Quantifying the Changing Role of Natural Aerosols in Brazil's Air Quality and Health Impacts

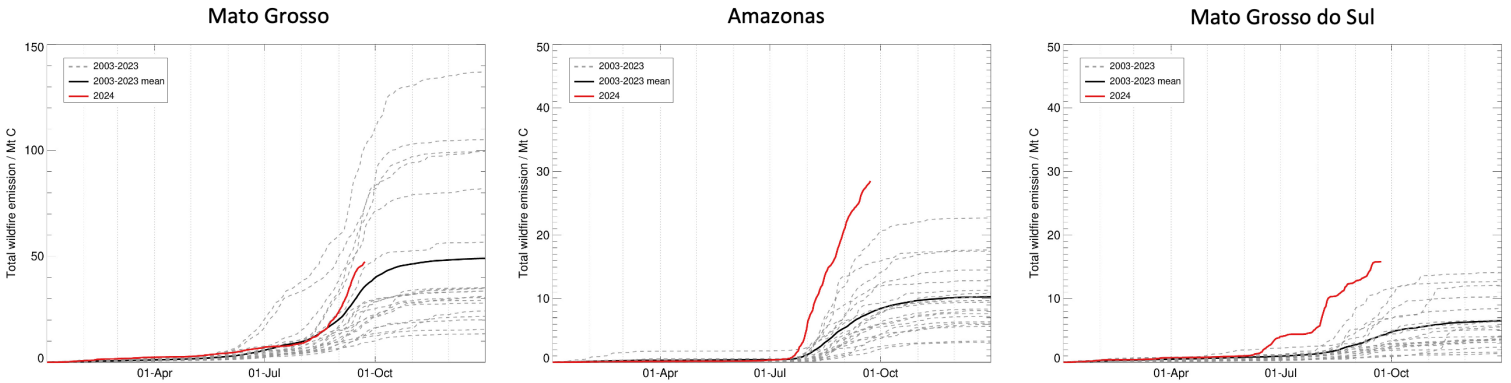
Authors:

Adwoa Aboagye-Okyere, Natalie Mahowald, Alistair Hayden, Fiona Lo

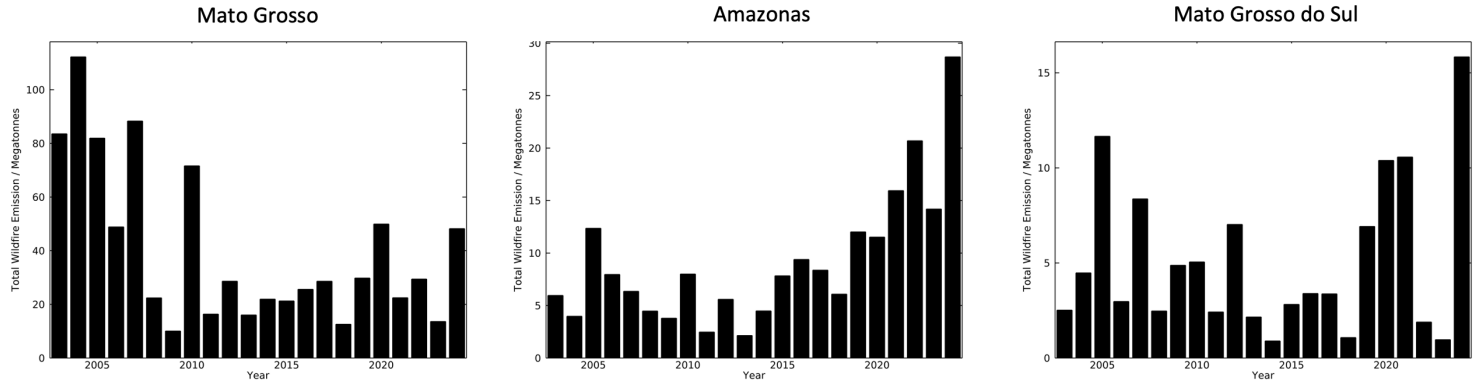
Wildfires in Brazil

- Extreme fire and dust events increasingly affect Brazil's air quality
- Health impacts in Latin America remain poorly quantified
- High-resolution, scale-consistent modeling is needed

