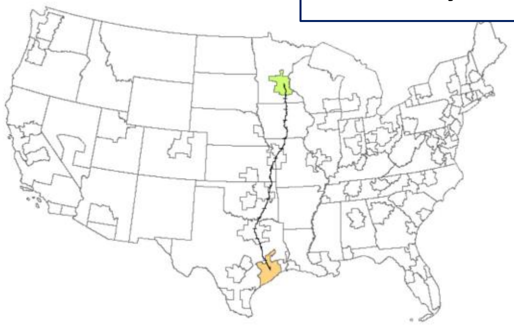
- Funding: U.S EPA: Center for Air, Climate, and Energy Solutions (CACES)

Research question

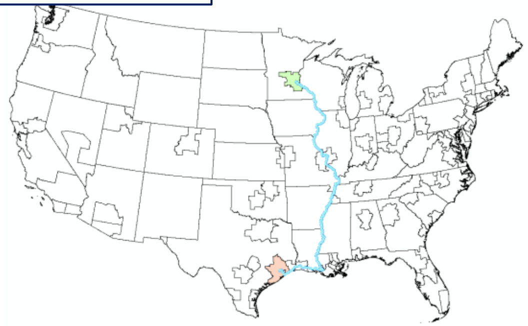
If a unit mass of freight is shipped from an origin to a destination, how do impacts on human health, climate, and exposure/human health disparity vary by mode of travel?

~30,000 routes

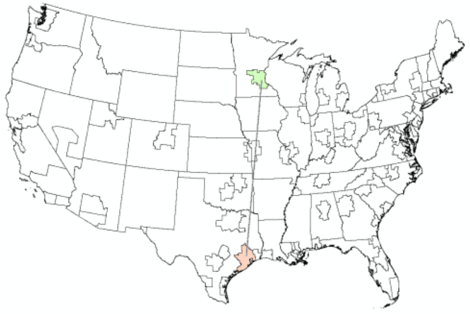
Heavy-duty Truck



Rail



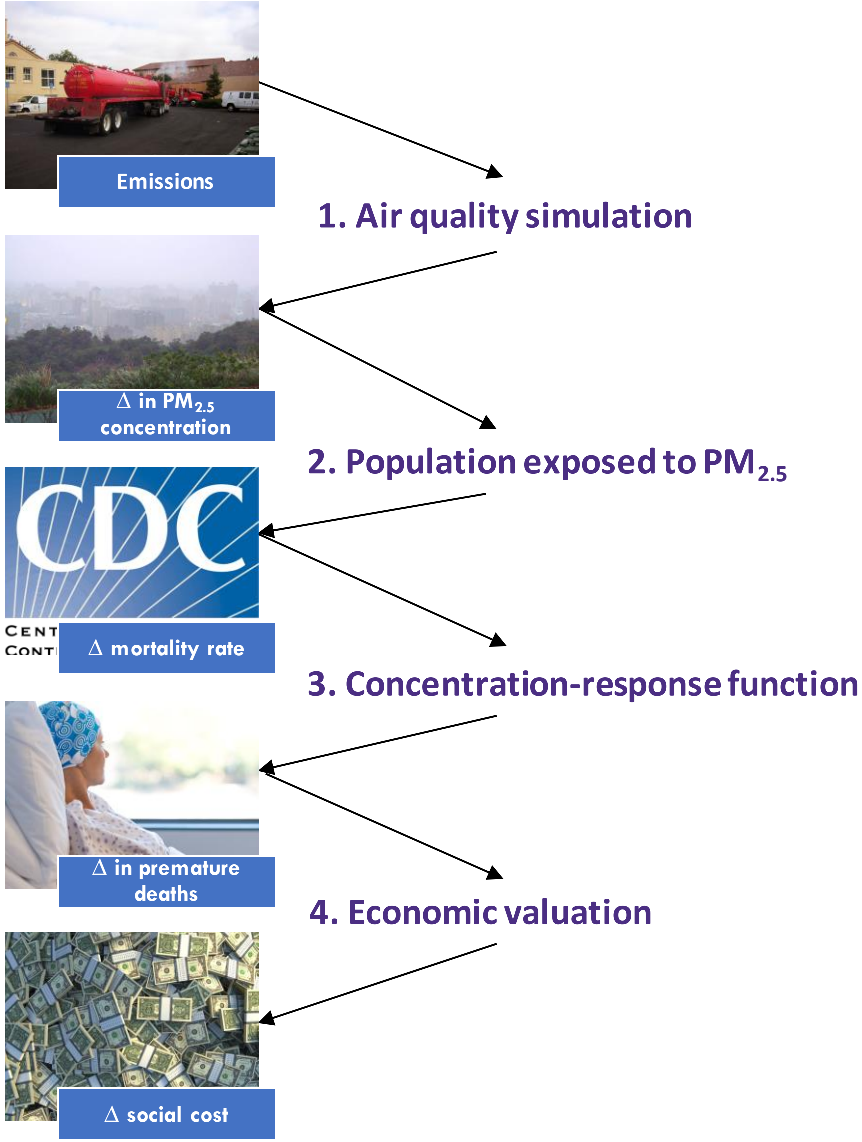
Barge



Aircraft

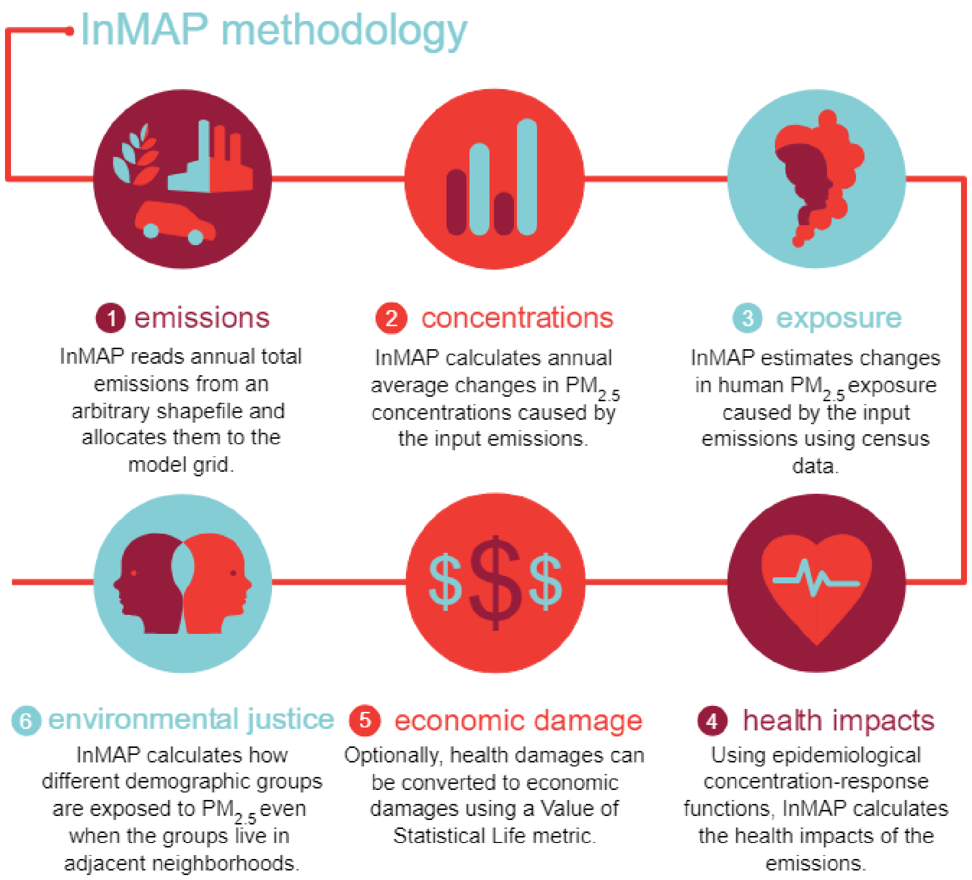
Method: reduced-complexity, high spatial-resolution AQ model for annual average $PM_{2.5}$

