Leveraging satellite-derived data in GEOS-Chem adjoint simulations to characterize the sources of $PM_{2.5}$-, O_3-, and NO_2-related health impacts at multiple spatial scales

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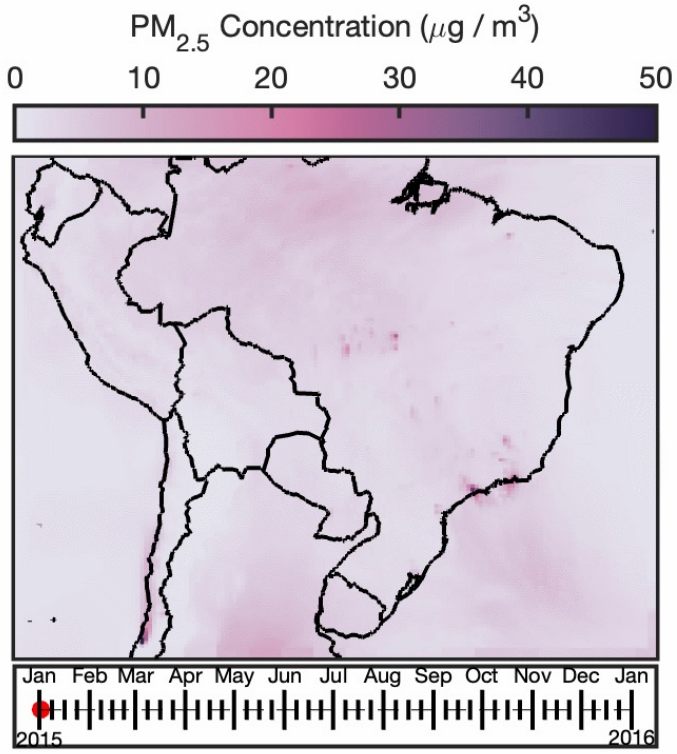
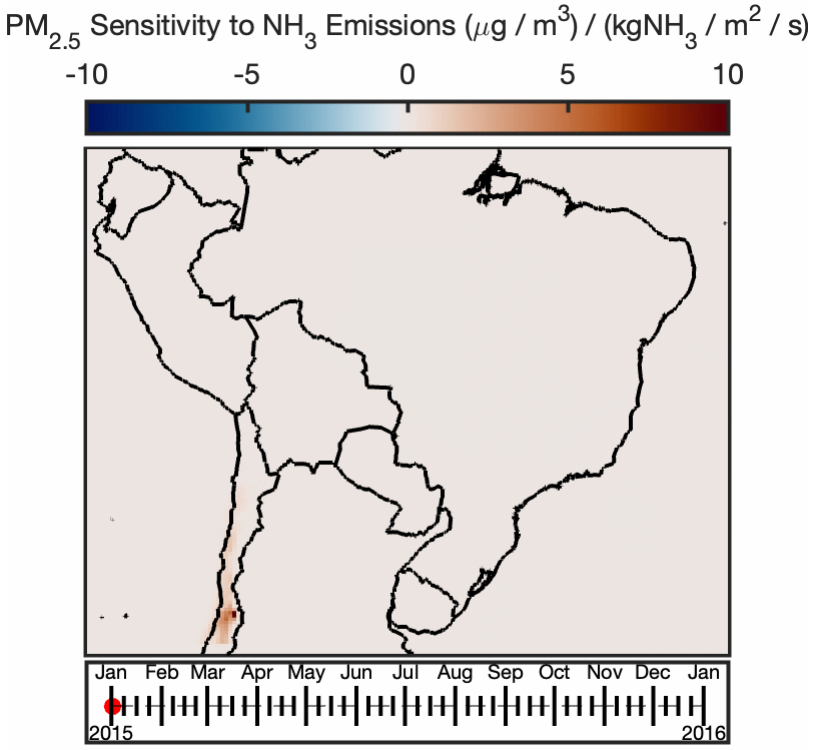


+ Satellite Data

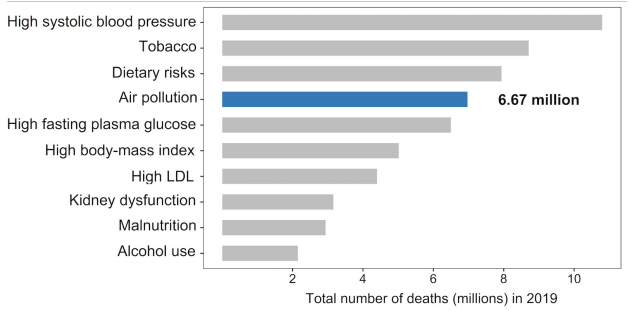
+ Population
+ Mask



The 10th International GEOS-Chem Meeting (IGC10)
Washington University in St. Louis, June 9th, 2022

