Washington University in St. Louis

ACAG Atmospheric Composition Analysis Group

Advances in Simulating the Global Spatial Heterogeneity of Air Quality Using GCHP and Its Implications for the Relation of AOD with $PM_{2.5}$

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with contributions from

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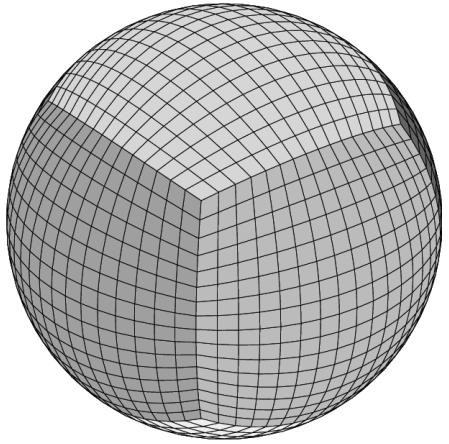
London, GCE2

15 August 2023

Spatial heterogeneity: emissions, meteorology, & chemical feedbacks

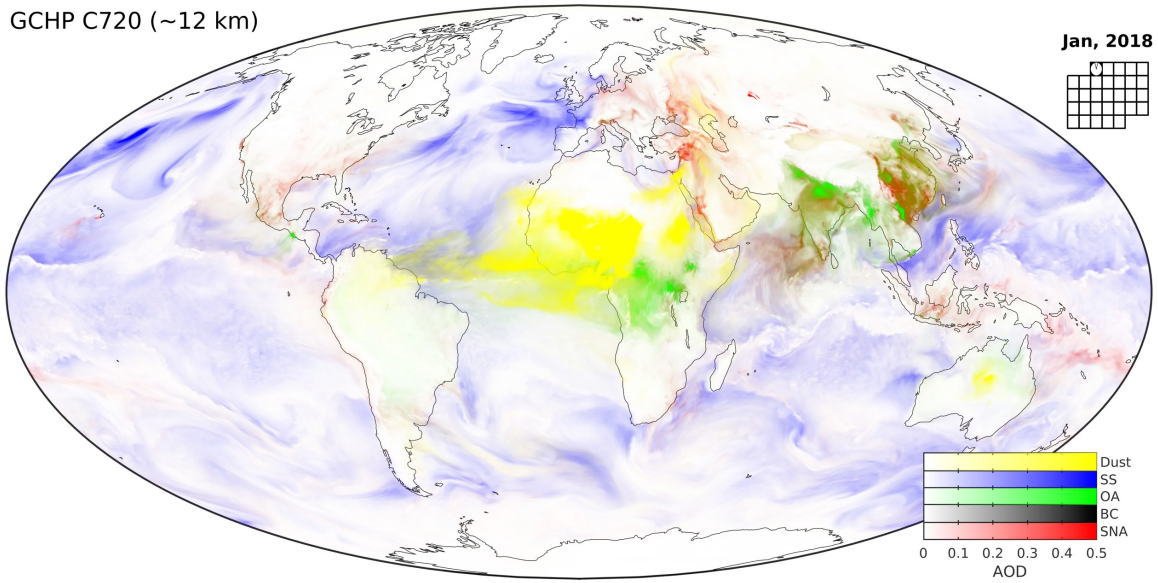


GEOS-Chem

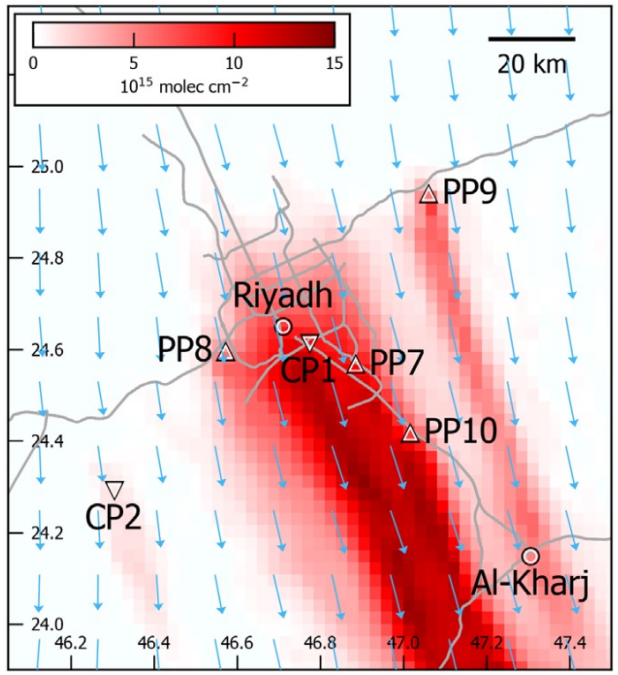
Fine resolution (C360, ~25 km)
Coarse resolution (C48, ~200 km)

Resolution effects on:

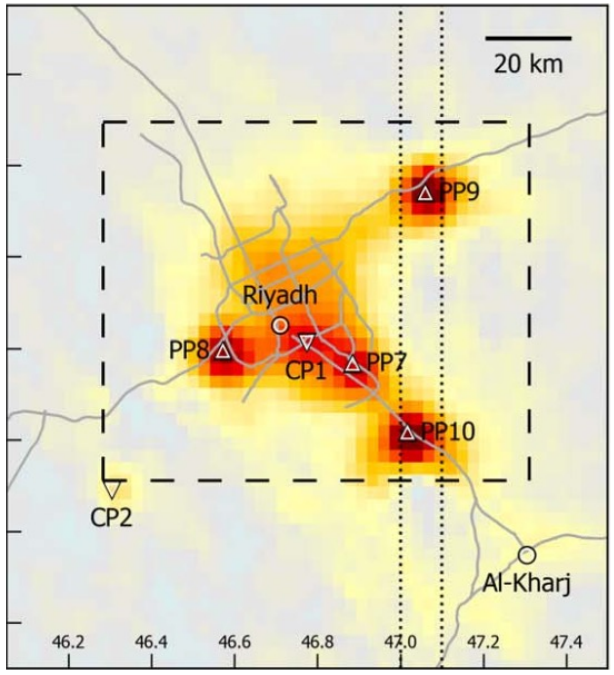
- Population exposure
- Sectoral contributions