- Mechanistic modeling approach



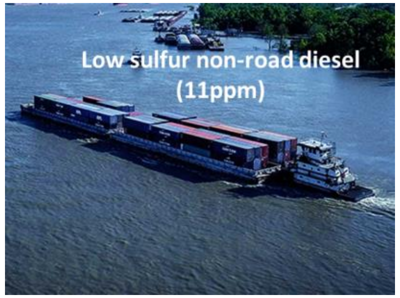
Interventional Model for Air Pollution (InMAP)

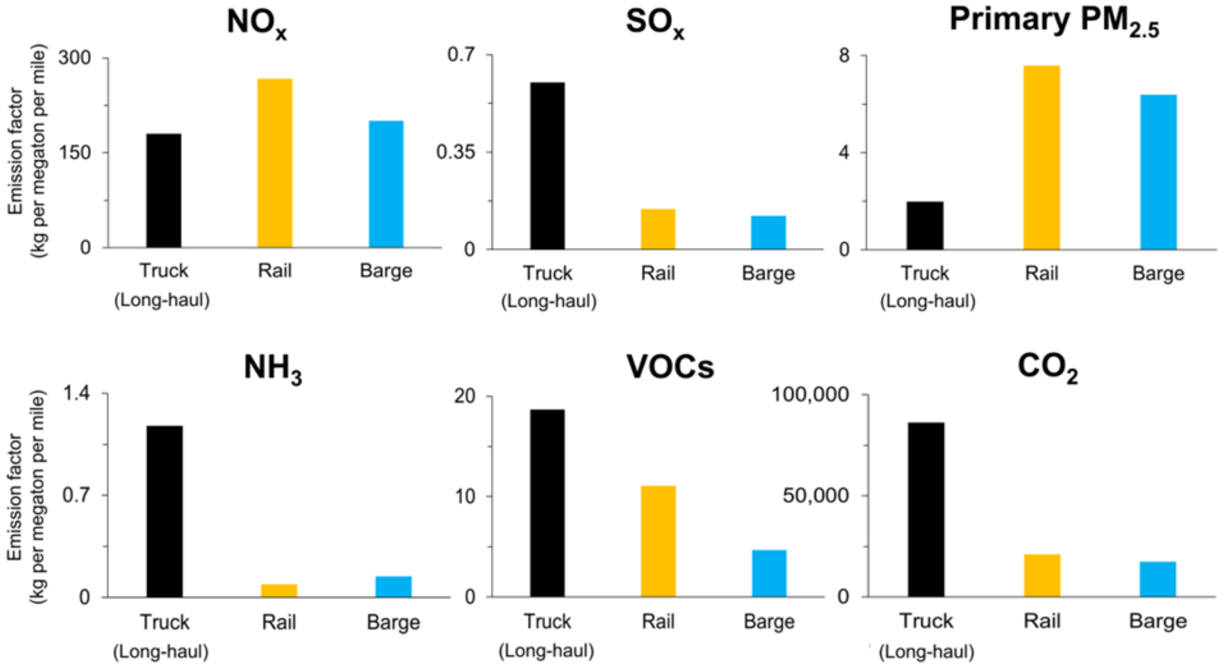
Tessum, C. W.; Hill, J. D.; Marshall, J. D. InMAP: A model for air pollution interventions. PLoS ONE 2017, 12 (4)