Cumulative Total Wildfire Carbon Emissions (CAMS GFASv1.2)



January-September (up to 21 September for 2024) Total Estimated Wildfire Carbon Emissions



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Cumulative total wildfire carbon emissions for 2024 (red) vs. 2003-2023 (top row) and total estimated wildfire carbon emissions for January to September (up to 21 September for 2024, bottom row) for the Braziian states of (left to right) Mato Grosso, Amazonas and Mato Grosso do Sul. Source: CAMS

Questions motivating the modeling approach

How do wildfire and dust emissions influence PM2.5 exposure across Brazil?

How does population distribution shape PM2.5 attributable mortality?

How does MUSICA improve exposure estimates relative to coarser global simulations?

Fig.2 Map of the study domain.

Model framework: MUSICAv0 in CESM

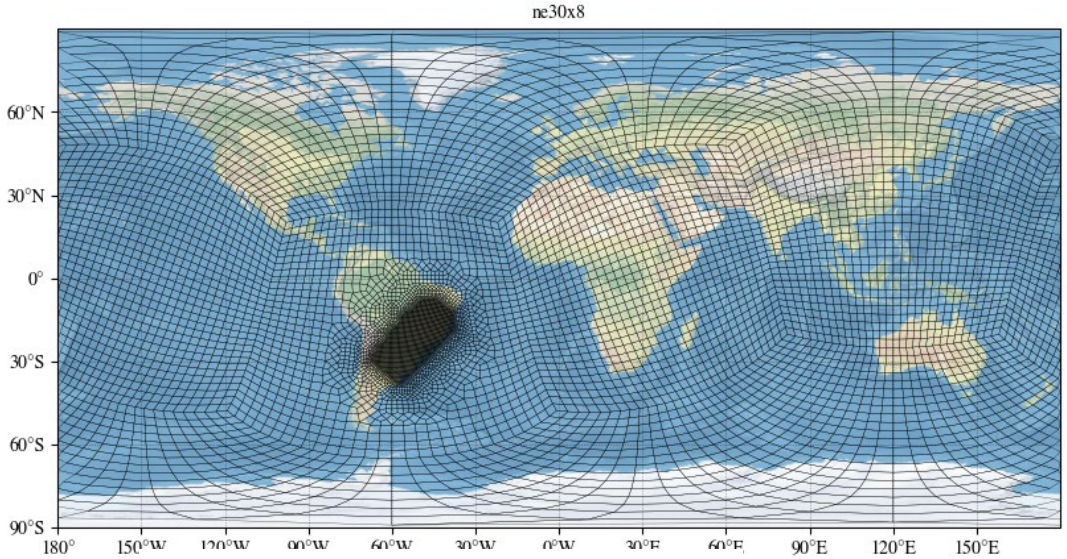
MUSICA is a multiscale chemistry-aerosol modeling framework that lets us study air quality consistently from regional to global scales within CESM

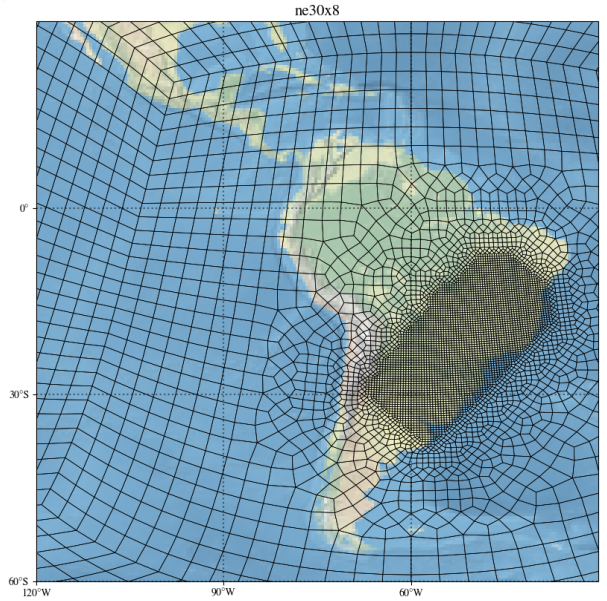
1. Global MUSICA simulation with a 14-km high-resolution region over Brazil