Background

Global air quality health burden

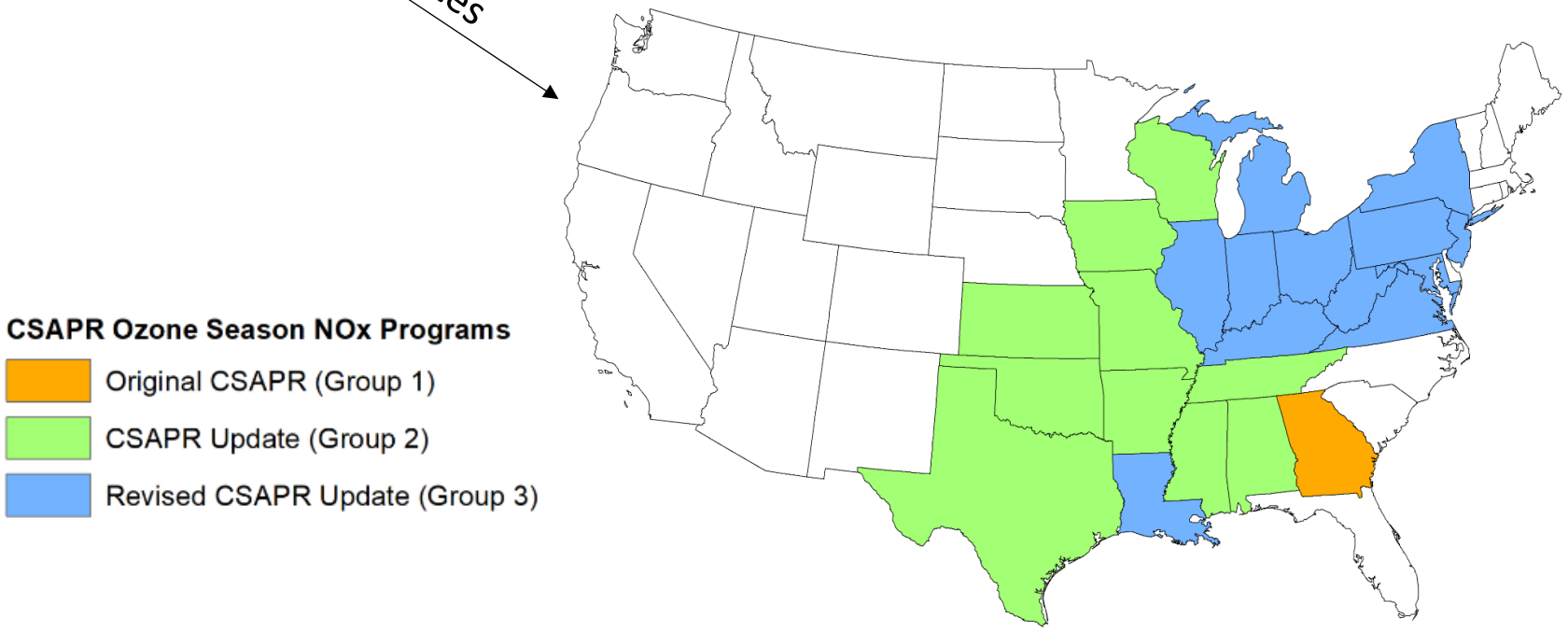


Motivates

Source apportionment and emission scenario impact analyses

Informs

Policy Interventions



Murray et al., 2020

How can we use adjoint sensitivities to characterize the sources of pollution and assess the impacts of changes in emissions?

(1) Run standard GEOS-Chem forward model and consider a single output

→

(2) Combine model output with population and masks to characterize pollutant exposures

→

(3) Apply satellite-derived scaling factor to complete definition of cost-function

↓

(4) The adjoint performs a reverse integration calculating the sensitivity of the cost-function to emissions

←

(5) Combine adjoint sensitivities with emission sources or scenarios to determine impact on cost-function

←

(6) Calculate health impacts associated with pollutant exposures and contributions

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Bey et al., 2001

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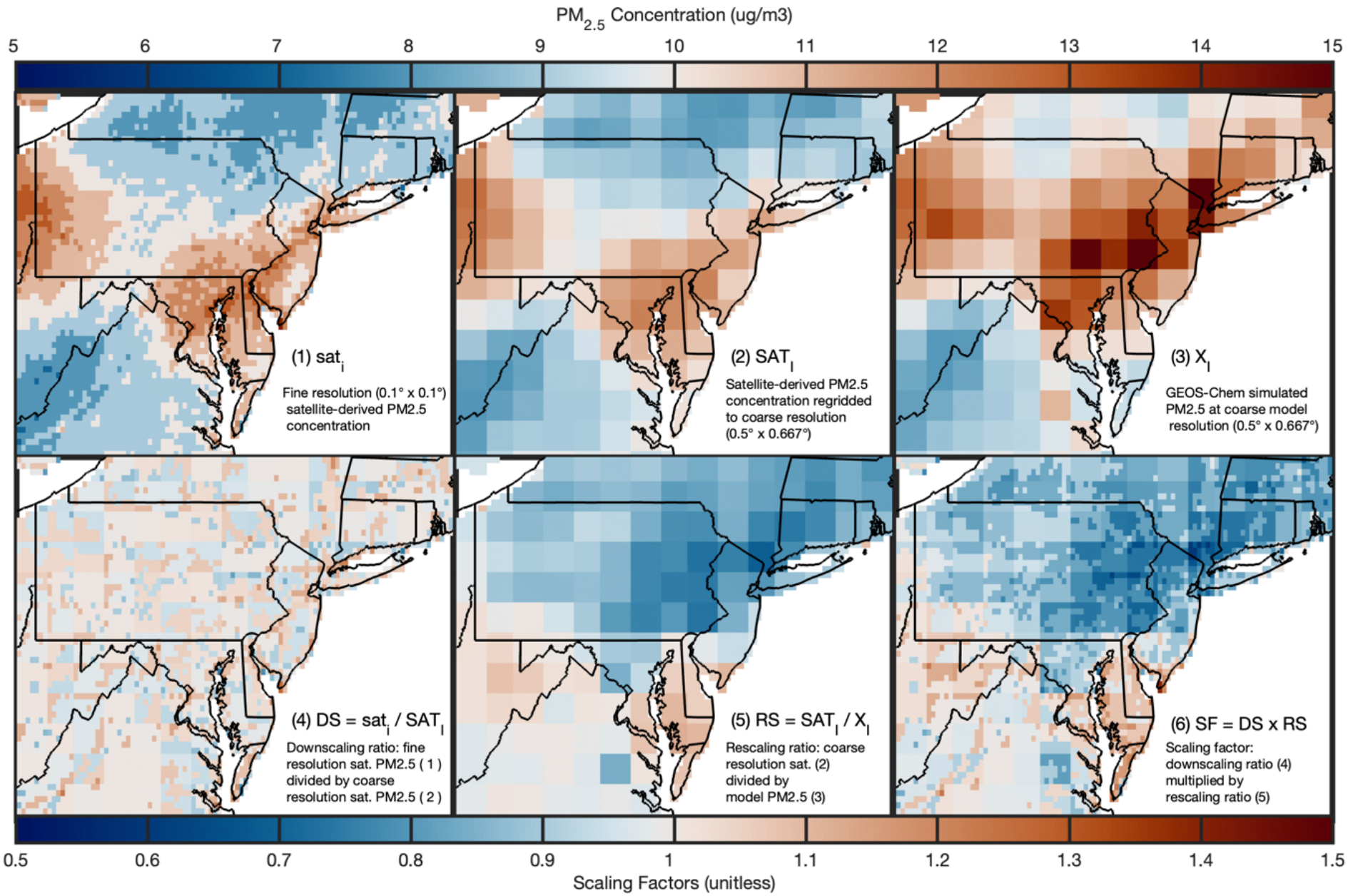