NO_2 column density

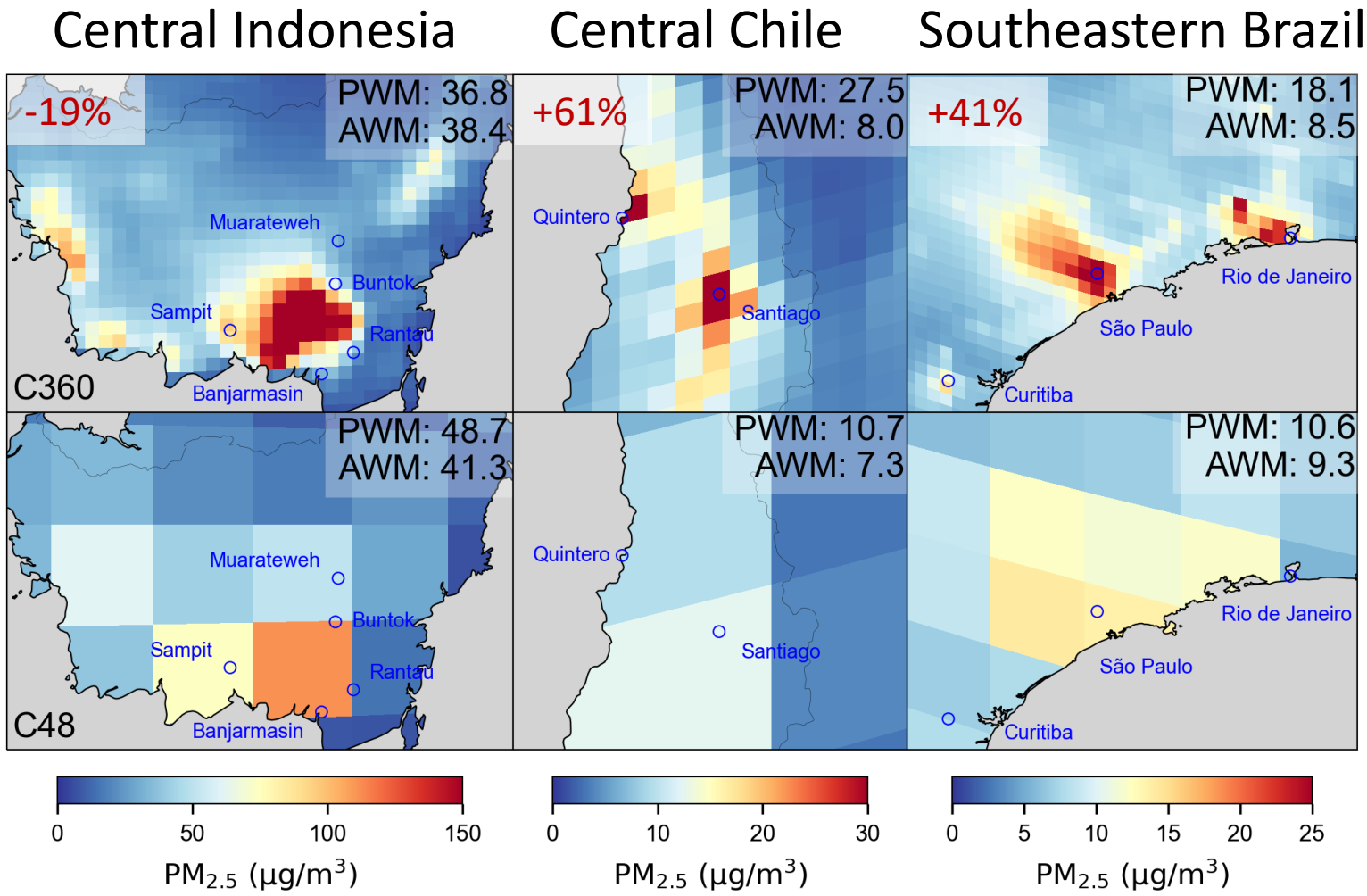


NO_x emissions



Ref: Beirle et al., 2019, *Sci. Adv.*

Resolution effects on simulating surface air quality



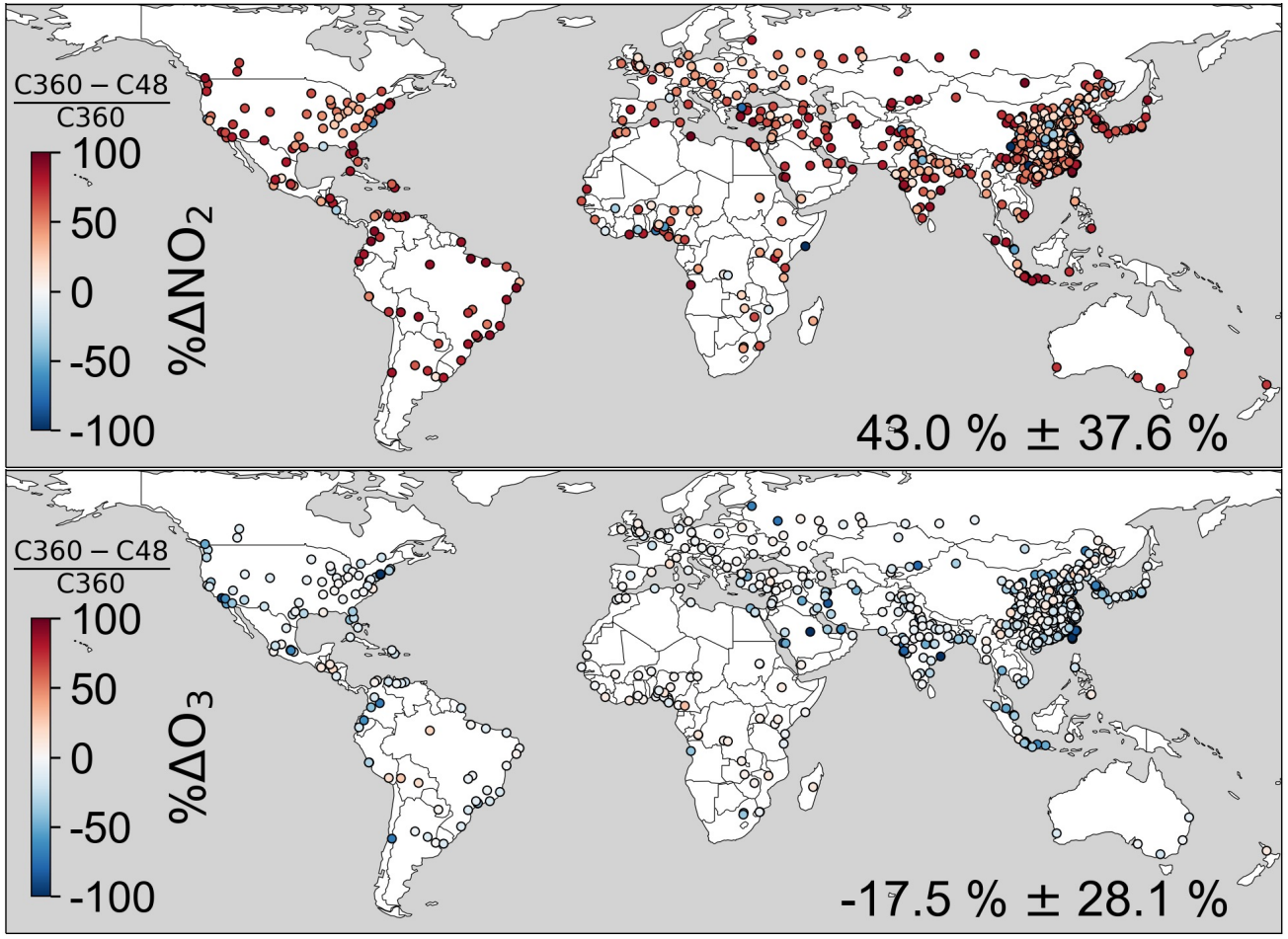