2. Same chemistry and physics everywhere (no separate regional model)

3. Smooth transition from coarse to refined grid

4. First MUSICA application centered on Latin America at high resolution





Emissions

1. Anthropogenic - CAMS

2. Biomass burning - FINN2.5

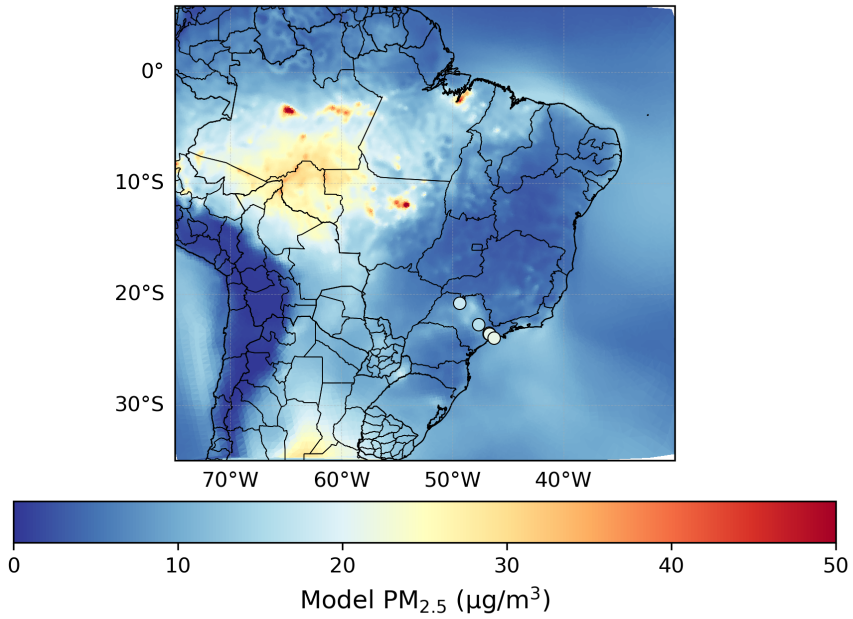
Model performance: PM2.5 over Brazil

Annual Means

Obs = 18.75 ug/m3

Model = 12.59 ug/m3

Model @ obs sites = 13.78 ug/m3



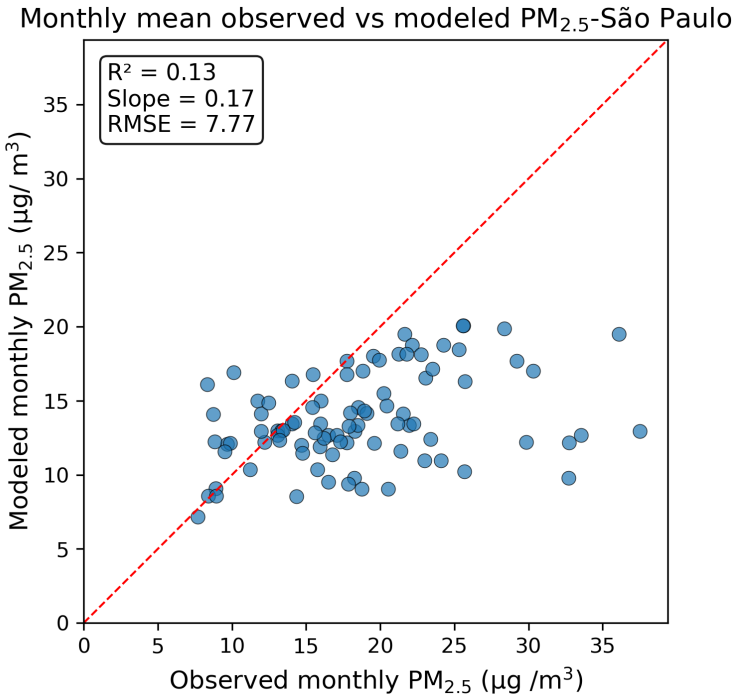


Fig. 4 Left: Model PM2.5 shown as the background, with dots representing observational sites in São Paulo. Right: Scatter plot comparing observed and modeled monthly PM2.5 at those sites.