Why do we use satellite-derived data?

It allows us to capture concentration gradients at finer-scales than GEOS-Chem improving our pollutant exposure and health impact estimates.

Van Donkelaar et al., 2016; Cooper et al., 2020; Nawaz et al., 2021

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Combine adjoint sensitivities with emission sources or scenarios

Amount of cost-function attributable to emission source

Emissions from a specific source or scenario

$$\Delta J \approx \sum_{I} \lambda_I \times \Delta E_I$$

Summing over spatial dimensions (I)

Adjoint sensitivity

Application One – Source Apportionment

ΔE_I are emissions from a source group combined with sensitivities to estimate the source group's "contribution" to the cost-function ΔJ

Application Two – Emission Scenario Impact Assessments

ΔE_I is a proposed change in emissions from a scenario combined with sensitivities to estimate the impact of the scenario on the cost-function ΔJ

Scale One – G20

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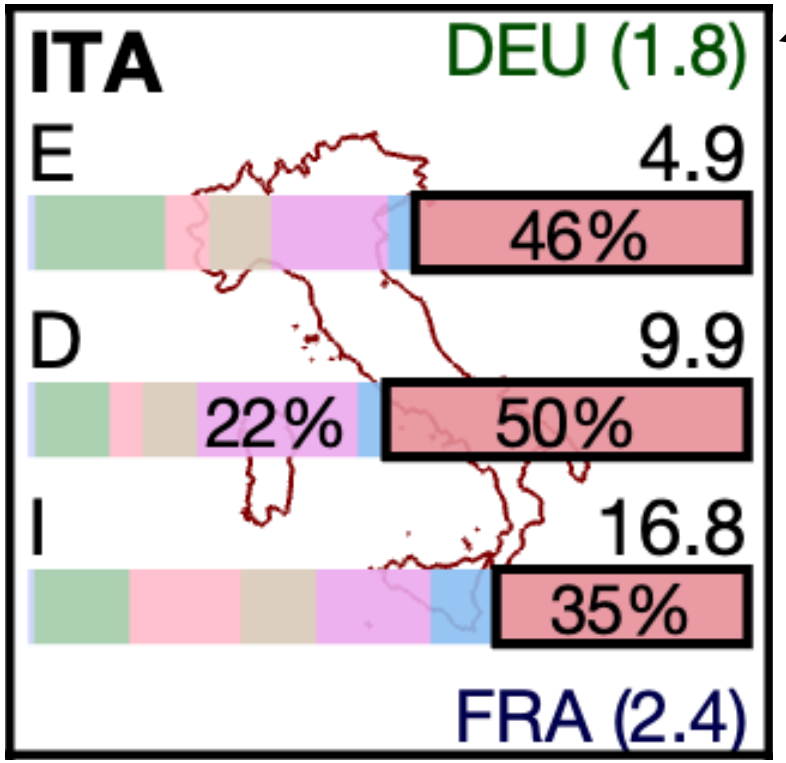
Receptor country

Relative sectoral contributions for exported (E), domestic (D), and imported (I) health impacts



Countries with the largest health impacts from Italian emissions

Number of premature deaths in other G20 countries attributable to Italian emissions

