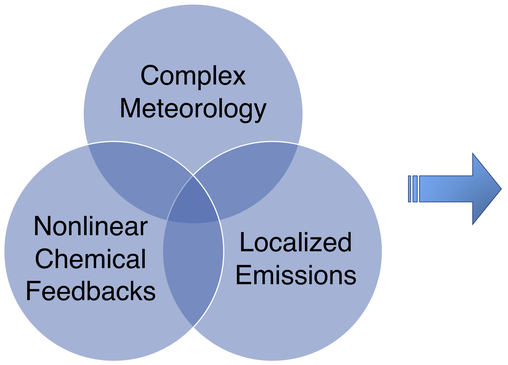
Advances in Simulating the Global Spatial Heterogeneity of Air Quality and Sectoral Contributions: Insights into the Global South

Dandan Zhang[1], Randall V. Martin[1], Liam Bindle[1], Chi Li[1], Sebastian D. Eastham[2], Aaron van Donkelaar[1]
[1]Washington University in St. Louis, [2]Massachusetts Institute of Technology

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.

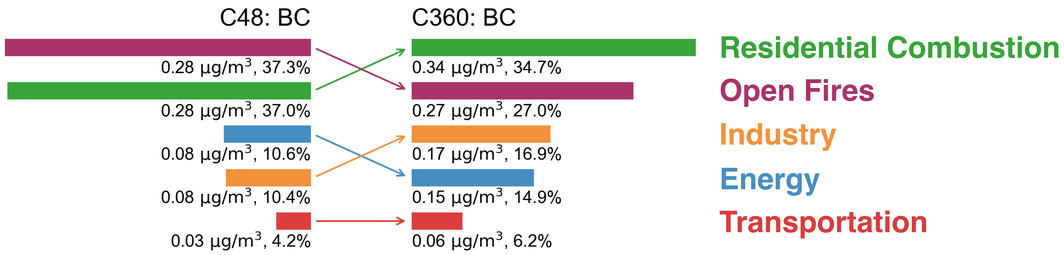
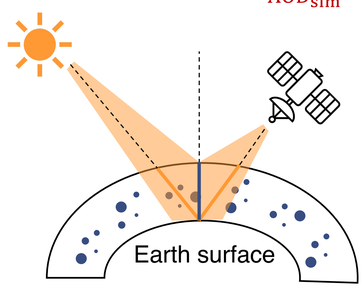


Fig. Fractional sectoral contributions of energy, industry, residential combustion, transportation, and open fire emissions for black carbon (BC) in the Global South in January 2015.

Plan: Resolution Effects on Satellite-derived $PM_{2.5}$

$$\text{Geophysical } PM_{2.5} = \frac{PM_{2.5,sim}}{AOD_{sim}} AOD_{satellite}$$



Potential benefits with simulated surface $PM_{2.5}$ to AOD ratio at high resolution

- Improve **spatial distribution** with resolved hotspots and sharp gradients
- Higher accuracy against ground observations

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.

This work was supported by the NASA grant 80NSSC20K0281 and NSF grant 2020673.

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.

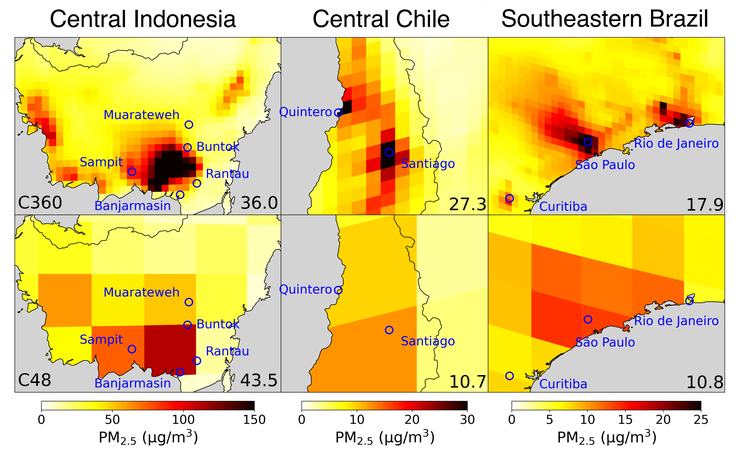


Fig. Surface $PM_{2.5}$ simulated at C360 (~25 km) and C48 (~200 km).

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 (%)	25.6	125.7	61.7	34.9	33.2	29.1	26.3	73.7
Global South								
PW-NRMSD (%)	33.4	89.2	83.9	118.5	68	40	74.7	129.3

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.

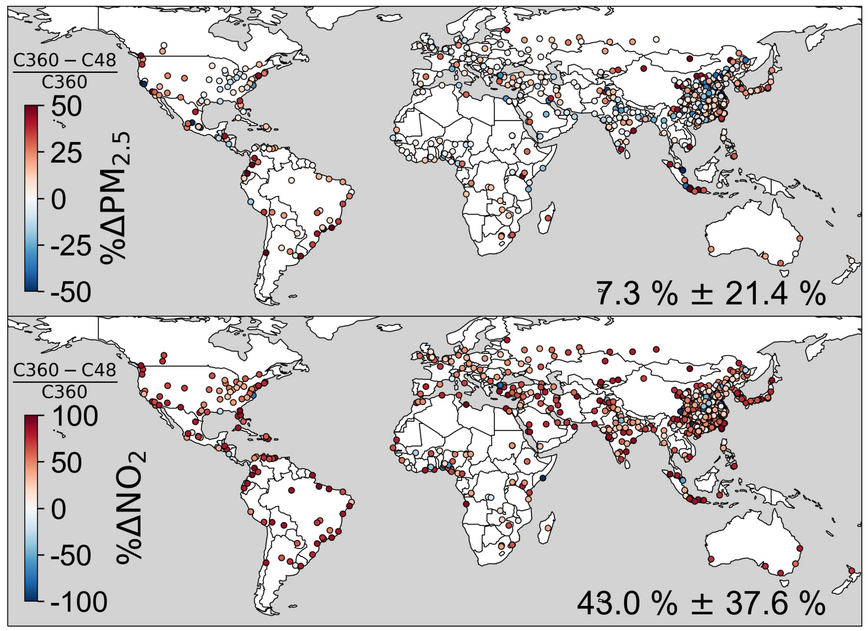


Fig. Relative differences across resolution of surface $PM_{2.5}$ and NO_2 for global populous cities.

[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.

Feel free to contact me with any further questions/comments at dandan.z@wustl.edu