1. The highest modeled PM2.5 occurs in fire-affected regions of central Brazil

2. Urban pollution in southeastern Brazil (São Paulo area) is captured

3. Broad spatial gradients align with available monitoring sites

4. MUSICA captures spatial patterns but underestimates magnitude

Health Impact Framework

- PM2.5 exposure increases risk of premature mortality
- We use established concentration-response relationships
- Health impacts depend on both pollution levels and the populations exposed.
- We use this framework to estimate cause-specific mortality (stroke, heart disease, COPD, lung cancer, LRI) from PM2.5 exposure.

Excess mortality was estimated as :

$$AF = \frac{(RR-1)}{RR}$$

$$\Delta Mort = pop \times mb \times AF$$

Sources; (Southerland et al, 2022, Aboagye-Okyere et al 2025)

AF = Attributable fraction

Pop = population exposed

Mb = baseline mortality rate

RR = Relative Risks

PM2.5 -Attributable Mortality

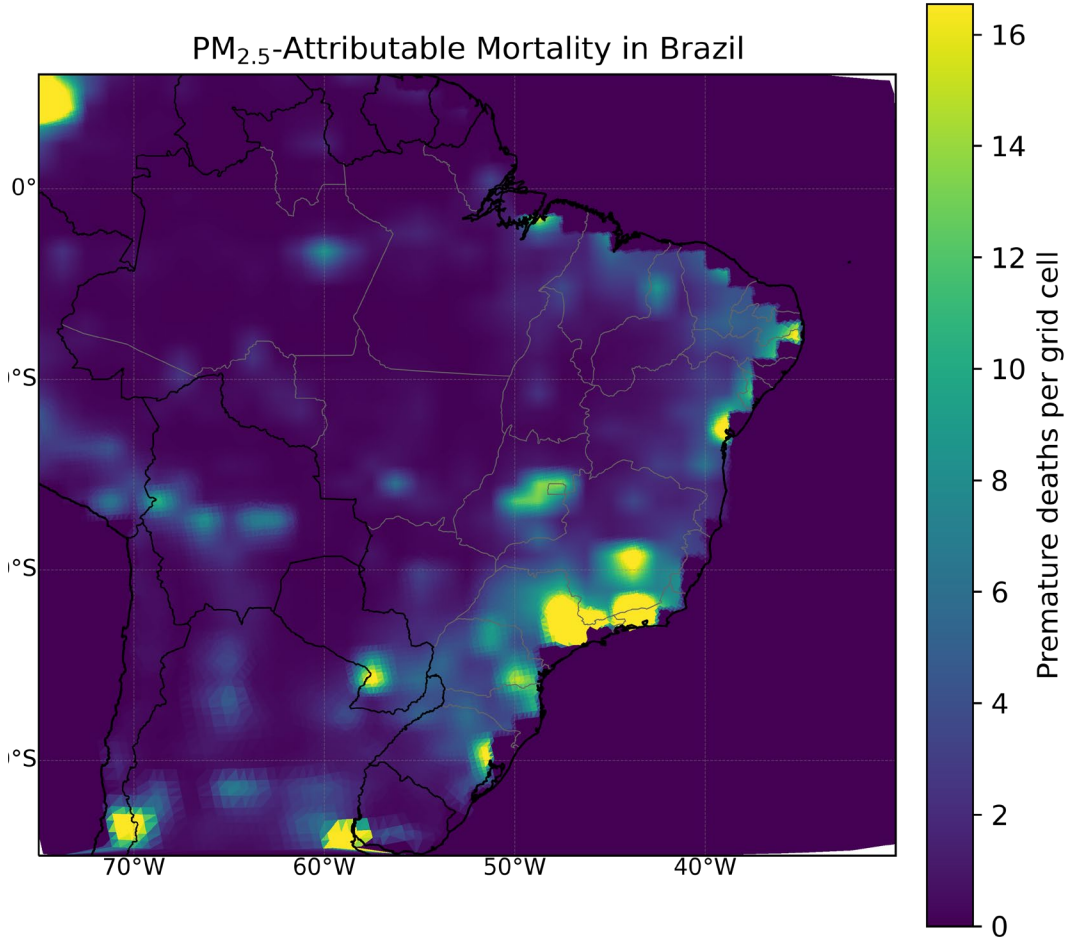


Fig 5. PM2.5 attributable mortality over Brazil