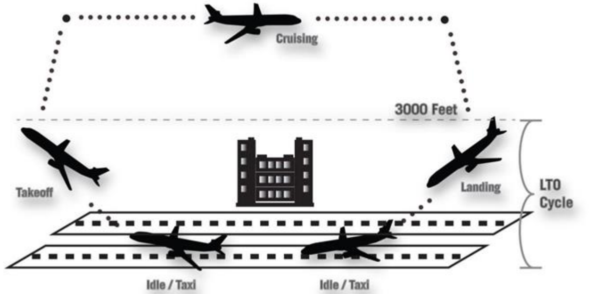
Emissions input to InMAP

Non-aircraft modes

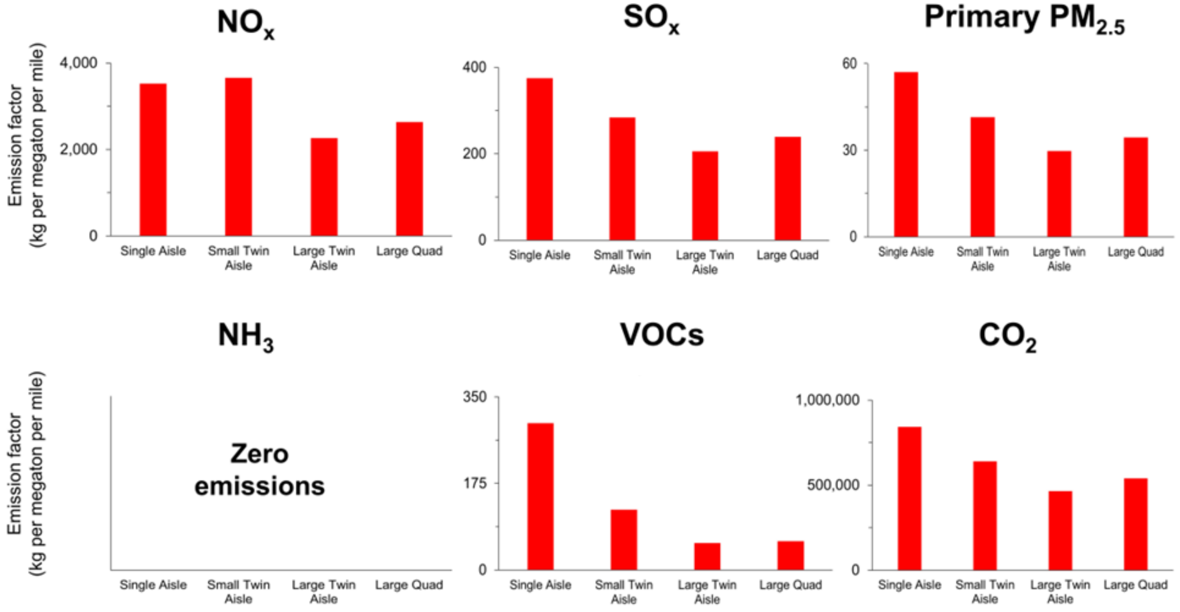




Aircraft

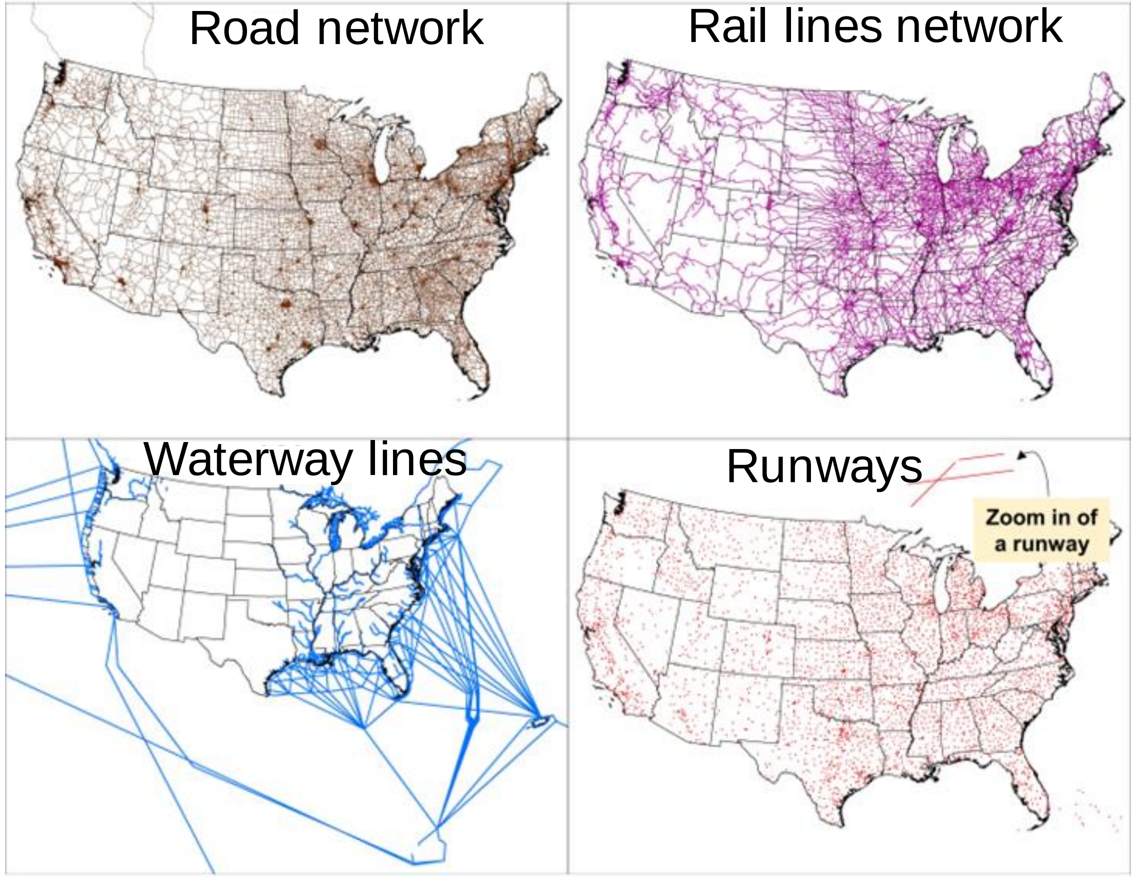


Source: ICAO



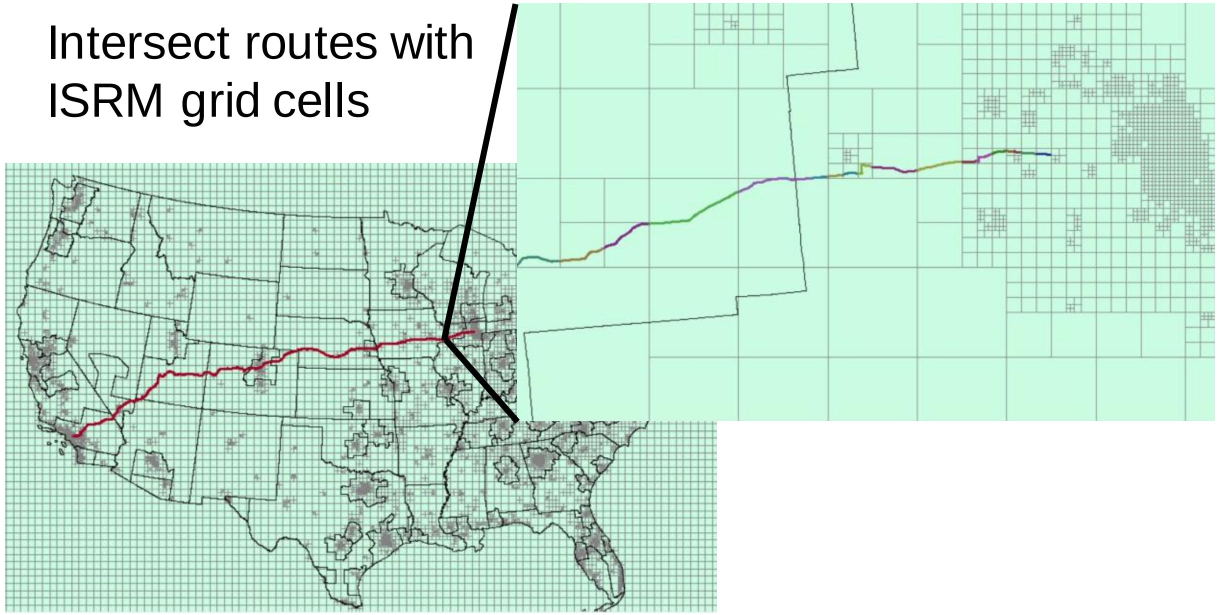
Cruise emission factors

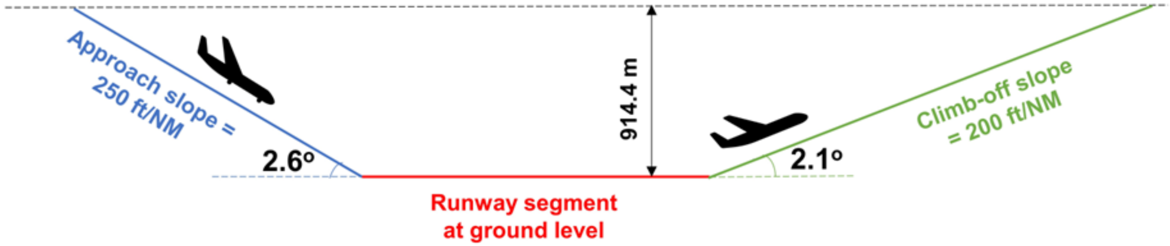
Geospatial allocation of emissions to routes



Source: U.S. DOT's National Transportation Atlas Databases (NTAD)