- Resolving spatial gradients in biomass burning regions.
- Resolving hotspots against cleaner mountains and oceans.

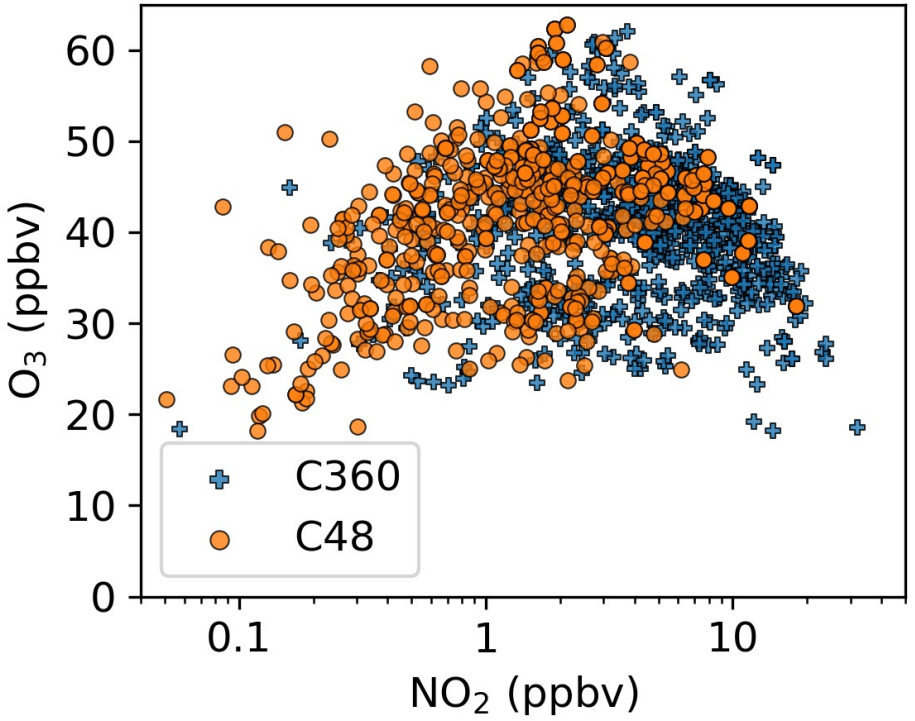
PWM: Population-weighted mean; AWM: Area-weighted mean