Number of premature deaths in Italy attributable to Italian emissions

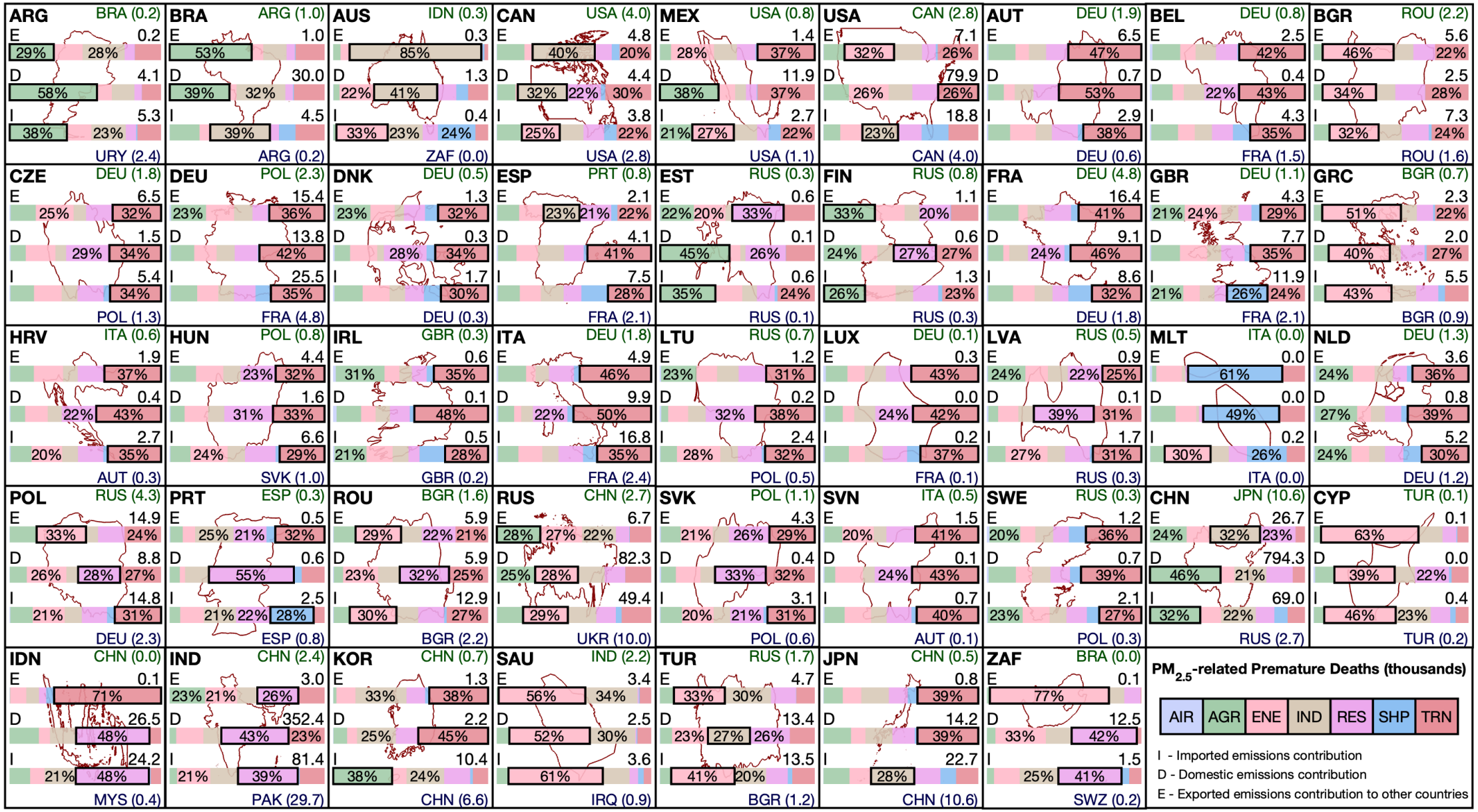
Number of premature deaths in Italy attributable to emissions outside of Italy

The countries whose emissions contribute the most to health impacts in Italy

$PM_{2.5}$-related Premature Deaths (thousands)