Intersect routes with ISRM grid cells



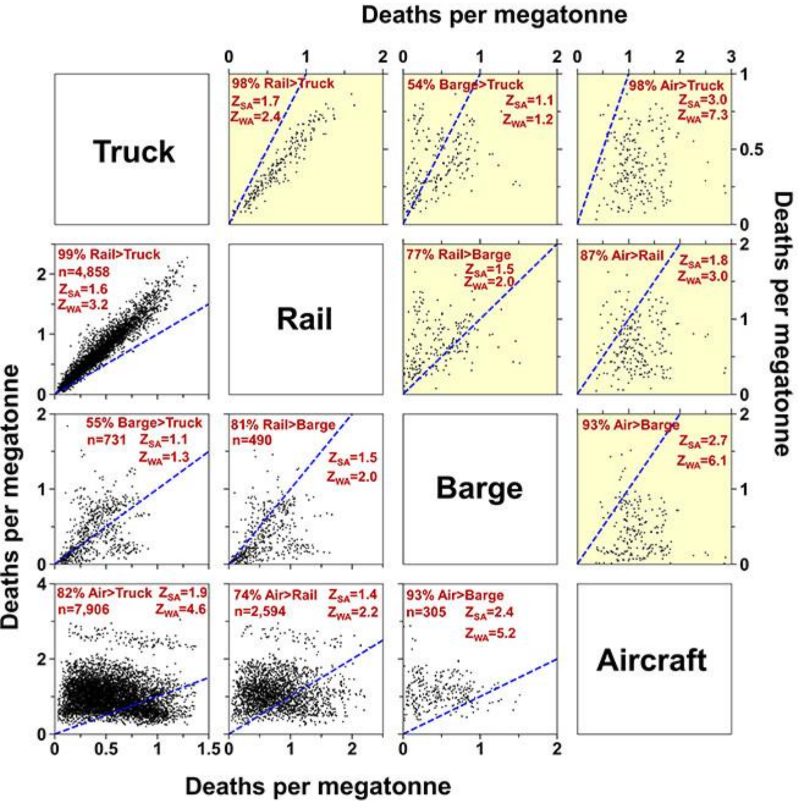


Side projection of simplified Landing and Take-off cycle

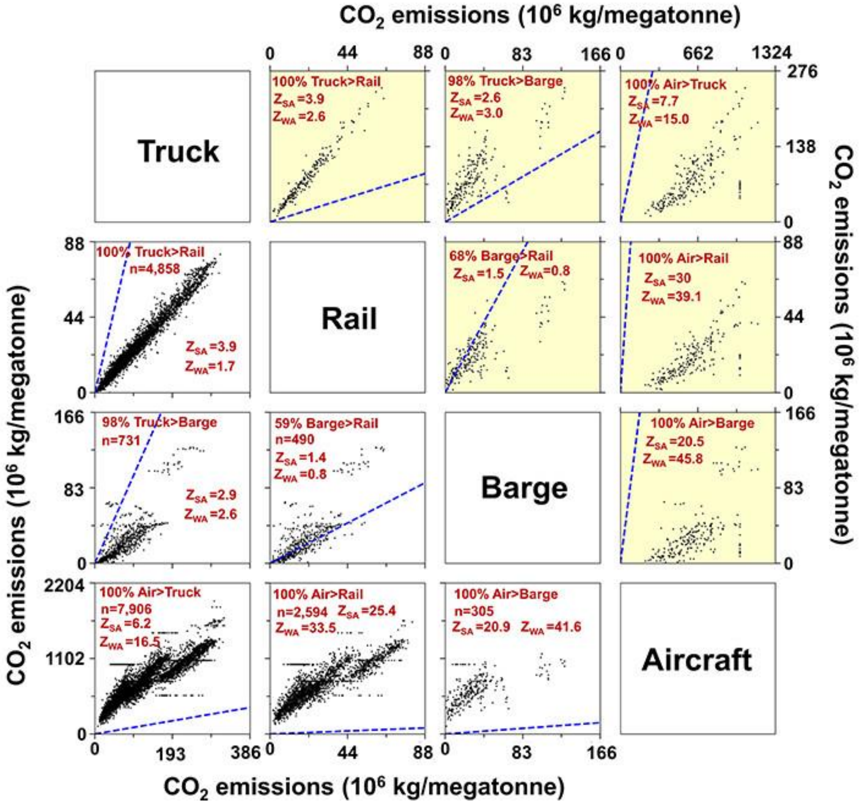
Results

Pairwise impacts from each origin–destination (O–D) pair

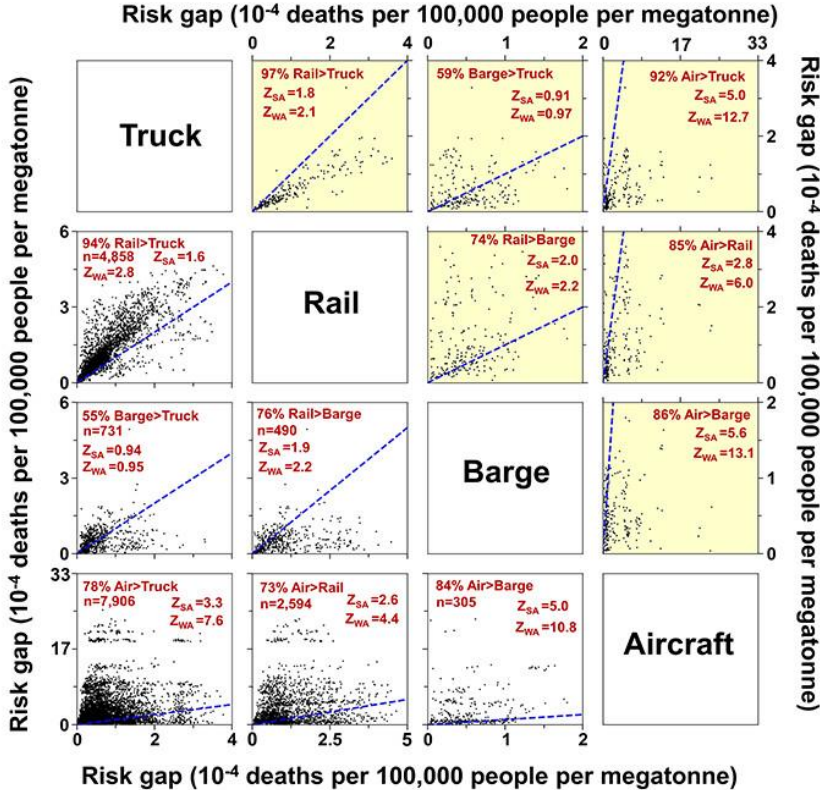
Deaths per megatonne



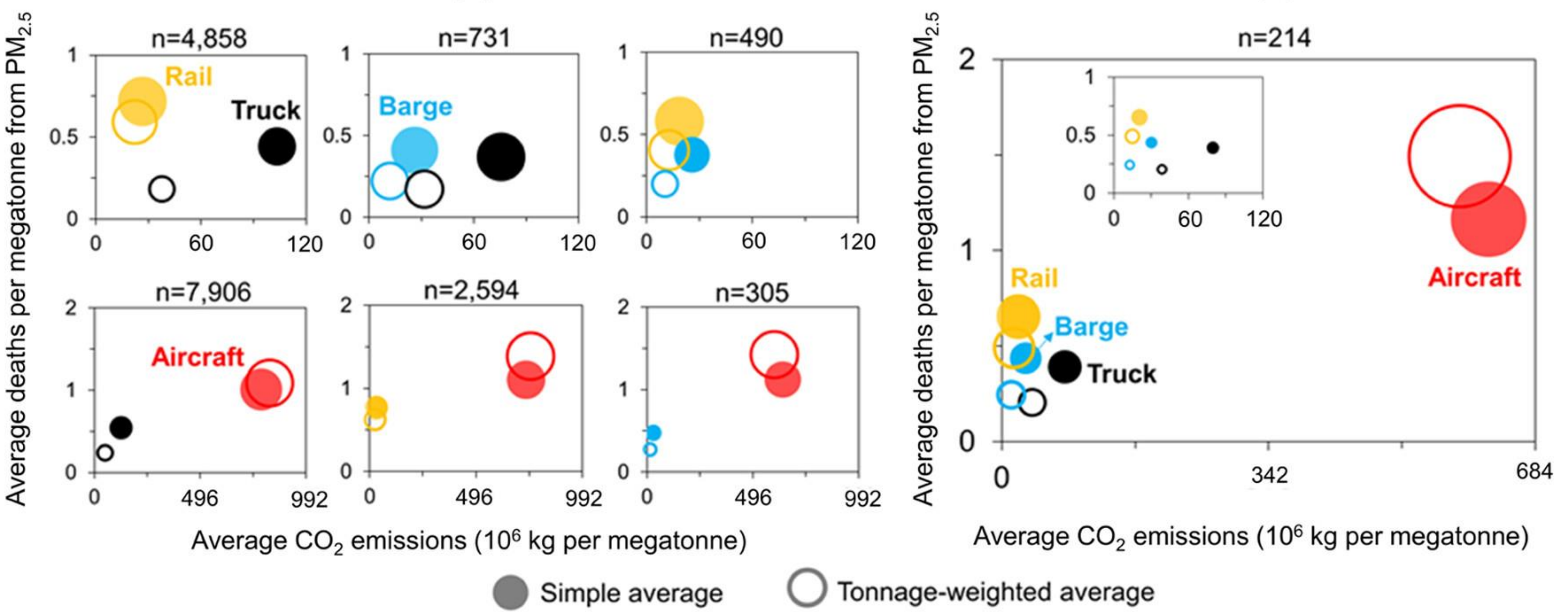
Kg CO_2 emissions per megatonne



Risk gap per megatonne



Comparison among modes



Urban vs rural

		deaths per megatonne[a]			[b]
mode	*n* (number of O–D pairs)	urban	rural	combined	percentage urban-impact routes (%)[b]