Ref: Zhang et al., 2023, *Environ. Sci. Technol.*

Resolution dependence of chemical regimes

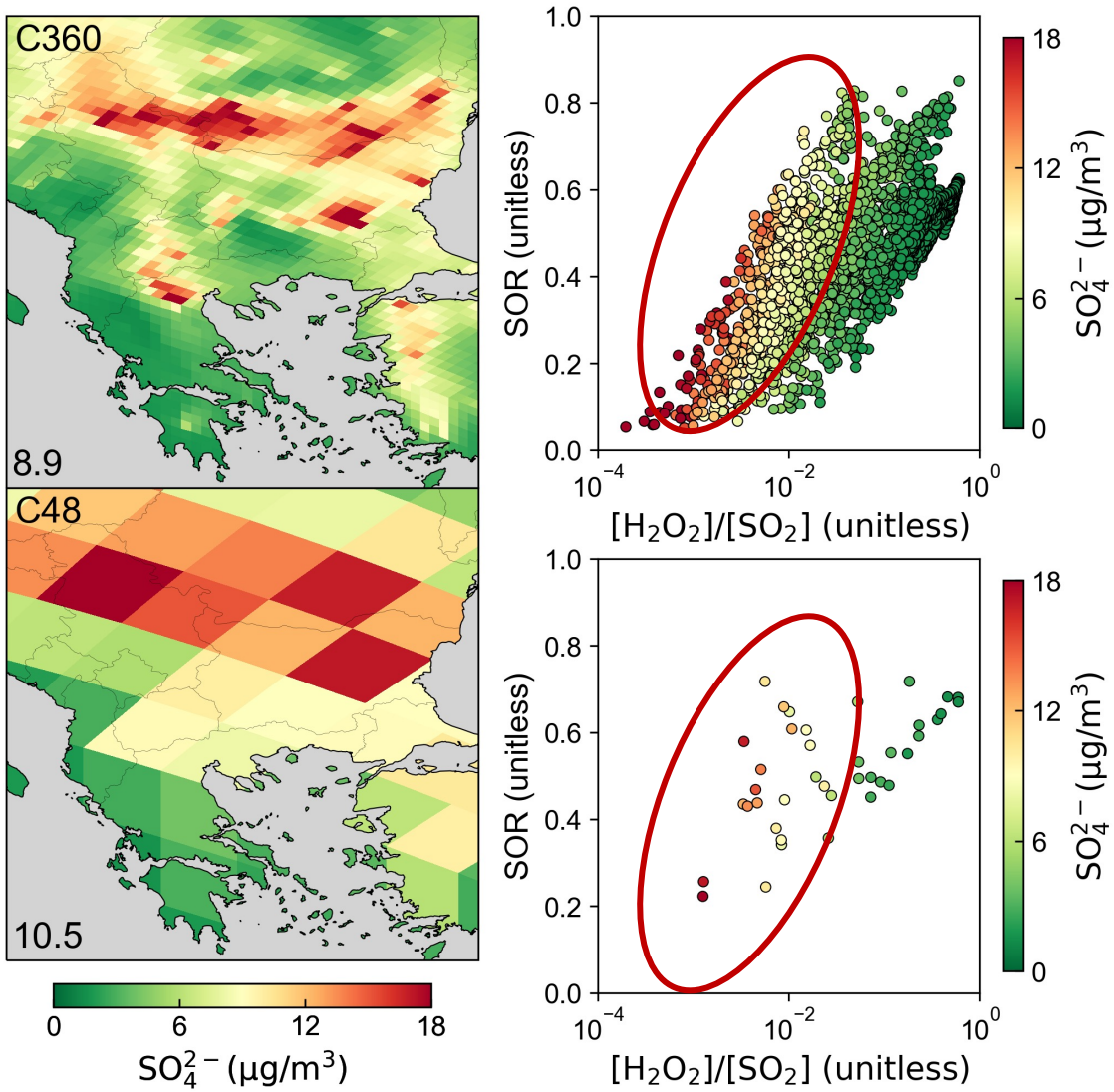
- Resolved NO_2 hotspots & O_3 depletion at urban centers
- Moving towards NO_x-saturated O_3 production at fine resolution





Ref: Zhang et al., 2023, *Environ. Sci. Technol.*

Different resolution responses in the Global North & South

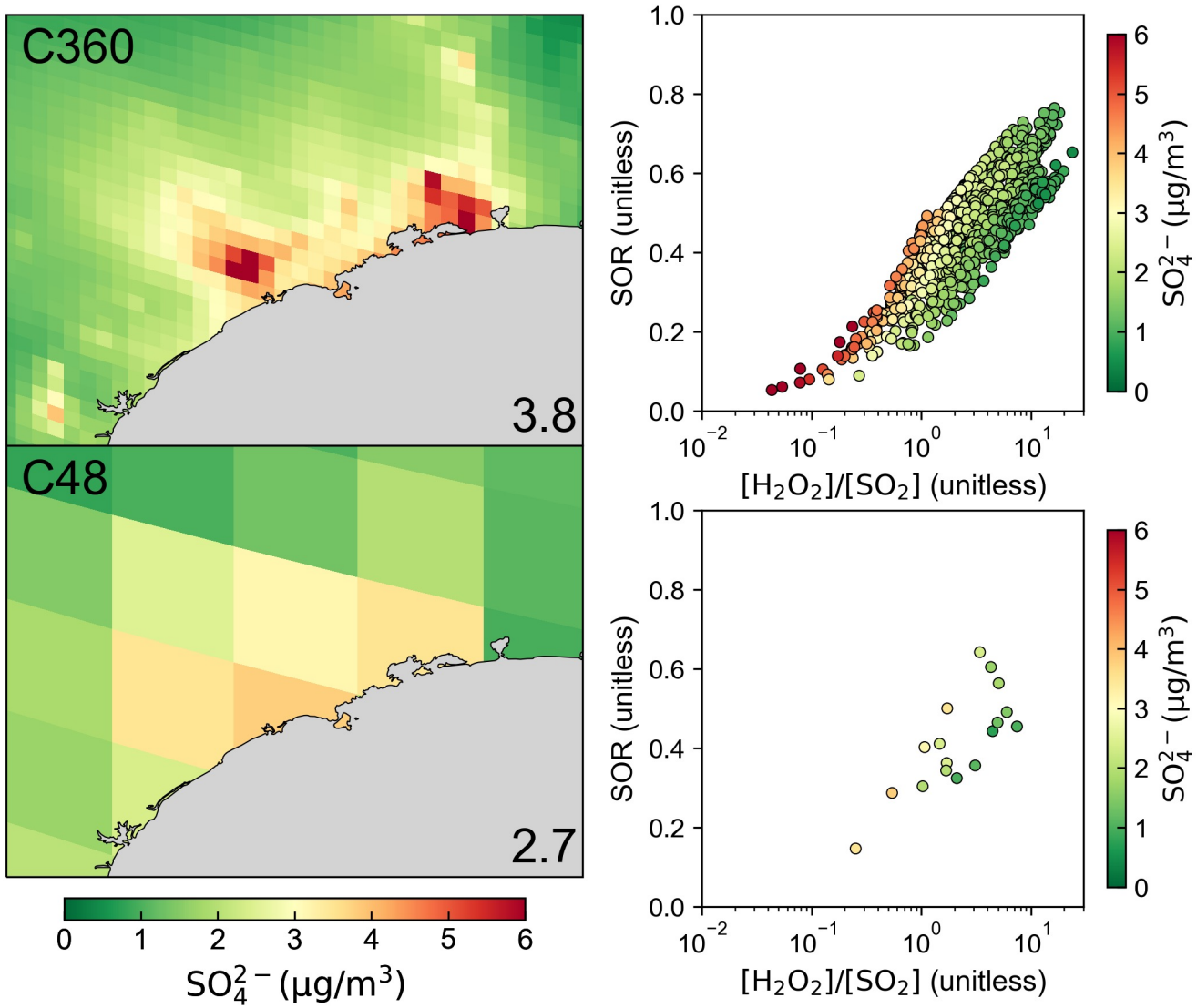


In the Global North with high SO_2 emissions:

Finer resolution
→ SO_2 hotspots captured
→ Higher oxidation burden
→ Lower sulfate produced

Note: SOR (sulfur oxidation ratio) = sulfate / (sulfate + SO_2)
Values at the bottom left are population-weighted concentrations

Different resolution responses in the Global North & South



In the Global South with low SO_2 emissions:

Dilution effects dominated

Finer resolution

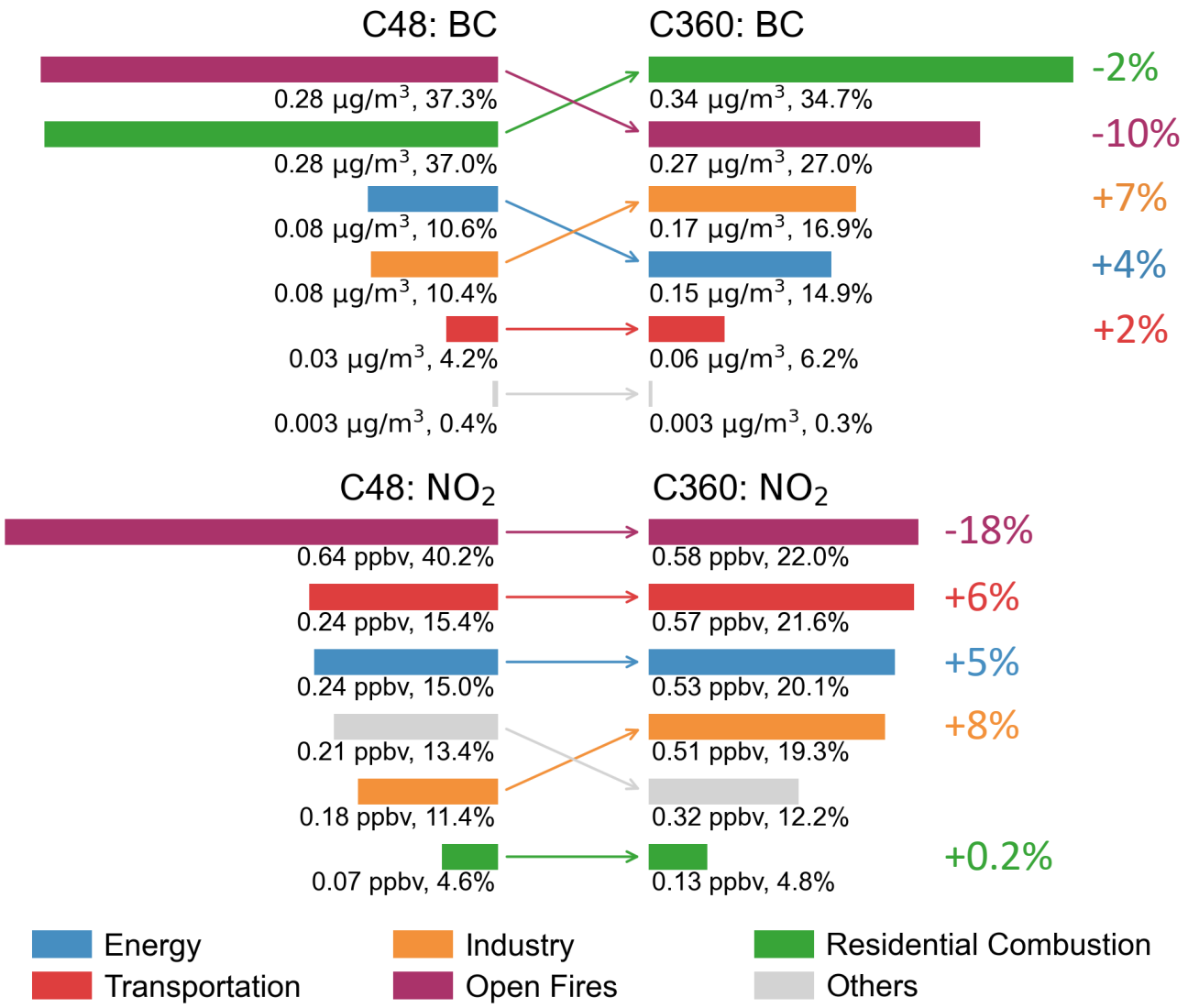
→ SO_2 hotspots captured