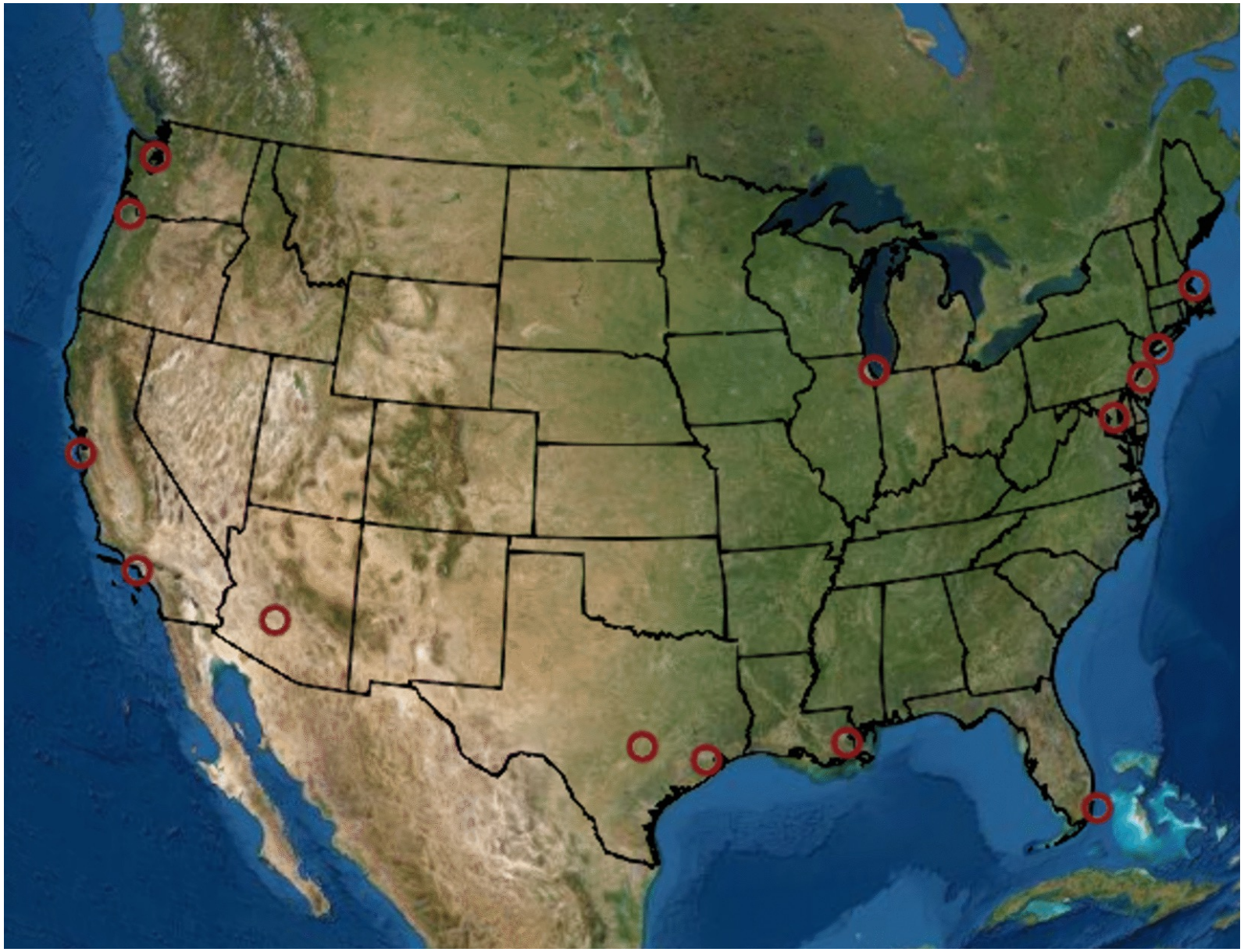
AIR	AGR	ENE	IND	RES	SHP	TRN

Scale One – G20



Scale Two – US Cities

- We expand our adjoint approach to the urban-scale.
- We perform source apportionments and emission impact analyses for 14 US cities (C40 cities).
- We consider a scenario developed by EPA and CAPCOG involving the implementation of a state-of-repair fee based on the age of a vehicle.