truck	16,293	0.27	0.30	0.57	32
rail	4875	0.37	0.42	0.79	32
barge	732	0.19	0.26	0.45	19
aircraft	7913	0.72	0.40	1.11	85

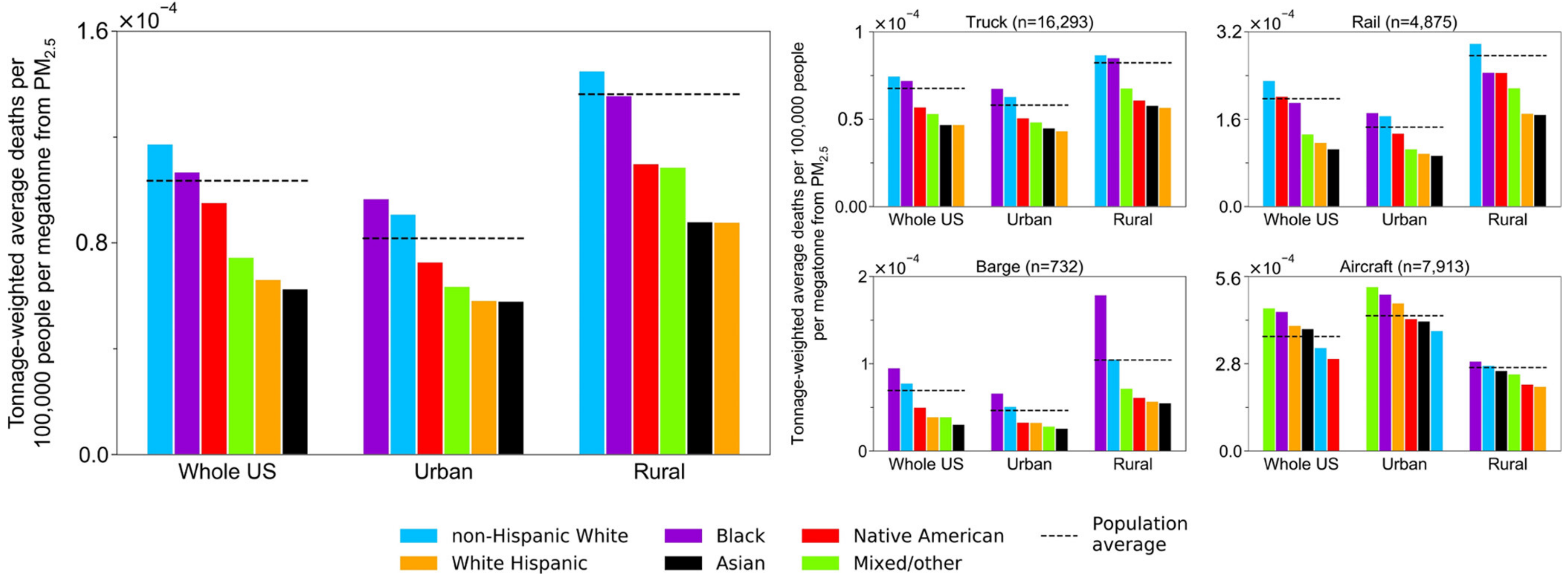
[a] Overall average for that mode ("combined"), subdivided into impacts to urban and rural populations. Values reflect, where the impacts occur (urban versus rural), attributable to total emissions. Numbers given here might not sum because of rounding.

[b] Percent of O–D pairs for which health impacts are greater in urban than in rural areas.