→ More sulfate generated

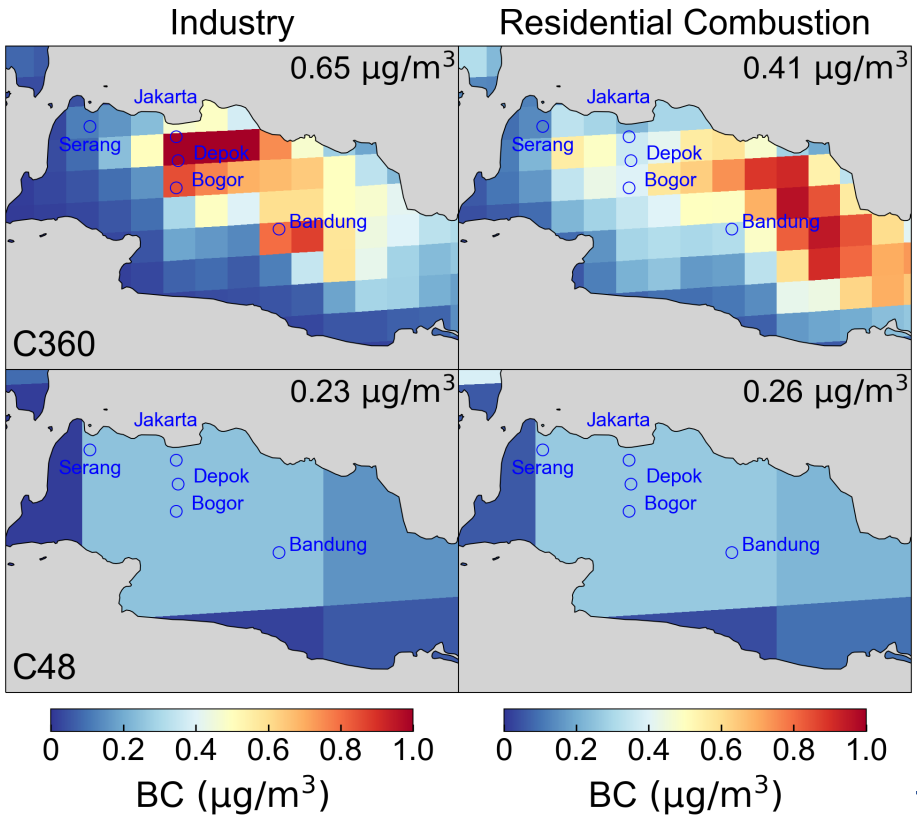
Note: SOR (sulfur oxidation ratio) = sulfate / (sulfate + SO_2)

Values at the bottom left are population-weighted concentrations

Altered sectoral importance at fine resolution in the Global South

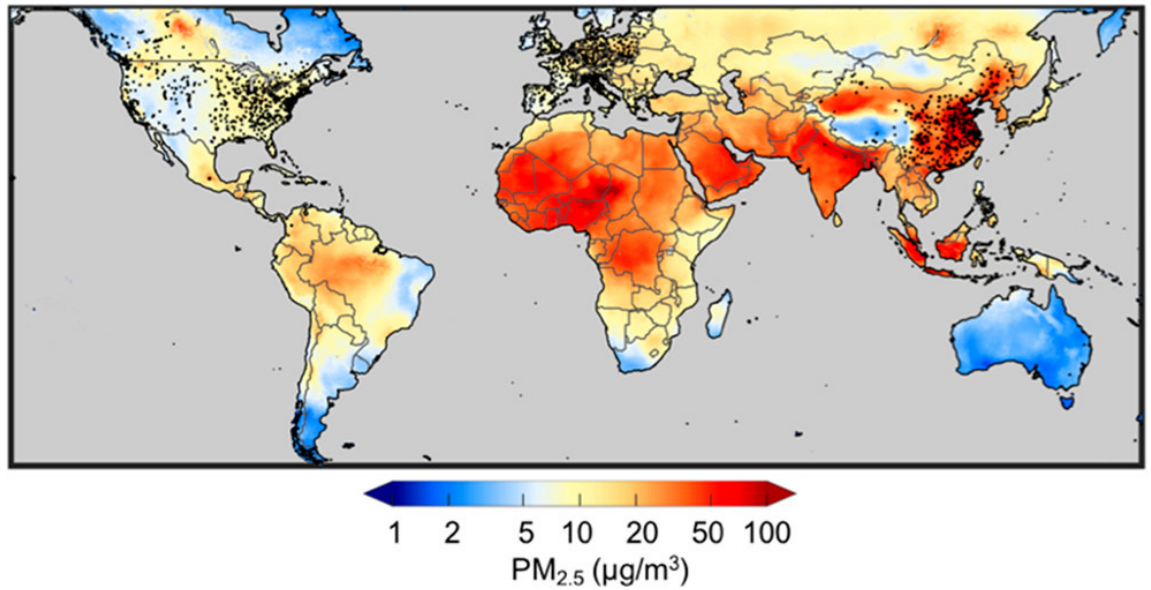


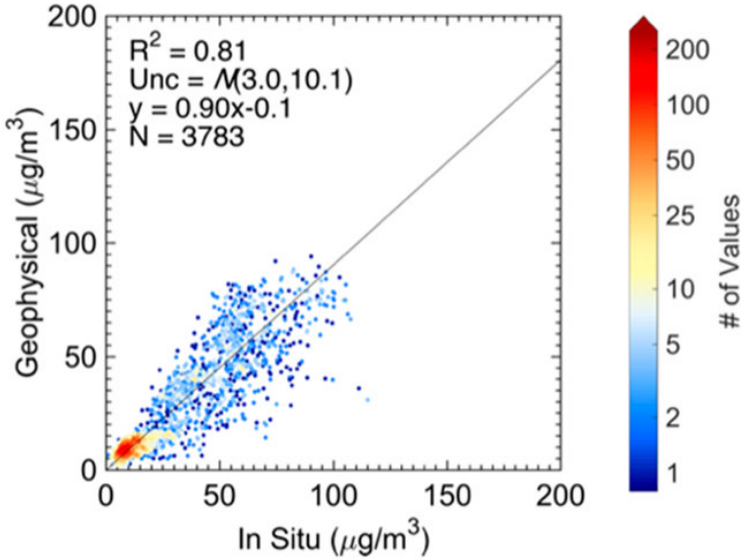
- Reduced contamination from open fires on adjacent cities.
- Enhanced importance of population collocated sectors.