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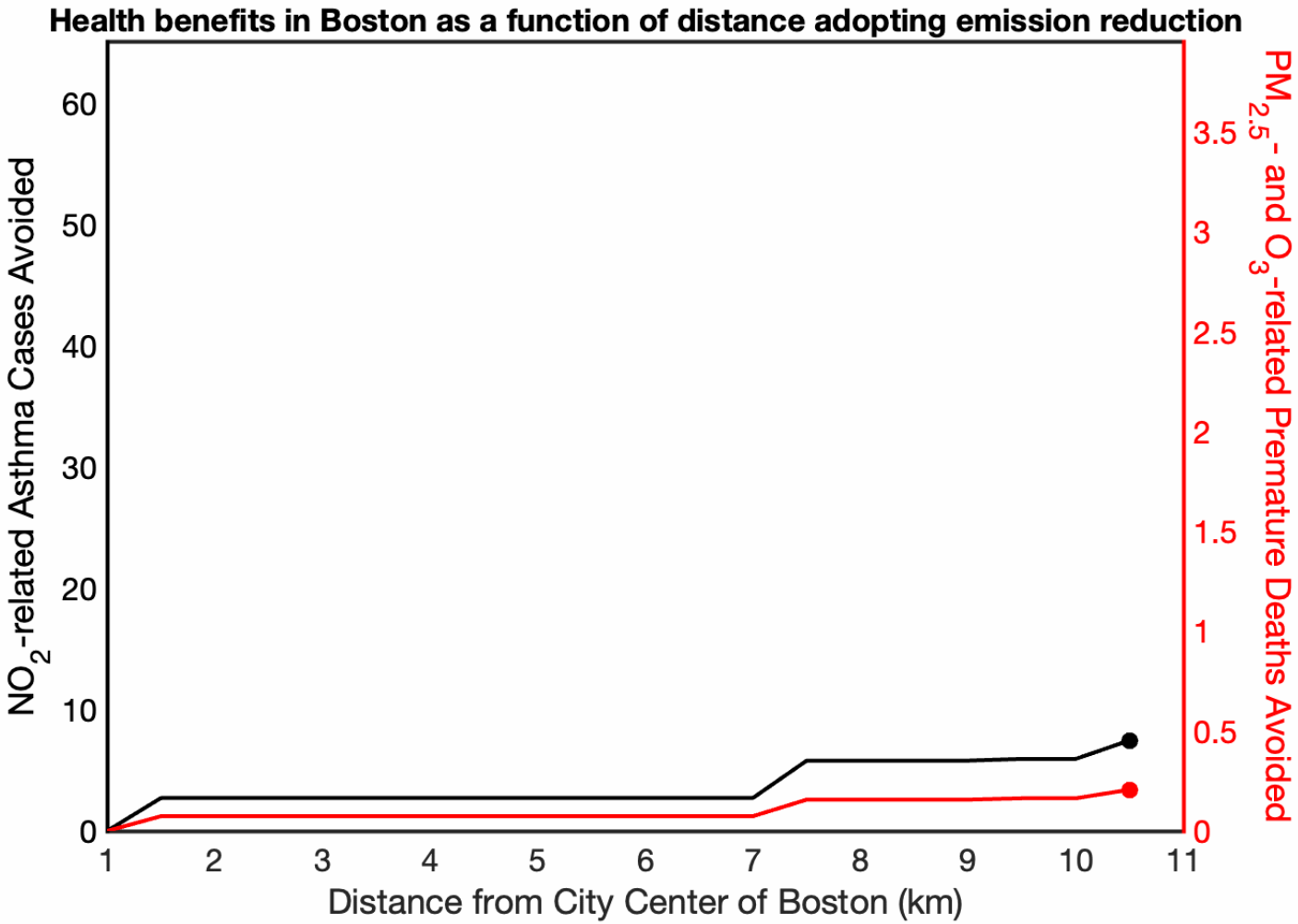
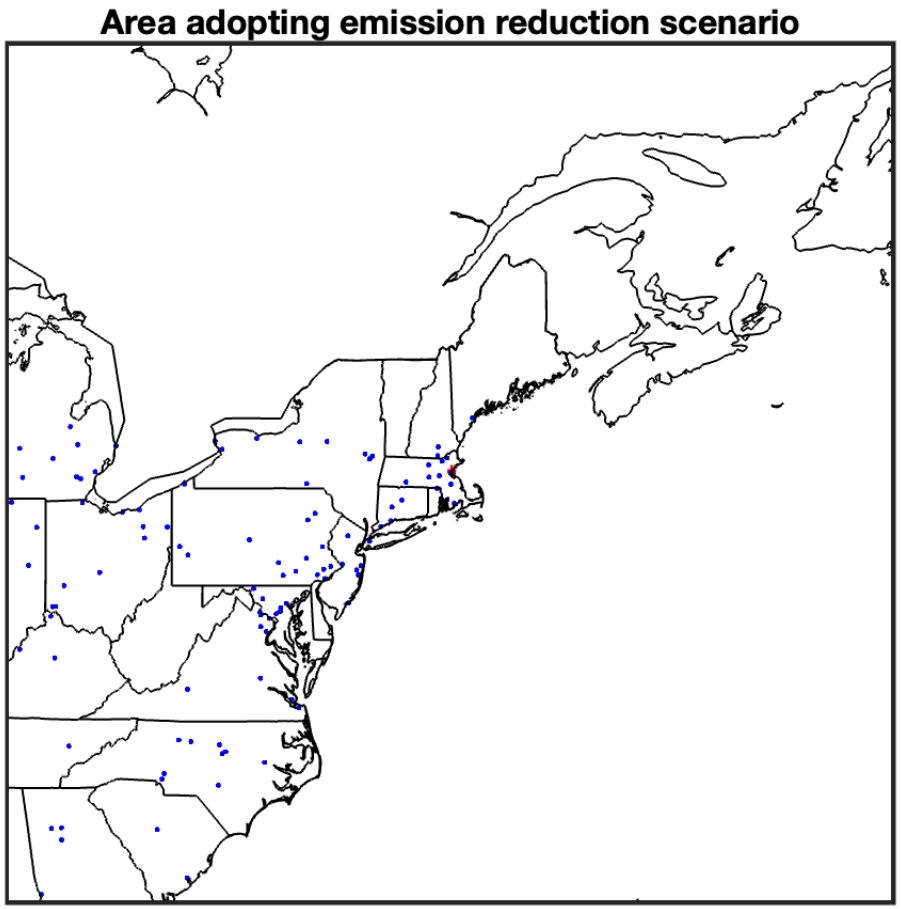
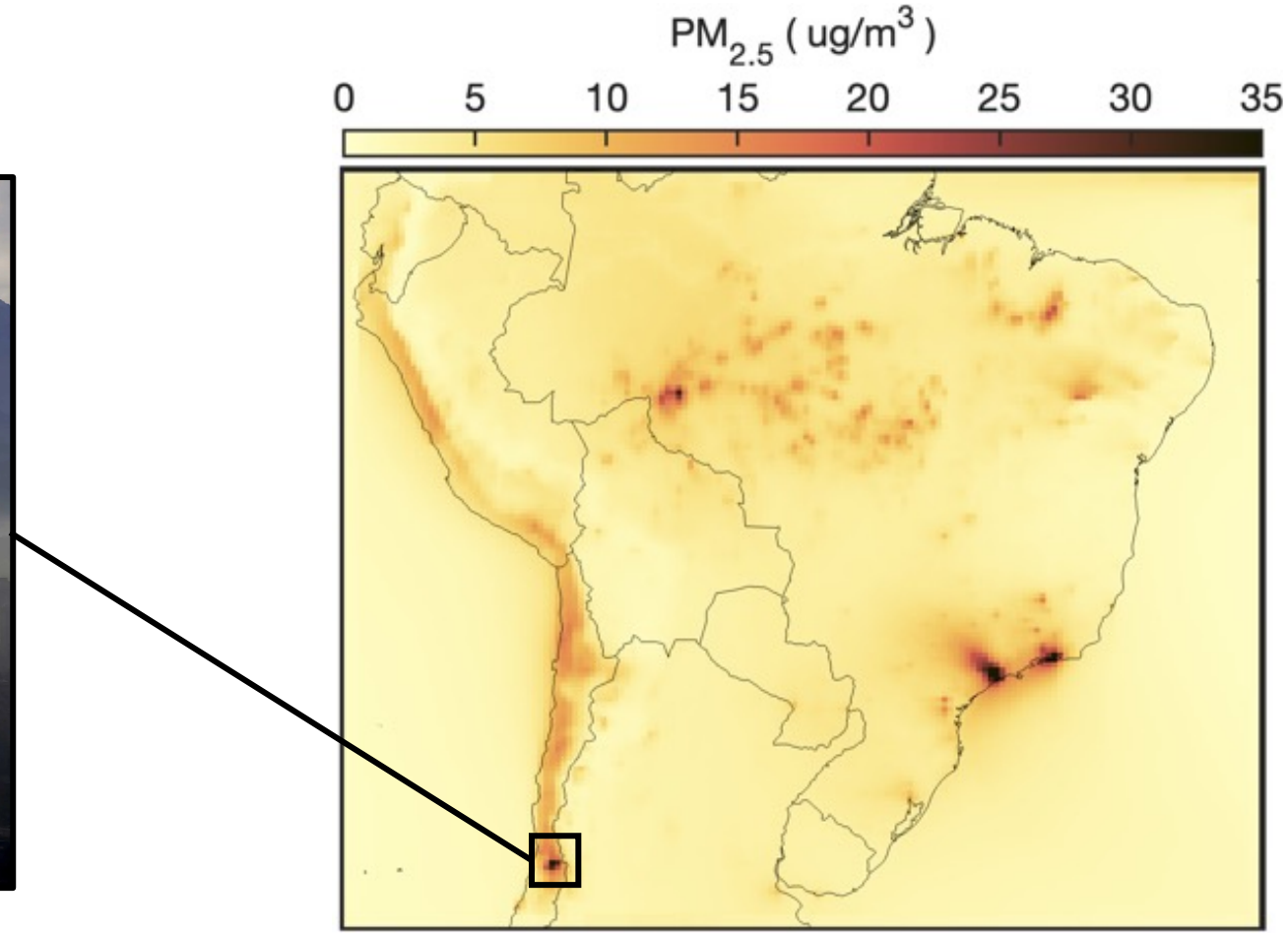