$PM_{2.5}$ health impacts by race–ethnicity

From all freight movement

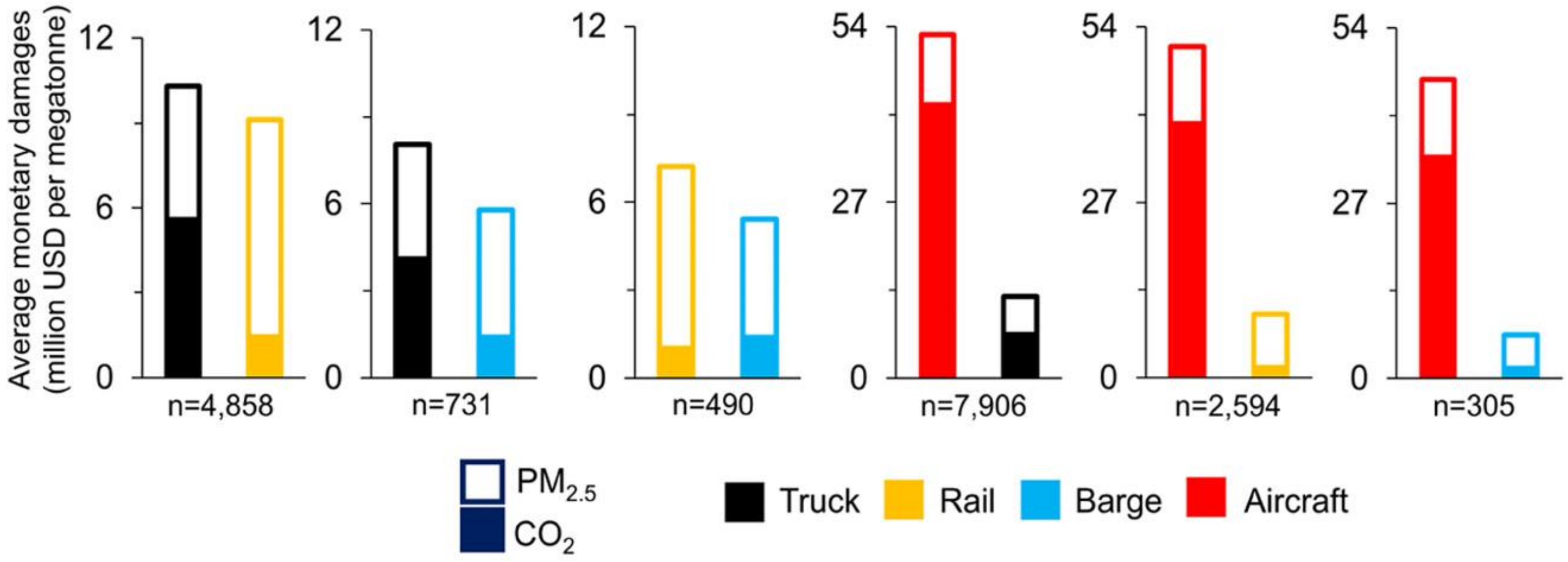
By mode



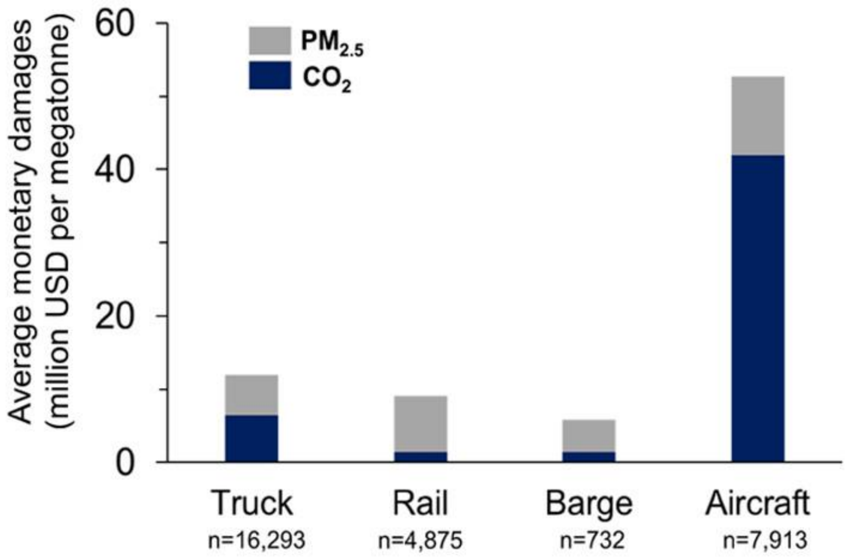
Monetized damages

CO_2 social cost: \$54 per tonne CO_2, VSL: \$9.7 million

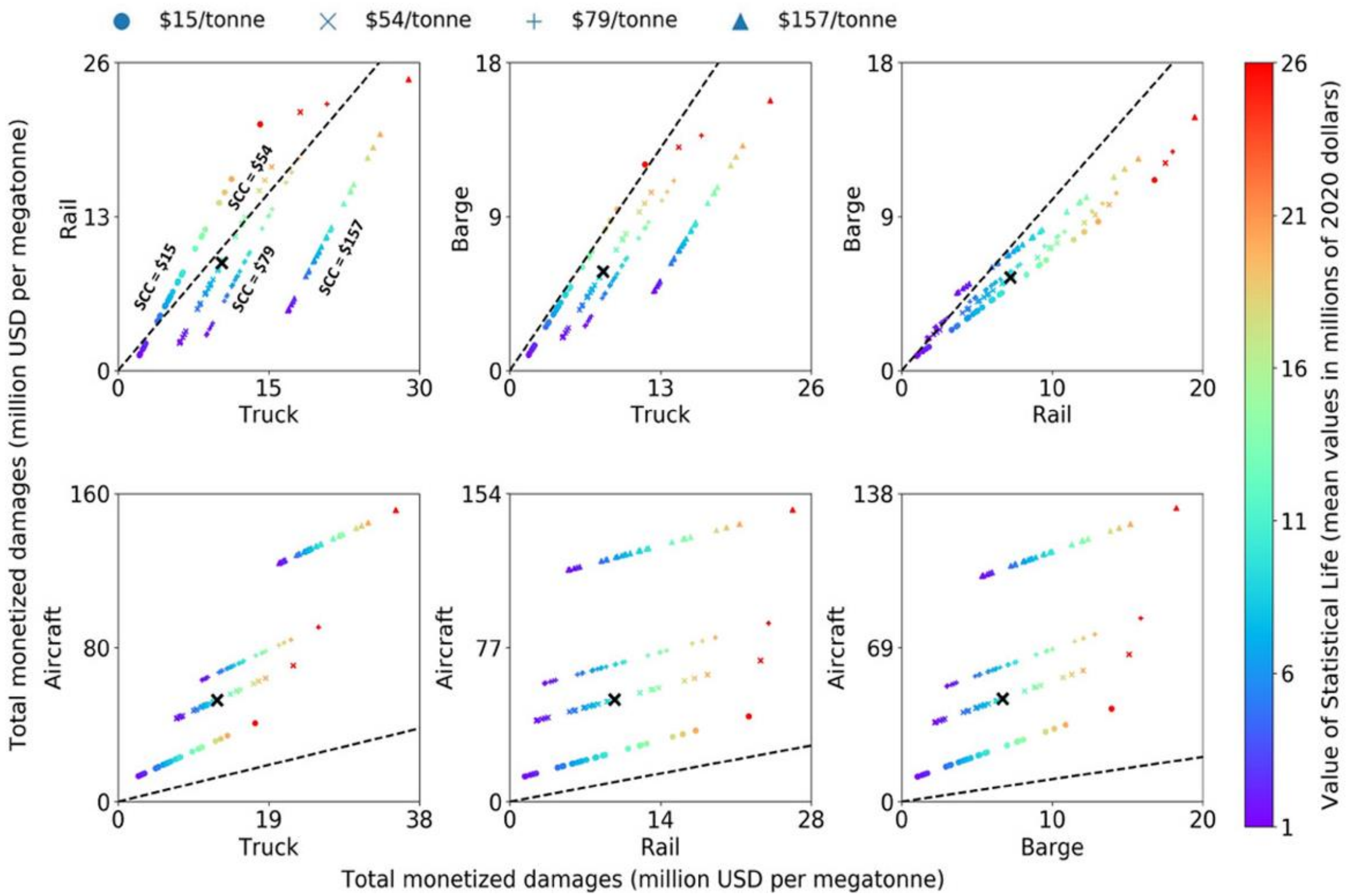
Pairwise comparison



from all routes for a mode



Sensitivity analysis of monetized results



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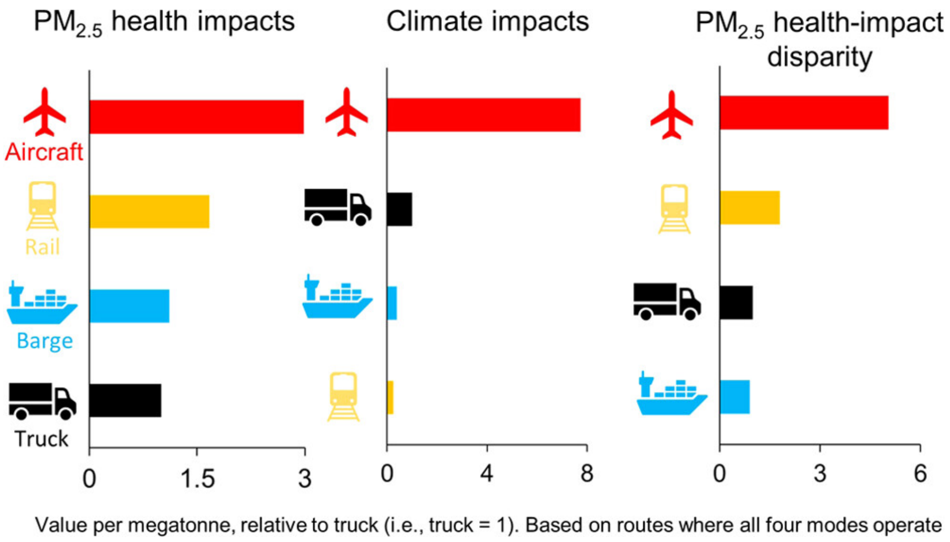
Conclusions

- Airplane > train > barge/truck (health)
- Health / EJ / climate
- Importance of urban / peri-urban freight
  - Greater EJ concern; more opportunities for solutions, e.g., electrification