Ref: Zhang et al., 2023, *Environ. Sci. Technol.*

Potential resolution effects on satellite-derived $PM_{2.5}$





Ref: Hammer et al., 2020, *Environ. Sci. Technol.*

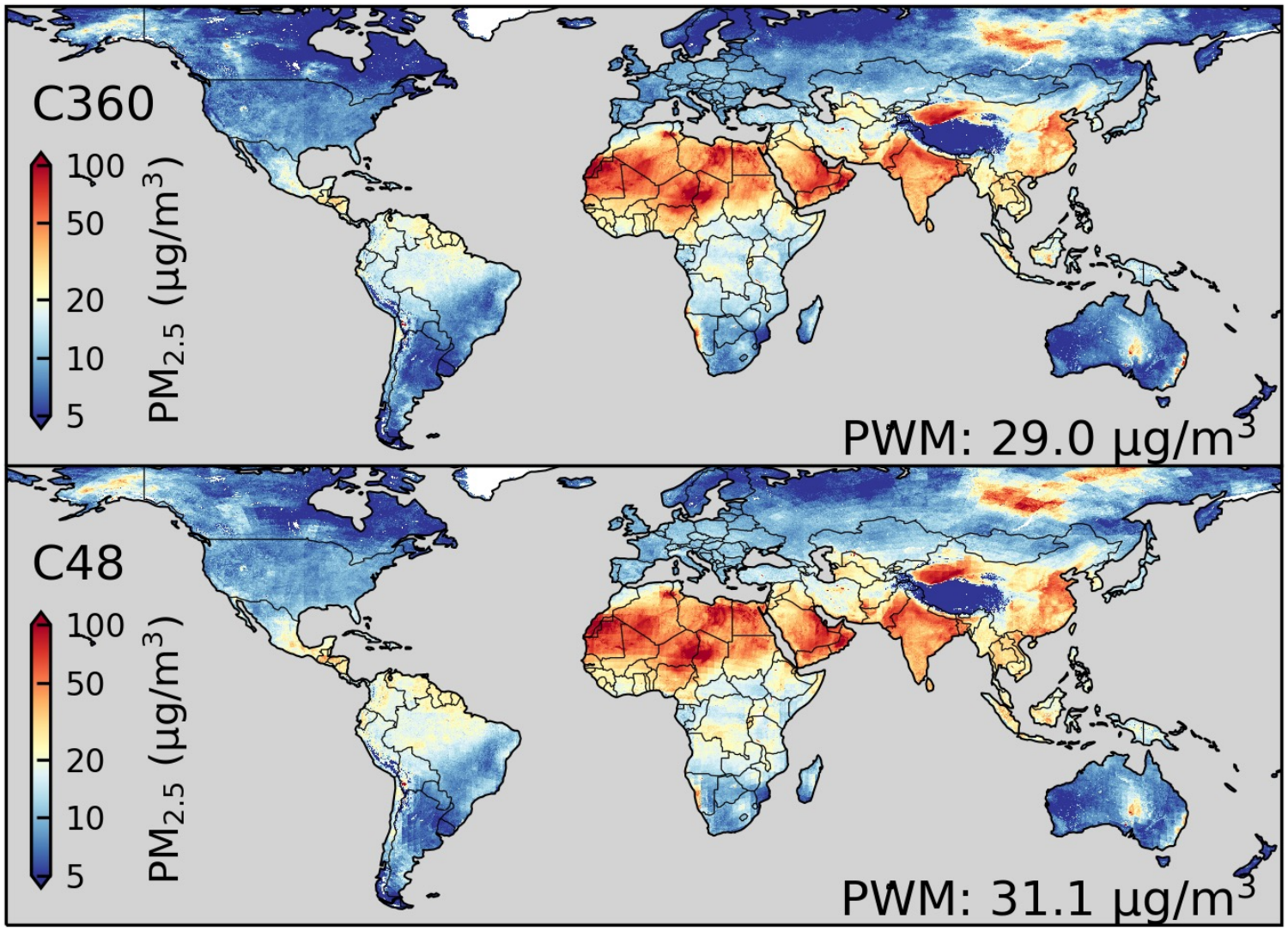
$$\text{Geophysical } PM_{2.5} = \frac{PM_{2.5,sim}}{AOD_{sim}} AOD_{sat}$$

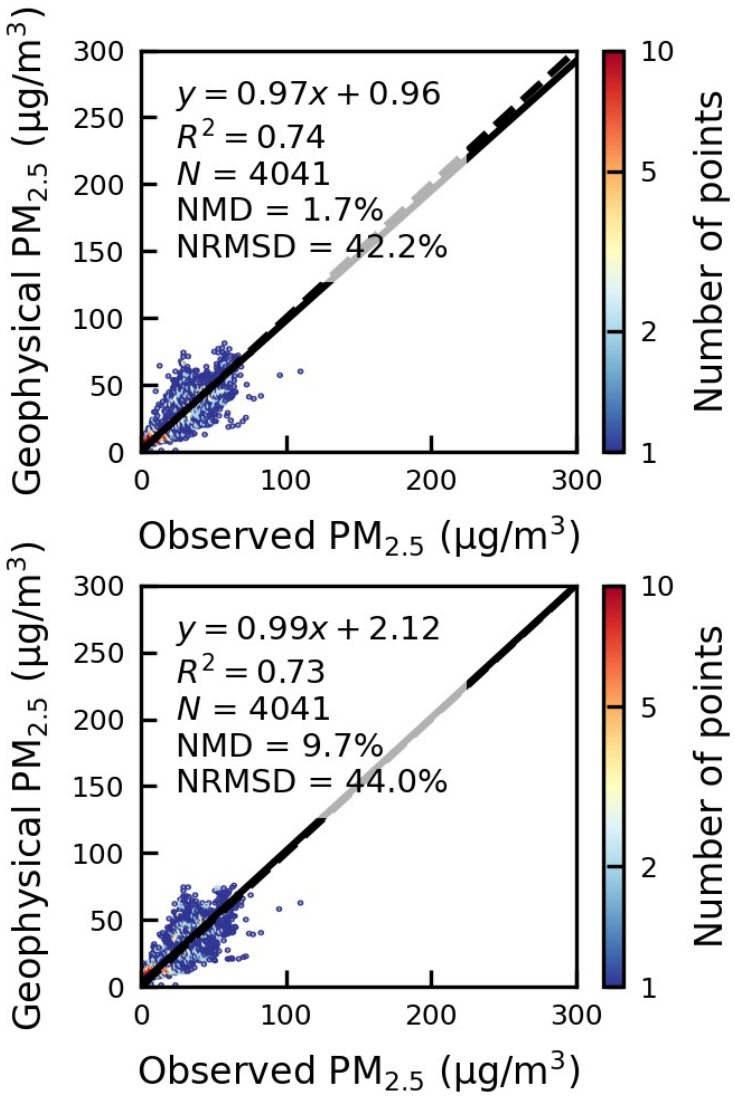
η: simulated surface $PM_{2.5}$ to AOD ratio

Potential effects with η at fine resolution

- Surface-controlling spatial heterogeneity?
- Resolution sensitivities of vertical profile?
- Improving agreements with ground observations?