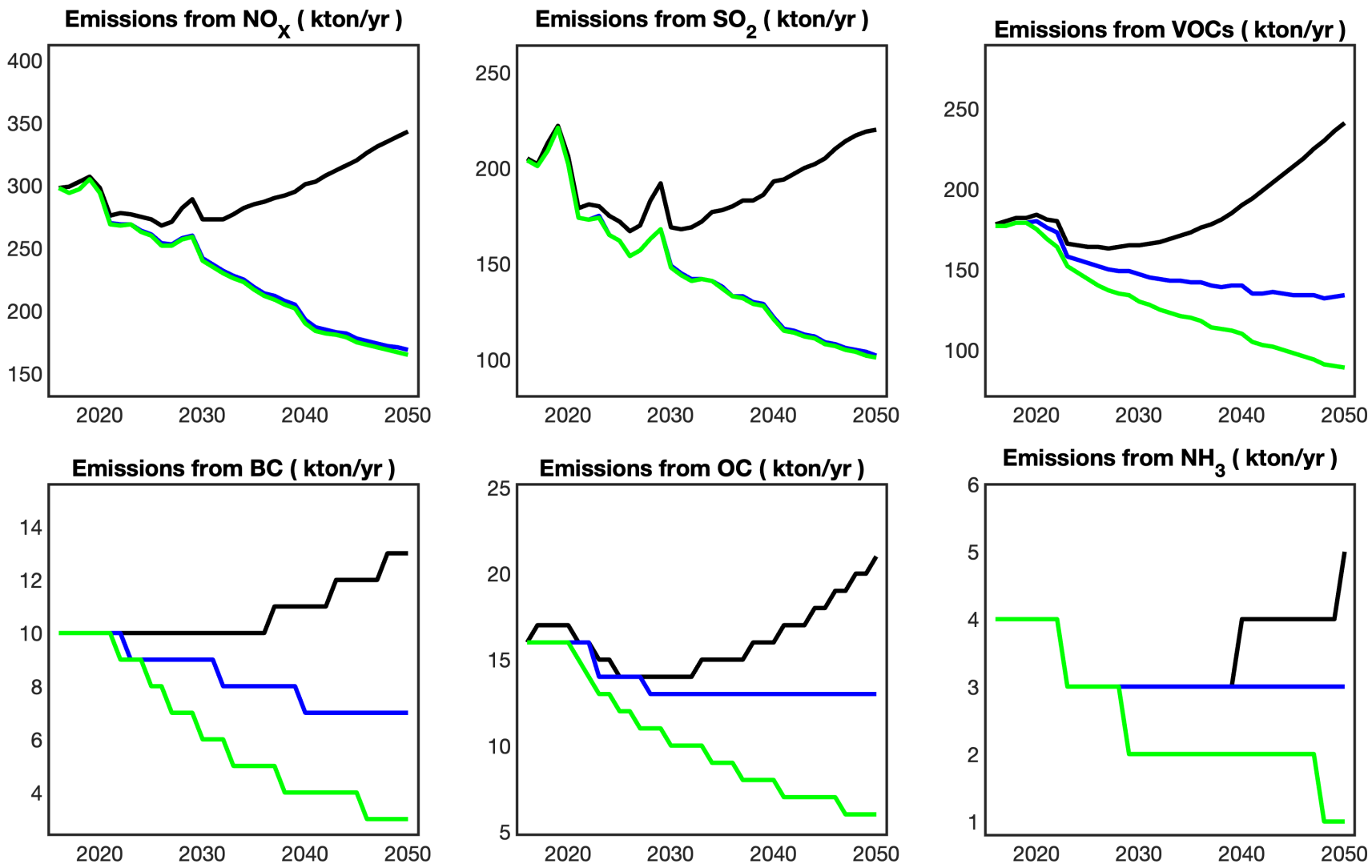
We consider the air pollution-related health benefits **in Boston** associated with **a larger and larger area of emission reduction action** in accordance with the previously mentioned EPA emission scenario