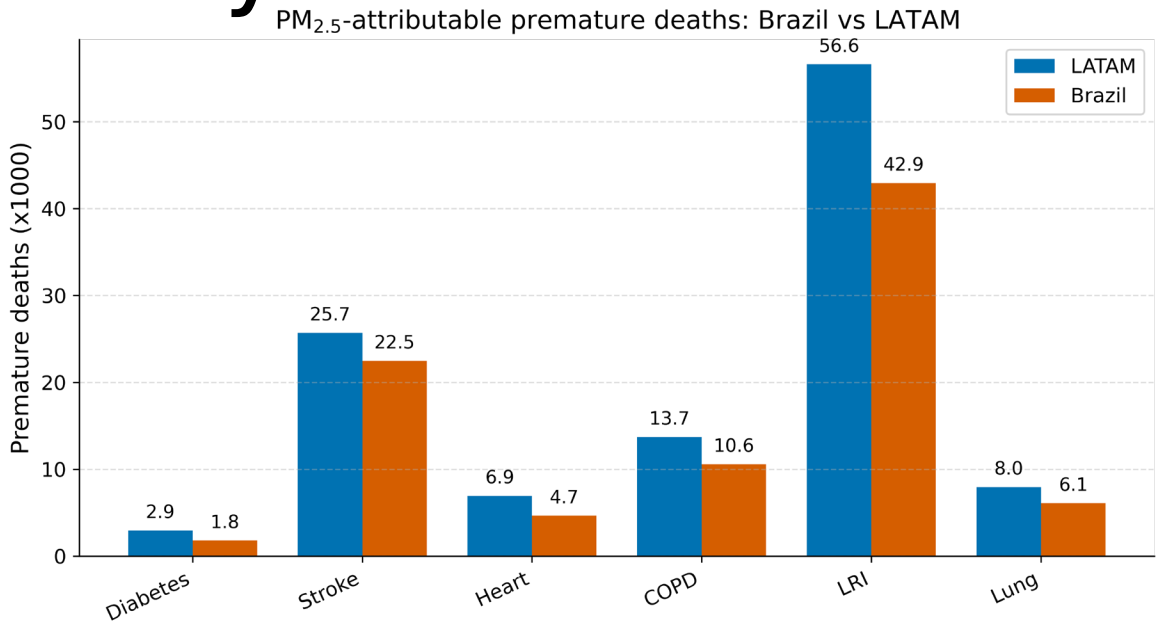


Fig. 6 Cause-specific PM2.5 attributable deaths over Brazil and Latin America

Mortality hotspots are **concentrated in southeastern Brazil** (São Paulo, Rio, Curitiba region)

Amazon regions show **low mortality** despite high PM2.5 driven by **low population density**

The spatial pattern is **population-weighted**, not PM2.5 -weighted

SUMMARY

MUSICA with a 14-km Brazil refinement reproduces major PM2.5 spatial patterns across Latin America

High-resolution modeling improves exposure estimates in densely populated areas.

Mortality is highest in urban regions where pollution and population overlap

Next Steps

- Isolate biomass burning contributions to quantify the specific role of fires in PM2.5 levels.
- Project future PM2.5 over Latin America and Brazil
- Evaluate economic impacts of PM2.5 exposure, including productivity loss
- Add more observational constraints (AOD, new stations)

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