Advances in Simulating the Global Spatial Heterogeneity of Air Quality and Sectoral Contributions: Insights into the Global South

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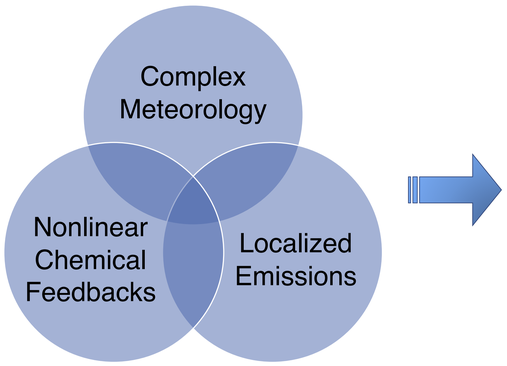
To Resolve Fine-Scale Pollution at High Resolution



- **Higher spatial heterogeneity** in discrete **southern cities** than more clustered northern cities for surface $PM_{2.5}$ and NO_2.
- Resolving pollution hotspots at high resolution alters the **relative importance of source sectors** in the Global South.

Altered Sectoral Importance at High Resolution

- Enhanced importance of population collocated sectors.
- Reduced contamination from open fires on adjacent cities.

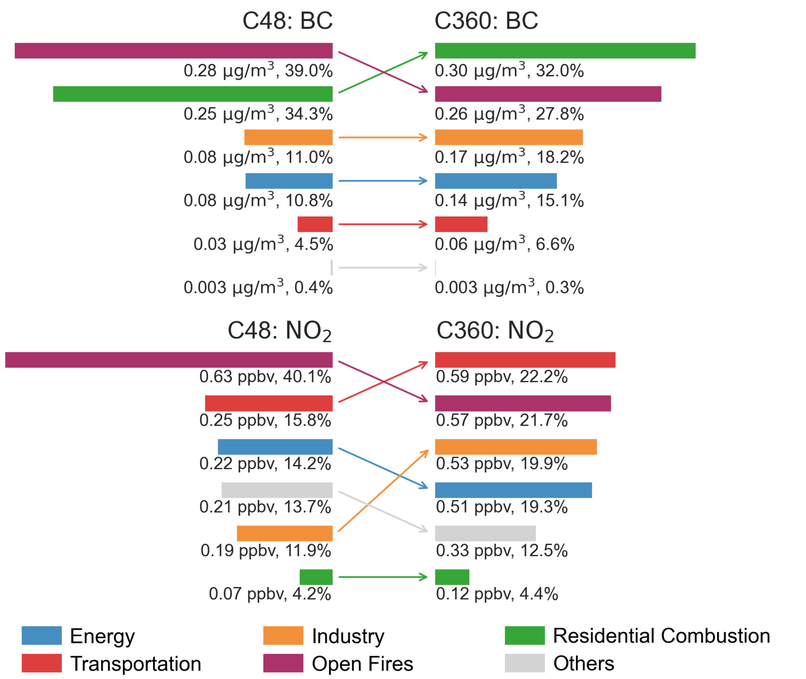


Fig. Fractional sectoral contributions of energy, industry, residential combustion, transportation, and open fire emissions for black carbon (BC) and NO_2 in the Global South in January 2015.

Methods

- **Chemical Transport Model**: We use the GEOS-Chem chemical transport model in its high performance implementation (GCHP)[1,2] version 13.2.1 at cubed-sphere resolutions of C360 (~25 km) and C48 (~200 km).
- **Sectoral Contributions**: We followed a zero-out method with sector sensitivity tests for energy, industry, residential combustion, transportation and open fires.

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Resolving Hotspots and Spatial Gradients at High Resolution

- Resolving spatial gradients in **biomass burning regions**.
- Resolving hotspots against cleaner **high-altitudes and oceans**.

- Pronounced differences across resolution globally.
- **Higher resolution sensitivities** for $PM_{2.5}$ and NO_2 **in the Global South** than globally.