Scale Three – Santiago, Chile



Scale Three – Santiago, Chile

- The Políticas Actuales scenario includes: 40% of private vehicles being electric by 2050 and 100% of public transportation by 2040 along with new construction regulations
- The Carbono neutralidad scenario additionally considers that by 2050 39% of home heating is electric along with solar energy being used for heating and the electrification of vehicles in mining and industry.
- The Carbono Neutralidad+ scenario includes 100% of heating in the regions with the highest firewood consumption transitioning to electric by 2050 and new regulations for off-road vehicles with less than 560 kW of power.



Políticas Actuales Carbono Neutralidad Carbono Neutralidad+

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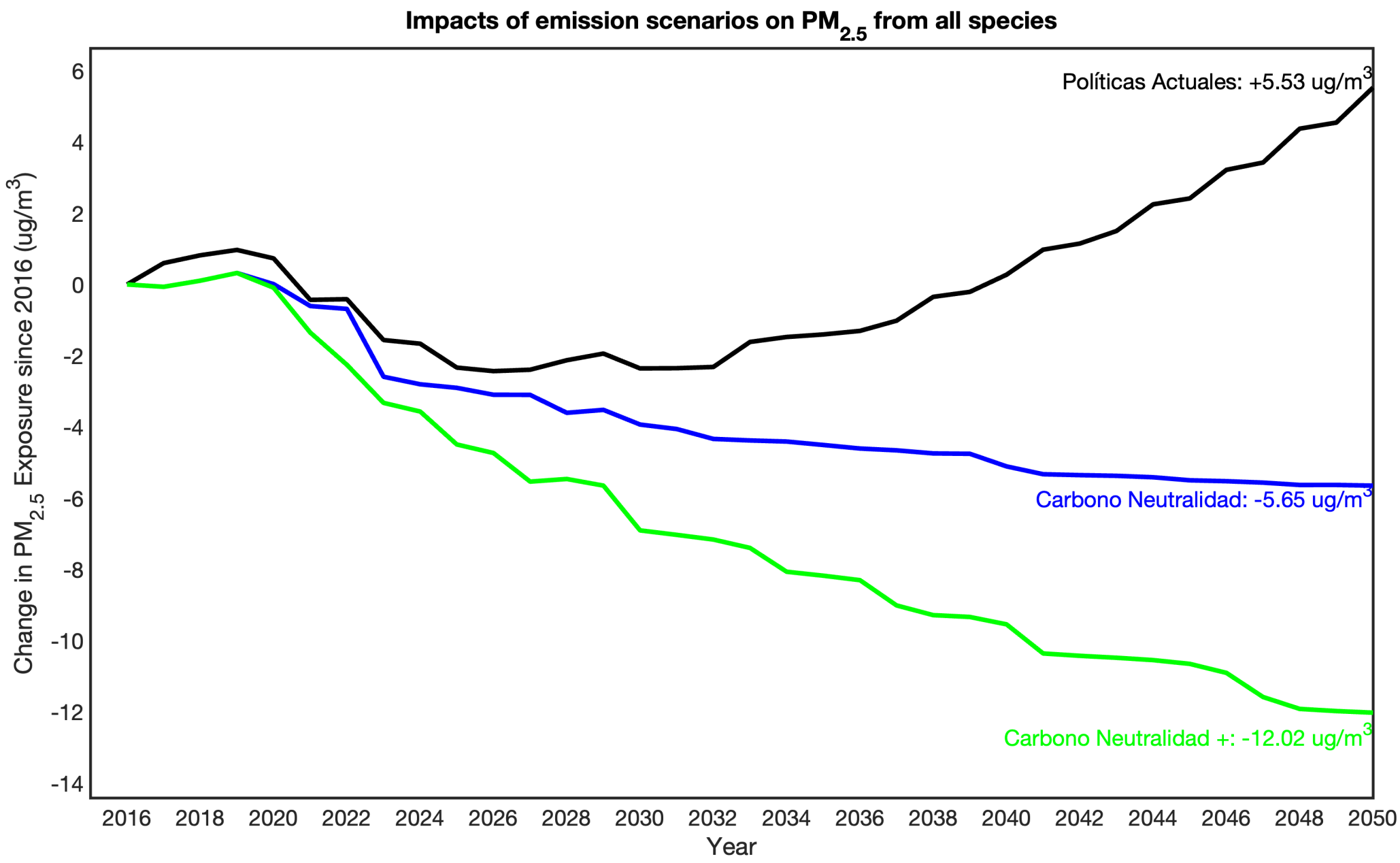

Thanks for your attention!

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