- Future work:
  - Community groups; not just air pollution
  - Technical "solutions" (vehicles/EVs; placement of distribution centers; vehicle-routing)

THANK YOU!

QUESTIONS?

Extra slides

Pairwise modal comparison of average deaths per megaton by $PM_{2.5}$ precursor type

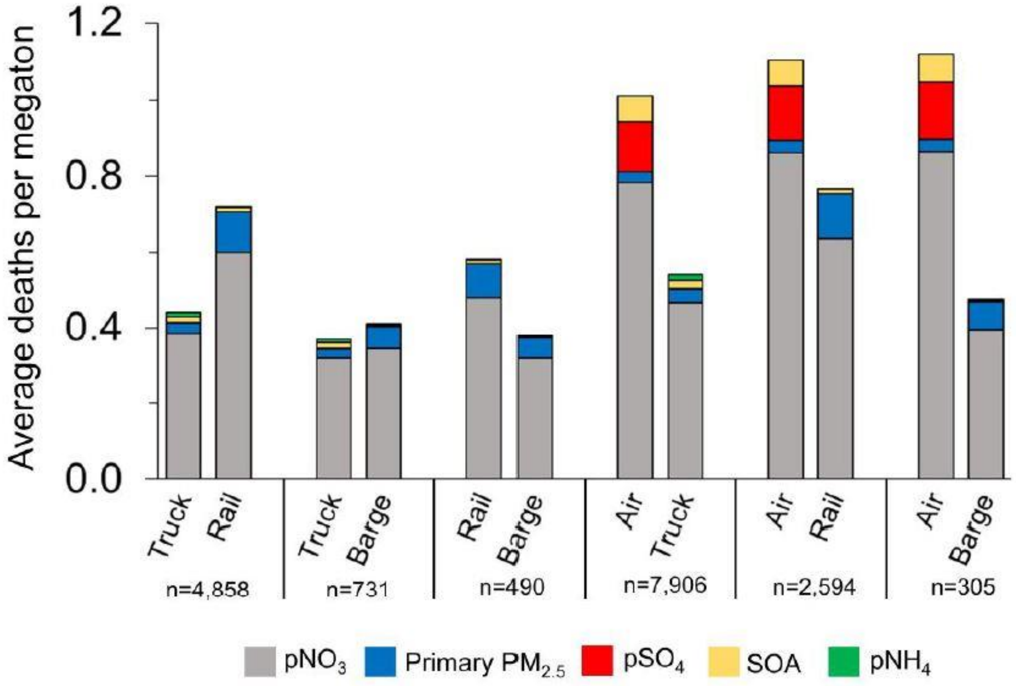


Figure S17. Pairwise modal comparison of average deaths per megaton by $PM_{2.5}$ precursor type.

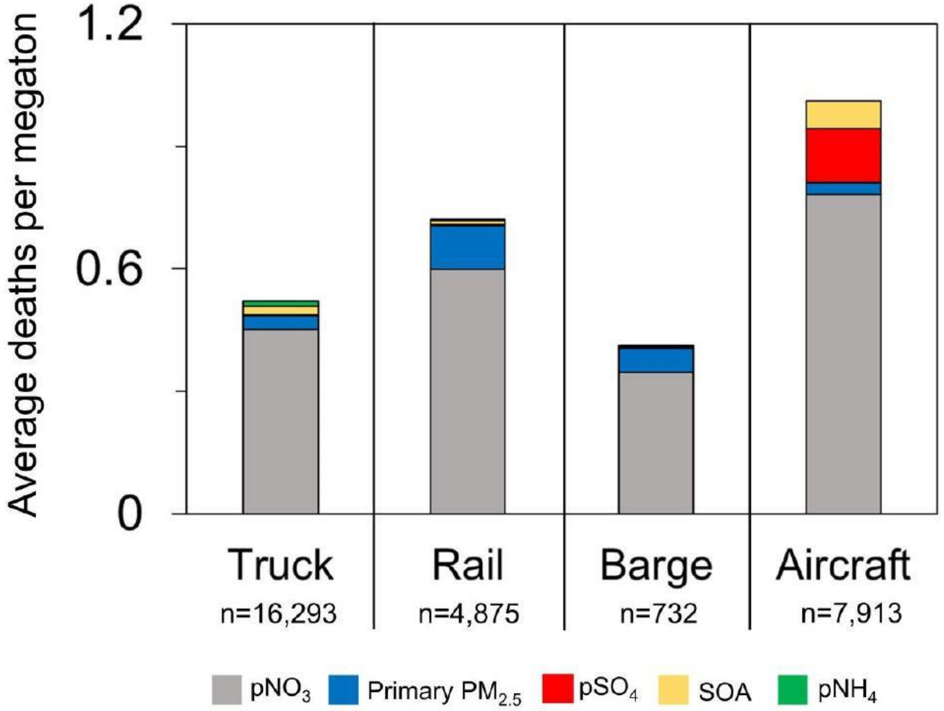
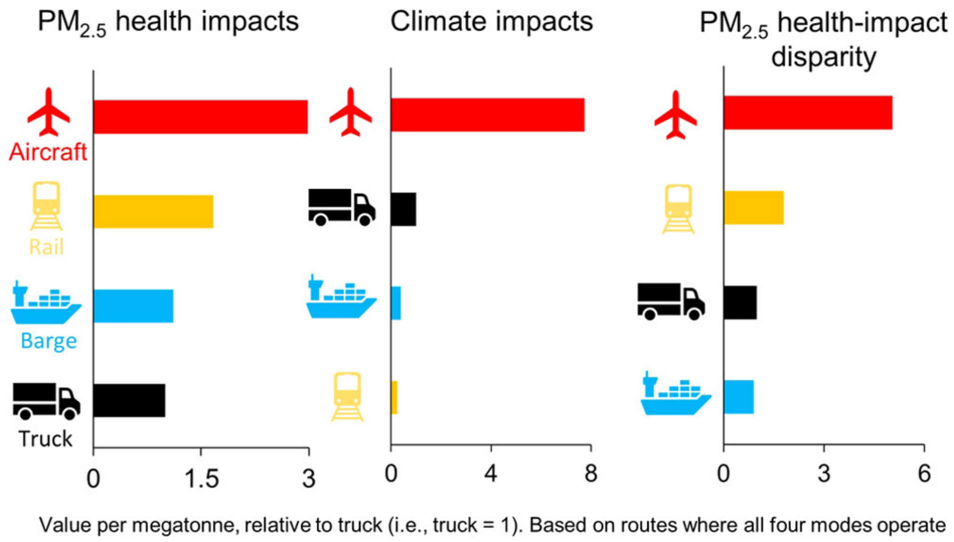


Figure S18. Average deaths per megaton by $PM_{2.5}$ precursor type for each mode for all O-D pairs.