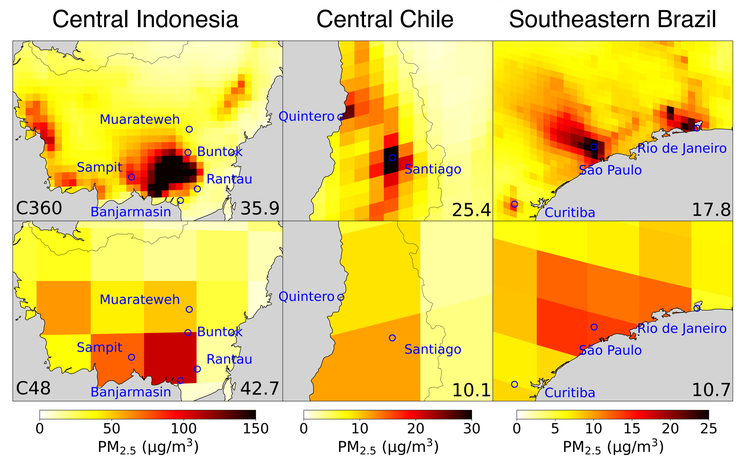

Fig. Surface $PM_{2.5}$ simulated at C360 (25 km) and C48 (200 km).

Table. Differences between surface concentrations at C360 and C48.

	$PM_{2.5}$	BC	POA	NO_3^-	SO_4^{2-}	SOA	NH_4^+	NO_2
Global								
PW-NRMSD (%)	25.1	106	50.7	35.4	32.5	27.8	26.3	72.1
Global South								
PW-NRMSD (%)	33.3	89.4	84.6	121.0	67.4	39.5	74.4	129.4

Notation: PW-NRMSD (population-weighted normalized root mean square difference)

City-level Air Quality Sensitivities to Spatial Resolution

- **Clustered northern cities**: Role of collocation extent between point sources and city centers.
- **Sparse southern cities**: Larger differences for isolated cities.

- Resolved NO_2 hotspots for both northern and southern cities.
- Shifting towards NO_x-saturated O_3 production regime with resolved hotspots.

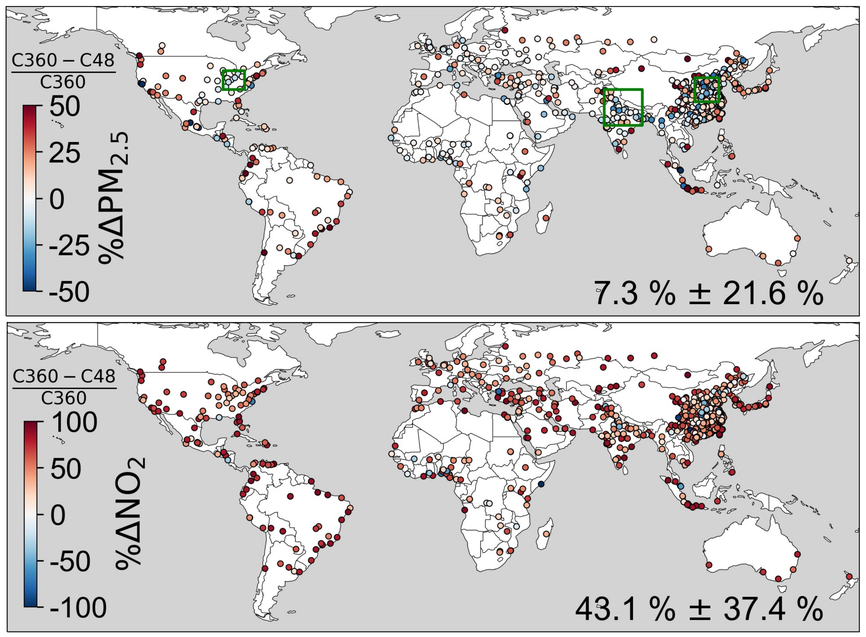

Fig. Relative differences across resolution of surface $PM_{2.5}$ and NO_2 for global populous cities.

[1] Eastham, S. D. *et al.*, (2018). *Geosci. Model Dev.*, *11*(7), 2941-2953. [2] Martin, R. V. *et al.*, (2022). *Geosci. Model Dev.*, *15*, 8731–8748.

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