Global distribution of geophysical $PM_{2.5}$ at different resolutions

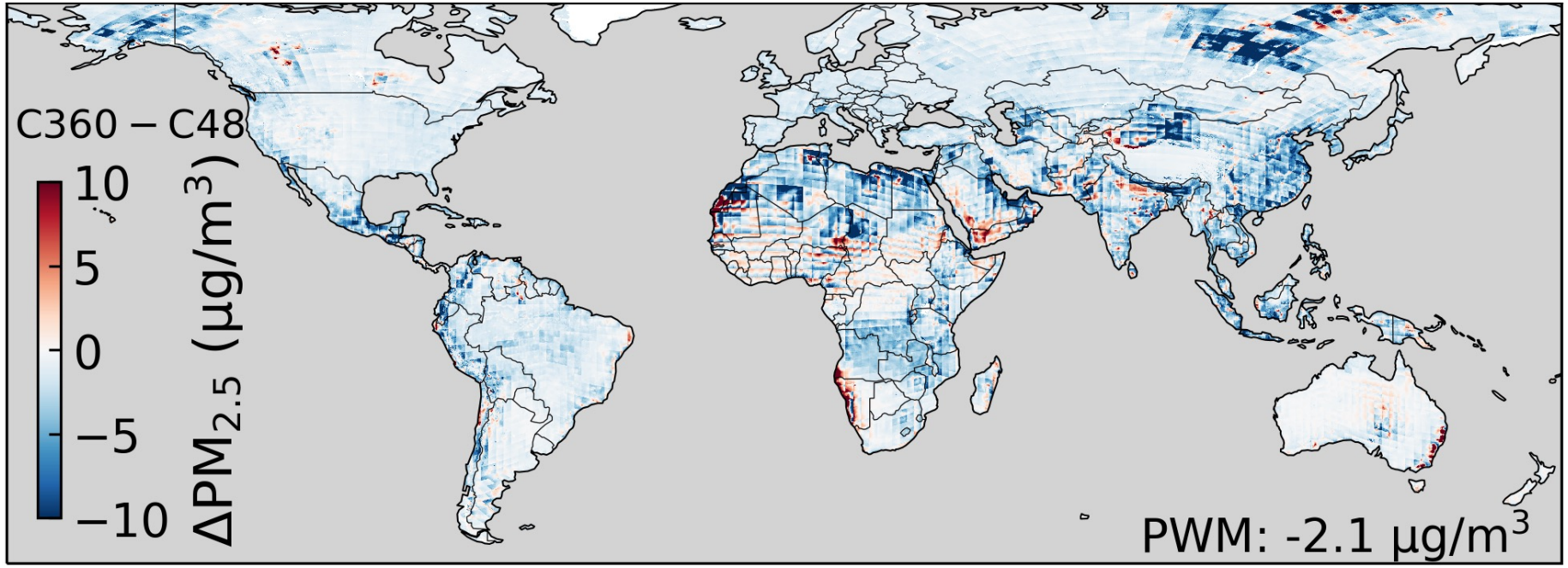




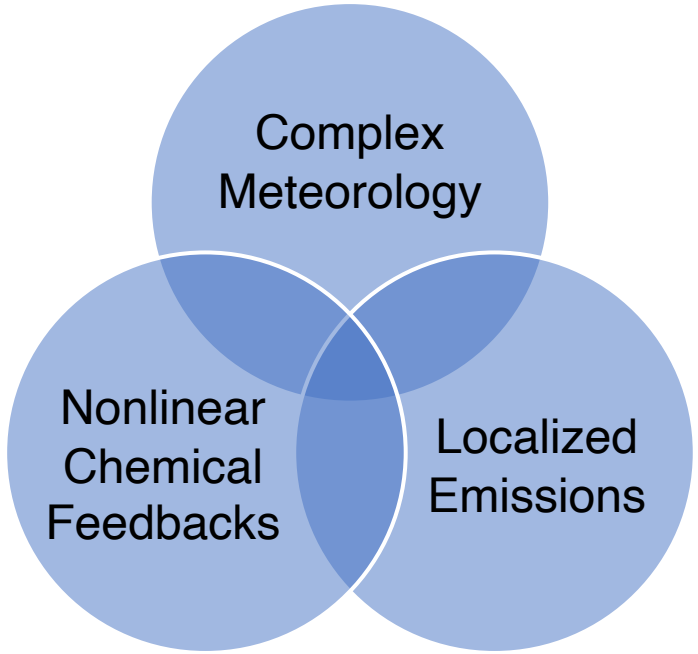
Enhanced aerosol loading aloft at fine resolution globally

AW-NMD(%)	Sim$PM_{2.5}$	SimAOD	Geo$PM_{2.5}$
GL	-10.6	-0.7	-9.7
AS	-17.8	-4.1	-10.7
EU	-14.7	0.4	-16.0
NA	-10.8	5.9	-16.5

- Surface-controlling spatial heterogeneity of geophysical $PM_{2.5}$
- Enhanced aerosol loading aloft
  - Vertical redistribution
  - Regional transport



Summary



- Resolving spatial gradients & hotspots of air pollution at fine resolution
  - Mountainous, coastal, & biomass burning regions
- Altered sectoral importance at fine resolution
  - Enhanced importance of anthropogenic sectors
  - Reduced importance of open fires
- Resolution effects on the relation of AOD with PM
  - Enhanced aerosol loading aloft globally at fine resolution (further investigation)