Electrification might be the only solution!

- Annual damages from freight movement:
  - ➢ ~1400 premature deaths (monetized: $13 billion)
  - ➢ 150 billion kg CO_2 (monetized: $8 billion)
  - ➢ Health disparity of 0.06 deaths per 100,000 people
- Health and climate impacts are often but not always aligned among modes.
- Level of exposure and disparity among racial−ethnic groups vary in urban versus rural areas.
- E-commerce is booming, so is emissions from freight.
- Important benefits from electrification of interregional (and other) freight transportation, combined with low emission or renewable electricity generation.
- Future work:
  - ➢ can look into impacts by different commodity types and value of commodity shipped.
  - ➢ explore impacts from within-region freight transport.



Concentration-Response Function for $PM_{2.5}$

- Log-linear concentration-response (C-R) function with no threshold derived from the ACS reanalysis study representative of US concentrations and population.

$$\text{No. of premature deaths} = \left(e^{(PM_{2.5}\,Linear\,Coefficient \times [PM_{2.5}])} - 1\right) \times P \times \frac{All\text{–}Cause\ Mortality\ Rate}{100{,}000}$$

Here, $PM_{2.5}$ Linear Coefficient = ln(1.078)/10 = 0.007510747, i.e., a 7.8% increase in the number of premature deaths for every 10 ug/m^3 increase in the concentration of $PM_{2.5}$. [$PM_{2.5}$] is the concentration of $PM_{2.5}$; P is total population.

- This C-R function is standard and most widely used in the literature.

We investigated air pollution and climate impacts of freight transportation by mode and…..

Source: Google images

...first to look at health disparity among demographic groups from freight modes.

Source: Environmental Health News

Focused on a health-damaging pollutant: fine particulate matter ($PM_{2.5}$)

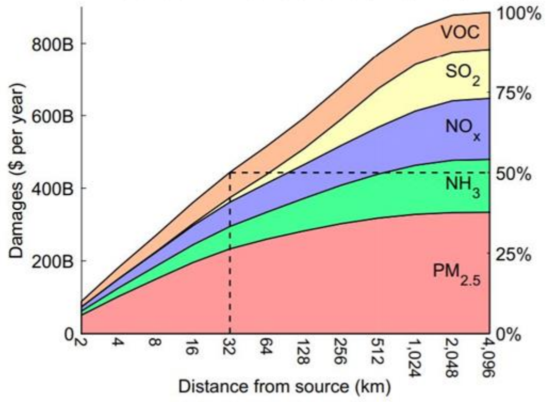
$$\text{Total } PM_{2.5} = \text{Primary } PM_{2.5} + pSO_4 + pNO_3 + pNH_4 + SOA$$

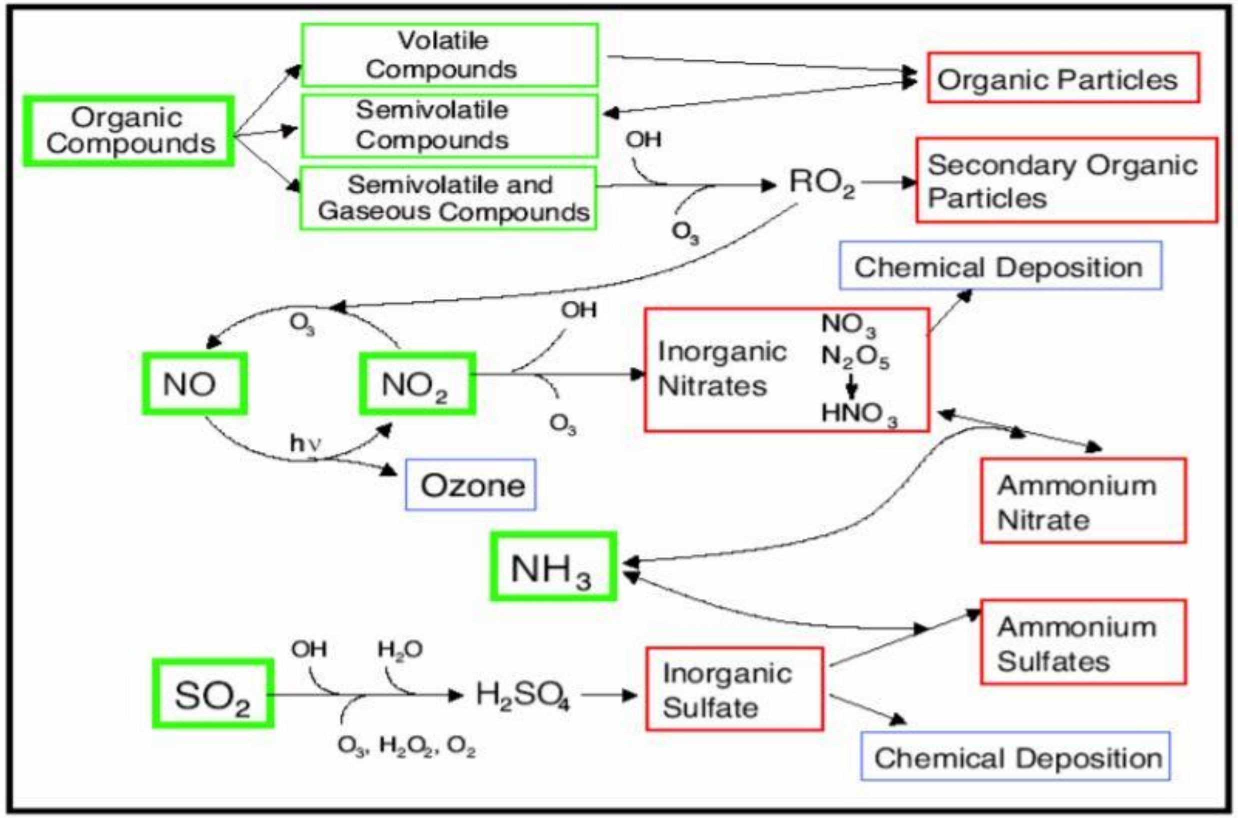
Chemical processes

- Chemical reaction of gases in the atmosphere
- Oxidation
- Gas- and particle-phase partitioning

Distance

Goodkind et al. (2019)





Source: U.S. EPA https://www3.epa.gov/ttnchie1/conference/ei13/mobile/hodan.pdf

Physical processes

- Coagulation
- Nucleation
- Condensation
- Deposition

Resolution

Paolella et al. (2018)